SECTION D-6

LANDFILL DESIGN SUMMARY

Revision No.
5.0

SECTION D-6

LANDFILL DESIGN SUMMARY

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LANDFILL DESIGN SUMMARY

This section describes the method that the Facility uses for the landfill disposal of wastes. The Facility believes that this method of landfill disposal of wastes fully complies with the requirements of 40 CFR Part 264, Subpart N and ADEM Administrative Code Rule 335-14-5-.14.

According to “Construction Documentation, Final Cover Construction of Cells 1 and 2 in Trench 21,” dated September 1992 and “Final Report – Quality Assurance, Monitoring Services, Final Closure Cover System, Trench 21, Cells 3 and 4,” dated March 17, 1999, Trench 21 is closed. Landfill design specifications, calculations, and related information associated with Trench 21, Trench 22, and Trench 23 can be found in these documents.

D-6-1 Types and Quantities of Wastes to Be Landfilled

The types and quantities of wastes landfilled at the Facility are described in Attachment D-6-1-1, Landfill Operations Plan, to Appendix D-6-1 of this Application.

D-6-2 Landfill Design

Full details of the location, size, and design of Trenches 22 and 23 are provided within Attachment D-6-1-1 through Attachment D-6-1-9 to Appendix D-6-1, Landfill Design Report. The associated Landfill Design Drawings are provided in Appendix D-6-2 to this section. This subsection summarizes the information provided within the Landfill Design Report.

Landfill cells are laid out in continuous trenches as described in Attachment D-6-1-2, Landfill Disposal System Development Plan. In Trench 22, each cell measures approximately 500 to 800 feet by 800 to 1,100 feet at the ground surface. Each Trench 22 cell will have side slopes of 2.5 horizontal : 1 vertical on three sides, and a low berm (about 10 to 20 feet high) on the fourth side. In Trench 23, each cell measures approximately 475 to 715 feet by 970 feet at the ground surface. Each Trench 23 cell will have side slopes of 4 horizontal : 1 vertical on the permanent edges, and a low berm (about 12 feet high initially) on the sides adjoining future cells of Trench 23. Calculation Packages for Trenches 22 and 23, presented in Attachments D-6-1-7 and D-6-1-9 respectively, include calculations verifying that these side slopes are stable as designed.

D-6-2a Double Liner System

Each landfill will be lined with a composite double liner system consisting, at a minimum, of a primary leachate collection and removal system, a primary liner consisting of a geomembrane liner and a low permeability geosynthetic clay liner, a secondary leachate collection and removal system, and a secondary liner consisting of a geomembrane liner and a low permeability soil layer. The functions of the primary leachate collection and removal system are to minimize the depth of leachate on the top liner during operation and to collect and remove leachate during operation and through the post-closure monitoring period. The primary liner is designed, constructed, operated, and maintained to prevent migration of leachate from the landfill trench. The secondary leachate collection system is designed to rapidly detect, collect, and remove any liquids that might escape through the primary liner. The secondary layer is designed to prevent any leachate that escapes from the primary layer into the secondary leachate collection system from entering into the environment. The minimum specifications for the components of the double liner system are provided in Attachment D-6-1-4.

The Facility has selected high density polyethylene (HDPE) from among the many liner materials now offered by manufacturers, because available data indicate that:

- HDPE has the broadest range of chemical compatibility with the various classes of hazardous wastes that will be placed in the trenches;
- HDPE demonstrates the best physical properties, particularly the properties of stress-deformation resistance, puncture resistance, and weatherability; and
- HDPE can be extrusion or fusion-welded to produce stronger and more consistent seams than solvent welding.

This material has been tested using landfill leachate from the Facility to determine compatibility in accordance with EPA Method 9090. The summary report for this testing is provided in Appendix D-6-3, Leachate-Liner Compatibility Study. Previous testing for the Facility at the Battelle Laboratories indicates that under normal conditions of exposure of the HDPE liner to a representative landfill leachate, the HDPE liner should not fail due to the mechanism of exposure to leachate within the Closure or Post Closure Periods or longer. This information is also included in Appendix D-6-3.

Soil and synthetic liner placement are carefully controlled as per the Construction Quality Assurance Plan (CQA) provided in Attachment D-6-1-5. Each cell is over-excavated and then backfilled to designed dimensions with compacted chalk. The compacted chalk layer on the cell walls and the intermediate berm is compacted in place to achieve the desired permeability using methods described in Attachment D-6-1-4, Specifications for Construction Materials. In all cells of Trench 22, a pressure relief layer of approximately one (1) foot layer of permeable granular material is placed over the cell floor. The purposes of this layer are to collect groundwater inflows and to control groundwater pressures during cell construction and the early phases of waste placement. The pressure relief layer in Trench 23 is constructed using a geocomposite drain.

The two-component secondary liner is installed by placing a minimum of three (3) feet of compacted chalk over the pressure relief layer on the cell floor, dressing the surface so that it is smooth, and no potentially damaging protrusions or cavities are visually observed, and then placing the secondary geomembrane liner over the compacted chalk layer. The compacted chalk layer has a hydraulic conductivity of not more than 1×10^{-7} cm/sec.

The secondary leachate collection system for Trench 22, shown in the Landfill Design Drawings in Appendix D-6-2, consists of a layer of permeable granular material a minimum of (one) 1 foot in thickness with a hydraulic conductivity of at least 1×10^{-2} cm/sec on the floors of the cells and a geosynthetic layer with a transmissivity of 3×10^{-5} m^2/sec or more on the slopes. A geotextile filter fabric will overlay the granular material to provide additional filtration capacity. In Trench 23, the secondary leachate collection system consists of a transmissive geocomposite.

The secondary leachate collection system on the floor of Trench 22 is covered with approximately 1.5 feet of compacted chalk (i.e., this layer is part of the primary liner system) on the cell floor. The chalk layer is dressed so that all cavities and protrusions are removed prior to laying the primary geomembrane liner. On the side slopes of Trench 22, the secondary leachate collection system is covered with the primary geomembrane liner. On the floor and side slopes of Trench 23, the secondary leachate collection system is covered with a geosynthetic clay liner and a geomembrane liner.

The primary geomembrane liner is protected with a geotextile cushion and covered with a minimum one (1) foot of permeable granular media on the cell floor and a transmissive geosynthetic layer on the slopes. A layer of protective geotextile filter fabric and approximately 1.5 feet of protective cover complete the liner system of the landfill. Waste is placed upon this protective cover layer.

The geosynthetic liners, transmissive geosynthetic layers, and geotextile filter fabric are anchored at the top of the cell wall. Details on installation of the liners can be found in Appendix D-6-1, Landfill Design Report, and the Landfill Design Drawings in Appendix D-6-2.

The liners are installed by the manufacturer, a qualified and experienced contractor, or trained Facility personnel, in accordance with the Construction Quality Assurance (CQA) Plan included as Attachment D-6-1-5. Additionally, an inspector witnesses and documents the installation of the liner and the performance of the quality assurance procedures. The inspector works under the direction of the CQA Officer, who is a registered Alabama Professional Engineer in accordance with ADEM Administrative Code Rule 335-14-8-.02(2)(d) as described in the CQA

Plan in Attachment D-6-1-5. Documentation and inspection records will be maintained in the Facility Operating Record, and "as-built" drawings of each completed cell will be submitted to the ADEM.

All field installation joints are fusion-welded by the double hot wedge welding technique or the extrusion welding technique. All welds are tested by air pressure tests or by vacuum tests. These are non-destructive tests. In addition, destructive seam testing for bonded-seam strength and peel adhesion is performed in accordance with the Facility's CQA plan.

The liner systems described above comply with 40 CFR 264.301(a)(1) and ADEM Administrative Code Rule 335-14-5-.14(2).

Each cell contains a pressure relief system, constructed beneath the lower geomembrane liner of each cell in order to prevent the buildup of hydrostatic head beneath the liner systems. The plan layout of the pressure relief system and design details is provided in Appendix D-6-1, Landfill Design Report and in Appendix D-6-2, Landfill Design Drawings.
Groundwater from the underlying saturated zone is pumped out through the pressure relief system and discharged to NPDES sediment basins. The pressure relief system is operated at least until the level of wastes in the cell approximates the phreatic surface in the surrounding chalk. Calculations indicating at what point the pumping can be discontinued are provided in Attachments D-6-1-7 and D-6-1-9.

D-6-2b Leachate Collection System

The leachate collection system in the floor of each cell consists of:

(l) the secondary leachate collection system, consisting of a granular layer in Trench 22, a minimum of one (1) foot in thickness, or a geocomposite drain layer in Trench 23, between the two geomembrane liners; and

(2) the primary leachate collection system above the primary liner.

The secondary leachate collection system consists of free-draining permeable material sloped to a sump in each landfill cell overlaid by a geotextile filter fabric. The secondary leachate collection sump has a riser for removal of liquid. The sump can be evacuated by pumping through the riser pipe. The riser pipe inclines parallel to the side slope and exits the cell without penetrating the geomembrane liners beneath the crest.

As stated above, no leachate collection side slope riser pipes penetrate any geomembrane liner beneath the crest of the landfill cell. This greatly reduces opportunities for leakage through the geomembrane liners. Details of the sump and evacuation systems for the secondary leachate collection system are provided in Attachment D-6-1-3 and in the Landfill Design Drawings in Appendix D-6-2.

The primary leachate collection system in the floor of each cell consists of a minimum one (1) foot of permeable granular material underlain and overlaid with a geotextile fabric and a leachate collection sump located in each landfill cell. Design details are presented in Appendix D-6-1 and in the Landfill Design Drawings in Appendix D-6-2.

The floors are sloped 2 to 4% to the primary leachate collection sump, and both floors and walls are entirely covered with drainage media overlaid by a geotextile fabric to prevent clogging of the drainage media. The side slopes of each cell will use a transmissive geosynthetic layer in lieu of granular material. In Trench 22 an approximately 18-inch layer of protective cover is laid over the geotextile fabric on the floor, and an approximately 12-inch layer of protective cover or equivalent is laid partially up the sides, to protect the primary leachate collection system from disturbances during initial landfilling operations. In Trench 23, the layer of protective cover is approximately 18-inches thick on both the cell floor and side slopes. A temporary protective geosynthetic layer will be placed over the exposed side slopes of primary leachate collection system (PLCS) to protect the PLCS from exposure to and the effects of the elements and light. The protective synthetic layer will be cut and removed from the side slopes in sections as waste is placed in the cells.

Materials used in the primary leachate collection system will withstand chemical attack from expected leachate constituents, will withstand the stresses of construction and the overlying waste, and are designed to function without clogging.

To provide redundancy for the primary leachate collection system, there are two systems for removal of primary leachate from the PLCS: the upslope riser and the vertical riser. The upslope risers will be used during the operation of the cell. Once the cell is completed, either riser system may be used to remove leachate. The vertical riser will be installed in sections as waste is placed in the cell and may not be used during operation of the cell due to possible interference from hoses and equipment. The PLCS utilizes a coarse granular material filled sump. Details are presented in Appendix D-6-1 and in Landfill Design Drawings in Appendix D-6-2.

The granular materials used in the leachate collection systems are naturally occurring quartz and feldspar materials. These materials are highly resistant to chemical degradation, and therefore are not expected to be degraded by the waste materials or any leachate developed in the cells.

The Facility believes that the above-described leachate collection system complies with 40 CFR 264.301(a)(2) and ADEM Administrative Code Rule 335-14-5-.14(2).

D-6-2c Run-on and Run-off Control

Run-on and run-off of surface water from the land disposal units is managed and controlled to prevent surface water contamination. The components of the management of surface water are described in detail in Subsection D-6-1-1-7, Surface Water Management, in Attachment D-6-1-1, Landfill Operations Plan. The Facility believes that these procedures comply with 40 CFR 264.301(g) and (h) and ADEM Administrative Code Rule 335-14-5-.14(2)(c) and (d).

D-6-2d Wind Dispersion Control

Wind dispersal is controlled within the landfill by minimizing the amount of exposed waste as described in Subsection D-6-1-1-5, Wind Dispersal Control, in Attachment D-6-1-1, Landfill Operations Plan. The Facility believes that these procedures comply with 40 CFR 264.301(j) and ADEM Administrative Code Rule 335-14-5-.14(2)(f).

D-6-2e Closure Cover Design

Appendix D-6-1, Landfill Design Report, provides a detailed description, including stress and stability calculations of the closure cover design for the landfill trenches. (See Subsections D-6-1-4-2l through D-6-1-4-2o in Attachment D-6-1-4, and Attachments D-6-1-7 and D-6-1-9, Calculation Package for Trench 22 and Trench 23). As shown on the grading plan in Appendix D-6-2, Landfill Design Report, the final closure covers have maximum slopes of 25 percent on the sides, tapering to 5 percent on top. Land disposal cells are closed after the above-grade module is completed. Sequential closure involves placement of fill material over the waste as needed to reach the required cover subgrade level, placement of a compacted chalk liner, placement of a geomembrane liner, placement of a transmissive geosynthetic layer, and final placement of loose chalk and/or topsoil. The cover geomembrane liner is specified in Attachment D-6-1-4. The growth media of chalk and topsoil are treated with the necessary pH adjustments and nutrients, and a vegetative cover is established according to specifications in Attachment D-6-1-4.

The closure covers are inspected weekly and after major storms until vegetation is well established, and then quarterly and after major storms until the post-closure period to ensure that erosion is controlled and any potential damage is identified and repaired. The vegetative cover is maintained by seasonal mowing and fertilization. The inspection program during the post-closure period is described in Section I of this Application.

The compacted chalk liner component of the closure cover has a minimum thickness of two (2) feet and a hydraulic conductivity of not more than 1×10^{-7} cm/sec. After grading to the final closure cover configuration, the chalk is prepared for geomembrane liner placement directly on the compacted chalk liner. The chalk provides a structural base which supports the geomembrane liner. Closure cover grades are shown in the Landfill Design Drawings in Appendix D-6-2. The final upper slope of the geomembrane liner, as shown on these drawings, is greater than two (2) percent.

The geomembrane closure liner will be installed, tested, and inspected in accordance with the CQA plan. The transmissive geosynthetic layer will be installed in accordance with specifications and quality assurance procedures in Attachment D-6-1-5, Construction Quality Assurance Plan.

The uncompacted topsoil/chalk layer supports the vegetative cover and protects the geomembrane liner from penetration by roots and burrowing animals. The vegetative cover controls erosion and increases evapotranspiration of moisture. Soil erosion losses for the vegetated slopes of closure covers are minimal, as demonstrated by the calculations and results presented in Attachments D-6-1-7 and D-6-1-9.

The closure cover is designed to accommodate the small amount of anticipated settlement in the landfill resulting from placement of succeeding lifts of waste beneath the cover and the cover itself. The computed post-closure settlements, presented in Attachments D-6-1-7 and D-6-1-9, cause only very low strain, which the closure cover can tolerate without disruption of the integrity of the closure cover. However, post-closure dressing of any depressions which might develop will ensure that the closure cover integrity and positive slope drainage is maintained. See Section I of this Application for further details on post-closure care of the closure cover.

The Facility believes that the closure cover design described above complies with 40 CFR 264.310 and ADEM Administrative Code Rule 335-14-5-.14 (11). Furthermore, the Facility believes this design can be easily and adequately maintained for long-term effectiveness.

D-6-2f Construction Design

Prior to construction of permitted landfill trenches, the Facility may prepare additional detailed construction drawings to facilitate constructability; however, these drawings shall not deviate from the information shown in the drawings provided in Appendix D-6-2, Landfill Design Drawings, unless a request for a modification of the Permit is submitted and approved by the Department. The additional detailed construction drawings that may be prepared at various stages of trench development, typically relate to the following:

- excavation, the liner systems, run-on controls, and interim cover;

- above-grade berms; and
- final closure cover grading and liner and drainage system construction.

D-6-3 Management of Landfill Disposal Operations

D-6-3a General Operation

Cell construction within any trench will be phased such that as waste is disposed in one cell, the adjacent cell is being excavated, lined, and prepared for waste placement. This sequential approach, in conjunction with interim cover, minimizes the area open for catchment of precipitation and provides for maximum land utilization for waste disposal.

From the start of excavation to the completion of the disposal cell, any time that construction is halted or suspended for a period 30 days or more, prior to restarting construction, all completed or partially completed components of the construction shall be inspected and assessed in accordance with Subsection D-6-1-5-11, Suspension of Construction, in Attachment D-6-1-5, Construction Quality Assurance Plan.

Within 30 days after the last load of waste is disposed in an "Above Grade Module" (AGM), an interim layer of chalk will be placed over the module. When the last above-grade module in a multi-cell landfill trench is filled, the final closure for the entire trench will begin within 30 days after the last load of waste is disposed in the trench.

Wastes are placed in the landfill cells in lifts as described in Subsection D-6-1-1-4b, Procedures for Mapping Waste in the Landfill, in Attachment D-6-1-1. The thickness of the lifts varies to suit the particular conditions of waste type and location within the cell. The vertical extent of each lift is determined by survey. All wastes and intermediate cover material are nominally compacted, as they are being placed, by the traffic of trucks and heavy equipment operating in the landfill.

As waste is placed in each cell, the intermediate berm is raised in increments of approximately ten (10) feet or more, in order to maintain a positive control of rainwater falling into the cell. The intermediate berm is described in detail in Appendix D-6-2 (Landfill Design Drawings). Traffic from the access road onto the waste surface is minimized by off-loading trucks from the clean chalk area. The layer of chalk placed on each waste lift surface is sufficient to carry traffic loads. The roads are pitched to the inside of the cell, directing any accidental spills of materials towards the waste placement area.

Leachate is pumped from the PLCS as often as necessary to maintain a depth of no more than 12 inches (i.e., 30 cm) of leachate above the rim of the leachate collection sump. This is accomplished by an automatic pump in the pipe serving the primary leachate collection system. The leachate is pumped by pipeline or conveyed by tank truck to appropriate on-site storage units (e.g. Units 1700A, B & C, Unit 1400, Tank T-A, etc.). Rainwater collected in the confines of the active waste placement area may be pumped out of the cell to storage units.

If after waste disposal begins in a cell, the steady-state quantity of water collected in the SLCS exceeds the Action Leakage Rates (ALR's) provided in Attachment D-6-1-6, the Facility will initiate Response Actions as described in Attachment D-6-1-6, Response Action Plan.

The Facility believes the operations plan complies with the requirements of 40 CFR 264.301 and ADEM Administrative Code Rule 335-14-5-.14(3).

D-6-3b Monitoring and Inspection

Landfill operations are inspected in accordance with the Inspection Program Plan presented in Section F of this Application. The Facility believes that its inspection program complies with the requirements of 40 CFR 264.303 and ADEM Administrative Code Rule 335-14-5-.14(4).

The installation of the liner and leachate collection system in each landfill cell is monitored in accordance with the CQA plan in Attachment D-6-1-5.

D-6-3c Surveying and Recordkeeping

The Facility maintains drawings showing the location and dimensions of each landfill disposal trench and cell, referenced to a permanently surveyed benchmark as described in Subsection D-6-1-1-4a, Location and Dimensions of Land Disposal Units, in Attachment D-6-1-1, Landfill Operations Plan, of this Application. The Facility believes these procedures comply with the requirement of 40 CFR 264.309(a) and ADEM Administrative Code Rule 335-14-5-.14(10)(a).

The Facility maintains a record of the location of placement of each load of wastes disposed in each landfill cell as described in detail in Subsection D-6-1-1-4b, Procedures for Mapping Waste in the Landfill, of Attachment D-6-1-1, Landfill Operations Plan, of this Application. The Facility believes that the foregoing procedures enable compliance with the requirement of 40 CFR 264.309(b) and ADEM Administrative Code Rule 335-14-5-.14(10)(b).

D-6-3d Special Requirements

The Facility maintains special requirements and prohibitions regarding the disposal of liquid wastes and wastes containing free-standing liquids, empty containers and containers that are less than 90% full, lab packs, ignitable or reactive wastes, and macroencapsulated wastes as described in Subsection D-6-1-1-6, Special Requirements For Certain Types of Waste, of

Attachment D-6-1-1, Landfill Operations Plan, of this Application. The Facility believes that these procedures enable compliance with 40 CFR 264.312 through 264.317, and ADEM Administrative Code Rule 335-14-5-.14(13) through 335-14-5-.14(18).

[End of Section D-6]

APPENDIX D-6-1

SECTION D-6

LANDFILL DESIGN REPORT

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APPENDIX D-6-1

LANDFILL DESIGN REPORT

SUMMARY OF ATTACHMENTS

Attachment D-6-1-1, Landfill Operations Plan, describes the operating requirements for the disposal units (i.e., disposal trenches). Additional information on the operating requirements of the secondary leachate collection system, or leak detection system, is provided in Attachment D-6-1-6, Response Action Plan.

Attachment D-6-1-2, Landfill Disposal System Development Plan, describes the subdivision of each trench into cells and provides the estimated waste disposal volume for each trench. It describes the construction sequence for a cell, the typical filling sequence for the trenches, and the closure cover construction.

Attachment D-6-1-3, Landfill Design, describes the design for each component of the landfill. The descriptions are organized by major components, including excavation, structural fill, pressure relief system, the secondary liner and leachate collection system, and the primary liner and leachate collection system.

Attachment D-6-1-4, Specifications for Construction Materials, provides performance specifications for soil, geosynthetic and HDPE pipe components of the landfill design.

Attachment D-6-1-5, Construction Quality Assurance Plan, provides a description of the requirements and procedures that will be followed during landfill construction to monitor compliance with the permit specifications.

Attachment D-6-1-6, Response Action Plan, provides descriptions of the calculations used to determine the Action Leakage Rate for each cell and the actions that will be taken if the Action Leakage Rate is exceeded.

Attachment D-6-1-7 includes calculations supporting the design of Trench 22.

Attachment D-6-1-8, Compacted Fill In-Situ Permeability Test Report, includes a report on test fills previously constructed at the Facility to evaluate compaction requirements needed to achieve the permeability specification for the compacted chalk layer in the liner systems.

Lastly Attachment D-6-1-9 includes calculations supporting the design of Trench 23.

[End of Appendix D-6-1 Text]

ATTACHMENT D-6-1-1

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SECTION D-6

LANDFILL OPERATIONS PLAN

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ATTACHMENT D-6-1-1

LANDFILL OPERATIONS PLAN

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LANDFILL OPERATIONS PLAN

The Landfill Operation Plan describes the operating requirements for the disposal units (i.e., disposal trenches). Additional information on the operating requirements of the secondary leachate collection system, or leak detection system, is provided in Attachment D-6-1-6, Response Action Plan.

D-6-1-1-1 Landfill Disposal of Wastes

Currently, bulk and containerized solid wastes that meet applicable Land Disposal Restrictions (LDR) treatment standards are landfilled directly after being received and analyzed (per Waste Analysis Plan, Section C). Bulk and containerized liquid wastes, after being received and analyzed, are stabilized or solidified before being landfilled. Treatment is performed using the methods described in Sections D-1, D-2, and D-9 of this Application. In short, the Facility's landfill disposal operations will be used for the direct disposal of both bulk and containerized solid wastes and treated and/or stabilized hazardous waste residuals.

D-6-1-1-1a Types and Quantities of Wastes to be Landfilled

Virtually all listed hazardous wastes from 40 CFR Part 261 and ADEM Administrative Code Chapter 335-14-2 are landfilled at the Facility. For purposes of this Application, the Facility has included EPA Waste Codes to be landfilled at the Facility in Section C of this Application.

The chemical and physical properties of the wastes landfilled at the Facility vary considerably. The Facility ensures waste compatibility for landfill disposal by employing the methods and practices included within the Waste Analysis Plan provided in Section C of this Application.

D-6-1-1-1b Standing Landfill Operating Capacity

For purposes of daily operation and to ensure enough operational airspace capacity in the event of an un-planned closure, a standing landfill operating capacity of at least 80,000 cy will be provided at all times during active land disposal operations at the Facility.

D-6-1-1-2 Pressure Relief Systems

Each cell is designed and will be constructed with a pressure relief system below the secondary composite liner so that groundwater seepage into open excavations will not pose construction problems. Evaporation of the water flowing from the natural chalk surrounding each trench occurs more rapidly than the inflow rate. As a result, no groundwater accumulates within the excavated areas. After placement of the secondary liner system, water removal from the pressure relief system will be initiated such that the hydrostatic pressure beneath the secondary liner is balanced by the weight of liners, leachate collection system components, soil, waste, or any combination thereof, in the landfill cell area. This will be accomplished by lowering a pump into the pressure relief system riser pipe and pumping water from the system. Discharge of this water shall be in accordance with NPDES Permit conditions.

The pressure relief system will be operated at least until the waste level in the cell imposes a force equal to or greater than the hydrostatic force exerted on the liner system at any point below the secondary liner. The calculations indicating at what point the pumping can be discontinued are provided in Attachments D-6-1-7 and D-6-1-9.

D-6-1-1-3 Leachate Collection Systems

D-6-1-1-3a Secondary Leachate Collection Systems (SLCS)

After completion of the placement of the liner of the primary leachate collection system (PLCS) in each cell, removal of construction water from the SLCS will be initiated. This will be accomplished by lowering a pump into the collection system riser and pumping water from the system. Until disposal operations are initiated in the cell, the water will be discharged to drainage channels in accordance with NPDES Permit conditions. After disposal operations in the cell have been initiated, water will be removed from the SLCS and will be managed as leachate and pumped or transported by tanker from the cell to storage units (e.g. Units 1700A, B & C, Unit 1400, and Tank T-A, etc.)

During the active life and closure period of the cell, the volume of liquids removed from the SLCS sump will be recorded at least once a week. All liquids shall be managed as leachate throughout the closure and post-closure period in accordance with the landfill closure and post-closure section of this permit. The quantity of liquids removed from the SLCS shall be recorded in the Facility's operating record (refer to Response Action Plan, Attachment D-6-1-6.) The pump operating level will be less than one (1) foot above the rim of the sump. A pump with a capacity of at least twice the flow capacity of the SLCS (refer to Response Action Plan, Attachment D-6-1-6) will be installed in the sump and will be activated prior to the liquid level reaching one (1) foot over the sump.

During the Post-Closure period, the amount of liquids removed from each leak detection system sump must be recorded at least monthly. If the liquid level in the sump stays below the pump operating level for two consecutive months, the amount of liquids in the sumps must be recorded at least quarterly. If the liquid level in the sump stays below the pump operating level for two consecutive quarters, the amount of liquids in the sumps must be recorded at least semi-annually. If at any time during the post-closure care period the pump operating level is exceeded at a sump on quarterly or semi-annual recording schedules, the owner or operator must return to monthly recording of amounts of liquids removed from each sump until the liquid level again stays below the pump operating level for two consecutive months.

D-6-1-1-3b Primary Leachate Collection System (PLCS)

To provide redundancy of the primary leachate collection system, there are two systems for removal of primary leachate from the landfill cells. Vertical risers are installed with perforated lateral HDPE pipes on HDPE foundations to permit leachate flow. Above the sump, the HDPE vertical risers are surrounded by concrete risers. Upslope risers may also be used to remove primary leachate from the landfill cell during operation of the cell. The vertical risers will be installed in sections as waste is placed in the cell and may not be used during operation of the cell due to possible interference of hoses and equipment. The vertical riser and upslope riser inlets reside in a common sump and are hydraulically connected with HDPE pipes.

Details of the above-described leachate collection systems are provided in the Landfill Design Drawings in Appendix D-6-2 of this Application.

The PLCS shall be operated such that the level of liquid over the geomembrane liner does not exceed 30 cm (1 foot) over the rim of the sump. The liquid level in the PLCS shall be measured and recorded weekly. A pump with a capacity of at least twice the capacity of the PLCS will be installed in the sump and will be activated prior to the liquid level reaching 30 cm (1 foot) over the rim of the sump. The liquid removed from the PCLS will be managed as a hazardous waste and shall be pumped or transported by tanker from the cell to storage units (e.g., Units 1700, Unit 1400 and Tank T-A, etc.).

D-6-1-1-4 Surveying and Recordkeeping

The Facility maintains drawings showing the location and dimensions of each landfill disposal trench and cell. In addition, the Facility maintains a record of the placement of each waste within the cell. The procedures for documenting the location and size of the disposal units and for mapping waste within a cell are outlined in the following subsections.

D-6-1-1-4a Location and Dimensions of Land Disposal Units

The Facility maintains drawings showing the location and dimensions of each landfill disposal trench and cell, referenced to a permanently surveyed benchmark. The current drawings are provided in Appendix D-6-2, Landfill Design Drawings, of this Application. These drawings are maintained at the Facility as part of the Operating Record. The Facility believes the drawings comply with the requirement of 40 CFR 264.309(a) and ADEM Administrative Code Rule 335-14-5-.14(10)(a).

D-6-1-1-4b Procedures for Mapping Waste in the Landfill

Before a load of waste enters the landfill, the delivery vehicle must stop at the entrance of the disposal cell (except for site vehicles transporting waste from the stabilization building). The Mapper (or a designee) at the disposal cell will review the required documents (i.e., the Receipt Control Form, Waste Transfer Log, or other forms providing equivalent information) that accompany the waste delivery vehicle. The Mapper (or designee) will transcribe onto a waste transfer log (see the Figures located at the end of this section for samples of typical waste transfer log forms) the date of transfer, the generator's manifest number, and the quantity of the load. The Mapper (or designee) will also check the Receipt Control Form for the wind dispersal potential of the waste, if any, and notify appropriate Facility personnel within the disposal unit so that the required measures are implemented, if applicable. The Mapper (or designee) will then direct the driver to a general location in the cell. As the waste is being disposed in the cell, the Mapper (or designee) will use a global positioning system (GPS) device, or other comparable electronic mapping device, to measure both the horizontal and vertical coordinates (which will be converted to the Facility’s coordinate system) of the waste. If a GPS device is not able to be used, the Mapper (or designee) will note on a transfer log form the location of the waste in relation to the horizontal grid coordinates for the cell and the vertical lift level in the cell. If the grid coordinates are used, the horizontal grid dimensions for the waste mapping system shall be capable of providing the location of the waste to within a grid interval of approximately 50 feet by 50 feet. The lift thickness does not exceed 12 feet (except for certain types of waste, such as transformers and debris, which due to their geometry cannot be placed within the typical lift thickness) and is normally separated by traffic surface cover consisting of loosely compacted chalk or materials as specified in Subsection D-6-1-4-2j of Attachment D-6-1-4, Specifications For Construction Materials. The vertical extent of each lift does not exceed the thickness as described above but may vary to suit disposal conditions and will be determined by survey and recorded as part of the mapping procedures. A daily record of transfer log form(s) shall become part of the Facility's Operating Record. The horizontal grid for the active cell of the disposal unit shall be referenced to the Facility's coordinate system, shall be established prior to initiation of waste placement, and shall become part of the Facility's operating record.

D-6-1-1-5 Wind Dispersal Control

Wastes which exhibit the potential for wind dispersal shall be identified in accordance with the Waste Analysis Plan (see Section C of this Application). The Receipt Control Form for waste that exhibits the potential for wind dispersal shall be marked "Wind Dispersal" or other appropriate wording to identify that load as potentially subject to wind dispersal. Landfill personnel shall note these loads and take necessary precautions to control wind dispersal. These precautions consider minimizing the amount of exposed wind dispersal waste by one or more of the following means:

- containerization of the waste;
- selective placement within the landfill (e.g. unloading on the lower side of a lift so that the waste will be covered intermediately with the progression of traffic surface cover);
- application of appropriate dust control spray (e.g., water, non-contaminated surface water or leachate treated to F039 standards) to the exposed surfaces of the waste;
- intermediate covering of the waste with a material that is not subject to wind dispersal;
- unloading of the waste within portable wind screens, allowing the screens to protect the waste until the waste is covered by the progression of traffic surface cover; or
- treatment of the waste prior to disposal.

When using non-contaminated surface water or leachate meeting F039 treatment standards as dust control spray to the exposed surfaces of waste, the following protocol will be used:

- Non-contaminated surface water and/or treated leachate will be stored in permitted tanks and analyzed to ensure the non-contaminated surface water/treated leachate meets the applicable F039 treatment standards.
- Only non-contaminated surface water/leachate that meets the applicable F039 treatment standards will be eligible for use as a dust suppressant within the active landfill.
- A dedicated water wagon or other such device will be used to apply the non-contaminated surface water/treated leachate as a dust suppressant agent within the active landfill.
- Prior to using the dedicated water wagon or other such device for dust suppression outside of the active landfill, this equipment will be filled with site water (non-potable basin water). This site water will serve as a rinsate to remove any non-contaminated surface water/treated leachate residue from the equipment and this rinsate will be applied within the active landfill for dust suppression.
- After the equipment has been rinsed it will be filled with site water and be available for unrestricted dust suppressant applications throughout the site.

D-6-1-1-6 Special Requirements for Certain Types of Waste

The Facility maintains special requirements and prohibitions regarding the disposal of liquid wastes and wastes containing freestanding liquids, empty containers, and containers that are less than 90% full, lab packs, ignitable or reactive wastes, and macroencapsulated wastes. The identification and determination of prohibited waste will be performed in accordance with the procedures provided in the Waste Analysis Plan (see Section C of this Application). These special requirements and prohibitions are outlined in the following subsections.

D-6-1-1-6a Liquid Wastes and Wastes Containing Free-Standing Liquids

Neither liquid wastes nor wastes containing freestanding liquids shall be placed in any landfill unit. Prior to disposal, the following procedures shall be followed to achieve this prohibition:

- Containers of wastes that are to be landfilled shall be inspected for the presence of freestanding liquids as described in the Waste Analysis Plan (see Section C). If freestanding liquids are observed, they will be removed by decanting, solidification or treatment. Decanted liquids will be managed in accordance with the applicable land ban rule. If no freestanding liquids are observed, the waste may be landfilled.
- Bulk solid wastes are sampled and analyzed as described in the Waste Analysis Plan (see Section C). If no free liquids are present, the waste is landfilled. If free liquids are present, the waste will be treated before being landfilled.

D-6-1-1-6b Empty Containers and Containers Less Than 90% Full

Containers of solid waste which are not empty but may be less than 90% full are shredded, crushed, or filled to at least 90% full with solidification agents before being landfilled. If these containers are crushed within the landfill, the containers will be reduced in volume to the maximum practical extent prior to burial (i.e., prior to being covered by other wastes, intermediate cover, interim cover, etc.) in the landfill. Empty containers may be crushed in place by heavy equipment as they are being landfilled.

D-6-1-1-6c Lab Packs

With respect to the landfill disposal of lab packs, the Facility shall require the generator to meet the requirements of 40 CFR 264.316 and ADEM Administrative Code Rule 335-14-5-.14(17).

D-6-1-1-6d Ignitable, Reactive, and Incompatible Wastes

Ignitable or reactive wastes are not placed in the landfill unless the wastes meet all of the LDR requirements of 40 CFR 268 and ADEM Administrative Code Chapter 335-14-9. The Facility does not landfill any incompatible wastes which cause any of the types of reactions listed in 40 CFR 264.1(b) and ADEM Administrative Code Rule 335-14-5-.02(8). Wastes placed in the landfill are all solids and compatible or are made compatible using stabilization or other treatment prior to landfilling. Corrosive wastes are treated or stabilized before being landfilled. The Facility does not expect mixing of incompatible materials to cause the types of reactions listed in 40 CFR 264.1(b) and ADEM Administrative Code Rule 335-14-5-.02(8), based on the following:

Mixing of Material:

- All waste meets the Land Disposal Treatment Standards as specified in the ADEM administrative code;
- No untreated ignitable/oxidizers (D001) are placed in the landfill;
- No untreated corrosive waste (D002) is placed in the landfill;
- No untreated reactive waste (D003) is placed in the landfill; and
- The laboratory evaluates waste to identify incompatible waste and stipulates any necessary treatment or precautions.

Mixing of Leachate/Surface Water:

- Due to the stabilization process, leaching of waste constituents is retarded and maintained at a low concentration;
- The leachate analytical data for the landfill is consistent, indicating that the waste in the landfill produces a uniform leachate;
- Surface water removal per Subsection D-6-1-1-7 reduces the amounts of liquids/leachate mixing in the landfill; and
- Intermediate cover may be placed between lifts to reduce exposure of wastes and to reduce the amount of water movement through the landfill.

The Facility believes that the aforementioned procedures enable compliance with 40 CFR 264.313 and ADEM Administrative Code Rule 335-14-5-.14(14).

D-6-1-1-6e Macroencapsulated Wastes

Debris waste treated by macroencapsulation, as described in Section D-1 and Section D-9 of this Application, may be disposed of at the Facility. Macroencapsulated wastes require specific management practices within the landfill to preserve the integrity of the macroencapsulation container. These management practices are as follows:

- the Mapper (or a designee) at the disposal cell will review the Facility required documents (i.e., the Receipt Control Form, a waste transfer log, or other forms providing equivalent information) that accompany the waste delivery vehicle to assure that the sealing of the macroencapsulation container has been inspected prior to delivery at the landfill;
- off-loading and placement of the macroencapsulation container onto the operating surface of the landfill will be performed as gently as practical to avoid damaging the container;
- placement of the macroencapsulation container onto the operating surface shall be such that adequate space is provided around the container to allow inspection and, if necessary, repairs;
- during and after the off-loading, the macroencapsulation container will be viewed and inspected for damage (e.g., tears, cracks, punctures, etc.), and if any damage is detected, the container will be repaired or replaced and re-inspected to assure that the repairs or replacement restore the container's seal and integrity;
- after inspection and repairs, if any, soil or select waste (i.e., waste that is free of objects that would damage the macroencapsulation container) is placed around the sides of the container for support and protection;
- the macroencapsulation container will be covered in a timely manner (i.e., as soon as practicable and in most cases in less than 30 days, to avoid degradation of the container by placing soil or select waste around and over the container as the adjacent vertical lift of the landfill is constructed and progresses, thereby completely surrounding the container and eliminating void spaces. (It is noted that containers normally used at the Facility for macroencapsulation are constructed of UV resistant materials; therefore, any UV degradation that may occur during the short duration that the containers will be uncovered is considered to be insignificant); and
- in the unlikely event that landfilled macroencapsulation containers are excavated and moved, procedures shall be such that the containers integrity is maintained (e.g., a possible scenario would be to excavate to the top of the container, hand excavate or excavate by other acceptable methods around the sides of the device to the bottom of the container, slide lifting straps under the container, and lift and move the container, and place, re-inspect and repair as necessary, and cover the container as described above).

D-6-1-1-7 Surface Water Management

Run-on and run-off of surface water from the land disposal units is managed and controlled to prevent surface water contamination. The primary components of the management of surface water include the following general items:

- prevention of run-on into active disposal units;
- prevention of run-off from active disposal units;
- prevention of surface water exceeding the capacities of the PLCS; and
- run-off and erosion control from inactive areas of the disposal unit that are covered by interim cover, closed areas of the disposal unit, and areas of the disposal unit that are under construction.

D-6-1-1-7a Run-on Control into Active Areas of Disposal Units

Run-on of surface drainage into the disposal unit from surrounding areas is prevented by a series of surface water control ditches and berms constructed around the perimeter of the disposal unit to route surface water around and away from the landfill. During the period of landfill operation, the run-on control ditches will be maintained to assure that the design flow capacity is provided. Surface water will be directed away from the landfill excavations by berms at the top of the slope and ditches that are designed to carry the run-off from a 24-hour, 25-year design storm. The run-on control berms and ditches are shown on the Landfill Design Drawings in Appendix D-6-2. These drainage ditches are designed to accommodate the peak discharge of a 24-hour, 25-year storm from the surrounding contributing area (including the perimeter berms and the final covers of the landfill when they become existent), and to convey this discharge to the drainage channels on the Facility. Calculations provided in Attachment D-6-1-7, Calculation Package for Trench 22, demonstrate that the minimum ditch and berm dimensions and grades shown in the drawings will prevent run-on during a 25-year, 24-hour storm event.

All drainage ditches and run-on control berms are constructed as specified in Attachment D-6-1-4, Specifications for Construction Materials, and are maintained to minimize erosion and potential breach or failure. If erosion results in excessive soil loss, soil will be replaced to maintain the structural integrity of the drainage ditches and run-on control berms. The drainage-ways are maintained free of debris which may hinder or block flow.

D-6-1-1-7b Run-off Control from Active Areas of Disposal Units

Run-off containment berms are constructed around the perimeter of the active disposal cell(s) to prevent contaminated precipitation from leaving a given cell. The run-off control berms are constructed as specified in Attachment D-6-1-4, Specifications for Construction Materials, and are maintained to minimize erosion and potential breach or failure. Calculations provided in Attachments D-6-1-7 and D-6-1-9, demonstrate that the minimum berm dimensions and grades shown in the drawings will prevent run-on during a 25-year, 24-hour storm event. Details of the run-off control systems are provided on the drawings in Appendix D-6-2, Landfill Design Drawings. If erosion results in excessive soil loss, soil will be replaced to maintain the structural integrity of the run-off control berm. Precipitation that falls within portions of the landfill that are not currently involved in active waste placement and that are covered by clean chalk or other materials that prohibit the rain water from contacting waste will be managed as non-contaminated surface water and will be directed out of the disposal unit into the sediment basins. Precipitation that contacts waste in the confines of an active waste placement area is managed as leachate. All waste placement within each cell of a trench will cease a minimum of two (2) feet below the current constructed chalk berm or dike crest, thus confining precipitation within the area of active waste placement. In particular instances, certain types of waste will be disposed beyond the vertical limits of the currently constructed containment berm. These waste types include items such as transformers, which due to geometry and time of placement, cannot be placed otherwise. These instances will not affect proper management of precipitation within the active area.

Within an active landfill disposal cell, waste is placed such that positive drainage to one or more low areas is achieved. Precipitation runoff which was in contact with waste from the active cell may be removed by pumps, transferred out of the disposal unit to a storage unit through contained piping systems or by tanker, and managed as leachate, or may be solidified in place using solidification agents which meet the requirements of ADEM Administration Code Rule 335-14-5-.14(15)(e). Any solidification of precipitation in place will be conducted in such a manner to control wind dispersal of material subject to wind dispersal, pursuant to ADEM Administrative Code Rule 335-14-5-.14(2)(f) (e.g. covers over trucks dumping reagent, bottom dumping reagent trucks, any other acceptable practices).

D-6-1-1-7c Controlling Infiltration into the Leachate Collection Systems

Large quantities of surface water falling in the active disposal cell during major storm events will be prevented from entering the leachate collection system by two features. A temporary protective geosynthetic layer will be placed over the PLCS to protect the PLCS from the effects of exposure to the elements and light. This geosynthetic will also prevent precipitation on the slope from entering the PLCS. Instead the precipitation will be directed to the bottom of the cell, thus substantially reducing the amount of water going directly into the PLCS. A berm will be constructed around the PLCS vertical riser to prevent direct flow of surface water into the PLCS sump. This berm will allow the surface water to temporarily pond in the bottom of a newly constructed disposal cell. The calculations provided in Attachment D-6-1-7, Calculation Package for Trench 22, show that the water ponded on the working surface above the PLCS will infiltrate through the loosely compacted chalk layer and sand windows at a rate that is much slower than the rate at which the granular layer in the leachate collection system can carry the leachate to the sump (at a head of one (1) foot over the liner). Similar materials used in Trench 23 will also limit infiltration to a rate much less than the rate at which liquids can be removed from the leachate collection system. The infiltration rate through the chalk under the worst-case conditions is also much less than the specified pumping capacity of the PLCS. Therefore, the head on the liner should not exceed one (1) foot, even during major storm events. However, during initial waste placement into the cells, the infiltration rate through exposed sand windows/rows may be great enough to exceed the pumping capacity of the PLCS pumps during major storm events, therefore causing the head above the liner to exceed one (1) foot. In this case the PLCS shall be pumped in an expedient manner to lower the head below the one (1) foot level. Surface water ponded in the newly constructed disposal cells will be managed in accordance with Subsection D-6-1-1-7d of this attachment. Water ponded on the working surface of the operating disposal cell will be removed as soon as practicable commensurate with the duration and intensity of the precipitation event.

During initial waste placement into a cell, a temporary berm may be constructed to segregate the cell to minimize the area receiving waste. Typical initial waste placement operations along with the sand window/row installation sequence and the temporary berm placement are outlined in Exhibit D-6-1-1a in this attachment. The purpose of the berm and the sand window/row installation sequence is to minimize the leachate generated from precipitation percolating through the active waste placement area.

D-6-1-1-7d Run-on/Run-off Control from Non-active Areas of Disposal Units

Precipitation on inactive portions of the active cells and on closed cells, and precipitation that has collected within construction areas is routed away from the active waste placement areas. Surface water accumulating and discharging beyond the limits of the disposal units is not contaminated because it does not contact waste. However, this discharge may carry a sediment load because of associated surrounding earth-moving activities. Sediment basins installed in the drainage channels will receive these discharges. These sediment basins are managed under the State of Alabama NPDES Permit Number AL0050580. Within the limits of the excavated area, rainfall will be segregated between those areas that are actively receiving waste and areas that are under construction. Rainfall that falls on previously closed cells or rainwater collecting in construction areas of future cells will be routed to sediment basins in accordance with NPDES Permit conditions.

D-6-1-1-8 Monitoring and Inspection

Landfill operations are inspected in accordance with the Inspection Program Plan presented in Section F of this Application.

D-6-1-1-9 Landfill Traffic

Vehicles delivering wastes to the active disposal cell and vehicular movement within the cell are managed as described in Subsection B-6e, Landfill Traffic, in Section B, Facility Description, of this Application.

[End of Attachment D-6-1-1 Text]

ATTACHMENT D-6-1-1

LANDFILL OPERATIONS PLAN

FIGURES

Figure 1

BULK ____________/____/____ SHIFT ____________

BULK CONTAINER TRANSFER LOG - LANDFILL

TIME	MANIFEST NUMBER	FROM LOCAT	TO					TO (FOR SPLIT LOADS)					REPACK CONTAINER
			LOC	CELL	LEVEL	SECT	QUAD	LOC	CELL	LEVEL	SECT	QUAD	
		LSA	21	[illegible]				21	3-4				
		LSA	21	3[illegible]				21	3-4				
		LSA	21	[illegible]				21	3-4				
		LSA	21	3[illegible]				21	3-4				
		LSA	21	3-4				21	3-4				
		LSA	21	3-4				21	3-4				
		LSA	21	3-4				[illegible]	3-4				
		LSA	21	3-4				21	3-4				
		LSA	21	3-4				21	[illegible]				
		LSA	21	3-4				[illegible]	3-4				
		LSA	21	3-4				21	3-4				
		LSA	21	3-4				21	[illegible]				
		LSA	21	3-4				21	3-[illegible]				
		LSA	21	3-4				21	3-4				
		LSA	21	3-4				21	3-4				
		LSA	21	3-4				21	3-4				
		LSA	21	3-4				21	3-4				

COMPLETED BY ____________ VERIFIED BY ____________

ORIGINAL

Figure 2

SAMPLE

CWM, INC. - EMELLE ***** Receipt # ________ ***** Page - 1

Date/Time In
Load Type Federal EPA ID EXEMPT
Transporter

** WEIGHT SUMMARY **
Gross
Tare
Net
Adj.
Adj. Net

Truck Number 646 Trailer/Contnr #1 299205 #2 #3

Rcpt Ln#	Doc Ln#	Document Number	Profile Sales	Profile Generator Invoicing Customer	Cnt #	Cnt Code	Total Quan.	W V	DCS Units	PCB	Sched Cat	Federal EPA Waste Status	ADEM #

BULK SOLID MATERIAL ONLY:
NEEDS SAMPLING/NEEDS INSPECTING: FREE LIQUIDS DETECTED? YES / NO
SELECT MATERIAL/NON-SELECT MATERIAL WIND DISPERSAL MATERIAL? YES / NO

PHYSICAL DESCRIPTION OF WASTE:________________ SAMPLER:________

COMMENTS:________________

____

____

APPROVALS:________________ DATE:________ TIME:________

DISPOSAL METHOD: HH /CH /HH2 /CH2 /HHSO1 /CHSO1 /S /SP-B /F /OTHER________ OD (OTHER):________
(circle one)

MIX RATIO:________/________ DENSITY:________
(reagent) (waste) (Tanker only)

WASH PAD RELEASE:________________ RELEASE FOR DISPOSAL BY:________________
(bulk only) signature signature

SPECIAL HANDLING CHARGE YES / NO

FINAL REVIEW SIGNATURE:________________

Figure 3

SAMPLE

DRUM CONTAINER TRANSFER LOG FOR: ____/______/______ SHIFT ______________________

DRUM PROCESS: INITIAL RECEIPT / 702 / 700 DRUM TRANSFER LOG

Time	Manifest Number	Cont. Number(s)	From Location	Created Cont No's	Created Cont Loc	To Tank	Tank Qty.	Box/Trlr/ Tnkr Nbr.	Box/Trlr/ Tnkr Loc.	Orig. Cont. Location	Proc. Code	Outgoi Manife

COMPLETED BY ______________________________ VERIFIED BY ______________________________

ORIGINAL

Figure 4

SAMPLE

DRUM CONTAINER TRANSFER LOG FOR: ____/_____/_____ SHIFT ____________________

DRUM PROCESS: DRUM TRANSFER TO TANKERS/ROLLOFFS/FLATBEDS/VANS

Time	Manifest Number	Cont. Number(s)	From Location	Created Cont No's	Created Cont Loc	To Tank	Tank Qty.	Box/Trlr/ Tnkr Nbr.	Box/Trlr/ Tnkr Loc.	Orig. Cont. Location	Proc. Code	Outgoing Manifest

COMPLETED BY ______________________________ VERIFIED BY ______________________________

ORIGINAL

Figure 5

SAMPLE

TANK FARM LOG FOR: ____________ / ____ / ____ SHIFT ______________

TANK TRANSFER LOG

Time	Manifest Number	Generator Name	From Loc. Tnk/Str	To Loc. Tnk/Fac/Str	Gallon X-ferred	Transporter Name	Outgoing Manifest	Density	BTU lbs.	% CL	% Solid	H

COMPLETED BY ______________________ VERIFIED BY ______________________

ORIGINAL

Figure 6

SAMPLE

DRUM CONTAINER TRANSFER LOG FOR: ____/______/_____ SHIFT ______________________

DRUM PROCESS: REPACK/SOLIDIFY DRUM TRANSFER LOG

Time	Manifest Number	Cont. Number(s)	From Location	Created Cont No's	Created Cont Loc	To Tank	Tank Qty.	Box/Trlr/ Tnkr Nbr.	Box/Trlr/ Tnkr Loc.	Orig. Cont. Location	Proc. Code	Outgoing Manifest

COMPLETED BY ______________________________ VERIFIED BY ______________________________

ORIGINAL

Figure 7

SAMPLE

RECEIPT CONTROL FORM

252559

Truck #: ________

Date: ______ Time: ______ Trailer #: ________

Manifest #'s: ________

Generator(s) ________

Waste I.D. ________ Transporter ________

WEIGHT

Gross

Tare

Net

Sched. Date: ________ Type (Circle one) Drums Dump Tanker Roll-off Other: ________

# of Wastestreams: ________ Approval (initials): ________ Date: ________ Time: ________

BULK LOADS

WPS #: ________

Sampler: ________

Technician: ________

PCB Analy Req.?: YES NO (CIRCLE ONE)

PCB Results: ________

CN^- Req.?: YES NO (CIRCLE ONE)

CN^- Results: ________

S Req.?: YES NO (CIRCLE ONE)

S Results: ________

Disposal Method D81 / T45 - D81 (CIRCLE ONE)

Disposal Method (Other): ________

Mix Ratio: ________ : ________
(FLUE DUST) : (WASTE)

Trench: ________

Section: ________

Density: ________ (TANKER ONLY)

Wash Pad Release: ________ Signature
(BULK ONLY)

SPECIAL INSTRUCTIONS

Released For Disposal By: ________ Signature

Figure 8

SAMPLE

WASTE INVENTORY SHEET
DRUM PROCESS

Page 1

Generator :
Address :

SLOT # : ______________________________
Trailer Count Before Offloading :

Receipt # :
Manifest # :
Trailer # :
Date Received :

WPS#	Waste Description	Manifest Quantity and Size	Counted Quantity and Size	Solids: # Solids & Size	Solids: # Solids <90% Ful	Solids: Process Code	Liquids/Sludges: # Liquid & Size	Liquids/Sludges: # Sludge & Size	Liquids/Sludges: Process Code	Drums Overpacked

Signatures:

Pre-Review Supervisor : ______________________________

Lab Technician : ______________________________

Waste Material Sampler : ______________________________

Waste Tracking Specialist : ______________________________

Final Approval : ______________________________

** END OF REPORT **

Figure 9

SAMPLE

CWM, INC. - EMELLE ***** Receipt # ________ ***** Page - 1

Date/Time In
Load Type Federal EPA ID
Transporter

** WEIGHT SUMMARY **
Gross
Tare
Net
Adj.
Adj. Net

Truck Number Trailer/Contnr # #2 #3

Rcpt Ln#	Doc Ln#	Document Number	Profile Sales	Profile Generator Invoicing Customer	Cnt #	Cnt Code	Total Quan.	W V	DCS Units	PCB	Sched Cat	Federal EPA Waste Status	ADEM #

>51% OR <51% DEBRIS (CIRCLE)
PREFILLED VAULT Y OR N (CIRCLE)
>51% OR <51% MAC 10% INSPECTION (CIRCLE)
BULK MATERIAL ONLY:
SAMPLED/INSPECTED________ FREE LIQUIDS DETECTED? YES / NO
SELECT MATERIAL/NON-SELECT MATERIAL________ WIND DISPERSAL MATERIAL? YES / NO

PHYSICAL DESCRIPTION OF WASTE:________ SAMPLER/APPROVAL________

SPOT SAMPLE:____ ________ | PHYS. DESCRIPTION________
RAD.SCREEN |
IGN.SCREEN
H20 SOL. |
H20 RXN/TEMP.________ |
ph (PAPER)________ |
CN__SCREEN__+__-__SULFIDE SCREEN__+__-_|
ADDITIONAL ANALYTICAL REQ'D?_Y__N________
DESCRIBE:________
PCB CONC.(PPM)________ SULFIDE (9030)________ FORM CODE________
%H20 BY KF________ CYANIDE (9010)________ TAB WASTE Y N
PAINT FILTER TEST/ P F SPEC. GRAVITY________ BNZ CONC.____PPM
COMMENTS:________

COMPAT. TEST W/________ OK___RXN__

ADD'L SPOT SAMPLE ATTACHED?_Y__N________
DISPOSAL METHOD: S SP ST-3 ST-3/PT P-ST-3 P-ST-3/PT ST-5 ST-5/PT P-ST-5 S01-PTA B-PIN OTHER________
P-ST-5/PT ST-8 ST-8/PT MIC MAC (MAC INSPECT) F INC SP-VS PCB-MAC P-MAC
P-ST-8 P-ST-8/PT VS-3 VS-5 VS-8
INDICATOR PARAMETER WILL BE CIRCLED
B-MAC LOADS REQUIRING INSPECTION THAT ARE FOUND TO BE LESS THAN 51% MUST
BE RETURNED TO LAB AND PLACED ON HOLD.________
RELEASED FOR DISPOSAL BY:________ DATE:________

________ EPA CODES REQUIRING TREATMENT AT STABILIZATION:________

ATTACHMENT D-6-1-1

LANDFILL OPERATIONS PLAN

EXHIBIT A

INITIAL WASTE PLACEMENT OPERATION;

SAND WINDOW INSTALLATION SEQUENCE; AND

TEMPORARY BERM

TRENCH 22

1.0 Waste Placement Sequence

In order to minimize the generation of leachate, initial waste placement shall be restricted to the downslope side of the cell. The waste may be segregated from the clean area by a temporary chalk berm. Run-off that comes in contact with the waste and run-off that is from clean areas will be separated by the berm. If the cell has only received partial approval for waste placement, (i.e., downslope side of the cell), or the waste will be deposited against the downslope side of the temporary berm (if installed), the berm may be expanded up to four lifts to allow the waste to be placed in uniform lifts against the downslope side of the berm. The waste lift shall remain a minimum of two feet below the berm to contain run-off from the waste area. When there is a need for expanding waste placement into the clean areas of the cell, the temporary berm will be excavated, as shown in Figure D-6-1-1D, prior to waste placement on the upslope side of the temporary berm.

If the entire cell has been approved for waste filling, and the waste will not be deposited against the downslope side of the temporary berm, the temporary berm may only be one lift high (in the event a temporary berm is installed) as shown in Figure D-6-1-1C. The waste will be placed on the downslope side of the temporary berm. When there is a need for expanding waste placement into the clean areas of the cell, the temporary berm will be excavated, as shown in Figure D-6-1-1D, prior to waste placement on the upslope side of the temporary berm.

2.0 Sand Window Placement

The sand windows shall have the following specifications:

- Dimensions: Minimum of 16 feet by 16feet;
- Spacing: Maximum Grid Spacing of 100 feet;
- The edges of the sand windows shall be a minimum of 25 feet from the toe of cell side slopes;
- The edges of the sand windows shall be no closer than five feet from the toe of the chalk berm surrounding the vertical riser; and
- Sand Windows under the entrance/exit road near the bottom of the access road ramps will not be installed due to possible damage from turning and braking trucks.

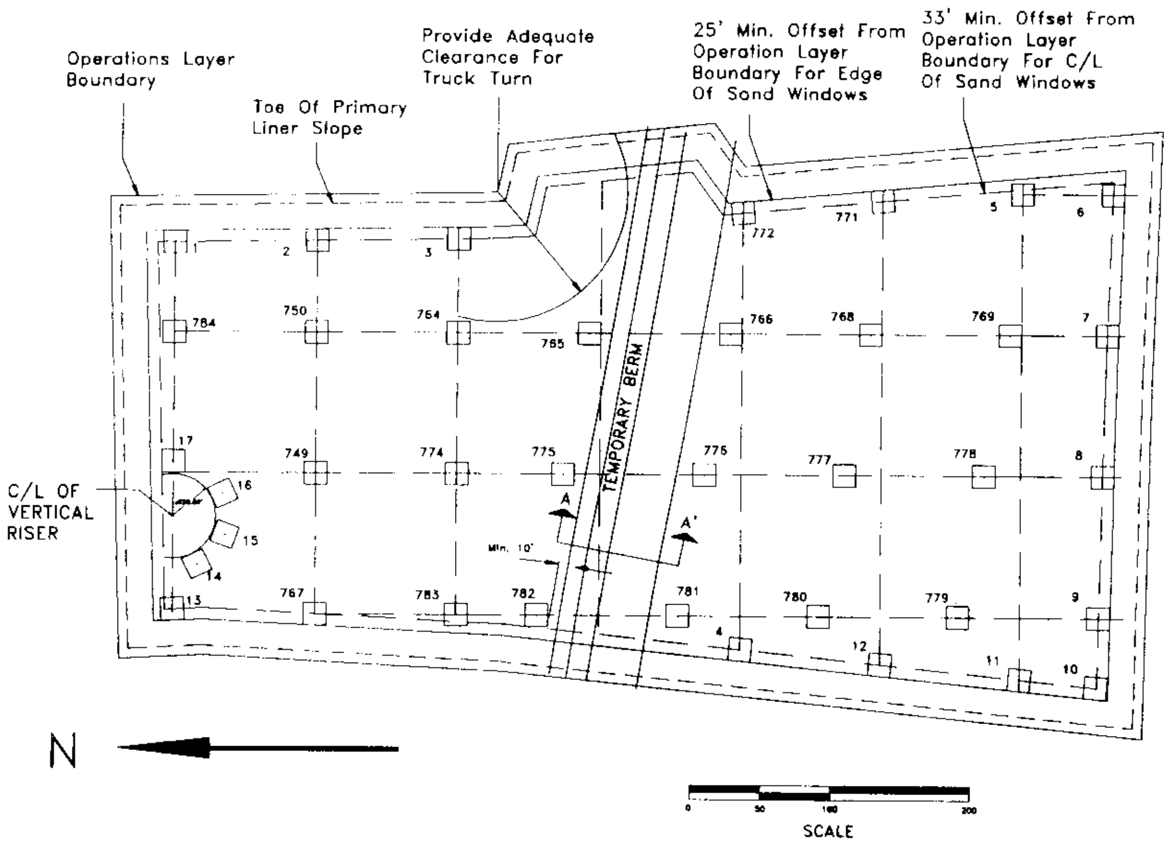
The sand windows shall be installed in the area of the waste placement, prior to agency approval of waste placement. Typical placement locations are shown on Figure D-6-1-1A in this Exhibit. Final locations may vary from cell to cell. Final locations will be noted in the as-built drawings in the CQA documentation. This will be submitted to the regulatory agency for review and approval prior to placement of waste.

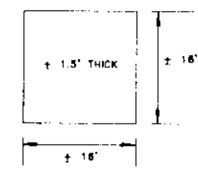
As waste placement expands, a new temporary berm may be relocated upslope. If the sand windows for clean areas have not been installed, the sand windows for that area will be installed and the CQA certified, prior to waste placement in the new area and partial removal of the old temporary berm. The CQA documentation and certification will be submitted to the regulatory agency for review and approval.

3.0 Temporary Berm

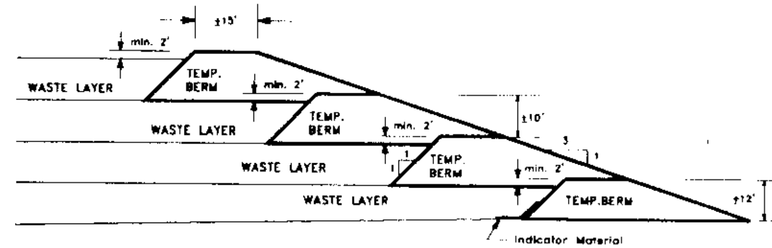
The temporary berm shall be constructed of chalk as shown in Figure D-6-1-1A, or Figure D-6-1-1C, with some modifications in the area of the entrance and exit roads to ensure truck access and containment of run-off. The top of the berm shall be approximately 15 feet in width. The upslope side of the berm shall have a slope of approximately three horizontal to one vertical, if waste is placed against the downslope side of the temporary berm. The height of each berm lift, if necessary, shall be approximately 10 feet, except the first berm shall be approximately 12 feet. Actual dimensions may vary from cell to cell. An indicator material (i.e., geotextile, geonet, etc.) shall be placed at the toe of the bottom berm on the downslope side to indicate the extent of the berm. Prior to expanding the waste placement in the area upslope of the temporary berm, the temporary berm shall be cut back to the indicator material, as shown in Figure D-6-1-1B, or Figure D-6-1-1D, whichever is applicable, to insure the removal of the bottom berm section. Material indicated as clean material, in Figure D-6-1-1B and Figure D-6-1-1D, may be utilized as clean cover or berm material. Material indicated as waste material, in Figure D-6-1-1B and Figure D-6-1-1D, shall be redeposited in the active cell as waste material.

[End of Exhibit A Text]





TYPICAL SAND WINDOW
N.T.S.



SECTION A – A'
TEMPORARY BERM
N.T.S.

SAND WINDOWS APPROXIMATE LOCATIONS

NUMBER	EAST	NORTH	NUMBER	EAST	NORTH	NUMBER	EAST	NORTH
1	8829.29	9772.04	14	8600.38	9755.08	772	8851.16	9372.04
2	8830.60	9672.04	15	8621.79	9735.80	774	8665.59	9572.04
3	8831.92	9572.04	16	8650.93	9734.34	775	8665.59	9498.27
4	8542.20	9372.04	17	8673.84	9772.04	776	8665.59	9398.27
5	8865.59	9172.04	749	8865.59	9672.04	777	8665.59	9298.27
6	8865.59	9107.58	750	8765.59	9672.04	778	8665.59	9198.27
7	8765.59	9111.07	764	8765.59	9572.04	779	8565.59	9216.31
8	8865.59	9113.66	765	8765.59	9480.25	780	8565.59	9316.31
9	8565.59	9116.31	766	8765.59	9380.25	781	8565.59	9416.31
10	8516.72	9117.82	767	8565.59	9672.04	782	8565.59	9516.31
11	8522.16	9172.04	768	8765.59	9280.25	783	8565.59	9572.04
12	8532.18	9272.04	769	8765.59	9180.25	784	8765.59	9772.04
13	8568.51	9772.04	771	8860.05	9272.04			

TYPICAL SAND WINDOW AND TEMPORARY BERM LOCATIONS

FIG. D-6-1-1A

REV.	DATE		CK. BY	APP. BY
B		Revised Temp. Berm Configuration	SJP	SJP
A		Revised Sand Window Locations	SJP	SJP

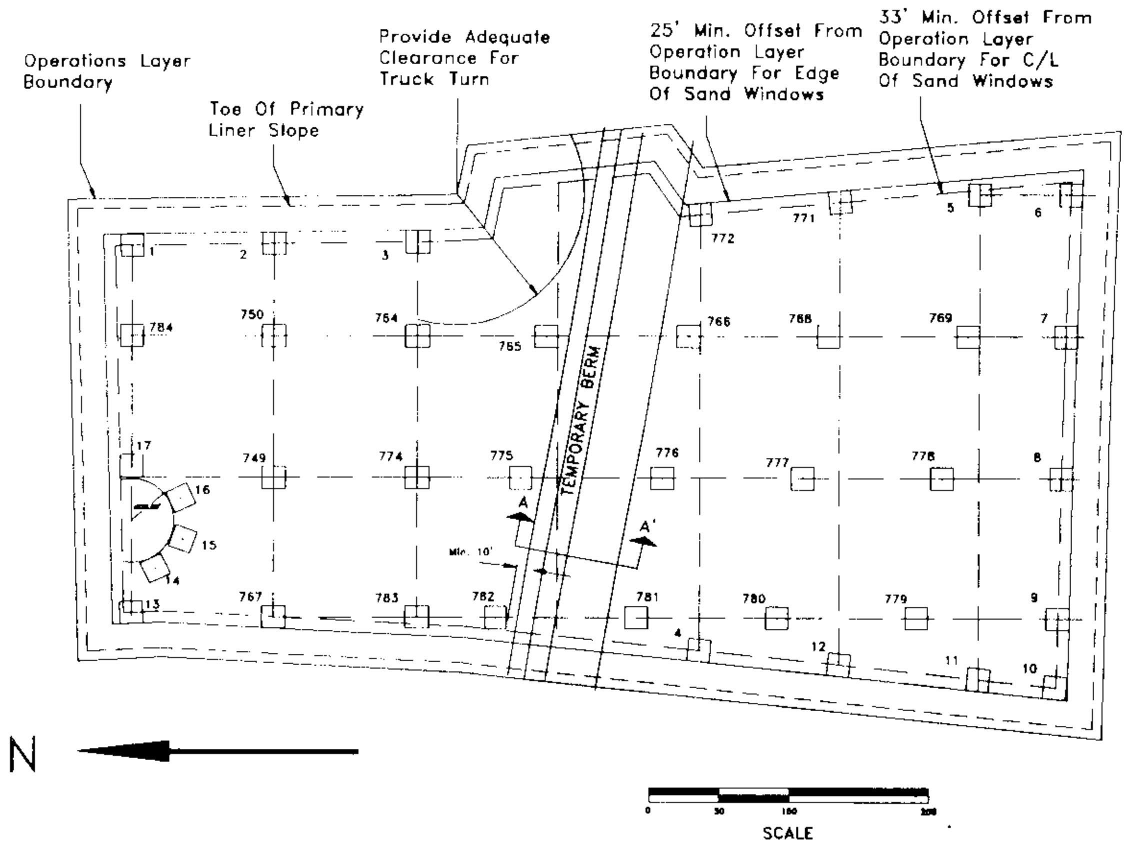
SCALE:
DATE: November 13, 1995
CAD File: 0200224A
DES BY: SJP
DRN BY: SJP

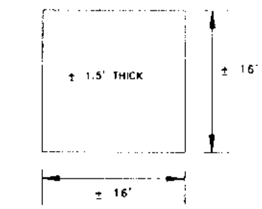
TYPICAL SAND WINDOW LOCATIONS

CWM EMELLE FACILITY
TRENCH 22, CELL 1

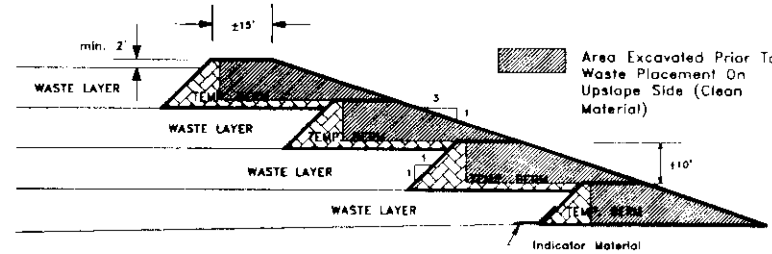
Chemical Waste Management, Inc.
P.O. Box 55
Emelle, Alabama 35459
(205) 652-9721

00-200-224A





TYPICAL SAND WINDOW
N.T.S.



SECTION A – A'
TEMPORARY BERM
N.T.S.

SAND WINDOWS APPROXIMATE LOCATIONS

NUMBER	EAST	NORTH
1	8829.29	9772.04
2	8830.60	9672.04
3	8831.92	9572.04
4	8542.20	9372.04
5	8865.59	9172.04
6	8865.59	9107.58
7	8765.59	9111.07
8	8865.59	9113.66
9	8565.59	9116.31
10	8516.72	9117.82
11	8522.16	9172.04
12	8532.18	9272.04
13	8568.51	9772.04

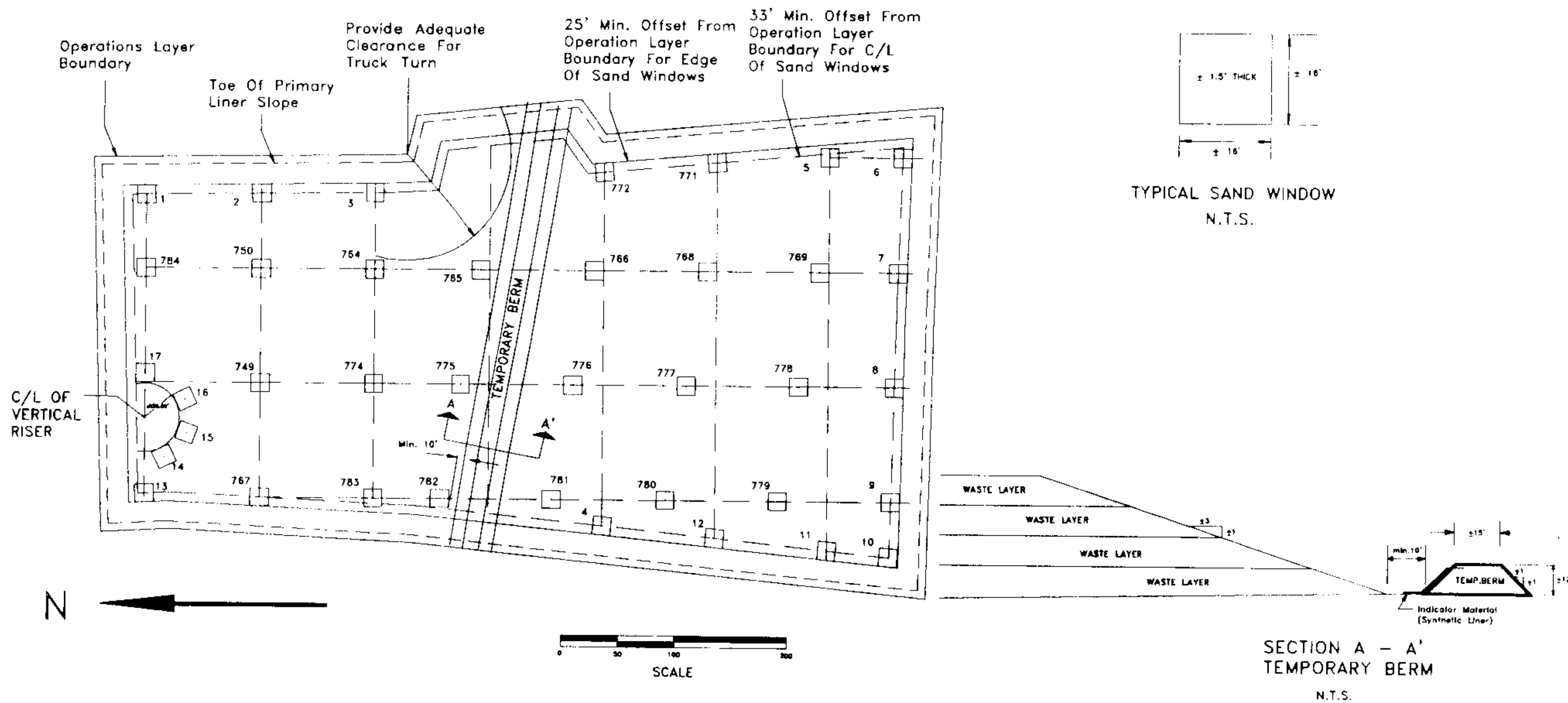
NUMBER	EAST	NORTH
14	8600.38	9755.08
15	8621.79	9735.80
16	8650.93	9734.34
17	8673.84	9772.04
749	8865.59	9672.04
750	8765.59	9672.04
764	8765.59	9572.04
765	8765.59	9480.25
766	8765.59	9380.25
767	8565.59	9672.04
768	8765.59	9280.25
769	8765.59	9180.25
771	8860.05	9272.04

NUMBER	EAST	NORTH
772	8851.16	9372.04
774	8665.59	9572.04
775	8665.59	9498.27
776	8665.59	9398.27
777	8665.59	9298.27
778	8665.59	9198.27
779	8565.59	9216.31
780	8565.59	9316.31
781	8565.59	9416.31
782	8565.59	9516.31
783	8565.59	9572.04
784	8765.59	9772.04

TEMPORARY BERM
CUTBACK

FIG. D-6-1-1B

Revised Berm Section
DATE: JUNE 21, 1996
TEMPORARY BERM CUTBACK
CWM EMELLE FACILITY
TRENCH 22, CELL 1
Chemical Waste Management, Inc.
00-200-224B



SAND WINDOWS APPROXIMATE LOCATIONS

NUMBER	EAST	NORTH
1	8829.29	9772.04
2	8830.60	9672.04
3	8831.92	9572.04
4	8542.20	9372.04
5	8865.59	9172.04
6	8865.59	9107.58
7	8765.59	9111.07
8	8865.59	9113.66
9	8565.59	9116.31
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13	8568.51	9772.04
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16	8650.93	9734.34
17	8673.84	9772.04
749	8865.59	9672.04
750	8765.59	9672.04
764	8765.59	9572.04
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766	8765.59	9380.25
767	8565.59	9672.04
768	8765.59	9280.25
769	8765.59	9180.25
771	8860.05	9272.04
772	8851.16	9372.04
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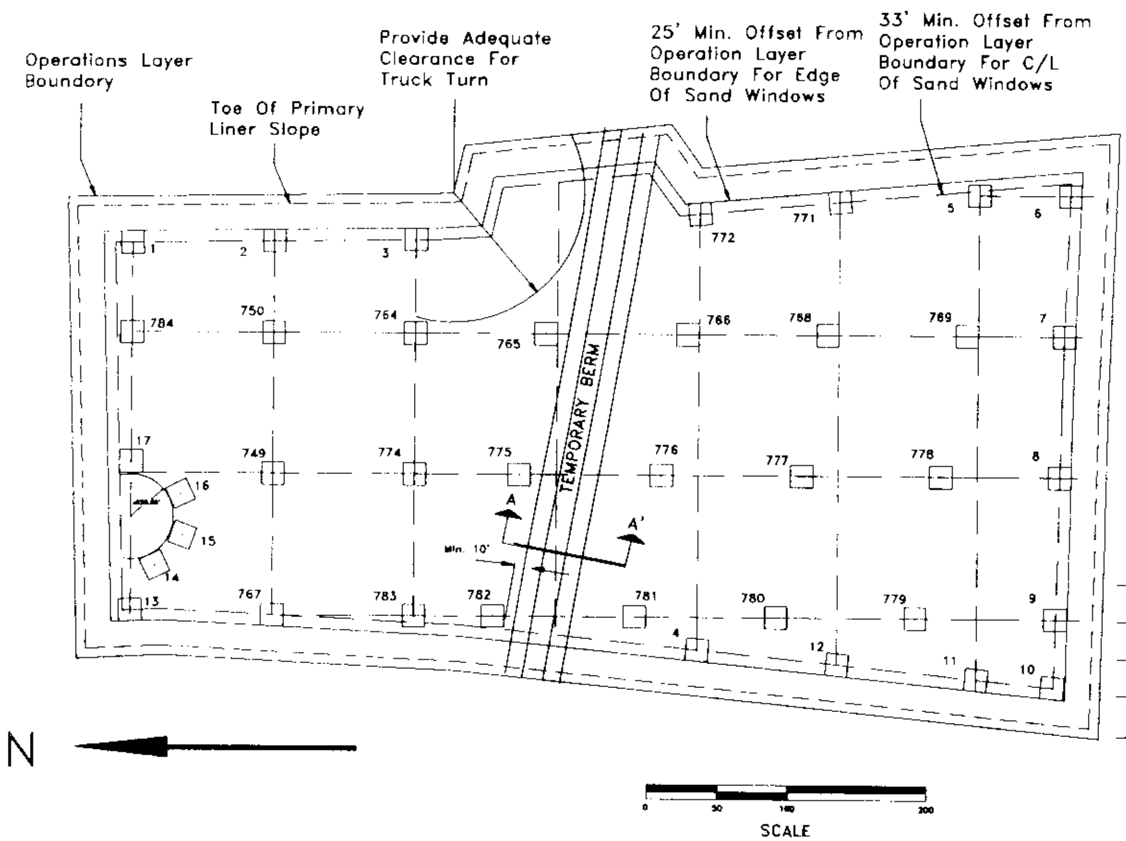
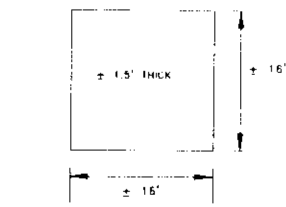
775	8665.59	9498.27
776	8665.59	9398.27
777	8665.59	9298.27
778	8665.59	9198.27
779	8565.59	9216.31
780	8565.59	9316.31
781	8565.59	9416.31
782	8565.59	9516.31
783	8565.59	9572.04
784	8765.59	9772.04

TYPICAL SAND WINDOW AND TEMPORARY BERM LOCATIONS

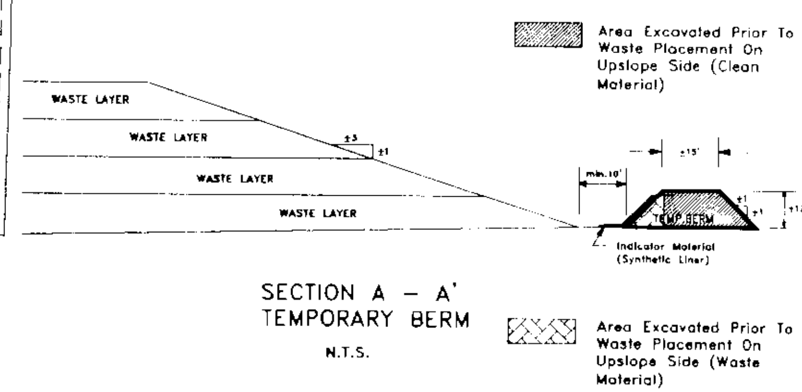
FIG. D-6-1-1C

DATE: February 21, 1997
CAD File: 0200224C
PROJECT: TYPICAL SAND WINDOW LOCATIONS
SHEET TITLE: CWM EMELLE FACILITY TRENCH 22, CELL 1
S.JP
S.JP
Chemical Waste Management, Inc.
P.O. Box 55
Emelle, Alabama 35459
(205) 652-9721
SHEET 1 OF 1
00-200-224C





TYPICAL SAND WINDOW
N.T.S.



SECTION A – A'
TEMPORARY BERM
N.T.S.

SAND WINDOWS APPROXIMATE LOCATIONS

NUMBER	EAST	NORTH
1	8829.29	9772.04
2	8830.60	9672.04
3	8831.92	9572.04
4	8542.20	9372.04
5	8865.59	9172.04
6	8865.59	9107.58
7	8765.59	9111.07
8	8865.59	9113.66
9	8565.59	9116.31
10	8516.72	9117.82
11	8522.16	9172.04
12	8532.18	9272.04
13	8568.51	9772.04

NUMBER	EAST	NORTH
14	8600.38	9755.08
15	8621.79	9735.80
16	8650.93	9734.34
17	8673.84	9772.04
749	8865.59	9672.04
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771	8860.05	9272.04

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776	8665.59	9398.27
777	8665.59	9298.27
778	8665.59	9198.27
779	8565.59	9216.31
780	8565.59	9316.31
781	8565.59	9416.31
782	8565.59	9516.31
783	8565.59	9572.04
784	8765.59	9772.04

TEMPORARY BERM CUTBACK

FIG. D-6-1-1D

DATE: February 21, 1997
CAD FILE: 0200224D
DES BY: SJP
DRN BY: SJP
PROJECT: TEMPORARY BERM CUTBACK
SHEET TITLE: CWM EMELLE FACILITY TRENCH 22, CELL 1
Chemical Waste Management, Inc
P.O. Box 55
Emelle, Alabama 35459
(205) 652-9721
00-200-224D

ATTACHMENT D-6-1-2

APPENDIX D-6-1

SECTION D-6

LANDFILL DISPOSAL SYSTEM DEVELOPMENT PLAN

Revision No.
5.0

ATTACHMENT D-6-1-2

LANDFILL DISPOSAL SYSTEM DEVELOPMENT PLAN

TABLE OF CONTENTS

ATTACHMENT D-6-1-2

LANDFILL DISPOSAL SYSTEM DEVELOPMENT PLAN

LIST OF EXHIBITS

EXHIBITS:

ATTACHMENT D-6-1-2

LANDFILL DISPOSAL SYSTEM DEVELOPMENT PLAN

The Landfill Disposal System Development Plan describes the subdivision of each trench into cells and provides the estimated waste disposal volume for each trench. It describes the construction sequence for a cell, the typical filling sequence for the trenches, and the closure cover construction.

D-6-1-2-1 General Design Criteria

1. All land area upon which waste will be placed shall be lined with a top geomembrane liner and a bottom composite liner with both synthetic and soil components.
2. Landfill cells shall be constructed with a pressure relief system to eliminate inward hydrostatic pressure beneath the lower most geomembrane liner.
3. Total design disposal volumes (wastes and inter-lift fill) are presented below in Subsection D-6-1-2-2 of this attachment.
4. Modification of existing topography (such as flattening of hilltops and filling of drainage ways) will be utilized to allow relatively standardized landfill design.
5. Landfill trenches will be divided into cells which will be constructed, operated, and closed in specified sequence.
6. Waste landfilled above grade shall be placed within the confines of the landfill in a controlled manner to prevent run-off of potentially contaminated rainfall and wind dispersal of particulate matter, as required by 40 CFR 264.301(h) and (j) and ADEM Administrative Code 335-14-5-.14(2)(d) and (f).

D-6-1-2-2 System Development

The location of the landfill development area is shown on the Landfill Design Drawings in Appendix D-6-2.

The landfill disposal system will consist of two trenches, designated as Trench 22 and Trench 23, consisting of four and six individual landfill cells each respectively. Each landfill cell of a trench is separated from the adjacent cells by an intermediate berm. This berm precludes flow of leachate between the cells. This approach allows one cell or one above grade module (2 to 4 cells) to be operated while adjacent cells, which are under construction or awaiting placement of waste, are maintained in a "clean" state.

The approximate disposal volumes (waste and inter-lift fill) of the trenches is listed below:

Trench 22 Total:	5,260,000 cu. yd.
Trench 23 Total:	14,710,000 cu. yd.

Disposal volume is defined as the volume within each trench available for disposal of waste and inter-lift fill. This volume is exclusive of the volume occupied by intermediate and above grade berms, haul roads, closure cover, leachate collection systems, and chalk liner.

D-6-1-2-3 Trench Construction and Operation Sequence

The general operation sequence of Trench 22 cells in the below grade portions and the above grade module are illustrated on the Landfill Design Drawings in Appendix D-6-2 and outlined below.

1. Seal all groundwater wells within the perimeter of the landfill using the procedures described in the attached Well Sealing Specifications provided in Supplement A to this attachment.
2. Remove all topsoil from the construction area and stockpile for later use. Construct any downstream sedimentation basins required.
3. Construct the initial cell of the trench and install the pressure relief, secondary and primary liners, and leachate collection systems.
4. Begin placement of waste in the initial cell and begin construction of the second cell of the trench.
5. While waste is being placed in the below grade portion of the active initial cell, complete construction of the second cell and install the liner and leachate collection systems, including the initial protective soil layer on the base and partially up the slopes and the temporary geosynthetic covering the rest of the slopes.
6. Continue waste placement below grade in the active initial cell until the below grade portion is nearly filled with waste. Add successive fill to the intermediate berm as the waste level increases.
7. Once the below grade portion of the first cell is nearly full, begin placement of the waste in the second cell. Cap the completed first cell with an interim cover.
8. Continue waste placement in the below grade portion of the second cell, adding successive fill to the intermediate berm as the waste level increases.
9. Waste placement will continue following one of the sequences described below depending upon amount of waste being received at the time.

Sequence A

1. When the below-grade portion of the second cell is nearly filled, remove the interim cover from the first cell and dispose of waste in the above grade portion of the first cell; place interim cover on the second cell and begin construction of the third cell. The above-grade areas where one or more cells are being operated will be referred to as an "Above Grade Modules." (AGM)
2. Finalize construction of the third cell.
3. When the AGM in the first cell is nearly full, begin waste placement of selected wastes in the third, lined cell. Place interim cover on the AGM in the first cell.
4. When the below-grade portion of the third cell is nearly filled, remove the interim cover from the second cell and the AGM in the first cell. Dispose of waste in the above grade portion of the second cell; place interim cover on the AGM in the third cell.
5. Finalize construction of the fourth cell.
6. When the AGM in the second cell is nearly full, begin waste placement of selected wastes in the fourth, lined cell.
7. Complete above grade waste placement in the AGM, while filling the below grade portion of the fourth cell.
8. Continue in this manner until all cells and trenches are completed.
9. Proceed with closure activities in accordance with the ADEM Approved Closure Plan when the last load of waste is placed in the landfill.

Sequence B

1. When the below-grade portion of the second cell is nearly filled, begin waste disposal in the AGM of the first or second cell to an interim elevation determined from slope stability analyses performed prior to waste disposal above-grade; interim cover to be removed prior to continued waste disposal; begin construction of the third cell below-grade.
2. Continue construction of the third cell below-grade.
3. As the AGM in the first and second cells reaches the interim elevation, begin disposal of selected waste in the completed third cell below-grade. Place interim cover over AGM 1 and 2.
4. Continue placing waste into the above-grade portion of the third cell. Begin construction of the fourth cell below grade.
5. Finalize the construction of the fourth cell.

6. When the AGM of the third cell is to an interim elevation determined from slope stability analyses performed prior to waste disposal above-grade, begin disposal of select waste in Cell 4. Place an interim cover over the AGM of the third cell.
7. Continue placing waste into the above-grade portion of the fourth cell.
8. At any point in this sequence, when a cell adjacent to an AGM is at-grade or at the interim elevation determined by slope stability analysis, remove the interim cover on the AGM and continue waste disposal to the final waste grade in the AGM.

Sequence C

Or other filling sequence that would not alter the footprint, design or the closure requirements provided a certified stability evaluation has been performed.

The general operation sequence of Trench 23 cells in the below grade portions and the above grade module are illustrated on the Landfill Design Drawings in Appendix D-6-2 and outlined below.

1. Seal all groundwater wells within the perimeter of the landfill using the procedures described in the attached Well Sealing Specifications provided in Supplement A to this attachment.
2. Remove all topsoil from the construction area and stockpile for later use. Construct any downstream sedimentation basins required.
3. Construct the initial cell of the trench and install the pressure relief, secondary and primary liners, and leachate collection systems.
4. Begin placement of waste in the initial cell and begin construction of the second cell of the trench.
5. While waste is being placed in the below grade portion of the active initial cell, complete construction of the second cell and install the liner and leachate collection systems, including the initial protective soil layer on the base and partially up the slopes and the temporary geosynthetic covering the rest of the slopes.
6. Continue waste placement below grade in the active initial cell until the below grade portion is nearly filled with waste. Add successive fill to the intermediate berm as the waste level increases.
7. Once the below grade portion of the first cell is nearly full, begin placement of the waste in the second cell. Cap the completed first cell with an interim cover.

8. Continue waste placement in the below grade portion of the second cell, adding successive fill to the intermediate berm as the waste level increases. Begin and finalize construction of the third cell.

9. When the below-grade portion of the second cell is nearly filled, cap the completed second cell with an interim cover; and dispose of waste in the third cell, adding successive fill to the intermediate berm as the waste level increases. Begin and finalize construction of the fourth cell.

10. When the below-grade portion of the third cell is nearly filled, cap the completed third cell with an interim cover; and dispose of waste in the fourth cell, adding successive fill to the intermediate berm as the waste level increases.

11. When the below grade portion of the fourth cell is nearly filled, remove the interim cover from the first three cells and begin dispose of waste in an AGM of the first four cells. Begin and finalize construction of the fifth cell.

12. As the AGM in the first four cells reaches the interim maximum elevation, begin disposal of selected waste in the completed fifth cell below-grade. Place interim cover over AGM in the first four cells; and begin construction of the sixth cell.

13. Finalize construction of the sixth cell.

14. When the below-grade portion of the fifth cell is nearly filled, cap the completed cell with an interim cover. Begin waste placement of selected wastes in the sixth, lined cell.

15. When the below-grade portion of the sixth cell is nearly filled, remove the interim cover from the fifth cell; dispose of waste in the AGM of the fifth and sixth cells until the maximum elevation in AGM 5 and 6 matches that in the AGM of first four cells.

16. Remove the interim cover from the AGM of the first four cells and dispose of waste in the AGM over all six cells.

17. Continue in this manner until all cells and trenches are completed.

18. Proceed with closure activities in accordance with the ADEM Approved Closure Plan when the last load of waste is placed in the landfill.

Below grade waste placement is temporarily suspended when the waste level in the cell is within two (2) vertical feet of the top of the perimeter containment berm for the below grade portion of the cell, as shown on the drawings. Sufficient volume will remain in the cell to ensure that run-off will be contained inside the cell. After ending below grade waste placement in a cell, all or part of the above grade modules must be surrounded by above grade waste containment berms constructed to contain run-off during additional waste placement to higher elevations.

Construction of waste containment berms continues until the final desired elevation is reached. When above grade waste is two (2) feet below the final containment berm, waste placement in the above grade module will cease, and a chalk crown will be constructed to bring the cover to grade.

Once the chalk fill is crowned to the desired elevations, a chalk liner is added. The chalk liner consists of a two-foot minimum layer of compacted chalk graded for the closure cover geomembrane liner. The liner is then installed on the prepared chalk surface. A transmissive geosynthetic layer is then installed on the geomembrane liner, followed by a minimum two-foot thick soil layer. Drawings showing the cover design are provided in Appendix D-6-2, Landfill Design Drawings and specifications are provided in Attachment D-6-1-4, Specifications for Construction Materials.

The operations sequence for waste placement must maintain all land disposal activities on double lined surfaces and within run-off containment berms. This approach is to minimize the area open for gathering of precipitation.

D-6-1-2-4 Cell Construction Sequence

Each cell will generally be constructed in the following sequence:

1. Excavate the slopes and floor to the general lines and grades of the final configuration. Over-excavate slightly to allow placement of the required slope and floor treatments;
2. Install a pressure relief drainage system across the floor of the cell;
3. Install a composite clay/synthetic secondary liner and a secondary leachate collection system;
4. Install a primary liner and a primary leachate collection system on both the floor and slopes of the cell;
5. Install a loose soil protective layer including sand windows or sand rows over the primary leachate collection system on the floor and partially up the side slopes; and
6. Install a temporary protective geosynthetic on the side slopes of the cell down to the top of the protective soil layer on the side slopes.

D-6-1-2-5 Closure Cover

Each land disposal trench will be closed when its above grade module is completed. Generally, closure of the cell(s) entails placement of a soil cap above the final waste surface, placement of low permeability fill above the cell(s), placement of a geomembrane liner, installation of a drainage layer, and placement of a growth media layer.

[End of Attachment D-6-1-2 Text]

ATTACHMENT D-6-1-2

LANDFILL DISPOSAL SYSTEM DEVELOPMENT PLAN

EXHIBIT A

TEST WELL SEALING SPECIFICATIONS

TEST WELL SEALING SPECIFICATIONS

1. Portland type cement grout or other grouting products approved by the owner and engineer shall be used.
2. Grout products used shall consist of pre-measured, pre-packaged materials supplied by the manufacturer requiring only the addition of water.
3. Potable water shall be used in mixing grout. The minimum water necessary for proper installation shall be used.
4. Cement grout to water ratio shall be approved by the owner and engineer.
5. The depth and diameter of the hole to be grouted shall be measured and recorded.
6. The required volume of grout to fill the bore hole shall be computed and recorded.
7. The grout hose shall be extended to the bottom of the bore hole.
8. To minimize the occurrence of entrapped air or other voids, the grout hose shall be raised slowly, and the end shall be continuously embedded in the grout.
9. The actual grout volume used to seal bore hole shall be computed and recorded.
10. The grout will be allowed to stand for 24 hours.
11. After 24 hours, grout settlement shall be measured and recorded.
12. The remaining void will be sealed and capped with concrete or other materials approved by owner and engineer.
13. All appropriate information shall be recorded.

[End of Exhibit A]

ATTACHMENT D-6-1-3

APPENDIX D-6-1

SECTION D-6

LANDFILL DESIGN

Revision No.
5.0

ATTACHMENT D-6-1-3

LANDFILL DESIGN

TABLE OF CONTENTS

ATTACHMENT D-6-1-3

LANDFILL DESIGN

Attachment D-6-1-3, Landfill Design, describes the design of each component of the landfill. The descriptions are organized by major components, including excavation, structural fill, pressure relief system, secondary system, and primary system.

D-6-1-3-1 Landfill System Excavation

Each cell of a given trench is constructed as an independent unit. The topsoil and thin layer of surficial chalk is first removed from the cell area and may be stockpiled for later use as closure growth media. The cell is then excavated to the general lines and grades designed. The cell is over-excavated slightly to accommodate the placement of the slope and bottom treatments required for the pressure relief, secondary, and primary systems. The material excavated during cell construction may be used for a variety of purposes including Facility-wide construction, cell construction, and cell closure grading fill.

The individual cells of Trench 22 are nominally 600 feet by 900 feet in plan dimension, while the individual cells of Trench 23 are nominally 450 to 750 feet by 950 feet in plan dimension. Trenches 21 and 22 comprised of four cells each, are rectangular shaped and nominally 2,400 feet in length and 900 feet wide. Trench 23 is comprised of six cells, is square in shape, and is 1,900 feet in length and width. The excavated configurations of the cells for Trench 22 are shown on Drawing No. 00-200-210, while those for Trench 23 are shown on Drawing 00-300-003.

The initial lined and intermediate berm slopes for trenches other than Trench 23 are designed to be 2.5 horizontal: 1.0 vertical and will be raised at 3.0 horizontal: 1.0 vertical as the waste is raised. The perimeter above-grade waste containment berms for trenches other than Trench 23 are initially raised at 4.0 horizontal: 1.0 vertical, gradually transitioning to a 10.0 horizontal: 1.0 vertical slope. For Trench 23, the lined and intermediate berm slopes are designed to be 4.0 horizontal: 1.0 vertical. The perimeter above-grade waste containment berms for Trench 23 are initially raised at 4.0 horizontal: 1.0 vertical, transitioning to a 20.0 horizontal: 1.0 vertical near the top of the above grade module.

D-6-1-3-2 Structural Fill

The over-excavated areas of each cell will require backfilling. Portions of these areas will be backfilled as part of the secondary and primary systems. These portions will be constructed as low permeability compacted chalk layers. The remaining portions of these areas will be constructed as structural backfill. This fill will be constructed using soils from the Facility including surficial clays and/or chalk. Fill will be placed and compacted so that it is capable of bearing the loads imposed by construction, operation, and closure of the cells and trenches without affecting the integrity of the overlying components of the double liner system.

D-6-1-3-3 Pressure Relief System

D-6-1-3-3a Overview

Each landfill cell will be underlain by a hydrostatic pressure relief drainage system. The system will function to lower the groundwater table to prevent the build-up of hydrostatic pressure beneath the landfill area and against the overlying liners and leachate collection systems.

The pressure relief system (PRS) will cover the entire floor of each cell and extend beneath the slopes around the perimeter of each trench. This system will intercept the natural groundwater beneath each cell and lower the groundwater level within the natural chalk surrounding the trenches. Plan views of the pressure relief system for Trench 22 are shown on Drawing No. 00-200-210 in Appendix D-6-2 while those for Trench 23 are shown on Drawing No. 00-300-003.

The floor of each cell of Trench 22 will be graded at a nominal 4% slope radially upward and outward from a sump located near one corner of the cell. The floor of each cell of Trench 23 will be graded upward and outward at a nominal 2% slope from a central corridor. The central corridor will be graded upward at a nominal slope of 1% upward from a sump located near the edge of the cell. The sump locations are designated on the drawings specified above. The floor of each cell and to the toe of the intermediate berm slope will be covered with a blanket drain.

D-6-1-3-3b Blanket Drain

The blanket drain will be continuous across the entire floor of each cell and will be nominally one (1) foot thick for Trench 22. The blanket drain for Trench 23 will also be continuous across the floor of each cell, but will be comprised of a geocomposite blanket drain. Specifications for granular material and geocomposite blanket drain are provided in Attachment D-6-1-4, Specifications for Construction Materials, and are further discussed in this subsection.

D-6-1-3-3b(1) Blanket Drain Granular Material/Geocomposite

The blanket drain will be placed in direct contact with either natural or compacted chalk. The granular material specified for the blanket drain is a natural filter for the natural compacted chalk and will function without clogging. The geosynthetic for the geocomposite will function as the filter for the compacted chalk and will function without clogging.

The blanket drain will be overlaid by the secondary system which is described in a subsequent subsection within this attachment. A portion of the blanket drain beneath the Trench 22 secondary system sump will be blocked out and replaced by a compacted chalk layer. The block out is necessary to maintain the required three (3) feet of compacted chalk beneath the secondary geomembrane. The blockout is less than 1% of the total blanket drain and will not affect drainage through the drainage layer. This area of the blanket drain is designated on the drawings in Appendix D-6-2.

The blanket drain beneath the toe of the side slopes around the perimeter of the trench will act to draw the groundwater from the surrounding chalk. The drain is designed and will function to draw this water down so that it does not exit the chalk on the slopes. This will eliminate the potential for hydrostatic pressure build-up behind the slope treatments applied as a part of the secondary and primary lining and leachate collection systems.

D-6-1-3-3b(2) Blanket Drain Geotextile

The coarse granular material to be used within the Trench 22 PRS sump will be covered with a geotextile filter prior to granular material placement. This fabric will serve a two-fold purpose of (1) filtration and (2) separation between the sump coarse granular material and the overlying blanket drain. Specifications for this geotextile filter are included in Attachment D-6-1-4. Since the geocomposite blanket drain for Trench 23 already incorporates a geotextile heat bonded to the geonet, a supplementary geotextile filter/separator will not be needed for Trench 23.

D-6-1-3-3c Sump and Appurtenances

The pressure relief system for Trench 22 will drain to a single sump located in a corner of each cell. The pressure relief system for Trench 23 will drain to a single sump located along the edge of each cell. The sumps will be located at the low points of the cells. The Trench 22 sump will have dimensions of 6 feet by 6 feet by 2 feet deep, with 1.0 horizontal to 1.0 vertical side slopes. The Trench 23 sump will have dimensions of 12 feet by 9 feet by 4.7 feet deep, with 2.0 horizontal to 1.0 vertical side slopes. The sump will be filled with coarse granular material as specified in Attachment D-6-1-4. A plan view of the sump is shown on Drawing Nos. 00-200-210 and 00-300-003. Details of the Trench 22 sumps are shown on Drawing Nos. 00-200-223 and 00-200-224. Details of the Trench 23 sumps are shown on Drawing No. 00-300-008.

Groundwater collecting in the pressure relief system will be evacuated by means of a pump which will be lowered through a pipe into the sump. The minimum size pipe for Trench 22 and Trench 23 will be a nominal 12 inch diameter SDR 11 and 18 inch diameter SDR 9 fusion welded HDPE pipe respectively, embedded in the side slope of each cell, with a minimum of three (3) feet of chalk between the pipe and the secondary geomembrane liner. The portion of the pipe within the Trench 22 sump will be perforated with one-inch diameter holes while that within Trench 23 sump will be perforated with 5/8-inch diameter holes. The Trench 22 sump pipe will be wrapped with geosynthetics so as to allow the inflow of liquid and prevent the holes from being blocked by coarse granular material. Because of the smaller diameter holes, Trench 23 sump pipes will not require wrapping with geosynthetics. Details of the pipe hole configuration for Trench 22 and Trench 23 are shown on Drawing Nos. 00-200-224 and 00-300-008 respectively.

A pumping system will be employed to allow the liquid level to be easily maintained below the overlying secondary system. Cross sections and details of the pressure relief system pipe are shown on Drawing Nos. 00-200-223, 00-200-224, and 00-300-008.

The outlet of each pipe will be protected by a concrete slab located at the crest of the landfill. The geosynthetic layers of the Trench 22 secondary and primary systems, which are described in subsequent sections, will be anchored around the outlet of the pipe on a concrete pad with stainless steel plates and anchor bolts as shown on Drawing No. 00-200-224. The geosynthetic layers of the Trench 23 secondary and primary systems, which are described in subsequent sections, will be provided with boots around the outlet of the pipe.

The pressure relief riser pipe system will extend upward from the pressure relief sump parallel to the secondary leachate collection pipe and exit the cell without penetrating the geomembrane liners within the landfill operating area.

D-6-1-3-4 Secondary System

D-6-1-3-4a Overview

The secondary system will consist of two major components: (1) a liner, and (2) a leachate collection system. Both of these components will cover the entire floor and side slopes of each cell of the trenches.

The floor of each cell of Trench 22 will be graded at a nominal 4% slope radially from a sump located near the corner. The floor of each cell of Trench 23 will be graded upward and outward at a nominal 2% slope from a central corridor. The central corridor will be graded upward at a nominal slope of 1% upward from a sump located near the edge of the cell. The side slopes of Trench 22 will nominally be 2.5 horizontal : 1.0 vertical from the crest to a cross-slope haul road and continue from the haul road downward to the floor. The side slopes of Trench 23 will nominally be 4.0 horizontal : 1.0 vertical from the crest to the floor, with the haul roads tacked-on above the side slopes. The haul roads traverse the side slopes from the crest to the top of the intermediate berms. A plan view illustrating these features of the secondary system is shown on Drawing Nos. 00-200-210 and 00-300-005. Specifications for soil and geosynthetic components are provided in Attachment D-6-1-4, and specifications for other components are provided on Drawing No. 00-200-227 in Appendix D-6-2.

D-6-1-3-4b Secondary Liner

The secondary liner system will be a two-component unit covering the floor and side slopes of each cell. The two components will consist of: (1) a lower compacted chalk layer, and (2) an upper geomembrane.

D-6-1-3-4b(1) Secondary Compacted Chalk Layer

The lower component of the liner, the compacted chalk layer, will be a minimum of three (3) feet thick across the entire floor and side slopes of each cell. This layer will be constructed using a soil from the Facility (chalk), and will be placed directly on the underlying pressure relief blanket drain across the floor and the structural fill chalk surface on the slopes. The pressure relief blanket drain is adequately filtered naturally, or with a geotextile filter. The permeability of the chalk layer is $1x10^{-7}$ cm/sec or less as specified in Attachment D-6-1-4, Specifications for Construction Materials.

D-6-1-3-4b(2) Secondary Geomembrane Liner

The secondary geomembrane liner will be installed immediately above and in direct contact with the secondary compacted chalk layer. The liner will extend up the side slopes and anchor in the haul roads (except it will pass under the tack-on haul roads for Trench 23) as shown on Drawing No. 002-200-225. The liner will continue up the slopes and be anchored again at the crest. The secondary geomembrane liner will also extend over the intermediate berms to be joined with the secondary geomembrane liner of the adjacent cells when constructed. Anchoring and connection details are shown on Drawing No. 00-200-225 and 00-300-007. The haul road and crest anchoring systems will adequately restrain the geomembrane liner.

D-6-1-3-4c Secondary Leachate Collection System

The secondary leachate collection system will be capable of detecting, collecting, and removing liquid that may enter it throughout the active life and post-closure care period of each cell. The materials of construction for the system will be chemically resistant to the waste and the leachate, if any, that escapes from the primary leachate collection system. The materials installed will also be resilient to the stresses anticipated during construction and operation and throughout the post-closure care period.

The secondary leachate collection system will cover the sides and bottom of the below grade portion of the disposal unit, as described herein. The details of each of the components of this system will be described in the following sections.

D-6-1-3-4c(1) Granular Material

The secondary leachate collection system on the floor of each cell of Trench 22 will consist of a minimum one-foot thick layer of granular material placed directly above the secondary geomembrane liner. Specifications for the granular material to be used are provided in Attachment D-6-1-4, Specifications for Construction Materials.

The granular material is selected to be mechanically compatible with the underlying secondary geomembrane liner and should not detrimentally affect the liner. The permeability of this granular material is a minimum of $1x10^{-2}$ cm/sec as specified in Attachment D-6-1-4, Specifications for Construction Materials. This granular material is a natural filter for the overlying chalk, although a geotextile filter fabric will also overlay the granular material to provide additional filtration capacity.

For Trench 23, the secondary leachate collection system on the floor of each cell will consist of a transmissive geosynthetic layer identical in specification to that used on the slopes of both Trench 22 and Trench 23.

D-6-1-3-4c(2) Transmissive Geocomposite

The secondary leachate collection system on the slopes of each cell of Trench 22, as well as on the slopes and floor of Trench 23 will consist of a transmissive geosynthetic layer. This layer will lie directly between the secondary geomembrane liner and the primary geomembrane liner on the slopes and on the floor (Trench 23 only), between the geomembrane layer and the primary clay liner. The transmissive layer may be a discrete material or materials, or may be combined with either the secondary geomembrane liner or primary geomembrane liner, or both, as a single product. The geosynthetic will extend upslope from the floor, across the haul roads, and into the anchor trenches at the crest. For Trench 22, the transmissive geosynthetic will transmit leachate that may be collected on the slopes of each cell to the granular portion of the system on the floor. The transmissive geosynthetic will tie into the Trench 22 leachate collection system granular material on the floor as shown on Drawing No. 00-200-225.

The application of a transmissive geosynthetic layer requires transmission of a liquid in the plane of the geosynthetic itself. The specified geosynthetic must have a minimum transmissivity of $3x10^{-5}$ m^2/sec as specified in Attachment D-6-1-4, Specifications for Construction Materials.

D-6-1-3-4d Flow Characteristics

Acting as a continuous unit, the transmissive geosynthetic layer and, in Trench 22, the granular material of each cell will conduct liquid that may reach the secondary leachate collection system to the sump.

D-6-1-3-4e Sump and Appurtenances

The secondary leachate collection sump will be located near the corner or edge of each cell, and the entire floor will grade to it. The sump dimensions for Trench 22 cells will be approximately 10 feet by 9 feet on the floor of the cell and approximately 2 feet deep below the rim. The sump dimensions for Trench 23 cells will be approximately 20 feet by 6 feet on the floor of the cell and approximately 4 feet deep below the rim. The side slope within the sumps will be 2 horizontal: 1 vertical.

The Trench 22 secondary geomembrane liner within the sump will be overlaid by a geotextile cushion. The secondary sump itself will be filled with course granular material. The geotextile cushion provides a protective layer between the geomembrane and the coarse granular material. Since the Trench 23 secondary liner geomembrane will be overlain by the geosynthetic drainage layer, a geotextile cushion will not be necessary between the sump granular material and the geomembrane. The secondary liner in the upslope riser trench will be protected from the upslope pipe by an HDPE rub sheet.

Liquid will be removed from the secondary leachate collection system by means of a pumping system. The pump will access the collection system of each cell through a pipe embedded in the side slope above the sump. The minimum size pipe will be a nominal 12-inch diameter fusion welded SDR 11 HDPE pipe for Trench 22 and a nominal 18-inch diameter fusion welded SDR 9 HDPE pipe for Trench 23. The portion of the Trench 22 pipe within the sump will be perforated and wrapped with transmissive geosynthetic so as to allow the inflow of liquid and prevent coarse granular material blockage. Because of the smaller diameter holes, Trench 23 sump pipes will not require wrapping with geosynthetics. A transmissive geosynthetic layer will also be installed across the sump and 10 feet beyond the sump for Trench 22. Since the transmissive geocomposite layer will be continuous across the cell side slopes and floors for Trench 23, this feature will not be necessary. Cross-sections and details of the secondary leachate collection system pipe are shown on Drawing Nos. 00-200-224 and 00-300-008. Details for the pipe perforations are also shown on Drawing Nos. 00-200-224 and 00-300-008.

The outlet of the pipe at the crest of the slope will be protected by a concrete slab. The geosynthetic layers of the secondary system for Trench 22 will be anchored around the outlet of the pipe on a concrete pad with stainless steel plates and anchor bolts. Details of these structures are shown on Drawing No. 00-200-224. The geosynthetic layers of the Trench 23 primary systems, which are described in subsequent sections, will be provided with boots around the outlet of the pipe.

This installation technique provides for construction of the secondary and primary systems without a protrusion through the geomembrane layers within the operating portion of the landfill.

D-6-1-3-5 Primary System

D-6-1-3-5a Overview

The primary system will consist of two major components: (1) a liner, and (2) a leachate collection system. Both of these components cover the entire floor and side slopes of each cell of the trenches.

The floor of each Trench 22 cell will be graded with a compound slope extending radially from a sump located near the corner. Within approximately a 300 to 350-foot radius of the sump, the floor will slope at nominally 2%. Beyond this "change-in-grade" radius, the floor will slope at nominally 4%. The floor of each cell of Trench 23 will be graded upward and outward at a nominal 2% slope from a central corridor. The central corridor will be graded upward at a nominal slope of 1% upward from a sump located near the edge of the cell.

The side slopes of Trench 22 will nominally be 2.5 horizontal : 1.0 vertical from the crest to a cross-slope haul road and continue from the haul road downward to the floor. The haul roads traverse the side slopes from the crest to the top of the intermediate berms. The side slopes of Trench 23 will nominally be 4.0 horizontal : 1.0 vertical from the crest to the floor, with the haul roads tacked-on above the side slopes.

A plan view illustrating these features of the primary system is shown on Drawing Nos. 00-200-214 and 00-300-004. Specifications for soil and geosynthetic components are provided in Attachment D-6-1-4, and Specifications for Construction Materials, while specifications for other components are provided on Drawing Nos. 00-200-227, 00-300-009, 00-300-010, and 00-300-011 in Appendix D-6-2.

D-6-1-3-5b Primary Liner

The primary system liner will be a two-component unit covering the floor of each Trench 22 cell and Trench 23 cell and side slopes but only a single-component unit covering the Trench 22 side slopes. The two components covering the floor of each Trench 22 cell will consist of: (1) a lower compacted chalk layer, and (2) an upper geomembrane. The single component covering the side slopes of each Trench 22 cell will be the geomembrane. The two components covering the floor and side slope of each Trench 23 cell will consist of: (1) a lower geosynthetic clay liner, and (2) an upper geomembrane.

D-6-1-3-5b(1) Primary Compacted Chalk Layer

The lower component of the Trench 22 liner, the compacted chalk layer, will be nominally 1.5 feet thick across the floor of each cell in the area which is graded at a 4% slope. This same layer will vary from the nominal 1.5-foot thickness at the "change-in-grade" radius to approximately 7.5 feet at the sump. This thickness will accommodate the desired primary leachate collection sump depth as described in other subsections of this section.

The compacted chalk liner layer will be constructed using soils from the Facility and will be placed on top of the geotextile filter fabric in the secondary leachate collection system. Although the granular material of the secondary leachate collection system provides an adequate natural filter for the chalk, the overlying geotextile filter fabric will provide additional filtration capacity.

D-6-1-3-5b(2) Primary Geosynthetic Clay Liner

The lower component of the Trench 23 liner, the Geosynthetic Clay Liner (GCL), shall be placed on side slope and floor of each cell. The GCL shall contain at least 80 percent of high swelling montmorillonite. The minimum thickness of GCL shall be 0.15 inches. Because the GCL incorporates a geotextile within its construction, a separate filter will not be required between it and the underlying secondary leachate collection system.

D-6-1-3-5b(3) Primary Synthetic Membrane liner

The primary geomembrane liner will be installed immediately above and in direct contact with the primary system compacted chalk layer or GCL. The primary geomembrane liner will extend up the side slopes and across or under the haul roads and will be anchored at the crest. The liner will also extend over the intermediate berms to be joined with the primary geomembrane liner of the adjacent cells when constructed.

D-6-1-3-5b(4) Primary Protective Synthetic Layer

On the floor of each cell, the upper surface of the primary geomembrane liner will be protected by a geotextile cushion. The cushion fabric will adequately protect the underlying geomembrane liner from the overlying primary leachate collection system during construction and operation.

D-6-1-3-5c Primary Leachate Collection System

The primary leachate collection system will be capable of collecting and removing liquid from within the disposal unit throughout the active life and post-closure care period. The materials of construction for the system will be chemically resistant to the waste and leachate anticipated. The materials installed will also be resilient to the stresses anticipated during construction, operation, and throughout the post-closure care period. The primary leachate collection system will cover the area corresponding to the primary geomembrane liner within the below-grade portions of the disposal unit, including the floor, slopes, and haul roads for each cell of the landfill.

D-6-1-3-5c(1) Floor

The primary leachate collection system on the floor of each cell will consist of a one (1) foot thick layer of granular material placed on the protective geotextile cushion above the primary geomembrane liner. Specifications for the granular material are provided in Attachment D-6-1-4, Specifications for Construction Materials.

D-6-1-3-5c(2) Geotextile Fabric Filter

The granular material to be used as the primary leachate collection system is not a natural filter for the chalk which will be placed over it. A geotextile filter will be required between the granular material on the floor of the primary leachate collection system and the overlying protective chalk layer. This geotextile will serve a two-fold purpose of filtration and separation. This geotextile is a needle punched, nonwoven, polyester geotextile, as specified in Attachment D-6-1-4, Specifications for Construction Materials. The geotextile will be covered with a protective chalk layer and sand windows (Trench 22) or sand rows (Trench 23) to prevent damage to the leachate collection system from equipment and waste.

D-6-1-3-5c(3) Slopes

The primary leachate collection system on the slopes of each cell will consist of a layer of a transmissive geosynthetic layer and a geotextile filter. These layers will extend upslope from the floor of each cell, across the haul roads, and into the anchor trenches at the crest. The transmissive geosynthetic and geotextile will transmit leachate down the slopes of the cell to the granular portion of the system on the floor. The transmissive geosynthetic and geotextile will tie into the leachate collection system granular material on the floor as shown on Drawing No. 00-200-227 in Appendix D-6-2.

This transmissive geosynthetic/geotextile composite will transmit liquid parallel to the plane of the underlying primary geomembrane liner. Specifications for these materials are provided in Attachment D-6-1-4, Specifications for Construction Materials. The geotextile will be covered with a protective soil layer to prevent damage to the leachate collection system from equipment and waste.

D-6-1-3-5d Flow Characteristics

Acting as a unit, the transmissive geosynthetic and geotextile, and the granular material on the floor of Trench 22, will conduct liquid that reaches the primary leachate collection system to the sump.

D-6-1-3-5e Sump and Appurtenances

As previously described, the primary leachate collection sump will be located near the corner or edge of each cell, and the entire floor will grade to it. The dimensions at the base of the Trench 22 sump will be approximately 16 feet by 19 feet in plan and approximately six feet deep below the rim. The dimensions at the base of the Trench 23 sump will be approximately 16 feet by 20 feet in plan and approximately four feet deep below the rim. The side slopes within the Trench 22 sumps will be 1 horizontal : 1 vertical towards the cell floor and 2.5 horizontal : 1 vertical toward the exterior slope of the cell. The side slopes within the Trench 23 sumps will be 2 horizontal : 1 vertical towards the cell floor and 4 horizontal : 1 vertical toward the exterior slope of the cell.

The primary geomembrane liner within the sump will be overlaid by nominally four (4) inches of compacted chalk prior to placement of the riser pipe base. The purpose of this four (4) inch layer of compacted clay is to provide a cushion between the geomembrane and the HDPE riser base. An additional geomembrane liner will extend from the perimeter of the riser base outward to prevent liquid within the system from ponding in direct contact with the underlying thin layer of chalk. The primary sump is filled with coarse granular material. The primary liner in the upslope riser trench will be protected from the upslope pipe with two (2) layers of protective fabric placed on top of the primary upslope transmissive geosynthetic layer. Additional protection will be provided by an HDPE rub sheet placed directly on the primary liner.

There are two systems for removal of primary leachate from the landfill cells. The riser pipe used when the cell begins operation will be a minimum 18 inch diameter fusion welded HDPE pipe laid on the landfill cell sloped wall. In Trench 22, the upslope riser pipe will be SDR 11, while in Trench 23, the upslope riser pipe will be SDR 9. Within the sump, this upslope riser will be SDR 7.3 HDPE to resist loading from the base of the vertical concrete riser. The second system will be a four-foot diameter vertical HDPE pipe installed on an HDPE pad foundation. In Trench 22, the vertical riser pipe will be SDR 21, while in Trench 23, the vertical riser pipe will be SDR 13.5. Above the sump, the vertical HDPE pipe is surrounded by a five (5) feet diameter coated, reinforced concrete pipe installed on a concrete foundation as shown on Drawing Nos. 00-200-223 and 00-300-009. The vertical and upslope risers reside in a common sump and are hydraulically connected with HDPE pipes. Cross-sections and details of the primary leachate collection system riser pipes and foundation are shown on Drawing Nos. 00-200-223 and 00-300-008. Both the HDPE and concrete riser pipes and foundations are structurally stable under the estimated applied loads of the post-closure configuration as demonstrated by the calculations provided in Attachment D-6-1-7, Calculation Package for Trench 22 and in Attachment D-6-1-9, Calculation Package for Trench 23.

D-6-1-3-5f Protective Soil Layer

<u>D-6-1-3-5f(1) Floor</u>

A protective soil layer (sometimes referred to on the drawings as the protective chalk layer) nominally 1.5 feet thick will be placed over the entire floor of each cell. This soil layer will be loosely placed over the geotextile filter above the primary leachate collection system. This protective soil layer will be interrupted by 16 feet x 16 feet x 1.5 foot thick windows in Trench 22, which are filled with granular material (i.e., sand), and placed in a near grid type fashion spaced at approximately 100 feet intervals. The protective soil layer will be interrupted by 5 feet wide x 1.5 foot thick rows in Trench 23, which are filled with granular material (i.e., sand), and placed in a linear fashion spaced at approximately 100 feet intervals along a majority of the cell floor. The sand rows and windows will be a minimum of 25 feet from the side slopes and shall be no closer than 5' from the toe of the chalk berm surrounding the vertical riser. The granular material used in these windows will be of the same type used in the floor of the Trench 22 secondary leachate collection system. The fabric filter between the protective soil layer and the one-foot thick layer of granular material will extend across the windows/rows thereby forming a filter for sand filling the window/row. During the early stages of cell development the window/row will be covered by a layer of soil which will be removed prior to placement of waste over the window/row.

This protective layer primarily supports traffic but will also function to protect the underlying components of the primary system from the anticipated construction loading conditions and the waste which will be placed within the cell. In addition to the one-foot protective soil layer, a berm of approximately eight feet in height will be constructed around the primary leachate collection system (PLCS) riser to prevent direct flow of rainfall into the PLCS sump.

D-6-1-3-5f(2) Side Slopes

A protective soil layer nominally 1.0 foot thick will be placed on the Trench 22 perimeter side slopes of the below grade portions of each cell. In Trench 23, the protective soil layer will be nominally 1.5 foot thick. This layer will be loosely placed upon the geotextile filter of the primary leachate collection system as waste placement ascends within the cell. The protective soil layer will extend a minimum of five feet (measured along the plane of the slope) up the side slopes in advance of any waste placement.

This protective layer will function to protect the components of both the primary and secondary systems on the slopes. In order to prevent damage to the liner and primary leachate collection system on the slopes, special procedures will be used during soil placement on the side slopes, as listed below:

1. Placement will be done only with the knowledge and approval of the Disposal Supervisor or his designee;
2. Soil will be spread on the slopes with bulldozers exerting suitably low ground pressure so as not to adversely affect synthetic materials;
3. Protective soil will be placed on the slope above the haul roads a minimum of five feet vertically, measured in the plane of the slope; and
4. Protective soil shall not be placed more than 12 feet vertically up the Trench 22 slopes or more than 49 feet vertically up the Trench 23 slopes above the level of

waste placement at any time. The calculations used to determine the height above the waste level are provided in Appendix D-6-1-7 and D-6-1-9.

The protective soil layer is pushed a maximum of 12 feet vertically up the slope above the level of waste placement for Trench 22 or a maximum of 49 feet vertically up the slope above the level of waste placement for Trench 23. The remaining part of the slope above the protective soil layer is temporarily covered with a protective geosynthetic layer. This temporary geosynthetic is placed over the primary PLCS to protect the PLCS from the effects of exposure to the elements and light. This geosynthetic also directs rainfall to the bottom of the cell, thus reducing the amount of water going directly into the PLCS. The temporary geosynthetic will be cut and removed in sections as waste is placed in the cell and the protective soil layer is progressively extended up the slope.

The removal of the temporary geosynthetic layer shall be progressive and sequential with the placement of the protective soil layer and the waste. As a result, there is a greater assurance that the protective soil layer and the waste are not placed over the temporary geosynthetic cover and that the volume of leachate is minimized by keeping the cover in place as long as practical.

The temporary geosynthetic layer will be removed in horizontal-cross-slope segments in widths corresponding to the area of the protective soil layer to be pushed up the slope in advance of waste placement. The sacrificial temporary geosynthetic cover material will be cut in a fashion to reduce the potential for damage to the underlying geosynthetic materials. Additionally, if the temporary cover is a geomembrane, the geomembrane will be surficially scored, held off the underlying geosynthetic layers, and torn.

The sacrificial temporary geosynthetic layer will be cut into sizes which are managed by hand, rather than by machine, and disposed of in the active waste disposal cell. As the material is disposed of in the waste disposal cell, it will be oriented and/or dispersed so as to minimize the potential for localized collection and ponding of leachate.

[End of Attachment D-6-1-3]

ATTACHMENT D-6-1-4

APPENDIX D-6-1

SECTION D-6

SPECIFICATIONS FOR CONSTRUCTION MATERIALS

Revision No.
5.0

ATTACHMENT D-6-1-4

SPECIFICATIONS FOR CONSTRUCTION MATERIALS

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SPECIFICATIONS FOR CONSTRUCTION MATERIALS

D-6-1-4-1 General

D-6-1-4-1a Scope

These specifications encompass the materials and services required for the procurement and installation of geosynthetic clay liners, geomembranes, geonets/geocomposites, and geotextiles as part of the primary and secondary liner and leachate collection systems as well as the final cover for Trench 22 and Trench 23 at the Facility. Additionally, these specifications include earthen materials for compacted chalk layers, structural fill, intermediate and interim cover soil layers, granular drainage layers, vegetative cover, and berm materials. Materials used for construction which are not addressed in this document are specified on the Landfill Design Drawings included as Appendix D-6-2 of this Application and/or the Construction Drawings which will be submitted prior to the construction of each landfill cell.

The quality assurance procedures for the materials and the construction/installation included in this document are detailed in the "Construction Quality Assurance Plan", Attachment D-6-1-5 of this Application.

D-6-1-4-1b Parties/Definitions

The Construction Quality Assurance Officer (CQA Officer) shall be the individual(s) responsible for development and implementation of the Construction Quality Assurance (CQA) program. The CQA Officer(s) shall be a registered professional engineer and may be an employee of the Quality Assurance Consultant(s) (QAC) [Soil QAC and/or Geosynthetic QAC]. The CQA Officer(s) shall be appointed by the Facility prior to construction of the pressure relief system and/or the structural fill.

The Soil Quality Assurance Consultant (Soil QAC) is the firm which, under the direction of the CQA Officer, observes and documents activities related to the quality assurance of the soil materials and construction associated with the lining, leachate collection and final cover systems on behalf of the Facility.

The Geosynthetic Quality Assurance Consultant (Geosynthetic QAC) is the firm which, under the direction of the CQA Officer, observes and documents activities related to the quality assurance of the geosynthetic materials and installation associated with the lining, leachate collection and final cover systems on behalf of the Facility.

The Geosynthetic Quality Assurance Laboratory (Geosynthetic QAL) is the firm which conducts laboratory tests on samples of geosynthetic materials obtained from the Facility.

The Earthwork Contractor is the firm which performs the earthwork preparation and construction of the soil components of the landfill structural, lining, leachate collection, and final cover systems.

The Geosynthetic Installer (Installer) is the firm which installs the geosynthetic components of the landfill lining, leachate collection and final cover systems.

D-6-1-4-1c Test Methods

Test methods for soil and geosynthetic materials shall be reviewed prior to the construction of each new cell. If new American Society of Testing and Materials (ASTM) or other standard test methods have been developed which reflect an improvement or enhancement to the technology, they will be used to analyze the suitability of the materials.

D-6-1-4-2 Materials

D-6-1-4-2a Pressure Relief System

The pressure relief system for Trench 22 shall consist of a granular blanket drainage layer installed across the floor of each landfill cell. The pressure relief system for Trench 23 shall consist of a transmissive geosynthetic layer (i.e., geocomposite) installed across the floor of each landfill cell.

D-6-1-4-2a(1) Pressure Relief Blanket Drain Granular Material

The pressure relief blanket drain granular material shall meet the following specifications:

1. The permeability shall be greater than or equal to 5 x 10^{-3} cm/sec.
2. The thickness shall be nominally 12 inches.
3. The maximum particle size shall be ½ inch in the largest dimension. The material shall also have a D_{15} less than or equal to 0.5 mm and a D_{85} greater than or equal to 0.5 mm. The D_{15} is defined as the grain diameter corresponding to 15% of the material sample passing, by weight. The D_{85} is defined as the grain diameter corresponding to 85% of the material sample passing, by weight.

This material shall be placed in one or more horizontal lifts in the locations shown on the Trench 22 Landfill Design Drawings provided in Appendix D-6-2 of this Application.

D-6-1-4-2a(1a) Pressure Relief Transmissive Geosynthetic Layer

The pressure relief transmissive geosynthetic layer material shall be installed on the floor of each landfill cell of Trench 23. The geosynthetic material selected may be a geonet and/or geotextile or other material and shall have a transmissivity greater than or equal to 3 x 10^{-5} m^2/sec. The transmissivity of the material to be provided shall be determined, prior to construction, through laboratory testing (ASTM D4716) under the anticipated field conditions, including:

1. The boundary conditions; i.e., the geosynthetics and/or soil layers in contact with the transmissive geosynthetic material.
2. The compressive stress applied on the transmissive geosynthetic layer by the waste and other materials above it.
3. The hydraulic gradients under which the transmissive geosynthetic material will function in service.

In addition, the transmissive geosynthetic layer material shall meet the following specifications:

1. The material shall retain its structure during handling, placement and long-term service.
2. The material shall be chemically compatible with the anticipated leachate.
3. The material shall meet the interface strength criteria detailed in Subsection D-6-1-4-2c(2)(b) of this attachment.

If a geonet is utilized in this layer, it shall have a minimum tensile strength of 50 lb/in. width, as determined by ASTM D5035, modified for use of a four-inch wide specimen with a four-inch gauge length and tested at a cross-head rate of eight (8) inches per minute. Similarly, if a geotextile is utilized in this layer, it shall have a minimum tensile strength of 5-lbs./in. width, as determined by ASTM D4595. In addition, the geotextile shall meet the filter requirements detailed in Subsections D-6-1-4-2a(3) of this attachment.

The installation specifications for geonet and geotextile materials that may be used as the transmissive geosynthetic layer are detailed in Subsections D-6-1-4-3b and D-6-1-4-3c of this attachment, respectively.

D-6-1-4-2a(2) Pressure Relief Coarse Granular Material

The pressure relief coarse granular material shall be installed in the sump and meet the following specifications:

1. The permeability shall be greater than or equal to 5 x 10^{-3} cm/sec.
2. The thickness shall be nominally as shown on the Landfill Design Drawings provided in Appendix D-6-2 of this Application.
3. The material shall consist of non-angular (sub-angular, sub-rounded or rounded) particles with a maximum size less than or equal to 1¼ inch in the largest dimension.

The material shall be placed in the locations shown on the Landfill Design Drawings provided in Appendix D-6-2 of this Application.

D-6-1-4-2a(3) Pressure Relief Geotextile Filter

The pressure relief geotextile filter shall be installed in the sump of Trench 22. The geotextile component of the pressure relief transmissive geosynthetic layer of Trench 23 shall also meet requirements for a geotextile filter. This geotextile will function as a filter between the natural chalk layer and the coarse granular material in Trench 22 and between the natural chalk layer and the geonet core of the transmissive geosynthetic layer in Trench 23, as well as between the pressure relief blanket drain granular material/geonet core and the pressure relief coarse granular material. The geotextile installation specifications are detailed in Subsection D-6-1-4-3c of this attachment.

The geotextile shall be comprised of polymeric yarns or fibers oriented into a stable network which retains its relative structure during handling, placement, and long-term service. Additionally, the geotextile shall meet the following physical/mechanical property specifications:

1.	Mass Per Unit Area (ASTM D5261)	≥ 7.5 oz/yd²
2.	Grab Strength (ASTM D4632)	≥ 100 lbs
3.	Puncture Strength (ASTM D4833)	≥ 175 lbs
4.	Burst Strength (ASTM D3786)	≥ 100 psi

The geotextile filter material shall also meet the specifications provided in the following subsections.

D-6-1-4-2a(3)(a) Between Natural Chalk and Pressure Relief Coarse Granular Material/Geonet Core

1. The permeability shall be greater than or equal to 1 x 10^{-6} cm/sec as determined by ASTM D5493.
2. The geotextile shall be placed such that the maximum particle size of the adjacent natural chalk is 1¼ inch, measured in the largest dimension. The large-sized chalk particles shall be non-angular (sub-angular, sub-rounded or rounded).
3. The pore size distribution shall be adequate to filter the adjacent excavated natural chalk without becoming clogged and preventing liquid flow. The adequacy of specific geotextiles shall be determined during design, by testing with soils from the Facility, as described in Supplement 1, "Geotextile Filtration Test", which is located at the end of Attachment D-6-1-4.

D-6-1-4-2a(3)(b) Between Pressure Relief Blanket Drain/Geonet Core and Pressure Relief Coarse Granular Material

1. The permeability shall be greater than or equal to 5 x 10^{-3} cm/sec as determined by ASTM D5493.
2. The geotextile shall have an O_{95} less than or equal to 0.5 mm. The O_{95}, also known as the Apparent Opening Size (AOS), is defined as the geotextile opening diameter corresponding to 95% of the smaller material pores.

D-6-1-4-2a(4) Geosynthetic Clay Liner

The Geosynthetic Clay Liner (GCL), shall be placed in areas as shown on the drawings in Appendix D-6-2 to Section D-6. The GCL shall contain at least 80 percent of high swelling montmorillonite. "Recycled" bentonite shall not be used. The hydraulic conductivity of GCL shall be less than 1.0 x 10^{-9} cm/sec, determined in accordance with ASTM D5887. The minimum thickness of GCL shall be 0.15 inches.

D-6-1-4-2b Structural Fill

The structural fill shall be placed and compacted to form the side slopes of each cell as shown in the Landfill Design Drawings included in Appendix D-6-2 of this Application, and in accordance with the following specifications:

1. The material shall be substantially free of organic, frozen, or other deleterious matter.
2. The material shall be placed and compacted in horizontal lifts not to exceed 12 inches thick, measured loose.

3. Each lift which has been smooth rolled shall be scarified prior to the placement of the next loose lift. Lifts compacted using equipment which leave the surface rough, such as sheeps-foot rollers, shall not require scarification.

4. The maximum particle size shall be nominally nine (9) inches in the largest dimension, after compaction. The overall particle gradation shall be such that the material is a fine-grained soil matrix containing sand, gravel, and cobble-sized chalk fragments.

5. The material shall be compacted to at least 95% of the maximum dry density and from -3% to +3% of the optimum moisture content as determined by the standard Proctor compaction test (ASTM D698).

6. Compaction shall be performed using a penetrating foot compactor(s) weighing not less than 50,000 pounds and capable of penetrating the thickness of each lift.

7. The penetrating compactor shall not be used on the first two lifts of a compacted soil layer immediately above a geosynthetic liner or other sensitive liner component. A non-penetrating compactor shall be used for the first two lifts.

8. Around features where heavy equipment cannot be used for compaction, soil shall be placed in maximum four-inch loose lifts and compacted using a hand operated, motorized tamper.

D-6-1-4-2c Secondary Liner

The secondary liner shall be placed across the floor and side slopes of each landfill cell and be composed of a composite system consisting of a compacted chalk layer lower component directly overlaid by a geomembrane liner upper component.

<u>D-6-1-4-2c(1) Secondary Compacted Chalk Layer</u>

The lower component of the secondary liner system, the compacted chalk layer, shall be a minimum of three (3) feet thick across the floor and side slopes of each cell, as shown in the Landfill Design Drawings included in Appendix D-6-2 of this Application. This chalk layer shall be constructed in accordance with the following specifications:

1. The material shall be free of organic, frozen, or other deleterious matter.

2. The material on the floor and the side slopes of Trench 22 shall be placed and compacted in horizontal lifts. The material on the side slopes of Trench 23 shall be placed parallel to the slope and compacted in sloped lifts. The lifts shall be nominally nine (9) inches thick, measured loose and perpendicular to the lift.

3. Each lift which has been smooth rolled shall be scarified prior to the placement of the next loose lift. Lifts compacted using equipment which leave the surface rough, such as sheeps-foot rollers, will not require scarification.

4. The maximum particle size shall be nominally four (4) inches in the largest dimension after compaction. The overall particle gradation shall be such that the material is a fine-grained soil matrix containing sand and gravel-sized chalk fragments.

5. The material shall be compacted to at least 95% of the maximum dry density and from 0% to 3% above the optimum moisture content as determined by the standard Proctor compaction test (ASTM D698).

6. The permeability of the compacted chalk layer placed and compacted in accordance with these specifications is to be less than or equal to 1×10^{-7} cm/s.

7. The final surface of the compacted chalk layer shall be graded and proof-rolled to provide a smooth, uniform surface, free from irregularities, depressions, protrusions, particles greater than ¾ inches in the largest dimension, or other features which may adversely affect the integrity of the geomembrane liner to be placed upon it.

8. Compaction shall be performed using penetrating foot compactor(s) weighing not less than 50,000 pounds and capable of penetrating the thickness of each lift.

9. The penetrating compactor shall not be used on the first two lifts of a compacted soil layer immediately above a geosynthetic or other sensitive liner components. A penetrating compactor shall be used for all lifts above the first two lifts.

10. Around features where heavy equipment cannot be used for compaction, soil shall be placed in maximum four-inch loose lifts and compacted using a hand operated, motorized tamper.

D-6-1-4-2c(2) Secondary Geomembrane

The secondary geomembrane shall be high density polyethylene (HDPE) material installed across the floor and side slopes of each cell in accordance with Subsection D-6-1-4-3a of this attachment and shall meet the specifications provided in the following subsections.

D-6-1-4-2c(2)(a) Raw Materials

The geomembrane shall be produced of new, first quality resin, and shall be designed and manufactured specifically for the intended purpose.

The polyethylene resin for the geomembrane shall meet the following specifications:

Specific Gravity (ASTM D792 Method A, or ASTM D1505)	≥ 0.938
Melt Index (ASTM D1238)	≤ 1.1 g/10 min.

Reclaimed polymer shall not be added to the resin. However, the use of polymer recycled during the manufacturing process shall be permitted if done with appropriate cleanliness, and if recycled polymer does not exceed 2% by weight.

D-6-1-4-2c(2)(b) Roll Materials

The minimum gauge thickness for the geomembrane liner shall be 60 mils. For the specified thickness, the geomembrane shall meet or exceed the properties detailed in Table D-6-1-4.1, HDPE Smooth Geomembrane, and Table D-6-1-4.2, HDPE Textured Geomembrane, provided at the end of Attachment D-6-1-4, for smooth and textured HDPE respectively.

The geomembrane rolls shall also meet the following specifications:

1. consist of unreinforced HDPE containing 3% by weight maximum additives, fillers or extenders;
2. not have striations, roughness (except as manufactured intentionally as textured geomembrane material), pinholes or bubbles on the surface; and
3. be produced so as to be free of holes, blisters, undispersed raw materials, or contamination by foreign matter.

In addition, all Trench 22 interfaces within the liner/leachate collection system between the pressure relief blanket drain and the protective chalk layer above the primary liner system shall have an effective shear strength equal to or greater than the strength defined by a failure envelope with an effective cohesion of zero and an effective friction angle of eight degrees which includes factors of safety. All Trench 23 interfaces within the liner/leachate collection system between the pressure relief geocomposite and the protective chalk layer above the primary liner system shall have an effective shear strength equal to or greater than the strength defined by a failure envelope with an effective cohesion of zero and an effective friction angle of fifteen degrees which includes factors of safety. The required strength shall be determined, prior to construction, through laboratory testing (ASTM D5321) of the critical interfaces at least once for each landfill cell constructed. The testing shall be done on the products that will be used in construction. The tests shall be performed over the range of normal stresses and the degree of saturation expected under field conditions. At a minimum, tests shall be conducted on the following critical interfaces:

1. compacted chalk layer and geomembrane;

2. GCL and geomembrane;
3. geotextile and geomembrane; and
4. geocomposite and geomembrane.

D-6-1-4-2c(2)(c) Field Seams

The field seams for HDPE geomembrane shall meet the specifications for the appropriate thickness shown in Table D-6-1-4.3, provided at the end of Attachment D-6-1-4.

D-6-1-4-2c(2)(d) Rub Sheets

Rub sheets may be installed in locations where the geomembrane is subject to an abrupt change in grade and/or stress concentrations, and at locations as shown on the Landfill Design Drawings provided in Appendix D-6-2 of this Application. Examples of such areas are cited on the Landfill Design Drawings and include the crest of the landfill cell side slopes and the crest of the haul roads.

Rub sheets shall be the same general geomembrane material as specified in Subsections D-6-1-4-2c(2)(a) and D-6-1-4-2c(2)(b) of this attachment. However, off-specification material may be used, subject to the approval of the Facility. Rub sheets shall not be seamed together or to the secondary, primary or final cover geomembrane liner.

D-6-1-4-2c(2)(e) Base Plates

The base plates shall be installed between the base of the secondary leachate collection system upslope riser pipe and the secondary HDPE geomembrane, as shown in the Landfill Design Drawings included in Appendix D-6-2 of this Application. The base plates shall be manufactured to meet the specifications detailed in Section D-6-1-4-2c(2)(a) of this attachment and to a nominal thickness as detailed on the Landfill Design Drawings included in Appendix D-6-2 of this Application and/or the Construction Drawings which shall be submitted prior to construction of each landfill cell.

D-6-1-4-2d Secondary Leachate Collection System

The secondary leachate collection system (SLCS) sump, side slopes and cell floor, from the secondary geomembrane liner to the primary geomembrane liner, are described in the following subsections to this attachment:

SLCS Sump	
Secondary Geomembrane Liner	Section D-6-1-4-2c(2)
Geotextile Cushion	Section D-6-1-4-2d(3)
Coarse Granular Material	Section D-6-1-4-2d(2)
Transmissive Geosynthetic Layer	Section D-6-1-4-2d(4)

Geotextile Filter	Section D-6-1-4-2d(3)
Blanket Drain Granular Material	Section D-6-1-4-2d(1)
SLCS Cell Floor	
Secondary Geomembrane Liner	Section D-6-1-4-2c(2)
Blanket Drain Granular Material	Section D-6-1-4-2d(1)
Geotextile Filter	Section D-6-1-4-2d(3)
Secondary Transmissive Geosynthetic Layer	Section D-6-1-4-2d(4)
Compacted Chalk Layer	Section D-6-1-4-2e(1)
Geosynthetic Clay Liner	Section D-6-1-4-2e(1a)
Primary Geomembrane Liner	Section D-6-1-4-2e(2)
SLCS Side slopes	
Secondary Geomembrane Liner	Section D-6-1-4-2c(2)
Secondary Transmissive Geosynthetic Layer	Section D-6-1-4-2d(4)
Geosynthetic Clay Liner	Section D-6-1-4-2e(1a)
Primary Geomembrane Liner	Section D-6-1-4-2e(2)

D-6-1-4-2d(1) SLCS Blanket Drain Granular Material

The SLCS blanket drain granular material for the floor of each Trench 22 cell shall meet the following specifications:

1. The permeability shall be greater than or equal to 1 x 10^{-2} cm/sec.
2. The thickness shall be a minimum of 12 inches.
3. The material shall be chemically resistant to the anticipated leachate.
4. The maximum particle size shall be ¾ inches in the largest dimension. The material shall have a D_{15} less than or equal to 0.5 mm and a D_{85} greater than or equal to 0.5 mm. The D_{15} is defined as the grain diameter corresponding to 15% of the material sample passing, by weight. The D_{85} is defined as the grain diameter corresponding to 85% of the material sample passing, by weight.
5. The interface strength criteria shall be detailed in Subsection D-6-1-4-2c(2)(b) of this attachment.

The granular material shall not be dropped, free-fall, from a height greater than five (5) feet during the placement process and shall be spread in one or more horizontal lifts. The granular material shall be placed such that the material is free of organic material and debris and in such a manner as to achieve a hydraulic conductivity equal to or greater than 1 x 10^{-2}cm/sec. The drainage layer shall be placed and smooth graded in such a manner as to promote drainage, prevent ponding, and prevent damage to underlying liner and drainage components. During the placement and spreading processes, bulldozers and other track-mounted equipment (up to a maximum of 15 psi ground pressure) shall operate over no less than a 6-inch thickness of material. Rubber-tired and other heavy equipment (such as scrapers, front-end loaders, compactors, etc.) and trucks (other than passenger-type) shall operate over no less than a 1.5 feet thickness of material.

D-6-1-4-2d(2) SLCS Coarse Granular Material

The SLCS coarse granular material shall be installed in the SLCS sump and shall meet the specifications detailed in Subsection D-6-1-4-2a(2) of this attachment, with the following exceptions:

1. The permeability shall be greater than or equal to the permeability of the material provided as the SLCS blanket drain granular material as detailed in Subsection D-6-1-4-2d(1) of this attachment and as determined by ASTM D2434.
2. The material shall be chemically resistant to the anticipated leachate.

The material shall also meet the interface strength criteria detailed in Subsection D-6-1-4-2c(2)(b) of this attachment. Additionally, the placement and spreading equipment restrictions detailed in Subsection D-6-1-4-2d(1) of this attachment shall apply.

D-6-1-4-2d(3) SLCS Geotextile Filter/Cushion

The SLCS geotextile shall be installed in the sump area and shall function as a cushion on top of the secondary geomembrane and as a filter between the SLCS coarse granular material and the SLCS blanket drain granular material. The SLCS geotextile shall also be installed above the blanket drain granular material to provide additional filtration capacity.

The geotextile shall be comprised of polymeric yarns or fibers which retain their relative structure during handling, placement, and long-term service. Additionally, the geotextile shall meet the following specifications:

1. The permeability shall be greater than or equal to 0.1 cm/sec, as determined by ASTM D5493.
2. The material shall be chemically resistant to the anticipated leachate.
3. The geotextile shall meet the physical/mechanical properties specifications detailed in Subsection D-6-1-4-2a(3) of this attachment.

4. The geotextile shall have an O_{95} less than or equal to 0.5 mm. The O_{95}, also known as the AOS, is defined as the geotextile opening diameter corresponding to 95% of the smaller material pores.

The installation specifications for the geotextile are detailed in Subsection D-6-1-4-3c of this attachment.

<u>D-6-1-4-2d(4) SLCS Transmissive Geosynthetic Layer</u>

The SLCS transmissive geosynthetic layer material shall be installed on the floor of Trench 22, in the vicinity of the sump, as shown on the Landfill Design Drawings included in Appendix D-2-6 of this Application, across the side slopes of each Trench 22 landfill cell, and across both the side slopes and the floor of each Trench 23 landfill cell. The geosynthetic material shall meet the specifications detailed in Subsection D-6-1-4-2a(1a) of this attachment with the following exceptions:

1. The geotextile shall meet the SLCS geotextile filter/cushion specifications detailed in D-6-1-4-2d(3) of this attachment.
2. The material shall be chemically resistant to the anticipated leachate.

D-6-1-4-2e Primary Liner

The primary liner shall be placed as a composite system across the floor of each landfill cell and shall consist of a compacted chalk layer lower component for Trench 22 cell floor and a GCL lower component for Trench 23 cell floor and side slopes overlaid by a geomembrane upper component. On the side slopes of each Trench 22 landfill cell, the primary liner shall consist of only a geomembrane.

<u>D-6-1-4-2e(1) Primary Compacted Chalk Layer</u>

The primary compacted chalk layer shall be constructed to a thickness no less than 1.5 feet across the floor of each landfill cell and shall be constructed in accordance with the specifications detailed in Subsection D-6-1-4-2c(1) of this attachment, with the following exceptions:

- within the sump area, the maximum chalk particle size on the surface shall be less than or equal to ½ inch;
- the compacted chalk between the primary geomembrane and the geomembrane cap sheet shall also be limited to particles less than or equal to ½ inch in the largest dimension; and

- the permeability of chalk placed and compacted is to be less than 1 x 10^{-7} cm/sec, except for the first two 6-inch thick horizontal lifts of the lower component of the 1.5-foot thick primary compacted chalk liner system which are directly above the filter fabric of the SLCS; compaction of these two lifts will be restricted so as to avoid damage to the underlying fabric.

D-6-1-4-2e(1a) Geosynthetic Clay Liner

The Geosynthetic Clay Liner (GCL), shall be placed as the lower component of the primary liner in Trench 23 and shall meet the specifications detailed in Subsection D-6-1-4-2a(4) of this attachment.

D-6-1-4-2e(2) Primary Geomembrane

The primary geomembrane shall be installed across the floor and side slopes of each landfill cell and shall meet the specifications detailed in Subsection D-6-1-4-2c(2) of this attachment.

D-6-1-4-2f Primary Leachate Collection System

The primary leachate collection system (PLCS) shall be installed across the floor and side slopes of each landfill cell. Across the floor, the PLCS shall consist of a blanket drain granular material layer placed above a geotextile cushion. On the side slopes, the PLCS shall consist of a transmissive geosynthetic layer, which may be a geonet and/or geotextile or geocomposite.

D-6-1-4-2f(1) PLCS Geotextile Cushion

The PLCS geotextile cushion shall be installed across the floor of each landfill cell and be comprised of polymeric yarns or fibers oriented into a stable network which retains its relative structure during handling, placement, and long-term service. The geotextile shall meet the interface strength criteria detailed in Subsection D-6-1-4-2c(2)(b) of this attachment. Additionally, the geotextile shall be chemically resistant to the anticipated leachate constituents and, with the exception of the material placed in the sump, shall meet the physical/mechanical property specifications detailed in Subsection D-6-1-4-2a(3) of this attachment, and shall not adversely affect the drainage through the system. The geotextile placed within the sump shall meet the following physical/mechanical property specifications:

1.	Mass Per Unit Area (ASTM (D5261)	≥ 7.5 oz/yd^2
2.	Grab Strength (ASTM D4632)	≥ 250 lbs
3.	Puncture Strength (ASTM D4833)	≥ 175 lbs
4.	Burst Strength (ASTM D3786)	≥ 150 psi

Multiple layers of this geotextile may be required in the sump, between the primary geosynthetic membrane liner and the drainage layer, as detailed on the Landfill Design Drawings provided in Appendix D-6-2 of this Application. The geotextile installation specifications are detailed in Subsection D-6-1-4-3c of this attachment.

D-6-1-4-2f(2) PLCS Blanket Drain Granular Material

The PLCS blanket drain granular material shall be installed across the floor of each landfill cell and shall meet the following specifications:

1. The permeability shall be greater than or equal to 3 cm/sec.
2. The thickness shall be a minimum of 12 inches.
3. The granular material shall be placed and smooth graded to promote drainage, prevent ponding and prevent damage to underlying liners and drainage systems.
4. The material shall be non-angular (sub-angular, sub-rounded or rounded) with a maximum particle size of 1¼ inch in the largest dimension. The material shall also have a D_{85} greater than or equal to 10 mm. The D_{85} is defined as the grain diameter corresponding to 85% of the material sample passing, by weight.

Additionally, the placement and spreading equipment restrictions detailed in Subsection D-6-1-4-2d(1) of this attachment shall apply.

D-6-1-4-2f(3) PLCS Coarse Granular Material

The PLCS coarse granular material shall be installed in the sump of each landfill cell and meet the following specifications:

1. The permeability shall be greater than or equal to 3 cm/sec.
2. The thickness shall be as shown on the Landfill Design Drawings provided in Appendix D-6-2 of this Application.
3. The material shall be non-angular (sub-angular, sub-rounded or rounded) with a maximum particle size of 2½ inches in the largest dimension. The granular material shall have a D_{15} less than or equal to 50 mm. The D_{15} is defined as the grain diameter corresponding to 15% of the material sample passing, by weight.

Additionally, the placement and spreading equipment restrictions detailed in Subsection D-6-1-4-2d(1) of this attachment shall apply.

D-6-1-4-2f(4) PLCS Geotextile Filter

The PLCS geotextile filter shall be installed across the floor of each landfill cell, as shown in the Landfill Design Drawings provided in Appendix D-6-2 of this Application, and shall function as a filter between the PLCS blanket drain granular material and the protective chalk cover.

The geotextile shall be comprised of polymeric yarns or fibers which retain their relative structure during handling, placement, and long-term service. The geotextile shall meet the interface strength criteria detailed in Subsection D-6-1-4-2c(2)(b) of this attachment. Additionally, the geotextile shall be chemically resistant to the anticipated leachate constituents and shall meet the physical/mechanical property specifications detailed in Subsection D-6-1-4-2a(3) of this attachment.

The geotextile filter shall also meet the following specifications:

1. The permeability shall be greater than or equal to 1×10^{-3} cm/sec., as determined by ASTM D5493.
2. The pore size distribution shall be adequate to filter the overlying soil without becoming clogged and preventing liquid flow. Adequacy of specific geotextiles shall be determined, prior to construction, through laboratory testing, under the anticipated field conditions with soils from the Facility, as described in Supplement 1, "Geotextile Filtration Test", which is located at the end of Attachment D-6-1-4.

The geotextile installation specifications are detailed in Subsection D-6-1-4-3c of this attachment.

D-6-1-4-2f(5) PLCS Transmissive Geosynthetic Layer

The PLCS transmissive geosynthetic layer material shall be installed across the side slopes of each landfill cell. The geosynthetic material selected may be a geonet and/or geotextile, or other material, and shall have a transmissivity greater than or equal to 3×10^{-5} m^2/sec. The required transmissivity shall be determined, prior to construction, through laboratory testing (ASTM D4716) under the anticipated field conditions detailed in Subsection D-6-1-4-2d(4) of this attachment. The material shall meet the interface strength criteria detailed in Subsection D-6-1-4-2c(2)(b) of this attachment. In addition, the transmissive geosynthetic layer material shall meet the specifications for the PLCS geotextile filter detailed in Subsection D-6-1-4-2f(4) of this attachment.

If a geonet is utilized in this layer, it shall have a minimum tensile strength of 50 lb/in. width, as determined by ASTM D5035, modified for use of a four-inch wide specimen with a four-inch gauge length and tested at a cross-head rate of eight (8) inches per minute. Similarly, if a geotextile is utilized in this layer, it shall have a minimum tensile strength of 5-lb/in. width, as determined by ASTM D4595.

The installation specifications for a geosynthetic transmissive layer consisting of a geonet or geotextile are detailed in Subsections D-6-1-4-3b and D-6-1-4-3e of this attachment, respectively.

D-6-1-4-2g Protective Cover

The protective cover shall be placed over the floor and side slopes of each landfill cell. Initially, the protective cover shall be a soil layer across the floor and a temporary geosynthetic layer over the side slopes. Ultimately, the soil layer shall cover both the floor and the side slopes.

D-6-1-4-2g(1) Protective Soil Cover

The protective soil cover shall be placed across the floor of each landfill cell and incrementally up the side slopes, as the temporary protective geosynthetic layer is removed. The protective soil cover will be interrupted by windows or rows filled with granular material.

The soil will be delivered to the fill area and spread by low-ground-pressure (a maximum ground pressure of 15 psi) dozers or other equipment. The soil will be spread from the working pad across the bottom of the cell and placed on the side slopes as the working pad reaches the toe of the slope. A minimum of six (6) inches of soil or other cover material will be maintained between the tread of this equipment and the geotextile filter or synthetic components of liner systems. A minimum of eighteen (18) inches will be maintained between the tires and the geotextile filter when rubber-tired heavy equipment (such as scrapers, front-end loaders, etc.) and trucks (other than passenger type) are used. The granular material windows/rows will be constructed during the placing of the soil layer, as the protective soil layer reaches the window/row location. The granular material will be placed, at the location of the windows/rows, to the size as shown on Drawing Nos. 00-200-215 and 00-300-008 in Appendix D-6-2 of this Application. The granular material will be covered by a separator material and temporary soil cover to prevent contamination of the window/row during construction. Prior to waste placement over a window/row, the temporary soil cover and the separator material will be removed.

The soil cover shall meet the following specifications:

1. The material shall be substantially free of organic, frozen, or other deleterious matter.
2. The material shall be placed, across the floor and side slopes, in one horizontal lift, to a total nominal thickness of 1.5 feet. On the side slopes, the material shall be

placed incrementally to not more than eight (8) feet, measured vertically, above the active waste placement level.

3. The maximum particle size shall be nominally soil four (4) inches in the largest dimension. The material placed immediately adjacent to the PLCS geotextile filter or the PLCS transmissive geosynthetic layer shall be non-angular (sub-angular, sub-rounded or rounded) with a maximum particle size of one (1) inch in the largest dimension.

The granular material used in the sand windows/rows shall meet the requirements of the specifications for the SLCS Blanket Drain Granular Material provided in Subsection D-6-1-4-2d(1) of this attachment.

<u>D-6-1-4-2g(2) Temporary Protective Geosynthetic Layer</u>

The PLCS transmissive geosynthetic layer on the side slopes of each landfill cell shall be temporarily covered with a protective geosynthetic layer. As waste placement progresses, this layer shall be removed in stages and replaced with protective soil, as described in Subsection D-6-1-4-2f(1) of this attachment. The material used as the protective geosynthetic layer shall be resistant to ultraviolet exposure for a minimum of two (2) years.

D-6-1-4-2h Anchor Trench Backfill

The anchor trenches for each landfill cell shall be backfilled with soil placed and compacted to meet the following specifications:

1. The material shall be free of organic, frozen, or other deleterious material.
2. The material shall be placed as shown on the Landfill Design Drawings provided in Appendix D-6-2 of this Application, in loose lifts not to exceed nominally nine (9) inches thick.
3. The maximum particle size shall be nominally three (3) inches in the largest dimension. The overall particle gradation shall be such that the material is a fine-grained soil matrix containing sand, gravel, and cobble-sized chalk fragments.
4. The material shall be compacted to at least 90% of the maximum dry density and from -3% to +3% of the optimum moisture content as determined by the standard Proctor compaction test (ASTM D698).
5. The first lift of backfill will be a minimal one (1) foot, to prevent damage to the underlying geomembrane.
6. A hand operated, motorized tamper will be used for compaction against the liner.

D-6-1-4-2i Intermediate and Perimeter Berms

D-6-1-4-2i(1) Perimeter Berms

During the operation of the landfill, perimeter berms shall be constructed in the locations shown on the Landfill Design Drawings provided in Appendix D-6-2 of this Application. The material used to construct these berms shall meet the specifications detailed in Subsection D-6-1-4-2c(1) of this attachment, except as noted as follows:

- The first lift of material placed on the waste shall be nominally eighteen (18) inches thick, measured loose. As a working pad for the remaining fill to be constructed upon, the specified relative compaction and moisture content requirements shall not apply to this lift.

D-6-1-4-2i(2) Intermediate Berms

Intermediate berms shall be constructed between the operating cells within a trench. These berms shall be constructed in accordance with the specifications for structural fill, as detailed in Subsection D-6-1-4-2b of this attachment.

D-6-1-4-2j Intermediate Cover

As each landfill cell is operated and filled, the upper lift of waste shall be temporarily covered with a soil layer for a limited period of time. This layer, the intermediate cover, is used during placement of waste in the cell to separate the operational machinery from the waste and to provide a drivable surface for the machinery and vehicles. The intermediate cover shall not be impervious to leachate migration to the PLCS and shall be of loosely placed chalk or other suitable material that will support the equipment, cover the waste, and does not form an impenetrable layer to leachate migration. This intermediate cover material shall be placed in one or more lifts, to a total thickness of nominally six (6) inches over the areas designated by landfill operations.

D-6-1-4-2k Interim Cover

As each landfill cell is filled to a level which requires operation in an adjacent cell, the upper lift of waste shall be temporarily closed with an interim cover. In addition, at other stages during the development of the landfill cell, the Facility may temporarily inactivate portions of the disposal unit by placing an interim cover over the waste.

The placement of interim covers over the waste will minimize the collection of rainwater within the PLCS prior to the transition from the below-grade portion of a cell to the above-grade portion of a cell and at other times that the Facility desires to inactivate a portion of the disposal cell.

The interim cover shall consist of a soil layer and may be overlaid by a geomembrane. The cover will be graded to the perimeter ditches to remove the surface run-off from the cell.

During the transition from the below-grade portion to the above-grade portion of each cell, and during construction of the final closure cover, portions of these interim covers will be partially removed. In areas where waste will be placed above interim covers, their continuity will be interrupted to prevent the formation of a barrier which could inhibit the flow of leachate to the PLCS.

In order to prevent the formation of a barrier to the advancement of leachate to the PLCS, the interim covers will be adjusted in accordance with the following general criteria and procedures. Prior to the placement of the first lift of waste within an area previously covered by an interim cover, the overlying geomembrane, if used, shall be removed, and the soil will be removed to within six (6) vertical inches of the underlying waste. The remaining soil that is within approximately six (6) vertical inches of the underlying waste (hereafter referred to as "transition cover soil") may be removed during waste placement and stockpiled within the containment boundaries of the disposal cell for subsequent use as cover for waste placed within the cell, or for leveling soil on the interior of the perimeter berms and on closure covers. The remaining transition cover soil shall be made discontinuous to prevent the formation of a barrier to the advancement of leachate to the PLCS. At a minimum and prior to waste placement in an area, the remaining transition cover soil, if any, that is adjacent to the interior of the perimeter waste containment dikes will be removed to a horizontal width of not less than eight (8) feet to expose the underlying waste, thereby providing discontinuity of the transition cover soil around the perimeter of the cell. In addition, as waste is placed in the cell atop remaining transition cover soil, if any, the remaining transition cover soil will be similarly disrupted by the removal of this soil in horizontal strips that extend vertically to the depth of the underlying waste. These strips shall not be less than eight (8) feet in width, horizontally, and shall be spaced at approximately 50-foot horizontal intervals throughout the surface area of the initial lift in the cell. The removal of the transition cover soil, at the perimeter and at these interior strips as described herein will provide discontinuities in the transition cover soil which will provide avenues for leachate to advance downward to the PLCS. In addition to the removal of interim cover soils, a limited portion of the waste containment dike soils at the perimeter of the cell will be removed or adjusted in order to accommodate the transition from the below-grade portion of a cell to the above-grade portion of an adjacent cell. Any geomembrane used on the interim cover that has not contacted waste may be salvaged and stored outside of the disposal unit and reused as needed.

As described above, soils removed from interim covers will be segregated for subsequent stockpile and reuse based on their previous proximity to the surface of the waste in a cell. Soils removed from interim covers that are more than six (6) inches above the surface of the waste in a cell and that have not contacted waste may be stockpiled outside of the disposal unit, and if suitable, can be used for the construction of other internal or external cell components, or can be used for other future construction activities at the Facility. Soils removed from areas that are within six (6) inches of the surface of the waste within a cell will be stockpiled within the confines of the associated disposal unit for subsequent use as previously described.

D-6-1-4-2k(1) Interim Cover Soil

The interim cover soil shall be placed and compacted to a nominal thickness of two (2) feet and to the same specifications as for the structural fill, as detailed in Subsection D-6-1-4-2b of this attachment. Additionally, the soil surface shall be graded to a relatively smooth surface, free of particles greater than four (4) inches in the largest dimension.

D-6-1-4-2k(2) Interim Cover Geomembrane

The interim cover geomembrane shall be designed and manufactured for the intended purpose. It shall be manufactured of polyethylene (high density, low density, etc.) or other polymeric material and shall be resistant to degradation from ultra violet exposure for at least five (5) years. The minimum gauge thickness of the interim cover geomembrane shall be 30 mils.

Additionally, the geomembrane shall:

1. not have striations, roughness (excluding that provided intentionally as textured geomembrane), pinholes, or bubbles on the surface.; and
2. be produced so as to be free of holes, blisters, undispersed raw materials, or contamination by foreign matter.

The interim cover geomembrane shall be installed in accordance with the specifications detailed in Subsections D-6-1-4-3a through D-6-1-4-3a(8) of this attachment, except as noted as follows:

1. Additional methods of seaming (and therefore overlap, temporary bonding, seam preparation, seaming equipment, seaming weather conditions and repairs) may be acceptable, dependent upon the geomembrane polymer type selected.
2. Seam nondestructive continuity testing and destructive testing are not required.

D-6-1-4-2l Closure Cover Liner

The closure cover liner shall be placed over the area of each landfill cell and shall consist of a compacted chalk layer overlaid by a geomembrane as shown in the Landfill Design Drawings provided in Appendix D-6-2 of this Application.

D-6-1-4-2l(1) Closure Cover Compacted Chalk Liner

The compacted chalk liner placed as part of the closure cover shall be constructed to a nominal thickness of two (2) feet and shall be constructed in accordance with the specifications detailed in Subsection D-6-1-4-2c(1) of this attachment, except as noted as follows:

1. The first lift of material may be required to be placed thicker than the six (6) inches (measured loose) required by ADEM Administrative Code Rule 335-14-5-.14(11)(b)3.(ii)(II) in order to achieve the specified relative compaction while protecting the underlying synthetic components. All lifts above the first lift will be placed no thicker than the six (6) inches (measured loose) as required by ADEM Administrative Code Rule 335-14-5-.14(11)(b)3.(ii)(II).
2. The material may be placed and compacted in lifts parallel to the slope.
3. Each lift which has been smooth rolled shall be scarified prior to the placement of the next lift. Lifts compacted using equipment such as a sheeps feet roller, which leaves the surface rough, will not require scarification.

D-6-1-4-2l(2) Closure Cover Geomembrane Liner

The closure cover geomembrane liner material shall meet the specifications detailed in Subsection D-6-1-4-2c(2), except as noted as follows:

1. The geomembrane shall have a minimum gauge thickness of 40 mils.
2. The geomembrane material may be manufactured of HDPE or other polymeric materials, provided the remaining requirements of this section are met. Additional methods of seaming (and therefore overlap, temporary bonding, seam preparation, seaming equipment, seaming weather conditions, seam repair, seam nondestructive testing and seam destructive testing) may be acceptable, dependent upon the geomembrane polymer type selected.

In addition, the layer interfaces within the closure cover system shall meet the following strength parameters. Interfaces within the cover system shall have an effective shear strength equal to or greater than the strength defined by a failure envelope with an effective cohesion of zero and an effective

angle of 18 degrees (which includes factors for safety). The required strength shall be determined, prior to construction, through laboratory testing (ASTM D5321) of the critical interfaces. The testing shall be done on the products that will be used in construction at a frequency of at least once for each closure construction contract. The tests shall be performed over the range of normal stresses and the degree of saturation expected under field conditions as detailed in Subsection D-6-1-4-2c(2)(b) of this attachment. At a minimum, tests shall be conducted on the critical interface between the geomembrane and the transmissive geosynthetic layer.

D-6-1-4-2m Final Cover Drainage Layer

The closure cover drainage system shall consist of a transmissive geosynthetic layer and regularly spaced downslope geosynthetic transmissive strips over the area of each landfill cell as shown in the Landfill Design Drawings provided in Appendix D-6-2 of this Application.

D-6-1-4-2m(1) Closure Cover Transmissive Geosynthetic Layer/Integrated Drainage Layer

A transmissive geosynthetic layer shall be installed over the closure cover geomembrane liner, as shown on the Landfill Design Drawings provided in Appendix D-6-2 of this Application. The material selected may be a geotextile and/or geonet or a drainage layer integrated into a structured geomembrane, and overlain by a geotextile, and shall have a transmissivity greater than or equal to 3 x 10^{-6} m^2/sec for Trench 22 and 3 x 10^{-5} m^2/sec for Trench 23. The transmissivity of the Trench 22 drainage layer, as shown in the Cover Drainage Layer Hydraulic Calculations in Attachment D-6-1-8, satisfies the required permeability of 1 x 10^{-3} cm/sec. The transmissivity of the Trench 23 drainage layer will therefore exceed the required permeability by a factor of 10. The transmissivity shall be determined, prior to construction, through laboratory testing (ASTM D4716) under the anticipated field conditions, as detailed in Subsection D-6-1-4-2d(4) of this attachment.

The transmissive geosynthetic layer shall retain its structure during handling, placement and long-term service. Additionally, it shall meet the physical/mechanical property specifications detailed in Subsection D-6-1-4-2a(3) of this attachment.

Additionally, the transmissive geosynthetic layer material shall meet the following specifications:

1. The permeability shall be greater than or equal to 1 x 10^{-2} cm/sec.
2. The first lift of final cover vegetative layer material placed adjacent to the closure cover transmissive geosynthetic layer shall have a maximum particle size of 1¼ inch. The large-sized chalk particles shall be non-angular (sub-angular, sub-rounded or rounded).
3. The pore size distribution shall be adequate to filter overlying soil without becoming clogged and preventing liquid flow. Adequacy of specific materials shall be determined, prior to construction, through laboratory testing, under the anticipated

field conditions with soils from the Facility, as described in Supplement 1, "Geotextile Filtration Test", which is located at the end of Attachment D-6-1-4.

4. The strength parameter specifications detailed in Subsections D-6-1-4-l(2)(a) and D-6-1-4-l(2)(b) of this document shall be met.

D-6-1-4-2m(2) Closure Cover Transmissive Geosynthetic Strips

Strips of a transmissive geosynthetic material, a minimum of five (5) feet wide each, shall be placed at 50-foot intervals on top of the Trench 22 closure cover geomembrane liner and beneath the transmissive geosynthetic layer, as shown on the Landfill Design Drawings provided in Appendix D-6-2 of this Application. Because of the higher required transmissivity of the drainage layer, the supplementary strips will not be required for Trench 23. The material selected for use as the transmissive geosynthetic strips may be a geotextile and/or geonet or other material. The selected material shall have a transmissivity greater than or equal to 3×10^{-6} m^2/sec. The required transmissivity shall be determined, prior to construction, through laboratory testing (ASTM D4716) under the anticipated field conditions, as detailed in Subsection D-6-1-4-2d(4) of this attachment.

D-6-1-4-2n Closure Cover Vegetative Layer

The vegetative layer shall be placed across the closure cover surface over each landfill cell as shown in the Landfill Design Drawings provided in Appendix D-6-2 of this Application. The top slopes, as shown on these drawings, are between three (3) and five (5) percent, and the side slopes are no greater than 25 percent. The uppermost six (6) inches of the vegetative layer shall be soil suitable for supporting vegetation. In addition, the closure cover vegetative layer material shall meet the following specifications:

1. The material shall be substantially free of frozen or other deleterious matter. Material containing organic matter shall generally be limited to use in the uppermost six (6) inches of the layer.

2. The material shall be placed in one or more lifts totaling nominally three (3) feet thick, with a minimum thickness of two (2) feet.

3. The maximum particle size shall be nominally six (6) inches in the largest dimension. The material placed immediately adjacent to the closure cover transmissive geosynthetic layer or the closure cover subsurface drain geotextile filter shall have a maximum particle size of 1¼ inch. The large-sized chalk particles shall be non-angular (sub-angular, sub-rounded or rounded).

In placing this material, dozers and other equipment (with a maximum ground pressure of 15 psi) shall operate over no less than a six-inch thickness of chalk bedding material above synthetic components. Rubber-tired heavy equipment (such as scrapers, front-end loaders, etc.) and trucks (other than passenger-type) shall operate over no less than a 1.5 feet thickness of chalk above synthetic components.

The primary vegetation shall consist of common bermuda grass, tall fescue and crimson clover. These grasses shall be established by broadcasting the seed with a spreader at the following approximate average rates and seasons:

1.	Common bermuda grass	30 lbs/acre	March - May
2.	Tall fescue	25 lbs/acre	September - October and March
3.	Crimson clover	30 lbs/acre	Late August - October

As secondary grass, brown-top millet shall be planted if it is done in May through August by broadcasting at an approximate average rate of 30 lbs/acre.

D-6-1-4-2o Closure Cover Subsurface Drains

The sub-surface interceptor drain shall be installed in the closure cover over Trench 22 and Trench 23, as shown on the Landfill Design Drawings provided in Appendix D-6-2 of this Application. The sub-surface cover drain shall be installed on the upper slope break of each bench and shall be placed above the closure cover geomembrane liner. These drains shall consist of a perforated corrugated pipe, nominally six (6) inches in diameter, surrounded by a coarse granular material and wrapped with a geotextile filter.

The sub-surface drain shall intercept the sub-surface flow carried by the drainage layer. The intercepted flow shall be carried in the drain by the perforated corrugated pipes to their junction with the downslope pipes. The sub-surface flow shall then flow through the downslope pipes along with the surface water.

The materials used to construct the closure cover subsurface drains shall meet the specifications provided within the Subsections D-6-1-4-2o(1) and D-6-1-4-2o(2).

D-6-1-4-2o(1) Geotextile Filter/Cushion

The geotextile shall function as a filter between the closure cover vegetative layer and the closure cover drain coarse granular material and as a cushion between the closure cover coarse drain granular material and the closure cover geomembrane.

The geotextile shall be comprised of polymeric yarns or fibers oriented into a stable network which retains its relative structure during handling, placement, and long-term service. Additionally, the geotextile shall meet the same physical/mechanical property specifications as for the closure cover transmissive geosynthetic layer detailed in Subsection D-6-1-4-2m(1) of this attachment.

The material shall also meet the following specifications:

1. The permeability shall be greater than or equal to 1 x 10^{-3} cm/sec., as determined by ASTM D5493.
2. The vegetative cover adjacent to the geotextile shall be free of irregularities and shall have a maximum particle size of 1¼ inch. The large-sized chalk particles shall be non-angular (sub-angular, sub-rounded or rounded).
3. The pore size distribution shall be adequate to filter overlying soil without becoming clogged and preventing liquid flow. Adequacy of specific geotextiles shall be determined, prior to construction, through laboratory testing, under the anticipated field conditions with soils from the Facility, as described in Supplement 1, "Geotextile Filtration Test", which is located at the end of Attachment D-6-1-4.

D-6-1-4-2o(2) Coarse Granular Material

The closure cover drain coarse granular material shall meet the specifications detailed in Subsection D-6-1-4-2f(2) of this attachment, except there shall be no D_{85} requirements.

D-6-1-4-2p Surface Water Drainage

A Surface Water Drainage System has been designed to control run-off from the closure covers on the completed landfill. Run-off shall be directed from the surface of the landfill closure cover along terraces into the downslope pipes. The flow from the terraces shall be intercepted by junction structures located at the lowest elevation on the terraces. The flow from the downslope pipe shall be carried by the perimeter ditches to the sediment basins. The location of the terraces and downslope pipes are shown on the final closure cover grading plan in the design drawing package.

The Facility controls run-on and run-off in and around active and inactive landfill cells, closed landfill cells, and cells that under construction as described in Attachment D-6-1-1 of this Application.

D-6-1-4-3 Geosynthetic Installation Specifications

The Facility will handle, store, test, and install all geosynthetics in accordance with the procedures and requirements described in the following subsections. In addition, the Facility will document the location of all repairs made to the liner system.

D-6-1-4-3a Geomembrane

D-6-1-4-3a(1) Handling and Storage

The handling of the materials is the responsibility of the Geosynthetics Installer from the time the materials arrive on Facility until the time the completed installation is accepted by the Owner. Handling of rolls of geomembrane shall be done in a competent manner such that damage does not occur to the product. In this regard, ASTM D4873 (Guide to Identification, Storage, and Handling of Geosynthetics) shall be followed. The Geosynthetics Installer shall be responsible for all damages which occur to the materials during handling and storage. This includes, but is not limited to, physical damage to the material resulting directly from equipment during off-loading, transport, and deployment processes, or indirectly from the leakage or spillage of any fluids.

Any material or portion thereof exposed to leaking hydrocarbon fluids shall be removed from the Facility, disposed of and replaced at no expense to the Owner.

The geomembrane material shall be protected from dirt, mud, dust and damage at all times prior to deployment. The geomembrane material may require a cover if it is to be exposed to ultra-violet light for more than one (1) year. In any event, the geomembrane shall meet or exceed the material specifications detailed in Subsections D-6-1-4-2c(2)(a) and D-6-1-4-2c(2)(b) of this attachment. Extended storage at the Facility may be cause for additional testing to substantiate that these specifications are met.

D-6-1-4-3a(2) Earthwork Preparation

The earth subgrade supporting the geomembrane shall be a smooth uniform surface, free of irregularities, depressions, protrusions, areas that have been softened by precipitation, or other features which would adversely affect the integrity of the geomembrane liner to be placed upon it. Geomembrane placement shall not proceed in areas which do not meet these specifications.

D-6-1-4-3a(3) Conformance Testing

Upon delivery of the rolls of geomembrane, samples shall be removed by the Installer and forwarded by the Geosynthetic QAC to the Geosynthetic QAL for testing to determine conformance with the material specifications, detailed in Subsection D-6-1-4-2c(2)(b) of this attachment. The samples shall be tested, at a minimum, for density, thickness and tensile properties.

Unless otherwise specified, these samples shall be taken at an average frequency of one per 100,000 ft^2 of geomembrane to be installed. Samples shall be taken across the entire width of the roll and shall not include the first three (3) feet. Unless otherwise specified, samples shall be three (3) feet long by the roll width.

D-6-1-4-3a(4) Placement

The secondary and cover geosynthetic liners shall be placed directly on the soil component of the respective liner systems as specified in Subsection D-6-1-4-3a(2). The Geosynthetics Installer shall not deploy more geomembrane panels than can reasonably be welded or seamed during the same day. The Geosynthetics Installer shall further limit the deployment of panels during periods of impending bad weather such that only one panel is unwelded at any given time. The Geosynthetics Installer shall temporarily load all deployed panels along their entire length and width such that the geomembrane is protected against lifting by wind. Further, the panels shall be placed such that the overlap of the panels will minimize the potential for uplifting by winds.

Geomembrane panels shall be placed in a controlled manner such as pulling, hoisting, or rolling. Uncontrolled placement methods such as "free-fall" shall not be allowed. The method of placement to be employed by the Geosynthetics Installer shall be agreed upon by the Owner prior to use. The panels shall be placed in such a manner that the geomembrane is not scratched or crimped. Any such damage shall be repaired in accordance with the procedures described in Subsection D-6-1-4-3a(8)(a) or disposed of and replaced by and at the expense of the Geosynthetics Installer. Personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in other activities which could damage the material. The Geosynthetics Installer shall provide adequate protection of the geomembrane from any equipment or concentrated personnel traffic associated with construction. Any damage to the geomembrane resulting from such activities will be repaired or removed, disposed of and replaced by and at the expense of the Geosynthetics Installer as directed by the Owner.

D-6-1-4-3a(4)(a) Weather Conditions

Geomembrane placement shall not proceed at an ambient temperature below 32°F or above 104°F unless otherwise authorized, in writing, by the Facility Manager. Geomembrane placement shall not be performed during precipitation events, in the presence of excessive moisture (e.g., fog, dew), in an area of ponded water, or in the presence of excessive winds, unless approved by the Facility Manager.

D-6-1-4-3a(4)(b) Damage

Any panel or portion thereof which becomes seriously damaged (torn or twisted permanently) shall be replaced. Less serious damage shall be repaired in accordance with Subsection D-6-1-

4-3a(8) of this attachment. Damaged panels or portions of damaged panels which have been rejected shall be removed from the work area.

D-6-1-4-3a(5) Field Seaming

D-6-1-4-3a(5)(a) Seam Layout

The Installer shall submit to the QAC Officer a geomembrane panel layout plan. In general, seams shall be oriented parallel to the line of maximum slope, i.e., oriented along, not across, the slope. In corners and odd-shaped geometric locations, the number of field seams shall generally be minimized.

D-6-1-4-3a(5)(b) Overlapping and Temporary Bonding

1. The geomembrane panels shall be overlapped prior to seaming nominally three (3) inches for extrusion welding and five (5) inches for fusion welding.
2. The procedure used to temporarily bond adjacent panels together shall not damage the geomembrane. In particular, the temperature of the air at the nozzle of any spot welding apparatus shall be controlled such that the geomembrane is not damaged.

D-6-1-4-3a(5)(c) Seam Preparation

1. Prior to seaming, the weld area shall be clean and free of moisture, dust, dirt, debris and foreign material.
2. If seam area and/or sheet edge grinding are required, the process shall be completed according to the material manufacturer's quality control procedures and in a way that does not damage the geomembrane.
3. Seams shall be aligned with the fewest possible number of wrinkles and "fishmouths".

D-6-1-4-3a(5)(d) Seaming Equipment

Fusion, extrusion welding processes, or new technology which has been proven to be as effective or more effective than the existing technology shall be used for permanent seaming of HDPE geomembrane.

The extrusion welding apparatus shall be equipped with gauges which indicate the temperature in the extruder and at the nozzle. Additionally, the Installer shall provide documentation regarding the HDPE extrudate and shall certify that the extrudate is compatible with the HDPE resin specifications detailed in Subsection D-6-1-4-2c(2)(a) of this attachment. The fusion welding apparatus shall be an automated, self-propelled device.

D-6-1-4-3a(5)(e)   Weather Conditions for Seaming

1. Unless authorized in writing by the Facility Manager, no seaming shall be attempted at ambient temperatures below 32 °F or above 104 °F. Prior to such seaming, the Installer shall submit documentation that seaming under these conditions produces seams which meet the specifications detailed in Table D-6-1-4.3, which is provided at the end of this attachment.
2. Below 32 °F, seaming shall be possible if the geomembrane sheet surface is preheated by either the sun or a hot air device to a temperature between 32 °F and 104 °F, and if there is not excessive cooling resulting from wind.
3. Below 32 °F, new trial seams shall be performed, as described in Subsection D-6-1-4-3a(5)(f) of this attachment, each time the ambient temperature drops by more than 10 °F. Such additional trial seams shall be conducted upon completion of production seams in progress during the temperature drop.

D-6-1-4-3a(5)(f)   Trial Seams

Trial seams shall be made on fragment pieces of geomembrane to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period, for each production seaming apparatus used that day. Each seamer shall make at least one trial seam each day that he/she performs seaming operations.

The trial seam sample shall be approximately five (5) feet long by one (1) foot wide, with the seam centered lengthwise. Two specimens shall be cut in the field by the Installer at locations selected randomly along the trial seam length. The two specimens shall be tested in the field by the Installer, both in peel or one in shear, using a tensiometer, and shall not fail in the seam. If a trial seam does not meet these specifications, the entire trial seam construction and testing operation shall be repeated. If the additional trial seam does not meet these specifications, the seaming apparatus or seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and a successful trial seam is achieved. The remainder portion of successful trial seam samples shall be retained for possible laboratory testing.

D-6-1-4-3a(5)(g)   General Seaming Procedures

The general seaming procedures used shall be as follows:

1. If required, a firm substrate shall be provided by using a flat board, a conveyor belt, or similar surface directly under the seam overlap.
2. Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles shall be seamed, and any portion where the overlap is inadequate shall then be covered

with an oval or round patch of the same geomembrane extending a minimum of six (6) inches beyond the cut in all directions.

3. Where extrusion welding is used, extrudate shall not be artificially cooled unless the Installer first demonstrates that such cooling produces satisfactory welds as specified herein.

D-6-1-4-3a(6) Nondestructive Seam Testing

The Installer shall nondestructively test all field seams over their full length using a vacuum test unit, air pressure test, spark test, "flood" test, or other approved method. Each of these methods is described in Subsections D-6-1-4-3a(6)(a) through D-6-1-4-3a(6)(d) of this attachment, respectively. Nondestructive testing shall be carried out as the seaming work progresses, not at the completion of all field seaming.

Seams that cannot be nondestructively tested shall be observed by the Geosynthetic QAC and/or cap-stripped with the same geomembrane. The cap-stripping operations shall be observed by the Geosynthetic QAC.

D-6-1-4-3a(6)(a) Vacuum Testing

The following procedures are applicable to vacuum testing.

1. The equipment shall consist of the following:
    a. A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, a porthole or valve assembly, and a vacuum gauge.
    b. A pump assembly equipped with a pressure controller and pipe connections.
    c. A rubber pressure/vacuum hose with fittings and connections.
    d. A soapy solution.
    e. A bucket and wide paint brush or other means of applying the soapy solution.

2. The following procedures shall be followed:
    a. Energize the vacuum pump and reduce the tank pressure to approximately 5 psi (gauge).
    b. With the soapy solution, wet a strip of geomembrane slightly larger than the vacuum box to be used.
    c. Place the box over the wetted area.

d. Close the bleed valve and open the vacuum valve.

e. Ensure that a leak-tight seal is created.

f. For a period of not less than ten (10) seconds, apply vacuum and examine the geomembrane through the viewing window for the presence of soap bubbles.

g. If no bubbles appear, open the bleed valve, move the box over the next adjoining area with a minimum three (3) inches overlap, and repeat the process.

h. All areas where soap bubbles appear shall be marked and repaired in accordance with Section D-6-1-4-3a(8) of this document.

D-6-1-4-3a(6)(b) Air Pressure Testing

The following procedures are applicable to air pressure testing.

1. The equipment shall consist of the following:

   a. An air pump (manual or motor driven) equipped with a pressure gauge capable of generating and sustaining a pressure of approximately 30 psi.

   b. A rubber hose with fittings and connections.

   c. A sharp hollow needle or other pressure feed device.

2. The following procedures shall be followed:

   a. Seal both ends of the seam to be tested.

   b. Insert the needle or other approved pressure feed device into the air channel.

   c. Energize the air pump to a pressure of approximately 30 psi (but not exceeding 50 psi), close the valve, allow approximately two (2) minutes for the pressure to stabilize, and sustain the pressure for at least an additional five (5) minutes.

   d. If the pressure does not stabilize or if the pressure loss exceeds the schedule provided by the material manufacturer for the geomembrane gauge thickness being installed, locate the faulty area of the seam and repair it in accordance with Subsection D-6-1-4-3a(8) of this attachment.

   e. Cut the opposite end of the tested seam area once testing is completed to verify continuity of the air channel. If air does not escape, locate the blockage and retest the unpressurized area. Seal the cut end of the air channel.

f. Remove the needle or other approved pressure feed device and seal.

D-6-1-4-3a(6)(c) Spark Testing

Extrusion welds, including patches, caps, and grind and weld repairs, may be nondestructively tested using the spark test method. This method employs either the use of a continuous length of copper wire embedded in the geomembrane overlap or metallic tape placed behind the weld area prior to seaming. A portable, pulse-type detector equipped with a brush-type electrode is used to detect discontinuities in the seam. All equipment used for spark testing shall be provided by the Installer.

The following procedures shall be followed:

1. Debris, such as scrap geomembrane, wire or metallic tape, and excessive dirt shall be removed from the weld area to be tested.
2. The portable detector shall be electrically charged to between 20,000 and 30,000 volts, and the brush electrode shall be passed over the seam at approximately the rate of 20 to 30 feet per minute and at a distance less than or equal to ¾ inch from the surface of the geomembrane.
3. A spark arcing from the wire or tape beneath the geomembrane to the electrode is indicative of a defect in the seam. The spark will be visible and will produce a crackling sound emanating from the defective area. A seam that sparks in this manner shall be considered as failing and shall be marked and repaired in accordance with the procedures detailed in Subsection D-6-1-4-3a(8) of this attachment and retested.

D-6-1-4-3a(6)(d) Flood Testing

Extrusion welds and fusion welds may be nondestructively tested using the flood test method. This method consists of submergence of the seam in water in a confined area and observing for leakage.

The equipment to be used shall consist of the following:

1. Tap water with enough volume to flood a specific confined area of the geomembrane.

2. Thin sheets of tissue paper.

The following procedures shall be followed:

1. Delineate the area to be tested. The maximum area to be tested at one time shall typically be six (6) feet by six (6) feet, unless otherwise directed by the Owner.
2. Insert tissue paper beneath the area to be tested, with at least one (1) foot extending beyond the boundaries of the test area.
3. Pour water into the confined area to be tested.
4. Observe the surface of the flooded area for a minimum of five (5) minutes for bubbles and observe the bottom and/or the tissue paper placed beneath the tested area for signs of water infiltration and leakage.
5. Areas where water leakage appears shall be marked and repaired in accordance with Subsection D-6-1-4-3a(8) of this attachment.

D-6-1-4-3a(6)(e) Test Failure Procedures

The Installer shall complete required repairs in accordance with Subsection D-6-1-4-3a(8) of this attachment.

D-6-1-4-3a(7) Destructive Seam Testing

Destructive seam tests shall be performed at selected locations. The purpose of these tests is to evaluate seam strength. Seam strength testing shall be done as the seaming work progresses, not at the completion of all field seaming.

D-6-1-4-3a(7)(a) Location and Frequency

The Geosynthetic QAC shall select locations where seam samples will be cut for laboratory testing. Those locations shall be established as follows:

1. An initial minimum frequency of one (1) test per 500 feet of seam length performed will be established.
2. The Method of Attributes, described in GRI-GM14, or Method of Control Charts, described in GRI-GM20 may then be utilized for a possible modification to the start-up sampling interval.
3. The Method of Attributes gives the procedure for establishing the batch size of the samples needed at the initial interval prior to any possible modification. Based upon the number of failed samples in the initial batch, the spacing is either increased (for

good seaming), kept the same, or decreased (for poor seaming). A second batch size is then determined and the process is continued. Depending on the project size, i.e., the total length of seaming, a number of decision cycles can occur until the project is finished.

4. The Method of Control Charts requires the establishment of an upper control limit (UCL) and lower control limit (LCL) of seam failure rates. It then proceeds with the calculation of the seam failure rate beginning with the first sample's test result. When the failure rate exceeds the UCL, the sampling frequency, or interval, should be decreased. When the failure rate drops beneath the LCL, the sampling frequency, or interval, should be increased. When the failure rate is between the UCL and the LCL, the sampling frequency, or interval, should remain the same.
5. Test locations shall be determined during seaming operations. Selection of such locations may be prompted by suspicion of overheating, contamination, offset welds, or other potential causes of imperfect welding. The Installer shall not be informed in advance of the locations where the seam samples will be taken.

D-6-1-4-3a(7)(b) Sampling Procedures

The Installer shall cut the sample from the geomembrane. Holes in the geomembrane resulting from destructive seam sampling shall be repaired in accordance with the procedures detailed in Subsection D-6-1-4-3a(8) of this attachment.

D-6-1-4-3a(7)(c) Size of Samples

The samples shall be approximately 12 inches wide and at least 44 inches in length, with the seam centered lengthwise. A one inch wide strip shall be cut from each end of the sample and tested by the Installer in the field using a tensiometer, for peel, or peel and shear, and shall not fail in the seam. The remainder of the sample shall be cut into three parts and distributed as follows:

1. one portion, measuring approximately 12 inches by 15 inches, to the Installer for potential laboratory testing;
2. one portion, measuring approximately 12 inches by 15 inches, to the Geosynthetic QAC for laboratory testing by the Geosynthetic QAL; and
3. one portion, measuring approximately 12 inches by 12 inches, to the Facility for archive storage.

D-6-1-4-3a(7)(d)   Procedures for Destructive Test Failure

The following procedures shall apply whenever a sample fails destructive testing. The Installer shall have two options:

1. Reconstruct the seam between the failed location and any passed test location.
2. Retrace the welding path to an intermediate location a minimum of 10 feet from the location of the failed test and obtain a sample for an additional test. If this additional sample passes testing, then the seam shall be reconstructed between that location and the original failed location. If this sample fails, then the process shall be repeated. In any case, all acceptable seams shall be bounded by two passed test locations (i.e., the above procedure shall be followed in both directions from the original failed location.)

Whenever a sample fails, additional testing may be required for seams that were welded by the same welder and/or welding apparatus or welded since the last trial seam. This shall be done if the cause of the failure is the welder's technique or the welding apparatus. Field trial seams may be used as destructive test samples if the retracing process continues to the start or completion of a welding period. In the event that a trial seam is used for this purpose, it shall be submitted for laboratory testing in accordance with Subsection D-6-1-4-3a(7) of this attachment.

D-6-1-4-3a(8)   Defects and Repairs

The geomembrane surface shall be swept or washed by the Installer if the amount of dust or mud inhibits observation. Suspected defect locations in seam and non-seam areas shall be nondestructively tested using the methods described in Subsection D-6-1-4-3a(6) of this attachment, as appropriate. Each location which fails the nondestructive testing shall be repaired.

D-6-1-4-3a(8)(a)   Repair Procedures

Any portion of the geomembrane exhibiting a flaw or failing a destructive or nondestructive test shall be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be agreed upon by all appropriate parties.

1. The repair procedures available include:
   a. Patching, used to repair large holes or tears, or to remove undispersed raw materials and contamination by foreign matter.
   b. Spot welding or seaming, used to repair small tears, pinholes, or other minor, localized flaws.

c. Capping, used to repair large lengths of failed seams.

d. Extrusion welding of the flap, used to repair areas of inadequate fusion seams which have an exposed edge.

e. Removing of a defective seam and replacing with a strip of new material welded into place.

f. Seam reconstruction for the extrusion welding process, achieved by grinding the existing seam and rewelding a new seam.

g. Seam reconstruction for the fusion process, achieved by cutting out the existing seam and welding in a replacement strip or continuously extrusion welding the flap.

2. For any repair method, the following provisions shall be satisfied:

a. Surfaces of the geomembrane which are to be repaired using extrusion methods shall be abraded no more than one hour prior to the repair.

b. All surfaces shall be clean and dry at the time of the repair.

c. All seaming equipment used in repair procedures shall meet the requirements of the specifications as detailed in this document.

d. Patches or caps shall extend at least six (6) inches beyond the edge of the defect, and all corners of patches shall be rounded with a radius of approximately three (3) inches.

D-6-1-4-3a(8)(b) Repair Verification

Each repair shall be documented by number and location. Each repair shall be nondestructively tested using one of the methods described in Subsection D-6-1-4-3a(6) of this document, as appropriate. Repairs which pass nondestructive testing shall be taken as an indication of an adequate repair. Failed tests indicate that the repair shall be redone and retested until a passing test results.

D-6-1-4-3a(9) Materials in Contact with the Geomembrane

Installation on rough surfaces such as concrete shall be performed carefully to prevent damage. Additional loosely placed geotextile sections may be used by the Installer as protection for the geomembrane.

D-6-1-4-3a(9)(a) Granular Materials

The following specifications shall be met during the installation of granular materials in contact with the geomembrane:

1. Placement of granular materials on the geomembrane shall not proceed at an ambient temperature below 32 °F.
2. Equipment used for placing the material shall not be driven directly on the geomembrane.
3. Bulldozers (up to a maximum ground pressure of 15 psi) shall operate over no less than six (6) inches of soil. Rubber-tired heavy equipment (such as scrapers, front-end loaders, etc.) and trucks (other than passenger-type) shall operate over no less than 1.5 feet of soil.
4. Placement of the material shall be done in such a manner that geomembrane damage is unlikely.

D-6-1-4-3a(9)(b) Concrete

Construction methods used to place concrete shall not damage the geomembrane. To this end, a geotextile shall be installed in areas within the waste placement limits where the concrete is placed directly over and in contact with the geomembrane liner.

D-6-1-4-3b Geonet

D-6-1-4-3b(1) Shipment and Storage

During shipment and storage, the geonet shall be protected from mud, dirt, dust, or any other damaging or deleterious conditions. If the geonet is not clean at the time of installation, it shall be washed by the Installer prior to use.

D-6-1-4-3b(2) Conformance Testing

Upon delivery of the rolls of geonet, the Geosynthetic QAC shall ensure that samples are removed by the Installer and forwarded to the Geosynthetic QAL for testing to determine conformance with the material specifications detailed herein. The samples shall be tested, at a minimum, for thickness, mass per unit area, tensile strength (wide width), and transmissivity. Unless otherwise specified, samples shall be obtained at an average frequency of one (1) test per 100,000 ft^2.

Samples shall be taken across the entire width of the roll and shall not include the first three (3) feet. Unless otherwise specified, samples shall be three (3) feet long by the roll width.

D-6-1-4-3b(3) Handling and Placement

The Installer shall handle all geonet in such a manner as to ensure the material is not damaged and that the following are complied with:

1. In the presence of wind, the geonet may require weighing with sandbags or the equivalent. If necessary, such sandbags shall be installed during placement and shall remain until replaced with cover material.
2. Unless otherwise specified, the geonet shall not be welded to geomembrane.
3. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geonet.
4. During placement of geonet, care shall be taken not to entrap dirt or excessive dust that could cause clogging of the drainage system, and/or stones that could damage the adjacent geomembrane.
5. Care shall be taken not to leave tools in the geonet.
6. Geonet shall be anchored at the top of the slope as indicated in the Landfill Design Drawings provided in Appendix D-6-2 of this Application.

<u>D-6-1-4-3b(4) Stacking and Joining</u>

When several layers of geonet are stacked, care shall be taken to prevent strands from one layer from penetrating the channels of the next layer. Stacked geonet shall be laid in the same direction (i.e., stacked geonet should not be laid in perpendicular directions, unless otherwise specified). In the corners of side slopes of rectangular landfills, where geonets may be installed in perpendicular directions, they shall be joined as end overlaps.

Adjacent geonet panels shall be joined according to the Construction Drawings developed prior to construction of each cell. At a minimum, the following requirements shall be met for overlaps:

1. Adjacent rolls shall be overlapped by at least four (4) inches.
2. These overlaps shall be secured with ties placed at the center of the overlap.
3. Tying shall be achieved by plastic fasteners. Tying devices shall be white or yellow. Metallic devices are not allowed.

4. Tying shall be every five (5) feet along the slope and every one (1) foot at the crest and toe of the slope for a distance of not less than five (5) feet. At the crest, the one (1) foot tie interval begins at least three (3) feet back from the crest. At the toe, the 1-foot tie interval begins at least five (5) feet upslope from the toe.

D-6-1-4-3b(5) Geonet Repair

Holes or tears in the geonet shall be repaired by placing a patch extending a minimum of six (6) inches beyond the edges of the hole or tear. The patch shall be secured to the original geonet by tying on at least one (1) foot centers. Tying devices shall be as indicated in Subsection D-6-1-4-3b(4) of this attachment. If the hole or tear width across the roll is more than 50% of the width, the damaged area shall be cut out, and the two portions of the geonet shall be joined as indicated in Subsection D-6-1-4-3b(4) of this attachment.

D-6-1-4-3b(6) Placement of Cover Materials

The Installer shall place all cover materials in such a manner to ensure that the geonet and underlying materials are not damaged.

D-6-1-4-3c Geotextile

D-6-1-4-3c(1) Shipment and Storage

During shipment and storage, the geotextile shall be protected from ultraviolet exposure, precipitation, or contamination by mud, dirt, dust, puncture, cutting or other damaging or deleterious conditions. To that end, geotextile rolls shall be shipped and stored in relatively opaque and watertight wrappings.

D-6-1-4-3c(2) Conformance Testing

Upon delivery of the rolls of geotextiles, the Geosynthetic QAC shall ensure that samples are removed by the Installer and forwarded to the Geosynthetic QAL for testing to determine conformance with the material specifications detailed herein. The samples shall be tested, at a minimum, for mass per unit area, puncture strength, grab strength and burst strength. If used as a filter, the geotextile shall also be tested for permeability and AOS. If used on the side slopes, the geotextile shall also be tested for wide width tensile strength. Unless otherwise specified, samples shall be taken at a rate of one (1) test per 100,000 ft^2.

Samples shall be taken across the entire width of the roll and shall generally not include the first three (3) feet. Unless otherwise specified, samples shall be three (3) feet long by the roll width.

D-6-1-4-3c(3) Handling and Placement

The Installer shall handle geotextiles in such a manner as to ensure they are not damaged, and the following are complied with:

1. In the presence of wind, the geotextile may require weighing with sandbags or the equivalent. Such sandbags shall be installed during placement and shall remain until replaced with cover material.

2. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geotextile.

3. During placement, care shall be taken not to entrap in or under the geotextile stones, excessive dust, or moisture that could damage the geomembrane or hamper subsequent geotextile seaming.

D-6-1-4-3c(4) Seams and Overlaps

On slopes steeper than 10H : 1V, geotextiles shall be seamed. Seaming can be achieved by sewing, adhesives, fusion or other approved means. Seams shall be continuously seamed (i.e. spot seaming is not allowed). Geotextiles shall be overlapped a minimum of six (6) inches prior to seaming. On slopes steeper than 10H : 1V, horizontal seams shall be allowed only if the adjacent geotextile panels are continuous throughout the length of the slope. Sewing shall be done using polymeric thread of contrasting color, with properties equal to or exceeding those of the geotextile.

On slopes flatter than 10H : 1V, geotextiles can either be seamed as detailed above, or overlapped a minimum of 12 inches. In the latter case, spot seaming may be considered as a measure against wind uplift. Overlaps shall be oriented (top to bottom) in the direction of earth filling.

D-6-1-4-3c(5) Geotextile Repair

Holes or tears in the geotextile shall be repaired as follows:

1. On slopes: A geotextile patch shall be seamed into place with a minimum of six (6) inches overlap in all directions beyond the hole or tear. Should any tear exceed 10% of the width of the roll, that panel shall be removed from the slope and replaced.

2. Non-slopes: A geotextile patch shall be spot-seamed in place with a minimum of six (6) inches overlap in all directions beyond the hole or tear.

Care shall be taken to remove any soil or other material which may have penetrated the torn geotextile.

D-6-1-4-3c(6) Cover Materials

The Installer shall place all cover materials in such a manner to ensure the geotextile and underlying materials are not damaged.

D-6-1-4-3d Geosynthetic Clay Liner

D-6-1-4-3d(1) Handling and Storage

The handling of the GCL shall be done in a competent manner such that damage does not occur to the material. The GCL shall be protected from physical damage resulting directly from off-loading, transport, and deployment processes, or indirectly from the leakage or spillage of any hydrocarbon fluids.

The GCL material shall be protected from dirt, mud, dust and damage at all times prior to deployment. The GCL rolls shall not be stacked more than two (2) high to avoid thinning at points of contact. In any event, the GCL shall meet or exceed the material specifications detailed herein. Extended storage at the Facility may be cause for additional testing to substantiate that these specifications are met.

D-6-1-4-3d(2) Earthwork Preparation

The earth subgrade supporting the GCL shall be a smooth uniform surface, free of irregularities, depressions, protrusions, areas which have been softened by precipitation, or other features which would adversely affect the integrity of the GCL to be placed upon it. GCL placement shall not proceed in areas which do not meet these specifications.

D-6-1-4-3d(3) Conformance Testing

Upon delivery of the rolls of GCL, samples shall be removed by the Installer and forwarded by the Geosynthetic QAC to the Geosynthetic QAL for testing to determine conformance with the material specifications detailed herein.

These samples shall be taken at an average frequency of one (1) per 250,000 ft^2 of GCL to be installed. Samples shall be taken across the entire width of the roll and shall not include the first three (3) feet. Unless otherwise specified, samples shall be three (3) feet long by the roll width.

D-6-1-4-3d(4) Placement

D-6-1-4-3d(4)(a) Weather Conditions

GCL placement shall not be performed during precipitation events, in the presence of excessive moisture (e.g., fog, dew, frost), in an area of ponded water, or in the presence of excessive winds, unless approved by the Facility Manager.

D-6-1-4-3d(4)(b) Damage

Any roll or portion thereof which becomes seriously damaged or moistened shall be replaced.

D-6-1-4-3d(4)(c) Deployment

The Installer shall deploy all GCL panels in such a manner as to ensure the material is kept dry and is not damaged, and that the following procedures are complied with:

1. In the presence of wind, the GCL may require weighing with sandbags or the equivalent. If necessary, such sandbags shall be installed during placement and shall remain until replaced with cover material.
2. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the GCL.
3. During placement of GCL, care shall be taken not to entrap in or under the GCL stones or moisture that could damage the adjacent geomembrane or GCL.
4. The GCL shall be anchored at the top of the slope as indicated in the Landfill Design Drawings included in Appendix D-6-2 of this Application.

D-6-1-4-3d(5) Seams and Overlaps

Each adjoining GCL panel shall be overlapped a minimum of six (6) inches on each side and twenty-four (24) inches end-to-end. The overlap area shall be free of dirt, gravel, and debris. The overlap shall be maintained to prevent seam openings during the installation and covering process.

D-6-1-4-4 HDPE Pipe Specification

The vertical and upslope riser pipes in Trench 22 and Trench 23 shall be of the size, type, and configuration as shown on the Landfill Design Drawings provided in Appendix D-6-2 of this Application. The HDPE pipes shall meet or exceed the minimum specifications as provided below. Joining of HDPE pipes shall be by butt-fusion welds, extrusion welds, flanges, or by means as shown on the Drawings. All welding of the pipe shall be in accordance with manufacturers recommendations.

Property	ASTM TEST Method Minimum	Specifications
Density	D1505	0.955 g/cm^3
Tensile Strength at Yield	D638	3,000 psi
Hydrostatic Design Basis	D2837	1,600 psi

D-6-1-4-5 Concrete Pipe Specification

The vertical concrete riser pipes in Trench 22 and Trench 23 shall be of the size, type, and configuration as shown on the Landfill Design Drawings. The reinforced concrete pipe sections and base plates shall meet or exceed the requirements specified in AASHO M199, pre-cast reinforced concrete manhole sections. Additionally, all concrete for pipe sections, base plates, and bearing rings shall have a minimum 28-day compressive strength of 4,000 psi. All concrete shall be coated including both the inside and outside of the pipe sections in accordance with the manufacturer's recommendations.

[End of Attachment D-6-1-4 Text]

ATTACHMENT D-6-1-4

SPECIFICATIONS FOR CONSTRUCTION MATERIALS

TABLES

TABLE D-6-1-4.1
HDPE SMOOTH GEOMEMBRANE

Property	Qualifier	Unit	Specified Value				All Thicknesses	Test Method
Thickness	min. average	mils	40	60	80	100		ASTM D5199
lowest individual of 10 values	min. reading	mils	36	54	72	90		ASTM D5199
Density (geomembrane)	min.	g/cc	0.940					ASTM D1505/D792
Tensile Properties *(1)* :								
1. Yield strength	min. average	lb/in	84	126	168	210	2,200 psi	ASTM D6693
2. Break strength	min. average	lb/in	152	228	304	380	3,800 psi	ASTM D6693
3. Yield elogation	min. average	%	12					ASTM D6693
4. Break elogation	min. average	%	700					ASTM D6693
Tear Resistance	min. average	lb	28	42	56	70	700 lb/in	ASTM D1004
Puncture Resistance	min. average	lb	72	108	144	180	1,800 lb/in	ASTM D4833
Stress Crack Resistance *(2)*	min.	hr	300					ASTM D5397
Carbon Black Content	range	%	2.0 to 3.0					ASTM D1603*(3)*
Carbon Black Dispersion	rating	N/A	note *(4)*					ASTM D5596
Oxidative Induction Time (OIT) *(5)*								
(a) Standard OIT	min. average	minutes	100					ASTM D3895
- or -								
(b) High Pressure OIT	min. average	minutes	400					ASTM D5885
Oven Aging at 85°C *(5), (6)*								ASTM D5721
(a) Standard OIT - % ret. after 90 days	min. average	%	55					ASTM D3895
- or -								
(b) High Pressure OIT - % ret. after 90 days	min. average	%	80					ASTM D5885
UV Resistance *(7)*								ASTM D7238
(a) Standard OIT	min. average	N.R. *(8)*	N.R. *(8)*					ASTM D3895
- or -								
(b) High Pressure OIT - % ret. after 1600 hours *(9)*	min. average	%	50%					ASTM D5885

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elogation is calculated using a gage length of 1.3 inches
Break elogation is calculated using a gage length of 2.0 inches

(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(3) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if appropriate correlation to D1603 (tube furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either on of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

TABLE D-6-1-4.2
HDPE TEXTURED GEOMEMBRANE

Property	Qualifier	Unit	Specified Value	All Thicknesses	Test Method
Thickness	min. average	mils	40 60 80 100		ASTM D5994
lowest individual for 8 out of 10 values	min. reading	mils	36 60 80 100		ASTM D5994
lowest individual of 10 values	min. reading	mils	34 51 68 85		ASTM D5994
Asperity Height *(1)*	min. average	mils	10		ASTM D7466
Density (geomembrane)	min. average	g/cc	0.940		ASTM D1505/D792
Tensile Properties*(2)* :					
1. Yield strength	min. average	lb/in	84 126 168 210	2,200 psi	ASTM D6693
2. Break strength	min. average	lb/in	60 90 120 150	3,800 psi	ASTM D6693
3. Yield elogation	min. average	%	12		ASTM D6693
4. Break elogation	min. average	%	100		ASTM D6693
Tear Resistance	min. average	lb	28 42 56 70	700 lb/in	ASTM D1004
Puncture Resistance	min. average	lb	60 90 120 150	1,800 lb/in	ASTM D4833
Stress Crack Resistance *(3)*	min.	hr	300		ASTM D5397
Carbon Black Content	range	%	2.0 to 3.0		ASTM D1603*(4)*
Carbon Black Dispersion	rating	N/A	note *(5)*		ASTM D5596
Oxidative Induction Time (OIT) *(6)*					
(a) Standard OIT	min. average	minutes	100		ASTM D3895
- or -					
(b) High Pressure OIT	min. average	minutes	400		ASTM D5885
Oven Aging at 85°C *(6), (7)*					ASTM D5721
(a) Standard OIT - % ret. after 90 days	min. average	%	55		ASTM D3895
- or -					
(b) High Pressure OIT - % ret. after 90 days	min. average	%	80		ASTM D5885
UV Resistance *(8)*					ASTM D7238
(a) Standard OIT	min. average	N.R. *(9)*	N.R. *(9)*		ASTM D3895
- or -					
(b) High Pressure OIT - % ret. after 1600 hours *(10)*	min. average	%	50%		ASTM D5885

(1) Of 10 readings; 8 out of 10 must be > or equal to 7 mils, and lowest individual reading must be > or equal to 5 mils.

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elogation is calculated using a gage length of 1.3 inches
Break elogation is calculated using a gage length of 2.0 inches

(3) P-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.

(4) Other methods such as D4218 (muffle furnace) or microwave methods are acceptable if appropriate correlation to D1603 (tube furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either on of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4hr. condensation at 60°C.

(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

TABLE D-6-1-4.3
HDPE GEOMEMBRANE SEAMS

Property	Qualifier	Unit	Specified Value				All Thicknesses	Test Method
Thickness (base sheet)	min. average	mils	40	60	80	100		
Bonded Seam Strength	min.	lb/in	80	120	160	200	2,200 psi	ASTM D6392*
Peel Adhesion:								
Fusion	min.	lb/in	60	91	121	151	1,500 psi	ASTM D6392*
Extrusion	min.	lb/in	52	78	104	130	1,300 psi	ASTM D6392*

Note:
*Test Methods Modified per Table 4.

TABLE D-6-1-4.4
TEST METHOD MODIFICATIONS

Property	Test Method	Modifications
Bonded Seam Strength and Peel Adhesion	ASTM D6392	For shear tests, the sheet shall yield before failure of the seam. For peel adhesion, seam separation shall not extend more than 25% into the seam. For either test, testing shall be discontinued when the sample has visually yielded. Sample failure shall conform to a passing configuration as outlined in Figure A-1.

ATTACHMENT D-6-1-4

SPECIFICATIONS FOR CONSTRUCTION MATERIALS

SUPPLEMENT 1

GEOTEXTILE FILTRATION TEST

ATTACHMENT D-6-1-4

SUPPLEMENT 1

GEOTEXTILE FILTRATION TEST

1.0 Scope

The purpose of this test is to define the filtration properties of a candidate geotextile for a Facility-specific soil.

2.0 Summary of Method

Soil taken from the area of proposed construction at the Facility is used to make a slurry. The soil slurry should have the consistency of motor oil, with a moisture content between 150 and 250 percent. The slurry is then poured on a piece of geotextile which has been securely placed in the bottom of a clear plastic cylinder, clamped within a permeameter mold. Hydrostatic pressure is then applied to the top of the slurry in the permeameter, and the outflow is observed for a period of time. A successful filter test result will be determined by observing the outflow, which should be cloudy for the first few minutes of applying the pressure and subsequently clear up and become stable over time. A soil cake will also form on the interface between the geotextile and the slurry above it. An unsuccessful filter test result will allow the entire contents of the cylinder to pass through the geotextile, and no soil cake will have formed.

3.0 Significance and Use

This method provides a direct means of observing, within a relatively short period of time, whether the candidate geotextile will have the ability to filter the Facility-specific soils without clogging.

4.0 Apparatus

The filtration test permeameter shall consist of a four-inch inside diameter clear plastic cylinder, fitted with a clamping device at the bottom to secure the geotextile and seal the chamber such that no soil or water can pass around the edges. The cylinder shall be fitted with an inflow and outflow tube. A graduated beaker shall be connected to the outflow tube.

5.0 Soil Slurry Preparation

A representative soil sample shall be obtained from the proposed area of construction at the Facility. Sufficient water is added to the soil sample to increase the water content within a range of 150 to 250 percent. The soil and water shall be mixed until a slurry with a homogenous consistency is obtained. The consistency of the slurry will resemble that of motor oil. The water content of the slurry shall be measured to verify that it is within an acceptable range. All clumps of soil that may have remained in the slurry shall be removed.

6.0 Geotextile Sampling

The geotextile sample shall be obtained as described in proposed ASTM Method 61-109 on Standard Practice for Sampling Geotextile for Testing. Each specimen shall be cut in a circle with a diameter required to fit the permeameter clamp.

7.0 Preparation of Test

Pieces of geonet shall be cut to fit the inside of the permeameter mold chamber and be placed beneath the geotextile specimen for support without restricting the outflow. The geonet and the geotextile shall be secured and sealed between the permeameter chamber and the clear plastic cylinder so that no soil or water can pass around the edges of the fabric. Care should be taken to avoid getting any sealant on the portion of the geotextile inside the cylinder.

A portion of the soil slurry prepared shall be poured into the permeameter. If large quantities of slurry were prepared, the entire slurry sample should be stirred before pouring it into the permeameter to remix particles that may have settled if the slurry was allowed to sit for an extended period of time. The outflow valve shall be closed before pouring slurry into the permeameter.

Once the permeameter is filled with soil slurry, the cover shall be put on and the top of the cylinder shall be sealed to the permeameter. The inflow pipe shall be connected to the permeameter cover and tightened securely. Water shall be allowed to slowly flow through the inlet (top of permeameter) until the cylinder is completely full.

8.0 Procedure

The test will begin when pressure is applied to the slurry, and the outflow valve is opened. The pressure applied shall be recorded. Low pressures such as 5 to 10 psi are acceptable, but higher pressures such as 20 to 50 psi will provide quicker results.

Flow through the permeameter shall begin by opening the outflow valve. The initial discharge will be measured after one (1) minute, and note the color of the fluid. The discharge shall be measured at equal intervals of time until the discharge clears. The test shall be allowed to run for as long as possible (several hours), periodically measuring the discharge. This will only be possible for a successful test. During an unsuccessful test, the entire contents of the cylinder will quickly flow through the geotextile.

9.0 Analysis of Results

All tests, whether successful or not, will produce an initial surge of cloudy water. For tests with successful filtration, the water becomes progressively clearer, and flow decreases, becoming stable at a flow less than the rate. When the geotextile is examined after the test, a soil "cake" will be present above the fabric.

For unsuccessful filters, the surge of cloudy water continues with no reduction in rate, and the test is stopped when the contents of the permeameter cylinder are emptied. Also, the outflow will consist of the slurry itself, rather than water with a small amount of fines.

[End of Supplement 1 to Attachment D-6-1-4]

ATTACHMENT D-6-1-5

APPENDIX D-6-1

SECTION D-6

CONSTRUCTION QUALITY ASSURANCE PLAN

Revision No.
5.0

ATTACHMENT D-6-1-5

CONSTRUCTION QUALITY ASSURANCE PLAN

TABLE OF CONTENTS

ATTACHMENT D-6-1-5

CONSTRUCTION QUALITY ASSURANCE PLAN

D-6-1-5-1 General

D-6-1-5-1a Introduction

The construction quality assurance (CQA) program is to ensure that each constructed landfill unit meets or exceeds the design criteria and specifications in the permit. The CQA program consists of this written CQA Plan and any additional quality assurance requirements that may be necessary as a result of the Construction Drawings developed prior to construction of each landfill cell.

The specifications for the materials and installation/construction included in this document are detailed in Attachment D-6-1-4, Specifications for Construction Materials, hereafter referred to as the Specifications.

D-6-1-5-1b Parties/Definitions

The Construction Quality Assurance Officer (CQA Officer) shall be the individual(s) responsible for development and implementation of the Construction Quality Assurance (CQA) program. The CQA Officer(s) shall be a registered professional engineer and may be an employee of the Quality Assurance Consultant(s) (QAC) [Soil QAC and/or Geosynthetic QAC]. The CQA Officer(s) shall be appointed by the Facility prior to construction of the pressure relief system and/or the structural fill.

The Soil Quality Assurance Consultant (Soil QAC) is the firm which, under the direction of the CQA Officer, observes and documents activities related to the quality assurance of the soil materials and construction associated with the lining, leachate collection and final cover systems on behalf of the Facility.

The Geosynthetic Quality Assurance Consultant (Geosynthetic QAC) is the firm which, under the direction of the CQA Officer, observes and documents activities related to the quality assurance of the geosynthetic materials and installation associated with the lining, leachate collection and final cover systems on behalf of the Facility.

The Geosynthetic Quality Assurance Laboratory (Geosynthetic QAL) is the firm which conducts laboratory tests on samples of geosynthetic materials obtained from the Facility.

The Earthwork Contractor is the firm which performs the earthwork preparation and construction of the soil components of the landfill structural, lining, leachate collection and final cover systems.

The Geosynthetic Installer (Installer) is the firm which installs the geosynthetic components of the landfill lining, leachate collection and final cover systems.

D-6-1-5-1c Documentation

The observations, documentation, and testing described throughout this document shall be performed by the Quality Assurance Consultant (QAC) [Soil QAC or Geosynthetic QAC] under the direction of the CQA Officer, unless otherwise noted. Quality assurance data which is collected during the construction of each cell shall be available for review by the Department. Following completion of cell construction, the Facility will submit a CQA Certification prepared by the CQA Officer to the Department which states that the cell has been constructed according to the approved plans and in compliance with the applicable ADEM Administrative Code Rules.

In accordance with ADEM Administrative Code Rule 335-14-8-.03(1)(l)2, ADEM shall conduct the required post-construction, pre-disposal inspection, and grant approval or reject, until any noted deficiencies are corrected, the new cell for waste placement. Upon approval by ADEM, the Facility may initiate waste disposal within the cell.

Within 90 days after submittal of the CQA Certification, the Facility will submit the "Record" documentation to the Department which will include "Record" engineering drawings and summaries of quality assurance data collected during construction of the cell. As required by Rule 335-14-8-.03(1)(h), at the request of the Administrator, this information will be provided to ADEM.

D-6-1-5-2 Geomembrane

D-6-1-5-2a Geomembrane Conformance Testing

No later than upon delivery of the rolls of geomembrane, the Installer shall remove samples for conformance testing in accordance with the Specifications. These samples shall be forwarded by the Geosynthetic QAC to the Geosynthetic QAL for testing to document conformance of the material will the Specifications.

D-6-1-5-2b Geomembrane Installation

The geomembrane shall be installed by the material manufacturer or a qualified contractor (Installer), in accordance with the Specifications. Additionally, qualified personnel (i.e., the

Geosynthetic QAC) shall observe and document with "Record" documentation the installation of the geomembrane under the direction of the CQA Officer.

D-6-1-5-2c Earthwork

D-6-1-5-2c(1) Structural Fill and Compacted Chalk Layer

Subsections D-6-1-5-6 and D-6-1-5-7 of this attachment detail the CQA requirements for the structural fill and/or the compacted chalk layer to be constructed prior to installation of geomembrane. Also, the materials and construction requirements of the structural fill and compacted chalk layer are detailed in the Specifications for Construction Materials, Attachment D-6-1-4 of this Application.

D-6-1-5-2c(2) Surface Preparation

The following shall be observed and documented:

1. The supporting soil meets the moisture content-density requirements detailed in the Specifications.
2. The area to be lined has been graded and proof-rolled to a smooth uniform surface free of irregularities, protrusions, depressions, oversize particles, loose soil, and abrupt changes in grade.
3. The surface of the supporting soil does not contain stones which may be damaging to the geomembrane.
4. No area is excessively softened by high water content.

Areas identified as not meeting the above criteria will be reworked, repaired, or removed and replaced by the Earthwork Contractor as determined during construction. These areas will be monitored and retested to establish that the above criteria are satisfied.

D-6-1-5-2d Geomembrane Placement

D-6-1-5-2d(1) Storage and Handling

The QAC shall observe and document that the geomembrane is stored and handled properly from the time the material arrives at the Facility until after it is installed, seamed and covered by the subsequent material.

Geomembrane which has been stored at the Facility for more than one (1) year may be subjected to testing to verify that is has retained its physical characteristics and meets the appropriate Specifications.

D-6-1-5-2d(2) Panel Identification

A field panel is defined as a unit of geomembrane which is to be seamed in the field. Each field panel shall be documented by an identification code (number or letter-number) consistent with the layout plan. Observation and documentation that field panels are installed at the locations indicated on the Installer's layout plan shall be made. The field panel identification code shall be used for all quality assurance records.

D-6-1-5-2d(3) Panel Placement Procedures

The panel deployment progress of the Installer (including consideration of issues relating to wind, rain, compacted chalk layer desiccation, and other Facility-specific conditions) shall be reviewed with respect to compliance with the approved panel layout drawing and its suitability to the actual field conditions. Only the Facility Manager can authorize changes to the panel placement procedure. Such changes shall be documented and included in the "Record" documentation. Observation and documentation that the condition of the supporting soil does not change detrimentally during installation shall be made.

D-6-1-5-2d(3)(a) Weather Conditions

The ambient temperature shall be observed and documented to ensure conformance with the Specifications and shall be measured in the area where the panels are deployed. The Owner shall be informed by the CQA Officer of any weather-related problems which may not allow geomembrane placement to proceed.

D-6-1-5-2d(3)(b) Method of Placement

The following shall be observed and documented:

1. Equipment used by the Installer does not damage the geomembrane by handling, trafficking, leakage of hydrocarbons, or other means.
2. Personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane.
3. The method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil.
4. The method used to place the geomembrane panels minimizes wrinkles (especially differential wrinkles between adjacent panels).
5. Adequate temporary loading (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind.
6. Direct contact with the geomembrane is minimized (i.e., the geomembrane in high foot-traffic areas is protected by geotextiles, additional geomembrane layers, or other suitable materials).

7. The anchor trench is backfilled as soon as practically possible after completion of geomembrane installation and seaming.

D-6-1-5-2d(3)(c) Damage and Defects

Geomembrane panels shall be observed, after placement and prior to seaming, for damage and/or defects by the Geosynthetic Quality Assurance Consultant. Panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels which have been rejected shall be marked, and their removal from the work area shall be documented.

D-6-1-5-2e Field Seaming

D-6-1-5-2e(1) Seam Layout

A seam numbering system compatible with the panel numbering system shall be assigned to each field seam. The seam layout shall be in accordance with the Specifications. The following shall be observed and documented:

1. Seam orientation with respect to the slope.
2. Field seams in corners and odd-shaped geometric locations.

D-6-1-5-2e(2) Overlap and Temporary Bonding

Procedures for geomembrane overlapping and temporary bonding are detailed in the Specifications. The following shall be observed and documented:

1. Geomembrane overlap.
2. The procedure used to temporarily bond adjacent panels together.

D-6-1-5-2e(3) Seam Preparation

The following shall be observed and documented:

1. Prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material.
2. If seam overlap grinding is required, the process is completed according to the material manufacturer's quality control procedures and in a way that does not damage the geomembrane.

3. Seams are aligned with the fewest possible number of wrinkles and "fishmouths".

D-6-1-5-2e(4) Seaming Equipment and Products

Approved processes for field seaming are detailed in the Specifications. The following shall be observed and documented for the field seaming methods employed:

1. Equipment used for seaming is not likely to damage the geomembrane.
2. The electric generator is placed on a smooth base, or such that no damage occurs to the geomembrane.
3. A smooth insulation plate or fabric is placed beneath the welding apparatus after usage, or such that no damage occurs to the geomembrane.
4. The geomembrane is protected from damage in heavily foot-trafficked areas.

D-6-1-5-2e(4)(a) Extrusion Seaming Process

Apparatus temperatures, extrudate temperatures, ambient temperatures, and geomembrane surface temperatures shall be recorded as required by the Specifications and/or as appropriate for the apparatus used.

The following shall be observed and documented:

1. Artificially induced cooling of the extrudate (with water, cloth, or other means) does not take place unless the Installer demonstrates that such cooling produces a satisfactory seam.
2. The extruder is purged prior to beginning a seam until heat degraded extrudate has been removed from the barrel.

D-6-1-5-2e(4)(b) Fusion Process

Ambient, seaming apparatus, and geomembrane surface temperatures as well as seaming apparatus pressures shall be recorded as required by the Specifications and/or as appropriate for the apparatus used.

The following shall be observed and documented:

1. For cross seams, the edge on the cross seams provides a smooth incline (top and bottom) prior to welding (if necessary).

D-6-1-5-2e(5) Weather Conditions for Seaming

The normally required weather conditions for seaming are as detailed in the Specifications. The weather conditions shall be observed and documented. If they are not met, the installation shall be stopped or postponed.

If seaming is performed below 32 °F, a certified statement from the Installer is required which specifically states that the low temperature seaming procedure does not cause any physical or chemical modification to the geomembrane that will generate any short or long-term damage to the geomembrane.

D-6-1-5-2e(6) Trial Seams

Trial seams shall be made on fragment pieces of geomembrane liner in accordance with the Specifications. Trial seam procedures shall be observed and documented.

Successful trial seam samples may be cut into three pieces, one to be retained by the Facility, one to be given to the Installer, and one to be retained by the Geosynthetic QAC for possible laboratory testing. Each portion of the trial seam sample shall be appropriately labeled.

If necessary, trial test seam samples may be subjected to laboratory destructive testing. These samples shall be forwarded to the Geosynthetic QAL, and if they fail the tests, the procedure indicated in Subsection D-6-1-4-3a(7)(d) (Procedures for Destructive Test Failure) of the Specifications (Attachment D-6-1-4) shall apply. The conditions of this paragraph shall be considered satisfied for a given seam if a destructive seam test sample has already been obtained.

D-6-1-5-2e(7) General Seaming Procedure

The seaming procedures detailed in the Specifications shall be observed and documented. If the Installer performs special testing to demonstrate that certain procedures are acceptable, such shall be observed and documented.

D-6-1-5-2e(8) Nondestructive Seam Continuity Testing

The following shall be performed for geomembrane seams:

1. Observe nondestructive testing procedures.
2. Record the location, date, test unit number, name of installation technician performing the test, and the outcome of testing.

3. Inform the Installer of any required repairs.

Any seams that cannot be nondestructively tested shall be observed and/or cap-stripped with the same geomembrane. The cap-stripping operations shall be observed for uniformity and completeness and documented.

Nondestructive seam continuity testing procedures shall be reported as follows for each of the available methods:

D-6-1-5-2e(8)(a) Vacuum Testing

The following general procedures shall be observed and documented during typical vacuum testing operations:

1. Pressure gauge reading.
2. Applied vacuum duration.
3. Overlap with adjoining test areas.
4. Soap bubbles, indicating defects in the geomembrane, if any.

All areas where soap bubbles appear shall be marked and repaired by the Installer and documented in accordance with the procedure detailed in Subsection D-6-1-5-2f of this attachment.

D-6-1-5-2e(8)(b) Air Pressure Testing

The following general procedures shall be observed and documented during typical air pressure testing operations:

1. Air pressure gauge readings.
2. Applied air pressure duration.
3. Pressure differential.
4. De-pressurization of the seam.

Seams failing the air pressure test shall be marked and repaired by the Installer and documented in accordance with Subsection D-6-1-5-2f of this attachment.

D-6-1-5-2e(8)(c) Spark Testing Method

The following general procedures shall be observed and documented during typical spark test operations:

1. Detector electric charge.
2. Rate at which the brush electrode passes over the seam.
3. Any visible spark.

Seams that spark shall be marked and repaired by the Installer and documented in accordance with the procedures detailed in Subsection D-6-1-5-2f of this attachment.

D-6-1-5-2e(8)(d) Flood Testing

The following general procedures shall be observed and documented during typical flood testing operations:

1. Extent of the area tested.
2. Any bubbles in the flooded area.
3. Any leaks at the bottom or on the tissue paper.

Areas where water leakage appears shall be marked and repaired by the Installer and documented in accordance with Subsection D-6-1-5-2f of this attachment.

D-6-1-5-2e(9) Destructive Seam Strength Testing

Destructive seam strength tests shall be performed at select locations in accordance with the Specifications.

D-6-1-5-2e(9)(a) Sampling Location and Procedures

The following shall be performed, observed and documented:

1. Locations where seam samples are removed for laboratory testing are recorded.
2. The minimum frequency of sampling shall be an average of one (1) test per 500 linear feet of seam.
3. Sample cutting, including assigning and marking a number for each portion, is recorded.
4. The reason for taking the sample at the selected location is recorded.

The Installer shall not be informed in advance of the locations where the seam samples will be taken. All holes in the geomembrane resulting from destructive seam sampling shall be repaired in accordance with the Specifications and documented as detailed in Subsection D-6-1-5-2f(3) of this attachment. The continuity of the new seams in the repaired area shall be tested in accordance with the Specifications and recorded as detailed in Subsection D-6-1-5-2e(8) of this attachment.

D-6-1-5-2e(9)(b) Laboratory Testing

Destructive seam strength test samples shall be packaged and shipped in a manner in which they will not be damaged.

Testing shall include bonded seam strength and peel adhesion (ASTM D6392). The minimum acceptable values to be obtained in these tests are detailed in the Specifications. At least ten (10) specimens shall be obtained from each sample and tested, five (5) in shear and five (5) in peel. Specimens shall be selected alternately by tests made from the samples (i.e., peel, shear, peel, shear). A passing test shall meet the minimum acceptable values in at least 4 out of 5 specimens for each method. The laboratory test results shall be reviewed as soon as they become available.

D-6-1-5-2e(9)(c) Installer's Laboratory Testing

If performed, all test results from the Installer's laboratory shall be submitted as soon as they become available for evaluation and recommendation. These results shall be reviewed and considered in the evaluation of seam quality.

D-6-1-5-2e(9)(d) Procedures for Destructive Test Failure

It shall be observed and documented that destructive test failures are traced and repaired in accordance with the Specifications.

D-6-1-5-2f Defects and Repairs

D-6-1-5-2f(1) Identification

All seams and non-seam areas of the geomembrane shall be observed for identification of defects, holes, blisters, undispersed raw materials and signs of contamination by foreign matter.

D-6-1-5-2f(2) Evaluation

Each suspect location both in seam and non-seam areas shall be non-destructively tested using the methods described in Subsection D-6-1-5-2e(8) of this attachment, as appropriate. Each location which fails the nondestructive testing shall be repaired and retested by the Installer. Each such area shall be marked and documented.

D-6-1-5-2f(3) Repair Procedures

Portions of the geomembrane exhibiting a flaw or failing a destructive or nondestructive test shall be repaired in accordance with the Specifications. The following shall be observed and documented.

1. The repair procedures, such as patching, spot welding, capping, extrusion welding, or replacing defective seams.
2. For any repair method, the following shall be observed:
   a. Geomembrane surface preparation methods.
   b. Geomembrane surfaces are clean and dry.
   c. Seaming equipment used.
   d. Overlap of patches and caps, and shape of patch used.

D-6-1-5-2f(4) Verification of Repairs

Each repair shall be located, numbered and logged. Each repair shall be nondestructively tested by the Installer and observed and documented as described in Subsection D-6-1-5-2e(8) of this attachment as appropriate. Repairs which pass nondestructive testing shall be taken as an indication of an adequate repair. Failed tests indicate that the repair shall be redone and retested by the Installer until a passing test results. Nondestructive testing of repairs shall be observed and documented by the number of each repair, date, and test outcome.

Documentation shall be made that all identified repairs have been completed, all nondestructive testing has been performed, and all destructive test samples have either passed or are bound by passing destructive tests, and the failed seams have been reconstructed.

D-6-1-5-2g Anchor Trench Backfill

The anchor trench shall be backfilled with fill placed and compacted in accordance with the Specifications. A minimum of one (1) moisture-density test shall be performed for the anchor trench backfill placed and compacted around each cell, in accordance with the methods detailed in Subsection D-6-1-5-6 of this attachment.

D-6-1-5-2h Materials in Contact with the Geomembrane

D-6-1-5-2h(1) Soils

Observations shall be made that the soil layers placed over the geomembrane are placed in accordance with the Specifications and that the construction methods do not damage the geomembrane. Observed geomembrane damage resulting from soil placement shall be repaired by the Installer and documented in accordance with Subsection D-6-1-5-2f of this attachment.

Measurement of the soil thickness shall be performed to document that the required thicknesses are present. In addition, a determination that final thicknesses are consistent with the design shall be made and documented. The thicknesses of the soil layers shall be determined by survey and calculated as the difference in elevations between the appropriate surfaces. The Facility Manager shall be informed if the above conditions are not fulfilled, and additional soil shall be placed to satisfy the required thickness.

D-6-1-5-2h(2) Concrete

Observations shall be made that geosynthetic layers are placed between concrete and the geomembrane according to the Specifications, and that the construction methods used do not damage the geomembrane. Observed geomembrane damage resulting from concrete placement shall be repaired by the Installer in accordance with Subsection D-6-1-5-2f of this attachment.

D-6-1-5-2h(3) Sumps and Appurtenances

A review of the design drawings and documentation shall be made to document that:

1. Installation of the geomembrane in sump and appurtenance areas, and connection of geomembrane to sumps and appurtenances have been made according to the Specifications. Where appropriate (particularly sump areas), this documentation shall be based on a survey and comparison with the design.
2. Extreme care is taken while welding is performed around appurtenances.
3. The geomembrane has not been visibly damaged while making connections to sumps and appurtenances.

If the geomembrane is damaged during installation of the sump or appurtenances, it shall be repaired by the Installer. The installation of sumps and appurtenances, and any repairs made to them, shall be observed and documented.

D-6-1-5-3 Geotextiles

Handling, testing and repair of geotextiles shall be performed, observed and/or documented as described in the following subsections.

D-6-1-5-3a Conformance Testing

No later than upon delivery of the rolls of geotextiles, samples shall be removed by the Installer and forwarded to the Geosynthetic QAL for testing to ensure conformance with the Specifications. The required conformance tests and sampling frequency are detailed in the Specifications.

D-6-1-5-3b Handling and Placement

The geotextile handling and placement procedures used by the Installer shall be observed for conformance with the Specifications.

D-6-1-5-3c Seams and Overlaps

Seams and overlaps shall be performed in accordance with the Specifications. The entire length of geotextile seams shall be observed. Areas of noncompliance with the Specifications shall be repaired by the Installer and observed until compliance is achieved.

D-6-1-5-3d Geotextile Repair

Holes or tears in the geotextile shall be repaired by the Installer as detailed in the Specifications. Repairs shall be observed. Areas of noncompliance with the Specifications shall be reported and shall be replaced or repaired by the Installer.

D-6-1-5-4 Geonet/Geocomposite

Handling, testing and repair of geonet/geocomposite shall be performed, observed and/or documented as described in the following subsections.

D-6-1-5-4a Conformance Testing

No later than upon delivery of the rolls of geonet/geocomposite, samples shall be removed by the Installer and forwarded to the Geosynthetic QAL for testing to ensure conformance with the Specifications. Conformance testing and the sampling frequency are detailed in the Specifications.

D-6-1-5-4b Handling and Placement

The geonet/geocomposite handling and placement procedures used by the Installer shall be observed for conformance with the Specifications.

D-6-1-5-4c Stacking and Joining

Geonet/geocomposite shall be joined in accordance with the Specifications and Construction Drawings to be submitted prior to construction of each landfill cell. Deployment and joining procedures shall be observed. Areas of noncompliance with the Specifications shall be repaired by the Installer and observed until compliance is achieved.

D-6-1-5-4d Geonet/Geocomposite Repair

Holes or tears in the geonet/geocomposite shall be repaired by the Installer as detailed in the Specifications. Repairs shall be observed. Areas of noncompliance with the Specifications shall be reported and shall be replaced or repaired by the Installer.

D-6-1-5-5 Geosynthetic Clay Liner

Handling, testing and placement of geosynthetic clay liners (GCL) shall be performed, observed and/or documented as described in the following subsections.

D-6-1-5-5a Conformance Testing

No later than upon delivery of the rolls of GCL, samples shall be removed by the Installer and forwarded to the Geosynthetic QAL for testing to ensure conformance with the Specifications. Conformance testing and the sampling frequency are detailed in the Specifications.

D-6-1-5-5b Handling and Placement

The GCL handling and placement procedures used by the Installer shall be observed for conformance with the Specifications.

D-6-1-5-5c Seaming and Overlaps

GCL panels shall be overlapped in accordance with the Specifications and Construction Drawings to be submitted prior to construction of each landfill cell. Deployment and overlapping procedures shall be observed.

D-6-1-5-6 Structural Fill and Berm Fill

The structural fill and berm fill shall be placed and compacted in accordance with the Specifications. All field tests, if required, shall be conducted during the course of construction. The testing procedures and results shall be documented.

Field moisture content/density tests shall be performed on the structural fill and berm fill compacted soil in accordance with the following:

Field Density by one of the following methods:

- D1556 - Sand Cone Method
- D2167 - Rubber Balloon Method

- D2922 - Nuclear Method
- D2937 - Drive Cylinder Method

Field Moisture Content by one of the following methods:

- D3017 - Nuclear Method
- D4643 - Microwave Method
- D4959 - Direct Heat Method
- D2216 - Oven Method

These tests (field moisture content and density) shall be performed at an average frequency of at least one (1) test per 3,500 cubic yards of material placed and compacted. Locations for tests shall be distributed evenly throughout the fill or selected based on a judgment as to the most marginal portion of the fill area. Unless otherwise noted in the Specifications, perforations of the soil shall be backfilled appropriately.

At locations where the test results indicate that the requirements of the Specifications are not met, the extent and nature of the deficient area shall be determined. The Earthwork Contractor shall correct all deficient areas to meet the Specifications. Appropriate retests shall be performed when the deficient area has been corrected. All retests shall document that the deficient area has been corrected before any additional work is performed in that area.

Additionally, the maximum particle size of the fill material shall be observed for conformance with the Specifications. Areas of noncompliance shall be corrected by the Earthwork Contractor. The procedures employed to correct areas of noncompliance shall also be observed.

Structural fill material placed directly over geomembrane and/or geosynthetic layer (i.e., Trench 21, structural fill over closure cover transmissive geosynthetic layer) shall be observed for conformance with the particle shape requirements detailed in the Specifications (i.e., only non-angular (sub-angular, sub-rounded, or rounded)). If the material placed does not comply with the Specifications, it shall be removed and replaced by the Earthwork Contractor. The corrective action procedures taken shall be observed. Observed damage to the geomembrane resulting from material placement shall be repaired by the Installer and documented in accordance with Subsection D-6-5-2f of this attachment.

D-6-1-5-7 Compacted Chalk Layers

The following procedures shall apply to the secondary compacted chalk layer, primary compacted chalk layer in Trench 22, and the final cover compacted chalk layer.

Field density and moisture content tests shall be performed at an average minimum frequency of one test per each 1,000 cubic yards of compacted material using one of the methods detailed in Subsection D-6-1-5-6 of this attachment. Locations for tests shall be distributed evenly throughout the fill or selected based on a judgment as to the most marginal portion of the fill area.

Additionally, compacted chalk material directly placed over geomembrane and/or geosynthetic layer shall be observed for conformance with the particle shape requirements detailed in the Specifications (i.e., only non-angular (sub-angular, sub-rounded, or rounded)). If the material placed does not comply with the Specifications, it shall be removed and replaced by the Earthwork Contractor. The corrective action procedures taken shall be observed. Observed damage to the geomembrane resulting from material placement shall be repaired by the Installer and documented in accordance with Subsection D-6-1-5-2f of this attachment.

Measurement of the compacted chalk layer thickness shall be performed to document that the Specifications are met. In addition, a determination that the final thickness is consistent with the design shall be made. The thickness of the compacted chalk layer shall be determined by survey and calculated as the difference in elevations between the appropriate surfaces. The addition of compacted chalk material, if necessary, to satisfy the required thickness shall be tested, observed and documented.

At locations where the testing indicates that the requirements of the Specifications are not met, the extent and the nature of the deficient area shall be determined, and corrective actions shall be taken. These areas shall be reworked (moisture conditioned and/or recompacted) or replaced and retested to document that the deficiency has been corrected. All retests shall document that the deficient area has been corrected before any additional work is performed in that area.

Critical areas such as sumps or areas of hand compaction shall be tested regardless of the volume placed. Normal quality assurance procedures shall include documentation of reworked areas and retests in areas where moisture or additional compaction was required.

The final surface of chalk shall be observed during proof-rolling operations. Additionally this surface shall be observed for features which may adversely affect the integrity of the geomembrane to be placed upon it. The maximum particle size of the compacted chalk layer material shall be observed for conformance with the Specifications. Areas of noncompliance shall be corrected by the Earthwork Contractor. The corrective action procedures employed shall be observed.

D-6-1-5-8 Granular Materials

The procedures detailed in this section apply to all granular material in the following locations: pressure relief system, primary leachate collection system drainage layer, and secondary leachate collection system, and final cover system.

A minimum of one (1) laboratory hydraulic conductivity test shall be performed in accordance with ASTM D2434 on each type of granular drainage material provided for the construction of each cell. If the results of the hydraulic conductivity testing indicate a permeability that does not meet the Specifications, the material shall not be used, or corrective action will be taken. If installed, the deficient area shall be defined and corrected by removal and replacement of the material. Additional hydraulic conductivity tests may also be performed if visually observable changes in the granular material delivered are noted.

Additionally, granular material placed directly over geomembrane and/or geosynthetic layers shall be observed for conformance with the shape requirements detailed in the Specifications (i.e., only non-angular (sub-angular, sub-rounded, or rounded particles)). If the material placed does not comply with the Specifications, it shall be defined, removed and replaced by the Earthwork Contractor. The corrective action methods and procedures employed shall be observed and documented. Observed damage to the geomembrane resulting from the granular material placement shall be repaired by the Installer and documented in accordance with Subsection D-6-1-5-2f of this attachment.

The granular material shall be randomly sampled and tested for particle grain size distribution in accordance with the ASTM D422, at an average frequency of not less than one (1) test per 500 cubic yards placed. The layer thickness will be controlled by markers, excavation, or other means that will not puncture the geomembrane, and will be visually monitored during placement.

The particle size analysis results shall be compared to the Specifications. If the results indicate that the material is not in compliance with the Specifications, the material shall not be used, or corrective action will be taken. If installed, the deficient area shall be defined and corrected by removal and replacement of the material.

Measurement of the granular material layer thickness shall be performed to document that the Specifications are met. In addition, a determination that the final thickness is consistent with the design shall be made. The thickness of the granular material layer shall be determined by survey and calculated as the difference in elevations between the appropriate surfaces. The addition of granular material, if necessary to satisfy the required thickness, shall be observed and documented.

D-6-1-5-9 Protective Cover Layer

It shall be observed that the equipment and soil layer thickness while placing the protective cover layer material shall be in accordance with the Specifications. Additionally, the maximum particle size of the material shall be observed for conformance with the Specifications. Material placed directly over geosynthetic layer shall be observed for conformance with the particle shape requirements detailed in the Specifications (i.e., only non-angular (sub-angular, sub-rounded or rounded)). If the material placed does not comply with the Specifications, it shall be removed and replaced by the Earthwork Contractor. The corrective action procedures taken shall be observed. Observed damage to the geosynthetic layer resulting from material placement shall be repaired by the Installer in accordance with Subsection D-6-1-5-2f of this attachment.

Measurement of the protective cover material thickness shall be performed to document that the Specifications are met. In addition, documentation that the final layer thickness is consistent with the design shall be made. The thickness of the material shall be determined by survey and calculated as the difference in elevations between the appropriate surfaces. The addition of protective cover material, if necessary, shall be observed and documented.

D-6-1-5-10 HDPE Pipe

The manufacturer shall provide certifications that the pipe materials meet the Specifications. The supplier shall provide certifications that shop fabrication was done in accordance with the manufacturer's specifications.

In the field, the pipe shall be inspected for damage incurred during transportation. The diameter and wall thickness shall be checked by measurements at the ends of each section, and the locations and size of perforations and other shop-fabricated items shall be checked for compliance with the manufacturer's fabrication specifications. After installation, the pipes shall be checked to ensure that they are installed in the specified locations relative to other landfill components.

The inspector shall check that the upslope pipes are supported by the counterweight system shown on the drawings and are not constrained from axial movement where they pass through concrete structures.

D-6-1-5-11 Suspension of Construction

From the start of excavation to the completion of the disposal cell, any time that construction is halted or suspended for a period 30 days or more prior to restarting construction, all completed or partially completed components of the construction shall be inspected and assessed by the CQA Officer (i.e., certifying engineer). After inspection and assessment, the CQA Officer will direct the remedial action to be taken on the cell to restore it to the conditions and requirements provided in this Construction Quality Assurance Plan, Attachment D-6-1-1, Landfill Operations Plan, Attachment D-6-1-3, Landfill Design and Attachment D-6-1-4, Specifications for Construction Materials. At a minimum, this shall include the removal and replacement of desiccated and eroded soil material, the removal and replacement of plugged or contaminated drainage layers, and the inspection and testing for UV degradation of synthetics.

All seam and non-seam areas of the geomembrane shall be visually inspected for signs of damage, blisters, punctures, and any sign of contamination by foreign matter. Any problems discovered shall be located, marked, repaired and tested in accordance with applicable sections of this Construction Quality Assurance Plan. Each defect shall be located, tracked, and documented.

Holes, tears, or damage to the geonet/geocomposite shall be repaired by placing a patch extending a minimum of one (1) foot beyond all edges of the defect.

Holes or tears in, and damage to the geotextile shall be repaired by patching. Patches shall be made from the same geotextile material as that used for panels. All repairs shall be made by sewing. Patches sewn into place shall extend a minimum of six (6) inches in all directions beyond the defect area.

[End of Attachment D-6-1-5]

ATTACHMENT D-6-1-6

APPENDIX D-6-1

SECTION D-6

RESPONSE ACTION PLAN

Revision No.
5.0

ATTACHMENT D-6-1-6

RESPONSE ACTION PLAN

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RESPONSE ACTION PLAN

D-6-1-6-1 Introduction

D-6-1-6-1a General

This Response Action Plan (RAP) describes the criteria used to evaluate and respond to liquid flow rates in the sumps of the Leak Detection System (Secondary Leachate Collection System or SLCS) of Trench 22 and Trench 23 at the Facility. This RAP has been developed in accordance with the Alabama Department of Environmental Management's (ADEM) Hazardous Waste Program in the Hazardous Waste Regulations Chapter 335-14-1 through 335-14-9, along with guidance provided in the Final Rule for Liners and Leak Detection Systems for Hazardous Waste Land Disposal Units and with guidance provided in the Final Rule for Liners and Leak Detection Systems for Hazardous Waste Land Disposal Units, published by the EPA in the Federal Register, Vol. 57, No.19, on January 29, 1992. The RAP cites the time frame and actions necessary to respond to liquid flow rates greater than the Action Leakage Rates (ALR's) at the sumps in the SLCS.

The regulations (ADEM Administrative Code 335-14-5-.14(3) and 40 CFR 264.301-304) require an ALR to be established and a RAP to be prepared for each landfill unit on which construction commences after January 29, 1992.

D-6-1-6-1b Description of Landfill Trenches

The design of Trench 22 at the Facility meets or exceeds the minimum technology guidance standards set forth by the ADEM Hazardous Waste Program, in the Hazardous Waste Regulations Chapter 335-14 -1 through 335-14-9 and the requirements of Title 40 of the Code of Federal Regulations (40 CFR) Part 264. The containment system for each cell consists of a double liner system. Drainage layers are installed above each of the two geomembrane liner systems. A pressure relief system is provided beneath the secondary containment system to control groundwater pressures beneath the base of the cell during construction and during early cell development. Typical details and cross-sections of the liner and leachate collection systems are shown in the Landfill Design Drawings in Appendix D-6-2.

D-6-1-6-2 Leakage Response

D-6-1-6-2a General

The ADEM and EPA rules require the Facility to establish a site-specific ALR. The ALR is the liquid flow rate that, when withdrawn from the SLCS sump, warrants follow-up actions by the

Facility. The ALR is not intended to represent an estimated flow rate which is expected to be removed from the SLCS. Rather, the ALR represents the capacity of the SLCS to transmit flow and is independent of the sources of the liquids flowing into the system. The rules require that the Facility develop a site-specific RAP specifying monitoring, inspection, and corrective measures to be implemented if the ALR within any cell is exceeded.

D-6-1-6-2b Action Leakage Rate

D-6-1-6-2b(1) Definition

The Action Leakage Rate is the maximum design flow rate that the SLCS can remove without the fluid head on the secondary liner exceeding one foot. The ALR serves as the trigger to initiate the RAP and associated response actions. The rules require that the owner or operator convert the weekly or monthly flow rate data obtained during the monitoring period to an average daily flow rate for each SLCS sump.

D-6-1-6-2b(2) Basis for Calculations and Results

The ALR's for the Facility were calculated using the concept described in the Federal Register, Vol. 57, No. 19, in the preamble to the Final Rule for Liners and Leak Detection Systems for Hazardous Waste Land Disposal Units. The ALR is calculated for Trench 22 using Darcy's Equation for saturated flow through a soil layer. For Trench 23, the ALR is calculated using methods by Giroud and assuming a geomembrane defect of one per acre and a maximum head of 1-foot on the secondary liner.

The ALR for each of the cells is presented in Table 1, and supporting calculations are attached as Supplements A and B to the RAP. As suggested in the Federal Register, Vol. 57, No.19, on January 29, 1992, a factor of safety (F.O.S.) of 2.0 was applied for each of the calculated flow rates.

D-6-1-6-3 Response Action Plan

D-6-1-6-3a General

Response actions will be implemented in Trench 22 or Trench 23 when the observed flows in the SLCS system exceed the ALR defined for each cell, as described in Section D-6-1-6-2b(2) of this attachment and presented in Table 1 below.

D-6-1-6-3b Flows Below ALR

Fluid volumes will be monitored weekly. Records of the fluid flows or rates will be maintained on-site for each sump located in the SLCS.

The rule requires that owners and operators must monitor the sumps in leak detection systems for the presence of liquids and record the amount of liquid removed from the sumps. The level of leachate in the sumps will therefore be measured, or the leachate will be pumped to remove any liquids as described in Subsection D-6-1-1-1 of the Landfill Operations Plan in Attachment D-6-1-1 to Appendix D-6-1. The daily average flow rate will be calculated as the volume of liquid pumped from the sump during the monitoring period, divided by the number of days in the monitoring period, divided by the acreage of surface area served by the sump. This average value is defined as the average daily flow rate and is to be expressed as gallons per acre per day (gpad). This daily average flow rate is then compared to the ALR to determine whether any response action is necessary.

TABLE 1
ACTION LEAKAGE RATES
CWM EMELLE FACILITY
EMELLE, ALABAMA

LDS SUMP	FLOW CAPACITY (gpd)	CELL AREA (acres)	ALR (w/F.O.S.=2.0) (gpad)
Trench 22 Cell 1	3121	11.3	138
Trench 22 Cell 2	3121	12.2	128
Trench 22 Cell 3	3121	12.4	126
Trench 22 Cell 4	3121	10.9	143
Trench 23 Cell 1	3221	15.9	101
Trench 23 Cell 2	3221	15.9	101
Trench 23 Cell 3	2046	10.1	101
Trench 23 Cell 4	2067	10.2	101
Trench 23 Cell 5	3100	15.3	101
Trench 23 Cell 6	3120	15.4	101

During the post-closure period, if it can be shown that the liquid levels in the sump have remained below the pump operating level for two consecutive months, the sump will be monitored quarterly. Further, semi-annual monitoring of the sumps will be proposed if the liquid levels in the sump remain below the pump operating levels for two consecutive quarters. However, if pumping is required to remove liquids from the SLCS at any time during the quarterly or semi-annual inspections, the monitoring frequency would be increased to monthly until the liquid level stays below the pump operating level for two consecutive months.

D-6-1-6-3c Flows above ALR

Whenever the average daily flow rate in the SLCS exceeds the ALR, response actions will be promptly implemented. The following series of responses will be implemented in sequential order:

1. Notify the ADEM Director, in writing, within 7 days after the leakage rate is determined to exceed the ALR.
2. Submit a preliminary written assessment to the ADEM Director within 14 days of the determination, describing the amount and likely sources of the liquids, the possible location, size, and cause of any leaks, and the short-term actions taken or planned.
3. Determine to the extent practicable the location, size, and cause of any leak.
4. Determine whether waste placement into the affected cell should be stopped or curtailed, whether any waste should be removed from the affected cell to allow inspection, repairs, or controls, or whether the cell should be closed.
5. Determine any other short-term or long-term actions to be taken and operational changes initiated to mitigate or stop any leaks.
6. Prepare and submit a report to the ADEM Director within 30 days after notification that the ALR has been exceeded. The report will give results of the actions and analyses specified in steps 3, 4, and 5 above and will list other actions planned.
7. Submit monthly reports to the ADEM summarizing the results of any actions taken and outlining planned actions for as long as the flow rate in the leak detection system exceeds the ALR.

To implement the leak and/or remediation determinations in steps 3, 4, and 5 as listed above, the Facility will:

- assess the source of the liquids and the amounts of the liquids by source;
- conduct a fingerprint, hazardous constituents, or other analyses of the liquids in the SLCS system to identify the source of the liquids and possible location of any leaks, and the hazard and mobility of the liquid; and
- assess the seriousness of any leaks in terms of potential for escaping into the environment or document why such assessments are not necessary.

D-6-1-6-3d Other Actions

When responding to an ALR exceedance, there are several additional actions which may be implemented. These actions include the following:

- the data collected may be reviewed to ensure that the flow rates listed are not in error;
- if the flow rates calculated for the sump are accurate, then the pumping system may be inspected to verify that the fluid level indicators, pump, and flow meters are functioning properly. For example, a larger daily flow rate would occur when pumping resumes after the pump has been temporarily out of service;
- the exposed components of the fluid removal system, including the riser pipe and any exposed portions of the liner system, may be inspected for areas of damage;
- review of the cell operating record, including inspection reports, may indicate a cause for the increased flow rates in the SLCS;
- if no areas of liner damage are identified, the pumping data may be reviewed to identify any trends in the flow rates. The time rate of cell filling may be evaluated and compared to the soil liner consolidation calculations to evaluate the possibility for increased water from the primary clay layer. Additionally, the flow rates in the sumps may be compared to groundwater levels and rainfall data;
- pumping and monitoring frequencies may be increased from both the primary and secondary sumps in the affected cell if pumpable quantities are present. The increased pumping would be maintained until the flow rate decreases below the ALR;
- during periods of high precipitation, consideration may be given to installing a temporary cover over portions of the affected area in order to determine if excluding rainwater influences the fluid production rates. The temporary cover would be constructed of HDPE, compacted soils, or any other material capable of reducing infiltration; and
- when the control measures implemented have consistently reduced the average daily flow rate to below the ALR, actions will return to those required for flow below the ALR.

D-6-1-6-4 Summary

This RAP was developed in accordance with ADEM rules and guidance provided in the Final Rule for Liners and Leak Detection Systems for Hazardous Waste Land Disposal Units, published by the U.S. EPA in the Federal Registry, Vol. 57, No. 19. The ALR's for each cell of

Trenches 22 and 23 of the Facility are presented in this report, along with actions that will be taken if the ALR is exceeded.

[End of Attachment D-6-1-6 Text]

ATTACHMENT D-6-1-6

RESPONSE ACTION PLAN

SUPPLEMENT A

CALCULATIONS OF ACTION LEAKAGE RATE - TRENCH 22

The following calculations pertaining to Trenches 22 through 24 were included in the original permit. The original Trenches 23 and 24 are no longer proposed. The calculations and information related to these original Trenches 23 and 24 are not intended to be considered for this permit application. Calculations for the new design of Trench 23 are presented in Supplement B.

SUBJECT	ACTION LEAKAGE RATE				
Job No.	933-3553	Made by	SK	Date	October 12, 1993
Ref.	CWM/PERMIT SUPPORT/AL	Checked	BHM/CMM	Sheet	1 of 3
		Reviewed	WRS		

Golder Associates

OBJECTIVE

Determine the Action Leakage Rate (ALR) for all the cells for Trenches 22 ~~through 24~~ for the Emelle facility. As defined by the Alabama state hazardous waste disposal regulations, Action Leakage Rate is the maximum design flow rate that the Leak Detection System (LDS or the secondary drainage layer) can remove without the fluid head on the bottom liner exceeding one foot. As per the EPA manual, the ALR must include a safety factor of 2 to allow for uncertainties in the design, construction, operation and location of the leak detection system; waste and leachate characteristics, likelihood and amounts of other sources of liquids in the LDS.

APPROACH

An Action Leakage Rate (ALR) can be calculated by determining the maximum flow capacity of the elements of the LDS: the drainage sand on the floor and the transmissive layer on the slopes.

CALCULATIONS

The capacity of the drainage layer can be calculated using Darcy Equation shown as follows:

$$Q = K * i * A$$

where:

Q = Flow through unit width of the drainage layer (cfs)
K = Permeability of sand or geotextile (ft/sec)
i = Hydraulic gradient (ft/ft)
A = Area of flow per unit width of drainage layer (ft^2)

The thickness of the secondary sand layer on the floor is 1 ft, thus:

$$A = 1 \text{ ft (Thick)} * 1 \text{ ft (wide)} = 1 \text{ ft}^2$$

Also, from the specifications, the following particle size distribution is to be provided for the sand drainage layer:

Sieve Size	% Passing
#4	-
#10	80-100
#40	20-80
#60	5-35
#100	0-10
#200	0-5

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SUBJECT	ACTION LEAKAGE RATE				
Job No.	933-3553	Made by	SK	Date	October 12, 1993
Ref.	CWM/PERMIT SUPPORT/AL	Checked	BHM/CMM	Sheet	2 of 3
		Reviewed	WRS		

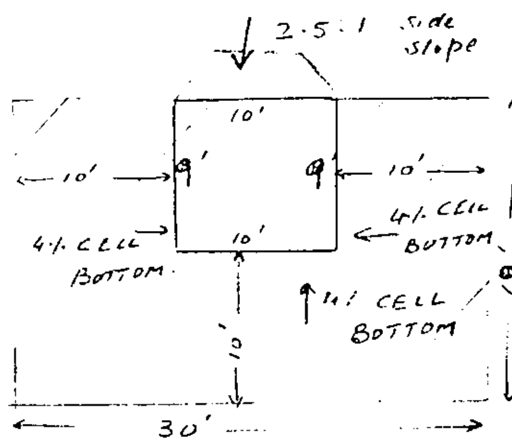
Please refer to the attached chart used to estimate the permeability of the sand drainage layer using the above grain size distribution. The permeability is estimated as 2.6x 10-2. For the purpose of these calculations, we will use the permeability of 10^{-2} cm/sec as specified in the permit application, section D-6.

Therefore :

$$K = 10^{-2} \text{ cm/sec}$$
$$= 3.28 \times 10^{-4} \text{ ft/sec}$$

A geonet blanket will be installed above and 10 feet outside the edge of the sump at the cell bottom. This will increase the capacity of the drainage layer to transfer leachate to the sump. Since the flow capacity of the geonet far exceeds that for the sand drainage layer, the amount of leachate transferred to the sump will depend on the perimeter length of the geonet blanket receiving leachate from the sand drainage layer.

As the sumps are located along the side slopes of their cells, they will get leachate from the cell bottom (4% slope) on three sides, and the side slopes (40% slope) on one side. The hydraulic gradient will be the same as the slope of the drainage layer which is 4% (25:1) for the cell bottom and 40% (2.5:1) for the side slopes of the cells. The following are the expected flow rates into the sump from the cell bottom and the side slopes as estimated using Darcy equation. These flow rates have been estimated for a unit width of drainage layer along the perimeter of the geonet blanket. Therefore, the total flow into the sump will be a function of the flow capacity of the drainage layer and the size the geonet blanket.



Flow Rate from the Cell Bottom:

$$Q_{4\%} = 3.28 \times 10^{-4} \text{ ft/sec} * 0.04 \text{ ft/ft} * 1 \text{ ft}^2\text{/unit width}$$
$$= 1.3 \times 10^{-5} \text{ cfs/unit width}$$
$$= 8.48 \text{ gpd/unit width}$$

Flow Rate from the Cell Side Slopes:

$$Q_{40\%} = 3.28 \times 10^{-4} \text{ ft/sec} * 0.4 \text{ ft/ft} * 1 \text{ ft}^2\text{/unit width}$$
$$= 1.3 \times 10^{-4} \text{ cfs/unit width}$$
$$= 84.8 \text{ gpd/unit width}$$

The following table summarizes the expected maximum drainage into the sump through the sand drainage layer and corresponding action leakage rates for all cases:

Golder Associates

SUBJECT	ACTION LEAKAGE RATE				
Job No.	933-3553	Made by	SK	Date	October 13, 1993
Ref.	CWM/PERMIT SUPPORT/AL	Checked	BHM/CMM	Sheet	3 of 3
		Reviewed	WRS		

CASE	PERIMETER LENGTH OF GEONET BLANKET (FT) 4% SLOPE	40% SLOPE	FLOW RATE (GPD)	CELL AREA (ACRES)	ALR (W/FOS=2) (GPAD)
Trench 22 Cell 1	68 ft	30 ft	3121	11.3	138
Trench 22 Cell 2	68 ft	30 ft	3121	12.2	128
Trench 22 Cell 3	68 ft	30 ft	3121	12.4	126
Trench 22 Cell 4	68 ft	30 ft	3121	10.9	143
Trench 23 Cell 1	68 ft	30 ft	3121	13.9	112
Trench 23 Cell 2	68 ft	30 ft	3121	14.3	109
Trench 23 Cell 3	68 ft	30 ft	3121	13.6	115
Trench 23 Cell 4	68 ft	30 ft	3121	14.2	110
Trench 23 Cell 5	68 ft	30 ft	3121	13	120
Trench 24 Cell 1	68 ft	30 ft	3121	13	120
Trench 24 Cell 2	68 ft	30 ft	3121	13.9	112
Trench 24 Cell 3	68 ft	30 ft	3121	12.9	121
Trench 24 Cell 4	68 ft	30 ft	3121	13.9	112
Trench 24 Cell 5	68 ft	30 ft	3121	9.8	159

F/N G:\MONTERO/3553CALC.SK

ATTACHMENT D-6-1-6

RESPONSE ACTION PLAN

SUPPLEMENT B

CALCULATIONS OF ACTION LEAKAGE RATE - TRENCH 23

Terracon	Made by:	RSG	Date:	12/31/14	Sheet No.:	COVER
	Checked by:	JCH	Date:	12/31/14	Job No.:	EJ147410
	Calculations for:	Action Leakage Rate				
	Emelle Facility – Trench 23					

Action Leakage Rate

CALCULATION COVER SHEET

Calculations by:

Signature: Rajendra S Gondhalekar

Name: Rajendra S. Gondhalekar, P.E.

Title: Project Engineer

12/31/2014
Date

Calculations Reviewed by:

Signature: J. Craig Hensley

Name: J. Craig Hensley, E.I.T.

Title: Staff Engineer

12/31/2014
Date

Calculations Approved by:

Signature:

Name: Michael A. Kemp P.E.

Title: Department Manager

12/31/2014
Date

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	12/31/14	ALL	Initial Submittal

1.0 OBJECTIVE

The purpose of this analysis is to establish the action leakage rate (ALR) for the leak detection system (LDS) of Trench 23.

2.0 BACKGROUND

Trench 23 at the CWM Emelle Facility is permitted in accordance with Division 14 regulations of the ADEM Administrative Code.

According to ADEM Administrative Code r. 335-14-5-.14-(3)-(a):

The Director shall approve an action leakage rate for landfill units subject to 335-14-5-.14(2)(b). The action leakage rate is the maximum design flow rate that the leak detection system (LDS) can remove without the fluid head on the bottom liner exceeding one foot. The action leakage rate must include an adequate safety margin to allow for uncertainties in the design (e.g., slope, hydraulic conductivity, thickness of drainage material), construction, operation, and location of the waste and leachate characteristics, likelihood and amounts of other sources of liquids in the LDS and proposed response actions (e.g., the action leakage rate must consider decreases in the flow capacity of the system over time resulting from siltation and clogging, rib layover and creep of synthetic components of the system, overburden pressures, etc.).

The proposed Trench 23, consists of six double-lined cells at the existing CWM Emelle Treatment Facility, located in Sumter County, Alabama. The LDS floor grades of the proposed cells have a slope of 2% towards a corridor located along the center of the cell. The proposed liner system on the floor of the cell consists of the following layers from top to bottom:

- 1.5 ft protective soil layer underlain by geotextile filter
- 1 ft granular material layer underlain by geotextile cushion
- 60 mil textured geomembrane primary liner
- geosynthetic clay liner (GCL)
- 200-mil geocomposite drainage layer, $\theta \geqq 3x10^{-5}$ m^2/s
- 60 mil textured geomembrane secondary liner
- 3 ft min. compacted chalk layer; $k \leq 1x10^{-7}$ cm/s

The cell side slopes are generally sloped at a grade of 25%. The 1 ft granular material layer is not continued along the side slopes. The side slope liners include a 200-mil geocomposite drainage layer, which will serve as the drainage layer for the side slopes. Any liquids in the geocomposite drainage layer will drain into the granular material layer at the toe of the slopes, where the two intersect.

3.0 CALCULATIONS

Action Leakage Rate (ALR)

To calculate the ALR, we first calculated the capacity of the LDS geocomposite drainage layer to convey the leachate flow from defects potentially located in the primary liner at a theoretical density of 1 per acre, without exceeding a fluid head of 1 ft on the secondary liner.

The capacity of a drainage layer to convey leachate from a single source of impingement was calculated using the methodology presented in Giroud, et al. [1997]. The maximum head on the secondary liner is required to be less than 1 ft, per the regulations. This is greater than the thickness of the proposed LDS geocomposite drainage layer. As a result of this, a portion of the geocomposite drainage layer could be in a full flow condition, with additional head, extending above the thickness of the drainage layer. In such a design condition, the capacity of the LDS can be computed using the following equation.

$$Q_{LDS} = k_{LDS} \cdot t_{LDS} \cdot (2 \cdot t_0 - t_{LDS}) \qquad (1)$$

Where:

Q_{LDS}	=	flow through the LDS drainage layer (m^3/s)
k_{LDS}	=	hydraulic conductivity of the LDS drainage layer (m/s)
t_{LDS}	=	thicknes of the LDS drainage layer (m)
t_0	=	maximum leachate head at the base of the LDS drainage layer (m)

The saturated hydraulic conductivity of studded surface drainage layer was computed for long term design condition using the following equations proposed by Giroud, Zornberg, and Zhao [2000]:

$$k_{design} = \frac{\theta_{design}}{t} \qquad (2)$$

$$\theta_{design} = \frac{\theta_{LTIS}}{FS} \qquad (3)$$

and

$$\theta_{LTIS} = \frac{\theta_{measured}}{RF_{IMCO} \cdot RF_{IMIN} \cdot RF_{CR} \cdot RF_{IN} \cdot RF_{CD} \cdot RF_{PC} \cdot RF_{CC} \cdot RF_{BC}} \qquad (4)$$

Where:

k_{design}	=	design hydraulic conductivity of the drainage layer
t	=	thickness of the drainage layer
θ_{design}	=	design hydraulic transmissivity of the drainage layer
θ_{LTIS}	=	long-term in-soil hydraulic transmissivity of the drainage layer
FS	=	factor of safety to account for all possible uncertainties;
$\theta_{measured}$	=	hydraulic transmissivity of the drainage layer as measured in laboratory tests
RF	=	reduction factors for immediate compression, immediate intrusion, creep, delayed intrusion, chemical degradation, and particulate, chemical, and biological clogging.

The hydraulic transmissivity of the geocomposite drainage layer was assumed to be a minimum of 3×10^{-5} m^2/s based on the permitted design requirements. The selected values for the factor of safety and reduction factors are listed in the following table. Based on these parameters, a long term design hydraulic transmissivity of 1.47×10^{-5} m^2/s was computed. This design hydraulic transmissivity corresponds to a saturated hydraulic conductivity of 2.89×10^{-3} m/s, because the estimated drainage layer thickness is 0.508 cm.

Reduction Factor	**FS**	**RF_{IMCO}**	**RF_{IMIN}**	**RF_{CR}**	**RF_{IN}**	**RF_{CD}**	**RF_{PC}**	**RF_{CC}**	**RF_{BC}**	**Overall Reduction Factor**
Selected Value	1.0	1.0	1.0	1.7	1.2	1.0	1.0	1.0	1.0	2.04

The maximum leachate head shall be 1 ft (i.e., 0.3048 m) to satisfy the regulatory requirements. Based on these parameters, the capacity of the LDS to convey flow from a single source of impingement, without excessive head, is calculated to be 8.88×10^{-6} m^3/s (i.e., 202.6 gal/day).

Applying a factor of safety of 2 to account for uncertainties, a flow rate of 101 gal/day will be utilized for ALR computation. Based on a theoretical defect density of 1 defect/acre, and the point sources of impingement are spaced far enough apart that they are effectively independent in terms of their flow contribution the ALR is computed to be 101.3 gal/acre/day.

4.0 ANALYSIS RESULTS

Based on the flow capacity of the LDS drainage layer, an ALR of 101.3 gal/acre/day is appropriate Trench 23. The lined area of the cells is listed in the following table to convert this to an ALR for each cell. In accordance with ADEM Administrative Code r. 335-14-5-.14-(3)-(b), weekly or monthly LDS flow rate monitoring data are to be converted to average daily flow rates in terms of gal/acre/day, to verify that the ALR is not exceeded.

Cell	Area (acres)	Allowable Weekly Flow Rate (gal/week)
Trench 23 Cell 1	15.9	11275
Trench 23 Cell 2	15.9	11275
Trench 23 Cell 3	10.1	7162
Trench 23 Cell 4	10.2	7233
Trench 23 Cell 5	15.3	10849
Trench 23 Cell 6	15.4	10920

5.0 REFERENCES

Giroud, J. P., Gross, B. A., Bonaparte, R., and McKelvey, J. A., "Leachate Flow in Leakage Collection Layers Due to Defects in Geomembrane Liners", Geosynthetics International, Vol. 4, Nos. 3-4, 1997

Giroud, J. P., Zornberg, J. G., and Zhao, A., "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers", Geosynthetics International, Vol. 7, Nos. 4-5, 2000.

ATTACHMENT D-6-1-7

APPENDIX D-6-1

SECTION D-6

CALCULATION PACKAGE FOR

TRENCH 22

Revision No.
5.0

The following calculations pertaining to Trenches 22, 23, and 24 were included in the original permit. Trenches 23 and 24, as designed in the original permit, are no longer proposed; therefore, calculations and references to Trenches 23 and 24 in this Attachment D-6-1-7 are no longer valid and are not to be considered for this Permit Application. New Trench 23 design and calculation packages have been incorporated into this current Permit Application (Revision 5.0) and can be found in Appendix D-6-1 of Section D-6 of this Permit Application.

CALCULATION PACKAGE

TRENCHES 22, 23 and 24

TABLE OF CONTENTS

SLOPE STABILITY ANALYSIS

SLOPE STABILITY ANALYSES OVERVIEW (Trenches 22, 23, and 24)

Slope Stability Analyses Overview

The stability of landfill Trenches 22, 23, and 24, and berms were evaluated. The slopes of the trenches were analyzed for:

- Overall Landfill Stability;
- Cut Slope Stability;
- Internal and Perimeter Berm Stability (with and without waste);
- Closure Cover System Stability; and
- Stability of Protective Chalk on Landfill Side Slope

The landfill was designed to achieve a minimum factor of 1.3 for temporary slopes and 1.5 for permanent slopes.

Selection of Cross Sections

Ten cross sections were selected for these slope stability analyses, based on their location, configuration, and material within the slope. These ten cross sections are considered to represent the most critical sections in the landfill trenches. The locations of the sections are shown on the attached figures.

Calculation Procedure

The stability analyses on the selected sections were performed using the program XSTABL. The analysis uses both circular and block trial surfaces. The block failure mode was used to guide the failure surface along the weakest planes within the liner system. A total of 200 trial surfaces were searched in each computer run, and the program reported the surface with the lowest safety factor calculated .

Material Properties

The material properties used in the slope stability analyses and the reference sources are listed in Table 1.

Concurrent with the analyses, laboratory testing was conducted to assess the shear strength of geosynthetic-geosynthetic interfaces and geomembrane-chalk interfaces for the materials planned to be used in landfill construction. The results of the interface strength testing are presented in Reference 7, listed on Table 1.

Tests and analyses were also conducted to evaluate the consolidation rate and corresponding increase in strength of the geosynthetic-chalk interfaces in the secondary and primary liner systems under the loading of the waste. These tests and analyses indicate that the chalk in the secondary and primary liner systems will consolidate under the waste loading such that excess pore water pressures have fully dissipated whrn waste placement is complete. Thus, the strength values of the geomembrane-chalk interface obtained under drained conditions are applicable to stability analyses involving interfaces on the base and side slopes of the trenches. Strength values obtained under undrained conditions for the geomembrane-chalk interface are not applicable, even for temporary waste slopes, given the filling rates planned for the trenches.

Stability analyses were first done using the bi-linear strength envelope for the critical interface on the base and inside slopes of the landfill. This bi-linear envelope was based on the assumptions that, (a) the geosynthetic-geosynthetic interfaces would be critical at low normal stresses and would have a friction angle of 8 degrees and (b) the geomembrane-chalk interface under undrained conditions would be critical at high normal stresses and would have a value of 1000 psf. As discussed above, undrained conditions at the geomembrane-chalk interface subsequently proved to be inapplicable. So, the shear strength at the geosynthetic-geosynthetic interface (friction angle of 8 degress) is critical for high as well as low normal stresses. The revised shear strength envelope gives strengths equal to or greater than the strengths used in the initial analyses. Thus, the initial analyses gave conservative results and were not revised, except in cases where the required factors of safety (1.3 for temporary slopes and 1.5 for permanent slopes) were not achieved. For those cases, a linear envelope defined by a friction angle of 8 degress was used in revised analyses and where necessary, the design was modified to achieve the required factors of safety.

The test results presented in Reference 7 (refer to Table 1) show that the interface strengths of the materials planned for use in construction equal or exceed the values used in these slope stability analyses. Further, specifications for the materials are provided in Attachment D-6-1-4 which require shear strengths that equal or exceed the values used in these analyses.

Summary of Stability Analysis Results

Landfill Overall Stability

The stability of landfill was analyzed at Section A-A' in Trench 23. The calculated safety factors are presented below:

Cross Sections	Failure Mode	Factor of Safety
A-A'	Circular	1.8
	Block	1.5

Cut Slope Stability

The stability of the cut slope was analyzed at sections C-C' and D-D' in Trench 24. The calculated safety factors are presented below:

Cross Sections	Failure Mode	Factor of Safety
C-C'	Circular, Short Term	3.7
	Circular, Long Term	5.4
D-D'	Circular, Short Term	3.9
	Circular, Long Term	6.2

Internal Berm Stability

The stability of the internal berm was analyzed. The calculated safety factor is 6.4, which is much higher than 1.5. However, as the internal berm is designed to buttress the waste placed in the operational cells, the stability of the internal berm with the waste was place was analyzed at sections G-G' and G-G'* in Trenches 23 and H-H' in Trench 24. The calculated safety factors are presented below:

Cross Sections	Failure Mode	Factor of Safety
G-G'	Block	1.35
G-G'	Block	1.33
H-H'	Block	1.33

Closure Cover System Stability

The stability of the closure cover system (benches every 20 ft. vertically) was analyzed for the 10H:1V and 4H:1V slopes for Trenches 22, 23, and 24 to determine the required interface frictional strength in the cover. The calculated results are presented below:

Cross Sections	Factor of Safety	Required Interface Friction Angle ϕ_i, degree
10H:1V	1.5	6
4H:1V	1.5	18

According to the analysis results, the interface friction angle should be at least 18 degrees for the 4H:1V and 6 degrees for the 10H:1V slopes to achieve a minimum factor of safety of 1.5 on the 4H:1V closure cover slope.

Stability of Structural Fill on Landfill Side Slope

The stability of the structural fill on the 2.5H:1V landfill side slope is analyzed. With the groundwater table at 20 feet below ground surface, the calculated factor of safety is FOS=2.4.

Height of Protective Chalk on Landfill Side Slope

The height of protective soil cover on a 2.5H:1V side slope for each lift was analyzed based on Giroud's analytical solution presented in '89 Geosynthetics Conference. In the analysis, weight of construction equipment is considered as an additional and temporary driving force on the soil cover.

According to the analysis, 8 feet (measured vertically) is the allowable maximum soil cover that can be placed along the slope for one foot soil cover at each lift during trench operation.

TABLE 1

MATERIAL PROPERTIES USED FOR LANDFILL STABILITY ANALYSIS

(TRENCHES 22, 23, AND 24)

Materials	Friction Angle ϕ' (degree)	Apparent Cohesion C' (psf)	Undrained Shear Strength S_u (psf)	Unit Weight γ (pcf)	References
Soil Cover (Chalk)	26	-	400	100	4
Smooth HDPE / Structural Fill (Chalk)	15	-	-	-	4
Waste	15	650	-	110	3
Structural Fill (Chalk)	26	600	1500	130	2
Compacted Clay Layer (Chalk)	26	600	-	130	2
Compacted Clay Layer (Chalk)/HDPE Liner	-	-	1000	-	5
Geotextile / Geonet	12	-	-	-	6
Geonet / HDPE Liner	8	-	-	-	5
Natural Intact Chalk (Short Term)	-	-	8000	130	1
Natural Int. Chalk (Horizontal, Long Term)	36	6000	-	130	1
Natural Int. Chalk (Vertical, Long Term)	43	2000	-	130	

References:

1. Bryan, J.J., "Chalk Slope Failure at Gainsville Lock, Alabama," Bulletin of the Association of Engineering Geologists, February 1981, Vol. XVII #1.
2. Golder Associates, Compacted Chalk Strength and Compression Testing - Laboratory Data, October 1984.
3. Golder Associates, Calculation Package - Back Analysis of Trench 17 Excavation, March 2, 1986.
4. Golder Associates, "Report on Failure of Soil Closure Cover Trench 21, Cells 1 and 2, Emelle, Alabama." 1992.
5. Seed, R.B., Mitchell, J.K., and Seed, H.B., "Kettleman Hills Waste Landfill Slope Failure," ASCE Geotechnical Journal, Vol. 116, No. 4, April 1990, pp 647-690.
6. "Proceedings of the 4th GRI Seminar on the topic of Landfill Closures," December 13, 1990, Philadelphia, PA.
7. GeoSyntec, Inc., "Draft Interface Direct Shear Tests on Emelle Site Specific Materials," October, 1993.

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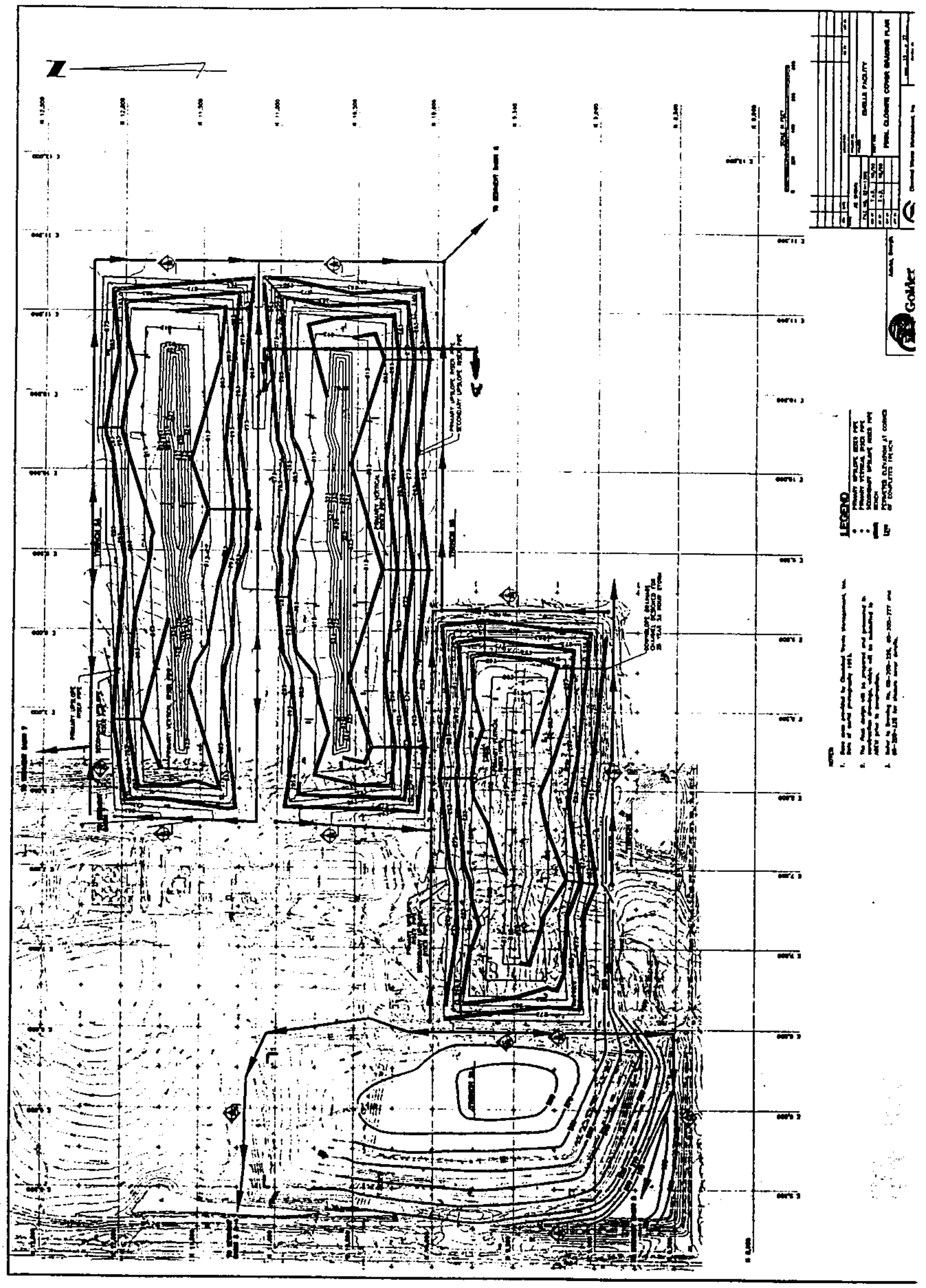
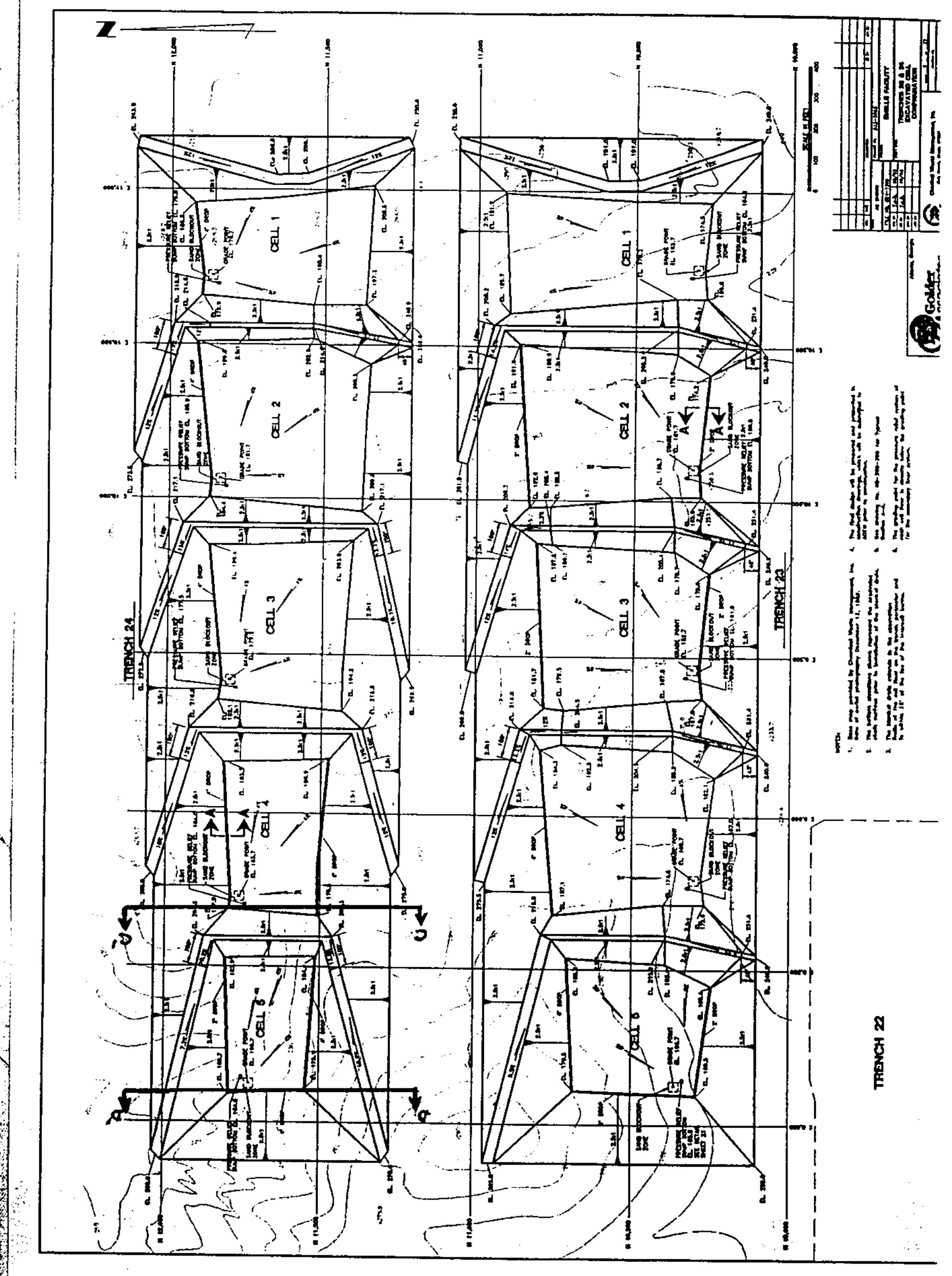
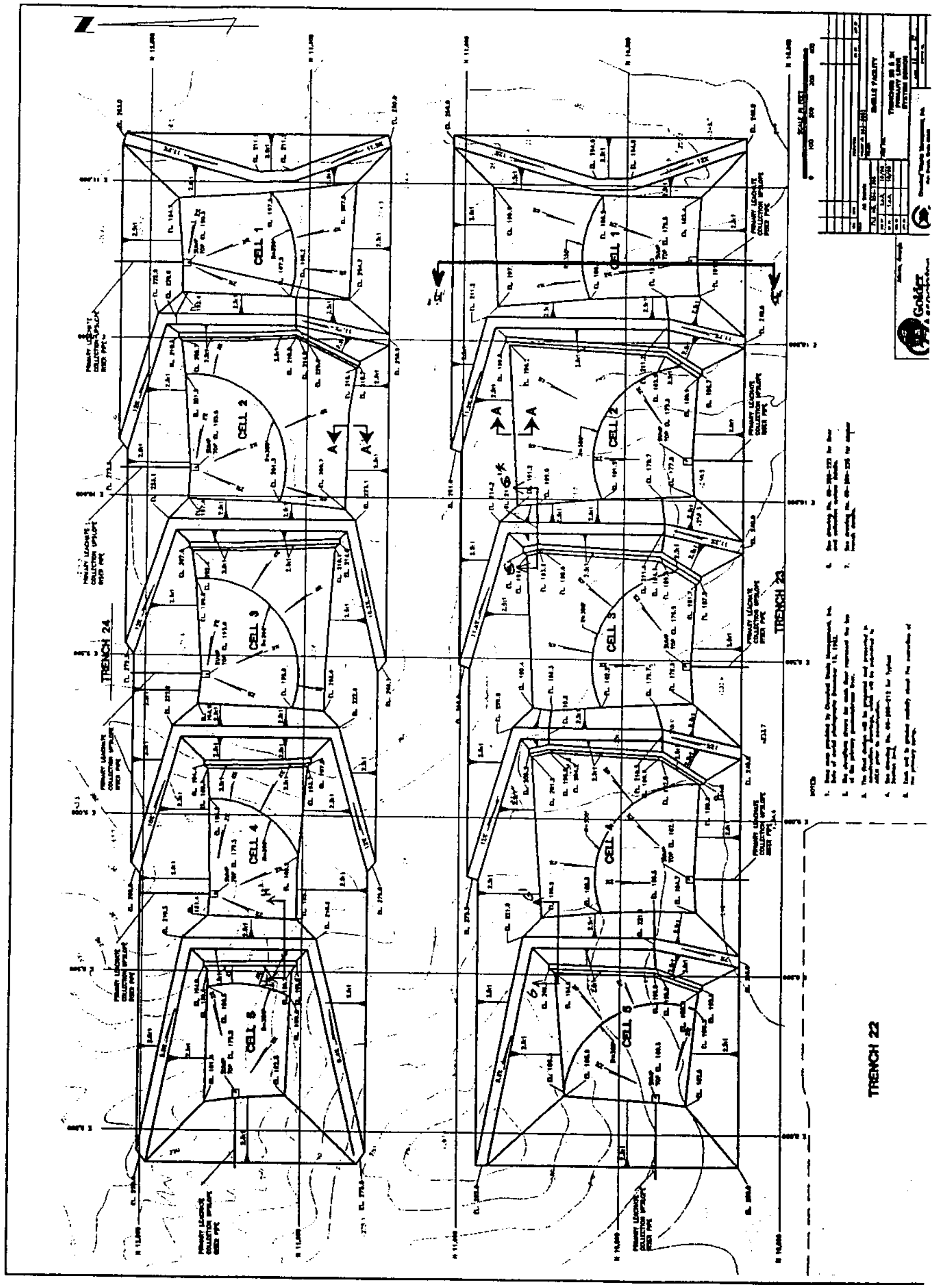



TRENCH 24
TRENCH 23
TRENCH 22
CELL 1
CELL 2
CELL 3
CELL 4
CELL 5


TRENCH 24
TRENCH 23
TRENCH 22
CELL 1
CELL 2
CELL 3
CELL 4
CELL 5

Golder Associates	SUBJECT Cross-section A-A Overall stability T22, T23, T24		
	Job No. 933-3553 Ref. Emelle	Made by SYZ Checked RID Reviewed WRS	Date 9/29/93 Sheet 1 of 25

Objective: The objective is to evaluate the landfill stability using the overall completed configuration for T22, T23 & T24 analyzing a representative section. (see sheet 2A/25)

Method: The XSTABL computer program was used in the Analysis. Both block and circular failure surfaces were used. A Search for the critical surface was also employed.

strength parameters:

The following table summarizes the shear strength values used in the Analysis:

Material	S_u (psf)	ϕ (deg)	unit wt. (pcf)	Cohesion (psf)
insitu	8000	—	130	—
Waste	—	15	110	650
synthetic interface	—	8	—	—
clay synthetic interface	1000	—	—	—
assumed top crack zone	—	15	110	0

Assumptions: As a worst scenario, pore water pressure is assumed to act between the geosynthetic system, i.e geomembrane is not 100% impermeable (conservative).

Golder Associates	SUBJECT Cross-section A–A overall stability		
	Job No. 931-3553	Made by SYI	Date 9/29/93
	Ref. Emelle	Checked RID	Sheet 2 of 25
		Reviewed	

Uplift pressure: (if pumping from pressure relief system stops)

The cells/trench are lined at the bottom with several layer of impermeable geosynthetic and clay layers. Therefor uplift forces will be acting along the liner system and will influence the stability analysis. The uplift pressure was modelled by using a pore pressure grid system where water pressure at various grid points was estimated by multiplying the water head at any point by 62.4 pcf. ✓

Results:

Based on the XSTABL analysis, The minimum safety factor is about 1.52 for block type failure. Sheet 3 shows the critical failure surface sheets 5 through 16 present the computer output.

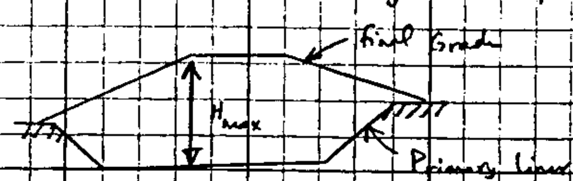
For circular failure surfaces, the minimum safety factor was 1.82 (sheet 4). Computer output is attached on pages 17 through 25. Sheet 4 shows the critical circular failure Surface.

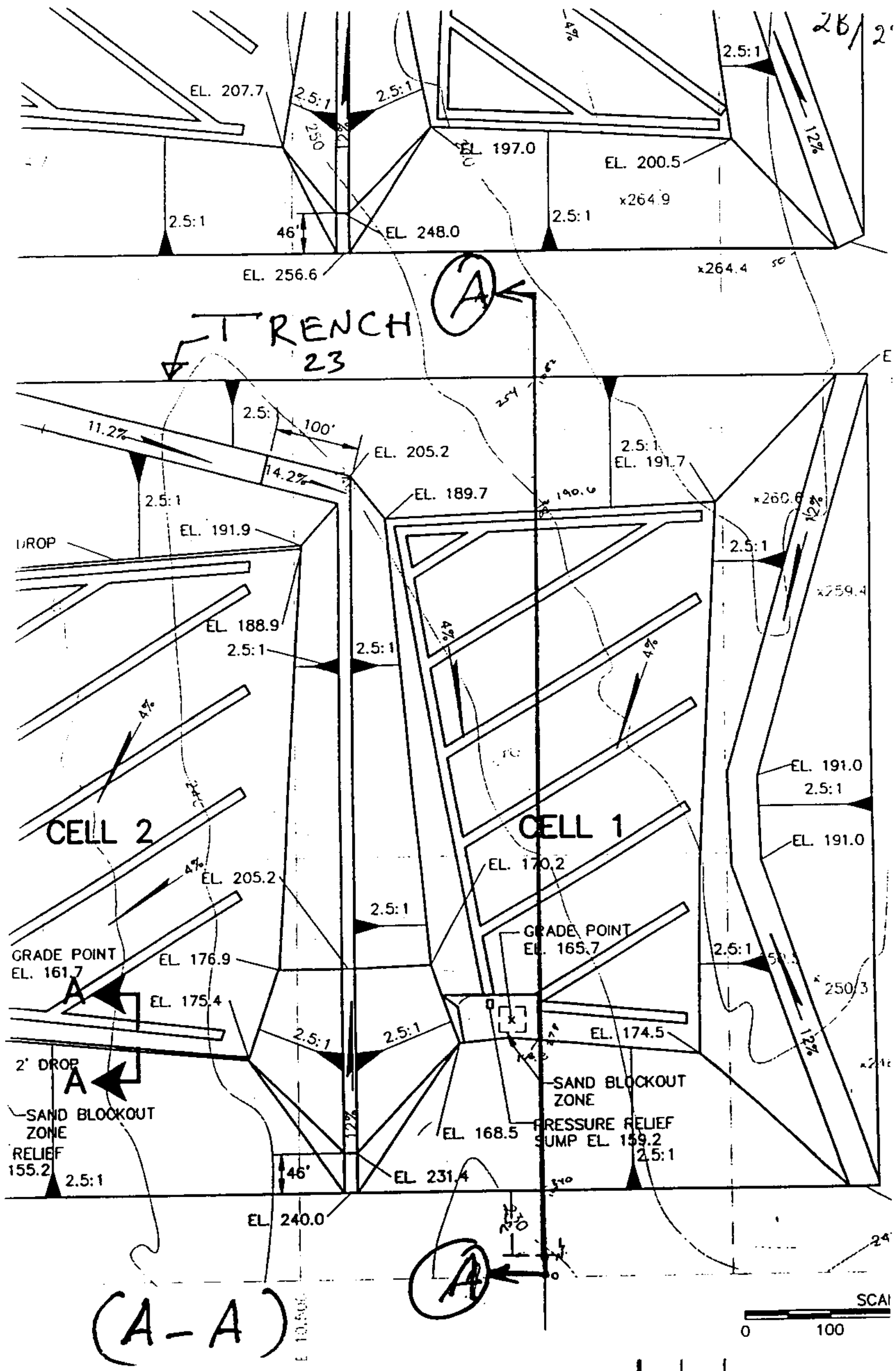
(Sheet 2B shows the location of section A–A)

Golder Associates	SUBJECT Waste thickness (total)		
	Job No. 933-3553.4 Ref. Emelle	Made by SYI Checked Reviewed	Date 10/13/93 Sheet 2A of 25

Trench No.	Cell No.	total waste thickness (Approx.) (ft)
22	1	122
	2	125
	3	118
	4	126
23	1	140
	2	145
	3	144
	4	138
	5	140
24	1	131
	2	126
	3	128
	4	142
	5	141

total waste thickness is based on primary liner plans/DWGs





EL. 207.7
2.5:1
EL. 197.0
EL. 200.5
x264.9
46'
EL. 248.0
EL. 256.6
x264.4
12%
TRENCH 23
A
2.5:
100'
EL. 205.2
11.2%
14.2%
EL. 191.7
EL. 189.7
x260.6
EL. 191.9
DROP
x259.4
EL. 188.9
4%
EL. 191.0
CELL 2
CELL 1
EL. 170.2
GRADE POINT
EL. 165.7
GRADE POINT
EL. 161.7
EL. 176.9
x250.3
EL. 175.4
EL. 174.5
2' DROP
SAND BLOCKOUT
ZONE
SAND BLOCKOUT
ZONE
EL. 168.5
PRESSURE RELIEF
SUMP EL. 159.2
RELIEF
155.2
EL. 231.4
EL. 240.0
(A-A)
SCA
0
100

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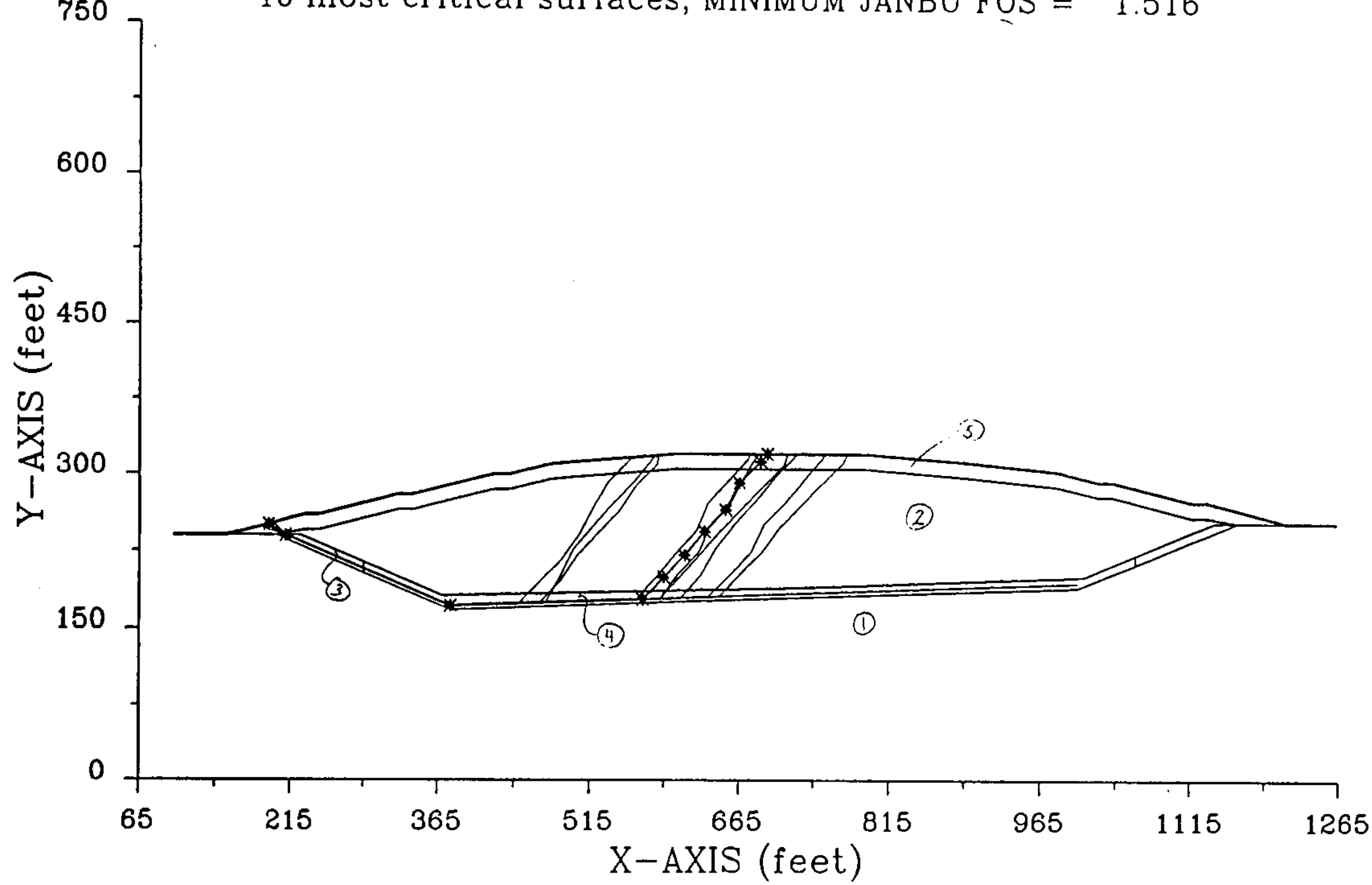
Cross Section A-A Overall Stability

10 most critical surfaces, MINIMUM JANBU FOS = 1.516



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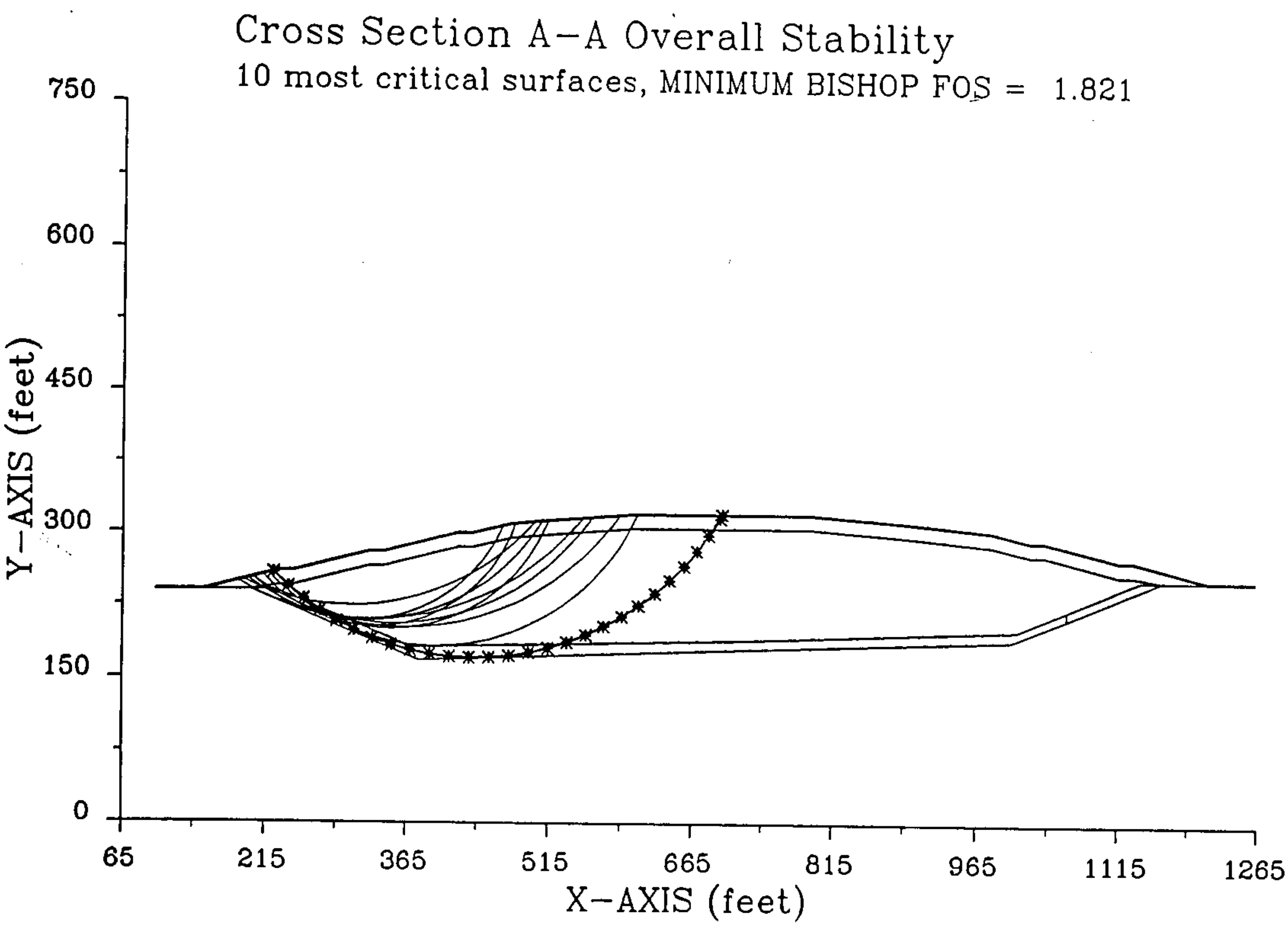

4/25

5/25

PROFIL FILE: A-A_1 10-03-93 3:12 ft

Cross Section A-A Overall Stability

54 20

100.0	240.0	150.0	240.0	1
150.0	240.0	230.0	260.0	2
230.0	260.0	245.0	260.0	4
245.0	260.0	325.0	280.0	4
325.0	280.0	340.0	280.0	4
340.0	280.0	420.0	300.0	4
420.0	300.0	435.0	300.0	4
435.0	300.0	476.0	310.2	4
476.0	310.2	502.0	312.8	4
502.0	312.8	602.0	320.9	4
602.0	320.9	695.0	320.9	4
695.0	320.9	793.0	320.9	4
793.0	320.9	893.0	312.8	4
893.0	312.8	982.6	303.9	4
982.6	303.9	1022.0	294.0	4
1022.0	294.0	1037.0	294.0	4
1037.0	294.0	1117.0	274.0	4
1117.0	274.0	1132.0	274.0	4
1132.0	274.0	1212.0	254.0	4
1212.0	254.0	1262.0	254.0	1
150.0	240.0	200.0	240.0	1
200.0	240.0	230.0	245.0	2
230.0	245.0	245.0	245.0	2
245.0	245.0	325.0	265.0	2
325.0	265.0	340.0	265.0	2
340.0	265.0	420.0	285.0	2
420.0	285.0	435.0	285.0	2
435.0	285.0	476.0	295.2	2
476.0	295.2	502.0	297.8	2
502.0	297.8	602.0	305.9	2
602.0	305.9	793.0	305.9	2
793.0	305.9	893.0	297.8	2
893.0	297.8	982.0	288.9	2
982.0	288.9	1022.0	279.0	2
1022.0	279.0	1037.0	279.0	2
1037.0	279.0	1117.0	259.0	2
1117.0	259.0	1132.0	259.0	2
1132.0	259.0	1162.0	254.0	2
1162.0	254.0	1212.0	254.0	1
200.0	240.0	225.0	240.0	3
225.0	240.0	290.0	214.0	3
290.0	214.0	370.0	182.4	4
370.0	182.4	723.0	189.9	4
723.0	189.9	1008.0	200.9	4
1008.0	200.9	1060.0	222.4	4
1060.0	222.4	1139.0	254.0	3
1139.0	254.0	1162.0	254.0	3
290.0	214.0	290.1	204.0	3
1060.0	222.4	1060.1	213.2	4
200.0	240.0	290.1	203.9	1
290.1	203.9	378.0	168.8	1
378.0	168.8	1002.0	190.6	1
1002.0	190.6	1060.1	213.2	1
1060.1	213.2	1162.0	254.0	1

SOIL

5

6/25

```
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   110.0     110.0      650.0     15.00      .000       .0    0
   130.0     130.0         .0      8.00      .000       .0    0
   130.0     130.0     1000.0       .00      .000       .0    0
   110.0     110.0         .0     15.00      .000       .0    0
 ANISO
   1
    1     3
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     45.00      6000.0      36.00
     90.00      2000.0      43.00
 NLSOIL
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    3     3
           .0          .0
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        460.0       240.0         .0
        500.0       240.0         .0
        550.0       240.0         .0
        600.0       240.0         .0
        723.0       240.0         .0
        850.0       240.0         .0
       1008.0       240.0         .0
       1073.3       240.0         .0
       1262.0       240.0         .0
        100.0       227.0         .0
        277.5       227.0         .0
        300.0       218.0         .0
        345.0       200.0         .0
        370.0       182.4         .0
        425.0       183.6         .0
        460.0       184.3         .0
        500.0       185.2         .0
        550.0       186.3         .0
        600.0       187.3         .0
        723.0       189.9         .0
        850.0       194.8         .0
       1008.0       200.9         .0
       1073.3       227.0         .0
       1262.0       227.0         .0
        100.0       226.9        6.2
        277.5       226.9        6.2
        300.0       217.9      567.8
        345.0       199.9     1691.0
        370.0       182.3     2789.3
        425.0       183.5     2789.3
        460.0       184.2     2789.3
        500.0       185.1     2789.3
        550.0       186.2     2789.3
        600.0       187.2     2789.3
        723.0       189.8     2321.3
```

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850.0	194.7	2321.3
1008.0	200.8	1634.9
1073.3	226.9	6.2
1262.0	226.9	6.2
100.0	221.9	318.2
277.5	221.9	318.2
300.0	212.9	879.8
345.0	194.9	2003.0
370.0	177.3	3101.3
425.0	178.5	3101.3
460.0	179.2	3101.3
500.0	180.1	3101.3
550.0	181.2	3101.3
600.0	182.2	3101.3
723.0	184.8	2633.3
850.0	189.7	2633.3
1008.0	195.8	1946.9
1073.3	221.9	318.2
1262.0	221.9	318.2
100.0	140.0	5428.8
277.5	140.0	5428.8
300.0	140.0	5428.8
370.0	140.0	5428.8
425.0	140.0	5428.8
460.0	140.0	5428.8
500.0	140.0	5428.8
550.0	140.0	5428.8
600.0	140.0	5428.8
723.0	140.0	5428.8
850.0	140.0	5428.8
1008.0	140.0	5428.8
1073.3	140.0	5428.8
1262.0	140.0	5428.8

BLOCK

200	3	30.0				
	210.0	240.0	210.1	240.0	.0	
	377.8	172.8	378.0	172.8	.0	
	380.0	172.0	1002.0	195.0	.0	

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XSTABL File: A-A_1   10-03-93   3:12

```
****************************************
*                XSTABL                *
*                                      *
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*   Simplified BISHOP or JANBU methods *
*                                      *
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*                                      *
*        Golder Associates, Inc.       *
*          Atlanta,  GA 30341          *
*                                      *
*  Ver. 4.1                      1049  *
****************************************
```

Problem Description : Cross Section A-A Overall Stability

SEGMENT BOUNDARY COORDINATES

20 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	100.0	240.0	150.0	240.0	1
2	150.0	240.0	230.0	260.0	2
3	230.0	260.0	245.0	260.0	4
4	245.0	260.0	325.0	280.0	4
5	325.0	280.0	340.0	280.0	4
6	340.0	280.0	420.0	300.0	4
7	420.0	300.0	435.0	300.0	4
8	435.0	300.0	476.0	310.2	4
9	476.0	310.2	502.0	312.8	4
10	502.0	312.8	602.0	320.9	4
11	602.0	320.9	695.0	320.9	4
12	695.0	320.9	793.0	320.9	4
13	793.0	320.9	893.0	312.8	4
14	893.0	312.8	982.6	303.9	4
15	982.6	303.9	1022.0	294.0	4
16	1022.0	294.0	1037.0	294.0	4
17	1037.0	294.0	1117.0	274.0	4
18	1117.0	274.0	1132.0	274.0	4
19	1132.0	274.0	1212.0	254.0	4
20	1212.0	254.0	1262.0	254.0	1

34 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	150.0	240.0	200.0	240.0	1

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2	200.0	240.0	230.0	245.0	2
3	230.0	245.0	245.0	245.0	2
4	245.0	245.0	325.0	265.0	2
5	325.0	265.0	340.0	265.0	2
6	340.0	265.0	420.0	285.0	2
7	420.0	285.0	435.0	285.0	2
8	435.0	285.0	476.0	295.2	2
9	476.0	295.2	502.0	297.8	2
10	502.0	297.8	602.0	305.9	2
11	602.0	305.9	793.0	305.9	2
12	793.0	305.9	893.0	297.8	2
13	893.0	297.8	982.0	288.9	2
14	982.0	288.9	1022.0	279.0	2
15	1022.0	279.0	1037.0	279.0	2
16	1037.0	279.0	1117.0	259.0	2
17	1117.0	259.0	1132.0	259.0	2
18	1132.0	259.0	1162.0	254.0	2
19	1162.0	254.0	1212.0	254.0	1
20	200.0	240.0	225.0	240.0	3
21	225.0	240.0	290.0	214.0	3
22	290.0	214.0	370.0	182.4	4
23	370.0	182.4	723.0	189.9	4
24	723.0	189.9	1008.0	200.9	4
25	1008.0	200.9	1060.0	222.4	4
26	1060.0	222.4	1139.0	254.0	3
27	1139.0	254.0	1162.0	254.0	3
28	290.0	214.0	290.1	204.0	3
29	1060.0	222.4	1060.1	213.2	4
30	200.0	240.0	290.1	203.9	1
31	290.1	203.9	378.0	168.8	1
32	378.0	168.8	1002.0	190.6	1
33	1002.0	190.6	1060.1	213.2	1
34	1060.1	213.2	1162.0	254.0	1

ISOTROPIC Soil Parameters

5 type(s) of soil

	Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
In-Situ Bulk	1	130.0	130.0	8000.0 (Su)	.00	.000	.0	0
waste	2	110.0	110.0	650.0	15.00	.000	.0	0
Slope	3	130.0	130.0	.0	8.00	.000	.0	0
Base	4	130.0	130.0	1000.0	.00	.000	.0	0
Cracked zone	5	110.0	110.0	.0	15.00	.000	.0	0

ANISOTROPIC Strength Parameters
1 soil type(s)

Soil Type 1 is ANISOTROPIC

Number of direction ranges specified = 3

Direction Range No.	Counterclockwise Direction Limit (deg)	Cohesion Intercept (psf)	Friction Angle (deg)
1	-45.00	2000.0	43.0
2	45.00	6000.0	36.0
3	90.00	2000.0	43.0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3 (Slope)

Point No.	Normal Stress (psf)	Shear Stress (psf)
1.	.0	.0
2.	7115.4	1000.0
3.	99999.0	1000.0

PORE WATER PRESSURES WILL BE ESTIMATED FROM VALUES
ASSIGNED BY THE USER AT DISCRETE POINTS IN THE SLOPE.

74 discrete points have been defined at :

x-coord (feet)	y-coord (feet)	Pore Pressure (psf)
100.0	240.0	.0
277.5	240.0	.0
300.0	240.0	.0
345.0	240.0	.0
370.0	240.0	.0
425.0	240.0	.0
460.0	240.0	.0
500.0	240.0	.0
550.0	240.0	.0
600.0	240.0	.0
723.0	240.0	.0
850.0	240.0	.0
1008.0	240.0	.0
1073.3	240.0	.0
1262.0	240.0	.0
100.0	227.0	.0
277.5	227.0	.0
300.0	218.0	.0
345.0	200.0	.0
370.0	182.4	.0
425.0	183.6	.0
460.0	184.3	.0
500.0	185.2	.0
550.0	186.3	.0
600.0	187.3	.0

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723.0	189.9	.0
850.0	194.8	.0
1008.0	200.9	.0
1073.3	227.0	.0
1262.0	227.0	.0
100.0	226.9	6.2
277.5	226.9	6.2
300.0	217.9	567.8
345.0	199.9	1691.0
370.0	182.3	2789.3
425.0	183.5	2789.3
460.0	184.2	2789.3
500.0	185.1	2789.3
550.0	186.2	2789.3
600.0	187.2	2789.3
723.0	189.8	2321.3
850.0	194.7	2321.3
1008.0	200.8	1634.9
1073.3	226.9	6.2
1262.0	226.9	6.2
100.0	221.9	318.2
277.5	221.9	318.2
300.0	212.9	879.8
345.0	194.9	2003.0
370.0	177.3	3101.3
425.0	178.5	3101.3
460.0	179.2	3101.3
500.0	180.1	3101.3
550.0	181.2	3101.3
600.0	182.2	3101.3
723.0	184.8	2633.3
850.0	189.7	2633.3
1008.0	195.8	1946.9
1073.3	221.9	318.2
1262.0	221.9	318.2
100.0	140.0	5428.8
277.5	140.0	5428.8
300.0	140.0	5428.8
370.0	140.0	5428.8
425.0	140.0	5428.8
460.0	140.0	5428.8
500.0	140.0	5428.8
550.0	140.0	5428.8
600.0	140.0	5428.8
723.0	140.0	5428.8
850.0	140.0	5428.8
1008.0	140.0	5428.8
1073.3	140.0	5428.8
1262.0	140.0	5428.8

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

200 trial surfaces will be generated and analyzed.

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3 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 30.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	210.0	240.0	210.1	240.0	.0
2	377.8	172.8	378.0	172.8	.0
3	380.0	172.0	1002.0	195.0	.0

Factors of safety have been calculated by the :

* * * * * MODIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	191.57	250.39
2	210.02	240.00
3	377.87	172.80
4	568.47	178.97
5	589.63	200.23
6	610.67	221.62
7	630.25	244.35
8	651.38	265.64
9	665.24	292.25
10	686.43	313.49
11	693.28	320.90

** Corrected JANBU FOS = 1.516 ** (Fo factor =1.080)

Failure surface No. 2 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	193.71	250.93
2	210.04	240.00
3	377.99	172.80
4	606.32	180.37
5	626.85	202.25
6	641.66	228.34
7	660.22	251.91
8	680.90	273.64
9	699.86	296.89
10	720.60	318.56

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11	721.69	320.90

** Corrected JANBU FOS = 1.557 ** (Fo factor =1.079)

Failure surface No. 3 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	196.90	251.72
2	210.06	240.00
3	377.97	172.80
4	585.67	179.60
5	606.28	201.40
6	626.69	223.39
7	646.71	245.73
8	667.87	267.00
9	688.54	288.74
10	709.75	309.96
11	712.60	320.90

** Corrected JANBU FOS = 1.560 ** (Fo factor =1.079)

Failure surface No. 4 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	182.99	248.25
2	210.04	240.00
3	377.85	172.80
4	560.74	178.68
5	581.75	200.10
6	601.47	222.71
7	621.67	244.89
8	633.51	272.46
9	653.92	294.44
10	674.36	316.40
11	674.91	320.90

** Corrected JANBU FOS = 1.577 ** (Fo factor =1.081)

Failure surface No. 5 specified by 10 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	196.33	251.58
2	210.01	240.00
3	377.98	172.80
4	585.24	179.59
5	603.71	203.23
6	624.74	224.62
7	636.71	252.13
8	657.07	274.16
9	671.40	300.52
10	683.31	320.90

** Corrected JANBU FOS = 1.577 ** (Fo factor =1.082)

Failure surface No. 6 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	197.29	251.82
2	210.01	240.00
3	377.97	172.80
4	470.52	175.35
5	485.60	201.28
6	499.36	227.94
7	519.23	250.42
8	539.22	272.78
9	560.01	294.41
10	579.00	317.64
11	580.49	319.16

** Corrected JANBU FOS = 1.594 ** (Fo factor =1.088)

Failure surface No. 7 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	197.77	251.94
2	210.07	240.00
3	377.87	172.80
4	444.15	174.37
5	465.34	195.61
6	486.55	216.82
7	504.04	241.20
8	518.19	267.66
9	533.87	293.23
10	554.62	314.89
11	556.83	317.24

** Corrected JANBU FOS = 1.597 ** (Fo factor =1.089)

Failure surface No. 8 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	197.76	251.94
2	210.03	240.00
3	377.98	172.80
4	464.43	175.12
5	485.55	196.43
6	502.82	220.96
7	523.31	242.88
8	544.51	264.11
9	560.95	289.20
10	582.12	310.45
11	583.77	319.42

** Corrected JANBU FOS = 1.598 ** (Fo factor =1.088)

Failure surface No. 9 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	197.99	252.00
2	210.00	240.00
3	377.81	172.80
4	644.75	181.79
5	665.95	203.01
6	687.08	224.31
7	705.18	248.23
8	726.12	269.71
9	747.16	291.10
10	768.27	312.41
11	772.67	320.90

** Corrected JANBU FOS = 1.603 ** (Fo factor =1.075)

Failure surface No.10 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	197.67	251.92
2	210.05	240.00
3	377.86	172.80
4	634.40	181.41
5	655.58	202.65
6	676.70	223.96
7	689.24	251.21
8	710.39	272.48
9	729.94	295.24
10	749.31	318.15
11	749.94	320.90

** Corrected JANBU FOS = 1.627 ** (Fo factor =1.077)

```
**********************************************************************
**                                                                  **
**  Out of the    200 surfaces generated and analyzed by XSTABL,    **
**        92 surfaces were found to have MISLEADING FOS values.     **
**                                                                  **
**********************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : Cross Section A-A Overall Stability

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Driving Force (lb)
1.	1.516	1.080	191.57	693.28	5.527E+05
2.	1.557	1.079	193.71	721.69	5.412E+05
3.	1.560	1.079	196.90	712.60	5.535E+05
4.	1.577	1.081	182.99	674.91	5.173E+05
5.	1.577	1.082	196.33	683.31	5.106E+05
6.	1.594	1.088	197.29	580.49	4.206E+05
7.	1.597	1.089	197.77	556.83	4.120E+05
8.	1.598	1.088	197.76	583.77	4.404E+05
9.	1.603	1.075	197.99	772.67	5.721E+05
10.	1.627	1.077	197.67	749.94	5.424E+05

* * * END OF FILE * * *

♠
PROFIL FILE: A-A_5 9-29-93 16:27 ft
Cross Section A-A Overall Stability
54 20

100.0	240.0	150.0	240.0	1
150.0	240.0	230.0	260.0	2
230.0	260.0	245.0	260.0	4
245.0	260.0	325.0	280.0	4
325.0	280.0	340.0	280.0	4
340.0	280.0	420.0	300.0	4
420.0	300.0	435.0	300.0	4
435.0	300.0	476.0	310.2	4
476.0	310.2	502.0	312.8	4
502.0	312.8	602.0	320.9	4
602.0	320.9	695.0	320.9	4
695.0	320.9	793.0	320.9	4
793.0	320.9	893.0	312.8	4
893.0	312.8	982.6	303.9	4
982.6	303.9	1022.0	294.0	4
1022.0	294.0	1037.0	294.0	4
1037.0	294.0	1117.0	274.0	4
1117.0	274.0	1132.0	274.0	4
1132.0	274.0	1212.0	254.0	4
1212.0	254.0	1262.0	254.0	1
150.0	240.0	200.0	240.0	1
200.0	240.0	230.0	245.0	2
230.0	245.0	245.0	245.0	2
245.0	245.0	325.0	265.0	2
325.0	265.0	340.0	265.0	2
340.0	265.0	420.0	285.0	2
420.0	285.0	435.0	285.0	2
435.0	285.0	476.0	295.2	2
476.0	295.2	502.0	297.8	2
502.0	297.8	602.0	305.9	2
602.0	305.9	793.0	305.9	2
793.0	305.9	893.0	297.8	2
893.0	297.8	982.0	288.9	2
982.0	288.9	1022.0	279.0	2
1022.0	279.0	1037.0	279.0	2
1037.0	279.0	1117.0	259.0	2
1117.0	259.0	1132.0	259.0	2
1132.0	259.0	1162.0	254.0	2
1162.0	254.0	1212.0	254.0	1
200.0	240.0	225.0	240.0	3
225.0	240.0	290.0	214.0	3
290.0	214.0	370.0	182.4	4
370.0	182.4	723.0	189.9	4
723.0	189.9	1008.0	200.9	4
1008.0	200.9	1060.0	222.4	4
1060.0	222.4	1139.0	254.0	3
1139.0	254.0	1162.0	254.0	3
290.0	214.0	290.1	204.0	3
1060.0	222.4	1060.1	213.2	4
200.0	240.0	290.1	203.9	1
290.1	203.9	378.0	168.8	1
378.0	168.8	1002.0	190.6	1
1002.0	190.6	1060.1	213.2	1
1060.1	213.2	1162.0	254.0	1

SOIL
5

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```
  130.0     130.0    8000.0       .00     .000        .0     0
  110.0     110.0     650.0     15.00     .000        .0     0
  130.0     130.0        .0      8.00     .000        .0     0
  130.0     130.0    1000.0       .00     .000        .0     0
  110.0     110.0        .0     15.00     .000        .0     0
ANISO
  1
   1     3
   -45.00      2000.0       43.00
    45.00      6000.0       36.00
    90.00      2000.0       43.00
NLSOIL
  1
   3     3
          .0          .0
      7115.4      1000.0
     99999.0      1000.0
PWGRID
 74
       100.0       240.0          .0
       277.5       240.0          .0
       300.0       240.0          .0
       345.0       240.0          .0
       370.0       240.0          .0
       425.0       240.0          .0
       460.0       240.0          .0
       500.0       240.0          .0
       550.0       240.0          .0
       600.0       240.0          .0
       723.0       240.0          .0
       850.0       240.0          .0
      1008.0       240.0          .0
      1073.3       240.0          .0
      1262.0       240.0          .0
       100.0       227.0          .0
       277.5       227.0          .0
       300.0       218.0          .0
       345.0       200.0          .0
       370.0       182.4          .0
       425.0       183.6          .0
       460.0       184.3          .0
       500.0       185.2          .0
       550.0       186.3          .0
       600.0       187.3          .0
       723.0       189.9          .0
       850.0       194.8          .0
      1008.0       200.9          .0
      1073.3       227.0          .0
      1262.0       227.0          .0
       100.0       226.9         6.2
       277.5       226.9         6.2
       300.0       217.9       567.8
       345.0       199.9      1691.0
       370.0       182.3      2789.3
       425.0       183.5      2789.3
       460.0       184.2      2789.3
       500.0       185.1      2789.3
       550.0       186.2      2789.3
       600.0       187.2      2789.3
       723.0       189.8      2321.3
```

19/25

850.0	194.7	2321.3
1008.0	200.8	1634.9
1073.3	226.9	6.2
1262.0	226.9	6.2
100.0	221.9	318.2
277.5	221.9	318.2
300.0	212.9	879.8
345.0	194.9	2003.0
370.0	177.3	3101.3
425.0	178.5	3101.3
460.0	179.2	3101.3
500.0	180.1	3101.3
550.0	181.2	3101.3
600.0	182.2	3101.3
723.0	184.8	2633.3
850.0	189.7	2633.3
1008.0	195.8	1946.9
1073.3	221.9	318.2
1262.0	221.9	318.2
100.0	140.0	5428.8
277.5	140.0	5428.8
300.0	140.0	5428.8
370.0	140.0	5428.8
425.0	140.0	5428.8
460.0	140.0	5428.8
500.0	140.0	5428.8
550.0	140.0	5428.8
600.0	140.0	5428.8
723.0	140.0	5428.8
850.0	140.0	5428.8
1008.0	140.0	5428.8
1073.3	140.0	5428.8
1262.0	140.0	5428.8

CIRCL2

20 10

150.0	250.0	450.0	800.0
.0	.0	.0	.0

XSTABL File: A-A_5   9-29-93   16:27

20/25

```
*****************************************
*                XSTABL                 *
*                                       *
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*****************************************
```

Problem Description : Cross Section A-A Overall Stability

SEGMENT BOUNDARY COORDINATES

20 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	100.0	240.0	150.0	240.0	1
2	150.0	240.0	230.0	260.0	2
3	230.0	260.0	245.0	260.0	4
4	245.0	260.0	325.0	280.0	4
5	325.0	280.0	340.0	280.0	4
6	340.0	280.0	420.0	300.0	4
7	420.0	300.0	435.0	300.0	4
8	435.0	300.0	476.0	310.2	4
9	476.0	310.2	502.0	312.8	4
10	502.0	312.8	602.0	320.9	4
11	602.0	320.9	695.0	320.9	4
12	695.0	320.9	793.0	320.9	4
13	793.0	320.9	893.0	312.8	4
14	893.0	312.8	982.6	303.9	4
15	982.6	303.9	1022.0	294.0	4
16	1022.0	294.0	1037.0	294.0	4
17	1037.0	294.0	1117.0	274.0	4
18	1117.0	274.0	1132.0	274.0	4
19	1132.0	274.0	1212.0	254.0	4
20	1212.0	254.0	1262.0	254.0	1

34 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	150.0	240.0	200.0	240.0	1

2	200.0	240.0	230.0	245.0	2
3	230.0	245.0	245.0	245.0	2
4	245.0	245.0	325.0	265.0	2
5	325.0	265.0	340.0	265.0	2
6	340.0	265.0	420.0	285.0	2
7	420.0	285.0	435.0	285.0	2
8	435.0	285.0	476.0	295.2	2
9	476.0	295.2	502.0	297.8	2
10	502.0	297.8	602.0	305.9	2
11	602.0	305.9	793.0	305.9	2
12	793.0	305.9	893.0	297.8	2
13	893.0	297.8	982.0	288.9	2
14	982.0	288.9	1022.0	279.0	2
15	1022.0	279.0	1037.0	279.0	2
16	1037.0	279.0	1117.0	259.0	2
17	1117.0	259.0	1132.0	259.0	2
18	1132.0	259.0	1162.0	254.0	2
19	1162.0	254.0	1212.0	254.0	1
20	200.0	240.0	225.0	240.0	3
21	225.0	240.0	290.0	214.0	3
22	290.0	214.0	370.0	182.4	4
23	370.0	182.4	723.0	189.9	4
24	723.0	189.9	1008.0	200.9	4
25	1008.0	200.9	1060.0	222.4	4
26	1060.0	222.4	1139.0	254.0	3
27	1139.0	254.0	1162.0	254.0	3
28	290.0	214.0	290.1	204.0	3
29	1060.0	222.4	1060.1	213.2	4
30	200.0	240.0	290.1	203.9	1
31	290.1	203.9	378.0	168.8	1
32	378.0	168.8	1002.0	190.6	1
33	1002.0	190.6	1060.1	213.2	1
34	1060.1	213.2	1162.0	254.0	1

ISOTROPIC Soil Parameters

5 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Constant (psf)	Water Surface No.
1	130.0	130.0	8000.0	.00	.000	.0	0
2	110.0	110.0	650.0	15.00	.000	.0	0
3	130.0	130.0	.0	8.00	.000	.0	0
4	130.0	130.0	1000.0	.00	.000	.0	0
5	110.0	110.0	.0	15.00	.000	.0	0

ANISOTROPIC Strength Parameters
1 soil type(s)

Soil Type 1 is ANISOTROPIC

Number of direction ranges specified = 3

22/25

Direction Range No.	Counterclockwise Direction Limit (deg)	Cohesion Intercept (psf)	Friction Angle (deg)
1	-45.00	2000.0	43.0
2	45.00	6000.0	36.0
3	90.00	2000.0	43.0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1.	.0	.0
2.	7115.4	1000.0
3.	99999.0	1000.0

PORE WATER PRESSURES WILL BE ESTIMATED FROM VALUES ASSIGNED BY THE USER AT DISCRETE POINTS IN THE SLOPE.

74 discrete points have been defined at :

x-coord (feet)	y-coord (feet)	Pore Pressure (psf)
100.0	240.0	.0
277.5	240.0	.0
300.0	240.0	.0
345.0	240.0	.0
370.0	240.0	.0
425.0	240.0	.0
460.0	240.0	.0
500.0	240.0	.0
550.0	240.0	.0
600.0	240.0	.0
723.0	240.0	.0
850.0	240.0	.0
1008.0	240.0	.0
1073.3	240.0	.0
1262.0	240.0	.0
100.0	227.0	.0
277.5	227.0	.0
300.0	218.0	.0
345.0	200.0	.0
370.0	182.4	.0
425.0	183.6	.0
460.0	184.3	.0
500.0	185.2	.0
550.0	186.3	.0
600.0	187.3	.0

23/25

723.0	189.9	.0
850.0	194.8	.0
1008.0	200.9	.0
1073.3	227.0	.0
1262.0	227.0	.0
100.0	226.9	6.2
277.5	226.9	6.2
300.0	217.9	567.8
345.0	199.9	1691.0
370.0	182.3	2789.3
425.0	183.5	2789.3
460.0	184.2	2789.3
500.0	185.1	2789.3
550.0	186.2	2789.3
600.0	187.2	2789.3
723.0	189.8	2321.3
850.0	194.7	2321.3
1008.0	200.8	1634.9
1073.3	226.9	6.2
1262.0	226.9	6.2
100.0	221.9	318.2
277.5	221.9	318.2
300.0	212.9	879.8
345.0	194.9	2003.0
370.0	177.3	3101.3
425.0	178.5	3101.3
460.0	179.2	3101.3
500.0	180.1	3101.3
550.0	181.2	3101.3
600.0	182.2	3101.3
723.0	184.8	2633.3
850.0	189.7	2633.3
1008.0	195.8	1946.9
1073.3	221.9	318.2
1262.0	221.9	318.2
100.0	140.0	5428.8
277.5	140.0	5428.8
300.0	140.0	5428.8
370.0	140.0	5428.8
425.0	140.0	5428.8
460.0	140.0	5428.8
500.0	140.0	5428.8
550.0	140.0	5428.8
600.0	140.0	5428.8
723.0	140.0	5428.8
850.0	140.0	5428.8
1008.0	140.0	5428.8
1073.3	140.0	5428.8
1262.0	140.0	5428.8

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

200 trial surfaces will be generated and analyzed.

10 Surfaces initiate from each of 20 points equally spaced

along the ground surface between x = 150.0 ft
and x = 250.0 ft

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Each surface terminates between x = 450.0 ft
and x = 800.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

21.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS :

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * * MODIFIED BISHOP METHOD * * * * *

The most critical circular failure surface is specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	223.68	258.42
2	239.14	244.21
3	255.55	231.10
4	272.83	219.16
5	290.89	208.44
6	309.64	199.00
7	329.01	190.89
8	348.89	184.13
9	369.20	178.76
10	389.82	174.82
11	410.67	172.31
12	431.65	171.25
13	452.64	171.64
14	473.56	173.49
15	494.30	176.78
16	514.76	181.50
17	534.85	187.63
18	554.47	195.13
19	573.51	203.97

25/25

20	591.90	214.11
21	609.55	225.50
22	626.36	238.08
23	642.26	251.80
24	657.18	266.58
25	671.03	282.36
26	683.76	299.06
27	695.30	316.61
28	697.72	320.90

**** Modified BISHOP FOS = 1.821 ****

The following is a summary of the TEN most critical surfaces

Problem Description : Cross Section A-A Overall Stability

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Driving Moment (ft-lb)
1.	1.821	436.45	474.34	303.13	223.68	697.72	1.590E+08
2.	2.077	329.84	493.21	282.82	186.84	550.68	9.973E+07
3.	2.109	324.82	423.33	213.66	197.37	507.92	6.258E+07
4.	2.206	315.33	374.17	165.36	202.63	466.81	3.806E+07
5.	2.253	349.91	460.45	254.29	202.63	560.01	9.140E+07
6.	2.296	363.00	478.57	276.64	202.63	589.43	1.113E+08
7.	2.312	395.38	415.77	232.89	223.68	608.02	1.001E+08
8.	2.325	305.29	486.05	261.31	192.11	500.70	6.377E+07
9.	2.360	330.63	359.51	156.71	213.16	479.16	3.851E+07
10.	2.447	348.63	378.75	178.19	218.42	514.43	5.254E+07

* * * END OF FILE * * *

Golder Associates

SUBJECT Hand check – section A-A Overall stability		
Job No. 933-3553	Made by SYI	Date 10/11/93
Ref. Emelle	Checked RJO	Sheet 1 of 4
	Reviewed WRS	

Objective: The objective is to hand check the slope stability analysis for the critical sliding surface considering overall stability.

Method: Ordinary method of slices

$$\text{safety factor} = \frac{\Sigma CL + \Sigma (W \cos\alpha - UL) \tan\phi}{\Sigma W \sin\alpha}$$

where
- Σ = summation
- C = cohesion
- L = base length of slice
- W = weight
- α = slope of base
- U = uplift pressure (p.w.p)
- ϕ = friction angle

unit wts.:
- cover layer = 130 pcf
- Waste = 110 pcf
- liner = 130 pcf

Golder Associates	SUBJECT Hand check - Section A-A Overall Stability		
	Job No. 933-3553.4	Made by SYT	Date 10/11/93
	Ref. Emelle	Checked RJO	Sheet 2 of 4
		Reviewed WRS	

Calculation:

Weights:

$W_1 \cong 48 * 15 * 130 + \frac{1}{2}(32-15) * 48 * 110 = 138,480$ Lbs

$W_2 = 50 * 20 * 130 + \frac{1}{2}(32-20+64-20) * 50 * 110 = 284,000$ Lbs

$W_3 = 50 * 20 * 130 + \frac{1}{2}(64-20+90-20) * 50 * 110 = 443,500$ Lbs

$W_4 = 38 * 20 * 130 + \frac{1}{2}(90-20+118-20) * 38 * 110 = 449,920$ Lbs

$W_5 = 60 * 20 * 130 + \frac{1}{2}(118-20+126-20) * 60 * 110 = 829,200$ Lbs

$W_6 = 60 * 20 * 130 + \frac{1}{2}(126-20+135-20) * 60 * 110 = 885,300$ Lbs

$W_7 = 70 * 20 * 130 + \frac{1}{2}(135-20+140-20) * 70 * 110 = 1,086,750$ Lbs

$W_8 = 50 * 15 * 130 + \frac{1}{2}(140-15+90-15) * 50 * 110 = 647,500$ Lbs

$W_9 = 30 * 15 * 130 + \frac{1}{2}(90-15+55-15) * 30 * 110 = 248,250$ Lbs

$W_{10} \cong 40 * 15 * 130 + \frac{1}{2}(55-15) * 40 * 110 = 166,000$ Lbs

(Refer to sheet 4/4 for slices and section details)

Golder Associates

SUBJECT: Hand Check - Section A-A, Overall Stability

Job No. 933-3553.4 | Made by SYE | Date 10/11/93
Ref. Emelle | Checked RJO | Sheet 3 of 4
Reviewed WRS

Slice No.	W (Lbs)	α (deg)	W cos α (Lbs)	W sin α (Lbs)	C (psf)	φ (deg)	L (ft)	U (psf)	CL (Lbs/ft)	W cos α - UL (Lbs)	(W cos α - UL) tan φ (Lbs)
1	138,480	21.8	128,577	-51,427	0	8	51	0	0	128,577	18,070
2	284,000	21.8	263,690	-105,469	0	8	52	~250*	0	250,190	35,162
3	443,500	21.8	411,794	-164,702	0	8	52	1311	0	343,612	48,291 ✓
4	449,920	21.8	417,744	-167,086	1000	0	40	2434	40,000	320,384	0
5	829,200	1.14	829,036	16,498	1000	0	60	2932	60,000	653,116	0
6	885,300	1.14	885,125	17,613	1000	0	60	2808	60,000	716,645	0
7	1,086,750	1.14	1,086,535	21,622	1000	0	70	2621	70,000	903,065	0
8	647,500	47	441,594	473,552	650	15	71	0**	46150	441,594	118,325
9	249,250	47	169,306	181,559	650	15	42	0	27,300	169,306	45,366
10	166,000	49	108,906	125,282	350*	15	60	0	21,000	108,906	29,181
				347,442 ✓					324,450 ✓		294,395 ✓

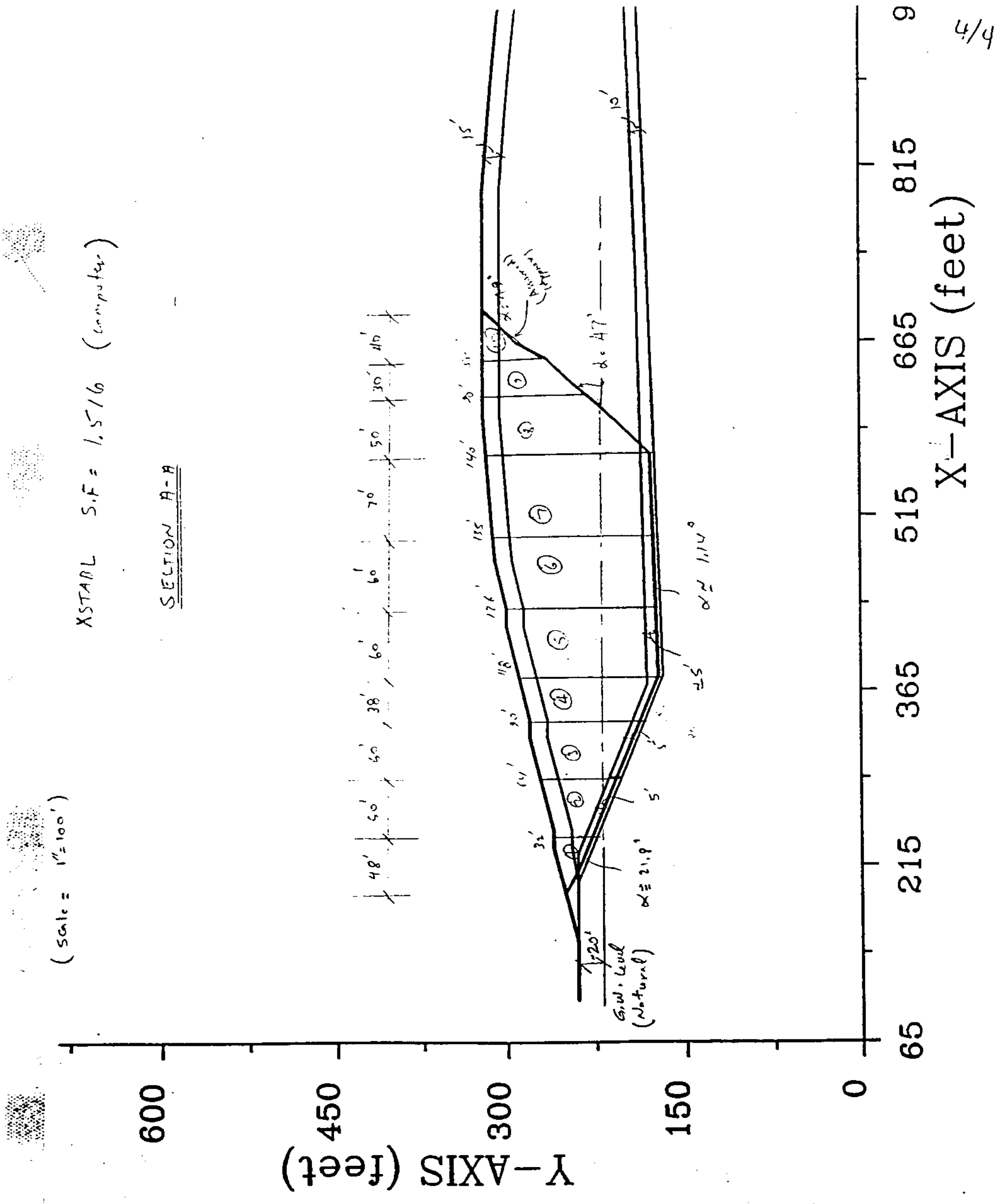
$$S.F = \frac{324,450 + 294,395}{347,442} \approx 1.78$$ ✓

compares with XSTABL safety factor of 1.52

OK ✓

Note: * Average value (approximated)

** uplift pressure is not acting on slide surface


4/4
XSTABL S.F = 1.516 (computer)
SECTION A-A
(Scale = 1"=100')
G.W. Level (Natural)
X-AXIS (feet)
65
215
365
515
665
815
9
Y-AXIS (feet)
0
150
300
450
600

Golder Associates	SUBJECT Cross-section C-C: T22, 23 & 24 Cut slope stability		
	Job No. 933-3553	Made by JJD	Date 10-1-93
	Ref. EMELLE	Checked SYI/RIO	Sheet 1 of 23
		Reviewed cm	

Objective: Evaluate the stability of cut slopes in Trenches 1, 22, 23 and 24 under static loading conditions

Method: Analysis was performed using the computer program XSTABL. XSTABL evaluated circular failure surfaces using the simplified Janbu Method. Both short term (undrained) and long term (drained) stability were analyzed. The factor of safety (F.S.) was determined by searching for the critical surface.

Soil Property Data: The slopes analyzed herein are cut in insitu chalk. The chalk has a unit weight of 130 pcf. The drained shear strength properties of the chalk are anisotropic. The shear strength properties used in the analysis are as follows:

Golder Associates	SUBJECT Cross-Section C-C T22, 23, & 24 Cut Slope Stability		
	Job No. 933-3553	Made by JJD	Date 10-1-93
	Ref. EMELLE	Checked SYI/RSO	Sheet 2 of 23
		Reviewed	

Type of Analysis	Direction	Su (psf)	c (psf)	Φ (deg.)
Short Term	Horizontal + Vertical	8000	—	—
Long Term	Horizontal	—	6000	36
	Vertical	—	2000	43

Assumptions: For cut slopes below the static water table elevation, the phreatic surface is assumed to follow the excavated surface ✓

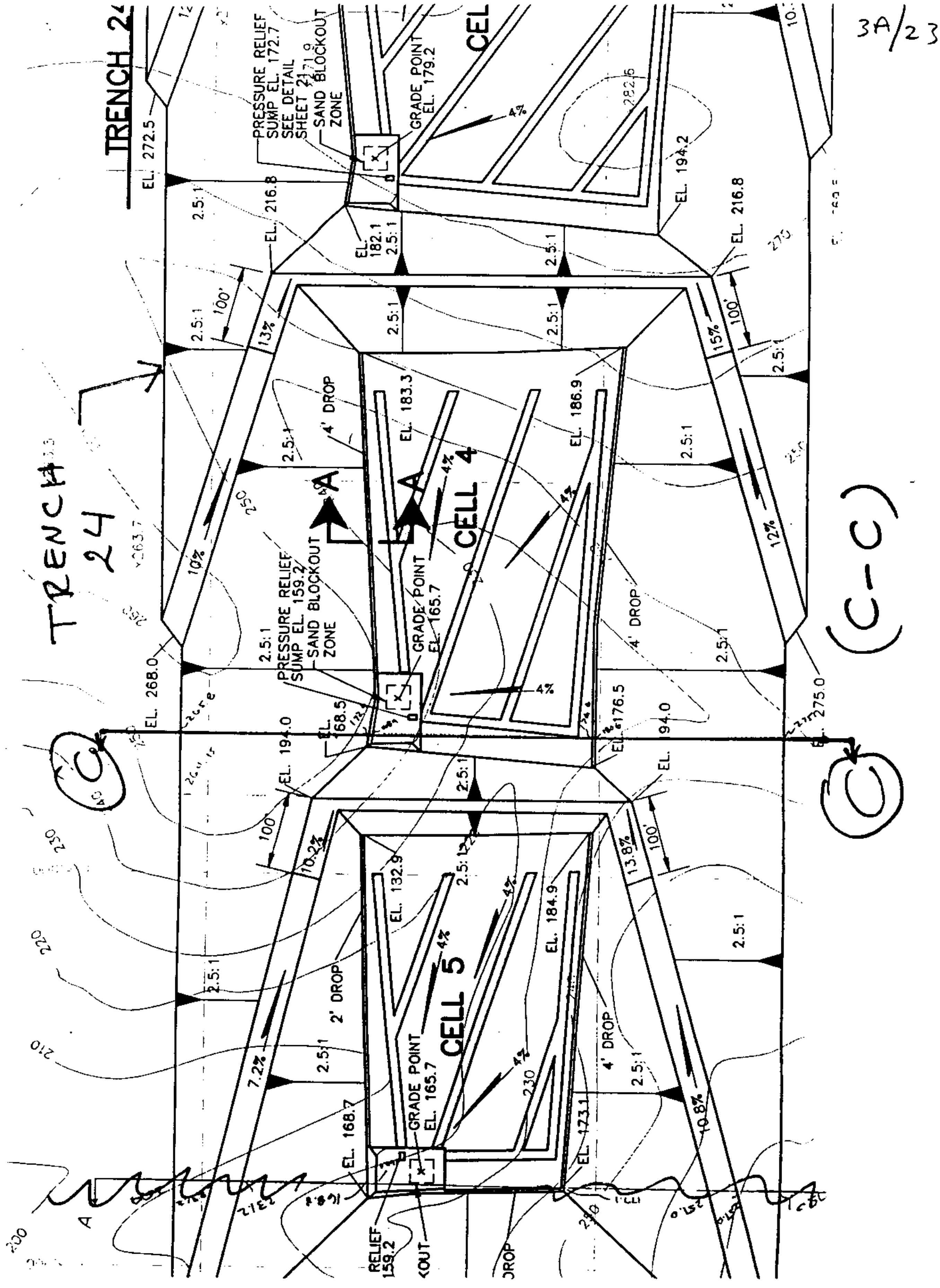
Results: Based on XSTABL analysis, the short term condition was deemed critical, as it had a lower factor of safety. The minimum factor of safety for a circular failure surface through cross section C-C is, F.S. ≅ 3.72. The figure on sheet 4/23 identifies the 10 most critical failure surfaces and highlights the most critical. Additionally, sheets 6 through 15 contain the XSTABL output file for the

Golder Associates

SUBJECT Cross-section C-C : T 21, 22, 23, & 24 Cut Slope Stability		
Job No. 933-3553	Made by JJD	Date 10-1-93
Ref.	Checked SYI/RJO	Sheet 3 of 23
	Reviewed	

Short term search analysis. The figure on sheet 5 identifies the ten most critical and highlights the single most critical failure surfaces for the long term analysis of cross section C-C. The output file for this search is included in sheets 16 through 23. The long term analysis was not deemed critical, as the short term analysis resulted in a lower factor of safety.

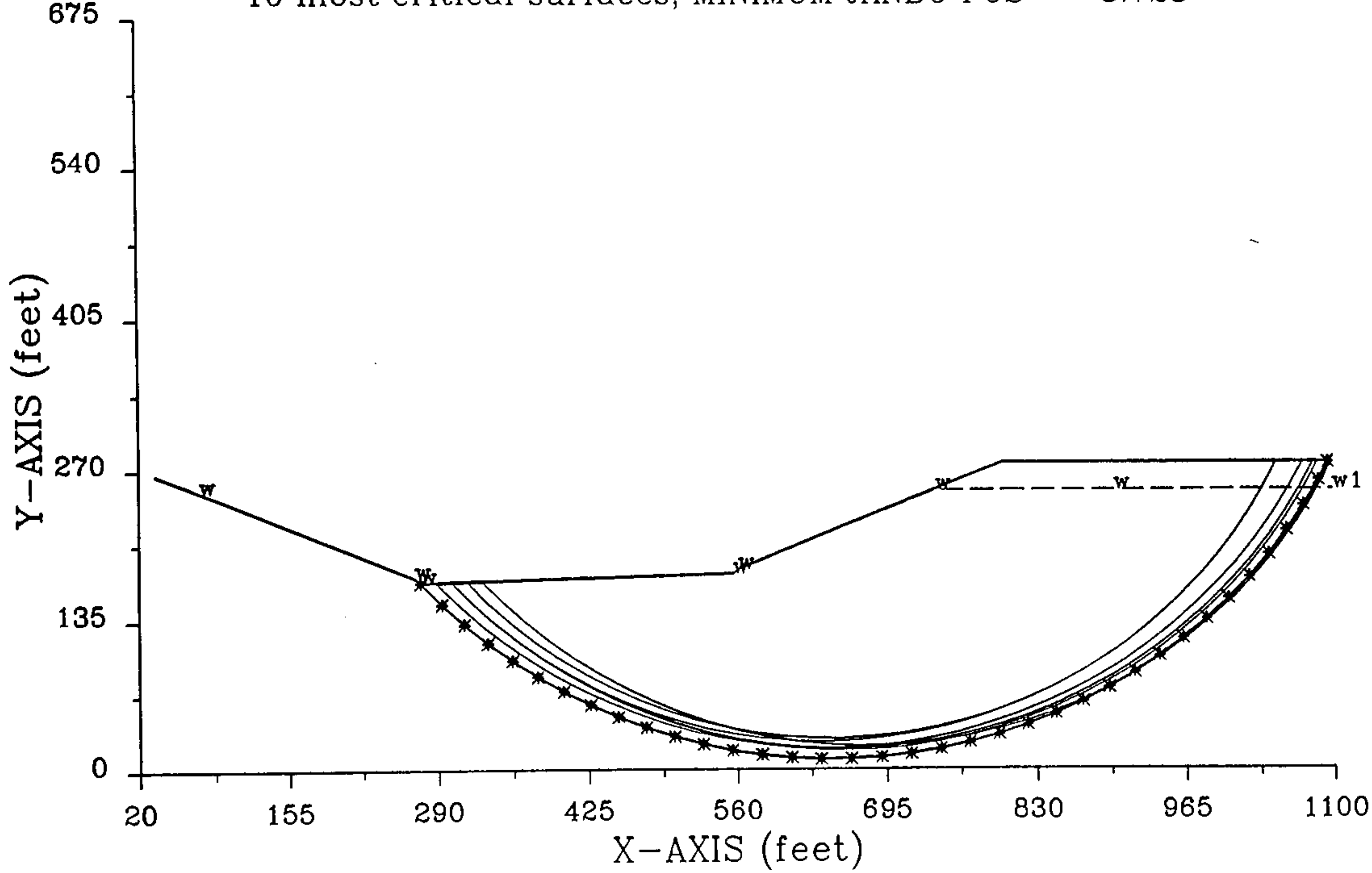
(sheet 3A shows the location of section C-C).


3A/23
TRENCH 24
CELL 4
CELL 5
(C-C)
PRESSURE RELIEF SUMP EL. 172.7 SEE DETAIL SHEET 21
SAND BLOCKOUT ZONE
GRADE POINT EL. 179.2
PRESSURE RELIEF SUMP EL. 159.2
SAND BLOCKOUT ZONE
GRADE POINT EL. 165.7
EL. 272.5
EL. 216.8
EL. 194.2
EL. 182.1
EL. 183.3
EL. 186.9
4' DROP
2' DROP
EL. 268.0
EL. 194.0
EL. 168.5
EL. 176.5
EL. 275.0
EL. 132.9
EL. 184.9
EL. 168.7
EL. 173.1
2.5:1
4%
100'
13%
15%
10%
12%
10.2%
13.8%
7.2%
10.8%

C-C2_1 10-05-93 11:59

Section C-C: Short Term Analysis

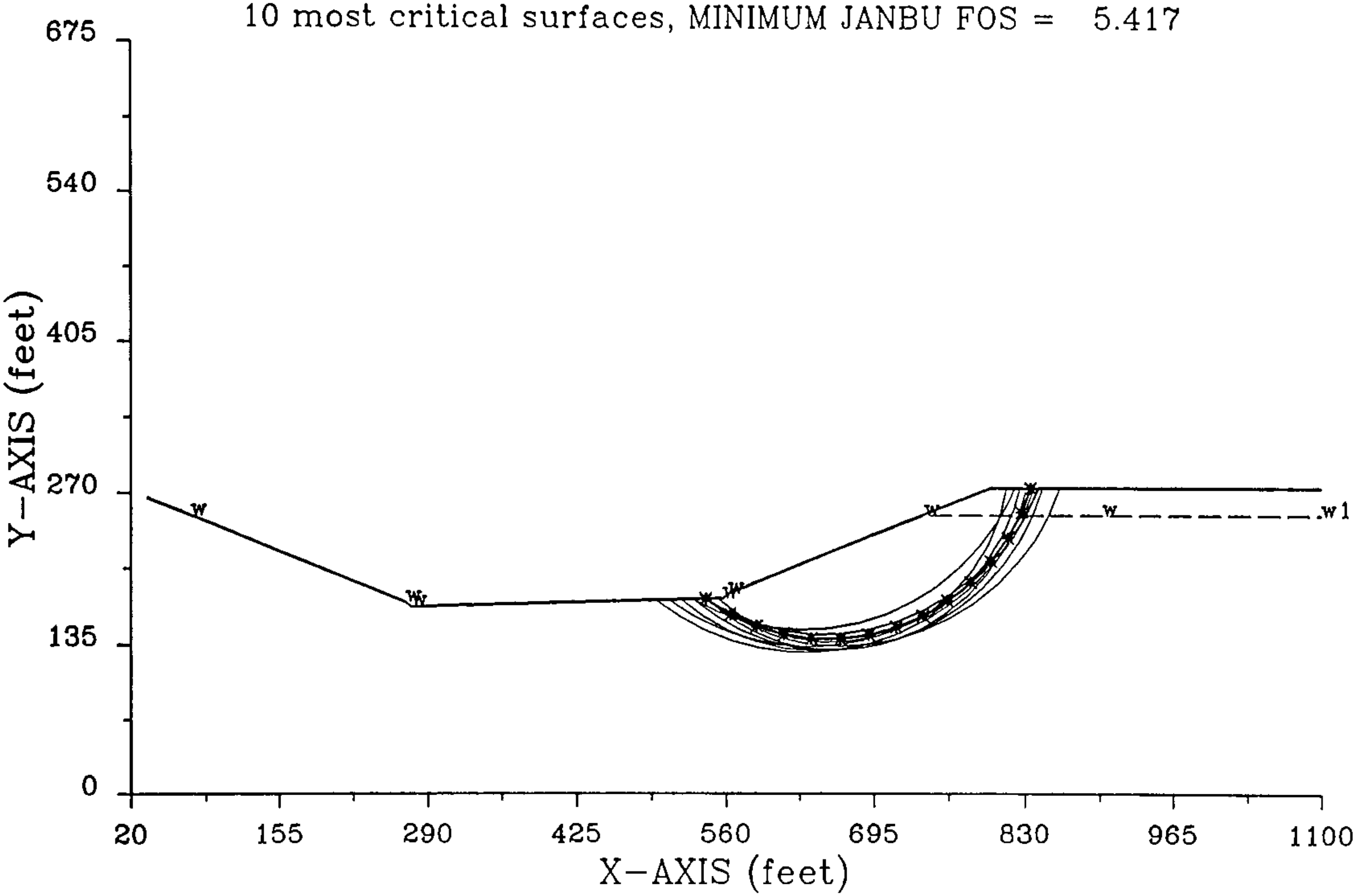
10 most critical surfaces, MINIMUM JANBU FOS = 3.723



C-C2_2 10-05-93 12:23

Section C-C: Long Term Analysis

10 most critical surfaces, MINIMUM JANBU FOS = 5.417



5/23

6/23

XSTABL File: C-C2_1   10-05-93   11:59

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*        Golder Associates, Inc.          *
*          Atlanta,  GA 30341             *
*                                         *
*  Ver. 4.1                         1049  *
*******************************************
```

Problem Description : Section C-C: Short Term Analysis

SEGMENT BOUNDARY COORDINATES

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	35.0	265.8	270.0	172.9	1
2	270.0	172.9	275.0	168.9	1
3	275.0	168.9	557.0	176.6	1
4	557.0	176.6	562.0	180.6	1
5	562.0	180.6	800.0	275.0	1
6	800.0	275.0	900.0	275.0	1
7	900.0	275.0	1100.0	275.0	1

ISOTROPIC Soil Parameters

1 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	130.0	8000.0	.00	.000	.0	0

1 Water surface(s) have been specified

Unit weight of water =   62.40 (pcf)

Water Surface No. 1 specified by 8 coordinate points

****
PHREATIC SURFACE,
****

Point No.	x-water (ft)	y-water (ft)
1	73.90	250.40
2	270.00	172.90
3	275.00	168.90
4	557.00	176.60
5	562.00	180.60
6	740.20	250.40
7	900.00	250.40
8	1100.00	250.40

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

200 trial surfaces will be generated and analyzed.

20 Surfaces initiate from each of 10 points equally spaced along the ground surface between x = 275.0 ft
and x = 400.0 ft

Each surface terminates between x = 1000.0 ft
and x = 1100.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

27.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS :

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * * MODIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 37 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	275.00	168.90
2	294.09	149.81
3	314.17	131.75
4	335.16	114.77
5	357.02	98.93
6	379.69	84.25
7	403.09	70.79
8	427.17	58.59
9	451.87	47.66
10	477.10	38.06
11	502.80	29.79
12	528.91	22.89
13	555.34	17.38
14	582.02	13.26
15	608.89	10.56
16	635.86	9.27
17	662.86	9.41
18	689.81	10.97
19	716.65	13.95
20	743.29	18.33
21	769.66	24.12
22	795.69	31.28
23	821.31	39.80
24	846.45	49.67
25	871.03	60.84
26	894.98	73.29
27	918.25	86.99
28	940.77	101.89
29	962.46	117.96
30	983.29	135.15
31	1003.17	153.41
32	1022.07	172.69
33	1039.93	192.94
34	1056.69	214.11
35	1072.32	236.13
36	1086.77	258.94
37	1095.79	275.00

** Corrected JANBU FOS = 3.723 ** (Fo factor =1.113)

Failure surface No. 2 specified by 37 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	275.00	168.90
2	294.11	149.82
3	314.19	131.78
4	335.19	114.81
5	357.06	98.97
6	379.72	84.30
7	403.13	70.84
8	427.21	58.62
9	451.90	47.69
10	477.13	38.07
11	502.82	29.79
12	528.92	22.87
13	555.35	17.33
14	582.03	13.18
15	608.89	10.44
16	635.85	9.12
17	662.85	9.21
18	689.81	10.72
19	716.65	13.64
20	743.30	17.97
21	769.69	23.69
22	795.74	30.79
23	821.38	39.25
24	846.54	49.04
25	871.16	60.14
26	895.15	72.52
27	918.46	86.14
28	941.03	100.97
29	962.79	116.96
30	983.67	134.07
31	1003.63	152.25
32	1022.61	171.46
33	1040.55	191.63
34	1057.41	212.72
35	1073.13	234.67
36	1087.69	257.41
37	1097.68	275.00

** Corrected JANBU FOS = 3.723 ** (Fo factor =1.113)

Failure surface No. 3 specified by 37 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	275.00	168.90
2	294.19	149.90
3	314.34	131.94
4	335.41	115.05
5	357.33	99.29
6	380.05	84.69
7	403.50	71.31
8	427.61	59.17
9	452.33	48.31
10	477.59	38.76
11	503.31	30.55

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12	529.42	23.69
13	555.86	18.21
14	582.55	14.12
15	609.41	11.43
16	636.38	10.15
17	663.38	10.29
18	690.34	11.84
19	717.18	14.80
20	743.82	19.15
21	770.20	24.90
22	796.25	32.02
23	821.89	40.49
24	847.04	50.30
25	871.65	61.40
26	895.65	73.78
27	918.96	87.40
28	941.53	102.22
29	963.29	118.20
30	984.19	135.30
31	1004.16	153.47
32	1023.16	172.66
33	1041.12	192.81
34	1058.01	213.88
35	1073.76	235.81
36	1088.35	258.52
37	1097.75	275.00

** Corrected JANBU FOS = 3.729 ** (Fo factor =1.113)

Failure surface No. 4 specified by 36 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	302.78	169.66
2	321.87	150.57
3	341.99	132.56
4	363.08	115.70
5	385.07	100.04
6	407.90	85.61
7	431.49	72.48
8	455.77	60.67
9	480.67	50.23
10	506.11	41.19
11	532.01	33.56
12	558.29	27.39
13	584.88	22.68
14	611.69	19.46
15	638.63	17.72
16	665.63	17.49
17	692.60	18.74
18	719.46	21.50
19	746.12	25.73
20	772.51	31.44
21	798.55	38.61
22	824.14	47.20
23	849.22	57.20
24	873.71	68.58
25	897.52	81.30

26	920.60	95.32
27	942.86	110.59
28	964.25	127.08
29	984.68	144.72
30	1004.11	163.48
31	1022.46	183.28
32	1039.69	204.06
33	1055.74	225.77
34	1070.57	248.34
35	1084.12	271.70
36	1085.80	275.00

** Corrected JANBU FOS = 3.740 ** (Fo factor =1.113)

Failure surface No. 5 specified by 35 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	302.78	169.66
2	321.94	150.63
3	342.12	132.70
4	363.28	115.92
5	385.33	100.35
6	408.21	86.02
7	431.86	72.98
8	456.19	61.28
9	481.14	50.95
10	506.62	42.03
11	532.56	34.53
12	558.87	28.49
13	585.48	23.92
14	612.31	20.83
15	639.26	19.25
16	666.26	19.16
17	693.22	20.57
18	720.07	23.48
19	746.71	27.88
20	773.06	33.75
21	799.05	41.08
22	824.59	49.84
23	849.60	60.00
24	874.01	71.55
25	897.74	84.43
26	920.71	98.61
27	942.87	114.04
28	964.13	130.68
29	984.43	148.48
30	1003.71	167.38
31	1021.92	187.32
32	1038.98	208.24
33	1054.86	230.08
34	1069.50	252.77
35	1082.14	275.00

** Corrected JANBU FOS = 3.745 ** (Fo factor =1.113)

Failure surface No. 6 specified by 36 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	288.89	169.28
2	308.15	150.36
3	328.43	132.53
4	349.65	115.84
5	371.77	100.35
6	394.70	86.10
7	418.38	73.13
8	442.74	61.49
9	467.71	51.20
10	493.20	42.31
11	519.14	34.83
12	545.46	28.80
13	572.07	24.22
14	598.89	21.11
15	625.84	19.48
16	652.84	19.34
17	679.81	20.69
18	706.66	23.52
19	733.31	27.83
20	759.69	33.59
21	785.71	40.80
22	811.29	49.43
23	836.36	59.46
24	860.84	70.85
25	884.66	83.57
26	907.73	97.59
27	930.00	112.85
28	951.40	129.32
29	971.86	146.94
30	991.32	165.66
31	1009.71	185.42
32	1026.99	206.17
33	1043.11	227.83
34	1058.00	250.35
35	1071.63	273.66
36	1072.32	275.00

** Corrected JANBU FOS = 3.751 ** (Fo factor =1.113)

Failure surface No. 7 specified by 35 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	330.56	170.42
2	349.65	151.33
3	369.79	133.35
4	390.92	116.53
5	412.96	100.95
6	435.86	86.63
7	459.53	73.64
8	483.89	62.01
9	508.88	51.77
10	534.40	42.97
11	560.38	35.62

12	586.74	29.76
13	613.38	25.41
14	640.23	22.56
15	667.20	21.24
16	694.20	21.46
17	721.15	23.20
18	747.95	26.46
19	774.52	31.23
20	800.78	37.51
21	826.65	45.26
22	852.03	54.46
23	876.85	65.08
24	901.03	77.10
25	924.49	90.46
26	947.16	105.13
27	968.96	121.06
28	989.82	138.20
29	1009.68	156.49
30	1028.47	175.88
31	1046.14	196.30
32	1062.61	217.69
33	1077.85	239.98
34	1091.81	263.09
35	1098.11	275.00

** Corrected JANBU FOS = 3.760 ** (Fo factor =1.114)

Failure surface No. 8 specified by 35 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	330.56	170.42
2	349.70	151.38
3	369.88	133.44
4	391.05	116.68
5	413.13	101.14
6	436.04	86.86
7	459.73	73.90
8	484.11	62.30
9	509.11	52.09
10	534.64	43.31
11	560.62	35.98
12	586.98	30.12
13	613.63	25.77
14	640.48	22.92
15	667.44	21.59
16	694.44	21.78
17	721.39	23.50
18	748.19	26.73
19	774.77	31.47
20	801.05	37.70
21	826.92	45.41
22	852.33	54.56
23	877.17	65.13
24	901.38	77.08
25	924.88	90.38
26	947.59	104.98
27	969.44	120.84

28	990.36	137.91
29	1010.29	156.13
30	1029.16	175.44
31	1046.90	195.79
32	1063.47	217.10
33	1078.82	239.32
34	1092.88	262.37
35	1099.65	275.00

** Corrected JANBU FOS = 3.764 ** (Fo factor =1.113)

Failure surface No. 9 specified by 34 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	302.78	169.66
2	321.89	150.58
3	342.08	132.66
4	363.29	115.95
5	385.44	100.51
6	408.45	86.39
7	432.26	73.65
8	456.76	62.32
9	481.89	52.44
10	507.56	44.05
11	533.67	37.18
12	560.13	31.85
13	586.87	28.08
14	613.78	25.87
15	640.77	25.25
16	667.76	26.21
17	694.64	28.75
18	721.32	32.85
19	747.72	38.51
20	773.75	45.71
21	799.30	54.42
22	824.31	64.61
23	848.67	76.24
24	872.31	89.28
25	895.15	103.69
26	917.11	119.40
27	938.10	136.38
28	958.07	154.55
29	976.94	173.86
30	994.65	194.24
31	1011.13	215.63
32	1026.34	237.94
33	1040.21	261.10
34	1047.46	275.00

** Corrected JANBU FOS = 3.764 ** (Fo factor =1.114)

Failure surface No.10 specified by 34 coordinate points

Point No.	x-surf (ft)	y-surf (ft)

1	316.67	170.04
2	335.76	150.95
3	355.97	133.04
4	377.20	116.37
5	399.40	100.99
6	422.47	86.97
7	446.35	74.36
8	470.93	63.19
9	496.13	53.51
10	521.87	45.35
11	548.05	38.75
12	574.58	33.72
13	601.36	30.29
14	628.30	28.46
15	655.30	28.25
16	682.26	29.65
17	709.09	32.65
18	735.70	37.26
19	761.98	43.45
20	787.85	51.19
21	813.20	60.47
22	837.96	71.24
23	862.03	83.48
24	885.32	97.13
25	907.76	112.15
26	929.26	128.48
27	949.74	146.07
28	969.14	164.85
29	987.38	184.76
30	1004.40	205.72
31	1020.14	227.66
32	1034.54	250.50
33	1047.54	274.16
34	1047.94	275.00

** Corrected JANBU FOS = 3.765 ** (Fo factor =1.114)

The following is a summary of the TEN most critical surfaces

Problem Description : Section C-C: Short Term Analysis

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Driving Force (lb)
1.	3.723	1.113	275.00	1095.79	2.304E+06
2.	3.723	1.113	275.00	1097.68	2.308E+06
3.	3.729	1.113	275.00	1097.75	2.301E+06
4.	3.740	1.113	302.78	1085.80	2.195E+06
5.	3.745	1.113	302.78	1082.14	2.180E+06
6.	3.751	1.113	288.89	1072.32	2.182E+06
7.	3.760	1.114	330.56	1098.11	2.143E+06
8.	3.764	1.113	330.56	1099.65	2.142E+06
9.	3.764	1.114	302.78	1047.46	2.083E+06
10.	3.765	1.114	316.67	1047.94	2.047E+06

XSTABL File: C-C2_2 10-05-93 12:23

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*****************************************
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Problem Description : Section C-C: Long Term Analysis

SEGMENT BOUNDARY COORDINATES

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	35.0	265.8	270.0	172.9	1
2	270.0	172.9	275.0	168.9	1
3	275.0	168.9	557.0	176.6	1
4	557.0	176.6	562.0	180.6	1
5	562.0	180.6	800.0	275.0	1
6	800.0	275.0	900.0	275.0	1
7	900.0	275.0	1100.0	275.0	1

ISOTROPIC Soil Parameters

1 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	130.0	8000.0	.00	.000	.0	0

ANISOTROPIC Strength Parameters
1 soil type(s)

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Soil Type 1 is ANISOTROPIC

Number of direction ranges specified = 3

Direction Range No.	Counterclockwise Direction Limit (deg)	Cohesion Intercept (psf)	Friction Angle (deg)
1	-45.00	2000.0	43.0
2	45.00	6000.0	36.0
3	90.00	2000.0	43.0

1 Water surface(s) have been specified

Unit weight of water = 62.40 (pcf)

Water Surface No. 1 specified by 8 coordinate points

****
PHREATIC SURFACE,
****

Point No.	x-water (ft)	y-water (ft)
1	73.90	250.40
2	270.00	172.90
3	275.00	168.90
4	557.00	176.60
5	562.00	180.60
6	740.20	250.40
7	900.00	250.40
8	1100.00	250.40

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

200 trial surfaces will be generated and analyzed.

20 Surfaces initiate from each of 10 points equally spaced along the ground surface between x = 475.0 ft
and x = 575.0 ft

Each surface terminates between x = 800.0 ft
and x = 900.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

26.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS :

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit :=   -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * *   MODIFIED JANBU METHOD   * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	541.67	176.18
2	563.81	162.55
3	587.59	152.05
4	612.58	144.87
5	638.31	141.14
6	664.31	140.94
7	690.10	144.26
8	715.20	151.05
9	739.14	161.17
10	761.50	174.45
11	781.84	190.64
12	799.81	209.44
13	815.06	230.49
14	827.32	253.42
15	835.31	275.00

** Corrected JANBU FOS =   5.417 **   (Fo factor =1.082)

Failure surface No. 2 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	541.67	176.18

2	564.51	163.76
3	588.75	154.36
4	614.00	148.15
5	639.83	145.23
6	665.83	145.64
7	691.56	149.39
8	716.59	156.40
9	740.52	166.57
10	762.95	179.72
11	783.51	195.63
12	801.86	214.05
13	817.70	234.67
14	830.76	257.16
15	838.26	275.00

** Corrected JANBU FOS = 5.422 ** (Fo factor =1.079)

Failure surface No. 3 specified by 17 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	530.56	175.88
2	551.65	160.67
3	574.56	148.38
4	598.89	139.22
5	624.22	133.36
6	650.10	130.88
7	676.08	131.84
8	701.71	136.22
9	726.54	143.94
10	750.13	154.88
11	772.07	168.82
12	791.98	185.55
13	809.51	204.75
14	824.35	226.10
15	836.25	249.21
16	844.99	273.70
17	845.27	275.00

** Corrected JANBU FOS = 5.468 ** (Fo factor =1.084)

Failure surface No. 4 specified by 16 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	541.67	176.18
2	562.24	160.28
3	584.94	147.60
4	609.26	138.43
5	634.68	132.95
6	660.63	131.31
7	686.54	133.52
8	711.83	139.54
9	735.95	149.25
10	758.37	162.42
11	778.59	178.76

12	796.16	197.92
13	810.71	219.47
14	821.90	242.94
15	829.50	267.80
16	830.57	275.00

** Corrected JANBU FOS = 5.489 ** (Fo factor =1.086)

Failure surface No. 5 specified by 16 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	519.44	175.57
2	540.38	160.15
3	563.22	147.74
4	587.55	138.57
5	612.90	132.81
6	638.81	130.58
7	664.77	131.92
8	690.31	136.80
9	714.94	145.13
10	738.20	156.75
11	759.65	171.45
12	778.88	188.95
13	795.54	208.91
14	809.31	230.96
15	819.93	254.69
16	825.84	275.00

** Corrected JANBU FOS = 5.494 ** (Fo factor =1.085)

Failure surface No. 6 specified by 16 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	541.67	176.18
2	563.37	161.87
3	586.71	150.40
4	611.30	141.97
5	636.76	136.69
6	662.68	134.65
7	688.65	135.90
8	714.26	140.40
9	739.10	148.08
10	762.77	158.83
11	784.90	172.48
12	805.14	188.80
13	823.17	207.53
14	838.70	228.39
15	851.48	251.03
16	861.27	275.00

** Corrected JANBU FOS = 5.519 ** (Fo factor =1.082)

Failure surface No. 7 specified by 18 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	497.22	174.97
2	518.78	160.43
3	541.88	148.50
4	566.21	139.32
5	591.44	133.04
6	617.22	129.73
7	643.22	129.44
8	669.08	132.16
9	694.44	137.88
10	718.97	146.50
11	742.33	157.91
12	764.21	171.95
13	784.31	188.45
14	802.36	207.16
15	818.11	227.85
16	831.36	250.22
17	841.91	273.99
18	842.23	275.00

** Corrected JANBU FOS = 5.520 ** (Fo factor =1.082)

Failure surface No. 8 specified by 17 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	508.33	175.27
2	530.36	161.45
3	553.85	150.32
4	578.50	142.05
5	603.95	136.73
6	629.85	134.46
7	655.84	135.25
8	681.55	139.11
9	706.63	145.97
10	730.73	155.74
11	753.50	168.29
12	774.63	183.43
13	793.84	200.96
14	810.83	220.64
15	825.40	242.18
16	837.31	265.28
17	840.95	275.00

** Corrected JANBU FOS = 5.530 ** (Fo factor =1.080)

Failure surface No. 9 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	530.56	175.88
2	553.91	164.46
3	578.53	156.08

22/23

4	604.00	150.89
5	629.93	148.96
6	655.90	150.33
7	681.48	154.98
8	706.27	162.82
9	729.86	173.74
10	751.89	187.56
11	771.99	204.05
12	789.84	222.96
13	805.15	243.97
14	817.69	266.75
15	820.95	275.00

** Corrected JANBU FOS = 5.539 ** (Fo factor =1.077)

Failure surface No.10 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	552.78	176.48
2	573.82	161.21
3	597.07	149.58
4	621.91	141.89
5	647.67	138.36
6	673.66	139.08
7	699.18	144.03
8	723.56	153.08
9	746.13	165.99
10	766.29	182.40
11	783.50	201.89
12	797.31	223.92
13	807.33	247.91
14	813.31	273.21
15	813.43	275.00

** Corrected JANBU FOS = 5.544 ** (Fo factor =1.087)

The following is a summary of the TEN most critical surfaces

Problem Description : Section C-C: Long Term Analysis

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Driving Force (lb)
1.	5.417	1.082	541.67	835.31	7.357E+05
2.	5.422	1.079	541.67	838.26	7.084E+05
3.	5.468	1.084	530.56	845.27	8.426E+05
4.	5.489	1.086	541.67	830.57	7.874E+05
5.	5.494	1.085	519.44	825.84	7.980E+05
6.	5.519	1.082	541.67	861.27	8.379E+05
7.	5.520	1.082	497.22	842.23	8.633E+05
8.	5.530	1.080	508.33	840.95	8.135E+05
9.	5.539	1.077	530.56	820.95	6.287E+05

10.	5.544	1.087	552.78	813.43	6.745E+05

* * * END OF FILE * * *

Objective: Evaluate the stability of cut slopes in Trenches 22, 23, & 24 under static loading conditions.

Method: The computer program XSTABL was used to analyze circular failure surfaces using the Modified Janbu Method. Both short term (undrained) and long term (drained) stability analysis were performed. The Factor of Safety (F.S.) was determined by searching for the critical surface.

Soil Property Data. The slopes analyzed are cut in insitu chalk. The chalk has a unit weight of 130 pcf. The drained shear strength parameters are anisotropic. The shear strength properties used in the analysis are as follows:

Golder Associates	SUBJECT Cross-section D-D: T21, 22, 23, & 24 Cut slope Stability		
	Job No. 933-3553	Made by JSD	Date 10/7/93
	Ref.	Checked RSO	Sheet 2 of 13
		Reviewed	

Type of Analysis	Direction	Su	C	Φ
Short Term	Horizontal Vertical	8000*	—	—
Long Term	Horizontal	—	6000	36
	Vertical	—	2000	43

* For determination of Su = 8000 psf refer to stability of in-situ berms calcs.

Assumptions: For cut slopes below the water table elevation, the phreatic surface is assumed to follow the excavated surface.

Results: Based on XSTABL analysis, the short term condition was deemed critical, as it had the lower factor of safety. The minimum factor of safety for a circular failure surface through cross section D-D is F.S. ≃ 3.94. The figure on sheet 4 identifies the the 10 most critical failure surfaces and highlights the most critical surface. Additionally, sheets through

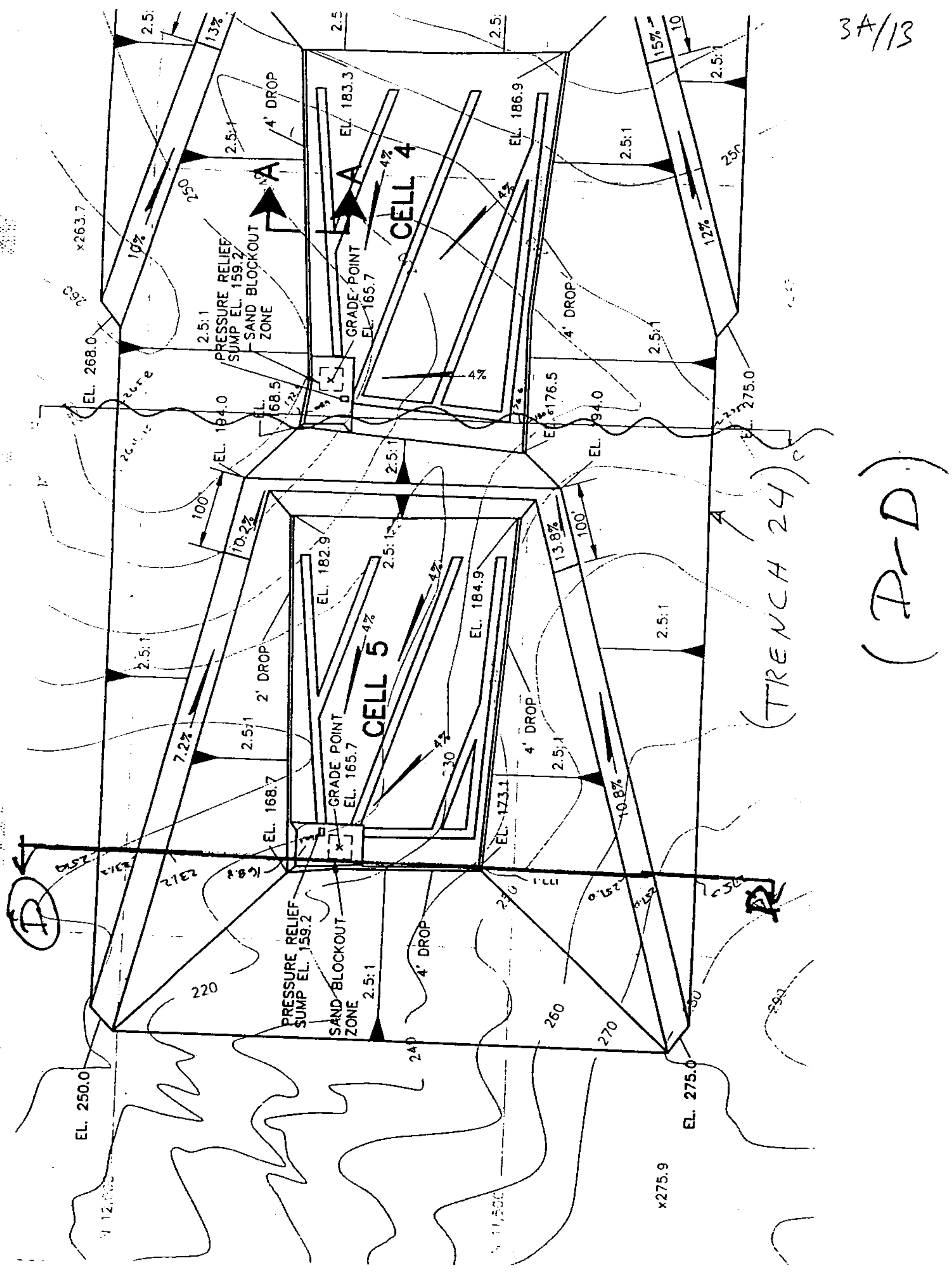
Golder Associates

SUBJECT Cross-section D-D: T21, 22, 23, & 24 Cut Slope Stability

Job No. 933-3553 | Made by JJD | Date 10/7/93
Ref. | Checked RJO | Sheet 3 of 13
Reviewed

contain the XSTABL output file for the short term search analysis. The figure on sheet identifies the ten most and highlights the most critical failure surfaces identified for cross-section D-D. The output file for this search is included in sheets through . The long term analysis was not deemed critical, as the short term analysis resulted in a lower factor of safety.

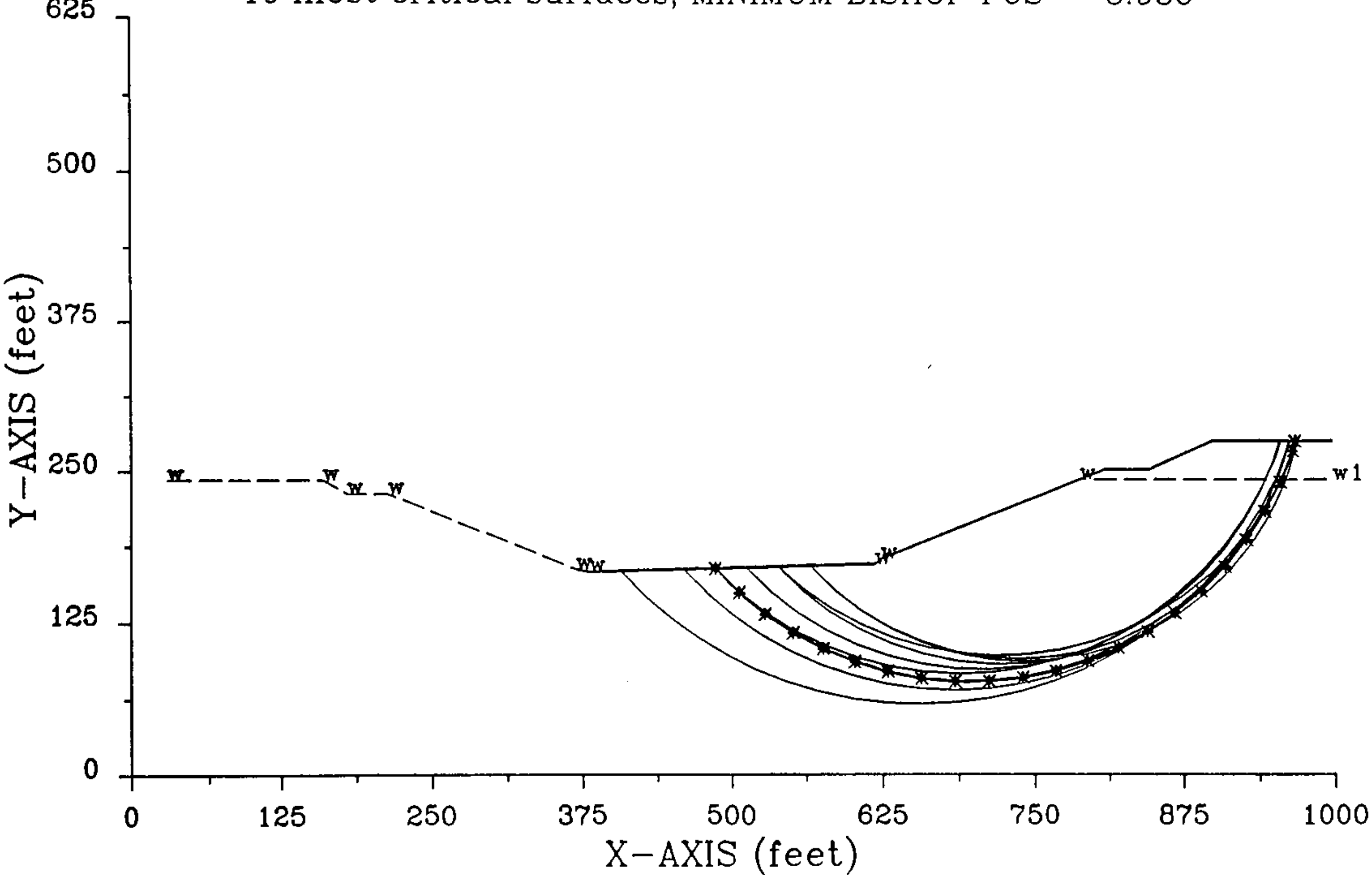
(sheet 3A shows section D-D location)


3A/13
CELL 4
CELL 5
EL. 183.3
EL. 186.9
4' DROP
PRESSURE RELIEF SUMP EL. 159.2
SAND BLOCKOUT ZONE
GRADE POINT EL. 165.7
EL. 268.0
EL. 275.0
EL. 176.5
EL. 182.9
EL. 184.9
2' DROP
EL. 168.7
EL. 173.1
EL. 250.0
EL. 275.0
2.5:1
10%
12%
10.2%
13.8%
7.2%
10.8%
4%
100'
x263.7
x275.9
TRENCH 24
(D-D)

D-DST_1 9-23-93 15:47

emelle

10 most critical surfaces, MINIMUM BISHOP FOS = 3.936



4/13

XSTABL File: D-DST_1   9-23-93   15:47

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Problem Description : emelle

SEGMENT BOUNDARY COORDINATES

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	370.0	168.8	381.0	166.8	1
2	381.0	166.8	619.0	173.1	1
3	619.0	173.1	624.0	177.1	1
4	624.0	177.1	810.0	251.0	1
5	810.0	251.0	846.0	251.0	1
6	846.0	251.0	900.0	275.0	1
7	900.0	275.0	1000.0	275.0	1

ISOTROPIC Soil Parameters

1 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Constant (psf)	Water Surface No.
1	130.0	130.0	8000.0	.00	.000	.0	0

1 Water surface(s) have been specified

Unit weight of water =   62.40 (pcf)

Water Surface No. 1 specified by 10 coordinate points

****
PHREATIC SURFACE,
****

Point No.	x-water (ft)	y-water (ft)
1	30.00	242.50
2	160.00	242.50
3	180.00	231.20
4	214.00	231.20
5	370.00	168.80
6	381.00	166.80
7	619.00	173.10
8	624.00	177.10
9	789.00	242.50
10	1000.00	242.50

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

200 trial surfaces will be generated and analyzed.

20 Surfaces initiate from each of 10 points equally spaced along the ground surface between x = 381.0 ft
and x = 619.0 ft

Each surface terminates between x = 730.0 ft
and x = 970.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

28.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS :

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * *   MODIFIED BISHOP METHOD   * * * * *

The most critical circular failure surface
is specified by 23 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	486.78	169.60
2	506.63	149.85
3	528.32	132.15
4	551.65	116.66
5	576.38	103.54
6	602.29	92.91
7	629.11	84.87
8	656.59	79.50
9	684.46	76.85
10	712.46	76.95
11	740.32	79.81
12	767.76	85.38
13	794.52	93.61
14	820.34	104.44
15	844.98	117.74
16	868.19	133.40
17	889.75	151.26
18	909.46	171.16
19	927.11	192.89
20	942.55	216.24
21	955.63	241.01
22	966.21	266.93
23	968.61	275.00

****   Modified BISHOP FOS =   3.936   ****

The following is a summary of the TEN most critical surfaces

Problem Description : emelle

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Driving Moment (ft-lb)
1.	3.936	697.41	361.50	284.95	486.78	968.61	3.454E+08
2.	3.948	683.91	372.77	302.57	460.33	969.91	3.844E+08
3.	3.973	694.90	357.92	280.67	486.78	962.90	3.339E+08
4.	3.993	722.97	340.97	249.98	539.67	964.06	2.662E+08

0/13

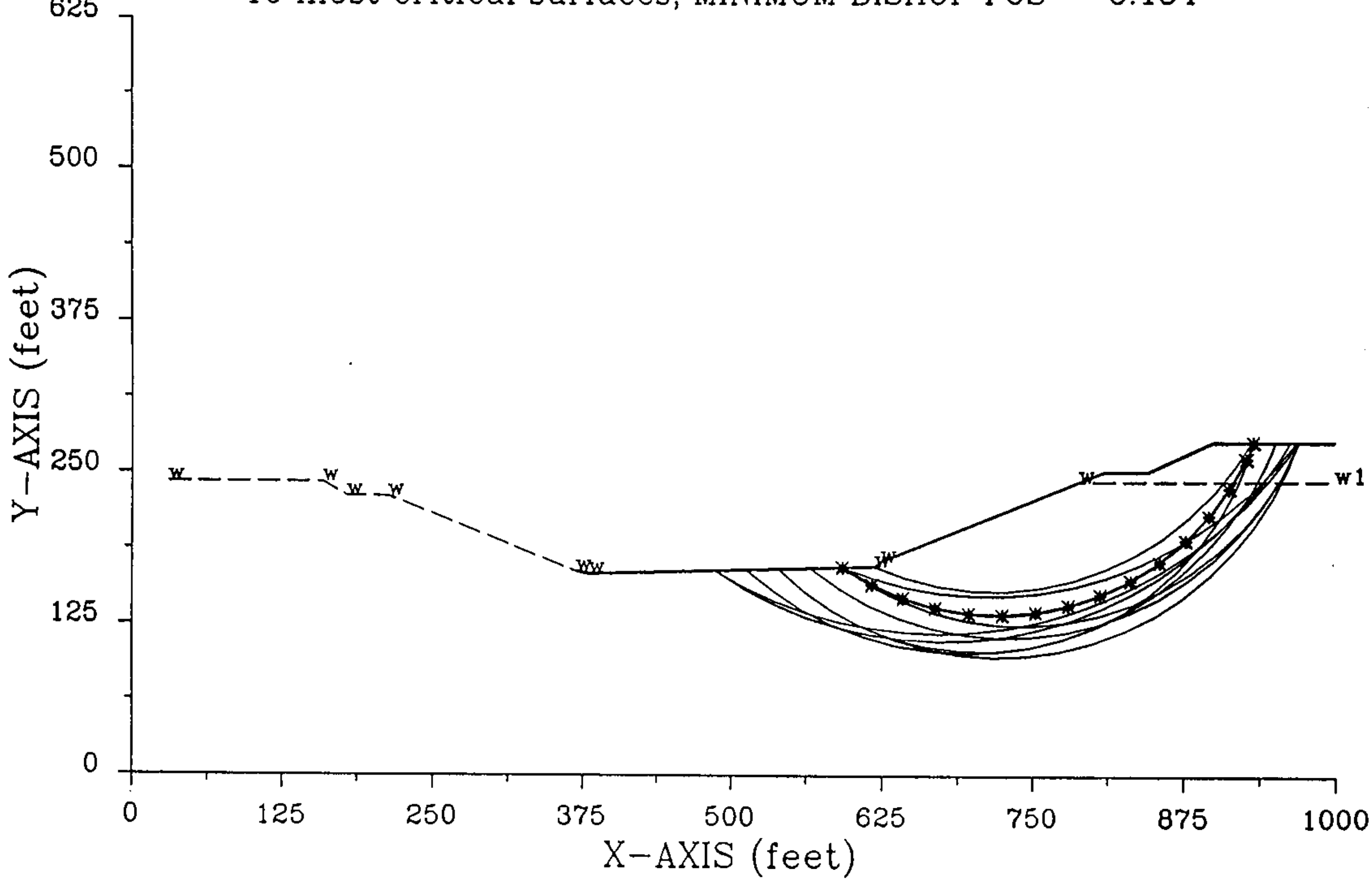
5.	4.009	721.38	360.75	262.72	539.67	969.43	2.756E+08
6.	4.016	741.34	328.76	235.31	566.11	970.07	2.403E+08
7.	4.027	655.59	395.90	337.25	407.44	970.12	4.587E+08
8.	4.036	704.34	348.22	261.11	513.22	954.62	2.846E+08
9.	4.057	689.58	365.33	281.85	486.78	956.21	3.206E+08
10.	4.058	737.48	326.11	230.67	566.11	962.40	2.291E+08

* * * END OF FILE * * *

9/13

emelle

10 most critical surfaces, MINIMUM BISHOP FOS = 6.154



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*****************************************
```

Problem Description : emelle

SEGMENT BOUNDARY COORDINATES

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	370.0	168.8	381.0	166.8	1
2	381.0	166.8	619.0	173.1	1
3	619.0	173.1	624.0	177.1	1
4	624.0	177.1	810.0	251.0	1
5	810.0	251.0	846.0	251.0	1
6	846.0	251.0	900.0	275.0	1
7	900.0	275.0	1000.0	275.0	1

ISOTROPIC Soil Parameters

1 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	130.0	8000.0	.00	.000	.0	0

ANISOTROPIC Strength Parameters
1 soil type(s)

Soil Type 1 is ANISOTROPIC

Number of direction ranges specified = 3

Direction Range No.	Counterclockwise Direction Limit (deg)	Cohesion Intercept (psf)	Friction Angle (deg)
1	-45.00	2000.0	43.0
2	45.00	6000.0	36.0
3	90.00	2000.0	43.0

1 Water surface(s) have been specified

Unit weight of water = 62.40 (pcf)

Water Surface No. 1 specified by 10 coordinate points

****
PHREATIC SURFACE,
****

Point No.	x-water (ft)	y-water (ft)
1	30.00	242.50
2	160.00	242.50
3	180.00	231.20
4	214.00	231.20
5	370.00	168.80
6	381.00	166.80
7	619.00	173.10
8	624.00	177.10
9	789.00	242.50
10	1000.00	242.50

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

200 trial surfaces will be generated and analyzed.

20 Surfaces initiate from each of 10 points equally spaced along the ground surface between x = 381.0 ft
and x = 619.0 ft

Each surface terminates between x = 730.0 ft
and x = 970.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

28.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS :

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit :=   -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * *   MODIFIED BISHOP METHOD   * * * * *

The most critical circular failure surface is specified by 16 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	592.56	172.40
2	616.66	158.15
3	642.32	146.94
4	669.15	138.93
5	696.75	134.25
6	724.72	132.97
7	752.64	135.10
8	780.10	140.61
9	806.67	149.42
10	831.98	161.40
11	855.64	176.37
12	877.31	194.11
13	896.65	214.35
14	913.38	236.80
15	927.26	261.12
16	933.08	275.00

**** Modified BISHOP FOS =   6.154 ****

The following is a summary of the TEN most critical surfaces

Problem Description : emelle

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Driving Moment (ft-lb)
1.	6.154	721.26	362.58	229.64	592.56	933.08	1.628E+08
2.	6.279	713.66	467.80	319.26	592.56	968.06	2.190E+08
3.	6.301	729.27	374.65	260.40	566.11	969.56	2.427E+08
4.	6.312	740.44	375.00	250.83	592.56	970.41	2.113E+08
5.	6.326	717.74	400.51	247.92	619.00	931.28	1.399E+08
6.	6.421	695.48	377.27	275.78	513.22	951.37	2.774E+08
7.	6.466	705.73	338.84	236.10	539.67	932.60	2.164E+08
8.	6.469	721.38	360.75	262.72	539.67	969.43	2.756E+08
9.	6.475	672.64	476.85	359.09	486.78	969.31	3.416E+08
10.	6.477	675.41	445.84	334.50	486.78	962.64	3.289E+08

* * * END OF FILE * * *

Golder Associates	SUBJECT Stability of In-Situ berms w/waste - Addendum		
	Job No. 933-3553 Ref.	Made by D. Jang Checked RSO Reviewed WRS	Date 10/22/93 Sheet 1 of 39

Objective: To analyze the following sections:

1) In-situ berm in Trench 23 between Cells 4&5. (G-G')
2) In-situ berm in Trench 24 between Cells 4&5. (H-H')
3) In-Situ berm in Trench 23 between Cells 2&3 (G-G')*

Analysis: Based on the laboratory shear test results, the geonet / HDPE geomembrane interface friction angle is 8° which is the lowest in the liner system.

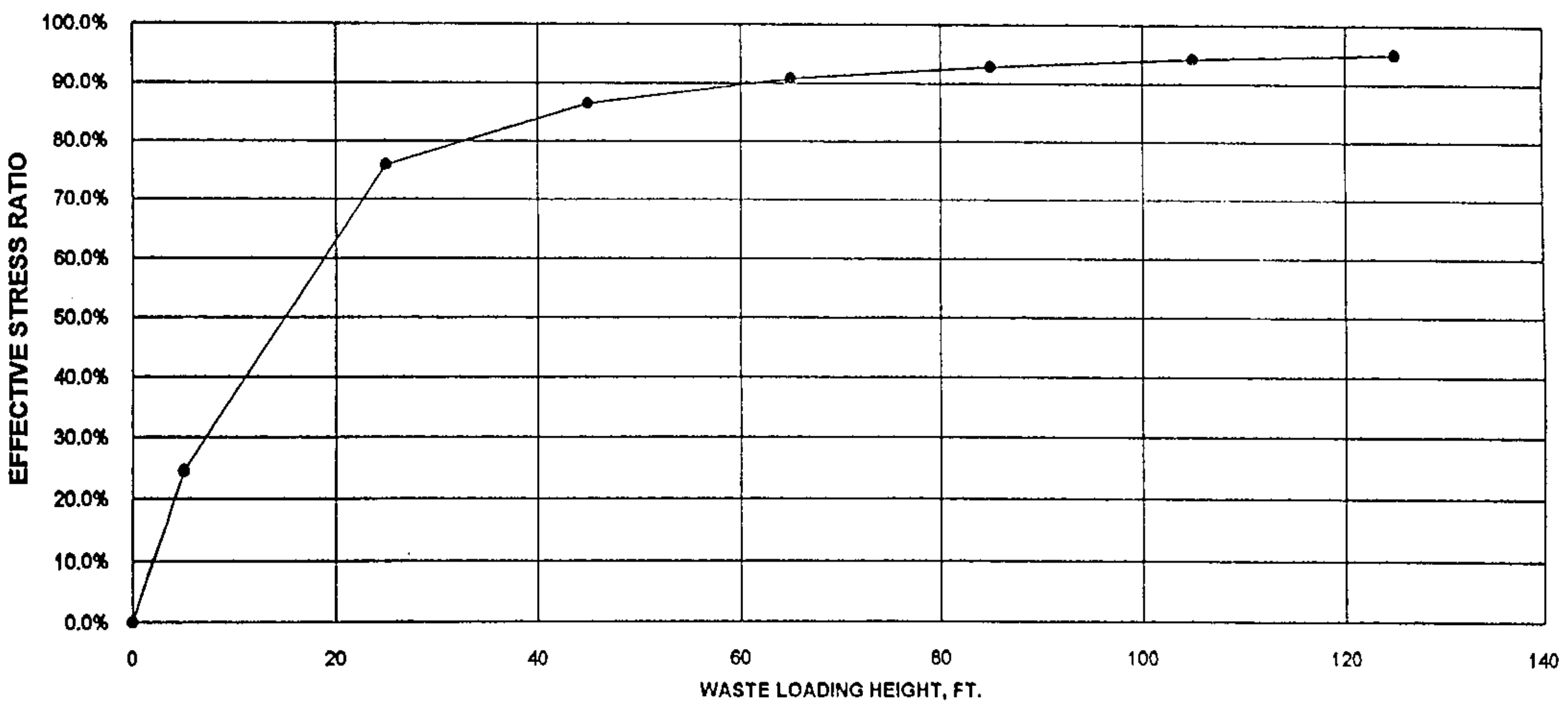
The interface friction angle in the liner system is therefore to be 8° in the analysis. *

Results: In order to have minimum FOS=1.3 in these two sections, the berm height have been adjusted to be analyzed.

The results of the XSTABL analysis show that in these two sections, a internal berm height of 25' is required to have FOS=1.3. for T23 C4&5 and T24 C4&5. A berm height of 22' is required for T23, C2&3.

* Base on consolidation test and analysis results obtained from a remolded sample of chalk, using an average waste placement rate of 30 psf/day, pore water pressure will be dissipated (90%) after placing ~ 60 ft of waste. For this reason, drained conditions of the clay/HDPE geomembrane interface should be used. The drained shear strength of this interface is greater than 8°.

EFFECTIVE STRESS RATIO
OF THE CLAY IMMEDIATELY BELOW THE GEOMEMBRANE LINER



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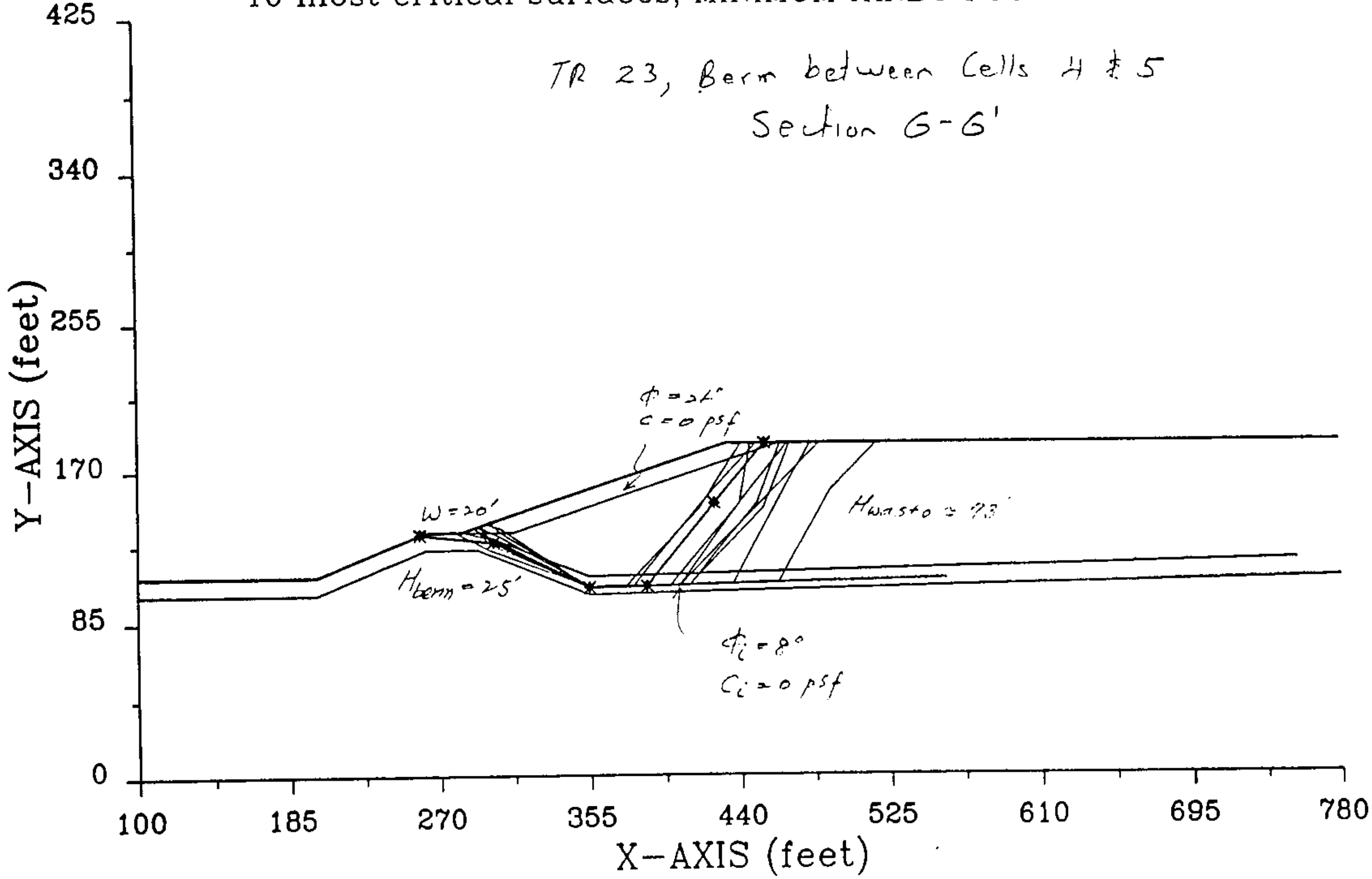
Berm Height 25, Berm Crest 20, Block

10 most critical surfaces, MINIMUM JANBU FOS = 1.350



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PROFIL                                          FILE: STB23825  10-22-93    9:53    ft
Berm Height 25, Berm Crest 20, Block
  16    6
    100.0      110.0      200.0      110.0   1
    200.0      110.0      262.5      135.0   1
    262.5      135.0      282.5      135.0   1
    282.5      135.0      432.5      185.0   4
    432.5      185.0      462.5      185.0   4
    462.5      185.0      780.0      185.0   3
    282.5      135.0      292.5      135.0   1
    292.5      135.0      312.5      135.0   3
    312.5      135.0      462.5      185.0   3
    292.5      135.0      355.0      110.0   1
    355.0      110.0      755.0      118.0   1
    100.0      100.0      200.0      100.0   2
    200.0      100.0      262.5      125.0   2
    262.5      125.0      292.5      125.0   2
    292.5      125.0      355.0      100.0   2
    355.0      100.0      780.0      108.0   2
SOIL
  4
  130.0    130.0        .0     8.00     .000       .0    0
  130.0    130.0    8000.0      .00     .000       .0    0
  110.0    110.0     650.0    15.00     .000       .0    0
  130.0    130.0        .0    26.00     .000       .0    0
BLOCK
  200    2     60.0
       355.0       104.0       356.0       104.0         .0
       357.0       104.0       557.0       108.0         .0
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XSTABL File: STB23B25 10-22-93 9:53

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*******************************************
```

Problem Description : Berm Height 25, Berm Crest 20, Block

SEGMENT BOUNDARY COORDINATES

6 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	100.0	110.0	200.0	110.0	1
2	200.0	110.0	262.5	135.0	1
3	262.5	135.0	282.5	135.0	1
4	282.5	135.0	432.5	185.0	4
5	432.5	185.0	462.5	185.0	4
6	462.5	185.0	780.0	185.0	3

10 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	282.5	135.0	292.5	135.0	1
2	292.5	135.0	312.5	135.0	3
3	312.5	135.0	462.5	185.0	3
4	292.5	135.0	355.0	110.0	1
5	355.0	110.0	755.0	118.0	1
6	100.0	100.0	200.0	100.0	2
7	200.0	100.0	262.5	125.0	2
8	262.5	125.0	292.5	125.0	2
9	292.5	125.0	355.0	100.0	2
10	355.0	100.0	780.0	108.0	2

ISOTROPIC Soil Parameters

4 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	130.0	.0	8.00	.000	.0	0

2	130.0	130.0	8000.0	.00	.000	.0	0
3	110.0	110.0	650.0	15.00	.000	.0	0
4	130.0	130.0	.0	26.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

200 trial surfaces will be generated and analyzed.

2 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 60.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	355.0	104.0	356.0	104.0	.0
2	357.0	104.0	557.0	108.0	.0

Factors of safety have been calculated by the :

* * * * * MODIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	259.05	133.62
2	300.88	129.36
3	355.26	104.00
4	387.52	104.61
5	425.58	151.00
6	454.15	185.00

** Corrected JANBU FOS = 1.350 ** (Fo factor =1.087)

Failure surface No. 2 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	283.29	135.26
2	301.53	131.22
3	355.00	104.00
4	375.46	104.37
5	416.80	147.86
6	440.55	185.00

** Corrected JANBU FOS = 1.385 ** (Fo factor =1.089)

Failure surface No. 3 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	279.92	135.00
2	299.65	124.96
3	355.87	104.00
4	400.61	104.87
5	439.47	150.59
6	446.03	185.00

** Corrected JANBU FOS = 1.479 ** (Fo factor =1.089)

Failure surface No. 4 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	290.46	137.65
2	301.92	130.42
3	355.79	104.00
4	411.39	105.09
5	453.15	148.17
6	468.30	185.00

** Corrected JANBU FOS = 1.483 ** (Fo factor =1.089)

Failure surface No. 5 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	290.10	137.53
2	300.48	127.94
3	355.49	104.00
4	435.89	105.58
5	464.55	158.29
6	480.16	185.00

** Corrected JANBU FOS = 1.558 ** (Fo factor =1.089)

Failure surface No. 6 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	293.13	138.54
2	303.56	133.41
3	355.85	104.00
4	406.00	104.98
5	441.49	153.36
6	466.79	185.00

** Corrected JANBU FOS = 1.568 ** (Fo factor =1.089)

Failure surface No. 7 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	292.17	138.22
2	303.48	133.56
3	355.70	104.00

4	379.49	104.45
5	417.76	150.66
6	449.28	185.00

** Corrected JANBU FOS = 1.614 ** (Fo factor =1.089)

Failure surface No. 8 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	297.33	139.94
2	305.13	137.30
3	355.05	104.00
4	405.68	104.97
5	448.05	147.46
6	485.27	185.00

** Corrected JANBU FOS = 1.674 ** (Fo factor =1.088)

Failure surface No. 9 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	299.40	140.63
2	304.76	135.32
3	355.94	104.00
4	411.11	105.08
5	449.69	151.04
6	462.53	185.00

** Corrected JANBU FOS = 1.713 ** (Fo factor =1.089)

Failure surface No.10 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	292.71	138.40
2	301.77	129.77
3	355.95	104.00
4	461.51	106.09
5	491.37	158.13
6	517.71	185.00

** Corrected JANBU FOS = 1.740 ** (Fo factor =1.086)

```
**********************************************************************
**                                                                  **
**  Out of the    200 surfaces generated and analyzed by XSTABL,    **
**       79 surfaces were found to have MISLEADING FOS values.      **
**                                                                  **
**********************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : Berm Height 25, Berm Crest 20, Block

Modified Correction Initial Terminal Driving

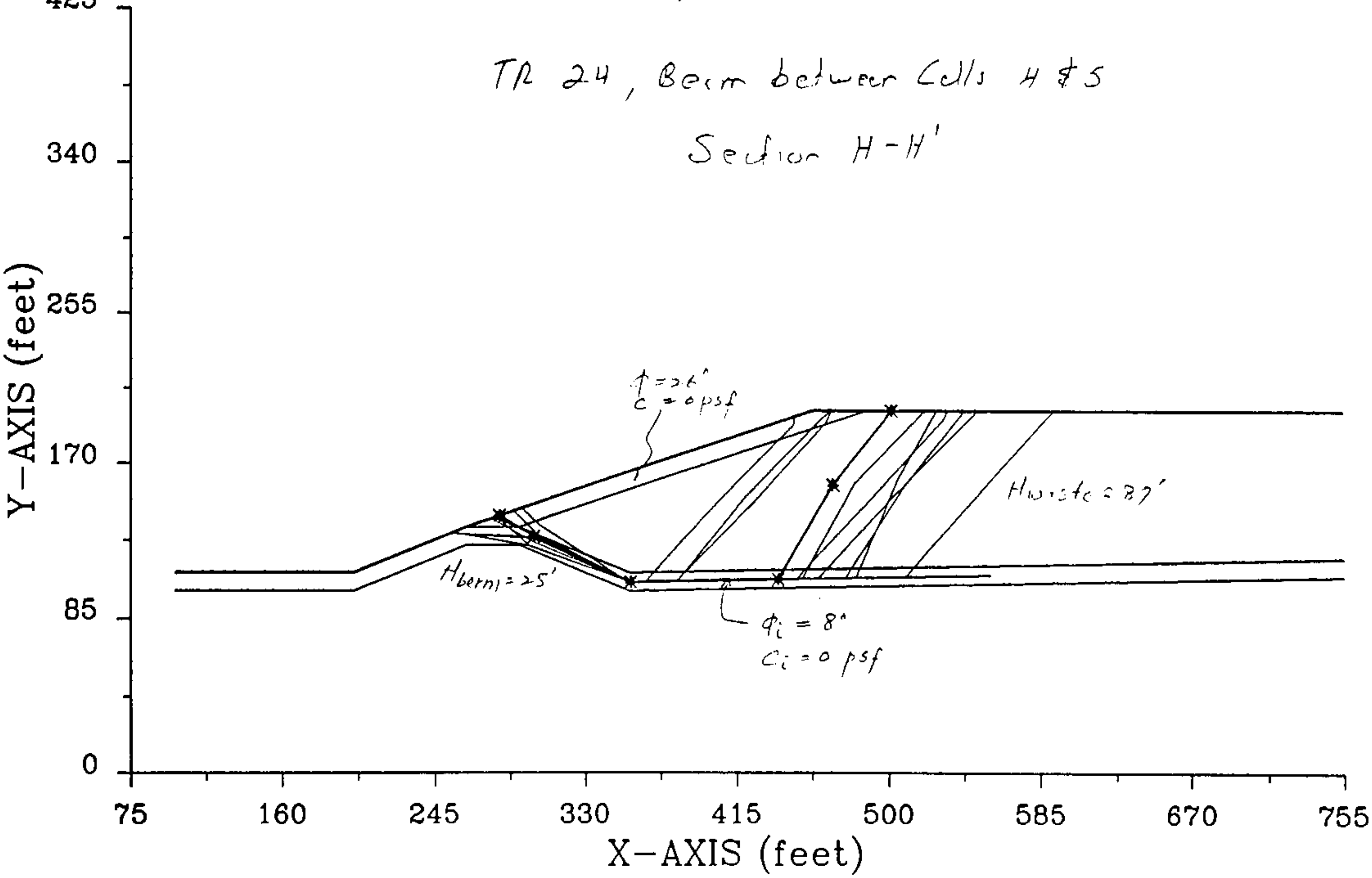
	JANBU FOS	Factor	x-coord (ft)	x-coord (ft)	Force (lb)
1.	1.350	1.087	259.05	454.15	1.627E+05
2.	1.385	1.089	283.29	440.55	1.437E+05
3.	1.479	1.089	279.92	446.03	1.505E+05
4.	1.483	1.089	290.46	468.30	1.741E+05
5.	1.558	1.089	290.10	480.16	1.694E+05
6.	1.568	1.089	293.13	466.79	1.711E+05
7.	1.614	1.089	292.17	449.28	1.458E+05
8.	1.674	1.088	297.33	485.27	1.831E+05
9.	1.713	1.089	299.40	462.53	1.634E+05
10.	1.740	1.086	292.71	517.71	1.795E+05

* * * END OF FILE * * *

STB24B25 10-22-93 10:28

Berm Height 25

10 most critical surfaces, MINIMUM JANBU FOS = 1.324



```
PROFIL                                  FILE: STB24B25  10-22-93   10:28    ft
Berm Height 25
  14    5
    100.0      110.0      200.0      110.0   1
    200.0      110.0      262.5      135.0   1
    262.5      135.0      457.5      200.0   4
    457.5      200.0      487.5      200.0   4
    487.5      200.0      755.0      200.0   3
    262.5      135.0      292.5      135.0   1
    292.5      135.0      487.5      200.0   3
    292.5      135.0      355.0      110.0   1
    355.0      110.0      755.0      118.0   1
    100.0      100.0      200.0      100.0   2
    200.0      100.0      262.5      125.0   2
    262.5      125.0      292.5      125.0   2
    292.5      125.0      355.0      100.0   2
    355.0      100.0      755.0      108.0   2
SOIL
  4
  130.0    130.0        .0     8.00     .000        .0    0
  130.0    130.0    8000.0      .00     .000        .0    0
  110.0    110.0     650.0    15.00     .000        .0    0
  110.0    110.0        .0    26.00     .000        .0    0
BLOCK
  200   2     60.0
       355.0       105.0       356.0       105.0          .0
       357.0       105.0       557.0       109.0          .0
```

XSTABL File: STB24B25 10-22-93 10:28

```
*********************************************
*                  XSTABL                   *
*                                           *
*      Slope Stability Analysis using       *
*    Simplified BISHOP or JANBU methods     *
*                                           *
*           Copyright (C) 1993              *
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*                                           *
*         Golder Associates, Inc.           *
*          Atlanta,  GA 30341               *
*                                           *
*  Ver. 4.1                          1049   *
*********************************************
```

Problem Description : Berm Height 25

SEGMENT BOUNDARY COORDINATES

5 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	100.0	110.0	200.0	110.0	1
2	200.0	110.0	262.5	135.0	1
3	262.5	135.0	457.5	200.0	4
4	457.5	200.0	487.5	200.0	4
5	487.5	200.0	755.0	200.0	3

9 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	262.5	135.0	292.5	135.0	1
2	292.5	135.0	487.5	200.0	3
3	292.5	135.0	355.0	110.0	1
4	355.0	110.0	755.0	118.0	1
5	100.0	100.0	200.0	100.0	2
6	200.0	100.0	262.5	125.0	2
7	262.5	125.0	292.5	125.0	2
8	292.5	125.0	355.0	100.0	2
9	355.0	100.0	755.0	108.0	2

ISOTROPIC Soil Parameters

4 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	130.0	.0	8.00	.000	.0	0
2	130.0	130.0	8000.0	.00	.000	.0	0
3	110.0	110.0	650.0	15.00	.000	.0	0

4	110.0	110.0	.0	26.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

200 trial surfaces will be generated and analyzed.

2 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 60.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	355.0	105.0	356.0	105.0	.0
2	357.0	105.0	557.0	109.0	.0

Factors of safety have been calculated by the :

* * * * * MODIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	281.26	141.25
2	300.89	129.79
3	355.53	105.00
4	438.02	106.62
5	468.56	158.26
6	501.17	200.00

** Corrected JANBU FOS = 1.324 ** (Fo factor =1.089)

Failure surface No. 2 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	277.90	140.13
2	301.64	131.25
3	355.60	105.00
4	381.08	105.48
5	423.31	148.10
6	463.84	192.34
7	467.87	200.00

** Corrected JANBU FOS = 1.335 ** (Fo factor =1.088)

Failure surface No. 3 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	279.50	140.67
2	298.84	124.40
3	355.61	105.00
4	460.59	107.07
5	501.13	151.30
6	543.50	193.79
7	549.47	200.00

** Corrected JANBU FOS = 1.345 ** (Fo factor =1.083)

Failure surface No. 4 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	279.72	140.74
2	301.17	131.07
3	355.21	105.00
4	381.66	105.49
5	419.61	151.97
6	461.74	194.69
7	466.93	200.00

** Corrected JANBU FOS = 1.379 ** (Fo factor =1.089)

Failure surface No. 5 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	254.09	131.64
2	300.41	129.04
3	355.39	105.00
4	363.79	105.14
5	404.26	149.44
6	446.43	192.11
7	447.04	196.51

** Corrected JANBU FOS = 1.392 ** (Fo factor =1.087)

Failure surface No. 6 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	276.83	139.78
2	299.85	127.23
3	355.58	105.00
4	475.46	107.37
5	508.05	157.75
6	542.26	200.00

** Corrected JANBU FOS = 1.420 ** (Fo factor =1.085)

Failure surface No. 7 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	289.31	143.94

2	302.14	131.71
3	355.86	105.00
4	451.45	106.89
5	480.52	159.38
6	519.81	200.00

** Corrected JANBU FOS = 1.457 ** (Fo factor =1.088)

Failure surface No. 8 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	255.62	132.25
2	299.10	124.88
3	355.72	105.00
4	509.08	108.04
5	549.27	152.60
6	589.27	197.32
7	591.86	200.00

** Corrected JANBU FOS = 1.489 ** (Fo factor =1.075)

Failure surface No. 9 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	254.08	131.63
2	300.53	129.52
3	355.29	105.00
4	481.15	107.48
5	505.00	162.54
6	526.40	200.00

** Corrected JANBU FOS = 1.528 ** (Fo factor =1.085)

Failure surface No.10 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	294.26	145.59
2	303.89	136.36
3	355.04	105.00
4	448.20	106.82
5	489.26	150.57
6	529.98	194.64
7	532.67	200.00

** Corrected JANBU FOS = 1.537 ** (Fo factor =1.087)

```
**********************************************************************
**                                                                  **
**  Out of the    200 surfaces generated and analyzed by XSTABL,    **
**       90 surfaces were found to have MISLEADING FOS values.      **
**                                                                  **
**********************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : Berm Height 25

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Driving Force (lb)
1.	1.324	1.089	281.26	501.17	2.460E+05
2.	1.335	1.088	277.90	467.87	1.972E+05
3.	1.345	1.083	279.50	549.47	3.027E+05
4.	1.379	1.089	279.72	466.93	1.811E+05
5.	1.392	1.087	254.09	447.04	1.578E+05
6.	1.420	1.085	276.83	542.26	2.770E+05
7.	1.457	1.088	289.31	519.81	2.528E+05
8.	1.489	1.075	255.62	591.86	3.182E+05
9.	1.528	1.085	254.08	526.40	2.433E+05
10.	1.537	1.087	294.26	532.67	2.784E+05

* * * END OF FILE * * *

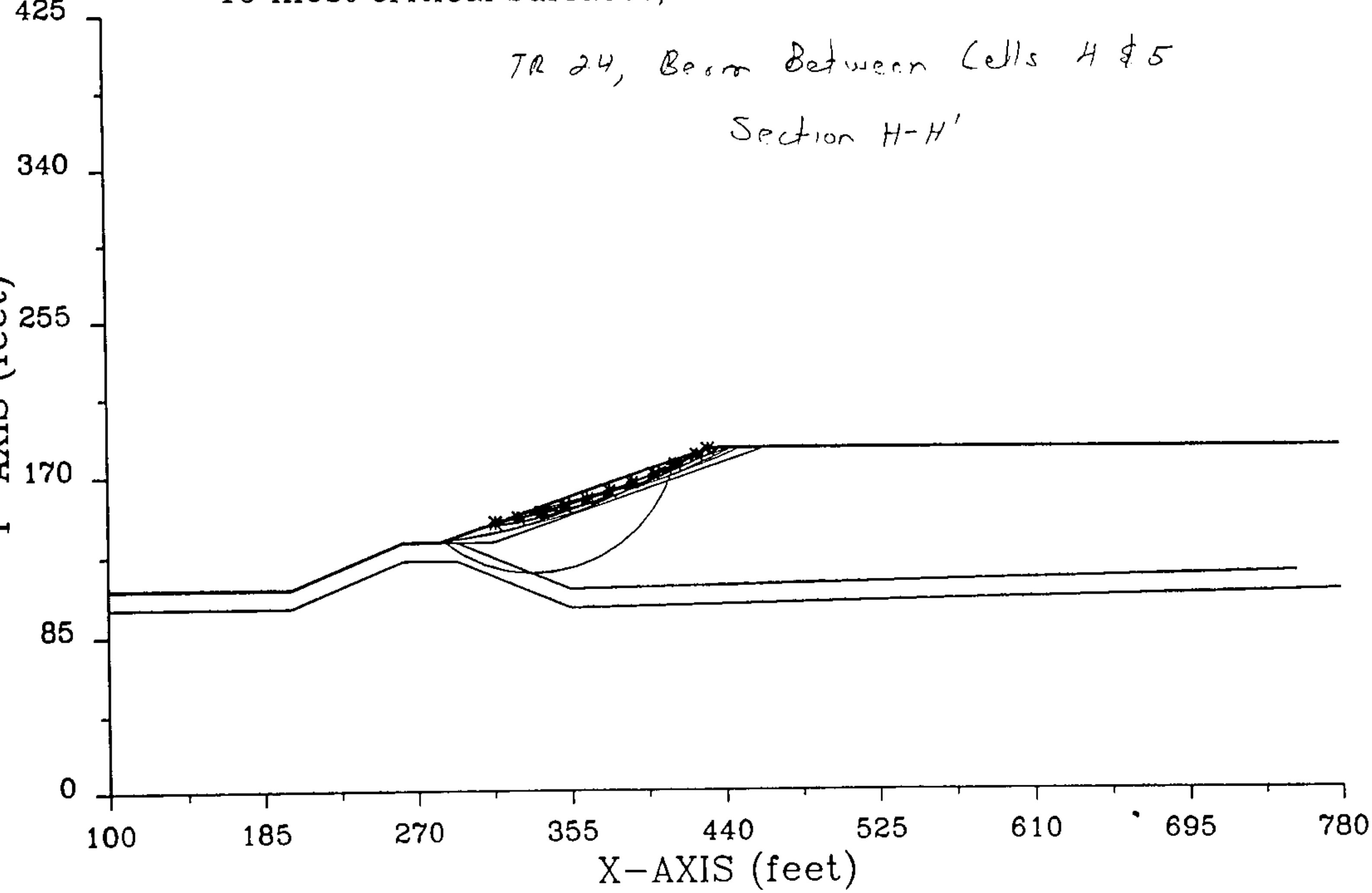
STC23B25 10-22-93 10:44

Berm Height 25, Berm Crest 20, Circ

10 most critical surfaces, MINIMUM JANBU FOS = 1.484

TR 24, Berm Between Cells 4 & 5

Section H-H'



```
PROFIL                                       FILE: STC23B25  10-22-93   10:44    ft
Berm Height 25, Berm Crest 20, Circ
  16    6
    100.0      110.0      200.0      110.0   1
    200.0      110.0      262.5      135.0   1
    262.5      135.0      282.5      135.0   1
    282.5      135.0      432.5      185.0   4
    432.5      185.0      462.5      185.0   4
    462.5      185.0      780.0      185.0   3
    282.5      135.0      292.5      135.0   1
    292.5      135.0      312.5      135.0   3
    312.5      135.0      462.5      185.0   3
    292.5      135.0      355.0      110.0   1
    355.0      110.0      755.0      118.0   1
    100.0      100.0      200.0      100.0   2
    200.0      100.0      262.5      125.0   2
    262.5      125.0      292.5      125.0   2
    292.5      125.0      355.0      100.0   2
    355.0      100.0      780.0      108.0   2
SOIL
  4
  130.0    130.0        .0     8.00     .000        .0    0
  130.0    130.0    8000.0      .00     .000        .0    0
  110.0    110.0     650.0    15.00     .000        .0    0
  130.0    130.0        .0    26.00     .000        .0    0
CIRCLE
  10    20
    285.0      350.0      400.0      600.0
    118.0         .0         .0         .0
```

XSTABL File: STC23B25 10-22-93 10:44

```
*********************************************
*                 XSTABL                    *
*                                           *
*     Slope Stability Analysis using        *
*    Simplified BISHOP or JANBU methods     *
*                                           *
*          Copyright (C) 1993               *
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*                                           *
*        Golder Associates, Inc.            *
*         Atlanta,  GA 30341                *
*                                           *
*  Ver. 4.1                        1049     *
*********************************************
```

Problem Description : Berm Height 25, Berm Crest 20, Circ

SEGMENT BOUNDARY COORDINATES

6 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	100.0	110.0	200.0	110.0	1
2	200.0	110.0	262.5	135.0	1
3	262.5	135.0	282.5	135.0	1
4	282.5	135.0	432.5	185.0	4
5	432.5	185.0	462.5	185.0	4
6	462.5	185.0	780.0	185.0	3

10 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	282.5	135.0	292.5	135.0	1
2	292.5	135.0	312.5	135.0	3
3	312.5	135.0	462.5	185.0	3
4	292.5	135.0	355.0	110.0	1
5	355.0	110.0	755.0	118.0	1
6	100.0	100.0	200.0	100.0	2
7	200.0	100.0	262.5	125.0	2
8	262.5	125.0	292.5	125.0	2
9	292.5	125.0	355.0	100.0	2
10	355.0	100.0	780.0	108.0	2

ISOTROPIC Soil Parameters

4 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	130.0	.0	8.00	.000	.0	0

2	130.0	130.0	8000.0	.00	.000	.0	0
3	110.0	110.0	650.0	15.00	.000	.0	0
4	130.0	130.0	.0	26.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

200 trial surfaces will be generated and analyzed.

20 Surfaces initiate from each of 10 points equally spaced along the ground surface between x = 285.0 ft
and x = 350.0 ft

Each surface terminates between x = 400.0 ft
and x = 600.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = 118.0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

13.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS :

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

****
ERROR # 48
****
Negative effective stresses have been calculated at the base of a slice. This error is usually reported for cases where slices have low self-weight and a relatively high "c" shear strength parameter. This error can only be eliminated by reducing the "c" value.
****

USER SELECTED option to maintain strength greater than zero

Factors of safety have been calculated by the :

* * * * * MODIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	313.89	145.46
2	326.63	148.04
3	339.29	150.99
4	351.87	154.29
5	364.34	157.95
6	376.71	161.96
7	388.95	166.33
8	401.07	171.04
9	413.04	176.09
10	424.87	181.49
11	431.02	184.51

** Corrected JANBU FOS = 1.484 ** (Fo factor =1.010)

Failure surface No. 2 specified by 12 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	285.00	135.83
2	297.87	137.67
3	310.66	139.99
4	323.36	142.79
5	335.94	146.07
6	348.38	149.82
7	360.68	154.05
8	372.80	158.73
9	384.74	163.87
10	396.48	169.46
11	408.00	175.49
12	413.58	178.69

** Corrected JANBU FOS = 1.498 ** (Fo factor =1.014)

Failure surface No. 3 specified by 13 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	285.00	135.83
2	297.90	137.44
3	310.73	139.51
4	323.48	142.05
5	336.13	145.05
6	348.66	148.51
7	361.06	152.43
8	373.30	156.79
9	385.38	161.60
10	397.28	166.85
11	408.97	172.53
12	420.45	178.63
13	430.03	184.18

** Corrected JANBU FOS = 1.502 ** (Fo factor =1.016)

Failure surface No. 4 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	306.67	143.06
2	319.58	144.54

3	332.41	146.65
4	345.12	149.37
5	357.69	152.71
6	370.07	156.65
7	382.26	161.19
8	394.21	166.30
9	405.90	171.99
10	417.29	178.24
11	423.33	181.94

** Corrected JANBU FOS = 1.506 ** (Fo factor =1.017)

Failure surface No. 5 specified by 10 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	328.33	150.28
2	341.15	152.47
3	353.88	155.11
4	366.51	158.19
5	379.02	161.72
6	391.40	165.69
7	403.63	170.09
8	415.70	174.91
9	427.59	180.16
10	437.58	185.00

** Corrected JANBU FOS = 1.511 ** (Fo factor =1.011)

Failure surface No. 6 specified by 12 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	306.67	143.06
2	319.51	145.05
3	332.29	147.45
4	344.98	150.26
5	357.58	153.47
6	370.07	157.08
7	382.43	161.09
8	394.67	165.49
9	406.75	170.29
10	418.67	175.46
11	430.43	181.02
12	438.20	185.00

** Corrected JANBU FOS = 1.511 ** (Fo factor =1.012)

Failure surface No. 7 specified by 13 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	306.67	143.06
2	319.50	145.14
3	332.27	147.57
4	344.97	150.34
5	357.59	153.47
6	370.12	156.93
7	382.55	160.73
8	394.88	164.87
9	407.08	169.34
10	419.16	174.14
11	431.11	179.26

12	442.91	184.71
13	443.50	185.00

** Corrected JANBU FOS = 1.546 ** (Fo factor =1.011)

Failure surface No. 8 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	328.33	150.28
2	340.98	153.28
3	353.58	156.48
4	366.13	159.88
5	378.62	163.47
6	391.06	167.25
7	403.44	171.23
8	415.75	175.40
9	428.00	179.76
10	440.18	184.31
11	441.95	185.00

** Corrected JANBU FOS = 1.553 ** (Fo factor =1.005)

Failure surface No. 9 specified by 12 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	313.89	145.46
2	326.70	147.67
3	339.46	150.17
4	352.15	152.98
5	364.78	156.08
6	377.32	159.47
7	389.79	163.16
8	402.17	167.14
9	414.45	171.40
10	426.62	175.96
11	438.69	180.79
12	448.52	185.00

** Corrected JANBU FOS = 1.602 ** (Fo factor =1.009)

Failure surface No.10 specified by 14 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	285.00	135.83
2	295.84	128.66
3	307.69	123.31
4	320.24	119.93
5	333.18	118.61
6	346.15	119.38
7	358.84	122.21
8	370.91	127.04
9	382.05	133.75
10	391.97	142.15
11	400.42	152.03
12	407.17	163.14
13	412.06	175.18
14	412.80	178.43

** Corrected JANBU FOS = 1.611 ** (Fo factor =1.084)

The following is a summary of the TEN most critical surfaces

Problem Description : Berm Height 25, Berm Crest 20, Circ

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Driving Force (lb)
1.	1.484	1.010	313.89	431.02	1.415E+04
2.	1.498	1.014	285.00	413.58	2.499E+04
3.	1.502	1.016	285.00	430.03	3.451E+04
4.	1.506	1.017	306.67	423.33	2.389E+04
5.	1.511	1.011	328.33	437.58	1.732E+04
6.	1.511	1.012	306.67	438.20	2.682E+04
7.	1.546	1.011	306.67	443.50	2.934E+04
8.	1.553	1.005	328.33	441.95	1.293E+04
9.	1.602	1.009	313.89	448.52	2.797E+04
10.	1.611	1.084	285.00	412.80	1.052E+05

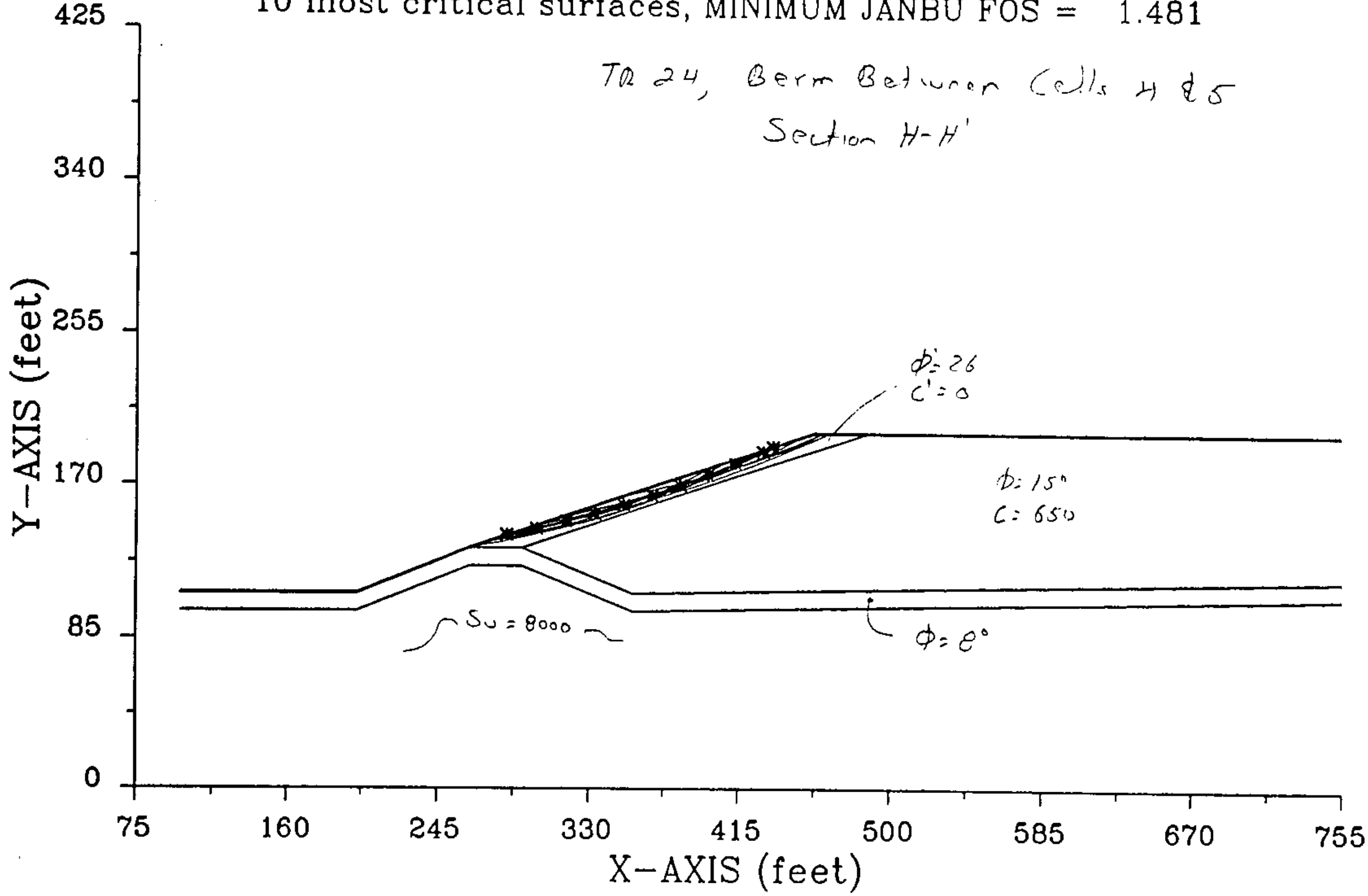
* * * END OF FILE * * *

STC24B25 10-22-93 10:48

Berm Height 25

10 most critical surfaces, MINIMUM JANBU FOS = 1.481

TR 24, Berm Between Cells 4 & 5
Section H-H'



```
PROFIL                                   FILE: STC24B25  10-22-93   10:48    ft
Berm Height 25
  14     5
    100.0      110.0      200.0      110.0    1
    200.0      110.0      262.5      135.0    1
    262.5      135.0      457.5      200.0    4
    457.5      200.0      487.5      200.0    4
    487.5      200.0      755.0      200.0    3
    262.5      135.0      292.5      135.0    1
    292.5      135.0      487.5      200.0    3
    292.5      135.0      355.0      110.0    1
    355.0      110.0      755.0      118.0    1
    100.0      100.0      200.0      100.0    2
    200.0      100.0      262.5      125.0    2
    262.5      125.0      292.5      125.0    2
    292.5      125.0      355.0      100.0    2
    355.0      100.0      755.0      108.0    2
SOIL
  4
  130.0    130.0        .0     8.00     .000        .0    0
  130.0    130.0    8000.0      .00     .000        .0    0
  110.0    110.0     650.0    15.00     .000        .0    0
  110.0    110.0        .0    26.00     .000        .0    0
CIRCLE
  10    20
    265.0      350.0      400.0      600.0
    118.0         .0         .0         .0
```

XSTABL File: STC24B25 10-22-93 10:48

```
******************************************
*                XSTABL                  *
*                                        *
*     Slope Stability Analysis using     *
*   Simplified BISHOP or JANBU methods   *
*                                        *
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*                                        *
*        Golder Associates, Inc.         *
*         Atlanta, GA 30341              *
*                                        *
* Ver. 4.1                         1049  *
******************************************
```

Problem Description : Berm Height 25

SEGMENT BOUNDARY COORDINATES

5 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	100.0	110.0	200.0	110.0	1
2	200.0	110.0	262.5	135.0	1
3	262.5	135.0	457.5	200.0	4
4	457.5	200.0	487.5	200.0	4
5	487.5	200.0	755.0	200.0	3

9 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	262.5	135.0	292.5	135.0	1
2	292.5	135.0	487.5	200.0	3
3	292.5	135.0	355.0	110.0	1
4	355.0	110.0	755.0	118.0	1
5	100.0	100.0	200.0	100.0	2
6	200.0	100.0	262.5	125.0	2
7	262.5	125.0	292.5	125.0	2
8	292.5	125.0	355.0	100.0	2
9	355.0	100.0	755.0	108.0	2

ISOTROPIC Soil Parameters

4 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	130.0	.0	8.00	.000	.0	0
2	130.0	130.0	8000.0	.00	.000	.0	0
3	110.0	110.0	650.0	15.00	.000	.0	0

4	110.0	110.0	.0	26.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

200 trial surfaces will be generated and analyzed.

20 Surfaces initiate from each of 10 points equally spaced along the ground surface between x = 265.0 ft
and x = 350.0 ft

Each surface terminates between x = 400.0 ft
and x = 600.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = 118.0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

17.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS :

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

****
ERROR # 48
****
Negative effective stresses have been calculated at the base of a slice. This error is usually reported for cases where slices have low self-weight and a relatively high "c" shear strength parameter. This error can only be eliminated by reducing the "c" value.
****

USER SELECTED option to maintain strength greater than zero

Factors of safety have been calculated by the :

* * * * * MODIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 11 coordinate points

Point x-surf y-surf

No.	(ft)	(ft)
1	283.89	142.13
2	300.50	145.74
3	317.01	149.78
4	333.42	154.24
5	349.70	159.12
6	365.86	164.42
7	381.87	170.12
8	397.73	176.24
9	413.43	182.76
10	428.96	189.68
11	434.58	192.36

** Corrected JANBU FOS = 1.481 ** (Fo factor =1.009)

Failure surface No. 2 specified by 10 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	302.78	148.43
2	319.44	151.80
3	335.98	155.74
4	352.37	160.23
5	368.61	165.28
6	384.66	170.87
7	400.52	177.00
8	416.15	183.67
9	431.56	190.86
10	434.37	192.29

** Corrected JANBU FOS = 1.485 ** (Fo factor =1.010)

Failure surface No. 3 specified by 12 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	265.00	135.83
2	281.74	138.81
3	298.38	142.29
4	314.91	146.27
5	331.31	150.74
6	347.57	155.70
7	363.67	161.15
8	379.60	167.08
9	395.35	173.48
10	410.90	180.35
11	426.24	187.69
12	436.59	193.03

** Corrected JANBU FOS = 1.489 ** (Fo factor =1.012)

Failure surface No. 4 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	274.44	138.98
2	291.18	141.98
3	307.77	145.68
4	324.19	150.07
5	340.42	155.14
6	356.42	160.88
7	372.17	167.28

8	387.64	174.33
9	401.32	181.27

** Corrected JANBU FOS = 1.490 ** (Fo factor =1.012)

Failure surface No. 5 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	321.67	154.72
2	338.42	157.58
3	355.04	161.18
4	371.48	165.49
5	387.72	170.53
6	403.72	176.26
7	419.46	182.70
8	434.90	189.81
9	449.50	197.33

** Corrected JANBU FOS = 1.492 ** (Fo factor =1.013)

Failure surface No. 6 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	274.44	138.98
2	291.27	141.42
3	307.97	144.60
4	324.51	148.51
5	340.87	153.13
6	357.01	158.47
7	372.91	164.51
8	388.52	171.23
9	403.82	178.64
10	418.79	186.70
11	420.28	187.59

** Corrected JANBU FOS = 1.497 ** (Fo factor =1.014)

Failure surface No. 7 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	350.00	164.17
2	366.63	167.71
3	383.12	171.81
4	399.47	176.47
5	415.66	181.66
6	431.66	187.40
7	447.46	193.67
8	461.97	200.00

** Corrected JANBU FOS = 1.500 ** (Fo factor =1.009)

Failure surface No. 8 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	283.89	142.13
2	300.74	144.34
3	317.45	147.51

4	333.94	151.63
5	350.17	156.67
6	366.10	162.63
7	381.65	169.49
8	396.79	177.22
9	406.92	183.14

** Corrected JANBU FOS = 1.503 ** (Fo factor =1.016)

Failure surface No. 9 specified by 12 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	293.33	145.28
2	310.04	148.42
3	326.66	151.98
4	343.19	155.97
5	359.61	160.37
6	375.91	165.20
7	392.08	170.43
8	408.12	176.08
9	424.01	182.13
10	439.73	188.58
11	455.29	195.43
12	464.99	200.00

** Corrected JANBU FOS = 1.506 ** (Fo factor =1.010)

Failure surface No.10 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	312.22	151.57
2	328.76	155.50
3	345.23	159.71
4	361.63	164.19
5	377.95	168.94
6	394.19	173.97
7	410.35	179.27
8	426.41	184.84
9	442.37	190.68
10	458.24	196.79
11	466.18	200.00

** Corrected JANBU FOS = 1.516 ** (Fo factor =1.006)

The following is a summary of the TEN most critical surfaces

Problem Description : Berm Height 25

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Driving Force (lb)
1.	1.481	1.009	283.89	434.58	1.751E+04
2.	1.485	1.010	302.78	434.37	1.534E+04
3.	1.489	1.012	265.00	436.59	3.034E+04
4.	1.490	1.012	274.44	401.32	1.690E+04
5.	1.492	1.013	321.67	449.50	1.811E+04
6.	1.497	1.014	274.44	420.28	2.709E+04
7.	1.500	1.009	350.00	461.97	1.180E+04

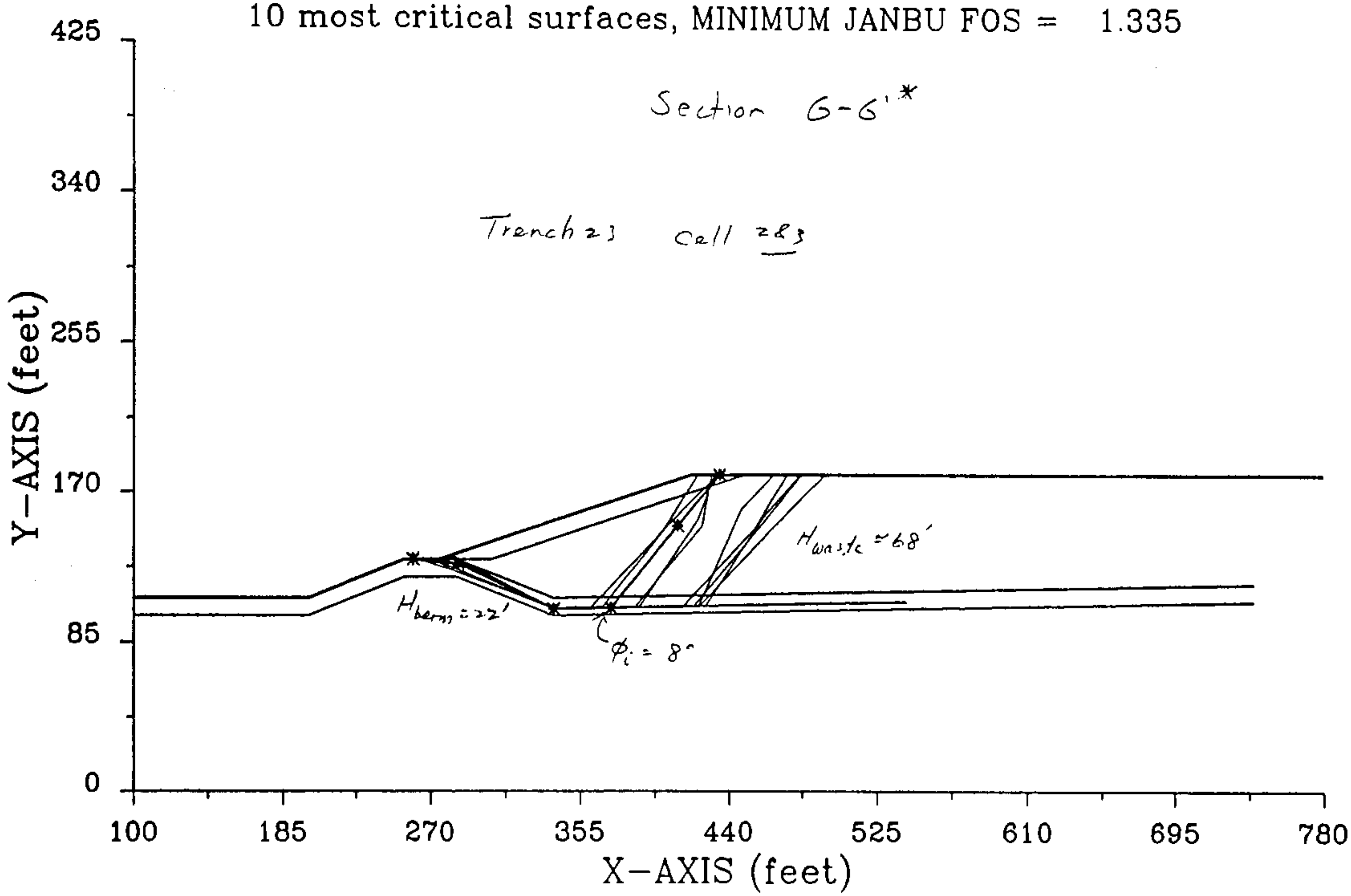
8.	1.503	1.016	283.89	406.92	2.123E+04
9.	1.506	1.010	293.33	464.99	3.209E+04
10.	1.516	1.006	312.22	466.18	1.883E+04

* * * END OF FILE * * *

STB23B23 10-22-93 16:30

Berm Height 25, Berm Crest 20, Block

10 most critical surfaces, MINIMUM JANBU FOS = 1.335



```
PROFIL                                FILE: STB23B23  10-22-93   16:30    ft
Berm Height 25, Berm Crest 20, Block
  16     6
    100.0      110.0      200.0      110.0   1
    200.0      110.0      255.0      132.0   1
    255.0      132.0      275.0      132.0   1
    275.0      132.0      419.0      180.0   4
    419.0      180.0      449.0      180.0   4
    449.0      180.0      780.0      180.0   3
    275.0      132.0      285.0      132.0   1
    285.0      132.0      305.0      132.0   3
    305.0      132.0      449.0      180.0   3
    285.0      132.0      340.0      110.0   1
    340.0      110.0      740.0      118.0   1
    100.0      100.0      200.0      100.0   2
    200.0      100.0      255.0      122.0   2
    255.0      122.0      285.0      122.0   2
    285.0      122.0      340.0      100.0   2
    340.0      100.0      740.0      108.0   2
SOIL
  4
  130.0    130.0       .0     8.00    .000        .0    0
  130.0    130.0   8000.0      .00    .000        .0    0
  110.0    110.0    650.0    15.00    .000        .0    0
  130.0    130.0       .0    26.00    .000        .0    0
BLOCK
  200    2     60.0
       340.0       104.0       341.0       104.0          .0
       342.0       104.0       542.0       108.0          .0
```

XSTABL File: STB23B23 10-22-93 16:30

```
******************************************
*                 XSTABL                 *
*                                        *
*     Slope Stability Analysis using     *
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*                                        *
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*                                        *
*        Golder Associates, Inc.         *
*         Atlanta,  GA 30341             *
*                                        *
*  Ver. 4.1                       1049   *
******************************************
```

Problem Description : Berm Height 25, Berm Crest 20, Block

SEGMENT BOUNDARY COORDINATES

6 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	100.0	110.0	200.0	110.0	1
2	200.0	110.0	255.0	132.0	1
3	255.0	132.0	275.0	132.0	1
4	275.0	132.0	419.0	180.0	4
5	419.0	180.0	449.0	180.0	4
6	449.0	180.0	780.0	180.0	3

10 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	275.0	132.0	285.0	132.0	1
2	285.0	132.0	305.0	132.0	3
3	305.0	132.0	449.0	180.0	3
4	285.0	132.0	340.0	110.0	1
5	340.0	110.0	740.0	118.0	1
6	100.0	100.0	200.0	100.0	2
7	200.0	100.0	255.0	122.0	2
8	255.0	122.0	285.0	122.0	2
9	285.0	122.0	340.0	100.0	2
10	340.0	100.0	740.0	108.0	2

ISOTROPIC Soil Parameters

4 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	130.0	.0	8.00	.000	.0	0

2	130.0	130.0	8000.0	.00	.000	.0	0
3	110.0	110.0	650.0	15.00	.000	.0	0
4	130.0	130.0	.0	26.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

200 trial surfaces will be generated and analyzed.

2 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 60.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	340.0	104.0	341.0	104.0	.0
2	342.0	104.0	542.0	108.0	.0

Factors of safety have been calculated by the :

* * * * * MODIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	259.95	132.00
2	285.88	129.36
3	340.26	104.00
4	372.52	104.61
5	410.58	151.00
6	434.95	180.00

** Corrected JANBU FOS = 1.335 ** (Fo factor =1.088)

Failure surface No. 2 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	271.75	132.00
2	285.21	126.55
3	340.81	104.00
4	388.22	104.92
5	422.30	154.31
6	431.55	180.00

** Corrected JANBU FOS = 1.351 ** (Fo factor =1.089)

Failure surface No. 3 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	278.96	133.32
2	286.17	130.07
3	340.21	104.00
4	366.66	104.49
5	404.61	150.97
6	433.24	180.00

** Corrected JANBU FOS = 1.380 ** (Fo factor =1.089)

Failure surface No. 4 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	278.21	133.07
2	286.53	131.22
3	340.00	104.00
4	360.46	104.37
5	401.80	147.86
6	422.35	180.00

** Corrected JANBU FOS = 1.390 ** (Fo factor =1.089)

Failure surface No. 5 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	270.82	132.00
2	284.65	124.96
3	340.87	104.00
4	385.61	104.87
5	424.47	150.59
6	430.07	180.00

** Corrected JANBU FOS = 1.424 ** (Fo factor =1.089)

Failure surface No. 6 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	276.15	132.38
2	285.92	129.17
3	340.39	104.00
4	413.81	105.44
5	454.75	149.30
6	473.44	180.00

** Corrected JANBU FOS = 1.429 ** (Fo factor =1.086)

Failure surface No. 7 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	279.37	133.46
2	287.02	131.45
3	340.38	104.00

4	419.81	105.56
5	458.71	151.23
6	482.11	180.00

** Corrected JANBU FOS = 1.492 ** (Fo factor =1.085)

Failure surface No. 8 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	278.26	133.09
2	284.61	126.85
3	340.09	104.00
4	426.51	105.69
5	459.78	155.62
6	481.28	180.00

** Corrected JANBU FOS = 1.495 ** (Fo factor =1.086)

Failure surface No. 9 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	282.70	134.57
2	286.66	131.02
3	340.23	104.00
4	422.81	105.62
5	464.44	148.82
6	495.52	180.00

** Corrected JANBU FOS = 1.505 ** (Fo factor =1.083)

Failure surface No.10 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	263.39	132.00
2	284.40	125.37
3	340.47	104.00
4	422.50	105.61
5	447.11	160.33
6	465.97	180.00

** Corrected JANBU FOS = 1.552 ** (Fo factor =1.087)

```
*********************************************************************
**                                                                 **
**  Out of the    200 surfaces generated and analyzed by XSTABL,   **
**       90 surfaces were found to have MISLEADING FOS values.     **
**                                                                 **
*********************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : Berm Height 25, Berm Crest 20, Block

Modified Correction Initial Terminal Driving

	JANBU FOS	Factor	x-coord (ft)	x-coord (ft)	Force (lb)
1.	1.335	1.088	259.95	434.95	1.414E+05
2.	1.351	1.089	271.75	431.55	1.432E+05
3.	1.380	1.089	278.96	433.24	1.320E+05
4.	1.390	1.089	278.21	422.35	1.239E+05
5.	1.424	1.089	270.82	430.07	1.384E+05
6.	1.429	1.086	276.15	473.44	1.761E+05
7.	1.492	1.085	279.37	482.11	1.759E+05
8.	1.495	1.086	278.26	481.28	1.715E+05
9.	1.505	1.083	282.70	495.52	1.831E+05
10.	1.552	1.087	263.39	465.97	1.525E+05

*** END OF FILE ***

TRENCH 24 Cell 4&5

Golder Associates

SUBJECT HAND CHECK – INTERNAL BERM (25' HEIGHT)		
Job No. 933-3553.4	Made by CCD	Date 10-22-93
Ref.	Checked RIO	Sheet 1 of 4
	Reviewed WRS	

OBJECTIVE: THE OBJECTIVE IS TO HAND CHECK THE SLOPE STABILITY ANALYSIS FOR THE CRITICAL SLIDING SURFACE CONSIDERING OVERALL STABILITY.

METHOD: ORDINARY METHOD OF SLICES

$$\text{SAFETY FACTOR} = \frac{\Sigma CL + \Sigma(W\cos\alpha - UL)\tan\phi}{\Sigma(W\sin\alpha)}$$

WHERE: Σ = SUMMATION
C = COHESION
L = BASE LENGTH OF SLICE
W = WEIGHT
α = SLOPE OF BASE
U = UPLIFT PRESSURE
ϕ = FRICTION ANGLE

UNIT WTS: COVER LAYER = 130 pcf
LINER = 130 pcf
WASTE = 110 pcf

Golder Associates	SUBJECT Hand Check – Internal Berm (25' Height)		
	Job No. 933-3553.4	Made by CCD	Date 10-22-93
	Ref.	Checked	Sheet 2 of 4
		Reviewed NES	

CALCULATIONS:

WEIGHTS:

$w_1 \cong 20' * 15' * 130pcf + 1/2(17-15) * 20' * 110pcf = 41,200 lbs/ft$

$w_2 = 27' * 15' * 130pcf + 1/2(39-15+17-15) * 27' * 110pcf = 91,260 lbs/ft_w$

$w_3 = 27' * 15' * 130pcf + 1/2(39-15+61-15) * 27' * 110pcf = 156,600 lb/ft_w$

$w_4 = 45' * 15' * 130pcf + 1/2(61-15+76-15) * 45 * 110pcf = 352575 lb/ft_w$

$w_5 = 37' * 15' * 130pcf + 1/2(76-15+87-15) * 37' * 110pcf = 342805 lb/ft_w$

$w_6 = 21' * 10' * 130pcf + 1/2(87-10+60-10) * 21' * 110pcf = 173985 lb/ft_w$

$w_7 = 11' * 10' * 130pcf + 1/2(60-10+40-10) * 11' * 110pcf = 62700$

$w_8 \cong 33' * 10' * 130pcf + 1/2(40-10+0) * 33' * 110pcf = 97350 lb/ft_w$

Golder Associates

SUBJECT Hand Check - Internal Berm (25' Height)

Job No. 933-3553.4 | Made by CCT | Date 10-22-93
Ref. | Checked | Sheet 3 of 4
Reviewed WES

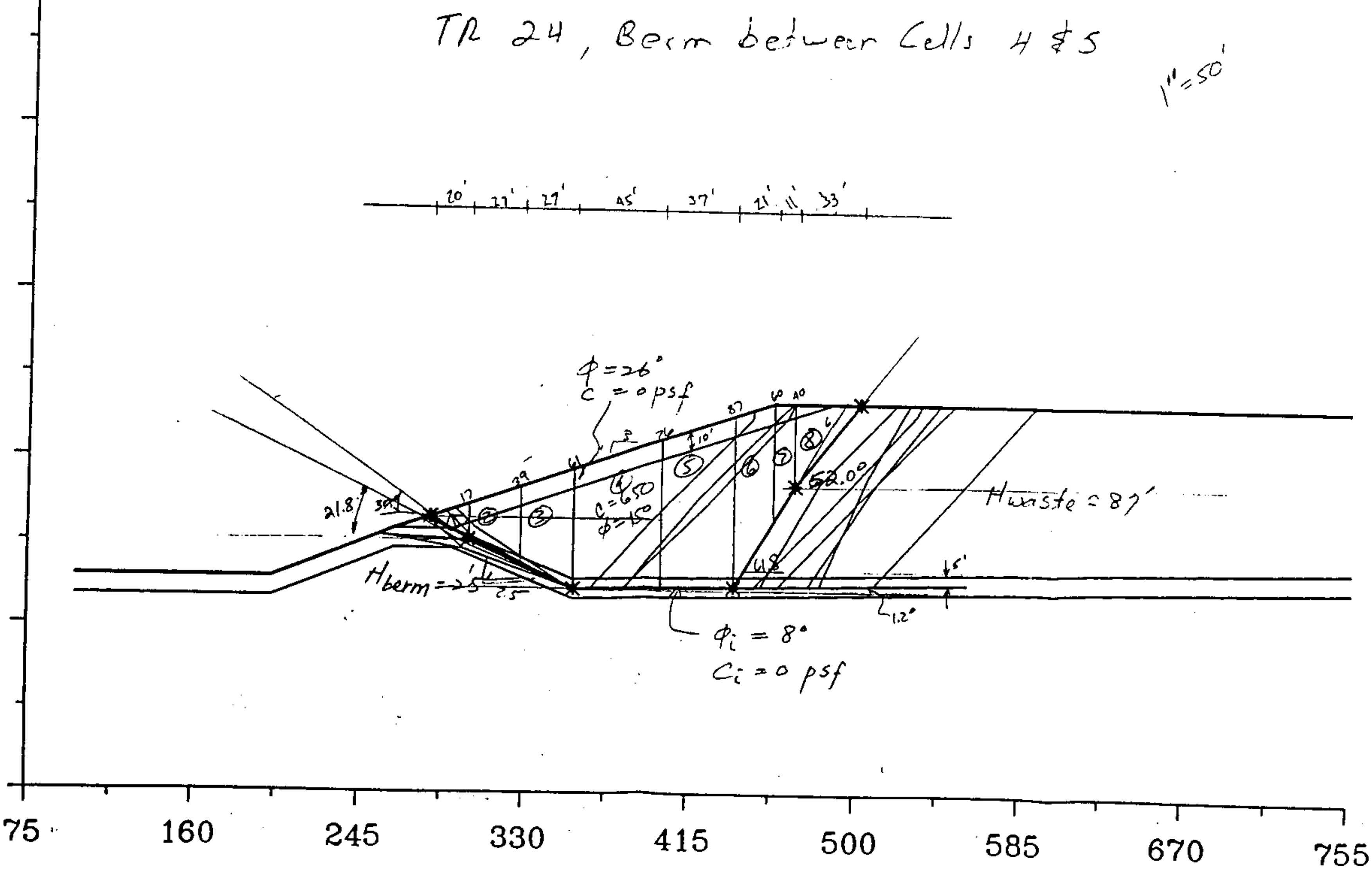
SLICE #	W (lb)	α (°)	W cos α	W sin α	C (psf)	φ (deg)	L ft	U (psf)	CL lbs/ft	W cos α - UL (lbs)	(W cos α - UL) tan φ (lbs)
1	41,200	-30.0°	35680	-20600	0	8	22	0	0	35680	5014
2	91260	-21.8°	84734	-33891	0	8	30	0	0	84734	11909
3	156600	-21.8°	145401	-58156	0	8	30	0	0	145401	20435
4	352575	1.2°	352498	7384	0	8	46	0	0	352498	49540
5	342805	1.2°	342730	7179	0	8	38	0	0	342730	48168
6	173985	61.8°	82217	153334	650	15	39	0	25350	82217	22030
7	62700	61.8°	29629	55258	650	15	20	0	13000	29629	7939
8	97350	52°	59935	76713	650	15	55	0	35750	59935	16059
				187227					74100		181094

$$S.F. = \frac{74100 + 181094}{187221} = 1.36 \checkmark$$

Compares with XSTABL Factor of 1.32

Berm Height 25

10 most critical surfaces, MINIMUM JANBU FOS = 1.324



Golder Associates	SUBJECT Perimeter berms Slope Stability Analysis		
	Job No. 933-3553.4 Ref. Emelle	Made by SYE Checked RIO Reviewed WRS	Date 9/30/93 Sheet 1 of 6

Objective: The objective is to evaluate the safety factor for the intermediate and/or the perimeter berms during construction and before waste placement. Assume short term conditions control.

Section Analyzed:

The berm is 11 ft high (including 1' Key) with 1H:1V internal slope and 3H:1V or 4H:1V external slopes.

Strength Data

Material	(psf) C	(deg) ϕ	(pcf) γ	(psf) S_u		
compacted fill	—	0	130	1300	✓	(Assumed)
Waste	650	15	110	—	✓	

Method:

The XSTABL computer program was used. Bishop's Circular slope stability analysis method with Search approach was used in the analysis.

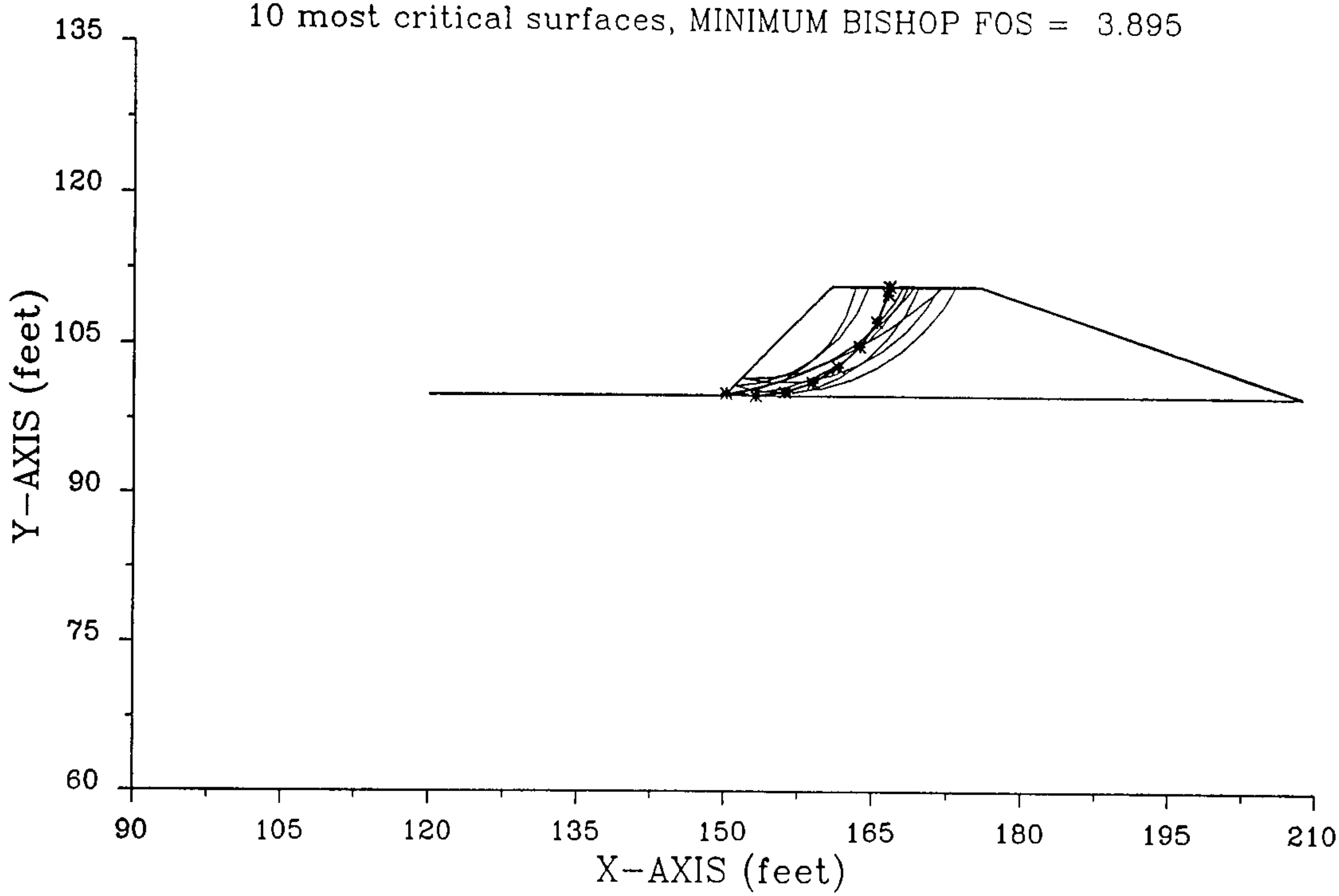
Results:

Based on the XSTABL analysis, the minimum Safety factor is about 3.9. The Computer output is attached (Sheet 2 through 6).

INTBRM1 9-30-93 14:28

INTERMEDIATE BERM STABILITY ANALYSIS

10 most critical surfaces, MINIMUM BISHOP FOS = 3.895



2/6

♠
PROFIL
INTERMEDIATE BERM STABILITY ANALYSIS FILE: INTBRM1 9-30-93 14:28 ft

```
   5     4
    120.0       100.0       150.0       100.0    1
    150.0       100.0       161.0       111.0    2
    161.0       111.0       176.0       111.0    2
    176.0       111.0       209.0       100.0    2
    150.0       100.0       209.0       100.0    1
SOIL
  2
  130.0    130.0    1300.0      .00     .000      .0    0
  110.0    110.0     650.0    15.00     .000      .0    0
CIRCL2
  20     10
    140.0       155.0       161.0       174.0
       .0          .0          .0          .0
```

XSTABL File: INTBRM1   9-30-93   14:28

4/6

```
****************************************
*                XSTABL                *
*                                      *
*    Slope Stability Analysis using    *
*   Simplified BISHOP or JANBU methods *
*                                      *
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*         All Rights Reserved          *
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*        Golder Associates, Inc.       *
*         Atlanta,  GA 30341           *
*                                      *
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****************************************
```

Problem Description : INTERMEDIATE BERM STABILITY ANALYSIS

SEGMENT BOUNDARY COORDINATES

4 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	120.0	100.0	150.0	100.0	1
2	150.0	100.0	161.0	111.0	2
3	161.0	111.0	176.0	111.0	2
4	176.0	111.0	209.0	100.0	2

1 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	150.0	100.0	209.0	100.0	1

ISOTROPIC Soil Parameters

2 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	130.0	1300.0	.00	.000	.0	0
2	110.0	110.0	650.0	15.00	.000	.0	0

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A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

200 trial surfaces will be generated and analyzed.

10 Surfaces initiate from each of 20 points equally spaced along the ground surface between x = 140.0 ft
and x = 155.0 ft

Each surface terminates between x = 161.0 ft
and x = 174.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

3.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS :

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * * MODIFIED BISHOP METHOD * * * * *

The most critical circular failure surface is specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	150.26	100.26
2	153.25	100.03
3	156.23	100.42
4	159.06	101.41
5	161.62	102.97
6	163.81	105.02
7	165.53	107.48

8	166.70	110.24
9	166.85	111.00

**** Modified BISHOP FOS = 3.895 ****

The following is a summary of the TEN most critical surfaces

Problem Description : INTERMEDIATE BERM STABILITY ANALYSIS

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Driving Moment (ft-lb)
1.	3.895	152.88	114.49	14.46	150.26	166.85	6.038E+04
2.	3.951	151.20	119.86	19.62	150.26	168.64	8.381E+04
3.	4.090	153.64	117.18	17.25	150.26	169.73	8.228E+04
4.	4.207	147.17	127.96	27.87	150.26	169.24	1.097E+05
5.	4.392	155.98	120.08	19.65	151.05	173.37	9.334E+04
6.	4.486	142.83	142.88	43.26	150.26	172.05	1.768E+05
7.	4.520	150.05	113.95	13.69	150.26	163.39	3.907E+04
8.	4.532	153.10	118.78	16.99	151.84	168.13	5.496E+04
9.	4.556	150.66	115.92	14.87	151.05	164.69	4.181E+04
10.	4.654	155.86	119.35	17.96	151.84	171.73	7.029E+04

* * * END OF FILE * * *

Golder Associates	SUBJECT Slope, stability of insitu berms, T 22, 23, 24		
	Job No. 933-3553 Ref. Emelle	Made by SYT Checked RSO Reviewed WRS	Date 10/4/93 Sheet 1 of 14

Objective: The objective is to evaluate the stability of the insitu excavated berms (chalk) prior to waste placement.

Method: The XSTABL computer program was used using search mode and circular failure surfaces

Strength parameters:

* Based on previous experience at the Emelle site, refusal of bore holes was generally reached at shallow depths. Therefore for the insitu chalk material which is about 80 - 100 ft below surface, assume that N (SPT) is about 100 (refusal) which is conservative.

Based on relationship between N & Su (sheet 3/14), for N=100 (off the chart) $\frac{S_u}{P_a} = 4.0$ (assumed)

Thus $S_u = 4 * 14.5 * 144 = 8352$ psf

Use $S_u = 8000$ psf

* From reference 1, equation 4-60, page 4-55, (see sheet 3 for reference 1)

$S_u/P_a = 0.29\ (N)^{0.72}$

Golder Associates	SUBJECT slope stability of insitu berms, T22, 23, 24		
	Job No. 933-3553	Made by SYT	Date 10/4/93
	Ref. Emelle	Checked RIO	Sheet 2 of 14
		Reviewed WRS	

Then $\frac{S_U}{14.5 \text{ psi}} = 0.29 (100)^{0.72} \simeq 8$

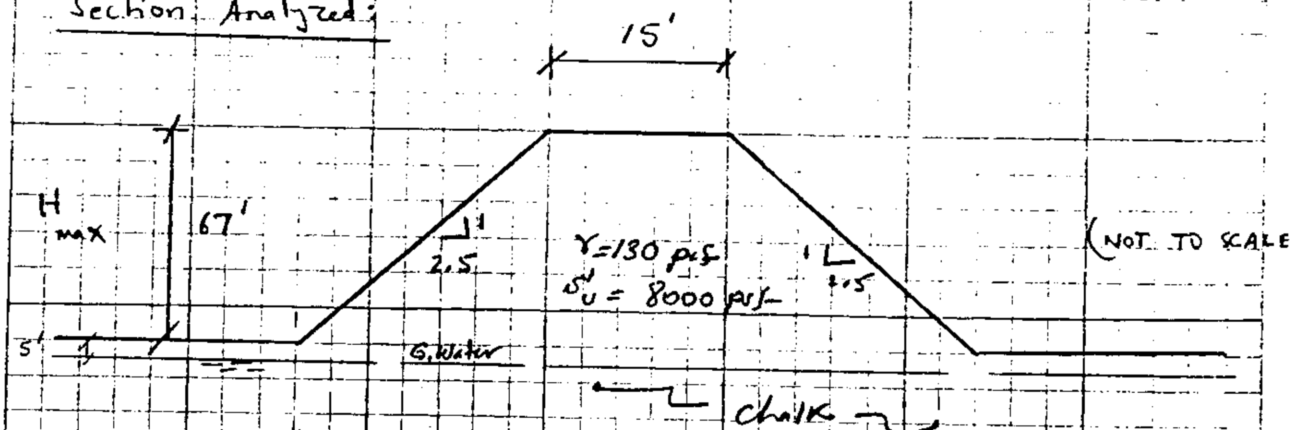
Then $S_U' = 8 * 14.5 * 144 \cong 16700$ psf

To be conservative, use $S'_{U\,design} = 8000$ psf ✓

Results:

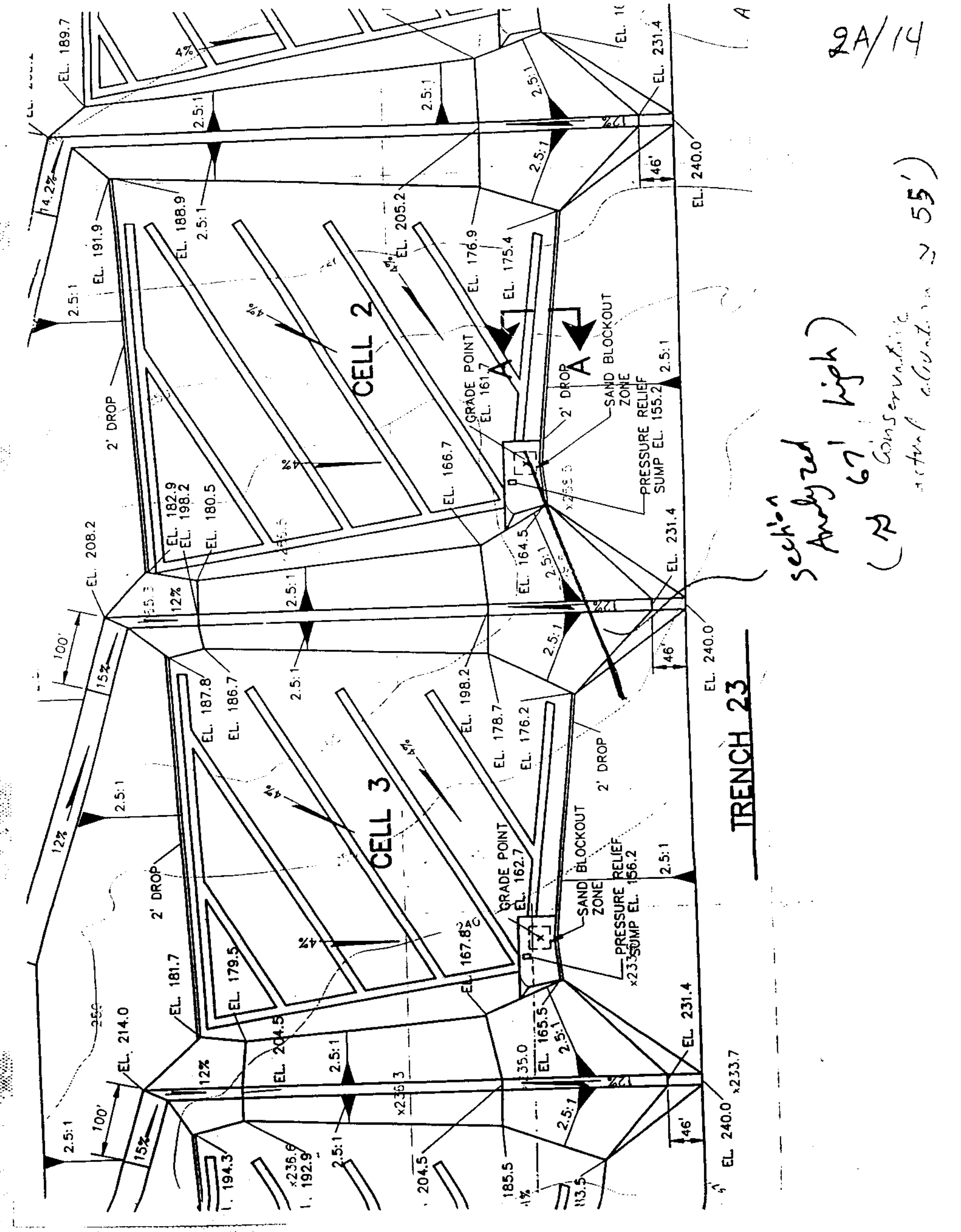
Based on the analysis, the safety factor is ~ 6.4 (see sheet 4), Hence, no problem is expected. Computer out-put is attached, sheet 5 through 14.

Section Analyzed:



Based on Excavated cell configuration, the maximum slope height is about 67 ft (conservative)

* Groundwater is assumed 5' below excavated surface because of dewatering activities during construction. (Sheet 2A shows section location).



2A/14
CELL 2
CELL 3
TRENCH 23
SAND BLOCKOUT ZONE
PRESSURE RELIEF SUMP EL. 155.2
PRESSURE RELIEF SUMP EL. 156.2
GRADE POINT EL. 161.7
GRADE POINT EL. 162.7
2' DROP
A
section analyzed
(~67' high)

Reference 1: Manual on Estimating Soil Properties for Foundation Design 3/1
EPRI EL-6800, 1990, Cornell University.

Table 4-10

APPROXIMATE s_u VERSUS N RELATIONSHIP

N Value (blows/ft or 305 mm)	Consistency	Approximate s_u/p_a
0 to 2	very soft	< 1/8
2 to 4	soft	1/8 to 1/4
4 to 8	medium	1/4 to 1/2
8 to 15	stiff	1/2 to 1
15 to 30	very stiff	1 to 2
> 30	hard	> 2

Source: Terzaghi and Peck (4), p. 347.

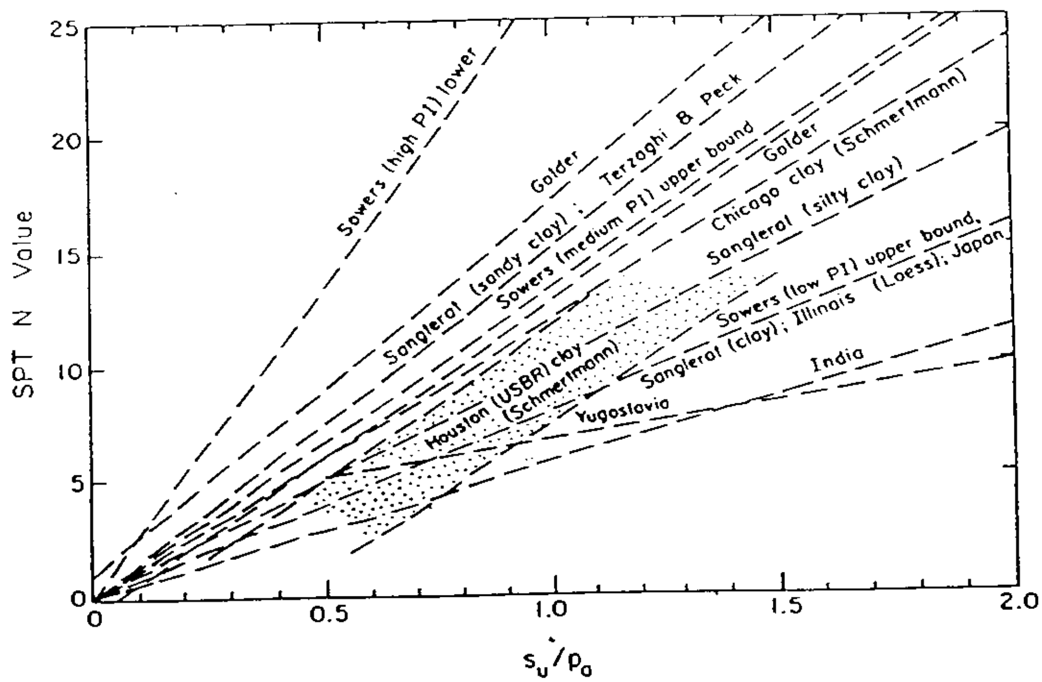


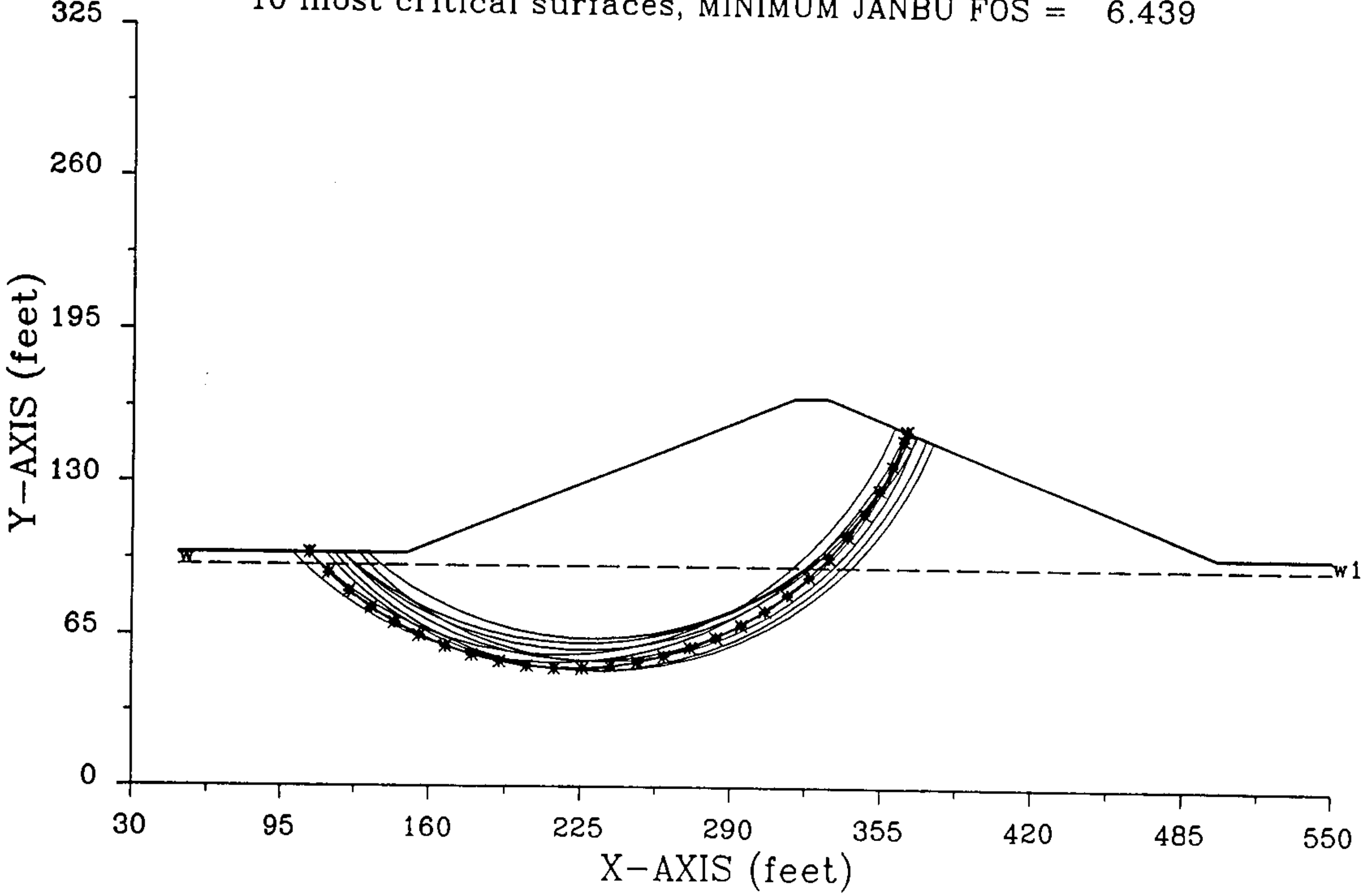
Figure 4-50. Selected Relationships Between N and s_u

Source: Djoenaidi (71), p. 5-93.

BERM-1 10-04-93 12:38

Slope Stability of Insitu Berms

10 most critical surfaces, MINIMUM JANBU FOS = 6.439



4/14

```
PROFIL                                          FILE: BERM-1     10-04-93    12:38     ft
Slope Stability of Insitu Berms
   5     5
     50.0        100.0        150.0        100.0    1
    150.0        100.0        317.5        167.0    1
    317.5        167.0        332.5        167.0    1
    332.5        167.0        500.0        100.0    1
    500.0        100.0        550.0        100.0    1
SOIL
  1
  130.0    130.0    8000.0       .00       .000        .0    0
WATER
  1       62.40
   2
        50.0          95.0
       550.0          95.0
CIRCLE
  20     10
    100.0        170.0        310.0        390.0
       .0           .0           .0           .0
```

```
*****************************************
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*  Ver. 4.1                       1049  *
*****************************************
```

Problem Description : Slope Stability of Insitu Berms

SEGMENT BOUNDARY COORDINATES

5 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	50.0	100.0	150.0	100.0	1
2	150.0	100.0	317.5	167.0	1
3	317.5	167.0	332.5	167.0	1
4	332.5	167.0	500.0	100.0	1
5	500.0	100.0	550.0	100.0	1

ISOTROPIC Soil Parameters

1 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	130.0	8000.0	.00	.000	.0	0

1 Water surface(s) have been specified

Unit weight of water =   62.40 (pcf)

Water Surface No. 1 specified by 2 coordinate points

7/14

```
**********************************
        PHREATIC SURFACE,
**********************************
```

Point No.	x-water (ft)	y-water (ft)
1	50.00	95.00
2	550.00	95.00

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

200 trial surfaces will be generated and analyzed.

10 Surfaces initiate from each of 20 points equally spaced along the ground surface between x = 100.0 ft
and x = 170.0 ft

Each surface terminates between x = 310.0 ft
and x = 390.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

12.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS :

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * * MODIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	107.37	100.00
2	115.93	91.59
3	125.11	83.86
4	134.86	76.87
5	145.13	70.65
6	155.84	65.25
7	166.94	60.68
8	178.36	56.99
9	190.03	54.20
10	201.88	52.31
11	213.84	51.34
12	225.84	51.30
13	237.80	52.19
14	249.67	54.00
15	261.35	56.72
16	272.80	60.34
17	283.92	64.83
18	294.67	70.17
19	304.98	76.32
20	314.77	83.25
21	324.01	90.91
22	332.62	99.27
23	340.56	108.27
24	347.78	117.85
25	354.24	127.96
26	359.90	138.54
27	364.73	149.53
28	366.13	153.55

** Corrected JANBU FOS = 6.439 ** (Fo factor =1.117)

Failure surface No. 2 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	100.00	100.00
2	108.92	91.98
3	118.41	84.63
4	128.41	77.99
5	138.87	72.11
6	149.73	67.00
7	160.93	62.70
8	172.42	59.23
9	184.13	56.61
10	196.00	54.85
11	207.96	53.97
12	219.96	53.96
13	231.93	54.83
14	243.81	56.58
15	255.52	59.18
16	267.01	62.64
17	278.22	66.92
18	289.09	72.02
19	299.55	77.89

9/14

20	309.56	84.52
21	319.05	91.85
22	327.98	99.86
23	336.31	108.51
24	343.98	117.74
25	350.95	127.50
26	357.20	137.75
27	362.67	148.43
28	365.03	153.99

** Corrected JANBU FOS = 6.439 ** (Fo factor =1.115)

Failure surface No. 3 specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	107.37	100.00
2	116.40	92.10
3	126.02	84.92
4	136.15	78.49
5	146.74	72.86
6	157.74	68.05
7	169.07	64.10
8	180.67	61.02
9	192.47	58.84
10	204.40	57.57
11	216.40	57.22
12	228.38	57.78
13	240.29	59.26
14	252.05	61.64
15	263.60	64.92
16	274.86	69.07
17	285.77	74.07
18	296.26	79.89
19	306.28	86.49
20	315.77	93.84
21	324.66	101.90
22	332.92	110.61
23	340.48	119.92
24	347.31	129.79
25	353.36	140.15
26	358.61	150.94
27	360.52	155.79

** Corrected JANBU FOS = 6.468 ** (Fo factor =1.115)

Failure surface No. 4 specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	122.11	100.00
2	130.75	91.68
3	140.05	84.09
4	149.93	77.29
5	160.34	71.31
6	171.19	66.19

7	182.43	61.98
8	193.97	58.70
9	205.74	56.37
10	217.66	55.00
11	229.66	54.61
12	241.64	55.20
13	253.54	56.76
14	265.27	59.28
15	276.76	62.75
16	287.93	67.14
17	298.70	72.43
18	309.00	78.58
19	318.78	85.55
20	327.95	93.29
21	336.46	101.74
22	344.25	110.87
23	351.28	120.60
24	357.49	130.87
25	362.84	141.61
26	367.30	152.75
27	367.39	153.04

** Corrected JANBU FOS = 6.510 ** (Fo factor =1.117)

Failure surface No. 5 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	114.74	100.00
2	123.25	91.54
3	132.39	83.77
4	142.10	76.72
5	152.32	70.43
6	163.00	64.95
7	174.07	60.31
8	185.45	56.53
9	197.10	53.64
10	208.94	51.66
11	220.89	50.59
12	232.89	50.44
13	244.86	51.21
14	256.74	52.90
15	268.46	55.51
16	279.94	59.00
17	291.11	63.37
18	301.92	68.58
19	312.30	74.61
20	322.18	81.42
21	331.51	88.96
22	340.23	97.21
23	348.29	106.09
24	355.65	115.58
25	362.25	125.60
26	368.06	136.09
27	373.05	147.01
28	374.26	150.30

** Corrected JANBU FOS = 6.520 ** (Fo factor =1.117)

Failure surface No. 6 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	122.11	100.00
2	131.25	92.22
3	140.96	85.19
4	151.20	78.92
5	161.89	73.48
6	172.98	68.88
7	184.39	65.16
8	196.05	62.35
9	207.90	60.45
10	219.86	59.47
11	231.86	59.43
12	243.83	60.33
13	255.69	62.16
14	267.37	64.90
15	278.80	68.55
16	289.92	73.07
17	300.65	78.45
18	310.92	84.65
19	320.68	91.62
20	329.87	99.34
21	338.43	107.75
22	346.31	116.80
23	353.46	126.44
24	359.84	136.60
25	365.41	147.23
26	367.82	152.87

** Corrected JANBU FOS = 6.525 ** (Fo factor =1.114)

Failure surface No. 7 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	122.11	100.00
2	131.58	92.63
3	141.57	85.99
4	152.03	80.11
5	162.90	75.01
6	174.11	70.74
7	185.61	67.31
8	197.33	64.75
9	209.21	63.06
10	221.19	62.26
11	233.19	62.35
12	245.15	63.33
13	257.00	65.19
14	268.68	67.93
15	280.13	71.53
16	291.28	75.96
17	302.07	81.21
18	312.44	87.25

19	322.33	94.04
20	331.70	101.55
21	340.48	109.73
22	348.63	118.54
23	356.10	127.93
24	362.85	137.85
25	368.85	148.24
26	370.56	151.78

** Corrected JANBU FOS = 6.584 ** (Fo factor =1.111)

Failure surface No. 8 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	118.42	100.00
2	126.91	91.51
3	136.02	83.71
4	145.71	76.63
5	155.91	70.32
6	166.58	64.81
7	177.63	60.14
8	189.01	56.34
9	200.65	53.42
10	212.48	51.41
11	224.43	50.32
12	236.43	50.16
13	248.41	50.92
14	260.29	52.60
15	272.01	55.19
16	283.49	58.67
17	294.67	63.03
18	305.48	68.24
19	315.86	74.27
20	325.74	81.08
21	335.07	88.63
22	343.78	96.88
23	351.84	105.77
24	359.18	115.26
25	365.78	125.29
26	371.58	135.79
27	376.55	146.71
28	377.40	149.04

** Corrected JANBU FOS = 6.587 ** (Fo factor =1.117)

Failure surface No. 9 specified by 25 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	133.16	100.00
2	142.60	92.59
3	152.60	85.96
4	163.10	80.15
5	174.03	75.20
6	185.32	71.13

13/14

7	196.90	67.97
8	208.69	65.75
9	220.62	64.48
10	232.62	64.16
11	244.60	64.80
12	256.49	66.39
13	268.22	68.93
14	279.71	72.39
15	290.89	76.76
16	301.68	82.01
17	312.02	88.10
18	321.84	95.00
19	331.08	102.65
20	339.68	111.02
21	347.59	120.05
22	354.75	129.68
23	361.11	139.85
24	366.65	150.50
25	367.68	152.93

** Corrected JANBU FOS = 6.616 ** (Fo factor =1.112)

Failure surface No.10 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	129.47	100.00
2	138.01	91.57
3	147.22	83.88
4	157.05	76.98
5	167.41	70.94
6	178.25	65.79
7	189.48	61.56
8	201.02	58.28
9	212.80	55.99
10	224.73	54.69
11	236.73	54.39
12	248.71	55.10
13	260.58	56.81
14	272.28	59.51
15	283.70	63.18
16	294.78	67.79
17	305.43	73.32
18	315.58	79.72
19	325.16	86.94
20	334.11	94.95
21	342.35	103.67
22	349.83	113.05
23	356.49	123.03
24	362.30	133.53
25	367.21	144.48
26	369.87	152.05

** Corrected JANBU FOS = 6.624 ** (Fo factor =1.118)

****

14/14

```
**                                                                  **
**  Out of the    200 surfaces generated and analyzed by XSTABL,    **
**       42 surfaces were found to have MISLEADING FOS values.      **
**                                                                  **
**********************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : Slope Stability of Insitu Berms

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Driving Force (lb)
1.	6.439	1.117	107.37	366.13	4.391E+05
2.	6.439	1.115	100.00	365.03	4.405E+05
3.	6.468	1.115	107.37	360.52	4.209E+05
4.	6.510	1.117	122.11	367.39	4.123E+05
5.	6.520	1.117	114.74	374.26	4.324E+05
6.	6.525	1.114	122.11	367.82	4.017E+05
7.	6.584	1.111	122.11	370.56	3.939E+05
8.	6.587	1.117	118.42	377.40	4.266E+05
9.	6.616	1.112	133.16	367.68	3.747E+05
10.	6.624	1.118	129.47	369.87	3.997E+05

* * * END OF FILE * * *

Analysis of Geosynthetic Liner System for the Landfill Cover System

Objective: The objective is to analyze the stability of the landfill cover slopes using 10H:1V slopes for trenches 22, 23, and 24.

Method: Use Giroud's method as presented in the below listed reference.

Reference: "Stability of Soil Layers on Geosynthetic Liner Systems" by J.P. Giroud and J.F. Beech, Geosynthetics 1989, San Diego.

Results: The minimum interface friction angle needed for this slope , with a safety factor of 1.5, is 6.2 degrees.

A. Define Unit:

$ft \equiv 1$ $\quad lb \equiv 1$ $\quad rad \equiv 1$

$deg \equiv \frac{\pi}{180} \cdot rad$ $\quad pcf \equiv 1 \cdot \frac{lb}{ft^3}$ $\quad in \equiv \frac{ft}{12}$

B. Define Parameters:

$H := 20 \cdot ft$ ......Slope Height

$\beta := atan\left(\frac{1}{10}\right) \cdot \frac{180}{\pi} \cdot deg$ ......Slope Angle

$FS := 1.50$

$T_c := 36 \cdot in$ ......Thickness of cover soil

$\gamma_{soil} := 100 \cdot pcf$ ......Soil Unit Weight

$\phi_{soil} := 26 \cdot deg$ ......Soil Friction Angle

$\phi_c := atan\left(\frac{\tan(\phi_{soil})}{FS}\right)$ ......Factored Soil Friction Angle

C. Formulate and Solve Equation:

Define a guess value for Interface Friction Angle

$\phi_i := 6$ (degree)

From Giroud and Beech, the required geogrid reinforcement force is:

$$\alpha(\phi_i) := \left(\frac{\gamma_{soil} \cdot T_c^2}{\sin(2\cdot\beta)}\right)\cdot\left[\left(2\cdot H\cdot\frac{\cos(\beta)}{T_c} - 1\right)\cdot\left(\frac{\sin(\beta - \phi_i\cdot deg)}{\cos(\phi_i\cdot deg)}\right) - \left(\frac{\sin(\phi_c)}{\cos(\beta + \phi_c)}\right)\right]$$

$$\phi_{i\_FS}(\phi_i) := \operatorname{atan}(FS\cdot\tan(\phi_i\cdot deg))\cdot(deg^{-1})$$

$$\phi_{i\_critical} := \operatorname{root}(\alpha(\phi_i), \phi_i)$$

$$\phi_{i\_critical} = 4.1$$

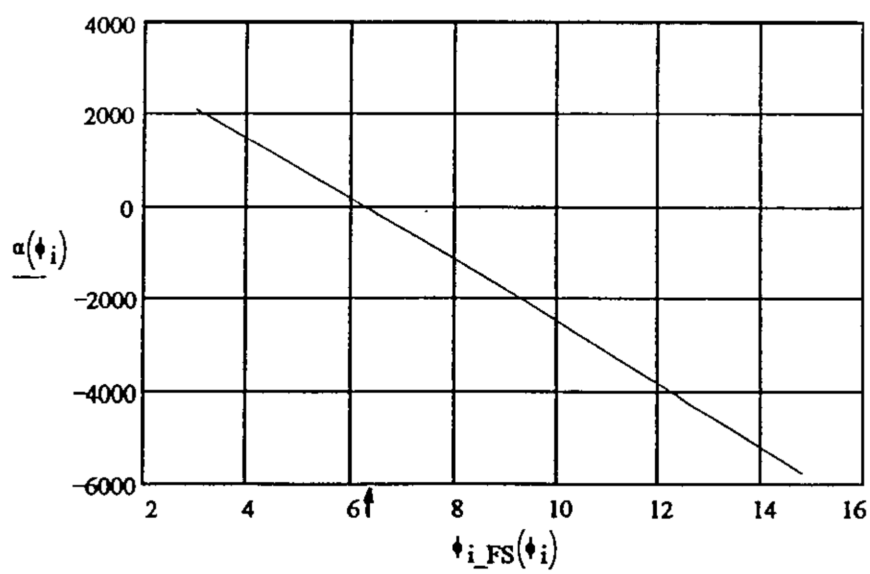
$\phi_{i\_FS}(\phi_{i\_critical}) = 6.2$ (degree) ......Required Interface Friction Angle with Factor of Safety

D. Interface Friction Angle vs. Required Tensile Force Table:

$\phi_i := 2..10$ ......Selected Interface Friction Angle Range, degree

ϕ_i	$\phi_{i\_FS}(\phi_i)$	$\alpha(\phi_i)$ (lbs/ft.)
2	3	2075
3	4.5	1105
4	6	133
5	7.5	-841
6	9	-1818
7	10.4	-2799
8	11.9	-3784
9	13.4	-4774
10	14.8	-5770

E. Interface Friction Angle vs. Required Tensile Force Plot:



Analysis of Geosynthetic Liner System for the Landfill Cover System

Objective: The objective is to analyze the stability of the landfill cover slopes using 4H:1V slopes for trenches 22, 23, and 24.

Method: Use Giroud's method as presented in the below listed reference.

Reference: "Stability of Soil Layers on Geosynthetic Liner Systems" by J.P. Giroud and J.F. Beech, Geosynthetics 1989, San Diego.

Results: The minimum interface friction angle needed for this slope, with a safety factor of 1.5, is 18.1 degrees.

A. Define Unit:

$ft \equiv 1$ $\quad lb \equiv 1$ $\quad rad \equiv 1$

$deg \equiv \frac{\pi}{180} \cdot rad$ $\quad pcf \equiv 1 \cdot \frac{lb}{ft^3}$ $\quad in \equiv \frac{ft}{12}$

B. Define Parameters:

$H := 20 \cdot ft$ ......Slope Height

$\beta := atan\left(\frac{1}{4}\right) \cdot \frac{180}{\pi} \cdot deg$ ......Slope Angle

$FS := 1.50$

$T_c := 36 \cdot in$ ......Thickness of cover soil

$\gamma_{soil} := 100 \cdot pcf$ ......Soil Unit Weight

$\phi_{soil} := 26 \cdot deg$ ......Soil Friction Angle

$\phi_c := atan\left(\frac{tan(\phi_{soil})}{FS}\right)$ ......Factored Soil Friction Angle

C. Formulate and Solve Equation:

Define a guess value for Interface Friction Angle

$\phi_i := 8$ (degree)

From Giroud and Beech, the required geogrid reinforcement force is:

$$\alpha(\phi_i) := \left(\frac{\gamma_{soil} \cdot T_c^2}{\sin(2\cdot\beta)}\right)\cdot\left[\left(2\cdot H\cdot\frac{\cos(\beta)}{T_c} - 1\right)\cdot\left(\frac{\sin(\beta - \phi_i\cdot deg)}{\cos(\phi_i\cdot deg)}\right) - \left(\frac{\sin(\phi_c)}{\cos(\beta + \phi_c)}\right)\right]$$

$$\phi_{i\_FS}(\phi_i) := atan(FS\cdot\tan(\phi_i\cdot deg))\cdot(deg^{-1})$$

$$\phi_{i\_critical} := root(\alpha(\phi_i), \phi_i)$$

$$\phi_{i\_critical} = 12.3$$

$\phi_{i\_FS}(\phi_{i\_critical}) = 18.1$ (degree) ......Required Interface Friction Angle with Factor of Safety

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LANDFILL DESIGN CALCULATION PACKAGE

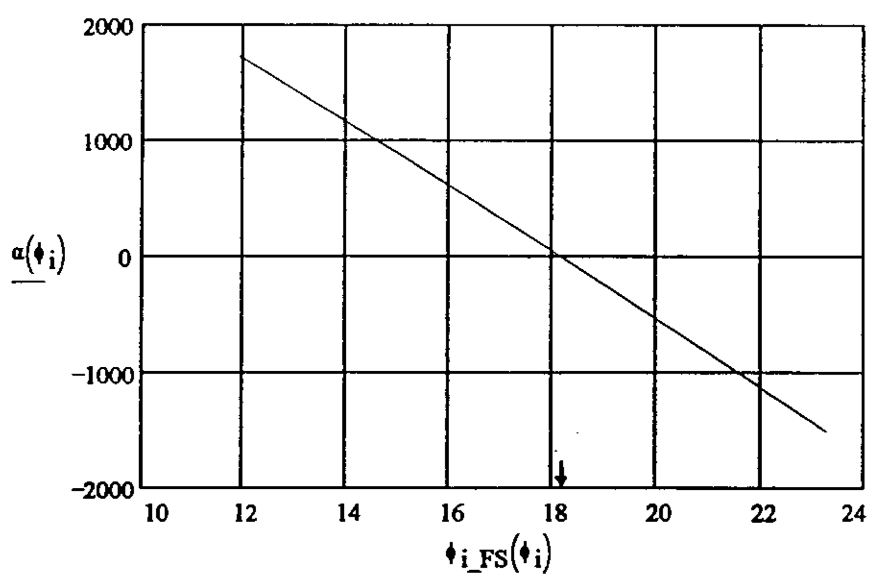
JOB NO.	933-3553	Page: 3/3	
MADE BY	SYI		
CHECKED	RIO		
REVIEWED			

D. Interface Friction Angle vs. Required Tensile Force Table:

$\phi_i := 8 .. 16$ ......Selected Interface Friction Angle Range, degree

ϕ_i	$\phi_{i\_FS}(\phi_i)$	$\alpha(\phi_i)$ (lbs/ft.)
8	11.9	1726
9	13.4	1331
10	14.8	934
11	16.3	534
12	17.7	131
13	19.1	-274
14	20.5	-683
15	21.9	-1095
16	23.3	-1511

E. Interface Friction Angle vs. Required Tensile Force Plot:



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SUBJECT Stability of Recompacted Slope		
Job No. 933-3553 Ref.	Made by D. Jang Checked RID Reviewed WRS	Date 10/25/93 Sheet 1 of

Objective: To determine stability of compacted chalk side slope.

Approach: Use XSTABL slope stability analysis program to perform the analysis.

Assumptions: 1.) compacted chalk properties (based on lab tests)

$\phi = 26°$
$c = 600$ psf
$\gamma = 130$ pcf

2.) Chalk is compacted to a width of 25ft on a 2.5H to 1V slope.

3.) The groundwater table is assumed to be 20 ft below the ground surface & along slope surface

4.) The failure surface is assumed to be through the interface of compacted chalk and natural intact chalk.

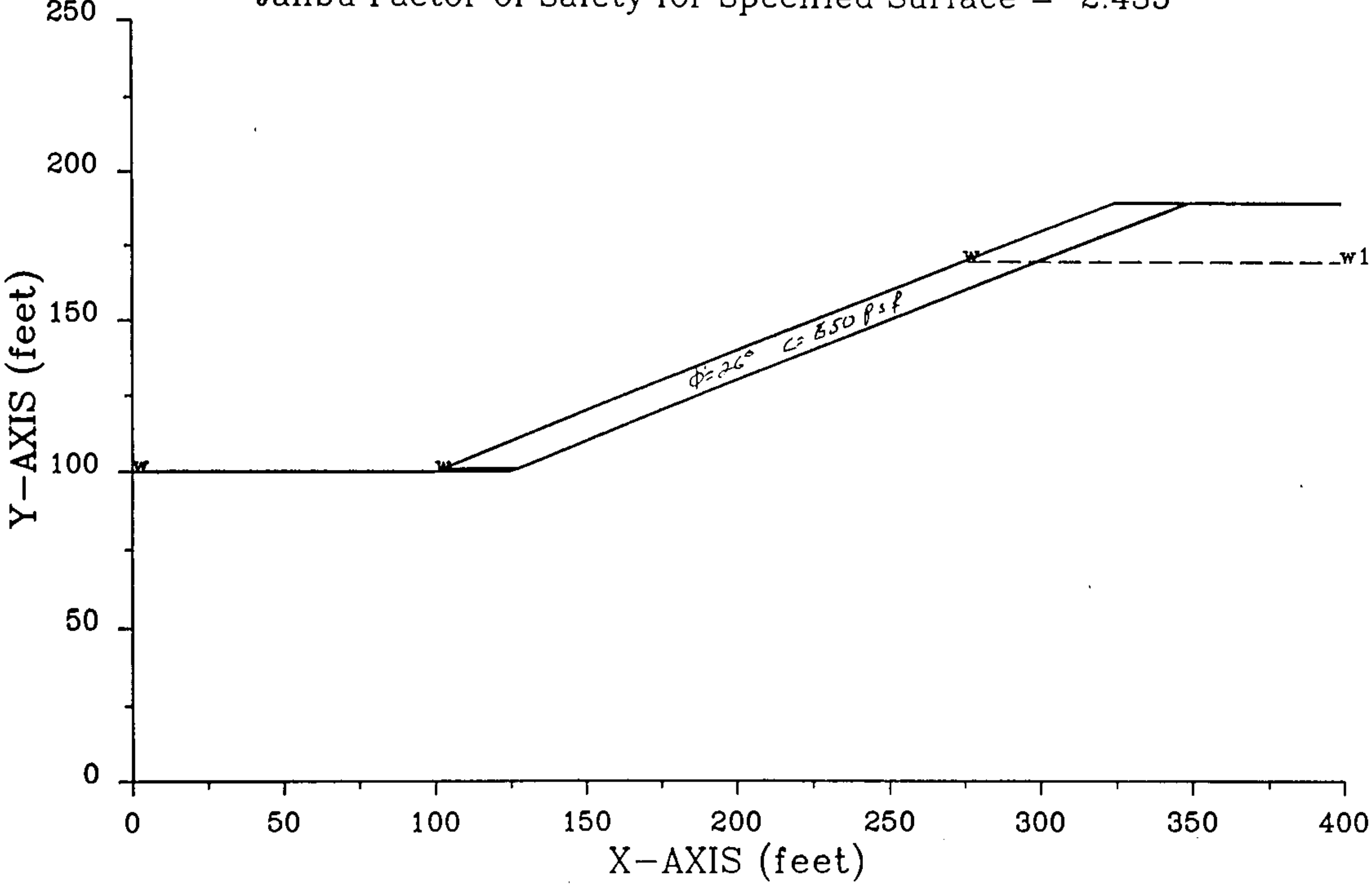
Analysis: As shown in the output attached in the following pages.

Conclusion: The calculated Factor of Safety is 2.4 which is higher than FOS=1.5. The stability of the slope is adequate.

SLOPEFIL 10-26-93 14:24

SLOPE FILL WITH 20' WATER

Janbu Factor of Safety for Specified Surface = 2.435



```
PROFIL                              FILE: SLOPEFIL  10-26-93   14:24    ft
SLOPE FILL WITH 20' WATER
   6     4
      .0       100.0      100.0      100.0   2
   100.0       100.0      325.0      190.0   1
   325.0       190.0      350.0      190.0   1
   350.0       190.0      400.0      190.0   2
   100.0       100.0      125.0      100.0   2
   125.0       100.0      350.0      190.0   2
SOIL
  2
  130.0    130.0    600.0    26.00     .000        .0    1
  130.0    130.0   8000.0      .00     .000        .0    0
WATER
  1       62.40
   4
          .0        100.0
       100.0        100.0
       275.0        170.0
       400.0        170.0
SURFAC
   3
   102.50      101.00
   127.50      101.00
   349.00      190.00
```

XSTABL File: SLOPEFIL 10-26-93 14:24

```
*******************************************
*                 XSTABL                  *
*                                         *
*     Slope Stability Analysis using      *
*   Simplified BISHOP or JANBU methods    *
*                                         *
*          Copyright (C) 1993             *
*   Interactive Software Designs, Inc.    *
*          All Rights Reserved            *
*                                         *
*                                         *
*        Golder Associates, Inc.          *
*          Atlanta,  GA 30341             *
*                                         *
* Ver. 4.1                          1049  *
*******************************************
```

Problem Description : SLOPE FILL WITH 20' WATER

SEGMENT BOUNDARY COORDINATES

4 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	100.0	100.0	100.0	2
2	100.0	100.0	325.0	190.0	1
3	325.0	190.0	350.0	190.0	1
4	350.0	190.0	400.0	190.0	2

2 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	100.0	100.0	125.0	100.0	2
2	125.0	100.0	350.0	190.0	2

ISOTROPIC Soil Parameters

2 type(s) of soil

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	130.0	130.0	600.0	26.00	.000	.0	1
2	130.0	130.0	8000.0	.00	.000	.0	0

1 Water surface(s) have been specified

Unit weight of water = 62.40 (pcf)

Water Surface No. 1 specified by 4 coordinate points

****
PHREATIC SURFACE,
****

Point No.	x-water (ft)	y-water (ft)
1	.00	100.00
2	100.00	100.00
3	275.00	170.00
4	400.00	170.00

Trial failure surface specified by 3 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	102.50	101.00
2	127.50	101.00
3	349.00	190.00

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION :
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	115.00	101.00	5.000	25.000	.000	21.801	16250.0
2	201.25	130.63	9.867	147.500	21.891	21.801	189196.3
3	287.11	165.13	9.712	24.225	21.891	21.801	30584.4
4	312.11	175.18	9.667	25.775	21.891	21.801	32390.8
5	337.00	185.18	4.822	24.000	21.891	.000	15043.6

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	phi	c-value (psf)	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	381.0	26.00	600.0	6724.1	.0	.0	.00
2	602.2	26.00	600.0	84371.5	.0	.0	.00
3	793.5	26.00	600.0	7928.4	.0	.0	.00
4	1068.8	26.00	600.0	.0	.0	.0	.00
5	486.5	26.00	600.0	.0	.0	.0	.00

For the single specified surface,
Corrected JANBU factor of safety = 2.435 (Fo factor =1.015)

Resisting Shear Strength = 240.28E+03 lb
Total Driving Shear Force = 100.22E+03 lb

Golder Associates	SUBJECT Height of Soil Cover on Side Slope		
	Job No. 933-3553.4 Ref. Emelle	Made by RJO/D. Jang Checked CW Reviewed RSO	Date 10/26/93 Sheet 1 of 17

Objective: Determine the maximum height of soil cover on 2.5:1 side slopes with buldozer Operation for a FOS = 1.5

Methodology: * Use Giroud's Method of analysis, modified to include cohesion along sliding surface in toe buttress, to determine tensile stresses in the liner components.

Assumptions: * The geotextile and the geonet in the primary leachate collection system will be subject to tensile stresses.

* The critical sliding interface will be between the geonet and the smooth geomembrane.

* A D6D (Low ground pressure) dozer will be used (conservative)

* The soil cover will be under undrained loading conditions.

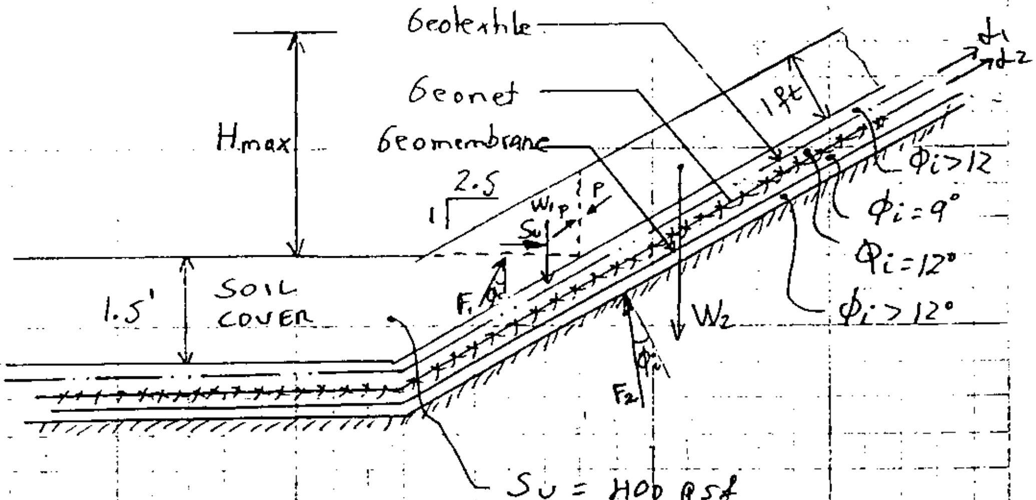
Golder Associates

SUBJECT Height of Soil Cover on Side slope		
Job No. 933-3553.4 Ref.	Made by RIO/D.Jang Checked Reviewed RIO	Date 10/26/93 Sheet 2 of 17

* The following shear strength parameters are applicable:

- Geotextile/Geonet $\phi_i = 12°$
- Geonet/Geomembrane $\phi_i = 9°$
- Soil Cover $S_u = 400$ psf.

Geometry:



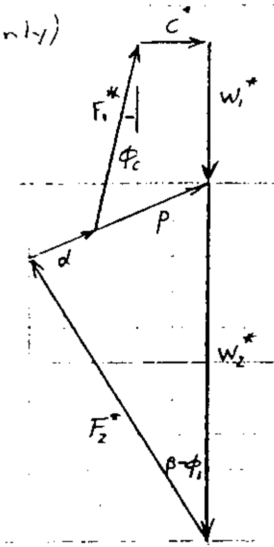
Results:

- Use $H_{max} = 8$ ft. (FOS = 1.5)
- Tensile stress in geotextile is ~ 50 lb/ft
- Tensile stress in geonet is ~ 400 lb/ft.

Golder Associates

SUBJECT Liner Slope Stability		
Job No. 933-3553	Made by D. Tony	Date 10/26/93
Ref.	Checked RDO	Sheet 3 of 17
	Reviewed RDO	

Derive the force polygon equation in the Giroud's method with cohesion c. (buttress only)



$$F_1^* \sin\phi_c + c^* = P \cdot \cos\beta$$

$$F_1^* \cos\phi_c = W_1^* + P \cdot \sin\beta$$

$$\Rightarrow W_1^* = F_1^* \cdot \cos\phi_c - P \cdot \sin\beta$$

$$= \left(\frac{P\cos\beta - c^*}{\sin\phi_c}\right) \cdot \cos\phi_c - P \cdot \sin\beta$$

$$W_1^* = P \cdot \frac{\cos\beta \cdot \cos\phi_c}{\sin\phi_c} - c^* \cdot \frac{\cos\phi_c}{\sin\phi_c} - P \cdot \sin\beta$$

$$\cos\beta \cdot \cos\phi_c - \sin\beta \cdot \sin\phi_c = \cos(\beta + \phi_c)$$

$$\Rightarrow P = \frac{\sin\phi_c}{\cos(\beta+\phi_c)} \cdot W_1^* + \frac{\cos\phi_c}{\cos(\beta+\phi_c)} \cdot c^*$$

From Giroud's paper:

$$d = W_2^* \cdot \frac{\sin(\beta - \phi_i)}{\cos\phi_i} - P$$

$$= \left\{ W_2^* \cdot \frac{\sin(\beta-\phi_i)}{\cos\phi_i} - W_1^* \cdot \frac{\sin\phi_c}{\cos(\beta+\phi_c)} \right\} - \frac{\cos\phi_c}{\cos(\beta+\phi_c)} \cdot c^*$$

(term inserted into the equation)

Use the MathCAD to perform the calculation.

* See sheet 12/17 for two part wedge diagram with loads without cohesion (Giroud's Method)

Golder Associates	SUBJECT Height of Soil Cover on Side Slope		
	Job No. 933-3553.4	Made by RJO/D.Jang	Date 10/26/93
	Ref.	Checked	Sheet 4 of 17
		Reviewed RJO	

From material supplier's physical properties data (sheets 13/17 & 14/17), the following are the ultimate tensile strengths for the liner components:

Liner Component	Tensile Strength (lb/ft)	Strain (%)
Geotextile (1155)	3360 *	75%
Geonet (PN 3000)	600 *	~25%
Geotextile (1155)	1500	~25%
* Ultimate		

From the above data, the geonet tensile strength controls. For a factor of safety (F.O.S) of FOS = 1.5, the allowable tensile strength is:

$$\mathcal{L}_{all} = \frac{600}{1.5} = 400 \text{ lbs/ft}$$

For $\mathcal{L}_{all} = 400$ lbs/ft, $H_{max} = 8$ ft (sheet 10/17)

Analysis of Geosynthetics Liner System with Bulldozer Operation

A. Define Parameters:

$i := 1, 2..6$

$H_i := 2 \cdot i \cdot ft$ ......Soil Cover Layer Height in each lift

$\beta := atan\left(\frac{1}{2.5}\right) \cdot \frac{180}{\pi} \cdot deg$ $\beta = 21.8 \cdot deg$ ......Slope Angle

$FS := 1.0$ ......Factor of Safety

$T_c := 12 \cdot in$ ......Average Sand Cover Layer Thickness in each Lift

$\gamma := 110 \cdot \frac{lbf}{ft^3}$ ......Sand Layer Unit Weight

$\phi_1 := 0 \cdot deg$ ......Soil Layer Friction Angle

$\phi_{soil} := atan\left(\frac{tan(\phi_1)}{FS}\right)$ $\phi_{soil} = 0 \cdot deg$ ......Factored Soil Layer Friction Angle

$S_u := 400 \cdot \frac{lbf}{ft^2}$ ......Soil Undrained Shear Strength

$\phi_2 := 12 \cdot deg$ ......Geotextile/Geonet Interface Friction Angle

$\phi_i := atan\left(\frac{tan(\phi_2)}{FS}\right)$ $\phi_i = 12 \cdot deg$ ......Factored Geocomposite/Geomembrane Interface Friction Angle

B. Calculate pressure exerted on top of Geosynthetics from a Bulldozer:

Bulldozer - D6D LGP dozer (low ground pressure)

Assuming that the dozer will not operate on top of the geosynthetics until 1.5 feet of soil cover is placed.

Data obtained from CAT. performance handbook (see reference):

One track shoe width W_T: 36 inches

One track length L_T: 113 inches

Operating weight: 38,300 lbs

Contact area: 8,300 square inches

Ground pressure P: 4.6 psi @ contact point

The contact pressure of 4.6 psi will be dissipated through the 1.5 feet of soil cover before it is exerted on the geosynthetics. Assume simplified pyramid stress dissipation approach. Stress extended to cover soil below at 1H:2V angle.

$H\_ratio := 1 \qquad V\_ratio := 2$

$W_T := 36 \cdot in \qquad L_T := 113 \cdot in$

$$P := 4.6 \cdot \frac{lbf}{in^2} \qquad \text{...... Contact Pressure}$$

$$P_D := P \cdot \frac{W_T}{W_T + 2 \cdot T_c \cdot \left(\frac{H\_ratio}{V\_ratio}\right)}$$

Weight of dozer = pressure on geosynthetic x 1 foot x track length

$$W_D := P_D \cdot L_T$$

$$W_D = 4678.2 \cdot \frac{lbf}{ft}$$

C. Formulate and Solve Equation:

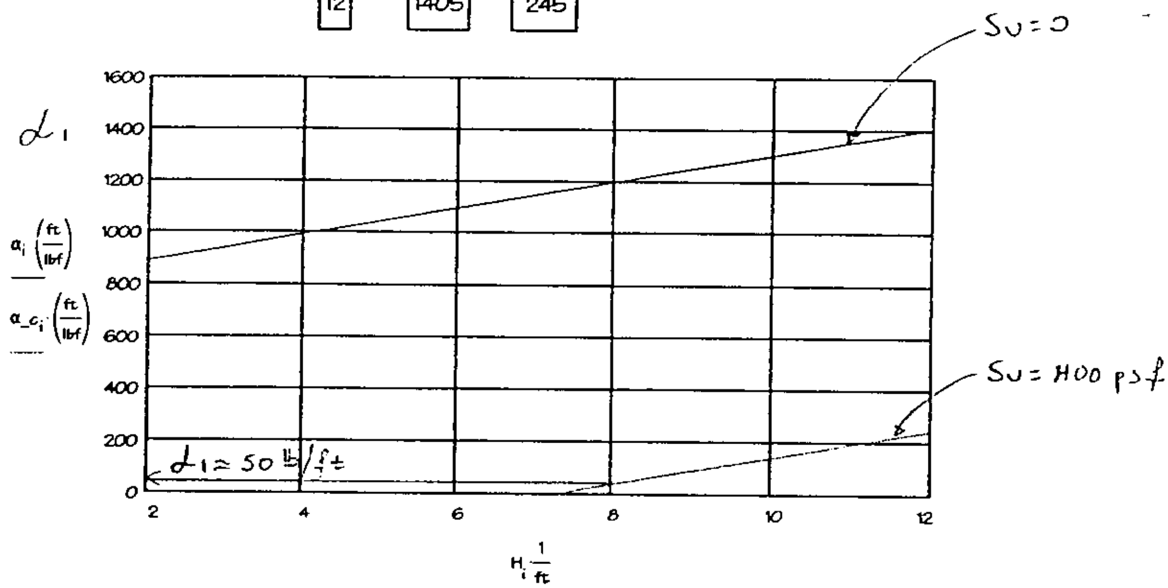
From Giroud and Beech, the required geogrid reinforcement force is:

$$\alpha_i := \frac{\gamma \cdot T_c^{\,2}}{\sin(2 \cdot \beta)} \cdot \left[\left(2 \cdot H_i \cdot \frac{\cos(\beta)}{T_c} - 1\right) \cdot \left(\frac{\sin(\beta - \phi_i)}{\cos(\phi_i)}\right) - \frac{\sin(\phi_{soil})}{\cos(\beta + \phi_{soil})}\right] + W_D \cdot \frac{\sin(\beta - \phi_i)}{\cos(\phi_i)}$$

$$\alpha\_c_i := \alpha_i - S_u \cdot \frac{T_c}{\sin(\beta)} \cdot \frac{\cos(\phi_{soil})}{\cos(\beta + \phi_{soil})} \qquad \frac{T_c}{\sin(\beta)} = 2.69 \cdot ft \qquad \frac{\cos(\phi_{soil})}{\cos(\beta + \phi_{soil})} = 1.08$$

Golder Associates	LANDFILL DESIGN CALCULATION PACKAGE		
		JOB NO. 933-3553	Page: 7/17
		MADE BY	D. Jang
		CHECKED	RDO
		REVIEWED	RDO

H_i (ft)	α_i (lbf/ft)	α_c_i (lbf/ft)
2	890	-270
4	993	-167
6	1096	-64
8	1199	39
10	1302	142
12	1405	245



Geotextile

Analysis of Geosynthetics Liner System with Bulldozer Operation

A. Define Parameters:

$i := 1, 2..6$

$H_i := 2 \cdot i \cdot ft$ ......Soil Cover Layer Height in each lift

$\beta := atan\left(\frac{1}{2.5}\right) \cdot \frac{180}{\pi} \cdot deg$ $\quad \beta = 21.8 \cdot deg$ ......Slope Angle

$FS := 1.0$ ......Factor of Safety

$T_c := 12 \cdot in$ ......Average Sand Cover Layer Thickness in each Lift

$\gamma := 110 \cdot \frac{lbf}{ft^3}$ ......Sand Layer Unit Weight

$\phi_1 := 0 \cdot deg$ ......Soil Layer Friction Angle

$\phi_{soil} := atan\left(\frac{\tan(\phi_1)}{FS}\right)$ $\quad \phi_{soil} = 0 \cdot deg$ ......Factored Soil Layer Friction Angle

$S_u := 400 \cdot \frac{lbf}{ft^2}$ ......Soil Undrained Shear Strength

$\phi_2 := 9 \cdot deg$ ......~~Geotextile~~/Geonet / Geomembrane Interface Friction Angle

$\phi_i := atan\left(\frac{\tan(\phi_2)}{FS}\right)$ $\quad \phi_i = 9 \cdot deg$ ......Factored Geocomposite/Geomembrane Interface Friction Angle

B. Calculate pressure exerted on top of Geosynthetics from a Bulldozer:

Bulldozer - D6D LGP dozer (low ground pressure)

Assuming that the dozer will not operate on top of the geosynthetics until 1.5 feet of soil cover is placed.

Data obtained from CAT. performance handbook (see reference):

One track shoe width W_T: 36 inches

One track length L_T: 113 inches

Operating weight: 38,300 lbs

Contact area: 8,300 square inches

Ground pressure P: 4.6 psi @ contact point

The contact pressure of 4.6 psi will be dissipated through the 1.5 feet of soil cover before it is exerted on the geosynthetics. Assume simplified pyramid stress dissipation approach. Stress extended to cover soil below at 1H:2V angle.

$H\_ratio := 1 \qquad V\_ratio := 2$

$W_T := 36 \cdot in \qquad L_T := 113 \cdot in$

$P := 4.6 \cdot \frac{lbf}{in^2}$ ...... Contact Pressure

$$P_D := P \cdot \frac{W_T}{W_T + 2 \cdot T_c \cdot \left(\frac{H\_ratio}{V\_ratio}\right)}$$

Weight of dozer = pressure on geosynthetic x 1 foot x track length

$W_D := P_D \cdot L_T$

$W_D = 4678.2 \cdot \frac{lbf}{ft}$

C. Formulate and Solve Equation:

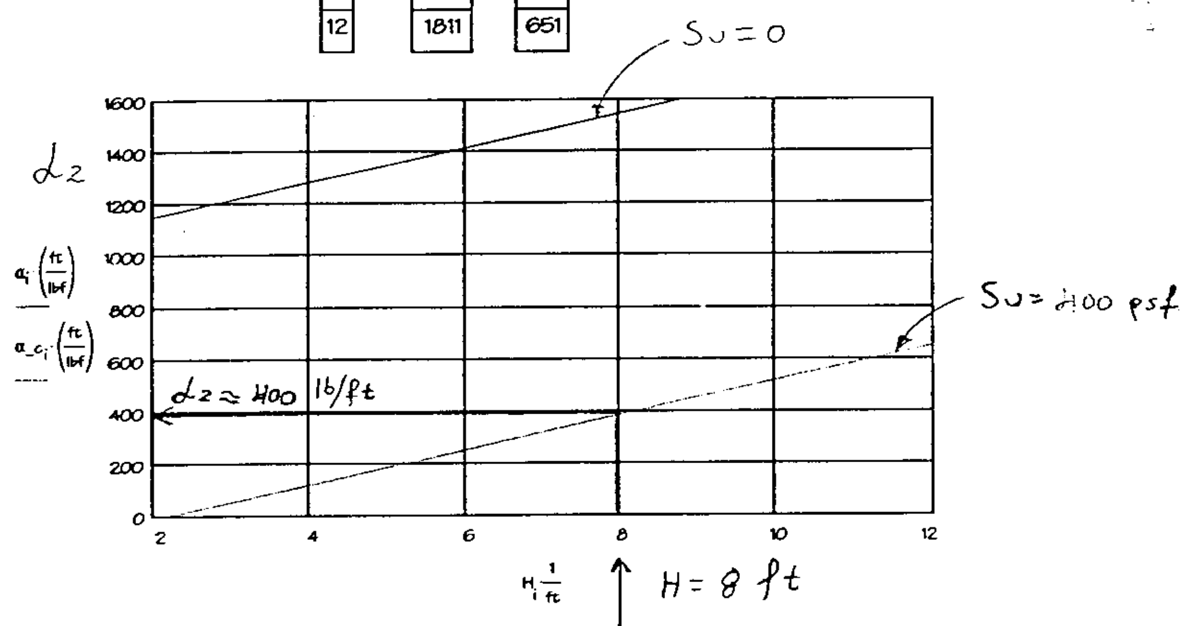
From Giroud and Beech, the required geogrid reinforcement force is:

$$\alpha_i := \frac{\gamma \cdot T_c^2}{\sin(2 \cdot \beta)} \cdot \left[\left(2 \cdot H_i \cdot \frac{\cos(\beta)}{T_c} - 1\right) \cdot \left(\frac{\sin(\beta - \phi_i)}{\cos(\phi_i)}\right) - \frac{\sin(\phi_{soil})}{\cos(\beta + \phi_{soil})}\right] + W_D \cdot \frac{\sin(\beta - \phi_i)}{\cos(\phi_i)}$$

$$\alpha\_c_i := \alpha_i - S_u \cdot \frac{T_c}{\sin(\beta)} \cdot \frac{\cos(\phi_{soil})}{\cos(\beta + \phi_{soil})} \qquad \frac{T_c}{\sin(\beta)} = 2.69 \cdot ft \qquad \frac{\cos(\phi_{soil})}{\cos(\beta + \phi_{soil})} = 1.08$$

Golder Associates	LANDFILL DESIGN CALCULATION PACKAGE		
		JOB NO. 933-3553	Page: 10/17
		MADE BY	D. Tang
		CHECKED	RSO
		REVIEWED	RIO

H_i (ft)	α_i (lbf/ft)	α_c_i (lbf/ft)
2	1147	-13
4	1279	119
6	1412	252
8	1545	385
10	1678	518
12	1811	651



Geonet

REFERENCES:

1). Koerner, Robert, "Designing with Geosynthetics", Prentice-Hall, 1986.

2) Williams, N.D., Haulihan, M., "Evaluation of Friction Coefficients between Geomembranes, Geotextiles, and Related Products", 3rd International Conference on Geotextiles, Vienna, Austria, 1986.

3) Seed, R.B., Boulanger, R.W., "Smooth-Clay Liner Interface Shear Strengths: Compaction Effects", Journal of Geotechnical Engineering, ASCE, April 1991.

4) Caterpillar Performance Handbook, Edition 11, Caterpillar Tractor Company, 1980.

5) Martin, J.P., Koerner, et. al., "Experimental Friction Evaluation of Slipage Between Geomembranes, Geotextiles, and Soils", Proceedings International Conference on Geomembranes, Denver, Colorado, June 1984.

6) Giroud, J.P., Beech, J.F., "Stability of Soil Layers on Geosynthetic Liner Systems", Geosynthetics '89 conference, San Diego, 1989.

7) "Geotechnics of Waste Fills - Theory and Practice", ASTM STP. 1070.

Giroud's Method
without cohesion

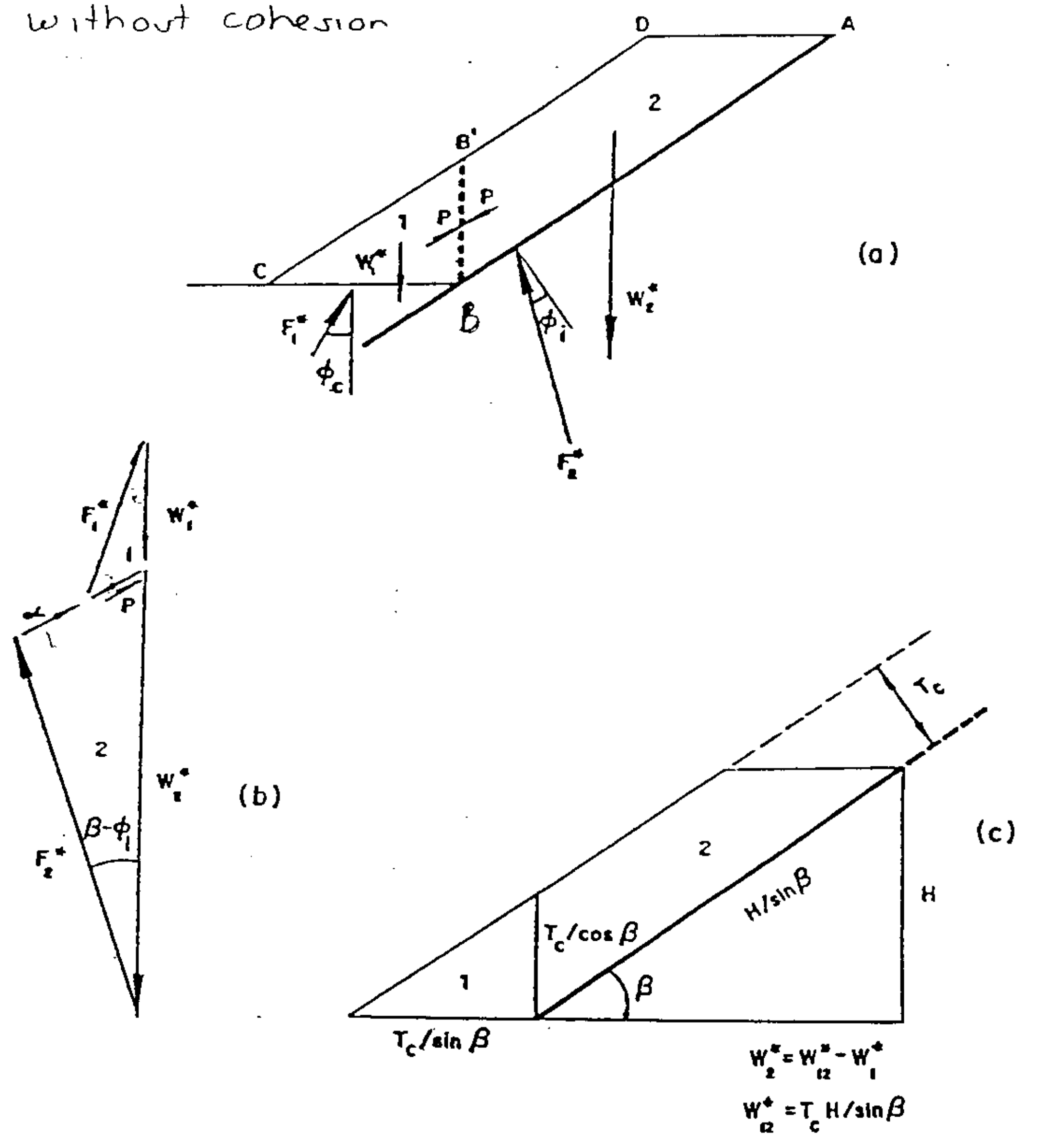


Figure 7. *Simplified Method:* (a) two-part wedge; (b) force-per-unit-width polygons; and (c) weight calculations. The forces per unit width are as follows: W_1* = weight of part 1 per unit width perpendicular tot he plane of the figure; W_2* = weight of part 2 per unit width perpendicular to the plane of the figure; P = force per unit width transmitted between the two wedges; F_1* = force per unit width due to soil friction; F_2* = force per unit width due to interface friction within the geosynthetic lining system or between the lining system and the soil; and α = tension in the geosynthetics located above the slip surface, including geosynthetic reinforcement layers, if any. Note: The simplified method is valid only in the case of a soil cover with a uniform thickness, constructed with a cohesionless material.

NSC materials Properties
13 of

HDPE DRAINAGE NET — GEOTEXTILE GEOCOMPOSITE

Recommended TEX-NET® Specifications

1. DESCRIPTION

These specifications describe a high density polyethylene (HDPE) drainage net - geotextile geocomposite. The supply and installation of this material shall be in strict accordance with these specifications and contract drawings.

2. MATERIALS AND PRODUCT CONSTRUCTION

The geocomposite drainage material shall be TEX-NET® by National Seal Company and shall meet or exceed the following criteria:

2.01

Drainage net shall be manufactured by extruding two sets of strands to form a three (3) dimensional structure to provide planar water flow.

The drainage net shall contain stabilizers to prevent ultraviolet light degradation.

2.02

The drainage net shall be POLY-NET® PN-3000 or approved equal. In addition to the material properties listed above, the drainage net shall conform to the following properties detailed in the table below.

POLY-NET® PN-3000

PROPERTY	TEST METHOD	UNIT	QUALIFIER	VALUE
POLYMER DENSITY	ASTM D-1505	g/cm^3	range	.937 ± .002
POLYMER MELT INDEX	ASTM D-1238	g/10 min	maximum	1.0
CARBON BLACK CONTENT	ASTM D-1603	%	range	2-3%
NOMINAL THICKNESS	ASTM D-1777	inches	range	0.220 ± 0.022
NOMINAL MASS PER UNIT AREA	ASTM D-3776	lbs/1000 ft^2	range	180 ± 18
TRANSMISSIVITY at 15,000 psf	*ASTM D-4716	m^2/sec	minimum	1×10^{-3}
TENSILE STRENGTH MACHINE DIRECTION	ASTM D-1682	lbs/in	range	50 ± 10

*Per ASTM D4716-87. The transmissivity was measured using water @ 20°C (68°F) with a gradient of one, between two steel plates, after one hour. Value may vary, based on dimensions of the transmissivity specimen and specific laboratory.

2.03

The geotextile filter fabric shall meet or exceed the following:

TREVIRA® 1120 OR EQUAL MEETING THE PROPERTIES LISTED BELOW

FABRIC PROPERTY	UNIT	TEST METHOD	*MINIMUM REQUIREMENT
FABRIC WEIGHT	oz/yd^2	ASTM D-3776	5.7
THICKNESS, t	mils	ASTM D-1777	75
GRAB STRENGTH	lbs	ASTM D-4632	160
GRAB ELONGATION	%	ASTM D-4632	60
TRAPEZOID TEAR STRENGTH	lbs	ASTM D-4533	60
PUNCTURE RESISTANCE	lbs	ASTM D-4833	80
MULLEN BURST STRENGTH	psi	ASTM D-3786	275
WATER FLOW RATE	gpm/ft^2	ASTM D-4491	130
PERMITTIVITY, Ψ	sec^{-1}	ASTM D-4491	1.74
PERMEABILITY, k = Ψt	cm/sec	ASTM D-4491	.33
AOS	Sieve Size mm	ASTM D-4751	70 .210

*These minimum values represent minimum test values determined from Q.C. testing on all lots produced in 1989.

TREVIRA® SPUNBOND

TABLE 1: STRENGTH CHARACTERISTICS OF TREVIRA® SPUNBOND GEOTEXTILES

	CBR Puncture Strength (lb)	CBR Puncture Elongation (in)	Measured Wide Width Tensile (lb/ft) Machine	Cross-M	Average	Measured Wide Width Strain % Machine	Cross-M	Average
Trevira 1114	341	1.9	674	529	602	63%	61%	62%
Trevira 1125	701	1.95	1770	1450	1610	69%	70%	70%
Trevira 1155	1420	1.99	3360	2670	3015	68%	77%	73%

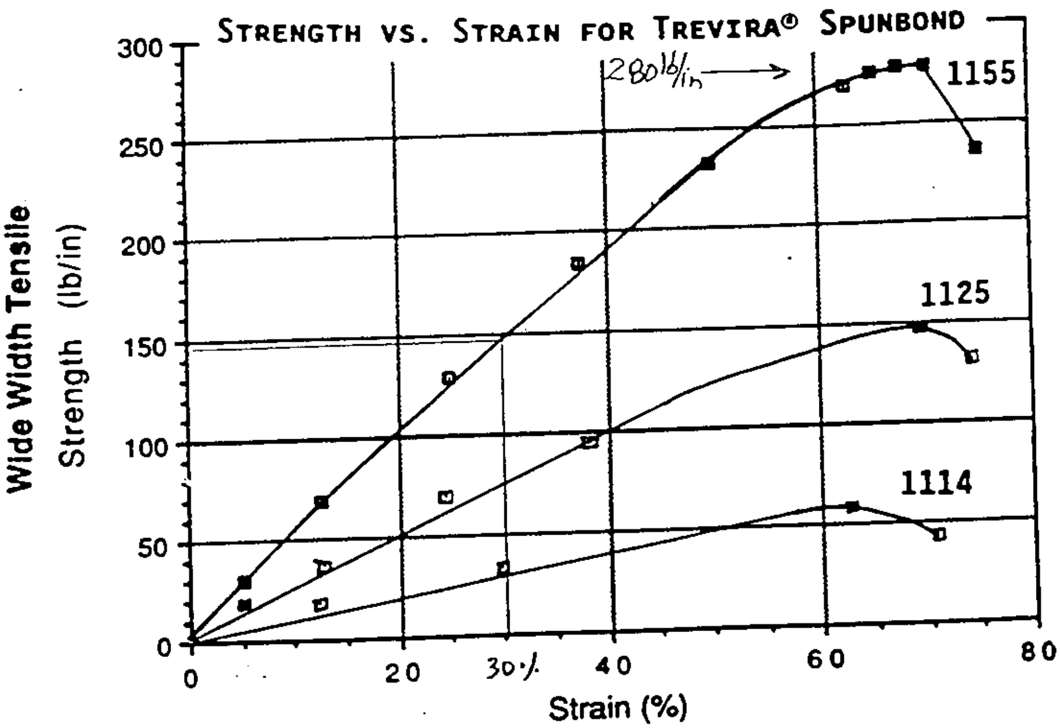


FIGURE 1: WIDE WIDTH TENSILE STRENGTH/STRAIN CURVES FOR TREVIRA® SPUNBOND GEOTEXTILES (MACHINE DIRECTION)

FSI
FLUID SYSTEMS, INC.

32 Triangle Park Drive
Suite 3201
Cincinnati, Ohio 45246

513/771-5656
800/346-9107
FAX: 513/771-4844

FACSIMILE MESSAGE

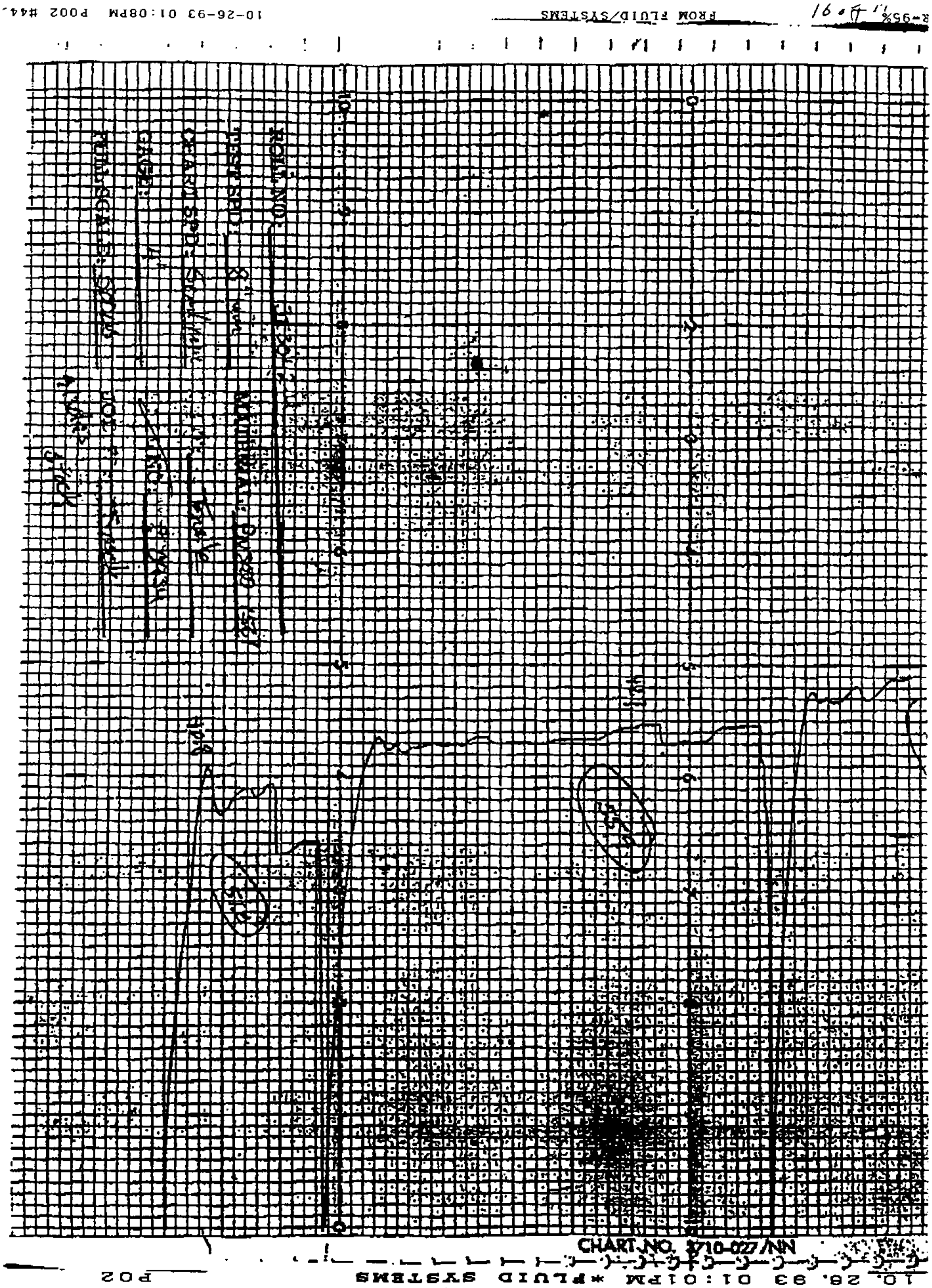
F A X T O	DATE: 10.26.93 PAGE 1 OF 3 (Includes cover sheet)
	ATTENTION: Raphael Ospina
	COMPANY: Golder
	FAX NUMBER: (404) 934.9476

F R O M	SENDERS NAME: GREG SOUDER
	IMPORTANT NOTE: IF YOU DO NOT RECEIVE ALL OF THE PAGES OR IF NOT LEGIBLE, PLEASE CALL GREG SOUDER AT 513/771-5656 OR 800/346-9107 AS SOON AS POSSIBLE FOR RE-TRANSMISSION.

MESSAGE: PolyNet Tensile Test Data and Method.

Any Questions, please call me.

Greg



** Technical Note - Geonet Tensile Strength

Currently, there is no standard test method for determining the tensile strength of geonet. NSC has traditionally referenced a geotextile tensile test method, ASTM D1682 (as modified by NSC) as our geonet tensile test method. Recently, ASTM D1682 was discontinued and broken down into two different standard test methods; ASTM D5034 (grab tensile) and ASTM D5035 (strip tensile). The D5035 method is identical to the old D1682 strip tensile method. Therefore, future geonet spec sheets will cite *ASTM D5035, NSC modified* as our standard test method for determining geonet tensile strength.

The NSC modifications include:

	NSC METHOD	ASTM D5035
Specimen Width:	4"	1 or 2"
Gage Length:	4"	3"
Cross-head Speed:	8"/min	12"/min

These modifications are necessary because the number of strand intersections or "nodes" included in the test specimen influence the tensile strength. And, in specimens only 1 or 2" wide, it is easy to prepare specimens with different numbers of nodes. Therefore, a different set of conditions which would decrease the variability inherent in this test was needed.

National Seal Company's modifications to the existing geotextile test method were a result of extensive testing in 1989 using a variety of specimen widths, test speeds, and gage lengths. It was determined that using the four-inch wide specimen, four-inch initial distance between the grips, and eight inch per minute test speed resulted in more reproducible test results than any other combination. The wider test specimen tended to include the same number of nodes no matter how the cutting die was placed on the material. Also, if there was a one node difference between test specimens, the influence on tensile strength was less for a 4-inch wide specimen versus a 2-inch wide specimen. The greater distance between the grips at the start of the test tended to focus failure toward the strands in the middle of the specimen as opposed to the edge of the grip. The slower test speed simply produced more consistent test results.

Technical Services recently verified the conclusions reached in 1989. Tensile strength was determined on a roll of PN3000 geonet chosen at random from stock using ASTM D5035 as written and as modified by NSC. The test results (machine direction) were:

	NSC METHOD	ASTM D5035
Average:	57.9 ppiw	55.8 ppiw
MARV:	53.3 ppiw	48.6 ppiw
Standard Deviation:	2.3 ppiw	3.6 ppiw
Range:	53.4 - 61.4 ppiw	52.6 - 62.2 ppiw
Coefficient of Variation:	4.0%	6.4%

Although the average tensile strengths are quite close, there is a significant difference in minimum average roll values (MARV) due to the greater scatter in data (i.e., larger standard deviation) for the D5035 test. Clearly, the NSC modified procedure results in more consistent data. Consistent and reproducible data reduces the likelihood of a third party laboratory failing good material due to inaccurate test results. NSC's decision to use these modified parameters is technically sound and, hopefully, will become an ASTM standard test method in the future.

Golder Associates	SUBJECT GEOLOGIC DATA		
	Job No. 933-3553 Ref. EMELLE	Made by NLW Checked RJO Reviewed WRS	Date 29-OCT93 Sheet 1 of 5

OBJECTIVE: CHECK POTENTIAL FOR SLIDING ALONG JOINT PLANE OR WEDGE SLIDING DUE TO INTERSECTION OF JOINT

GIVEN: I) CUT ORIENTATIONS

A) STRIKE NORTH SOUTH - DIP 22° EAST AND WEST

B) STRIKE EAST-WEST DIP 22° NORTH AND SOUTH

II) FRICTION ANGLE FOR JOINT SURFACES - 25° (REF. 1)

III MAJOR JOINT PLANE ORIENTATIONS (REF. 2)

JOINT SET	DIP (degrees)	DIP DIRECTION (degrees)
J_1	43 ± 10	030 ± 10
J_2	42 ± 5	330 ± 5
J_3	87 ± 0	030 ± 0
J_4	85 ± 0	330 ± 4
J_5	82 ± 0	285 ± 5
J_6	58 ± 0	148 ± 0

CALCULATIONS:

PLANAR SLIDING - SLIDING MAY OCCUR IF JOINT SURFACES PARALLEL CUT AND DAYLIGHT (DIP LESS STEEPLY THAN CUT).

FROM JOINT MEASUREMENTS - NO JOINTS DAYLIGHT IN CUT SLOPE, THEREFORE SLIDING ALONG JOINT PLANES NOTED ABOVE SHOULD NOT OCCUR.

Golder Associates	SUBJECT GEOLOGIC DATA		
	Job No. 933-3553 Ref. EMELLE	Made by WKW Checked RJO Reviewed WPS	Date 29 OCT 93 Sheet 2 of 5

Joint intersections –

SETS	POINT	PLUNGE	
J_1 & J_2	I_{12}	38°	
J_1 & J_4	I_{14}	42°	
J_1 & J_5	I_{15}	42	
J_1 & J_6	I_{16}	30°	
J_2 & J_3	I_{23}	40°	
J_2 & J_4	I_{24}	6°	⊗ (< 22°)
J_2 & J_5	I_{25}	35°	
J_3 & J_4	I_{34}	85°	
J_3 & J_5	I_{35}	80°	
J_3 & J_6	I_{36}	42°	
J_4 & J_5	I_{45}	82°	
J_4 & J_6	I_{46}	6°	⊗ (< 22°)
J_5 & J_6	I_{56}	42°	

INTERSECTIONS OF SET J_2 & J_4 AND J_4 & J_6
DAYLIGHT IN SLOPE

Golder Associates	SUBJECT Geologic Data		
	Job No. 933-3553	Made by WLW	Date 29-OCT 93
	Ref. EMELLE	Checked RSO	Sheet 3 of 5
		Reviewed WRS	

CONCLUSIONS:

Wedge sliding is only possible when the plunge of the line of intersection of two joint surfaces is less than the dip of the slope face when measured in the direction of sliding - From the stereonet plot (Attachment 1) there are only two points of intersection a which plunge less than the dip of the cut slope. These points are $I_{2,4}$ and $I_{4,6}$

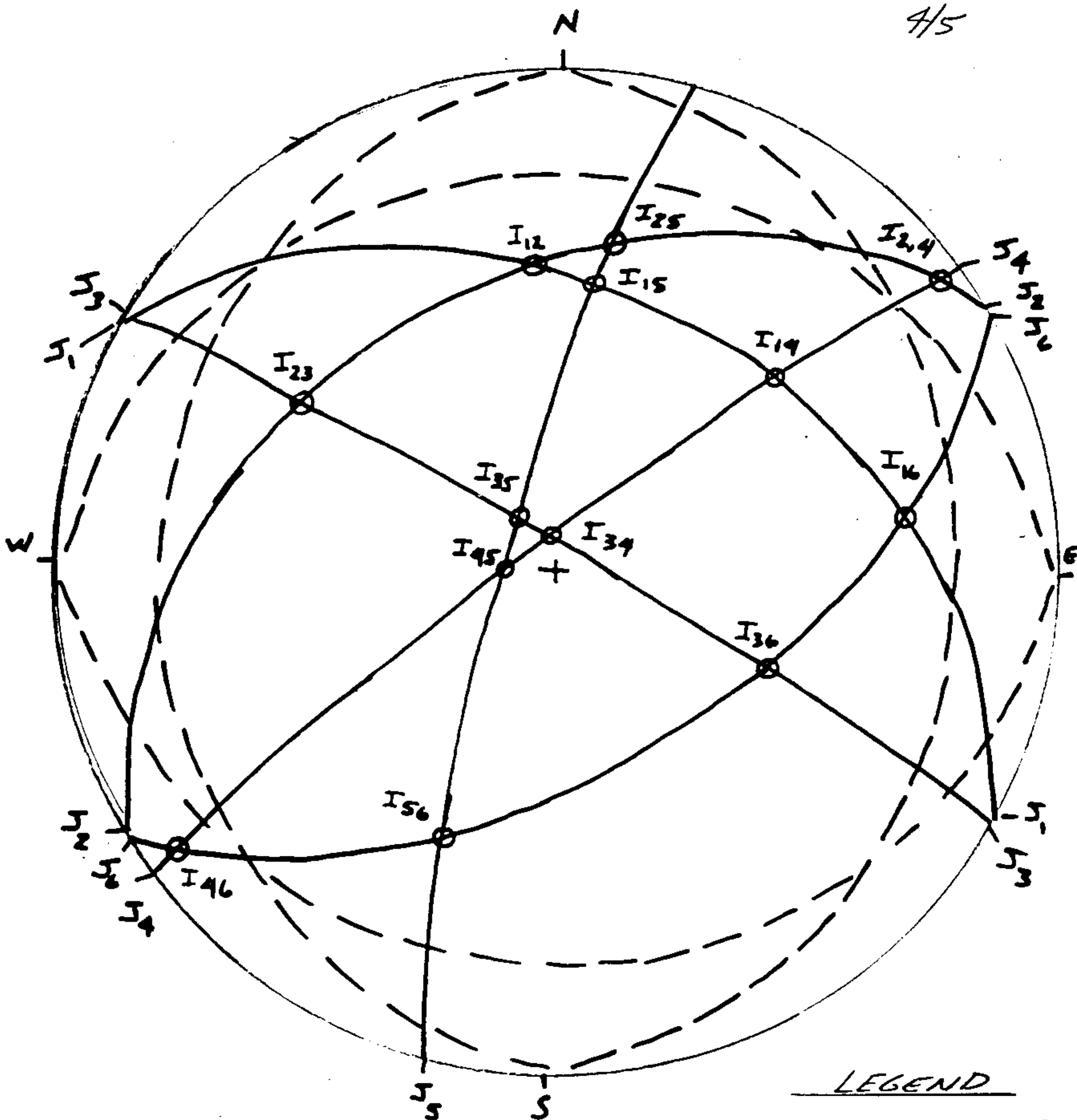
Sliding of these two wedges are unlikely since the plunge of the lines of intersection (6°) is less than the friction angle 25° as shown Attachment 2.

REFERENCES:

1.) Golder Associates, Geological and Geotechnical Evaluation of the Emelle Facility Dec, 1982, Rev. June 1983

2.) Slope Stability Analysis Calculation Package Appendix A June 1986

4/5



LEGEND

- - - CUT SLOPE

—— MAJOR JOINT SET

⊗ I_{12} INTERSECTION OF JOINT SETS

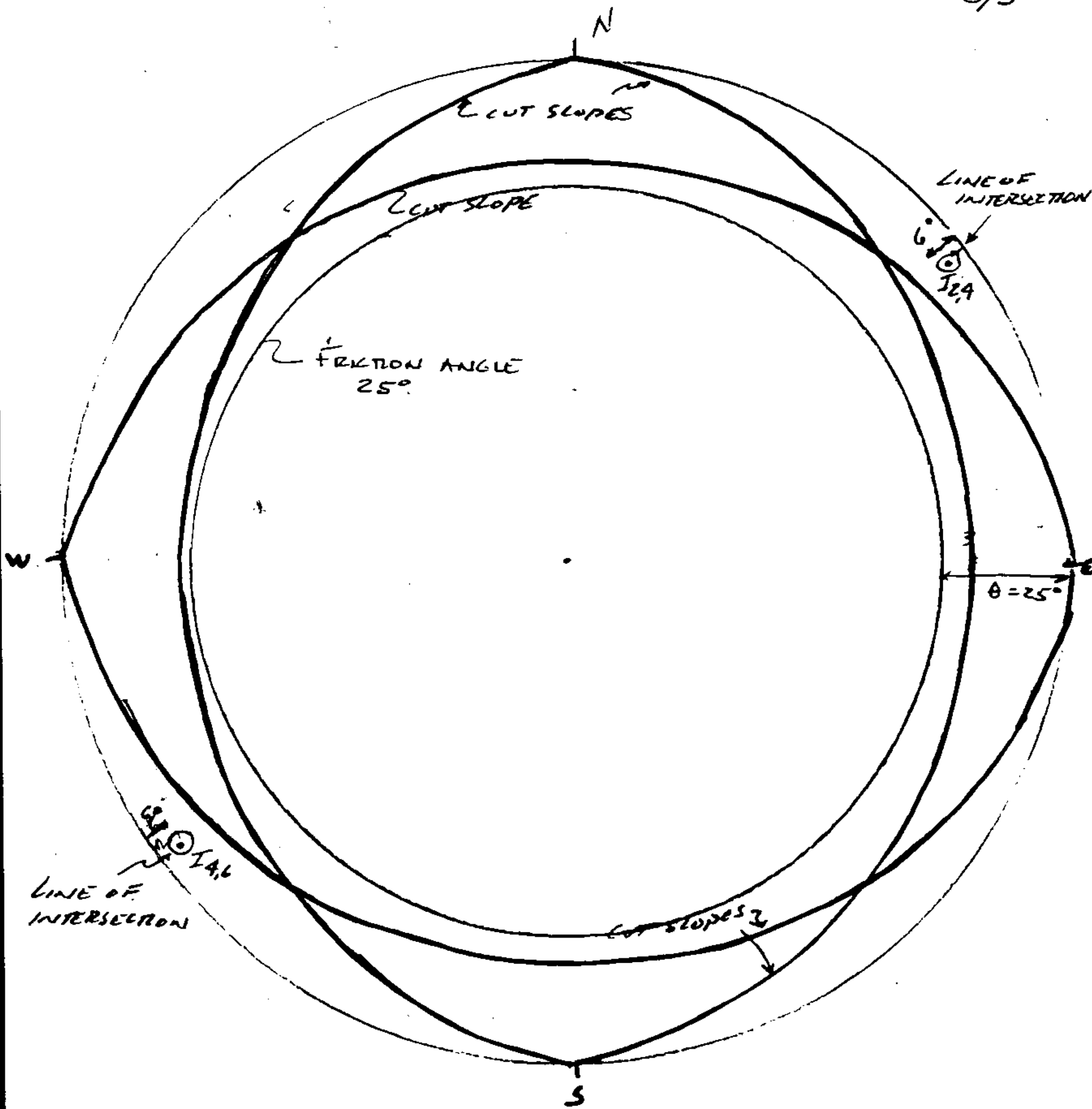
ATTACHMENT

Golder Associates Atlanta, Georgia

TITLE	STEREONET PLOT OF MAJOR JOINT SETS AND CUT SLOPES		
DRAWN WLW	DATE 29 OCT 93	JOB NO. 933-3553	
CHECKED RJW	SCALE NTS	DWG NO.	REV. NO.
REVIEWED WRS	FILE NO.	SUBTITLE	FIGURE NO.

CLIENT/PROJECT: CWM / PERMIT SUPPORT / AL

N77309



ATTACHMENT 2

Golder Associates, Atlanta, Georgia	TITLE: PLOT OF JOINT INTERSECTIONS THAT DAYLIGHT ON CUT SLOPES.			
CLIENT/PROJECT: CWM/PERMIT SUPPORT/AL	DRAWN: WLW	DATE: 20 OCT 93	JOB NO. 933-3553	
	CHECKED: REW	SCALE: NTS	DWG NO.	REV. NO.
	REVIEWED: WRS	FILE NO.	SUBTITLE	FIGURE NO.

E77309

SETTLEMENT AND STRESS ANALYSIS

Golder Associates	SUBJECT Settlement and stress analysis T21, T22, T23, T24		
	Job No. 933-3553.4 Ref. Emelle	Made by SYI Checked RIO Reviewed CW	Date 10/11/93 Sheet 1 of 18

Objective: the objective is to estimate the settlement at various points in the landfill to check: 1) grade reversals, 2) tensile strains in geomembranes and liner components, and differential settlement, for trenches T21, T22, T23 & T24

Evaluation of strength / deformation parameters:

I) Insitu chalk

i) from "Introduction to Rock mechanics" by R.E Goodman, 1980

E/q_u ratio as provided in table 6.1 is

E/q_u	material
214	siltstone
157	shale

(sheet 15/18)

chalk is generally grouped with siltstone and shale depending on its strength and weathering degree.

assume $E/q_u \cong 190$ as average & $S_u = 8000$ psf (chalk)

$q_u \cong 16{,}000$ psf ($q_u = 2S_u$) for chalk

Then E = elastic modulus = $190 * 16000 * \frac{1}{2000} = 1520$ tsf

Golder Associates

SUBJECT Settlement and stress analysis, T21, 22, 23 & ?		
Job No. 933-3553	Made by SYE	Date 10/11/93
Ref. Emelle	Checked RIO	Sheet 2 of 18
	Reviewed CW	

ii) From figure 11.9 attached on sheet 16/18,

$E_{lower\ chalk} \cong 0.2 - 0.9 * 10^6$ psi

$\simeq 14,400 - 64,700$ TSF

The expected material behavior is somewhat between black shale and lower chalk, hence

$E \simeq 0.10 * 10^6$ psi $\simeq 7200$ tsf

As an average use $E_{chalk} \simeq 8000$ tsf

B) Waste material:

$\gamma = 110$ pcf

$e_o = 1.2$

$C_c = 0.135$ Refer to calculation package "Estimation of e_o, C_c for waste"

C) Compacted chalk (low permeability layer):

The compacted chalk is expected to perform or behave similar to a typical CL (low plasticity clay) material.

From "An introduction to Geotechnical Engineering" by Holtz & Kovacs,

Table 8-3 : $C_c \cong 0.15 - 0.3$ silty clay (sheet 18/18)

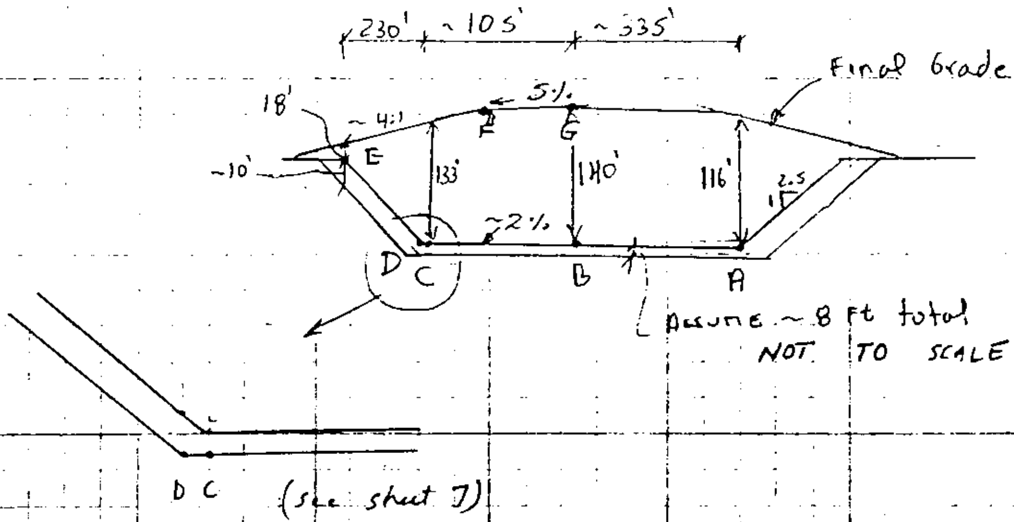
$\cong 0.3 - 0.5$ Blue clay

From laboratory test on chalk sample: $C_c = 0.25$ & $e_o = 0.84$ & $\sigma_p = 4$ KSF

Golder Associates	SUBJECT Settlement and Stress Analysis, T21, 22, 23, 24		
	Job No. 933-3553.4 Ref. Emelle	Made by SYT Checked RIO Reviewed CM	Date 10/12/93 Sheet 3 of 18

By inspection, section (A-1) - (A-1') in trench 23 appears to be a representative section for settlement analysis among the cells & trenches designed for the Emelle facility. Sheet 17/18 shows section (A-1)-(A-1') location in plan view for reference. This section will be used for base settlement calculations.

The following sketch presents the points of interest for settlement estimation:



In this analysis, the rebound of insitu material due to excavation is neglected, which is conservative.

Golder Associates	SUBJECT Settlement & stress Analysis, T21, 22, 23, ...		
	Job No. 933-3553.011	Made by SYZ	Date 10/12/93
	Ref. Emelle	Checked RIO	Sheet 4 of 18
		Reviewed	

Settlement components:

A). For the base liner:

The waste loading will produce settlement in the underlying chalk foundation and the 4.5' thick (total thickness) compacted chalk layer of the liner systems.
The compressibility of the sand/gravel layers in the liner systems is neglected.

At point A – (sheet 16/18)
i). Settlement of foundation chalk:

$\Delta\sigma_1$ = applied stress ≈ 116' * 110 + 8 * 130 = 13,800 psf
(116 = max waste; 8 = liner system)

Assume that the upper 100' of chalk will be compressible

Then expected settlement = $\frac{13800}{8000 * 2000} * 100 * 12 \doteq 1.0''$
((E) tsf; ft; in/ft)

$\Delta\sigma / E = \Delta\epsilon$

ii) settlement of compacted chalk layers: $\Delta\sigma_v$ = 116 (H) * 110 (γ) = 12,760 psf

$\Delta\delta = \frac{C_c}{1+e_o} H \log \frac{\sigma_o + \Delta\sigma_v}{\sigma_o}$

Golder Associates	SUBJECT Settlement & stress analysis, T-21, 22, 23 & 24		
	Job No. 933-1551.4 Ref. Emelle	Made by SYT Checked RIO Reviewed CR	Date 10/12/93 Sheet 5 of 18

Based on the laboratory test conducted on a remolded sample of chalk, the preconsolidation stress is 4000 psf. Neglect settlement caused by recompression.

$\sigma_0 = \frac{4.5}{2} \times 130 = 292.5$ psf ≈ 300 psf (middle of layer)

$\sigma_0 + \Delta\sigma \cong 16,250$ psf

$$\Delta S' = \frac{0.25}{1+0.84} \times (4.5' \times 12'') \times \log \frac{13060}{4000} \cong 3.8''$$

total settlement $\approx 3.8'' + 1.0'' = 4.8''$
(at A)

Similarly at points B & C:

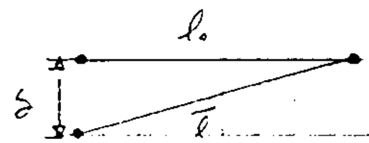
point	(on foundation) applied stress psf ($\Delta\sigma_1$)	foundation settlement	$\sigma_0 + \Delta\sigma_v$ (psf)	Liner settlement	total settlement
A	13 800	~ 1.0"	13 060	3.8"	4.8"
B	16 440	~ 1.2"	15 700	4.3"	5.5"
C	15 670	~ 1.1	14 930	4.2"	5.3"
E	3 640	~ 0.3"	2 990	0	0.3"

the secondary settlement of the compacted chalk layers has been neglected.

Golder Associates	SUBJECT Settlement + stress Analysis, T21, 22, 23, 4.14		
	Job No. 932-3353.4	Made by SYT	Date 10/12/93
	Ref. Emelle	Checked RIO	Sheet 6 of 18
		Reviewed CM	

Strains at landfill base:

point	settlement (in)	l_o distance (ft)	(δ) relative settlement (in)	$\bar{l}$ (ft)	ε (%)
A	4.8"				
		335	0.7	≈ 335	≈ 0
B	5.5"				
		105	0.2	~ 105	~ 0
C	5.3"				



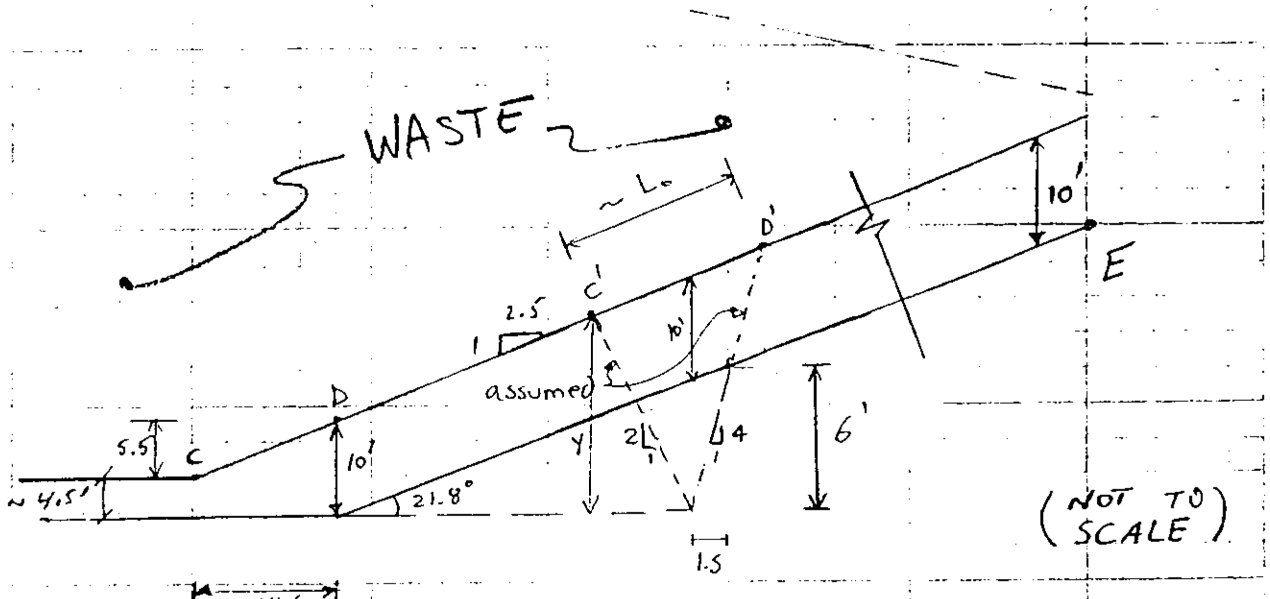
$$\varepsilon = \text{strain} = \frac{\bar{l} - l_o}{l_o} * 100$$

∴ no significant strains are expected in the liner system at the landfill bottom due to settlement.

Golder Associates	SUBJECT Settlement & stress Analysis, T21, 22, 23, 42		
	Job No. 933-3553.4	Made by SYZ	Date 10/12/93
	Ref. Emelle	Checked PIO	Sheet 7 of 18
		Reviewed CM	

B) Along side slopes:

the following is a typical section along side slope critical area:



At point D, the compacted chalk layer is about 10.0' thick.

Total waste thickness above D is about 133 ft.

Use consolidation approach for settlement evaluation:

At point D:

$\sigma_c = \frac{10}{2} \times 130 = 650$ psf

$\Delta\sigma_v = 133' \times 110^{pcf} = 14630$ psf , $\sigma_{vo} + \Delta\sigma_v = 15280$ psf

$$S' = \frac{10' \times 12''}{1+0.84} \times 0.25 \times \log \frac{15280}{4000} = 9.5''$$

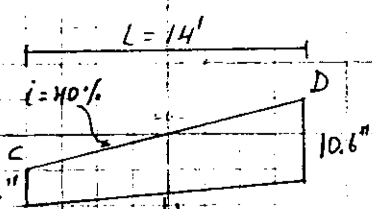
(neglect settlement below preconsolidation pressures)

Total settlement at D:

$S'_{Total} = 9.5 + 1.1 = 10.6''$ (1.1 = foundation chalk)

Similarly @ point E: $S_{Tot} = 0 + 0.3'' = 0.3''$

strain between points C & D:



% Slope change $= \frac{(10.6 - 5.3)/12}{14} = 3.1\%$

New slope = 40% − 3.1% = 36.9% ✓

Slope reversal will not occur.

Because the way settlement occurred, the new length/Distance between C-D will be less than the original length. Thus, strains in the liner will not be generated at this location.

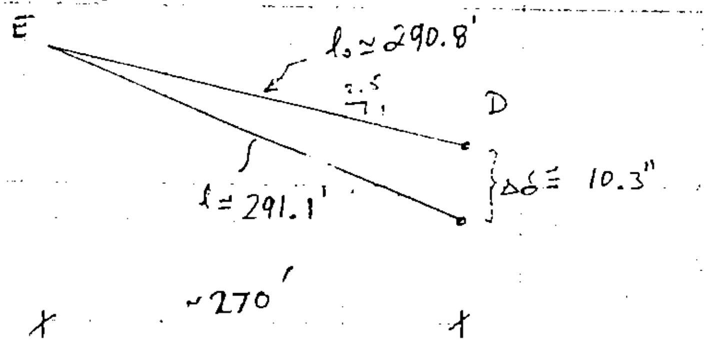
At point E.

at edge of landfill / excavation

from previous page settlement @ E = 0.3"

Distance between E + D is about 290.8'

Thus: $\Delta\delta = 10.6'' - 0.3'' =$



$$\text{Strain} = \varepsilon = \frac{l - l_o}{l_o} * 100 = \frac{291.1 - 290.8}{290.8} * 100 \cong 0.1\ \%$$

low OK ✓

Golder Associates	SUBJECT Settlement and stress analysis, T21, 22, 23 & 24		
	Job No. 933-3553.4 Ref. Emelle.	Made by D. Jang Checked RIO Reviewed cm	Date 10/21/93 Sheet 9-1 of 18

At point D', the compacted chalk layer is about 10.0' thick

Total waste thickness above D' is about

$H_{D'} = 133' - 6' = 127'$

Use consolidation approach for settlement evaluation.

At point D': $\sigma_o = \frac{10'}{2} \times 130 \text{ pcf} = 650 \text{ psf}$

$\Delta\sigma_v = 110 \text{ pcf} \times 127' = 13970 \text{ psf}$

$\sigma_o + \Delta\sigma_v = 14620 \text{ psf}$

$S' = \frac{10' \times 12''}{1+0.94} \times 0.25 \times \log \frac{14620}{4000}$

$= 9.2''$

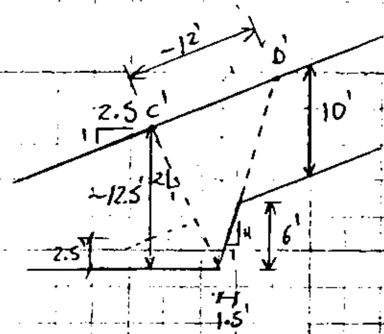
(neglect settlement below preconsolidation pressures)

Total settlement at D':

$S_{total} = 9.2'' + 1.1 = 10.3''$ ← foundation chalk

At point C', $H_{C'} = 133' - 2.5' = 131.5'$

$L_{C'-D'} \approx 12'$ (scaled)



$\sigma_o = \frac{12.5}{2} \times 130 \text{ pcf} = 812.5 \text{ psf}$

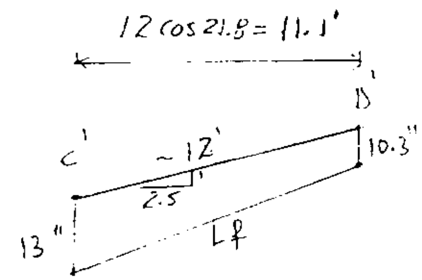
$\Delta\sigma_v = 110 \text{ pcf} \times 131.5' = 14465 \text{ psf}$

$\sigma_o + \Delta\sigma_v = 15278 \text{ psf}$

$S' = \frac{12.5' \times 12''}{1+0.94} \times 0.25 \times \log \frac{15278}{4000} = 11.9''$

$S_{total} = 11.9 + 1.1 = 13''$

Golder Associates	SUBJECT Settlement & stress analysis T21, 22, 23 & 24		
	Job No. 933-3533.4 Ref. Emelle	Made by RJO Checked CM Reviewed CM	Date 10/25/93 Sheet 9-2 of 18



$$Lf = \sqrt{(11.1)^2 + \left(\frac{11.1}{2.5} + \frac{13" - 10.3"}{12}\right)^2}$$

$$Lf = 12.04 \ ft$$

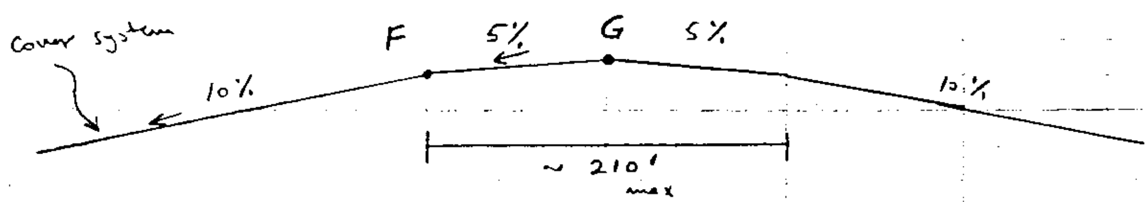
$$\% E = \frac{12.04 - 12}{12} \times 100 = 0.3 \ \% \quad \text{Low OK}$$

∴ Maximum strain between points C'-D' will be on the order of ~0.3%, which is not detrimental to the liner system.

Golder Associates	SUBJECT Settlement & stress analysis, T21, 22, 23, & 24		
	Job No. 933-3553.4 Ref. Emelle	Made by SYT Checked RIO Reviewed (R)	Date 10/12/93 Sheet 10 of 18

C.) Settlement of the Cover system:

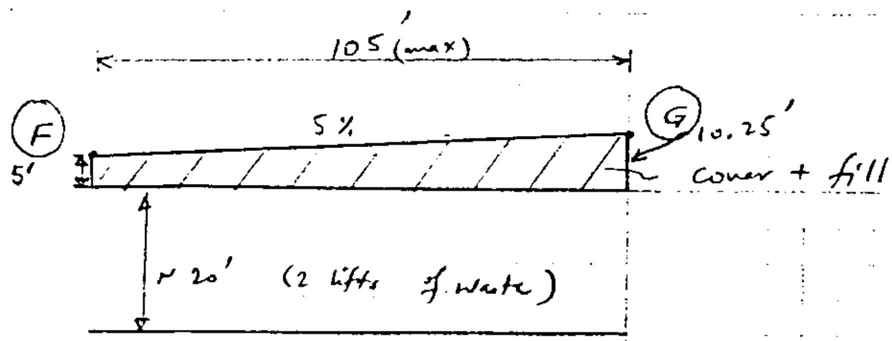
the worst condition for the cover lies in Trench 24 around cells 1 & 2 area. This cover area has the widest flat area @ 5% slope. Based on final cover configuration, this area is about 210' wide (symmetrical, sloping in both directions)



Assume that the last 2 lifts will settle by the ✓ Construction of the cover system. In general, primary settlement takes place during construction.

sheet 14/18 shows the location of section analyzed.

Golder Associates	SUBJECT Settlement and stress analysis, T21, 22, 23 & 24		
	Job No. 933-3553.4 Ref. Emelle	Made by SYZ Checked RIO Reviewed	Date 10/12/93 Sheet 11 of 18



At point F:

$\sigma_o = \frac{20'}{2} * 110 = 1100$ psf

$\Delta\sigma_v = 5' * 130$ pcf $= 650$ psf

$\Delta S = \frac{H}{1+e_o} C_c \log \frac{\sigma_o + \Delta\sigma_v}{\sigma_o}$ (see sheet 2 for waste properties)

ΔS = settlement = $\frac{20' * 12''}{1+1.2} * 0.35 \log \left(\frac{1100+650}{1100}\right) \cong 7.7''$

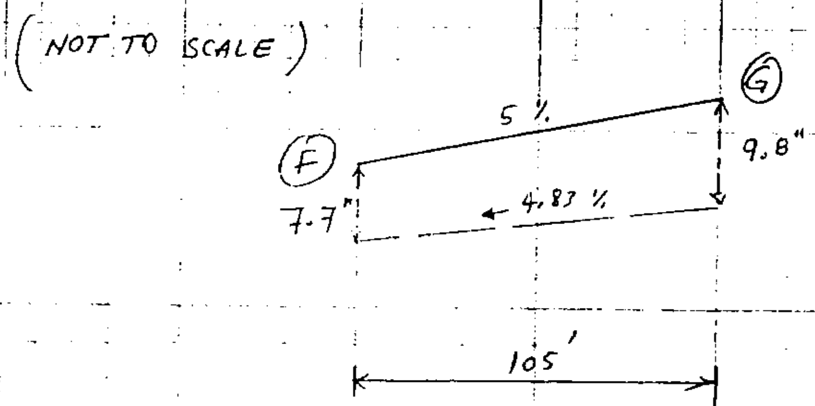
At point G:

$\sigma_o = 1100$ psf

$\Delta\sigma_v = 10.25 * 130 = 1332.5$ psf say 1335 psf

ΔS = settlement = $\frac{20' * 12''}{1+1.2} * 0.35 \log \left(\frac{1335+650}{1100}\right) \cong 9.8''$

Golder Associates			
SUBJECT	Settlement And Stress Analysis, T21, 22, 23, + 24		
Job No. 933-3553.4	Made by SHE	Date 10/12/93	
Ref. Emelle	Checked CM	Sheet 12 of 18	
	Reviewed CM		



The settled configuration slope may be estimated as follows:

$$\text{new Slope} = \left(105 * 0.05 + \frac{7.7''}{12} - \frac{9.8''}{12}\right) * \frac{1}{105} * 100$$

$$\simeq +4.83\ \%$$

Therefore No grade reversal is expected.

- Note that secondary settlement is expected to be about the same at both locations.

- Note that the clay will be subject to compressive stresses.

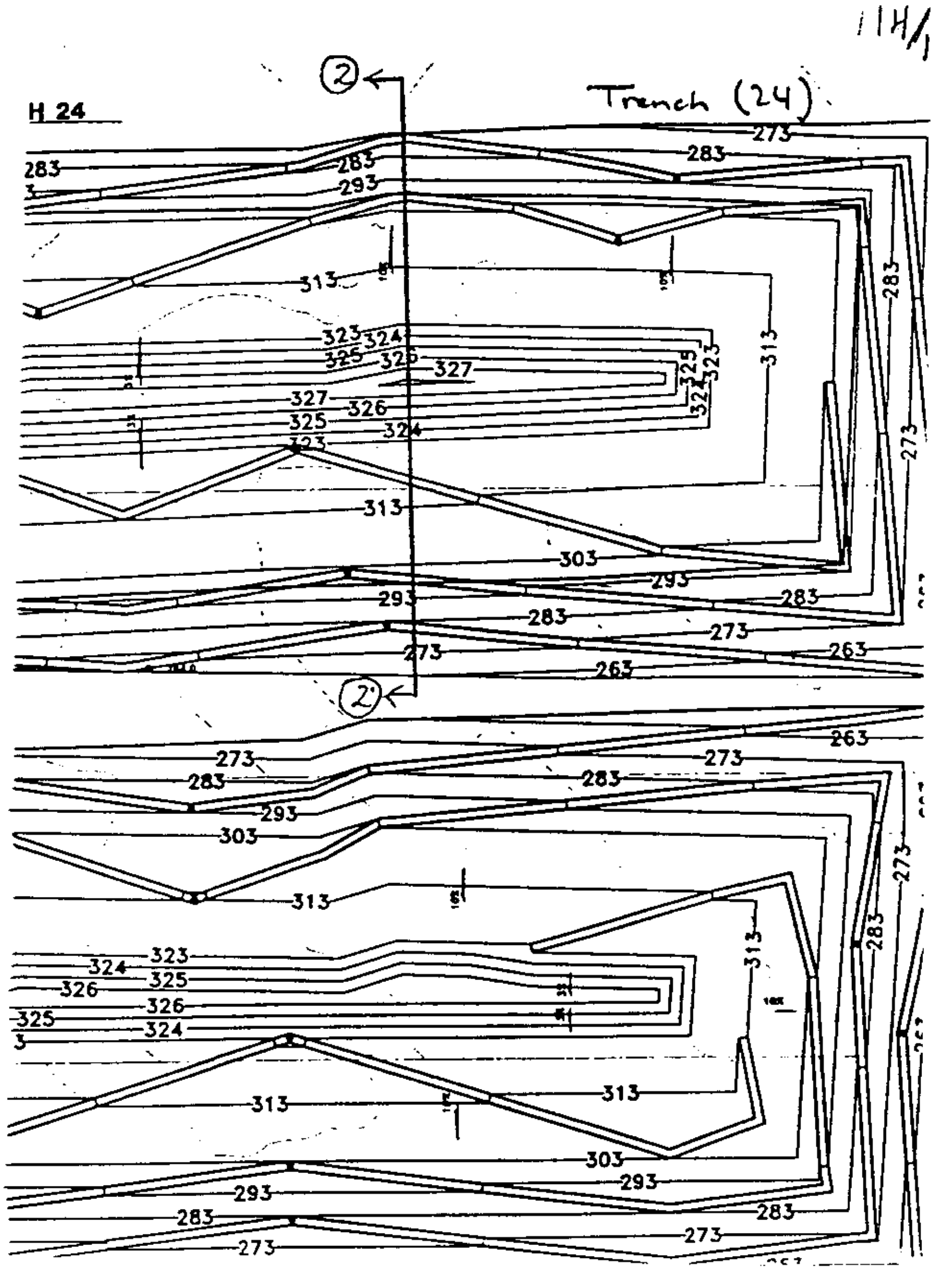
Golder Associates	SUBJECT Settlement and Stress analysis, T21, 22, 23 + 24		
	Job No. 933-3553.4 Ref. Emelle	Made by SYZ Checked RIO Reviewed [illegible]	Date 10/12/93 Sheet 13 of 18

Conclusions:

Based on the settlement analysis of the critical section in the landfill, the relative displacements at the base and along the slopes are small and producing a maximum strain level of about 0.3 %.

For the cover system, relatively flat areas with 5 % are expected to maintain +ve drainage after settlement with an estimate new grade of + 4.8 %

Based on these calcs, settlement is expected to be of no concern.



11H/1
H 24
Trench (24)
2
2'
273
283
293
303
313
323
324
325
326
327
263

"Introduction to Rock Mechanics"
R.E Goodman

15/18

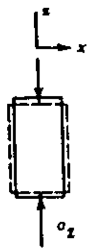


TABLE 6.1

Modulus Ratio (E/q_u) and Poisson's Ratio (ν) for the Rock Specimens of Table 3.1[a]

Description	E/q_u	ν
Berea sandstone	261	0.38
Navajo sandstone	183	0.46
Tensleep sandstone	264	0.11
Hackensack siltstone	214	0.22
Monticello Dam greywacke	253	0.08
Solenhofen limestone	260	0.29
Bedford limestone	559	0.29
Tavernalle limestone	570	0.30
Oneota dolomite	505	0.34
Lockport dolomite	565	0.34
Flaming Gorge shale	157	0.25
Micaceous shale	148	0.29
Dworshak Dam gneiss	331	0.34
Quartz mica schist	375	0.31
Baraboo quartzite	276	0.11
Taconic marble	773	0.40
Cherokee marble	834	0.25
Nevada Test Site granite	523	0.22
Pikes Peak granite	312	0.18
Cedar City tonalite	189	0.17
Palisades diabase	339	0.28
Nevada Test Site basalt	236	0.32
John Day Basalt	236	0.29
Nevada Test Site tuff	323	0.29

[a] E reported here includes both recoverable and nonrecoverable deformation, mixed in unknown proportions.

the slope of the rising portion of a virgin loading curve, the determined property should be reported as a modulus of deformation rather than as a modulus of elasticity. Unfortunately, this is not universal practice at present.

The negative slope of the tail of the complete stress curve is not a stress-strain curve in the conventional sense but is a yield function; in particular, it is the envelope of yield points from all reloading curves. Figure 6.3c shows the value of ν calculated from lateral deformation of a compression specimen on its virgin loading

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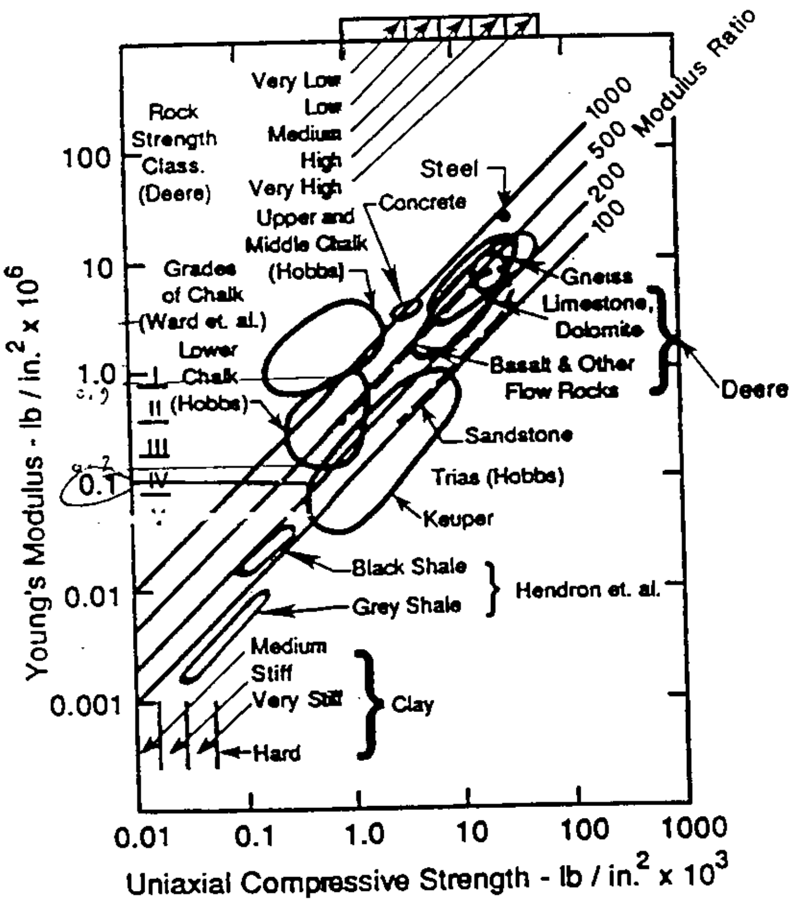
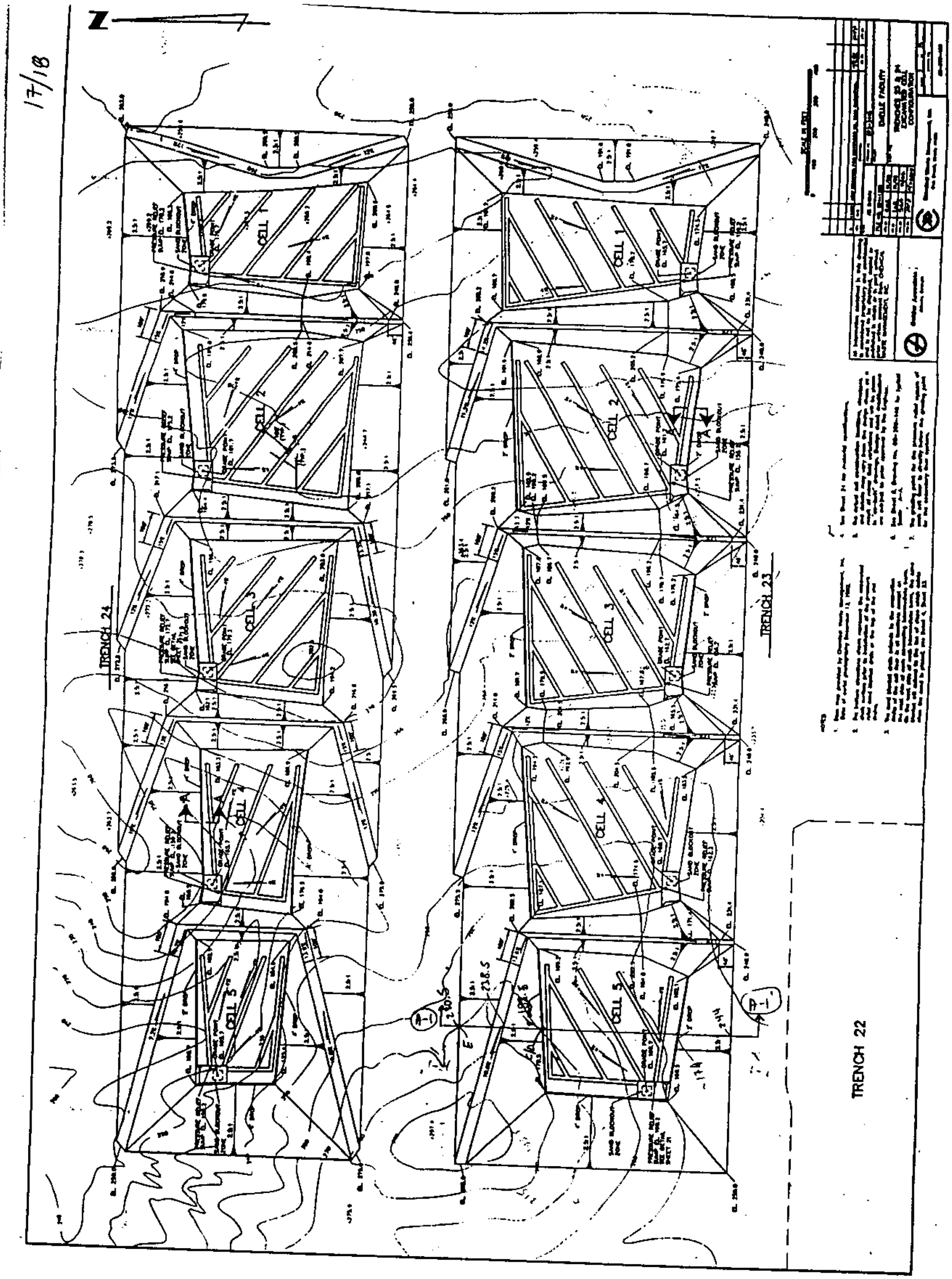
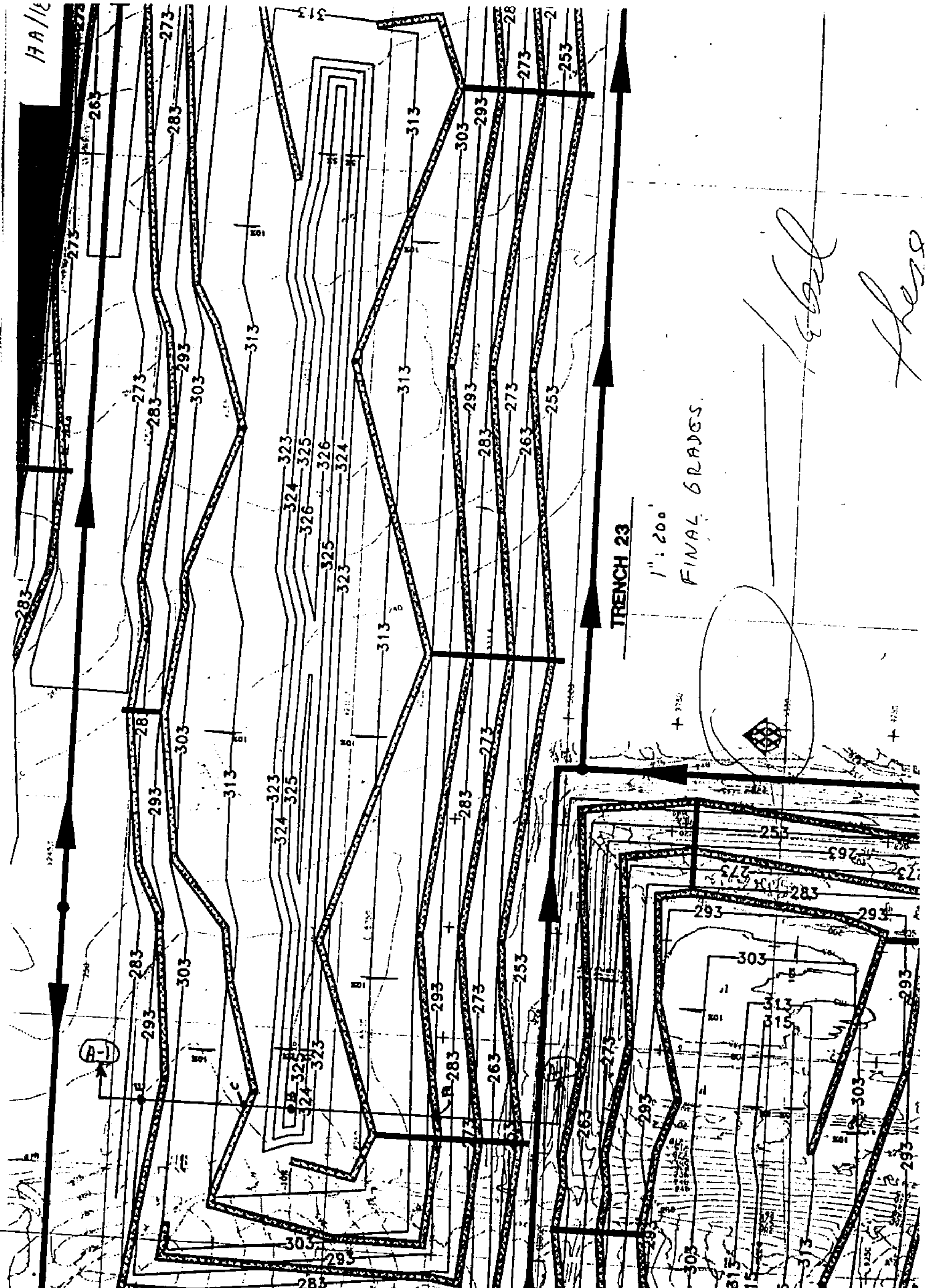


Figure 11.9. Engineering classification of intact rock (after Deere, 1968, and Peck, 1976, as presented by Horvath and Kenney, 1979).


17/18
TRENCH 24
TRENCH 23
TRENCH 22
CELL 1
CELL 2
CELL 3
CELL 4
CELL 5


TRENCH 23
1":200'
FINAL GRADES

"Introduction to Geotech. Eng."
Holtz + Kovacks

18/8

TABLE 8-3 Typical Values of the Compression Index C_c

Soil	C_c
Normally consolidated medium sensitive clays	0.2 to 0.5
Chicago silty clay (CL)	0.15 to 0.3
Boston blue clay (CL)	0.3 to 0.5
Vicksburg buckshot clay (CH)	0.5 to 0.6
Swedish medium sensitive clays (CL-CH)	1 to 3
Canadian Leda clays (CL-CH)	1 to 4
Mexico City clay (MH)	7 to 10
Organic clays (OH)	4 and up
Peats (Pt)	10 to 15
Organic silt and clayey silts (ML-MH)	1.5 to 4.0
San Francisco Bay Mud (CL)	0.4 to 1.2
San Francisco Old Bay clays (CH)	0.7 to 0.9
Bangkok clay (CH)	0.4

8.12 STRESS DISTRIBUTION

In the previous sections of this chapter when we calculated settlements, the increase in stress $\Delta\sigma$ caused by an applied load was given. In this section, we shall show you how to estimate the stress increase in the soil due to boundary or surface loads.

Suppose a very large area such as a subdivision or shopping mall is to be filled with several metres of select compacted material. In this instance, the loading is *one dimensional*, and the stress increase felt at depth would be 100% of the applied stress at the surface. However, near the edge or end of the filled area you might expect a certain amount of attenuation of stress with depth because no stress is applied beyond the edge. Likewise, with a footing of limited size, the applied stress would dissipate rather rapidly with depth.

One of the simplest methods to compute the distribution of stress with depth for a loaded area is to use the *2 to 1 (2:1) method*. This is an empirical approach based on the assumption that the area over which the load acts increases in a systematic way with depth. Since the same vertical force is spread over an increasingly larger area, the unit stress decreases with depth, as shown in Fig. 8.19. In Fig. 8.19a, a strip or continuous footing is seen in elevation view. At a depth z, the enlarged area of the footing increases by $z/2$ on each side. The width at depth z is then $B + Z$, and the stress σ_z at that depth is

$$\sigma_z = \frac{\text{load}}{(B + z) \times 1} = \frac{\sigma_o(B \times 1)}{(B + z) \times 1} \qquad (8\text{-}22)$$

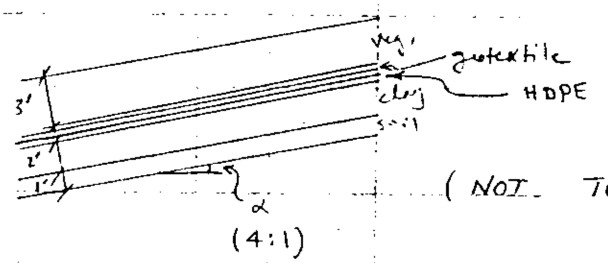
Golder Associates

SUBJECT Stresses in geosynthetic components - Cover System		
Job No. 93	Made by SYI	Date 2/21/93
Ref. Emelle	Checked CCD / RIO	Sheet 1 of 4
	Reviewed WRS	

Objective: The objective is to estimate the tensile forces in the geotextile & HDPE layers and design the anchor trench.

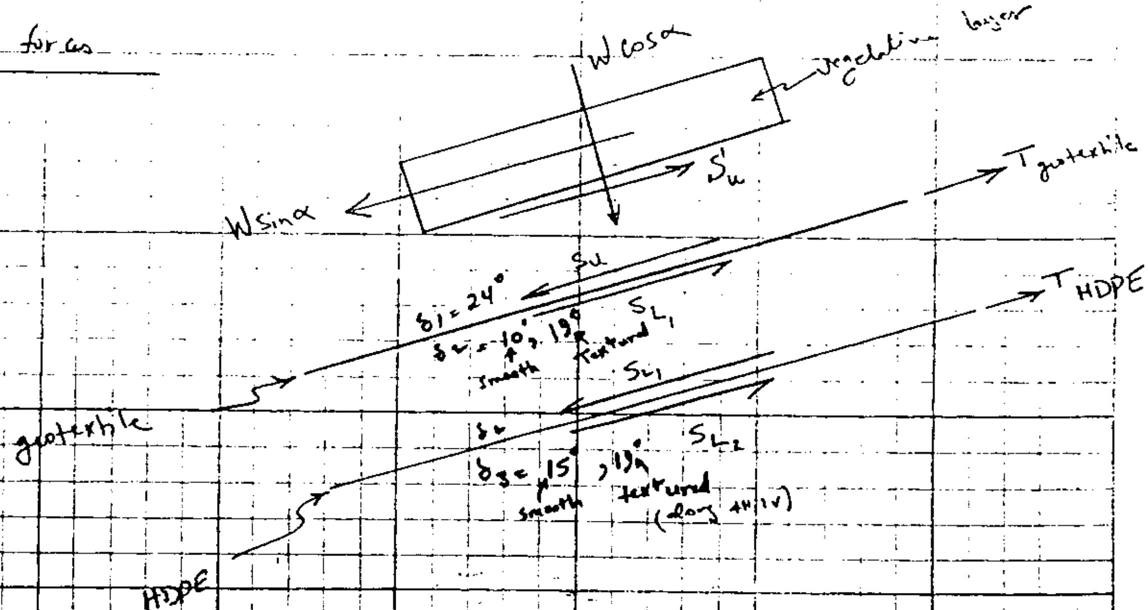
Cover systems

The cover system is as follows:



(NOT TO SCALE)

Acting forces



δ_i = interface friction angle, interface i where : W = weight of vegetative cover

α = angle of cover slope

S'_u = shear force mobilized between veg. cover & geotextile

S'_{L_1} = Shear force mobilized between geotextile & HDPE membrane

S'_{L_2} = shear force mobilized between HDPE liner & clay cover layer

<u>Using limit equilibrium method:</u>

Mobilized Shear force = minimum Shear force of applied shear & shear strength.

= force transmitted to the underlying layer

<u>for geotextile:</u> i) At geotextile & veg. layer interface:

applied shear = $W \sin\alpha$

Shear strength (force) = $W \cos\alpha \tan\delta_1$ (neglect cohesion/adhesion)

$\alpha \cong 14^0$ (4:1 slope)

δ_1 = interface friction angle between veg. cover & geotextile

⇒ applied Shear = $W \sin 14^\circ \cong$ 7229 Lbs

Shear strength = $W \cos 14 \tan 24^\circ$ = 12,908 Lbs (max at failure (USING TEXTURED GEOTEXTILE

Then mobilized shear (upper) = S_u = 7229 (min)

From design dwgs,

$W = 1' \times 3' \times 83' \times 120 = 29,880$ Lbs.

(1' strip; 3' thickness; 83' max. slope length (4:1 slope / vertical spacing between benches = 20'); 120 unit wt.)

Golder Associates	SUBJECT Anchor trench Design for cover system		
	Job No. 923-3553.6	Made by SYI	Date 9/21/93
	Ref. Emelle	Checked CCY/RIO	Sheet 3 of 4
		Reviewed WRS	

ii) at the HDPE interface:

applied shear = $W \sin\alpha \cong 7229$ Lbs
shear strength = $W \cos\alpha \tan\delta_2$ = 9983 Lbs ✓

δ_2 = interface friction between HDPE & geotextile (using TEXTURED)

The mobilized shear (lower) = S_{L_1} = 7229 Lbs (min)

From geosynthetic equilibrium:

$$T_{geo} = S_u' - S_{L_1} = \text{Zero}$$

for HDPE:

i) At HDPE & geotextile interface: S_{L_1} = 7229 Lbs

ii) At HDPE & clay layer interface:

applied shear = $W \sin\alpha$ = 7229 Lbs

shear strength = $W \cos\alpha \tan\delta_3$ = 9983 Lbs (textured)

δ_3 = interface angle between clay & HDPE

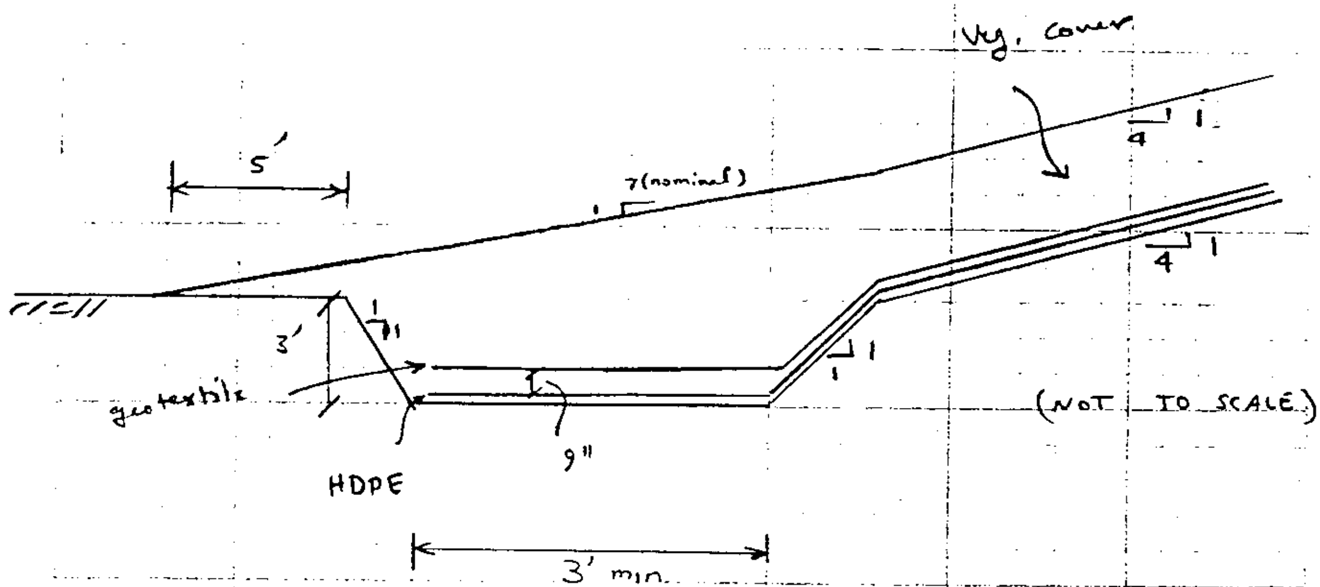
Then mobilized shear = S_{L_2} = 7229 Lbs

$$T_{HDPE} = S_{L_1} - S_{L_2} = \text{Zero}$$

Therefore, no tensile forces exist within either the geotextile or HDPE layers.

Golder Associates	SUBJECT Anchor trench Design for Cover system		
	Job No. 933-3553.6 Ref. Emelle	Made by SYI Checked RJD Reviewed WRS	Date 3/21/93 Sheet 4 of 4

Then The anchor trench may be adequately and satisfactorily be as follows:



Ref: "Structural Integrity of Geosynthetics lining and cover systems for solid Waste landfills", James Long, James Daly, and Robert Gilbert, Dept. of C.E., University of illinois, July 1993, project # OSWR 06-005

PRESSURE RELIEF SYSTEM SHUTOFF ANALYSIS

Golder Associates

SUBJECT	Evaluation of uplift — Pressure Relief T22, 23 & 24		
Job No. 933-3553.6	Made by SYI	Date 7/20/93	
Ref. Emelle	Checked CM	Sheet 1 of 6	
	Reviewed NRS		

Objective: The objective is to evaluate the uplift pressure and compare it to the applied load at various stages of construction.

Assumptions:

Based on "Groundwater contour map in active area of Emelle facility", (DWG. # 00-150-005, dated 12-24-82), the Ground water level in the site vicinity ranges from about 10' to about 60' below ground surface. In general, Ground water in most areas appears to be about 20' below ground surface.

Approach:

For variable waste depth, the applied load will be evaluated and the uplift pressure will be also estimated. The safety factor against uplift will be then calculated. Then a plot showing safety factor vs. waste thickness will be presented.

U = uplift pressure = $\gamma_w H_w$ = $62.4\, H_w$ (psf)

P = load/pressure applied = $\Sigma \gamma_i H_i$

S.F = Safety factor = $\frac{P}{U}$

Golder Associates	SUBJECT Evaluation of uplift - Pressure Relief		
	Job No. 933-3553.6 Ref. Emelle	Made by SYI Checked Reviewed WRS	Date 9/20/93 Sheet 2 of 6

where: γ_w = unit weight of water = 62.4 pcf
H_w = height of water in ft. causing uplift,

Σ = Summation
γ_i = unit wt. of applied load, for layer i
H_i = Thickness of layer i

Applied Load (stress) may be divided into two components;

① liner system load; and
② Waste load

<u>Calculations:</u>

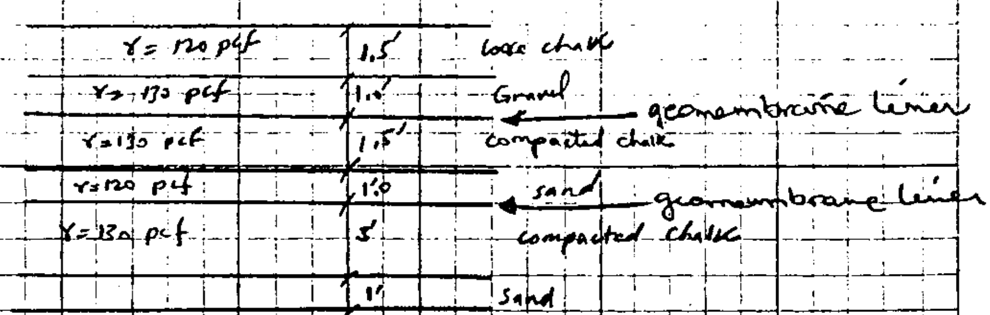
A) <u>applied load due to waste placement:</u>

$P = \gamma_{Waste} * H_{Waste}$, assume γ_{waste} = 110 pcf

$P = 110 * H_{Waste}$, H_{Waste} will be varied.

B) <u>Applied load due to liner system:</u>

The cover system consists of the following configuration:



The compacted chalk layer is generally impermeable, and therefore all layer above it will contribute to the applied liner stress.

Golder Associates	SUBJECT Evaluation of uplift - Pressure Relief		
	Job No. 933-355.6 Ref. Emmelle	Made by SYI Checked Reviewed WRS	Date 9/20/93 Sheet 3 of 6

P_{liner} = 130 * 3 + 120 * 1 + 130 * 1.5 + 130 * 1 + 120 * 1.5
= 1015 psf (neglect wt. of geosynthetic liners)

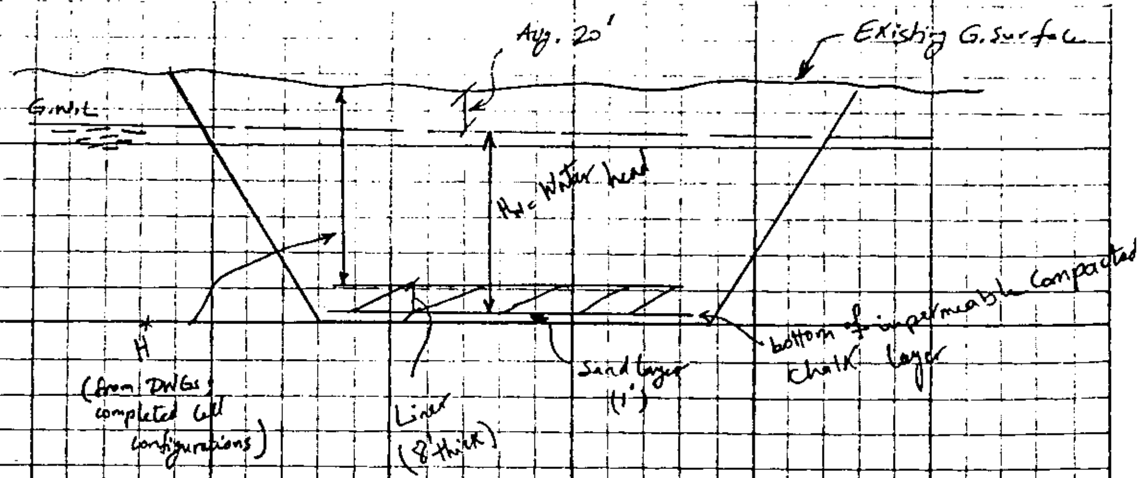
Therefore applied stress is:

P = 1015 + 110 * H_{waste}

c) Uplift pressure:

Uplift pressure = 62.4 * H_w
where H_w = head of water at liner bottom which may be estimated by the difference between estimated ground water level and bottom of liner level.

The Head water will be assumed/estimated based on the worst case among all the cells in Trenches 22, 23, and 24.



Golder Associates

SUBJECT Evaluation of uplift - Pressure Relief		
Job No. 933-3553.6 Ref. Emelle	Made by SYZ Checked CM Reviewed WRS	Date 9/20/93 Sheet 4 of 6

Using information available in "Trenches 22, 23, & 24 completed Cell configurations", DWGs # 00-200-215 & 00-200-216, the following Head water in feet was obtained:

$H_W = H^* - 20' + 8'$ (see sketch on sheet 3)

H* — difference between G. surface & completed cell config. elev.

20' — G.W. Depth below G. surface

8' — liner

Trench	Cell	(max) H* (ft)	Hw (ft)
22	1	~ ~~70~~ 43	~~58~~ 31
	2	~ ~~100~~ 53	~~88~~ 41
	3	~ ~~75~~ 53	~~65~~ 41
	4	~ ~~100~~ 68	~~88~~ 56
23	1	~ 60	48 ✓
	2	~ 80	68 ✓
	3	~ 70	58 ✓
	4	~ 70	58 ✓
	5	~ 90	78 ✓
24	1	~ 65	53 ✓
	2	~ 62	50 ✓
	3	~ 75	63 ✓
	4	~ 62	50 ✓
	5	~ 55	43 ✓

Use max Hw for uplift calculations.

Then max Head water expected = 78' say 80'

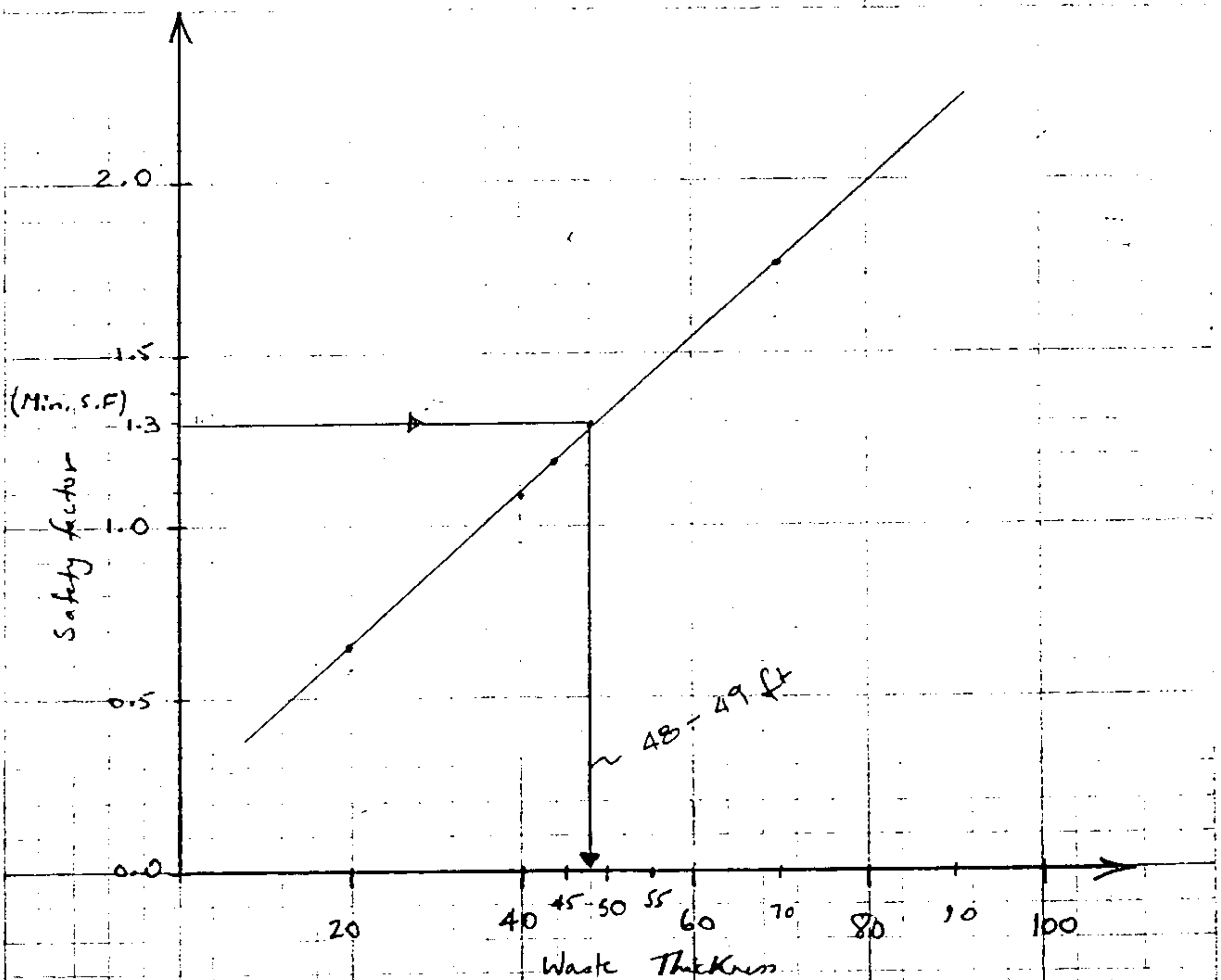
The max target uplift pressure is = 62.4 x 80 = 4992 psf

Golder Associates	SUBJECT Evaluation of uplift – Pressure Relief	
Job No. 933-3553.6	Made by SYE	Date 1/20/93
Ref. Emelle	Checked CM	Sheet 5 of 6
	Reviewed WRS	

H_{waste} (ft)	Applied stress (psf)	Max. uplift stress (psf)	S.F
20	3215	4992	0.64
40	5415	4992	1.08
45	5965	4992	1.19
→ 50	6515	4992	(1.31)
55	7065	4992	1.42
60	7615	4992	1.53
70	8715	4992	1.75
80	9815	4992	1.97
90	10915	4992	2.19
100	12015	4992	2.41

Since the uplift pressure is based on the maximum expected uplift pressure among all the cells in trenches 22, 23, and 24, which is conservative, a reasonable safety factor may be used. Therefore, The pressure relief system may be turned off when waste thickness in any cell reaches 50 feet or Waste level is within 10' below the Original Ground Surface. This would produce a reasonable safety factor against uplift.

Golder Associates			
SUBJECT Evaluation of uplift - Pressure relief			
Job No. 933-3553.6	Made by SYZ	Date 9/20/93	
Ref. Emelle	Checked CM	Sheet 6	of 6
	Reviewed WLS		



PRIMARY LEACHATE COLLECTION SYSTEM
25-YEAR 24-HOUR STORM DESIGN

Subject: Primary Leachate Collection System 25 Year 24 Hour Storm Design

Objective: Design the Primary Leachate Collection System (PLCS) such that the leachate in the PLCS sump does not rise over 1 foot above the rim of the sump.

Approach: After the construction of each cell, the PLCS is covered with 1.5 ft of loosely compacted chalk on the floor of the cell and a 1 ft layer up the sideslopes a minimum of 5 feet. This layer protects the PLCS from damage during filling of the cell. The remaining portion of the PLCS is exposed. To prevent damage to the PLCS due to exposure and to reduce the direct inflow of rainfall into the PLCS a sacrificial geomembrane will be placed on the sideslopes. All rain falling on the sideslopes will be directed to the base of the cell and allowed to pond. The ponded water will be pumped out of the cell to storage units. A berm will be constructed around the PLCS riser to prevent direct flow of water to the PLCS sump. The system must be designed such that the leachate in the PLCS sump does not rise over 1 foot above the rim of the sump.

Given the above, determine the flow into the PLCS due to infiltration through the chalk layer, the maximum flow of the PLCS, and the maximum flow into the sump..

Conclusion: A berm of 8 feet at the PLCS riser is required to allow ponding of the 25 yr 24 hr storm. Leachate in the PLCS sump will not exceed 1 foot above the rim of the sump.

Assumptions:

$R_{25yr24hr} \equiv 7.5 \cdot in$	Design Rainstorm (25 Year 24 Hour)
$K_{chalk} := 10^{-5} \cdot \frac{cm}{sec}$	Permiability of Chalk (Loose)
$K_{gravel} \equiv 2 \cdot \frac{cm}{sec}$	Permiability of Gravel
$i_{gravel} \equiv .02$	Gradient to sump
$L_{sump} \equiv 24 \cdot ft$	Length of Sump
$W_{sump} \equiv 28 \cdot ft$	Width of Sump
$Q_{pump} := 30 \cdot \frac{gal}{min}$	Pump Capacity

E_i = Elevation @ Edge of area i

Calculations:

Estimate height of water in cell due to Design Storm.

Trench 23 Cell 1 Sump elevation 182 MSL (see page 7 of 8)

$A_{T23C1} := 541000 \cdot ft^2$

$Vol_{rainfall} := A_{T23C1} \cdot R_{25yr24hr}$

$Vol_{rainfall} = 338125 \cdot ft^3$ ✓✓

$i := 0, 1 .. 5$

$E_i :=$	$A_i :=$
182	0
186	64400
189.1	123800 ✓
190	132000 ✓

$n := 1 .. 3$

$V_0 := 0$

$$V_n := \frac{A_n + A_{n-1}}{2} \cdot (E_n - E_{n-1}) + V_{n-1}$$

$$V = \begin{bmatrix} 0 \\ 128800 \\ 420510 \\ 535620 \end{bmatrix} \begin{matrix} V_0 \\ V_1 \\ V_2 \\ V_3 \end{matrix}$$

$VV := 338125$

$Vol_{rainfall} = 338125 \cdot ft^3$

$$H_{required} := \frac{VV - V_1}{V_2 - V_1} \cdot (E_2 - E_1) + (E_1 - E_0)$$ ✓

(handwritten annotations: E_2 = 189.1, E_1 = 186, E_1 = 186, E_0 = 182; V_2 = 420,510; V_1 = 128,800)

$H_{required} = 6.2$ ✓

About 7 feet of water will occur in Trench 23 Cell 1.

SUBJECT	PLCS 25 Year 24 Hour Storm Design				
Job No.	933-3553	Made by	JEF	Date	9/27/93
Ref.	CWM/Permit Support/AL	Checked	SYI / RID	Sheet	3 of 8
		Reviewed	[signature]		

Golder Associates

Trench 23 Cell 2 **(see page 7 of 8)**

$A_{T23C2} := 600200 \cdot ft^2$

$Vol_{rainfall} := A_{T23C2} \cdot R_{25yr24hr}$

$Vol_{rainfall} = 375125 \cdot ft^3$

$E_i :=$ $A_i :=$ $n := 1..3$

E_i	A_i
178	0
180	17200
184	126000
186	161900

$V_0 := 0$

$$V_n := \frac{A_n + A_{n-1}}{2} \cdot \left(E_n - E_{n-1}\right) + V_{n-1}$$

$$V = \begin{bmatrix} 0 \\ 17200 \\ 303600 \\ 591500 \end{bmatrix}$$

$VV := 375125$ $k := 3$

$Vol_{rainfall} = 375125 \cdot ft^3$

$$H_{required} := \frac{VV - V_{k-1}}{V_k - V_{k-1}} \cdot \left(E_k - E_{k-1}\right) + \left(E_{k-1} - E_0\right)$$

$H_{required} = 6.5$ $H := 6.5 \cdot ft$ $Unit := 1 \cdot ft^2$

$$Area := \left[\left(A_k - A_{k-1}\right) \cdot \frac{E_0 + H_{required} - E_{k-1}}{E_k - E_{k-1}} + A_{k-1}\right] \cdot Unit$$

$Area = 134918.9 \cdot ft^2$

About 7 feet of water will occur in Trench 23 Cell 2.

Trench 24 Cell 3 (see page 8 of 8)

$A_{T24C3} := 527000 \cdot ft^2$

$Vol_{rainfall} := A_{T24C3} \cdot R_{25yr24hr}$

$Vol_{rainfall} = 329375 \cdot ft^3$

$E_i :=$ $A_i :=$ $n := 1..3$

$V_0 := 0$

E_i	A_i
195.5	0
198	29000
201.5	118500
204	167000

$$V_n := \frac{A_n + A_{n-1}}{2} \cdot \left(E_n - E_{n-1}\right) + V_{n-1}$$

$$V = \begin{bmatrix} 0 \\ 36250 \\ 294375 \\ 651250 \end{bmatrix}$$

$VV := 329375$ $k := 3$

$Vol_{rainfall} = 329375 \cdot ft^3$

$$H_{required} := \frac{VV - V_{k-1}}{V_k - V_{k-1}} \cdot \left(E_k - E_{k-1}\right) + \left(E_{k-1} - E_0\right)$$

$H_{required} = 6.2$

About 7 feet of water will occur in Trench 24 Cell 3

Trench 24 Cell 4 (see page 8 of 8)

$A_{T24C4} := 516300 \cdot ft^2$

$Vol_{rainfall} := A_{T24C4} \cdot R_{25yr24hr}$

$Vol_{rainfall} = 322687.5 \cdot ft^3$

$E_i :=$ $A_i :=$

E_i	A_i
182	0
184	19700
186	60000
190	136000

$n := 1..3$

$V_0 := 0$

$$V_n := \frac{A_n + A_{n-1}}{2} \cdot (E_n - E_{n-1}) + V_{n-1}$$

$$V = \begin{bmatrix} 0 \\ 19700 \\ 99400 \\ 491400 \end{bmatrix}$$

$VV := 322687.5$ $k := 3$

$Vol_{rainfall} = 322687.5 \cdot ft^3$

$$H_{required} := \frac{VV - V_{k-1}}{V_k - V_{k-1}} \cdot (E_k - E_{k-1}) + (E_{k-1} - E_0)$$

$H_{required} = 6.3$

About 7 feet will occur in Trench 24 Cell 4

FLOW THROUGH LOOSELY COMPACTED CHALK LAYER

$i_{chalk} := 1$ Assume saturated

$Area = 134918.9 \cdot ft^2$ Use Area of Cell 2 Trench 23

$Q_{chalk} := K_{chalk} \cdot i_{chalk} \cdot Area$

$Q_{chalk} = 28609 \cdot \frac{gal}{day}$

$Q_{chalk} = 19.87 \cdot \frac{gal}{min}$

MAXIMUM FLOW INTO SUMP

$Q_{sump} := K_{gravel} \cdot i_{gravel} \cdot (L_{sump} \cdot 2 + W_{sump} \cdot 2) \cdot 1 \cdot ft$

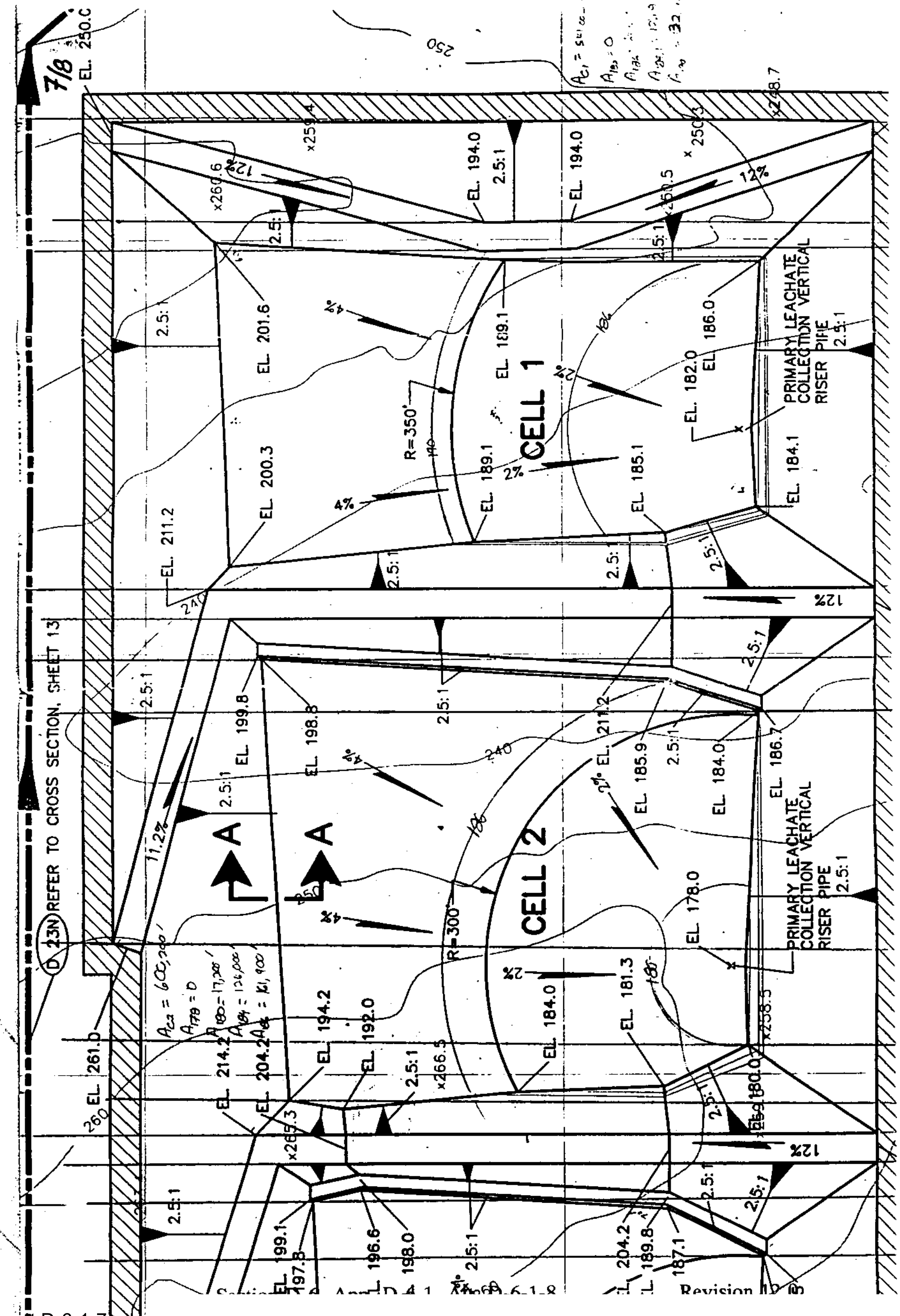
Area = perimeter of sump * 1 ft depth of gravel

$Q_{sump} = 88211.2 \cdot \frac{gal}{day}$ $Q_{sump} = 61.3 \cdot \frac{gal}{min}$

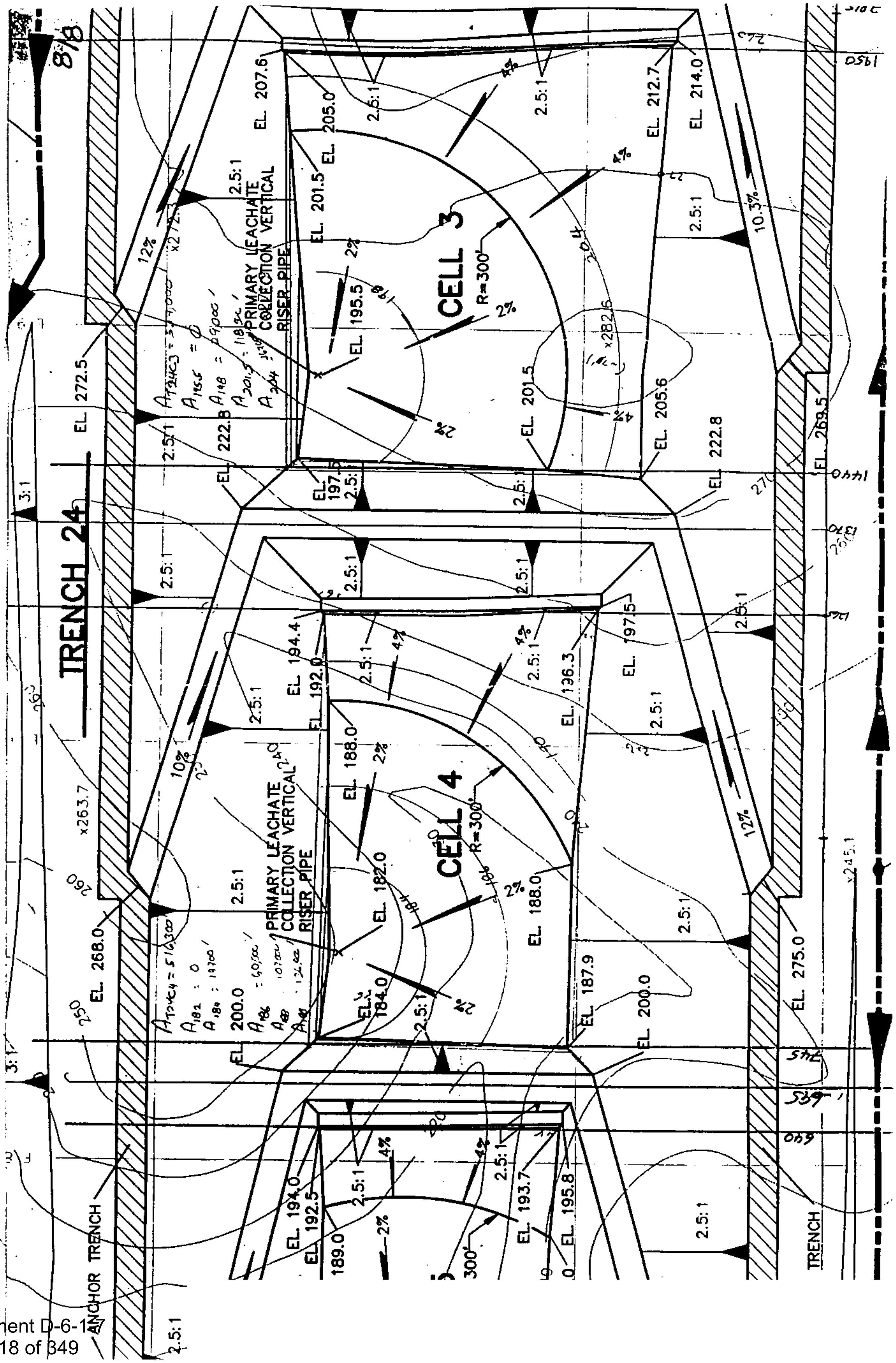
$Q_{pump} = 43200 \cdot \frac{gal}{day}$ $Q_{pump} = 30 \cdot \frac{gal}{min}$

CONCLUSIONS:

A 8 foot berm must be constructed around the PLCS riser to prevent rainwater from directly flowing into the PLCS sump. The ponded water will infiltrate the loosely compacted chalk at a rate of 20 gal/min. The maximum inflow into the sump is 61 gal/min which carry the flow from the infiltration through the chalk. The pumping capacity of 30 gal/min is greater than the infiltrated flow of 20 gal/min. Therefore the system with the rainwater flowing into the base of the cell and ponding the water will not exceed the 1 foot maximum head above the PLCS sump rim.



D 23N REFER TO CROSS SECTION, SHEET 13
CELL 1
CELL 2
PRIMARY LEACHATE COLLECTION VERTICAL RISER PIPE
PRIMARY LEACHATE COLLECTION VERTICAL RISER PIPE
R=350'
R=300'
EL. 194.0
EL. 194.0
EL. 201.6
EL. 200.3
EL. 211.2
EL. 189.1
EL. 189.1
EL. 182.0
EL. 186.0
EL. 185.1
EL. 184.1
EL. 199.8
EL. 198.8
EL. 211.2
EL. 185.9
EL. 184.0
EL. 186.7
EL. 178.0
EL. 181.3
EL. 184.0
EL. 194.2
EL. 192.0
EL. 214.2
EL. 204.2
EL. 261.0
EL. 250.0
2.5:1
12%
11.2%
4%
2%
A
A


TRENCH 24
CELL 3
CELL 4
R=300'
PRIMARY LEACHATE COLLECTION VERTICAL RISER PIPE
ANCHOR TRENCH
TRENCH
EL. 207.6
EL. 205.0
EL. 201.5
EL. 195.5
EL. 212.7
EL. 214.0
EL. 272.5
EL. 222.8
EL. 205.6
EL. 269.5
EL. 197.5
EL. 194.4
EL. 192.0
EL. 188.0
EL. 182.0
EL. 184.0
EL. 136.3
EL. 187.9
EL. 200.0
EL. 268.0
EL. 275.0
EL. 194.0
EL. 192.5
EL. 189.0
EL. 193.7
EL. 195.8
2.5:1
3:1
2%
4%
10%
12%
10.5%

PERIMETER DITCH DESIGN

Golder Associates	SUBJECT Perimeter Ditch Design		
	Job No. 933 3553	Made by TDF	Date 10/8/93
	Ref. Cum/Emelle	Checked JST	Sheet 1 of 9
		Reviewed CM	

OBJECTIVE: Size perimeter drainage ditch for trenches 21, 22, 23 & 24 for closure condition & for during operation.

ASSUME: All ditches will be sized for the 25 yR, 24 hr Storm event.

Size the ditches for the worst case drainage condition. (i.e. Largest drainage area / largest runoff flow rate). Assume for "during operation" that the slopes on cover are set.

GIVEN: Cover grading plan as shown on drawing.

25 yR 24 hr storm = 7.5 in

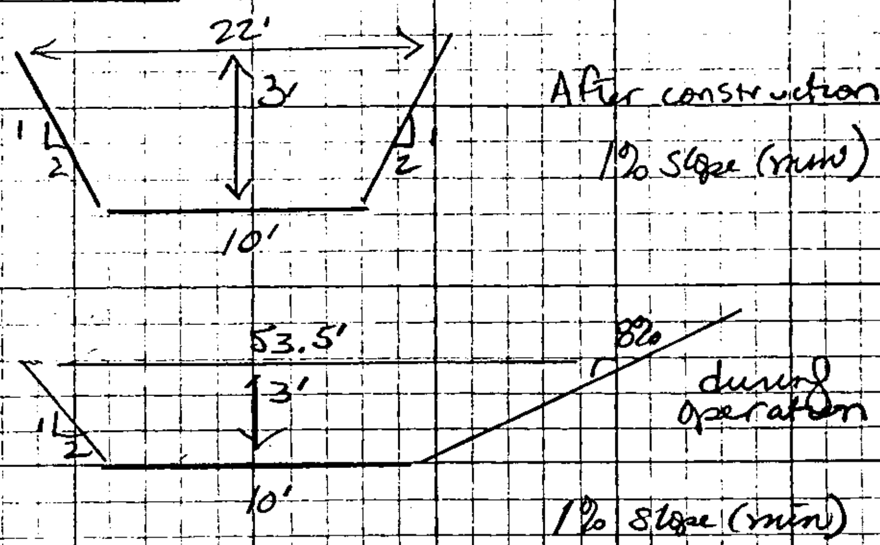
2 yR 24 hr storm = 4.5 in

Rainfall Distribution = Type III

Use SCS, TR-55 methodology for Runoff estimates. Soil type D (conservative)

Use Manning Equation for Ditch Sizing

Results.

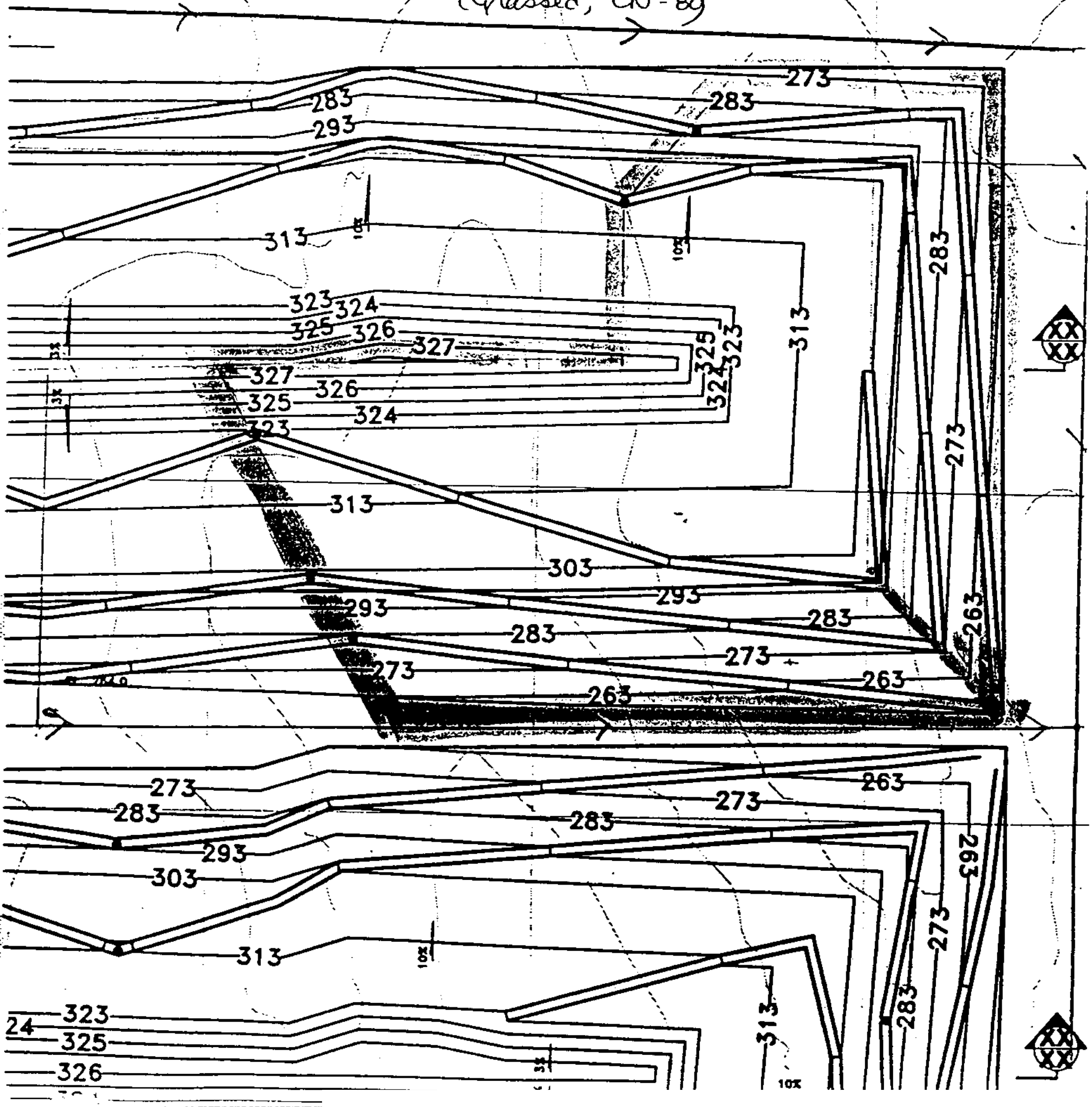


2/9

Scale 1" = 200'

[travel length]
100' sheet @ 4%
1000' shall conc @ 3%
300' pipe/open chan @ 13%
(use V = 15 ft/sec)

Drainage Area
= 818,750 ft² = 18.8 acres
(Grassed, CN = 80)



TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : EMELLE User: TOMF Date: ~~01-05~~-93
County : State: AL Checked: [initials] Date: 10/25/93
Subtitle: MAXIMUM DITCH SIZING
Subarea : A

COVER DESCRIPTION	A	B	C	D
	Hydrologic Soil Group Acres (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)				
Open space (Lawns,parks etc.)				
Good condition; grass cover > 75%	-	-	-	89.9(80)
Total Area (by Hydrologic Soil Group)				89.9

SUBAREA: A TOTAL DRAINAGE AREA: 89.9 Acres WEIGHTED CURVE NUMBER:80

TR-55 Tc and Tt THRU SUBAREA COMPUTATION VERSION 1.11

Project : EMELLE User: TOMF Date: 01-05-93
County : State: AL Checked: JSZ Date: 10/25/93
Subtitle: MAXIMUM DITCH SIZING

Subarea #1 - A

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	4.5	80	.03	E					0.093
Shallow Concent'd		1050	.03	U					0.104
Open Channel		180						15	0.003
Open Channel		2775						4	0.193

Time of Concentration = 0.39*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense

--- Shallow Concentrated ---
--- Surface Codes ---
P Paved
U Unpaved

* - Generated for use by TABULAR method

TR-55 TABULAR DISCHARGE METHOD VERSION 1.11

Project : EMELLE User: TOMF Date: 01-05-93
County : State: AL Checked: [illegible] Date: 10/25/[illegible]
Subtitle: MAXIMUM DITCH SIZING

Total watershed area: 0.140 sq mi Rainfall type: III Frequency: 25 years

--------------------------- Subareas ---------------------------

	A
Area(sq mi)	0.14*
Rainfall(in)	7.5
Curve number	80*
Runoff(in)	5.16
Tc (hrs)	0.39*
(Used)	0.40
TimeToOutlet	0.00
Ia/P	0.07
(Used)	0.10

Time (hr)	Total Flow	------------- Subarea Contribution to Total Flow (cfs) ------------ A
11.0	17	17
11.3	21	21
11.6	28	28
11.9	47	47
12.0	66	66
12.1	96	96
12.2	143	143
12.3	223	223
12.4	306	306
12.5	325P	325P
12.6	302	302
12.7	250	250
12.8	199	199
13.0	117	117
13.2	78	78
13.4	59	59
13.6	49	49
13.8	44	44
14.0	41	41
14.3	36	36
14.6	33	33
15.0	30	30
15.5	25	25
16.0	22	22
16.5	18	18
17.0	16	16
17.5	14	14
18.0	13	13
19.0	11	11
20.0	9	9
22.0	8	8
26.0	0	0

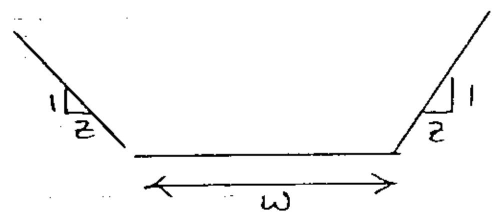
P - Peak Flow * - value(s) provided from TR-55 system routines

Golder Associates	SUBJECT Ditch Sizing / Closure condit.		
	Job No. 933 3553 Ref. Cum/Emelle	Made by RBF Checked JST Reviewed CM	Date 10/8/93 Sheet 6 of 9

From TR55 Results, Peak 25-yr, 24 hour flow Rate For Ditch @ Point "A" as labeled on Drawing = 325 cfs

---

Assume, For Ditch sizing, the Following Dimensions / Geometry



Base slope = 1%

Side slope (z) = 2:1

Trial width (w) = 10'

Trial depth (D) = ?

η (grass lined) = .030 approx

η (chalk) = .040
nat soils
(est) previously

Mannings $Q = \frac{1.49}{n} \frac{A^{5/3}}{P^{2/3}} S^{1/2}$

use final, grassed lined conditions for Roughness Condit.

$$\therefore Q = \frac{1.49}{.030} * \frac{\left[(10*d)+(2d*d)\right]^{5/3}}{\left[10 + 2\sqrt{(2d)^2 + d^2}\right]^{2/3}} (.01)^{1/2}$$

Golder Associates	SUBJECT Ditch Sizing / Closure Condit		
	Job No. 933 3553 Ref. arm/Emelle	Made by TPF Checked JEF Reviewed CM	Date 10/8/93 Sheet 7 of 9

Simplifying gives:

$$Q = 4.97 * \frac{(10d + 2d^2)^{5/3}}{(10 + 4.47d)^{2/3}}$$

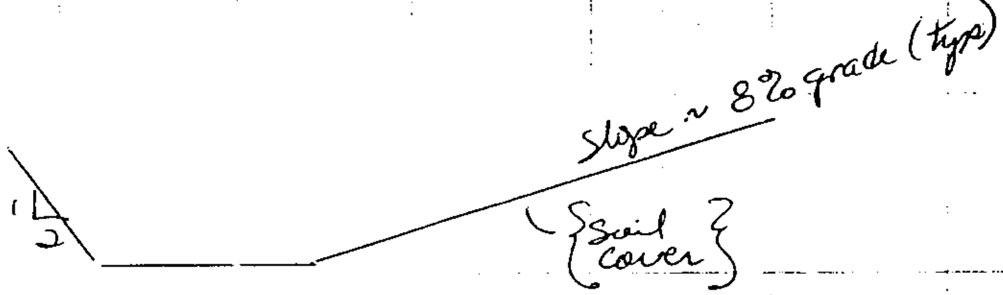
depth	Q calc
3	385.94 **
2.5	273.32

∴ minimum depth after closure = 3'

(since $Q_{Req'd}$ = 325 cfs)

Golder Associates

SUBJECT Operational channel Sizing		
Job No. 933 3553	Made by PJF	Date 10/8/93
Ref. Cvm/Emelle	Checked [illegible]	Sheet 8 of 9
	Reviewed CM	



Assume chalk $n = .040$ (per NPDES applic, 1986)

Use Qcalc as previously (i.e. 325 cfs max). Note that this may be a high estimate for consideration, however it is therefore likely to be <u>very</u> conservative.

$$Q = \frac{1.49}{.040} \frac{A^{5/3}}{P^{2/3}} (.01)^{1/2}$$

try a Base width of 10'

$$\therefore \frac{1.49}{.040} \frac{\left(10d + \left[(2 * d * d)/2 + ((12.5 * d)(d))/2\right]\right)^{5/3}}{\left(10 + ((2d)^2 + d^2)^{1/2} + ((12.5d)^2 + (d)^2)^{1/2}\right)^{2/3}} (.01)^{1/2}$$

$$= 3.73 \frac{\left(10d + (2d^2/2 + 12.5d^2/2)\right)^{5/3}}{\left(10 + (5d^2)^{1/2} + (157.25d^2)^{1/2}\right)^{2/3}}$$

Golder Associates

SUBJECT	Operational Channel Sizing
Job No. 933-3553	Made by DBF
Ref. CWM/Emelle	Checked [illegible]
	Reviewed CM
Date	10/8/93
Sheet	9 of 9

Trial d	Q cfs
1'	50.5 cfs
2.5'	343
3'	~~349.14 cfs~~ 516 CFS

Since 325 cfs < ~~349.14~~ 343 cfs, minimum Berm ht (and/or channel depth) = ~~3.0~~ 2.5'

2.5 OK

SOIL EROSION LOSS ANALYSIS

Annual Soil Erosion for the Final Cover

Objective: Determine the annual soil loss expected from the final cover after the vegetation has been established.

Approach: The universal soil loss equation (USLE), as shown below, will be used to determine the annual loss from the final cover.

Define Parameters:

R ......Rainfall Erosion Index

K ......Soil Erodibility Factor

LS ......Slope Length and Steepness Factor

C ......Vegetative Cover/Management Factor

P ......Erosion Control Practice Factor

Using the above parameters, the annual soil loss is estimated as:

$A = R{*}K{*}LS{*}C{*}P$ ......Universal Soil Loss Equation

CALCULATIONS :

Rainfall Erosion Index (R) : Based on a discussion with the SCS office in Livingston, Alabama.

$R := 375$

Soil Erodibility Factor (K) : Based on a discussion with the SCS office in Livingston, Alabama.

$K := 0.37$

Slope Length Steepness Factor (LS) : Refer to the Manual of Erosion and Sediment Control in Georgia.. Using a slope length of 85 ft and a slope of 25% the following is the LS factor (20 ft vertical rise (approx) per erosion control bench).

$LS := 5.43$

Vegetative Cover/Mgmt Factor (C) : Refer to table B-2.3 of the Manual of Erosion and Sediment Control in Georgia. Assuming 80% ground cover with no appreciable canopy, the C factor is 0.013.

$C := 0.013$

Erosion Control Practice Factor (P) : Refer to the Manual of Erosion and Sediment Control in Georgia. For the proposed practice of terracing, the following is the P factor

$$P := 0.18$$

Using the above parameters, the Universal Soil Loss Equation as shown below can be used to estimate the soil loss per year as :

$$A := R \cdot K \cdot LS \cdot C \cdot P \cdot \frac{ton}{acre \cdot year} \qquad \text{where } year \equiv 365 \cdot day$$

Substituting all the parameters in the above equation, the annual soil loss is :

$$A = 1.8 \cdot \frac{ton}{acre \cdot year}$$

CONCLUSION :

The Emelle landfill, as designed will have a 4:1 side slope and a maximum slope length of 85 ft. The results of the above calculations indicate that the annual erosion rate will be 1.8 tons/acre/year.

HAUL ROAD GEOSYNTHETIC SURVIVABILITY

Subject: Haul Road Geosynthetic Survivability

Objective: Determine survivablity of the 60 mil HDPE liner in contact with the compacted chalk and the 60 mil HDPE liner with the geosynthetic transmissive layer.

Approach: Determine the required puncture resistance for static and dynamic conditions.

Assumptions:

- 60 mil HDPE liner for the Primary Leachate Collection System (PLCS)

- Maximum particle size of the compacted chalk - $d_{max\_chalk} := \frac{3}{4} \cdot in$

- Rail width of geonet = 0.1 in $d_{max\_geonet} := 0.1 \cdot in$

- Diameter of a circular hole used for burst test. (ASTM 3786 Burst Test) $b_b := 1.2 \cdot in$

- Factor of Safety for dynamic loading - $FS_{dynamic} := 3$

- Factor of Safety for static loading - $FS_{static} := 1.5$

Dynamic Loading:

Assume chalk will be placed in > 18 inch lifts $d_{chalk} := 18 \cdot in$

$$\gamma_{chalk} := 110 \cdot \frac{lb}{ft^3}$$

$$\sigma_{DL} := d_{chalk} \cdot \gamma_{chalk}$$

$$\sigma_{DL} = 1.1 \cdot \frac{lb}{in^2}$$

$$\sigma_{LL} := 43 \cdot \frac{lb}{in^2}$$

(Figure 1 - 633D Scraper operating with 18" of cover)

$$P_{dynamic} := (\sigma_{LL} + \sigma_{DL}) \cdot FS_{dynamic} \qquad P_{dynamic} = 132 \cdot \frac{lb}{in^2}$$

Golder Associates	SUBJECT	HAUL ROAD GEOSYNTHETIC SURVIVABILITY				
	Job No.	933-3553	Made by	JEF	Date	11/15/93
	Ref.	CWM/Permit Support/AL	Checked	CW	Sheet	2 of 4
			Reviewed	LKO		

- Static loading

$max\_height := 150 \cdot ft$ $\qquad \gamma_{waste} := 110 \cdot \frac{lb}{ft^3}$

$\sigma_{DL} := max\_height \cdot \gamma_{waste}$

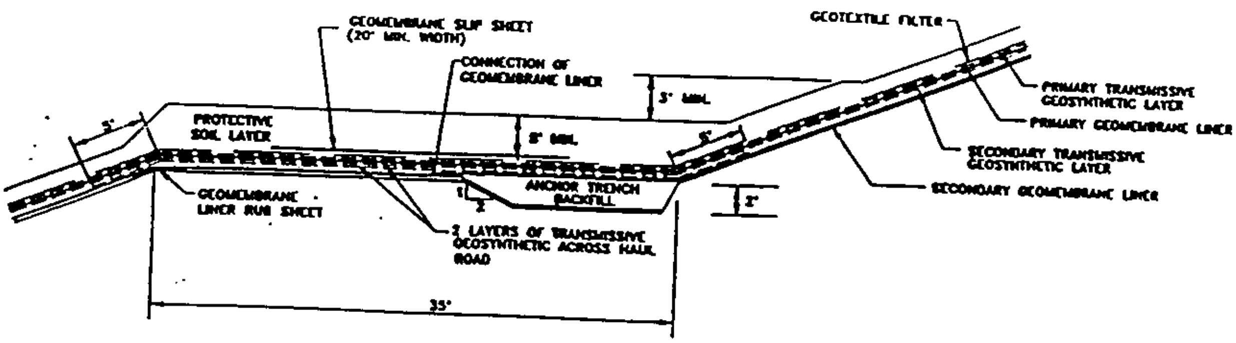
$\sigma_{DL} = 115 \cdot \frac{lb}{in^2}$

$P_{static} := \sigma_{DL} \cdot FS_{static}$ $\qquad P_{static} = 172 \cdot \frac{lb}{in^2}$

Therefore the critical loading is the static condition.

$P_{critical} := P_{static}$

$P_{critical} = 172 \cdot \frac{lb}{in^2}$



TYPICAL HAUL ROAD ANCHOR TRENCH

SCALE IN FEET
0 5 10

Calculations:

Chalk-Liner

Puncture Analysis:

$R_{puncture} := P_{critical} \cdot d_{max\_chalk}^2$ (Reference 1, Eq. 2.4)

$R_{puncture} = 96.7 \cdot lb$

Liner-GeoNet

Puncture Analysis:

$R_{puncture} := P_{critical} \cdot d_{max\_geonet}^2$ (Reference 1, Eq. 2.4)

$R_{puncture} = 1.7 \cdot lb$

CONCLUSIONS:

The specifications for 60 mil HDPE geomembrane are provided in Table 1 - Geosynthetic Material Specifications, HDPE Smooth Geomembrane and Table 2 - Geosynthetic Material Specifications, HDPE Textured Geomembrane in Attatchment D-6-1-4. The specified Puncture Strength for the smooth and textured 60 mil HDPE is 108 lb. Therefore 18 inches of chalk is of sufficient thickness to protect the liner system.

REFERENCES:

1. Giroud, J.P. (1985). Designing with Geotextiles" Geotextiles and Geomembranes: Definitions Properties and Design-Selected Papers, Revisions and Comments. Third Edition. Industrial Fabrics Association.

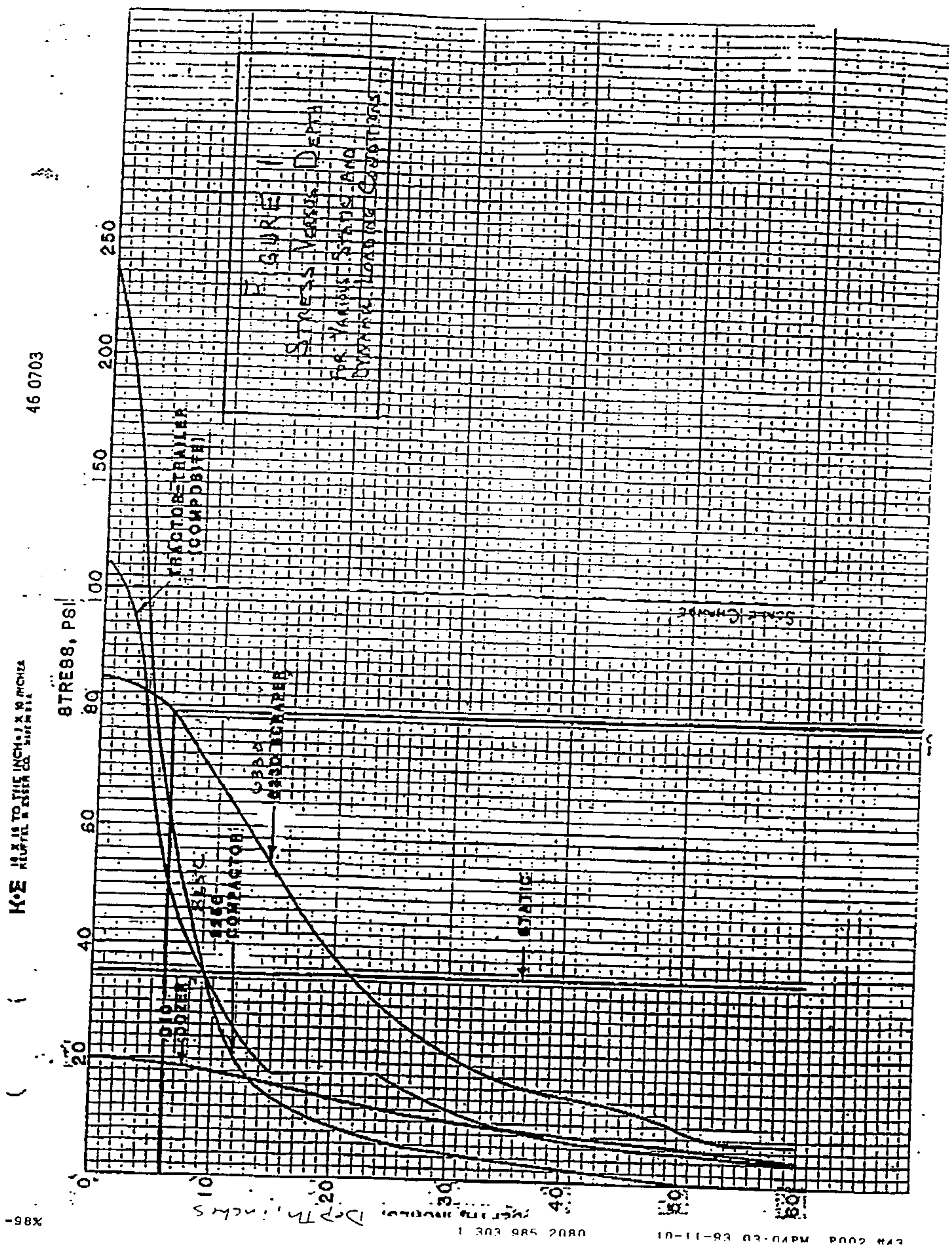


FIGURE 1
STRESS VERSUS DEPTH
FOR VARIOUS STATIC AND
DYNAMIC LOADING CONDITIONS
TRACTOR-TRAILER
(COMPOSITE)
631D SCRAPER
825C COMPACTOR
D10 DOZER
STATIC
STRESS, PSI
0
20
40
60
80
100
150
200
250
DEPTH, inches
0
10
20
30
40
50
60
K•E
46 0703
1 303 985 2080
10-11-93 03:04PM P002 #43

Designing with geotextiles

J.-P. Giroud [1]

This paper deals with three current functions of geotextiles: geotextile drains; geotextile filters; geotextile separators.
The impartant properties of geotextiles in each function are discussed and permeability, filtration and strength criteria are proposed. Examples of design are presented for each function.

NOTATION

A	=	area of geotextile	m^2
b	=	width of span (either width of a crack or diameter of a circular hole) or typical length to be used in equations (27) to (32)	m
b_b	=	width of hole in burst test	m
b_t	=	width of hole in trough test	m
B	=	width of embankment	m
c_v	=	coefficient of consolidation of soil in the vertical direction	m^2/s
d	=	diameter of soil particles	mm
d_f	=	diameter of filaments	mm
d_{15}	=	15% soil size (15% by weight is finer)	mm
d_{50}	=	50% soil size (50% by weight is finer)	mm
d_{85}	=	85% soil size (85% by weight is finer)	mm
F	=	factor of safety	dimensionless
g	=	acceleration of gravity	m/s^2
h	=	height of embankment	m
H_g	=	thickness of geotextile	mm
H'_g	=	thickness of compressed geotextile	mm
i	=	hydraulic gradient	dimensionless
k	=	coefficient of permeability of soil in the vertical direction	m/s
k_N	=	coefficient of normal permeability of geotextile	m/s
k_p	=	coefficient of permeability of geotextile in its plane	m/s
K_b	=	modulus of geotextile in burst test	N/m
K_t	=	modulus of geotextile in trough test	N/m
L	=	length of cross section of geotextile perpendicular to flow direction	m
L'	=	length of geotextile parallel to flow direction	m
n_s	=	porosity of soil	dimensionless
n_g	=	porosity of geotextile	dimensionless
O	=	opening size	mm
O_{50}	=	50% geotextile opening size (50% of the openings are smaller than O_{50})	mm
O_{95}	=	95% geotextile opening size (95% of the openings are smaller than O_{95})	mm
O'	=	opening size corresponding to a compressed geotextile	mm
O'_{50}	=	50% compressed geotextile opening size	mm
O'_{95}	=	95% compressed geotextile opening size	mm
p	=	pressure exerted on a geotextile in the field	Pa
p_{max}	=	maximum pressure withstood by a geotextile in the field	Pa

[1] Director of Geotextiles and Geomembranes Group Woodward-Clyde Consultants, Chicago, USA.

0025-5432/1981/257 / $ 5.00/ © BORDAS-DUNOD

REF. #1

p_b	=	pressure in burst test	Pa
p_{bf}	=	pressure at failure in burst test	Pa
p_t	=	pressure in trough test	Pa
p_{tf}	=	pressure at failure in trough test	Pa
Q	=	rate of flow	m^3/s
R_G	=	grab strength of geotextile	N
R_S	=	snag strength of geotextile	N
R_P	=	puncture strength of geotextile	N
t	=	time to build an embankment	s
U	=	soil uniformity coefficient	dimensionless
y	=	deflection of geotextile	m
α	=	anguish (force per unit width)	N/m
α_b	=	anguish in burst test	N/m
α_{bf}	=	anguish at failure in burst test	N/m
α_t	=	anguish in trough test	N/m
α_{tf}	=	anguish at failure in trough test	N/m
β	=	slope angle	degree
Δh	=	hydraulic head loss	m
Δp	=	difference in water pressure	Pa
Δz	=	difference in elevation	m
ε	=	elongation of geotextile	dimensionless
ε_b	=	elongation of geotextile in burst test	dimensionless
ε_{bf}	=	elongation of geotextile at failure in burst test	dimensionless
ε_{gf}	=	elongation of geotextile at failure in grab test	dimensionless
ε_t	=	elongation of geotextile in trough test	dimensionless
ε_{tf}	=	elongation of geotextile at failure in trough test	dimensionless
θ	=	transmissivity of geotextile	m^2/s
λ	=	coefficient	dimensionless
μ	=	mass per unit area of geotextile	kg/m^2
ν	=	Poisson's ratio of geotextile	dimensionless
ρ	=	mass per unit volume of embankment material	kg/m^3
ρ_f	=	mass per unit volume of filaments	kg/m^3
ρ_{sat}	=	mass per unit volume of saturated soil	kg/m^3
ρ_w	=	mass per unit volume of water	kg/m^3
Ψ	=	permittivity of geotextile	s^{-1}

INTRODUCTION

When dealing with geotextiles, the engineering profession is faced with a lack of rational design methods and a multitude of tests for identification and quality control of geotextiles. At present, the design of geotextile applications remains mostly empirical and is guided by the results of index property tests.

The purpose of this paper is to show that the results of tests can be directly used for the design of geotextile applications. Three functions of geotextiles are considered: drainage, filtration and separation. For each function, a design procedure is established by using basic concepts of mechanics, hydraulics and geotechnics. Practical examples are presented.

DESIGN OF A GEOTEXTILE DRAIN

The drainage function

Definition of a geotextile drain: the geotextile is placed in contact with a material of low permeability (fine soil, concrete, geomembrane, etc.) through which water is seeping slowly; its function is to gather the water and to convey it towards the outlet.

Typical examples are presented in figure 1.

Transmissivity of a geotextile

In order to acts as a drain, a geotextile must exhibit transmissivity.

The flow of water into the plane of a geotextile is governed by Darcy's formula. To introduce the property of transmissivity in a simple way, the case of a uniform flow is considered (*fig.* 2). In this case Darcy's formula is written:

$$\frac{Q}{L} = k_p H_g \frac{\Delta h}{L'} = \theta i, \qquad (1)$$

where: Q: rate of flow (m^3/s); L: length of the cross section of geotextile perpendicular to the flow direction (m); $\theta = k_p H_g$: transmissivity of the geotextile (m^2/s); k_p: coefficient of permeability of the geotextile in its plane (m/s); H_g: thickness of the geotextile (m); $i = \Delta h/L'$: hydraulic gradient (dimensionless); Δh: hydraulic head loss (m); L': length of geotextile parallel to the flow direction (m).

The hydraulic head loss is defined by:

$$\Delta h = \Delta z + \frac{\Delta p}{\rho_w g}, \qquad (2)$$

where: Δz: difference in elevation between the two extremities of the geotextile (m); Δp: difference in water pressure between the two extremities of the geotextile (Pa); ρ_w: mass per unit volume of water (kg/m^3); g: gravity (9.81 m/s^2).

To exhibit a large transmissivity, a geotextile must be thick and/or have a large permeability in its plane. Wovens or heatbonded nonwovens have almost no transmissivity and cannot be used as drains. The only types of geotextiles used as drains are:

— Needlepunched nonwovens: typical values are 3 to 6 mm, or more, for the thickness, 10^{-4} to 10^{-3} m/s for the permeability and 10^{-7} to 10^{-5} m^2/s for the transmissivity.

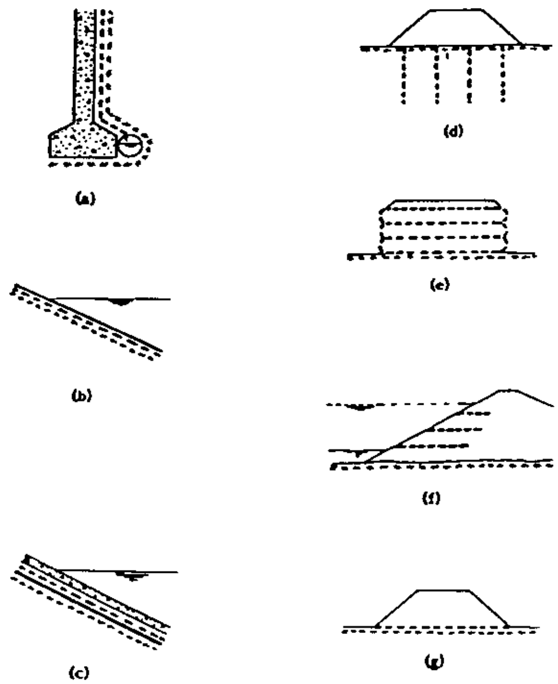


Fig. 1. — Examples of geotextiles acting as drains: (1) *gravity drainage*: (*a*) vertical drain along a wall, (*b*) geotextile below a geomembrane, (*c*) geotextile between concrete lining and geomembrane; (2) *drainage by pressure*: (*d*) vertical drain, (*e*) horizontal drain in a geotextile reinforced embankment, (*f*) horizontal drains of a dam, (*g*) horizontal drain under an embankment.

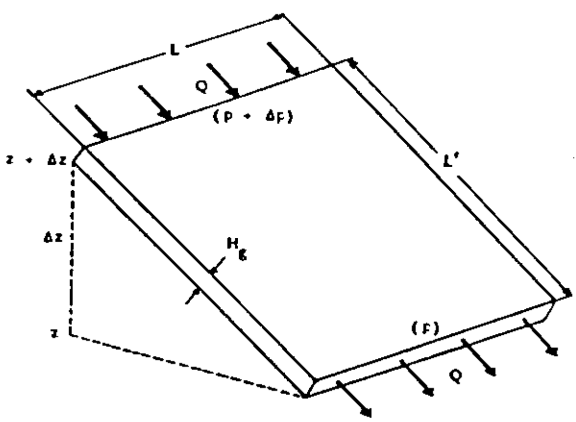


Fig. 2. — Uniform flow of water in the plane of a geotextile.

— Thick and porous materials such as plastic grids or mats (protected by two geotextiles acting as filters, when used in contact with soils); typical values for these materials are 10 to 20 mm, or more, for the thickness, 10^{-1} to 1 m/s for the permeability and 10^{-3} to 10^{-2} m²/s for the transmissivity.

The values given above for thickness, permeability and transmissivity decrease if the geotextile is subjected to compressive stresses. This effect is important in the case of mats and needlepunched nonwoven geotextiles. An example is presented in figure 3.

Design principle of a geotextile drain

The design of a geotextile drain is made by equating the discharge of water flowing from the soil to the geotextile with the discharge of water carried by the geotextile. According to Darcy's formula, both flows are governed by permeability and hydraulic gradient.

The *flow in the soil* is governed by permeability of the soil and hydraulic gradient in the soil. This gradient depends on the geometry of the soil and on the difference between water pressure in the soil and water pressure in the geotextile. Drainage is fast if the gradient in soil is maximum, hence if water pressure in geotextile is minimum. So, the design must be such that the water pressure in the geotextile has the smallest possible value compatible with flow in the geotextile.

The *flow in the geotextile* is governed by permeability of the geotextile and hydraulic gradient in the geotextile. This gradient depends on the slope of the geotextile and on the difference in water pressure within the geotextile and at the outlet of the geotextile. Practically two cases need to be considered:

1) Drains where water flows downwards by gravity. In this case, the hydraulic gradient in the geotextile is due to

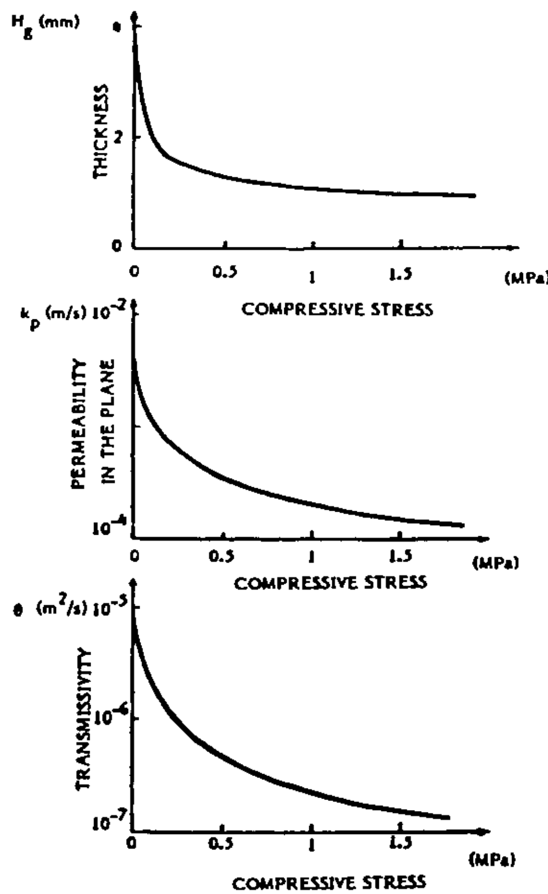


Fig. 3. — Thickness, permeability in the plane and transmissivity of a typical needlepunched nonwoven geotextile.

the slope and the water pressure in the geotextile is equal to the pressure at the outlet (usually zero).

2) Drains where the water does not flow by gravity, such as horizontal drains or drains where water flows upwards (for example, vertical drains in figure 1 *d*). In this case the pressure in the geotextile cannot be constant. The pressure decreases from a maximum value at the origin of the flow to a minimum value at the outlet. The difference between the maximum and the minimum values of the pressure in the geotextile ***must be large enough*** to create a sufficient gradient in the geotextile to ensure flow of water in the geotextile. As previously mentioned, however, the water pressure in the geotextile ***must be low enough*** to create a sufficient hydraulic gradient in the soil to ensure a fast drainage. Consequently, the design must achieve a compromise between the two requirements concerning water pressure in the geotextile.

Two examples of design are presented hereafter. The first example is related to the simple case where the water pressure is constant in the geotextile. The second example is related to the more complex case where the water pressure varies in the geotextile.

Design of a chimney drain in an earth dam

The cross-section of the dam is presented in figure 4. Since water is flowing downwards in the geotextile, no pressure is needed to ensure the flow. Moreover, a zero water pressure is required in a chimney drain to prevent the buildup of water pressure in the downstream part of the dam.

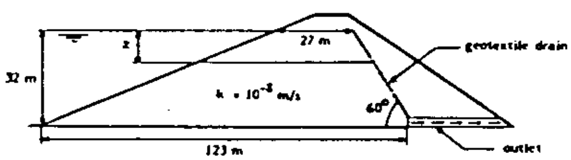


Fig. 4. — Cross section of the dam.

With the assumption of a zero water pressure in the geotextile, the discharge of water through the soil can easily be calculated using a flow net. This classical technique is not presented in detail here. It is worth mentioning that the clay in this dam is very anisotropic, the coefficient of permeability being much larger in the horizontal direction than in the vertical direction. Therefore, the flow lines are almost horizontal and the top of the geotextile drain must be at the level of the impounded water. Since all the water seeping through the dam is gathered by the geotextile, the discharge of water in the geotextile is easily deduced from the flow net. The values thus obtained are presented in table I.

From the anticipated flow rate in the geotextile, the required transmissivity using Darcy's formula is deduced:

$$\theta = k_p H_g = Q/(L i), \qquad (3)$$

TABLE I

DISCHARGE, REQUIRED TRANSMISSIVITY AND COMPRESSIVE STRESS AT DIFFERENT POINTS OF THE GEOTEXTILE IN THE DAM

Depth under the water surface z (m)	Discharge of water in the geotextile per unit width perpendicular to the plane of figure 4 Q/L (m^2/s)	Required transmissivity [calculated with equation (5) using a factor of safety of 10] (*) θ (m^2/s)	Compressive stress applied by the soil on the geotextile σ (kPa)
0.	0	0	98
1.	1.73×10^{-10}	2.44×10^{-9}	118
10.	1.09×10^{-8}	1.54×10^{-7}	294
15.	2.06×10^{-8}	2.91×10^{-7}	392
20.	3.16×10^{-8}	4.46×10^{-7}	490
25.	4.35×10^{-8}	6.15×10^{-7}	589
30.	5.60×10^{-8}	7.92×10^{-7}	687
32.	6.12×10^{-8}	8.65×10^{-7}	726

(*) $F = 10$ because the permeability of the dam may be larger than predicted (an uncertainty in the order of 10 for the coefficient of permeability of a soil is common).

where: Q: flow rate in the geotextile (m^3/s); L: length of the cross section of geotextile perpendicular to the flow direction (m); θ: transmissivity of the geotextile (m^2/s); k_p: coefficient of permeability of the geotextile in its plane (m/s); H_g: thickness of the geotextile (m); i: hydraulic gradient in the geotextile (dimensionless).

Since there is no water pressure in the geotextile, the hydraulic gradient is governed by the slope, β:

$$i = \sin \beta. \qquad (4)$$

If the geotextile were laid on a perfect plane, β would be the slope of the chimney drain ($\beta = 60°$ in figure 4). Because the dam is built in successive layers, the geotextile is likely to have an accordion shape. Therefore, it is more conservative to assume $\beta = 45°$ (the layers have about a one to one slope). Finally, equation (3) leads to the following expression for the required transmissivity:

$$k_p H_g = F \sqrt{2}\, Q/L \qquad (5)$$

(where F is a factor of safety).

The numerical values of the required transmissivity, θ, for different values of depth, z, are listed in table I. Also tabulated is the compressive stress exerted by the embankment on the geotextile at various depths (as previously mentioned, this stress affects the transmissivity of the geotextile). This compressive stress has been obtained by classical soil mechanics computations.

The final step of the geotextile drain design is better achieved using a graphical procedure. First, the required transmissivity is plotted versus the compressive stress (*fig.* 5). Then, the transmissivity of available geotextiles is compared with the required transmissivity. For example, if the geotextile presented in figure 3 is to be used, it may be seen in figure 5 that one layer is necessary between the top and depth 24 m, and two layers between depth 24 m and depth 32 m (base of the dam, as shown in figure 4).

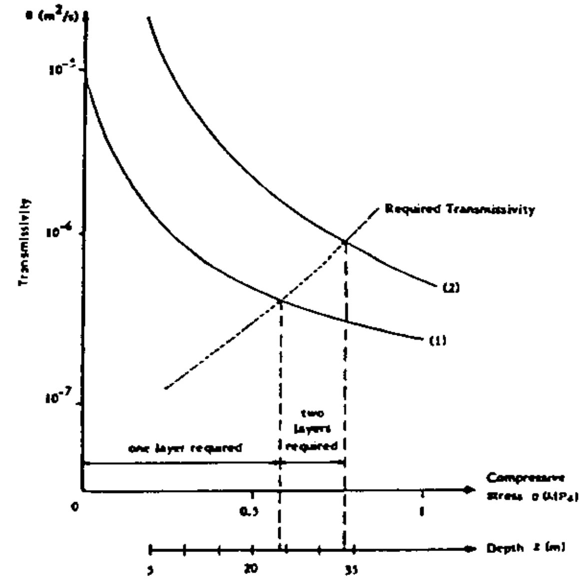


Fig. 5. – Graphical solution of the chimney drain design. Solid curves represent the actual transmissivity of one (1) or two (2) layers of the geotextile presented in figure 3.

Design of a horizontal drain under an embankment

Let us consider an embankment built on a soft, saturated soil (*fig.* 6). Because of the compressive load, water is expelled from the soil and the embankment settles. This is the consolidation phenomenon. If the embankment material is not pervious, a drain placed between the embankment and the foundation soil will help to gather the expelled water and convey it laterally towards the outlets (edges of the embankment).

The drain is horizontal, the water flows only if its pressure in the central part of the drain is larger than at the edges. However, the pressure of the water in the central part of the drain must be smaller than the pressure of the water in the soil to ensure the flow of water through the soil to the geotextile. Consequently, a compromise is necessary, as previously explained.

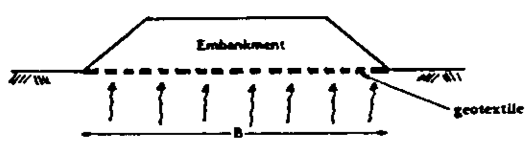


Fig. 6. – Drainage under embankment on a soft soil.

This problem is more complex than the chimney drain design where the water pressure was zero in the drain. In this case, computations are lengthy and no details are given here. Assuming that the maximum water pressure in the geotextile is 10 to 15% of the maximum water pressure in the soil, the following equation has been derived:

$$\theta = k_p H_g = \frac{B^2 k}{\sqrt{c_{vt}}}, \qquad (6)$$

where: θ: required transmissivity of the geotextile drain (m^2/s); k_p: coefficient of permeability of the geotextile in its plane (m/s); H_g: thickness of the geotextile (m); B: width of the embankment (*fig.* 6) (m); k: coefficient of permeability of the foundation soil in the vertical direction (m/s); c_v: coefficient of consolidation of the foundation soil in the vertical direction (m^2/s); t: time to build the embankment (s).

For example, for a 30-m-wide embankment built in 10 days (864,000 seconds) on a soil with a coefficient of permeability of 10^{-10} m/s and a coefficient of consolidation of 10^{-7} m^2/s, the required transmissivity of the geotextile drain is:

$$\theta = 3.1 \times 10^{-7} \, m^2/s,$$

This can be achieved, for example, by the geotextile presented in figure 3 if the compressive stress is smaller than about 1 MPa (which corresponds approximately to a 50-m-high embankment).

DESIGN OF A GEOTEXTILE FILTER

The filtration function

Three cases must be considered: filter for particles suspended in a liquid, filter for removing water from a granular solid and filter associated with an armor.

Filter for particles suspended in a liquid: the geotextile is placed across a flow of liquid carrying fines particles in suspension; the function of the geotextile is to *stop the fines particles* while allowing water to go through it.

Examples are presented in figure 7 *a* through *e*. From the viewpoint of filtration, fresh concrete can be considered as a liquid (*fig.* 7 *f* and *g*).

Filter associated to the removal of water from a soil: the geotextile is placed between the soil, from which water is removed (by drainage or pumping), and the open material (aggregate, perforated pipe, porous plastic mat) the function of which is to collect and convey the water; the function of the geotextile is to *prevent movement of soil particles* while allowing the water to go through it.

Examples are presented in figure 7: drainage (cases *h* through *k*), wells (case *l*), filters associated with geotechnical structure (cases *m* through *q*) and consolidation (cases *r* and *s*).

Filter associated with an armor: the geotextile is placed between the soil which has to be protected from the wave action and the coarse material (rocks, concrete blocks, gabions) which constitutes the armor; the function of the geotextile is to *minimize movement and loss of soil particles* while allowing the water to go through it.

Examples are presented in figure 7 *t* and *u*.

The difference between the case of water removal and the case of armor is related to the flow:

– in the case of water removal (by drainage or pumping), the flow of water is *in one direction* (from the soil to the drain or the pump) and practically *steady:*

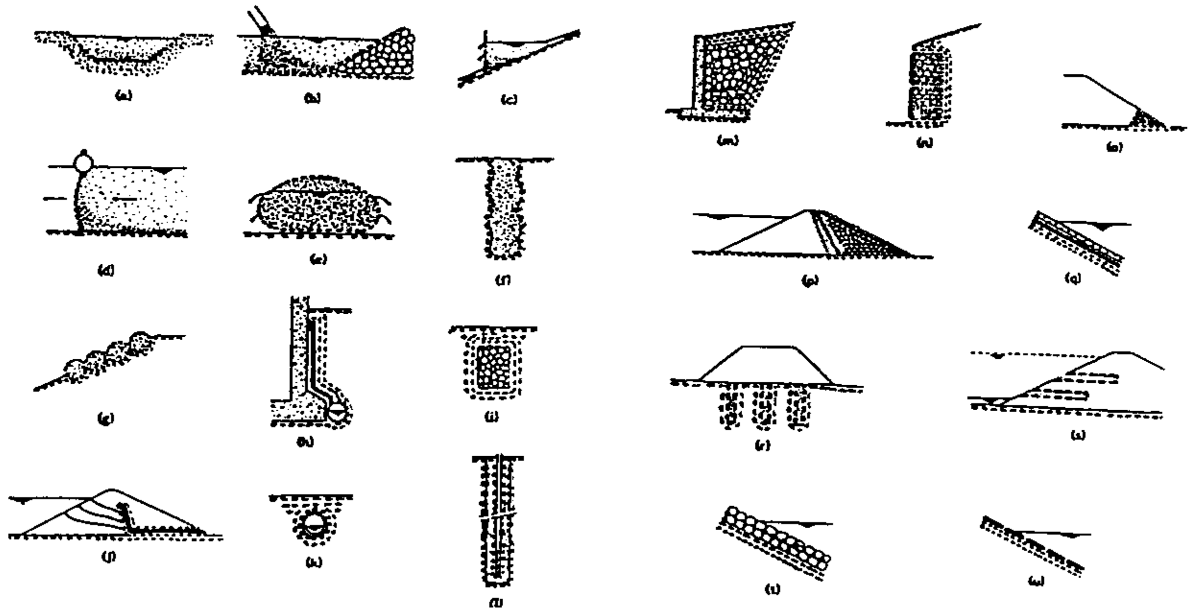


Fig. 7. – Examples of geotextiles acting as filters: (1) *filtration of a liquid carrying particles in suspension:* (*a*) Settling pond for ground water recharge, (*b*) hydraulic fill, (*c*) silt fence, (*d*) silt curtain, (*e*) bag or sausage containing hydraulic fill; (2) *filtration of fresh concrete:* (*f*) cast pile, (*g*) mat for slope or bank protection; (3) *drainage:* (*h*) basement geotextile filter, (*i*) trench, (*j*) chimney and blanket, (*k*) pipe; (4) *wells:* (*l*) pumping well, or piezometer; (5) *geotextile filter associated with a geotechnical structure:* (*m*) retaining wall, (*n*) gabions, (*o*) rock toe, (*p*) filter in a zoned dam, (*q*) canal lining; (6) *consolidation:* (*r*) vertical sand drain, (*s*) horizontal sand drain; (7) *filter associated with an armor:* (*t*) rocks, (*u*) concrete blocks.

– in the case of an armor exposed to waves, the direction of flow *alternates* (from the armor to the soil or vice versa, as the water level moves up and down) and the flow is *unsteady and dynamic.*

Key properties of a geotextile used as a filter are the size of its openings that governs the retention of solid particles, and its permeability to water.

Opening size of a geotextile

One should not imagine an idealistically simple woven geotextile with all the openings having the same size and a perfectly rectangular shape. In fact, a woven geotextile is never that simple because threads are irregular and because the geotextile is more or less irregularly deformed. So, practically, openings are not perfectly rectangular and do not have the same size. Also, some woven geotextiles have various openings size by construction.

All nonwoven geotextiles have openings of various shapes and sizes.

Therefore, in all cases, an opening size distribution curve must be given (*fig.* 8*a*). The opening size distribution curve of a geotextile is similar in principle to the grain size distribution of a soil (*fig.* 8*b*). For the idealistically simple woven geotextile described above, the opening size distribution curve would be a vertical line. There are several ways to obtain the opening size distribution curve for a nonwoven geotextile, including: sieving calibrated glass beads through the geotextile, and direct measurement of spaces between filaments, using a microscope. Results from these two methods are not in perfect agreement, especially in the lower part of the curve. Also, results of sieving tests are not perfectly reproducible. The best agreement between all tests appears to be near the top of the curve. For this reason, the opening O_{95} is often used as a basis for filter criteria.

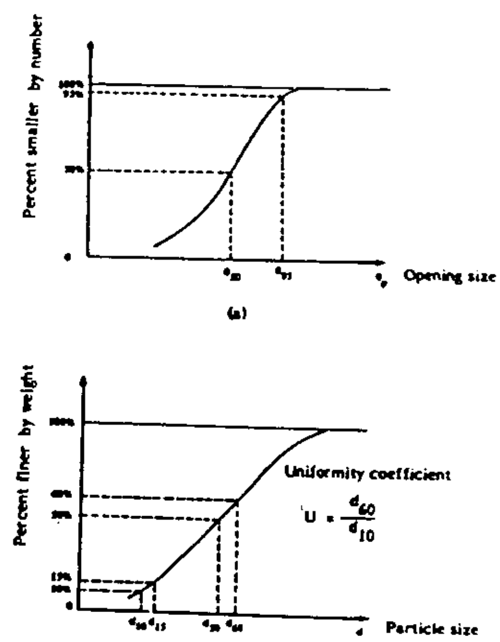


Fig. 8. – Characterization of geotextile and soil: (*a*) opening size distribution curve of a geotextile; (*b*) grain size distribution curve of a soil.

As previously mentioned (*fig*. 3), needlepunched nonwoven geotextiles (often used as filters) are compressible. Therefore, the size of their openings is reduced when they are subjected to a compressive stress (e. g. an overburden load). No tests have been performed to evaluate the influence of a compressive stress on the openings size of a geotextile. However, in the case of needlepunched nonwovens, a simple formula can be proposed:

$$\frac{O+d_f}{O'+d_f}=\sqrt{\frac{H_g}{H'_g}}, \tag{7}$$

where: O: average space between filaments corresponding to thickness H_g (mm) for a given geotextile (mm); O': average space between filaments corresponding to thickness H'_g (mm) for the same geotextile (mm); d_f: diameter of filaments (mm).

The demonstration of this formula stems from the fact that all the geometrical models used for describing the structure of a nonwoven geotextile lead to the same type of expression for the spaces between filaments:

$$O=d_f(\lambda\sqrt{H_g\rho_f/\mu}-1), \tag{8}$$

where: μ: mass per unit area of the geotextile (kg/m^2); ρ_f: mass per unit volume of the filaments (kg/m^3); λ: coefficient depending on the geometrical model (dimensionless).

Permeability of a geotextile

As previously mentioned, some geotextiles are able to convey water in their plane and exhibit the property of transmissivity. All geotextiles (if not coated or impregnated) allow water to flow through them, perpendicularly to their plane. The normal flow through a geotextile is governed by Darcy's formula:

$$\frac{Q}{A}=\frac{k_N}{H_g}\Delta h=\Psi\Delta h,$$

where: Q: rate of flow (m^3/s); A: area of the geotextile sample (m^2); k_N: coefficient of normal permeability of the geotextile (m/s); H_g: thickness of the geotextile (m); $\Psi=k_N/H_g$: permittivity of the geotextile (s^{-1}); Δh: hydraulic head loss through the geotextile (m).

For needlepunched geotextiles, the coefficient of normal permeability is about of the same order of magnitude as the coefficient of permeability in the plane, and both decrease of about the same amount when a compressive stress is applied on the geotextile (*fig*. 3). Mats are also often compressible.

Nets, woven and heatbonded nonwoven geotextiles are not very compressible. Consequently, their permeability is not significantly affected by compressive stresses.

Principle of design of a geotextile filter

Only the case of a geotextile filter associated with water removal is discussed hereafter.

A geotextile filter, as any filter, must fulfill two criteria:

– Retention criterion. A geotextile filter must have openings small enough to prevent movement of soil particles;

– Permeability criterion. A geotextile filter must be permeable enough not to slow down the flow of water. The larger the openings of a geotextile, the larger its permeability (for a given porosity).

A careful selection of the geotextile is required to make sure that its openings fulfill the two criteria.

Retention criterion

Two types of parameters are involved in the retention of a soil by a filter:

– mechanical parameters: (i) hydraulic drag forces which tend to move the particles; (ii) strength of the soil which depends on compressive stresses between filter and soil and cohesion of the soil, which tends to prevent movement of particles; and (iii) gravity which may tend either to cause or to prevent the movement of the particles, depending on the direction of the flow;

– geometrical parameters: (i) size of geotextile openings; (ii) soil particle size and soil particle distribution; and (iii) density of the soil.

A comprehensive analysis including all these parameters would be extremely complex. The classical approach, for granular filters such as sand, is to eliminate the mechanical parameters. This is achieved by assuming conservative values for these parameters: (i) the hydraulic gradient, which controls the drag forces, is supposed to be large; and (ii) compressive stresses and cohesion of the soil are neglected (usually the role of gravity is not important and is not considered). Since all mechanical parameters are eliminated, the retention criterion depends only on geometrical parameters. In the classical approach, two geometrical parameters also are neglected: the density and the grain size distribution of the soil. This oversimplification does not seem appropriate for geotextiles. A theoretical analysis, corroborated by experimental results [1], leads to the retention criterion presented in figure 9. It is beyond the scope of this paper to present in detail this theoretical analysis which will be published elsewhere. The following comments can be made:

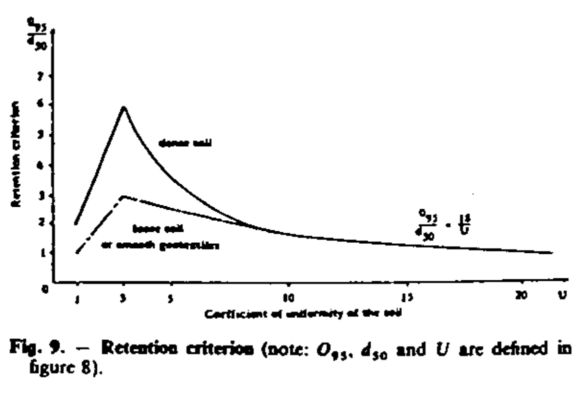


Fig. 9. – **Retention criterion (note: O_{95}, d_{50} and U are defined in figure 8).**

— for a given soil, characterized by d_{50} and U (see *fig.* 8 *b*), the openings of the geotextile can be larger when the soil is dense than when it is loose; this means that the particles in a dense soil are less likely to move than in a loose soil;

— the maximum of the curves occurs for $U = 3$; this value of the coefficient of uniformity corresponds to the maximum interlocking between soil particles [2];

— in the case of a perfectly uniform soil ($U = 1$), the openings of the geotextile must be smaller than the particles if the soil is loose, but they can be larger if the soil is dense.

On the basis of a few tests conducted with medium dense soils, results related to needlepunched geotextiles are close to the curve for dense soils while results for other geotextiles (wovens and heatbonded nonwovens) are close to the curve for loose soils. A possible explanation is that soil particles in contact with a smooth geotextile (such as a woven or a heatbonded nonwoven) are rather free to move and have a tendency to loosen, while soil particles in contact with a rough geotextile (such as a needlepunched nonwoven) are kept in a dense state. As a result the recommended practice is that:

— The upper curve in figure 9 should be used in the case of dense soils with a needlepunched geotextile filter;

— The lower curve in figure 9 should be used in the case of loose soils, regardless of the type of geotextile, and in the case of smooth geotextiles (wovens, heatbonded nonwovens) regardless of the density of the soil;

— For most usual soils, no factor of safety needs to be applied on the retention criterion and it is more advisable to apply a factor of safety on the permeability criterion. For dispersive clays, however, it is more advisable to apply a factor of safety on the retention criterion.

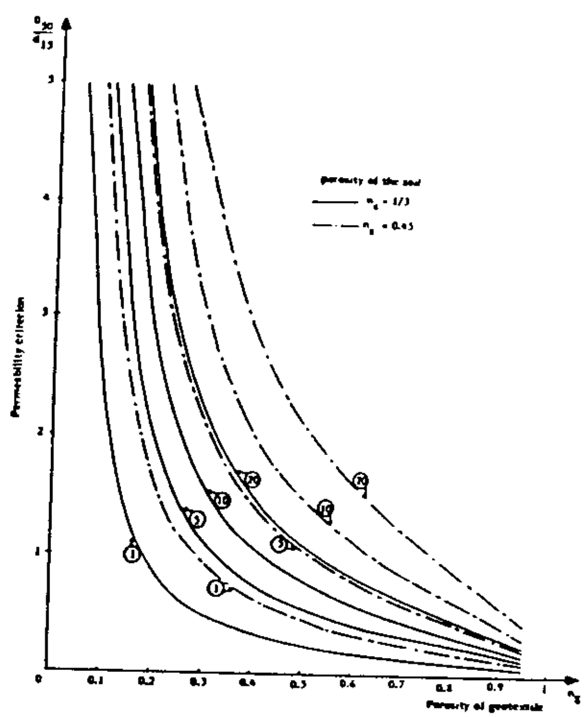


Fig. 10. — **Permeability criterion** (the numbers in the circles represent the values of k_g/k_s).

Permeability criterion

As previously mentioned, the retention criterion is one of the two filter criteria. The second criterion is the permeability criterion. The permeability of a geotextile filter must be large enough not to slow down the flow of water.

It is beyond the scope of this paper to present in detail the theoretical analysis leading to the permeability criterion. This analysis can be outlined as follows. A theoretical relationship between void distribution (openings size and porosity) and permeability of geotextiles has been established. A similar relationship was already known for soils. Comparing these two relationships led to the chart presented in figure 10. This chart gives the minimum value for the openings O_{50} of the geotextile (see *fig.* 8 *a*) as a function of the density of the soil (porosity n_s), the porosity of the geotextile n_g and the ratio between coefficients of permeability of geotextile k_g and soil k_s. This ratio must not be smaller than one. A value of 10 is recommenced for this ratio.

If the coefficients of permeability of the geotextile and of the soil are known, it is not necessary to use the chart presented in figure 10. Instead, it can be checked directly that the coefficient of permeability of the geotextile is larger than the coefficient of permeability of the soil. A factor of safety of 10 is recommended.

Design example

Valcros Dam, built in 1970, was the first earth dam where a geotextile was used. In addition, the drainage trenches in Valcros Dam were the first drainage trenches ever built with a nonwoven geotextile as a filter. The grain size distribution of the soil and the opening size distribution for the geotextile used are presented in figure 11. Two curves are presented for the geotextile. The first curve gives the values of the openings as measured when the geotextile is not compressed. The second curve is for the compressed geotextile and is deduced from the previous curve using equation (7). The geotextile in the dam is subjected to a compressive stress of about 0.2 MPa (10 m of earth) and its thickness, according to figure 3, is 0.45 times its thickness when it is not compressed. For example, equation (7) (with a filament diameter equal to 0.027 mm) yields:

$$O'_{95} = (0.180 + 0.027)\ 0.45 - 0.027 = 0.112 \text{ mm};$$

$$O'_{50} = (0.080 + 0.027)\ 0.45 - 0.027 = 0.045 \text{ mm}.$$

In fact, the geotextile in the dam is not uniformly compressed and its opening size distribution curve varies from one point to another one. The average curve lies between the two curves presented in figure 11.

At the time of the construction of Valcros Dam, little was known about filter criteria for geotextiles. The only

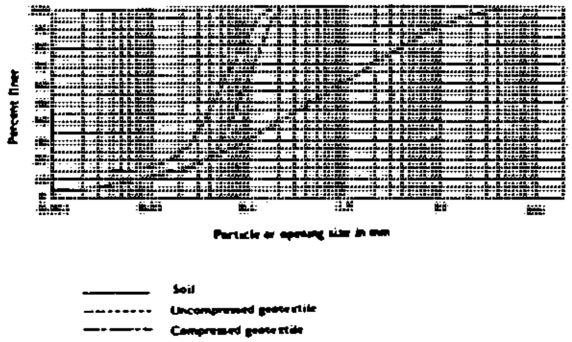


Fig. 11. – Grain size distribution of soil and opening size distribution of uncompressed and compressed geotextile in Valcros dam. The uniformity coefficient of the soil, as defined in figure 8*b*, is approximately equal to 100.

design consideration was to check that the average opening size of the geotextile (then believed to be approximately 0.1 mm) was smaller than the d_{85} of the soil (7 mm, according to figure 11). During 10 years, Valcros Dam performed well [3]. Today it is an interesting exercise to verify this early design by the more sophisticated criteria presented above.

First, the retention criterion is considered. For a uniformity coefficient of 100, the retention criterion is, according to figure 9:

$O_{95}/d_{50} \leq 18/U = 0.18.$

Since $d_{50} = 0.55$ mm:

$O_{95} \leq 0.099$ mm.

The actual value for the compressed geotextile (0.112 mm) is slightly larger than this maximum required value. So it may be concluded that the retention criterion, presented in figure 9, is rather conservative in the case of Valcros Dam, probably because it does not take into account the cohesion of the soil.

The permeability criterion must then be satisfied. The soil in the dam is dense and the needlepunched geotextile is compressed ($n_g = 0.7$). So, according to the chart (*fig.* 10), the ratio O_{50}/d_{15} must be larger than 0.5 (safety factor of 10). Since d_{15} is 0.020 mm, O_{50} must be larger than 0.010 mm. The permeability criterion is easily satisfied because $O_{50} = 0.045$ mm in the compressed state (*fig.* 11). This is not surprising since the actual permeability ratio between the geotextile and the soil was about 1,000.

In conclusion, a geotextile with smaller openings could have been used in Valcros Dam.

DESIGN OF A GEOTEXTILE SEPARATOR

The separation function

Definition of a geotextile separator: the geotextile is placed between two materials which have a tendency to mix when they are squeezed together under the applied loads; the function of the geotextile is to separate these two materials.

Typical examples are presented in figure 12.

A separator must retain the soil particles and must have sufficient strength to withstand the stresses induced by the applied loads. Consequently, designing a geotextile separator involves retention analysis and strength analysis.

Retention analysis for a geotextile separator

The key property of a geotextile involved in retention analysis is its opening size. This property has already

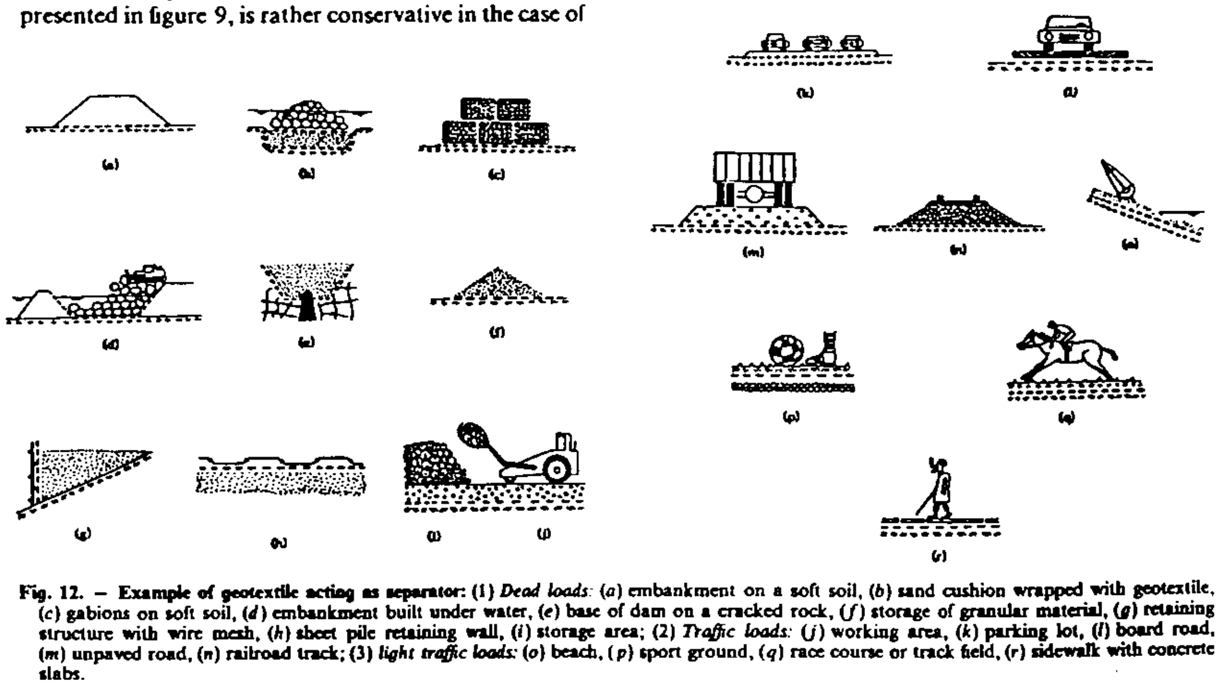


Fig. 12. – Example of geotextile acting as separator: (1) *Dead loads:* (*a*) embankment on a soft soil, (*b*) sand cushion wrapped with geotextile, (*c*) gabions on soft soil, (*d*) embankment built under water, (*e*) base of dam on a cracked rock, (*f*) storage of granular material, (*g*) retaining structure with wire mesh, (*h*) sheet pile retaining wall, (*i*) storage area; (2) *Traffic loads:* (*j*) working area, (*k*) parking lot, (*l*) board road, (*m*) unpaved road, (*n*) railroad track; (3) *light traffic loads:* (*o*) beach, (*p*) sport ground, (*q*) race course or track field, (*r*) sidewalk with concrete slabs.

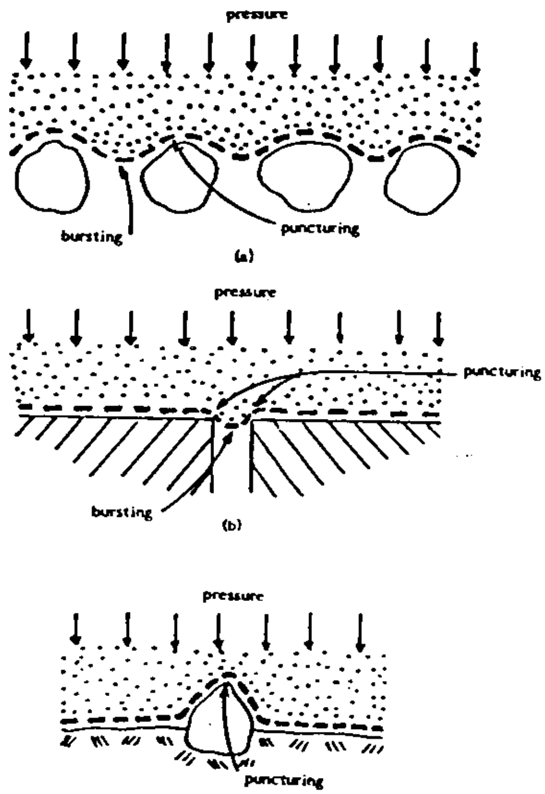


Fig. 13. — Typical situations of a geotextile separator between fine soil and (*a*) stone bed; (*b*) solid material such as concrete, rock or boards with cracks or gaps; (*c*) isolated stones.

been discussed in the section devoted to filtration. In fact, many results related to filtration are applicable to the retention analysis for a geotextile used as separator.

For the retention analysis, three situations must be considered depending on the moisture in the soil and the loading conditions.

When the soil is dry, there is usually no need for separation, except for dust protection in the case of a storage of granular material, such as sand or cereal, placed directly on a geotextile. In this case, one should use a geotextile with openings as small as possible. A geotextile coated with some plastic or elastomeric material is recommended.

Usually separation is needed *when the soil is wet*. In this case the geotextile must be permeable to prevent the buildup of water pressure. When the soil is wet, two cases must be considered depending on the load characteristics.

If *the load is static* (dead load) or quasi static (slow traffic loads), the soil particles can go through the geotextile by two processes:

— Hydraulic process. Some water flows through the geotextile (at least water expelled from the soil by consolidation). This water may carry some soil particles. So, the geotextile must fulfill the filter criteria with respect to the fine soil in contact. Since the flow is usually very slow, in this case, the filter criteria to be considered are the criteria, related to steady flow, presented in figures 9 and 10.

— Mechanical process. Because of the applied pressures, plastic flow of the wet fine soil might occur if the geotextile openings were large. If the filter criteria are fulfilled, there is almost no chance for a plastic flow of fine soil particles to go through the openings of the geotextile. Much larger openings would be needed to allow plastic flow of the fine wet soil to go through the geotextile.

If *the load is dynamic*, such as in the case of a railroad track, pumping phenomenon will occur, with two consequences for the soil in contact with the geotextile: its water content increases and its structure is disturbed. Consequently, particles are easily carried by water and, also, plastic flow may occur. In this case, soil particles may go through a geotextile even if the retention criterion for steady flow (*fig.* 9) is fulfilled. Therefore, in the case of dynamic loads, a more restrictive criterion is required. Since the structure of the fine soil is disturbed, it seems logical that, in the case of dynamic loads, the retention criterion curve (see *fig.* 9) should not exhibit a maximum. The following criterion is suggested:

$$O_{95} < d_{50} \quad \text{if} \quad U \leqq 18, \tag{10}$$

$$O_{95} < 18\, d_{50}/U \quad \text{if} \quad U \geqq 18. \tag{11}$$

Even smaller values of O_{95} would be acceptable provided the permeability criterion is fulfilled.

Strength analysis for a geotextile separator

When a geotextile is acting as a separator, it is squeezed between a fine soil and a coarse material. The geotextile is then subjected to concentrated actions perpendicular to its plane, from the fine soil on one side and from the coarse material on the other side (*fig.* 13):

— the pressure exerted by *the fine soil* over a gap in the coarse material tends to induce bursting of the geotextile. In the laboratory, this situation can be modeled by a burst test or a trough test (*fig.* 14 *a*);

— sharp edges of *the coarse material* tend to puncture the geotextile. In the laboratory, this situation can be modeled by a puncture test (*fig.* 14 *b*).

These concentrated actions, *perpendicular to the plane* of the geotextile, generate concentrated tensile stresses *in the plane* of the geotextile. If the coarse material is made of stones, concentrated tensile stresses can be induced in the geotextile in three different ways:

— grabbing effect: the geotextile is grabbed by two stones and is submitted to tension between them. In the laboratory, this effect can be modeled using a grab test (*fig.* 15 *a*);

— snagging effect: the geotextile is first punctured by a sharp stone, then subjected to tensile stresses. In the laboratory, this effect can be modeled using a nail test (*fig.* 15 *b*);

— tearing effect: if a small cut has been made in the geotextile during installation, this cut may extend wher tension is applied to the geotextile. In the laboratory, this effect can be modeled using a tear test (*fig.* 15*c*).

Grab test and nail test are similar in principle because the load is applied to a small portion of the sample. The measured strength is smaller in the nail test than in the grab test because the diameter of the nail is generally much smaller than the size of the clamps in the grab test.

In addition to the quasi static effects, repeated loads must be considered. Indeed, they submit geotextile to abrasion, thus weakening it and making it more prone to damage by the concentrated actions described above.

Membrane effect

As previously shown (*fig.* 13), if a geotextile placed over a gap is subjected to normal loads, it exhibits a curved shape and tensile stresses are generated. This is known as the "membrane effect". Two typical gaps can be considered: an infinitely long crack and a circular hole. These two situations are modeled in the laboratory by a trough test and a burst test, respectively (*fig.* 14*a*). The curved shape of a geotextile subjected to pressure is circular in the case of a trough test of infinite length but it is extremely complex in a burst test and in a trough test of finite length. The formulas given hereafter are rigorous in the case of an ideal, infinitely long trough test (plane strain) and approximate in the case of a trough test of finite length and of a burst test (circular hole).

The following formulas have been established, assuming a circular curved shape:

1) Elongation of the geotextile for both trough test and burst test (*fig.* 16).

$$1+\varepsilon=\frac{1}{2}\left(\frac{2y}{b}+\frac{b}{2y}\right)\text{Arcsin}\,\frac{1}{1/2((2y/b)+(b/2y))}$$

if $y/b \leq 0.5$, (12)

$$1+\varepsilon=\frac{1}{2}\left(\frac{2y}{b}+\frac{b}{2y}\right)\left[\pi-\text{Arcsin}\,\frac{1}{1/2((2y/b)+(b/2y))}\right]$$

if $y/b \geq 0.5$, (13)

$$f(\varepsilon)=\frac{1}{4}\left(\frac{2y}{b}+\frac{b}{2y}\right), \quad (14)$$

where: ε: elongation of the geotextile (dimensionless, usually expressed in per cent); y: deflection (m) (*fig.* 16); b: span (either width of a crack or diameter of a circular hole) (m).

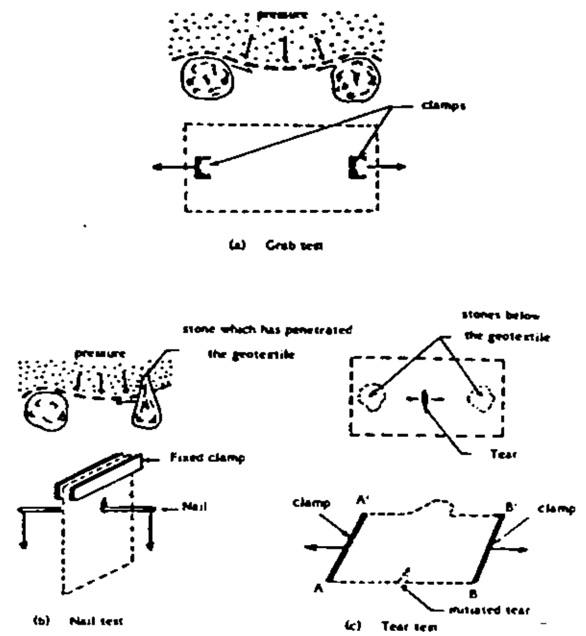


Fig. 15. — Concentrated tensile stresses generated by pressure exerted perpendicular to the plane of the geotextile by adjacent materials: (*a*) grab stresses evaluated by the grab test (the narrow clamps simulate the local contacts between stones and geotextile); (*b*) snag stresses simulated by the nail test; (*c*) tear stresses likely to occur when an existing tear is submitted to tensile stresses; tearing effect is simulated by the trapezoidal tear test (the clamped ends *AA'* and *BB'* are parallel, the free edge *A'B'* is longer than the free edge *AB*, a tear is initiated in the middle of *AB* and propagates towards the middle of *A'B'* when tensile load is applied).

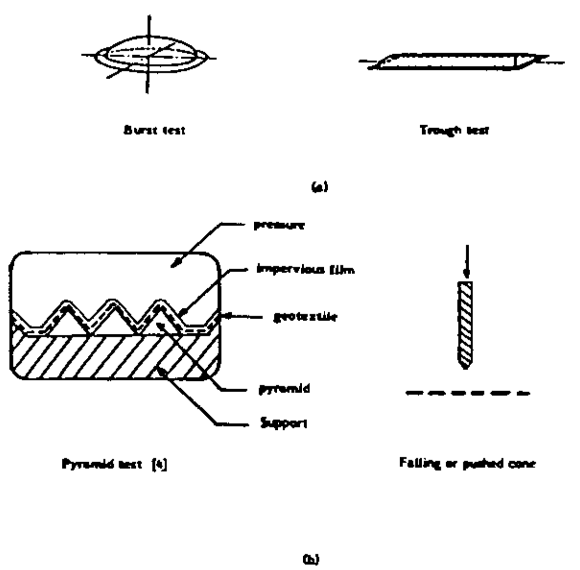


Fig. 14. — Laboratory tests simulating: (*a*) bursting; (*b*) puncturing.

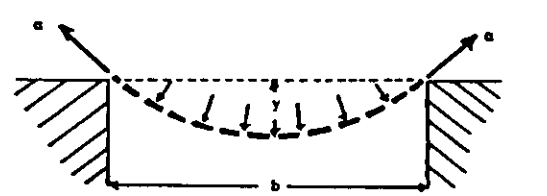


Fig. 16. — Circular curved shape of a geotextile subjected to pressure.

TABLE II
FUNCTION $f(\varepsilon)$

ε (%)	$f(\varepsilon)$
0	∞
2	1.47
3	1.23
4	1.08
5	0.97
6	0.90
8	0.80
10	0.73
12	0.69
15	0.64
20	0.58
25	0.55
30	0.53
35	0.52
40	0.51
45-70	0.50
75	0.51
90	0.52
100	0.53
110	0.54
120	0.55
130	0.56

Table II gives the values of the function $f(\varepsilon)$ defined by equations (12) or (13), and (14).

2) Equilibrium of the trough test:

$$\alpha_t = p_t b_t f(\varepsilon_t), \quad (15)$$

$$\alpha_t = K_t \varepsilon_t, \quad (16)$$

where: α_t: anguish (force per unit width) of the geotextile in the trough test (N/m); p_t: pressure exerted on the geotextile (Pa); b_t: width of the trough (m); ε_t: elongation of the geotextile in the trough test (dimensionless); K_t: modulus of the geotextile in the trough test (N/m).

There are two ways to report the results of a trough test. One way is to give the width of the trough, b_t, and to report the pressure, p_t, versus the deflection, y. The other way is to give the anguish, α_t, as a function of the elongation, ε_t. The second way is more usual since the trough test is primarily intended to give the anguish-elongation curve of a geotextile in a plane strain situation.

At failure, p_t, α_t and ε_t are designated by p_{tf}, α_{tf} and ε_{tf}, respectively. From equation (15), the maximum pressure, p_{max}, withstood by a geotextile over an infinitely long crack of width b is given by:

$$p_{max} = p_{tf} b_t / b. \quad (17)$$

3) Equilibrium of the burst test:

$$\alpha_b = \frac{p_b b_b}{2} f(\varepsilon_b), \quad (18)$$

$$\alpha_b = K_b \varepsilon_b, \quad (19)$$

where: α_b: anguish (force per unit width) of the geotextile in the burst test (N/m); p_b: pressure exerted on the geotextile (Pa); b_b: diameter of the circular hole (m); ε_b: elongation of the geotextile in the burst test (dimensionless); K_b: modulus of the geotextile in the burst test (N/m).

Since equation (18) is only approximate, the only unquestionable way to report a burst test is to give the pressure, p_b, as it is measured. Usually only the pressure at failure is given. It would be better to give the curve of pressure, p_b, versus deflection, y.

At failure, p_b, α_b and ε_b are designated by p_{bf}, α_{bf} and ε_{bf}, respectively. From equation (18), the maximum pressure, p_{max}, withstood by a geotextile over a circular hole of diameter b is given by:

$$p_{max} = p_{bf} b_b / b. \quad (20)$$

4) Relationships between trough and burst tests:

$$K_b = (1+\nu) K_t. \quad (21)$$

Approximate relationships at failure only:

$$\alpha_{bf} = (1+\nu)^{2/3} \alpha_{tf}, \quad (22)$$

$$\varepsilon_{bf} = \varepsilon_{tf} / \sqrt[3]{1+\nu}, \quad (23)$$

where: ν: Poisson's ratio of the geotextile.

According to few tests, recommended values for ν are 0.15 for woven geotextiles and 0.35 for nonwoven geotextiles.

Principle of design of a geotextile separator

As previously mentioned, a retention analysis and a strength analysis must be made. Retention analysis has been described and there is no need for presenting practical examples because they would be similar to the practical example related to filtration (see *fig.* 11).

Concerning strength analysis, five basic mechanisms have been presented: bursting, puncturing, grabbing, snagging and tearing. A method of design is presented hereafter for each mechanism except tearing. The first step of each method is to compute the concentrated stress exerted on the geotextile.

Puncturing analysis

Two types of specifications must be considered: the required elongation and the required puncture resistance.

A geotextile with a large elongation at failure would be the most able to follow the shape of stones without damage. It is not easy to give a precise value because it would depend on the way the geotextile is placed. The risk of puncturing is higher when the geotextile is taut than when it is loose. Theoretically, an elongation at failure in the order of 100% (as measured in a plane-strain tensile test) would prevent puncture of the geotextile in most cases even if its puncture resistance is low. Such an elongation would require elastomeric fibers (however this is not recommended because an elastomeric fabric would have a low bursting strength). Practically, elongation of most geotextiles in a plane strain test do not exceed about 30%. Consequently, the lack of deformability, with respects to puncture, must be compensated for by puncture resistance.

To determine the required puncture resistance, contact forces between geotextile and protruding objects must be determined. The value of the contact forces depends on the number of contacts per unit area. In the case of small stones (say, smaller than 100 mm) there is only one contact point per stone. Consequently, the required puncture strength, at least equal to the contact force, can be expressed approximately by:

$$R_p = pd^2, \quad (24)$$

where: p: average normal stress on the geotextile (Pa); d: size of the stone (m).

For example, if the normal stress induced by the traffic at the bottom of a ballast layer in a railroad track is 150 kPa and if the maximum size of the ballast stones is 40 mm, the required puncture resistance is:

$$R_p = 150{,}000 \times (0.04)^2 = 240 \text{ N}.$$

A factor of safety of 3, for example, is recommended to take into account additional stresses due to *dynamic loading* caused by traffic and tamping of ballast during maintenance operations. Also, a factor of safety is always recommended in the case of concentrated stresses to take into account the non-homogeneity of geotextiles.

In the case of a *dead load*, there is no need for such a high factor of safety. If a geotextile is placed under an embankment, the average normal stress is expressed by:

$$p = \rho g h, \quad (25)$$

where: ρ: mass per unit volume of the embankment material (kg/m^3); g: gravity (9.81 m/s^2); h: height of the embankment (m).

The expression of the required puncture resistance is obtained by combining equation (24) and (25):

$$R_p = \rho g h d^2. \quad (26)$$

For example, if a geotextile is placed under a 10 m high embankment made of sharp stones 100 mm in diameter, the required puncture strength is:

$$R_p = 1.5 \times 1{,}900 \times 9.81 \times 10 \times (0.1)^2 = 2{,}800 \text{ N},$$

(1.5 is a factor of safety and 1,900 is the assumed mass per unit volume of the embankment).

In the previous analysis it is implied that the puncture strength is measured in a puncture test where the shape and the size of the pyramid or the cone (*fig.* 14*b*) are similar to the shape and the size of the stones.

Bursting analysis

Bursting may occur when a geotextile bridges gaps on one side and is subjected to soil pressure on the other side. Gaps are cracks in rocks, spaces between boards, plates, slabs, etc. or merely voids between coarse particles such as gravel or stones. Typical situations are presented in figure 13. Parameters involved in bursting design are the soil pressure and the shape and size of gaps.

The average normal stress exerted by the fine soil on the geotextile can be computed by classical soil mechanics technique. For example, the average normal stress, p, at the base of an embankment is given by equation (25). Surcharges and traffic loads exerted on top of the embankment have to be added to the value computed using equation (25).

Because of arching in the soil, the actual soil pressure over a gap is smaller than the average normal stress. The actual soil pressure can even be zero if the fine soil has cohesion and if the gap is narrow. In this case, the soil itself bridges the gap and no geotextile is needed. It would not be safe to rely on arching except if loads and gaps are small. Usually a more conservative approach is recommended:

– First, the pressure exerted on the geotextile must be taken as high as the maximum water pressure likely to occur in the future at the level of the geotextile. This would prevent the geotextile from bursting under the water pressure if it happens to clog;

– An even more conservative approach is to consider that arching can be destroyed and plastic flow may occur if the soil becomes locally very wet. This would tend to extrude the fine soil through the gap and the pressure over the gap would be as high as the average normal stress at the level of the geotextile. In this case, if the fine soil constitutes the embankment on the geotextile, the mass per unit volume of the saturated fine soil (ρ_{sat}) must be used in equation (25).

Concerning the shape of the gaps, two cases must be considered: (i) long gaps with a constant width such as cracks in rocks, spaces between boards, sheet piles, plates, slabs, etc; and (ii) holes of finite size, such as square holes in a grid or a wire mesh or voids between stones. The trough test is used in the first case and the circular bursting test in the second case. Also, relationships between these tests can be used when the appropriate test is not available.

Bursting design in the case of a long gap

In the case of a long gap, several design cases must be considered.

Case 1. A trough test has been performed on a geotextile and the pressure at failure is known. The maximum soil pressure, p_{max}, likely to be supported by this geotextile over a gap is given by equation (17):

Example. A geotextile fails under a pressure of 150 kPa in a trough test with a hole-width of 200 mm. The use of this geotextile is considered between a cracked rock foundation and the clay core of a dam (*fig.* 12*e*). The maximum width of the cracks is 40 mm. Which soil pressure is this geotextile able to withstand?

This pressure is determined using equation (17)

$$p_{max} = 150{,}000 \times 0.2/0.04 = 750{,}000 \text{ Pa}.$$

This pressure is equivalent to about 40 m of soil.

Case 2. A trough test has been performed on the considered geotextile but the pressure at failure is not reported. The reported values are the anguish (force per unit width) and the elongation of the geotextile at failure. This is the most usual case, as previously mentioned. In this case, equation (15) must be used.

Example. For the geotextile considered in the previous example, the results of the trough test at failure are: $\alpha_{tf} = 16{,}000$ N/m and $\varepsilon_{tf} = 30\%$. The width of the cracks is 40 mm. What is the maximum soil pressure withstood by the geotextile?

According to table II:

$f(30\%) = 0.53.$

According to equation (15):

$p = 16{,}000/(0.04 \times 0.53),$

$p = 750{,}000$ Pa.

Case 3. The soil pressure and the width of the long gap are known. Select the geotextile. Equation (15) or (17) can be used.

Example. A geotextile must be placed between the clay core of a dam and a cracked rock foundation. The soil pressure at the base of the dam is 750 kPa and the width of the cracks is 40 mm. Write requirements for the bursting strength of the geotextile. There are several ways to write the specifications.

The best way is to require that the candidate geotextile withstands a pressure of 750 kPa (times a factor of safety) in a 40 mm wide trough test.

A second way is to specify the use of an available trough test equipment. For example, if $b_t = 200$ mm is the width of this equipment, equation (17) yields:

$p_t = 750{,}000 \times 0.04/0.2,$

$P_t = 150{,}000$ Pa.

Therefore, the required pressure at failure in the 200 mm wide trough test must be 150,000 Pa times a factor of safety.

A third way is to specify a minimum value for the anguish at failure measured in a plane strain test (such as the trough test). According to equation (15), the anguish depends on the elongation at failure. Therefore the required anguish depends on the deformability of the geotextile. Equation (15) can be written:

$\alpha_{tf} = 750{,}000 \times 0.04 f(\varepsilon_t),$

$\alpha_{tf} = 30{,}000 f(\varepsilon_t),$

with the value of $f(\varepsilon_t)$ given in table II.

So, the required anguish (without factor of safety) is:

$\alpha_{tf} = 16{,}000$ N/m if $\varepsilon_{tf} = 30\%$ (nonwoven),

$\alpha_{tf} = 19{,}000$ N/m if $\varepsilon_{tf} = 15\%$ (woven),

$\alpha_{tf} = 37{,}000$ N/m if $\varepsilon_{tf} = 3\%$ (woven fiberglass).

It is noteworthy that the higher tensile strength is required for the stiffer geotextile.

Bursting design in the case of a hole of finite size

The case of "circular or almost circular" holes is more complex than the case of a long gap.

First, if the hole is not circular, the diameter of the equivalent circular hole must be determined. If the hole is square, it is suggested to take the diameter of a circle having the same area as the square. If the coarse material in contact with the geotextile is made up of stones of uniform size, the diameter of the circular hole to be used in the calculation is 0.4 times the size of the stones. This figure is the result of theoretical considerations corroborated by an analysis of a large number of bursting tests.

Then, several design cases must be considered. The most typical are discussed hereafter.

Case 1. A burst test has been performed on a geotextile and the bursting pressure is known. The maximum soil pressure likely to be supported by the geotextile over the considered circular hole is given by equation (20).

Example. A geotextile bursts under a pressure of 2.5 MPa in a burst test performed according to ASTM 774 (hole diameter: 30.5 mm). This geotextile is to be used as a separator between a fine soil and a rockfill made of 150 mm diameter rocks. What is the maximum allowable soil pressure?

As aforementioned, the diameter of the equivalent circular hole is 0.4 times the size of rocks, hence 60 mm. Then, according to equation (20), the maximum soil pressure is:

$$p_{max} = \frac{2{,}500{,}000 \times 0.0305}{0.060},$$

$p_{max} = 1.3$ MPa.

This pressure is equivalent to a 70 m high rockfill approximately.

Case 2. A trough test or any other plane strain test has been performed on the considered geotextile so the anguish (force per unit width) and the elongation at failure of the geotextile are known. In this case, equations (18), (22) and (23) must be used.

Example. For the nonwoven geotextile considered in the previous example, the results of a plane strain test at failure are: $\alpha_{tf} = 16{,}000$ N/m and $\varepsilon_{tf} = 30\%$. The diameter of the equivalent circular hole is 60 mm. What is the maximum soil pressure the geotextile is capable of withstanding?

Since the considered geotextile is a nonwoven, a value of 0.35 can be used for the Poisson's ratio. According to equation (22), the anguish at failure over a circular hole is:

$\alpha_{bf} = 16{,}000 \times (1.35)^{2/3},$

$\alpha_{bf} = 19{,}500$ N/m.

According to equation (23), the elongation at failure over a circular hole is:

$\varepsilon_{bf} = 0.3/\sqrt[3]{1.35},$

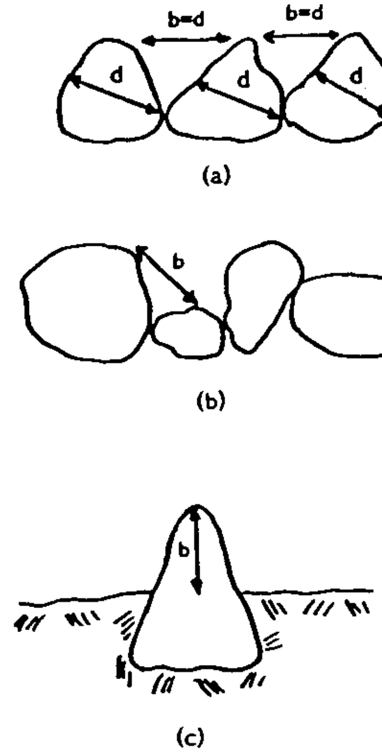


Fig. 17. — Values of b for different stone arrangements.

$\varepsilon_{bf} = 27\%$.

Table II yields:

$f(\varepsilon) = 0.54$.

Equation (18) gives:

$p = 2 \times 19{,}500/(0.06 \times 0.54) = 1.2\ MPa$.

Case 3. The soil pressure and the diameter of the equivalent circular hole are known. Select the geotextile. Equation (18) through 23 can be used.

Example. A geotextile must be placed between a rock fill and a fine foundation soil. The soil pressure at the base of the rockfill is 1.2 MPa and the size of the rocks is 150 mm. Write requirements for the bursting strength of the geotextile.

First, the diameter of the equivalent circular hole must be computed. As aforementioned, this diameter is 0.4 times the size of the rocks, hence 60 mm.

Then, there are several ways to write the specifications.

The best way is to require that the candidate geotextile withstands a pressure of 1.2 MPa (times a factor of safety) in a burst test conducted with a 60 mm diameter hole.

A second way is to specify the use of an available burst test equipment, for example the ASTM D 774 standard test (hole diameter 30.5 mm). In this case, equation (20) yields:

$p_b = 1{,}200{,}000 \times 0.06/0.0305 = 2.4$ MPa.

Therefore, the required bursting strength, measured according to ASTM D 774, should be 2.4 MPa (times a factor of safety).

A third way is to specify a minimum value for the anguish at failure measured in a plane strain test (such as the trough test). In order to use equations (18), (22) and (23), it is necessary to make assumptions concerning Poisson's ratio, ν, and elongation at failure, ε_t, in the plane strain test. Typical assumptions are:

– for a nonwoven: $\nu = 0.35$, $\varepsilon_{tf} = 30\%$;

– for a woven: $\nu = 0.15$, $\varepsilon_{tf} = 15\%$ (except for fiberglass and kevlar).

Only the nonwoven is considered now. Equation (23) gives:

$\varepsilon_{bf} = 0.3/\sqrt[3]{1.35} = 27\%$.

Table II gives:

$f(\varepsilon) = 0.54$.

Equation (18) yields:

$\alpha_{bf} = 1{,}200{,}000 \times 0.06 \times 0.54/2 = 19{,}500$ N/m.

Equation (22) gives:

$\alpha_{tf} = 19{,}500/(1.35)^{2/3}$,

$\alpha_{tf} = 16{,}000$ N/m.

Therefore, the required anguish measured in any plane strain test is 16,000 N/m (times a factor of safety).

Grab analysis

As previously explained, the situation of a geotextile stretched between two stones can be simulated by a grab test. In the simple case of uniform stones, the tensile force transmitted to each stone is approximately equal to:

$$T = \alpha b, \qquad (27)$$

where: α: anguish (tensile force per unit width) of the geotextile (N/m); b: average distance between adjacent stones (m).

The grab strength of the geotextile, R_G should be at least equal to this force. Hence, according to equation (15):

$$R_G = \alpha b = p b^2 f(\varepsilon_{gf}), \qquad (28)$$

where: p: pressure exerted on the geotextile (Pa); ε_{gf}: elongation of the geotextile at failure in the grab test (dimensionless); $f(\varepsilon)$: function tabulated in table II.

Concerning the value of b, several cases must be considered (*fig.* 17):

– if the stones are uniform (*fig.* 17 *a*), the average distance between two adjacent stones is equal to the size of the stones ($b = d$);

– if the stones are not uniform, the distance b must be evaluated according to figure 17 *b*;

— in the case of an isolated stone, more or less embedded in the soil, the distance b is approximately equal to the emerging height of the stone (*fig.* 17 *c*).

According to the values of $f(\varepsilon)$ as tabulated in table II, the following practical rule is proposed:

— Nonwovens and very deformable wovens (elongation in grab test 25 to 125%):

$$R_G \geqq 0.55\, pb^2. \qquad (29)$$

— Usual wovens (elongation in grab test 12 to 20%):

$$R_G \geqq 0.6 \text{ to } 0.7\, pb^2. \qquad (30)$$

— Very stiff wovens such as fiberglass or kevlar (elongation in grab test 2% to 5%):

$$R_G \geqq 1 \text{ to } 1.5\, pb^2. \qquad (31)$$

It is noteworthy that a higher strength is required for stiffer geotextiles.

Example. What is the required grab strength for a nonwoven geotextile placed in contact with 100 mm diameter stones under a pressure of 2×10^5 Pa (about 10 m of earth)?

$$R_G = 0.55 \times 200{,}000 \times (0.1)^2,$$

$$R_G = 1{,}100 \text{ N}.$$

Snag analysis

The approach followed for the grab analysis is valid for the snag analysis. It leads to the same expression for the snag strength and the grab strength:

$$R_N = pb^2 f(\varepsilon). \qquad (32)$$

Since the elongation, ε, is not clearly defined in a nail test, it is recommended to use a conservative value. According to table II, it seems reasonable to take $f(\varepsilon) = 1$, regardless of the type of geotextile. Consequently, the required snag resistance can be expressed as follows:

$$R_N = pb^2 \qquad (33)$$

To be representative of field situation, the nail used in the nail test (AFNOR G 07-055 B) should have a much larger diameter. A diameter of 20 mm is suggested instead of the 3 mm diameter currently used.

CONCLUSION

The three cases which have been discussed illustrate three different relationships between geotextiles design and classical geotechnical design.

— For drainage design, the proposed method related to geotextiles is essentially the same as for granular drains. The only special consideration is the relatively high compressibility of geotextiles.

— For filtration design, filter criteria are inspired from classical filter criteria for sand filters; however some alterations have been made to fit the special characteristics of geotextiles.

— For separation design, the design procedures proposed in this paper are totally new. This is not surprising because the separation function can be considered as the most original function of geotextiles.

Because several design procedures presented in this article are original, comments and criticisms are expected and welcome. They will help in improving the proposed methods and progressively replacing the empirical approach used for geotextiles applications by a rational design.

The author is indebted to J.-Y. Perez, R. G. Berggreen and P. M. Mallard for many valuable comments and assistance for the editing of this paper.

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Schober W., Teindl H., *Filter-criteria for geotextiles*, Proceedings of the Seventh European Conference on Soil Mechanics and Foundation Engineering, Vol. 2, Brighton, England, September 1979, pp. 121-129.

[2] Horsfield H. T., *The strength of asphalt mixtures*, *J. Soc. Chem. Ind.*, 53, (1934), pp. 107-115.

[3] Giroud J. P., Gourc J. P., Bally P., Delmas P., *Comportement d'un textile non-tissé dans un barrage en terre*, Coll. Int. Sols et Textiles, Vol. II, Paris, April 1977, pp. 213-218.

[4] Rigo J. M., *Corrélation entre la résistance au poinçonnement sur ballast et les caractéristiques mécaniques des membranes d'étanchéité*, Matériaux et Constructions, Vol. II, No. 65, September-October 1978, pp. 347-359.

Construire avec les géotextiles. — *Cet article concerne trois fonctions classiques des géotextiles : drainage, filtration et séparation. Pour chacune de ces fonctions, les propriétés importantes des géotextiles sont examinées et une analyse théorique du comportement du géotextile est établie à partir des concepts classiques de la mécanique, de l'hydraulique et de la géotechnique. Ainsi l'analyse du rôle drainant des géotextiles présentée dans cet article est essentiellement semblable à celle des matériaux granulaires (la seule caractéristique originale des géotextiles par rapport aux matériaux granulaires étant leur grande compressibilité). Le critère de filtration relatif aux géotextiles est différent du critère classique de filtration relatif aux sables afin de mieux tenir compte de certaines particularités de l'association sol-géotextile. Pour la fonction de séparation, une approche nouvelle est proposée qui fait intervenir les résultats d'essais textiles classiques tels que l'essai d'arrachement (grab test), l'essai de perforation, l'essai d'éclatement et l'essai d'accroc. Pour chacune des applications, une méthode de conception est proposée sur la base non plus d'une approche empirique mais sur des données obtenues par des essais. Des exemples d'application sont présentés.*

2.2

GIROUD, J. P., "Geotextile Drainage Layers for Soil Consolidation", Civil Engineering for Practicing and Design Engineers, Volume II, (1983), 275-295.

STRENGTH AND STABILITY OF VERTICAL RISER SYSTEM

Golder Associates	SUBJECT STRUCTURAL STABILITY OF CONCRETE RISER		
	Job No. 933-3600.001	Made by SM	Date 12/20/94
	Ref.	Checked / Reviewed	Sheet 1 of 11

OBJECTIVE: DETERMINE THE STRUCTURAL STABILITY OF THE CONCRETE RISER PIPE AGAINST CRUSHING FROM DOWNDRAG FORCES AND LATERAL FORCES. ALSO, EVALUATE THE REINFORCED CONCRETE BASE PLATE FOR A BEARING CAPACITY FAILURE.

APPROACH: DETERMINE THE MAXIMUM LATERAL AND AXIAL LOADS ACTING ON THE CONCRETE RISER PIPE. DETERMINE THE COMPRESSIVE LOADS ACTING ON THE PIPE, COMPUTE THE STRESSES AND COMPARE WITH THE ALLOWABLE STRESSES.

ASSUMPTIONS:

- PIPE DETAILS
  - 60" ϕ INSIDE DIAM. (d_i)
  - 70" ϕ OUTSIDE DIAM (d_o)
  - SEE PG. 10 — f'_c = 4000 PSI
  - 5" = WALL THICKNESS (t)
  - CROSS-SECT AREA = 1,021 IN^2

- ASSUME THE COEFFICIENT OF FRICTION BETWEEN WASTE AND PLASITE COATED RISER PIPE IS 0.2. (μ) * SEE NOTE BELOW

- THE WASTE MATERIAL HAS EFFECTIVE STRENGTH PROPERTIES OF c = 650 PSF AND $\phi = 15°$ (REF - GOLDER JOB NO. 933-3553)

- UNIT WEIGHT OF WASTE AND COVER MATERIAL IS 110 PCF. (γ_w) (REF. F/N: 6218 JOB NO. 933-3553)

NOTE: CALCULATIONS WILL BE PERFORMED TO CHECK WORST CASE (TRENCH 24 - CELL 4) WITH A TOTAL LENGTH OF PIPE OF APPROXIMATELY 139 FT (SEE ATTACHED TABLE ON PG. 11)

$K_o = 1 - \sin\phi$ $\qquad \phi = 15°$ (WORST CASE: ASSUME WASTE BACKFILL)

$K_o = 1 - \sin(15°)$

$= 0.74$

- UNIT WEIGHT OF CONCRETE IS 150 PCF. (γ_c)

* THE COEFFICIENT OF FRICTION ASSUMES THAT THE CONCRETE RISER PIPE IS PLASITE COATED. IF THE PIPE IS NOT PLASITE COATED THE COEFFICIENT OF FRICTION WILL BE HIGHER AND THUS THESE CALCULATIONS ARE NOT APPLICABLE.

Golder Associates	SUBJECT STRUCTURAL STABILITY OF CONCRETE RISER		
	Job No. 933-3600.001	Made by SM	Date 1-3-95
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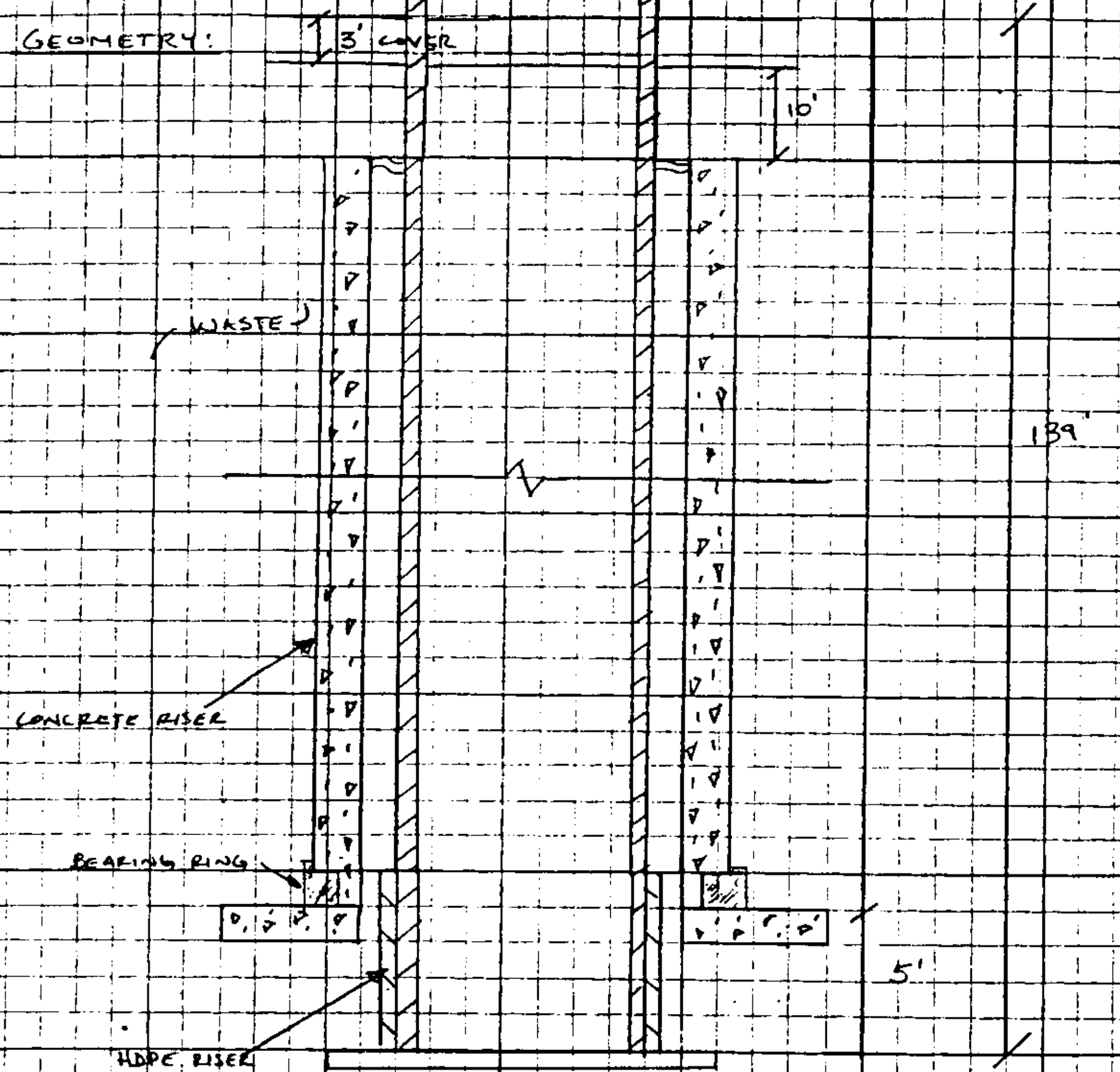
		Reviewed	

GEOMETRY:



TOTAL HEIGHT OF CONCRETE RISER

= 139' - 13' - 5'

= 121' (MAX. LENGTH EXPERIENCING DOWNDRAG)

Golder Associates	SUBJECT STRUCTURAL STABILITY OF CONCRETE RISER		
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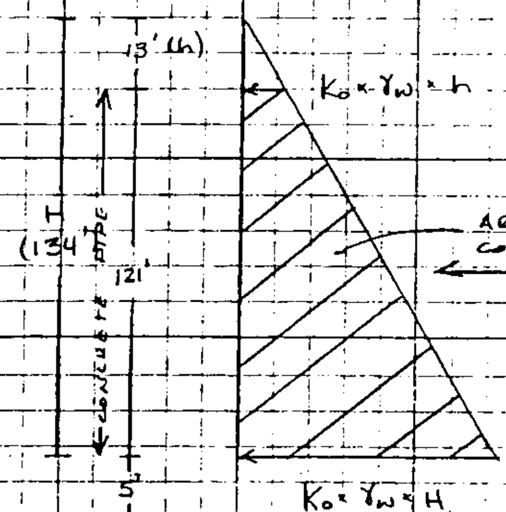
CALCULATIONS:

DOWNDRAG FORCE ON CONCRETE PIPE



HORIZONTAL PRESSURE DIAGRAM

HORIZONTAL FORCE (P_H) ACTING ON PIPE PER FOOT AROUND CIRCUMFERENCE.

$P_H = \frac{1}{2}[(K_o \times \gamma_w \times H) + (K_o \times \gamma_w \times h)] \times (H - h)$

$P_H = (\frac{1}{2} K_o \gamma_w (H + h)) \times (H - h)$

$P_H = [(\frac{1}{2}(0.74)(110)(134 + 13)] \times (134 - 13)$

$P_H = 723,930$ LBS/FT

TOTAL DOWNDRAG FORCE (P_D) ACTING ON PIPE.

$P_D = P_H \times \pi \times d_o \times \mu$

$P_D = 723,930 \times \pi \times 5.8' \times 0.2$

$P_D = 2,638$ KIPS TOTAL DOWNDRAG FORCE APPLIED TO CONCRETE RISER PIPE.

NOTE: THE ABOVE VALUE IS A CONSERVATIVE ESTIMATE SINCE A HIGH VALUE OF K_o WAS USED IN THE ANALYSIS AND FULL MOBILIZATION OF DOWNDRAG FORCE ACTING ALONG THE ENTIRE CONCRETE RISER WAS ASSUMED.

ADDITIONAL FORCE ON BEARING PLATE

① WEIGHT OF CONCRETE RISER PIPE (W_p)

UNIT WT OF CONCRETE (γ_c) = 150 LBS/FT^3

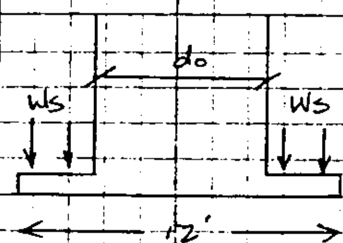
$W_p = \gamma_c \times$ (CROSS-SECTIONAL AREA) $\times (H - h)$

W_p = 150 LBS/FT^3 × (1,021 IN^2 × 1 FT^2/144 IN^2) × (121')

W_p = 129 KIPS

② WEIGHT OF WASTE ABOVE CONCRETE BEARING PLATE (W_s)

H = 134'



AREA OF PLATE (A_B)
= 12' × 12'
= 144 FT^2

AREA OF PIPE (A_p)
= $\pi (d_o)^2/4$
= $\pi (5.8')^2/4$
= 26 FT^2

$W_s = \gamma_w \times (A_B - A_p) \times H$

W_s = 110 × (144 − 26) × 134'

W_s = 1,739 KIPS

TOTAL APPLIED BEARING PRESSURE

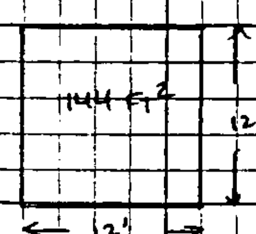
LOADS ON BEARING PLATE

P_D = 2,638 KIPS

W_p = 129 KIPS

W_s = 1,739 KIPS

BEARING PLATE



TOTAL LOAD ON BEARING PLATE

= 4,506 KIPS

BEARING PRESSURE = 31 KSF

Golder Associates	SUBJECT STRUCTURAL STABILITY OF CONCRETE RISER		
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CALCULATE STRESS IN CONCRETE RISER AT THE BASE

TOTAL FORCE ACTING ON CONCRETE RISER AT BASE

$F = P_D + W_p$

$= 2638 + 129$

$= 2{,}767$ KIPS

MAXIMUM STRESS ACTING ON CONCRETE RISER

$\sigma = F/A$ $\qquad A = 1{,}021 \text{ in}^2$

$= 2767 / 1{,}021$

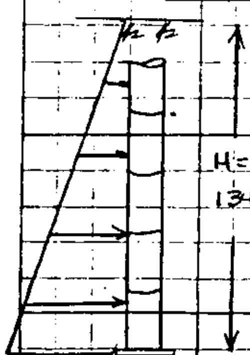
$= 2.71$ KSI (2710 PSI)

ASSUME 4000 PSI ALLOWABLE COMPRESSIVE STRENGTH OF CONCRETE

SAFETY FACTOR $= \frac{4000 \text{ PSI}}{2710 \text{ PSI}} = 1.5$ O.K.

ASSUME NO REDUCTION IN CONCRETE STRENGTH FOR COMPRESSION.

DETERMINATION OF LATERAL LOADS ON CONCRETE RISER



- VERTICAL STRESS NEAR BASE OF RISER

$\sigma_v = H \times \gamma_w$

$= 134' \times 110$ PCF

$= 14{,}740$ PSF

- HORIZONTAL STRESS NEAR BASE OF RISER

$\sigma_h = \sigma_v \times K_o$

$= 14{,}740 \times 0.74$

$= 10{,}908$ PSF (76 PSI)

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SUBJECT: STRUCTURAL STABILITY OF CONCRETE RISER		
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Ref.	Checked [initials]	Sheet 6 of 11
	Reviewed [initials]	

- CHECK WALL STRESS ON THE PIPE DUE TO LATERAL LOADS

MAXIMUM HOOP STRESS OCCURS AT THE INSIDE WALL AS FOLLOWS:

$$\sigma_t = -P_{MAX}\left(\frac{2a^2}{a^2-b^2}\right)$$ (REF 1: p 504) THICK VESSELS UNDER EXTERNAL PRESSURE.

WHERE: σ_t = MAX. TANGENTIAL STRESS (PSI)

P_{MAX} = MAX. LATERAL STRESS (PSI)

b = INSIDE RADIUS, (IN) (30 IN.)

a = OUTSIDE RADIUS, (IN) (35 IN)

THE MAXIMUM LATERAL PRESSURE WILL OCCUR NEAR THE BASE OF THE RISER

σ_h = 76 PSI

NOTE:
SINCE t/R > 1/10 THE CONCRETE PIPE IS CONSIDERED TO BE THICK WALLED

t = THICKNESS OF PIPE
R = INSIDE RADIUS
$t/R = 5/30 = 1/6$ WHICH IS GREATER THAN 1/10

MAXIMUM TANGENTIAL STRESS (PSI)

$$\sigma_t = -76\ PSI\left(\frac{2(35)^2}{35^2-30^2}\right)$$

$= 76\ PSI\ (7.54)$

$= 572\ PSI$

ASSUME 30% REDUCTION IN CONCRETE STRENGTH DUE TO FLEXURAL LOADING.

CALCULATE THE SAFETY FACTOR AGAINST FLEXURE COMPRESSION FAILURE OF CONCRETE.

FS = (0.77) (4000 PSI) / (572 PSI) = 4.9 ok

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SUBJECT: STRUCTURAL STABILITY OF CONCRETE RISER

Job No. 933-3600.001	Made by SM	Date 1-3-95
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	Reviewed [signature]	

– CHECK RADIAL STRESS DUE TO LATERAL LOADS

RADIAL STRESS = $\sigma_R = \dfrac{-Pa^2(r^2-b^2)}{r^2(a^2-b^2)}$ (REF. 1, p. 504)

WHERE: σ_R = RADIAL STRESS (PSI)

a = OUTSIDE RADIUS (IN.)

b = INSIDE RADIUS (IN.)

r = RADIUS FROM AXIS TO POINT WHERE MAXIMUM STRESS IS TO BE FOUND (IN.)

SINCE MAXIMUM STRESS OCCURS AT PIPE EXTERIOR:

$a = r$

$\therefore \sigma_R = \dfrac{-Pa^2(r^2-b^2)}{r^2(a^2-b^2)}$ $\sigma_R = P$

$\sigma_R = 76$ PSI

THE CALCULATED RADIAL STRESS IS A COMPRESSIVE STRESS IN THE RADIAL DIRECTION. COMPARE THIS TO THE ALLOWABLE COMPRESSIVE STRESS:

FS = 4000 PSI / 76 = 53 O'K

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SUBJECT STRUCTURAL STABILITY OF CONCRETE RISER

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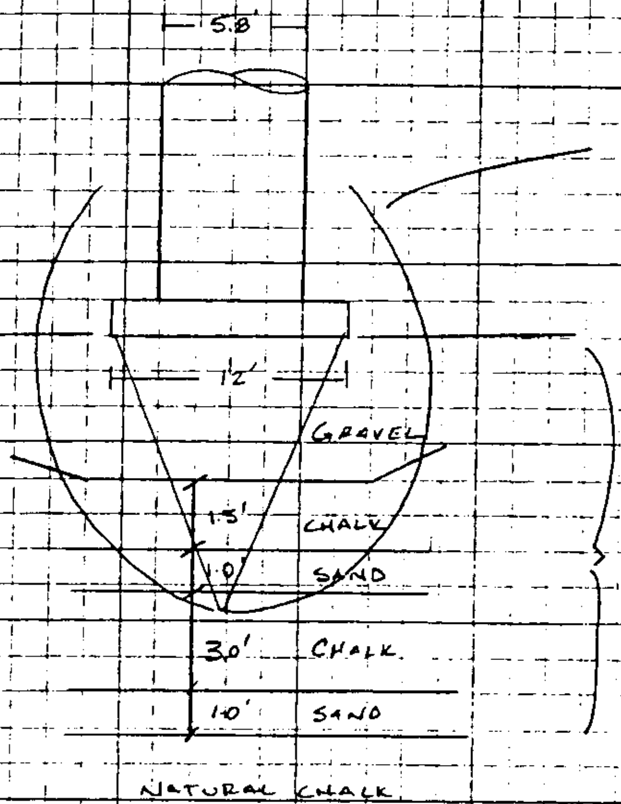
BEARING CAPACITY OF CONCRETE RISER PIPE



ASSUME SHEAR FAILURE WILL DEVELOP AS A DEEP FOUNDATION (i.e. PILE)

ASSUME THAT THE STRENGTH OF THE COMPOSITE SOIL-LAYER SHOWN WILL HAVE THE STRENGTH OF COMPACTED CHALK

$C = 600$ PSF
$\phi = 26°$

MEYERHOFF'S BEARING CAPACITY EQUATION FOR PILE FOUNDATIONS. (REF 2)

$$q_u = \frac{B\gamma}{2} N_\gamma + C N_c + q_q N_q$$

FOR $\phi = 26°$ DEEP LOCAL SHEAR FAILURE

$N_\gamma = 18$
$N_c = 36$
$N_q = 13$

} SEE ATTACHED PAGES FROM REF: 2

MEYERHOFF RECOMMENDS THAT THE OVERBURDEN STRESS q_q BE CONSIDERED CONSTANT FROM 10 TIMES THE DIAMETER OF THE PILE DOWN TO THE PILE TIP.

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SUBJECT STRUCTURAL STABILITY OF CONCRETE RISER		
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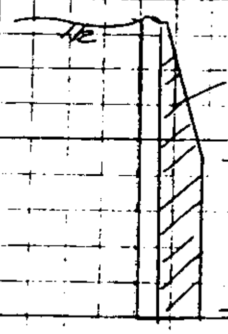

VERTICAL STRESS

$-10\phi = 10(5.8') = 58'$

STRESS $= 58' \times 110$ PCF
$= 6{,}380$ PSF

$-6{,}380$

$$q_o = \frac{12\text{ FT }(110\text{ PCF})}{2}(18) + 600\text{ PSF }(36) + 6{,}380\text{ PSF }(18)$$

$$= 148{,}320 \text{ PSF} \quad (148 \text{ KSF})$$

SAFETY FACTOR AGAINST BEARING CAPACITY FAILURE

$$SF = \frac{148 \text{ KSF}}{31 \text{ KSF}} = 4.8 \quad \text{o'k}$$

CONCLUSION:

THE ABOVE CALCULATIONS SHOW THAT THE STRUCTURAL STABILITY OF THE CONCRETE RISER IS ADEQUATE AGAINST CRUSHING FROM DOWNDRAG FORCES AND LATERAL FORCES. THERE IS ALSO AN ADEQUATE FACTOR OF SAFETY AGAINST A BEARING CAPACITY FAILURE.

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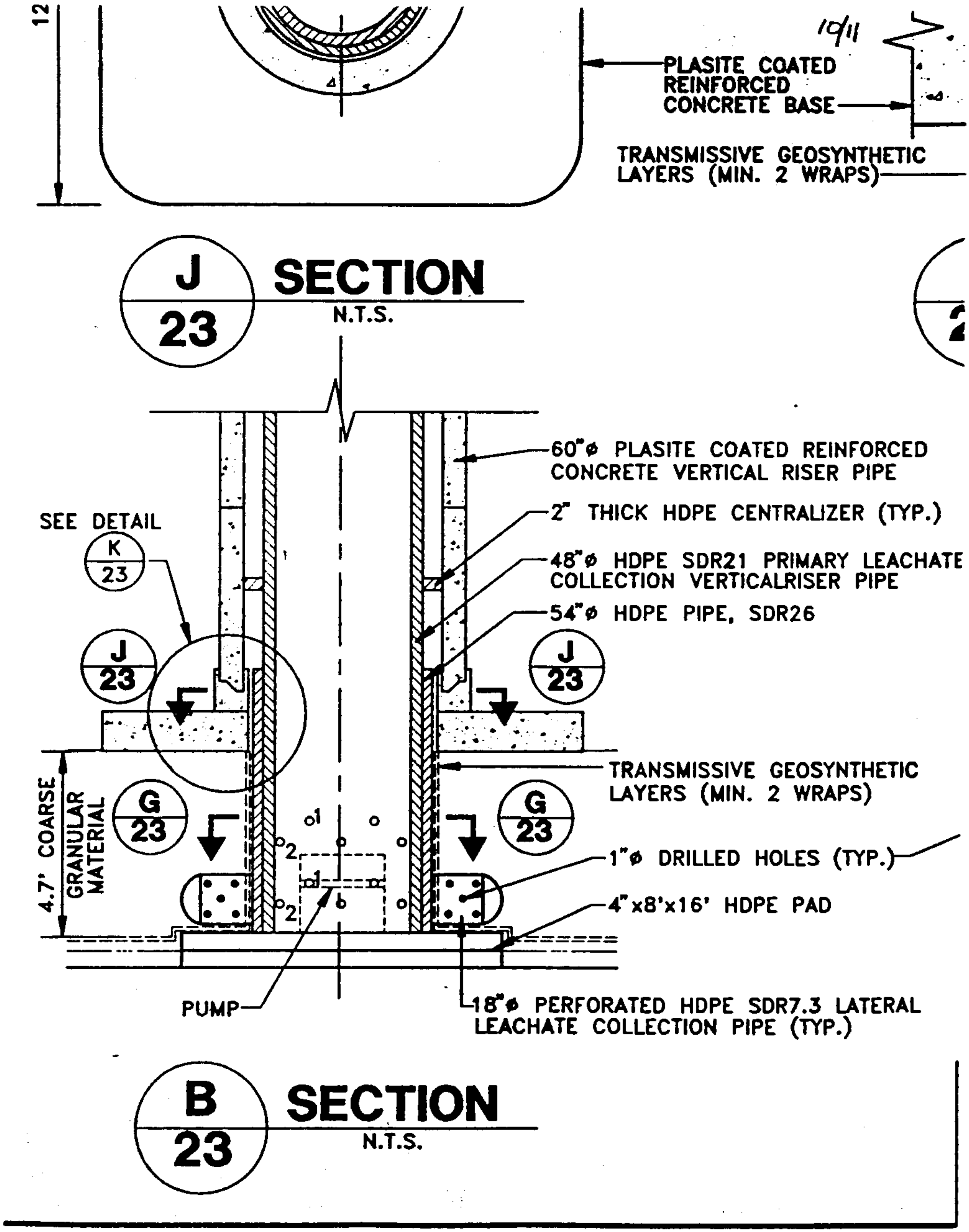
2) SOWERS, GEORGE F., INTRODUCTORY SOIL MECHANICS AND FOUNDATIONS, MACMILLAN PUBLISHING CO. INC, NEW YORK, 1979.



12
10/11
PLASITE COATED REINFORCED CONCRETE BASE
TRANSMISSIVE GEOSYNTHETIC LAYERS (MIN. 2 WRAPS)
J
23
SECTION
N.T.S.
60"ø PLASITE COATED REINFORCED CONCRETE VERTICAL RISER PIPE
SEE DETAIL
K
23
2" THICK HDPE CENTRALIZER (TYP.)
48"ø HDPE SDR21 PRIMARY LEACHATE COLLECTION VERTICALRISER PIPE
54"ø HDPE PIPE, SDR26
J
23
TRANSMISSIVE GEOSYNTHETIC LAYERS (MIN. 2 WRAPS)
4.7' COARSE GRANULAR MATERIAL
G
23
1"ø DRILLED HOLES (TYP.)
4"x8'x16' HDPE PAD
PUMP
18"ø PERFORATED HDPE SDR7.3 LATERAL LEACHATE COLLECTION PIPE (TYP.)
B
23
SECTION
N.T.S.

11/11

VERTICAL RISER LENGTHS FOR TRENCHES 22 THROUGH 24

	Primary Liner System		Final Closure Cover	
	Top of Sump El. (ft. - MSL)	Bottom of Sump El. (1) (ft. - MSL)	Top of Cover/4:1 Slope @ Sump Location (2) (ft. - MSL)	Length of Riser (ft.)
Trench 22 (3)				
Cell 1	187.0	183.0	293	110.0
Cell 2	184.5	180.5	294	113.5
Cell 3	191.5	187.5	296	108.5
Cell 4	185.0	181.0	303	122.0
Trench 23				
Cell 1	179.5	175.5	303	127.5
Cell 2	175.5	171.5	303	131.5
Cell 3	176.5	172.5	303	130.5
Cell 4	182.5	178.5	303	124.5
Cell 5	180.5	176.5	310	133.5
Trench 24				
Cell 1	190.5	186.5	313	126.5
Cell 2	195.5	191.5	314	122.5
Cell 3	193.0	189.0	316	127.0
Cell 4	179.5	175.5	314	138.5
Cell 5	179.5	175.5	313	137.5

Notes:
1. The sumps were determined to be 4 feet in depth from the design drawings.
2. The maximum height of waste above each sump was assumed to be the top of cover grades grades in the area or the break in the 4:1 slope whichever was greater.
3. The sump elevations represent the high design grades for Trench 22.

SUMP_EL.XLS

Formulas for Stress and Strain

FIFTH EDITION

RAYMOND J. ROARK

WARREN C. YOUNG

McGraw-Hill Book Company

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Düsseldorf Johannesburg London Madrid Mexico
Montreal New Delhi Panama Paris São Paulo
Singapore Sydney Tokyo Toronto

REF: 1
PAGE 1 OF 5

$$q' = \frac{t}{R}\,\frac{\sigma_y}{1 + (4\sigma_y/E)(R/t)^2} \qquad \text{(see Refs. 1, 7, and 8)}$$

In Refs. 8 and 9, charts are given for designing vessels under external pressure.

A special instability problem should be considered when designing long cylindrical vessels or even *relatively short corrugated tubes* under internal pressure. Haringx (Refs. 54 and 55) and Flügge (Ref. 5) have shown that vessels of this type will buckle laterally if the ends are restrained against longitudinal displacement and if the product of the internal pressure and the cross-sectional area reaches the Euler load for the column as a whole. For cylindrical shells this is seldom a critical factor, but for corrugated tubes or bellows this is recognized as a so-called *squirming instability*. To determine the Euler load for a bellows, an equivalent thin-walled circular cross section can be established which will have a radius equal to the mean radius of the bellows and a product Et, for which the equivalent cylinder will have the same axial deflection under end load as would the bellows. The overall bending moment of inertia I of the very thin equivalent cylinder can then be used in the expression $P_u = K\pi^2 EI/l^2$ for the Euler load. In a similar way Seide (Ref. 56) discusses the effect of pressure on the lateral bending of a bellows.

EXAMPLE

A corrugated-steel tube has a mean radius of 5 in, a wall thickness of 0.015 in, and 60 semicircular corrugations along its 40-in length. The ends are rigidly fixed, and the internal pressure necessary to produce a squirming instability is to be calculated. Given: $E = 30(10^6)$ lb/in² and $\nu = 0.3$.

Solution. Refer to Table 30, case 5b: $a = 5$ in, length = 40 in, $b = \frac{40}{120} = 0.333$ in, and $t = 0.015$ in

$$\mu = \frac{b^2}{at}\sqrt{12(1-\nu^2)} = \frac{0.333^2}{5(0.015)}\sqrt{12(1-0.3^2)} = 4.90$$

$$\text{Axial stretch} = \frac{-0.577Pbn\sqrt{1-\nu^2}}{Et^2} = \frac{0.577P(0.333)(60)(\sqrt{0.91})}{30(10^6)(0.015^2)} = -0.00163P$$

If a cylinder with a radius of 5 in and product E_1t_1 were loaded in compression with a load P, the stretch would be

$$\text{Stretch} = \frac{-Pl}{A_1E_1} = \frac{-P(40)}{2\pi 5 t_1 E_1} = -0.00163P$$

or

$$t_1E_1 = \frac{40}{2(5)(0.00163)} = 780.7 \text{ lb/in}$$

The bending moment of inertia of such a cylinder is $I_1 = \pi R^3 t_1$ (see Table 1, case 12). The Euler load for fixed ends is

$$P_{cr} = \frac{4\pi^2 E_1 I_1}{l^2}$$

or

$$P_{cr} = \frac{4\pi^2 E_1 \pi R^3 t_1}{l^2} = \frac{4\pi^3 5^3(780.7)}{40^2} = 7565 \text{ lb}$$

The internal pressure is therefore

$$q' = \frac{P_{cr}}{\pi R^2} = \frac{7565}{\pi 5^2} = 96.3 \text{ lb/in}^2$$

From Table 30, case 5c, the maximum stresses caused by this pressure are

$$\text{Max } \sigma_2 = 0.955(96.3)(0.91)^{1/6}\left[\frac{5(0.333)}{0.015^2}\right]^{2/3} = 34{,}400 \text{ lb/in}^2$$

$$\text{Max } \sigma_1' = 0.955(96.3)(0.91)^{-1/3}\left[\frac{5(0.333)}{0.015^2}\right]^{2/3} = 36{,}060 \text{ lb/in}^2$$

If the yield strength is greater than 36,000 lb/in², the corrugated tube should buckle laterally, that is, squirm, at an internal pressure of 96.3 lb/in².

12.6 *Thick shells of revolution*

If the wall thickness of a vessel is more than about one-tenth the radius, the meridional and hoop stresses cannot be considered uniform throughout the thickness of the wall and the radial stress cannot be considered negligible. These stresses in thick vessels, called *wall stresses,* must be found by formulas that are quite different from those used in finding membrane stresses in thin vessels.

It can be seen from the formulas for cases 1a and 1b of Table 32 that the stress σ_2 at the inner surface of a thick cylinder approaches q as the ratio of outer to inner radius approaches infinity. It is apparent, therefore, that if the stress is to be limited to some specified value σ, the pressure must never exceed $q = \sigma$, no matter how thick the wall is made. To overcome this limitation, the material at and near the inner surface must be put into a state of initial compression. This can be done by shrinking on one or more jackets (as explained in Art. 2.12 and in the example which follows) or by subjecting the vessel to a high internal pressure that stresses the inner part into the plastic range and, when removed, leaves residual compression there and residual tension in the outer part. This procedure is called *autofrettage,* or *self-hooping*. If many successive jackets are superimposed on the original tube by shrinking or wrapping, the resulting structure is called a *multilayer vessel.* Such a construction has certain advantages, but it should be noted that the formulas for hoop stresses are based on the assumption that an isotropic material is used. In a multilayered vessel the effective radial modulus of elasticity is less than the tangential modulus, and in consequence the hoop stress at and near the outer wall is less than the formula would indicate; therefore, the outer layers of material contribute less to the strength of the vessel than might be supposed.

Cases 1e and 1f in Table 32 represent radial body-force loading, which can be superimposed to give results for centrifugal loading, etc. (see Art. 15.2). Case 1f is directly applicable to thick-walled disks with embedded electrical conductors used to generate magnetic fields. In many such cases

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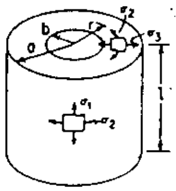
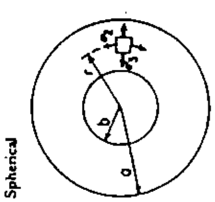
TABLE 32 *Formulas for thick-walled vessels under internal and external loading*

NOTATION: q = unit pressure (pounds per square inch); δ and δ_b = radial body forces (pounds per cubic inch); a = outer radius; b = inner radius; σ_1, σ_2, and σ_3 are normal stresses in the longitudinal, circumferential, and radial directions, respectively (positive when tensile); E = modulus of elasticity; ν = Poisson's ratio. Δa, Δb, and Δl are the changes in the radii a and b and in the length l, respectively. ϵ_1 = unit normal strain in the longitudinal direction

Case no., form of vessel	Case no., manner of loading	Formulas
1. Cylindrical disk or shell 	1a. Uniform internal radial pressure, q lb/in²; longitudinal pressure zero or externally balanced; for a disk or a shell	$\sigma_1 = 0$ $\sigma_2 = \frac{qb^2(a^2+r^2)}{r^2(a^2-b^2)}$ $\max \sigma_2 = q\frac{a^2+b^2}{a^2-b^2}$ at $r = b$ $\sigma_3 = \frac{-qb^2(a^2-r^2)}{r^2(a^2-b^2)}$ $\max \sigma_3 = -q$ at $r = b$ Max shear stress $= \frac{\sigma_2-\sigma_3}{2} = q\frac{a^2}{a^2-b^2}$ at $r = b$ $\Delta a = \frac{q}{E}\frac{2ab^2}{a^2-b^2}$ $\Delta b = \frac{qb}{E}\left(\frac{a^2+b^2}{a^2-b^2}+\nu\right)$ $\Delta l = \frac{-q\nu l}{E}\frac{2b^2}{a^2-b^2}$
	1b. Uniform internal pressure, q lb/in², in all directions; ends capped; for a disk or a shell	$\sigma_1 = \frac{qb^2}{a^2-b^2}$ (σ_2, σ_3, and the max shear stress are the same as for case 1a) $\Delta a = \frac{qa}{E}\frac{b^2(2-\nu)}{a^2-b^2}$ $\Delta b = \frac{qb}{E}\frac{a^2(1+\nu)+b^2(1-2\nu)}{a^2-b^2}$ $\Delta l = \frac{ql}{E}\frac{b^2(1-2\nu)}{a^2-b^2}$
	1c. Uniform external radial pressure, q lb/in²; longitudinal pressure zero or externally balanced; for a disk or a shell	$\sigma_1 = 0$ $\sigma_2 = \frac{-qa^2(b^2+r^2)}{r^2(a^2-b^2)}$ $\max \sigma_2 = \frac{-q2a^2}{a^2-b^2}$ at $r = b$ $\sigma_3 = \frac{-qa^2(r^2-b^2)}{r^2(a^2-b^2)}$ $\max \sigma_3 = -q$ at $r = a$ Max shear stress $= \frac{\max \sigma_2}{2} = \frac{qa^2}{a^2-b^2}$ at $r = b$ $\Delta a = \frac{-qa}{E}\left(\frac{a^2+b^2}{a^2-b^2}-\nu\right)$ $\Delta b = \frac{-q}{E}\frac{2a^2b}{a^2-b^2}$ $\Delta l = \frac{q\nu l}{E}\frac{2a^2}{a^2-b^2}$

Case no., form of vessel	Case no., manner of loading	Formulas
	1d. Uniform external pressure, q lb/in², in all directions; ends capped; for a disk or a shell	$\sigma_1 = \frac{-qa^2}{a^2-b^2}$ (σ_2, σ_3, and the max shear stress are the same as for case 1c) $\Delta a = \frac{-qa}{E}\frac{a^2(1-2\nu)+b^2(1+\nu)}{a^2-b^2}$ $\Delta b = \frac{-qb}{E}\frac{a^2(2-\nu)}{a^2-b^2}$ $\Delta l = \frac{-ql}{E}\frac{a^2(1-2\nu)}{a^2-b^2}$
	1e. Uniformly distributed radial body force, δ lb/in³, acting outward throughout the wall; for a disk only	$\sigma_1 = 0$ $\sigma_2 = \frac{\delta(2+\nu)}{3(a+b)}\left[a^2+ab+b^2-(a+b)\left(\frac{1+2\nu}{2+\nu}\right)r+\frac{a^2b^2}{r^2}\right]$ $\text{Max } \sigma_2 = \frac{\delta a^2}{3}\left[\frac{2(2+\nu)}{a+b}+\frac{b}{a^2}(1-\nu)\right]$ at $r = b$ $\sigma_3 = \frac{\delta(2+\nu)}{3(a+b)}\left[a^2+ab+b^2-(a+b)r-\frac{a^2b^2}{r^2}\right]$ (*Note*: $\sigma_3 = 0$ at both $r = b$ and $r = a$.) Max shear stress $= \frac{\max \sigma_2}{2}$ at $r = b$ $\Delta a = \frac{\delta a^2}{3E}\left[1-\nu+\frac{2(2+\nu)b^2}{a(a+b)}\right]$ $\Delta b = \frac{\delta ab}{3E}\left[\frac{b}{a}(1-\nu)+\frac{2a(2+\nu)}{a+b}\right]$ $\epsilon_1 = \frac{-\delta a\nu}{E}\left[\frac{2(a^2+ab+b^2)}{3a(a+b)}(2+\nu)-\frac{r}{a}(1+\nu)\right]$
	1f. Linearly varying radial body force from δ_b lb/in³ outward at $r = b$ to zero at $r = a$; for a disk only	$\sigma_1 = 0$ $\sigma_2 = \delta_b\left[\frac{(7+5\nu)a^4-8(2+\nu)ab^3+3(3+\nu)b^4}{24(a-b)(a^2-b^2)}-\frac{(1+2\nu)a}{3(a-b)}r+\frac{1+3\nu}{8(a-b)}r^2+\frac{b^3a^3}{24r^2}\frac{(7+5\nu)a^2-8(2+\nu)ab+3(3+\nu)b^2}{(a-b)(a^2-b^2)}\right]$ $\sigma_3 = \delta_b\left[\frac{(7+5\nu)a^4-8(2+\nu)ab^3+3(3+\nu)b^4}{24(a-b)(a^2-b^2)}-\frac{(2+\nu)a}{3(a-b)}r+\frac{(3+\nu)}{8(a-b)}r^2-\frac{b^3a^3}{24r^2}\frac{(7+5\nu)a-3(3+\nu)b}{a^2-b^2}\right]$ (*Note*: $\sigma_3 = 0$ at both $r = b$ and $r = a$) $\text{Max } \sigma_2 = \frac{\delta_b}{12}\frac{2a^4+(1+\nu)a^2(5a^2-12ab+6b^2)-(1-\nu)b^2(4a-3b)}{(a-b)(a^2-b^2)}$ at $r = b$

TABLE 32 *Formulas for thick-walled vessels under internal and external loading* (*Cont.*)

Case no., form of vessel	Case no., manner of loading	Formulas
		Max shear stress $= \frac{\max \sigma_2}{2}$ at $r = b$ $\Delta a = \frac{\delta_b a}{12E} \frac{(1-\nu)a^4 - 8(2+\nu)ab^3 + 3(3+\nu)b^4 + 6(1+\nu)a^2b^2}{(a-b)(a^2-b^2)}$ $\Delta b = \max \sigma_2 \frac{b}{E}$ $\epsilon_1 = \frac{-\delta_b r}{E}\left[\frac{(7+5\nu)a^4 - 8(2+\nu)ab^3 + 3(3+\nu)b^4}{12(a-b)(a^2-b^2)} - \frac{1+\nu}{a-b}\left(a - \frac{r}{2}\right)r\right]$
2. Spherical 	2a. Uniform internal pressure, q lb/in²	$\sigma_1 = \sigma_2 = \frac{qb^3}{2r^3}\frac{a^3+2r^3}{a^3-b^3}$ $\max \sigma_1 = \max \sigma_2 = \frac{q}{2}\frac{a^3+2b^3}{a^3-b^3}$ at $r = b$ $\sigma_3 = \frac{-qb^3}{r^3}\frac{a^3-r^3}{a^3-b^3}$ $\max \sigma_3 = -q$ at $r = b$ Max shear stress $= \frac{q3a^3}{4(a^3-b^3)}$ at $r = b$ The inner surface yields at $q = \frac{2\sigma_y}{3}\left(1 - \frac{b^3}{a^3}\right)$ (Ref. 20) $\Delta a = \frac{qa}{E}\frac{3(1-\nu)b^3}{2(a^3-b^3)}$ $\Delta b = \frac{qb}{E}\left[\frac{(1-\nu)(a^3+2b^3)}{2(a^3-b^3)} + \nu\right]$ (Ref. 3)
	2b. Uniform external pressure, q lb/in²	$\sigma_1 = \sigma_2 = \frac{-qa^3}{2r^3}\frac{b^3+2r^3}{a^3-b^3}$ $\max \sigma_1 = \max \sigma_2 = \frac{-q3a^3}{2(a^3-b^3)}$ at $r = b$ $\sigma_3 = \frac{-qa^3}{r^3}\frac{r^3-b^3}{a^3-b^3}$ $\max \sigma_3 = -q$ at $r = a$ $\Delta a = \frac{-qa}{E}\left[\frac{(1-\nu)(b^3+2a^3)}{2(a^3-b^3)} - \nu\right]$ $\Delta b = \frac{-qb}{E}\frac{3(1-\nu)a^3}{2(a^3-b^3)}$ (Ref. 3)

the magnetic field varies linearly through the wall to zero at the outside. If there is a field at the outer turn, cases 1e and 1f can be superimposed in the necessary proportions.

The tabulated formulas for elastic wall stresses are accurate for both thin and thick vessels, but formulas for predicted yield pressures do not always agree closely with experimental results (Refs. 21, 34, 35, 37, and 39). The expression for q_y given in Table 32 is based on the minimum strain-energy theory of elastic failure. The expression for bursting pressure

$$q_u = 2\sigma_u \frac{a-b}{a+b}$$

commonly known as the *mean diameter formula*, is essentially empirical but agrees reasonably well with experiment for both thin and thick cylindrical vessels and is convenient to use. For very thick vessels the formula

$$q_u = \sigma_u \ln \frac{a}{b}$$

is preferable. Greater accuracy can be obtained by using with this formula a multiplying factor that takes into account the strain-hardening properties of the material (Refs. 10, 20, and 37). With the same objective, Faupel (Ref. 39) proposes (with different notation) the formula

$$q_u = \frac{2\sigma_y}{\sqrt{3}}\left(2 - \frac{\sigma_y}{\sigma_u}\right)\ln\frac{a}{b}$$

A rather extensive discussion of bursting pressure is given in Ref. 38, which presents a tabulated comparison between bursting pressures as calculated by a number of different formulas and as determined by actual experiment.

EXAMPLE

At the powder chamber, the inner radius of a 3-in gun tube is 1.605 in and the outer radius is 2.425 in. It is desired to shrink a jacket on this tube so as to produce a radial pressure between the tube and jacket of 7600 lb/in². The outer radius of this jacket is 3.850 in. It is required to determine the difference between the inner radius of the jacket and the outer radius of the tube in order to produce the desired pressure, calculate the stresses in each part when assembled, and calculate the stresses in each part when the gun is fired, generating a powder pressure of 32,000 lb/in².

Solution. Using the formulas for Table 32, case 1c, it is found that for an external pressure of 7600, the stress σ_2 at the outer surface of the tube is −19,430, the stress σ_2 at the inner surface is −27,050, and the change in outer radius $\Delta a = -0.001385$; for an internal pressure of 7600, the stress σ_2 at the inner surface of the jacket is +17,630, the stress σ_2 at the outer surface is +10,050, and the change in inner radius $\Delta b = +0.001615$. (In making these calculations the inner radius of the jacket is assumed to be 2.425 in.) The initial difference between the inner radius of the jacket and the outer radius of the tube must be equal to the sum of the radial deformations they suffer, or 0.001385 + 0.001615 = 0.0030; therefore the initial radius of the jacket should be 2.425 − 0.0030 = 2.422 in.

The stresses produced by the powder pressure are calculated at the inner surface of the tube, at the common surface of tube and jacket (r = 2.425), and at the outer surface of the jacket.

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These stresses are then superimposed on those found previously. The calculations are as follows: For the tube at the inner surface,

$$\sigma_2 = +32{,}000\left(\frac{3.85^2 + 1.605^2}{3.82^2 - 1.605^2}\right) = +45{,}450$$

$$\sigma_3 = -32{,}000$$

For tube and jacket at the interface,

$$\sigma_2 = +32{,}000\left(\frac{1.605^2}{2.425^2}\right)\left(\frac{3.85^2 + 2.425^2}{3.85^2 - 1.605^2}\right) = +23{,}500$$

$$\sigma_3 = -32{,}000\left(\frac{1.605^2}{2.425^2}\right)\left(\frac{3.85^2 - 2.425^2}{3.85^2 - 1.605^2}\right) = -10{,}200$$

For the jacket at the outer surface,

$$\sigma_2 = +32{,}000\left(\frac{1.605^2}{3.85^2}\right)\left(\frac{3.85^2 + 3.85^2}{3.85^2 - 1.605^2}\right) = +13{,}500$$

These are the stresses due to the powder pressure. Superimposing the stresses due to the shrinkage, we have as the resultant stresses:

At inner surface of tube,

$$\sigma_2 = -27{,}050 + 45{,}450 = +18{,}400 \text{ lb/in}^2$$
$$\sigma_3 = 0 - 32{,}000 = -32{,}000 \text{ lb/in}^2$$

At outer surface of tube,

$$\sigma_2 = -19{,}430 + 23{,}500 = +4070 \text{ lb/in}^2$$
$$\sigma_3 = -7600 - 10{,}200 = -17{,}800 \text{ lb/in}^2$$

At inner surface of jacket,

$$\sigma_2 = +17{,}630 + 23{,}500 = +41{,}130 \text{ lb/in}^2$$
$$\sigma_3 = -7600 - 10{,}200 = -17{,}800 \text{ lb/in}^2$$

At outer surface of jacket,

$$\sigma_2 = +10{,}050 + 13{,}500 = +23{,}550 \text{ lb/in}^2$$

12.7 *Pipe on supports at intervals*

For a pipe or cylindrical tank supported at intervals on saddles or pedestals and filled or partly filled with liquid, the stress analysis is difficult and the results are rendered uncertain by doubtful boundary conditions. Certain conclusions arrived at from a study of tests (Refs. 11 and 12) may be helpful in guiding design:

1. For a circular pipe or tank supported at intervals and held circular at the supports by rings or bulkheads, the ordinary theory of flexure is applicable if the pipe is completely filled.

2. If the pipe is only partially filled, the cross section at points between supports becomes out of round and the distribution of longitudinal fiber stress is neither linear nor symmetrical across the section. The highest stresses occur for the half-full condition; then the maximum longitudinal compressive stress

and the maximum circumferential bending stresses occur at the ends of the horizontal diameter, the maximum longitudinal tensile stress occurs at the bottom, and the longitudinal stress at the top is practically zero. According to theory (Ref. 4), the greatest of these stresses is the longitudinal compression, which is equal to the maximum longitudinal stress for the full condition divided by

$$K = \left(\frac{L}{R}\sqrt{\frac{t}{R}}\right)^{\frac{1}{2}}$$

where R = pipe radius, t = thickness, and L = span. The maximum circumferential stress is about one-third of this. Tests (Ref. 11) on a pipe having $K = 1.36$ showed a longitudinal stress that is somewhat less and a circumferential stress that is considerably greater than indicated by this theory.

3. For an unstiffened pipe resting in saddle supports, there are high local stresses, both longitudinal and circumferential, adjacent to the tips of the saddles. These stresses are less for a large saddle angle β (total angle subtended by arc of contact between pipe and saddle) than for a small angle, and for the ordinary range of dimensions they are practically independent of the thickness of the saddle, i.e., its dimension parallel to the pipe axis. For a pipe that fits the saddle well, the maximum value of these localized stresses will probably not exceed that indicated by the formula

$$\sigma_{max} = k\frac{P}{t^2}\ln\frac{R}{t}$$

where P = total saddle reaction, R = pipe radius, t = pipe thickness, and k = coefficient given by

$$k = 0.02 - 0.00012(\beta - 90)$$

where β is in degrees. This stress is almost wholly due to circumferential bending and occurs at points about 15° above the saddle tips.

4. The maximum value of P the pipe can sustain is about 2.25 times the value that will produce a maximum stress equal to the yield point of the pipe material, according to the formula given above.

5. For a pipe supported in flexible slings instead of on rigid saddles, the maximum local stresses occur at the points of tangency of sling and pipe section; in general, they are less than the corresponding stresses in the saddle-supported pipe but are of the same order of magnitude.

REFERENCES

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2. Roark, R. J.: The Strength and Stiffness of Cylindrical Shells under Concentrated Loading, *ASME J. Appl. Mech.*, vol. 2, no. 4, p. A-147, 1935.
3. Timoshenko, S.: "Theory of Plates and Shells," Engineering Societies Monograph, McGraw-Hill Book Company, 1940.

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$D_r > 70\%$, $z_c = 20D$; for intermediate densities it is approximately proportional to relative density.

The lateral pressure of soil against the pile surface can be expressed by the equation above the depth z_c,

$$\sigma'_h = K_s(\gamma z - u) \quad (11{:}2a)$$

Below z_c, σ'_h remains constant,

$$\sigma'_h = K_s(\gamma z_c - u) \quad (11{:}2b)$$

The earth pressure coefficient K_s depends on the displacement of the pile and the density or compressibility of the soil. (See Table 11:2.) For the jetted or drilled piles the values of K_s increase with load; the maximum occurs at failure.

TABLE 11:2 / COEFFICIENT OF LATERAL EARTH PRESSURE IN COHESIONLESS SOIL ADJACENT TO PILE AT FAILURE

Soil	Displacement Condition	K_s
Loose sand, $D_r < 30\%$	Jetted	0.5 to 0.75
	Drilled pile	0.75 to 1.5
	Driven pile	2 to 3
Dense sand, $D_r > 70\%$	Jetted	0.5 to 1
	Drilled pile	1 to 2
	Driven pile	3 to 4

STATIC ANALYSIS OF BEARING CAPACITY / The ultimate bearing capacity of the pile or pier is the sum of end bearing and skin friction at the instant of maximum load:

$$Q_0 = Q_{EB} + Q_{SF} \quad (11{:}3)$$

The ultimate values for Q_{EB} and Q_{SF} can be analyzed separately. Both are based upon the state of stress around the pile (or any deep foundation) and on the shear patterns that develop at failure.

In end bearing the pile tip resembles a deeply buried spread footing. When the pile is loaded, a cone of intact soil adheres to the tip. As the tip penetrates deeper with increasing load, the cone forces the soil aside, shearing the mass along a curved surface (Fig. 11.6c). If the soil is loose or compressible or has a low modulus of elasticity, the mass beyond the shear zone compresses or deforms, allowing the cone to penetrate further. This is a form of local shear, similar to that described for shallow foundation (Chapter 10). If the soil or rock is very rigid, the shear zone expands until the total displacement allows the cone to punch downward. Various forms of shear zone have been proposed to evaluate end bearing. Like the results of shallow foundation analyses these can be expressed in the general form

$$q_0 = \frac{B\gamma}{2} N_\gamma + cN_c + q_q N_q \qquad (11:3)$$

For piles where B is small, the first term is often omitted:

$$q_0 = cN_c + q_q N_q \qquad (11:4)$$

Although many different bearing-capacity factors have been derived for deep foundations, the range that has been verified to some extent by full size test piles is depicted in Fig. 11.11. The lower curves are the Meyerhof factors for shallow foundations, corrected for a circular or square shape. The upper curves are for general shear failure, adapted from Meyerhof,[11:5] and require the complete development of the shear zone that can only occur in a rigid-plastic solid or a dense sand. The middle curves are adapted from Berezantzev's work in sands; they fit the results of load tests of driven large-scale models and full-sized piles.[11:12]

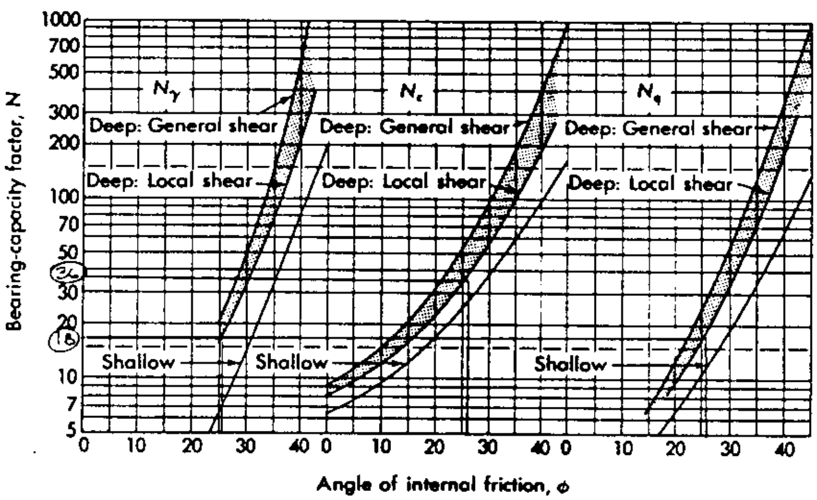

Figure 11.11 Bearing-capacity factors for shallow and deep square or cylindrical foundations. (Adapted from Meyerhof[11:5] and Berezantzev.[11:11])

Figure 11.11 shows a considerable range in N for deep foundations, the shaded zone. It represents the uncertainties caused by changes in soil density with pile driving as well as the reduction in vertical stress with depth below z_c. The lower shallow curves apply to depths of $z/2D$. They also apply to a pile or pier extending through a weak stratum and end bearing on a hard

GOLDER WORK SHEET

Strength and Stability of HPDE Vertical Riser Pipe

Objective: Determine the structural stability of the 48-inch HDPE vertical riser pipe under the maximum design pressure. The pipe is enclosed in a 60-inch concrete riser as shown on the design drawings (see page 6) except the area immediately below the base of the concrete riser. The area around the exposed HDPE riser pipe is backfilled with compacted crushed stone. For additional stability for the exposed portion of the 48-inch HDPE pipe, a 54-inch diameter HDPE pipe is used as a stiffener. THE TWO PIPES ACT AS A COMPOSITE SECTION (I.E. THE WALL THICKNESS IS THE SUM OF THE TWO PIPES.)

Method: 1. Determine the maximum vertical pressure acting on the HDPE vertical riser pipe and convert to horizontal pressure. The design pressure occurs just below the base of the concrete riser section near the base of the landfill at which point the HDPE pipe is not enclosed by the concrete riser.

2. Evaluate the pipe for
   - a) wall crushing;
   - b) wall buckling; and
   - c) ring deflection.

Conclusions: A perforated 48-inch diameter HDPE SDR 21 pipe with a supporting 54-inch diameter HDPE SDR 26 pipe is structurally stable under the anticipated maximum pressure and can be used as the vertical riser pipe. FOR THIS APPLICATION, THE TWO PIPES WILL ACT AS A COMPOSITE SECTION W/ AN O.D = 54" AND SDR = 12.5.

F.S. against wall crushing = 2.4
F.S. against wall buckling = 1.3
Ring deflection = 0.04 < 0.09 recommended 9%

Define Parameters:

$\sigma_v := 215\ psi$ .....Maximum vertical pressure acting on the HDPE vertical riser pipe. (The maximum pressure is due to the bearing pressure of the concrete riser section. See calcs. for concrete riser - 31 KSF)

$\gamma_{refuse} := 110 \cdot \frac{lbf}{ft^3}$ .....Unit weight of refuse

$\phi_{backfill} := 30 \cdot deg$ .....Interface friction angle of soil backfill around riser pipe - Assume gravel backfill around pipe.

Properties of Backfill Material Adjacent to Pipe

$E_{soil} := 2000 \cdot \frac{lbf}{in^2}$ ....Elastic modulus of soil (Driscopipe, 1989 for coarse grained soils compacted to 85%-95% Standard Proctor's maximum dry density)

$E_{reaction} := 2 \cdot E_{soil}$ ....Subgrade reaction of soil (Selig, 1990 suggested that the subgrade reaction is two times the elastic modulus of soil)

Properties of perforated 48-inch diameter HDPE vertical riser pipe with 54-inch supporting pipe (obtained from Driscopipe, 1988):

$T_{yield} := 1500 \cdot \frac{lbf}{in^2}$ ....Yield strength of Driscopipe

$E_{pipe} := 13000 \cdot \frac{lbf}{in^2}$ ....Elastic modulus of HDPE pipe

$\epsilon_{allow} := 0.09$ ....Allowable ring deflection of pipe

$SDR := 12.5$ ....Standard Dimension Ratio (48-inch and 54-inch pipe - p. 5, Ref.1) THIS IS A COMPOSITE SECTION OF THE TWO PIPES. - 48" SDR 21; 54" SDR 26

$D_{pipe} := 54 \cdot in$ ....Outside diameter of 54-inch pipe

$D_{per} := 1 \cdot in$ ....Diameter of perforation

$N_{per} := 12$ ....Number of perforations per linear foot

$A_{per} := \frac{N_{per} \cdot \pi \cdot D_{per}^2}{4}$ ....Area of perforations per linear foot of pipe

$A_{pipe} := \pi \cdot D_{pipe} \cdot 12 \cdot in$ ....Surface area per linear foot of pipe

$A_{pipe\_net} := A_{pipe} - A_{per}$ ....Net surface area per linear foot of pipe

$\frac{A_{pipe\_net}}{A_{pipe}} = 0.995$ ....Correction is insignificant and is therefore neglected in these calculations.

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$D_L := 1.0$ ....Deflection lag factor = 1 for load prism

$k := 0.1$ ....Bedding constant; mostly recommended to be 0.1

$K_o := 1 - \sin(\phi_{backfill})$ ....Coefficient for at rest earth pressure

Maximum Vertical Stress

$\sigma_v = 3.1 \cdot 10^4 \cdot \frac{lbf}{ft^2}$ $\sigma_v = 215 \cdot \frac{lbf}{in^2}$

Computation of Maximum Horizontal Stress acting on Pipe

$\sigma_h := \sigma_v \cdot K_o$

$\sigma_h = 1.5 \cdot 10^4 \cdot \frac{lbf}{ft^2}$ $\sigma_h = 107.5 \cdot \frac{lbf}{in^2}$

Design for Wall Crushing

$S_A := \frac{(SDR - 1) \cdot \sigma_h}{2}$ ......Compressive stress in pipe

$S_A = 618.1 \cdot \frac{lbf}{in^2}$

$FS_{crush} := \frac{T_{yield}}{S_A}$ ......Factor of safety against wall crushing

$FS_{crush} = 2.4$ > 2 o'k per page 2, Ref. 1.

Design for Wall Buckling

$P_c := \frac{2.32 \cdot E_{pipe}}{SDR^3}$ ......Hydrostatic, critical collapse differential pressure

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$P_{cb} := 0.8 \cdot \sqrt{E_{soil} \cdot P_c}$ ....Critical buckling soil pressure

$P_c = 15.4 \cdot \frac{lbf}{in^2}$

$P_{cb} = 140.6 \cdot \frac{lbf}{in^2}$

$FS_{buckling} := \frac{P_{cb}}{\sigma_h}$ ....Factor of safety against wall buckling

$FS_{buckling} = 1.3$ > 1 o'k per page 3, Ref. 1.

Design for Ring Deflection

$\Delta Y := \frac{D_L \cdot k \cdot \sigma_h \cdot D_{pipe}}{\left[\frac{2 \cdot E_{pipe}}{\left[3 \cdot (SDR - 1)^3\right]}\right] + 0.061 \cdot E_{reaction}}$ ....Ring deflection (Modified Iowa Formula) (REF: No. 5)

$E_{reaction} = 4 \cdot 10^3 \cdot \frac{lbf}{in^2}$

$\Delta Y = 2.325 \cdot in$

$\frac{\Delta Y}{D_{pipe}} = 0.043$ < 9%, the recommended maximum deflections immediately after filling of the trench by Lars-Eric Janson, et. al. in "Design and installation of Underground Plastic Sewer Pipes" in International Conference on Underground Plastic Pipe, 1981, New Orleans, pp 79-88; pp 104-116.

Conclusions: A perforated 48-inch diameter HDPE SDR 21 pipe with a supporting 54-inch diameter HDPE SDR 26 pipe is structurally stable under the anticipated maximum pressure and can be used as the vertical riser pipe with crushed stone backfill around the pipe. FOR THIS APPLICATION THE TWO PIPES WILL ACT AS A COMPOSITE SECTION W/ AN O.D. = 54" AND AN SDR = 12.5.

F.S. against wall crushing = 2.4
F.S. against wall buckling = 1.3
Ring deflection = 0.04 < 0.09 recommended 9%

Golder Associates

SUBJECT: STRENGTH AND STABILITY OF VERTICAL RISER PIPE

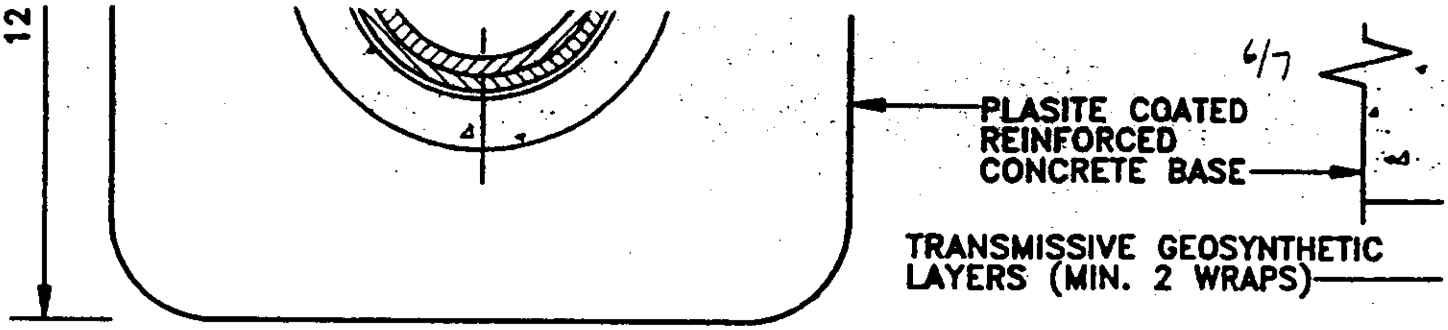
Job No. 933-3600 | Made by SM | Date 1/10/95
Ref. 001 | Checked | Sheet 5 of 7
Reviewed

* References:

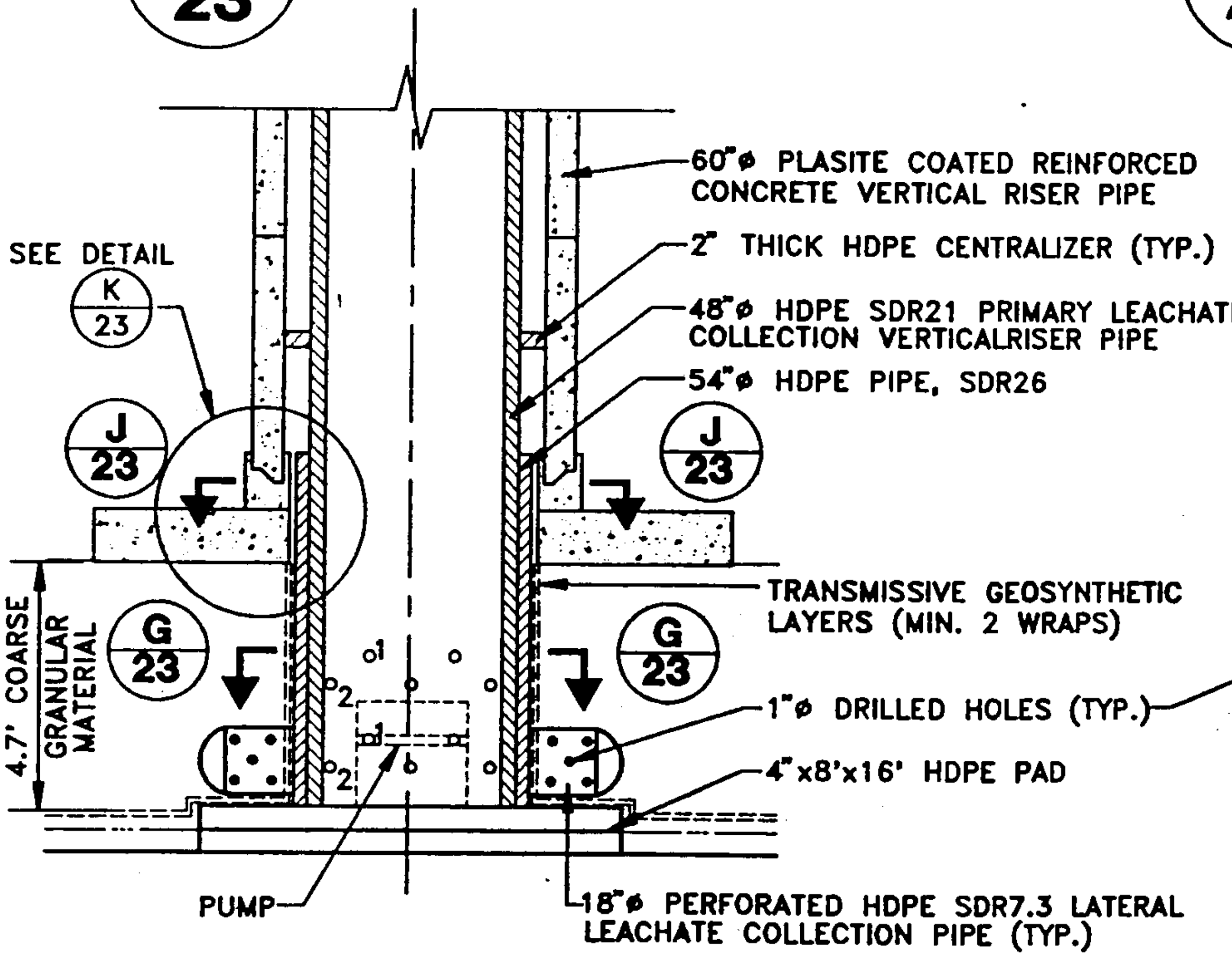
(1) Driscopipe, 1988. "System and Design by Phillips 66".
(2) Selig, E. T., 1990. "Soil Properties for Plastic Pipe Installations," ASTM STP 1093 Buried Plastic Pipe Technology.
(3) Lars-Eric Janson, et. al., "Design and Installation of Underground Plastic Sewer Pipes" in International Conference on Underground Plastic Pipe, 1981, New Orleans, pp 79-88; pp 104-116. Attached
(4) Goddard, J. B. "Plastic Pipe Design" in Ohio Transportation Engineering Conference, December, 1992. Attached

(5) HANDBOOK OF PVC PIPE + DESIGN AND CONSTRUCTION, UNI-BELL PVC PIPE ASSOCIATION, DALLAS, TX, 1982.

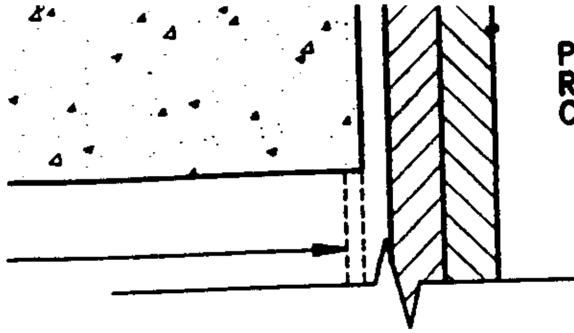
* References attached at end of these calc's.

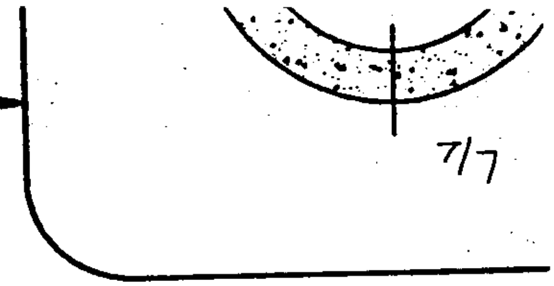


J
23
SECTION
N.T.S.



B
23
SECTION
N.T.S.





K 3 DETAIL
N.T.S.

L 23 BASE PL
N.T.S.

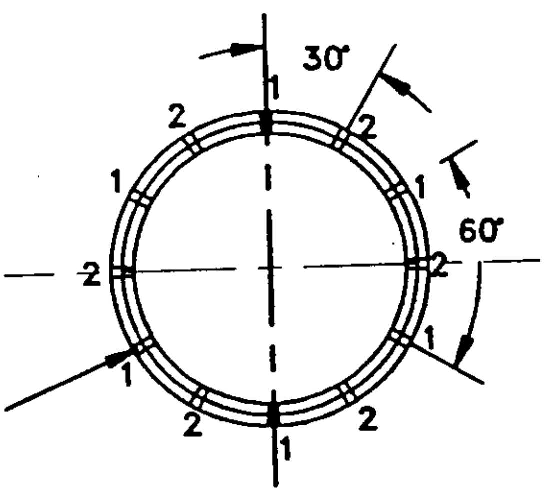
NOTES:

1. Geotextile cushion protecting cap sheet in prim sump from coarse granular material shall con

Max. Particle Used	# Cushion Lay
1"	1
1 1/4"	2
1 1/2"	2
1 3/4"	3
2"	3
2 1/2"	4

2. Depth of primary sump in trench 23 & 24 is
3. The cleanout riser and the upslope riser shall within the sump limits and SDR of 11 along
4. The primary leachate collection vertical riser shall be a 54"ø & 48"ø composite HDPE pipe

12 HOLES TOTAL/FT



G 23 SECTION
N.T.S.

REV.	DATE	DESCRIPTION
3	1/95	REVISED VERTICAL & UPSLOPE RISER PIPE DETAILS
2	11/94	REVISE NOTES
1	1/94	REVISION TO SUMPS

SCALE: AS SHOWN		
FILE NO. 824-1308		
DES BY	T.L.R.	10/93
DR BY	T.s.R.	10/93
CHK BY	JEF	10/29/93
APP BY	WRS	10/29/93

PROJECT NO. 933-3600

PROJECT: EMEL

SHEET TITLE: TYPICAL MISC (SHE TREN

Atlanta, Georgia

Golder Associates

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

DRISCOPIPE

Ref. #1

1/5

Driscopipe® Systems Design

Introduction

This manual presents design parameters applicable to the design of Driscopipe Polyethylene Pipe Systems, including applications and installations. It is a compilation of extensive research, field performance data and mathematical derivations supported by laboratory investigations. It is offered as information for your consideration in specifying Driscopipe. It is intended to be an aid to, but not a substitute for, your own investigation and evaluation of the product in each application or installation. As you proceed with your design, questions may arise. Your Driscopipe representative will be quite willing to answer your questions and discuss your needs.

Preliminary Design Data

The industries served by Driscopipe are quite diverse. The applications within each industry are extensive and can be demanding. Some are simple and straightforward. Others are complex and may require considerable thought even beyond the scope of this manual.

Since Driscopipe offers the advantages of flexibility, resiliency and toughness, it differs from rigid plastic and steel pipe in some pleasant ways. Driscopipe pipe by itself is strong, extremely tough and very durable. It can stand alone or be considered as a portion of the environment. Each installation becomes a "system" within the environment, can gather additional strength from its surroundings and is responsive to changes in its physical environment.

Proper system design should give consideration to the following six design criteria:

Fluid Properties

Compatibility: There are many chemical handling problems which can be solved with Driscopipe.

It is one of the most chemically resistant plastics commercially available. Because of its inherent chemical composition and structure, Driscopipe does not react with most products being pumped. It is virtually inert. There are only a very few strong chemicals which affect it. When reviewing the chemical compatibility charts presented in the *Engineering Characteristics* brochure, it is helpful to keep the following three factors in mind.

1. The chemical resistance of Driscopipe is related to the chemical itself, the operating temperature and the concentration of the chemical.
2. Strong oxidizing agents such as nitric acid, sulfuric acid, chlorine gas and liquid bromine are most aggressive and deserve special consideration (See Chemical Resistance charts – *Engineering Characteristics* brochure.).
3. Permeation of the pipe wall is negligible for most products. However, aromatic hydrocarbon permeation rates should be reviewed.

Specific Gravity: A close approximation should be made of the fluid's density or specific gravity for later use in flow calculations and/or installation calculations.

Viscosity: Some measure of the fluid's viscosity should be made or approximated over the system's operating temperature range. Flow and pressure calculations are related to this property. For example, if oil is the medium being pumped during summer and winter at constant pressure, the winter output (flow) decreases as its viscosity increases (ie: gets colder).

Solids Content: Driscopipe is used to convey many slurry mixtures. Some are primary processing pipelines. Some are secondary waste conveying pipelines. The system designer should consider the slurry solids content, its particle structure, abrasiveness, size distribution, net specific gravity, etc.

Pipeline Life Requirements

A determination should be made of the estimated "life" of the installed pipeline. For example, a city sewer system should have a minimum 50 year life. A temporary, gravity-flow, mine "tailings" slurry line may need be of service only five years before operations are moved. A specialized chemical process plant may be obsoleted or renovated in 15 to 20 years due to technology changes. Different design parameters are allowable dependent upon maximum operating conditions and expected "life".

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Simplified Burial Design: A conservative estimate of the ability of Driscopipe pipelines to perform in a buried environment is found in Chart 24. It is based on a minimum 2:1 safety factor and 50 year design service life. A detailed burial design starts on page 37. The detailed design should be used for critical or marginal applications or whenever a more precise solution is desired.

Detailed Burial Design:
Design by Wall Crushing: Wall crushing would theoretically occur when the stress in a pipe wall, due to the external vertical pressure, exceeded the long-term compressive strength of the pipe material. To ensure that the Driscopipe wall is strong enough to endure the external pressure the following check should be made:

$$S_A = \frac{(SDR - 1)}{2} P_T$$

Values of E′

Based on Soil Type (ASTM D2321) and Degree of Compaction

Soil Type of Initial Backfill Embedment Material	Description	E′ (psi) for Degree of Compaction (Proctor Density, %) Loose	Slight (70-85%)	Moderate (85-95%)	High (95%)
I	Manufactured angular, granular materials (crushed stone or rock, broken coral, cinders, etc.)	1,000	3,000	3,000	3,000
II	Coarse grained soils with little or no fines	N.R.	1,000	2,000	3,000
III	Coarse grained soils with fines	N.R.	N.R.	1,000	2,000
IV	Fine-grained soils	N.R.	N.R.	N.R.	N.R.
V	Organic soils (peat, muck, clay, etc.)	N.R.	N.R.	N.R.	N.R.

N.R. = Not Recommended for use by ASTM D2321 for pipe wall support

Chart 24

SDR	Maximum Burial Depth, ft. in dry soil of 100 lbs/cu. ft. — Soil Modulus, psi*			Maximum External Pressure psi — Soil Modulus, psi*			Maximum Deflection, % after installation — Soil Modulus, psi*		
	1000	2000	3000	1000	2000	3000	1000	2000	3000
32.5	25	32	37	17	22	26	1.7	0.9	0.6
26	33	45	52	23	31	36	2.3	1.2	0.8
21	46	61	71	32	42	49	3.2	1.6	1.1
19	52	69	81	36	48	56	3.6	1.8	1.2
17	61	121	181	42	84	126	4.2	2.1	1.4
15.5	56	112	168	39	78	117	3.9	2.0	1.3
13.5	49	98	147	34	68	102	3.4	1.7	1.1
11	39	78	117	27	54	81	2.7	1.4	0.9
9.3	33	68	101	23	47	70	2.3	1.2	0.8
8.3	30	61	89	21	42	62	2.1	1.1	0.7
7.3	26	52	79	18	36	55	1.8	0.9	0.6

*assumes no external loads

Where: S_A = Actual compressive stress, psi
SDR = Standard Dimension Ratio
P_T = External Pressure, psi

Safety Factor = 1500 psi ÷ S_A where 1500 psi is the Compressive Yield Strength of Driscopipe.

Design by Wall Buckling: Local wall buckling is a longitudinal wrinkling of the pipe wall. Tests of *non-pressurized* Driscopipe show that buckling and collapse do not occur when the soil envelope is in full contact with the pipe and is compacted to a dense state. However, it can be forced to occur over the long term in *non-pressurized* pipe if the total external soil pressure, P_t, is allowed to exceed the pipe-soil system's critical buckling pressure, P_{cb}. If $P_t > P_{cb}$, gradual collapse may occur over the long term. A calculated, conservative value for the critical buckling pressure may be obtained by the following approximate formula. All pipe diameters with the same SDR in the same burial situation have the same critical collapse and critical buckling endurance

$$P_{cb} = 0.8\sqrt{E' \times P_c}$$

Where:

P_t = Total vertical soil pressure at the top of the pipe, psi

P_{cb} = Critical buckling soil pressure at the top of the pipe, psi

E' = Soil modulus in psi calculated as the ratio of the vertical soil pressure to vertical soil strain at a specified density

P_C = Hydrostatic, critical-collapse differential pressure, psi

$$P_C = \frac{2E\,(t/D)^3\,(D_{MIN}/D_{MAX})^3}{(1-\mu^2)}$$

$$P_c = \frac{2.32\,E}{(SDR)^3}$$

Where: (D_{MIN}/D_{MAX}) = .95
μ = Poission's Ratio
μ = .45 for Driscopipe
E = stress and time dependent tensile modulus of elasticity, psi

In a direct burial pressurized pipeline, the internal pressure is usually great enough to exceed the external critical-buckling soil pressure. When a pressurized line is to be shut down for a period, wall buckling should be examined.

Design by Wall Buckling Guidelines:
Although wall buckling is seldom the limiting factor in the design of a Driscopipe system, a check of non-pressurized pipelines can be made according to the following steps to insure $P_t < P_{cb}$.

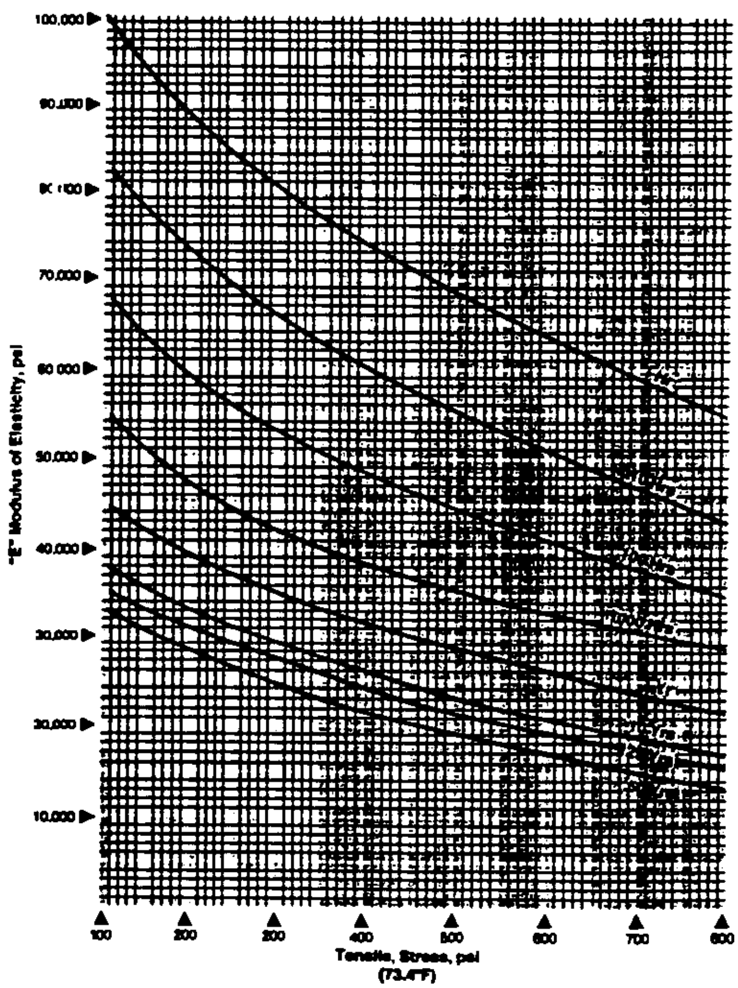
1. Calculate or estimate the total soil pressure, P_t, at the top of the pipe.
2. Calculate the stress "S_A" in the pipe wall according to the formula:

$$S_A = \frac{(SDR - 1)\,P_t}{2}$$

3. Based upon the stress "S_A" and the estimated time duration of non-pressurization, use Chart 25 to find the value of the pipe's modulus of elasticity, E, in psi.

Chart 25

Time Dependent Modulus of Elasticity for Polyethylene Pipe vs. Stress Intensity (73.4°F)



NOTE: The short term modulus of elasticity of Driscopipe per ASTM D 638 is approximately 100,000 psi. Due to the cold flow (creep) characteristic of the pipe material, this modulus is dependent upon the stress intensity and the time duration of the applied stress.

DRISCOPIPE

Dimensions & Pressure Ratings
1000 Series Pipe

Size	SDR	PSI @73.4	Weight lbs. per ft	Dimensions - inches: Nominal O D	Approx. I D	Min. Wall	Packaging
1"	11	160	.19	1.315	1.075	.120	500 ft.coil
1-1/4	11	160	.30	1.660	1.358	.151	500 ft.coil
1-1/2	11	160	.40	1.900	1.554	.173	500 ft.coil
2"	11	160	.62	2.375	1.943	.216	88 jts.per bundle
	13.5	128	.52		2.023	.176	14 bundles per truck
	15.5	110	.46		2.069	.153	
	17	100	.42		2.095	.140	
3"	7	267	2.00	3.500	2.500	.500	46 jts.per bundle
	9	200	1.62		2.722	.389	
	11	160	1.35		2.864	.318	
	13.5	128	1.12		2.982	.259	14 bundles per truck
	15.5	110	.99		3.048	.226	
	17	100	.91		3.088	.206	
	19	89	.82		3.132	.184	
	21	80	.74		3.166	.167	
	26	64	.61		3.230	.135	
	32.5	51	.49		3.284	.108	
4"	7	267	3.31	4.500	3.214	.643	29 jts.per bundle
	9	200	2.67		3.500	.500	
	11	160	2.23		3.682	.409	14 bundles per truck
	13.5	128	1.85		3.834	.333	
	15.5	110	1.63		3.920	.290	
	17	100	1.50		3.970	.265	
	19	89	1.35		4.026	.237	
	21	80	1.23		4.072	.214	
	26	64	1.00		4.154	.173	
	32.5	51	.81		4.224	.138	
5-3/8"	21	80	1.75	5.375	4.863	.256	15 jts.per bundle
	26	64	1.43		4.961	.207	
	32.5	51	1.15		5.045	.165	14 bundles per truck
5"	7	267	5.05	5.563	3.973	.795	
	9	200	4.08		4.327	.618	
	11	160	3.42		4.551	.506	
	13.5	128	2.84		4.739	.412	
	15.5	110	2.50		4.845	.359	
	17	100	2.29		4.909	.327	
	19	89	2.07		4.977	.293	
	21	80	1.88		5.033	.265	
	26	64	1.53		5.135	.214	
	32.5	51	1.23		5.221	.171	
6"	7	267	7.16	6.625	4.733	.946	13 jts.per bundle
	9	200	5.78		5.153	.736	
	11	160	4.84		5.421	.602	
	13.5	128	4.03		5.643	.491	14 bundles per truck
	15.5	110	3.54		5.771	.427	
	17	100	3.25		5.845	.390	
	19	89	2.93		5.927	.349	
	21	80	2.66		5.995	.315	
	26	64	2.17		6.115	.255	
	32.5	51	1.75		6.217	.204	
7"	7	267	8.29	7.125	5.089	1.018	11 jts.per bundle
	9	200	6.69		5.541	.792	
	11	160	5.61		5.829	.648	
	13.5	128	4.66		6.069	.528	12 bundles per truck
	15.5	110	4.10		6.205	.460	
	17	100	3.76		6.287	.419	
	19	89	3.39		6.375	.375	
	21	80	3.08		6.445	.340	
	26	64	2.51		6.577	.274	
	32.5	51	2.02		6.685	.220	

Size	SDR	PSI @73.4	Weight lbs.	Dimensions - inches: Nominal O D	Approx. I D	Min. Wall	Packaging
8"	7	267	12.14	8.625	6.161	1.232	9 jts.per bundle
	9	200	9.80		6.709	.958	
	11	160	8.21		7.057	.784	
	13.5	128	6.82		7.347	.639	10 bundles per truck
	15.5	110	6.00		7.513	.556	
	17	100	5.50		7.611	.507	
	19	89	4.96		7.717	.454	3600 ft. per truck
	21	80	4.52		7.803	.411	
	26	64	3.68		7.961	.332	
	32.5	51	2.97		8.095	.265	
10"	7	267	18.86	10.750	7.678	1.536	per truck
	9	200	15.23		8.362	1.194	
	11	160	12.75		8.796	.977	80 jts.per loose load
	13.5	128	10.59		9.158	.796	
	15.5	110	9.33		9.362	.694	
	17	100	8.55		9.486	.632	56 jts.per strip load
	19	89	7.71		9.618	.566	
	21	80	7.01		9.726	.512	
	26	64	5.71		9.924	.413	
	32.5	51	4.62		10.088	.331	
12"	7	267	26.53	12.750	9.108	1.821	per truck
	9	200	21.44		9.916	1.417	
	11	160	17.94		10.432	1.159	52 jts.per loose load
	13.5	128	14.89		10.862	.944	
	15.5	110	13.12		11.104	.823	
	17	100	12.03		11.250	.750	42 jts.per strip load
	19	89	10.84		11.408	.671	
	21	80	9.86		11.536	.607	
	26	64	8.04		11.770	.490	
	32.5	51	6.48		11.966	.392	
13"	7	267	29.24	13.386	9.562	1.912	per truck
	9	200	23.62		10.412	1.487	
	11	160	19.78		10.952	1.217	48 jts.per loose load
	13.5	128	16.43		11.402	.992	
	15.5	110	14.46		11.658	.864	
	17	100	13.26		11.812	.787	42 jts.per strip load
	19	89	11.96		11.976	.705	
	21	80	10.86		12.112	.637	
	26	64	8.87		12.356	.515	
	32.5	51	7.15		12.562	.412	
14"	7	267	31.99	14.000	10.000	2.000	per truck
	9	200	25.84		10.888	1.556	
	11	160	21.64		11.454	1.273	48 jts.per loose load
	13.5	128	17.97		11.926	1.037	
	15.5	110	15.81		12.194	.903	
	17	100	14.52		12.352	.824	30 jts.per strip load
	19	89	13.07		12.526	.737	
	21	80	11.90		12.666	.667	
	26	64	9.69		12.924	.538	
	32.5	51	7.83		13.138	.431	
16"	9	200	33.75	16.000	12.444	1.778	per truck
	11	160	28.27		13.090	1.455	
	13.5	128	23.46		13.630	1.185	35 jts.per loose load
	15.5	110	20.65		13.956	1.032	
	17	100	18.95		14.118	.941	
	19	89	17.07		14.316	.842	30 jts.per strip load
	21	80	15.53		14.476	.762	
	26	64	12.66		14.770	.615	
	32.5	51	10.21		15.016	.492	

revised

DRISCOPIPE
FIFE PIPE COMPANY
P.O. BOX 751
BRANDON, FL 33509
(813) 681-3765 OR BARTOW 533-9068
FAX (813) 684-1284

Dimensions & Pressure Ratings
1000 Series Pipe

5/5

Size	SDR	PSI @73.4	Weight lbs.	Dimensions - inches: Nominal O D	Approx. I D	Min. Wall	Packaging per truckload
18"	11	160	35.76	18.000	14.728	1.636	27 jts.per
	13.5	128	29.69		15.334	1.333	loose load
	15.5	110	26.14		15.678	1.161	
	17	100	23.99		15.882	1.059	20 jts.per
	19	89	21.60		16.106	0.947	strip load
	21	80	19.65		16.286	0.857	
	26	64	16.03		16.616	0.692	
	32.5	51	12.94		16.892	0.554	
20"	11	160	44.15	20.000	16.364	1.818	20 jts.per
	13.5	128	36.66		17.038	1.481	loose load
	15.5	110	32.27		17.420	1.290	
	17	100	29.60		17.648	1.176	16 jts.per
	19	89	26.68		17.894	1.053	strip load
	21	80	24.26		18.096	0.952	
	26	64	19.79		18.462	0.769	
	32.5	51	15.96		18.770	0.615	
21.5	11	160	51.04	21.500	17.590	1.955	18 jts.per
	13.5	128	42.38		18.314	1.593	loose load
	15.5	110	37.30		18.726	1.387	
	17	100	34.23		18.970	1.265	16 jts.per
	19	89	30.84		19.236	1.132	strip load
	21	80	28.05		19.452	1.024	
	26	64	22.88		19.846	0.827	
	32.5	51	18.46		20.176	0.662	
22"	11	160	53.43	22.000	18.000	2.000	16 jts.per
	13.5	128	44.38		18.740	1.630	loose load
	15.5	110	39.04		19.162	1.419	
	17	100	35.83		19.412	1.294	12 jts.per
	19	89	32.28		19.684	1.158	strip load
	21	80	29.37		19.904	1.048	
	26	64	23.95		20.308	0.846	
	32.5	51	19.32		20.646	0.677	
24"	11	160	63.59	24.000	19.636	2.182	16 jts.per
	13.5	128	52.81		20.444	1.778	loose load
	15.5	110	46.47		20.904	1.548	
	17	100	42.65		21.176	1.412	12 jts.per
	19	89	38.41		21.474	1.263	strip load
	21	80	34.95		21.714	1.143	
	26	64	28.50		22.154	0.923	
	32.5	51	22.98		22.524	0.738	
26"	11	160	74.63	26.000	21.272	2.364	12 jts.per
	13.5	128	61.97		22.148	1.926	loose load
	15.5	110	54.55		22.646	1.677	
	17	100	50.03		22.942	1.529	9 jts.per
	19	89	45.07		23.264	1.368	strip load
	21	80	41.01		23.524	1.238	
	26	64	33.45		24.000	1.000	
	32.5	51	26.98		24.400	0.800	
28"	11	160	86.55	28.000	22.910	2.545	10 jts.per
	13.5	128	71.86		23.852	2.074	loose load
	15.5	110	63.26		24.388	1.806	
	17	100	58.04		24.706	1.647	9 jts.per
	19	89	52.29		25.052	1.474	strip load
	21	80	47.55		25.334	1.333	
	26	64	38.80		25.846	1.077	
	32.5	51	31.31		26.276	0.862	

Size	SDR	PSI @73.4	Weight lbs.	Dimensions - inches: Nominal O D	Approx. I D	Min. Wall	Packaging per truckload
30"	11	160	99.34	30.000	24.546	2.727	9 jts.per
	13.5	128	82.50		25.556	2.222	loose load
	15.5	110	72.62		26.130	1.935	
	17	100	66.64		26.470	1.765	9 jts.per
	19	89	60.02		26.842	1.579	strip load
	21	80	54.61		27.142	1.429	
	26	64	44.54		27.692	1.154	
	32.5	51	35.92		28.154	0.923	
800 mm	13.5	128	90.93	31.496	26.830	2.333	9 jts.per
	15.5	110	80.04		27.432	2.032	loose load
	17	100	73.45		27.790	1.853	
	19	89	66.17		28.180	1.658	6 jts.per
	21	80	60.19		28.496	1.500	strip load
	26	64	49.07		29.074	1.211	
	32.5	51	39.59		29.558	0.969	
32"	13.5	128	93.85	32.000	27.260	2.370	9 jts.per
	15.5	110	82.64		27.870	2.065	loose load
	17	100	75.79		28.236	1.882	
	19	89	68.28		28.632	1.684	6 jts.per
	21	80	62.13		28.952	1.524	strip load
	26	64	50.68		29.538	1.231	
	32.5	51	40.89		30.030	0.985	
34"	13.5	128	105.98	34.000	28.962	2.519	6 jts.per
	15.5	110	93.29		29.612	2.194	loose load
	17	100	85.58		30.000	2.000	
	19	89	77.07		30.422	1.789	4 jts.per
	21	80	70.13		30.762	1.619	strip load
	26	64	57.22		31.384	1.308	
	32.5	51	46.14		31.908	1.046	
36"	13.5	128	118.81	36.000	30.666	2.667	6 jts.per
	15.5	110	104.57		31.354	2.323	loose load
	17	100	95.96		31.764	2.118	
	19	89	86.44		32.210	1.895	4 jts.per
	21	80	78.61		32.572	1.714	strip load
	26	64	64.15		33.230	1.385	
	32.5	51	51.74		33.784	1.108	
1000 mm	17	100	114.75	39.370	34.738	2.316	4 jts.per
	19	89	103.36		35.226	2.072	loose load
	21	80	94.04		35.620	1.875	
	26	64	76.69		36.342	1.514	4 jts.per
	32.5	51	61.85		36.948	1.211	strip load
42"	17	100	130.61	42.000	37.058	2.471	same as
	19	89	117.66		37.578	2.211	1000 mm
	21	80	107.01		38.000	2.000	
	26	64	87.27		38.770	1.615	
	32.5	51	70.39		39.416	1.292	
1200 mm	17	100	165.23	47.244	41.686	2.779	same as
	19	89	148.87		42.270	2.487	1000 mm
	21	80	135.42		42.744	2.250	
48"	26	64	110.45		43.610	1.817	
	32.5	51	89.11		44.336	1.454	
54"	26	64	144.30	54.000	49.846	2.077	same as
	32.5	51	116.42		50.676	1.662	1000 mm

TOTAL WALL THICK OF 48 AND 54 = 4.327
SDR = 54/4.327 = 12.5

Approximate ID = Nominal OD -- (2 times Min.Wall)

SDR (Standard Dimension Ratio) = $\frac{OD}{\text{min. wall}}$

Pressure rating = $\frac{2\,s}{SDR-1}$ @ 73.4 deg. F

s = hydrostatic design stress (800 psi)

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Ernest T. Selig

SOIL PROPERTIES FOR PLASTIC PIPE INSTALLATIONS

REFERENCE: Selig, E. T., "Soil Properties for Plastic Pipe Installations," Buried Plastic Pipe Technology, ASTM STP 1093, George S. Buczala and Michael J. Cassady, Eds., American Society for Testing and Materials, Philadelphia, 1990.

ABSTRACT: Soil property requirements for the basic trench and embankment installation conditions are discussed. Characteristics of compacted soils are described and representative stress-strain parameters given. Preliminary values of existing ground stiffness properties are suggested. The applications of these properties for analyzing pipe deflection, wall thrust and buckling strength are indicated.

KEYWORDS: soil properties, stress-strain behavior, strength, compaction, flexible pipe, plastic pipe, Young's modulus, Poisson's ratio, bulk modulus, constrained modulus, deflection, buckling, wall thrust.

INTRODUCTION

The installed shape of a buried plastic (flexible) pipe is strongly influenced by the soil placement process and the resulting soil stiffness properties. The long-term pipe deflections are controlled by soil deformation subsequent to installation in addition to the time-dependent pipe response. This soil deformation results from soil consolidation, creep, moisture changes, and erosion, as well as from loading changes. Pipe buckling stability is highly dependent on the value of soil stiffness. The pipe wall stresses and strains induced by earth and live loading are dependent on the relative stiffness of the soil and pipe. The type of soil and level of compaction are the fundamental factors determining these characteristics for placed soils. The soil type, in situ state, and stress history are the corresponding factors determining the relevant characteristics for undisturbed ground. To help illustrate these principles the relationships between soil type, amount of compaction and compaction effort will be discussed and their influence on resulting soil properties will be shown. The role of these soil properties in analyzing plastic pipe deflection, wall thrust, and buckling stability will be indicated.

Dr. Ernest T. Selig is Professor of Civil Engineering at the University of Massachusetts, Amherst, MA 01003.

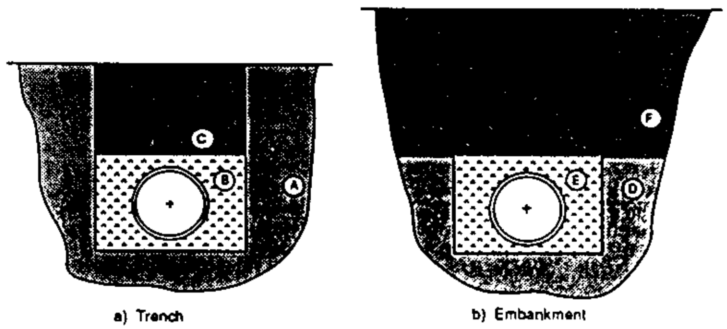

Fig. 1 -- Pipe installation type.

INSTALLATION TYPE

The two basic plastic pipe installation type are shown in Fig. 1. The trench case (Fig. 1a) represents a situation in which the existing ground (zone A) is excavated to the depth required for pipe installation. The resulting trench is backfilled with two zones of compacted soil. Zone B is the zone immediately surrounding the pipe which requires certain restrictions on the placement and compaction to avoid distressing the pipe, and restrictions on the type of soil to provide needed stiffness and stability. The remainder of the trench (zone C) is usually filled with the excavated soil appropriately placed and compacted. The specific trench dimensions as well as the dividing line between zones B and C depend on the requirements of the installation.

The embankment case (Fig. 1b) shows the pipe installed in a shallow trench excavated in the existing ground (zone D) and backfilled with zone E material meeting requirements similar to those of zone B. An earth embankment (zone F) is then constructed on top of the existing ground. This configuration is known as a negative projecting embankment pipe installation [1]. The pipe may also be installed above the existing ground, in which case zone E is laterally supported by embankment soil in zone F rather than by existing ground.

The soil property requirements for plastic pipe design are different in various ways for each zone in Fig. 1.

SOIL REQUIREMENTS

Existing Ground

In the case of existing ground in zone A the stress level remains essentially unchanged by the pipe installation. The main requirement is stability of the trench walls and bottom during construction. This is provided as needed by bracing and dewatering. Unless the existing ground is unsuitable, as may be the case with peats and organic deposits, the existing soil properties are accepted and the design and construction are carried out considering these properties. For analyzing the soil-pipe interaction, soil strength and stiffness during filling of the trench are the primary parameters required for zone A soil.

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The requirements are different for existing ground in zone D because the stresses are significantly increased by construction of the embankment. It is necessary to insure that the ground is stable under the weight of the embankment and that excessive immediate and consolidation settlement will not occur. If the soil in zone D is not saturated then volumetric compression will occur under the embankment load. Whether or not the soil is saturated, shear strains will occur under the embankment load. Both of these characteristics result in immediate settlement. If the soil is saturated or becomes so because of compression under increased load, then consolidation will take place over a period of time after construction as the excess pore water pressure is dissipated. Thus for zone D soil knowledge of the strength and consolidation characteristics is required as well as the nonlinear stress-strain properties during construction.

Soil Envelope

Zones B and E which immediately surround the pipe will be termed the soil envelope. This envelope includes the bedding, the side fill, and the top fill (Fig. 2). The haunch zone is included within the bedding and side fill as shown in Fig. 2. Zones B and E will be considered together because their required properties are essentially the same.

The stability of flexible plastic pipe is substantially controlled by the properties of the material in the soil envelope. The following are the requirements of this envelope:

1. Constructability - ability to be placed and compacted to the desired properties without distorting the pipe.

2. Provide the stiffness needed for limiting the pipe deformations (the particularly important areas are those shown by arrows A and B in Fig. 3a).

3. Provide the stiffness needed to achieve adequate pipe buckling strength.

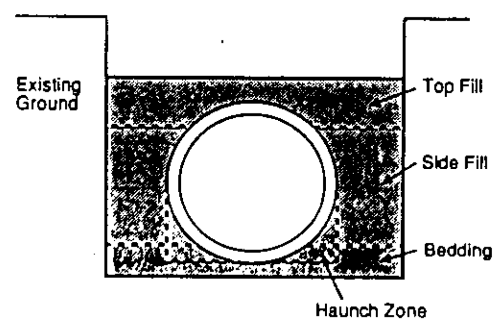

Fig. 2 -- Soil envelope.

4. Be stable under long-term moisture changes.

5. Exhibit little creep and consolidation deformation.

6. Provide drainage of excess pore water pressure.

7. Reduce the earth and live load carried by the pipe wall.

8. Prevent erosion or piping of surrounding fine soil as a result of pipe leaks or ground water movement.

These soil envelope requirements dictate the use of compacted coarse-grained soils (mainly sand and gravel components) in most cases. The material in the envelop thus may be referred to as structural backfill.

Trench Backfill

Zone C represents the trench backfill remaining above the structural backfill zone B. If a pavement or a structure requiring limited settlement is to be placed on the surface above the trench, then zone C soil must provide firm support (arrow C in Fig. 3a). Suitable material adequately compacted for zones B and C will be needed to prevent settlement as shown in Fig. 3b. The main mechanisms of settlement in zone C are: 1) volume reduction and shear strain from the surface load, particularly from repeated wheel loading, and 2) shrinkage from cycles of moisture change. These problems diminish with increased level of compaction, but even so soils whose behavior is controlled by fine-grained (silt and clay) components generally will not perform satisfactorily in this application. Thus coarse-grained soils (sand and gravel components) are most appropriate.

When surface settlement is not a concern, then zone C may be backfilled with the excavated soil using appropriate compaction. This is the most economical solution.

Embankment

In a negative projecting installation (Fig. 1b), the embankment, zone F, acts primarily as dead load. However some arching of the embankment load will occur which results in the pressure applied to

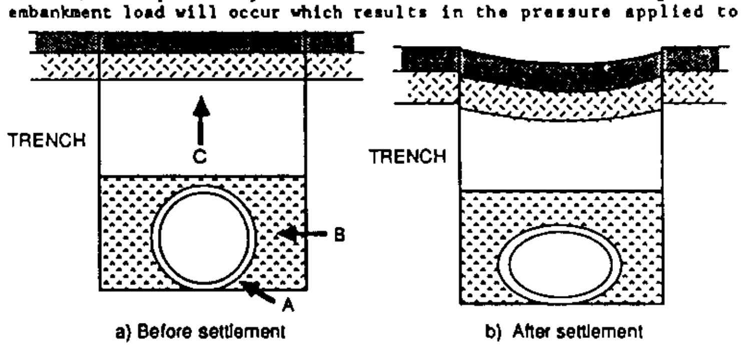

Fig. 3 -- Settlement with too little compaction.

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the top of zone E being either more or less than the average pressure at the base of the embankment. The unit weight of embankment fill is thus its most important property. Also important is the soil stiffness in the lower part of the embankment, i.e., within 3 trench widths of the top of zone E.

If the pipe were installed in either a positive projecting or imperfect trench condition [1], then the embankment stiffness properties would become much more important.

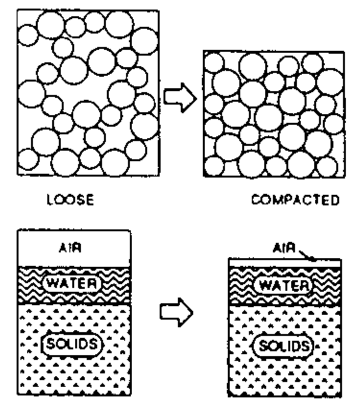

Fig. 4 -- Illustration of compaction.

CHARACTERISTICS OF COMPACTED SOILS

Compaction Reference Test

Compaction is immediate densification of soil by mechanical means. The water content remains constant and the void air space is reduced (Fig. 4). Consolidation, in contrast, is gradual squeezing out of water from saturated soils (no air in voids) which results in some densification.

Compaction is performed to achieve suitable properties of soil being placed. Increasing the amount of compaction increases strength, decreases compressibility, decreases permeability, reduces collapse potential, and reduces swelling and shrinking with moisture change. The magnitude of these effects depends on the soil type.

Standardized tests by ASTM and AASHTO are used to determine the amount of compaction that can be achieved for each soil with specified standard compaction efforts. For cohesionless, free-draining material (clean sands and gravels) the soil is vibrated vertically in a rigid mold with a surcharge weight placed on the soil surface (ASTM Test for Maximum Index Density of Soils Using a Vibratory Table D4253) as illustrated in Fig. 5a. The maximum density achieved is used as a reference for field compaction.

For other soils, compaction is achieved in a mold by a falling weight impacting the soil (Fig. 5b). The standardized impact tests are known as standard compaction effort (ASTM Test for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop D698; same as AASHTO T-99) or modified compaction effort (ASTM Test for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop D1557; same as AASHTO T-180). The modified test applies 4 to 5 times greater compaction effort to the soil than the standard test.

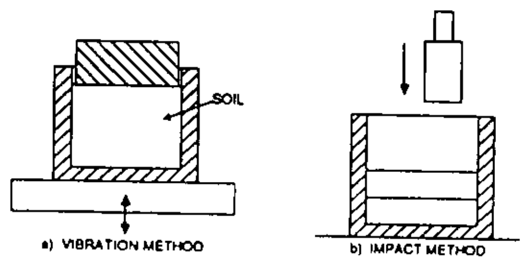

Fig. 5 -- Laboratory compaction test.

In the impact tests soil is compacted at different water contents with the same effort and the resulting compaction is represented by the calculated dry unit weight. The characteristic compaction curves for the two efforts are illustrated in Fig. 6. The moisture content corresponding to the maximum dry density (MDD) in each case is known as optimum moisture content because the soil is easiest to densify at this moisture content. Figure 6 shows that as the compaction effort increases the maximum dry density increases and the optimum moisture content decreases.

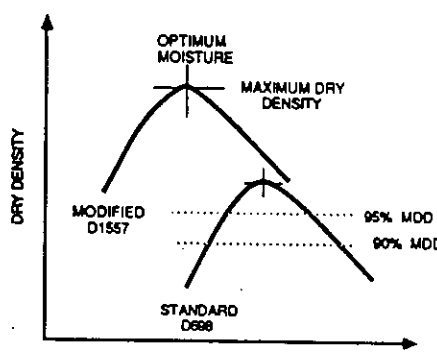

Fig. 6 -- Compaction test results.

Maximum density is not actually the highest that can be achieved for a given soil, but rather the maximum for a constant effort. Field compaction methods usually produce less than the maximum density in the standard test (ASTM D698). The density achieved in the field divided by the reference density and expressed as a percent is termed percent compaction. Values of 90 and 95% are shown in Fig. 6.

The characteristic curves shown in Fig. 6 apply to most soils. However the numerical values of the parameters vary with the soil type as illustrated in Fig. 7. Even within a given soil type the values of optimum moisture content and maximum dry density vary with changes in such characteristics particle gradation and plasticity. For this reason the ASTM compaction test needs to be repeated frequently during field construction to account for normal soil variability in order to be able to accurately check percent compaction.

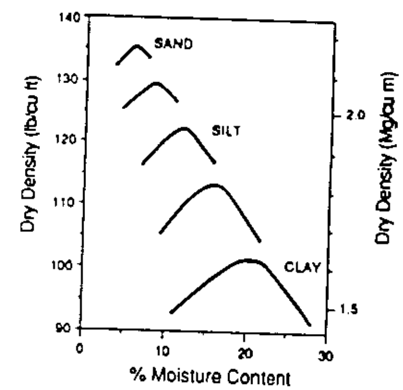

Fig. 7 -- Effect of type of soil on compaction.

<u>Compactability</u>

For the same effort, the percent compaction achieved varies significantly with the soil type (Fig. 8a). Granular soils are much easier to compact than silty soils, which are easier to compact than clayey soils. In this example the 100% effort represents the ASTM D698 test effort. This is calculated as the product of hammer weight times drop height times number of drops (impacts) divided by the volume of compacted soil, i.e., total hammer potential energy per unit volume of soil. For the D698 test this value is about 12000 ft-lb/cu ft (580 kN·m/m^3); for the D1557 test this value is about 56000 ft-lb/cu ft (2700 kN·m/m^3). To achieve the curves in Fig. 8a the standard test was repeated numerous times but with the number of hammer drops and height of drop reduced to provide a range of compactive efforts.

Figure 8a shows that considerably higher compaction effort is required to obtain a specified percent compaction for clay than for sand. What is not universally recognized is that even when the same

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percent compaction is achieved, the resulting stiffness and strength properties are not the same for all soils. This results in a dramatic difference in stiffness among soils when related to compaction effort as illustrated in Fig. 8b. Quantitative examples of these comparisons may be found in Refs. [2-4]. These characteristics are not generally considered in compaction specifications because the same percent compaction is commonly specified regardless of the backfill soil type.

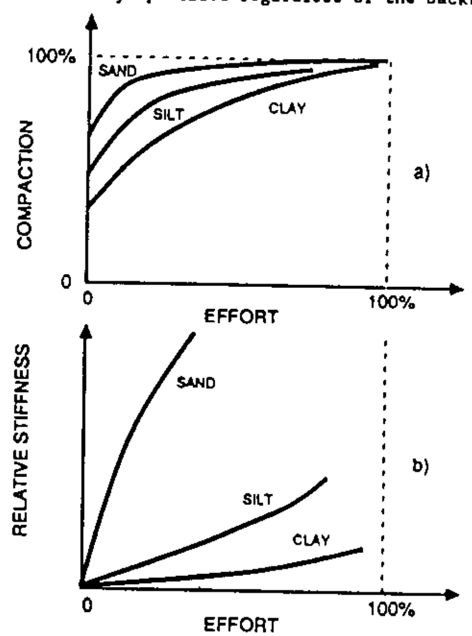

Fig. 8 -- Effect of soil type on variation of percent compaction and soil stiffness with compaction effort.

The relative compactability illustrated in Fig. 8 is very important in flexible pipe installation, because, for a given soil stiffness required to support the pipe, the less the required compaction effort the less the pipe distortion during placement of the soil envelope. This is one of the reasons for using coarse-grained soils for the envelope.

Changes After Compaction

When soils are subject to wetting and drying cycles after compaction, they will decrease in volume over time from the effects of the water. With increasing compaction the magnitude of this effect diminishes. The magnitude of volume change is much more significant for clays than for silts, and for silts it is much more significant than for sands.

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The strength and stiffness of any soil will be higher when compacted at water contents less than optimum, than at optimum, but clay soils will swell more if the water content should increase later. This will cause a reduction in strength and stiffness. Conversely strength and stiffness will be lower when compacted at water contents higher than optimum, but fine-grained soils, especially clays, will shrink more upon drying. Compaction of soils that are too wet should be avoided because low strength and stiffness will result.

When soils are placed loosely around buried pipe they are subject to substantial volume reduction if they should become saturated. This phenomenon, known as collapse, will result in pipe deflection after construction. The reason for this behavior is that loosely placed soils are unsaturated and develop their resistance to deformation from effective stress induced by capillary water tension. When these soils become saturated the capillary tension is lost, causing the soil particles to settle into a denser packing.

The collapse characteristic is illustrated in Fig. 9 from tests on a silty sand. To perform the test the soil first was lightly compacted at around optimum moisture content in an oedometer. For one test (dashed curve) the soil was loaded in steps and then unloaded with the moisture content remaining at around optimum. In the other test (solid curve) the sample was loaded at optimum moisture content to 3.5 psi (24 kPa) and then allowed to saturate. As water entered the sample a sudden large strain occurred under constant load. Further loading while saturated gradually produced additional strain as in the moist sample case.

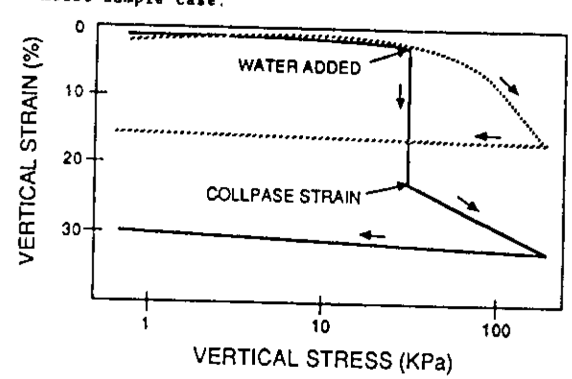

Fig. 9 -- Collapse of lightly compacted silty sand from soaking.

Tests on a variety of specimens showed that the magnitude of the collapse strain decreased as the amount of compaction increased, and diminished to an insignificant amount when the percent compaction reached about 85 to 90% D698 or about 85% D1557 maximum dry density.

Another cause of pipe deformation after construction is migration of fine soil particles from the trench walls into the soil envelope.

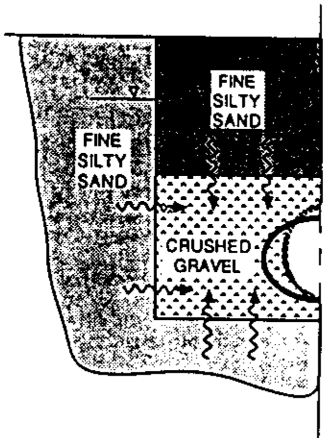

Fig. 10 -- Migration of fine soil into coarse soil envelope.

This occurs as a result of groundwater movement when the soil envelope gradation is much coarser than that of the existing ground. An example is given in Fig. 10. This problem should not occur if the traditional filter criteria [5] are used in selecting the soil envelope gradation or if a geotextile (filter fabric) is used to provide proper separation.

PROPERTIES OF COMPACTED SOILS

Finite element analysis has been shown to be a good approach for evaluating soil-pipe interaction. Duncan [6] has proposed the use of a hyperbolic model for representing the non-linear, stress-dependent soil behavior. Modifications to this model were proposed by Boscardin, Selig, Lin and Yang [3] and design parameters determined for a variety of soils and compaction levels from laboratory tests [2]. These parameters were modified for flexible pipe by Haggag [4]. The values were then extended to other soil type and compaction levels by the writer and incorporated into CANDE [7]. The values are given in Table 1. These parameters may be used to calculate tangent Young's modulus and bulk modulus as a function of stress state using the appropriate equations in the literature [2,3].

The linear-elastic model is a special case of the hyperbolic model in which the parameters are constant, independent of stress state. This is the simplest model for representing soil behavior in soil-pipe interaction analysis. Two independent elastic constants are needed. The choice is normally from among Young's modulus (E_s), bulk modulus (B), Poisson's ratio (ν_s), and shear modulus (G). Values of Young's modulus were estimated from the hyperbolic model for various values of maximum principal stress (σ_1) with the minimum principal stress (σ_3) equal to one-half to one times the maximum principal

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Table 1 -- Recommended hyperbolic parameters for compacted soils.

Tested Soil	Soil Type USCS	Soil Type AASHTO	% T-99	% T-180	Soil No.	Wet Density (lb/ft³)	Wet Density (Mg/m³)	K	n	R_f	c (psi)	c (kPa)	ϕ_o (deg)	$\Delta\phi$ (deg)	B_i/P_a	ϵ_u
Gravelly Sand (SW)	SW, SP, GW, GP	A1, A3	100	95	27	148	2.37	1300	0.90	0.65	0	0	54	15	272.0	0.007
			95	90	21	141	2.25	950	0.60	0.70	0	0	48	8	187.0	0.014
			90	85	1	134	2.14	640	0.43	0.75	0	0	42	4	102.0	0.036
			85	80	22	126	2.02	450	0.35	0.80	0	0	38	2	31.8	0.057
			80	75	2	119	1.90	320	0.35	0.83	0	0	36	1	15.3	0.078
			61	59	3	91	1.46	54	0.85	0.90	0	0	29	0	4.3	0.163
Sandy Silt (ML)	GM, SM, ML; Also GC, SC with < 20% passing #200 seive.	A2, A4	100	95	28	134	2.14	800	0.54	1.02	5.5	38	36	0	197.5	0.021
			95	90	23	127	2.03	440	0.40	0.95	4	28	34	0	120.8	0.043
			90	85	4	120	1.92	200	0.26	0.89	3.5	24	32	0	46.0	0.071
			85	80	24	114	1.82	110	0.25	0.85	3	21	30	0	23.8	0.100
			80	75	5	107	1.71	75	0.25	0.80	2.5	17	28	0	12.8	0.134
			49	46	6	66	1.06	16	0.95	0.55	0	0	23	0	3.3	0.305
Silty Clay (CL)	CL, MH, GC, SC	A5, A6	100	90	29	125	2.00	170	0.37	1.07	11	76	12	0	81.3	0.064
			95	85	25	119	1.90	120	0.45	1.00	9	62	15	4	53.0	0.092
			90	80	7	112	1.79	75	0.54	0.94	7	48	17	7	25.5	0.121
			85	75	26	106	1.69	50	0.60	0.90	6	41	18	8	13.0	0.149
			80	70	8	100	1.60	35	0.66	0.87	5	34	19	8.5	8.8	0.178
			45	40	9	56	0.90	16	0.95	0.75	0	0	23	11	1.8	0.391
	CH	A7	100	90	7	112	1.79	75	0.54	0.94	7	48	17	7	25.5	0.121
			95	85	26	106	1.69	50	0.60	0.90	6	41	18	8	13.0	0.149
			90	80	8	100	1.60	35	0.66	0.87	5	34	19	8.5	8.8	0.178
			45	40	9	56	0.89	16	0.95	0.75	0	0	23	11	1.8	0.391

stress. The hyperbolic parameters used were those in Table 1. Values of bulk modulus were estimated in the same manner. Then Poisson's ratio, ν_s, was derived from the relationship

$$\nu_s = 0.5\ (1 - \frac{E_s}{3B}) \quad .$$

The resulting parameter values are given in Table 2.

Table 2 -- Elastic soil parameters.

Soil Type: SW, SP, GW, GP

Stress level	95% D698			85% D698		
psi (kPa)	E_s	B	ν_s	E_s	B	ν_s
1 (7)	1600 (11)	2800 (19)	0.40	1300 (9)	900 (6)	0.26
5 (34)	4100 (28)	3300 (23)	0.29	2100 (14)	1200 (8)	0.21
10 (70)	6000 (41)	3900 (27)	0.24	2600 (18)	1400 (10)	0.19
20 (140)	8600 (59)	5300 (37)	0.23	3300 (23)	1800 (12)	0.19
40 (280)	13000 (90)	8700 (60)	0.25	4100 (28)	2500 (17)	0.23
60 (410)	16000 (110)	13000 (90)	0.29	4700 (32)	3500 (24)	0.28

Soil Type: GM, SM, ML, and GC, SC with < 20% fines

Stress level	95% D698			85% D698		
psi (kPa)	E_s	B	ν_s	E_s	B	ν_s
1 (7)	1800 (12)	1900 (13)	0.34	600 (4)	400 (3)	0.25
5 (34)	2500 (17)	2000 (14)	0.29	700 (5)	450 (3)	0.24
10 (70)	2900 (20)	2100 (14)	0.27	800 (6)	500 (3)	0.23
20 (140)	3200 (22)	2500 (17)	0.29	850 (6)	700 (5)	0.30
40 (280)	3700 (25)	3400 (23)	0.32	900 (6)	1200 (8)	0.38
60 (410)	4100 (28)	4500 (31)	0.35	1000 (7)	1800 (12)	0.41

Soil Type: CL, MH, GC, SC

Stress level	95% D698			85% D698		
psi (kPa)	E_s	B	ν_s	E_s	B	ν_s
1 (7)	400 (3)	800 (6)	0.42	100 (1)	100 (1)	0.33
5 (34)	800 (6)	900 (6)	0.35	250 (2)	200 (1)	0.29
10 (70)	1100 (8)	1000 (7)	0.32	400 (3)	300 (2)	0.28
20 (140)	1300 (9)	1100 (8)	0.30	600 (4)	400 (3)	0.25
40 (280)	1400 (10)	1600 (11)	0.35	700 (5)	800 (6)	0.35
60 (410)	1500 (10)	2100 (14)	0.38	800 (6)	1300 (9)	0.40

Note: Units of E_s and B are psi (MPa).

Deflections of buried flexible pipe are commonly calculated using the Iowa formula [1] which uses the modulus of soil reaction (E') as the parameter representing soil stiffness. Since E' is not a directly measureable soil parameter, but must be determined by back-calculation using observed pipe deflections, studies have been carried out to seek a correlation between E' and soil stiffness parameters such as Young's modulus (E_s) and constrained modulus (M_s), where E_s and M_s are related

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through Poisson's ratio (ν_s) by

$$M_s = \frac{E_s\ (1 - \nu_s)}{(1 + \nu_s)(1 - 2\nu_s)} \quad . \qquad (1)$$

These studies [8-10] and analysis by the writer indicate that for

$$E' = k\ M_s \quad , \qquad (2)$$

the value of k may vary from 0.7 to 2.3, with k = 1.5 as a representative value. For ν_s = 0.3, combining Eqs. 1 and 2 gives

$$E' = 2E_s \quad , \qquad (3)$$

although the factor k could easily be higher than a value of 2.

The E' values developed by Howard [11] based on back-calculation from field observations may be converted to E_s values for comparison with the values in Table 2 for σ_1 = 5 to 10 psi (34 to 69 kPa). The comparison is as follows for compaction levels of 85 to 95% D698:

	E_s (psi/MPa)	
Soil Type	Howard	Table 2
CL	200/1.4	250-1100/1.7-7.6
ML	500/3.5	700-2900/4.8-20
SW	1000/7	2100-6000/14-41

PROPERTIES OF EXISTING GROUND

A thorough review of the characteristics of existing ground is beyond the scope of this paper, and indeed encompasses most of the field of soil behavior. The complexity of soil behavior is part of the problem in defining the required soil properties for analysis. Equally critical is the spatial variability of natural soils combined with the practical necessity to estimate the properties from a very limited amount of sampling and testing.

Time-dependent stress-strain response, characterized by consolidation and creep, is often an important consideration for existing ground. However, the present state-of-the-art does not provide means for incorporating this response in pipe design except with very rough approximations.

A typical static-triaxial test stress-strain curve with unloading and reloading is illustrated in Fig. 11. This figure shows that unloading and reloading behavior is considerably more linear than the primary loading curve. This observation together with the recognized complexities of existing ground already discussed has resulted in approximating existing ground in zone A (Fig. 1) by constant modulus values representing linear elastic behavior. This approach is not as satisfactory for zone D (Fig. 1) because the stress-strain relationships may be very non-linear. If the embankment loading produces stresses well above those previously experienced by thenatural ground (considering stress history) then nonlinear modeling such as used for compacted soil may be desired.

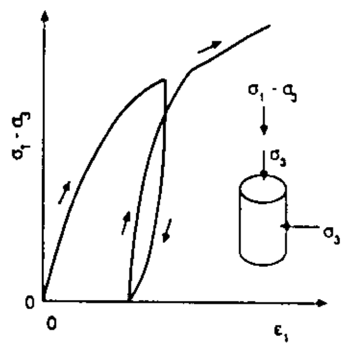

Fig. 11 -- Static triaxial test results: increase in axial strain with increase in axial stress.

The existing ground parameters proposed for concrete pipe design [12] are listed in Table 3. These are preliminary estimates which need considerable refining by more study.

Table 3 -- Existing ground properties.

Material	Wet density (pcf)	Wet density (Mg/m^3)	E_s (psi)	E_s (Mpa)	ν_s
1. Coarse-grained					
A. Dense	145	2.32	10000	69	0.49
B. Medium	130	2.08	6000	41	0.35
C. Loose	115	1.84	2000	14	0.20
2. Fine-grained					
A. Stiff	125	2.00	6000	41	0.3
B. Firm	118	1.89	3500	24	0.4
C. Soft	110	1.76	1000	7	0.49
3. Concrete	150	2.40	$3x10^6$	$21x10^3$	0.17
4. Rock					
A. Weak	145	2.32	$0.1x10^6$	700	0.2
B. Competent	160	2.56	$5x10^6$	$34x10^3$	0.3

APPLICATIONS OF SOIL PROPERTIES

There are three common calculations in pipe design using soil properties: 1) deflection, 2) wall thrust, and 3) buckling strength. Examples of each will be given to illustrate the use of soil properties.

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Deflection

The use of the Iowa formula to calculate pipe deflection has already been mentioned. The deflection given is the horizontal diameter change produced by earth load placed above the crown of the pipe. Deflection caused by placing the soil envelope around the pipe is not included in the Iowa formula. The earth load needs to consider arching action caused by the installation conditions, for example the difference between trench and embankment as shown in Fig. 1. The required soil parameter (really a soil-structure interaction parameter) is E'. Design values of E' may be estimated from the Howard table [11], or from experience with similar installations.

An alternative approach which uses the conventional soil properties E_s and ν_s is the elasticity solution by Burns and Richard [13]. As for the Iowa formula, the deflection is just for earth load above the crown, which also needs to be adjusted for arching because the solution is based on a pipe deeply buried in a homogeneous soil and subjected to uniform surface pressure. The Burns and Richard solution not only provides horizontal pipe deflection, but also pipe deflection, wall thrust, bending moment and radial pressure at any point on the circumference for both no-slip and frictionless conditions at the soil-pipe interface. Soil properties may be estimated by: 1) using values in Table 2, 2) conducting field or lab tests on representative soil, or 3) back calculation with the elasticity solution for similar installations. The Burns and Richard solution is available as part of the CANDE computer program [7,14].

In critical or unusual cases more precise deflection analysis may be performed using finite element methods such as in CANDE. The soil may be represented by properties in Tables 1 and 3, unless data are available from tests on the specific soils involved. In most installations at least two zones of soil surround the pipe such as shown in Fig. 1. Only the finite element method is capable of determining the composite effect of these separate zones from a knowledge of properties of the individual zones.

Wall Thrust

Wall thrust can be estimated by the Burns and Richard solution or by the finite element methods described for the deflection analysis. The Marston-Spangler method may also be applicable [1].

Buckling Strength

Buckling strength is an important consideration in the design of buried flexible pipe. Buckling strength is normally determined for plastic pipe using equations based on some form of elastic spring soil model (Fig. 12) such as derived by Luscher [15]. The soil properties represented by the spring constant suffer the same limitation as E' in that they can not be directly measured, although approximate correlations with M_s and E_s have been proposed. Empirical corrections for depth of cover have also been suggested.

The approach representing soil as an elastic continuum (Fig. 13) is recommended as more suitable because it gives a more realistic representation of the soil-pipe interaction, it used directly measureable soil parameters, E_s and ν_s, and it provides a means of accounting for such factors as pipe shape, shallow cover and nonhomogeneous soil conditions [16,17]. The solution is presented in the form of critical hoop (wall) thrust, N_c, which is compared with actual wall thrust to determine the factor of safety against buckling. The critical hoop thrust is given by

$$N_c = 0.55\, N_{ch}\, R_h \quad , \quad (4)$$

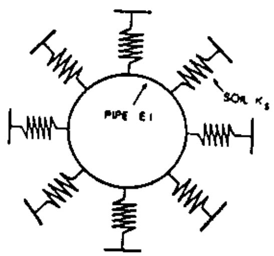

Fig. 12 -- Soil spring model for buckling.

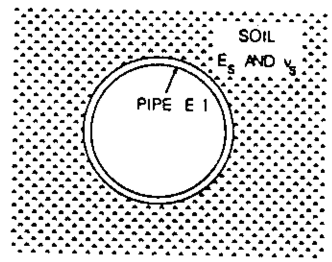

Fig. 13 -- Soil continuum model for buckling.

where R_h is a correction factor for shallow burial and nonhomogeneous soil (see examples in [4,17]), and N_{ch} is the critical thrust for a circular pipe deeply embedded in a homogeneous soil. For a smooth soil-pipe interface (conservative assumption) and for $EI/E_s^* < 0.01$, then

$$N_{ch} = 1.2\, (EI)^{1/3}\, (E_s^*)^{2/3} \quad , \quad (5)$$

where

- E = pipe Young's modulus,
- I = pipe wall moment of inertia,
- E_s^* = $E_s/(1 - \nu_s^2)$,
- E_s = soil Young's modulus,
- ν_s = soil Poisson's ratio.

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For deep burial in homogeneous soil then Eq. 4 becomes

$$N_c = 0.7\, (EI)^{1/3}\, [E_s/(1 - \nu_s^2)]^{2/3} \quad . \quad (6)$$

The soil properties, E_s and ν_s, may be estimated from Table 3.

SUMMARY

The main requirements for the different soil zones encountered in buried plastic pipe installations were discussed. Characteristics of compacted soils were described, including the relative ease of compaction and the changes after compaction. Representative values of stress-strain properties were provided for compacted soils and for existing ground. Applications of these properties in analysis of pipe deflections, wall thrust and buckling stability were described.

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A. P. Moser, O. K. Shupe, and R. R. Bishop

IS PVC PIPE STRAIN LIMITED AFTER ALL THESE YEARS?

REFERENCE: Moser, A. P., Shupe O. K., and Bishop, R.R., "Is PVC Pipe Strain Limited After All These Years," Buried Plastic Pipe Technology, ASTM STP 1093, George S. Buczala and Michael J. Cassady, Eds., American Society for Testing Materials, Philadelphia, 1990.

ABSTRACT: PVC (Polyvinyl chloride) sewer pipes have seen wide use in the United States and this has prompted concern for an appropriate material property design limit. It had been proposed that the imposition of a strain limit derived from long-term creep testing would also be appropriate for buried gravity flow pipes subjected to constant strain. Laboratory tests of pipe ring samples exposed to various strains and temperatures have been conducted for the past 13 years on filled and unfilled PVC compound formulations. Samples of pipe, from a test installation of buried pipe, have been excavated after 14 years and a post evaluation has been conducted. These test results are used to draw some conclusions concerning the applicability of a material strain limit for constant strain design conditions.

KEYWORDS: buried pipes, PVC (polyvinyl chloride) Pipes, stress-relaxation, strain, filled PVC

INTRODUCTION

The use of PVC (polyvinyl chloride) pipe as sewer pipe in the United States began in the early to mid 1960's as early manufacturers of PVC resin looked for potentially high volume applications for their resin. Throughout the sixty's, PVC pipe of various types were provided for gravity sewer applications. Formal Standards [ASTM D3033 "Type PSP Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings," and D3034 "Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings"] were adopted in 1972 launching a virtual explosion of PVC sewer pipe use. Today, 90 percent of all sewer pipes in sizes 4 - 15 inches used in the United States, are made of PVC. (Note: ASTM D3033 was dropped as a formal standard in 1989.)

The first issue of ASTM D3034 and D3033 contained material requirements for a single PVC cell class of 12454B as described in ASTM D1784 "Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC)." The second issue published in 1973 contained a 13364B cell class as a second option.

Dr. Moser is the Head of the Mechanical Engineering Department, and Dr. Shupe is Professor of Mechanical Engineering at Utah State University, Logan, Utah 84321-4130. Mr. Bishop is Director of Technical Services at Carlon, 25701 Science Park Drive, Beachwood, Ohio 44122.

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Technischer Ueberwachungs-Verein Bayern e.V., Februar 1979

DESIGN AND INSTALLATION OF UNDERGROUND PLASTIC SEWER PIPES

By Lars-Eric Janson[x], D.Sc. (Civ.Eng.), Professor, M.ASCE and Jan Molin[xx], D.Sc. (Civ.Eng.)

Abstract

More than 10 years'use and experience of underground plastic sewer pipes in Scandinavia is now available. The majority of existing pipelines are in good soils with non-cohesive material as surrounding fill around the pipe. Field measurements of the deflection of old existing pipelines have been performed and long-term measurements of the creep strength and modulus for HDPE and uPVC have been carried out.

However, the possibility of also using plastic pipes in loose soils such as clay and silt has recently been investigated and reported.

On the basis of these results, the paper gives recommendations on the use of different pipe classes and states the requirements for installation work.

1. Background of Nordic cooperation on plastic sewer pipes buried in the ground (NUVG 70)

Towards the end of the 1950's and during the 1960's, the use of thermoplastic pipes as pressure water pipes expanded widely in many European countries. Because of its low price and the comparatively well-developed jointing system used, uPVC won over cast iron and ducile cast iron pipes, especially in the case of diameters of up to 250 mm. Encouraged by the success of pressure pipes, several trials were launched in the mid-1960's for the introduction of sewer gravity pipes buried in the ground.

[x]Research director, Chief Engineer at VBB Consulting Group, P.O. Box 5038, S-10241 Stockholm, Sweden

[xx]Principal Engineer at VBB Consulting Group, Geijersg. 8, S-21618 Malmö, Sweden

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The difference in design principles seemed simple - pressure pipes are mainly subjected to inner hydraulic pressure, while sewer pipes are mainly subjected to external soil pressure. However, in order to find an economical wall thickness for sewer pipes, it was found necessary to make both theoretical and experimental studies to define the stability criterion for thinwalled (flexible) pipes subjected to soil pressure. ("Flexible pipes" are here defined as pipes with a wall thickness so thin compared to the diameter that they cannot withstand the surplus of vertical soil pressure alone, but must be supported by earth on the side of the pipe.)

The need for research and development as regards stability condition and long-term strength of sewer pipes was recognized quite early in the Nordic countries. In 1967, a first step was taken towards Nordic cooperation on this subject. At that time, some research work financed by manufacturers was being carried out in Finland on the subject of soil pressure on flexible pipes, (K-H.Korhonen and H. Jääskeläinen). At the same time, extensive theoretical and experimental studies were being made at Höganäs AB, Sweden, (J. Molin) of similar problems with regard to flexible pipes of glass fiber reinforced polyester (GRP), /1/.

2. Initiation of work in Nordic countries 1968

Research and developement cooperation was established between the plastic industry associations in Finland, Sweden, Norway and Denmark in 1968, in the form of the Nordic Committee for Buried Plastic Sewer Pipes. The aim of the Committee was to coordinate current research and to start new research and development projects on subjects connected with buried plastic pipes. For the technical evaluation of the various projects and their adaptation to a basis for standards and specifications, an independent Evaluation Group (NUVG 70) was appointed, consisting of official research experts working independently of the plastic manufacturers. The group consisted of two people from each of the four countries. The Author, Lars-Eric Janson, VBB Stockholm, was appointed chairman of the group. The task of this group was very clearly stated from the beginning: to produce a qualified basis for joint Nordic standards for plastic sewer pipes buried in the ground. Four seminars were held, at which research work was evalueated: Copenhagen 1968, Trondheim 1969, Helsinki 1970, and Stockholm 1972.

Two main problems, which both had to be solved, were identified at the earliest stages of the work; a) a soil mechanics and pipe stability problem, and b) a pipe material strength problem.

These two problems can easily be illustrated in the form of a diagram, see Fig. 1. In this diagram, the relative strain ϵ in the pipe wall is given as a function of the "stiffness" of the pipe expressed as s/D (wall thickness versus pipe diameter), using the relative pipe deflection δ/D as a parameter. The soil mechanics problem concerned the determination of this relation for various soils and various installation and refilling techniques used. The pipe material strength problem concerned the determination of the maximum relative strain ϵ_{max} in the pipe wall which could be allowed during long-term loading of the pipe subjected to bending stress under relaxation.

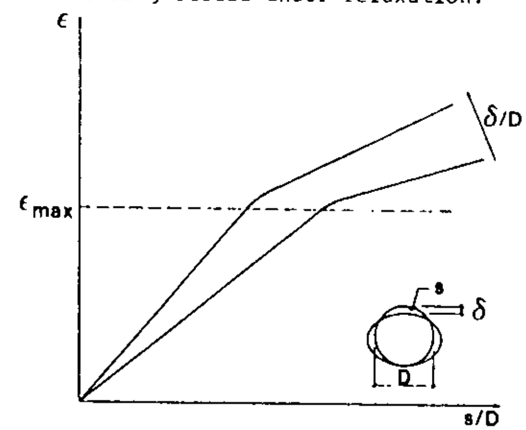

Fig 1

3. Basic standard proposed in the work of NUVG 70

The result of the work of NUVG 70 was that the soil mechanics problem could be solved but with the limitation that the refilled soil around the pipe had to be coarse-grained material such as sand and pea gravel, /2/, /3/. In the case of the material strength problem, the difficulties were somewhat greater, as long term tests with relaxing bending stresses were not available at that time. Consequently, the maximum allowable strains ϵ_{max}, were chosen conservatively, and were estimated mainly on the basis of studies of the literature at 0.5 % for uPVC, 1.5 % for HDPE, and 3 % for LDPE. The additional requirement was that the pipe material should have the same quality as valid for water pressure pipes according to available international standards, /4/.

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With these strain values as limiting factors, the largest allowable pipe deflection δ/D caused by earth load was determined by pipe material strength criteria and not by pipe stability criteria. Thus it was stated that the pipe deflection δ/D after completed trench refilling work should normally not exceed 5 % for all the three types of thermoplastic pipes. To this could be added a small deflection value corresponding to the normal ovalities of unloaded pipes.

Furthermore, the sewer pipes were divided into two stiffness classes, one for light loading conditions, Class L, and one for heavy loading conditions, inclusive of traffic load, Class T. The pipe stiffness expressed as s/D_m as a percentage (%) was

Class	uPVC	HDPE	LDPE
L	2	3	5
T	3	4	6

where

s = nominal wall thickness

D_m = D-s

D = nominal external diameter

In order to maintain a high standard for the pipes, an official Control Council for Plastic Pipes (the "KP-Council") was set up in 1970. Pipe manufacturers could, by applying to the KP-Council and after approved standard quality control, obtain a quality certificate for their pipes, which could then be marked with the registered KP-sign.

4. NUVG 80

4.1 Identified problems

In 1980 it was proposed that the experience of the use of buried plastic sewer pipes should be evaluated as a joint Nordic project, to be called NUVG 80. The purpose was to utilize the 10 years of practical experience gained in the Scandinavian countries concerning pipes buried in firm soils. During this period, additional investigations had also been performed, the purpose of which was to create standards for pipes buried in loose, silty and clayey soils.

Furthermore, knowledge within the pipe material strength field had increased significantly since deflected pipes had now been kept loaded for more than 10 years in accordance with a Finnish laboratory test programme

running since 1969, /5/, /6/. Simultaneously, greater knowledge had been gained concerning quality control methods particularly for HDPE pipes. These studies have opened the way to a better understanding of the design criteria for pipes subjected to constant strain and stress relaxation, and consequently a better understanding of the relation between pipe deflection and the long-term strength of a buried gravity pipe.

Thus, if the maximum allowable relative strain could be increased above what was accepted in the work of NUVG 70, the consequence would be that the allowable pipe deflection could be increased. This in turn should mean that the soil mechanics and the long-term pipe stability criteria would be of increased significance in the design of buried pipes.

The two main topics for the work of NUVG 80 were therefore the question of allowable strain in the plastic material and the question of feasible stiffness classes and installation regulations for gravity pipes buried in loose fine-grained soils. The studies concerned uPVC pipes and HDPE pipes as the two dominating thermoplastic materials.

Concerning stiffness classes, it was generally expressed as desirable to try to minimize the number of classes. Including pressure pipes for 10 atm. internal pressure, there are five classes today available for uPVC and HDPE, see Table 1.

uPVC:

Class	L	H	T	E	W
s/D_m (%)	2	2.5	3	4	5
D/s	51	41	34	26	21
Equivalent nominal pressure NP (atm)	4	5	6	10	10

HDPE:

Class	L	T	E_1	E_2	W
s/D_m (%)	3	4	6	8	10
Equivalent nominal pressure NP (atm)	3	4	6	10	10

Table 1

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For uPVC, Class M is the medium class used mostly in Germany and Holland, but not up to now in Scandinavia. Class N is the normal pressure pipe (NP 10) and E for uPVC and E_2 for HDPE are the pressure pipe classes, given as a result of an increase of the design stress from 10 to 12.5 MPa for uPVC and from 5 to 6.3 MPa for HDPE. For gravity pipes in loose fine-grained soils, there was obviously a need for a stiffer pipe than that corresponding to Class T. Consequently, it was desirable to investigate the possibility of using the E classes for that purpose. In Finland Class E, had been investigated as a gravity pipe class for loose soils.

4.2 Reports

The NUVG 80 Seminar was held in Denmark in 1980 with expert participants from Denmark, Finland, Norway and Sweden. The seminar was organized by the Swedish Plastics Federation and led by the Authors.

A great number of the reports concerned experience of the use of plastic gravity pipes in firm soils such as sand and gravel. Most of the measurements were focussed on the long-term deflection of the cross section of the pipe, see Table 2.

Test project	Test period	Years of observation	Pipe type, diameter and length	Pipe deflection /D % Mean	Max	Project responsibility
1. 3 places in Sweden	1973-1974	2	uPVC, T,200-315 1200 m	6	10	VAV, Sweden
2. Granholla Finland	1968-1978	10 10	uPVC, T, 315, 53 m uPVC, L, 315, 103 m	4 7	8 9	VTT, Finland VTT, Finland
3. St Michel Finland	1968-1978	10	HDPE, L, 400, 100 m	5	8	VTT, Finland
4. Botbyhöjden Finland	1969-1973	4	uPVC, L and T, 315 HDPE, L and T, 315	4	6	VTT, Finland
5. Oslo PRA 4.3 Furuset and Europaveien	1975-1979	4	uPVC, T, 200-400 uPVC, L and HDPE, L, 200, 620 m	4	8	Oslo, Norway
6. Copenhagen, Denmark	1971-1978	7	uPVC, T, 400, 240 m	4	8	Wavin, Holland

Table 2

The maximum deflection in a single point of a pipeline is normally below 10 % and the mean value is approximately 5 %. The local maximum deflections are mainly due to uneven pipe bed, as had already been indicated in NUVG 70, /2/. Therefore, the increase of such a deflection with time is insignificant. The extrapolation of the deflection to 50 years was discussed and it was stated that this final deflection should most probably not exceed 15 %.

On the basis of investigations of plastic sewer pipes subjected to constant strain caused by deflection /7/, it was found that the strain in the pipe material caused by deflections up to 20 % could not give rise to failure within a 50-year period and an average operation temperature of +20°C.

A Finnish report (VTT)/5/, /6/ on the change of the creep modulus in the course of a time period of 10 years for deflected uPVC and HDPE sewer pipes was presented. An attempt to extrapolate the creep modulus to 50 years' loading time at normal deflection gave a modulus of 800 MPa for uPVC and 100 MPa for HDPE.

A special topic concerned gravity sewer pipes buried in silt and clay. A report on this forms the subject of a separate paper at this conference /7/ and will not be further discussed here. However, the practical results and recommendations are included below.

4.3 Results and recommendations of the work of NUVG 80

4.3.1 Sewer pipes in firm sandy soils

In the work of NUVG 70, it was recommended that the pipe deflection caused by earth load should be limited to 5 % for all types of thermoplastic gravity sewer pipes.

As an addendum, it was proposed that a single local exceeding of this deflection limit by up to 50 %, i.e. up to 7.5 % should not cause rejection. To this increased value should be added the normal ovality of the various pipe material, corresponding to 1 % for uPVC, 2 % for HDPE and 3 % for LDPE.

The 10 years of experience have verified the feasibility of this proposal. Thus it was recommended that the following deflections immediately after refilling of the trench should be allowed: for uPVC 8 %, for HDPE 9 % and for LDPE 10 %.

With these initial deflections, the final deflection after 50 years will most probably not exceed 15 % as a maximum. The increase of deflection in the course of time

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can normally be expected to occur linearly by the logarithm of time. No pipe material failure will occur during the 50-year period, provided that the material quality requirements set up for standardized plastic pressure pipes are fullfilled.

The experience from the use of the stiffness classes L and T was reported as satisfactory. On the basis of experience, from Holland in particular, Class M had also been proved acceptable. Thus, it was concluded that Class M could be used instead of Class T in sandy soils with good compaction work, even in traffic areas. However, it should be noted that the experience does not include a systematic study of the watertightness of the pipe with time. Until such studies have been reported and evaluated care is recommended in the use in traffic areas of classes lighter than T.

Concerning the refill material around the pipe, experience shows that natural coarse-grained soil can normally be used, provided that stones are removed. Thus it was recommended that all sandy materials should be accepted with a limitation on the size of the stones corresponding to 10 % of the pipe diameter for pipes larger than 200 mm. However, stone size shall never exceed 50 mm.

4.3.2 Sewer pipes in silty and clayey soils

On the basis of investigations in fine-grained soil of sewer pipes of Classes M, T and E for uPVC and Class E_1 for HDPE, it was stated that plastic sewer pipes can be used under certain conditions. It was also concluded that the previous limitation of the relative strain in the pipe wall could now be ignored. This makes it possible to use thicker pipe walls than previously without requiring a lower deflection of the pipe (cf. Fig. 1).

Thus the following conditions shall prevail for pipes in areas with light or normal traffic. The refill soil is expected to be silt or clay excavated from the trench. The pipe shall be laid on an even trench bottom. The same pipe deflection requirement shall be applied as for pipes in sandy soils.

	uPVC	HDPE
s/D_m (%)	4	8

With these stiffness classes, no treatment or compaction is necessary if the soil is loose clay and the fill height is less than 4 m. If the clay is hard and firm, compaction of the refilled material is necessary for fill heights between 2.5 and 4 m. (In the case of firm clay the pipes can be installed down to a fill height of 6 m,

provided the refill is of compacted sand.) If the refilled material is of loose clay or firm clay which is compacted, also in the case of fill heights of less than 2.5 m, the more thin-walled pipe, uPVC s/D_m = 3 % and HDPE s/D_m = 6 %, can be used.

In the case of heavy traffic areas, it is always recommended that sand be used as refill material, and compacted.

It was especially stressed that the performance of joints and fittings must secure a watertightness which does not change in the long run. Thus the laboratory acceptance test for watertightness must be designed to simulate the long-term behaviour of the pipe, joint and fitting.

5. Concluding remarks

The 10 years of experience of buried plastic pipes in Scandinavia, together with current research and development work, have contributed to greater understanding of the use and behaviour of plastic pipes in the ground. Sewer pipes can now also be used in silty and clayey soils. For sandy soils it is sufficient to utilize only one stiffness Class T. In the case of clayey soils, Class E shall be used, which also corresponds to the stiffness of a pressure pipe NP 10 atm, provided that the design stress is increased by 25 %. Consequently, this could open up a practical possibility of limiting the number of classes for the most frequently used plastic pipes to not more than two.

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STRAIN AS A DESIGN BASIS FOR PVC PIPES?

by

A. P. Moser*
(Member ASME)

ABSTRACT

The validity of the design basis which limits the maximum strain in the wall of PVC pipe to 0.5 percent was investigated. Pertinent literature was searched. No supportive evidence was found to justify setting a 0.5 percent strain as a design limit for the maximum strain in PVC sewer or drainage pipe.

Tests were initiated to determine if a lower bound strain exists for PVC beyond which PVC will eventually fail. Methods and procedures used to conduct these tests as well as results of tests are included in the report. Indications from the tests show that using such a lower bound strain limit theory in designing PVC sewer or drainage pipe will lead to greater design deflections than engineers will permit.

INTRODUCTION

The allowable strain for design has been suggested to be one-half the so-called ultimate strain. The ultimate strain is also referred to as the initial strain the pipe experiences at the time of installation which will produce failure after 50 years of service. For PVC this ultimate strain has been suggested to be 1.0 percent and the suggested allowable strain, for design is 0.5 percent (Chambers and Heger, 1975).

Strains due to bending of the pipe wall can be calculated from equation (1), which assumes the pipe deflects into an elliptical form. This equation should be used for deflections of 10 percent or less.

$$\epsilon = \pm\left(\frac{t}{D}\right)\left(\frac{3\Delta Y/D}{1-2\Delta Y/D}\right) \qquad (1)$$

ϵ = maximum strain in the pipe wall due to bending or flexure (can be assumed to occur at the crown or invert of the pipe)

t = pipe wall thickness

*Professor and Head Department of Mechanical Engineering, Utah State University, Logan, Utah

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PLASTIC GRAVITY SEWER PIPES SUBJECTED TO CONSTANT STRAIN BY DEFLECTION

By Lars-Eric Janson[x], D.Sc. (Civ. Eng.), Professor, M.ASCE

Abstract and Introduction

In 1968 Nordic cooperation was initiated among manufacturers of plastic piping. The aim was to work out joint Nordic standards for uPVC and HDPE gravity sewer pipes buried in the ground. The work was completed in 1972, resulting in recommendations for national draft standards /1/.

One of the research programmes within the total work concerned the permissible constant strain in the pipe material as a consequence of the deflection of the pipe cross section in the ground. A vast study on this subject was performed at the Technical Research Centre of Finland, where pipe samples were kept constantly deflected at +23°C in air and also in water containing 2 % detergents. The deflection of the pipe was achieved by two linear loads acting against each other in a diameter plane. The samples have now been kept continuously deflected for about 10 years. They were released in July 1979 and have then been examined by VBB with regard to pipe material quality. The result of the investigation shows that the design criterion is not the strain caused by pipe deflection but the limitation of the deflection for preventing instability and buckling of the pipe.

1. Basic data

In the Finnish investigation, 18 HDPE pipe samples and 16 uPVC samples were studied. In the following, the HDPE samples are referred to as Nos 1-18, /2/ and /3/. From these series, 8 samples were taken out for quality control, numbered 1, 5, 6, 11, 13, 16, 17 and 18. Of the total number of 18 samples, 3 had failed, Nos 5, 15 and 18. Sample No 15 was missed and could not be examined. In Appendix 1 the basic data for the HDPE pipe samples are given.

[x]Research Director, Chief Engineer at VBB Consulting Group, P.O. Box 5038, S-102 41 Stockholm, Sweden

The maximum strain ϵ in the pipe has been calculated according to eq. (1),

$$\epsilon = 4.28 \cdot \left(\frac{s}{D_m}\right) \cdot \left(\frac{\delta}{D_m}\right) \qquad (1)$$

where s = wall thickness
δ = maximum decrease of the diameter
D_m = mean pipe diameter = D-s
D = external pipe diameter

The eq. (1) is not valid for thick-walled pipes and certainly not for deflections exceeding 10 %. In spite of this fact, the formula has been used even for the extensively deflected samples up to about 50 % just to gain a rough idea about the extremely high strain conditions arising. As can be seen in Appendix 1, all samples were still able to recover after release of the load. Three months after load release, the deflection was checked once more and found to have decreased further to approximately half of the value measured after three days.

2. Material quality tests of HPDE pipes

2.1 Sampling

All quality tests were performed in accordance with methods described in /4/ and verified in /5/. The pipe samples were cut in 8 specimens located as shown in Appendix 2. All samples from each pressure class were taken from the same pipe manufacturing. The resin was a common high density type with a MI_5 value of less than 0.5 g/10 min. Specimen No 1 was always chosen along one and the same line, which was recognized from the extrusion as giving axial scratches in the pipe of pressure class 4 and some similar shortcomings from the processing of the pressure class 6 pipe. This means that the scratches happened to coincide with the area having maximum strain at the inside pipe surface in samples Nos 5 and 13 and in sample No 11. See further /2/ concerning the surface morphology.

The bars for testing the tensile strength have been taken out in the axial direction of the pipe, see Appendix 2, positions A, B, C and D.

Samples for MI_5 measurements have been taken from an approximately 0.5 mm thick layer on the inside of the pipe wall (position A) and from a 3 mm thick layer behind this surface layer (position B). Samples from the outside of the pipe wall were approximately 1 mm thick, (position D).

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The density profile in the pipe wall was determined by taking out samples with thickness and position as shown in Appendix 2.

2.2 Melt Index MI5

The melt index was measured with a weight of 5 kg at a temperature of 190°C. The result is given in Appendix 3 for the various samples and specimens.

As can be seen from the results, the MI_5 values on the inside surface (position A) are everywhere lower than on the outside of the pipe (position D) and generally also lower than the values from position B. The samples from the pressure class 6 pipe have lower MI_5 than those from the pressure class 4 pipe. This is particularly the case in position A. An important observation is that all measurements of MI_5 in position A showed melting fracture, indicating a degradation of the very thin layer closest to the inside of the pipe wall.

In order to verify this observation, two specimens, one from the pressure class 4 pipe and one from the pressure class 6 pipe, were examined by IR analysis. It could be proved that both pipes had and oxidized inside surface, somewhat more pronounced for the thick-walled pipe than for the thin-walled. Both pipes had been exposed to air.

2.3 Density profile

The result of the measurement of the density distribution through the pipe wall is given in Appendix 4. As can be seen, the shape of the density profile shows a discontinuity on the inside of the pipe wall. Thus, a sudden increase of the density can be observed, more pronounced for the thin-walled pipe than for the thick-walled. The exposure to water containing 2 % detergent does not seem to have affected the result when compared with the samples exposed to air.

According to /5/, the measurements give support to the observations in Section 3.2 to the effect that the inside part of the pipe wall is oxidized.

2.4 Tensile Strength

The bars extended from the pipe wall in the axial direction of the pipe were subjected to a constant tensile stress of 5.4 ± 0.1 MPa. The bars were exposed to water at a temperature of + 80 ± 0.5°C. The time to failure was recorded. The test equipment is the same as that referred to in /4/ and /5/.

By extensive comparative studies, /5/, it has been found by experience that the time to failure for bars (position A) from an excellent pipe should exceed approximately 150 h. As can be seen in Appendix 3, this is the case only for sample No 11. Obviously the oxidation has given rise to a cross linking, which in this case favours the strength of the pipe. In all other cases, particularly for samples Nos 5, 6 and 13, the low tensile strength supports the observations of a degraded inside of the pipe wall.

For bars in position B, C and D, the strength is satisfactory. For all bars, the failures are of a brittle type with a strain at break of less than 20 %.

An interesting observation is that all bars from position A have become discoloured on the surface corresponding to the inside of the pipe wall. The coating is black, like carbon. No other bars have any such coating.

3. Discussion

The following observations can be noted from the investigation of the HPDE pipes.

In spite of a rather poor pipe material quality, identified as arising from an oxidized inside surface of the pipe, the failure-free loading time is very long for 15 of the total 18 samples. In particular, it seems unexpected that pipes with deflections up to 50 % should withstand a loading time of 10 years as in the case of sample No 6, in spite of a verified low tensile strength. It is true that one sample, No 5, of the same quality as No 6, already failed after 28,000 h (3 years), but in this case the early failure was most certainly due to the notch effect as a consequence of scratches coincident with the area of maximum strain. It seems highly probable that this situation was the case also for sample No 15 (not examined), which failed after 2,000 h in water containing 2 % detergent. At the same time it is interesting to state that no failure occurred during the 10 years of testing in sample No 13, which also had scratches in the area of maximum strain and was exposed to water containing detergent. The maximum strain was here 0.9 % and the deflection 4.7 %.

In the case of no scratches, sample No 17 exposed to water with detergent has withstood 10 years of a 9.2 % deflection, corresponding to a strain of 2.5 %. At a deflection of 20.2 %, corresponding to a strain of 5.5 %, sample No 18 exposed to water with detergent failed after 53,500 h (6 years). With air surrounding the pipe, sample No 11, which had about the same deflection and strain as sample No 18, did not fail within the 10 years of testing.

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Finally, it should again be stated that all the HDPE pipe samples are more of less oxidized and consequently have reduced long-term strength. The experience according to /5/ is that the pipes used in this study would not fulfil the internal hydraulic pressure tests according to current Nordic standards. In addition, scratches and similar shortcomings originating from the pipe manufacturing have most certainly given rise to local notch effects.

4. uPVC pipes

At the Technical Research Centre of Finland (VTT), pipes of uPVC were subjected to similar tests as those of HDPE. The maximum pipe deflection was in this case 25 %, corresponding to a relative strain in the pipe wall of 2.5 %. In one special case, a half cross section of a pipe was bent totally upside down, resulting in a pipe acting with the original inside surface exposed as an outside surface.

No deficiencies could be found in this case with regard to pipe material quality. Thus, all uPVC pipes tested were deemed to fulfil the long-term strength requirements stipulated in Nordic or international standards for uPVC pressure pipes, including the 1000 h-60°C-test.

None of the 16 pipe samples, which were stored both in water and in water with a content of 2 % detergent, showed any failures or cracks after a loading exposure time of more than 10 years.

5. Evaluation

Thus, in spite of very high forced strains up to 8 % for HDPE pipes and more than 2.5 % for uPVC, corresponding to a pipe deflection of up to 50 %, the pipes not damaged initially have withstood a loading time of 10 years without failure. It should then be noted that, as regards the HDPE pipes tested, these have in all cases been thermo-oxidized and consequently been extremely susceptible to brittle failure.

In Fig. 1 the result of the HDPE investigation has been plotted in a stress-time diagram. In this diagram, those curves have also been included which illustrate the stress relaxation procedure for material subjected to constant strain. From the diagram it can be seen that the actual strain values in the NUVG 70-80 studies approach the intersection between the constant strain-curves and the failure curve for pipes subjected to internal hydraulic pressure (constant stress and free creeping). Thus it seems to be possible to gain support for the hypothesis that a pipe which has initially been deflected to 50 %,

(corresponding to a relative strain of 8-10 %) and which is kept constantly deflected, reaches the failure stage after not less than 50 years.

This hypothesis can also be supported by the investigations of HDPE pipes with artificially expanded diameters, corresponding to contant tensile strains of 2, 5 and 15 %, performed by the German company Hoechst AG, which was also referred to in the NUVG 70 work. (In this case, the stress is not a bending stress but a straight tensile stress. The samples are stored in water during the test.) Since then, Hoechst have continued the investigations up to a loading time of totally 15 years. The final results of the investigation have been put at the disposal of NUVG 80 by Hoechst, accordinging to Fig. 2. If the curves valid for 5 % strain are extrapolated to a temperature of +20°C, it will be found that failure should occur after several hundred years. This point has been plotted in Fig. 1, where it matches rather well the failure hypothesis referred to above.

Further support can be provided if the stress-time diagram and the strain curves during stress ralaxation are studied as shown in Fig. 3 for +60°C and in Fig. 4 for +80°C. In Fig. 3, both Hoechst's failure points at +60°C and the values given in NUGV 70 by the Norwegian research institute Sintef have been plotted. The latter values refer to pipes deflected to a corresponding relative strain of 2.5 % and exposed to water with a detergent concentration of 2 %. Thus the values must be compared with the failure curve valid for pipes exposed to water containing detergents. It is then found that the actual points fall about one decade

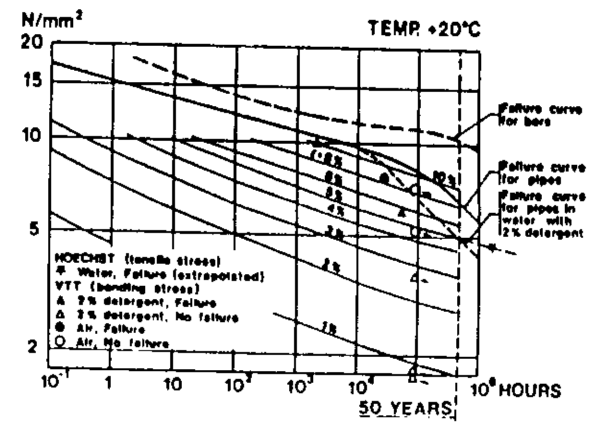

Fig 1

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to the right of the failure curve for pipes subjected to internal pressure. Similar indication is given by the failure points in water according to the Hoechst investigation. Neither is the hypothesis contradicted by Fig. 4, valid for +80°C. Thus, the Hoechst values are more than one decade to the right of the failure curve for pressure pipes. The same indication is given by the test performed by VBB on a pipe ring deflected to 50 %, corresponding to a relative strain of approximately 10 %.

The conclusion of these investigations should be that HDPE pipes of approved standard quality, deflected so that the relative strain in the pipe wall is 5 % and exposed to water containing detergents, has a life length of at least 50 years (cf. Fig. 1). With the calculation method used, such a strain value corresponds to a pipe deflection of approximately 20 %, acting from the date of installation. On the basis of these investigations, it seems reasonable to believe that a pipe deflection below 20 % has no practical significance for the lifetime of the HDPE pipe as far as the material strength is concerned. However, it can be expected that a pipe which already has from the beginning a deflection as great as 20 %, also has been installed so badly that there is an obvious risk of buckling failure in the long run. Thus, it is not the strain value which is the limiting factor for the lifetime of the pipe, but more likely the long-term stability criterion for the ring cross section or the water tightness criterion for the joints.

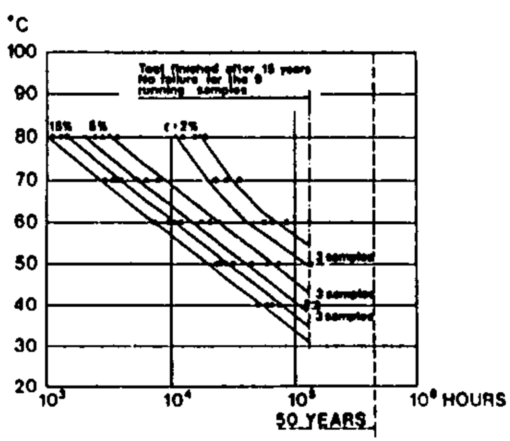

Fig 2

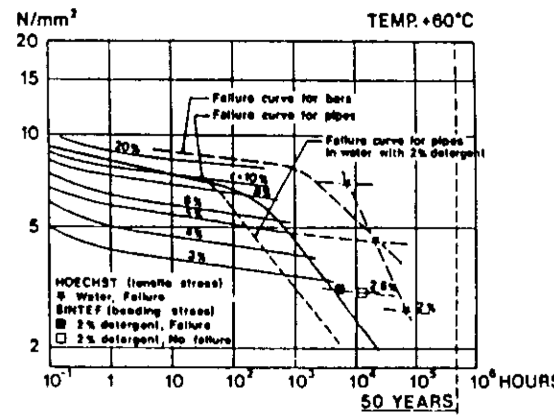

Fig 3

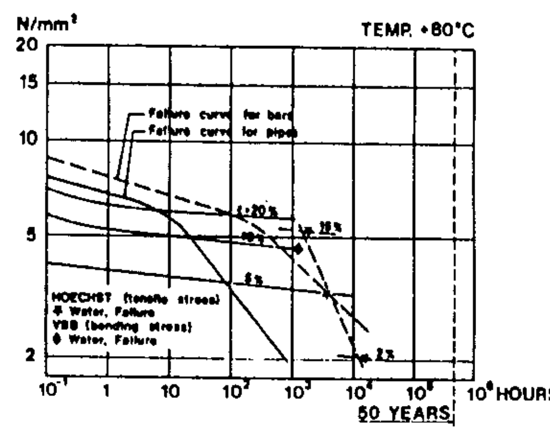

Fig 4

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The same conclusion can be drawn concerning uPVC pipes. Thus, the investigations indicate as they do for HDPE pipes, that the relative strain due to practically possible bending stresses in buried sewer pipes is not a design criterion. Consequently, there is no practical pipe deflection which cannot be accepted as far as material strength is concerned. As is the case for HDPE pipes, it is more a question of limiting uPVC pipe deflection with respect to the long-term pipe stability and the water-tightness of the joints.

6. Final conclusion

With all this as a background, nothing seems to contradict the hypothesis already indicated in /1/ to the effect that constant strain in HDPE and uPVC pipes as a result of even rather large pipe deflections should not give rise to failure, provided that the pipe material is perfect and the standards for normal pressure pipes are fulfilled. Thus, it is not the strain caused by the deflection which should be the design criterion, but the limitation of the deflection in order to prevent instability and buckling of the pipe.

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Appendix 1

Sample Nos	Nominal pressure class (atm)	External diameter D (mm)	Length (mm)	Wall thickness s (mm)	Mean pipe diameter D_m (mm)	s/D_m (%)	Deflection δ/D_m (%)	Calculated strain ε (%)	Environment surrounding the sample	Loading time (h)	Deflection 3 days after load release (%)
1	4	318.5	318.3	12.58	305.92	4.11	4.1	0.7	air	91 000	1.7
5	4	318.0	317.5	12.53	305.47	4.10	48.9	8.6	"	28 000 (failure)	(26.2)
6	4	318.0	314.3	12.56	305.44	4.11	47.2	8.3	"	91 000	18.3
11	6	316.0	318.0	18.83	297.17	6.34	17.4	4.7	"	91 000	7.3
13	4	317.5	317.0	12.87	304.63	4.22	4.7	0.9	water + detergent x)	87 000	1.2
15 (Not examined)	4	317.3	320.3	12.76	304.54	4.19	59.4	10.7	"	2 000 (failure)	-
16	6	316.8	317.8	18.90	297.90	6.34	2.8	0.8	"	87 000	0.4
17	6	316.0	312.0	19.03	296.97	6.41	9.2	2.5	"	87 000	1.4
18	6	316.0	316.5	19.02	296.98	6.40	20.2	5.5	"	53 500 (failure)	(9.8)

x) 2 % Hostapal W

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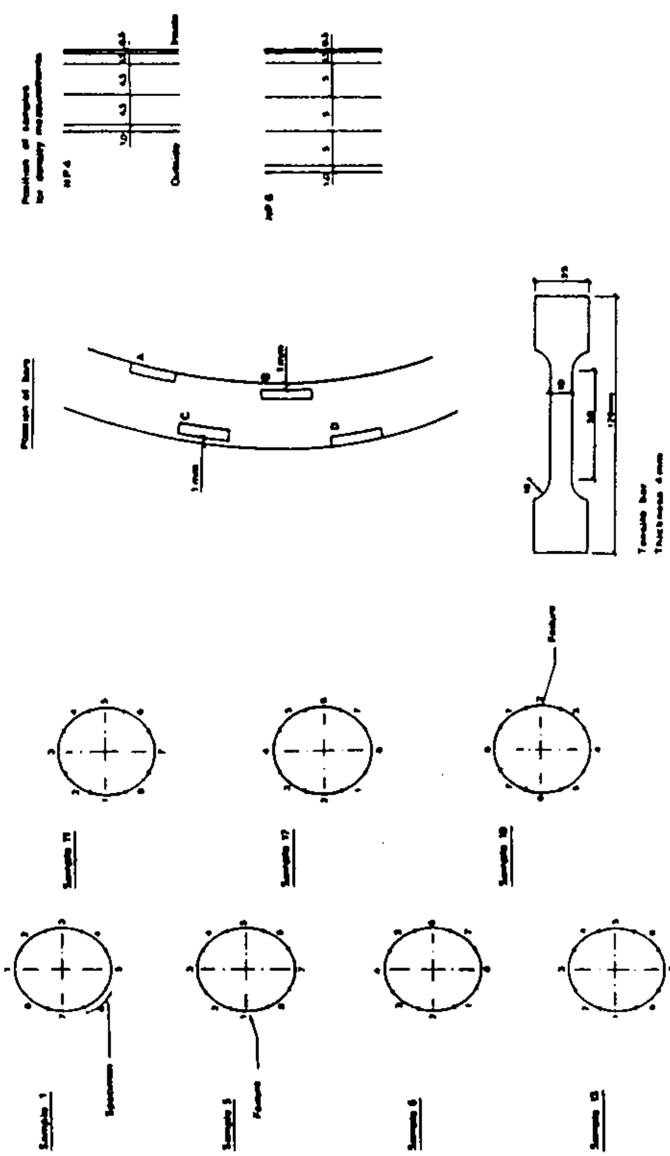
Appendix 2



Appendix 3

Sample	Specimen	MI_5 (5/10 min) Position A	B	D	Tensile bar testing Time to failure (h) Position A	B	C	D
1	1	0.30	0.30	0.44	117, 470			
	3	0.31			105, 146			
	5	0.24	0.31	0.46	44, 67			
	7	0.29				170, 252		
5	1		0.34					
	2				57, 80			
	3						134 107, 270	
	4					129, 135 273, 468		
	5	0.34	0.30	0.41	54, 63		205	
6	5	0.32	0.34	0.44	50, 58			
11	1	0.16	0.23	0.39				
	2	0.18			190, 434			
	3	0.16			169, <250 >169			
	4							
	5	0.16				133, 250	324, 367	447
	7	0.15				196	300, 420, 455	460
13	1	0.24	0.35	0.46	66, 120			
	3	0.28						
	5	0.27						
	7	0.31	0.29	0.42	30, 104			
17	1	0.14	0.28	0.39				
	2	0.14						
18	1	0.13	0.22	0.34	140, 161			171
	2	0.15			67, 104			207, 273
	6					179, 280, 306		340
	7					188	249, 305	
	5						188, 193	

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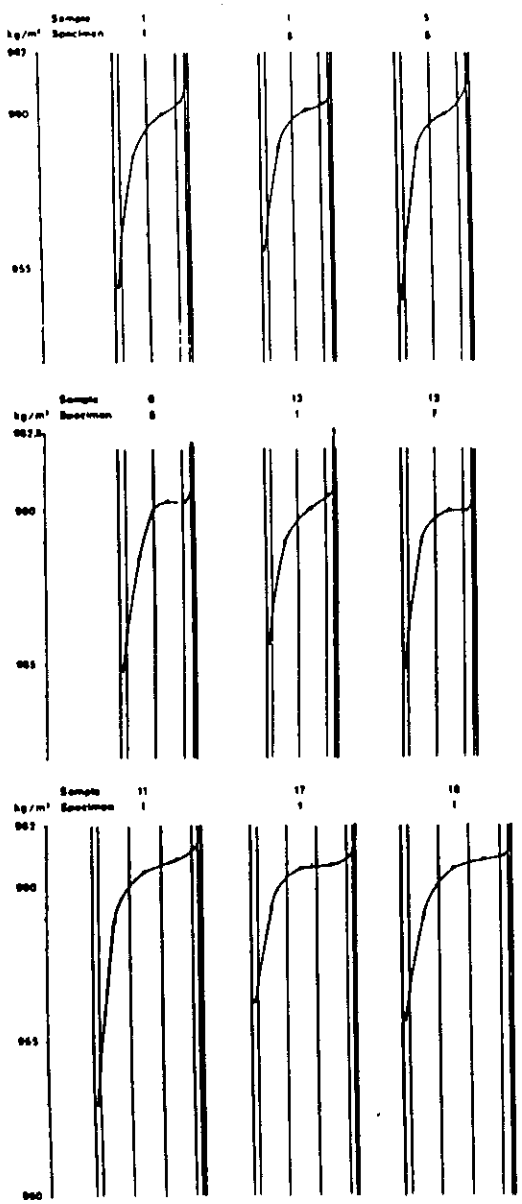
Appendix 4



THE RELATIONSHIP BETWEEN THE STIFFNESS OF A GRP PIPE AND ITS PERFORMANCE WHEN INSTALLED

C. Barrie Greatorex, C. Eng. M.I. Mech.E.

SYNOPSIS

The normal ring stiffness, EI/D_2^3 of GRP water and sewer pipes in the U.S.A. is approximately 1280 N/m^2. In Europe, however, a wide range of stiffnesses has been used and there has sometimes been a tendency to assume that a stiffer pipe is a better pipe. This paper shows that this is not necessarily correct.

The factors controlling the design of GRP pipes are discussed and charts showing safe burial depths as a function of pipe stiffness are presented. It is concluded that, although very stiff or very flexible pipes may be desirable in certain applications, they are generally inferior in performance to pipes of intermediate stiffness, and pipes having a stiffness of 1280 N/m^2 are close to the optimum for most applications.

1. DESIGN CONSIDERATIONS

It is relatively simple and inexpensive to adjust the stiffness of reinforced plastic mortar (RPM) pipes of the type made by Stanton and Staveley to meet particular service conditions (1). The optimum design of these pipes, as of all GRP pipes, is obtained by considering every possible failure mode and establishing suitable factors of safety against each. Factors to be considered are ring deflection, ring bending strain, pressure strain, combined strain, strain corrosion, ring compression strain, buckling and handlability.

Considering each of the above factors in turn, it can be seen that changing the pipe stiffness has the following effects:-

1.1 Pipe Deflection

This is normally limited to 5% reduction in vertical diameter. The deflection can be calculated with reasonable accuracy by the modified Spangler equation:-

$$\Delta = \frac{kx\ PD}{\frac{8EI}{D^3} + \frac{0.061\ E'_R}{D_{LR}}} \qquad (1)$$

Mr. Greatorex is currently employed as Specialist Engineer with Stanton and Staveley, British Steel Corporation, P.O. Box 72, Near Nottingham, England.

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OHIO TRANSPORTATION ENGINEERING CONFERENCE

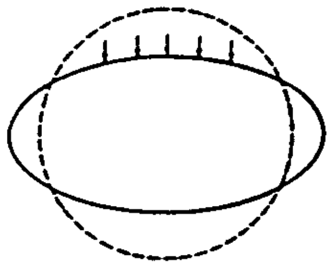
"PLASTIC PIPE DESIGN"

by

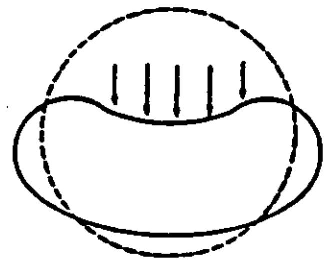
James B. Goddard

December 1-2, 1992

Deflection limits are set to avoid reversal of curvature, limit bending stress and strain, and avoid pipe flattening. Excessive deflection may reduce the flow capacity of the pipe and may cause joint leakage. Deflection of flexible pipe is primarily controlled by the method of installation and the backfill and insitu soil properties.

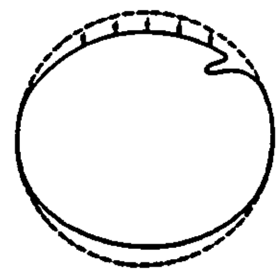


Ring deflection in a flexible pipe



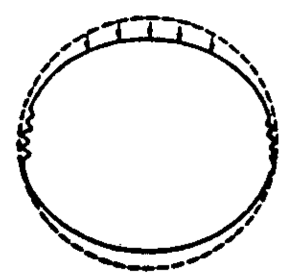
Reversal of curvature due to over-deflection

Wall buckling should be considered. Large diameter flexible pipe design may be governed by buckling, particularly when subjected to high soil pressures in low stiffness soils.



Localized wall buckling

Wall stress in compression can theoretically lead to wall crushing if excessive. If the ring compressive stress is greater than the compressive strength of the wall of the pipe, wall crushing may occur. The viscoelastic properties of thermoplastic material make this mode of failure very unlikely and field and lab tests tend to confirm that view.

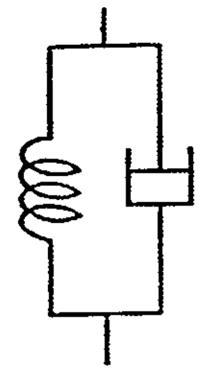


Wall crushing at the 3 and 9 o'clock positions

Pipe wall strain, generally in bending should be checked. Typically, these are outer wall fiber strains brought about by excessive deflection or localized deformations. Strain limits for thermoplastic pipe materials are generally assumed to be from 3.5 to 8% depending on wall design and resin used. Note that this is fiber strain, not deflection.

The equations to determine deflections, wall buckling, wall stress, and wall strain were developed primarily for evaluating flexible pipes manufactured from elastic materials and do not adequately reflect the effect of viscoelastic properties; in some cases treating a positive attribute as a negative. Again, using an analogy, the viscoelastic material is treated as a spring and dash pot (or shock absorber) connected in parallel with the spring handling sudden or short term loads and the dash pot responding to long term loads. The effect of this combined response is significant on the soil structure interaction system (Figure 1).

Figure 1



DESIGN PRACTICE

1. Deflection

Probably the most commonly used formula in plastic pipe design is Spangler's Iowa Deflection Formula. It, at least in some form, is referenced or utilized in the ASCE Plastic Design Manual; by Moser in his textbook, Buried Pipe Design; by Koerner in his textbook, Designing With Geosynthetics; by the Bureau of Reclamation; and by the Environmental Protection Agency. The most common form of the equation is:

$$\Delta x = D_L\,(kWr^3)/(EI + 0.061\,E'r^3) \qquad (1)$$

Where:
- Δx = Horizontal deflection of the pipe in inches
- D_L = Deflection lag factor (usually 1.5)
- k = Bedding constant
- W = Load per unit length of pipe in lbs/linear inch
- r = Pipe radius in inches
- E = Modulus of elasticity of pipe material in lbs/in2
- I = Moment of inertia of the pipe wall in in4/in
- E' = Modulus of soil reactions in lbs/in2

Developed by Dr. Merlin G. Spangler based on work begun in 1927 with rigid and flexible pipes, this built on previous work by Dr. Marston which predicted loads on culverts. The form above is the modified formula developed by Dr. Reynold Watkins based on his work in 1958.

It should be noted that this equation was developed largely from test installations with from 15 to 25 feet of cover.

A number of factors in the equation are contentious and deserve explanation:

A. The deflection lag factor (D_L) was included in the equation because Dr. Spangler believed that deflections could increase as much as 30% over a period of 40 years. He recommended a D_L of 1.5 to be conservative. We now know virtually all of the deflection occurs during the first year, therefore a D_L of 1.0 may be used.

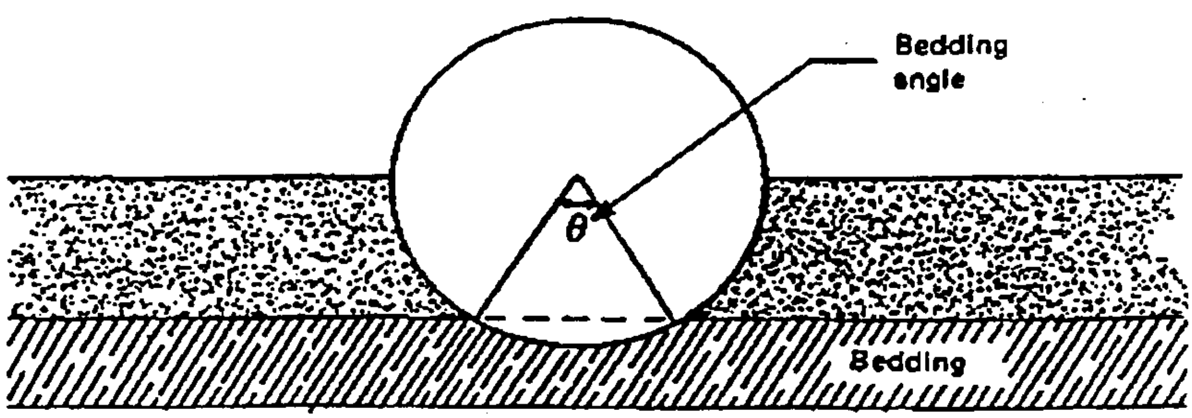
B. The bedding constant (k) is usually assumed to equal 0.1, although, as shown in Table 1, other values may be appropriate for specific installation conditions. A bedding angle (see Figure 2) of 0° would indicate a very firm foundation which would not be recommended for any pipe type.

Table 1

Values of Bedding Constant, K

Bedding angle, degrees	K
0	0.110
30	0.108
45	0.105
60	0.102
90	0.096
120	0.090
180	0.083

Figure 2



C. The load per unit length of pipe (W) is Marston's prism load, which assumes that the entire weight of the vertical prism of soil over the pipe is pressing down on the pipe. For very deep fills, this is probably very conservative in that it assumes no soil arching. This may be unconservative for very shallow cover.

D. The modulus of soil reaction E' has been studied extensively and continues to be a point of contention between rigid and flexible pipe manufacturers. Probably the most used values are those developed by Amster Howard of the U.S. Bureau of Reclamation and shown in Table 2. These values are based on field measurements of flexible pipe installations whose installation conditions were known and then back calculating to find the E' values.

Recent work by Dr. Mike Duncan at V.P.I. indicates that E' varies with depth. When looked upon as a confining pressure, this seems logical. Amster Howard's work limits his E' values to 50 foot or less. Richard Chamber's work published in 1980 showed that E' can be replaced by M_s (constrained soil modulus) in the Iowa Formula. M_s does vary with depth. Dr. Duncan's values are shown in Table 3. These values may be more appropriate than those shown in Table 2.

Values of E' have been given as high as 8,000 psi in very high fills.

Selection of the appropriate E' value is up to the design engineer who must make that decision based on experience and knowledge of the project conditions. Clearly, values less than 400 psi would indicate backfill conditions inappropriate for pipe installation.

RESEARCH

One way to verify design and installation procedures for any product is to compare research findings with predicted performance. Over the past ten years, there has been a substantial amount of research done by the plastic pipe industry or by users of plastic pipe to verify the existing design procedures or to improve upon them.

A considerable amount of research has been conducted at Utah State University by either Dr. Reynold Watkins or Dr. Al Moser. Much of Dr. Watkins work has involved the large soil cell at U.S.U. to attempt to simulate very large soil pressures on buried pipe. Depending on the specific test, different backfill material and installation practice have been used as well. Based on work done in 1982 (TRR 903) (Figures 8 and 9) and 1990 on corrugated polyethylene pipe, the measured deflections were 1/2 to 2/3 those predicted by the Modified Iowa Formula (1) (Figure 10). At the soil pressures in the test cells in both tests, the resultant wall thrust exceeded that predicted by the AASHTO equations (8 & 9) by a factor of 2 using short-term material values and by a factor of 10 using long term (50 year) material values. In these tests, however, no wall thrust failure occurred, so ultimate wall thrust loads must be greater than those in these tests. These tests also exceeded the predicted wall buckling pressures by approximately 50%. With deflections less than 5% in these tests, wall strain was about 1%, well under the strain limit for HDPE.

In 1987, under the direction of Dr. Ernest Selig, a 24" diameter corrugated polyethylene pipe was installed in a 100' highway fill under I-279 North of Pittsburgh, PA as a test of the pipe's performance under high soil pressures in a realistic installation. Pipe shape and circumference have been monitored along with soil pressure at crown and springline, free field soil strain, and trench strain (pipe & backfill). Under 100 feet of fill, this pipe has shortened vertically 4.3%, with 1.6% of that reflected in circumferential shortening. The actual deflection is therefore only 2.7%. The free field soil strain is 4.2%. Because of the combination of circumferential shortening and deflection, a soil arch has developed over the pipe in the fill reducing the vertical soil pressure at the crown to only 22% of the predicted (by Marsten) soil pressure. Total vertical shortening is 55% of that predicted by the Iowa Formula (1) as deflection. Actual deflection (out of roundness) is only 35% of that predicted by the Iowa Formula. This study demonstrates that the soil arching and the circumferential shortening, which are not taken into consideration in the traditional calculations add a considerable degree of conservatism to the predicted performance values. Using the AASHTO design calculations, this pipe should have failed in wall crushing at about one half of the actual fill height. Dr. Selig has shown that finite element analysis programs, specifically CANDE and SOILCON, can predict the kind of results found in this study.

In 1989, Dr. Lester Gabriel conducted a series of tests in a soil cell at California State University on 4", 6", 8", & 12" corrugated polyethylene pipe. The backfill was Class 1, Type A aggregate as defined by Caltrans. This material was dumped into place to model poor quality backfill placement. Deflections in this test were approximately 1/2 those predicted by the Iowa Formula (1), using an E' of 1,000 psi for dumped gravel.

Dr. Michael Katona has published two papers; one on minimum cover, one on maximum cover, on corrugated polyethylene pipe using finite element analysis (CANDE). The minimum cover analysis had excellent correlation with Dr. Watkins work discussed earlier. The maximum cover analysis, which based its input on the AASHTO design procedure, has been shown to be very conservative, based on Dr. Selig's work in Pennsylvania.

Dr. Shad Sargand has begun a research project for the Ohio D.O.T. evaluating the structural performance of a variety of plastic pipe products with varying wall profiles. This work, when completed, will add considerably to the research already completed. One goal is to determine the mode of failure for these products as well as the failure point. Ohio University has constructed a very large soil cell for these tests.

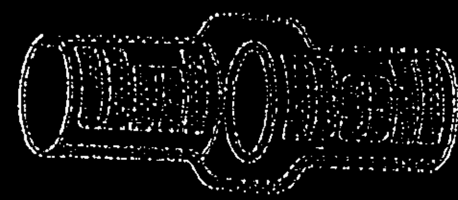
In one additional study of note, Mr. R.W. Culley of the Saskatchewan Department of Highways and Transportation conducted a test where 25,000 cycles of load were passed over a 600 mm (24 inch) diameter corrugated polyethylene pipe with no increase in deflection. Backfill was gravel compacted to 85 to 90% AASHTO T-99 density.

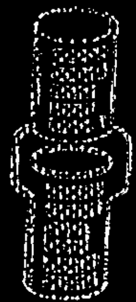
Research done by Dr. Al Moser (on PVC) and Dr. Lans-Eric Janson (on PE) has shown that the strain limits of 3.5 and 8% respectively for these materials are conservative and in typical installation should not be a failure mode.

Dr. Watkins and Dr. Janson both provide guidance on the use of short and long term modulus and tensile values in the design equations with Dr. Watkins stating that, "because stresses in the pipe relax, design should be based on quick modulus of elasticity and early strength - not 50 or 100 year strength under persistent stresses." Dr. Janson states that, "for each new short term change of deflection, whenever it comes up, the pipe material has a stiffness corresponding to the short term loading condition". Further, "it should be the short-term creep modulus which shall be used in determining the ring stiffness from a pipe classification point of view". The exception to this may be the Buckling Equation, particularly in poor soils.

INSTALLATIONS

The performance of plastic pipe in "real world" installations is the more telling proof of whether the design calculations and the research projects truly represent the type of results found in the field. With only a





HANDBOOK of PVC PIPE

Design and Construction

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CHAPTER VII

DESIGN OF BURIED PVC PIPE

A flexible pipe may be defined as a conduit that will deflect at least 2 percent without any sign of structural distress such as injurious cracking. Although this definition is arbitrary, it is widely used. For a conduit to behave as a flexible pipe when buried it is required that the pipe be more yielding than the embedment soil surrounding it. Some pipes that can deflect 2 percent or more without structural distress are not able to derive additional load carrying capacity from the surrounding soil because they are too stiff (*i.e.*, not flexible enough).

A flexible pipe derives its soil load carrying capacity from its flexibility. Under soil load, the pipe tends to deflect thereby developing passive soil support at the sides of the pipe. At the same time, the ring deflection relieves the pipe of the major portion of the vertical soil load which is then carried by the surrounding soil through the mechanism of an arching action over the pipe.

The effective strength of the pipe-soil system is remarkably high. For example, tests at Utah State University indicate that a rigid pipe with a three-edge bearing strength of 3300 lb/ft (48.15 kN/m) buried in Class C bedding will fail with a soil load of 5000 lb/ft (72.95 kN/m). However, under the identical soil conditions and loading, PVC sewer pipe with a minimum pipe stiffness of 46 psi deflects only 5%. This deflection is far below that which could cause damage to the PVC pipe wall. Thus, in this example, the rigid pipe has failed but the flexible pipe has performed successfully.

Of course, in flat plate or three-edge loading, the rigid pipe will support much more than the flexible pipe. This anomaly tends to mislead many would-be flexible pipe users because they relate low flat plate supporting strength for flexible pipe to the in-soil load capacity. Flat plate or three-edge loading is an appropriate measure of load bearing strength for rigid pipes but not for flexible pipes..

Pipe Stiffness. The inherent strength of flexible pipe is called pipe stiffness which is measured, according to ASTM D2412 Standard Test Method for External Loading Properties of Plastic Pipe by Parallel-Plate Loading, at an arbitrary datum of 5% deflection. See Figure 20 for typical pipe stiffness test results with PVC sewer pipe. Pipe stiffness is defined as:

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EQUATION 22

$$PS = F/\Delta y > \frac{EI}{0.149r^3} = \frac{6.71EI}{r^3} = \frac{6.71Et^3}{12r^3} = 0.559E(\frac{t}{r})^3$$

Where:
- PS = pipe stiffness, lbf/in/in. or psi
- F = force, lbs./Lin.
- Δy = vertical deflection, in.
- E = modulus of elasticity, psi
- I = moment of inertia of the wall cross-section per unit length of pipe, in^4/Lin. = in^3
- r = mean radius of pipe, in.
- t = wall thickness, in.

For PVC pipe with outside diameter controlled dimensions (rather than I.D.) this results in the equation:

EQUATION 23

$$PS = 4.47 \frac{E}{(DR - 1)^3}$$

Where: DR = Dimension ratio or SDR

The resulting PS values for various dimension ratios of PVC pipe are as shown in Table 27.

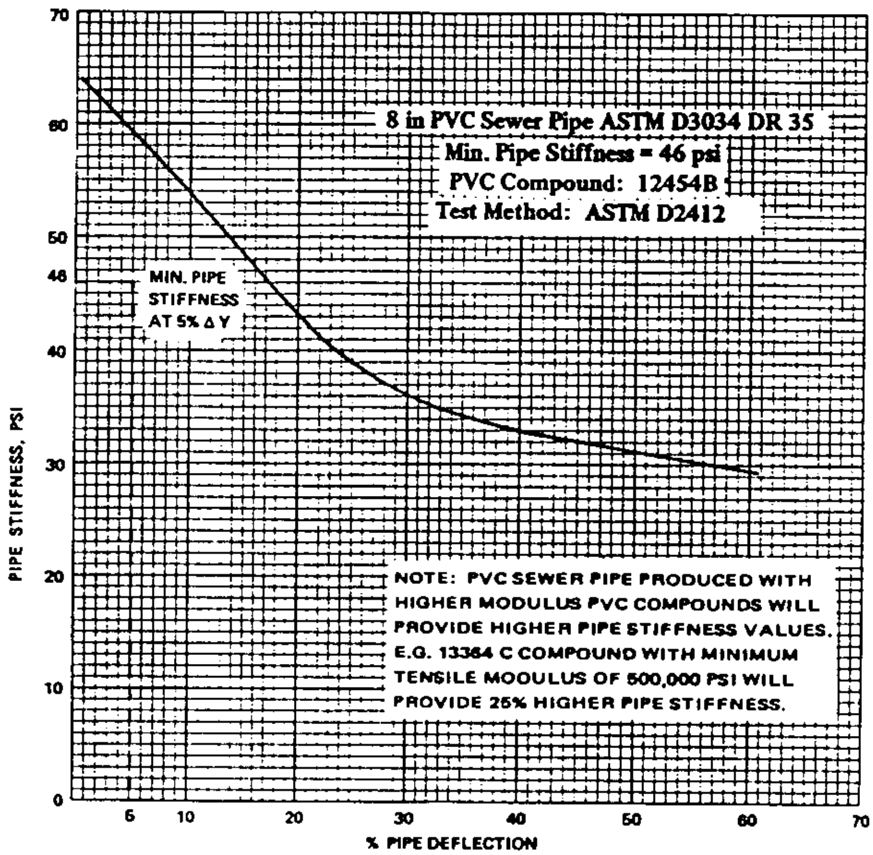
TABLE 27 – PVC PIPE STIFFNESSES (psi)

DR or SDR	Min. E = 400,000 psi	Min. E = 500,000 psi
42	26	32
41	28	35
35	46	57
33.5	52	65
32.5	57	71
28	91	114
26	115	144
25	129	161
21	234	292
18	364	455
17	437	546
14	815	1,019
13.5	916	1,145

5: 3/11

FIGURE 20

TYPICAL PIPE STIFFNESS TEST RESULTS
PIPE STIFFNESS VS. PERCENT DEFLECTION



Because a flexible conduit interacts with the surrounding soil in supporting the soil load, soil properties are very important. Just as bedding is important in limiting soil pressure concentrations on rigid pipes, soil compaction or soil density is an important parameter in limiting ring deflection in flexible pipes. Thus, soil and soil placement, as well as pipe properties, are important in the design of any buried pipe installation.

The manner in which flexible pipe performance differs from rigid pipe performance can be understood by visualizing pipe response to applied earth load. In a rigid pipe system, the applied earth load must be carried totally by the inherent strength of the unyielding, rigid pipe since the soil

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at the sides of the pipe tends to compress and deform away from the load. In a flexible pipe system, the applied earth load is in large measure carried by the earth at the sides of the pipe, since the flexible pipe deflects away from the load. That portion of the load carried by the flexible pipe, a vertical vector of force, is transferred principally through the deflection mechanism into approximately horizontal force vectors assumed by the compressed soil at the sides of the pipe. Through the deflection mechanism, the distribution of earth load is carried principally by the surrounding soil envelope and to a lesser extent by the flexible pipe. The strength provided by most buried flexible pipe is derived through the deflection mechanism from the combined strength provided by the pipe-soil system.

Spangler's Iowa Deflection Formula. M. G. Spangler, a student of Anson Marston, observed that a theory of loads on buried pipe was not adequate for flexible pipe design. Spangler noted that flexible pipes may provide little inherent strength in comparison to rigid pipes, yet when buried a significant ability to support vertical loads is derived from the passive pressures induced as the sides of the pipe move outward against the earth. This fact coupled with the idea that the ring deflection may also be a basis for flexible pipe design prompted M. G. Spangler to publish his Iowa Formula in 1941.

Spangler's first step was to define the ability of a flexible pipe to resist ring deflection when not buried in the soil.

Applying the elastic theory of flexure to thin rings for deflections studied which were in the range of less than about 10%, he established the following relationships:

EQUATION 24

$$\Delta Y = 0.149 \frac{Wr^3}{EI}$$

EQUATION 25

$$\Delta X = 0.136 \frac{Wr^3}{EI}$$

EQUATION 26

$$\Delta X = 0.913 \Delta Y$$

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Where: ΔY and ΔX = the vertical and horizontal deflections or diameter changes, in., which are derived mathematically for ovalization into the shape of an ellipse.

W = the load on the pipe per unit length, lb/in

E = modulus of elasticity of the pipe material, lb/in^2

I = moment of inertia of the wall cross-section per unit length, $in^4/Lin = in^3$

r = mean radius, in.

Spangler's next step was to incorporate the effects of the surrounding soil on the pipe's deflection. This was accomplished by assuming that Marston's theory of loads applied and that this load would be uniformly distributed at the plane at the top of the pipe. He also assumed a uniform pressure over part of the bottom, depending upon the bedding angle. On the sides, he assumed the horizontal pressure on each side would be proportional to the deflection of the pipe in the soil. The constant of proportionality was defined as shown in Figure 21 and was called the modulus of passive resistance of the soil. The modulus would presumably be a constant for a given soil and could be measured in a simple lab test. Through analysis he derived the Iowa Formula:

EQUATION 27

$$\Delta X = D_L \frac{KW_c r^3}{EI + 0.061er^4}$$

Where: D_L = deflection lag factor

K = bedding constant

W_c = Marston's load per unit length of pipe, lb/Lin.

r = mean radius of the pipe, in.

E = modulus of elasticity of the pipe material, psi

I = moment of inertia of the pipe wall per unit length, $in^4/Lin = in^3$

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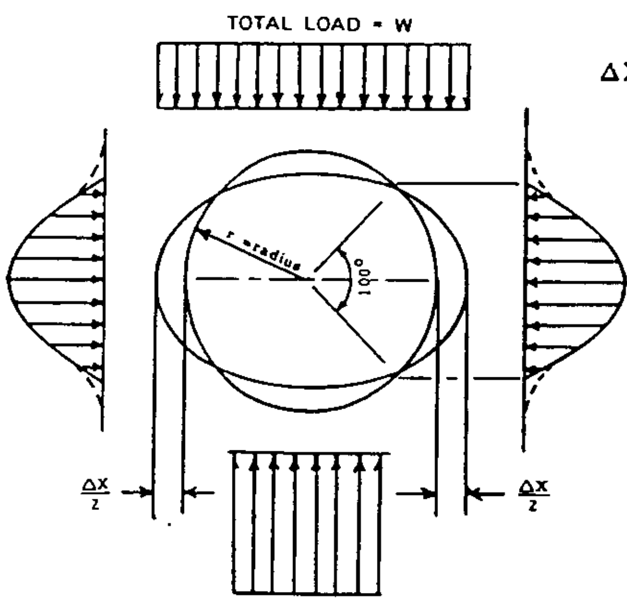
e = modulus of passive resistance of the side fill, $lb/in^2/in$.

ΔX = horizontal deflection or change in diameter, in.

Equation 27 can be used to predict deflections of buried pipe if the three empirical constants K, D_L, and e are known. The bedding constant, K, accommodates the response of the buried flexible pipe to the opposite and equal reaction to the load force derived from the bedding under the pipe. The bedding constant varies with the width and angle of the bedding achieved in the installation. The bedding angle is shown in Figure 22. Table 28 contains a list of bedding factors, K, dependent upon the bedding angle. These were determined theoretically by Spangler and published in 1941. As a general rule, a value of K = 0.1 is assumed.

FIGURE 21 – BASIS OF SPANGLER'S DERIVATION OF THE IOWA FORMULA FOR DEFLECTION OF BURIED PIPES



(EQUATION 27)

$$\Delta X = \frac{D_L K W_c r^3}{EI + 0.061 e r^4}$$

THE IOWA FORMULA

$e = 2h/\Delta X$

$2r = D$ = Pipe diameter

K = Bedding constant

D_L = Deflection lag factor

EI = Stiffness factor (related to pipe stiffness)

SOURCE: UTAH STATE UNIVERSITY

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FIGURE 22 – BEDDING ANGLE

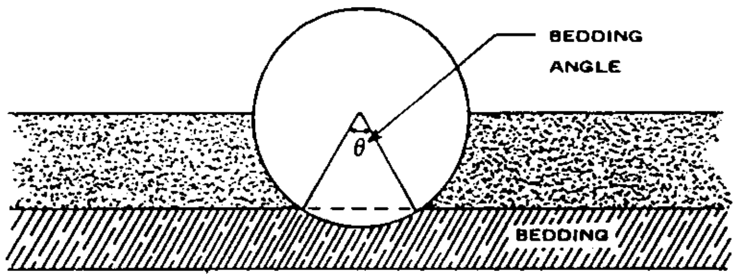

TABLE 28 – VALUES OF BEDDING CONSTANT, K

BEDDING ANGLE (DEGREES)	K
0	0.110
30	0.108
45	0.105
60	0.102
90	0.096
120	0.090
180	0.083

In 1955, Reynold K. Watkins, a graduate student of Spangler, was investigating the modulus of passive resistance through model studies and examined the Iowa Formula dimensionally. The analysis determined that e could not possibly be a true property of the soil in that its dimensions are not those of a true modulus. As a result of Watkins' effort, another soil parameter was defined. This was the modulus of soil reaction, E' = er. Consequently, a new formula called the Modified Iowa Formula was written:

EQUATION 28

$$\Delta X = D_L \frac{KW_c r^3}{EI + 0.061 E' r^3}$$

Two other observations from Watkins' work are of particular note. There is little point in evaluating E' by a model test and then using the modulus to predict ring deflection; the model gives ring deflection directly. Ring deflection may not be the only performance limit.

Many research efforts have attempted to measure E' without success. The most useful method has involved the measure of deflections for a pipe

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under which other conditions were known followed by back-calculation through the Modified Iowa Formula to determine the correct value of E'. This requires assumptions regarding the load, bedding factor and deflection lag factor to be used and has led to a variation in reported values of E'.

One of the most recent and thorough attempts to acquire information on values of E' was conducted by Amster K. Howard of the United States Bureau of Reclamation. Howard reviewed both laboratory and field data from many sources. Using information from over 100 laboratory and field tests, he compiled a table of average E' values for various soil types and densities (see Table 29). He was able to do this by assuming values of

TABLE 29 – AVERAGE VALUES OF MODULUS OF SOIL REACTION, E'
(For Initial Flexible Pipe Deflection)

Soil type-pipe bedding material (Unified Classification System[a]) (1)	E' for Degree of Compaction of Bedding, in pounds per square inch			
	Dumped (2)	Slight, <85% Proctor, <40% relative density (3)	Moderate, 85%–95% Proctor, 40%–70% relative density (4)	High, >95% Proctor, >70% relative density (5)
Fine-grained Soils (LL > 50)[b] Soils with medium to high plasticity CH, MH, CH-MH	No data available; consult a competent soils engineer; Otherwise use E' = 0			
Fine-grained Soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with less than 25% coarse-grained particles	50	200	400	1,000
Fine-grained Soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with more than 25% coarse-grained particles Coarse-grained Soils with Fines GM, GC, SM, SC[c] contains more than 12% fines	100	400	1,000	2,000
Coarse-grained Soils with Little or No Fines GW, GP, SW, SP[c] contains less than 12% fines	200	1,000	2,000	3,000
Crushed Rock	1,000	3,000	3,000	3,000
Accuracy in Terms of Percentage Deflection[d]	±2	±2	±1	±0.5

[a]ASTM Designation D-2487, USBR Designation E-3.

[b]LL = Liquid limit.

[c]Or any borderline soil beginning with one of these symbols (i.e., GM-GC, GC-SC).

[d]For ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Note: Values applicable only for fills less than 50 ft (15 m). Table does not include any safety factor. For use in predicting initial deflections only, appropriate Deflection Lag Factor must be applied for long-term deflections. If bedding falls on the borderline between two compaction categories, select lower E' value or average the two values. Percentage Proctor based on laboratory maximum dry density from test standards using about 12,500 ft-lb/cu ft (598,000 J/m³) (ASTM D-698, AASHO T-99, USBR Designation E-11). 1 psi = 6.9 kN/m².

SOURCE: "SOIL REACTION FOR BURIED FLEXIBLE PIPE" BY AMSTER K. HOWARD, U. S. BUREAU OF RECLAMATION, DENVER, COLORADO. REPRINTED WITH PERMISSION FROM AMERICAN SOCIETY OF CIVIL ENGINEERS JOURNAL OF GEOTECHNICAL ENGINEERING DIVISION, JANUARY 1977, PP. 33-43.

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E′, K and W_c and then using the Modified Iowa Formula to calculate a theoretical value of deflection. This theoretical deflection was then compared with actual measurements. By assuming the E′ values of Table 29, a bedding constant K = 0.1 and deflection lag factor D_L = 1.0, Howard was able to correlate the theoretical and empirical results to within ±2 percent deflection when he used the prism soil load. This means that if theoretical deflections using Table 29 were approximately 5%, measured deflection would range between 3 and 7%. Although the vast majority of data from this study was taken from tests on steel and reinforced plastic mortar pipe with diameters greater than 24 inches, it does provide some useful information to guide designers of all flexible pipe including PVC pipe since it helps to give an understanding of the Modified Iowa Deflection Formula.

The only parameter remaining in the Iowa Formula now needed to calculate deflections is the deflection lag factor D_L. Spangler recognized that in pipe-soil systems, as with all engineering systems involving soil, the soil consolidation at the sides of the pipe continues with time after the maximum load reaches the top of the pipe. His experience had shown that deflections could increase by as much as 30 percent over a period of 40 years. For this reason he recommended the incorporation of a deflection lag factor of 1.5 as a conservative design procedure.

Time lag will be discussed in much greater detail in another section of this chapter.

Under most soil conditions, flexible PVC pipe tends to deflect into a nearly elliptical shape and the horizontal and vertical deflections may be considered equal for small deflections (Δ). Since most PVC pipe is described by either pipe stiffness (F/ΔY) or outside diameter to thickness ratio (DR), the Modified Iowa Equation (28) can be transposed and rewritten as follows:

EQUATION 29

$$\% \frac{\Delta Y}{D} = \frac{D_L K P(100)}{0.149 \frac{F}{\Delta Y} + 0.061E'}$$

EQUATION 30

$$\% \frac{\Delta Y}{D} = \frac{D_L K P(100)}{[2E/3 (DR - 1)^3] + 0.061E'}$$

Where: P = Prism Load (soil pressure), psi

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The above equations may be used in conjunction with the values for the empirical constants E′, D_L and K. The following example illustrates their use.

Example: What will be the deflection of a DR 35 PVC pipe if buried on a flat bottom trench in a fine grained soil with unit weight of 120 lbs per ft^3 and with liquid limit less than 50% if the depth of burial is 10 feet?

From Table 29, E′ = 200 psi and incorporating a bedding constant, K = 0.1, and the prism load as assumed in the derivation of Table 30 along with a deflection lag factor of D_L = 1.0, the following results are derived:

$$P = wH \qquad \% \frac{\Delta Y}{D} = \frac{D_L KP\,(100)}{[2E/3(DR-1)^3] + 0.061E'}$$

$$P = 120\ \frac{lb}{ft^3} \times 10\ ft \times \frac{1\ ft^2}{144\ in^2} = 8.33\ psi$$

$$\frac{2E}{3(DR-1)^3} = \frac{2(400{,}000)}{3(35-1)^3} = 6.78\ psi$$

$$\% \frac{\Delta Y}{D} = \frac{1.0(0.1)(8.33)(100)}{6.78 + 0.061(200)} = 4.4\ percent$$

For the general case, live loads should be added to the earth load to determine the total load at the depth being considered.

In Table 30, results of calculations for deflections of buried AWWA C900 DR 14, 18 and 25 PVC pipe are presented for cases where either highway or railway loads are present.

Deflection Lag and Creep. The length of time that a buried flexible pipe will continue to deflect after the maximum imposed load is realized is limited and is a function of soil density in the pipe zone. As soil density at the sides of the pipe increases, the time during which the pipe will continue to deflect decreases, and the total deflection in response to load decreases.

In fact, after the trench load reaches a maximum, the pipe-soil system continues to deflect only as long as the soil around the pipe is in the process of consolidation. Once the embedment soil has reached the density required to support the load, the pipe will not continue to deflect.

The full load on any buried pipe is not reached immediately after installation unless the final backfill is compacted to a high density. For a

5: 11/11

STRENGTH AND STABILITY OF HDPE UPSLOPE RISER PIPE

Golder Associates	SUBJECT STRENGTH AND STABILITY OF UPSLOPE RISER PIPES		
	Job No. 953-3600 001 Ref.	Made by SM Checked Reviewed	Date 1/11/95 Sheet 1 of 7

GOLDER WORK SHEET

Strength and Stability of HDPE Upslope Riser Pipes and Vertical Riser Inlets

Objective: Determine the structural stability of the 18-inch HDPE upslope riser pipes and vertical riser inlets under the maximum design pressure. The pipes are located within the primary leachate collection sump. The design pressure will be due to the bearing pressure of the base for the concrete riser section.

Method: 1. Determine the maximum vertical pressure acting on the upslope riser pipes and vertical riser inlets. The maximum pressure is equal to the bearing pressure exerted by the base for the concrete riser section.

2. Evaluate the pipe for
   a) wall crushing;
   b) wall buckling; and
   c) ring deflection.

Conclusions: A perforated 18-inch diameter HDPE SDR 7.3 pipe is structurally stable under the anticipated maximum pressure and can be used as the upslope riser pipes and the vertical riser inlets.

F.S. against wall crushing = 2.2
F.S. against wall buckling = 1.5
Ring deflection = 0.08 < 0.09 recommended 9%

Define Parameters:

$\sigma_v := 215 \cdot psi$ ......Maximum bearing pressure acting on the HDPE upslope riser pipes and the vertical riser inlets. (The maximum pressure is due to the bearing pressure of the concrete riser section. See calcs. for concrete riser - 31 KSF)

$\gamma_{refuse} := 110 \cdot \frac{lbf}{ft^3}$ ......Unit weight of refuse.

$\phi_{backfill} := 30 \cdot deg$ ......Interface friction angle of soil backfill ~~around riser pipe- Assume gravel backfill~~ around pipes.

Properties of Backfill Material Adjacent to Pipe

$E_{soil} := 2000 \cdot \frac{lbf}{in^2}$ ....Elastic modulus of soil (Driscopipe, 1989 for coarse grained soils compacted to 85%-95% Standard Proctor's maximum dry density)

$E_{reaction} := 2 \cdot E_{soil}$ ....Subgrade reaction of soil (Selig, 1990 suggested that the subgrade reaction is two times the elastic modulus of soil)

Properties of perforated 18-inch diameter HDPE upslope riser pipes and vertical riser inlets (extracted from Driscopipe, 1988):

$T_{yield} := 1500 \cdot \frac{lbf}{in^2}$ ....Yield strength of Driscopipe

$E_{pipe} := 13000 \cdot \frac{lbf}{in^2}$ ....Elastic modulus of HDPE pipe

$\epsilon_{allow} := 0.09$ ....Allowable ring deflection of pipe

$SDR := 7.3$ ....Standard Dimension Ratio

$D_{pipe} := 18 \cdot in$ ....Outside diameter of pipe

$D_{per} := 1 \cdot in$ ....Diameter of perforation

$N_{per} := 4$ ....Number of perforations per linear foot

$A_{per} := \frac{N_{per} \cdot \pi \cdot D_{per}^2}{4}$ ....Area of perforations per linear foot of pipe

$A_{pipe} := \pi \cdot D_{pipe} \cdot 12 \cdot in$ ....Surface area per linear foot of pipe

$A_{pipe\_net} := A_{pipe} - A_{per}$ ....Net surface area per linear foot of pipe

$\frac{A_{pipe\_net}}{A_{pipe}} = 0.995$ ....Correction is insignificant and is therefore neglected in these calculations.

Golder Associates

SUBJECT: STRENGTH AND STABILITY OF UPSLOPE RISER PIPES

Job No. 933-3600 001 | Made by SM | Date 1/11/95
Ref. | Checked [illegible] | Sheet 3 of 7
Reviewed

$D_L := 1.0$ ....Deflection lag factor = 1 for load prism

$k := 0.1$ ....Bedding constant; mostly recommended to be 0.1

Maximum Vertical Stress acting on Pipe

$\sigma_v = 3.1 \cdot 10^4 \cdot \frac{lbf}{ft^2}$ $\sigma_v = 215 \cdot \frac{lbf}{in^2}$

Design for Wall Crushing

$S_A := \frac{(SDR - 1) \cdot \sigma_v}{2}$ ....Compressive stress in pipe

$S_A = 677.3 \cdot \frac{lbf}{in^2}$

$FS_{crush} := \frac{T_{yield}}{S_A}$ ....Factor of safety against wall crushing

$FS_{crush} = 2.2$ > 2 o'k per page 2, Ref. 1.

Design for Wall Buckling

$P_c := \frac{2.32 \cdot E_{pipe}}{SDR^3}$ ....Hydrostatic, critical collapse differential pressure

$P_{cb} := 0.8 \cdot \sqrt{E_{soil} \cdot P_c}$ ....Critical buckling soil pressure at the top of pipe

$P_c = 77.5 \cdot \frac{lbf}{in^2}$

$P_{cb} = 315 \cdot \frac{lbf}{in^2}$

$FS_{buckling} := \frac{P_{cb}}{\sigma_v}$ ....Factor of safety against wall buckling

$FS_{buckling} = 1.5$ > 1 o'k per page 3, Ref. 1.

1/11/95 UPSL_RIS.MCD

Golder Associates	SUBJECT: STRENGTH AND STABILITY OF UPSLOPE RISER PIPES		
	Job No. 933-3600 Ref. 001	Made by SM Checked Reviewed	Date 1/11/95 Sheet 4 of 7

Design for Ring Deflection

$$\Delta Y := \frac{D_L \cdot k \cdot \sigma_v \cdot D_{pipe}}{\left[\frac{2 \cdot E_{pipe}}{\left[3 \cdot (SDR - 1)^3\right]}\right] + 0.061 \cdot E_{reaction}}$$

.......Ring deflection (Modified Iowa Formula) (REF. No. 5)

$E_{reaction} = 4 \cdot 10^3 \cdot \frac{lbf}{in^2}$

$\Delta Y = 1.389 \cdot in$

$\frac{\Delta Y}{D_{pipe}} = 0.077$ < 9%, the recommended maximum deflections immediately after filling of the trench by Lars-Eric Janson, et. al. in "Design and installation of Underground Plastic Sewer Pipes" in International Conference on Underground Plastic Pipe, 1981, New Orleans, pp 79-88; pp 104-116.

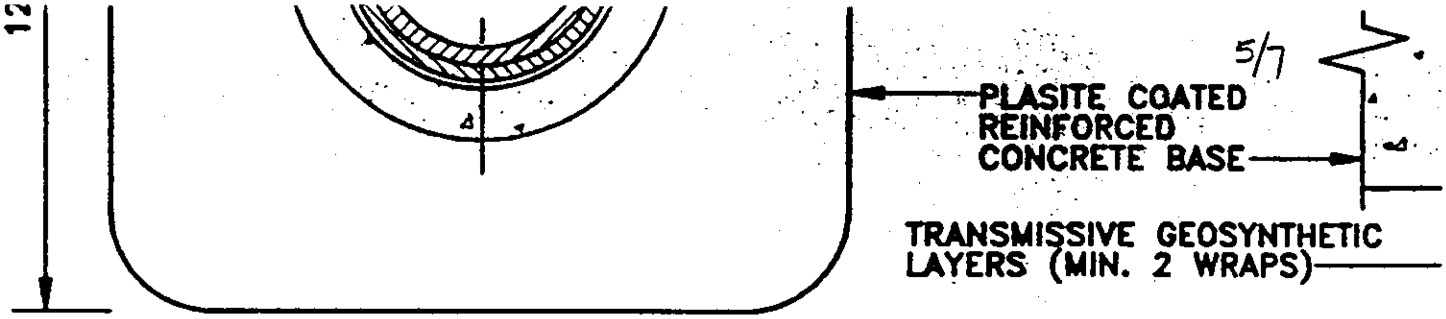
Conclusions: A perforated 18-inch diameter HDPE SDR 7.3 pipe is structurally stable under the anticipated maximum pressure and can be used as the upslope riser pipes and vertical riser inlets.

F.S. against wall crushing = 2.2
F.S. against wall buckling = 1.5
Ring deflection = 0.08 < 0.09 recommended 9%

References:

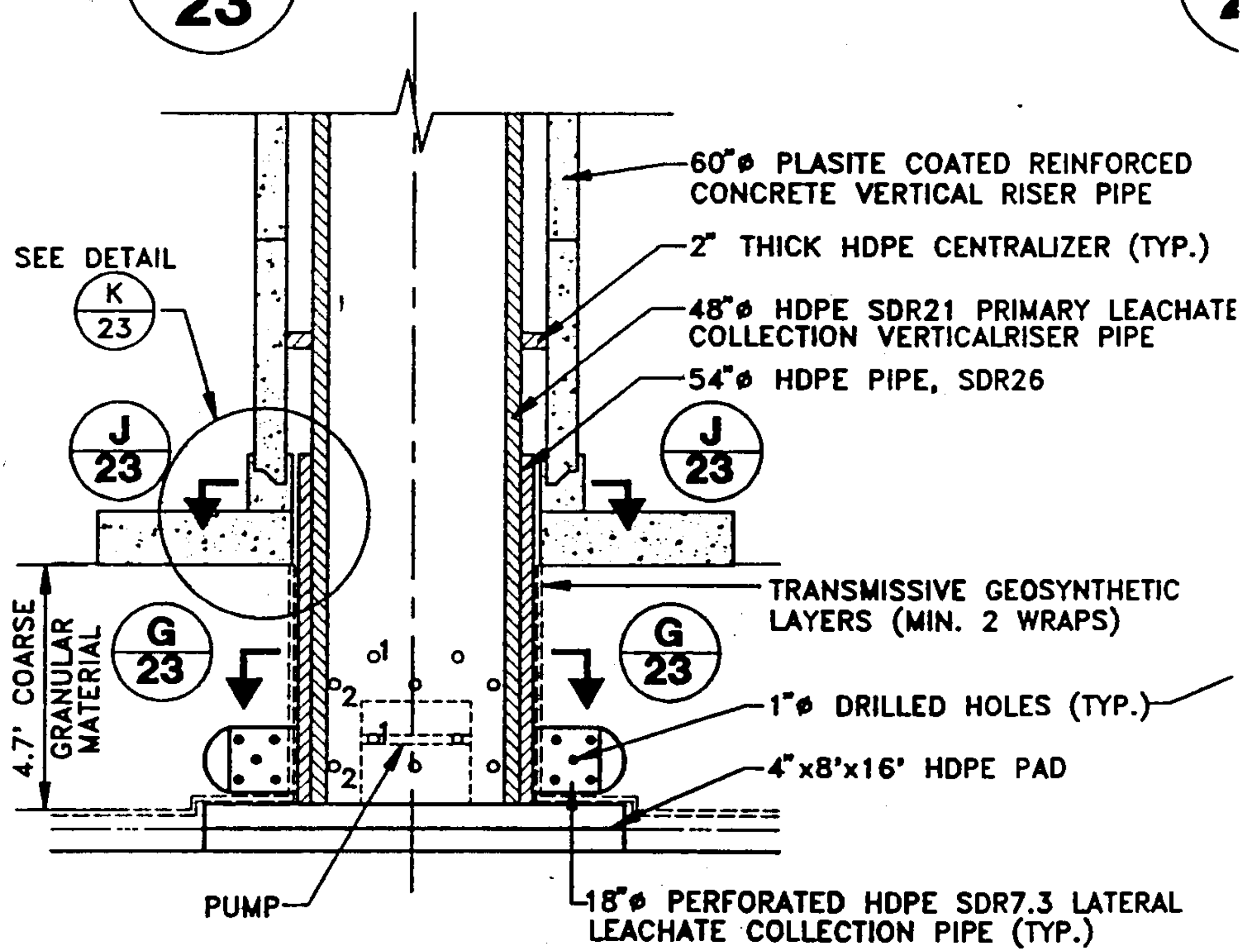
* (1) Driscopipe, 1988. "System and Design by Phillips 66".
(2) Selig, E. T., 1990. "Soil Properties for Plastic Pipe Installations," ASTM STP 1093 Buried Plastic Pipe Technology.
(3) Lars-Eric Janson, et. al., "Design and Installation of Underground Plastic Sewer Pipes" in International Conference on Underground Plastic Pipe, 1981, New Orleans, pp 79-88; pp 104-116. Attached
(4) Goddard, J. B. "Plastic Pipe Design" in Ohio Transportation Engineering Conference, December, 1992. Attached
(5) HANDBOOK OF PVC PIPE – DESIGN AND CONSTRUCTION, UNI-BELL PVC PIPE ASSOCIATION; DALLAS, TX, 1982.

* All references found at end of vertical riser pipe calc's.



J / 23 SECTION

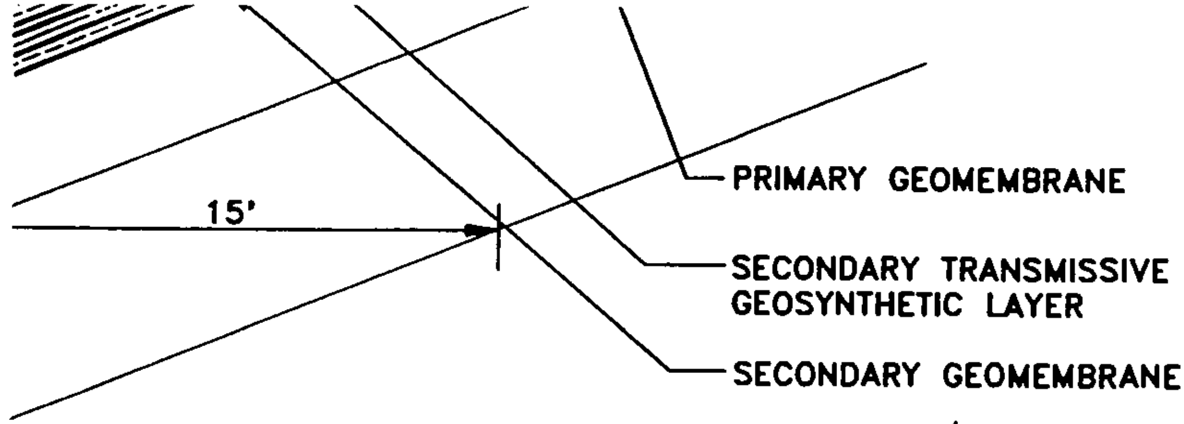
N.T.S.

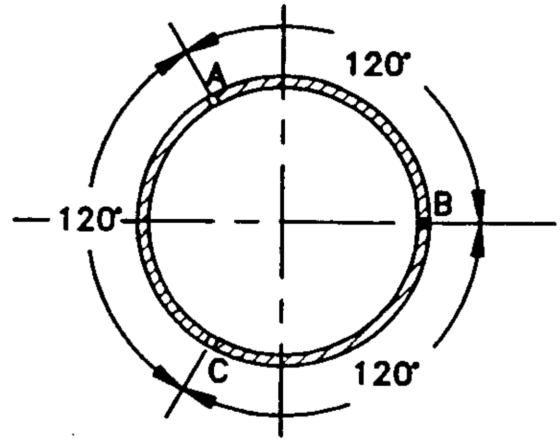


B / 23 SECTION

N.T.S.

6/7





H / 23 **SECTION**

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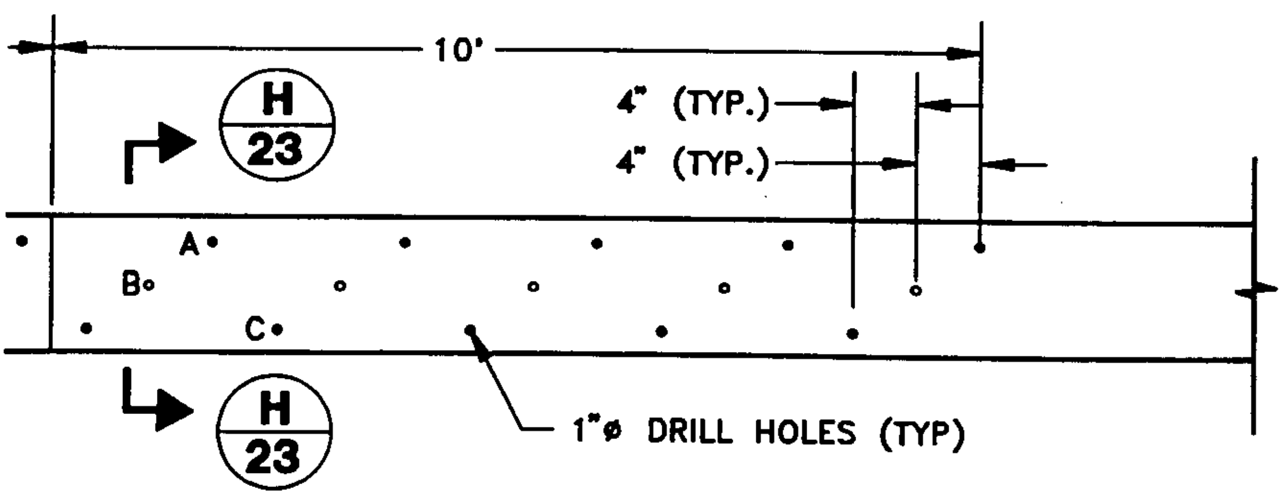
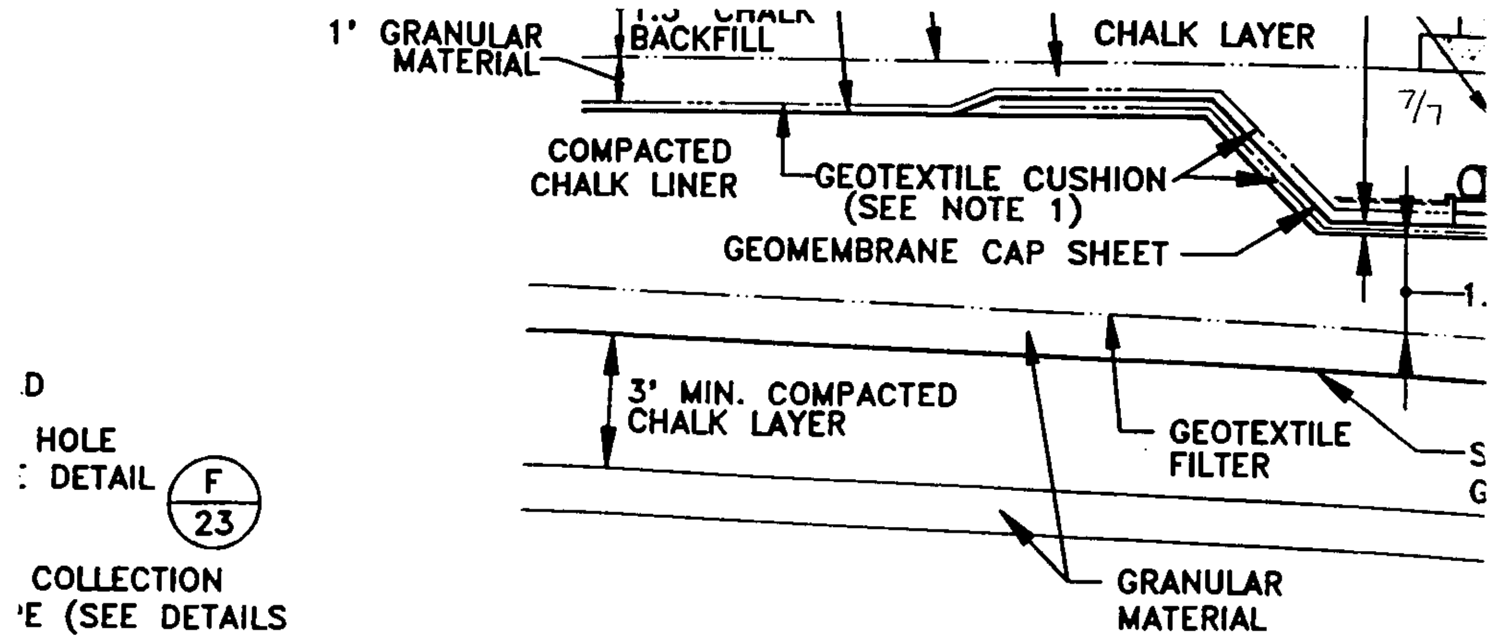


NOTE: PERFORATED SECTION OF PIPE SHALL BE WRAPPED WITH 2 LAYERS (MIN.) TRANSMISSIVE GEOSYNTHETIC LAYER



C
23
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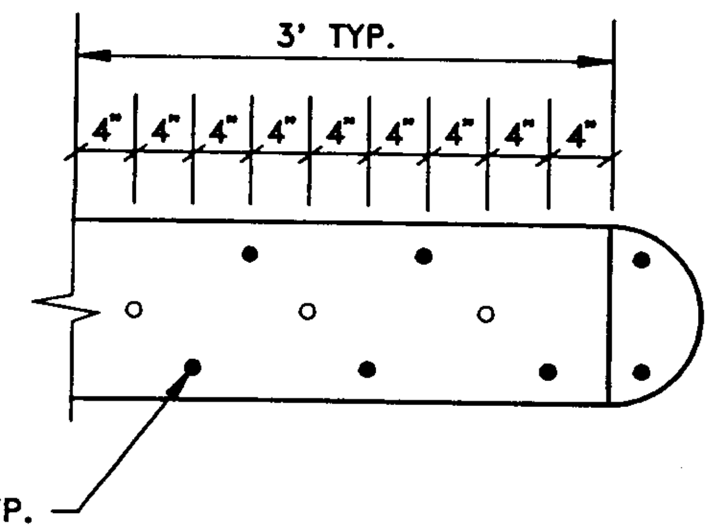
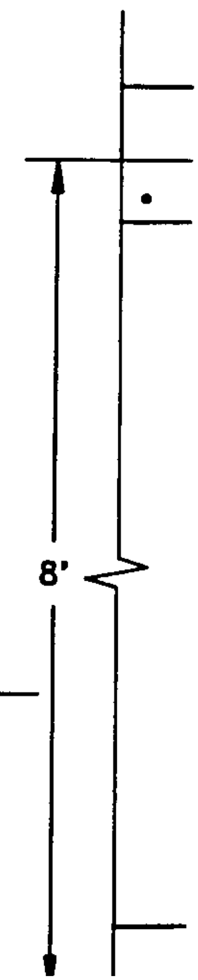
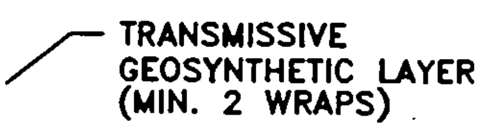
NOTE: PERFORATED SECTION OF PIPE SHALL BE WRAPPED WITH 2 LAYERS (MIN.) TRANSMISSIVE GEOSYNTHETIC LAYER.





L LEACHATE COLLECTION PIPE

N.T.S.



UPSLOPE RISER PIPE COUNTER WEIGHT AND THERMAL EXPANSION CALCULATION

Golder Associates	SUBJECT Upslope Riser Pipe Counter Weight Thermal Expansion		
	Job No. 933-3600.1 Ref.	Made by D. Jang Checked SY Reviewed	Date 1/6/93 Sheet 1 of 3

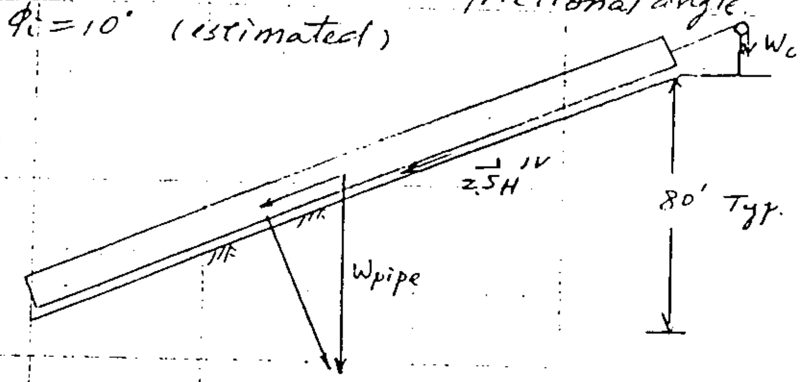
Objective: Calculate the required counter weight for the up slope riser pipe to maintain the pipe alignment.

Data / Assumption:

Pipe diameter $\phi = 18''$, SDR = 11
Unit weight of the pipe $\gamma_{pipe} = 35.76$ lbs/ft
– from Driscopipe manual.
Landfill side slope at 2.5H : 1V
The HDPE pipe is laid on a geotextile cushing layer

Linear thermal expansion of the pipe is
$\alpha_p = 1.2 \times 10^{-4}$ in/in/°F, in the range of 0°F to 140°F

Pipe / Geotextile contact frictional angle
$\varphi_i = 10°$ (estimated)



Golder Associates	SUBJECT Up Slope Rise Pipe		
	Job No. 933-3606.1 Ref.	Made by D Jang Checked SM Reviewed	Date 1/6/93 Sheet 2 of 3

Analysis: The total length of up slope riser

$L = 80^{ft} \times \frac{\sqrt{2.5^2+1^2}}{1}$

$= 215 ft$ ✓

Total weight of the pipe.

$W_{pipe} = L \times \gamma_{pipe}$

$= 215^{ft} \times 35.76 \, lbs/ft$

$= 7,700 \, lbs$

Tensile force along the 2.5H:1V slope

$T_{pipe} = W_{pipe} \times \frac{1}{\sqrt{2.5^2+1^2}}$

$= 7,700 \, lbs \times \frac{1}{2.69}$

$= 2,861 \, lbs$ ✓

Normal force on the slope

$N_{pipe} = W_{pipe} \times \frac{2.5}{2.69}$

$= 7,156 \, lbs$

Frictional force alonge pipe

$F_{pipe} = 7,156 \, lbs \times \tan 10°$

$= 1,262 \, lbs$ ✓

Required counter weight

$W_c = T_{pipe} - F_{pipe}$

$= 2,861 \, lbs - 1,262 \, lbs$

$= 1600 \, lbs.$ ✓

Golder Associates	SUBJECT Up Slope Riser Pipe		
	Job No. 933-3600.1 Ref.	Made by D. Tang Checked EM Reviewed	Date 1/6/93 Sheet 3 of 3

Thermal expansion / contraction for temperature change from: $T_i = 20°F$ to $T_f = 120°F$ (assumed)

$\Delta T = T_f - T_i = 100°F$

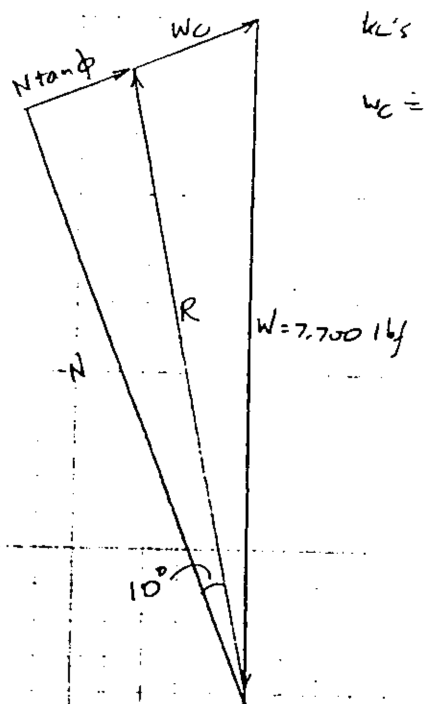
$\alpha_T = 1.2 \times 10^{-4}$ in/in/°F

$\Delta L = L \times \Delta T \times \alpha_T$

$= 215 \text{ ft} \times 100°F \times 1.2 \times 10^{-4} \text{ in/in/°F} \times 12 \text{ in/ft}$

$= 31^{in} = 2.6 \text{ ft}$ ✓

$\frac{\Delta L}{L} = \frac{2.6 \text{ ft}}{215 \text{ ft}} - 1.2\%$



KL's check.

$w_c \doteq 1,500$ lbf OK

GEOSYNTHETIC SURVIVABILITY

Golder Associates	SUBJECT Geosynthetic Survivability		
	Job No. 933-3553 Ref. Emelle	Made by SK Checked Reviewed WE	Date 10/18/94 Sheet 1 of 5

Survivability of Geomembrane and Geotextile

Objective: Determine the survivability of the geomembrane and geotextile during construction. The geomembrane and geotextile must meet the required puncture resistance for their application in the liner system.

Approach:
1. Determine the maximum static and dynamic loads to be experienced by the geomembrane and the geotextile in the liner system during construction.
2. Determine the required puncture resistance of the 60 mil. HDPE geomembrane and the geotextile at the bottom of the landfill.

Conclusion: The puncture resistance of the 60 mil HDPE geomembrane has to be at least 10.8 lbs and that for the geotextile has to be 16.5 lbs to prevent possible puncture under the loads they may experience during its service life.

Assumptions:

The maximum particle size of the compacted chalk liner is 0.75 inch in diameter and that of gravel in the leachate collection system is 1 inch.

There will be a minimum of 6-inch soil or protective cover over the geomembrane prior to deployment of bulldozer or track mounted equipment. For rubber tired and other heavy equipment (such as scrapers, compactors etc.), there shall be a minimum of 18" cover.

The heavy equipment anticipated to be used during construction are as follows:
a) D-10 dozer or equivalent.
b) 633D scraper or equivalent;
c) 825C compactor or equivalent; and

Factor of Safety = 3 for dynamic loads and 1.5 for static loads.

Maximum Height = 150 feet

Average unit weight of static loading = 110 pcf

$FOS_{dynamic} := 3 \quad FOS_{static} := 1.5$

$\gamma_{avg} := 110 \cdot \frac{lb}{ft^3}$

$H_{max} := 150 \cdot ft$

Golder Associates	SUBJECT Geosynthetic Survivability		
	Job No. 933-3553 Ref. Emelle	Made by SK Checked [illegible] Reviewed WF	Date 10/18/94 Sheet 2 of 5

Calculations:

Case A: Post Closure
Maximum Static Load (at bottom liner system):

Total static load:

$P_{static} := \gamma_{avg} \cdot H_{max}$

$P_{static} = 16500 \cdot \frac{lb}{ft^2}$ $\quad P_{static} = 114.6 \cdot \frac{lb}{in^2}$

$\sigma_{z\_static} := P_{static} \cdot FOS_{static}$

$\sigma_{z\_static} = 172 \cdot \frac{lb}{in^2}$

Case B: During Construction
Maximum Dynamic Load :

From the attached chart, three typical dynamic loadings were identified:

1). A D10 dozer operating with 6" cover P = 19 psi

2). A 825C compactor operating with 18" cover P = 10 psi

3). A 633D scraper operating with 18" cover P = 43 psi

$P_{dynamic} := 43 \cdot \frac{lb}{in^2}$

$\sigma_{z\_dynamic} := P_{dynamic} \cdot FOS_{dynamic}$

$\sigma_{z\_dynamic} = 129 \cdot \frac{lb}{in^2}$

The maximum stress, as shown above, corresponds to static load:

$\sigma_{z\_design} := 172 \cdot \frac{lb}{in^2}$

Puncture resistance of geomembrane for liner system (Giroud, 1984):

$d_{avg} := 0.75 \cdot in$ (From compacted chalk)

$R_p := \sigma_{z\_design} \cdot d_{avg}^2$ puncture resistance

$R_p = 96.7 \cdot lb$

Puncture resistance of geomembranes is determined from FTMS 101.2065 which uses a 1/4" diameter probe. Since a 0.75 inch crush stone has a larger contact area, the puncture resistance values should be corrected according to the surface area of the probe.

Correction:

$Area_{stone} := \frac{\pi}{4} \cdot d_{avg}^2$ $Area_{stone} = 0.4 \cdot in^2$

$Area_{probe} := \frac{\pi}{4} \cdot \frac{1}{4^2} \cdot in^2$ $Area_{probe} = 0.05 \cdot in^2$

$R_{p\_corrected} := \frac{Area_{probe}}{Area_{stone}} \cdot R_p$

$R_{p\_corrected} = 10.8 \cdot lb$

This is below 80 lbs which is the puncture resistance of a typical 60 mil HDPE geomembrane.

Puncture resistance of geotextile for liner system :

$d_{avg} := 1 \cdot in$ (From gravel in the leachate collection system)

$R_p := \sigma_{z\_design} \cdot d_{avg}^2$ puncture resistance

$R_p = 172 \cdot lb$

Puncture resistance of geotextile is determined from ASTM D-4833 which uses a 0.31" diameter probe. Since a one inch crush stone has a larger contact area, the puncture resistance values should be corrected according to the surface area of the probe.

Golder Associates	SUBJECT Geosynthetic Survivability		
	Job No. 933-3553 Ref. Emelle	Made by SK Checked JAJ Reviewed WE	Date 10/18/94 Sheet 4 of 5

Correction:

$Area_{stone} := \frac{\pi}{4} \cdot d_{avg}^2$ $Area_{stone} = 0.8 \cdot in^2$

$Area_{probe} := \frac{\pi}{4} \cdot (0.31^2) \cdot in^2$ $Area_{probe} = 0.08 \cdot in^2$

$$R_{p\_corrected} := \frac{Area_{probe}}{Area_{stone}} \cdot R_p$$

$R_{p\_corrected} = 16.5 \cdot lb$

This is below 40 lbs which is the puncture resistance of a very light (3.5 oz/yd2) geotextile

Conclusions: The geomembrane should exhibit puncture resistance of at least 10.8 lbs and the geotextile should exhibit puncture resistance of at least 16.5 lb to avoid possible rupture under the anticipated loadings during construction

References:

1. Geotextiles and Geomembrane Definitions, Properties and Design, Giroud, J-P, Industrial Fabrics Association International, 1984.

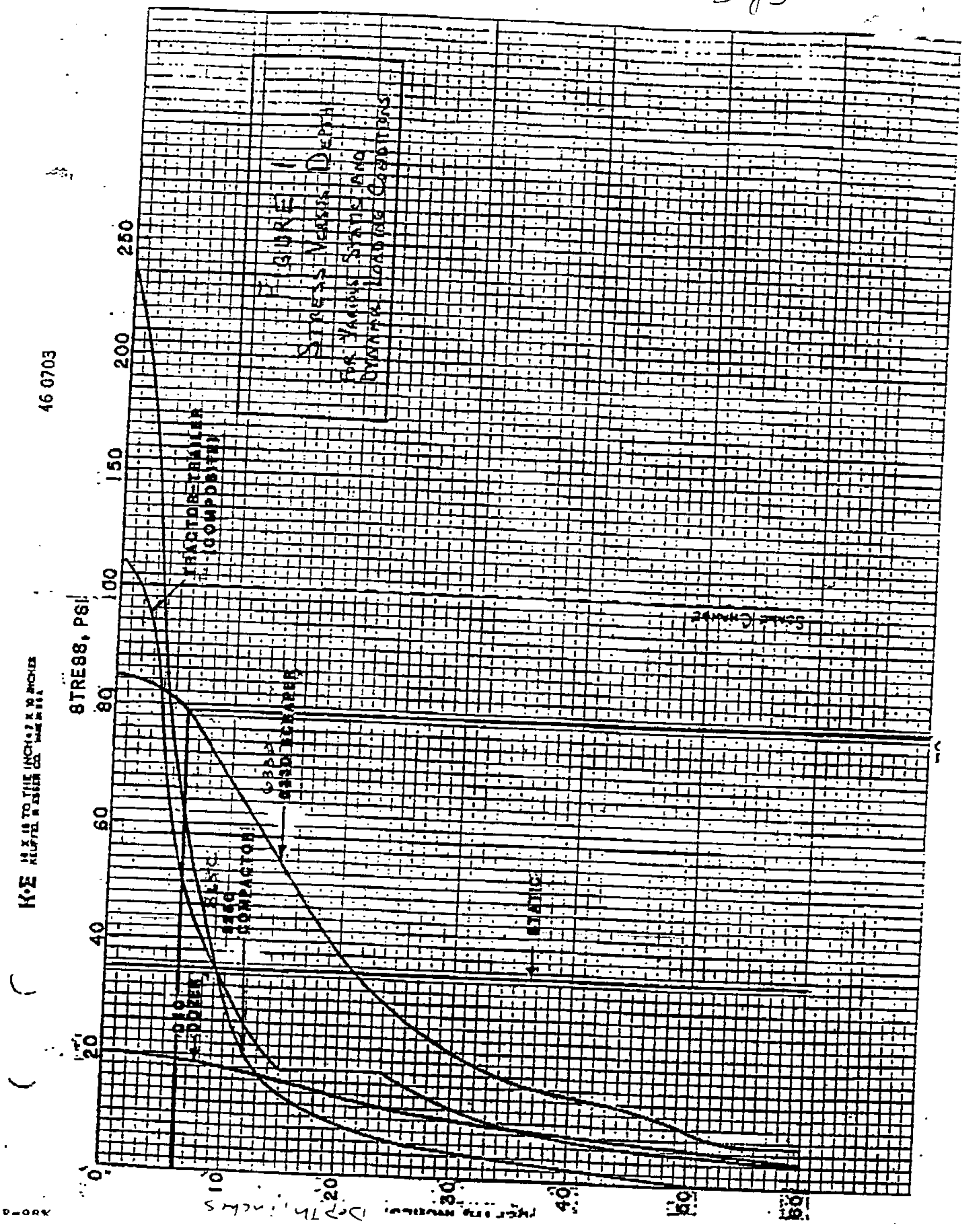


FIGURE 1
STRESS VERSUS DEPTH
FOR VARIOUS STATIC AND
DYNAMIC LOADING CONDITIONS
STRESS, PSI
0
20
40
60
80
100
150
200
250
TRACTOR-TRAILER (COMPOSITE)
SCRAPER
COMPACTOR
DOZER
STATIC
DEPTH, INCHES
10
20
30
40
50
60
46 0703

DRAINAGE INTO PRIMARY LEACHATE COLLECTION SYSTEM SUMP

Golder Associates

SUBJECT Drainage into Sump (PLCS)		
Job No. 933-3553 Ref. CHM/Emelle/AL.	Made by SK Checked [illegible] Reviewed [illegible]	Date 10/17/94 Sheet 1 of 2

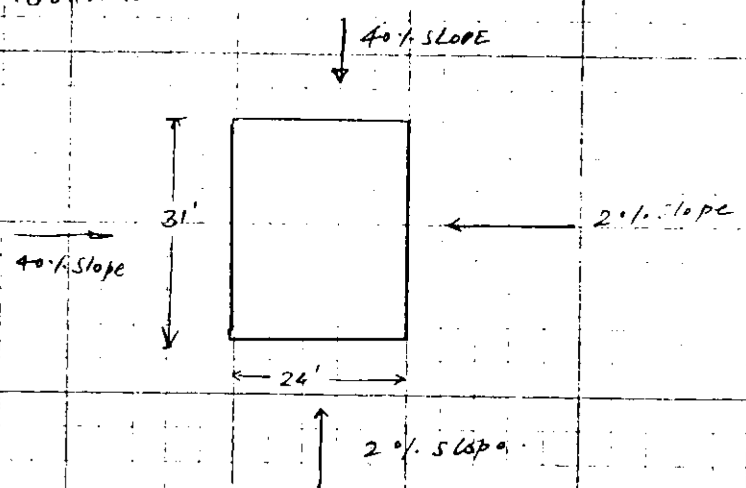
OBJECTIVE: FOR THE PRIMARY LEACHATE COLLECTION, COMPARE THE DRAINAGE FLOW RATE INTO THE SUMP TO THE PUMPING RATE.

CALCULATIONS:

TRANSMISSIVITY OF DRAINAGE LAYER

$= 3 \times 10^{-6}\ m^2/sec.$

CORRESPONDING TO THE WORST CONDITION, SUMP IS AT THE CORNER OF THE CELL W/ THE FOLLOWING CONFIGURATION.



FOLLOWING IS THE CAPACITY OF DRAINAGE LAYER PER FOOT WIDTH

GRADIENT	FLOW Rate/ft
40%	$3\times10^{-6}\ m^2/sec \times 0.4\ ft/ft = 5.86\times10^{-3}$ gpm/ft
2%	$3\times10^{-6}\ m^2/sec \times 0.02\ ft/ft = 2.93\times10^{-4}$ gpm/ft

Golder Associates

SUBJECT Drainage Into Sump (PLCS)		
Job No. 933-3553 Ref. CNM/Emelle/AL	Made by SK Checked [illegible] Reviewed [illegible]	Date 10/14/94 Sheet 2 of 2

AS SHOWN IN THE FIGURE ABOVE

LENGTH OF PERIMETER @ 40% SLOPE = LENGTH OF PERIMETER @ 2% SLOPE = 55'

FLOW INTO SUMP

$= (5.86 \times 10^{-3}$ gpm/ft $\times$ 55 ft$) + (2.93 \times 10^{-4}$ gpm/ft $\times$ 55 ft$)$

= **0.34 gpm**

~~PUMPING RATE = 30 gpm~~

~~PUMPING RATE EXCEEDS THE RATE OF DRAINAGE~~ EXPECTED INTO THE SUMP.

COVER DRAINAGE LAYER HYDRAULIC CALCULATIONS

Golder Associates	SUBJECT Cover Drainage Layer Hydraulic Calcs.		
	Job No. 933-3553 Ref. CWM/Emelle/AL	Made by SK Checked JT7 Reviewed WE	Date 10/11/94 Sheet 1 of 1

OBJECTIVE: THE ADEM CODE R 335 14-5-14(11)(b)(2)(i) STATES THAT THE DRAINAGE LAYER MUST BE AT LEAST 12 INCHES THICK WITH $K \geq 10^{-3}$ cm/sec. IT IS PROPOSED THAT INSTEAD A TRANSMISSIVE GEOSYNTHETIC LAYER WITH TRANSMISSIVITY OF 3×10^{-6} m^2/sec OR GREATER BE USED AS DRAINAGE LAYER. EXPLAIN HOW THE GEOSYNTHETIC LAYER WILL MEET OR EXCEED STANDARDS.

CALCULATIONS:

MIN. TRANSMISSIVITY OF GEOSYNTHETIC LAYER (GEOTEXTILE PROPOSED)

$= 3 \times 10^{-6}$ m^2/sec.

MIN. TRANSMISSIVITY OF STANDARD DRAINAGE LAYER AS PROPOSED BY RULE $= 10^{-3}$ cm/sec × 12 inches

$$= \left(10^{-5} \text{ m/sec}\right) \times \left(12 \text{ in} \times \frac{2.54 \text{cm}}{\text{in}} \times \frac{1}{100 \text{cm/m}}\right)$$

$$= \underline{\underline{3 \times 10^{-6} \text{ m}^2\text{/sec}}}$$

∴ THE GEOSYNTHETIC IS PROPOSED TO HAVE THE TRANSMISSIVITY AS THAT OF THE STANDAD <u>SATISFYING THE REQUIREMENT.</u> ADDITIONALLY, ADDITIONAL DRAINAGE CAPACITY IS OBTAINED FROM GEONET STRIPS PROPOSED TO BE PLACED 5' WIDE @ EVERY 50' INTERVAL.

ATTACHMENT D-6-1-8

APPENDIX D-6-1

SECTION D-6

COMPACTED FILL IN-SITU PERMEABILITY TEST REPORT

Revision No.
5.0

Report On

COMPACTED FILL IN SITU PERMEABILITY TEST

Submitted To:

Chemical Waste Management, Inc.
P.O. Box 3065
Marietta, Georgia 30061

DISTRIBUTION:

8 Copies - Chemical Waste Management, Inc., Marietta
2 Copies - Golder Associates

December 1984

824-1308
844-1440.6

1.0 INTRODUCTION

Chemical Waste Management, Inc. is constructing a land disposal cell at its Emelle Facility in accordance with plans and specifications submitted to the Alabama Department of Environmental Management (ADEM). These plans were entitled "Lined Landfill Disposal Cell Design" and were dated June 1984. These plans include land disposal cells which are approximately 300 ft. by 400 ft. in plan area, side slopes of 2.5 hor.:1.0 ver., a leachate collection system and synthetic membrane (HDPE) liner. The liner will be placed on compacted chalk fill which has been placed under moisture and density quality control. The cell currently under construction is designated as Trench 19 and is ready for liner placement.

Laboratory tests performed by Golder Associates indicate that permeabilities (hydraulic conductivity) ranging from about $2x10^{-7}$ to $6x10^{-8}$ cm./sec. can be achieved in compacted chalk when compacted to a density equal to or greater than 95% of the Standard Proctor maximum dry density and at a moisture content between 0% and 3% wet of the optimum moisture content as defined by ASTM D-698. A summary of the laboratory results was presented in Appendix I-4 "Geologic and Geotechnical Evaluation" of the Part B Permit for the Emelle Facility. The Alabama Department of Environmental Management (ADEM) has requested field verification of laboratory results. To verify that low permeability values can be achieved in the field, an in situ permeability test was performed on a portion of the Trench 19 backfill. Golder Associates inspected this fill placement and performed density and moisture testing.

It should be noted that the chalk fill in Trench 19 is to serve as a foundation for the HDPE liner. The liner itself is, therefore, the impermeable barrier to leachate exfiltration rather than the compacted chalk.

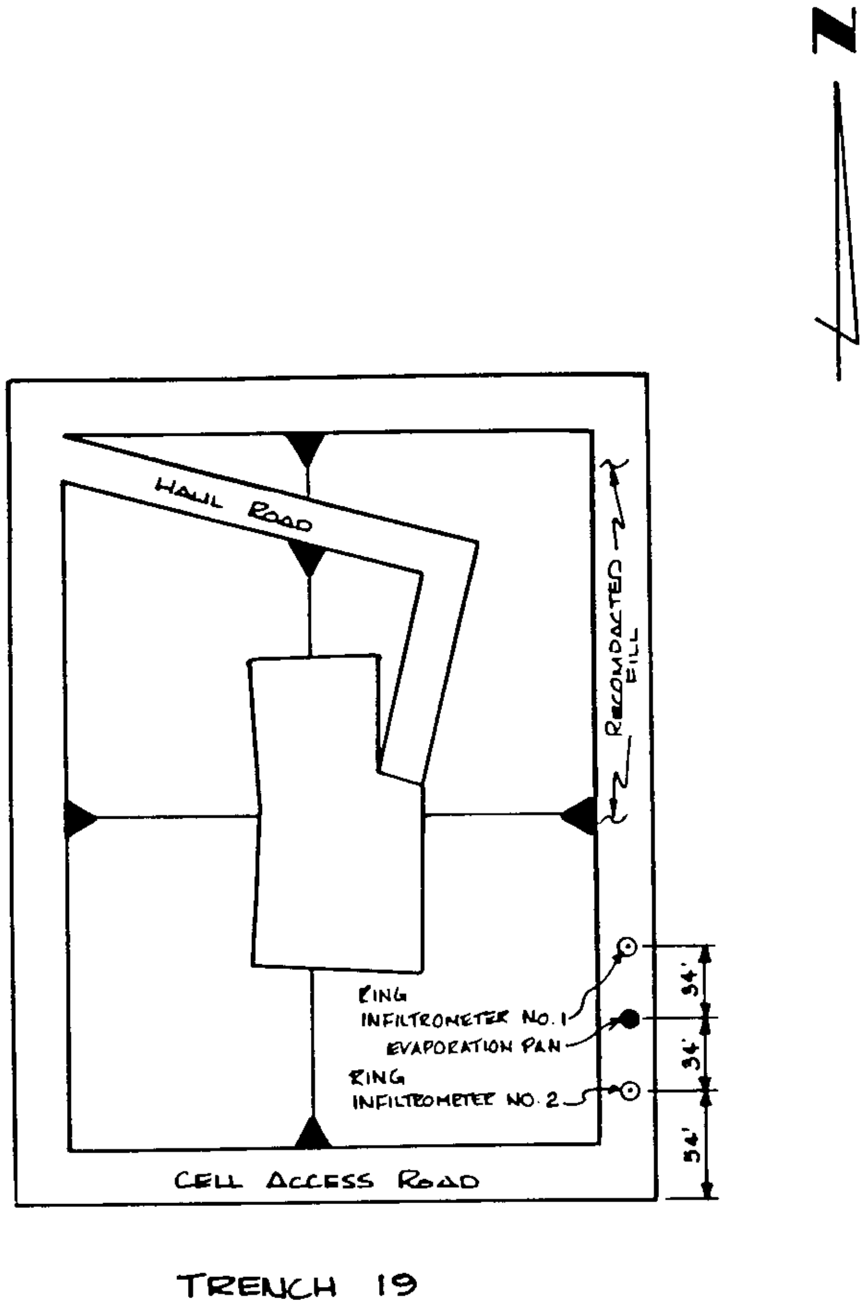
The in situ permeability test setup, theory, and analysis were previously described in the Golder Associates proposal titled "Compacted Fill In Situ Permeability Test", which has been included as Appendix A. As noted in the latter report, an in situ field test on material of such low permeability is not a standard test and has rarely been performed. During the field setup some modifications and additions were made to the original list of procedures. Any changes which were made are noted in the following report. Analyses of the results, using the theory developed in the original proposal, are presented along with additional qualitative observations made during the actual field test.

2.0 IN SITU PERMEABILITY TEST SETUP

Prior to performing the in situ permeability test the area to be tested was compacted to a density equal to or greater than 95% of the Standard Proctor maximum dry density, and at a moisture content between 0% and 3% wet of optimum moisture content as defined by ASTM D-698. Although many intact chalk particles were placed in the fill, these were generally noted to be no greater than a nominal effective diameter of 4 in. The chalk fill was tested by Golder Associates and compaction test results are included as Appendix B. Test results are considered representative of a normal range of field densities and moisture contents for the chalk when it is compacted wet of optimum. The fill is compacted at or wet of optimum to achieve a low permeability. It should be noted that this is not the same as the structural fill at the site which is compacted between ± 3% of optimum where compaction on the dry side of the optimum moisture content is permissible because the primary concern is strength rather than permeability reduction.

Placement of the fill adjacent to Trench 19 was finished on September 28, 1984. Plastic was placed over a 50 ft. by 100 ft. area of the recompacted fill to keep the surface moist and avoid desiccation.

The installation of the two 10 ft. diameter infiltration rings, Ring No. 1 and Ring No. 2, and the 10 ft. diameter evaporation pan was begun on Monday, October 15, 1984. The ring locations and evaporation pan location are shown in Figure 1.



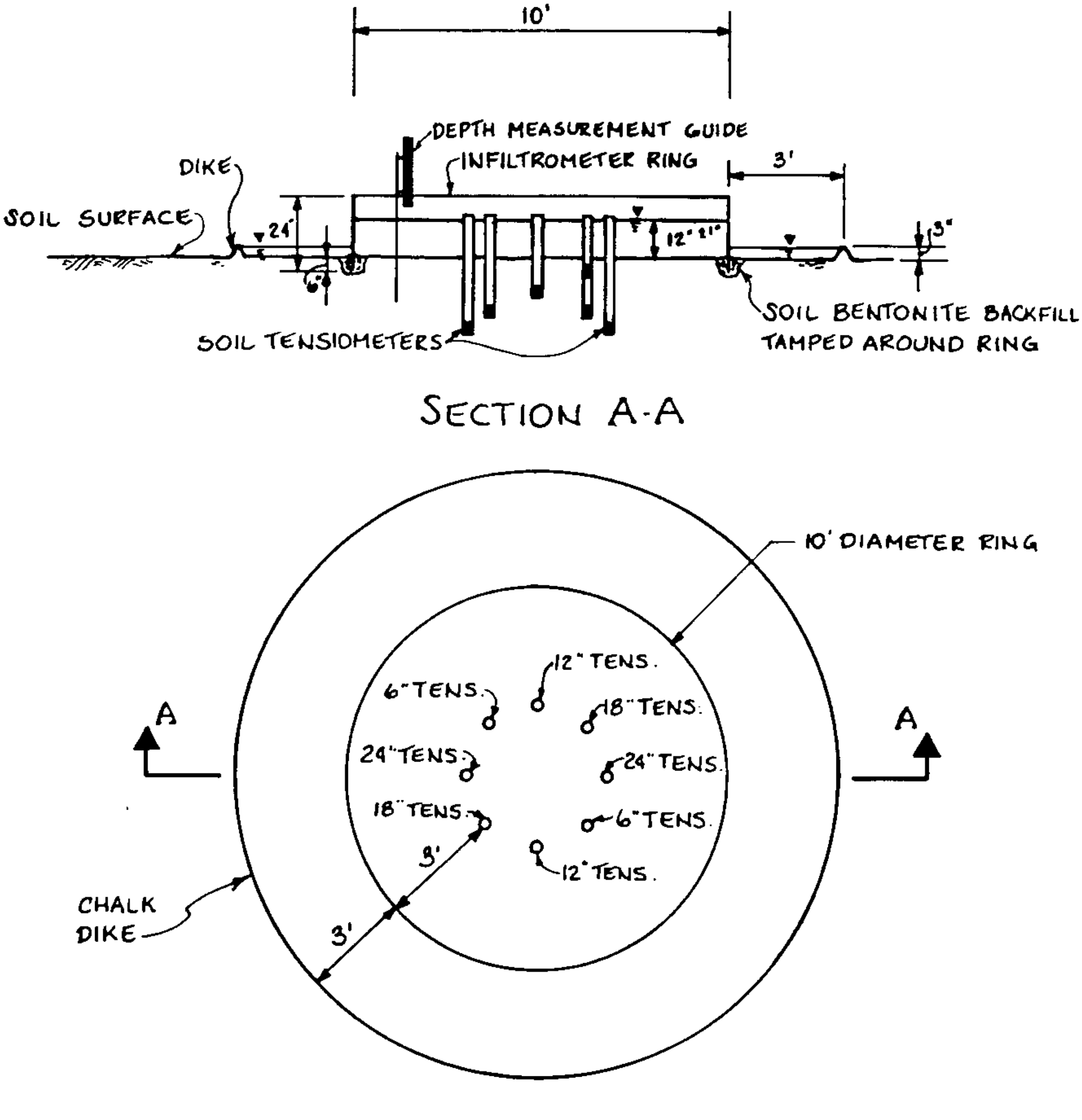
JOB NO 824-1308	SCALE 1" = 100'	PLAN LOCATION of RING INFILTROMETER AND EVAPORATION PAN
DRAWN SKB	DATE 10-1-84	
CHECKED SAR	DWG NO 91	
Golder Associates		CHEMICAL WASTE MANAGEMENT, INC. — FIGURE 1

Prior to ring placement, a caterpillar D-3 bulldozer, which was able to travel over the surface without causing deep ruts, was used to level the test area.

However, the D-3 did leave some cleat marks on the surface of the fill, but these were shallow and are not considered to have impacted the test. Once the test rings were in place, insertion of the tensiometers was begun. A 1/2 in. diameter steel pipe was used to create a hole in which the soil tensiometer was inserted. The tensiometers were placed approximately 3 ft. from the outer edge of the infiltrometer ring in a circular pattern as shown in Figure 2. Two sets of tensiometers (4 per set) were installed in each ring for redundancy. After the tensiometers were installed, they were monitored to insure that the soil tension readings stabilized prior to test initiation. On October 16, 1984, a heavy rainfall partially covered the test area. To prevent additional rainfall from covering the test area, the tensiometers were removed from the ground and approximately 1.5 ft. of compacted fill was placed over the test area. A density test was made in the additional fill (Test T-19-9).

On Friday, October 19, 1984, the rings were reset and the 16 tensiometers reinserted. Plastic was placed over the top of the two rings to keep rainwater out until the tensiometers stabilized. During the following 5 days that the tensiometers were monitored, prior to filling the rings with water, the weather consisted of overcast and rainy days.

AC 20440A-B



SECTION A-A

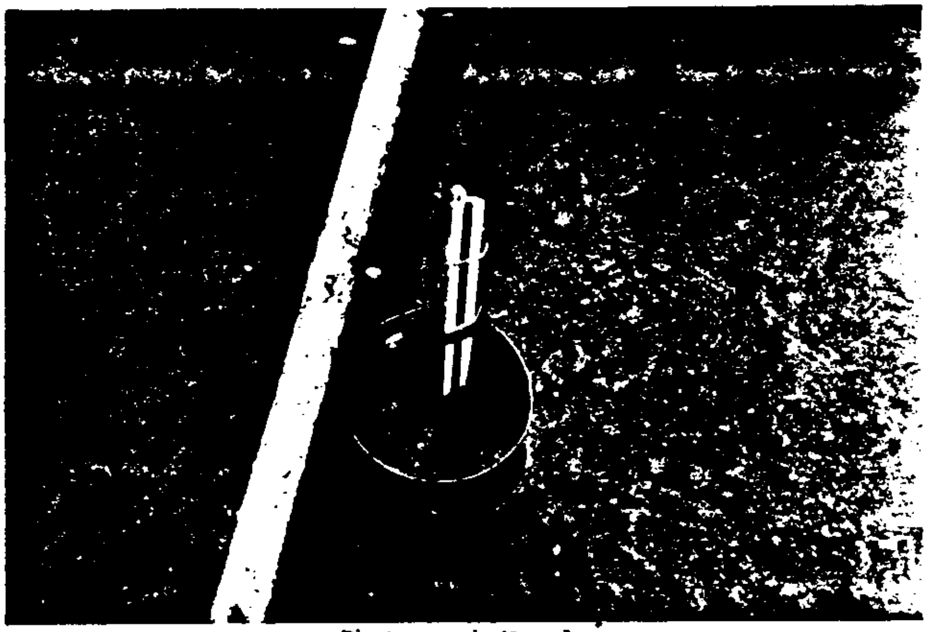
PLAN VIEW

JOB NO. 824-1308	SCALE 1" = 4'	RING INFILTROMETER
DRAWN C.A.T.	DATE 11-16-84	
CHECKED GLR	DWG. NO. 97	
Golder Associates		CHEMICAL WASTE MANAGEMENT, INC. — FIGURE 2

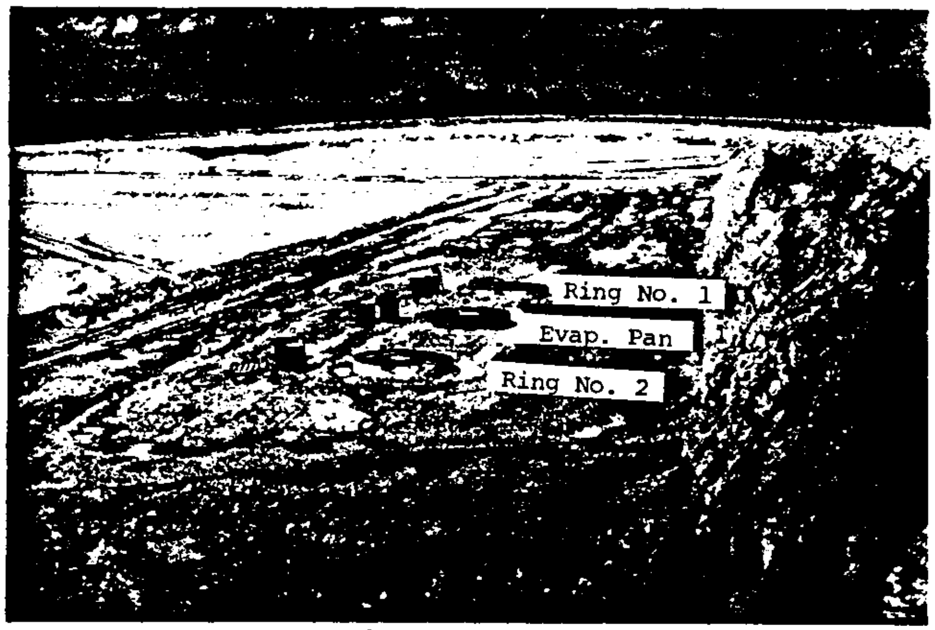
Approximately 1/2 in. of rainwater leaked into Ring No. 2 during this period; Ring No. 1 remained dry. Some of the rainwater in Ring No. 2 may have passed directly down the sides of the tensiometers. In order to prevent this from happening in Ring No. 1 and to prevent it from continuing in Ring No. 2, a bentonite plug was placed around each tensiometer at ground surface.

Before the test was begun, a small dike was constructed around each ring and the area filled with water to prevent surface drying and to minimize lateral movement of water. The dike was about 3 inches high and extended approximately 3 ft. from the ring as shown in Figure 2. About 2 inches of water was kept in the outer pool throughout the test.

Finally, the devices used to measure water levels in the two test rings and in the evaporation pan were installed. The measuring device consisted of an engineers scale and a piece of 1/8 in. welding rod shaped into a hook and sharpened to a point to provide good resolution when the tip was raised, breaking the water surface to make a water level measurement. A pin was welded to the top of the rod so that an accurate determination of the scale reading could be obtained. Measurements were made in a stilling well (6 in. diameter can) to minimize wave motion. Photograph No. 1 shows the water level indicator and stilling basin and a sketch is included as Figure 3 of Appendix A. Since low intake rates were anticipated, the 1 in.=50 ft. scale (50 scale) was used to record water level changes. Ten units on the 50 scale is equivalent to 0.2 inches. In the two rings this measurement system was fastened to steel angles driven into the ground surface; in the evaporation pan the angle was welded to the bottom.



Photograph No. 1
Water Level Indicator and Stilling Basin



Photograph No. 2
In Situ Permeability Test Set-up Showing Ring No. 1, Ring No. 2, and the Evapoaration Pan.

Following is a summary of the modifications and additions made to the initial procedures listed in the original report enclosed as Appendix A.

1. A caterpillar D-3 bulldozer was used to level the test area.

2. The tensiometers were placed in a concentric ring.

3. A bentonite plug was placed around each tensiometer at the ground surface.

4. A 3 inch high dike was constructed around the rings.

5. A thin layer of chalk was placed on the bottom of the evaporation pan to match the reflective characteristics of the bottom of the infiltration rings.

6. A stilling basin was added to the water level measuring device.

On Wednesday, October 24, 1985, the in situ permeability test was begun. Ring No. 1 and Ring No. 2 were filled with water by hand using 5 gallon buckets filled from 55 gallon drums. The evaporation pan had been previously filled on Monday, October 22, 1984. Prior to filling the evaporation pan, a thin layer of chalk was placed on the bottom so that the pan would have the same bottom reflective properties as the two rings. Water was placed in the pan on October 22 to allow enough time for the chalk in the evaporation pan to become fully saturated. The in situ permeability test was continued until the wetting front reached the tensiometers placed 18 inches deep. Tables 1 through 4 contain the water level data and tensiometer data recorded during the test.

TABLE 1

RING 1 INTAKE DATA SUMMARY

DATE	TIME	CUM. TIME (min.)	RING* READING	EVAP.* PAN READING	CUM. INTAKE (x0.2 to get inches)	CUM. INTAKE (cm)
10/24/84	5:23 PM	0	41.80	13.50	0	0
	11:41 PM	378	41.70	13.50	0.10	0.0508
10/25/84	7:22 AM	839	41.50	13.45	0.25	0.1270
	11:55 AM	1112	41.50	13.45	0.25	0.1270
	4:12 PM	1369	41.40	13.40	0.30	0.1524
10/26/84	8:11 AM	2328	40.90	12.90	0.30	0.1524
	5:19 PM	2876	40.65	12.65	0.30	0.1524
10/27/84	1:34 AM	3371	40.50	12.50	0.30	0.1524
	1:38 PM	4095	40.40	12.50	0.40	0.2032
10/28/84	11:34 AM	5471	40.70	12.90	0.50	0.2540
	5:34 PM	5831	40.60	12.80	0.50	0.2540
10/29/84	10:36 AM	6913	40.40	12.60	0.50	0.2540
	3:29 PM	7266	40.30	12.50	0.50	0.2540
	10:56 PM	7773	40.20	12.40	0.50	0.2540
10/30/84	8:09 AM	8386	40.00	12.20	0.50	0.2540
	5:38 PM	9015	39.90	12.10	0.50	0.2540
	11:36 PM	9433	39.80	12.05	0.55	0.2794
10/31/84	7:33 AM	9970	39.55	11.80	0.55	0.2794
	8:51 PM	10828	39.25	11.50	0.55	0.2794

*On 1/50 inch engineers scale

TABLE 2

RING 2 INTAKE DATA SUMMARY

DATE	TIME	CUM. TIME (min.)	RING* READING	EVAP.* PAN READING	CUM. INTAKE (x0.2 to get inches)	CUM. INTAKE (cm)
10/24/84	5:26 PM	0	47.20	13.50	0	0
	11:46 PM	380	47.20	13.50	0	0
10/25/84	7:28 AM	842	47.00	13.45	0.15	0.0762
	12:03 PM	1117	46.95	13.45	0.20	0.1016
	4:20 PM	1374	46.85	13.40	0.25	0.1270
10/26/84	8:20 AM	2334	46.30	12.90	0.30	0.1524
	5:29 PM	2883	45.90	12.65	0.45	0.2286
10/27/84	1:41 AM	3375	45.80	12.50	0.40	0.2032
	1:45 PM	4099	45.60	12.50	0.60	0.3048
10/28/84	11:39 AM	5473	45.85	12.90	0.75	0.3810
	5:39 PM	5833	45.70	12.80	0.80	0.4064
10/29/84	10:39 AM	6913	45.50	12.60	0.80	0.4064
	3:35 PM	7269	45.35	12.50	0.85	0.4318
	11:03 PM	7777	45.25	12.40	0.85	0.4318
10/30/84	8:15 AM	8389	45.00	12.20	0.90	0.4572
	5:48 PM	9022	44.90	12.10	0.90	0.4572
	11:43 PM	9437	44.80	12.05	0.95	0.4826
10/31/84	7:38 AM	9972	44.50	11.80	1.00	0.5080
	8:54 PM	10828	44.20	11.50	1.00	0.5080

*On 1/50 inch engineers scale.

TABLE 3

RING 1 TENSIOMETER DATA

DATE	TIME	Tensiometer Readings (Centibars) No. 1-1 (24 in.)	No. 1-2 (18 in.)	No. 1-3 (12 in.)	No. 1-4 (6 in.)	No. 1-5 (24 in.)	No. 1-6 (18 in.)	No. 1-7 (12 in.)	No. 1-8 (6 in.)
10/24/84	5:37 PM	*2.0	3.5	4.0	2.0	2.0	7.0	7.5	10.0
	11:50 PM	2.0	2.0	2.0	2.0	2.0	5.0	5.5	7.5
10/25/84	7:30 AM	2.0	2.0	2.0	2.0	2.0	5.0	4.5	6.5
	12:06 PM	2.0	5.0	4.0	2.5	2.0	8.0	5.5	8.0
	4:27 PM	2.0	5.0	4.0	2.0	2.0	8.5	5.0	6.5
10/26/84	8:22 AM	2.0	2.0	2.0	2.0	2.0	4.0	2.0	4.0
	5:31 PM	2.0	3.0	2.0	2.0	2.0	6.5	3.0	4.0
10/27/84	1:42 AM	2.0	2.0	2.0	2.0	2.0	3.5	2.0	2.0
	1:48 PM	2.0	2.5	2.0	2.0	2.0	5.0	2.0	4.0
10/28/84	11:40 AM	2.0	2.5	2.0	2.0	2.0	6.0	2.0	2.5
	5:40 PM	2.0	2.0	2.0	2.0	2.0	4.5	2.0	2.0
10/29/84	10:42 AM	2.0	3.0	2.0	2.0	2.0	6.0	2.0	2.0
	3:37 PM	2.0	3.0	2.0	2.0	2.0	7.0	2.0	2.0
	11:04 PM	2.0	2.0	2.0	2.0	2.0	2.5	2.0	2.0
10/30/84	8:17 AM	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0
	5:50 PM	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0
	11:48 PM	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
10/31/84	7:40 AM	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	8:57 PM	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0

*2.0 cb is the lowest value which can be read on the tensiometer gauge and indicates saturated conditions.

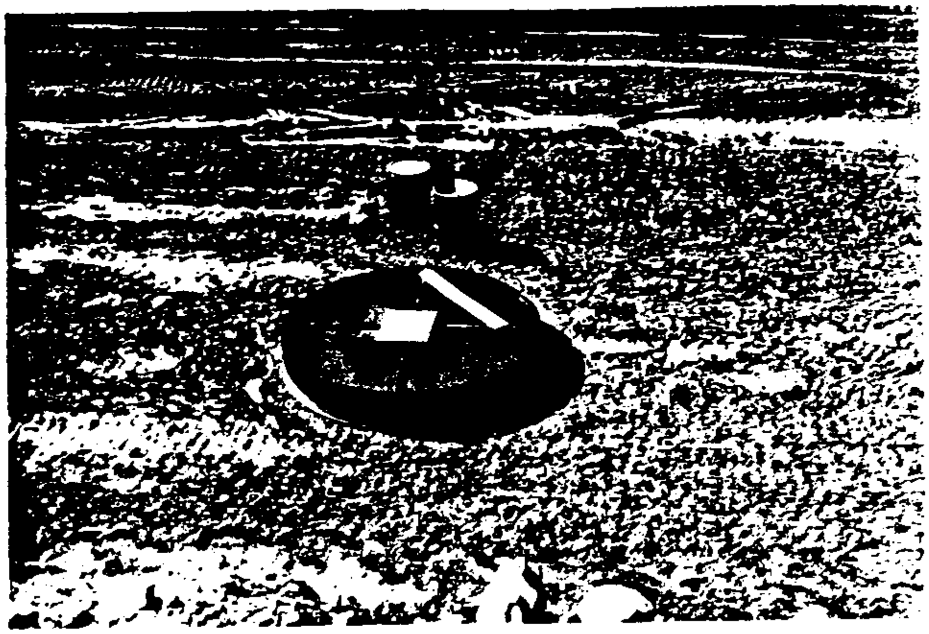
TABLE 4

RING 2 TENSIOMETER DATA

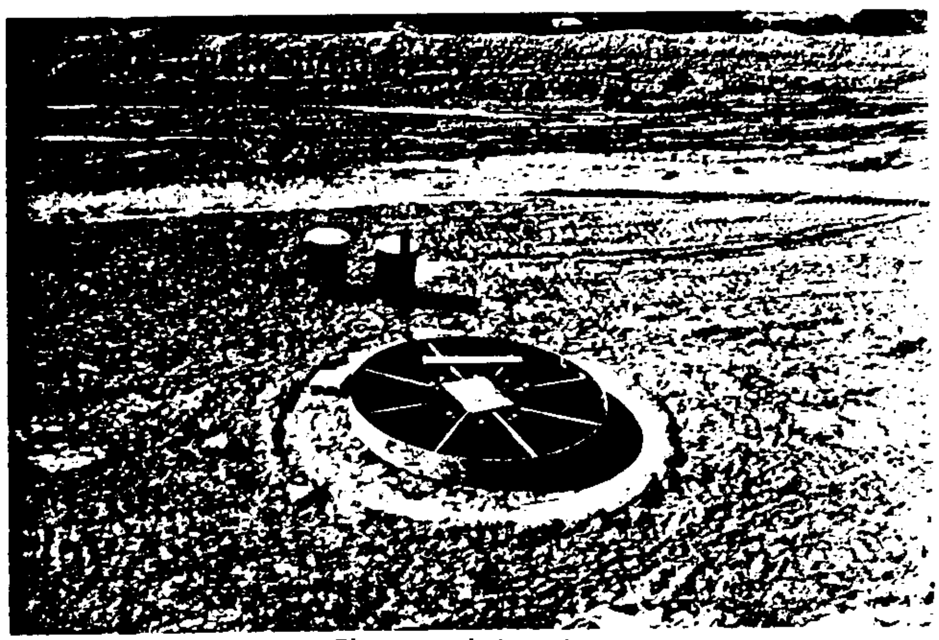
DATE	TIME	Tensiometer Readings (Centibars) No. 2-1 (24 in.)	No. 2-2 (18 in.)	No. 2-3 (12 in.)	No. 2-4 (6 in.)	No. 2-5 (24 in.)	No. 2-6 (18 in.)	No. 2-7 (12 in.)	No. 2-8 (6 in.)
10/24/84	5:42 PM	2.0*	5.0	2.0	2.0	2.0	2.0	3.0	2.0
	11:59 PM	2.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0
10/25/84	7:36 AM	2.0	3.5	2.0	2.0	2.0	2.0	2.0	2.0
	12:12 PM	2.0	7.0	2.0	2.0	2.0	2.0	2.0	2.0
	4:31 PM	2.0	5.5	2.0	2.0	2.0	2.0	2.0	2.0
10/26/84	8:27 AM	2.0	4.5	2.0	2.0	2.0	2.0	2.0	2.0
	5:34 PM	2.0	5.0	2.0	2.0	2.0	2.0	2.0	2.0
10/27/84	1:46 AM	1.0	3.5	2.0	2.0	2.0	2.0	2.0	2.0
	1:51 PM	2.0	5.0	2.0	2.0	2.0	2.0	2.0	2.0
10/28/84	11:47 AM	2.0	4.5	2.0	2.0	2.0	2.0	2.0	2.0
	5:43 PM	2.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0
10/29/84	10:44 AM	2.0	4.5	2.0	2.0	2.0	2.0	2.0	2.0
	3:41 PM	2.0	4.5	2.0	2.0	2.0	2.0	2.0	2.0
	11:07 PM	2.0	2.5	2.0	2.0	2.0	2.0	2.0	2.0
10/30/84	8:23 AM	2.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0
	5:53 PM	2.0	2.5	2.0	2.0	2.0	2.0	2.0	2.0
	11:51 PM	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
10/31/84	7:42 AM	2.0	2.5	2.0	2.0	2.0	2.0	2.0	2.0
	8:59 PM	2.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0

*2.0 cb is the lowest value which can be read on the tensiometer gauge and indicates saturated conditions.

Photograph No. 2 shows the final set-up of the two rings and the evaporation pan. Photographs No. 3 and No. 4 show close-ups of the evaporation pan and Ring No. 1, respectively.



Photograph No. 3
Evaporation Pan



Photograph No. 4
Ring No. 1 with Soil Tensiometers

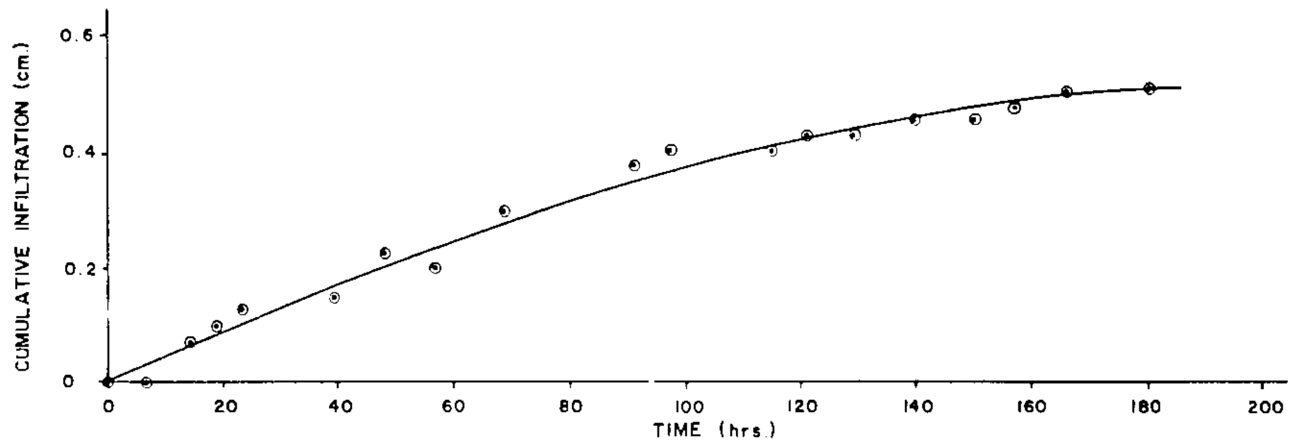
3.0 ANALYSIS

The theory and analysis for the in situ permeability test were developed in the Golder proposal included as Appendix A. The test results were analyzed using equation 4 from Appendix A, as given below.

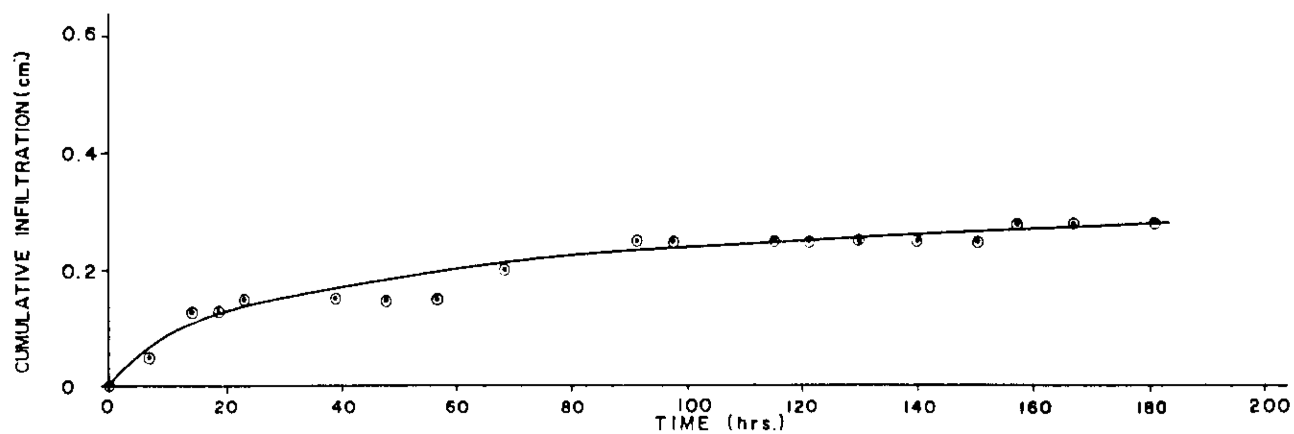
$$i = k\ (1 + D_f/L_f + \psi\ /L_f)$$

The only change to the analytical procedure presented in the original report is the method of determining ψ. The ψ (soil tension) values were not as constant with depth as originally anticipated. Instead, much higher soil tensions were noted at the surface and diminished with depth. In addition, all soil suctions gradually decreased as the wetting front advanced. Therefore, ψ was determined by taking an average value of the soil tensions for the tensiometer being analyzed prior to passage of the wetting front. The intake value, i, for the above equation was determined as the slope of the cumulative infiltration versus time curve at the point in time when the wetting front passed the tensiometer. A plot of cumulative infiltration versus time for each ring is shown in Figure 3.

Due to the dense, plastic nature of the compacted chalk, Golder Associates had anticipated that some of the tensiometers might not respond or may develop leaks along the tensiometer stem during the permeability test. Therefore, two sets of tensiometers were placed in each ring. The tensiometer response in Ring No. 1 was excellent. The wetting front could be tracked in one of the 6 in. tensiometers, both of the 12 in. tensiometers, and both of the 18 in. tensiometers.



RING 2



RING 1

JOB NO. 824 - 1308	SCALE AS SHOWN	CUMULATIVE INFILTRATION	
DRAWN C.A.T.	DATE 11-16-84		
CHECKED	DWG NO. 96		
Golder Associates		CHEMICAL WASTE MANAGEMENT, INC.	FIGURE 3

Note that the 6 in. tensiometer No. 1-8 (see Table 3) shows the wetting front passing at a later time than it had passed the 12 in. tensiometers. This may be attributable to lower permeability material in the area of the 6 in. tensiometer. The tensiometer response in Ring No. 2 was poor. The wetting front could be tracked in only one 18 in. tensiometer. All of the other tensiometers showed saturated conditions which is probably due to rainwater passing down the sides of the tensiometers in Ring No. 2 before the test was begun.

The analysis method presented in Appendix A report assumes vertical flow only and does not consider the effect of lateral soil tension gradients. High lateral gradients result in higher intake rates and artificially high permeability rates if only vertical flow is assumed. Though some lateral flow probably took place during the test, it was not considered a major factor in the test. The rain which occurred prior to test initiation partially saturated the soil around the test site, diminishing soil tensions and thereby reducing lateral effects. The shallow water filled dike surrounding the test rings also helped to diminish the effect of lateral soil tension at the surface.

4.0 RESULTS

The permeability values obtained for both test rings ranged from $1.5x10^{-7}$ cm./sec. to $4.3x10^{-8}$ cm./sec. with the average permeability being $7.8x10^{-8}$ cm./sec. A summary of the permeability values is presented in Table 5.

As can be seen from the results in Table 5, the permeability for the 18 in. wetting front in Ring No. 2 is higher than the corresponding permeabilities for Ring No. 1. There are two possible reasons for the higher permeability in Ring No. 2. First, the soil tensions in Ring No. 2, prior to the rainfall which is considered to have interfered with the tensiometers, were much higher than those in Ring No. 1. This indicates that the soil beneath Ring No. 2 was compacted at slightly dryer moisture contents than the soil beneath Ring No. 1. Visual observations made of the two test areas prior to starting the test also indicated that the area under Ring No. 2 was dryer. This correlates with laboratory data indicating higher permeability values for chalk compacted at lower moisture.

The second factor that may have influenced the results was slightly stronger winds in the area of Ring No. 2. On several occasions, it was difficult to get a reading in Ring No. 2 due to slight wave action, while no wave action was noted in Ring No. 1 or the evaporation pan.

TABLE 5

SUMMARY OF PERMEABILITY DATA

Ring Number	Tensiometer Number	Depth of Wetting Front L_f (in.)	Average Depth Flooding, D_f (in.)	Date and Time of Wetting Front Passage	Infiltration Rate (cm./sec.)	Average Soil Tension (centibars)	Permeability (cm./sec.)
1	1-8	6	11.5	10-28-84 @ 11:41 A.M.	2.8×10^{-7}	5.5	5.9×10^{-8}
1	1-3	12	11.5	10-25-84 @ 4:27 P.M.	4.3×10^{-7}	3.2	1.4×10^{-7}
1	1-7	12	11.5	10-26-84 @ 5:32 P.M.	4.3×10^{-7}	4.7	7.2×10^{-8}
1	1-2	18	11.5	10-29-84 @ 3:37 P.M.	1.3×10^{-7}	2.9	5.7×10^{-8}
1	1-6	18	11.5	10-30-84 @ 5:51 P.M.	1.2×10^{-7}	5.3	4.3×10^{-8}
2	2-2	18	11.5	10-30-84 @ 11:51 P.M.	1.5×10^{-7}	4.2	1.5×10^{-7}

Average Permeability*, Ring 1 = 6.8×10^{-8} cm./sec.
Average Permeability, Ring 2 = 1.5×10^{-7} cm./sec.
Average Permeability, Both Rings = 7.8×10^{-8} cm./sec.

*Average determined using geometric mean.

This is likely due to a slight wind eddy created above Ring No. 2 when northeasterly winds blew over the 20 ft. high chalk wall which bordered the south side of the test area. Stronger winds result in higher evaporation rates. When measuring the small intake rates observed during the test, a slight difference in evaporation rate could have a large impact on test results.

5.0 POST TEST OBSERVATIONS

Upon the completion of the in situ permeability test the test rings were removed and the compacted chalk under each of the rings was excavated. Numerous gravel size to cobble size particles ranging from 1 in. to 4 in. were noted. These particles were surrounded by silt size chalk of a very plastic consistency. The fill which was observed under the rings is typical of the chalk fill compacted wet of optimum at the site.

At a depth of about 12 inches under each test ring, the soil density and moisture content were determined. A sand cone was used to determine the density and the soil moisture was determined by oven drying representative soil samples. The results of these tests are presented in Table 6. The final soil saturations, using a specific gravity of 2.76 as given in the Part B permit application, are 97.5% and 99.3% for Ring No. 1, and Ring No. 2, respectively. Prior to initiating the permeability tests the degree of saturation of the chalk fill located centrally between Ring No. 1 and Ring No. 2 (see compaction test No. T-19-9 in Appendix B) was 90.4%.

TABLE 6

POST TEST DATA

Ring No.	Wet Density ($lb./ft.^3$)	Dry Density ($lb./ft.^3$)	Moisture Content (%)	Saturation (%)
1	126.9	102.2	24.2	97.5
2	127.8	102.8	24.3	99.3

6.0 CONCLUSION

The results of the in situ permeability test show that the laboratory tests are valid and that it is possible to achieve permeabilities on the order of 8×10^{-8} cm./sec. in the field when chalk, with a maximum 4 in. particle size, is compacted to a density equal to or greater than 95% of the Standard Proctor maximum dry density and at a moisture content between 0% and 3% wet of the optimum moisture content as defined by ASTM D-698. In addition, the field test showed that, as indicated by laboratory tests, permeabilities are moisture sensitive with lower permeabilities being achieved in wetter fill.

GOLDER ASSOCIATES

Susan A. Reese
Susan A. Reese
Geotechnical Engineer

J E Baker
J. Edmund Baker, P.E.
Associate

SAR:JEB:das

APPENDIX A

Proposal on
Compacted Fill In Situ Permeability Test

Proposal on

COMPACTED FILL IN SITU PERMEABILITY TEST

Submitted to:

Chemical Waste Management, Inc.
P. O. Box 3065
Marietta, Georgia 30061

DISTRIBUTION:

2 copies - Chemical Waste Management, Inc.
1 copy - Alabama Department of Environmental Management
2 copies - Golder Associates

October 1984

844-1440.6

Golder Associates

CONSULTING GEOTECHNICAL AND MINING ENGINEERS

Proposal on

COMPACTED FILL IN SITU
PERMEABILITY TEST

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October 1984 844-1440.6

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

October 2, 1984 844-1440.6

Chemical Waste Management
P.O. Box 3065
Marietta, GA 30061

Attn: Mr. Don R. McCombs, P.E.

Re: In Situ Permeability Testing of Trench 19 Fill
Emelle Facility

Gentlemen:

Please find enclosed our technical proposal to perform in situ permeability tests of the chalk fill around Trench 19. The tests proposed are two large diameter (10 ft) ring infiltrometers with associated underlying soil tension and evaporation monitoring.

Golder Associates considers a test of this type in such low permeability unsaturated material to be quite difficult to accurately perform and interpret. Therefore, significant redundancy is provided.

At your request, we are forwarding a copy of this proposal to Mr. Samuel W. Shannon of ADEM via overnite courier for his review. We appreciate the opportunity to work with CWM on this task and should you have any questions, please contact us.

Very truly yours,

GOLDER ASSOCIATES

J. Edmund Baker, P.E.
Associate

JEB/bja

1.0 INTRODUCTION AND BACKGROUND

Chemical Waste Management, Inc. is constructing a land disposal cell at its Emelle Facility in accordance with plans and specifications submitted to the Alabama Department of Environmental Management (ADEM). These plans were entitled "Lined Landfill Disposal Cell Design" and were dated June, 1984. These plans include land disposal cells which are approximately 300 ft. by 300 ft. in plan area, side slopes of 2.5 hor.:1.0 ver., a leachate collection system and a synthetic membrane (HDPE) liner. The liner will be placed on compacted chalk fill which has been placed under moisture and density quality control. The cell currently under construction is designated as Trench 19 and is ready for liner placement.

Laboratory tests performed by Golder Associates on compacted chalk indicate that permeabilities (hydraulic conductivity) on the order of 6×10^{-8} cm/sec can be achieved in compacted chalk when compacted to a density equal to or greater than 95% of the Standard Proctor maximum dry density and at a moisture content at or 3% wet of the optimum moisture content as defined by ASTM D-698. In order to verify that these permeability volumes can be achieved in the field, an in situ permeability test has been proposed in the Trench 19 backfill. This chalk fill was tested by Golder Associates at regular intervals as specified in the plans and specifications. The in situ permeability test has been designed by and will be monitored by Golder Associates. The following sections outline the theory, setup and analysis of this test.

2.0 IN SITU PERMEABILITY TEST SETUP

The in situ permeability test chosen is a large diameter ring infiltrometer test. This test was chosen because:

1) A relatively large mass of in situ fill is tested, therefore, the results should reflect actual permeabilities that can be achieved in the fill.

2) Primarily vertical flow is induced, thus simplifying the analysis.

3) A significant body of literature has been developed regarding the test setup and analysis.

It should be noted, however, that any in situ permeability test on an unsaturated fill with a permeability on the order of 6 x 10^{-8} cm/sec is a nonstandard test which must be setup, run and analyzed with extreme care. A recent paper by David E. Daniel entitled "Predicting Hydraulic Conductivity of Clay Liners" pointed out that without proper field compaction control and test analysis, overestimation of field permeability with respect to laboratory determined permeability is common. In addition, the interpretation of the results must be done in conjunction with laboratory data and the expected purpose of the fill.

The large ring infiltrometer test consists of a 10 ft. diameter ring about 18 in. high placed securely on the chalk fill and filled with about 12 in. of water. The infiltration, evaporation and underlying soil tension (moisture) must be measured during the test. Figure 1 shows the ring and evaporation pan in section.

The infiltration rate will be very small, on the order of millimeters per hour, and evaporation will be significant. Therefore, an evaporation pan will be constructed of approximately the same dimensions and material as the infiltrometer and placed immediately adjacent the test area with the same exposure to wind and sun. Evaporation from this pan will be read each time the infiltration is measured and the evaporation losses will be assumed to apply to the infiltrometer.

In order to provide redundancy, two ring infiltrometers will be set up and run. Figure 2 shows the plan layout of the two ring infiltrometers and the evaporation pan with respect to Trench 19.

The capillary suction or soil tension in the chalk fill is a significant force which will act to speed the advance of the moisture into the chalk. If this factor is not considered in the analysis of the test results, the permeability of the chalk may be significantly overestimated. Therefore, soil tensiometers will be placed at various depths in the chalk fill in the flooded area of the infiltrometer in order to quantify this force. Tensiometers will be placed in the chalk at depths of 6 in., 12 in., 18 in. and 24 in.; two sets of tensiometers will be installed to provide redundancy. Preliminary test show that 24 to 48 hours will be required for the tensiometers to stabilize in the low permeability chalk. It should also be noted that measurement of tension in very fine grained, low permeability is difficult. As will be discussed in the next section, measurement of the absolute tension the soil is not strictly necessary since the tensiometers will reflect saturated conditions (i.e. tension of zero) accurately.

The water levels in both of the infiltrometers and in the evaporation pan will be measured in the same manner. The small infiltration rates require that a measurement method free of interference from surface tension or menisci be used. Therefore, a pointed hook will be used which will slide along an engineers scale and will be raised until the tip breaks the water surface. This setup is shown on Figure 3. This system provides very sensitive readings of water levels.

The above outlined setup and test performance is summarized in the following list of procedures:

1. Compare chalk fill to "specified" density and moisture with testing at a minimum frequency of one every 2,500 c.y.

2. Prevent compacted chalk surface in the test area from drying by covering with plastic sheeting to avoid desiccation cracking.

3. Install a 10 ft. diameter ring infiltrometer; seal infiltrometer in compacted chalk by placing ring in a trench excavated about 6 in. deep. Backfill the trench around the ring with a mixture of chalk and bentonite to minimize the possibility of getting seepage around the ring.

4. Install four soil tensiometers to approximately 6 in., 12 in., 18 in., and 24 in. depths. Carefully measure actual placement depths.

5. Install water level monitoring gage in infiltrometer.

6. Allow soil tensiometers to stabilize and record initial soil tension.

7. Construct an evaporation test ring with an impermeable bottom between 5 ft. and 10 ft. in diameter with the same freeboard as the ring infiltrometer. Measure evaporation losses when

infiltrometer is measured. Place in same area as test ring with respect to wind and sun exposure.

8. Fill ring with approximately 12 in. of water being very careful not to suspend fine particles. Use a splash pad and lay the hose on the bottom of the ring.

9. Check for leaks around the outside of the ring. Tamp soil tightly to spot leaks if they occur. If leaks cannot be stopped, pump out ring and reinstall.

10. Immediately begin measuring infiltration rate, evaporation rate, recording soil tension and time.

11. Maintain water levels in ring within ± 1 in. of 12 in. during test, carefully recording depth changes and times of filling.

12. Continue test until a steady state infiltration rate is reached or until saturated zone has passed 3 of the tensiometers.

3.0 TEST THEORY AND ANALYSIS

The ring infiltrometer tests effectively measures the rate of infiltration of water into the chalk fill and the advance of the resulting saturated wetting front. The theory of the unsaturated/saturated flow induced by this test is straight forward, allowing simple analysis. However, the extremely low chalk permeability dictates that extreme precision be used in performing the test and unavoidable measurement inaccuracies will cause variations in the test results.

The object of this test is to measure the saturated permeability (hydraulic conductivity) of the in situ chalk. The saturated permeability of the chalk can be computed using a form of Darcy's Law which includes both a gravity gradient and a tension gradient. The equation governing the flow of water into the chalk is developed below. The terms are shown in the sketch included as Figure 4.

$$i = k(dh/dz) \qquad (1)$$

where: i = infiltration rate per unit area (L/T)

k = saturated permeability (hydraulic conductivity) (L/T)

dh/dz = combined gravity and tension gradient(L/L)

ψ = soil tension (L)

Separating terms for estimation of gradient term at points 1 and 2 taken at ground surface and immediately below the wetting front (see Figure 4):

$$i = k[(\psi_1+Z_1) - (\psi_2+Z_2)]/L_f \qquad (2)$$

Rewritting:

$$i = k[1+(\psi_1/L_f) - (\psi_2/L_f)] \qquad (3)$$

By reviewing Figure 4, it can be seen that at point 1 the soil tension is equal to the depth of flooding, or $\psi_1 = D_f$. Also, since the chalk fill was placed at a controlled, relatively constant moisture content and density, it can be assumed that the in situ soil tension will be negative and constant with depth in the range of the test (upper 5 ft.). Therefore ψ_2 is constant and will be designated simply as ψ. Substituting into equation 3:

$$i = k[1+(D_f/L_f) + (\psi/L_f)] \qquad (4)$$

The above equation is time dependent. That is, the infiltration rate i and L_f are interrelated and vary throughout the test. The infiltration rate decreases as the wetting front advances.

The test will be analyzed by plotting the infiltration rate with time. The wetting front position, L_f, will be known when the soil tension at that depth goes to zero, and will be registered on the soil tensiometer. By having four tensiometers, several estimates of permeability can be back calculated using equation 4.

The in situ soil suction will be taken as the average stabilized reading (prior to test startup) of the three lower tensiometers. The uppermost tensiometer will quite likely be different due to surface wetting to avoid desiccation cracking. However, there is a possibility that the in situ soil tension will be greater than one atmosphere, which is the limit of the tensiometers. In this event, the test will be analyzed by two sets of measured infiltration rates and wetting front depths. The two resulting forms of equation 4 can be solved simultaneously for the two unknown values, K and ψ. Several such pairs will be analyzed for comparison.

This procedure will give significant redundancy in that two infiltrometers and two sets of tensiometers in each infiltrometer will be used. Because of the time expected required to complete the test, it is important that redundancy be built into the procedures.

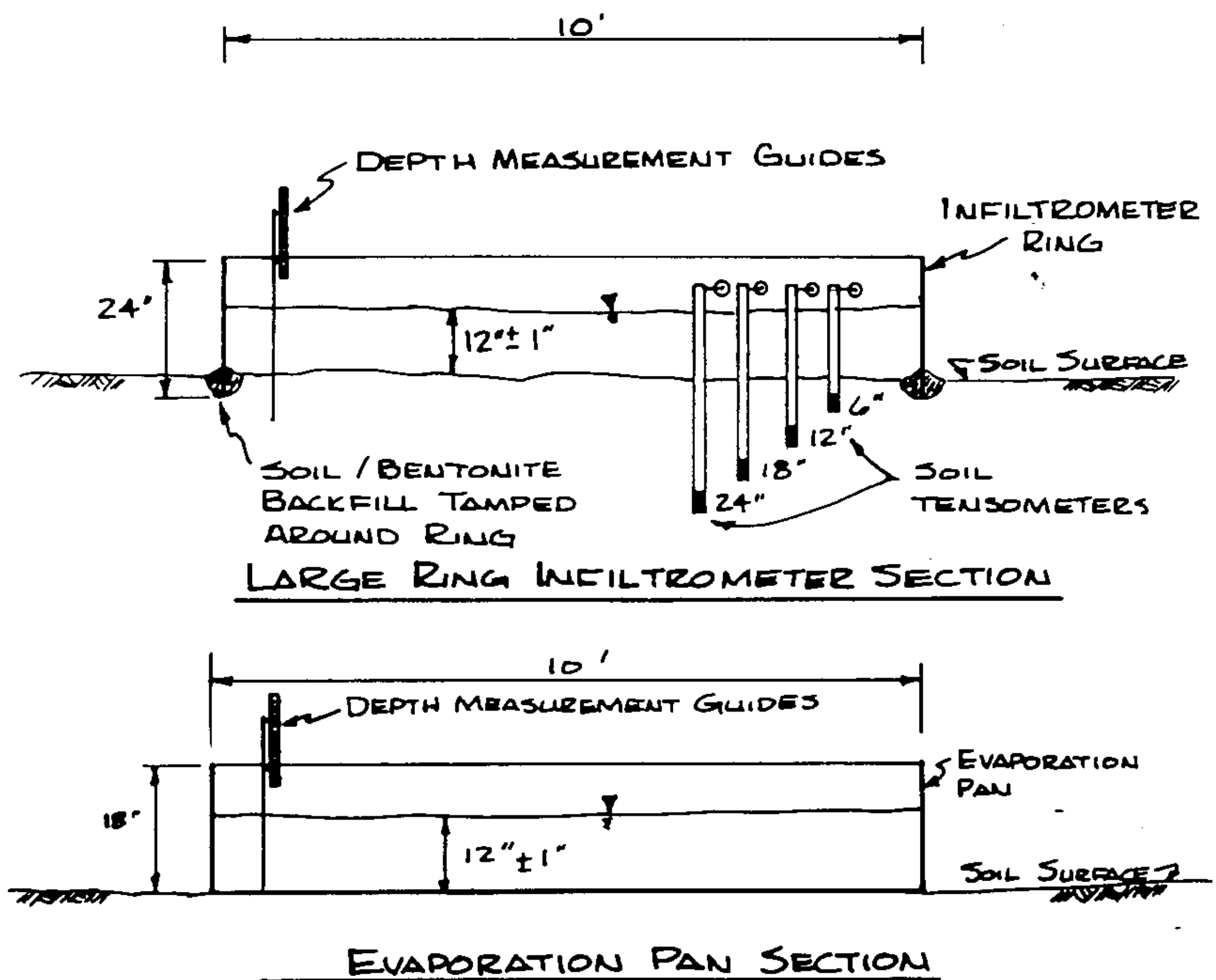
4.0 SUMMARY

In summary, a highly redundant in situ permeability test will be performed on the recently completed compacted chalk fill around Trench 19 at CWM's Emelle Facility. Any such test in low permeability, unsaturated soils is approximate at best and must be run with extreme caution and precision. Also, analysis of the test results must include soil tension which will act as "inverted capillarity", thus hastening the advance of the wetting front and increasing the observed infiltration rate. The procedures outlined herein are designed to achieve the most accurate results possible. However, interpretation of the test results should be done in conjunction with previously presented laboratory results and the intended purpose of the fill material. Such interpretation within the overall context of the disposal system design is considered by Golder Associates to be desirable and necessary.

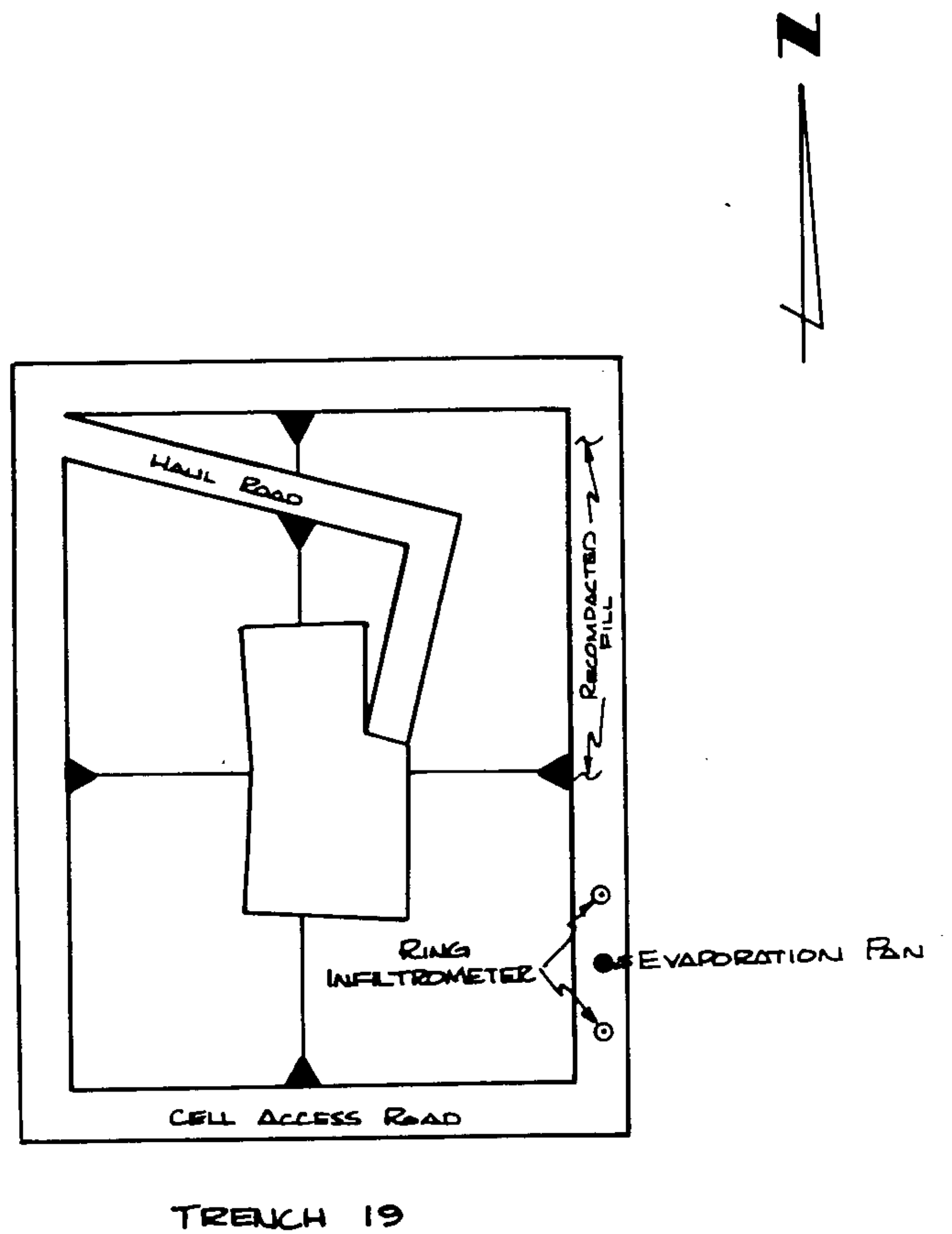
GOLDER ASSOCIATES

J. E. Baker, P.E.
Associate

JEB/tlh

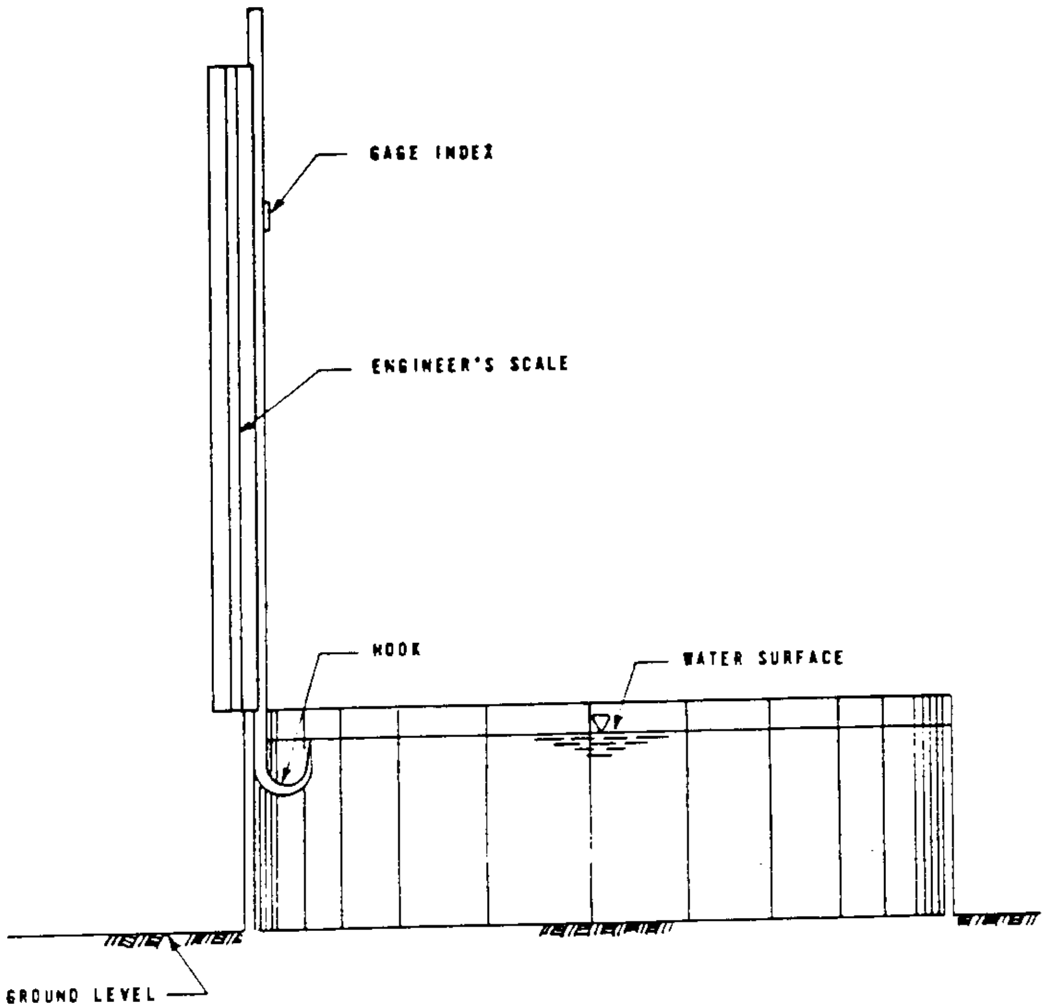


JOB NO. 824-1308	SCALE 1" = 2.5'	LARGE RING INFILTROMETER AND EVAPORATION PAN
DRAWN SKB	DATE 9-25-84	
CHECKED DEB	DWG. NO. 89	
Golder Associates		CHEMICAL WASTE MANAGEMENT, INC. — FIGURE 1

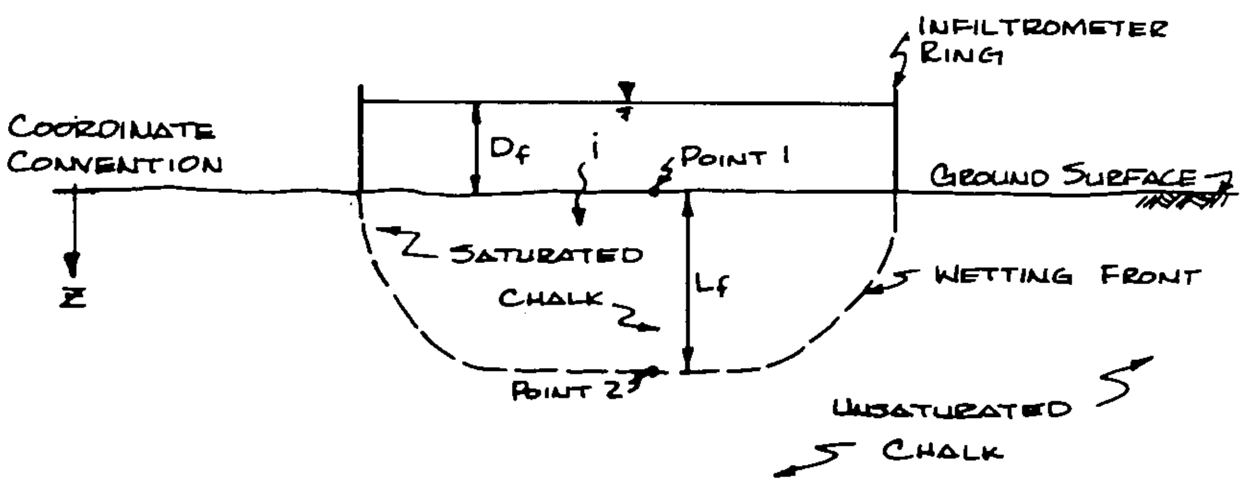


JOB NO. 824-1308	SCALE 1" = 100'	PLAN LOCATION of RING INFILTROMETER AND EVAPORATION PAN
DRAWN SKB	DATE 10-1-84	
CHECKED SAR	DWG. NO. 91	
Golder Associates		CHEMICAL WASTE MANAGEMENT, INC. — FIGURE 2

AF 20440A-B



JOB NO 824 - 1308	SCALE NOT TO SCALE	DETAIL OF SETUP TO MEASURE WATER LEVEL
DRAWN SKB	DATE 10-1-84	
CHECKED PEB	DWG NO. 92	
Golder Associates		CHEMICAL WASTE MANAGEMENT, INC. — FIGURE 3



TERMS

i = INFILTRATION RATE (L/T)

Lf = DEPTH OF WETTING FRONT (L)

Df = DEPTH OF FLOODING (L)

JOB NO. 824-1508	SCALE NOT TO SCALE	VERTICAL INFILTRATION THEORY
DRAWN SKB	DATE 10-1-84	
CHECKED SAR	DWG. NO. 90	
Golder Associates		CHEMICAL WASTE MANAGEMENT, INC. — FIGURE 4

APPENDIX B

Compaction Test Results

FIELD DENSITY TEST RECORD – SAND CONE METHOD ASTM D 1556

TEST NUMBER T-19-1 LOCATION E Wall ELEVATION ______ JOB NUMBER 824-1508.30
JOB NAME WMI/EMELLE/AL

IN SITU DENSITY — SAND CONE METHOD

SAND CONE NO. 1 SAND = 95.9 lb./ft.³

CONTAINER NUMBER		
WT. CONTAINER + SOIL, lb.	4.76	
CONTAINER WEIGHT, lb.	0.03	
WEIGHT OF SOIL, lb.	4.73	
INITIAL WT. (SAND + CONE), lb.	17.02	
FINAL WT. (SAND + CONE), lb.	9.42	
WT. OF SAND USED, lb.	7.60	
CONE CORRECTION WT., lb.	3.86	
NET WT. OF SAND, lb.	3.74	
VOLUME, ft.³	0.03899	
WET DENSITY, lb./ft.³	121.3	
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2	T-1
WT. WET SOIL + CONTAINER, gm.	278.3	282.7
WT. DRY SOIL + CONTAINER, gm.	247.8	234.9
WT. CONTAINER, gm.	111.1	9.5
WT. WATER, gm.	30.5	47.8
WT. DRY SOIL, gm.	136.7	225.4
MOISTURE CONTENT %	22.3	21.2
DRY DENSITY, lb./ft.³	99.2	100.1

PROCTOR COMPACTION TEST

☒ STANDARD ☐ MODIFIED ☐ 4" ☒ 6" ☒ ONE-POINT METHOD ☐ RAPID THREE-POINT METHOD ☐ OTHER ______

MOLD NO. ______
MOLD VOLUME = 1/13.304 ft.³

WT. MOLD + WET SOIL, lb.	23.27			
WT. MOLD, lb.	14.43			
WT. WET SOIL, lb.	8.84			
WET DENSITY, lb./ft.³	117.6			
ADDED WATER % OF TOTAL WEIGHT				
CONVERTED WET DENSITY, lb./ft.³				
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2	1022		
WT. WET SOIL + CONTAINER, gm.	285.3	322.3		
WT. DRY SOIL + CONTAINER, gm.	257.8	275.1		
WT. CONTAINER, gm.	111.1	9.7		
WT. WATER, gm.	27.5	47.2		
WT. DRY SOIL, gm.	146.7	265.4		
MOISTURE CONTENT, %	18.7	17.8		
DRY DENSITY, lb./ft.³	99.6	99.8		

MATERIAL DESCRIPTION: Chalk

PROCTOR CURVE NUMBER	1
MAX. DRY DENSITY, lb./ft.³	102.1
OPT. MOISTURE CONTENT, %	20.5
PERCENT COMPACTION	97.61
DIFFERENCE FROM O.M.C.	1.8

SPECIFICATIONS:
95 % STANDARD MODIFIED
0 to 3 % OF O.M.C.

RESULTS:
☒ PASS
☐ FAIL
☐ DENSITY
☐ MOISTURE

REMARKS: ______

GOLDER ASSOCIATES

DATE TESTED: 9/24/84 TESTED BY: SAR CHECKED BY: MAS

COMPACTION TEST REFERENCE CURVES

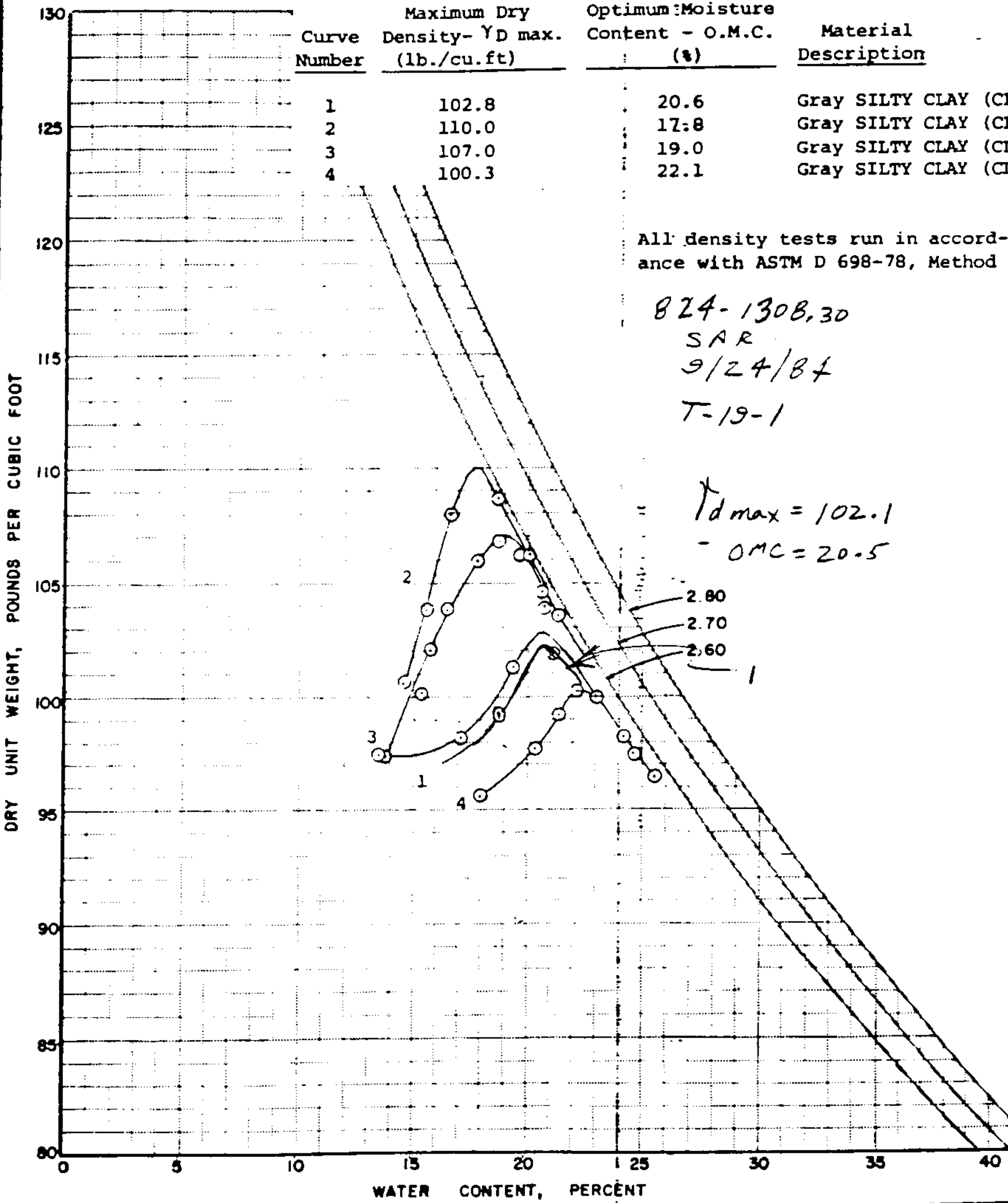
FIGURE 6

Curve Number	Maximum Dry Density- γ_D max. (lb./cu.ft)	Optimum Moisture Content - O.M.C. (%)	Material Description
1	102.8	20.6	Gray SILTY CLAY (CL)
2	110.0	17.8	Gray SILTY CLAY (CL)
3	107.0	19.0	Gray SILTY CLAY (CL)
4	100.3	22.1	Gray SILTY CLAY (CL)

All density tests run in accordance with ASTM D 698-78, Method C.

824-1308,30
SAR
9/24/87
T-19-1

$\gamma_{d\,max} = 102.1$
OMC = 20.5



Date 9/2/82
Job No. 824-1308

Golder Associates

Drawn SKB
Checked LKO
Approved WJN

FIELD DENSITY TEST RECORD – SAND CONE METHOD ASTM D 1556

TEST NUMBER T-19-2 LOCATION E Wall ELEVATION ______ JOB NUMBER 824-1308.30
JOB NAME CWM/Emelle/Al

IN SITU DENSITY SAND CONE NO. 1	SAND CONE METHOD SAND: 95.9 lb./ft.³	
CONTAINER NUMBER		
WT. CONTAINER + SOIL, lb.	4.25	
CONTAINER WEIGHT, lb.	0.02	
WEIGHT OF SOIL, lb.	4.23	
INITIAL WT. (SAND + CONE), lb.	16.19	
FINAL WT. (SAND + CONE), lb.	9.10	
WT. OF SAND USED, lb.	7.09 ✓	
CONE CORRECTION WT., lb.	3.86	
NET WT. OF SAND, lb.	3.23 ✓	
VOLUME, ft.³	0.03368	
WET DENSITY, lb./ft.³	125.6 ✓	
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2	1066
WT. WET SOIL + CONTAINER, gm.	376.6	265.8
WT. DRY SOIL + CONTAINER, gm.	329.9	219.1
WT. CONTAINER, gm.	111.1	9.4
WT. WATER, gm.	46.7 ✓	46.7 ✓
WT. DRY SOIL, gm.	218.8 ✓	209.7 ✓
MOISTURE CONTENT %	21.3 ✓	22.3 ✓
DRY DENSITY, lb./ft.³	103.5 ✓	102.7 ✓

PROCTOR COMPACTION TEST

☐ STANDARD ☐ MODIFIED ☐ 4" ☒ 6" ☒ ONE-POINT METHOD ☐ RAPID THREE-POINT METHOD ☐ OTHER ______

MOLD NO. ______
MOLD VOLUME: 1/13.[illegible] ft.³

WT. MOLD + WET SOIL, lb.	23.51			
WT. MOLD, lb.	14.43			
WT. WET SOIL, lb.	9.08 ✓			
WET DENSITY, lb./ft.³	120.8 ✓			
[illegible] % OF TOTAL WEIGHT				
CONVERTED WET DENSITY, lb./ft.³				
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2	1064		
WT. WET SOIL + CONTAINER, gm.	319.5	272.4		
WT. DRY SOIL + CONTAINER, gm.	290.1	233.4		
WT. CONTAINER, gm.	111.1	9.5		
WT. WATER, gm.	29.4 ✓	39 ✓		
WT. DRY SOIL, gm.	179 ✓	223.9 ✓		
MOISTURE CONTENT, %	16.4 ✓	17.4 ✓		
DRY DENSITY, lb./ft.³	103.8 ✓	102.9 ✓		

MATERIAL DESCRIPTION: chalk

PROCTOR CURVE NUMBER	2
MAX DRY DENSITY, lb./ft.³	107 ✓
OPT. MOISTURE CONTENT, %	19.0 ✓
PERCENT COMPACTION	96.7 ✓
DIFFERENCE FROM O.M.C.	2.3

SPECIFICATIONS: 95 % STANDARD MODIFIED; 0 to 3 % OF O.M.C.

RESULTS: ☒ PASS ☐ FAIL ☐ DENSITY ☐ MOISTURE

REMARKS: Need to [illegible]
[illegible]
Looked wet of opt.

GOLDER ASSOCIATES

DATE TESTED: 9/25/84 TESTED BY: SAE CHECKED BY: MAS

COMPACTION TEST REFERENCE CURVES

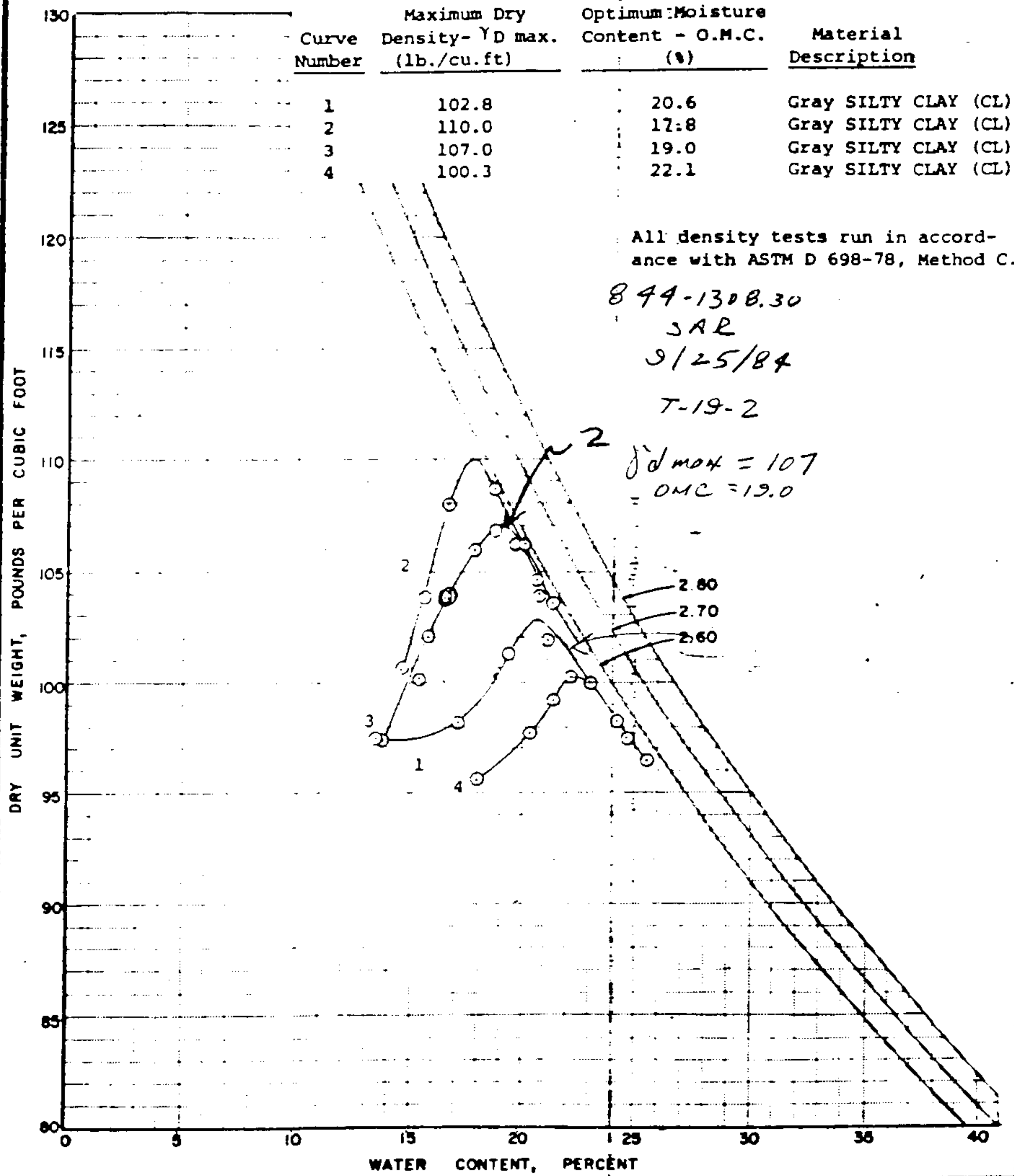
FIGURE 6

Curve Number	Maximum Dry Density- γD max. (lb./cu.ft)	Optimum Moisture Content - O.M.C. (%)	Material Description
1	102.8	20.6	Gray SILTY CLAY (CL)
2	110.0	17.8	Gray SILTY CLAY (CL)
3	107.0	19.0	Gray SILTY CLAY (CL)
4	100.3	22.1	Gray SILTY CLAY (CL)

All density tests run in accordance with ASTM D 698-78, Method C.

844-1308.30
SAR
9/25/84
T-19-2

γd max = 107
OMC = 19.0



Date 9/2/82
Job No. 824-1308

Golder Associates

Drawn SKB
Checked LKO
Approved WJN

FIELD DENSITY TEST RECORD – SAND CONE METHOD ASTM D 1556

TEST NUMBER T-19-3 LOCATION Enwall ELEVATION ______ JOB NUMBER 827-1308.30
JOB NAME CWM/EMELLE/AL

IN SITU DENSITY — SAND CONE METHOD

SAND CONE NO. 1 SAND = 95.9 lb./ft.³

CONTAINER NUMBER		
WT. CONTAINER + SOIL, lb.	5.265	
CONTAINER WEIGHT, lb.	0.02	
WEIGHT OF SOIL, lb.	5.245	
INITIAL WT. (SAND + CONE), lb.	16.10	
FINAL WT. (SAND + CONE), lb.	8.17	
WT. OF SAND USED, lb.	7.93 ✓	
CONE CORRECTION WT., lb.	3.86	
NET WT. OF SAND, lb.	4.07 ✓	
VOLUME, ft.³	0.04244	
WET DENSITY, lb./ft.³	123.6 ✓	
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2	1054
WT. WET SOIL + CONTAINER, gm.	296.4	359.1
WT. DRY SOIL + CONTAINER, gm.	268.4	302.0
WT. CONTAINER, gm.	111.1	9.4
WT. WATER, gm.	28 ✓	57.1 ✓
WT. DRY SOIL, gm.	157.3 ✓	292.6 ✓
MOISTURE CONTENT %	17.8 ✓	19.5 ✓
DRY DENSITY, lb./ft.³	104.9 ✓	103.4 ✓

PROCTOR COMPACTION TEST

☒ STANDARD ☐ MODIFIED ☐ 4" ☒ 6" ☒ ONE-POINT METHOD ☐ RAPID THREE-POINT METHOD ☐ OTHER ______

MOLD NO. ______
MOLD VOLUME = 1/13.33 ft.³

WT. MOLD + WET SOIL, lb.	23.02			
WT. MOLD, lb.	14.43			
WT. WET SOIL, lb.	8.59 ✓			
WET DENSITY, lb./ft.³	114.3 ✓			
ADDED WATER % OF TOTAL WEIGHT				
CONVERTED WET DENSITY, lb./ft.³				
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A2	1065		
WT. WET SOIL + CONTAINER, gm.	285.3	324.6		
WT. DRY SOIL + CONTAINER, gm.	260.0	280.1		
WT. CONTAINER, gm.	111.1	9.6		
WT. WATER, gm.	25.3 ✓	44.5 ✓		
WT. DRY SOIL, gm.	148.9 ✓	270.5 ✓		
MOISTURE CONTENT, %	17.0 ✓	16.4 ✓		
DRY DENSITY, lb./ft.³	97.7 ✓	98.2 ✓		

MATERIAL DESCRIPTION:
Use oven
dry test – probably did not dry quick fry enough
Material looked closer to 19.5

PROCTOR CURVE NUMBER	3
MAX. DRY DENSITY, lb./ft.³	102.2 ✓
OPT. MOISTURE CONTENT, %	20.6 ✓
PERCENT COMPACTION	101.2 ✓
DIFFERENCE FROM O.M.C.	1.1

SPECIFICATIONS:
95 % STANDARD MODIFIED
0 to 3 % OF O.M.C.

RESULTS: ☒ PASS ☐ FAIL ☐ DENSITY ☐ MOISTURE
wetted surface + placed next lift very wet – should now be wet of opt.

REMARKS: Looked wet of opt. or at opt.

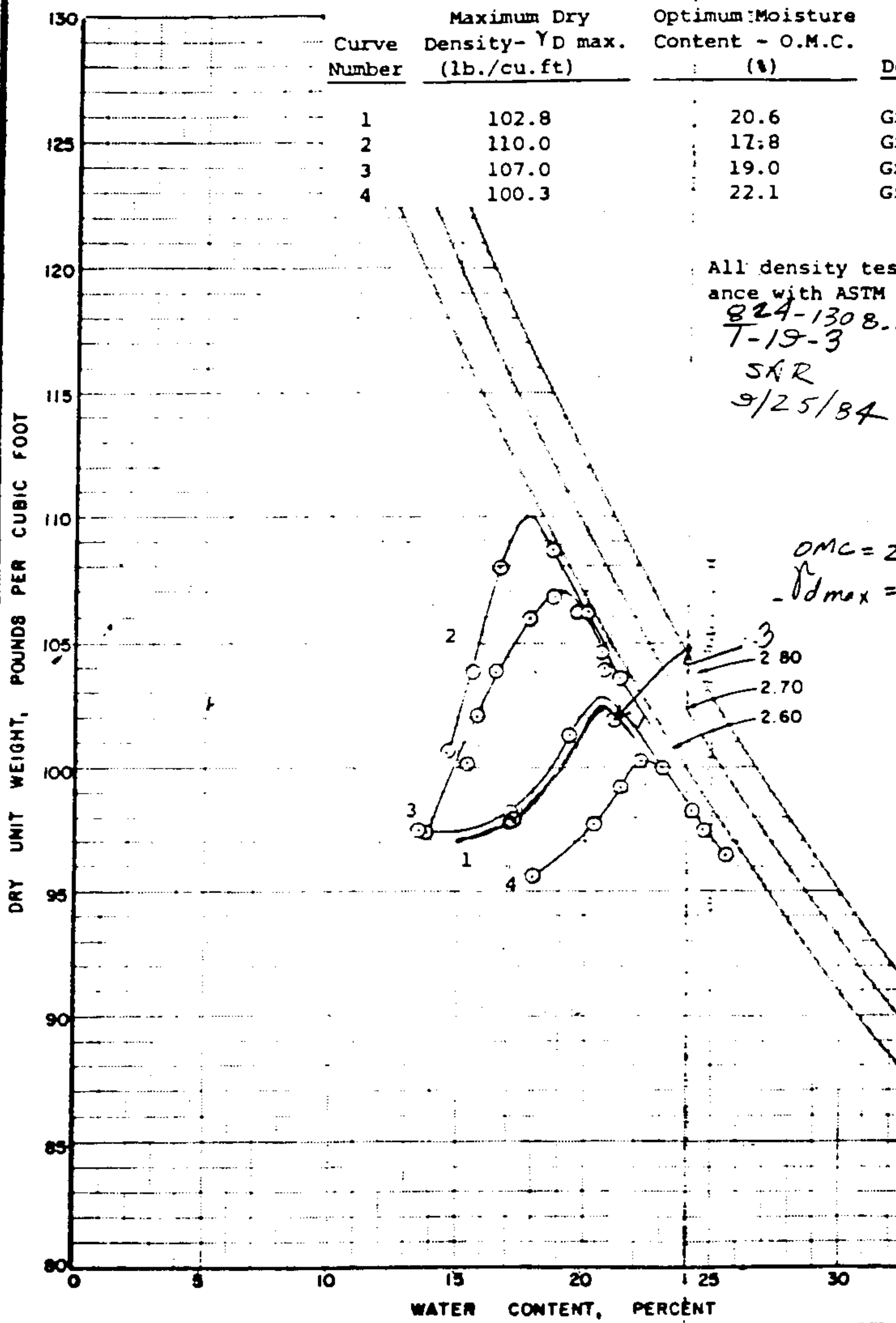
GOLDER ASSOCIATES

DATE TESTED: 9/25/84 TESTED BY: SAB CHECKED BY: MAS

COMPACTION TEST REFERENCE CURVES

Curve Number	Maximum Dry Density- γD max. (lb./cu.ft)	Optimum Moisture Content - O.M.C. (%)	De
1	102.8	20.6	Gr
2	110.0	17.8	Gr
3	107.0	19.0	Gr
4	100.3	22.1	Gr

All density test
ance with ASTM I



Date 9/2/82
Job No. 824-1308

Golder Associates

Dr
Ch
A

N ← 160' 23' 2' ...

FIELD DENSITY TEST RECORD – SAND CONE METHOD ASTM D 1556

TEST NUMBER T-19-4 LOCATION E. Wall ELEVATION ______ JOB NUMBER 824-[illegible] JOB NAME CWM/EMELLE/AL

IN SITU DENSITY — SAND CONE METHOD

SAND CONE NO. 1 SAND = 95.9 lb./ft.³

CONTAINER NUMBER		
WT. CONTAINER + SOIL, lb.	4.57	
CONTAINER WEIGHT, lb.	0.02	
WEIGHT OF SOIL, lb.	4.55	
INITIAL WT. (SAND + CONE), lb.	16.14	
FINAL WT. (SAND + CONE), lb.	8.84	
WT. OF SAND USED, lb.	7.30 ✓	
CONE CORRECTION WT., lb.	3.86	
NET WT. OF SAND, lb.	3.44 ✓	
VOLUME, ft.³	0.03587	
WET DENSITY, lb./ft.³	126.8 ✓	
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2	51
WT. WET SOIL + CONTAINER, gm.	257.8	250.1
WT. DRY SOIL + CONTAINER, gm.	231.8	209.3
WT. CONTAINER, gm.	111.1	9.8
WT. WATER, gm.	26 ✓	40.8 ✓
WT. DRY SOIL, gm.	120.7 ✓	199.5 ✓
MOISTURE CONTENT %	21.5 ✓	20.4 ✓
DRY DENSITY, lb./ft.³	104.4 ✓	105.3 ✓

PROCTOR COMPACTION TEST

☒ STANDARD ☐ MODIFIED ☐ 4" ☒ 6" ☒ ONE-POINT METHOD ☐ RAPID THREE-POINT METHOD ☐ OTHER ______

MOLD NO. ______
MOLD VOLUME = 1/13.304 ft.³

WT. MOLD + WET SOIL, lb.	23.18			
WT. MOLD, lb.	14.43			
WT. WET SOIL, lb.	8.75 ✓			
WET DENSITY, lb./ft.³	116.4 ✓			
ADDED WATER % OF TOTAL WEIGHT				
CONVERTED WET DENSITY, lb./ft.³				
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2	1055		
WT. WET SOIL + CONTAINER, gm.	297.0	312.2		
WT. DRY SOIL + CONTAINER, gm.	270.0	267.9		
WT. CONTAINER, gm.	111.1	10.1		
WT. WATER, gm.	27 ✓	44.3 ✓		
WT. DRY SOIL, gm.	158.9 ✓	257.8 ✓		
MOISTURE CONTENT, %	17.0 ✓	17.2 ✓		
DRY DENSITY, lb./ft.³	99.5 ✓	99.3 ✓		

MATERIAL DESCRIPTION: Chalk

PROCTOR CURVE NUMBER	4
MAX. DRY DENSITY, lb./ft.³	104.0 ✓
OPT. MOISTURE CONTENT, %	20% ✓
PERCENT COMPACTION	100.4 ✓
DIFFERENCE FROM O.M.C.	1.5 ✓

SPECIFICATIONS: 95 % STANDARD MODIFIED; 0 ± 3 % OF O.M.C.

RESULTS: ☒ PASS ☐ FAIL ☐ DENSITY ☐ MOISTURE

REMARKS: Test looked good - very compact + wet of opt.

GOLDER ASSOCIATES

DATE TESTED: 9/25/84 TESTED BY: SKR CHECKED BY: MAS

COMPACTION TEST REFERENCE CURVES

FIGURE 6

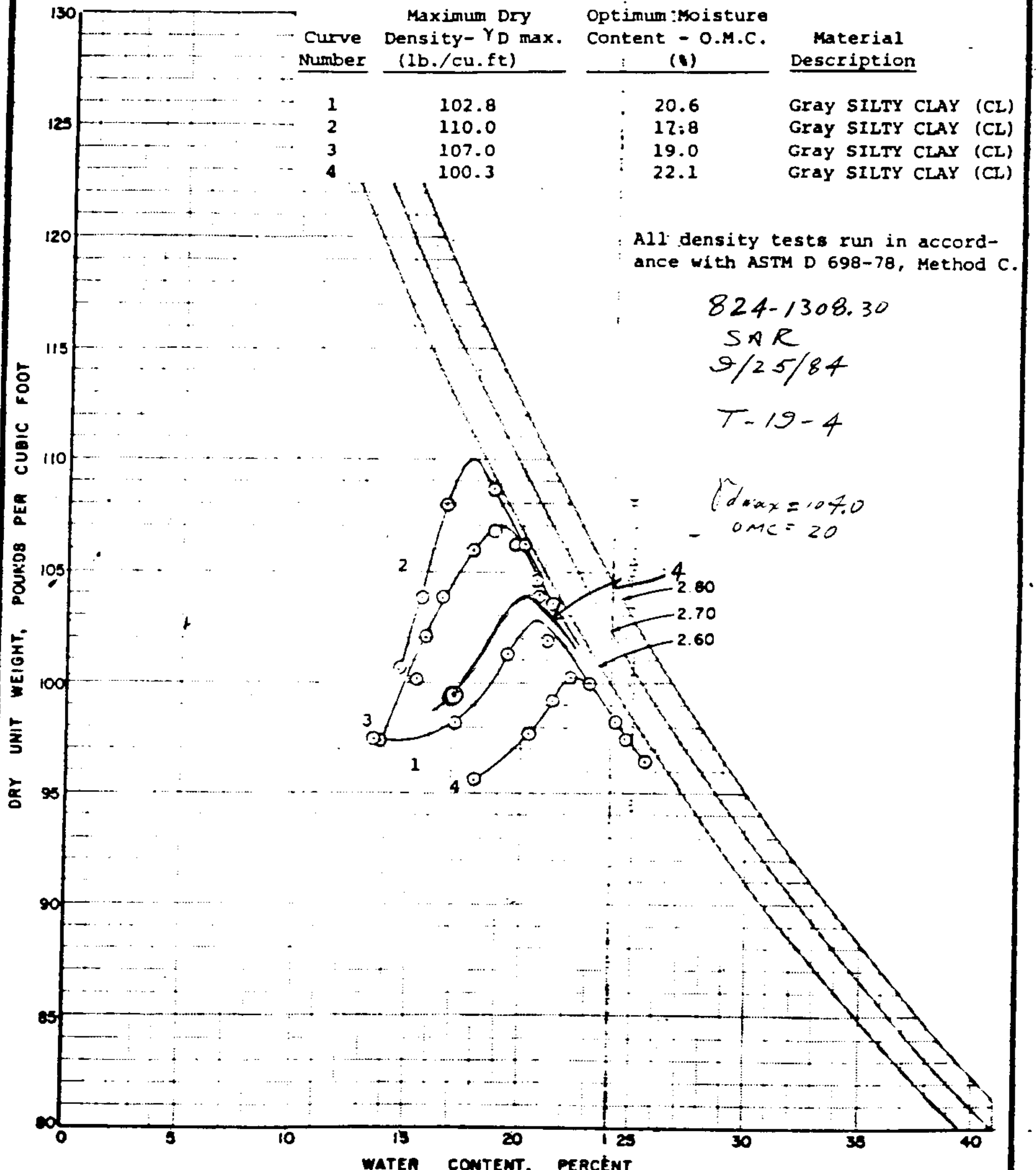
Curve Number	Maximum Dry Density- γ_D max. (lb./cu.ft)	Optimum Moisture Content - O.M.C. (%)	Material Description
1	102.8	20.6	Gray SILTY CLAY (CL)
2	110.0	17.8	Gray SILTY CLAY (CL)
3	107.0	19.0	Gray SILTY CLAY (CL)
4	100.3	22.1	Gray SILTY CLAY (CL)

All density tests run in accordance with ASTM D 698-78, Method C.

824-1308.30
SAR
9/25/84

T-19-4

$\gamma_{d\,max}$ = 104.0
OMC = 20



Date 9/2/82
Job No. 824-1308

Golder Associates

Drawn SKB
Checked LKO
Approved WJN

N ← 50' 25' 7' down from top

FIELD DENSITY TEST RECORD – SAND CONE METHOD ASTM D 1556

TEST NUMBER T-19-5 LOCATION E. Wall ELEVATION ______ JOB NUMBER 824-1409.30
JOB NAME CWM / EMELLE, AL

IN SITU DENSITY — SAND CONE METHOD

SAND CONE NO. 1 SAND = 95.9 lb./ft.³

CONTAINER NUMBER		
WT. CONTAINER + SOIL, lb.	4.94	
CONTAINER WEIGHT, lb.	0.01	
WEIGHT OF SOIL, lb.	4.93 ✓	
INITIAL WT. (SAND + CONE), lb.	15.855	
FINAL WT. (SAND + CONE), lb.	8.260	
WT. OF SAND USED, lb.	7.595 ✓	
CONE CORRECTION WT., lb.	3.86	
NET WT. OF SAND, lb.	3.735 ✓	
VOLUME, ft.³	0.03895	
WET DENSITY, lb./ft.³	126.6 ✓	
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2	1023
WT. WET SOIL + CONTAINER, gm.	249.2	267.1
WT. DRY SOIL + CONTAINER, gm.	224.5	221.5
WT. CONTAINER, gm.	111.1	9.7
WT. WATER, gm.	24.7 ✓	45.6 ✓
WT. DRY SOIL, gm.	113.4 ✓	211.8 ✓
MOISTURE CONTENT %	21.8 ✓	21.5 ✓
DRY DENSITY, lb./ft.³	103.9 ✓	104.2 ✓

PROCTOR COMPACTION TEST

☒ STANDARD ☐ MODIFIED ☐ 4" ☒ 6" ☒ ONE-POINT METHOD ☐ RAPID THREE-POINT METHOD ☐ OTHER ______

MOLD NO. ______
MOLD VOLUME = 1/13.304 ft.³

WT. MOLD + WET SOIL, lb.	23.27			
WT. MOLD, lb.	14.43			
WT. WET SOIL, lb.	8.84 ✓			
WET DENSITY, lb./ft.³	117.6 ✓			
ADDED WATER % OF TOTAL WEIGHT				
CONVERTED WET DENSITY, lb./ft.³				
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2	T-1		
WT. WET SOIL + CONTAINER, gm.	270.8	360.2		
WT. DRY SOIL + CONTAINER, gm.	246.1	307.8		
WT. CONTAINER, gm.	111.1	9.5		
WT. WATER, gm.	24.7 ✓	52.4 ✓		
WT. DRY SOIL, gm.	135.0 ✓	298.3 ✓		
MOISTURE CONTENT, %	18.3 ✓	17.6 ✓		
DRY DENSITY, lb./ft.³	99.4 ✓	100.0 ✓		

MATERIAL DESCRIPTION: chalk

PROCTOR CURVE NUMBER	5
MAX. DRY DENSITY, lb./ft.³	102.8 ✓
OPT. MOISTURE CONTENT, %	20.6 ✓
PERCENT COMPACTION	101.1%
DIFFERENCE FROM O.M.C.	1.2 ✓

SPECIFICATIONS: 101 % STANDARD MODIFIED; 0 to 3 % OF O.M.C.

RESULTS: ☒ PASS ☐ FAIL ☐ DENSITY ☐ MOISTURE

REMARKS: Good moisture

GOLDER ASSOCIATES

DATE TESTED: 9/26/84 TESTED BY: SAR CHECKED BY: MAS

COMPACTION TEST REFERENCE CURVES

FIGURE 6

Curve Number	Maximum Dry Density- γ_D max. (lb./cu.ft)	Optimum Moisture Content - O.M.C. (%)	Material Description
1	102.8	20.6	Gray SILTY CLAY (CL)
2	110.0	17.8	Gray SILTY CLAY (CL)
3	107.0	19.0	Gray SILTY CLAY (CL)
4	100.3	22.1	Gray SILTY CLAY (CL)

All density tests run in accordance with ASTM D 698-78, Method C.

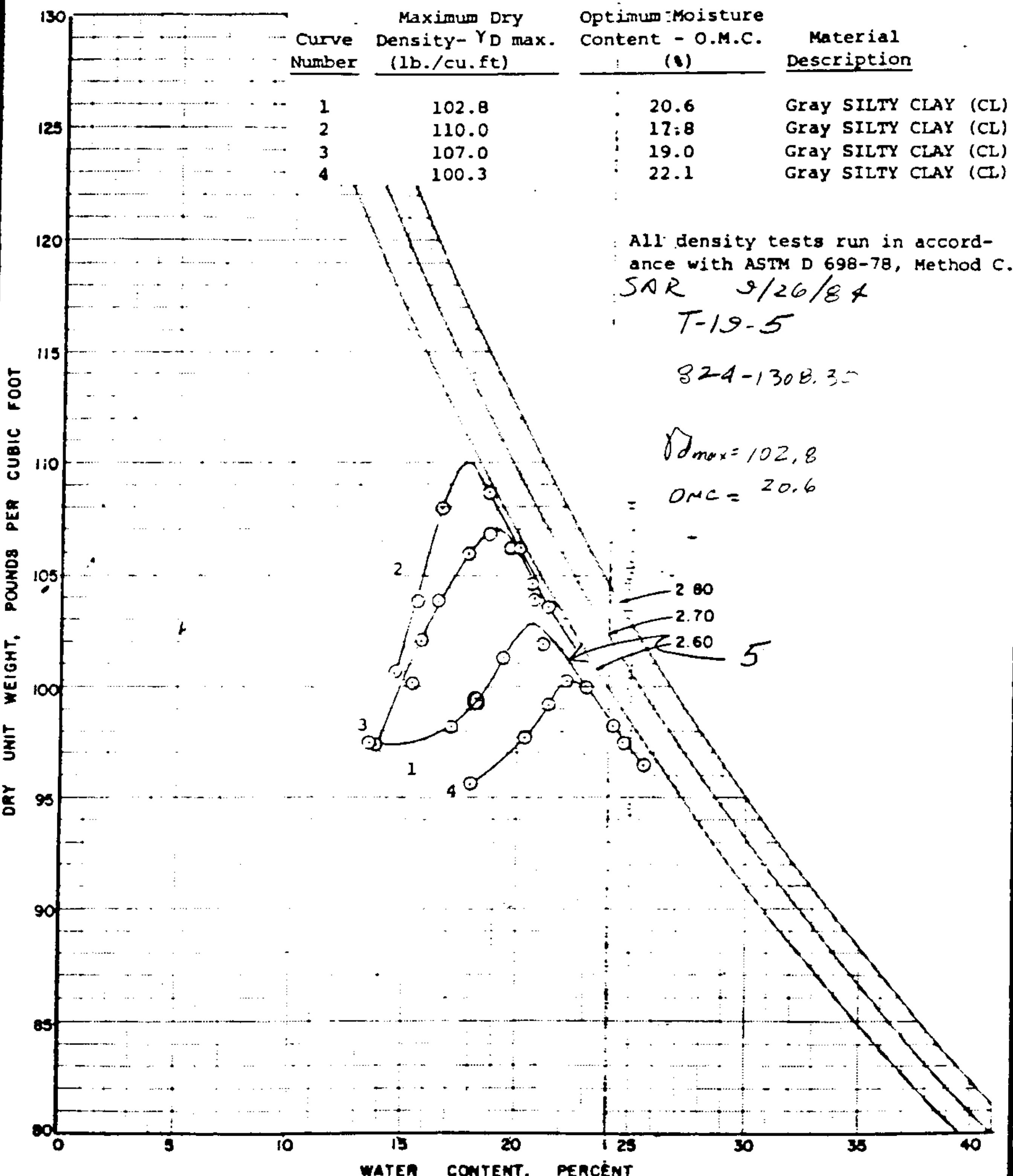
SAR 9/26/84

T-19-5

824-1308.35

$\gamma_{d\,max}$ = 102.8

OMC = 20.6



Date 9/2/82

Job No. 824-1308

Golder Associates

Drawn SKB

Checked LKO

Approved WJN

N ← [10' $\frac{?}{2:0}$], 3' down from top

FIELD DENSITY TEST RECORD – SAND CONE METHOD ASTM D 1556

TEST NUMBER T-19-6 LOCATION E Wall ELEVATION ______ JOB NUMBER 824-1308.30
JOB NAME CWM/EMELLE/AL

IN SITU DENSITY	SAND CONE METHOD	
SAND CONE NO. 1	SAND = 95.9 lb./ft.³	
CONTAINER NUMBER		
WT. CONTAINER + SOIL, lb.	5.59	
CONTAINER WEIGHT, lb.	0.01	
WEIGHT OF SOIL, lb.	5.58 ✓	
INITIAL WT. (SAND + CONE), lb.	15.99	
FINAL WT. (SAND + CONE), lb.	7.80	
WT. OF SAND USED, lb.	8.19 ✓	
CONE CORRECTION WT., lb.	3.86	
NET WT. OF SAND, lb.	4.33 ✓	
VOLUME, ft.³	0.04515	
WET DENSITY, lb./ft.³	123.6 ✓	
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2	1022
WT. WET SOIL + CONTAINER, gm.	241.3	300.9
WT. DRY SOIL + CONTAINER, gm.	217.1	247.2
WT. CONTAINER, gm.	111.1	9.7
WT. WATER, gm.	24.2 ✓	53.7 ✓
WT. DRY SOIL, gm.	106 ✓	237.5 ✓
MOISTURE CONTENT %	22.8 ✓	22.6 ✓
DRY DENSITY, lb./ft.³	100.6 ✓	100.8 ✓

PROCTOR COMPACTION TEST

☒ STANDARD ☐ MODIFIED ☐ 4" ☒ 6"

☒ ONE-POINT METHOD ☐ RAPID THREE-POINT METHOD ☐ OTHER ______

MOLD NO. ______
MOLD VOLUME = 1/13.304 ft.³

WT. MOLD + WET SOIL, lb.	23.19			
WT. MOLD, lb.	14.43			
WT. WET SOIL, lb.	8.76 ✓			
WET DENSITY, lb./ft.³	116.5 ✓			
[MOLD WATER] % OF TOTAL WEIGHT				
CONVERTED WET DENSITY, lb./ft.³				
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2	1066		
WT. WET SOIL + CONTAINER, gm.	242.2	344.4		
WT. DRY SOIL + CONTAINER, gm.	224.1	294.6		
WT. CONTAINER, gm.	111.1	9.4		
WT. WATER, gm.	18.1 ✓	49.8 ✓		
WT. DRY SOIL, gm.	113.0 ✓	285.2 ✓		
MOISTURE CONTENT, %	16.0 ✓	17.5 ✓		
DRY DENSITY, lb./ft.³	100.4 ✓	99.1 ✓		

MATERIAL DESCRIPTION: Chalk

PROCTOR CURVE NUMBER	6
MAX. DRY DENSITY, lb./ft.³	105.5 ✓
OPT. MOISTURE CONTENT, %	19.5 ✓
PERCENT COMPACTION	95.4 ✓
DIFFERENCE FROM O.M.C.	3.3 ✓

SPECIFICATIONS:
95 % STANDARD MODIFIED
0 to 3 % OF O.M.C.

RESULTS:
☒ PASS
☐ FAIL
☐ DENSITY
☐ MOISTURE

REMARKS: Wet of opt. moisture + density looked good

GOLDER ASSOCIATES

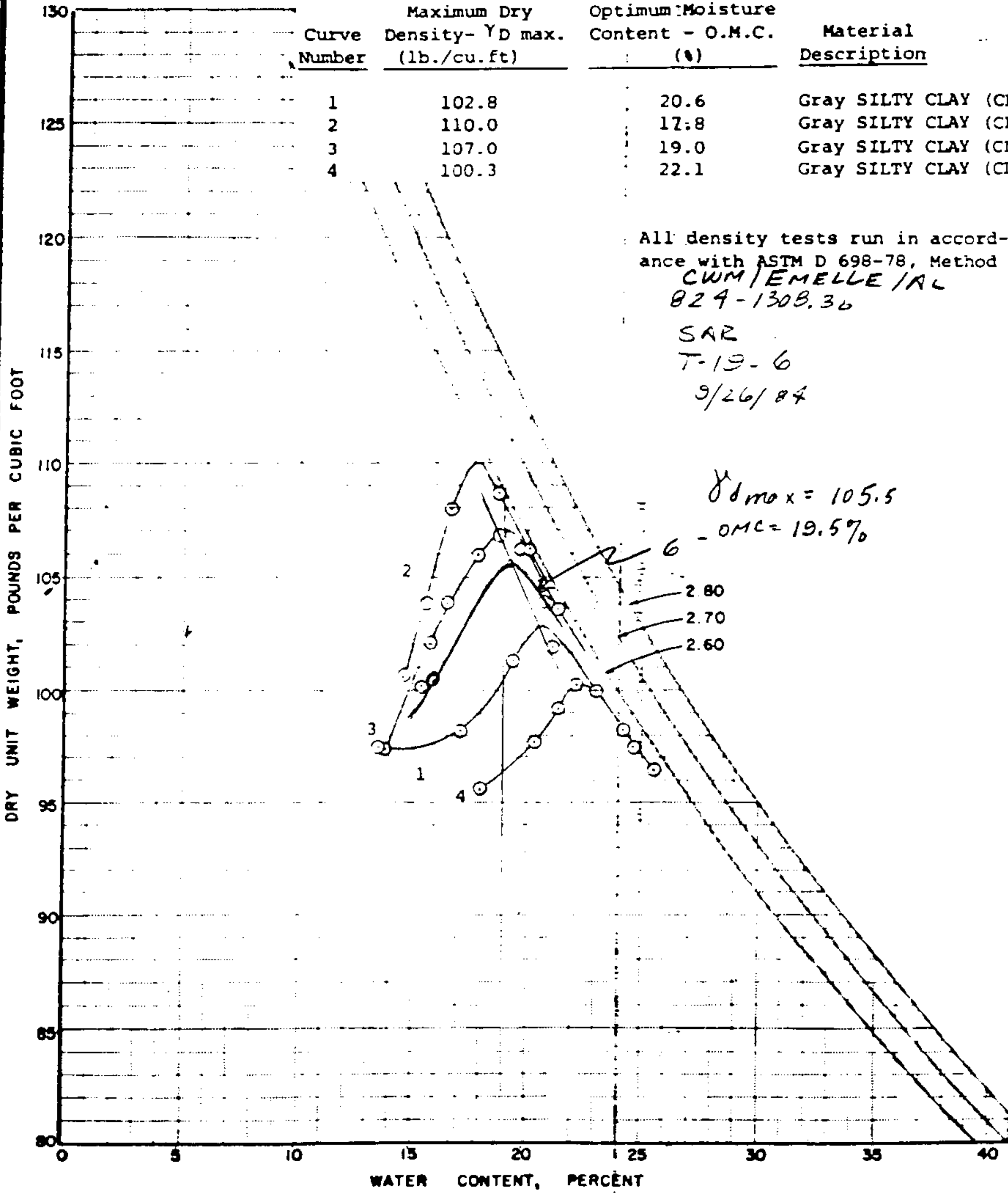
DATE TESTED: 9/26/84 TESTED BY: SAR CHECKED BY: MAS

COMPACTION TEST REFERENCE CURVES

FIGURE 6

Curve Number	Maximum Dry Density- γ_D max. (lb./cu.ft)	Optimum Moisture Content - O.M.C. (%)	Material Description
1	102.8	20.6	Gray SILTY CLAY (CL)
2	110.0	17.8	Gray SILTY CLAY (CL)
3	107.0	19.0	Gray SILTY CLAY (CL)
4	100.3	22.1	Gray SILTY CLAY (CL)

All density tests run in accordance with ASTM D 698-78, Method C.



Date 9/2/82
Job No. 824-1308

Golder Associates

Drawn SKB
Checked LKO
Approved WJN

N ← [illegible] ½' down from top

FIELD DENSITY TEST RECORD – SAND CONE METHOD ASTM D 1556

TEST NUMBER T-19-7 LOCATION E. Wall ELEVATION ______ JOB NUMBER 824-1308.30
JOB NAME CWM/EMELLE/AL

IN SITU DENSITY — SAND CONE METHOD		
SAND CONE NO. 1 — SAND: 95.9 lb./ft.³		
CONTAINER NUMBER		
WT. CONTAINER + SOIL, lb.	6.00	
CONTAINER WEIGHT, lb.	0.01	
WEIGHT OF SOIL, lb.	5.99 ✓	
INITIAL WT. (SAND + CONE), lb.	15.87	
FINAL WT. (SAND + CONE), lb.	7.19	
WT. OF SAND USED, lb.	8.68 ✓	
CONE CORRECTION WT., lb.	3.86	
NET WT. OF SAND, lb.	4.82 ✓	
VOLUME, ft.³	0.05026	
WET DENSITY, lb./ft.³	119.2 ✓	
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A2	1054
WT. WET SOIL + CONTAINER, gm.	246.2	329.8
WT. DRY SOIL + CONTAINER, gm.	223.6	275.8
WT. CONTAINER, gm.	111.1	9.4
WT. WATER, gm.	22.6 ✓	54 ✓
WT. DRY SOIL, gm.	112.5 ✓	266.4 ✓
MOISTURE CONTENT %	20.1 ✓	20.3 ✓
DRY DENSITY, lb./ft.³	99.2 ✓	99.1 ✓

PROCTOR COMPACTION TEST

☒ STANDARD ☐ MODIFIED ☐ 4" ☒ 6" ☒ ONE-POINT METHOD ☐ RAPID THREE-POINT METHOD ☐ OTHER ______

MOLD NO. ______
MOLD VOLUME = 1/13.304 ft.³

WT. MOLD + WET SOIL, lb.	23.26			
WT. MOLD, lb.	14.43			
WT. WET SOIL, lb.	8.83 ✓			
WET DENSITY, lb./ft.³	117.5 ✓			
ADDED WATER % OF TOTAL WEIGHT				
CONVERTED WET DENSITY, lb./ft.³				
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2	51		
WT. WET SOIL + CONTAINER, gm.	268.8	342.8		
WT. DRY SOIL + CONTAINER, gm.	245.1	296.4		
WT. CONTAINER, gm.	111.1	9.8		
WT. WATER, gm.	23.7 ✓	46.4 ✓		
WT. DRY SOIL, gm.	134.0 ✓	286.6 ✓		
MOISTURE CONTENT, %	17.7 ✓	16.2 ✓		
DRY DENSITY, lb./ft.³	99.8 ✓	101.1 ✓		

MATERIAL DESCRIPTION: Chalk

PROCTOR CURVE NUMBER	7
MAX. DRY DENSITY, lb./ft.³	103.1 ✓
OPT. MOISTURE CONTENT, %	20.2 ✓
PERCENT COMPACTION	96.2 ✓
DIFFERENCE FROM O.M.C.	0.1 ✓

SPECIFICATIONS:
95 % STANDARD MODIFIED
0 to 3 % OF O.M.C.

RESULTS: ☒ PASS ☐ FAIL ☐ DENSITY ☐ MOISTURE
They rewet area to assure it would be wet of opt.

REMARKS: Looked at optimum or just wet of opt
Not a good test - [illegible]
& re-[illegible]

GOLDER ASSOCIATES

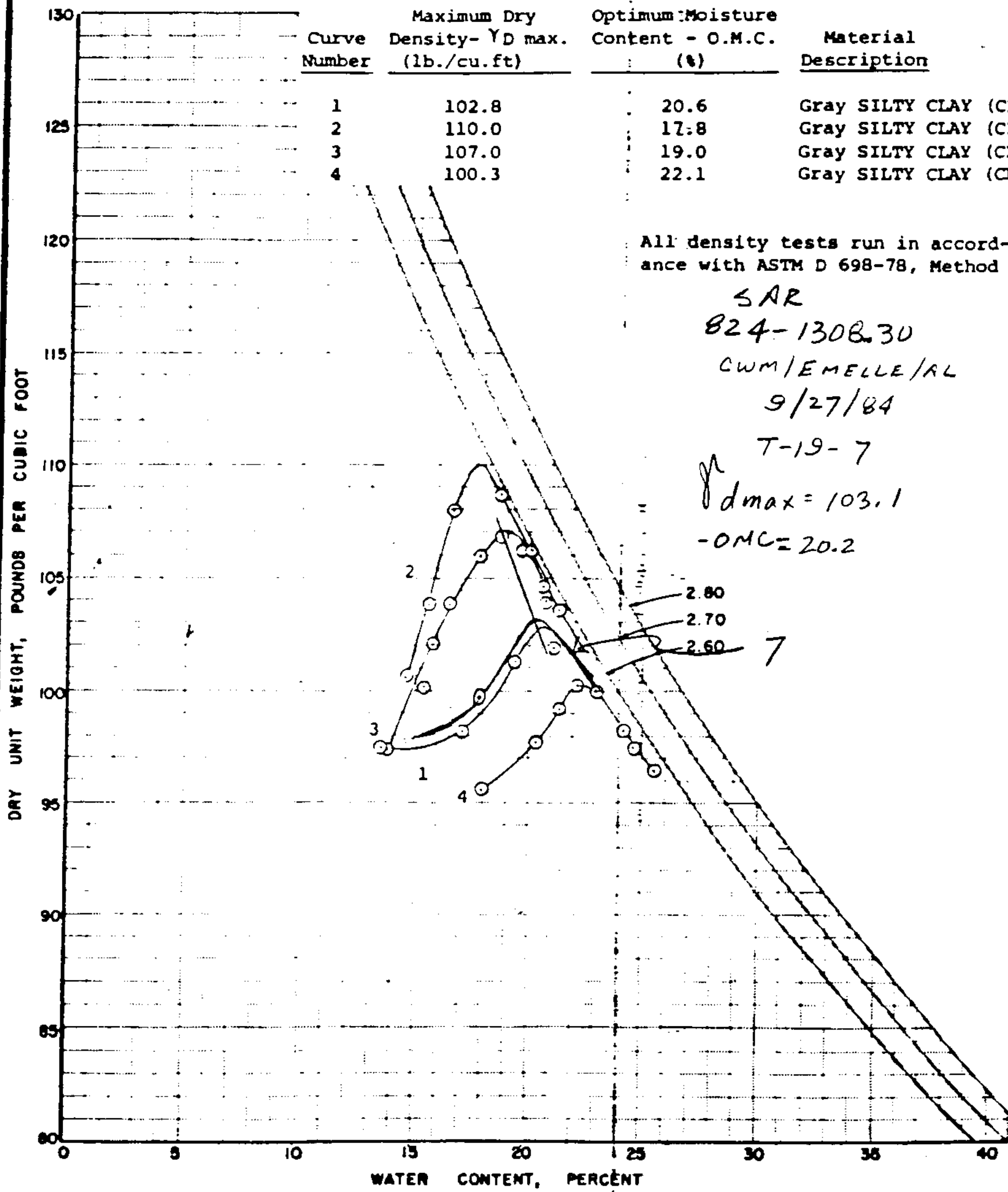
DATE TESTED: 2/27/84 TESTED BY: SAP CHECKED BY: MAS

COMPACTION TEST REFERENCE CURVES	FIGURE 6

Curve Number	Maximum Dry Density- γ_D max. (lb./cu.ft)	Optimum Moisture Content - O.M.C. (%)	Material Description
1	102.8	20.6	Gray SILTY CLAY (CL)
2	110.0	17.8	Gray SILTY CLAY (CL)
3	107.0	19.0	Gray SILTY CLAY (CL)
4	100.3	22.1	Gray SILTY CLAY (CL)

All density tests run in accordance with ASTM D 698-78, Method C.

SAR
824-1308.30
CWM/EMELLE/AL
9/27/84
T-19-7
γ_{dmax} = 103.1
-OMC = 20.2



Date 9/2/82
Job No. 824-1308

Golder Associates

Drawn SKB
Checked LKO
Approved WJN

N ←

FIELD DENSITY TEST RECORD – SAND CONE METHOD ASTM D 1556

TEST NUMBER T-19-8 LOCATION E. Wall ELEVATION ______ JOB NUMBER 824-1308.30

JOB NAME CWM/Emelle/AL

IN SITU DENSITY — SAND CONE METHOD

SAND CONE NO. 1 SAND = 95.9 lb./ft.³

CONTAINER NUMBER		
WT. CONTAINER + SOIL, lb.	5.16	
CONTAINER WEIGHT, lb.	0.01	
WEIGHT OF SOIL, lb.	5.15 ✓	
INITIAL WT. (SAND + CONE), lb.	16.11	
FINAL WT. (SAND + CONE), lb.	8.33	
WT. OF SAND USED, lb.	7.78 ✓	
CONE CORRECTION WT., lb.	3.86	
NET WT. OF SAND, lb.	3.92 ✓	
VOLUME, ft.³	0.040876	
WET DENSITY, lb./ft.³	126.0 ✓	
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER	[✓ OVEN DRY] ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER		1064
WT. WET SOIL + CONTAINER, gm.		316.5
WT. DRY SOIL + CONTAINER, gm.		260.2
WT. CONTAINER, gm.		9.5
WT. WATER, gm.		56.3 ✓
WT. DRY SOIL, gm.		250.7 ✓
MOISTURE CONTENT %		22.4 ✓
DRY DENSITY, lb./ft.³		102.9 ✓

PROCTOR COMPACTION TEST

[✓ STANDARD] ☐ MODIFIED ☐ 4" [✓ 6"] [✓ ONE-POINT METHOD] ☐ RAPID THREE-POINT METHOD ☐ OTHER ______

MOLD NO. ______

MOLD VOLUME = 1/13.304 ft.³

WT. MOLD + WET SOIL, lb.	22.95			
WT. MOLD, lb.	14.43			
WT. WET SOIL, lb.	8.52 ✓			
WET DENSITY, lb./ft.³	113.4 ✓			
ADDED WATER % OF TOTAL WEIGHT				
CONVERTED WET DENSITY, lb./ft.³				
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY [✓ QUICK FRY] ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	A-2			
WT. WET SOIL + CONTAINER, gm.	313.0			
WT. DRY SOIL + CONTAINER, gm.	284.8			
WT. CONTAINER, gm.	111.1			
WT. WATER, gm.	28.2 ✓			
WT. DRY SOIL, gm.	173.7 ✓			
MOISTURE CONTENT, %	16.2 ✓			
DRY DENSITY, lb./ft.³	97.6 ✓			

MATERIAL DESCRIPTION: Chalk

PROCTOR CURVE NUMBER	8
MAX. DRY DENSITY, lb./ft.³	102.7
OPT. MOISTURE CONTENT, %	~~21.4~~ 20.4
PERCENT COMPACTION	100.2 ✓
DIFFERENCE FROM O.M.C.	~~1%~~ 2%

SPECIFICATIONS:

95 % STANDARD MODIFIED

0 ± 3 % OF O.M.C.

RESULTS: [✓ PASS] ☐ FAIL ☐ DENSITY ☐ MOISTURE

REMARKS: Looked very wet of opt.

GOLDER ASSOCIATES

DATE TESTED: 9/27/84 TESTED BY: SAR CHECKED BY: MAS

COMPACTION TEST REFERENCE CURVES

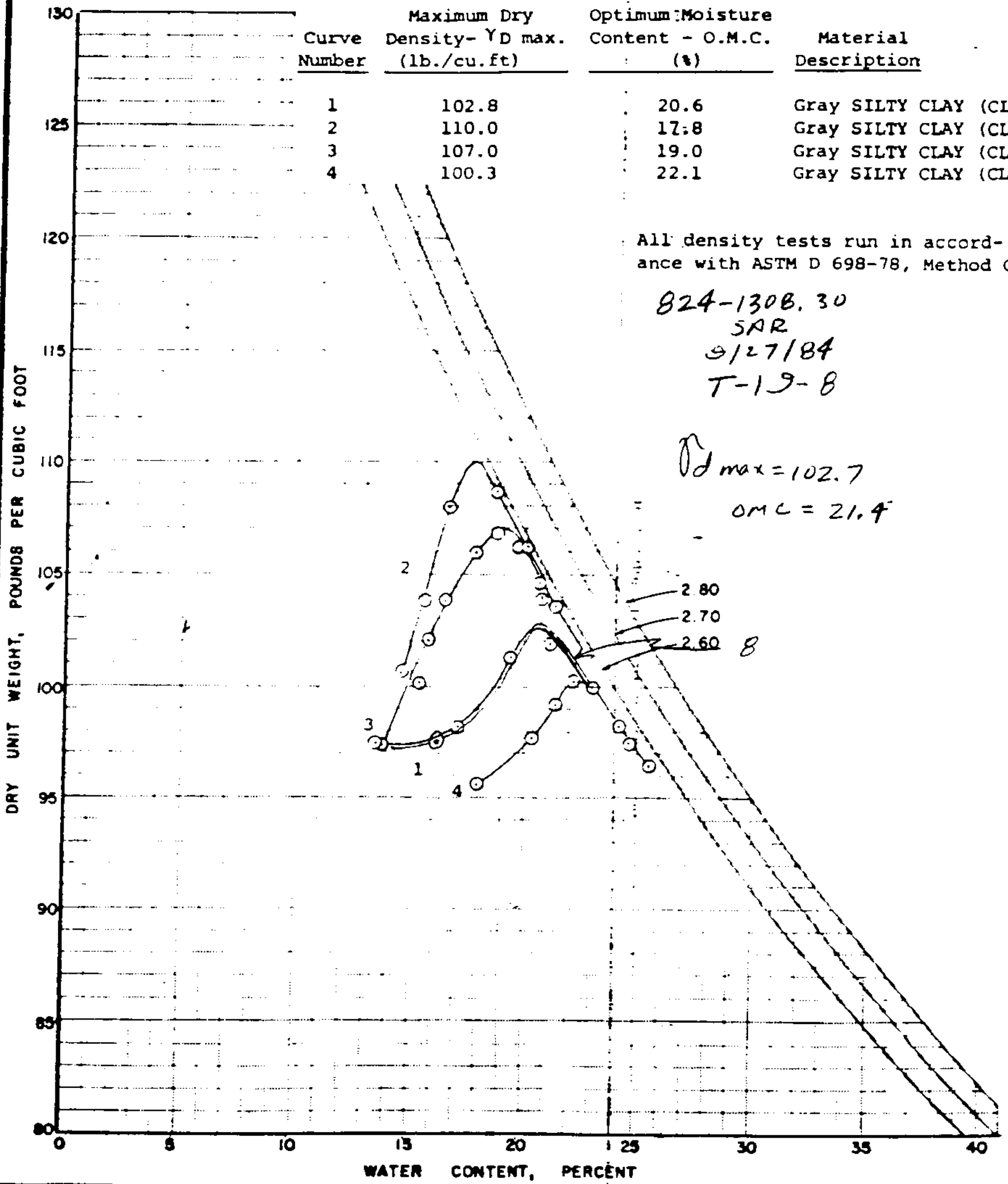
FIGURE 6

Curve Number	Maximum Dry Density- γ_D max. (lb./cu.ft)	Optimum Moisture Content - O.M.C. (%)	Material Description
1	102.8	20.6	Gray SILTY CLAY (CL)
2	110.0	17.8	Gray SILTY CLAY (CL)
3	107.0	19.0	Gray SILTY CLAY (CL)
4	100.3	22.1	Gray SILTY CLAY (CL)

All density tests run in accordance with ASTM D 698-78, Method C.

824-1308.30
SAR
9/27/84
T-19-8

γ_d max = 102.7
OMC = 21.4



Date 9/2/82
Job No. 824-1308

Golder Associates

Drawn SKB
Checked LKO
Approved WJN

FIELD DENSITY TEST RECORD – SAND CONE METHOD ASTM D 1556

N ←

0°32' / 0° 173'[illegible]

TEST NUMBER I-19-9 LOCATION E. Wall ELEVATION ______ JOB NUMBER 8[illegible]-13[illegible].3[illegible]
JOB NAME CWM/EMELLE/AL

IN SITU DENSITY — SAND CONE METHOD

SAND CONE NO. 1 SAND: 96.1 lb./ft.³

CONTAINER NUMBER		
WT. CONTAINER + SOIL, lb.	6.44	
CONTAINER WEIGHT, lb.	0.02	
WEIGHT OF SOIL, lb.	6.42	
INITIAL WT. (SAND + CONE), lb.	16.68	
[illegible]L WT. (SAND + CONE), lb.	7.88	
WT. OF SAND USED, lb.	8.80	
CONE CORRECTION WT., lb.	3.87	
NET WT. OF SAND, lb.	4.93	
VOLUME, ft.³	0.0513	
WET DENSITY, lb./ft.³	125.1	
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	Pan	1987
WT. WET SOIL + CONTAINER, gm.	181.8	335.8
WT. DRY SOIL + CONTAINER, gm.	162.5	279.9
WT. CONTAINER, gm.	76.7	9.5
[illegible] WATER, gm.	19.3	55.9
WT. DRY SOIL, gm.	85.8	270.4
MOISTURE CONTENT %	22.5	20.7
DRY DENSITY, lb./ft.³	*102.1	103.6

PROCTOR COMPACTION TEST

☒ STANDARD ☐ MODIFIED ☐ 4" ☒ 6" ☒ ONE-POINT METHOD ☐ RAPID THREE-POINT METHOD ☐ OTHER ______

MOLD NO. ______
MOLD VOLUME = 1/13.304 ft.³

WT. MOLD + WET SOIL, lb.	23.32			
WT. MOLD, lb.	14.43			
WT. WET SOIL, lb.	8.89			
WET DENSITY, lb./ft.³	115.27			
ADDED WATER % OF TOTAL WEIGHT				
CONVERTED WET DENSITY, lb./ft.³				
MOISTURE CONTENT DETERMINATION	☐ OVEN DRY ☒ QUICK FRY ☐ OTHER	☒ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER	☐ OVEN DRY ☐ QUICK FRY ☐ OTHER
CONTAINER NUMBER	Pan	1063		
WT. WET SOIL + CONTAINER, gm.	235.0	361.2		
WT. DRY SOIL + CONTAINER, gm.	[illegible]12.2	310.9		
WT. CONTAINER, gm.	76.7	9.6		
WT. WATER, gm.	22.8	50.3		
WT. DRY SOIL, gm.	135.5	301.3		
MOISTURE CONTENT, %	16.8	16.7		
DRY DENSITY, lb./ft.³	101.2	101.3		

MATERIAL DESCRIPTION: ______
* S = 90.4%

PROCTOR CURVE NUMBER	9
MAX. DRY DENSITY, lb./ft.³	105
OPT. MOISTURE CONTENT, %	12.5
PERCENT COMPACTION	97.2
DIFFERENCE FROM O.M.C.	3

SPECIFICATIONS:
9[illegible] % STANDARD MODIFIED
0 to 3 % OF O.M.C.

RESULTS:
☒ PASS
☐ FAIL ☐ DENSITY ☐ MOISTURE

REMARKS:
Took test at surface [illegible]
[illegible] Wall had [illegible]
dry surface out [illegible] test [illegible]

GOLDER ASSOCIATES

DATE TESTED: 10/18/91 TESTED BY: [illegible] CHECKED BY: ______

COMPACTION TEST REFERENCE CURVES

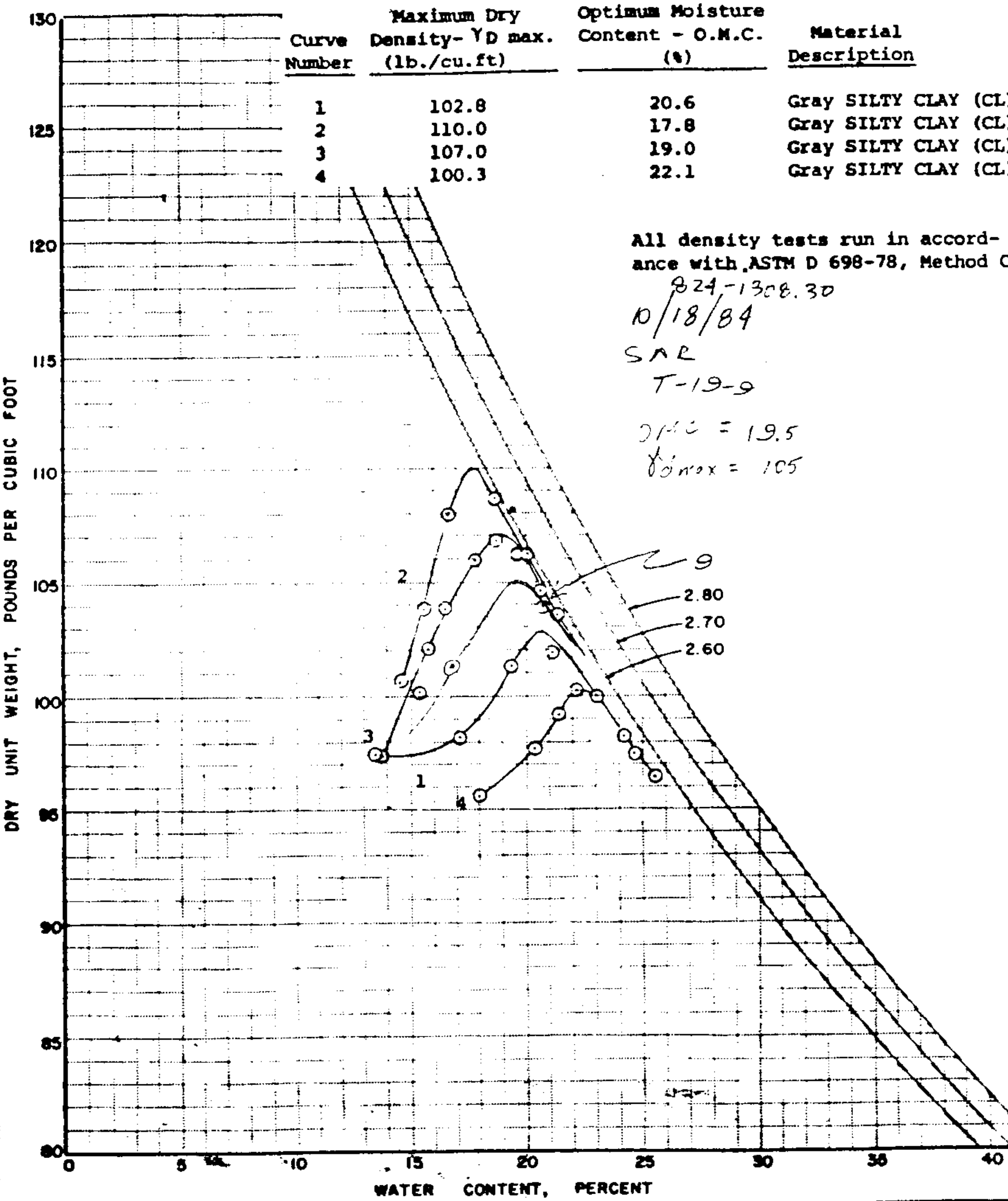
FIGURE 6

Curve Number	Maximum Dry Density- γD max. (lb./cu.ft)	Optimum Moisture Content - O.M.C. (%)	Material Description
1	102.8	20.6	Gray SILTY CLAY (CL)
2	110.0	17.8	Gray SILTY CLAY (CL)
3	107.0	19.0	Gray SILTY CLAY (CL)
4	100.3	22.1	Gray SILTY CLAY (CL)

All density tests run in accordance with ASTM D 698-78, Method C.

824-1308.30
10/18/84
SAR
T-19-9

OMC = 19.5
γd max = 105



Date 9/2/82
Job No. 824-1308

Golder Associates

Drawn SKB
Checked LKO
Approved WJN

ATTACHMENT D-6-1-9

APPENDIX D-6-1

SECTION D-6

CALCULATION PACKAGE FOR

TRENCH 23

<u>Revision No.</u>

5.0

Terracon	Made by:	RSG	Date:	1/29/15	Sheet No.:	COVER
	Checked by:	JCH	Date:	1/29/15	Job No.:	EJ147410
	Calculations for:	Excavation Slope Stability Analysis				
	Emelle Facility – Trench 23					

EXCAVATION SLOPE STABILITY ANALYSIS

CALCULATION COVER SHEET

Calculations by:

Signature: [signature]
Name: Rajendra S. Gondhalekar, P.E.
Title: Project Engineer

1/29/2015
Date

Calculations Reviewed by:

Signature: [signature]
Name: J. Craig Hensley, E.I.T.
Title: Staff Engineer

1/29/2015
Date

Calculations Approved by:

Signature: [signature]
Name: Michael A. Kemp P.E.
Title: Department Manager

1/29/2015
Date

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	1/29/15	ALL	Initial Submittal

1.0 OBJECTIVE

Our objective is to calculate the stability of the excavation slopes for Trench 23 of the Emelle Facility. The analysis includes evaluation of deep seated surfaces, which provides factors of safety (FOS) against failures through the underlying native chalk. Since the excavation represents an interim condition, a FOS greater than 1.3 is considered acceptable.

2.0 METHODOLOGY

The slope stability analysis was performed using a method of slices analysis using a slope-stability software program. The stability modeling software used for our analysis is Slope/W 2007 which is a part of GeoStudio developed by Geo-Slope International, Ltd. The most critical cross section was selected based on the deepest depth of excavation. The location of the selected slope stability section is indicated in Figure 1 with respect to the existing grades and proposed excavation grades.

Slope stability analysis was performed at east and west facing excavations along the cross-section. The analysis was performed for a deep seated slope stability analysis. The analysis searched for a deep seated slope-failure surface with the minimum FOS against sliding. This analysis provides us with a FOS against failure through the chalk after the completion of the excavation. The Morgenstern-Price Method was used to calculate the FOS against failure.

3.0 SUBSURFACE CONDITIONS AND MATERIALS

Detailed description of the subsurface conditions is provided in various reports contained in Attachment E of the permit application. The information was previously compiled into engineering properties for slope stability analysis by Golder Associates in the engineering calculation package for Trench 22, contained in Attachment D-6-1-7. A majority of the information remains relevant to the analysis of Trench 23. The values for various materials used in the excavation stability analysis are listed in the table below:

Material	Unit Weight (lb/ft^3)	Cohesion (lb/ft^2)	Friction Angle (°)
Structural Fill (Chalk)	130	600	26
Natural Intact Chalk (Short Term)	130	8000	0
Natural Intact Chalk (Horizontal, Long Term)	130	6000	36
Natural Intact Chalk (Vertical, Long Term)		2000	43

The stability analysis was performed utilizing both the short term isotropic, and the long term anisotropic properties of the natural intact chalk and for both east and west facing excavation slopes. The groundwater surface in the intact chalk, prior to the excavation, was based on the Golder Associates site wide chalk water level data acquired May 30, 1983 to June 9, 1983, and shown on Figure 00-150-16, 7/29/1985 (part of Permit Application Revision 3.3). The bottom of the analysis was limited to approximately 500 ft below MSL, which is the average elevation of the bottom of the chalk formation.

4.0 ANALYSIS RESULTS

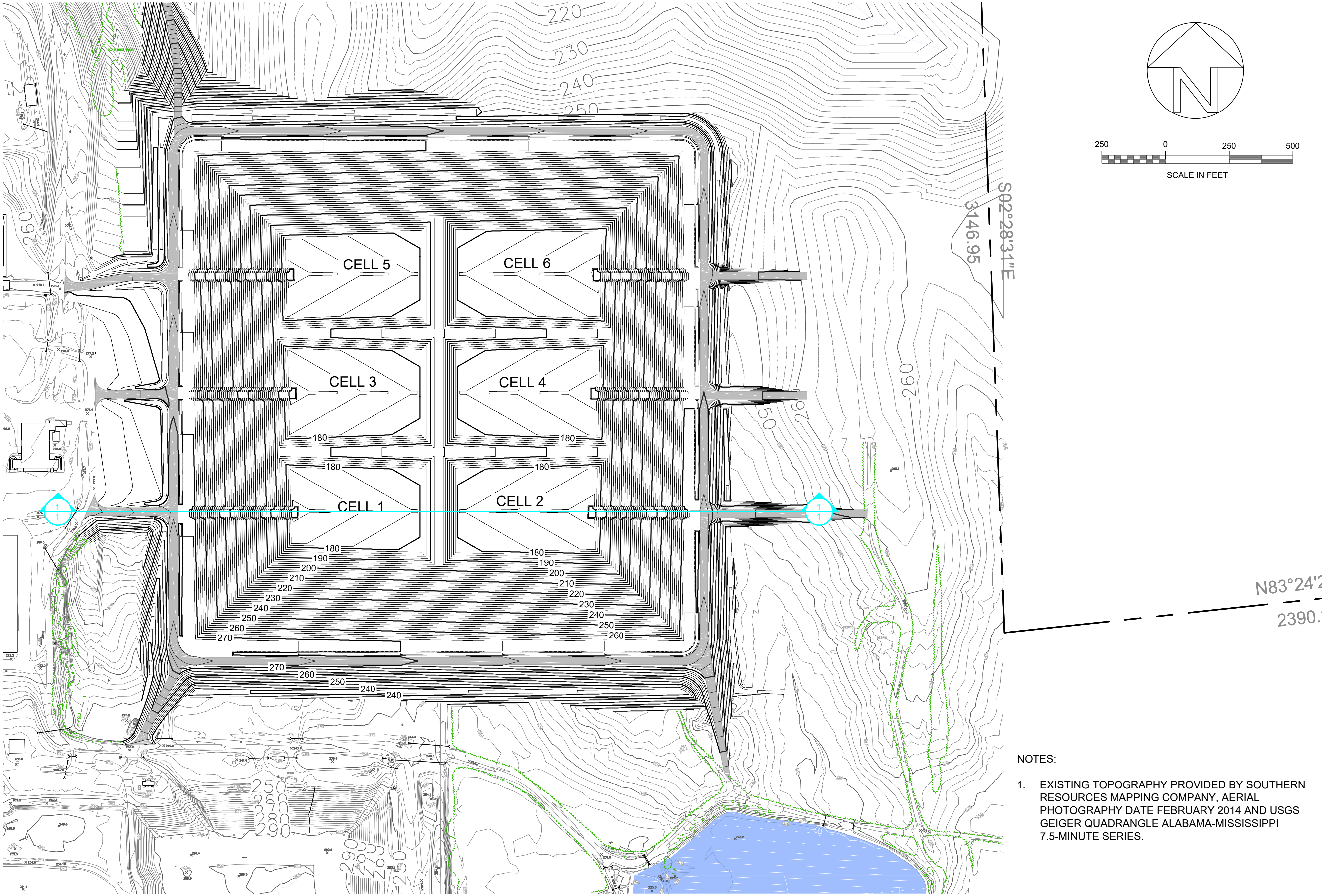
The input properties and the output results for the analysis are presented in Attachment 1. The following table presents the results of our analysis for the various scenarios.

Cross Section	Failure Mode	Factor of Safety
East Facing	Short Term	3.16
	Long Term	5.02
West Facing	Short Term	3.65
	Long Term	5.44

5.0 CONCLUSIONS

Based on the results of the analysis, the Trench 23 excavations appear stable for deep-seated circular failure modes under both long term and short term conditions of analysis.

FIGURES



NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.

File Path: N:\PROJECTS\2014\EJ147410\WORKING FILES\CALCULATIONS-ANALYSES\STABILITY\EXCAVATION\FIGURES\EJ147410-FIG_1.DWG

Last Saved By: RSGONDHALEKAR Date: 12/15/2014 3:08 PM

Project Mngr: MAK	Project No. EJ147410	
Drawn By: RSG	Scale: AS-SHOWN	
Checked By: JCH	File No. --	
Approved By: RSG	Date: 12-31-2014	

Terracon
Consulting Engineers and Scientists
240 HERITAGE WALK, SUITE 103 WOODSTOCK, GA 30188
PH. (770) 924-9799 FAX. (770) 924-7866

ANALYSIS CROSS SECTION LOCATION

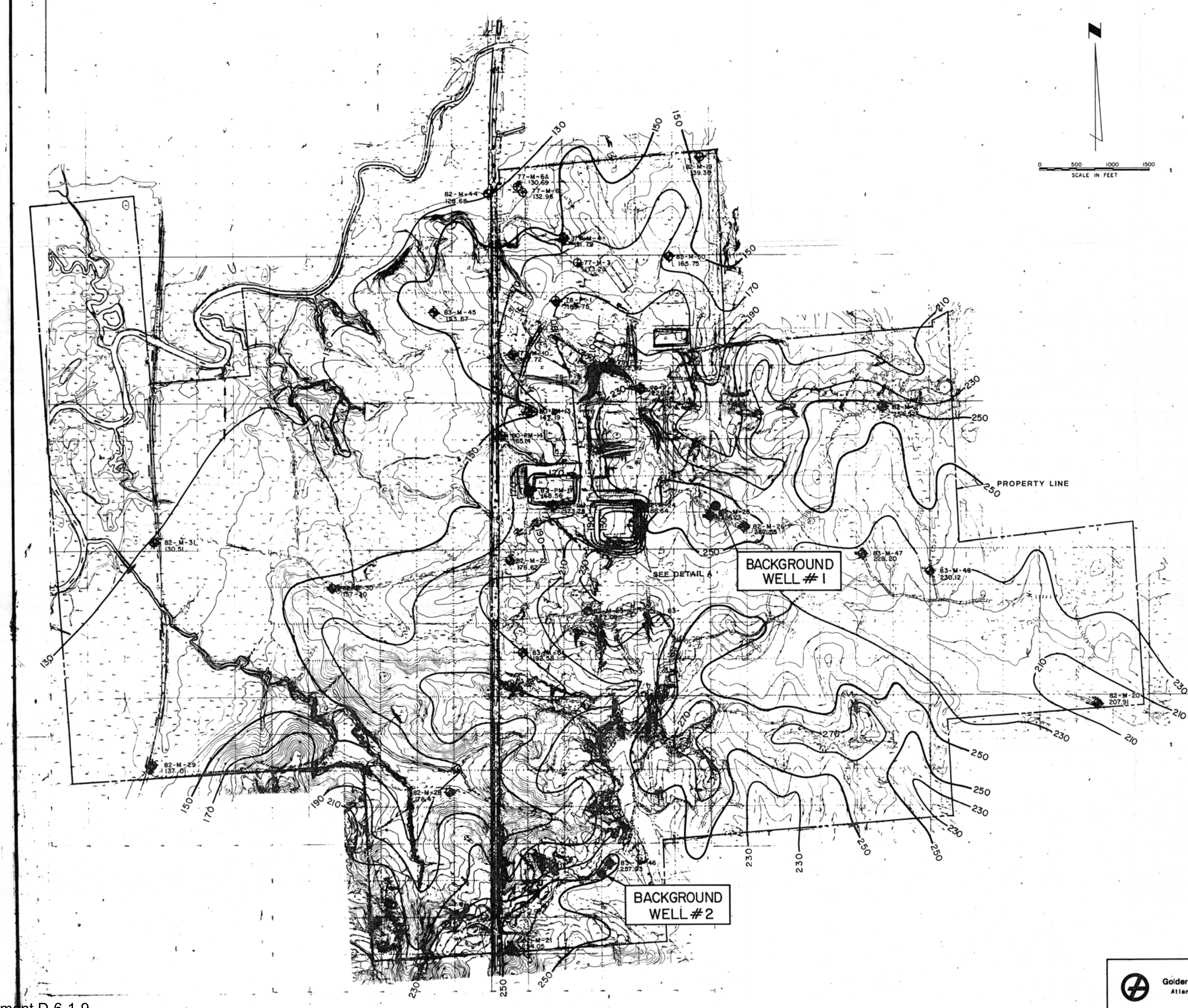
EXCAVATION SLOPE STABILITY ANALYSIS

EMELLE FACILITY

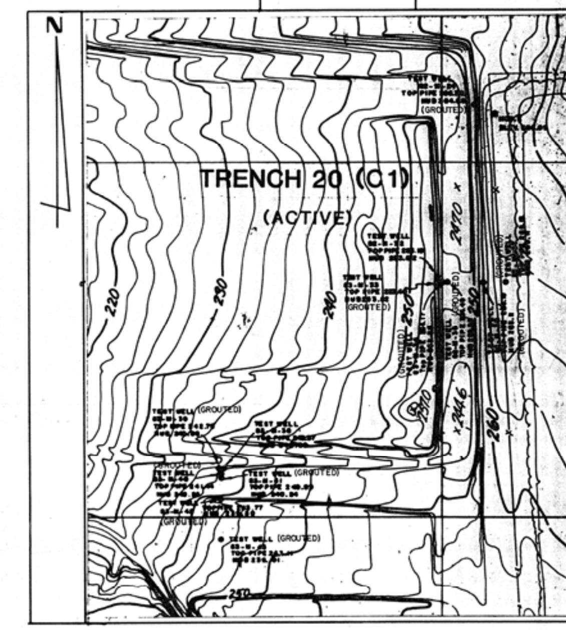
CHEMICAL WASTE MANAGEMENT

FIG. No. 1

PLATE 2



WELL NO.	WATER LEVEL ELEVATION (FT-MSL)
82-M-24	188.64
82-M-34	dry to 144.55
82-M-35	dry to 144.55
82-M-36	190.53
83-M-37	259.22
83-M-38	150.52
83-M-39	caved
83-M-40	163.32
83-M-41	168.19
83-M-43	212.40



DETAIL A
WELL LOCATIONS
SCALE 1" = 100'

LEGEND

—210— ESTIMATED CHALK WATER TABLE SURFACE CONTOURS (FT.-MSL)

83-M-50 230.05 MONITORING WELL DESIGNATION CHALK WATER TABLE SURFACE ELEVATIONS (FT.-MSL)

83-M-48 GROUTED BETWEEN 5/13/85 AND 7/15/85

NOTE

1. CHALK WATER LEVEL DATA ACQUIRED MAY 30, 1983 TO JUNE 9, 1983.
2. BASE MAP PROVIDED BY CHEMICAL WASTE MANAGEMENT, INC. DATE OF AERIAL PHOTOGRAPHY, DECEMBER 13, 1982.

Section C, Figures Revision 3.3

REV.	DATE	DESCRIPTION	DR BY	APP BY
1	7/29/85	GROUTED WELLS AND BACKGROUND WELL LOCATIONS.	S.B.C.	

SCALE: 1" = 500'
GAI JOB NO. 853 3098
DES BY JEB 7-21-85
DR BY SKB 1-22-85
CHK BY 7/22/85
APP BY JEB 8/9/85

PROJECT: EMELLE FACILITY
SHEET TITLE: APPROXIMATE BACKGROUND WELL LOCATIONS

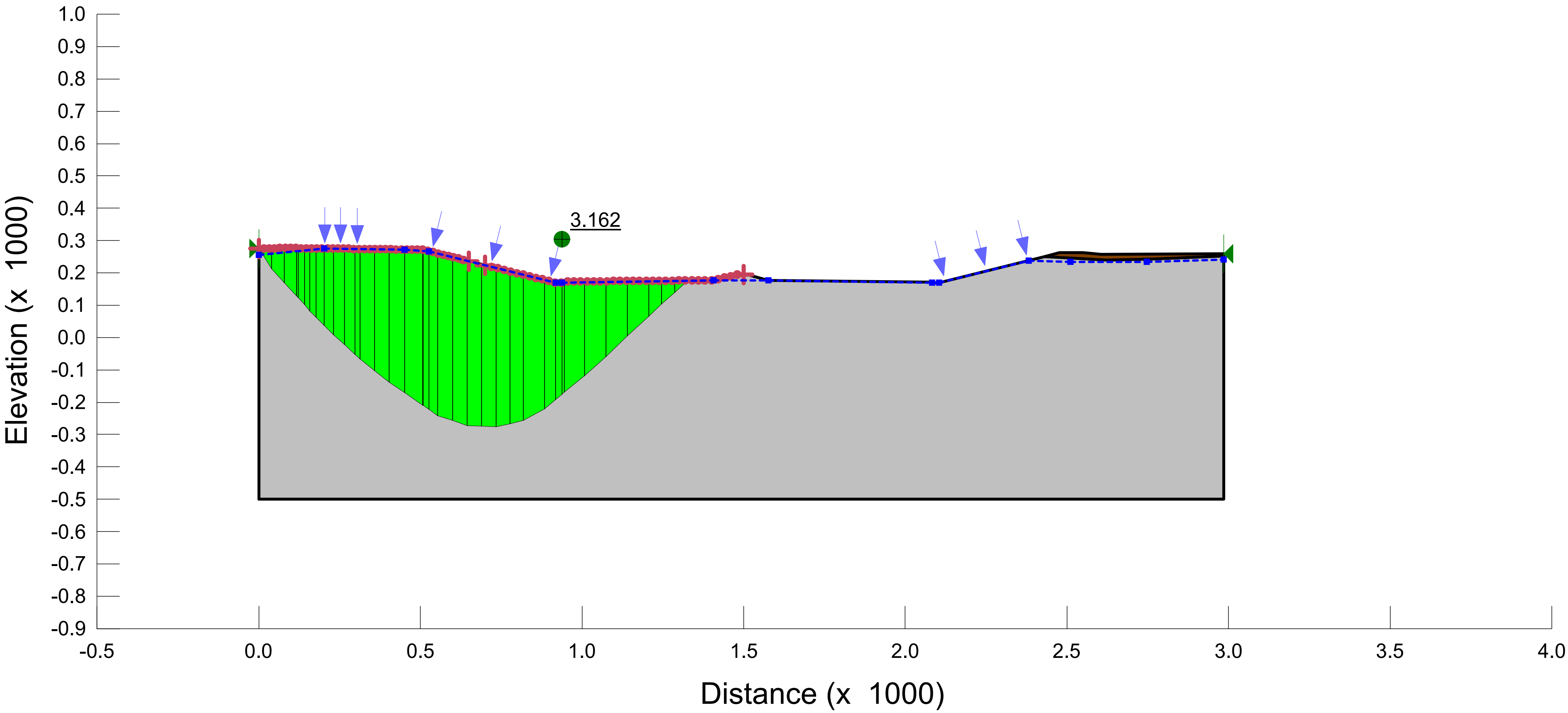
Golder Associates
Atlanta, Georgia

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

ATTACHMENT 1

Excavation Stability Output Data

East Facing Slope
Short Term Strength Analysis



SLOPE/W Analysis

File Information

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Revision Number: 16
Last Edited By: Gondhalekar, Rajendra S.
Date: 12/10/2014
Time: 5:12:31 PM
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Directory: N:\Projects\2014\EJ147410\Working Files\Calculations-Analyses\Stability\Excavation\
Last Solved Date: 12/10/2014
Last Solved Time: 5:13:16 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Apply Phreatic Correction: No
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

Slip Surface
- Direction of movement: Left to Right
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: Yes
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution

FOS Calculation Option: Constant

Advanced

Number of Slices: 30

Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 0.1 ft

Optimization Maximum Iterations: 20000

Optimization Convergence Tolerance: 1e-007

Starting Optimization Points: 8

Ending Optimization Points: 16

Complete Passes per Insertion: 1

Driving Side Maximum Convex Angle: 5 °

Resisting Side Maximum Convex Angle: 1 °

Materials

Structural Fill

Model: Mohr-Coulomb

Unit Weight: 130 pcf

Cohesion: 600 psf

Phi: 26 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Chalk (Short Term)

Model: Undrained (Phi=0)

Unit Weight: 130 pcf

Cohesion: 8000 psf

Pore Water Pressure

Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range

Left-Zone Left Coordinate: (0, 275.5204) ft

Left-Zone Right Coordinate: (650, 236.209) ft

Left-Zone Increment: 40

Right Projection: Range

Right-Zone Left Coordinate: (700, 223.7081) ft

Right-Zone Right Coordinate: (1500, 194) ft

Right-Zone Increment: 40

Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 275.5204) ft

Right Coordinate: (2985.553, 259.7822) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	255.1389
	202.1461	275.3234
	451.071	272.2157
	526.729	267.029
	918.1415	169.1687
	938.9086	169.1687
	1407.7683	177.1254
	1577.7648	177.1254
	2083.9204	168.8062
	2104.6876	168.8062
	2382.2656	238.2051
	2511.8947	234.8255
	2747.8299	234.1993
	2985.553	240.7074

Regions

	Material	Points	Area (ft²)
Region 1	Structural Fill	1,2,3,4,5,6,7,8,9,10	7794.3046
Region 2	Chalk (Short Term)	11,12,1,2,3,4,5,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29	2135903.8
Region 3		25,27,26	21.282755

Points

	X (ft)	Y (ft)
Point 1	2985.553	251.6444
Point 2	2771.2301	242.2954
Point 3	2623.9439	240.0761
Point 4	2465.5776	248.0137
Point 5	2431.0482	250.4015
Point 6	2477.5025	262.0158
Point 7	2494.1359	262.0158
Point 8	2550.1359	262.0158
Point 9	2605.1357	257
Point 10	2985.553	259.7822
Point 11	0	-500
Point 12	2985.553	-500
Point 13	2104.6876	168.8062
Point 14	2083.9204	168.8062

Point 15	2077.2314	172.1308
Point 16	1577.7648	177.1254
Point 17	1510.2666	194
Point 18	1475.2666	194
Point 19	1407.7683	177.1254
Point 20	945.9786	172.7182
Point 21	938.9086	169.1687
Point 22	918.1415	169.1687
Point 23	508.7814	271.5162
Point 24	507.107	271.5162
Point 25	158.5668	275.8674
Point 26	141.4553	274.9071
Point 27	122.3082	276.3201
Point 28	117.5381	276.6721
Point 29	0	275.5204

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	3.162	(680.158, 494.625)	630.9973	(5.68358e-005, 275.52)	(1327.41, 176.358)
2	159	3.502	(680.158, 494.625)	714.578	(0, 275.52)	(1319.91, 176.287)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	6.1820884	265.94695	-635.88129	-2661.1981	0	8000
2	Optimized	26.23181	234.89805	1426.4711	1401.5921	0	8000
3	Optimized	59.45915	191.96795	4312.4017	8108.5056	0	8000
4	Optimized	98.17845	149.0587	7231.1107	13663.898	0	8000
5	Optimized	119.92315	124.96095	8870.2673	16742.263	0	8000
6	Optimized	131.88175	111.70825	9771.9516	18314.056	0	8000
7	Optimized	150.01105	91.61709	11138.408	20834.891	0	8000
8	Optimized	167.78225	71.92279	12477.959	23374.047	0	8000
9	Optimized	189.5719	49.248225	14028.697	26525.198	0	8000
10	Optimized	216.7074	22.355125	15773.853	29869.253	0	8000
11	Optimized	247.8624	-7.14035	17590.158	33770.338	0	8000
12	Optimized	281.04985	-37.26885	19444.325	37498.304	0	8000
13	Optimized	305.97745	-59.08769	20786.433	40498.983	0	8000
14	Optimized	336.607	-83.91294	22312.434	43567.348	0	8000
15	Optimized	381.1984	-120.05425	24532.004	48036.107	0	8000
16	Optimized	427.28255	-154.38635	26638.557	52740.941	0	8000
17	Optimized	479.089	-189.80055	28710.583	57158.928	0	8000
18	Optimized	507.9442	-209.5256	29817.116	59628.316	0	8000
19	Optimized	517.7552	-216.2323	30193.765	60201.7	0	8000
20	Optimized	540.47535	-231.7635	30910.685	61470.044	0	8000

21	Optimized	576.6197	-249.08785	31427.356	63898.503	0	8000
22	Optimized	621.4157	-264.94295	31717.766	64576.125	0	8000
23	Optimized	666.6	-273.78695	31565.827	65661.831	0	8000
24	Optimized	712.1726	-275.6199	30967.267	64523.909	0	8000
25	Optimized	755.60005	-271.4102	30028.477	63846.659	0	8000
26	Optimized	796.8823	-261.1578	28744.867	61218.315	0	8000
27	Optimized	850.6072	-238.2404	26476.049	57632.093	0	8000
28	Optimized	900.91625	-206.25985	23694.973	52809.588	0	8000
29	Optimized	928.52505	-183.517	22007.539	49182.741	0	8000
30	Optimized	942.4436	-172.05155	21296.161	47875.149	0	8000
31	Optimized	977.0383	-143.554	19554.732	44308.154	0	8000
32	Optimized	1041.0865	-88.45035	16183.617	37183.463	0	8000
33	Optimized	1107.25	-27.335	12440.469	29198.377	0	8000
34	Optimized	1173.549	35.3783	8596.9617	20829.817	0	8000
35	Optimized	1226.684	84.70365	5575.346	14245.971	0	8000
36	Optimized	1266.7055	121.1223	3345.1337	9478.4023	0	8000
37	Optimized	1306.727	157.54095	1115.0692	4740.2176	0	8000
38	Optimized	1327.072	176.05435	-18.620822	2341.9341	0	8000

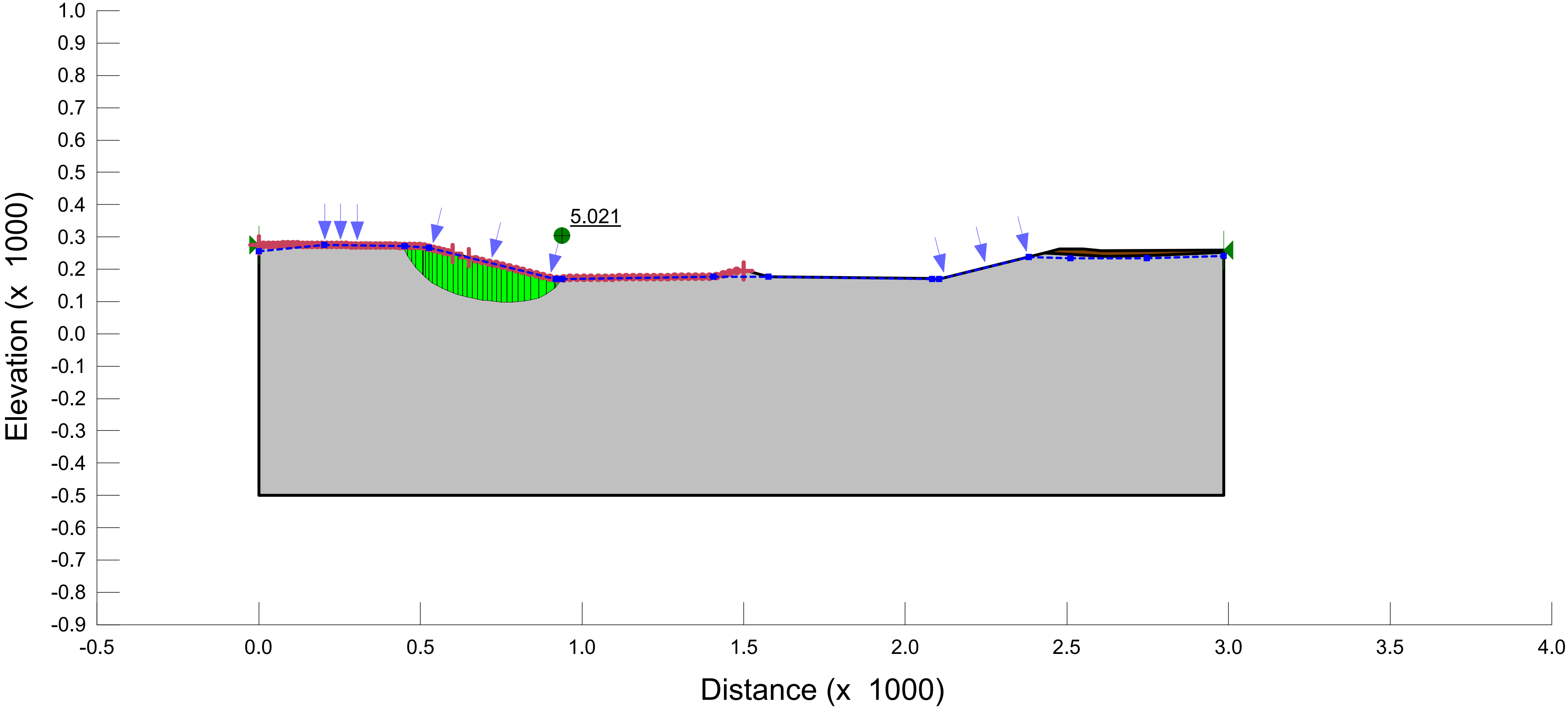
Slices of Slip Surface: 159

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	159	3.334785	265.66265	-635.89728	-5460.0202	0	8000
2	159	25.14766	212.85085	2795.4517	2865.9181	0	8000
3	159	62.103835	137.88355	7703.7161	13923.259	0	8000
4	159	99.06001	79.97483	11547.455	22134.586	0	8000
5	159	119.92315	51.06693	13481.545	26138.062	0	8000
6	159	131.88175	36.594675	14459.042	28017.7	0	8000
7	159	150.01105	15.664753	15878.053	30857.385	0	8000
8	159	180.35645	-15.167922	17991.311	35092.888	0	8000
9	159	220.8403	-52.23217	20424.824	40068.11	0	8000
10	159	258.2287	-81.62177	22229.511	44005.844	0	8000
11	159	295.6171	-107.25345	23801.029	47448.793	0	8000
12	159	337.1046	-131.68195	25291.932	50747.397	0	8000
13	159	382.69115	-154.61015	26687.279	53873.126	0	8000
14	159	428.2777	-173.6447	27840.287	56509.851	0	8000
15	159	479.089	-190.4589	28750.197	58897.664	0	8000
16	159	507.9442	-198.8899	29153.422	60118.754	0	8000
17	159	517.7552	-201.1923	29255.625	60190.038	0	8000

18	159	548.47415	-207.36585	29264.044	60186.889	0	8000
19	159	591.96445	-214.15065	29008.12	59937.489	0	8000
20	159	635.4547	-218.22005	28582.437	59335.809	0	8000
21	159	678.94495	-219.62065	27992.423	58389.978	0	8000
22	159	722.43525	-218.3682	27236.417	57089.514	0	8000
23	159	765.92555	-214.44855	26312.984	55436.004	0	8000
24	159	809.4158	-207.8169	25219.101	53414.201	0	8000
25	159	852.90605	-198.39515	23953.031	51011.746	0	8000
26	159	896.39635	-186.0669	22506.136	48216.164	0	8000
27	159	928.52505	-175.30945	21495.536	46260.845	0	8000
28	159	942.4436	-170.065	21172.224	45878.416	0	8000
29	159	969.32875	-158.3291	20467.895	44734.118	0	8000
30	159	1016.0289	-135.54275	19095.059	42029.915	0	8000
31	159	1062.7295	-108.28064	17444.044	38733.403	0	8000
32	159	1109.43	-75.894675	15472.58	34775.532	0	8000
33	159	1156.13	-37.43685	13122.272	30052.723	0	8000
34	159	1202.8305	8.56058	10301.494	24416.542	0	8000
35	159	1249.531	64.58503	6854.9449	17622.613	0	8000
36	159	1296.231	135.56474	2475.3089	9227.3375	0	8000
37	159	1319.745	175.95785	-20.357385	4627.3709	0	8000

East Facing Slope

Long Term Strength Analysis



SLOPE/W Analysis

File Information

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Last Edited By: Gondhalekar, Rajendra S.
Date: 12/10/2014
Time: 5:21:42 PM
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Last Solved Time: 5:22:20 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

- Kind: SLOPE/W
- Method: Morgenstern-Price
- Settings
  - Apply Phreatic Correction: No
  - Side Function
    - Interslice force function option: Half-Sine
  - PWP Conditions Source: Piezometric Line
  - Use Staged Rapid Drawdown: No
- Slip Surface
  - Direction of movement: Left to Right
  - Use Passive Mode: No
  - Slip Surface Option: Entry and Exit
  - Critical slip surfaces saved: 1
  - Optimize Critical Slip Surface Location: Yes
  - Tension Crack
    - Tension Crack Option: (none)
- FOS Distribution

FOS Calculation Option: Constant

Advanced

Number of Slices: 30

Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 0.1 ft

Optimization Maximum Iterations: 20000

Optimization Convergence Tolerance: 1e-007

Starting Optimization Points: 8

Ending Optimization Points: 16

Complete Passes per Insertion: 1

Driving Side Maximum Convex Angle: 5 °

Resisting Side Maximum Convex Angle: 1 °

Materials

Structural Fill

Model: Mohr-Coulomb

Unit Weight: 130 pcf

Cohesion: 600 psf

Phi: 26 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Chalk (Long Term)

Model: Anisotropic Strength

Unit Weight: 130 pcf

C-Horizontal: 6000 psf

C-Vertical: 2000 psf

Phi-Horizontal: 36 °

Phi-Vertical: 43 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range

Left-Zone Left Coordinate: (0, 275.5204) ft

Left-Zone Right Coordinate: (600, 248.7099) ft

Left-Zone Increment: 40

Right Projection: Range

Right-Zone Left Coordinate: (650, 236.209) ft

Right-Zone Right Coordinate: (1500, 194) ft

Right-Zone Increment: 40

Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 275.5204) ft

Right Coordinate: (2985.553, 259.7822) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	255.1389
	202.1461	275.3234
	451.071	272.2157
	526.729	267.029
	918.1415	169.1687
	938.9086	169.1687
	1407.7683	177.1254
	1577.7648	177.1254
	2083.9204	168.8062
	2104.6876	168.8062
	2382.2656	238.2051
	2511.8947	234.8255
	2747.8299	234.1993
	2985.553	240.7074

Regions

	Material	Points	Area (ft^2)
Region 1	Structural Fill	1,2,3,4,5,6,7,8,9,10	7794.3046
Region 2	Chalk (Long Term)	11,12,1,2,3,4,5,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29	2135903.8
Region 3		25,27,26	21.282755

Points

	X (ft)	Y (ft)
Point 1	2985.553	251.6444
Point 2	2771.2301	242.2954
Point 3	2623.9439	240.0761
Point 4	2465.5776	248.0137
Point 5	2431.0482	250.4015
Point 6	2477.5025	262.0158
Point 7	2494.1359	262.0158
Point 8	2550.1359	262.0158
Point 9	2605.1357	257
Point 10	2985.553	259.7822

Point 11	0	-500
Point 12	2985.553	-500
Point 13	2104.6876	168.8062
Point 14	2083.9204	168.8062
Point 15	2077.2314	172.1308
Point 16	1577.7648	177.1254
Point 17	1510.2666	194
Point 18	1475.2666	194
Point 19	1407.7683	177.1254
Point 20	945.9786	172.7182
Point 21	938.9086	169.1687
Point 22	918.1415	169.1687
Point 23	508.7814	271.5162
Point 24	507.107	271.5162
Point 25	158.5668	275.8674
Point 26	141.4553	274.9071
Point 27	122.3082	276.3201
Point 28	117.5381	276.6721
Point 29	0	275.5204

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	5.021	(733.467, 484.233)	240.7421	(444.938, 272.292)	(938.891, 169.169)
2	5813	5.198	(733.467, 484.233)	376.629	(421.935, 272.58)	(942.712, 171.078)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	448.00455	266.1555	380.54514	-134.71734	-457.48751	2799.2
2	Optimized	455.66195	250.831	1314.7864	1535.7024	196.14534	2799.2
3	Optimized	466.7095	232.60575	2404.7534	3701.0577	1112.4415	3351.7
4	Optimized	479.6227	214.5307	3477.4142	5570.3811	1796.1085	3351.7
5	Optimized	496.59315	194.4257	4659.2523	7912.7041	2699.054	3897.5
6	Optimized	507.9442	182.47695	5356.4164	9089.2899	3096.7808	3897.5
7	Optimized	511.90045	178.3124	5599.3792	9414.4428	3164.9655	3897.5
8	Optimized	520.87425	170.3781	6056.0671	10399.483	3480.7279	4452.4
9	Optimized	531.737	161.74875	6491.3663	10961.744	3582.4729	4452.4
10	Optimized	544.3013	153.42235	6814.6247	11972.909	3992.6746	5005
11	Optimized	559.41395	144.7262	7122.0341	12454.096	4127.1843	5005
12	Optimized	575.62115	136.7914	7364.1807	13369.568	4529.8223	5413.3
13	Optimized	592.92285	129.61795	7541.9718	13693.116	4639.7656	5413.3
14	Optimized	608.7891	123.9452	7648.2383	14427.071	5023.4	5691.5
15	Optimized	623.2199	119.77325	7683.5204	14544.9	5084.5707	5691.5
16	Optimized	637.6507	115.6013	7718.8026	14675.378	5155.1144	5691.5
17	Optimized	652.9144	111.975	7706.5154	15210.453	5501.5102	5858.7
18	Optimized	669.011	108.8944	7647.9386	15200.08	5536.8509	5858.7
19	Optimized	685.1076	105.8138	7588.7515	15195.808	5577.1124	5858.7

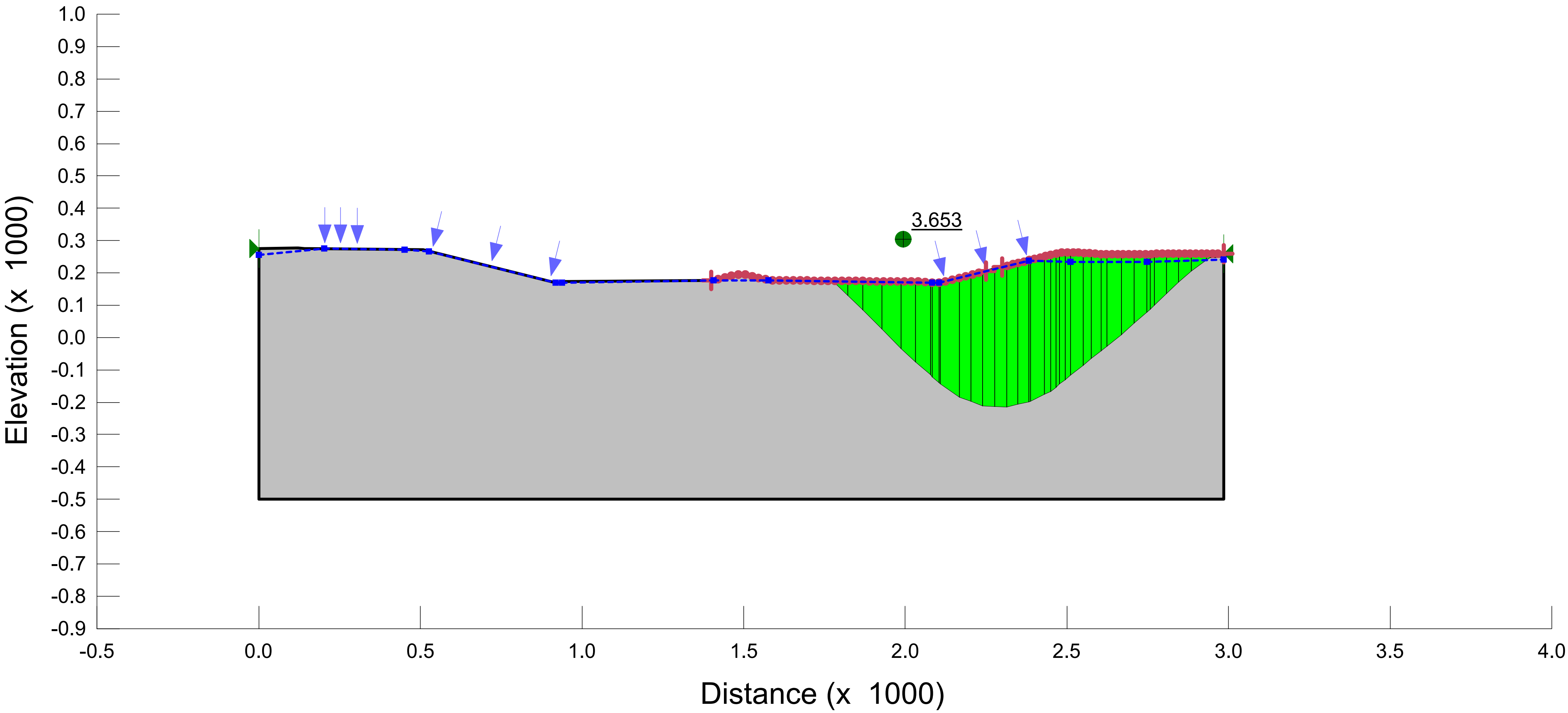
20	Optimized	700.3822	103.5685	7491.0803	15608.828	5912.1876	5962.3
21	Optimized	714.83485	102.1585	7353.3513	15429.78	5882.095	5962.3
22	Optimized	729.28755	100.7485	7215.6223	15245.223	5847.9901	5962.3
23	Optimized	743.7402	99.3385	7078.582	15053.78	5808.3682	5962.3
24	Optimized	759.3966	98.7024	6873.9487	15264.436	6096.0462	5999.7
25	Optimized	776.2568	98.8402	6602.3121	14742.515	5914.2033	5999.7
26	Optimized	793.117	98.978	6330.6755	14200.428	5717.7095	5999.7
27	Optimized	811.4826	100.419	5953.7608	13983.835	5862.2886	5925.1
28	Optimized	831.3536	103.1632	5472.6941	12852.207	5387.3515	5925.1
29	Optimized	853.6214	107.95235	4826.5426	11793.83	5155.3337	5714.8
30	Optimized	878.23435	117.0428	3875.3487	9925.8454	4597.7388	5296.5
31	Optimized	902.8375	132.00105	2558.0159	7139.1767	3648.5911	4551.4
32	Optimized	916.65075	143.03745	1653.8474	5401.5959	3151.3165	3680.3
33	Optimized	928.5163	156.97885	760.66056	3012.8743	1893.7872	3680.3

Slices of Slip Surface: 5813

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	5813	429.21875	262.5811	618.2111	435.3548	-156.57739	3386.9
2	5813	443.7869	243.8064	1778.4268	2621.5432	711.10244	3631.5
3	5813	460.41035	225.1857	2894.7341	4745.8886	1535.985	3894.8
4	5813	479.089	206.77875	3963.5514	6825.3271	2333.7578	4173.2
5	5813	497.76765	190.71655	4885.7011	8645.9879	3017.3018	4431.9
6	5813	507.9442	182.591	5349.0771	9579.837	3366.5041	4565.8
7	5813	517.7552	175.6912	5737.7285	10144.797	3480.2433	4686.8
8	5813	535.23795	164.1477	6287.1214	11044.551	3708.8952	4891.2
9	5813	552.2559	154.206	6641.9326	11804.561	3978.9178	5073.4
10	5813	569.27385	145.4105	6925.1177	12474.836	4232.4995	5239.3
11	5813	586.29175	137.67355	7142.6485	13064.026	4473.431	5388.8
12	5813	603.3097	130.92535	7298.1914	13576.864	4703.2027	5522
13	5813	620.32765	125.11	7395.2683	14015.42	4922.298	5638.8
14	5813	637.34555	120.18265	7437.5907	14377.486	5127.0095	5739.3
15	5813	654.3635	116.1076	7426.0085	14659.559	5315.3206	5823.5
16	5813	671.38145	112.8567	7363.4672	14854.44	5480.5561	5891.2
17	5813	688.39935	110.40835	7250.9678	14954.064	5617.1942	5942.7
18	5813	705.4173	108.7469	7089.2188	14948.419	5718.2206	5977.8
19	5813	722.43525	107.8619	6878.6108	14826.81	5775.9766	5996.6
20	5813	739.4532	107.7478	6620.4115	14578.066	5781.999	5999
21	5813	756.47115	108.4039	6313.8645	14190.799	5728.391	5985.1
22	5813	773.48905	109.8343	5959.1385	13654.192	5607.0108	5954.8
23	5813	790.507	112.04795	5555.5588	12960.144	5411.6009	5908.2
24	5813	807.52495	115.05895	5102.2125	12101.76	5136.2261	5845.3
25	5813	824.54285	118.88705	4597.8191	11073.765	4776.2241	5766
26	5813	841.5608	123.55835	4040.8583	9876.2903	4330.1408	5670.3
27	5813	858.57875	129.1062	3429.1665	8511.8128	3798.571	5558.3
28	5813	875.59665	135.57255	2760.1552	6984.5937	3182.996	5430
29	5813	892.6146	143.00985	2030.5785	5303.3087	2488.732	5285.3
30	5813	909.63255	151.4833	1236.3048	3478.5937	1722.5594	5124.3

31	5813	928.52505	162.27905	429.92109	1646.5414	946.43117	4926
32	5813	939.37925	168.87735	18.678138	756.36763	578.25614	4804.4
33	5813	941.28075	170.13135	-57.555915	714.72037	561.03707	4782.2

West Facing Slope
Short Term Strength Analysis



SLOPE/W Analysis

File Information

- Created By: Gondhalekar, Rajendra S.
- Revision Number: 19
- Last Edited By: Gondhalekar, Rajendra S.
- Date: 12/10/2014
- Time: 5:17:57 PM
- File Name: Trench 23-Excavation_Short_Term_Right.gsz
- Directory: N:\Projects\2014\EJ147410\Working Files\Calculations-Analyses\Stability\Excavation\
- Last Solved Date: 12/10/2014
- Last Solved Time: 5:18:40 PM

Project Settings

- Length(L) Units: feet
- Time(t) Units: Seconds
- Force(F) Units: lbf
- Pressure(p) Units: psf
- Strength Units: psf
- Unit Weight of Water: 62.4 pcf
- View: 2D

Analysis Settings

SLOPE/W Analysis

- Kind: SLOPE/W
- Method: Morgenstern-Price
- Settings
  - Apply Phreatic Correction: No
  - Side Function
    - Interslice force function option: Half-Sine
  - PWP Conditions Source: Piezometric Line
  - Use Staged Rapid Drawdown: No
- Slip Surface
  - Direction of movement: Right to Left
  - Use Passive Mode: No
  - Slip Surface Option: Entry and Exit
  - Critical slip surfaces saved: 1
  - Optimize Critical Slip Surface Location: Yes
  - Tension Crack
    - Tension Crack Option: (none)
- FOS Distribution

FOS Calculation Option: Constant

Advanced

Number of Slices: 30

Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 0.1 ft

Optimization Maximum Iterations: 20000

Optimization Convergence Tolerance: 1e-007

Starting Optimization Points: 8

Ending Optimization Points: 16

Complete Passes per Insertion: 1

Driving Side Maximum Convex Angle: 5 °

Resisting Side Maximum Convex Angle: 1 °

Materials

Structural Fill

Model: Mohr-Coulomb

Unit Weight: 130 pcf

Cohesion: 600 psf

Phi: 26 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Chalk (Short Term)

Model: Undrained (Phi=0)

Unit Weight: 130 pcf

Cohesion: 8000 psf

Pore Water Pressure

Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range

Left-Zone Left Coordinate: (1400, 177.0513) ft

Left-Zone Right Coordinate: (2250, 205.1366) ft

Left-Zone Increment: 40

Right Projection: Range

Right-Zone Left Coordinate: (2300, 217.6374) ft

Right-Zone Right Coordinate: (2985.553, 259.7822) ft

Right-Zone Increment: 40

Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 275.5204) ft

Right Coordinate: (2985.553, 259.7822) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	255.1389
	202.1461	275.3234
	451.071	272.2157
	526.729	267.029
	918.1415	169.1687
	938.9086	169.1687
	1407.7683	177.1254
	1577.7648	177.1254
	2083.9204	168.8062
	2104.6876	168.8062
	2382.2656	238.2051
	2511.8947	234.8255
	2747.8299	234.1993
	2985.553	240.7074

Regions

	Material	Points	Area (ft²)
Region 1	Structural Fill	1,2,3,4,5,6,7,8,9,10	7794.3046
Region 2	Chalk (Short Term)	11,12,1,2,3,4,5,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29	2135903.8
Region 3		25,27,26	21.282755

Points

	X (ft)	Y (ft)
Point 1	2985.553	251.6444
Point 2	2771.2301	242.2954
Point 3	2623.9439	240.0761
Point 4	2465.5776	248.0137
Point 5	2431.0482	250.4015
Point 6	2477.5025	262.0158
Point 7	2494.1359	262.0158
Point 8	2550.1359	262.0158
Point 9	2605.1357	257
Point 10	2985.553	259.7822
Point 11	0	-500
Point 12	2985.553	-500
Point 13	2104.6876	168.8062
Point 14	2083.9204	168.8062

Point 15	2077.2314	172.1308
Point 16	1577.7648	177.1254
Point 17	1510.2666	194
Point 18	1475.2666	194
Point 19	1407.7683	177.1254
Point 20	945.9786	172.7182
Point 21	938.9086	169.1687
Point 22	918.1415	169.1687
Point 23	508.7814	271.5162
Point 24	507.107	271.5162
Point 25	158.5668	275.8674
Point 26	141.4553	274.9071
Point 27	122.3082	276.3201
Point 28	117.5381	276.6721
Point 29	0	275.5204

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	3.653	(2304.46, 445.052)	549.5428	(2960.22, 259.597)	(1776.41, 175.139)
2	3659	4.107	(2304.46, 445.052)	606.639	(2881.87, 259.024)	(1761.1, 175.292)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	1777.084	174.48865	-39.890492	2209.706	0	8000
2	Optimized	1800.3705	151.8851	1346.6927	5140.2215	0	8000
3	Optimized	1845.603	107.9785	4040.0938	10865.803	0	8000
4	Optimized	1897.7265	56.39145	7205.5902	17732.404	0	8000
5	Optimized	1956.8285	-3.7292	10896.539	25782.137	0	8000
6	Optimized	2009.125	-54.58022	14015.988	32224.148	0	8000
7	Optimized	2054.529	-95.30847	16511.29	37668.89	0	8000
8	Optimized	2080.5755	-118.67265	17941.699	40577.486	0	8000
9	Optimized	2094.304	-130.9869	18707.116	42021.024	0	8000
10	Optimized	2106.28	-141.7292	19402.162	43526.34	0	8000
11	Optimized	2137.36	-164.00745	21276.61	46954.467	0	8000
12	Optimized	2184.8265	-191.43415	23729.254	51029.923	0	8000
13	Optimized	2220.7835	-204.58725	25110.911	53913.382	0	8000
14	Optimized	2257.499	-212.14895	26155.575	54957.354	0	8000
15	Optimized	2294.973	-214.1192	26864.428	56361.734	0	8000
16	Optimized	2330.849	-211.07515	27232.974	56025.623	0	8000
17	Optimized	2365.127	-203.0169	27264.781	56017.103	0	8000

18	Optimized	2384.6125	-198.4361	27243.424	56015.466	0	8000
19	Optimized	2409.0035	-186.70705	26470.338	54285.939	0	8000
20	Optimized	2440.267	-170.8554	25430.997	53211.019	0	8000
21	Optimized	2457.532	-159.7914	24712.404	51355.822	0	8000
22	Optimized	2471.5405	-148.6665	23995.335	50377.726	0	8000
23	Optimized	2485.8195	-137.32645	23264.803	49122.744	0	8000
24	Optimized	2503.0155	-123.6699	22384.456	47381.16	0	8000
25	Optimized	2531.0155	-101.43326	20979.416	44561.55	0	8000
26	Optimized	2563.1725	-75.89521	19380.504	41177.601	0	8000
27	Optimized	2590.6725	-53.867325	18001.432	38036.499	0	8000
28	Optimized	2614.54	-34.60164	16795.347	35448.294	0	8000
29	Optimized	2646.1455	-9.089665	15198.132	32263.633	0	8000
30	Optimized	2688.218	26.20944	12988.447	27674.77	0	8000
31	Optimized	2727.9595	60.965525	10813.067	23327.799	0	8000
32	Optimized	2752.758	82.653485	9464.821	20609.833	0	8000
33	Optimized	2764.458	93.40136	8814.3633	19076.204	0	8000
34	Optimized	2790.064	117.74421	7338.9973	16011.186	0	8000
35	Optimized	2827.732	153.55395	5168.8337	11483.069	0	8000
36	Optimized	2865.9925	188.34775	3062.9469	7239.6573	0	8000
37	Optimized	2908.8195	222.242	1021.1514	3217.047	0	8000
38	Optimized	2939.5915	244.6042	-321.67688	341.62222	0	8000
39	Optimized	2953.593	254.77905	-932.69332	456.31081	222.55765	600

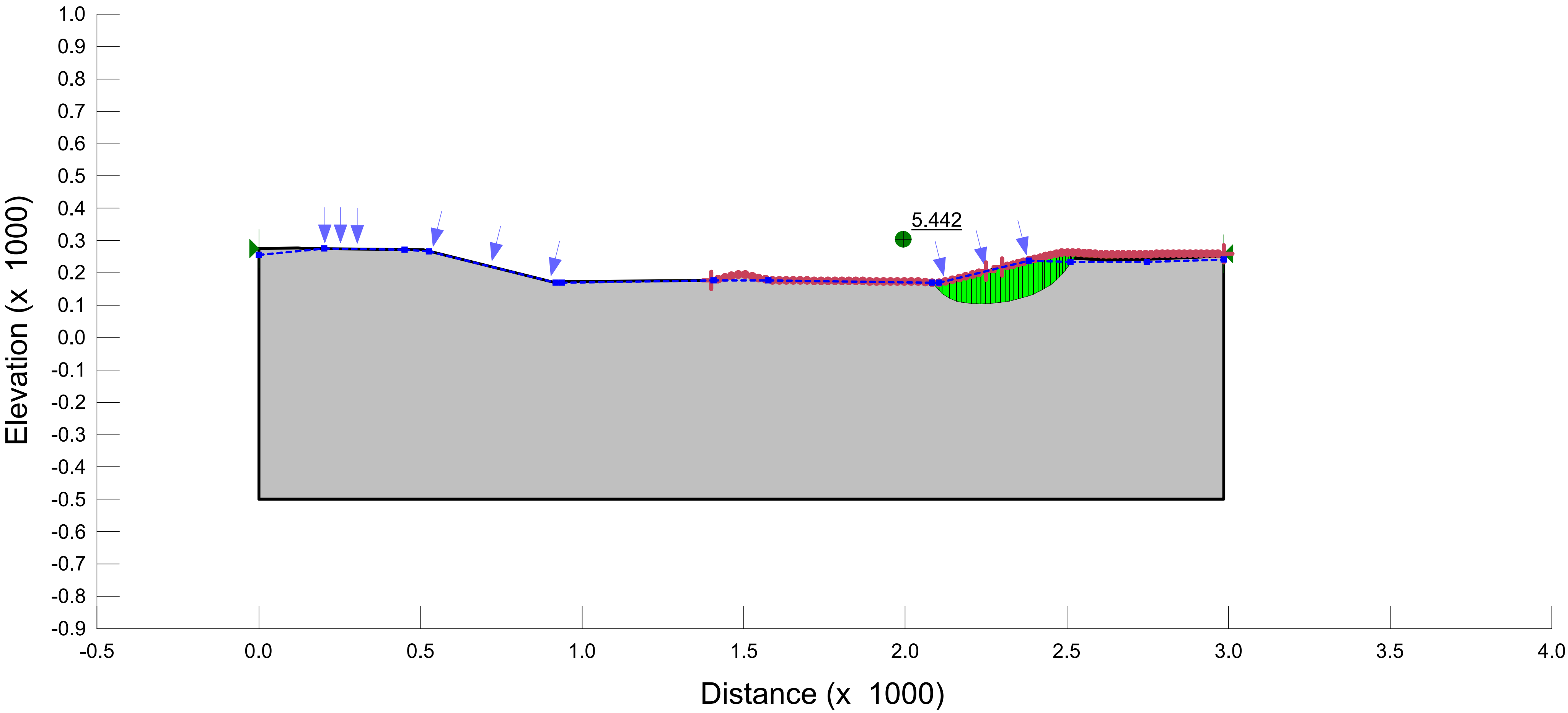
Slices of Slip Surface: 3659

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	3659	1761.391	174.69725	-36.813971	3990.5128	0	8000
2	3659	1781.4085	140.25885	2091.6272	7913.3612	0	8000
3	3659	1820.8515	80.269815	5794.4538	15015.686	0	8000
4	3659	1860.2945	32.87259	8711.6877	20772.499	0	8000
5	3659	1899.7375	-6.07196	11101.241	25555.973	0	8000
6	3659	1939.1805	-38.657545	13094.118	29565.405	0	8000
7	3659	1978.6235	-66.1212	14767.426	32926.011	0	8000
8	3659	2018.0665	-89.26267	16171.06	35726.137	0	8000
9	3659	2057.5095	-108.62918	17338.971	38026.538	0	8000
10	3659	2080.5755	-118.7532	17947.606	38993.7	0	8000
11	3659	2094.304	-123.9165	18265.925	39380.735	0	8000
12	3659	2124.515	-133.9139	19199.014	41175.146	0	8000
13	3659	2164.169	-144.7917	20496.505	43667.683	0	8000
14	3659	2203.823	-152.8444	21617.562	45772.691	0	8000
			-				

15	3659	2243.477	158.18575	22569.449	47505.914	0	8000
16	3659	2283.131	-160.8878	23356.7	48882.835	0	8000
17	3659	2322.785	-160.98595	23981.571	49911.613	0	8000
18	3659	2362.439	-158.48145	24443.865	50596.713	0	8000
19	3659	2406.657	-152.4042	24333.624	50938.359	0	8000
20	3659	2448.313	-144.01555	23743.148	50919.772	0	8000
21	3659	2471.5405	-138.0909	23335.435	50754.792	0	8000
22	3659	2485.8195	-133.77665	23043.146	50299.528	0	8000
23	3659	2503.0155	-128.09465	22660.582	49459.65	0	8000
24	3659	2531.0155	-117.3154	21970.322	47902.039	0	8000
25	3659	2577.636	-95.72026	20615.304	44533.147	0	8000
26	3659	2614.54	-76.23424	19392.969	41512.56	0	8000
27	3659	2644.5915	-56.641635	18165.659	38860.413	0	8000
28	3659	2685.887	-25.920869	16241.727	34719.824	0	8000
29	3659	2727.1825	10.905855	13936.933	29760.139	0	8000
30	3659	2759.53	44.296395	11870.063	25241.254	0	8000
31	3659	2788.4495	80.439625	9664.0218	20302.273	0	8000
32	3659	2822.888	131.79445	6518.2307	13147.737	0	8000
33	3659	2857.3265	198.9802	2384.6936	3391.7269	0	8000
34	3659	2876.191	242.30705	-286.64115	-3320.3235	0	8000
35	3659	2879.852	252.9848	-946.64723	254.67748	124.21451	600

West Facing Slope

Long Term Strength Analysis



SLOPE/W Analysis

File Information

Created By: Gondhalekar, Rajendra S.
Revision Number: 17
Last Edited By: Gondhalekar, Rajendra S.
Date: 12/10/2014
Time: 5:19:53 PM
File Name: Trench 23-Excavation_Long_Term_Right.gsz
Directory: N:\Projects\2014\EJ147410\Working Files\Calculations-Analyses\Stability\Excavation\
Last Solved Date: 12/10/2014
Last Solved Time: 5:20:52 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

- Kind: SLOPE/W
- Method: Morgenstern-Price
- Settings
  - Apply Phreatic Correction: No
  - Side Function
    - Interslice force function option: Half-Sine
  - PWP Conditions Source: Piezometric Line
  - Use Staged Rapid Drawdown: No
- Slip Surface
  - Direction of movement: Right to Left
  - Use Passive Mode: No
  - Slip Surface Option: Entry and Exit
  - Critical slip surfaces saved: 1
  - Optimize Critical Slip Surface Location: Yes
  - Tension Crack
    - Tension Crack Option: (none)
- FOS Distribution

FOS Calculation Option: Constant

Advanced

Number of Slices: 30

Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 0.1 ft

Optimization Maximum Iterations: 20000

Optimization Convergence Tolerance: 1e-007

Starting Optimization Points: 8

Ending Optimization Points: 16

Complete Passes per Insertion: 1

Driving Side Maximum Convex Angle: 5 °

Resisting Side Maximum Convex Angle: 1 °

Materials

Structural Fill

Model: Mohr-Coulomb

Unit Weight: 130 pcf

Cohesion: 600 psf

Phi: 26 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Chalk (Long Term)

Model: Anisotropic Strength

Unit Weight: 130 pcf

C-Horizontal: 6000 psf

C-Vertical: 2000 psf

Phi-Horizontal: 36 °

Phi-Vertical: 43 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range

Left-Zone Left Coordinate: (1400, 177.0513) ft

Left-Zone Right Coordinate: (2250, 205.1366) ft

Left-Zone Increment: 40

Right Projection: Range

Right-Zone Left Coordinate: (2300, 217.6374) ft

Right-Zone Right Coordinate: (2985.0719, 259.7787) ft

Right-Zone Increment: 40

Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 275.5204) ft

Right Coordinate: (2985.553, 259.7822) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	255.1389
	202.1461	275.3234
	451.071	272.2157
	526.729	267.029
	918.1415	169.1687
	938.9086	169.1687
	1407.7683	177.1254
	1577.7648	177.1254
	2083.9204	168.8062
	2104.6876	168.8062
	2382.2656	238.2051
	2511.8947	234.8255
	2747.8299	234.1993
	2985.553	240.7074

Regions

	Material	Points	Area (ft^2)
Region 1	Structural Fill	1,2,3,4,5,6,7,8,9,10	7794.3046
Region 2	Chalk (Long Term)	11,12,1,2,3,4,5,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29	2135903.8
Region 3		25,27,26	21.282755

Points

	X (ft)	Y (ft)
Point 1	2985.553	251.6444
Point 2	2771.2301	242.2954
Point 3	2623.9439	240.0761
Point 4	2465.5776	248.0137
Point 5	2431.0482	250.4015
Point 6	2477.5025	262.0158
Point 7	2494.1359	262.0158
Point 8	2550.1359	262.0158
Point 9	2605.1357	257
Point 10	2985.553	259.7822

Point 11	0	-500
Point 12	2985.553	-500
Point 13	2104.6876	168.8062
Point 14	2083.9204	168.8062
Point 15	2077.2314	172.1308
Point 16	1577.7648	177.1254
Point 17	1510.2666	194
Point 18	1475.2666	194
Point 19	1407.7683	177.1254
Point 20	945.9786	172.7182
Point 21	938.9086	169.1687
Point 22	918.1415	169.1687
Point 23	508.7814	271.5162
Point 24	507.107	271.5162
Point 25	158.5668	275.8674
Point 26	141.4553	274.9071
Point 27	122.3082	276.3201
Point 28	117.5381	276.6721
Point 29	0	275.5204

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	5.442	(2271.56, 453.166)	219.2119	(2533.67, 262.016)	(2083.94, 168.806)
2	6638	5.633	(2271.56, 453.166)	340.855	(2553.56, 261.703)	(2082.73, 169.4)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	2094.3155	157.36345	714.02163	2712.5052	1667.6163	3804.2
2	Optimized	2109.414	140.707	1827.0894	5655.7065	3194.7545	3804.2
3	Optimized	2125.3305	128.348	2846.649	7605.1484	3721.3596	4841.5
4	Optimized	2147.761	116.90325	3910.7327	9777.5588	4403.8169	5489.4
5	Optimized	2167.137	110.99195	4581.8512	10911.638	4643.5704	5848.9
6	Optimized	2183.4095	107.7682	5036.9197	12022.635	5124.7632	5848.9
7	Optimized	2198.493	105.8342	5392.8864	12266.331	4996.5995	5991.4
8	Optimized	2212.3875	105.19005	5649.9027	12819.186	5211.6571	5991.4
9	Optimized	2226.2825	104.5459	5906.8472	13357.662	5416.3145	5991.4
10	Optimized	2240.963	104.6329	6130.4409	13340.97	5242.6023	5988.8
11	Optimized	2256.429	105.4511	6320.6572	13664.454	5339.498	5988.8
12	Optimized	2271.895	106.2693	6511.0027	13975.024	5426.9107	5988.8
13	Optimized	2286.827	107.72485	6653.0443	13730.293	5169.3378	5917.2
14	Optimized	2301.225	109.8177	6747.0676	13820.33	5166.4261	5917.2
15	Optimized	2315.623	111.91055	6841.0909	13910.367	5163.5143	5917.2
16	Optimized	2329.4115	114.51075	6893.9795	13510.41	4872.5295	5789.3
17	Optimized	2342.59	117.6183	6905.6487	13455.756	4823.6878	5789.3
18	Optimized	2355.7685	120.72585	6917.3179	13407.75	4779.7411	5789.3
19	Optimized	2372.312	125.7217	6863.7132	12797.896	4430.9418	5572.8

20	Optimized	2389.338	131.60945	6640.0336	12564.862	4423.9573	5572.8
21	Optimized	2403.6065	137.4647	6251.4598	11855.968	4266.8637	5266.7
22	Optimized	2418	144.28395	5802.5366	11499.969	4337.6092	5266.7
23	Optimized	2428.1225	149.55105	5457.4121	10771.413	4153.3958	4850.9
24	Optimized	2440.453	157.3794	4948.6931	10291.002	4175.5208	4850.9
25	Optimized	2457.718	169.88255	4140.5838	9063.7649	3966.8347	4365.8
26	Optimized	2467.0075	177.6031	3643.7231	8528.6464	3936.0087	4365.8
27	Optimized	2472.97	183.60755	3259.305	7712.8013	3698.9398	3878.8
28	Optimized	2481.6985	192.8819	2666.401	6893.4567	3510.865	3878.8
29	Optimized	2490.015	202.4575	2055.3684	5704.4863	3088.769	3573.5
30	Optimized	2498.807	213.3756	1359.7541	4564.3134	2712.4756	3573.5
31	Optimized	2507.6865	225.14715	610.77313	3167.9681	2197.7493	3327.5
32	Optimized	2513.199	232.9683	115.67223	2315.0792	1890.2528	3327.5
33	Optimized	2518.1595	240.00675	-324.35153	1585.246	1362.4199	3327.5
34	Optimized	2527.7435	253.60535	-1174.5063	816.85769	398.40811	600

Slices of Slip Surface: 6638

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	6638	2083.1695	169.10565	-17.916578	632.13007	496.33064	4778.1
2	6638	2083.7665	168.7099	6.1666599	645.80453	501.99099	4785.8
3	6638	2094.304	162.28105	407.17127	1531.7495	875.30269	4916.9
4	6638	2112.3985	151.8802	1176.4497	3274.1401	1611.1856	5127.2
5	6638	2127.8195	144.21945	1895.0614	4921.68	2301.1608	5288.2
6	6638	2143.2405	137.49765	2555.1378	6439.8076	2926.5646	5432.7
7	6638	2158.6615	131.65565	3160.2114	7819.3067	3481.3919	5560.9
8	6638	2174.0825	126.6461	3713.4131	9051.4523	3960.4762	5672.7
9	6638	2189.5035	122.43115	4216.9964	10132.447	4362.203	5768
10	6638	2204.9245	118.9806	4672.9329	11059.741	4686.0872	5847
11	6638	2220.3455	116.2709	5082.5769	11834.065	4933.7465	5909.6
12	6638	2235.7665	114.28425	5447.0977	12459.058	5108.8993	5955.9
13	6638	2251.1875	113.00795	5767.3685	12941.592	5217.1629	5985.7
14	6638	2266.6085	112.434	6043.7163	13289.562	5264.6084	5999.2
15	6638	2282.0295	112.55885	6276.526	13511.552	5257.9044	5996.2
16	6638	2297.4505	113.3833	6465.6669	13619.179	5204.9649	5976.9
17	6638	2312.8715	114.91245	6610.6361	13621	5112.6076	5941.2
18	6638	2328.2925	117.1559	6711.3193	13528.782	4988.532	5889.1
19	6638	2343.7135	120.12815	6766.6957	13350.234	4838.5666	5820.7
20	6638	2359.1345	123.84895	6775.1128	13093.371	4668.7833	5735.8
21	6638	2374.5555	128.3441	6735.2264	12763.303	4483.2146	5634.6
22	6638	2390.3965	133.81435	6500.7821	12348.547	4382.8104	5513.5
23	6638	2406.657	140.3511	6066.351	11842.511	4368.4754	5371.2
24	6638	2422.9175	147.8935	5569.2135	11254.131	4343.4611	5210.7
25	6638	2439.6805	156.8218	4984.924	10551.426	4302.9023	5026.1
26	6638	2456.9455	167.3174	4301.9087	9715.9	4240.9931	4815.7
27	6638	2471.5405	177.23705	3659.1659	8915.3551	4167.6475	4622.5

28	6638	2485.8195	188.28555	2946.5134	7764.4135	3869.4012	4418
29	6638	2503.0155	203.23575	1985.6463	6003.9142	3280.958	4153.3
30	6638	2522.5765	223.11375	729.05716	3662.3642	2444.2862	3826
31	6638	2537.0685	239.5041	-296.11611	1759.6521	1489.6028	3572.2
32	6638	2545.5075	250.4953	-983.38431	1191.1126	580.94443	600
33	6638	2551.849	259.22725	-1529.2906	166.85464	81.380447	600

Made by:	RSG	Date:	1/29/15	Sheet No.:	COVER
Checked by:	JCH	Date:	1/29/15	Job No.:	EJ147410
Calculations for:	Interim Slope Stability Analysis				
Emelle Facility – Trench 23					

INTERIM SLOPE STABILITY ANALYSIS

CALCULATION COVER SHEET

Calculations by:

Signature: Rajendra S Gondhalekar

Name: Rajendra S. Gondhalekar, P.E.

Title: Project Engineer

1/29/2015
Date

Calculations Reviewed by:

Signature: J. Craig Hensley

Name: J. Craig Hensley, E.I.T.

Title: Staff Engineer

1/29/2015
Date

Calculations Approved by:

Signature: Michael A. Kemp

Name: Michael A. Kemp P.E.

Title: Department Manager

1/29/2015
Date

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	1/29/15	ALL	Initial Submittal

1.0 OBJECTIVE

Our objective is to calculate the stability of the interim slopes for Trench 23 of the Emelle Facility. The analysis includes evaluation of both circular and sliding block failure surfaces, which provides factors of safety (FOS) against failures through the estimated interim configuration of the constructed landfill, landfilled waste, the critical interface for the proposed liner system, and the underlying chalk material. Since the analysis represents an interim condition, a FOS greater than 1.3 is considered acceptable.

2.0 METHODOLOGY

The slope stability analysis was performed using a method of slices analysis using a slope-stability software program. The stability modeling software used for our analysis is Slope/W 2007 which is a part of GeoStudio developed by Geo-Slope International, Ltd. The most critical cross section was selected based on the tallest potential interior, interim landfill slope. The location of the selected slope stability section is indicated in Figures 1 and 2 with respect to the existing grades and proposed liner grades respectively. The interim grades were estimated by assuming that the tallest potential interim waste slope will be constructed from the intercell berm between Cells 4 and 6 to the maximum height, based on a slope inclination of 4H:1V.

Slope stability analysis was performed at the selected cross-section. The analysis was performed to search for both a circular failure surface (based on an entry and exit method), and a sliding block surface passing through the critical liner interface. The analysis searched for a slope-failure surface with the minimum FOS against sliding. This analysis provides us with a FOS against failure through the most critical interim landfill slope during landfilling activities in Trench 23. The Morgenstern-Price Method was used to calculate the FOS against failure.

3.0 SUBSURFACE CONDITIONS AND MATERIALS

Detailed description of the subsurface conditions is provided in various reports contained in Attachment E of the permit application. The information was previously compiled into engineering properties for slope stability analysis by Golder Associates in the engineering calculation package for Trench 22, contained in Attachment D-6-1-7. A majority of the information remains relevant to the analysis of Trench 23. Therefore, properties for a majority of the engineered materials were selected to be identical to those previously utilized. The major exception to this was the interface shear strength for the critical liner interface, which was previously based on a smooth liner. Since the proposed Trench 23 design will utilize textured liners throughout, interface shear strength appropriate for the textured liner was utilized instead. The values for various materials used in the interim stability analysis are listed in the table below:

Material	Unit Weight (lb/ft^3)	Cohesion (lb/ft^2)	Friction Angle (°)
Interim Cover Soil	110	0	26
Structural Fill (Chalk)	130	600	26
Waste	110	650	15
Liner Protective Soil	110	0	26
Critical Geosynthetic Interface	110	0	15
Natural Intact Chalk (Short Term)	130	8000	0

Although the chalk is expected to exhibit both long term anisotropic and short term isotropic properties, the stability analysis was performed utilizing the short term isotropic properties, as they are more critical. The groundwater surface in the intact chalk, prior to the excavation was based on the Golder Associates site wide chalk water level data acquired May 30, 1983 to June 9, 1983, and shown on Figure 00-150-16, 7/29/1985 (part of Permit Application Revision 3.3). The bottom of the analysis was limited to approximately 500 ft below MSL, which is the average elevation of the bottom of the chalk formation.

4.0 ANALYSIS RESULTS

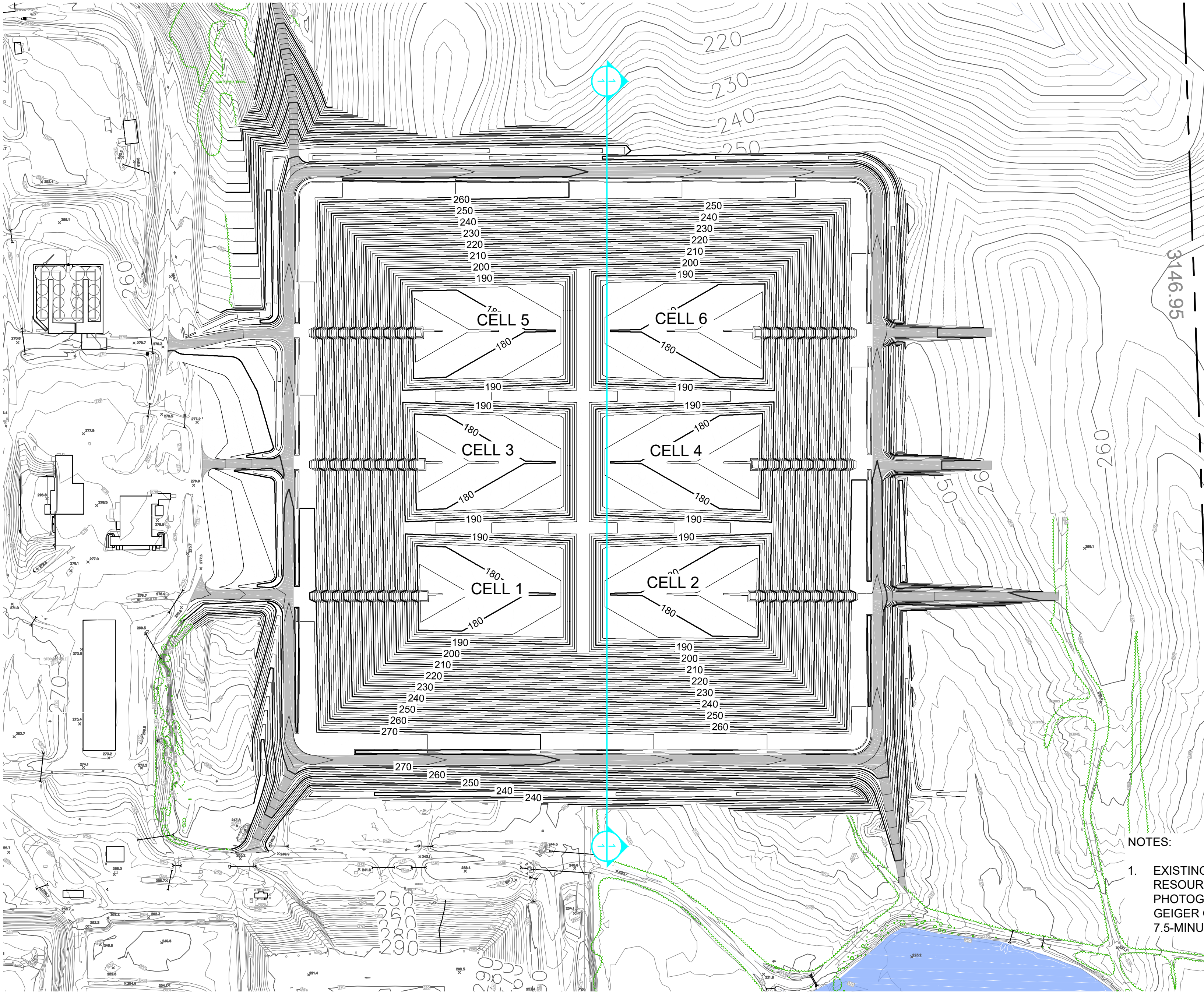
The input properties and the output results for the analysis are presented in Attachment 1. The following table presents the results of our analysis for the various scenarios.

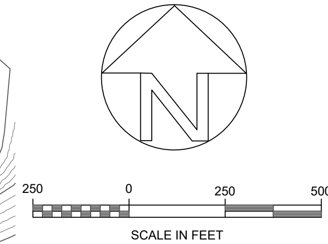
Cross Section	Failure Mode	Factor of Safety
Interim	Circular	1.51
	Block	1.44

5.0 CONCLUSIONS

Based on the results of the analysis, the Trench 23 interim slopes appear stable for both deep-seated circular and sliding block failure modes with FOS exceeding 1.3.

FIGURES





NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.

Project Mngr: MAK	Project No. EJ147410		
Drawn By: RSG	Scale: AS-SHOWN		
Checked By: JCH	File No. --		
Approved By: RSG	Date: 12-31-2014		

Terracon
Consulting Engineers and Scientists
240 HERITAGE WALK, SUITE 103 WOODSTOCK, GA 30188
PH. (770) 924-9799 FAX. (770) 924-7866

ANALYSIS CROSS SECTION LOCATION

INTERIM SLOPE STABILITY ANALYSIS

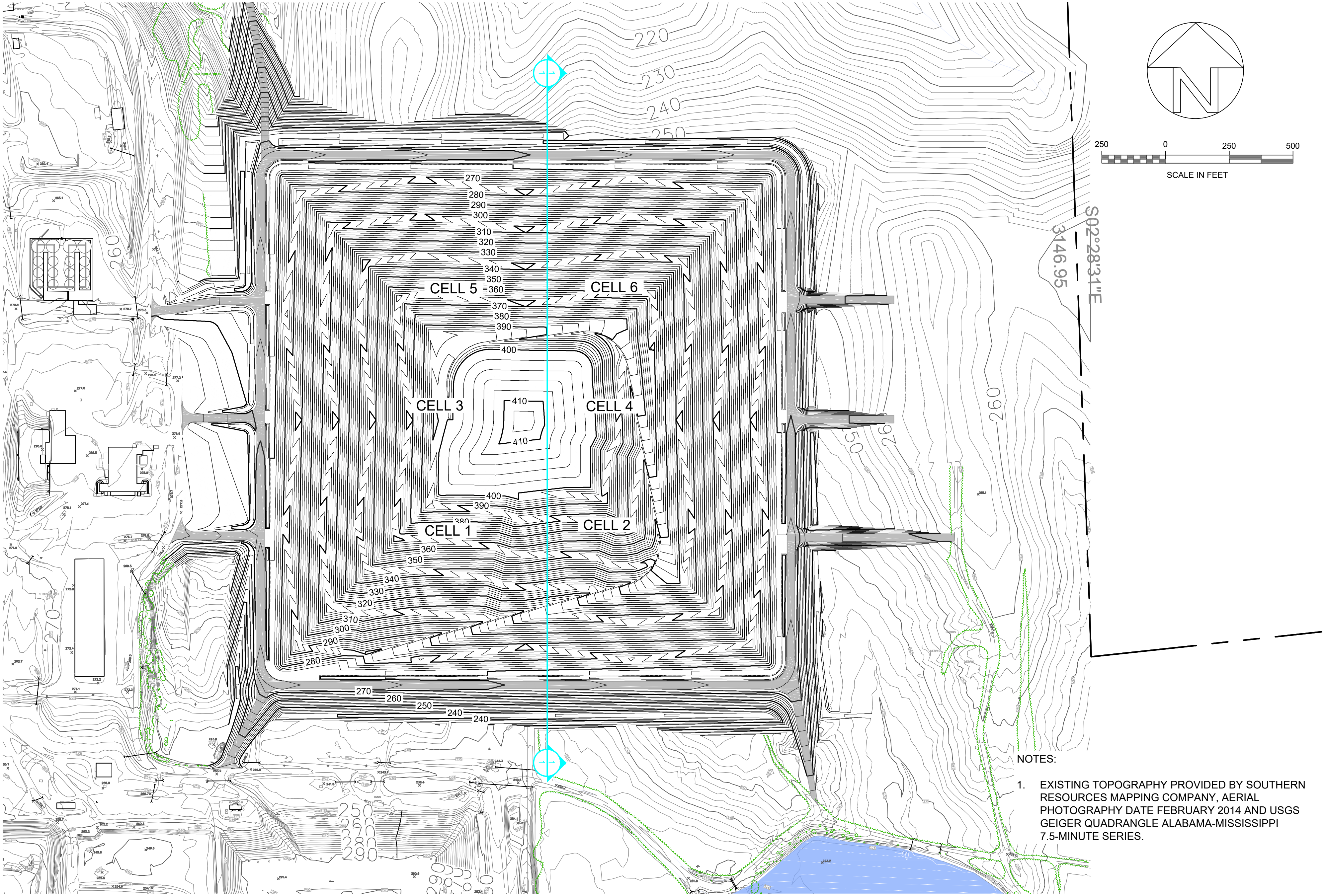
EMELLE FACILITY

CHEMICAL WASTE MANAGEMENT

FIG. No. 1

File Path: N:\PROJECTS\2014\EJ147410\WORKING FILES\CALCULATIONS-ANALYSES\STABILITY\INTERIM\FIGURES\EJ147410-FIG_1_2.DWG

Last Saved By: RSGONDHALEKAR Date: 12/15/2014 5:11 PM



NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.

Project Mngr: MAK	Project No. EJ147410		
Drawn By: RSG	Scale: AS-SHOWN		
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Terracon
Consulting Engineers and Scientists
240 HERITAGE WALK, SUITE 103 WOODSTOCK, GA 30188
PH. (770) 924-9799 FAX. (770) 924-7866

ANALYSIS CROSS SECTION LOCATION

INTERIM SLOPE STABILITY ANALYSIS

EMELLE FACILITY

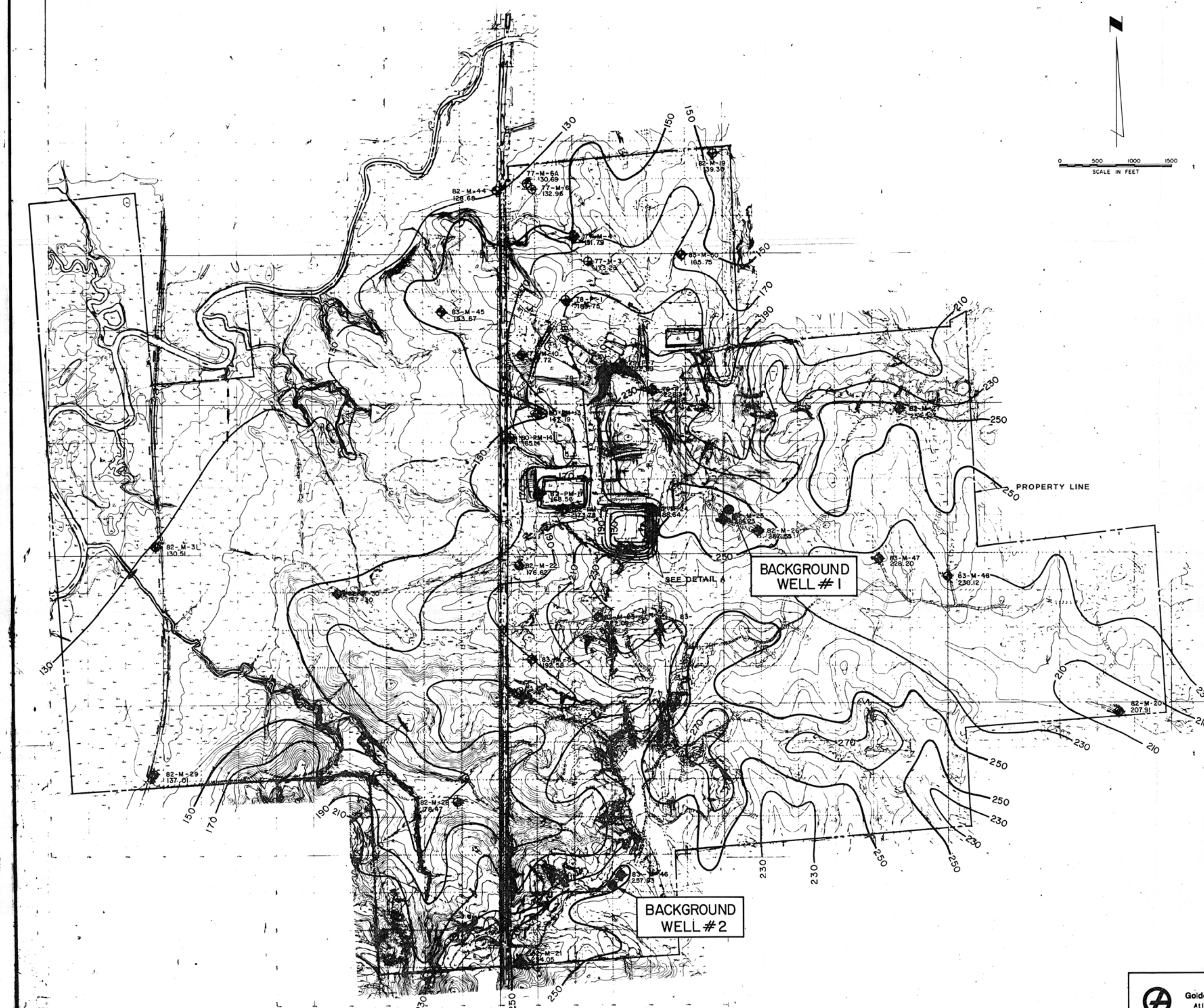
CHEMICAL WASTE MANAGEMENT

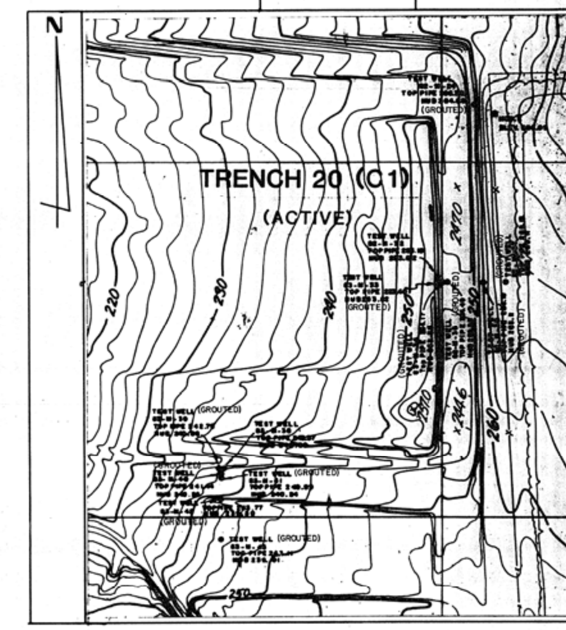
FIG. No. 2

Last Saved By: RSGONDHALEKAR Date: 12/15/2014 5:11 PM File Path: N:\PROJECTS\2014\EJ147410\WORKING FILES\CALCULATIONS-ANALYSES\STABILITY\INTERIM\FIGURES\EJ147410-FIG_1_2.DWG

PLATE 2

WELL NO.	WATER LEVEL ELEVATION (FT-MSL)
82-M-24	188.64
82-M-34	dry to 144.55
82-M-35	dry to 144.55
82-M-36	190.53
83-M-37	259.22
83-M-38	150.52
83-M-39	caved
83-M-40	163.32
83-M-41	168.19
83-M-43	212.40





DETAIL A
WELL LOCATIONS
SCALE 1" = 100'

LEGEND

—210— ESTIMATED CHALK WATER TABLE SURFACE CONTOURS (FT.-MSL)

83-M-50 / 230.05 — MONITORING WELL DESIGNATION; CHALK WATER TABLE SURFACE ELEVATIONS (FT.-MSL)

83-M-48 — GROUTED BETWEEN 5/13/85 AND 7/15/85

NOTE

1. CHALK WATER LEVEL DATA ACQUIRED MAY 30, 1983 TO JUNE 9, 1983.
2. BASE MAP PROVIDED BY CHEMICAL WASTE MANAGEMENT, INC. DATE OF AERIAL PHOTOGRAPHY, DECEMBER 13, 1982.

Section C, Figures Revision 3.3

REV.	DATE	DESCRIPTION	DR BY	APP BY
1	7/29/85	GROUTED WELLS AND BACKGROUND WELL LOCATIONS.	S.B.C.	

SCALE: 1" = 500'
GAI JOB NO. 853 3098
DES BY JEB 7-21-85
DR BY SKB 1-22-85
CHK BY 7/22/85
APP BY JEB 8/9/85

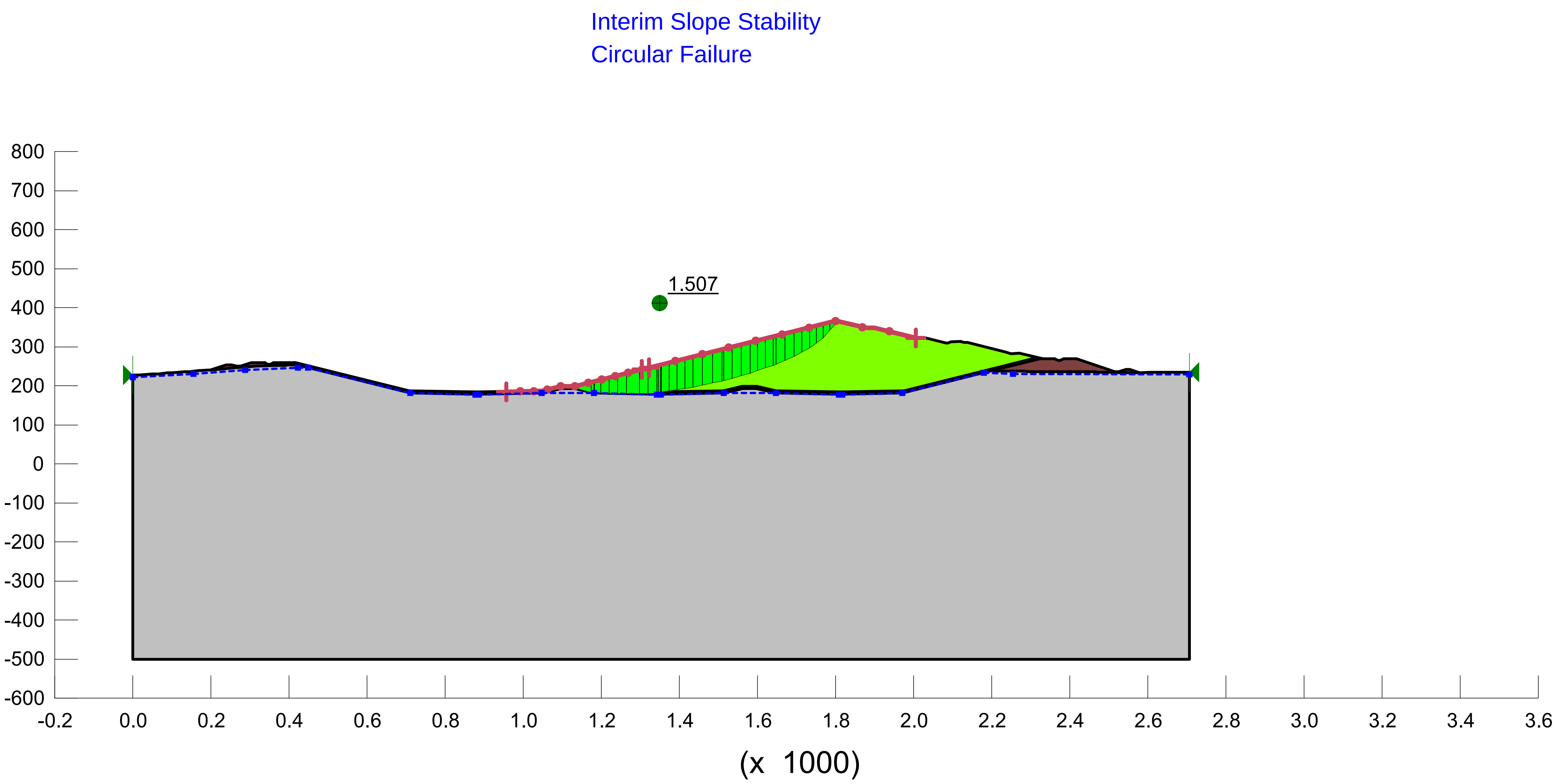
PROJECT: EMELLE FACILITY
SHEET TITLE: APPROXIMATE BACKGROUND WELL LOCATIONS

Golder Associates, Atlanta, Georgia

Chemical Waste Management, Inc., Oak Brook, Illinois 60521

ATTACHMENT 1

Interim Stability Output Data


Interim Slope Stability
Circular Failure
1.507
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
(x 1000)

Slope Stability

File Information

Title: Trench 23 - Final Stability
Created By: Gondhalekar, Rajendra S.
Revision Number: 27
Last Edited By: Gondhalekar, Rajendra S.
Date: 12/16/2014
Time: 11:03:18 AM
File Name: Trench 23-Interim-Global.gsz
Directory: N:\Projects\2014\EJ147410\Working Files\Calculations-Analyses\Stability\Interim\Model\
Last Solved Date: 12/16/2014
Last Solved Time: 11:03:45 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Slope Stability

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Apply Phreatic Correction: No
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

Slip Surface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: Yes
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced
- Number of Slices: 30
- Optimization Tolerance: 0.01
- Minimum Slip Surface Depth: 0.1 ft
- Optimization Maximum Iterations: 20000
- Optimization Convergence Tolerance: 1e-007
- Starting Optimization Points: 8
- Ending Optimization Points: 16
- Complete Passes per Insertion: 1
- Driving Side Maximum Convex Angle: 5 °
- Resisting Side Maximum Convex Angle: 1 °

Materials

Chalk

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 8000 psf
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
- Piezometric Line: 1

Structural Fill

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 600 psf
Phi: 26 °
Phi-B: 0 °
Pore Water Pressure
- Piezometric Line: 1

Synthetic Interface

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 15 °
Phi-B: 0 °

Liner Protective Soil

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 26 °
Phi-B: 0 °

Waste

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 650 psf
Phi: 15 °
Phi-B: 0 °

Cover Protective Soil

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 26 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (956.1224, 184.925) ft
Left-Zone Right Coordinate: (1303.5215, 241.6669) ft
Left-Zone Increment: 10
Right Projection: Range
Right-Zone Left Coordinate: (1321.6687, 246.2037) ft
Right-Zone Right Coordinate: (2005.824, 322.2179) ft
Right-Zone Increment: 10
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (0, 226.7995) ft
Right Coordinate: (2705.7308, 234.692) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	221.0627
	155.0862	230
	287.816	240.0841
	421.8726	246.1443
	448.7952	246.6011
	710.8845	181.0919
	877.0396	177.264
	886.0717	177.264
	1047.1947	181.0046
	1181.2026	181.0046
	1342.3256	177.264
	1351.3577	177.264
	1512.4807	181.0046
	1646.4886	181.0046
	1807.6116	177.264
	1816.6437	177.264
	1970.7486	180.8828
	2179.1154	232.9641
	2253.9109	230
	2705.7308	228.6573

Regions

	Material	Points	Area (ft²)
Region 1	Waste	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30	114682.2
Region 2	Structural Fill	31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51	1443.3965
Region 3	Structural Fill	52,53,54,55,56,57,30,29,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92	7045.8702
Region 4	Chalk	93,94,95,96,97,98,99,100,101,102,103,104,88,87,86,85,84,83,82,81,80,79,78,77,76,75,74,73,72,71,70,69,68,67,66,65,64,63,62,61,60,59,58,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,47,46,45,44,43,42,41,40,39,38,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142	1913229.7
Region 5	Synthetic Interface	29,58,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,47,48,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,28	5820.2117
Region 6	Liner Protective Soil	166,167,168,169,170,171,18,19,20,21,22,23,24,25,26,27,28,165,164,163,162,161,160,159,158,157,156,155,154,153,152,151,150,149,148,147,146,145,144,143	4174.1387
Region 7	Cover Protective Soil	171,18,17,172	2512.2624

Points

	X (ft)	Y (ft)
Point 1	2269.6175	283.8513
Point 2	2249.4166	282.7406
Point 3	2243.9222	284.1139

Point 4	2235.5183	286.1139
Point 5	2137.7003	310.5643
Point 6	2129.3828	311.4462
Point 7	2123.62	312.0187
Point 8	2121.5351	312.483
Point 9	2120.8379	313.4976
Point 10	2094.6591	312.8069
Point 11	2087.3422	309.3331
Point 12	2082.8447	309.3685
Point 13	2025.8235	323.4794
Point 14	2005.824	322.2179
Point 15	1898.1806	348.8667
Point 16	1878.1811	347.6056
Point 17	1809.8895	364.5091
Point 18	1139.8754	197.0056
Point 19	1181.928	186.4924
Point 20	1346.8416	183.6314
Point 21	1511.7553	186.4924
Point 22	1561.3078	198.8806
Point 23	1597.6614	198.8806
Point 24	1647.214	186.4924
Point 25	1812.1276	183.6314
Point 26	1974.4566	186.4476
Point 27	2304.0504	268.8301
Point 28	2310.2362	268.8301
Point 29	2322.6079	268.8301
Point 30	2329.7408	268.8301
Point 31	337.2386	259.3301
Point 32	320.2386	259.6701
Point 33	303.2386	259.3301
Point 34	275.015	249.9222
Point 35	265.015	249.9221
Point 36	253.015	253.9221
Point 37	238.015	253.9221
Point 38	197.6839	240.4784
Point 39	232.6561	243.3488
Point 40	260.6098	245.6203
Point 41	315.224	250
Point 42	362.8444	251.7626
Point 43	366.6774	251.8701
Point 44	387.6347	252.3511
Point 45	398.2564	252.7737
Point 46	405.6546	253.1438
Point 47	421.0154	253.5447
Point 48	397.8693	259.3301
Point 49	359.2386	259.3301
Point 50	351.2386	255.3301
Point 51	345.2386	255.3301
Point 52	2417.2386	268.8301
Point 53	2400.2386	269.1701
Point 54	2383.2386	268.8301
Point 55	2375.2386	264.8301
Point 56	2369.2386	264.8301
Point 57	2361.2386	268.8301
Point 58	2200.6548	238.3479
Point 59	2211.9132	238.1239
Point 60	2215.3768	238.1144
Point 61	2219.5534	238.0164
Point 62	2220.9212	238.02
Point 63	2223.1024	237.9362
Point 64	2280.1274	236.9054
Point 65	2285.8846	236.872
Point 66	2292.6637	236.7291
Point 67	2298.5508	236.6573
Point 68	2325.1496	236.4277
Point 69	2334.4903	236.2203
Point 70	2385.1052	235.7983
Point 71	2386.6778	235.8012
Point 72	2389.8982	235.7582
Point 73	2392.1363	235.7757
Point 74	2415.3189	235.527
Point 75	2420.5189	235.6589
Point 76	2456.9543	235.4725
Point 77	2464.855	235.4518
Point 78	2472.4591	235.2229
Point 79	2478.6393	234.912
Point 80	2483.5504	234.777
Point 81	2496.5636	234.6326
Point 82	2505.9458	234.5075
Point 83	2536.3264	233.8072
Point 84	2542.0903	233.8135
Point 85	2557.2984	233.6461
Point 86	2564.4024	233.772
Point 87	2570.4246	233.7174
Point 88	2577.3767	233.8197
Point 89	2552.8336	242
Point 90	2542.8328	242
Point 91	2525.2788	236.15
Point 92	2515.2788	236.15
Point 93	2705.7308	234.692
Point 94	2692.2664	234.2709

Point 95	2688.6929	234.1923
Point 96	2683.961	234.1565
Point 97	2679.9854	234.2071
Point 98	2674.736	234.1463
Point 99	2624.932	234.2295
Point 100	2620.6084	234.1508
Point 101	2615.0572	234.2206
Point 102	2611.1429	234.2376
Point 103	2608.3573	234.183
Point 104	2604.661	234.221
Point 105	1970.7486	180.8828
Point 106	1818.6014	178.2428
Point 107	1816.6437	177.264
Point 108	1807.6116	177.264
Point 109	1805.653	178.2433
Point 110	1646.4886	181.0046
Point 111	1596.9846	193.3806
Point 112	1561.9846	193.3806
Point 113	1512.4807	181.0046
Point 114	1353.3163	178.2433
Point 115	1351.3577	177.264
Point 116	1342.3256	177.264
Point 117	1340.367	178.2433
Point 118	1181.2026	181.0046
Point 119	1131.6986	193.3806
Point 120	1096.6986	193.3806
Point 121	1047.1947	181.0046
Point 122	888.0303	178.2433
Point 123	886.0717	177.264
Point 124	877.0396	177.264
Point 125	875.0819	178.2429
Point 126	710.8845	181.0919
Point 127	191.8853	240
Point 128	173.8967	238.644
Point 129	169.3044	238.2765
Point 130	144.0291	236.3473
Point 131	131.9812	235.5427
Point 132	115.4852	234.3153
Point 133	97.3517	233.1385
Point 134	88.2316	232.4766
Point 135	64.9565	231.0077
Point 136	62.0926	230.8048
Point 137	48.9879	230
Point 138	14.6059	227.7243
Point 139	8.4602	227.3522
Point 140	0	226.7995
Point 141	0	-500
Point 142	2705.7308	-500
Point 143	410.2409	259.3301
Point 144	711.2794	184.0855
Point 145	875.8146	181.2306
Point 146	877.7478	180.264
Point 147	885.3634	180.264
Point 148	887.2976	181.231
Point 149	1046.7997	183.9982
Point 150	1096.3293	196.3806
Point 151	1132.068	196.3806
Point 152	1181.5975	183.9982
Point 153	1341.0997	181.231
Point 154	1343.0338	180.264
Point 155	1350.6494	180.264
Point 156	1352.5836	181.231
Point 157	1512.0857	183.9982
Point 158	1561.6153	196.3806
Point 159	1597.354	196.3806
Point 160	1646.8835	183.9982
Point 161	1806.3857	181.231
Point 162	1808.3198	180.264
Point 163	1815.9354	180.264
Point 164	1817.8686	181.2306
Point 165	1970.3537	183.8764
Point 166	416.4268	259.3301
Point 167	707.1778	186.6566
Point 168	881.5556	183.6314
Point 169	1046.4693	186.4924
Point 170	1096.0218	198.8806
Point 171	1132.3754	198.8806
Point 172	1802.3521	366.3741

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.507	(1291.19, 836.585)	318.3562	(1805.86, 365.506)	(1127.86, 198.881)
2	675	1.640	(1291.19, 836.585)	657.35	(1731.76, 348.727)	(1131.69, 198.881)

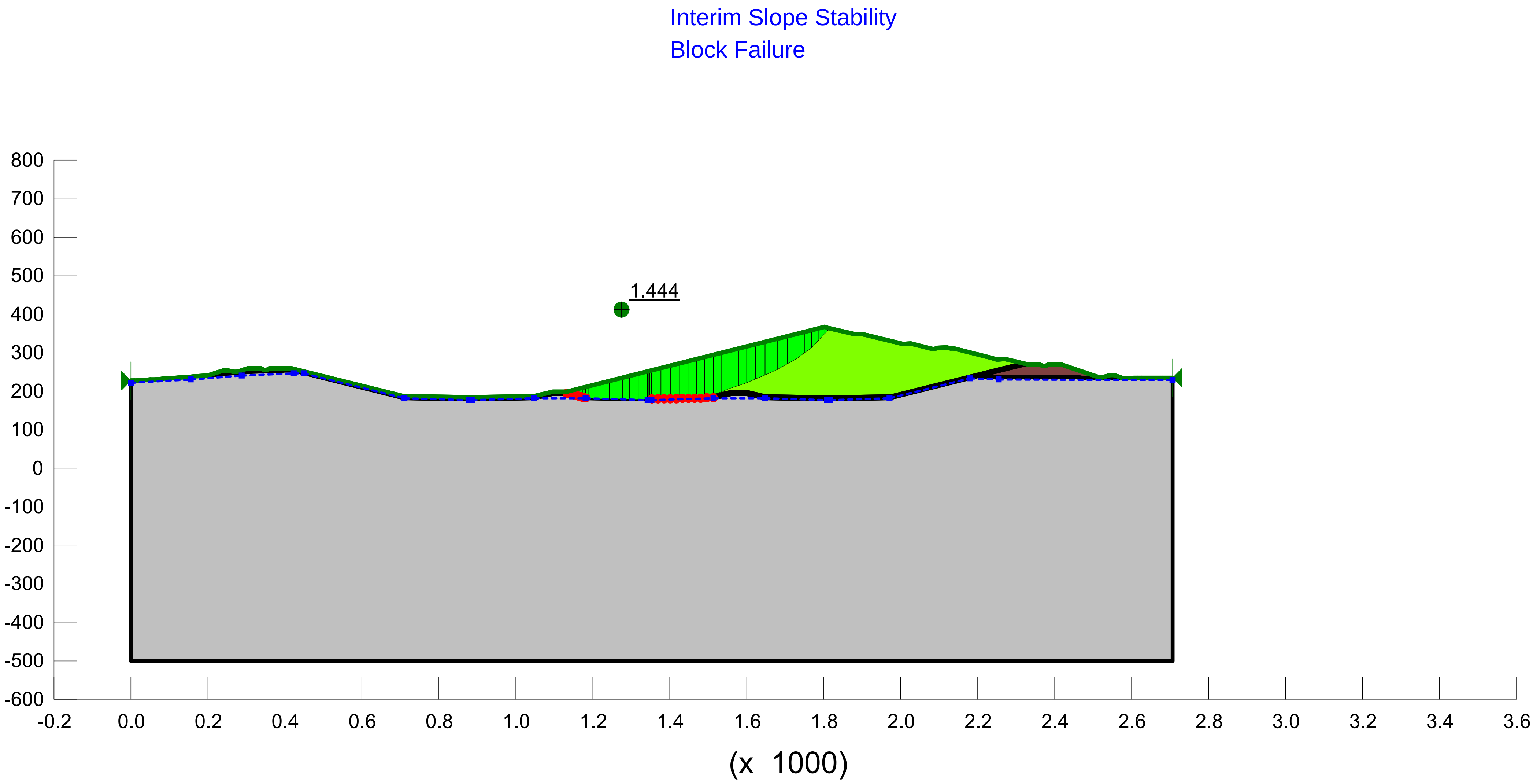
Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	1129.973	197.62865	0	171.44339	83.61853	0
2	Optimized	1132.229	196.29015	0	322.20476	86.334505	0
3	Optimized	1136.125	193.97895	0	760.14513	203.68027	0
4	Optimized	1140.505	191.38055	0	1262.7693	338.35802	0

5	Optimized	1157.241	187.165	0	2181.0876	584.42067	0
6	Optimized	1177.275	182.9039	0	3203.1176	858.27278	0
7	Optimized	1181.4005	182.46355	0	3368.8083	902.66948	0
8	Optimized	1189.6785	181.57995	0	3743.022	1002.9397	0
9	Optimized	1208.73	180.5273	0	4362.3741	1168.8946	0
10	Optimized	1230.672	180.1471	0	5068.4905	1358.0979	0
11	Optimized	1252.614	179.7669	0	5780.7129	1548.9374	0
12	Optimized	1280.3985	179.4285	0	6645.2543	1780.5905	0
13	Optimized	1308.184	179.7596	0	7278.4836	1950.2638	0
14	Optimized	1330.6665	180.7419	0	7789.8655	2087.2882	0
15	Optimized	1342.2515	181.26265	0	7431.1254	3624.402	0
16	Optimized	1344.584	181.8223	0	7433.1776	3625.403	0
17	Optimized	1349.1	182.9059	0	7436.8885	3627.2129	0
18	Optimized	1351.9465	183.58895	0	7439.0978	3628.2904	0
19	Optimized	1352.9205	183.8227	0	7438.9283	1993.2548	650
20	Optimized	1363.4635	185.45095	0	7850.7797	2103.6101	650
21	Optimized	1383.7785	188.52245	0	8056.1752	2158.6456	650
22	Optimized	1404.0935	191.5939	0	8256.2167	2212.2466	650
23	Optimized	1424.408	194.66535	0	8450.9044	2264.413	650
24	Optimized	1446.84	198.8584	0	8304.2776	2225.1245	650
25	Optimized	1471.39	204.17305	0	8352.0514	2237.9254	650
26	Optimized	1495.94	209.4877	0	8399.0289	2250.513	650
27	Optimized	1510.348	212.7293	0	8188.7678	2194.1737	650
28	Optimized	1523.7785	216.4082	0	8138.3997	2180.6776	650
29	Optimized	1546.373	222.5974	0	8056.0169	2158.6032	650
30	Optimized	1568.9675	228.7866	0	7977.0489	2137.4438	650
31	Optimized	1590.152	235.2701	0	7611.4787	2039.4896	650
32	Optimized	1609.9255	242.04785	0	7427.7699	1990.2649	650
33	Optimized	1629.6985	248.8256	0	7247.8883	1942.0658	650
34	Optimized	1643.037	253.69165	0	6870.3526	1840.9054	650
35	Optimized	1658.1075	260.141	0	6629.2266	1776.2959	650
36	Optimized	1681.345	270.08535	0	6259.3097	1677.177	650
37	Optimized	1702.989	280.5954	0	5559.6253	1489.6971	650
38	Optimized	1723.0395	291.67115	0	5033.1307	1348.6233	650
39	Optimized	1741.819	303.60565	0	4149.0446	1111.7332	650
40	Optimized	1759.3275	316.39895	0	3416.8169	915.53333	650
41	Optimized	1776.6495	332.48175	0	2045.7702	548.16247	650
42	Optimized	1793.7845	351.8541	0	723.19194	193.7787	650
43	Optimized	1802.968	362.23645	0	-38.966698	-10.441095	650
44	Optimized	1804.722	364.21935	0	126.13254	61.51895	0

Slices of Slip Surface: 675

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	675	1132.0305	198.7946	0	10.223109	4.9861434	0
2	675	1136.125	197.7983	0	241.0785	117.58184	0
3	675	1143.0285	196.15845	0	645.04428	314.60912	0
4	675	1154.937	193.5737	0	1381.075	370.05794	650
5	675	1172.4475	190.11035	0	2317.3898	620.94272	650
6	675	1188.276	187.3809	0	3122.0721	836.5567	650
7	675	1206.442	184.81715	0	4015.7316	1958.6032	0
8	675	1227.832	182.37745	0	4830.8394	1294.4195	0
9	675	1248.4265	180.7088	0	5647.8943	1513.3487	0
10	675	1269.021	179.68985	0	6351.1337	1701.7811	0
11	675	1289.615	179.3176	0	6938.8806	1859.2674	0
12	675	1310.209	179.59095	0	7408.7485	1985.1682	0
13	675	1330.8885	180.5172	0	7765.1664	2080.6701	0
14	675	1341.7985	181.18615	0	8094.7006	3948.0493	0
15	675	1344.584	181.4109	0	8130.7075	3965.611	0
16	675	1349.1	181.7946	0	8185.7616	3992.4627	0
17	675	1360.953	183.0185	0	8297.0932	4046.7628	0
18	675	1380.686	185.43605	0	8330.6135	2232.1812	650
19	675	1400.962	188.5467	0	8382.2435	2246.0154	650
20	675	1421.238	192.31035	0	8353.8796	2238.4153	650
21	675	1441.514	196.7385	0	8253.2653	2211.4558	650
22	675	1461.7905	201.8451	0	8085.9645	2166.6277	650
23	675	1482.067	207.64665	0	7856.8068	2105.225	650
24	675	1502.343	214.16265	0	7570.3971	2028.4818	650
25	675	1522.053	221.19275	0	7240.756	1940.1547	650
26	675	1541.197	228.72045	0	6871.5308	1841.2211	650
27	675	1560.341	236.95375	0	6454.4261	1729.4583	650
28	675	1579.485	245.92215	0	5988.4737	1604.6067	650
29	675	1598.629	255.65975	0	5468.7143	1465.3376	650
30	675	1617.773	266.20605	0	4891.2191	1310.5982	650
31	675	1636.917	277.6069	0	4248.2036	1138.3027	650
32	675	1656.4185	290.1641	0	3514.8245	941.79439	650
33	675	1676.2775	303.9805	0	2675.2021	716.81823	650
34	675	1696.137	318.9276	0	1723.6907	461.86154	650
35	675	1715.9965	335.1068	0	638.37357	171.05168	650
36	675	1728.8445	346.12265	0	162.34829	79.18255	0



Interim Slope Stability
Block Failure
1.444
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
(x 1000)

Slope Stability

File Information

- Title: Trench 23 - Final Stability
- Created By: Gondhalekar, Rajendra S.
- Revision Number: 30
- Last Edited By: Gondhalekar, Rajendra S.
- Date: 12/16/2014
- Time: 10:51:30 AM
- File Name: Trench 23-Interim-Block.gsz
- Directory: N:\Projects\2014\EJ147410\Working Files\Calculations-Analyses\Stability\Interim\Model\
- Last Solved Date: 12/16/2014
- Last Solved Time: 10:54:24 AM

Project Settings

- Length(L) Units: feet
- Time(t) Units: Seconds
- Force(F) Units: lbf
- Pressure(p) Units: psf
- Strength Units: psf
- Unit Weight of Water: 62.4 pcf
- View: 2D

Analysis Settings

Slope Stability

- Kind: SLOPE/W
- Method: Morgenstern-Price
- Settings
  - Apply Phreatic Correction: No
  - Side Function
    - Interslice force function option: Half-Sine
  - PWP Conditions Source: Piezometric Line
  - Use Staged Rapid Drawdown: No
- Slip Surface
  - Direction of movement: Right to Left
  - Use Passive Mode: No
  - Slip Surface Option: Block
  - Critical slip surfaces saved: 1
  - Optimize Critical Slip Surface Location: Yes
  - Tension Crack
    - Tension Crack Option: (none)
- FOS Distribution
  - FOS Calculation Option: Constant
- Restrict Block Crossing: No
- Advanced
  - Number of Slices: 30
  - Optimization Tolerance: 0.01
  - Minimum Slip Surface Depth: 0.1 ft
  - Optimization Maximum Iterations: 20000
  - Optimization Convergence Tolerance: 1e-007
  - Starting Optimization Points: 8
  - Ending Optimization Points: 16
  - Complete Passes per Insertion: 1
  - Driving Side Maximum Convex Angle: 5 °
  - Resisting Side Maximum Convex Angle: 1 °

Materials

Chalk

- Model: Mohr-Coulomb
- Unit Weight: 130 pcf
- Cohesion: 8000 psf
- Phi: 0 °
- Phi-B: 0 °
- Pore Water Pressure
  - Piezometric Line: 1

Structural Fill

- Model: Mohr-Coulomb
- Unit Weight: 130 pcf
- Cohesion: 600 psf
- Phi: 26 °
- Phi-B: 0 °
- Pore Water Pressure
  - Piezometric Line: 1

Synthetic Interface

- Model: Mohr-Coulomb
- Unit Weight: 110 pcf
- Cohesion: 0 psf
- Phi: 15 °
- Phi-B: 0 °

Liner Protective Soil
Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 26 °
Phi-B: 0 °

Waste
Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 650 psf
Phi: 15 °
Phi-B: 0 °

Cover Protective Soil
Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 26 °
Phi-B: 0 °

Slip Surface Limits
Left Coordinate: (0, 226.7995) ft
Right Coordinate: (2705.7308, 234.692) ft

Slip Surface Block
Left Grid
- Upper Left: (1133, 196) ft
- Lower Left: (1132, 193.5) ft
- Lower Right: (1181.2, 181.005) ft
- X Increments: 10
- Y Increments: 5
- Starting Angle: 135 °
- Ending Angle: 180 °
- Angle Increments: 4

Right Grid
- Upper Left: (1353, 181) ft
- Lower Left: (1353, 178) ft
- Lower Right: (1512.4807, 181.0046) ft
- X Increments: 10
- Y Increments: 4
- Starting Angle: 45 °
- Ending Angle: 65 °
- Angle Increments: 4

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	221.0627
	155.0862	230
	287.816	240.0841
	421.8726	246.1443
	448.7952	246.6011
	710.8845	181.0919
	877.0396	177.264
	886.0717	177.264
	1047.1947	181.0046
	1181.2026	181.0046
	1342.3256	177.264
	1351.3577	177.264
	1512.4807	181.0046
	1646.4886	181.0046
	1807.6116	177.264
	1816.6437	177.264
	1970.7486	180.8828
	2179.1154	232.9641
	2253.9109	230
	2705.7308	228.6573

Regions

	Material	Points	Area (ft²)
Region 1	Waste	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30	114682.2
Region 2	Structural Fill	31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51	1443.3965
Region 3	Structural Fill	52,53,54,55,56,57,30,29,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92	7045.8702
Region 4	Chalk	93,94,95,96,97,98,99,100,101,102,103,104,88,87,86,85,84,83,82,81,80,79,78,77,76,75,74,73,72,71,70,69,68,67,66,65,64,63,62,61,60,59,58,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,47,46,45,44,43,42,41,40,39,38,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142	1913229.7
Region 5	Synthetic Interface	29,58,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,47,48,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,28	5820.2117
Region 6	Liner Protective Soil	166,167,168,169,170,171,18,19,20,21,22,23,24,25,26,27,28,165,164,163,162,161,160,159,158,157,156,155,154,153,152,151,150,149,148,147,146,145,144,143	4174.1387

Region 7	Cover Protective Soil	171,18,17,172	2512.2624

Points

	X (ft)	Y (ft)
Point 1	2269.6175	283.8513
Point 2	2249.4166	282.7406
Point 3	2243.9222	284.1139
Point 4	2235.5183	286.1139
Point 5	2137.7003	310.5643
Point 6	2129.3828	311.4462
Point 7	2123.62	312.0187
Point 8	2121.5351	312.483
Point 9	2120.8379	313.4976
Point 10	2094.6591	312.8069
Point 11	2087.3422	309.3331
Point 12	2082.8447	309.3685
Point 13	2025.8235	323.4794
Point 14	2005.824	322.2179
Point 15	1898.1806	348.8667
Point 16	1878.1811	347.6056
Point 17	1809.8895	364.5091
Point 18	1139.8754	197.0056
Point 19	1181.928	186.4924
Point 20	1346.8416	183.6314
Point 21	1511.7553	186.4924
Point 22	1561.3078	198.8806
Point 23	1597.6614	198.8806
Point 24	1647.214	186.4924
Point 25	1812.1276	183.6314
Point 26	1974.4566	186.4476
Point 27	2304.0504	268.8301
Point 28	2310.2362	268.8301
Point 29	2322.6079	268.8301
Point 30	2329.7408	268.8301
Point 31	337.2386	259.3301
Point 32	320.2386	259.6701
Point 33	303.2386	259.3301
Point 34	275.015	249.9222
Point 35	265.015	249.9221
Point 36	253.015	253.9221
Point 37	238.015	253.9221
Point 38	197.6839	240.4784
Point 39	232.6561	243.3488
Point 40	260.6098	245.6203
Point 41	315.224	250
Point 42	362.8444	251.7626
Point 43	366.6774	251.8701
Point 44	387.6347	252.3511
Point 45	398.2564	252.7737
Point 46	405.6546	253.1438
Point 47	421.0154	253.5447
Point 48	397.8693	259.3301
Point 49	359.2386	259.3301
Point 50	351.2386	255.3301
Point 51	345.2386	255.3301
Point 52	2417.2386	268.8301
Point 53	2400.2386	269.1701
Point 54	2383.2386	268.8301
Point 55	2375.2386	264.8301
Point 56	2369.2386	264.8301
Point 57	2361.2386	268.8301
Point 58	2200.6548	238.3479
Point 59	2211.9132	238.1239
Point 60	2215.3768	238.1144
Point 61	2219.5534	238.0164
Point 62	2220.9212	238.02
Point 63	2223.1024	237.9362
Point 64	2280.1274	236.9054
Point 65	2285.8846	236.872
Point 66	2292.6637	236.7291
Point 67	2298.5508	236.6573
Point 68	2325.1496	236.4277
Point 69	2334.4903	236.2203
Point 70	2385.1052	235.7983
Point 71	2386.6778	235.8012
Point 72	2389.8982	235.7582
Point 73	2392.1363	235.7757
Point 74	2415.3189	235.527
Point 75	2420.5189	235.6589
Point 76	2456.9543	235.4725
Point 77	2464.855	235.4518
Point 78	2472.4591	235.2229
Point 79	2478.6393	234.912
Point 80	2483.5504	234.777
Point 81	2496.5636	234.6326
Point 82	2505.9458	234.5075
Point 83	2536.3264	233.8072
Point 84	2542.0903	233.8135

Point 85	2557.2984	233.6461
Point 86	2564.4024	233.772
Point 87	2570.4246	233.7174
Point 88	2577.3767	233.8197
Point 89	2552.8336	242
Point 90	2542.8328	242
Point 91	2525.2788	236.15
Point 92	2515.2788	236.15
Point 93	2705.7308	234.692
Point 94	2692.2664	234.2709
Point 95	2688.6929	234.1923
Point 96	2683.961	234.1565
Point 97	2679.9854	234.2071
Point 98	2674.736	234.1463
Point 99	2624.932	234.2295
Point 100	2620.6084	234.1508
Point 101	2615.0572	234.2206
Point 102	2611.1429	234.2376
Point 103	2608.3573	234.183
Point 104	2604.661	234.221
Point 105	1970.7486	180.8828
Point 106	1818.6014	178.2428
Point 107	1816.6437	177.264
Point 108	1807.6116	177.264
Point 109	1805.653	178.2433
Point 110	1646.4886	181.0046
Point 111	1596.9846	193.3806
Point 112	1561.9846	193.3806
Point 113	1512.4807	181.0046
Point 114	1353.3163	178.2433
Point 115	1351.3577	177.264
Point 116	1342.3256	177.264
Point 117	1340.367	178.2433
Point 118	1181.2026	181.0046
Point 119	1131.6986	193.3806
Point 120	1096.6986	193.3806
Point 121	1047.1947	181.0046
Point 122	888.0303	178.2433
Point 123	886.0717	177.264
Point 124	877.0396	177.264
Point 125	875.0819	178.2429
Point 126	710.8845	181.0919
Point 127	191.8853	240
Point 128	173.8967	238.644
Point 129	169.3044	238.2765
Point 130	144.0291	236.3473
Point 131	131.9812	235.5427
Point 132	115.4852	234.3153
Point 133	97.3517	233.1385
Point 134	88.2316	232.4766
Point 135	64.9565	231.0077
Point 136	62.0926	230.8048
Point 137	48.9879	230
Point 138	14.6059	227.7243
Point 139	8.4602	227.3522
Point 140	0	226.7995
Point 141	0	-500
Point 142	2705.7308	-500
Point 143	410.2409	259.3301
Point 144	711.2794	184.0855
Point 145	875.8146	181.2306
Point 146	877.7478	180.264
Point 147	885.3634	180.264
Point 148	887.2976	181.231
Point 149	1046.7997	183.9982
Point 150	1096.3293	196.3806
Point 151	1132.068	196.3806
Point 152	1181.5975	183.9982
Point 153	1341.0997	181.231
Point 154	1343.0338	180.264
Point 155	1350.6494	180.264
Point 156	1352.5836	181.231
Point 157	1512.0857	183.9982
Point 158	1561.6153	196.3806
Point 159	1597.354	196.3806
Point 160	1646.8835	183.9982
Point 161	1806.3857	181.231
Point 162	1808.3198	180.264
Point 163	1815.9354	180.264
Point 164	1817.8686	181.2306
Point 165	1970.3537	183.8764
Point 166	416.4268	259.3301
Point 167	707.1778	186.6566
Point 168	881.5556	183.6314
Point 169	1046.4693	186.4924
Point 170	1096.0218	198.8806
Point 171	1132.3754	198.8806
Point 172	1802.3521	366.3741

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.444	(1374.76, 364.484)	327.1918	(1815.56, 363.106)	(1125.67, 198.881)
2	14351	1.684	(1374.76, 364.484)	254.743	(1663.02, 331.54)	(1135.91, 199.764)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	1127.6925	197.6306	0	206.39468	100.66541	0
2	Optimized	1130.8935	195.6562	0	461.2244	123.5847	0
3	Optimized	1132.2215	194.83705	0	565.94851	151.64545	0
4	Optimized	1134.448	193.46375	0	807.39032	216.33959	0
5	Optimized	1138.198	191.76585	0	1056.6457	283.12736	0
6	Optimized	1156.035	187.30585	0	2133.8073	571.75194	0
7	Optimized	1176.699	182.6351	0	3255.5193	872.31378	0
8	Optimized	1181.4005	181.9774	0	3479.4097	932.30502	0
9	Optimized	1185.252	181.43855	0	3662.3063	981.31201	0
10	Optimized	1202.4025	180.68045	0	4144.8328	1110.6046	0
11	Optimized	1229.3955	180.1867	0	5014.9144	1343.7423	0
12	Optimized	1259.7605	179.6443	0	6001.023	1607.9693	0
13	Optimized	1285.2935	179.2023	0	6831.815	1830.5793	0
14	Optimized	1305.7435	178.8631	0	7495.0582	2008.2948	0
15	Optimized	1329.3145	178.47775	0	8257.3322	2212.5455	0
16	Optimized	1341.713	178.27505	0	8662.6799	2321.1581	0
17	Optimized	1342.68	178.2592	0	8703.2994	2332.0421	0
18	Optimized	1344.938	178.2223	0	8778.4368	2352.1751	0
19	Optimized	1347.5015	178.1804	0	8859.9232	2374.0093	0
20	Optimized	1349.405	178.19145	0	8787.2777	2354.544	0
21	Optimized	1351.0035	178.2195	0	8827.5251	2365.3282	0
22	Optimized	1351.971	178.2365	0	8844.3824	2369.8451	0
23	Optimized	1364.8045	178.4619	0	9184.2913	2460.9234	0
24	Optimized	1389.2455	178.89115	0	9835.9583	2635.5371	0
25	Optimized	1413.6865	179.32045	0	10473.307	2806.3143	0
26	Optimized	1436.6065	180.21215	0	10768.269	2885.3491	0
27	Optimized	1458.0055	181.5663	0	11174.953	2994.3198	0
28	Optimized	1479.4045	182.92045	0	11570.911	3100.4162	0
29	Optimized	1492.988	184.7889	0	9869.1463	4813.5043	0
30	Optimized	1504.1765	188.85115	0	10132.722	2715.0548	650
31	Optimized	1523.314	195.46705	0	9917.4498	2657.3727	650
32	Optimized	1544.98	202.9572	0	9681.4551	2594.1381	650
33	Optimized	1566.646	210.4474	0	9453.3123	2533.0074	650
34	Optimized	1588.312	217.9376	0	9232.5852	2473.8638	650
35	Optimized	1610.981	226.8354	0	8592.1408	2302.2572	650
36	Optimized	1634.653	237.1408	0	8190.0923	2194.5286	650
37	Optimized	1662.421	249.2296	0	7727.2659	2070.5147	650
38	Optimized	1691.281	263.3901	0	6807.0872	1823.9535	650
39	Optimized	1717.137	277.8389	0	6126.446	1641.5763	650
40	Optimized	1739.5095	291.9495	0	5103.7672	1367.5503	650
41	Optimized	1758.3985	305.7219	0	4334.6302	1161.4607	650
42	Optimized	1776.4705	321.73865	0	2991.2074	801.4916	650
43	Optimized	1793.725	339.99975	0	1796.8579	481.46662	650
44	Optimized	1804.982	351.9135	0	871.46635	233.50871	650
45	Optimized	1808.751	355.9021	0	423.4567	113.46488	650
46	Optimized	1812.7235	360.10685	0	-54.374951	-14.569724	650

Slices of Slip Surface: 14351

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	14351	1138.734	198.59515	0	236.15036	115.17823	0
2	14351	1144.116	196.36575	0	831.18097	222.71427	650
3	14351	1154.521	192.0557	0	1642.094	800.90277	0
4	14351	1171.785	184.9054	0	3041.0408	814.84444	0
5	14351	1181.4005	181.005	0	3498.1008	937.31328	0
6	14351	1190.606	181.005	0	3768.7109	1009.823	0
7	14351	1208.4565	181.005	0	4299.1698	1151.9591	0
8	14351	1226.142	181.00495	0	4827.6182	1293.5564	0
9	14351	1243.828	181.0049	0	5357.4236	1435.5173	0
10	14351	1261.514	181.0049	0	5886.6635	1577.3267	0
11	14351	1279.1995	181.0049	0	6414.2072	1718.6816	0
12	14351	1296.885	181.00485	0	6937.7928	1858.976	0
13	14351	1314.571	181.0048	0	7454.5934	1997.4523	0
14	14351	1332.87	181.0048	0	7981.3279	2138.5904	0
15	14351	1344.584	181.0048	0	8629.0965	4208.6916	0
16	14351	1349.1	181.0048	0	8766.1921	4275.5575	0
17	14351	1351.7445	181.0048	0	8846.8355	4314.89	0
18	14351	1361.2	181.0048	0	8779.8128	2352.5437	0
19	14351	1379.112	181.0048	0	9263.3953	2482.1193	0
20	14351	1396.798	181.00475	0	9726.4802	2606.2025	0
21	14351	1414.484	181.0047	0	10174.864	2726.3466	0
22	14351	1432.1695	181.0047	0	10607.416	2842.2485	0
23	14351	1449.855	181.0047	0	11024.701	2954.0598	0
24	14351	1467.541	181.00465	0	11425.589	3061.4774	0
25	14351	1485.227	181.0046	0	11811.211	3164.8043	0
26	14351	1503.2755	181.0046	0	12189.902	3266.2745	0
27	14351	1514.5425	183.06615	0	8792.845	2356.0357	0
28	14351	1518.322	186.8456	0	7959.6467	3882.1791	0
29	14351	1529.072	197.59555	0	7748.5971	2076.2303	650
30	14351	1547.136	215.6597	0	6777.4291	1816.0067	650
31	14351	1565.2	233.72385	0	5790.995	1551.6924	650
32	14351	1583.264	251.788	0	4777.1598	1280.0361	650
33	14351	1601.328	269.85215	0	3722.693	997.49258	650
34	14351	1619.392	287.9163	0	2615.7729	700.89424	650
35	14351	1637.4565	305.98045	0	1444.8521	387.14694	650
36	14351	1652.253	320.77675	0	432.76494	115.95902	650

37	14351	1660.5165	329.04065	0	159.17747	77.63604	0

Terracon	Made by: RSG	Date: 1/29/15	Sheet No.: COVER
	Checked by: JCH	Date: 1/29/15	Job No.: EJ147410
	Calculations for:	Overall Slope Stability Analysis	
	Emelle Facility – Trench 23		

OVERALL SLOPE STABILITY ANALYSIS

CALCULATION COVER SHEET

Calculations by:

Signature: Rajendra S. Gondhalekar — 1/29/2015 (Date)

Name: Rajendra S. Gondhalekar, P.E.

Title: Project Engineer

Calculations Reviewed by:

Signature: J. Craig Hensley — 1/29/2015 (Date)

Name: J. Craig Hensley, E.I.T.

Title: Staff Engineer

Calculations Approved by:

Signature: Michael A. Kemp — 1/29/2015 (Date)

Name: Michael A. Kemp P.E.

Title: Department Manager

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	1/29/15	ALL	Initial Submittal

1.0 OBJECTIVE

Our objective is to calculate the overall stability of the proposed final slopes for Trench 23 of the Emelle Facility. The analysis includes evaluation of both circular and sliding block failure surfaces, which provides factors of safety (FOS) against failures through the final configuration of the constructed landfill, landfilled waste, the critical interface for the proposed liner system, and the underlying chalk material. Since the analysis was performed for a final condition, a FOS greater than 1.5 is considered acceptable.

2.0 METHODOLOGY

The slope stability analysis was performed using a method of slices analysis with a slope-stability software program. The stability modeling software used for our analysis is Slope/W 2007 which is a part of GeoStudio developed by Geo-Slope International, Ltd. The most critical cross section was selected based on the tallest landfill slope. The location of the selected slope stability section is indicated in Figures 1 and 2 with respect to the existing grades, and proposed excavation grades and proposed final grades respectively.

Slope stability analysis was performed at the selected cross-section. The analysis was performed to search for both a circular failure surface (based on an entry and exit method), and a sliding block surface passing through the critical liner interface. The analysis searched for a slope-failure surface with the minimum FOS against sliding. This analysis provides us with a FOS against failure for the overall landfill at the completion of landfilling activities in Trench 23. The Morgenstern-Price Method was used to calculate the FOS against failure.

3.0 SUBSURFACE CONDITIONS AND MATERIALS

Detailed description of the subsurface conditions is provided in various reports contained in Attachment E of the permit application. The information was previously compiled into engineering properties for slope stability analysis by Golder Associates in the engineering calculation package for Trench 22, contained in Attachment D-6-1-7. A majority of the information remains relevant to the analysis of Trench 23. Therefore, properties for a majority of the engineered materials were selected identical to those previously utilized. The major exception to this was the interface shear strength for the critical liner interface, which was previously based on a smooth liner. Since the proposed Trench 23 design will utilize textured liners throughout, interface shear strength appropriate for the textured liner was utilized instead. The values for various materials used in the overall stability analysis are listed in the table below:

Material	Unit Weight (lb/ft^3)	Cohesion (lb/ft^2)	Friction Angle (°)
Final Cover Vegetative Soil	110	0	26
Final Cover Barrier Soil (Chalk)	130	600	0
Structural Fill (Chalk)	130	600	26
Waste	110	650	15
Liner Protective Soil	110	0	26
Critical Geosynthetic Interface	110	0	15
Natural Intact Chalk (Short Term)	130	8000	0

Although the chalk is expected to exhibit both long term anisotropic and short term isotropic properties. The stability analysis was performed utilizing the short term isotropic properties, as they are more critical. Both east and west facing excavation slopes were analyzed. The groundwater surface in the intact chalk, prior to the excavation was based on the Golder Associates site wide chalk water level data acquired May 30, 1983 to June 9, 1983, and shown on Figure 00-150-16, 7/29/1985 (part of Permit Application Revision 3.3). The bottom of the analysis was limited to approximately 500 ft below MSL, which is the average elevation of the bottom of the chalk formation.

4.0 ANALYSIS RESULTS

The input properties and the output results for the analysis are presented in Attachment 1. The following table presents the results of our analysis for the various scenarios.

Cross Section	Failure Mode	Factor of Safety
West Facing	Circular	1.95
	Block	1.94
East Facing	Circular	2.01
	Block	2.45

5.0 CONCLUSIONS

Based on the results of the analysis, the Trench 23 slopes appear stable for both deep-seated circular and sliding block failure modes, with FOS's exceeding 1.5.

FIGURES

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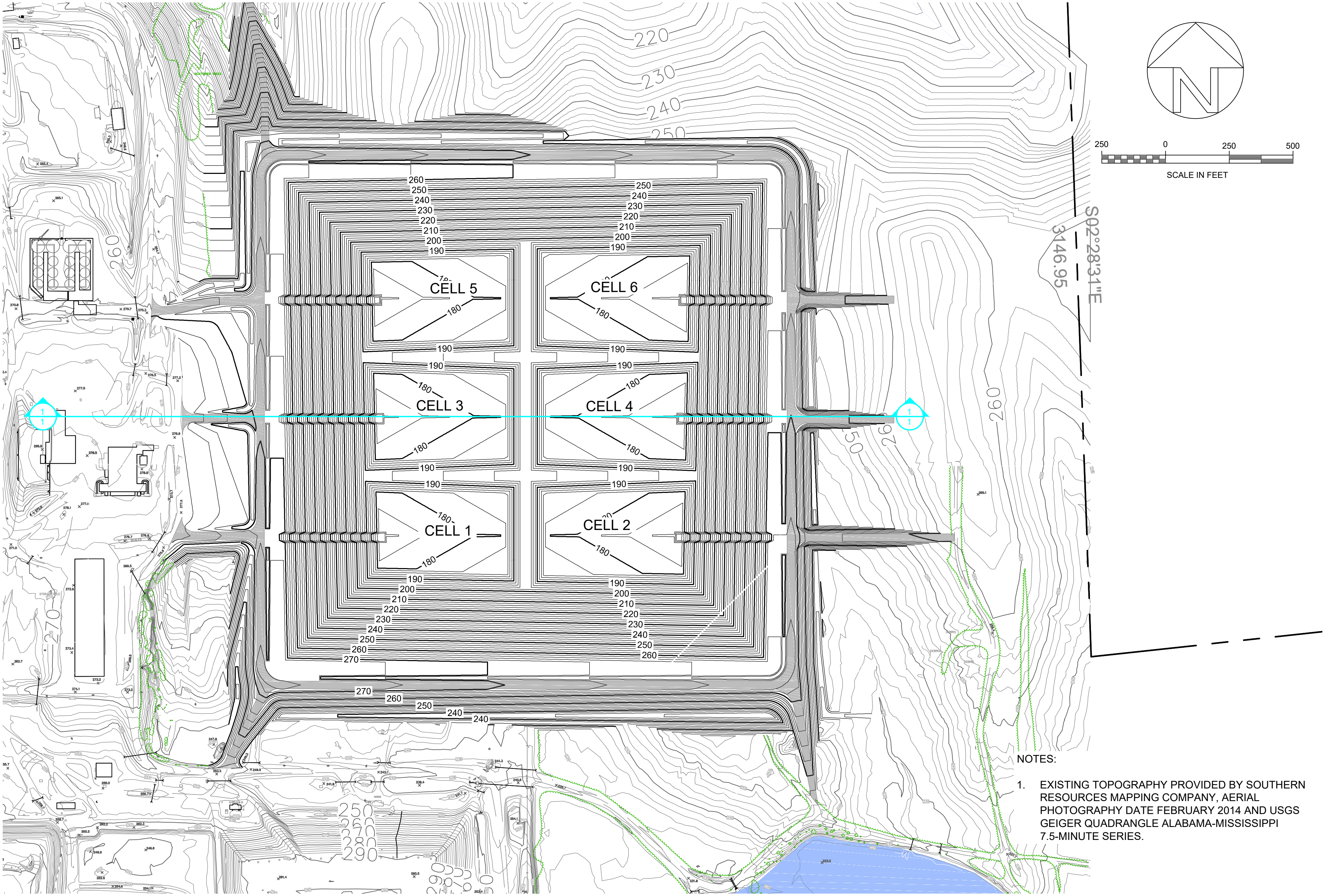

NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.

Project Mngr:	MAK	Project No.	EJ147410
Drawn By:	RSG	Scale:	AS-SHOWN
Checked By:	JCH	File No.	--
Approved By:	RSG	Date:	12-31-2014

Terracon
Consulting Engineers and Scientists
240 HERITAGE WALK, SUITE 103 WOODSTOCK, GA 30188
PH. (770) 924-9799 FAX. (770) 924-7866

ANALYSIS CROSS SECTION LOCATION

OVERALL SLOPE STABILITY ANALYSIS

EMELLE FACILITY

CHEMICAL WASTE MANAGEMENT

FIG. No. 1

NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.

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Project Mngr:	MAK
Drawn By:	RSG
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Approved By:	RSG

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Terracon
Consulting Engineers and Scientists
240 HERITAGE WALK, SUITE 103 WOODSTOCK, GA 30188
PH. (770) 924-9799 FAX. (770) 924-7866

ANALYSIS CROSS SECTION LOCATION

OVERALL SLOPE STABILITY ANALYSIS

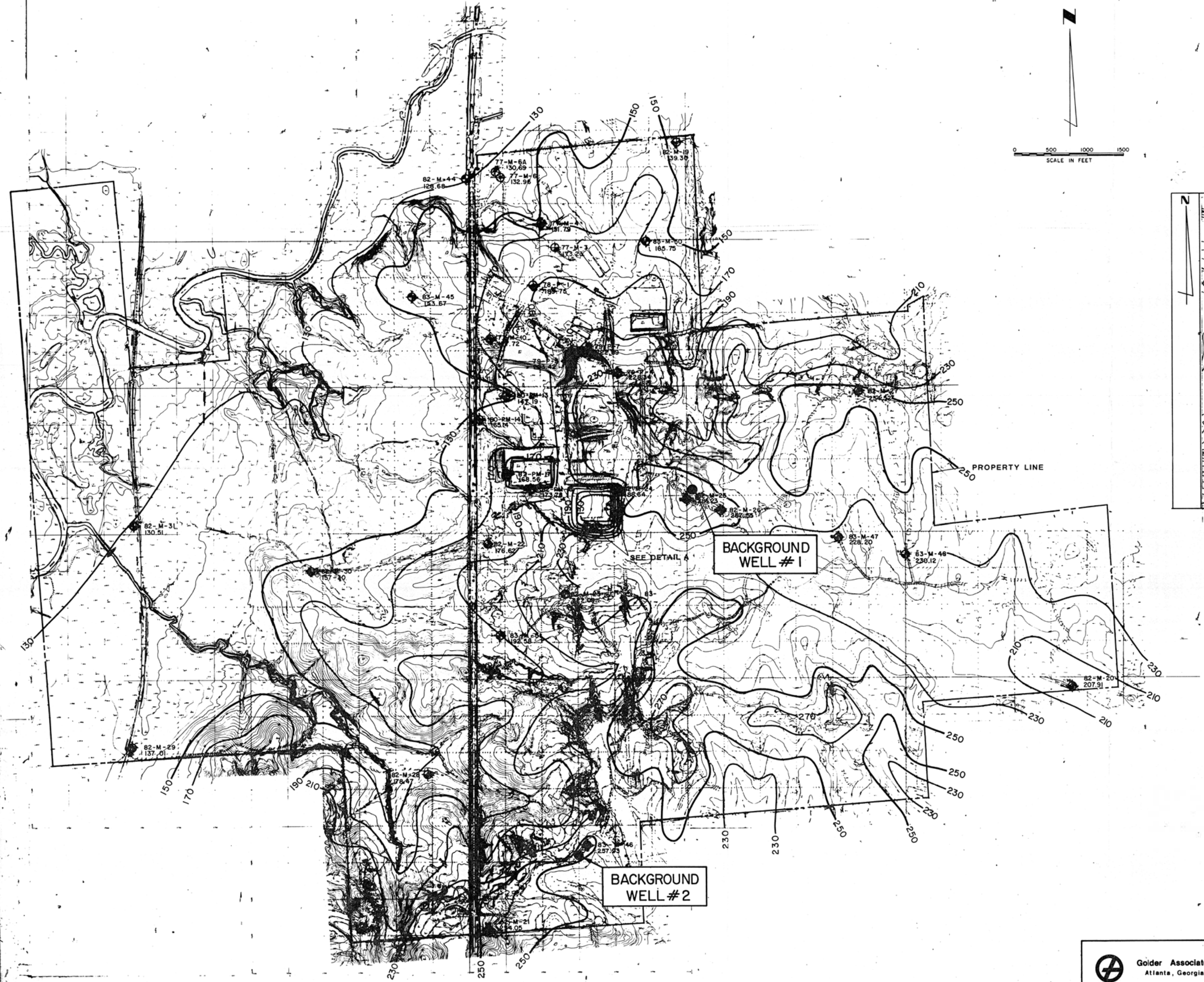
EMELLE FACILITY

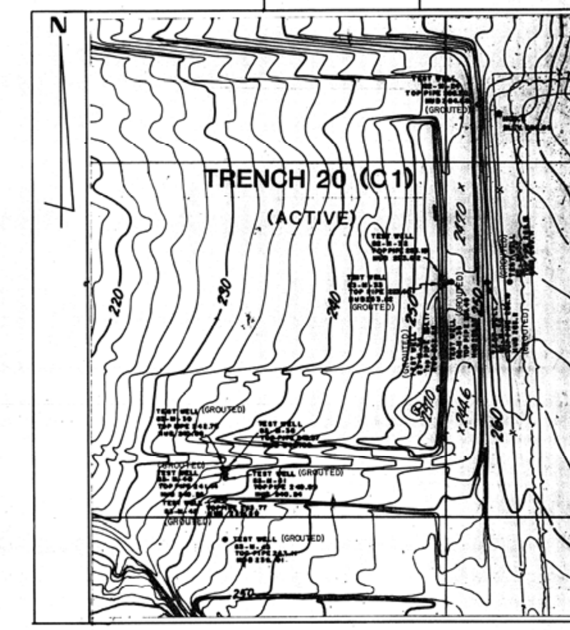
CHEMICAL WASTE MANAGEMENT

FIG. No. 2

PLATE 2

WELL NO.	WATER LEVEL ELEVATION (FT.-MSL)
82-M-24	188.64
82-M-34	dry to 144.55
82-M-35	dry to 144.55
82-M-36	190.53
83-M-37	259.22
83-M-38	150.52
83-M-39	caved
83-M-40	163.32
83-M-41	168.19
83-M-43	212.40





DETAIL A
WELL LOCATIONS
SCALE 1" = 100'

LEGEND

—210— ESTIMATED CHALK WATER TABLE SURFACE CONTOURS (FT.-MSL)

83-M-50 230.05 MONITORING WELL DESIGNATION CHALK WATER TABLE SURFACE ELEVATIONS (FT.-MSL)

83-M-48 GROUTED BETWEEN 5/13/85 AND 7/15/85

NOTE

1. CHALK WATER LEVEL DATA ACQUIRED MAY 30, 1983 TO JUNE 9, 1983.
2. BASE MAP PROVIDED BY CHEMICAL WASTE MANAGEMENT, INC. DATE OF AERIAL PHOTOGRAPHY, DECEMBER 13, 1982.

Section C, Figures Revision 3.3

REV.	DATE	DESCRIPTION	DR BY	APP BY
1	7/29/85	GROUTED WELLS AND BACKGROUND WELL LOCATIONS.	S.B.C.	

SCALE: 1" = 500'
GAI JOB NO. 853 3098
DES BY JEB 1-21-85
DR BY SKB 1-22-85
CHK BY 7/31/85
APP BY JEB 8/9/85

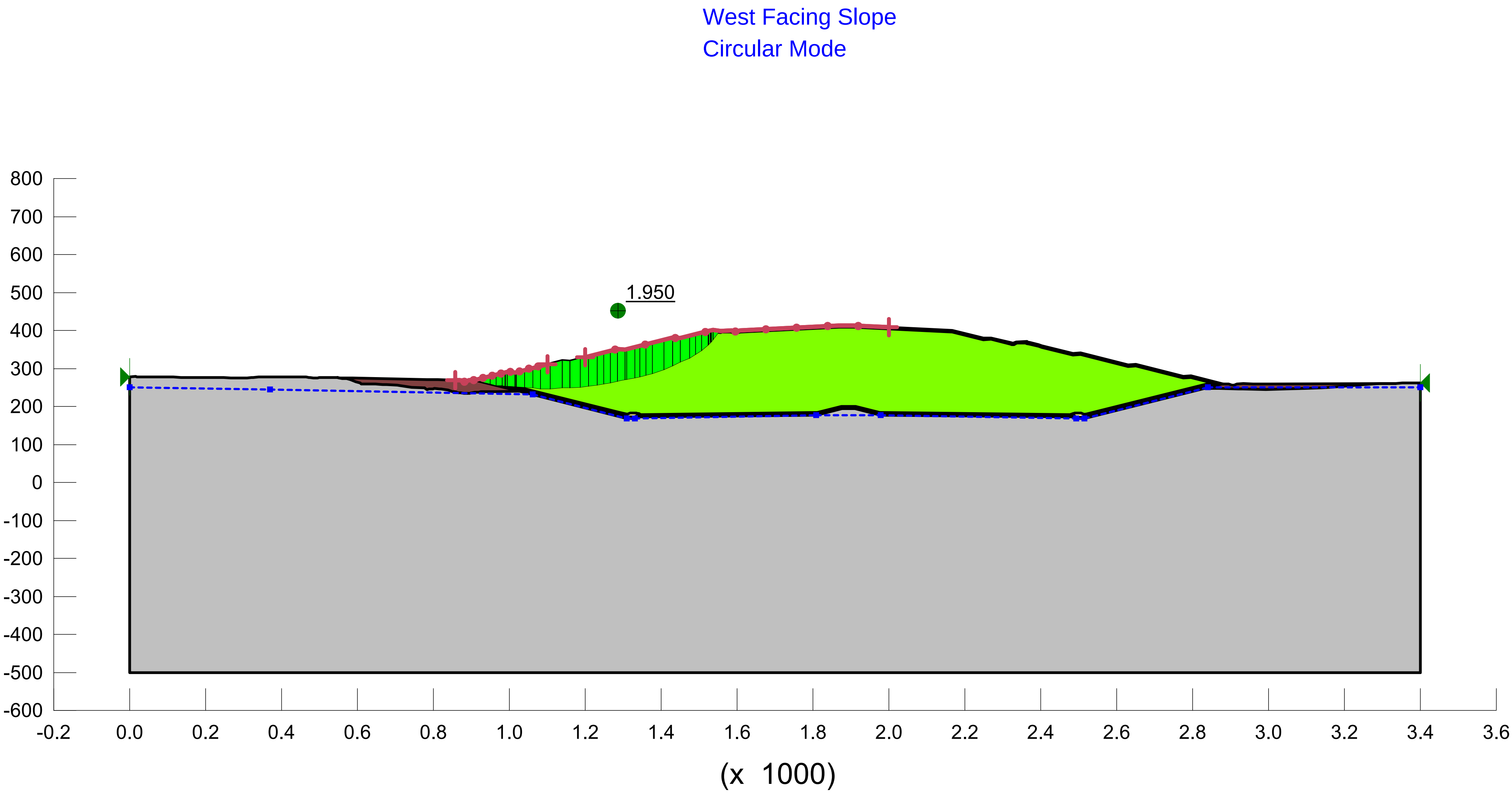
PROJECT: EMELLE FACILITY
SHEET TITLE: APPROXIMATE BACKGROUND WELL LOCATIONS

Golder Associates
Atlanta, Georgia

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

ATTACHMENT 1

Overall Stability Output Data


West Facing Slope
Circular Mode
1.950
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
(x 1000)

Slope Stability

File Information

- Title: Trench 23 - Final Stability
- Created By: Gondhalekar, Rajendra S.
- Revision Number: 20
- Last Edited By: Gondhalekar, Rajendra S.
- Date: 12/16/2014
- Time: 10:46:42 AM
- File Name: Trench 23-Final-Global_Left.gsz
- Directory: N:\Projects\2014\EJ147410\Working Files\Calculations-Analyses\Stability\Global\Model\
- Last Solved Date: 12/16/2014
- Last Solved Time: 10:47:04 AM

Project Settings

- Length(L) Units: feet
- Time(t) Units: Seconds
- Force(F) Units: lbf
- Pressure(p) Units: psf
- Strength Units: psf
- Unit Weight of Water: 62.4 pcf
- View: 2D

Analysis Settings

Slope Stability

- Kind: SLOPE/W
- Method: Morgenstern-Price
- Settings
  - Apply Phreatic Correction: No
  - Side Function
    - Interslice force function option: Half-Sine
  - PWP Conditions Source: Piezometric Line
  - Use Staged Rapid Drawdown: No
- Slip Surface
  - Direction of movement: Right to Left
  - Use Passive Mode: No
  - Slip Surface Option: Entry and Exit
  - Critical slip surfaces saved: 1
  - Optimize Critical Slip Surface Location: Yes
  - Tension Crack
    - Tension Crack Option: (none)
- FOS Distribution
  - FOS Calculation Option: Constant
- Advanced
  - Number of Slices: 30
  - Optimization Tolerance: 0.01
  - Minimum Slip Surface Depth: 0.1 ft
  - Optimization Maximum Iterations: 20000
  - Optimization Convergence Tolerance: 1e-007
  - Starting Optimization Points: 8
  - Ending Optimization Points: 16
  - Complete Passes per Insertion: 1
  - Driving Side Maximum Convex Angle: 5 °
  - Resisting Side Maximum Convex Angle: 1 °

Materials

Chalk

- Model: Mohr-Coulomb
- Unit Weight: 130 pcf
- Cohesion: 8000 psf
- Phi: 0 °
- Phi-B: 0 °
- Pore Water Pressure
  - Piezometric Line: 1

Structural Fill

- Model: Mohr-Coulomb
- Unit Weight: 130 pcf
- Cohesion: 600 psf
- Phi: 26 °
- Phi-B: 0 °
- Pore Water Pressure
  - Piezometric Line: 1

Synthetic Interface

- Model: Mohr-Coulomb
- Unit Weight: 110 pcf
- Cohesion: 0 psf
- Phi: 15 °
- Phi-B: 0 °

Liner Protective Soil

- Model: Mohr-Coulomb
- Unit Weight: 110 pcf
- Cohesion: 0 psf
- Phi: 26 °
- Phi-B: 0 °

Waste

- Model: Mohr-Coulomb
- Unit Weight: 110 pcf
- Cohesion: 650 psf
- Phi: 15 °
- Phi-B: 0 °

Cover Barrier Soil

- Model: Undrained (Phi=0)
- Unit Weight: 130 pcf
- Cohesion: 650 psf

Cover Vegetative Soil

- Model: Mohr-Coulomb
- Unit Weight: 110 pcf
- Cohesion: 0 psf
- Phi: 26 °
- Phi-B: 0 °

Slip Surface Entry and Exit

- Left Projection: Range
- Left-Zone Left Coordinate: (857.6036, 269.4407) ft
- Left-Zone Right Coordinate: (1100, 310.9992) ft
- Left-Zone Increment: 10
- Right Projection: Range
- Right-Zone Left Coordinate: (1200, 329.7166) ft
- Right-Zone Right Coordinate: (2000, 408.298) ft
- Right-Zone Increment: 10
- Radius Increments: 10

Slip Surface Limits

- Left Coordinate: (0, 278.2613) ft
- Right Coordinate: (3400, 262.6701) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	249.9317
	369.2937	244.8771
	1061.126	231.1795
	1309.4927	169.0844
	1330.2601	169.0844
	1808.1117	177.1246
	1978.1114	177.1254
	2493.2421	168.7168
	2514.0095	168.7168
	2839.1241	250
	3400	250

Regions

	Material	Points	Area (ft²)
Region 1	Cover Vegetative Soil	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86	4003.3142
Region 2	Cover Barrier Soil	85,84,83,82,81,80,79,78,77,76,75,74,73,72,71,70,69,68,67,66,65,64,63,62,61,60,59,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130	3969.1616
Region 3	Waste	131,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,166,167,168,169,170,171,172,173,174,175,176,177,178,179,180,181,182,183,184,185,186,129,128,127,126,125,124,123,122,121,120,119,118,117,116,115,114,113,112,111,110,109,108,107,106,105,104,103,102,101,100,99,98,97,96,95,94,93,92,91,90,89,88	301500.29
Region 4	Liner Protective Soil	87,187,188,189,190,191,192,193,194,195,196,197,130,129,186,185,184,183,182,181,180,179,178,177,176,175,174,173,172,171,170,169,168,167,166,165,164,163,162,161,160,159,158,157,156,155,154,153,152,151,150,149,148,147,146,145,144,143,142,141,140,139,138,137,136,135,134,133,132,131,88	9446.0036
Region 5	Structural Fill	198,199,200,201,202,203,204,205,206,207,208,209,43,42,210,211,212,213,214,215,216,217,218	4420.7882
Region 6	Structural Fill	219,220,221,222,223,224,225,226,227,228,229,230,231,232,1,86,233,234,235,236,237,238,239,240,241,242,243,244,245,246,247,248,249,250,251,252,253,254,255,256,257,258,259,260,261,262,263,264,265,266,267,268,269,270,271,272,273,274,275,276,277,278,279,280,281,282,283,284	8757.3274
Region 7	Chalk	285,286,287,288,289,290,291,292,293,294,295,296,297,298,299,300,301,302,303,304,305,306,307,308,309,310,311,312,313,314,315,316,317,318,319,320,321,322,323,324,325,326,327,328,329,330,331,332,333,334,335,336,337,338,339,340,341,342,343,344,284,283,282,281,280,279,278,277,276,275,274,273,272,271,270,269,268,267,266,265,264,263,262,261,260,259,258,257,256,255,254,253,252,251,250,249,248,247,246,245,244,243,242,241,240,239,238,237,236,235,234,233,345,346,347,348,349,350,351,352,353,354,355,209,208,207,206,205,204,203,202,201,200,199,198,356,357	2450432.5
Region 8	Synthetic Interface	355,354,353,352,351,350,349,348,347,346,345,233,86,85,130,197,196,195,194,193,192,191,190,189,188,187,87,44,43,209	5956.0448

Points

	X (ft)	Y (ft)
Point 1	907.4825	269.1831
Point 2	988.6018	289.4624
Point 3	993.6508	290.7125
Point 4	1013.8471	289.4975
Point 5	1015.973	290
Point 6	1138.985	320.7419
Point 7	1159.1665	319.5108
Point 8	1284.2118	350.7641
Point 9	1304.3933	349.5308
Point 10	1429.4437	380.784
Point 11	1449.6252	379.5489
Point 12	1523.4313	398
Point 13	1530.7506	399.7774
Point 14	1535.7576	401.0265
Point 15	1555.7852	398.8865
Point 16	1556.1855	398.936
Point 17	1585.154	400.3492
Point 18	1592.1565	396.8514
Point 19	1595.1576	396.8523
Point 20	1607.7373	400
Point 21	1867.7863	413
Point 22	1905.7797	413
Point 23	2166.2808	400
Point 24	2249.0114	379.3569
Point 25	2269.0561	380.564
Point 26	2319.4047	368
Point 27	2324.358	367.0274
Point 28	2327.4105	367.0136
Point 29	2334.533	370.467
Point 30	2363.023	371.2405
Point 31	2364.0405	369.7324
Point 32	2370.3834	368
Point 33	2394.369	362
Point 34	2402.8621	360
Point 35	2484.6063	339.5641
Point 36	2504.7876	340.7946
Point 37	2629.8331	309.5407
Point 38	2650.0144	310.7689
Point 39	2775.0683	279.5109
Point 40	2795.2513	280.729
Point 41	2800.297	279.479
Point 42	2879.4825	259.6831
Point 43	2877.8543	259.6831
Point 44	2871.2361	259.6831
Point 45	2799.814	277.5382
Point 46	2795.0669	278.7142
Point 47	2774.8817	277.496
Point 48	2649.8283	308.7539
Point 49	2629.647	307.5256
Point 50	2504.6017	338.7795
Point 51	2484.4203	337.549
Point 52	2402.3903	358.0564
Point 53	2393.8971	360.0564
Point 54	2369.8772	366.065
Point 55	2362.7976	367.9986
Point 56	2361.9793	369.2114
Point 57	2335.0179	368.4795
Point 58	2327.8655	365.0115
Point 59	2324.159	365.0283
Point 60	2318.9696	366.0472
Point 61	2268.8698	378.5491
Point 62	2248.8251	377.3421
Point 63	2165.9861	398.0122
Point 64	1905.7299	411
Point 65	1867.8362	411
Point 66	1608.0327	398.0123
Point 67	1595.4043	394.8524
Point 68	1591.685	394.8512
Point 69	1584.6793	398.3507
Point 70	1557.3409	397.0638
Point 71	1555.8021	396.8733
Point 72	1535.8976	399.0002
Point 73	1531.2287	397.8354
Point 74	1523.9098	396.0581
Point 75	1449.8109	377.5338
Point 76	1429.6294	378.7689
Point 77	1304.5791	347.5157
Point 78	1284.3976	348.749
Point 79	1159.3524	317.4957
Point 80	1139.1709	318.7268
Point 81	1016.4455	288.0566
Point 82	1014.0208	287.4834
Point 83	993.8353	288.6978
Point 84	989.0846	287.5216
Point 85	915.7289	269.1831
Point 86	909.1204	269.1831
Point 87	2865.4856	259.6831
Point 88	2862.9897	259.6831
Point 89	2799.3311	275.5974
Point 90	2794.8824	276.6994
Point 91	2774.6951	275.4811
Point 92	2649.6423	306.7389
Point 93	2629.461	305.5106
Point 94	2504.4157	336.7645
Point 95	2484.2343	335.534
Point 96	2401.9186	356.1128
Point 97	2393.4252	358.1128
Point 98	2369.371	364.13
Point 99	2361.5547	366.2648
Point 100	2360.9357	367.1823
Point 101	2335.5028	366.4919
Point 102	2328.3204	363.0094
Point 103	2323.96	363.0292
Point 104	2318.5346	364.0945
Point 105	2268.6835	376.5343
Point 106	2248.6389	375.3273
Point 107	2165.6914	396.0244
Point 108	1905.68	409
Point 109	1867.8862	409
Point 110	1608.3282	396.0245
Point 111	1595.651	392.8525
Point 112	1591.2136	392.8511
Point 113	1584.2047	396.3522
Point 114	1558.4964	395.1916
Point 115	1555.8189	394.8601
Point 116	1536.0377	396.9738
Point 117	1531.7067	395.8933
Point 118	1524.3883	394.1162
Point 119	1449.9967	375.5187
Point 120	1429.8151	376.7538
Point 121	1304.7649	345.5006
Point 122	1284.5834	346.7339
Point 123	1159.5383	315.4807
Point 124	1139.3568	316.7117
Point 125	1016.918	286.1132
Point 126	1014.1944	285.4693
Point 127	994.0198	286.6831
Point 128	989.5675	285.5808
Point 129	923.9753	269.1831
Point 130	921.4891	269.1831

Point 131	2837.2943	259.6831
Point 132	2518.4991	180
Point 133	2517.8299	179.7028
Point 134	2515.4694	178.9154
Point 135	2513.2901	179.8249
Point 136	2511.6282	180.4861
Point 137	2505.7593	182.2763
Point 138	2504.355	182.5261
Point 139	2503.0345	182.7008
Point 140	2501.7671	182.8091
Point 141	2501.0211	182.8445
Point 142	2500.2794	182.8584
Point 143	2494.2794	182.8584
Point 144	2493.3522	182.8337
Point 145	2492.3458	182.7696
Point 146	2491.313	182.6644
Point 147	2490.2391	182.5149
Point 148	2489.3966	182.3705
Point 149	2488.2081	182.1294
Point 150	2486.9229	181.8242
Point 151	2485.5101	181.4417
Point 152	2483.929	180.9638
Point 153	2482.5999	180.5275
Point 154	2481.1133	180.0083
Point 155	2479.427	179.3858
Point 156	2477.4832	178.6322
Point 157	1974.6479	183.6605
Point 158	1911.29	199.5
Point 159	1874.9364	199.5
Point 160	1811.5714	183.6588
Point 161	1345.1308	178.984
Point 162	1342.7209	179.8901
Point 163	1340.2404	180.7485
Point 164	1338.1673	181.3896
Point 165	1337.0646	181.6955
Point 166	1336.0431	181.9534
Point 167	1335.0876	182.1699
Point 168	1334.1853	182.3503
Point 169	1333.326	182.4986
Point 170	1332.5008	182.6179
Point 171	1331.7019	182.7107
Point 172	1330.9226	182.7787
Point 173	1330.1567	182.8233
Point 174	1329.2487	182.8468
Point 175	1323.2487	182.8468
Point 176	1322.2416	182.8227
Point 177	1321.2232	182.7587
Point 178	1320.4438	182.6834
Point 179	1319.3721	182.5442
Point 180	1318.535	182.4082
Point 181	1317.3595	182.1797
Point 182	1311.8013	180.5008
Point 183	1310.026	179.823
Point 184	1308.6991	179.2973
Point 185	1290.4702	184
Point 186	949.6707	269.1831
Point 187	2513.6402	171.7168
Point 188	2493.9476	171.7168
Point 189	2487.2849	175.0339
Point 190	1978.4955	180.1217
Point 191	1910.9825	197
Point 192	1875.2439	197
Point 193	1807.7276	180.1209
Point 194	1338.9977	175.4293
Point 195	1336.6153	175.6273
Point 196	1329.5501	172.0844
Point 197	1309.862	172.0844
Point 198	3335.1097	261.1052
Point 199	3291.2035	260
Point 200	3251.3717	257.0262
Point 201	3161.003	250
Point 202	3139.6041	249.405
Point 203	3096.134	248.2296
Point 204	3042.0937	246.7302
Point 205	2991.9884	245.4134
Point 206	2932.2279	246.6667
Point 207	2920.9715	246.7982
Point 208	2867.979	247.8314
Point 209	2830.8804	247.939
Point 210	2894.4825	259.6831
Point 211	2902.4825	255.6831
Point 212	2908.4825	255.6831
Point 213	2916.4825	259.6831
Point 214	2933.4825	260.0231
Point 215	2959.3667	259.5195
Point 216	2967.9024	259.3931
Point 217	2982.3458	259.151
Point 218	3005.4824	259
Point 219	547.2476	275.7861
Point 220	547.9454	275.735
Point 221	550.1719	275.6329
Point 222	553.4501	275.5308
Point 223	557.8376	275.4255
Point 224	569.2025	275.214
Point 225	586.669	274.9465
Point 226	781.5012	270.7345
Point 227	811.0945	270.2699
Point 228	853.4825	269.5231
Point 229	870.4825	269.1831
Point 230	878.4825	265.1831
Point 231	884.4825	265.1831
Point 232	892.4825	269.1831
Point 233	1024.7998	240.2616
Point 234	969.7329	239.1612
Point 235	935.7837	239.4083
Point 236	930.1714	238.8042
Point 237	924.9444	238.4321
Point 238	918.2309	237.7453
Point 239	908.5449	236.83
Point 240	901.5966	235.8431
Point 241	893.9899	235.2773
Point 242	882.631	234.6916
Point 243	879.4693	235.0451
Point 244	871.3931	235.7514
Point 245	866.5978	236.2003
Point 246	864.6292	236.4185
Point 247	857.169	238.9666
Point 248	850.2221	239.2694
Point 249	837.7766	243.6033
Point 250	819.4863	246.352
Point 251	814.5664	246.3112
Point 252	802.3617	246.8773
Point 253	798.3886	246.5569
Point 254	794.7647	246.1802
Point 255	791.6199	246.2516
Point 256	787.2904	245.9571
Point 257	783.823	244.6145
Point 258	782.6659	244.3408
Point 259	777.2506	248.2884
Point 260	776.7924	248.4049
Point 261	773.1533	248.8746
Point 262	741.6862	251.1687
Point 263	731.8911	252.0628
Point 264	711.8077	255.2082
Point 265	703.8142	255.9695
Point 266	675.8165	257.0628
Point 267	671.5882	257.399
Point 268	669.5557	257.5325
Point 269	666.0148	257.8233
Point 270	646.9889	258.6654
Point 271	644.3982	258.734
Point 272	638.6573	258.9551
Point 273	621.0833	259.3458
Point 274	610.0674	259.2766
Point 275	606.2513	261.6178
Point 276	595.5808	265.2299
Point 277	595.1652	265.3965
Point 278	580.3881	270.9263
Point 279	570.2704	272.9851
Point 280	567.5599	273.6727
Point 281	565.9097	273.5198
Point 282	561.7326	273.4916
Point 283	559.7531	273.6296
Point 284	546.6354	275.7428

Point 285	3400	-500
Point 286	0	-500
Point 287	0	278.2613
Point 288	14.4819	278.5356
Point 289	17.7173	278.0348
Point 290	28.0753	278.1122
Point 291	29.9204	278.1787
Point 292	32.3072	278.0543
Point 293	37.1211	277.533
Point 294	78.5246	277.5313
Point 295	99.8253	277.4823
Point 296	113.8189	277.1463
Point 297	135.1112	276.736
Point 298	156.0552	276.6258
Point 299	179.9408	276.3417
Point 300	205.0185	275.8303
Point 301	218.5546	275.7088
Point 302	230.2246	275.8722
Point 303	242.6138	276.0108
Point 304	246.1872	275.9778
Point 305	265.6484	275.4973
Point 306	273.8252	275.2475
Point 307	286.9292	275.0257
Point 308	296.3136	274.495
Point 309	303.3885	274.7572
Point 310	308.9925	275.4236
Point 311	320.1975	275.9575
Point 312	323.9502	276.3472
Point 313	339.2177	277.5329
Point 314	360.3106	278.2429
Point 315	364.8484	278.233
Point 316	366.1583	278.3013
Point 317	366.9738	278.3144
Point 318	377.7148	278.4168
Point 319	379.4153	278.307
Point 320	388.6644	277.5731
Point 321	401.6953	277.8894
Point 322	408.4536	277.9966
Point 323	414.1013	278.2749
Point 324	429.0825	278.4981
Point 325	445.3886	278.5139
Point 326	450.8759	278.4505
Point 327	455.9523	278.33
Point 328	458.6764	278.4031
Point 329	463.6569	278.3876
Point 330	470.7521	276.9089
Point 331	472.2721	276.5605
Point 332	473.1578	276.4049
Point 333	474.7735	276.227
Point 334	482.5145	275.4688
Point 335	494.5043	275.6387
Point 336	498.0201	275.7161
Point 337	499.3265	275.7669
Point 338	504.7851	276.0468
Point 339	508.4981	276.1311
Point 340	514.9038	276.4622
Point 341	524.7969	276.4279
Point 342	527.0296	276.5527
Point 343	532.3761	276.5479
Point 344	535.0957	276.3224
Point 345	1309.4927	169.0844
Point 346	1330.2601	169.0844
Point 347	1337.2067	172.5678
Point 348	1338.8882	172.428
Point 349	1808.1117	177.1246
Point 350	1875.6132	194
Point 351	1910.6132	194
Point 352	1978.1114	177.1254
Point 353	2486.5653	172.0409
Point 354	2493.2421	168.7168
Point 355	2514.0095	168.7168
Point 356	3352.1727	261.5347
Point 357	3400	262.6701

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.950	(1089.71, 1201.31)	288.3183	(1555.15, 398.954)	(908.301, 269.388)
2	300	2.027	(1089.71, 1201.31)	950.123	(1595.35, 396.899)	(905.636, 269.183)

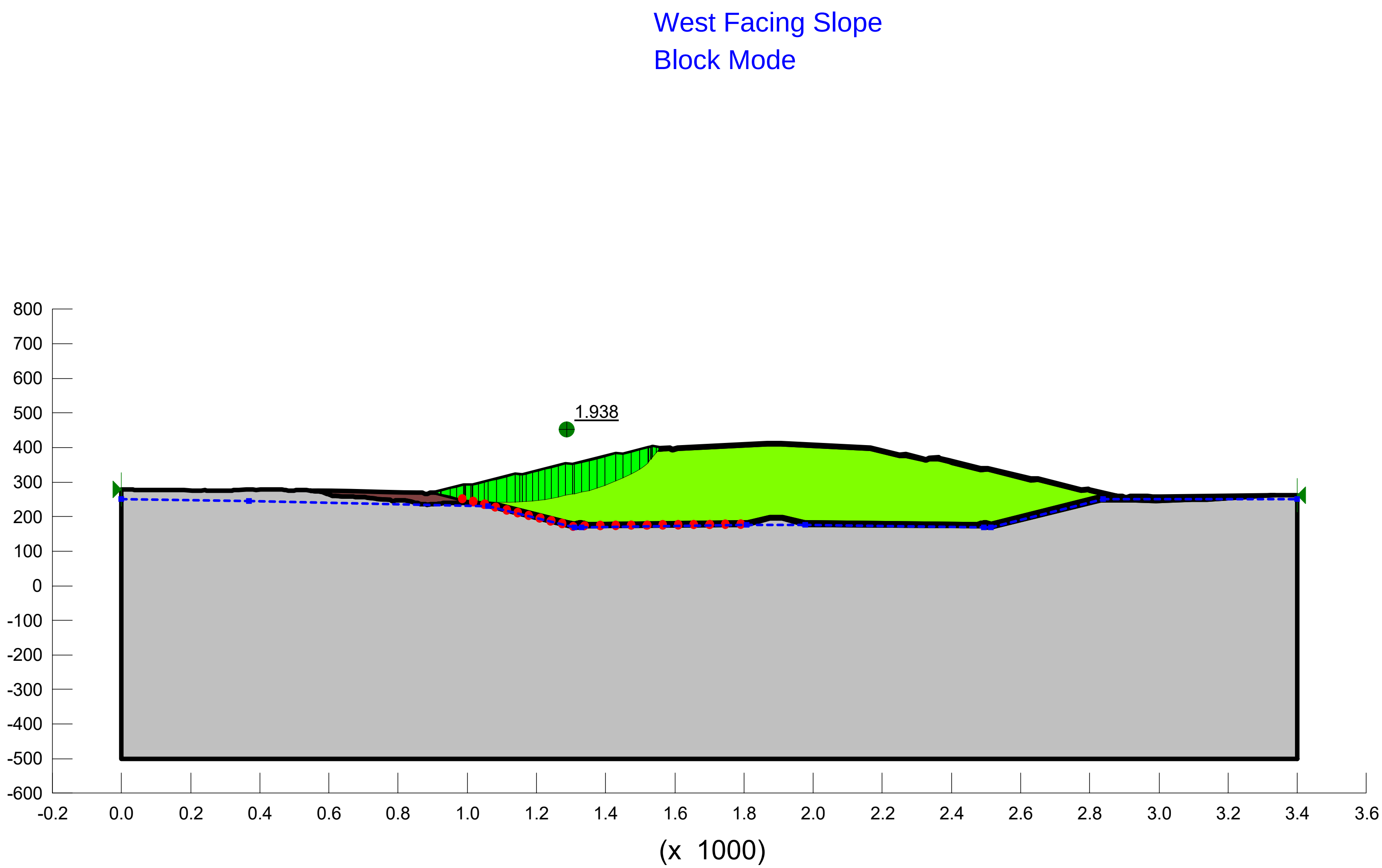
Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	908.7177	269.2854	0	24.210237	11.808121	0
2	Optimized	912.43165	268.3736	0	233.77434	62.639645	0
3	Optimized	918.609	266.85705	0	600.51423	160.9073	0
4	Optimized	922.7322	265.8448	0	858.38905	230.00465	0
5	Optimized	936.823	262.38545	0	1685.134	451.53029	0
6	Optimized	957.6023	257.28405	0	2917.7936	781.82045	0
7	Optimized	973.1897	254.84	0	3553.4781	952.1516	0
8	Optimized	984.72365	254.0915	0	4051.9369	1976.2617	0
9	Optimized	988.8432	253.82415	0	4211.9362	2054.2985	0
10	Optimized	989.32605	253.7928	0	4230.6947	2063.4477	0
11	Optimized	991.60915	253.64465	0	4319.0321	2106.5327	0
12	Optimized	993.74305	253.5062	0	4398.5524	2145.3174	0
13	Optimized	1003.8412	252.85085	0	4430.6117	2160.9537	0
14	Optimized	1013.934	252.1959	0	4466.1949	2178.3088	0
15	Optimized	1014.1075	252.18465	0	4473.251	2181.7503	0
16	Optimized	1015.0835	252.1213	0	4510.4725	2199.9044	0
17	Optimized	1016.2095	252.04825	0	4553.1738	2220.7312	0
18	Optimized	1016.682	252.01755	0	4571.759	2229.7959	0
19	Optimized	1017.5225	251.963	0	4604.7776	2245.9001	0
20	Optimized	1029.098	251.0229	0	5063.0439	1356.6385	650
21	Optimized	1050.5975	249.2575	0	5933.9386	1589.9941	650
22	Optimized	1071.3565	247.55295	0	6776.537	1815.7676	650
23	Optimized	1094.403	246.62355	0	7380.628	1977.6333	650
24	Optimized	1123.102	247.422	0	7925.4844	2123.6271	650
25	Optimized	1139.078	248.315	0	8263.5928	2214.223	650
26	Optimized	1149.169	248.8791	0	8126.6022	2177.5165	650
27	Optimized	1159.2595	249.44315	0	7992.9019	2141.6916	650
28	Optimized	1172.8565	250.2032	0	8275.0916	2217.3041	650
29	Optimized	1196.943	251.92945	0	8598.8346	2304.0508	650
30	Optimized	1219.2865	254.4153	0	8772.64	2350.6218	650
31	Optimized	1239.7275	257.4515	0	8797.5375	2357.2931	650
32	Optimized	1257.087	260.49485	0	8904.7761	2386.0276	650
33	Optimized	1274.9895	263.8987	0	8889.1911	2381.8516	650
34	Optimized	1284.305	265.79985	0	8916.3107	2389.1183	650
35	Optimized	1294.3955	267.85925	0	8617.7496	2309.119	650
36	Optimized	1304.486	269.91865	0	8323.0502	2230.1546	650
37	Optimized	1307.036	270.439	0	8332.9894	2232.8178	650
38	Optimized	1319.8765	273.0596	0	8377.2538	2244.6784	650
39	Optimized	1336.8835	276.53055	0	8438.0196	2260.9605	650
40	Optimized	1351.662	280.06575	0	8253.543	2211.5302	650
41	Optimized	1367.9725	284.43265	0	8216.8237	2201.6913	650
42	Optimized	1391.2615	291.81285	0	7865.7805	2107.6295	650
43	Optimized	1417.9195	302.06665	0	7322.4725	1962.0506	650
44	Optimized	1429.5365	307.16445	0	7127.4966	1909.807	650
45	Optimized	1439.627	311.5924	0	6644.4589	1780.3774	650
46	Optimized	1449.718	316.02035	0	6164.4413	1651.7571	650
47	Optimized	1461.956	321.3904	0	5960.6861	1597.161	650
48	Optimized	1482.2195	331.69255	0	5249.0305	1406.4735	650
49	Optimized	1498.4565	341.6383	0	4729.4686	1267.2573	650
50	Optimized	1515.003	354.2746	0	3679.821	986.00506	650
51	Optimized	1523.6705	362.15555	0	3174.7549	850.673	650
52	Optimized	1524.149	362.5906	0	3146.1493	843.00816	650
53	Optimized	1526.5295	364.7552	0	3003.5353	804.79485	650
54	Optimized	1529.711	367.9686	0	2577.3465	690.59791	650
55	Optimized	1530.99	369.52605	0	2468.6337	661.46841	650
56	Optimized	1531.468	370.1083	0	2427.9955	650.57944	650
57	Optimized	1533.7325	372.8662	0	2235.1021	598.8938	650
58	Optimized	1535.828	375.41825	0	2053.3164	550.18448	650
59	Optimized	1544.007	385.37965	0	1063.7599	285.03359	650
60	Optimized	1552.875	396.1804	0	-52.607206	0	650
61	Optimized	1554.393	398.02955	0	84.698017	41.309983	0

Slices of Slip Surface: 300

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	300	906.55905	269.0017	-2169.1383	86.421249	42.150459	600
2	300	908.30145	268.661	-2150.0099	157.17396	76.658863	600
3	300	912.42465	267.8741	-2106.1035	368.28194	179.6231	600
4	300	917.87885	266.8512	-2048.9484	651.42557	317.72148	600
5	300	920.75895	266.32395	0	732.28059	196.21399	0
6	300	922.7322	265.97005	0	839.11831	224.84107	0
7	300	936.823	263.65325	0	1515.5903	406.1012	0
8	300	952.4535	261.1521	0	225[illegible].3246	603.77651	0

9	300	971.91905	258.66115	0	3179.4786	1550.7353	0
10	300	988.8432	256.5507	0	3933.9388	1918.7102	0
11	300	989.32605	256.49925	0	3954.136	1928.561	0
12	300	991.60915	256.2617	0	4049.9439	1975.2896	0
13	300	993.74305	256.0404	0	4136.0292	2017.2762	0
14	300	1000.6182	255.39215	0	4168.7063	2033.2139	0
15	300	1010.624	254.4841	0	4186.2991	1121.7155	650
16	300	1013.934	254.20795	0	4199.8771	1125.3537	650
17	300	1014.1075	254.19405	0	4206.7226	1127.1879	650
18	300	1015.0835	254.11705	0	4242.7269	1136.8353	650
19	300	1016.2095	254.02865	0	4283.8436	1147.8524	650
20	300	1027.734	253.27235	0	4701.5009	1259.7634	650
21	300	1050.074	252.0729	0	5470.2607	1465.7519	650
22	300	1074.1025	251.39815	0	6209.6199	1663.8626	650
23	300	1100.0555	251.3262	0	6910.9296	1851.778	650
24	300	1126.0085	251.96365	0	7506.5571	2011.3759	650
25	300	1139.078	252.46465	0	7774.317	2083.122	650
26	300	1149.169	253.0964	0	7602.7446	2037.1493	650
27	300	1159.2595	253.73015	0	7435.0858	1992.2252	650
28	300	1171.9125	254.82785	0	7617.6395	2041.1404	650
29	300	1196.9405	257.3349	0	7927.8551	2124.2624	650
30	300	1221.875	260.50255	0	8150.6652	2183.9642	650
31	300	1246.8095	264.34435	0	8292.2118	2221.8914	650
32	300	1271.7445	268.86865	0	8356.8815	2239.2196	650
33	300	1284.305	271.322	0	8368.2824	2242.2745	650
34	300	1294.3955	273.54715	0	8022.832	2149.7113	650
35	300	1304.486	275.7745	0	7684.9234	2059.169	650
36	300	1307.036	276.37335	0	7679.5792	2057.737	650
37	300	1319.8765	279.5434	0	7632.3146	2045.0725	650
38	300	1342.658	285.5608	0	7514.252	2013.4378	650
39	300	1367.454	292.7755	0	7329.3329	1963.8888	650
40	300	1392.25	300.73055	0	7084.7262	1898.3467	650
41	300	1417.046	309.4459	0	6779.9305	1816.6769	650
42	300	1429.5365	314.03185	0	6609.8679	1771.1088	650
43	300	1439.627	318.02815	0	6130.8219	1642.7488	650
44	300	1449.718	322.0269	0	5658.761	1516.2604	650
45	300	1462.143	327.31995	0	5431.5594	1455.382	650
46	300	1486.714	338.20465	0	4947.7537	1325.7466	650
47	300	1511.192	349.89315	0	4391.9899	1176.8301	650
48	300	1523.6705	356.0748	0	4089.1861	1095.6941	650
49	300	1524.149	356.3206	0	4076.2875	1092.2379	650
50	300	1527.5695	358.0955	0	3983.0084	1067.2439	650
51	300	1530.99	359.8728	0	3889.7244	1042.2485	650
52	300	1531.468	360.1237	0	3876.7831	1038.7809	650
53	300	1533.7325	361.31985	0	3814.4582	1022.081	650
54	300	1535.828	362.42775	0	3754.3381	1005.9719	650
55	300	1545.8415	367.90735	0	3098.1256	830.14026	650
56	300	1555.7935	373.3545	0	2446.4029	655.51169	650
57	300	1555.994	373.46725	0	2437.7617	653.19629	650
58	300	1556.7635	373.9013	0	2399.2891	642.88758	650
59	300	1571.2475	382.40485	0	1609.7779	431.3387	650
60	300	1587.5295	392.04355	0	583.77552	156.42218	650
61	300	1590.795	394.0573	0	208.8859	0	650
62	300	1591.879	394.73055	0	52.221681	0	650
63	300	1592.115	394.87735	0	190.53501	92.930135	0
64	300	1593.6575	395.8422	0	96.4269	47.030541	0
65	300	1595.252	396.8402	0	3.4039641	1.6602242	0


West Facing Slope
Block Mode
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800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
(x 1000)

Slope Stability

File Information

Title: Trench 23 - Final Stability
Created By: Gondhalekar, Rajendra S.
Revision Number: 22
Last Edited By: Gondhalekar, Rajendra S.
Date: 12/16/2014
Time: 10:28:23 AM
File Name: Trench 23-Final-Block_Left.gsz
Directory: N:\Projects\2014\EJ147410\Working Files\Calculations-Analyses\Stability\Global\Model\
Last Solved Date: 12/16/2014
Last Solved Time: 10:29:48 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Slope Stability

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Apply Phreatic Correction: No
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

Slip Surface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Block
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: Yes
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Restrict Block Crossing: Yes
Advanced
- Number of Slices: 30
- Optimization Tolerance: 0.01
- Minimum Slip Surface Depth: 0.1 ft
- Optimization Maximum Iterations: 20000
- Optimization Convergence Tolerance: 1e-007
- Starting Optimization Points: 8
- Ending Optimization Points: 16
- Complete Passes per Insertion: 1
- Driving Side Maximum Convex Angle: 5 °
- Resisting Side Maximum Convex Angle: 1 °

Materials

Chalk

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 8000 psf
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
- Piezometric Line: 1

Structural Fill

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 600 psf
Phi: 26 °
Phi-B: 0 °
Pore Water Pressure
- Piezometric Line: 1

Synthetic Interface

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 15 °
Phi-B: 0 °

Liner Protective Soil

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 26 °
Phi-B: 0 °

Waste

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 650 psf
Phi: 15 °
Phi-B: 0 °

Cover Barrier Soil

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 650 psf

Cover Vegetative Soil

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 26 °
Phi-B: 0 °

Slip Surface Limits

Left Coordinate: (0, 278.2613) ft
Right Coordinate: (3400, 262.6701) ft

Slip Surface Block

Left Grid
- Upper Left: (986, 253) ft
- Lower Left: (985, 250) ft
- Lower Right: (1306, 170) ft
- X Increments: 10
- Y Increments: 5
- Starting Angle: 135 °
- Ending Angle: 180 °
- Angle Increments: 2

Right Grid
- Upper Left: (1339, 175) ft
- Lower Left: (1338.89, 172.428) ft
- Lower Right: (1791, 177) ft
- X Increments: 10
- Y Increments: 5
- Starting Angle: 45 °
- Ending Angle: 65 °
- Angle Increments: 2

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	249.9317
	369.2937	244.8771
	1061.126	231.1795

	1309.4927	169.0844
	1330.2601	169.0844
	1808.1117	177.1246
	1978.1114	177.1254
	2493.2421	168.7168
	2514.0095	168.7168
	2839.1241	250
	3400	250

Regions

	Material	Points	Area (ft²)
Region 1	Cover Vegetative Soil	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86	4003.3142
Region 2	Cover Barrier Soil	85,84,83,82,81,80,79,78,77,76,75,74,73,72,71,70,69,68,67,66,65,64,63,62,61,60,59,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130	3969.1616
Region 3	Waste	131,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,166,167,168,169,170,171,172,173,174,175,176,177,178,179,180,181,182,183,184,185,186,129,128,127,126,125,124,123,122,121,120,119,118,117,116,115,114,113,112,111,110,109,108,107,106,105,104,103,102,101,100,99,98,97,96,95,94,93,92,91,90,89,88	301500.29
Region 4	Liner Protective Soil	87,187,188,189,190,191,192,193,194,195,196,197,130,129,186,185,184,183,182,181,180,179,178,177,176,175,174,173,172,171,170,169,168,167,166,165,164,163,162,161,160,159,158,157,156,155,154,153,152,151,150,149,148,147,146,145,144,143,142,141,140,139,138,137,136,135,134,133,132,131,88	9446.0036
Region 5	Structural Fill	198,199,200,201,202,203,204,205,206,207,208,209,43,42,210,211,212,213,214,215,216,217,218	4420.7882
Region 6	Structural Fill	219,220,221,222,223,224,225,226,227,228,229,230,231,232,1,86,233,234,235,236,237,238,239,240,241,242,243,244,245,246,247,248,249,250,251,252,253,254,255,256,257,258,259,260,261,262,263,264,265,266,267,268,269,270,271,272,273,274,275,276,277,278,279,280,281,282,283,284	8757.3274
Region 7	Chalk	285,286,287,288,289,290,291,292,293,294,295,296,297,298,299,300,301,302,303,304,305,306,307,308,309,310,311,312,313,314,315,316,317,318,319,320,321,322,323,324,325,326,327,328,329,330,331,332,333,334,335,336,337,338,339,340,341,342,343,344,284,283,282,281,280,279,278,277,276,275,274,273,272,271,270,269,268,267,266,265,264,263,262,261,260,259,258,257,256,255,254,253,252,251,250,249,248,247,246,245,244,243,242,241,240,239,238,237,236,235,234,233,345,346,347,348,349,350,351,352,353,354,355,209,208,207,206,205,204,203,202,201,200,199,198,356,357	2450432.5
Region 8	Synthetic Interface	355,354,353,352,351,350,349,348,347,346,345,233,86,85,130,197,196,195,194,193,192,191,190,189,188,187,87,44,43,209	5956.0448

Points

	X (ft)	Y (ft)
Point 1	907.4825	269.1831
Point 2	988.6018	289.4624
Point 3	993.6508	290.7125
Point 4	1013.8471	289.4975
Point 5	1015.973	290
Point 6	1138.985	320.7419
Point 7	1159.1665	319.5108
Point 8	1284.2118	350.7641
Point 9	1304.3933	349.5308
Point 10	1429.4437	380.784
Point 11	1449.6252	379.5489
Point 12	1523.4313	398
Point 13	1530.7506	399.7774
Point 14	1535.7576	401.0265
Point 15	1555.7852	398.8865
Point 16	1556.1855	398.936
Point 17	1585.154	400.3492
Point 18	1592.1565	396.8514
Point 19	1595.1576	396.8523
Point 20	1607.7373	400
Point 21	1867.7863	413
Point 22	1905.7797	413
Point 23	2166.2808	400
Point 24	2249.0114	379.3569
Point 25	2269.0561	380.564
Point 26	2319.4047	368
Point 27	2324.358	367.0274
Point 28	2327.4105	367.0136
Point 29	2334.533	370.467
Point 30	2363.023	371.2405
Point 31	2364.0405	369.7324
Point 32	2370.3834	368
Point 33	2394.369	362
Point 34	2402.8621	360
Point 35	2484.6063	339.5641
Point 36	2504.7876	340.7946
Point 37	2629.8331	309.5407
Point 38	2650.0144	310.7689
Point 39	2775.0683	279.5109
Point 40	2795.2513	280.729
Point 41	2800.297	279.479
Point 42	2879.4825	259.6831
Point 43	2877.8543	259.6831
Point 44	2871.2361	259.6831
Point 45	2799.814	277.5382
Point 46	2795.0669	278.7142
Point 47	2774.8817	277.496
Point 48	2649.8283	308.7539
Point 49	2629.647	307.5256
Point 50	2504.6017	338.7795
Point 51	2484.4203	337.549
Point 52	2402.3903	358.0564
Point 53	2393.8971	360.0564
Point 54	2369.8772	366.065
Point 55	2362.7976	367.9986
Point 56	2361.9793	369.2114
Point 57	2335.0179	368.4795
Point 58	2327.8655	365.0115
Point 59	2324.159	365.0283
Point 60	2318.9696	366.0472
Point 61	2268.8698	378.5491
Point 62	2248.8251	377.3421
Point 63	2165.9861	398.0122
Point 64	1905.7299	411
Point 65	1867.8362	411
Point 66	1608.0327	398.0123
Point 67	1595.4043	394.8524
Point 68	1591.685	394.8512
Point 69	1584.6793	398.3507
Point 70	1557.3409	397.0638
Point 71	1555.8021	396.8733
Point 72	1535.8976	399.0002
Point 73	1531.2287	397.8354
Point 74	1523.9098	396.0581
Point 75	1449.8109	377.5338
Point 76	1429.6294	378.7689
Point 77	1304.5791	347.5157
Point 78	1284.3976	348.749
Point 79	1159.3524	317.4957
Point 80	1139.1709	318.7268
Point 81	1016.4455	288.0566
Point 82	1014.0208	287.4834
Point 83	993.8353	288.6978
Point 84	989.0846	287.5216
Point 85	915.7289	269.1831
Point 86	909.1204	269.1831
Point 87	2865.4856	259.6831
Point 88	2862.9897	259.6831
Point 89	2799.3311	275.5974
Point 90	2794.8824	276.6994
Point 91	2774.6951	275.4811
Point 92	2649.6423	306.7389
Point 93	2629.461	305.5106
Point 94	2504.4157	336.7645
Point 95	2484.2343	335.534
Point 96	2401.9186	356.1128
Point 97	2393.4252	358.1128
Point 98	2369.371	364.13
Point 99	2361.5547	366.2648
Point 100	2360.9357	367.1823
Point 101	2335.5028	366.4919
Point 102	2328.3204	363.0094
Point 103	2323.96	363.0292
Point 104	2318.5346	364.0945
Point 105	2268.6835	376.5343
Point 106	2248.6389	375.3273
Point 107	2165.6914	396.0244
Point 108	1905.68	409
Point 109	1867.8862	409
Point 110	1608.3282	396.0245
Point 111	1595.651	392.8525
Point 112	1591.2136	392.8511
Point 113	1584.2047	396.3522
Point 114	1558.4964	395.1916
Point 115	1555.8189	394.8601
Point 116	1536.0377	396.9738
Point 117	1531.7067	395.8933
Point 118	1524.3883	394.1162
Point 119	1449.9967	375.5187
Point 120	1429.8151	376.7538

Point 121	1304.7649	345.5006
Point 122	1284.5834	346.7339
Point 123	1159.5383	315.4807
Point 124	1139.3568	316.7117
Point 125	1016.918	286.1132
Point 126	1014.1944	285.4693
Point 127	994.0198	286.6831
Point 128	989.5675	285.5808
Point 129	923.9753	269.1831
Point 130	921.4891	269.1831
Point 131	2837.2943	259.6831
Point 132	2518.4991	180
Point 133	2517.8299	179.7028
Point 134	2515.4694	178.9154
Point 135	2513.2901	179.8249
Point 136	2511.6282	180.4861
Point 137	2505.7593	182.2763
Point 138	2504.355	182.5261
Point 139	2503.0345	182.7008
Point 140	2501.7671	182.8091
Point 141	2501.0211	182.8445
Point 142	2500.2794	182.8584
Point 143	2494.2794	182.8584
Point 144	2493.3522	182.8337
Point 145	2492.3458	182.7696
Point 146	2491.313	182.6644
Point 147	2490.2391	182.5149
Point 148	2489.3966	182.3705
Point 149	2488.2081	182.1294
Point 150	2486.9229	181.8242
Point 151	2485.5101	181.4417
Point 152	2483.929	180.9638
Point 153	2482.5999	180.5275
Point 154	2481.1133	180.0083
Point 155	2479.427	179.3858
Point 156	2477.4832	178.6322
Point 157	1974.6479	183.6605
Point 158	1911.29	199.5
Point 159	1874.9364	199.5
Point 160	1811.5714	183.6588
Point 161	1345.1308	178.984
Point 162	1342.7209	179.8901
Point 163	1340.2404	180.7485
Point 164	1338.1673	181.3896
Point 165	1337.0646	181.6955
Point 166	1336.0431	181.9534
Point 167	1335.0876	182.1699
Point 168	1334.1853	182.3503
Point 169	1333.326	182.4986
Point 170	1332.5008	182.6179
Point 171	1331.7019	182.7107
Point 172	1330.9226	182.7787
Point 173	1330.1567	182.8233
Point 174	1329.2487	182.8468
Point 175	1323.2487	182.8468
Point 176	1322.2416	182.8227
Point 177	1321.2232	182.7587
Point 178	1320.4438	182.6834
Point 179	1319.3721	182.5442
Point 180	1318.535	182.4082
Point 181	1317.3595	182.1797
Point 182	1311.8013	180.5008
Point 183	1310.026	179.823
Point 184	1308.6991	179.2973
Point 185	1290.4702	184
Point 186	949.6707	269.1831
Point 187	2513.6402	171.7168
Point 188	2493.9476	171.7168
Point 189	2487.2849	175.0339
Point 190	1978.4955	180.1217
Point 191	1910.9825	197
Point 192	1875.2439	197
Point 193	1807.7276	180.1209
Point 194	1338.9977	175.4293
Point 195	1336.6153	175.6273
Point 196	1329.5501	172.0844
Point 197	1309.862	172.0844
Point 198	3335.1097	261.1052
Point 199	3291.2035	260
Point 200	3251.3717	257.0262
Point 201	3161.003	250
Point 202	3139.6041	249.405
Point 203	3096.134	248.2296
Point 204	3042.0937	246.7302
Point 205	2991.9884	245.4134
Point 206	2932.2279	246.6667
Point 207	2920.9715	246.7982
Point 208	2867.979	247.8314
Point 209	2830.8804	247.939
Point 210	2894.4825	259.6831
Point 211	2902.4825	255.6831
Point 212	2908.4825	255.6831
Point 213	2916.4825	259.6831
Point 214	2933.4825	260.0231
Point 215	2959.3667	259.5195
Point 216	2967.9024	259.3931
Point 217	2982.3458	259.151
Point 218	3005.4824	259
Point 219	547.2476	275.7861
Point 220	547.9454	275.735
Point 221	550.1719	275.6329
Point 222	553.4501	275.5308
Point 223	557.8376	275.4255
Point 224	569.2025	275.214
Point 225	586.669	274.9465
Point 226	781.5012	270.7345
Point 227	811.0945	270.2699
Point 228	853.4825	269.5231
Point 229	870.4825	269.1831
Point 230	878.4825	265.1831
Point 231	884.4825	265.1831
Point 232	892.4825	269.1831
Point 233	1024.7998	240.2616
Point 234	969.7329	239.1612
Point 235	935.7837	239.4083
Point 236	930.1714	238.8042
Point 237	924.9444	238.4321
Point 238	918.2309	237.7453
Point 239	908.5449	236.83
Point 240	901.5966	235.8431
Point 241	893.9899	235.2773
Point 242	882.631	234.6916
Point 243	879.4693	235.0451
Point 244	871.3931	235.7514
Point 245	866.5978	236.2003
Point 246	864.6292	236.4185
Point 247	857.169	238.9666
Point 248	850.2221	239.2694
Point 249	837.7766	243.6033
Point 250	819.4863	246.352
Point 251	814.5664	246.3112
Point 252	802.3617	246.8773
Point 253	798.3886	246.5569
Point 254	794.7647	246.1802
Point 255	791.6199	246.2516
Point 256	787.2904	245.9571
Point 257	783.823	244.6145
Point 258	782.6659	244.3408
Point 259	777.2506	248.2884
Point 260	776.7924	248.4049
Point 261	773.1533	248.8746
Point 262	741.6862	251.1687
Point 263	731.8911	252.0628
Point 264	711.8077	255.2082
Point 265	703.8142	255.9695
Point 266	675.8165	257.0628
Point 267	671.5882	257.399
Point 268	669.5557	257.5325
Point 269	666.0148	257.8233
Point 270	646.9889	258.6654
Point 271	644.3982	258.734
Point 272	638.6573	258.9551
Point 273	621.0833	259.3458
Point 274	610.0674	259.2766

Point 275	606.2513	261.6178
Point 276	595.5808	265.2299
Point 277	595.1652	265.3965
Point 278	580.3881	270.9263
Point 279	570.2704	272.9851
Point 280	567.5599	273.6727
Point 281	565.9097	273.5198
Point 282	561.7326	273.4916
Point 283	559.7531	273.6296
Point 284	546.6354	275.7428
Point 285	3400	-500
Point 286	0	-500
Point 287	0	278.2613
Point 288	14.4819	278.5356
Point 289	17.7173	278.0348
Point 290	28.0753	278.1122
Point 291	29.9204	278.1787
Point 292	32.3072	278.0543
Point 293	37.1211	277.533
Point 294	78.5246	277.5313
Point 295	99.8253	277.4823
Point 296	113.8189	277.1463
Point 297	135.1112	276.736
Point 298	156.0552	276.6258
Point 299	179.9408	276.3417
Point 300	205.0185	275.8303
Point 301	218.5546	275.7088
Point 302	230.2246	275.8722
Point 303	242.6138	276.0108
Point 304	246.1872	275.9778
Point 305	265.6484	275.4973
Point 306	273.8252	275.2475
Point 307	286.9292	275.0257
Point 308	296.3136	274.495
Point 309	303.3885	274.7572
Point 310	308.9925	275.4236
Point 311	320.1975	275.9575
Point 312	323.9502	276.3472
Point 313	339.2177	277.5329
Point 314	360.3106	278.2429
Point 315	364.8484	278.233
Point 316	366.1583	278.3013
Point 317	366.9738	278.3144
Point 318	377.7148	278.4168
Point 319	379.4153	278.307
Point 320	388.6644	277.5731
Point 321	401.6953	277.8894
Point 322	408.4536	277.9966
Point 323	414.1013	278.2749
Point 324	429.0825	278.4981
Point 325	445.3886	278.5139
Point 326	450.8759	278.4505
Point 327	455.9523	278.33
Point 328	458.6764	278.4031
Point 329	463.6569	278.3876
Point 330	470.7521	276.9089
Point 331	472.2721	276.5605
Point 332	473.1578	276.4049
Point 333	474.7735	276.227
Point 334	482.5145	275.4688
Point 335	494.5043	275.6387
Point 336	498.0201	275.7161
Point 337	499.3265	275.7669
Point 338	504.7851	276.0468
Point 339	508.4981	276.1311
Point 340	514.9038	276.4622
Point 341	524.7969	276.4279
Point 342	527.0296	276.5527
Point 343	532.3761	276.5479
Point 344	535.0957	276.3224
Point 345	1309.4927	169.0844
Point 346	1330.2601	169.0844
Point 347	1337.2067	172.5678
Point 348	1338.8882	172.428
Point 349	1808.1117	177.1246
Point 350	1875.6132	194
Point 351	1910.6132	194
Point 352	1978.1114	177.1254
Point 353	2486.5653	172.0409
Point 354	2493.2421	168.7168
Point 355	2514.0095	168.7168
Point 356	3352.1727	261.5347
Point 357	3400	262.6701

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.938	(1276.09, 434.564)	291.1006	(1557.84, 399.017)	(908.343, 269.398)
2	4396	3.010	(1276.09, 434.564)	341.797	(1657.99, 402.512)	(927.971, 274.305)

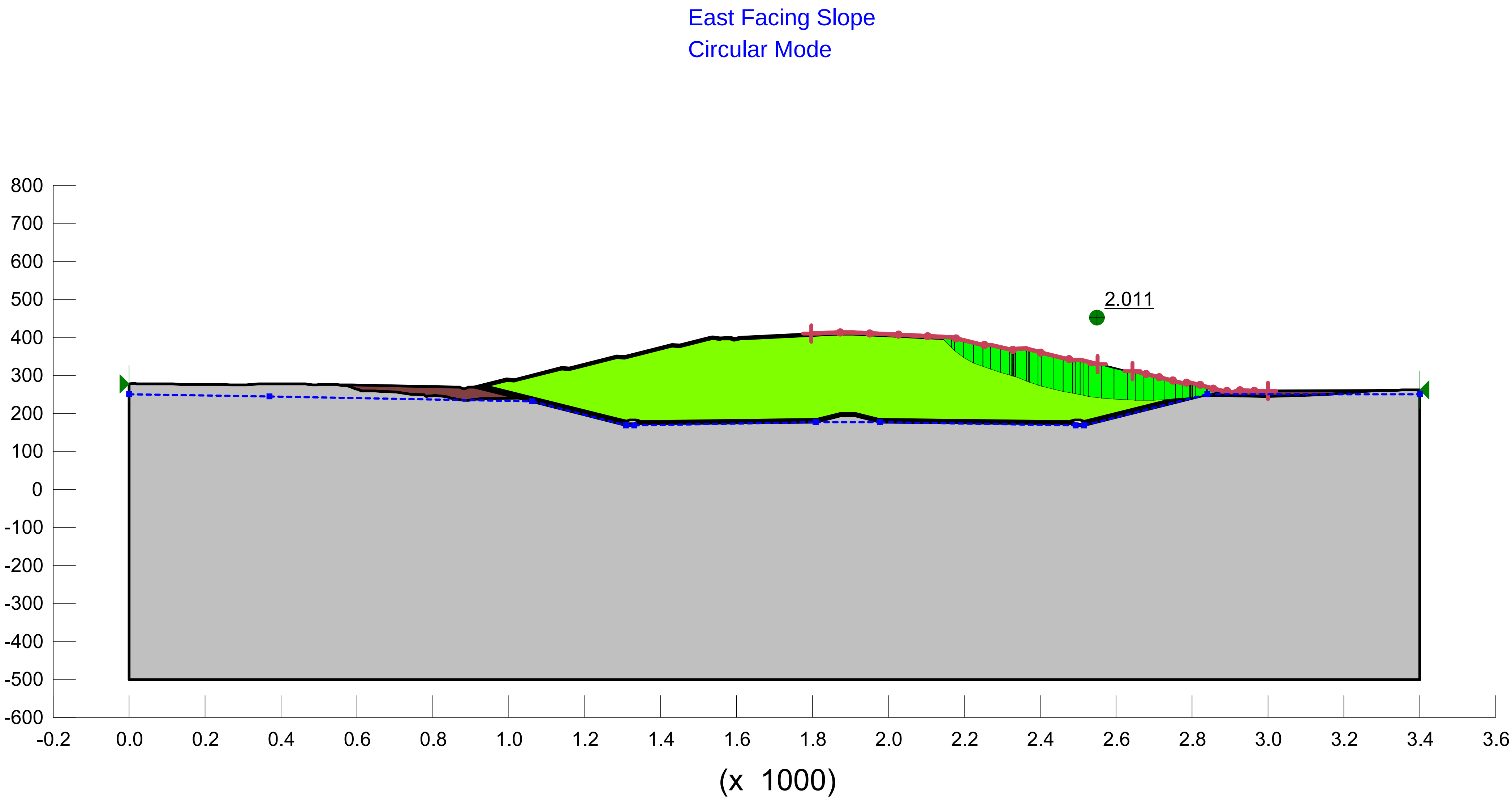
Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	908.7867	269.29065	0	25.606682	12.489213	0
2	Optimized	912.47965	268.3954	0	232.59441	62.323485	0
3	Optimized	918.609	266.9095	0	594.30994	159.24487	0
4	Optimized	922.7322	265.90995	0	850.59409	227.916	0
5	Optimized	936.823	262.49405	0	1671.6554	447.91871	0
6	Optimized	959.4035	257.02005	0	3003.5907	804.80971	0
7	Optimized	978.86905	252.3012	0	4181.911	1120.5397	0
8	Optimized	988.8432	249.88325	0	4794.4369	1284.6655	0
9	Optimized	989.32605	249.7662	0	4824.2357	1292.6501	0
10	Optimized	991.60915	249.21275	0	4965.0476	1330.3805	0
11	Optimized	993.74305	248.69545	0	5093.6032	1364.8269	0
12	Optimized	993.92755	248.6507	0	5097.7118	1365.9278	0
13	Optimized	994.63885	248.47825	0	5115.3057	1370.642	0
14	Optimized	1002.217	247.79415	0	4955.0905	1327.7125	0
15	Optimized	1011.5115	247.08085	0	5103.4468	2489.1173	0
16	Optimized	1013.934	246.89495	0	5118.6867	2496.5503	0
17	Optimized	1014.1075	246.88165	0	5126.1154	2500.1735	0
18	Optimized	1015.0835	246.80675	0	5165.3465	2519.3078	0
19	Optimized	1016.2095	246.72035	0	5210.2886	2541.2275	0
20	Optimized	1024.815	246.05995	0	5566.5096	2714.9681	0
21	Optimized	1041.3165	244.7936	0	6253.1109	3049.846	0
22	Optimized	1055.2875	243.62165	0	6783.7653	1817.7044	650
23	Optimized	1072.785	241.97975	0	7524.7844	2016.2599	650
24	Optimized	1099.432	240.8616	0	8190.9628	2194.7619	650
25	Optimized	1126.7025	241.61335	0	8671.2365	2323.4508	650
26	Optimized	1139.078	242.39505	0	8918.7499	2389.7718	650
27	Optimized	1145.3895	242.7937	0	8827.1948	2365.2397	650
28	Optimized	1155.3875	243.3262	0	8783.2437	2353.4631	650
29	Optimized	1159.2595	243.46935	0	8741.2089	2342.1999	650
30	Optimized	1164.938	243.67925	0	8873.1715	2377.5591	650
31	Optimized	1179.4285	244.67935	0	8962.094	2401.3858	650
32	Optimized	1197.2375	246.26665	0	9249.0108	2478.265	650
33	Optimized	1215.185	248.41485	0	9248.6061	2478.1565	650
34	Optimized	1233.2705	251.12395	0	9407.7349	2520.795	650
35	Optimized	1252.7875	254.68365	0	9288.8078	2488.9286	650
36	Optimized	1273.737	259.094	0	9337.8536	2502.0703	650
37	Optimized	1284.305	261.31875	0	9360.482	2508.1336	650
38	Optimized	1294.3955	263.4431	0	9054.0276	2426.0194	650
39	Optimized	1304.486	265.56745	0	8752.7064	2345.2806	650
40	Optimized	1307.036	266.1042	0	8760.2707	2347.3075	650
41	Optimized	1319.8765	268.8074	0	8794.8613	2356.576	650
42	Optimized	1341.1485	273.28565	0	8854.2022	2372.4763	650
43	Optimized	1363.4355	279.17925	0	8490.0416	2274.8998	650
44	Optimized	1386.2325	286.3819	0	8341.5558	2235.1131	650
45	Optimized	1413.5375	296.79715	0	7734.4781	2072.4472	650
46	Optimized	1429.5365	303.65085	0	7480.8832	2004.4966	650
47	Optimized	1439.627	307.9735	0	7007.2224	1877.5796	650
48	Optimized	1449.718	312.2962	0	6536.4298	1751.4311	650
49	Optimized	1462.0005	317.5578	0	6344.5059	1700.0052	650
50	Optimized	1486.2095	329.765	0	5569.0029	1492.2098	650
51	Optimized	1509.943	346.2409	0	4373.8581	1171.9717	650
52	Optimized	1522.544	356.75105	0	3442.6541	922.45638	650
53	Optimized	1523.6705	358.0457	0	3355.7157	899.16132	650
54	Optimized	1524.149	358.5957	0	3318.4041	889.1637	650
55	Optimized	1527.5695	362.527	0	3050.4592	817.36807	650
56	Optimized	1530.99	366.45805	0	2780.8073	745.11507	650
57	Optimized	1531.468	367.0075	0	2743.2147	735.04216	650
58	Optimized	1533.7325	369.6102	0	2564.0245	687.02828	650
59	Optimized	1535.828	372.01865	0	2395.1416	641.77627	650
60	Optimized	1541.3725	378.39175	0	1761.7329	472.05492	650
61	Optimized	1550.794	389.8298	0	554.8338	148.66727	650
62	Optimized	1555.263	395.65565	0	-48.615986	0	650

63	Optimized	1555.9855	396.59705	0	-175.416	0	650
64	Optimized	1557.0135	397.9374	0	85.941319	41.916382	0

Slices of Slip Surface: 4396

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	4396	929.5228	273.6623	0	121.75099	59.381923	0
2	4396	932.62655	272.37665	0	452.65732	0	650
3	4396	937.2574	270.45845	0	848.96987	227.48079	650
4	4396	945.00355	267.2499	0	1400.329	682.98609	0
5	4396	959.35225	261.30645	0	2572.9895	1254.9308	0
6	4396	977.1169	253.9481	0	3913.7874	1048.6962	0
7	4396	986.9009	250.3061	0	4498.856	1205.4648	0
8	4396	988.8432	249.9705	0	4595.936	1231.4773	0
9	4396	989.32605	249.88705	0	4619.8802	1237.8932	0
10	4396	991.60915	249.49255	0	4733.5665	1268.3553	0
11	4396	993.74305	249.12385	0	4836.6724	1295.9825	0
12	4396	1003.8412	247.37895	0	4986.6188	1336.1605	0
13	4396	1013.934	245.635	0	5141.2006	1377.5806	0
14	4396	1014.1075	245.605	0	5150.2334	1380.0009	0
15	4396	1015.0835	245.4363	0	5198.4618	1392.9236	0
16	4396	1016.2095	245.2418	0	5253.7852	1407.7475	0
17	4396	1016.682	245.1602	0	5277.7685	1414.1738	0
18	4396	1018.2465	244.8898	0	5356.8753	1435.3704	0
19	4396	1029.9625	242.8653	0	6075.8759	2963.4027	0
20	4396	1050.738	239.27545	0	7175.7944	3499.8688	0
21	4396	1073.5815	235.32825	0	8398.9171	4096.4256	0
22	4396	1098.493	231.02375	0	9743.0287	4751.9926	0
23	4396	1124.967	226.44925	0	10960.406	2936.832	650
24	4396	1139.078	224.01095	0	11689.605	3132.2201	650
25	4396	1149.169	222.26735	0	11842.158	3173.0966	650
26	4396	1159.2595	220.52375	0	11997.574	3214.7404	650
27	4396	1171.9125	218.33735	0	12645.109	3388.2468	650
28	4396	1196.9405	214.01275	0	13912.71	3727.8994	650
29	4396	1221.875	209.70425	0	15155.192	4060.8214	650
30	4396	1246.8095	205.3957	0	16370.8	4386.5427	650
31	4396	1271.7445	201.08715	0	17554.793	4703.7927	650
32	4396	1284.305	198.91685	0	18135.976	4859.5202	650
33	4396	1294.3955	197.17325	0	18223.922	4883.0851	650
34	4396	1304.486	195.42965	0	18312.054	4906.7	650
35	4396	1307.036	194.98905	0	18427.271	4937.5723	650
36	4396	1319.8765	192.7703	0	18993.459	5089.282	650
37	4396	1341.3285	189.0635	0	19917.339	5336.835	650
38	4396	1363.466	185.2383	0	20837.868	5583.4899	650
39	4396	1385.6035	181.41315	0	21724.567	5821.0802	650
40	4396	1406.229	177.84925	0	23076.031	11254.932	0
41	4396	1422.615	175.0822	0	22969.436	6154.6419	0
42	4396	1429.5365	174.05935	0	17502.128	4689.681	0
43	4396	1429.722	174.24505	0	17485.754	4685.2937	0
44	4396	1430.8255	175.3482	0	17391.137	4659.9411	0
45	4396	1433.601	178.12345	0	16359.611	7979.1154	0
46	4396	1442.4955	187.0182	0	16246.508	4353.2386	650
47	4396	1449.718	194.24085	0	15632.122	4188.6144	650
48	4396	1462.143	206.6657	0	14919.37	3997.633	650
49	4396	1486.714	231.2368	0	13518.346	3622.23	650
50	4396	1511.192	255.715	0	12124.539	3248.7603	650
51	4396	1523.6705	268.19335	0	11410.501	3057.4346	650
52	4396	1524.149	268.67185	0	11382.72	3049.9905	650
53	4396	1527.5695	272.09225	0	11184.03	2996.7518	650
54	4396	1530.99	275.51245	0	10984.189	2943.2045	650
55	4396	1531.468	275.9905	0	10956.605	2935.8133	650
56	4396	1533.7325	278.25495	0	10825.406	2900.6589	650
57	4396	1535.828	280.3504	0	10701.556	2867.4733	650
58	4396	1545.8415	290.3642	0	9780.5144	2620.6809	650
59	4396	1555.7935	300.31645	0	8857.6628	2373.4036	650
60	4396	1555.994	300.5166	0	8843.0763	2369.4952	650
61	4396	1556.7635	301.286	0	8783.4505	2353.5185	650
62	4396	1571.2475	315.77025	0	7619.9367	2041.7559	650
63	4396	1588.184	332.7066	0	6079.0689	1628.8816	650
64	4396	1591.4495	335.9721	0	5631.3538	1508.9167	650
65	4396	1591.921	336.44355	0	5564.7729	1491.0764	650
66	4396	1593.6575	338.17985	0	5398.4312	1446.5053	650
67	4396	1595.281	339.80375	0	5256.1506	1408.3813	650
68	4396	1601.5705	346.0936	0	4841.9574	1297.3986	650
69	4396	1607.885	352.4078	0	4418.8188	1184.0189	650
70	4396	1619.542	364.0646	0	3391.7403	908.81408	650
71	4396	1642.4125	386.935	0	1311.5102	351.4181	650
72	4396	1654.8275	399.3503	0	134.67638	0	650
73	4396	1656.935	401.4582	0	94.651288	46.164518	0


East Facing Slope
Circular Mode
2.011
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
(x 1000)

Slope Stability

File Information

Title: Trench 23 - Final Stability
Created By: Gondhalekar, Rajendra S.
Revision Number: 27
Last Edited By: Gondhalekar, Rajendra S.
Date: 12/16/2014
Time: 10:48:17 AM
File Name: Trench 23-Final-Global_Right.gsz
Directory: N:\Projects\2014\EJ147410\Working Files\Calculations-Analyses\Stability\Global\Model\
Last Solved Date: 12/16/2014
Last Solved Time: 10:48:39 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Slope Stability

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
  Apply Phreatic Correction: No
  Side Function
    Interslice force function option: Half-Sine
  PWP Conditions Source: Piezometric Line
  Use Staged Rapid Drawdown: No
Slip Surface
  Direction of movement: Left to Right
  Use Passive Mode: No
  Slip Surface Option: Entry and Exit
  Critical slip surfaces saved: 1
  Optimize Critical Slip Surface Location: Yes
  Tension Crack
    Tension Crack Option: (none)
FOS Distribution
  FOS Calculation Option: Constant
Advanced
  Number of Slices: 30
  Optimization Tolerance: 0.01
  Minimum Slip Surface Depth: 0.1 ft
  Optimization Maximum Iterations: 20000
  Optimization Convergence Tolerance: 1e-007
  Starting Optimization Points: 8
  Ending Optimization Points: 16
  Complete Passes per Insertion: 1
  Driving Side Maximum Convex Angle: 5 °
  Resisting Side Maximum Convex Angle: 1 °

Materials

Chalk

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 8000 psf
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
  Piezometric Line: 1

Structural Fill

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 600 psf
Phi: 26 °
Phi-B: 0 °
Pore Water Pressure
  Piezometric Line: 1

Synthetic Interface

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 15 °
Phi-B: 0 °

Liner Protective Soil

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 26 °
Phi-B: 0 °

Waste

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 650 psf
Phi: 15 °
Phi-B: 0 °

Cover Barrier Soil

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 650 psf

Cover Vegetative Soil

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 26 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (1797.2178, 409.4722) ft
Left-Zone Right Coordinate: (2550, 329.4942) ft
Left-Zone Increment: 10
Right Projection: Range
Right-Zone Left Coordinate: (2642.4659, 310.3095) ft
Right-Zone Right Coordinate: (3000, 259.0358) ft
Right-Zone Increment: 10
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (0, 278.2613) ft
Right Coordinate: (3400, 262.6701) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	249.9317
	369.2937	244.8771
	1061.126	231.1795
	1309.4927	169.0844
	1330.2601	169.0844
	1808.1117	177.1246
	1978.1114	177.1254
	2493.2421	168.7168
	2514.0095	168.7168
	2839.1241	250
	3400	250

Regions

	Material	Points	Area (ft²)
Region 1	Cover Vegetative Soil	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86	4003.3142
Region 2	Cover Barrier Soil	85,84,83,82,81,80,79,78,77,76,75,74,73,72,71,70,69,68,67,66,65,64,63,62,61,60,59,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130	3969.1616
Region 3	Waste	131,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,166,167,168,169,170,171,172,173,174,175,176,177,178,179,180,181,182,183,184,185,186,129,128,127,126,125,124,123,122,121,120,119,118,117,116,115,114,113,112,111,110,109,108,107,106,105,104,103,102,101,100,99,98,97,96,95,94,93,92,91,90,89,88	301500.29
Region 4	Liner Protective Soil	87,187,188,189,190,191,192,193,194,195,196,197,130,129,186,185,184,183,182,181,180,179,178,177,176,175,174,173,172,171,170,169,168,167,166,165,164,163,162,161,160,159,158,157,156,155,154,153,152,151,150,149,148,147,146,145,144,143,142,141,140,139,138,137,136,135,134,133,132,131,88	9446.0036
Region 5	Structural Fill	198,199,200,201,202,203,204,205,206,207,208,209,43,42,210,211,212,213,214,215,216,217,218	4420.7882
Region 6	Structural Fill	219,220,221,222,223,224,225,226,227,228,229,230,231,232,1,86,233,234,235,236,237,238,239,240,241,242,243,244,245,246,247,248,249,250,251,252,253,254,255,256,257,258,259,260,261,262,263,264,265,266,267,268,269,270,271,272,273,274,275,276,277,278,279,280,281,282,283,284	8757.3274
Region 7	Chalk	285,286,287,288,289,290,291,292,293,294,295,296,297,298,299,300,301,302,303,304,305,306,307,308,309,310,311,312,313,314,315,316,317,318,319,320,321,322,323,324,325,326,327,328,329,330,331,332,333,334,335,336,337,338,339,340,341,342,343,344,284,283,282,281,280,279,278,277,276,275,274,273,272,271,270,269,268,267,266,265,264,263,262,261,260,259,258,257,256,255,254,253,252,251,250,249,248,247,246,245,244,243,242,241,240,239,238,237,236,235,234,233,345,346,347,348,349,350,351,352,353,354,355,209,208,207,206,205,204,203,202,201,200,199,198,356,357	2450432.5
Region 8	Synthetic Interface	355,354,353,352,351,350,349,348,347,346,345,233,86,85,130,197,196,195,194,193,192,191,190,189,188,187,87,44,43,209	5956.0448

Points

	X (ft)	Y (ft)
Point 1	907.4825	269.1831
Point 2	988.6018	289.4624
Point 3	993.6508	290.7125
Point 4	1013.8471	289.4975
Point 5	1015.973	290
Point 6	1138.985	320.7419
Point 7	1159.1665	319.5108
Point 8	1284.2118	350.7641
Point 9	1304.3933	349.5308
Point 10	1429.4437	380.784
Point 11	1449.6252	379.5489
Point 12	1523.4313	398
Point 13	1530.7506	399.7774
Point 14	1535.7576	401.0265
Point 15	1555.7852	398.8865
Point 16	1556.1855	398.936
Point 17	1585.154	400.3492
Point 18	1592.1565	396.8514
Point 19	1595.1576	396.8523
Point 20	1607.7373	400
Point 21	1867.7863	413
Point 22	1905.7797	413
Point 23	2166.2808	400
Point 24	2249.0114	379.3569
Point 25	2269.0561	380.564
Point 26	2319.4047	368
Point 27	2324.358	367.0274
Point 28	2327.4105	367.0136
Point 29	2334.533	370.467
Point 30	2363.023	371.2405
Point 31	2364.0405	369.7324
Point 32	2370.3834	368
Point 33	2394.369	362
Point 34	2402.8621	360
Point 35	2484.6063	339.5641
Point 36	2504.7876	340.7946
Point 37	2629.8331	309.5407
Point 38	2650.0144	310.7689
Point 39	2775.0683	279.5109
Point 40	2795.2513	280.729
Point 41	2800.297	279.479
Point 42	2879.4825	259.6831
Point 43	2877.8543	259.6831
Point 44	2871.2361	259.6831
Point 45	2799.814	277.5382
Point 46	2795.0669	278.7142
Point 47	2774.8817	277.496
Point 48	2649.8283	308.7539
Point 49	2629.647	307.5256
Point 50	2504.6017	338.7795
Point 51	2484.4203	337.549
Point 52	2402.3903	358.0564
Point 53	2393.8971	360.0564
Point 54	2369.8772	366.065
Point 55	2362.7976	367.9986
Point 56	2361.9793	369.2114
Point 57	2335.0179	368.4795
Point 58	2327.8655	365.0115
Point 59	2324.159	365.0283
Point 60	2318.9696	366.0472
Point 61	2268.8698	378.5491
Point 62	2248.8251	377.3421
Point 63	2165.9861	398.0122
Point 64	1905.7299	411
Point 65	1867.8362	411
Point 66	1608.0327	398.0123
Point 67	1595.4043	394.8524
Point 68	1591.685	394.8512
Point 69	1584.6793	398.3507
Point 70	1557.3409	397.0638
Point 71	1555.8021	396.8733
Point 72	1535.8976	399.0002
Point 73	1531.2287	397.8354
Point 74	1523.9098	396.0581
Point 75	1449.8109	377.5338
Point 76	1429.6294	378.7689
Point 77	1304.5791	347.5157
Point 78	1284.3976	348.749
Point 79	1159.3524	317.4957
Point 80	1139.1709	318.7268
Point 81	1016.4455	288.0566
Point 82	1014.0208	287.4834
Point 83	993.8353	288.6978
Point 84	989.0846	287.5216
Point 85	915.7289	269.1831
Point 86	909.1204	269.1831
Point 87	2865.4856	259.6831
Point 88	2862.9897	259.6831
Point 89	2799.3311	275.5974
Point 90	2794.8824	276.6994
Point 91	2774.6951	275.4811
Point 92	2649.6423	306.7389
Point 93	2629.461	305.5106
Point 94	2504.4157	336.7645
Point 95	2484.2343	335.534
Point 96	2401.9186	356.1128
Point 97	2393.4252	358.1128
Point 98	2369.371	364.13
Point 99	2361.5547	366.2648
Point 100	2360.9357	367.1823
Point 101	2335.5028	366.4919
Point 102	2328.3204	363.0094
Point 103	2323.96	363.0292
Point 104	2318.5346	364.0945
Point 105	2268.6835	376.5343
Point 106	2248.6389	375.3273
Point 107	2165.6914	396.0244
Point 108	1905.68	409
Point 109	1867.8862	409
Point 110	1608.3282	396.0245
Point 111	1595.651	392.8525
Point 112	1591.2136	392.8511
Point 113	1584.2047	396.3522
Point 114	1558.4964	395.1916
Point 115	1555.8189	394.8601
Point 116	1536.0377	396.9738
Point 117	1531.7067	395.8933
Point 118	1524.3883	394.1162
Point 119	1449.9967	375.5187
Point 120	1429.8151	376.7538
Point 121	1304.7649	345.5006
Point 122	1284.5834	346.7339
Point 123	1159.5383	315.4807
Point 124	1139.3568	316.7117
Point 125	1016.918	286.1132
Point 126	1014.1944	285.4693
Point 127	994.0198	286.6831
Point 128	989.5675	285.5808
Point 129	923.9753	269.1831
Point 130	921.4891	269.1831

Point 131	2837.2943	259.6831
Point 132	2518.4991	180
Point 133	2517.8299	179.7028
Point 134	2515.4694	178.9154
Point 135	2513.2901	179.8249
Point 136	2511.6282	180.4861
Point 137	2505.7593	182.2763
Point 138	2504.355	182.5261
Point 139	2503.0345	182.7008
Point 140	2501.7671	182.8091
Point 141	2501.0211	182.8445
Point 142	2500.2794	182.8584
Point 143	2494.2794	182.8584
Point 144	2493.3522	182.8337
Point 145	2492.3458	182.7696
Point 146	2491.313	182.6644
Point 147	2490.2391	182.5149
Point 148	2489.3966	182.3705
Point 149	2488.2081	182.1294
Point 150	2486.9229	181.8242
Point 151	2485.5101	181.4417
Point 152	2483.929	180.9638
Point 153	2482.5999	180.5275
Point 154	2481.1133	180.0083
Point 155	2479.427	179.3858
Point 156	2477.4832	178.6322
Point 157	1974.6479	183.6605
Point 158	1911.29	199.5
Point 159	1874.9364	199.5
Point 160	1811.5714	183.6588
Point 161	1345.1308	178.984
Point 162	1342.7209	179.8901
Point 163	1340.2404	180.7485
Point 164	1338.1673	181.3896
Point 165	1337.0646	181.6955
Point 166	1336.0431	181.9534
Point 167	1335.0876	182.1699
Point 168	1334.1853	182.3503
Point 169	1333.326	182.4986
Point 170	1332.5008	182.6179
Point 171	1331.7019	182.7107
Point 172	1330.9226	182.7787
Point 173	1330.1567	182.8233
Point 174	1329.2487	182.8468
Point 175	1323.2487	182.8468
Point 176	1322.2416	182.8227
Point 177	1321.2232	182.7587
Point 178	1320.4438	182.6834
Point 179	1319.3721	182.5442
Point 180	1318.535	182.4082
Point 181	1317.3595	182.1797
Point 182	1311.8013	180.5008
Point 183	1310.026	179.823
Point 184	1308.6991	179.2973
Point 185	1290.4702	184
Point 186	949.6707	269.1831
Point 187	2513.6402	171.7168
Point 188	2493.9476	171.7168
Point 189	2487.2849	175.0339
Point 190	1978.4955	180.1217
Point 191	1910.9825	197
Point 192	1875.2439	197
Point 193	1807.7276	180.1209
Point 194	1338.9977	175.4293
Point 195	1336.6153	175.6273
Point 196	1329.5501	172.0844
Point 197	1309.862	172.0844
Point 198	3335.1097	261.1052
Point 199	3291.2035	260
Point 200	3251.3717	257.0262
Point 201	3161.003	250
Point 202	3139.6041	249.405
Point 203	3096.134	248.2296
Point 204	3042.0937	246.7302
Point 205	2991.9884	245.4134
Point 206	2932.2279	246.6667
Point 207	2920.9715	246.7982
Point 208	2867.979	247.8314
Point 209	2830.8804	247.939
Point 210	2894.4825	259.6831
Point 211	2902.4825	255.6831
Point 212	2908.4825	255.6831
Point 213	2916.4825	259.6831
Point 214	2933.4825	260.0231
Point 215	2959.3667	259.5195
Point 216	2967.9024	259.3931
Point 217	2982.3458	259.151
Point 218	3005.4824	259
Point 219	547.2476	275.7861
Point 220	547.9454	275.735
Point 221	550.1719	275.6329
Point 222	553.4501	275.5308
Point 223	557.8376	275.4255
Point 224	569.2025	275.214
Point 225	586.669	274.9465
Point 226	781.5012	270.7345
Point 227	811.0945	270.2699
Point 228	853.4825	269.5231
Point 229	870.4825	269.1831
Point 230	878.4825	265.1831
Point 231	884.4825	265.1831
Point 232	892.4825	269.1831
Point 233	1024.7998	240.2616
Point 234	969.7329	239.1612
Point 235	935.7837	239.4083
Point 236	930.1714	238.8042
Point 237	924.9444	238.4321
Point 238	918.2309	237.7453
Point 239	908.5449	236.83
Point 240	901.5966	235.8431
Point 241	893.9899	235.2773
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Point 243	879.4693	235.0451
Point 244	871.3931	235.7514
Point 245	866.5978	236.2003
Point 246	864.6292	236.4185
Point 247	857.169	238.9666
Point 248	850.2221	239.2694
Point 249	837.7766	243.6033
Point 250	819.4863	246.352
Point 251	814.5664	246.3112
Point 252	802.3617	246.8773
Point 253	798.3886	246.5569
Point 254	794.7647	246.1802
Point 255	791.6199	246.2516
Point 256	787.2904	245.9571
Point 257	783.823	244.6145
Point 258	782.6659	244.3408
Point 259	777.2506	248.2884
Point 260	776.7924	248.4049
Point 261	773.1533	248.8746
Point 262	741.6862	251.1687
Point 263	731.8911	252.0628
Point 264	711.8077	255.2082
Point 265	703.8142	255.9695
Point 266	675.8165	257.0628
Point 267	671.5882	257.399
Point 268	669.5557	257.5325
Point 269	666.0148	257.8233
Point 270	646.9889	258.6654
Point 271	644.3982	258.734
Point 272	638.6573	258.9551
Point 273	621.0833	259.3458
Point 274	610.0674	259.2766
Point 275	606.2513	261.6178
Point 276	595.5808	265.2299
Point 277	595.1652	265.3965
Point 278	580.3881	270.9263
Point 279	570.2704	272.9851
Point 280	567.5599	273.6727
Point 281	565.9097	273.5198
Point 282	561.7326	273.4916
Point 283	559.7531	273.6296
Point 284	546.6354	275.7428

Point 285	3400	-500
Point 286	0	-500
Point 287	0	278.2613
Point 288	14.4819	278.5356
Point 289	17.7173	278.0348
Point 290	28.0753	278.1122
Point 291	29.9204	278.1787
Point 292	32.3072	278.0543
Point 293	37.1211	277.533
Point 294	78.5246	277.5313
Point 295	99.8253	277.4823
Point 296	113.8189	277.1463
Point 297	135.1112	276.736
Point 298	156.0552	276.6258
Point 299	179.9408	276.3417
Point 300	205.0185	275.8303
Point 301	218.5546	275.7088
Point 302	230.2246	275.8722
Point 303	242.6138	276.0108
Point 304	246.1872	275.9778
Point 305	265.6484	275.4973
Point 306	273.8252	275.2475
Point 307	286.9292	275.0257
Point 308	296.3136	274.495
Point 309	303.3885	274.7572
Point 310	308.9925	275.4236
Point 311	320.1975	275.9575
Point 312	323.9502	276.3472
Point 313	339.2177	277.5329
Point 314	360.3106	278.2429
Point 315	364.8484	278.233
Point 316	366.1583	278.3013
Point 317	366.9738	278.3144
Point 318	377.7148	278.4168
Point 319	379.4153	278.307
Point 320	388.6644	277.5731
Point 321	401.6953	277.8894
Point 322	408.4536	277.9966
Point 323	414.1013	278.2749
Point 324	429.0825	278.4981
Point 325	445.3886	278.5139
Point 326	450.8759	278.4505
Point 327	455.9523	278.33
Point 328	458.6764	278.4031
Point 329	463.6569	278.3876
Point 330	470.7521	276.9089
Point 331	472.2721	276.5605
Point 332	473.1578	276.4049
Point 333	474.7735	276.227
Point 334	482.5145	275.4688
Point 335	494.5043	275.6387
Point 336	498.0201	275.7161
Point 337	499.3265	275.7669
Point 338	504.7851	276.0468
Point 339	508.4981	276.1311
Point 340	514.9038	276.4622
Point 341	524.7969	276.4279
Point 342	527.0296	276.5527
Point 343	532.3761	276.5479
Point 344	535.0957	276.3224
Point 345	1309.4927	169.0844
Point 346	1330.2601	169.0844
Point 347	1337.2067	172.5678
Point 348	1338.8882	172.428
Point 349	1808.1117	177.1246
Point 350	1875.6132	194
Point 351	1910.6132	194
Point 352	1978.1114	177.1254
Point 353	2486.5653	172.0409
Point 354	2493.2421	168.7168
Point 355	2514.0095	168.7168
Point 356	3352.1727	261.5347
Point 357	3400	262.6701

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	2.011	(2677.33, 1321.81)	325.0731	(2138.43, 401.39)	(2878.44, 259.943)
2	564	2.103	(2677.33, 1321.81)	1083.625	(2102.55, 403.18)	(2892.12, 259.683)

Slices of Slip Surface: Optimized

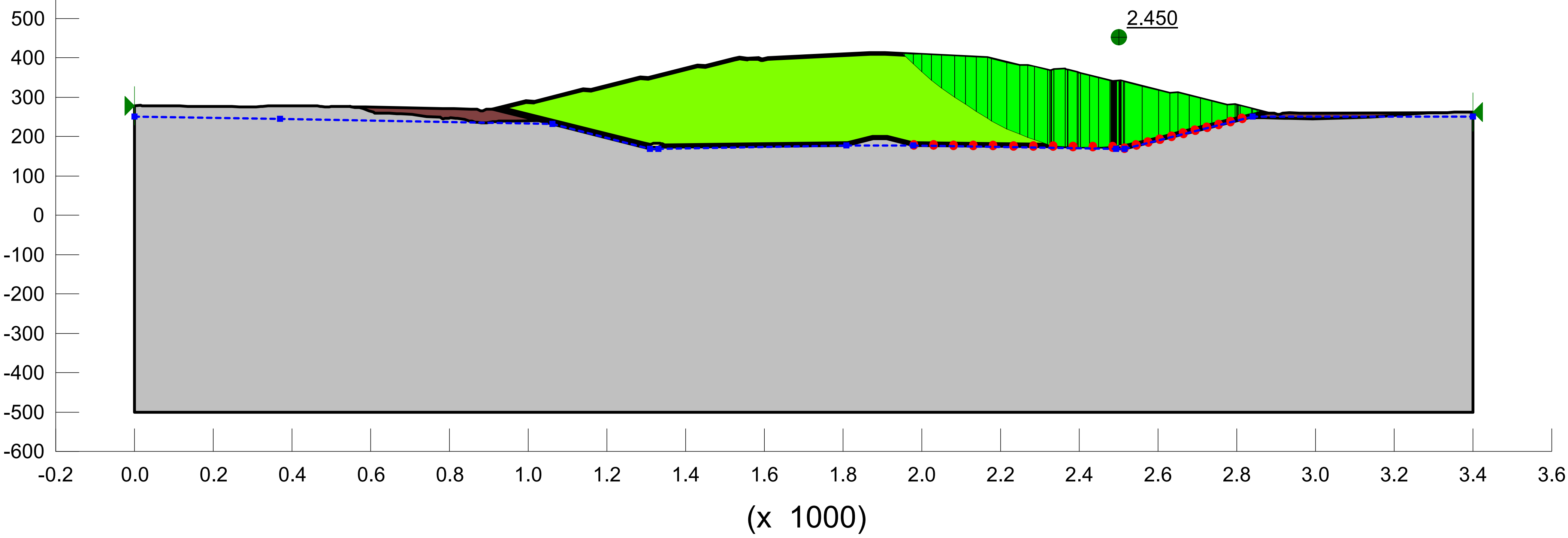
	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	2139.4305	400.3387	0	87.640031	42.744899	0
2	Optimized	2141.427	398.23655	0	11.290419	0	650
3	Optimized	2154.353	384.6285	0	1258.9627	337.33804	650
4	Optimized	2169.6605	368.51365	0	2620.9989	702.29455	650
5	Optimized	2185.3305	355.84365	0	3644.7891	976.6183	650
6	Optimized	2210.748	339.95875	0	4748.3876	1272.3266	650
7	Optimized	2236.443	328.55605	0	5398.7706	1446.5962	650
8	Optimized	2259.0335	320.23395	0	5962.5739	1597.6669	650
9	Optimized	2281.4525	311.97505	0	6523.3666	1747.9308	650
10	Optimized	2306.627	303.8608	0	6869.363	1840.6403	650
11	Optimized	2321.8815	299.6257	0	6921.8819	1854.7127	650
12	Optimized	2325.8845	298.5144	0	6984.3098	1871.4402	650
13	Optimized	2327.638	298.0275	0	7045.1721	1887.7482	650
14	Optimized	2328.0925	297.90115	0	7083.1536	1897.9253	650
15	Optimized	2330.756	297.1618	0	7295.3935	1954.7948	650
16	Optimized	2333.8625	296.23805	0	7333.8603	1965.1019	650
17	Optimized	2334.7755	295.901	0	7400.4756	1982.9515	650
18	Optimized	2349.0205	290.64235	0	7953.1267	2131.0339	650
19	Optimized	2363.532	285.28535	0	8444.4477	2262.6829	650
20	Optimized	2366.706	284.1136	0	8410.5962	2253.6125	650
21	Optimized	2369.624	283.0363	0	8436.5798	2260.5747	650
22	Optimized	2370.13	282.84945	0	8441.0276	2261.7665	650
23	Optimized	2381.85	278.52295	0	8573.9051	2297.371	650
24	Optimized	2393.371	274.2751	0	8987.3691	2408.1583	650
25	Optimized	2393.661	274.19575	0	8988.4053	2408.4359	650
26	Optimized	2394.133	274.06665	0	8989.6317	2408.7646	650
27	Optimized	2398.144	272.96935	0	9006.3502	2413.2443	650
28	Optimized	2402.1545	271.8721	0	9023.5016	2417.84	650
29	Optimized	2402.626	271.74305	0	9025.6793	2418.4235	650
30	Optimized	2419.093	267.238	0	9074.4263	2431.4852	650
31	Optimized	2447.5515	260.46545	0	9333.6841	2500.9531	650
32	Optimized	2472.1925	255.7659	0	9209.6595	2467.7208	650
33	Optimized	2488.924	252.5749	0	9267.9735	2483.346	650
34	Optimized	2499.015	250.6504	0	9551.1163	2559.2139	650
35	Optimized	2509.399	248.67	0	9691.5017	2596.83	650
36	Optimized	2520.418	246.56845	0	9638.1498	2582.5344	650
37	Optimized	2543.399	242.8178	0	9592.919	2570.4149	650
38	Optimized	2576.8215	238.6351	0	9372.81	2511.4369	650
39	Optimized	2611.752	236.34295	0	8896.805	2383.8917	650
40	Optimized	2639.9235	235.34895	0	8572.4077	2296.9697	650
41	Optimized	2661.609	234.5838	0	8398.0378	2250.2474	650
42	Optimized	2685.9485	234.3447	0	7859.0995	2105.8394	650
43	Optimized	2712.6785	235.64155	0	7075.2826	1895.8163	650
44	Optimized	2741.2825	237.9463	0	5931.4788	1589.3349	650
45	Optimized	2765.4845	239.7303	0	4996.5922	2437.0008	0
46	Optimized	2783.7925	240.88815	0	4603.9691	2245.5058	0
47	Optimized	2793.6995	241.5147	0	4506.6141	1207.5436	0
48	Optimized	2794.9745	241.59535	0	4504.9835	1207.1067	0
49	Optimized	2795.159	241.60705	0	4505.2076	1207.1667	0
50	Optimized	2797.291	241.7419	0	4430.5815	1187.1707	0
51	Optimized	2799.5725	241.88615	0	4347.4954	1164.9079	0
52	Optimized	2800.0555	241.9167	0	4330.0652	1160.2375	0
53	Optimized	2804.4195	242.1927	0	4170.2516	1117.4156	0
54	Optimized	2822.918	246.0506	0	3303.1331	885.07184	0
55	Optimized	2838.209	249.87675	0	2384.4085	638.90034	0
56	Optimized	2851.057	253.0915	0	1626.9419	435.93777	0
57	Optimized	2864.238	256.38955	0	851.19681	228.0775	0
58	Optimized	2868.361	257.42125	0	591.95794	158.61465	0
59	Optimized	2874.318	258.9119	0	235.2936	63.04673	0
60	Optimized	2877.9205	259.8133	0	30.494836	14.873325	0

Slices of Slip Surface: 564

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	564	2104.295	402.09205	0	96.139481	46.890358	0
2	564	2107.8055	399.9144	0	160.56784	0	650
3	564	2123.5995	390.4831	0	1053.0327	282.15926	650
4	564	2151.9555	374.1987	0	2561.4836	686.34747	650
5	564	2180.007	359.1651	0	3656.0119	979.62544	650
6	564	2207.4595	345.46795	0	4340.5222	1163.0394	650
7	564	2235.0985	332.64215	0	4939.0785	1323.4221	650
8	564	2259.0335	322.22815	0	5708.0347	1529.4633	650
9	564	2281.4255	313.17885	0	6388.662	1711.8368	650

10	564	2306.6	303.66115	0	6745.013	1807.3208	650
11	564	2321.8815	298.13875	0	6954.4491	1863.439	650
12	564	2325.8845	296.75555	0	7051.295	1889.3888	650
13	564	2327.638	296.1547	0	7126.4204	1909.5186	650
14	564	2328.0925	295.9997	0	7167.5615	1920.5423	650
15	564	2331.4265	294.876	0	7455.8142	1997.7794	650
16	564	2334.7755	293.7489	0	7732.1998	2071.8367	650
17	564	2349.0205	289.2161	0	8262.6292	2213.9648	650
18	564	2363.532	284.61015	0	8734.6091	2340.4315	650
19	564	2366.706	283.65875	0	8688.5459	2328.0889	650
20	564	2369.624	282.78635	0	8704.1645	2332.2738	650
21	564	2370.13	282.63655	0	8706.7455	2332.9654	650
22	564	2382.376	279.1691	0	8783.6941	2353.5837	650
23	564	2398.144	274.76995	0	8886.1773	2381.044	650
24	564	2402.1545	273.7015	0	8912.4988	2388.0969	650
25	564	2402.626	273.5778	0	8915.5575	2388.9164	650
26	564	2416.424	270.1514	0	8961.8272	2401.3144	650
27	564	2443.548	263.79015	0	9019.9839	2416.8974	650
28	564	2470.858	258.1249	0	9006.661	2413.3275	650
29	564	2488.924	254.69395	0	9107.8472	2440.4403	650
30	564	2499.015	252.96855	0	9400.2081	2518.7782	650
31	564	2509.399	251.2822	0	9541.0968	2556.5292	650
32	564	2528.441	248.55695	0	9403.8013	2519.741	650
33	564	2557.3035	244.9465	0	9131.0396	2446.6547	650
34	564	2586.1665	242.11955	0	8758.6745	2346.8798	650
35	564	2615.2155	240.0618	0	8278.4866	2218.2138	650
36	564	2639.9235	238.87395	0	8137.8356	2180.5265	650
37	564	2664.477	238.3539	0	7913.9364	2120.5329	650
38	564	2693.4025	238.397	0	7140.3386	1913.248	650
39	564	2722.328	239.21275	0	6255.1813	1676.0708	650
40	564	2751.2535	240.803	0	5260.9287	1409.6616	650
41	564	2770.392	242.1952	0	4585.7491	2236.6193	0
42	564	2785.1595	243.60755	0	4346.7929	2120.0726	0
43	564	2797.291	244.84405	0	4207.0307	2051.906	0
44	564	2799.5725	245.0987	0	4109.8554	2004.5104	0
45	564	2800.0555	245.1536	0	4089.2531	1994.462	0
46	564	2807.2455	246.02025	0	3773.9987	1840.7022	0
47	564	2825.744	248.4565	0	2881.2064	772.01692	0
48	564	2838.209	250.19095	0	2321.8322	622.13306	0
49	564	2840.8095	250.58555	0	2201.6751	589.93706	0
50	564	2852.7425	252.52385	-157.48577	1745.3052	851.24224	600
51	564	2864.238	254.42345	-276.02355	1196.9006	583.76741	600
52	564	2868.361	255.15695	-321.79059	974.70078	475.39333	600
53	564	2874.545	256.2844	-392.14865	655.8097	319.85976	600
54	564	2878.6685	257.05085	-439.97333	447.42027	218.22145	600
55	564	2885.8035	258.44395	-526.89882	231.42746	112.87472	600

East Facing Slope
Block Mode



Slope Stability

File Information

Title: Trench 23 - Final Stability
Created By: Gondhalekar, Rajendra S.
Revision Number: 25
Last Edited By: Gondhalekar, Rajendra S.
Date: 12/16/2014
Time: 10:43:46 AM
File Name: Trench 23-Final-Block_Right.gsz
Directory: N:\Projects\2014\EJ147410\Working Files\Calculations-Analyses\Stability\Global\Model\
Last Solved Date: 12/16/2014
Last Solved Time: 10:45:08 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Slope Stability

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
  Apply Phreatic Correction: No
  Side Function
    Interslice force function option: Half-Sine
  PWP Conditions Source: Piezometric Line
  Use Staged Rapid Drawdown: No
Slip Surface
  Direction of movement: Left to Right
  Use Passive Mode: No
  Slip Surface Option: Block
  Critical slip surfaces saved: 1
  Optimize Critical Slip Surface Location: Yes
  Tension Crack
    Tension Crack Option: (none)
FOS Distribution
  FOS Calculation Option: Constant
Restrict Block Crossing: Yes
Advanced
  Number of Slices: 30
  Optimization Tolerance: 0.01
  Minimum Slip Surface Depth: 0.1 ft
  Optimization Maximum Iterations: 20000
  Optimization Convergence Tolerance: 1e-007
  Starting Optimization Points: 8
  Ending Optimization Points: 16
  Complete Passes per Insertion: 1
  Driving Side Maximum Convex Angle: 5 °
  Resisting Side Maximum Convex Angle: 1 °

Materials

Chalk

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 8000 psf
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
  Piezometric Line: 1

Structural Fill

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 600 psf
Phi: 26 °
Phi-B: 0 °
Pore Water Pressure
  Piezometric Line: 1

Synthetic Interface

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 15 °
Phi-B: 0 °

Liner Protective Soil

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 26 °
Phi-B: 0 °

Waste

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 650 psf
Phi: 15 °
Phi-B: 0 °

Cover Barrier Soil

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 650 psf

Cover Vegetative Soil

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 26 °
Phi-B: 0 °

Slip Surface Limits

Left Coordinate: (0, 278.2613) ft
Right Coordinate: (3400, 262.6701) ft

Slip Surface Block

Left Grid
  Upper Left: (1979, 180) ft
  Lower Left: (1979, 177) ft
  Lower Right: (2485, 172) ft
  X Increments: 10
  Y Increments: 5
  Starting Angle: 115 °
  Ending Angle: 135 °
  Angle Increments: 2
Right Grid
  Upper Left: (2514, 172) ft
  Lower Left: (2515, 169) ft
  Lower Right: (2814, 244) ft
  X Increments: 10
  Y Increments: 5
  Starting Angle: 0 °
  Ending Angle: 45 °
  Angle Increments: 2

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	249.9317
	369.2937	244.8771
	1061.126	231.1795

	1309.4927	169.0844
	1330.2601	169.0844
	1808.1117	177.1246
	1978.1114	177.1254
	2493.2421	168.7168
	2514.0095	168.7168
	2839.1241	250
	3400	250

Regions

	Material	Points	Area (ft²)
Region 1	Cover Vegetative Soil	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86	4003.3142
Region 2	Cover Barrier Soil	85,84,83,82,81,80,79,78,77,76,75,74,73,72,71,70,69,68,67,66,65,64,63,62,61,60,59,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130	3969.1616
Region 3	Waste	131,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,166,167,168,169,170,171,172,173,174,175,176,177,178,179,180,181,182,183,184,185,186,129,128,127,126,125,124,123,122,121,120,119,118,117,116,115,114,113,112,111,110,109,108,107,106,105,104,103,102,101,100,99,98,97,96,95,94,93,92,91,90,89,88	301500.29
Region 4	Liner Protective Soil	87,187,188,189,190,191,192,193,194,195,196,197,130,129,186,185,184,183,182,181,180,179,178,177,176,175,174,173,172,171,170,169,168,167,166,165,164,163,162,161,160,159,158,157,156,155,154,153,152,151,150,149,148,147,146,145,144,143,142,141,140,139,138,137,136,135,134,133,132,131,88	9446.0036
Region 5	Structural Fill	198,199,200,201,202,203,204,205,206,207,208,209,43,42,210,211,212,213,214,215,216,217,218	4420.7882
Region 6	Structural Fill	219,220,221,222,223,224,225,226,227,228,229,230,231,232,1,86,233,234,235,236,237,238,239,240,241,242,243,244,245,246,247,248,249,250,251,252,253,254,255,256,257,258,259,260,261,262,263,264,265,266,267,268,269,270,271,272,273,274,275,276,277,278,279,280,281,282,283,284	8757.3274
Region 7	Chalk	285,286,287,288,289,290,291,292,293,294,295,296,297,298,299,300,301,302,303,304,305,306,307,308,309,310,311,312,313,314,315,316,317,318,319,320,321,322,323,324,325,326,327,328,329,330,331,332,333,334,335,336,337,338,339,340,341,342,343,344,284,283,282,281,280,279,278,277,276,275,274,273,272,271,270,269,268,267,266,265,264,263,262,261,260,259,258,257,256,255,254,253,252,251,250,249,248,247,246,245,244,243,242,241,240,239,238,237,236,235,234,233,345,346,347,348,349,350,351,352,353,354,355,209,208,207,206,205,204,203,202,201,200,199,198,356,357	2450432.5
Region 8	Synthetic Interface	355,354,353,352,351,350,349,348,347,346,345,233,86,85,130,197,196,195,194,193,192,191,190,189,188,187,87,44,43,209	5956.0448

Points

	X (ft)	Y (ft)
Point 1	907.4825	269.1831
Point 2	988.6018	289.4624
Point 3	993.6508	290.7125
Point 4	1013.8471	289.4975
Point 5	1015.973	290
Point 6	1138.985	320.7419
Point 7	1159.1665	319.5108
Point 8	1284.2118	350.7641
Point 9	1304.3933	349.5308
Point 10	1429.4437	380.784
Point 11	1449.6252	379.5489
Point 12	1523.4313	398
Point 13	1530.7506	399.7774
Point 14	1535.7576	401.0265
Point 15	1555.7852	398.8865
Point 16	1556.1855	398.936
Point 17	1585.154	400.3492
Point 18	1592.1565	396.8514
Point 19	1595.1576	396.8523
Point 20	1607.7373	400
Point 21	1867.7863	413
Point 22	1905.7797	413
Point 23	2166.2808	400
Point 24	2249.0114	379.3569
Point 25	2269.0561	380.564
Point 26	2319.4047	368
Point 27	2324.358	367.0274
Point 28	2327.4105	367.0136
Point 29	2334.533	370.467
Point 30	2363.023	371.2405
Point 31	2364.0405	369.7324
Point 32	2370.3834	368
Point 33	2394.369	362
Point 34	2402.8621	360
Point 35	2484.6063	339.5641
Point 36	2504.7876	340.7946
Point 37	2629.8331	309.5407
Point 38	2650.0144	310.7689
Point 39	2775.0683	279.5109
Point 40	2795.2513	280.729
Point 41	2800.297	279.479
Point 42	2879.4825	259.6831
Point 43	2877.8543	259.6831
Point 44	2871.2361	259.6831
Point 45	2799.814	277.5382
Point 46	2795.0669	278.7142
Point 47	2774.8817	277.496
Point 48	2649.8283	308.7539
Point 49	2629.647	307.5256
Point 50	2504.6017	338.7795
Point 51	2484.4203	337.549
Point 52	2402.3903	358.0564
Point 53	2393.8971	360.0564
Point 54	2369.8772	366.065
Point 55	2362.7976	367.9986
Point 56	2361.9793	369.2114
Point 57	2335.0179	368.4795
Point 58	2327.8655	365.0115
Point 59	2324.159	365.0283
Point 60	2318.9696	366.0472
Point 61	2268.8698	378.5491
Point 62	2248.8251	377.3421
Point 63	2165.9861	398.0122
Point 64	1905.7299	411
Point 65	1867.8362	411
Point 66	1608.0327	398.0123
Point 67	1595.4043	394.8524
Point 68	1591.685	394.8512
Point 69	1584.6793	398.3507
Point 70	1557.3409	397.0638
Point 71	1555.8021	396.8733
Point 72	1535.8976	399.0002
Point 73	1531.2287	397.8354
Point 74	1523.9098	396.0581
Point 75	1449.8109	377.5338
Point 76	1429.6294	378.7689
Point 77	1304.5791	347.5157
Point 78	1284.3976	348.749
Point 79	1159.3524	317.4957
Point 80	1139.1709	318.7268
Point 81	1016.4455	288.0566
Point 82	1014.0208	287.4834
Point 83	993.8353	288.6978
Point 84	989.0846	287.5216
Point 85	915.7289	269.1831
Point 86	909.1204	269.1831
Point 87	2865.4856	259.6831
Point 88	2862.9897	259.6831
Point 89	2799.3311	275.5974
Point 90	2794.8824	276.6994
Point 91	2774.6951	275.4811
Point 92	2649.6423	306.7389
Point 93	2629.461	305.5106
Point 94	2504.4157	336.7645
Point 95	2484.2343	335.534
Point 96	2401.9186	356.1128
Point 97	2393.4252	358.1128
Point 98	2369.371	364.13
Point 99	2361.5547	366.2648
Point 100	2360.9357	367.1823
Point 101	2335.5028	366.4919
Point 102	2328.3204	363.0094
Point 103	2323.96	363.0292
Point 104	2318.5346	364.0945
Point 105	2268.6835	376.5343
Point 106	2248.6389	375.3273
Point 107	2165.6914	396.0244
Point 108	1905.68	409
Point 109	1867.8862	409
Point 110	1608.3282	396.0245
Point 111	1595.651	392.8525
Point 112	1591.2136	392.8511
Point 113	1584.2047	396.3522
Point 114	1558.4964	395.1916
Point 115	1555.8189	394.8601
Point 116	1536.0377	396.9738
Point 117	1531.7067	395.8933
Point 118	1524.3883	394.1162
Point 119	1449.9967	375.5187
Point 120	1429.8151	376.7538

Point 121	1304.7649	345.5006
Point 122	1284.5834	346.7339
Point 123	1159.5383	315.4807
Point 124	1139.3568	316.7117
Point 125	1016.918	286.1132
Point 126	1014.1944	285.4693
Point 127	994.0198	286.6831
Point 128	989.5675	285.5808
Point 129	923.9753	269.1831
Point 130	921.4891	269.1831
Point 131	2837.2943	259.6831
Point 132	2518.4991	180
Point 133	2517.8299	179.7028
Point 134	2515.4694	178.9154
Point 135	2513.2901	179.8249
Point 136	2511.6282	180.4861
Point 137	2505.7593	182.2763
Point 138	2504.355	182.5261
Point 139	2503.0345	182.7008
Point 140	2501.7671	182.8091
Point 141	2501.0211	182.8445
Point 142	2500.2794	182.8584
Point 143	2494.2794	182.8584
Point 144	2493.3522	182.8337
Point 145	2492.3458	182.7696
Point 146	2491.313	182.6644
Point 147	2490.2391	182.5149
Point 148	2489.3966	182.3705
Point 149	2488.2081	182.1294
Point 150	2486.9229	181.8242
Point 151	2485.5101	181.4417
Point 152	2483.929	180.9638
Point 153	2482.5999	180.5275
Point 154	2481.1133	180.0083
Point 155	2479.427	179.3858
Point 156	2477.4832	178.6322
Point 157	1974.6479	183.6605
Point 158	1911.29	199.5
Point 159	1874.9364	199.5
Point 160	1811.5714	183.6588
Point 161	1345.1308	178.984
Point 162	1342.7209	179.8901
Point 163	1340.2404	180.7485
Point 164	1338.1673	181.3896
Point 165	1337.0646	181.6955
Point 166	1336.0431	181.9534
Point 167	1335.0876	182.1699
Point 168	1334.1853	182.3503
Point 169	1333.326	182.4986
Point 170	1332.5008	182.6179
Point 171	1331.7019	182.7107
Point 172	1330.9226	182.7787
Point 173	1330.1567	182.8233
Point 174	1329.2487	182.8468
Point 175	1323.2487	182.8468
Point 176	1322.2416	182.8227
Point 177	1321.2232	182.7587
Point 178	1320.4438	182.6834
Point 179	1319.3721	182.5442
Point 180	1318.535	182.4082
Point 181	1317.3595	182.1797
Point 182	1311.8013	180.5008
Point 183	1310.026	179.823
Point 184	1308.6991	179.2973
Point 185	1290.4702	184
Point 186	949.6707	269.1831
Point 187	2513.6402	171.7168
Point 188	2493.9476	171.7168
Point 189	2487.2849	175.0339
Point 190	1978.4955	180.1217
Point 191	1910.9825	197
Point 192	1875.2439	197
Point 193	1807.7276	180.1209
Point 194	1338.9977	175.4293
Point 195	1336.6153	175.6273
Point 196	1329.5501	172.0844
Point 197	1309.862	172.0844
Point 198	3335.1097	261.1052
Point 199	3291.2035	260
Point 200	3251.3717	257.0262
Point 201	3161.003	250
Point 202	3139.6041	249.405
Point 203	3096.134	248.2296
Point 204	3042.0937	246.7302
Point 205	2991.9884	245.4134
Point 206	2932.2279	246.6667
Point 207	2920.9715	246.7982
Point 208	2867.979	247.8314
Point 209	2830.8804	247.939
Point 210	2894.4825	259.6831
Point 211	2902.4825	255.6831
Point 212	2908.4825	255.6831
Point 213	2916.4825	259.6831
Point 214	2933.4825	260.0231
Point 215	2959.3667	259.5195
Point 216	2967.9024	259.3931
Point 217	2982.3458	259.151
Point 218	3005.4824	259
Point 219	547.2476	275.7861
Point 220	547.9454	275.735
Point 221	550.1719	275.6329
Point 222	553.4501	275.5308
Point 223	557.8376	275.4255
Point 224	569.2025	275.214
Point 225	586.669	274.9465
Point 226	781.5012	270.7345
Point 227	811.0945	270.2699
Point 228	853.4825	269.5231
Point 229	870.4825	269.1831
Point 230	878.4825	265.1831
Point 231	884.4825	265.1831
Point 232	892.4825	269.1831
Point 233	1024.7998	240.2616
Point 234	969.7329	239.1612
Point 235	935.7837	239.4083
Point 236	930.1714	238.8042
Point 237	924.9444	238.4321
Point 238	918.2309	237.7453
Point 239	908.5449	236.83
Point 240	901.5966	235.8431
Point 241	893.9899	235.2773
Point 242	882.631	234.6916
Point 243	879.4693	235.0451
Point 244	871.3931	235.7514
Point 245	866.5978	236.2003
Point 246	864.6292	236.4185
Point 247	857.169	238.9666
Point 248	850.2221	239.2694
Point 249	837.7766	243.6033
Point 250	819.4863	246.352
Point 251	814.5664	246.3112
Point 252	802.3617	246.8773
Point 253	798.3886	246.5569
Point 254	794.7647	246.1802
Point 255	791.6199	246.2516
Point 256	787.2904	245.9571
Point 257	783.823	244.6145
Point 258	782.6659	244.3408
Point 259	777.2506	248.2884
Point 260	776.7924	248.4049
Point 261	773.1533	248.8746
Point 262	741.6862	251.1687
Point 263	731.8911	252.0628
Point 264	711.8077	255.2082
Point 265	703.8142	255.9695
Point 266	675.8165	257.0628
Point 267	671.5882	257.399
Point 268	669.5557	257.5325
Point 269	666.0148	257.8233
Point 270	646.9889	258.6654
Point 271	644.3982	258.734
Point 272	638.6573	258.9551
Point 273	621.0833	259.3458
Point 274	610.0674	259.2766

Point 275	606.2513	261.6178
Point 276	595.5808	265.2299
Point 277	595.1652	265.3965
Point 278	580.3881	270.9263
Point 279	570.2704	272.9851
Point 280	567.5599	273.6727
Point 281	565.9097	273.5198
Point 282	561.7326	273.4916
Point 283	559.7531	273.6296
Point 284	546.6354	275.7428
Point 285	3400	-500
Point 286	0	-500
Point 287	0	278.2613
Point 288	14.4819	278.5356
Point 289	17.7173	278.0348
Point 290	28.0753	278.1122
Point 291	29.9204	278.1787
Point 292	32.3072	278.0543
Point 293	37.1211	277.533
Point 294	78.5246	277.5313
Point 295	99.8253	277.4823
Point 296	113.8189	277.1463
Point 297	135.1112	276.736
Point 298	156.0552	276.6258
Point 299	179.9408	276.3417
Point 300	205.0185	275.8303
Point 301	218.5546	275.7088
Point 302	230.2246	275.8722
Point 303	242.6138	276.0108
Point 304	246.1872	275.9778
Point 305	265.6484	275.4973
Point 306	273.8252	275.2475
Point 307	286.9292	275.0257
Point 308	296.3136	274.495
Point 309	303.3885	274.7572
Point 310	308.9925	275.4236
Point 311	320.1975	275.9575
Point 312	323.9502	276.3472
Point 313	339.2177	277.5329
Point 314	360.3106	278.2429
Point 315	364.8484	278.233
Point 316	366.1583	278.3013
Point 317	366.9738	278.3144
Point 318	377.7148	278.4168
Point 319	379.4153	278.307
Point 320	388.6644	277.5731
Point 321	401.6953	277.8894
Point 322	408.4536	277.9966
Point 323	414.1013	278.2749
Point 324	429.0825	278.4981
Point 325	445.3886	278.5139
Point 326	450.8759	278.4505
Point 327	455.9523	278.33
Point 328	458.6764	278.4031
Point 329	463.6569	278.3876
Point 330	470.7521	276.9089
Point 331	472.2721	276.5605
Point 332	473.1578	276.4049
Point 333	474.7735	276.227
Point 334	482.5145	275.4688
Point 335	494.5043	275.6387
Point 336	498.0201	275.7161
Point 337	499.3265	275.7669
Point 338	504.7851	276.0468
Point 339	508.4981	276.1311
Point 340	514.9038	276.4622
Point 341	524.7969	276.4279
Point 342	527.0296	276.5527
Point 343	532.3761	276.5479
Point 344	535.0957	276.3224
Point 345	1309.4927	169.0844
Point 346	1330.2601	169.0844
Point 347	1337.2067	172.5678
Point 348	1338.8882	172.428
Point 349	1808.1117	177.1246
Point 350	1875.6132	194
Point 351	1910.6132	194
Point 352	1978.1114	177.1254
Point 353	2486.5653	172.0409
Point 354	2493.2421	168.7168
Point 355	2514.0095	168.7168
Point 356	3352.1727	261.5347
Point 357	3400	262.6701

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	2.450	(2377.21, 443.742)	409.2859	(1949.79, 410.804)	(2860.07, 264.536)
2	1553	2.901	(2377.21, 443.742)	384.714	(1947.9, 410.898)	(2775.23, 279.52)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	1950.892	409.7475	0	92.462728	45.097086	0
2	Optimized	1953.104	407.63465	0	97.34686	0	650
3	Optimized	1966.1605	395.16145	0	1271.437	340.68053	650
4	Optimized	1988.6545	373.6727	0	3238.076	867.63986	650
5	Optimized	2011.847	353.3926	0	5162.0536	1383.1681	650
6	Optimized	2037.1445	332.9764	0	6948.3622	1861.8081	650
7	Optimized	2066.063	310.98	0	8948.8404	2397.8346	650
8	Optimized	2096.226	290.3478	0	10857.57	2909.2771	650
9	Optimized	2124.012	272.66	0	12337.002	3305.6898	650
10	Optimized	2152.093	254.78465	0	13821.684	3703.5092	650
11	Optimized	2171.506	242.42715	0	14744.702	3950.8311	650
12	Optimized	2196.14	229.2316	0	15791.847	4231.4127	650
13	Optimized	2232.28	212.59345	0	16895.747	4527.2017	650
14	Optimized	2259.0335	201.77025	0	17616.095	4720.2184	650
15	Optimized	2277.2845	194.38695	0	18218.085	4881.5212	650
16	Optimized	2302.459	185.22815	0	18822.168	5043.3847	650
17	Optimized	2321.8815	178.54605	0	18811.842	9175.1484	0
18	Optimized	2325.8845	177.1689	0	18909.587	9222.8218	0
19	Optimized	2327.4275	176.63805	0	18966.713	9250.684	0
20	Optimized	2327.6545	176.5598	0	19275.125	5164.7541	0
21	Optimized	2327.924	176.4671	0	19299.012	5171.1547	0
22	Optimized	2328.1515	176.43835	0	20857.715	5588.8078	0
23	Optimized	2331.4265	176.2724	0	21065.59	5644.5079	0
24	Optimized	2334.7755	176.1027	0	21263.708	5697.5933	0
25	Optimized	2349.0205	175.38085	0	21435.732	5743.687	0
26	Optimized	2363.532	174.64555	0	21531.108	5769.2429	0
27	Optimized	2366.706	174.4847	0	21396.43	5733.1561	0
28	Optimized	2369.624	174.3368	0	21335.722	5716.8895	0
29	Optimized	2370.13	174.31115	0	21323.884	5713.7175	0
30	Optimized	2382.376	173.6906	0	21097.693	5653.1098	0
31	Optimized	2395.8535	173.0077	0	20850.399	5586.8477	0
32	Optimized	2399.6285	172.9244	0	21050.315	5640.415	0
33	Optimized	2402.1545	172.91545	0	20993.507	5625.1931	0
34	Optimized	2402.626	172.9138	0	20983.122	5622.4106	0
35	Optimized	2414.2605	172.87265	0	20701.145	5546.855	0
36	Optimized	2437.0575	172.792	0	20143.622	5397.4673	0
37	Optimized	2462.9695	173.5943	0	19737.114	5288.5437	0
38	Optimized	2478.455	174.49335	0	19228.349	5152.2207	0
39	Optimized	2480.27	174.59875	0	19168.334	5136.1397	0
40	Optimized	2481.8565	174.69085	0	19116.206	5122.172	0
41	Optimized	2483.2645	174.77255	0	19069.538	5109.6672	0
42	Optimized	2484.0815	174.81995	0	19042.287	5102.3655	0
43	Optimized	2484.327	174.8342	0	19033.541	5100.022	0
44	Optimized	2484.513	174.845	0	19026.564	5098.1524	0
45	Optimized	2485.058	174.87665	0	19024.173	5097.5117	0
46	Optimized	2486.2165	174.9439	0	19027.275	5098.343	0
47	Optimized	2487.046	174.99205	0	19029.029	5098.813	0
48	Optimized	2487.227	175.01145	0	19875.077	5325.5108	0
49	Optimized	2487.7465	175.1209	0	20608.442	10051.409	0
50	Optimized	2488.8025	175.34325	0	20588.407	10041.637	0
51	Optimized	2489.818	175.5571	0	20569.624	10032.476	0
52	Optimized	2490.776	175.7589	0	20552.114	10023.936	0
53	Optimized	2491.8295	175.98075	0	20532.435	10014.338	0
54	Optimized	2492.794	176.18385	0	20514.034	10005.363	0
55	Optimized	2493.297	176.2898	0	20504.858	10000.887	0
56	Optimized	2493.8155	176.39905	0	20495.261	9996.2069	0
57	Optimized	2497.279	177.12845	0	20430.24	9964.494	0
58	Optimized	2500.65	177.8383	0	20366.309	9933.3124	0
59	Optimized	2501.394	177.99495	0	20352.541	9926.5976	0
60	Optimized	2502.401	178.20695	0	20332.799	9916.9685	0
61	Optimized	2503.7255	178.4858	0	20307.561	9904.6591	0
62	Optimized	2504.509	178.6508	[illegible]	20293.088	9897.6003	0

63	Optimized	2504.695	178.68995	0	20289.793	9895.993	0
64	Optimized	2505.2735	178.81185	0	20260.579	9881.7446	0
65	Optimized	2508.6935	179.53215	0	20062.955	9785.357	0
66	Optimized	2511.904	180.20825	0	19876.668	9694.4989	0
67	Optimized	2513.095	180.45895	0	19210.892	5147.5429	650
68	Optimized	2536.4725	185.3819	0	17914.385	4800.1449	650
69	Optimized	2580.173	195.4203	0	15532.451	4161.9077	650
70	Optimized	2615.622	204.27995	0	13322.979	3569.8815	650
71	Optimized	2639.9235	210.3535	0	12175.729	3262.4767	650
72	Optimized	2664.3235	216.4516	0	11024.349	2953.9655	650
73	Optimized	2692.942	223.60395	0	9247.639	2477.8974	650
74	Optimized	2721.56	230.7563	0	7486.862	2006.0986	650
75	Optimized	2755.4685	239.24755	0	5428.1554	1454.4699	650
76	Optimized	2785.1595	246.69325	0	4007.6528	1073.8473	650
77	Optimized	2797.291	249.73545	0	3648.2511	977.54593	650
78	Optimized	2799.5725	250.30755	0	3513.8936	941.54495	650
79	Optimized	2800.0555	250.42865	0	3485.4527	933.92424	650
80	Optimized	2802.262	250.982	0	3355.1366	899.00614	650
81	Optimized	2805.997	251.8887	0	3125.803	837.55638	650
82	Optimized	2822.5305	255.75585	0	2174.6729	1060.6589	0
83	Optimized	2838.209	259.42305	0	1276.723	622.69942	0
84	Optimized	2845.3365	261.0901	0	919.10065	246.27228	650
85	Optimized	2853.679	263.04145	0	424.74423	0	650
86	Optimized	2857.9395	264.03795	0	119.05567	58.067331	0

Slices of Slip Surface: 1553

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	1553	1948.956	409.8441	0	94.199507	45.944169	0
2	1553	1951.0635	407.73645	0	126.54402	0	650
3	1553	1965.114	393.6856	0	1459.5883	391.09552	650
4	1553	1991.51	367.29005	0	3882.1138	1040.2093	650
5	1553	2018.3075	340.4929	0	6249.8549	1674.6436	650
6	1553	2045.1045	313.69575	0	8535.795	2287.1594	650
7	1553	2071.9015	286.8986	0	10753.392	2881.3627	650
8	1553	2098.6985	260.10145	0	12917.158	3461.1421	650
9	1553	2125.4955	233.3043	0	15042.663	4030.6694	650
10	1553	2152.5875	206.21245	0	17169.45	4600.5402	650
11	1553	2171.723	187.0773	0	18569.29	4975.6263	650
12	1553	2178.9325	179.86755	0	18167.928	8861.0904	0
13	1553	2197.8595	177.4468	0	23011.026	6165.7859	0
14	1553	2232.015	176.48745	0	22447.847	6014.8824	0
15	1553	2259.0335	176.00035	0	22233.684	5957.4976	0
16	1553	2281.4255	175.59665	0	22114.296	5925.5078	0
17	1553	2306.6	175.14275	0	21587.436	5784.336	0
18	1553	2321.8815	174.86725	0	21279.323	5701.7774	0
19	1553	2325.8845	174.7951	0	21250.274	5693.9936	0
20	1553	2327.638	174.7635	0	21273.248	5700.1497	0
21	1553	2328.0925	174.7553	0	21302.98	5708.1164	0
22	1553	2331.4265	174.6952	0	21506.017	5762.5198	0
23	1553	2334.7755	174.6348	0	21695.794	5813.3704	0
24	1553	2349.0205	174.37795	0	21825.692	5848.1766	0
25	1553	2363.532	174.11635	0	21876.551	5861.8041	0
26	1553	2366.706	174.05915	0	21731.766	5823.0092	0
27	1553	2369.624	174.00655	0	21659.853	5803.74	0
28	1553	2370.13	173.9974	0	21648.002	5800.5645	0
29	1553	2382.376	173.7766	0	21380.187	5728.8039	0
30	1553	2398.144	173.49235	0	21040.079	5637.6723	0
31	1553	2402.1545	173.42005	0	20958.008	5615.6814	0
32	1553	2402.626	173.41155	0	20948.481	5613.1285	0
33	1553	2419.345	173.1101	0	20576.743	5513.5217	0
34	1553	2452.3115	172.51575	0	19833.682	5314.419	0
35	1553	2473.139	172.1403	-193.14496	19481.358	0	8000
36	1553	2478.455	172.04445	-192.5811	19358.927	0	8000
37	1553	2480.27	172.0117	-192.39002	19316.674	0	8000
38	1553	2481.8565	171.9831	-192.21948	19279.789	0	8000
39	1553	2483.2645	171.95775	-192.0687	19246.74	0	8000
40	1553	2484.0815	171.943	-191.98322	19227.797	0	8000
41	1553	2484.327	171.93855	-191.95808	19221.61	0	8000
42	1553	2484.513	171.9352	-191.93658	19216.772	0	8000
43	1553	2485.058	171.92535	-191.88074	19219.049	0	8000
44	1553	2486.0375	171.9077	-191.7809	19230.204	0	8000
45	1553	2486.714	171.89555	-191.70458	19235.69	0	8000
46	1553	2486.893	171.89235	0	19111.228	5120.8382	0
47	1553	2487.104	171.8885	0	19114.022	5121.5869	0
48	1553	2487.7465	171.8769	0	19121.677	5123.6378	0
49	1553	2488.8025	171.8579	0	19132.779	5126.6126	0
50	1553	2489.818	171.8396	0	19144.664	5129.7972	0
51	1553	2490.776	171.8223	0	19155.087	5132.5901	0
52	1553	2491.8295	171.8033	0	19167.099	5135.8087	0
53	1553	2492.794	171.7859	0	19177.96	5138.719	0
54	1553	2493.297	171.77685	0	19183.076	5140.0896	0
55	1553	2493.5995	171.7714	0	19186.758	5141.0764	0
56	1553	2494.063	171.763	0	19374.809	9449.7255	0
57	1553	2495.4535	171.73795	0	19389.207	9456.748	0
58	1553	2498.4535	171.6839	0	19239.105	5155.1028	0
59	1553	2500.65	171.6443	0	19263.42	5161.6179	0
60	1553	2501.394	171.6309	0	19271.668	5163.8279	0
61	1553	2502.401	171.61275	0	19282.806	5166.8122	0
62	1553	2503.7255	171.58885	0	19297.479	5170.7438	0
63	1553	2504.509	171.5747	0	19306.543	5173.1725	0
64	1553	2504.695	171.57135	0	19308.859	5173.7932	0
65	1553	2505.2735	171.56095	0	19298.089	5170.9073	0
66	1553	2508.6935	171.4993	0	19218.536	5149.5912	0
67	1553	2512.459	171.4314	0	19128.609	5125.4953	0
68	1553	2513.465	171.41325	0	19105.15	5119.2094	0
69	1553	2513.825	171.40675	0	19096.545	5116.9039	0
70	1553	2514.105	171.4017	0	19089.807	5115.0983	0
71	1553	2514.8345	171.6629	0	21142.818	5665.2011	0
72	1553	2516.2255	172.239	0	21022.903	5633.0699	0
73	1553	2517.406	172.7279	0	21939.797	10700.754	0
74	1553	2528.543	177.3411	0	20905.746	10196.414	0
75	1553	2549.6345	186.07755	0	18942.582	9238.9146	0
76	1553	2571.588	195.17085	0	16291.568	4365.3125	650
77	1553	2594.7375	204.7596	0	14271.734	3824.0997	650
78	1553	2618.0725	214.4254	0	12250.94	3282.6296	650
79	1553	2639.9235	223.4765	0	10749.823	2880.4065	650
80	1553	2664.8805	233.814	0	9008.0852	2413.7092	650
81	1553	2694.613	246.1296	0	6532.1824	1750.293	650
82	1553	2724.3455	258.4452	0	4117.1828	1103.1958	650
83	1553	2754.078	270.76075	0	1766.9706	473.45833	650
84	1553	2770.496	277.56135	0	455.31203	0	650
85	1553	2773.558	278.8297	0	125.318	61.121672	0
86	1553	2775.147	279.4878	0	3.293708	1.6064487	0

Terracon	Made by:	RSG	Date:	1/29/15	Sheet No.:	COVER
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	Calculations for:	Final Cover System Veneer Stability Analysis				
	Emelle Facility – Trench 23					

FINAL COVER SYSTEM VENEER STABILITY ANALYSIS

CALCULATION COVER SHEET

Calculations by:

Signature: [signature]
Name: Rajendra S. Gondhalekar, P.E.
Title: Project Engineer

1/29/2015
Date

Calculations Reviewed by:

Signature: [signature]
Name: J. Craig Hensley, E.I.T.
Title: Staff Engineer

1/29/2015
Date

Calculations Approved by:

Signature: [signature]
Name: Michael A. Kemp P.E.
Title: Department Manager

1/29/2015
Date

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	1/29/15	ALL	Initial Submittal

1.0 OBJECTIVE

The purpose of this calculation package is to demonstrate the stability of the final cover system vegetative soil in a veneer mode. The analysis applies to the final condition where the vegetative cover soil will be placed over the final cover system along the exterior slopes of the landfill. The final cover system along the side slope of Trench 23 includes multiple layers of geosynthetic materials above a layer of compacted chalk. Because of the multiple interfaces involved, this analysis uses a parametric approach to arrive at the minimum interface/internal strength needed to reach stability.

2.0 APPROACH

Slope stability of the landfill final cover system was analyzed using a finite slope approach, where the toe buttressing effect of the soil above the slip plane was considered. The stability was analyzed using an idealized two wedge analysis approach. The derivation of the governing equation for the analyzed failure mode is included in Attachment 1. The governing equation was coded into a Microsoft Excel spreadsheet to analyze the slope stability.

The analysis was performed under two scenarios. Scenario 1 represents the typical condition for the exterior slope, with the slope being covered with the vegetative soil layer. Scenario 2 is similar to Scenario 1, except the effect of water buildup during a peak storm event is being considered. Since Scenario 1 represent a long term condition, a target factor of safety (FOS) of 1.5 was used for this scenario. Since Scenario 2 represents a transient condition, a factor FOS of 1.3 was used for this scenario. The target FOS was used to parametrically calculate the minimum interface shear strength, at which the stability results become acceptable.

3.0 DATA

The following input parameters were used for the stability analysis:

Soil Properties

- The 24-inch vegetative soil layer above the critical interface (i.e., slip plane) was assumed to have the following properties:

Analysis Parameter	Soil Property	Value
c	Apparent Cohesion	400 psf
ϕ	Internal Friction Angle	0°
γ	Total Unit Weight	110 pcf
γ_{sat}	Saturated Unit Weight	110 pcf

The assumed engineering properties used for slope stability analysis match those used by Golder Associates in the engineering calculation package for Trench 22, contained in Attachment D-6-1-7. The actual values of these parameters for the soils selected for use in cover construction should be measured using laboratory testing to confirm that actual soil engineering properties meet or exceed those assumed for this analysis.

Peak Horizontal Acceleration

- Since the site is not located in a seismic impact zone, a peak horizontal acceleration was not used in this analysis.

Water Head Buildup

- The analysis was performed for two scenarios. For Scenario 1, the water head buildup was not considered. For scenario 2, a maximum water head buildup of 24 inches was conservatively used in the analysis.

Geosynthetic Tension

- The reinforcing effect provided by allowable tension in the geosynthetics was conservatively neglected for this analysis in Scenario 1, but a maximum tension in geosynthetics of 600 lb/ft was permitted to occur during the transient Scenario 2.

Interface Shear Strength

- The stability analysis was performed by solving the finite slope stability equation to identify the minimum interface friction angle (i.e., δ) to satisfy the target factor of safety. The apparent interface adhesion (i.e., a) was assumed to be zero for this parametric shear strength analysis.

Slope Inclination

- The slope of the proposed final cover system configuration is 4H:1V, which corresponds to a slope inclination of 14°. The height of the slope is modeled as the maximum vertical spacing of 30 ft between benches.

Additional Surcharge

- No additional surcharge was modeled in this analysis, as the final cover slopes are not expected to be accessed with heavy equipment after the completion of the closure.

4.0 CONCLUSION

The results of the stability analysis are provided in Attachment 2 and are summarized below. As indicated, the proposed configuration of the final cover system will meet the target factors of safety if the actual peak interface shear strength values exceed the required minimum shear strength values at a confining pressure of 220 psf.

The required minimum values are typically achievable by commercially available products; however we recommend that the actual interface shear strength of the site specific liner configuration be measured using laboratory testing to verify that it is satisfactory.

Analysis Condition	**Target Factor of Safety**	**Required Interface Friction Angle (Normal Stress = 220 psf)**
Scenario 1	1.5	13.6°
Scenario 2	1.3	20.5°

ATTACHMENT 1

Derivation of the Governing Equation

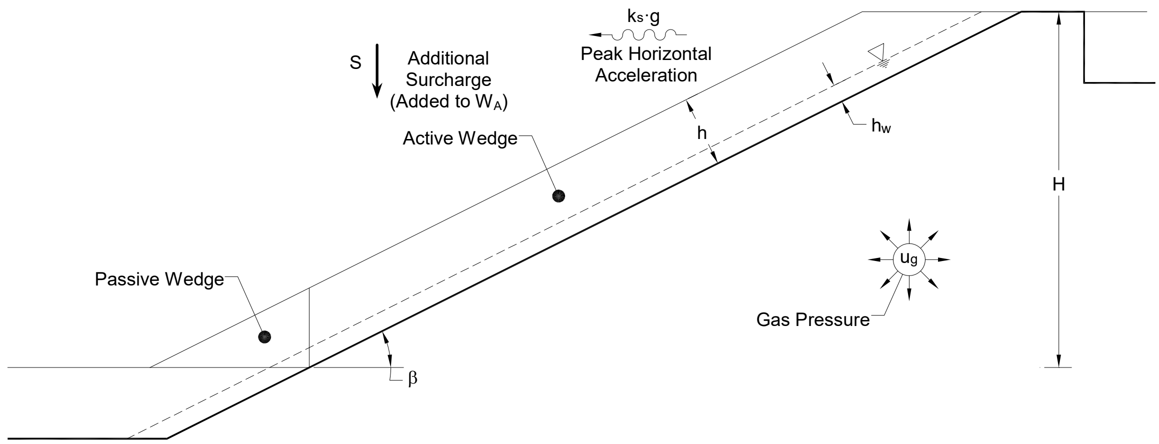


Figure 1

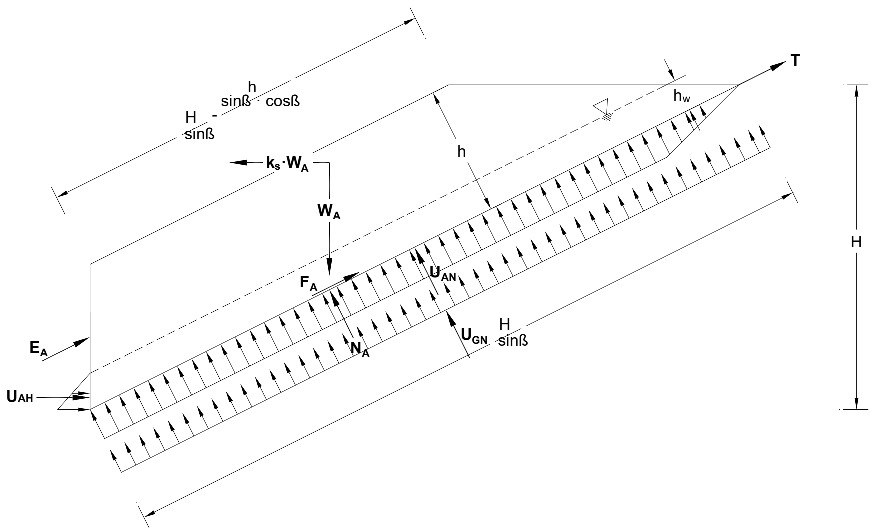


Figure 2

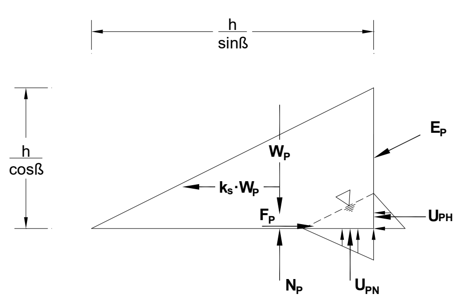


Figure 3

Consider the force equilibrium of the active wedge (Figure 2)

$$\sum F_y = 0$$

$$N_A + U_{AN} + U_{GN} + k_s \cdot W_A \cdot \sin\beta = W_A \cdot \cos\beta + U_{AH} \cdot \sin\beta$$

$$N_A = W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN} \quad \text{..........(1)}$$

$$\sum F_x = 0$$

$$E_A + F_A + T + U_{AH} \cdot \cos\beta = W_A \cdot \sin\beta + k_s \cdot W_A \cdot \cos\beta$$

$$E_A = W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - F_A - T - U_{AH} \cdot \cos\beta \quad \text{..........(2)}$$

Based on interface shear strength

$$F_A = (a \cdot H / \sin\beta + N_A \cdot \tan\delta) / FS \quad \text{..........(3)}$$

Substituting Equation 1 into Equation 3 gives

$$F_A = \{a \cdot H / \sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} / FS \quad \text{..........(4)}$$

Substituting Equation 4 into Equation 2 gives

$$\begin{aligned} E_A &= W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta \\ &\quad - \{a \cdot H / \sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} / FS \end{aligned} \quad \text{..........(5)}$$

Consider the force equilibrium of the passive wedge (Figure 3)

$$\sum F_y = 0$$

$$N_P + U_{PN} = W_P + E_P \cdot \sin\beta$$

$$N_P = W_P + E_P \cdot \sin\beta - U_{PN}$$

Since $E_P = E_A$

$$N_P = W_P + E_A \cdot \sin\beta - U_{PN} \quad \text{..........(6)}$$

Substituting Equation 5 into Equation 6 gives

$$N_P = W_P - U_{PN} + \left\langle \begin{array}{l} W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta - \\ \{a \cdot H / \sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} / FS \end{array} \right\rangle \cdot \sin\beta$$

$$\begin{aligned} N_P = {} & W_P - U_{PN} + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \sin\beta \\ & - \{a \cdot H / \sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} \cdot \sin\beta / FS \end{aligned} \quad (7)$$

$$\sum F_x = 0$$

$$F_P = U_{PH} + E_P \cdot \cos\beta + k_s \cdot W_P$$

Since $E_P = E_A$

$$F_P = U_{PH} + E_A \cdot \cos\beta + k_s \cdot W_P \quad \text{.....(8)}$$

Substituting Equation 5 into Equation 8 gives

$$\begin{aligned} F_P = {} & U_{PH} + \left\langle \begin{array}{l} W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta \\ - \{a \cdot H / \sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} / FS \end{array} \right\rangle \cdot \cos\beta \\ & + k_s \cdot W_P \end{aligned}$$

$$\begin{aligned} F_P = {} & U_{PH} + k_s \cdot W_P + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \cos\beta \\ & - \{a \cdot H / \sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} \cdot \cos\beta / FS \end{aligned} \quad (8)$$

Based on soil strength

$$F_P = (c \cdot h / \sin\beta + N_P \cdot \tan\phi) / FS$$

$$FS = (c \cdot h / \sin\beta + N_P \cdot \tan\phi) / F_P \quad \text{.....(9)}$$

Substituting Equations 7 and 8 into Equation 9 gives

$$FS = \frac{c \cdot h / \sin\beta + \left\langle \begin{array}{l} W_P - U_{PN} + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \sin\beta \\ - \left\{ a \cdot H / \sin\beta + \begin{bmatrix} W_A \cdot (\cos\beta - k_s \cdot \sin\beta) \\ + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN} \end{bmatrix} \cdot \tan\delta \right\} \cdot \sin\beta / FS \end{array} \right\rangle \cdot \tan\phi}{\begin{array}{l} U_{PH} + k_s \cdot W_P + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \cos\beta \\ - \{a \cdot H / \sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} \cdot \cos\beta / FS \end{array}}$$

$$FS \cdot \left\langle \begin{array}{l} U_{PH} + k_s \cdot W_P + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \cos\beta \\ -\{a \cdot H/\sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} \cdot \cos\beta/FS \end{array} \right\rangle$$

$$= c \cdot h/\sin\beta + \left\langle \begin{array}{l} W_P - U_{PN} + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \sin\beta \\ -\left\{ \begin{array}{l} a \cdot H/\sin\beta + \\ [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta \end{array} \right\} \cdot \sin\beta/FS \end{array} \right\rangle \cdot \tan\phi$$

$$\begin{array}{l} FS \cdot \{U_{PH} + k_s \cdot W_P + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \cos\beta\} \\ -\{a \cdot H/\sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} \cdot \cos\beta \\ = c \cdot h/\sin\beta + [W_P - U_{PN} + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \sin\beta] \cdot \tan\phi \\ -\{a \cdot H/\sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} \cdot \sin\beta \cdot \tan\phi/FS \end{array}$$

$$\begin{array}{l} \{U_{PH} + k_s \cdot W_P + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \cos\beta\} \cdot FS^2 \\ + \left\langle \begin{array}{l} -\left\{ a \cdot H/\sin\beta + \left[\begin{array}{l} W_A \cdot (\cos\beta - k_s \cdot \sin\beta) \\ + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN} \end{array} \right] \cdot \tan\delta \right\} \cdot \cos\beta \\ - c \cdot h/\sin\beta - \left[W_P - U_{PN} + \left[\begin{array}{l} W_A \cdot (\sin\beta + k_s \cdot \cos\beta) \\ - T - U_{AH} \cdot \cos\beta \end{array} \right] \cdot \sin\beta \right] \cdot \tan\phi \end{array} \right\rangle \cdot FS \quad \text{................(10)} \\ + \left\{ a \cdot H/\sin\beta + \left[\begin{array}{l} W_A \cdot (\cos\beta - k_s \cdot \sin\beta) \\ + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN} \end{array} \right] \cdot \tan\delta \right\} \cdot \sin\beta \cdot \tan\phi = 0 \end{array}$$

Because $U_{PH} = U_{AH} = U_H$

$$\begin{array}{l} \{U_H + k_s \cdot W_P + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_H \cdot \cos\beta] \cdot \cos\beta\} \cdot FS^2 \\ - \left(\begin{array}{l} W_P \cdot \tan\phi + W_A \cdot \sin^2\beta \cdot \tan\phi + W_A \cdot \cos^2\beta \cdot \tan\delta - U_{AN} \cdot \cos\beta \cdot \tan\delta \\ - U_{GN} \cdot \cos\beta \cdot \tan\delta - U_{PN} \cdot \tan\phi + U_H \cdot \sin\beta \cdot \cos\beta \cdot \tan\delta \\ - U_H \cdot \sin\beta \cdot \cos\beta \cdot \tan\phi - k_s \cdot W_A \cdot \sin\beta \cdot \cos\beta \cdot \tan\delta \\ + k_s \cdot W_A \cdot \sin\beta \cdot \cos\beta \cdot \tan\phi + a \cdot H/\tan\beta + c \cdot h/\sin\beta - T \cdot \sin\beta \cdot \tan\phi \end{array} \right) \cdot FS \quad \text{.............(11)} \\ + \left\{ a \cdot H/\sin\beta + \left[\begin{array}{l} W_A \cdot (\cos\beta - k_s \cdot \sin\beta) \\ + U_H \cdot \sin\beta - U_{AN} - U_{GN} \end{array} \right] \cdot \tan\delta \right\} \cdot \sin\beta \cdot \tan\phi = 0 \end{array}$$

Using $A \cdot x^2 + B \cdot x + C = 0$

$$FS = \frac{-B \pm \sqrt{B^2 - 4 \cdot A \cdot C}}{2 \cdot A} \quad \text{...(12)}$$

Where:

$$A = W_A \cdot \sin\beta \cdot \cos\beta + U_H \cdot \sin^2\beta + k_s \cdot W_A \cdot \cos^2\beta + k_s \cdot W_P - T \cdot \cos\beta \quad \text{..........................(13)}$$

$$B = -\begin{bmatrix} W_P \cdot \tan\phi + W_A \cdot \left(\sin^2\beta \cdot \tan\phi + \cos^2\beta \cdot \tan\delta\right) - U_{AN} \cdot \cos\beta \cdot \tan\delta \\ -U_{GN} \cdot \cos\beta \cdot \tan\delta - U_{PN} \cdot \tan\phi + U_H \cdot \sin\beta \cdot \cos\beta \cdot \left(\tan\delta - \tan\phi\right) \\ -k_s \cdot W_A \cdot \sin\beta \cdot \cos\beta \cdot \tan\delta + k_s \cdot W_A \cdot \sin\beta \cdot \cos\beta \cdot \tan\phi \\ +a \cdot H / \tan\beta + c \cdot h / \sin\beta - T \cdot \sin\beta \cdot \tan\phi \end{bmatrix} \quad \text{..................(14)}$$

$$C = a \cdot H \cdot \tan\phi + \begin{pmatrix} W_A \cdot \cos\beta - k_s \cdot W_A \cdot \sin\beta \\ -U_{AN} - U_{GN} + U_H \cdot \sin\beta \end{pmatrix} \cdot \sin\beta \cdot \tan\phi \cdot \tan\delta \quad \text{.................................(15)}$$

$$W_A = \gamma \cdot (h - h_w) \cdot \left(\frac{H}{\sin\beta} - \frac{h + h_w}{2 \cdot \sin\beta \cdot \cos\beta}\right) + \gamma_{sat} \cdot h_w \cdot \left(\frac{H}{\sin\beta} - \frac{h_w}{2 \cdot \sin\beta \cdot \cos\beta}\right) \quad \text{............(16)}$$

$$W_P = \gamma \cdot \left(\frac{h^2 - h_w^{\ 2}}{2 \cdot \sin\beta \cdot \cos\beta}\right) + \gamma_{sat} \cdot \left(\frac{h_w^{\ 2}}{2 \cdot \sin\beta \cdot \cos\beta}\right) \quad \text{...(17)}$$

$$U_H = \frac{\gamma_w \cdot h_w^{\ 2}}{2} \quad \text{...(18)}$$

$$U_{AN} = \gamma_w \cdot h_w \cdot \left(\frac{H}{\tan\beta} - \frac{h_w \cdot \cos^2\beta}{2 \cdot \sin\beta}\right) \quad \text{...(19)}$$

$$U_{PN} = \frac{\gamma_w \cdot h_w^{\ 2}}{2 \cdot \tan\beta} \quad \text{...(20)}$$

$$U_{GN} = \frac{u_g \cdot H}{\sin\beta} \quad \text{...(21)}$$

For case where critical interface is below geomembrane, ignore pose pressure on critical interface by setting $U_{AN} = 0$.

ATTACHMENT 2

Stability Analysis Results

Scenario 1

Final Cover System Stability
Veneer Mode
Finite Slope Analysis

Units

(●) Customary ( ) SI

a	Apparent Interface Adhesion	=	0 psf
δ	Interface Friction Angle	=	13.6 degrees
c	Apparent Soil Cohesion	=	400 psf
ϕ	Soil Internal Friction Angle	=	0 degrees
γ	Moist Soil Unit Weight	=	110 pcf
γ_{sat}	Saturated Soil Unit Weight	=	110 pcf
γ_w	Water Unit Weight	=	62.4 pcf
h	Depth of Cover Soil Above Critical Interface	=	2 ft
h_w	Average Water Depth Above Critical Interface	=	0.00 ft
β	Slope Inclination	=	14.0 degrees
H	Vertical Height of Slope	=	30 ft
S	Additional Surcharge	=	0 lb/ft
u_g	Average Landfill Gas Pressure	=	0 psf
T	Allowable Tension in Geosynthetics	=	0 lb/ft
k_s	Peak Seismic Horizontal Acceleration	=	0.000 gravity

☑ Critical Interface Above Geomembrane

W_A	Weight of Active Wedge	=	26277.50 lb/ft
W_P	Weight of Passive Wedge	=	935.00 lb/ft
U_H	Horizontal Hydrostatic Force at Toe	=	0.00 lb/ft
U_{AN}	Pore Water Pressure Resultant on Active Wedge	=	0.00 lb/ft
U_{PN}	Pore Water Pressure Resultant on Passive Wedge	=	0.00 lb/ft
U_{GN}	Gas Water Pressure Resultant on Active Wedge	=	0.00 lb/ft
A		=	6182.94
B		=	-9279.97
C		=	0.00
FS		=	1.50

Scenario 2

Final Cover System Stability
Veneer Mode
Finite Slope Analysis

Units

(●) Customary ( ) SI

a	Apparent Interface Adhesion	=	0 psf
δ	Interface Friction Angle	=	20.5 degrees
c	Apparent Soil Cohesion	=	400 psf
ϕ	Soil Internal Friction Angle	=	0 degrees
γ	Moist Soil Unit Weight	=	110 pcf
γ_{sat}	Saturated Soil Unit Weight	=	110 pcf
γ_w	Water Unit Weight	=	62.4 pcf
h	Depth of Cover Soil Above Critical Interface	=	2 ft
h_w	Average Water Depth Above Critical Interface	=	2.00 ft
β	Slope Inclination	=	14.0 degrees
H	Vertical Height of Slope	=	30 ft
S	Additional Surcharge	=	0 lb/ft
u_g	Average Landfill Gas Pressure	=	0 psf
T	Allowable Tension in Geosynthetics	=	600 lb/ft
k_s	Peak Seismic Horizontal Acceleration	=	0.000 gravity

☑ Critical Interface Above Geomembrane

W_A	Weight of Active Wedge	=	26277.50 lb/ft
W_P	Weight of Passive Wedge	=	935.00 lb/ft
U_H	Horizontal Hydrostatic Force at Toe	=	124.86 lb/ft
U_{AN}	Pore Water Pressure Resultant on Active Wedge	=	14498.21 lb/ft
U_{PN}	Pore Water Pressure Resultant on Passive Wedge	=	499.42 lb/ft
U_{GN}	Gas Water Pressure Resultant on Active Wedge	=	0.00 lb/ft
A		=	5608.20
B		=	-7294.67
C		=	0.00
FS		=	1.30

LINER SYSTEM VENEER STABILITY ANALYSIS

CALCULATION COVER SHEET

Calculations by:

Signature: Rajendra S Gondhalekar

Name: Rajendra S. Gondhalekar, P.E.

Title: Project Engineer

1/29/2015
Date

Calculations Reviewed by:

Signature: J. Craig Hensley

Name: J. Craig Hensley, E.I.T.

Title: Staff Engineer

1/29/2015
Date

Calculations Approved by:

Signature: Michael A. Kemp

Name: Michael A. Kemp P.E.

Title: Department Manager

1/29/2015
Date

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	1/29/15	ALL	Initial Submittal

1.0 OBJECTIVE

The purpose of this calculation package is to demonstrate the stability of the liner system protective soil in a veneer mode. The liner system along the side slope consists of multiple layers of geosynthetics, over which protective soil will be added prior to waste placement. The analysis calculates the maximum height of liner system side slopes along which protective cover can be added.

2.0 APPROACH

Slope stability of the landfill liner system was analyzed using a finite slope approach, where the toe buttressing effect of the soil above the slip plane was considered. The stability was analyzed using an idealized two wedge analysis approach. The derivation of the governing equation for the analyzed failure mode is included in Attachment 1. The governing equation was coded into a Microsoft Excel spreadsheet to analyze the slope stability.

The analysis was performed under three scenarios. Scenario 1 represents the typical condition for the side slope, with a portion of the side slope being covered with the protective soil layer. Scenario 2 is similar to Scenario 1, with the exception of equipment operating on the side slope. Scenario 3 is also similar to Scenario 1, except the effect of water head buildup in considered in the analysis. Since all three scenarios represent an interim operating condition, a target factor of safety (FOS) of 1.3 was used in all three scenarios to parametrically calculate the maximum height at which the protective cover soil could be installed over the side slopes.

3.0 DATA

The following input parameters were used for the stability analysis:

Soil Properties

- The 18-inch protective soil layer above the critical interface (i.e., slip plane) was assumed to have the following properties:

Analysis Parameter	Soil Property	Value
c	Apparent Cohesion	400 psf
ϕ	Internal Friction Angle	0°
γ	Total Unit Weight	110 pcf
γ_{sat}	Saturated Unit Weight	110 pcf

The engineering properties assumed for slope stability analysis match those used by Golder Associates in the engineering calculation package for Trench 22, contained in Attachment D-6-1-7. The actual values of these parameters for soils selected for use in protective cover construction should be measured using laboratory testing to confirm that actual soil engineering properties meet or exceed those assumed in this analysis.

Peak Horizontal Acceleration

- Since the site is not located in a seismic impact zone, a peak horizontal acceleration was not used in this analysis.

Water Head Buildup

- The analysis was performed for three scenarios. For scenarios 1 and 2, the water head buildup was not considered. For scenario 3, a water head buildup of 5.4 inches was used in this analysis. This value was calculated in the HELP model as average the head on the liner on a peak day.

Geosynthetic Tension

- The reinforcing effect provided by allowable tension in the geosynthetics was conservatively neglected for this analysis in Scenario 1, but a maximum tension in geosynthetics of 600 lb/ft was permitted to occur during the transient Scenarios 2 and 3.

Interface Shear Strength

- A minimum peak face friction angle (i.e., δ) of 15 degrees was selected for the liner system critical interface. The apparent interface adhesion (i.e., a) was assumed to be zero.

Slope Inclination

- The slope of the proposed liner system configuration is 4H:1V, which corresponds to a slope inclination of 14°. The vertical height of the slope was varies parametrically for each scenario to calculate the height to which protective soil cover can be installed without exceeding the target FOS.

Additional Surcharge

- The additional surcharge of the equipment operating on the side slope in Scenario 2 was calculated using the properties for a Caterpillar D60 crawler tractor, which has an operating weight of 31,460 lb, supported on tracks with a length of 7.7 ft, with a width over tracks of also 7.7 ft. This corresponds to a surcharge load of 4,085.7 lb/ft.

4.0 CONCLUSION

The results of the stability analysis are provided in Attachment 2 and are summarized below. As indicated, the proposed configuration protective soil installed over a portion of Trench 23 side slopes will meet the target factors of safety. As indicated the results of scenario 3 represent the most critical condition, and the height of protective cover over the side slopes will be limited to 49.7 ft maximum.

Analysis Condition	Target Factor of Safety	Maximum Permissible Height of Protective Cover
Scenario 1	1.3	68.3’
Scenario 2	1.3	83.1’
Scenario 3	1.3	49.7’

ATTACHMENT 1

Derivation of the Governing Equation

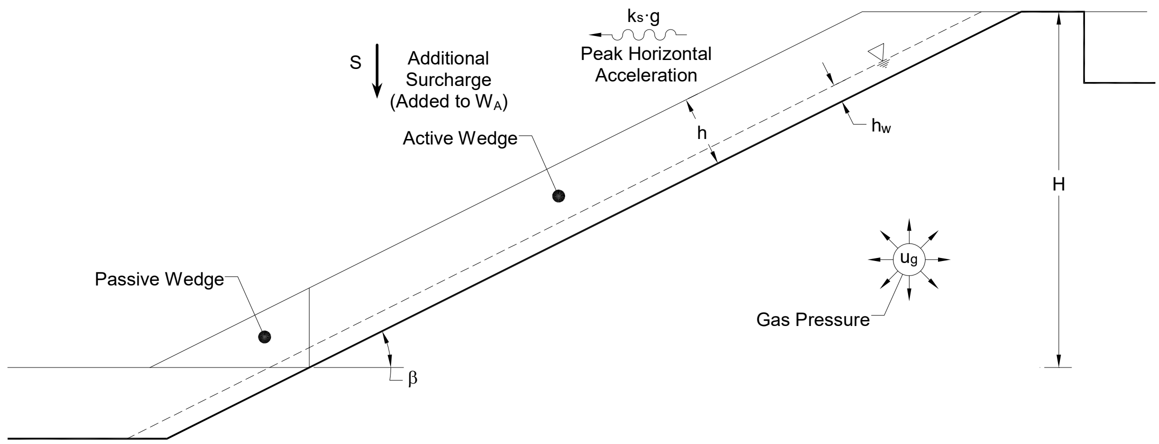


Figure 1

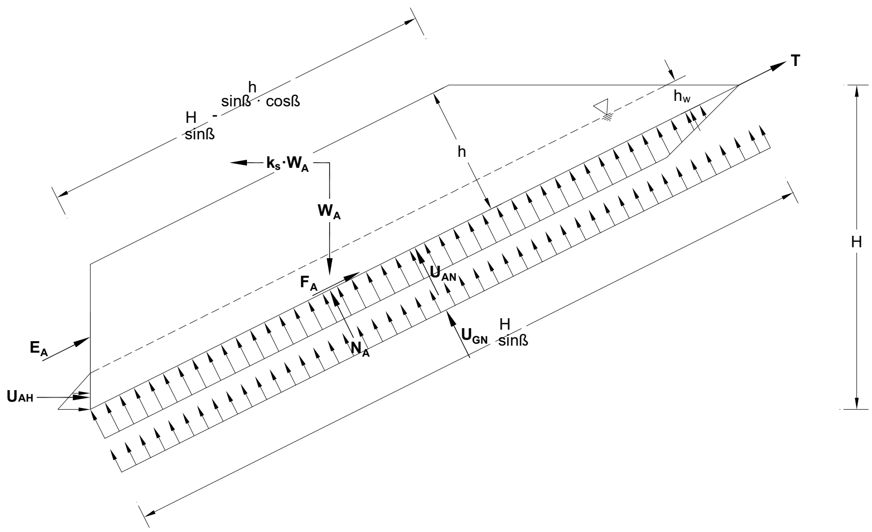


Figure 2

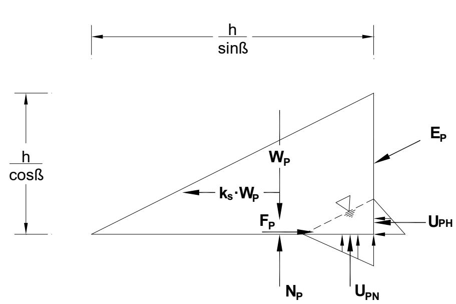


Figure 3

Consider the force equilibrium of the active wedge (Figure 2)

$$\sum F_y = 0$$

$$N_A + U_{AN} + U_{GN} + k_s \cdot W_A \cdot \sin\beta = W_A \cdot \cos\beta + U_{AH} \cdot \sin\beta$$

$$N_A = W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN} \quad \text{......(1)}$$

$$\sum F_x = 0$$

$$E_A + F_A + T + U_{AH} \cdot \cos\beta = W_A \cdot \sin\beta + k_s \cdot W_A \cdot \cos\beta$$

$$E_A = W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - F_A - T - U_{AH} \cdot \cos\beta \quad \text{......(2)}$$

Based on interface shear strength

$$F_A = (a \cdot H / \sin\beta + N_A \cdot \tan\delta)/FS \quad \text{......(3)}$$

Substituting Equation 1 into Equation 3 gives

$$F_A = \{a \cdot H/\sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\}/FS \quad \text{......(4)}$$

Substituting Equation 4 into Equation 2 gives

$$\begin{aligned} E_A = {} & W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta \\ & - \{a \cdot H/\sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\}/FS \end{aligned} \quad \text{......(5)}$$

Consider the force equilibrium of the passive wedge (Figure 3)

$$\sum F_y = 0$$

$$N_P + U_{PN} = W_P + E_P \cdot \sin\beta$$

$$N_P = W_P + E_P \cdot \sin\beta - U_{PN}$$

Since $E_P = E_A$

$$N_P = W_P + E_A \cdot \sin\beta - U_{PN} \quad \text{......(6)}$$

Substituting Equation 5 into Equation 6 gives

$$N_P = W_P - U_{PN} + \left\langle \begin{array}{l} W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta - \\ \{a \cdot H/\sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\}/FS \end{array} \right\rangle \cdot \sin\beta$$

$$\begin{array}{l} N_P = W_P - U_{PN} + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \sin\beta \\ \quad - \{a \cdot H/\sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} \cdot \sin\beta/FS \end{array} \quad (7)$$

$$\sum F_x = 0$$

$$F_P = U_{PH} + E_P \cdot \cos\beta + k_s \cdot W_P$$

Since $E_P = E_A$

$$F_P = U_{PH} + E_A \cdot \cos\beta + k_s \cdot W_P \quad \text{.......} (8)$$

Substituting Equation 5 into Equation 8 gives

$$F_P = U_{PH} + \left\langle \begin{array}{l} W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta \\ - \{a \cdot H/\sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\}/FS \end{array} \right\rangle \cdot \cos\beta + k_s \cdot W_P$$

$$\begin{array}{l} F_P = U_{PH} + k_s \cdot W_P + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \cos\beta \\ \quad - \{a \cdot H/\sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} \cdot \cos\beta/FS \end{array} \quad (8)$$

Based on soil strength

$$F_P = (c \cdot h/\sin\beta + N_P \cdot \tan\phi)/FS$$

$$FS = (c \cdot h/\sin\beta + N_P \cdot \tan\phi)/F_P \quad \text{.......} (9)$$

Substituting Equations 7 and 8 into Equation 9 gives

$$FS = \frac{c \cdot h/\sin\beta + \left\langle \begin{array}{l} W_P - U_{PN} + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \sin\beta \\ - \left\{ a \cdot H/\sin\beta + \begin{bmatrix} W_A \cdot (\cos\beta - k_s \cdot \sin\beta) \\ + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN} \end{bmatrix} \cdot \tan\delta \right\} \cdot \sin\beta/FS \end{array} \right\rangle \cdot \tan\phi}{\begin{array}{l} U_{PH} + k_s \cdot W_P + [W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta] \cdot \cos\beta \\ - \{a \cdot H/\sin\beta + [W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN}] \cdot \tan\delta\} \cdot \cos\beta/FS \end{array}}$$

$$FS \cdot \left\langle \begin{array}{l} U_{PH} + k_s \cdot W_P + \left[W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta \right] \cdot \cos\beta \\ -\left\{ a \cdot H / \sin\beta + \left[W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN} \right] \cdot \tan\delta \right\} \cdot \cos\beta / FS \end{array} \right\rangle$$

$$= c \cdot h / \sin\beta + \left\langle \begin{array}{l} W_P - U_{PN} + \left[W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta \right] \cdot \sin\beta \\ -\left\{ \begin{array}{l} a \cdot H / \sin\beta + \\ \left[W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN} \right] \cdot \tan\delta \end{array} \right\} \cdot \sin\beta / FS \end{array} \right\rangle \cdot \tan\phi$$

$$\begin{array}{l} FS \cdot \left\{ U_{PH} + k_s \cdot W_P + \left[W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta \right] \cdot \cos\beta \right\} \\ -\left\{ a \cdot H / \sin\beta + \left[W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN} \right] \cdot \tan\delta \right\} \cdot \cos\beta \\ = c \cdot h / \sin\beta + \left[W_P - U_{PN} + \left[W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta \right] \cdot \sin\beta \right] \cdot \tan\phi \\ -\left\{ a \cdot H / \sin\beta + \left[W_A \cdot (\cos\beta - k_s \cdot \sin\beta) + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN} \right] \cdot \tan\delta \right\} \cdot \sin\beta \cdot \tan\phi / FS \end{array}$$

$$\begin{array}{l} \left\{ U_{PH} + k_s \cdot W_P + \left[W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_{AH} \cdot \cos\beta \right] \cdot \cos\beta \right\} \cdot FS^2 \\ + \left\langle \begin{array}{l} -\left\{ a \cdot H / \sin\beta + \left[\begin{array}{l} W_A \cdot (\cos\beta - k_s \cdot \sin\beta) \\ + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN} \end{array} \right] \cdot \tan\delta \right\} \cdot \cos\beta \\ -c \cdot h / \sin\beta - \left[W_P - U_{PN} + \left[\begin{array}{l} W_A \cdot (\sin\beta + k_s \cdot \cos\beta) \\ -T - U_{AH} \cdot \cos\beta \end{array} \right] \cdot \sin\beta \right] \cdot \tan\phi \end{array} \right\rangle \cdot FS \\ + \left\{ a \cdot H / \sin\beta + \left[\begin{array}{l} W_A \cdot (\cos\beta - k_s \cdot \sin\beta) \\ + U_{AH} \cdot \sin\beta - U_{AN} - U_{GN} \end{array} \right] \cdot \tan\delta \right\} \cdot \sin\beta \cdot \tan\phi = 0 \end{array} \qquad \text{................(10)}$$

Because $U_{PH} = U_{AH} = U_H$

$$\begin{array}{l} \left\{ U_H + k_s \cdot W_P + \left[W_A \cdot (\sin\beta + k_s \cdot \cos\beta) - T - U_H \cdot \cos\beta \right] \cdot \cos\beta \right\} \cdot FS^2 \\ - \left(\begin{array}{l} W_P \cdot \tan\phi + W_A \cdot \sin^2\beta \cdot \tan\phi + W_A \cdot \cos^2\beta \cdot \tan\delta - U_{AN} \cdot \cos\beta \cdot \tan\delta \\ -U_{GN} \cdot \cos\beta \cdot \tan\delta - U_{PN} \cdot \tan\phi + U_H \cdot \sin\beta \cdot \cos\beta \cdot \tan\delta \\ -U_H \cdot \sin\beta \cdot \cos\beta \cdot \tan\phi - k_s \cdot W_A \cdot \sin\beta \cdot \cos\beta \cdot \tan\delta \\ + k_s \cdot W_A \cdot \sin\beta \cdot \cos\beta \cdot \tan\phi + a \cdot H / \tan\beta + c \cdot h / \sin\beta - T \cdot \sin\beta \cdot \tan\phi \end{array} \right) \cdot FS \\ + \left\{ a \cdot H / \sin\beta + \left[\begin{array}{l} W_A \cdot (\cos\beta - k_s \cdot \sin\beta) \\ + U_H \cdot \sin\beta - U_{AN} - U_{GN} \end{array} \right] \cdot \tan\delta \right\} \cdot \sin\beta \cdot \tan\phi = 0 \end{array} \qquad \text{.............(11)}$$

Using $A \cdot x^2 + B \cdot x + C = 0$

$$FS = \frac{-B \pm \sqrt{B^2 - 4 \cdot A \cdot C}}{2 \cdot A} \qquad \text{..(12)}$$

Where:

$$A = W_A \cdot \sin\beta \cdot \cos\beta + U_H \cdot \sin^2\beta + k_s \cdot W_A \cdot \cos^2\beta + k_s \cdot W_P - T \cdot \cos\beta \quad \text{..........(13)}$$

$$B = -\begin{bmatrix} W_P \cdot \tan\phi + W_A \cdot \left(\sin^2\beta \cdot \tan\phi + \cos^2\beta \cdot \tan\delta\right) - U_{AN} \cdot \cos\beta \cdot \tan\delta \\ -U_{GN} \cdot \cos\beta \cdot \tan\delta - U_{PN} \cdot \tan\phi + U_H \cdot \sin\beta \cdot \cos\beta \cdot \left(\tan\delta - \tan\phi\right) \\ -k_s \cdot W_A \cdot \sin\beta \cdot \cos\beta \cdot \tan\delta + k_s \cdot W_A \cdot \sin\beta \cdot \cos\beta \cdot \tan\phi \\ +a \cdot H/\tan\beta + c \cdot h/\sin\beta - T \cdot \sin\beta \cdot \tan\phi \end{bmatrix} \quad \text{..........(14)}$$

$$C = a \cdot H \cdot \tan\phi + \begin{pmatrix} W_A \cdot \cos\beta - k_s \cdot W_A \cdot \sin\beta \\ -U_{AN} - U_{GN} + U_H \cdot \sin\beta \end{pmatrix} \cdot \sin\beta \cdot \tan\phi \cdot \tan\delta \quad \text{..........(15)}$$

$$W_A = \gamma \cdot \left(h - h_w\right) \cdot \left(\frac{H}{\sin\beta} - \frac{h + h_w}{2 \cdot \sin\beta \cdot \cos\beta}\right) + \gamma_{sat} \cdot h_w \cdot \left(\frac{H}{\sin\beta} - \frac{h_w}{2 \cdot \sin\beta \cdot \cos\beta}\right) \quad \text{..........(16)}$$

$$W_P = \gamma \cdot \left(\frac{h^2 - {h_w}^2}{2 \cdot \sin\beta \cdot \cos\beta}\right) + \gamma_{sat} \cdot \left(\frac{{h_w}^2}{2 \cdot \sin\beta \cdot \cos\beta}\right) \quad \text{..........(17)}$$

$$U_H = \frac{\gamma_w \cdot {h_w}^2}{2} \quad \text{..........(18)}$$

$$U_{AN} = \gamma_w \cdot h_w \cdot \left(\frac{H}{\tan\beta} - \frac{h_w \cdot \cos^2\beta}{2 \cdot \sin\beta}\right) \quad \text{..........(19)}$$

$$U_{PN} = \frac{\gamma_w \cdot {h_w}^2}{2 \cdot \tan\beta} \quad \text{..........(20)}$$

$$U_{GN} = \frac{u_g \cdot H}{\sin\beta} \quad \text{..........(21)}$$

For case where critical interface is below geomembrane, ignore pose pressure on critical interface by setting $U_{AN} = 0$.

ATTACHMENT 2

Stability Analysis Results

Scenario 1

Liner System Stability
Veneer Mode
Finite Slope Analysis

Units

◉ Customary ○ SI

a	Apparent Interface Adhesion	=	0 psf
δ	Interface Friction Angle	=	15.0 degrees
c	Apparent Soil Cohesion	=	400 psf
ϕ	Soil Internal Friction Angle	=	0 degrees
γ	Moist Soil Unit Weight	=	110 pcf
γ_{sat}	Saturated Soil Unit Weight	=	110 pcf
γ_w	Water Unit Weight	=	62.4 pcf
h	Depth of Cover Soil Above Critical Interface	=	1.5 ft
h_w	Average Water Depth Above Critical Interface	=	0.00 ft
β	Slope Inclination	=	14.0 degrees
H	Vertical Height of Slope	=	68.3 ft
u_g	Average Landfill Gas Pressure	=	0 psf
S	Additional Surcharge	=	0.0 lb/ft
T	Maximum Tension in Geosynthetics	=	0 lb/ft
k_s	Peak Seismic Horizontal Acceleration	=	0.000 gravity

☑ Critical Interface Above Geomembrane

W_A	Weight of Active Wedge	=	45971.35 lb/ft
W_P	Weight of Passive Wedge	=	525.94 lb/ft
U_H	Horizontal Hydrostatic Force at Toe	=	0.00 lb/ft
U_{AN}	Pore Water Pressure Resultant on Active Wedge	=	0.00 lb/ft
U_{PN}	Pore Water Pressure Resultant on Passive Wedge	=	0.00 lb/ft
U_{GN}	Gas Water Pressure Resultant on Active Wedge	=	0.00 lb/ft
A		=	10816.79
B		=	-14067.26
C		=	0.00
FS		=	1.30

Scenario 2

Liner System Stability

Veneer Mode

Finite Slope Analysis

Units

◉ Customary ○ SI

a	Apparent Interface Adhesion	=	0 psf
δ	Interface Friction Angle	=	15.0 degrees
c	Apparent Soil Cohesion	=	400 psf
ϕ	Soil Internal Friction Angle	=	0 degrees
γ	Moist Soil Unit Weight	=	110 pcf
γ_{sat}	Saturated Soil Unit Weight	=	110 pcf
γ_w	Water Unit Weight	=	62.4 pcf
h	Depth of Cover Soil Above Critical Interface	=	1.5 ft
h_w	Average Water Depth Above Critical Interface	=	0.00 ft
β	Slope Inclination	=	14.0 degrees
H	Vertical Height of Slope	=	83.1 ft
u_g	Average Landfill Gas Pressure	=	0 psf
S	Additional Surcharge	=	4085.7 lb/ft
T	Maximum Tension in Geosynthetics	=	600 lb/ft
k_s	Peak Seismic Horizontal Acceleration	=	0.000 gravity

☑ Critical Interface Above Geomembrane

W_A	Weight of Active Wedge	=	60091.89 lb/ft
W_P	Weight of Passive Wedge	=	525.94 lb/ft
U_H	Horizontal Hydrostatic Force at Toe	=	0.00 lb/ft
U_{AN}	Pore Water Pressure Resultant on Active Wedge	=	0.00 lb/ft
U_{PN}	Pore Water Pressure Resultant on Passive Wedge	=	0.00 lb/ft
U_{GN}	Gas Water Pressure Resultant on Active Wedge	=	0.00 lb/ft
A		=	13557.18
B		=	-17628.28
C		=	0.00
FS		=	1.30

Scenario 3

Liner System Stability

Veneer Mode

Finite Slope Analysis

Units

(●) Customary ( ) SI

a	Apparent Interface Adhesion	=	0 psf
δ	Interface Friction Angle	=	15.0 degrees
c	Apparent Soil Cohesion	=	400 psf
ϕ	Soil Internal Friction Angle	=	0 degrees
γ	Moist Soil Unit Weight	=	110 pcf
γ_{sat}	Saturated Soil Unit Weight	=	110 pcf
γ_w	Water Unit Weight	=	62.4 pcf
h	Depth of Cover Soil Above Critical Interface	=	1.5 ft
h_w	Average Water Depth Above Critical Interface	=	0.45 ft
β	Slope Inclination	=	14.0 degrees
H	Vertical Height of Slope	=	49.7 ft
u_g	Average Landfill Gas Pressure	=	0 psf
S	Additional Surcharge	=	0.0 lb/ft
T	Maximum Tension in Geosynthetics	=	600 lb/ft
k_s	Peak Seismic Horizontal Acceleration	=	0.000 gravity

☑ Critical Interface Above Geomembrane

W_A	Weight of Active Wedge	=	33289.84 lb/ft
W_P	Weight of Passive Wedge	=	525.94 lb/ft
U_H	Horizontal Hydrostatic Force at Toe	=	6.32 lb/ft
U_{AN}	Pore Water Pressure Resultant on Active Wedge	=	5559.96 lb/ft
U_{PN}	Pore Water Pressure Resultant on Passive Wedge	=	25.27 lb/ft
U_{GN}	Gas Water Pressure Resultant on Active Wedge	=	0.00 lb/ft
A		=	7251.19
B		=	-9424.24
C		=	0.00
FS		=	1.30

Terracon	Made by:	RSG	Date:	1/29/15	Sheet No.:	COVER
	Checked by:	JCH	Date:	1/29/15	Job No.:	EJ147410
	Calculations for:	Tack-On Road Slope Stability Analysis				
	Emelle Facility – Trench 23					

TACK-ON ROAD SLOPE STABILITY ANALYSIS

CALCULATION COVER SHEET

Calculations by:

Signature: Rajendra S Gondhalekar

Name: Rajendra S. Gondhalekar, P.E.

Title: Project Engineer

1/29/2015
Date

Calculations Reviewed by:

Signature: J. Craig Hensley

Name: J. Craig Hensley, E.I.T.

Title: Staff Engineer

1/29/2015
Date

Calculations Approved by:

Signature: Michael A. Kemp

Name: Michael A. Kemp P.E.

Title: Department Manager

1/29/2015
Date

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	1/29/15	ALL	Initial Submittal

1.0 OBJECTIVE

Our objective is to calculate the stability of the tack-on road proposed for cell access during the operation of Trench 23 of the Emelle Facility. The analysis includes evaluation of sliding block failure surfaces to determine factors of safety (FOS) against failure through two critical configurations of the proposed tack-on road. Since the analysis represents an interim condition, a FOS greater than 1.3 is considered acceptable.

2.0 METHODOLOGY

The slope stability analysis was performed using a method of slices analysis using a slope-stability software program. The stability modeling software used for our analysis is Slope/W 2007 which is a part of GeoStudio developed by Geo-Slope International, Ltd. The proposed excavation for Trench 23 is to be at an inclination of 4H:1V, and a 30 ft wide tack-on access road is proposed to access the floor of the landfill. Based on veneer stability analysis of the liner protective cover soil, performed separately, the landfill liner protective cover is expected to be placed over a portion of the side slopes. As a result a portion of the tack-on access road will be constructed over side slopes with protective soil cover in-place, while another portion is expected to be constructed over side slopes with no protective soil cover. Therefore, both of these potential scenarios for the tack-on access road were analyzed as separate cross sections.

Slope stability analysis was performed using the geometry and both potential scenarios described above. The analysis were performed to search for both a circular failure surface (based on an entry and exit method), and a sliding block surface passing through the critical liner interface. The analysis searched for a slope-failure surface with the minimum FOS against sliding. This analysis provides us with FOS's against failure during landfilling activities in Trench 23. The Morgenstern-Price Method was used to calculate the FOS against failure.

3.0 SUBSURFACE CONDITIONS AND MATERIALS

The engineering properties for slope stability analysis were primarily based on those used in the previous analysis by Golder Associates in the engineering calculation package for Trench 22, contained in Attachment D-6-1-7. The major exception to this was the interface shear strength for the critical liner interface, which was previously based on a smooth liner. Since the proposed Trench 23 design will utilize textured liners throughout, interface shear strength appropriate for the textured liner was utilized instead. The values for the materials used in the tack-on road stability analysis are listed in the table below:

Material	Unit Weight (lb/ft^3)	Cohesion (lb/ft^2)	Friction Angle (°)
Liner Protective Soil	110	400	0
Critical Geosynthetic Interface	110	0	15

Because the tack-on road stability will be happen at very low confining pressures, the undrained properties of the liner protective soil were utilized in the analysis, rather than the drained properties. Since the tack on road will be subjected to traffic, an additional surcharge load was added to the road surface of the cross section. The surcharge road was calculated as 65 pcf, based on an estimated vehicle weight of 80,000 lb, an estimated vehicle length of 52 ft, and estimated 30 ft between vehicles along the road, and based on two lanes of traffic.

4.0 ANALYSIS RESULTS

The input properties and the output results for the analysis are presented in Attachment 1. The following table presents the results of our analysis for the various scenarios.

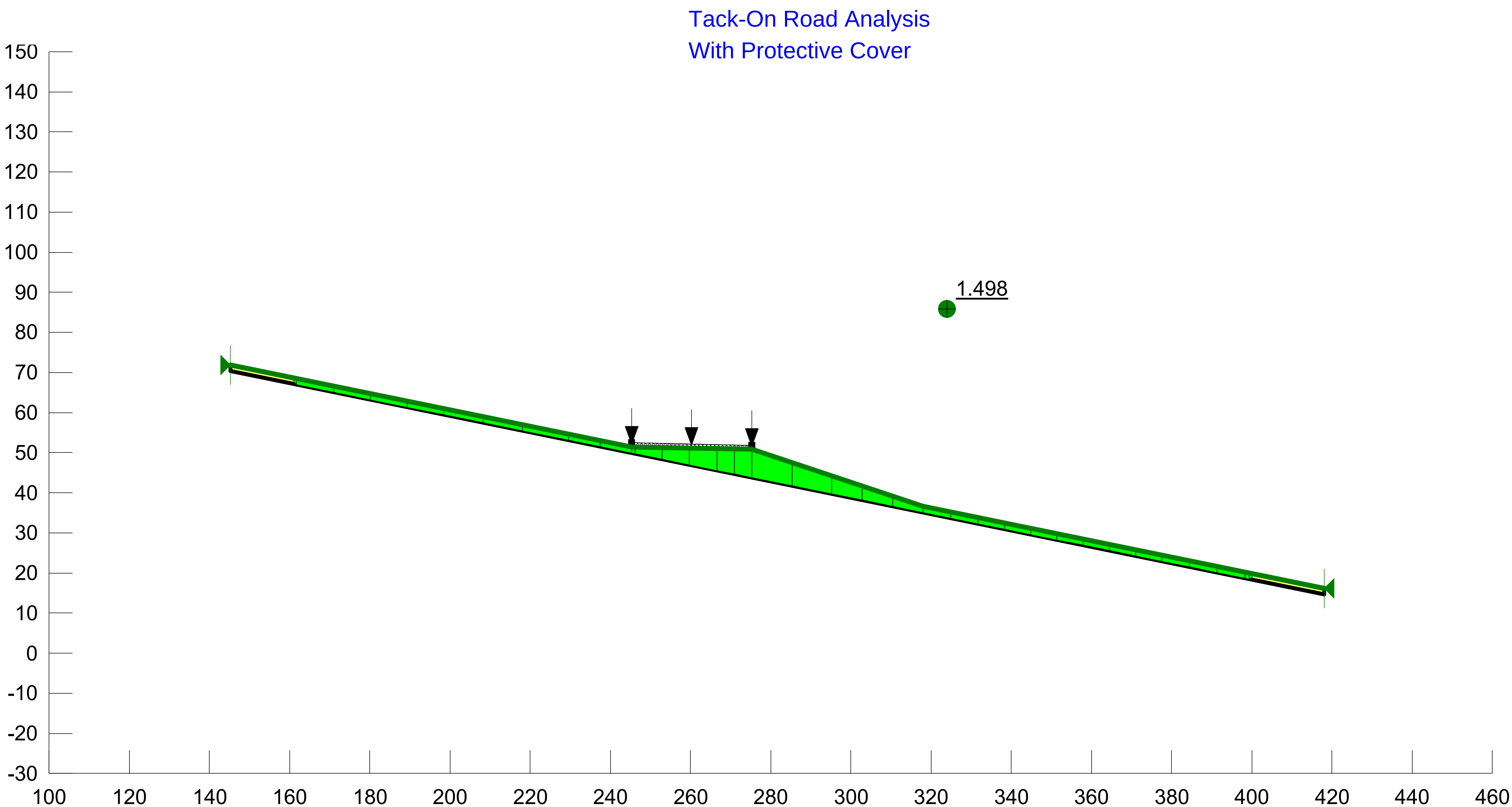
Cross Section	Scenario	Factor of Safety
Tack-On Road	With Protective Cover	1.50
	Without Protective Cover	1.31

5.0 CONCLUSIONS

Based on the results of the analysis, the Trench 23 tack-on roads appear stable for both scenarios, with the sliding block failure mode FOS exceeding 1.3.

ATTACHMENT 1

Tack-On Road Stability Output Data


Tack-On Road Analysis
With Protective Cover
1.498
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460

Slope Stability

File Information

Title: Trench 23 - Final Stability
Created By: Gondhalekar, Rajendra S.
Revision Number: 62
Last Edited By: Gondhalekar, Rajendra S.
Date: 12/8/2014
Time: 1:40:07 PM
File Name: Trench 23-Tack-on Cell Access Road-Case 1.gsz
Directory: N:\Projects\2014\EJ147410\Working Files\Calculations-Analyses\Stability\Tack on Road\
Last Solved Date: 12/12/2014
Last Solved Time: 12:46:38 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Slope Stability

- Kind: SLOPE/W
- Method: Morgenstern-Price
- Settings
  - Side Function
    - Interslice force function option: Half-Sine
  - PWP Conditions Source: (none)
- Slip Surface
  - Direction of movement: Left to Right
  - Use Passive Mode: No
  - Slip Surface Option: Auto-Search
  - Critical slip surfaces saved: 1
  - Optimize Critical Slip Surface Location: Yes
  - Tension Crack
    - Tension Crack Option: (none)
- FOS Distribution
  - FOS Calculation Option: Constant

Advanced

Number of Slices: 30

Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 5 ft

Optimization Maximum Iterations: 20000

Optimization Convergence Tolerance: 1e-007

Starting Optimization Points: 8

Ending Optimization Points: 16

Complete Passes per Insertion: 1

Driving Side Maximum Convex Angle: 5 °

Resisting Side Maximum Convex Angle: 1 °

Materials

Liner Protective Soil

Model: Undrained (Phi=0)

Unit Weight: 110 pcf

Cohesion: 400 psf

Liner Interface

Model: Mohr-Coulomb

Unit Weight: 110 pcf

Cohesion: 0 psf

Phi: 15 °

Phi-B: 0 °

Slip Surface Limits

Left Coordinate: (145.2999, 71.8779) ft

Right Coordinate: (418.0263, 16.2194) ft

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 65 pcf

Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	245.2999	51.4697
	245.2999	52.4697
	275.2999	51.8697
	275.2999	50.8697

Regions

	Material	Points	Area (ft²)
Region 1	Liner Protective Soil	3,4,5,6,7,1,2	618.33043
Region 2	Liner Interface	8,2,1,9	0.02727264

Points

	X (ft)	Y (ft)
Point 1	418.0263	14.6885
Point 2	145.2999	70.347
Point 3	145.2999	71.8779
Point 4	245.2999	51.4697
Point 5	275.2999	50.8697
Point 6	318.0263	36.6276
Point 7	418.0263	16.2194
Point 8	145.2999	70.3469
Point 9	418.0263	14.6884

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.498	(322.732, 189.444)	99.63701	(160.214, 68.8341)	(400.92, 19.7106)
2	95	1.503	(322.732, 189.444)	197.706	(167.182, 67.4121)	(418.026, 16.2194)

Slices of Slip Surface: Optimized

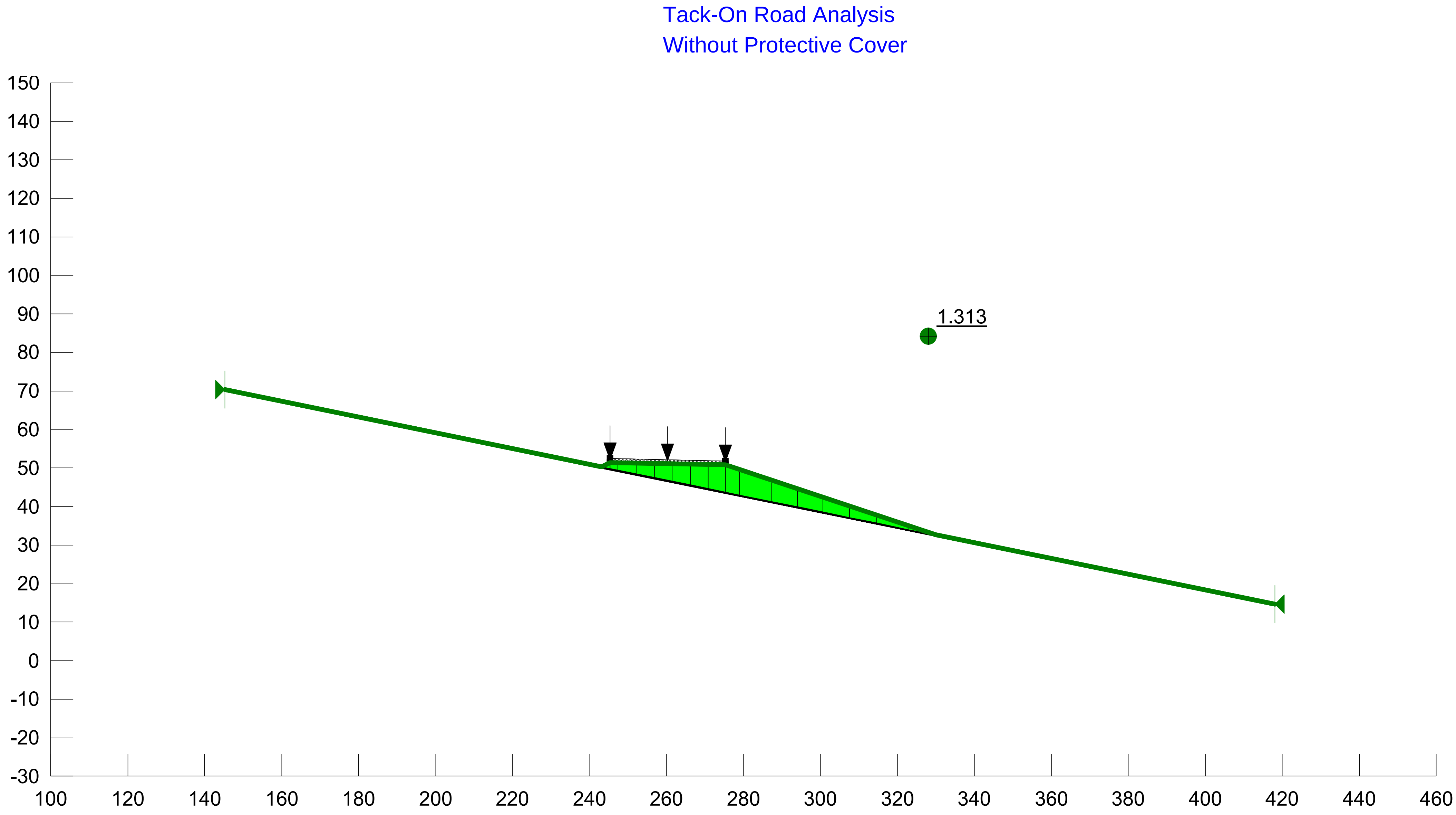
	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	160.96615	67.915205	0	-240.6973	0	400
2	Optimized	166.36435	66.04803	0	163.81093	43.893007	0
3	Optimized	175.5849	64.16628	0	163.65764	43.851932	0
4	Optimized	184.7329	62.299335	0	163.49698	43.808883	0
5	Optimized	193.8809	60.43239	0	163.3149	43.760095	0
6	Optimized	203.37375	58.495085	0	163.13111	43.71085	0
7	Optimized	213.2114	56.48741	0	162.93192	43.657476	0
8	Optimized	223.87635	54.310875	0	162.72979	43.603315	0
9	Optimized	233.54185	52.338315	0	162.54486	43.553764	0
10	Optimized	241.38055	50.738585	0	162.41986	43.520271	0
11	Optimized	245.69295	49.858505	0	232.5246	62.30478	0
12	Optimized	249.50385	49.08077	0	306.66893	82.171691	0
13	Optimized	256.33955	47.68573	0	439.65674	117.80567	0
14	Optimized	263.17525	46.29069	0	572.63022	153.43581	0
15	Optimized	268.75925	45.1511	0	681.26784	182.54517	0
16	Optimized	273.11265	44.262645	0	765.98669	205.24551	0
17	Optimized	280.29105	42.79766	0	677.81238	181.61928	0
18	Optimized	290.27335	40.760455	0	541.39793	145.06714	0
19	Optimized	299.05815	38.96764	0	421.40329	112.91467	0
20	Optimized	306.6454	37.419215	0	317.78292	85.149676	0

21	Optimized	314.23265	35.87079	0	214.14963	57.381221	0
22	Optimized	321.48215	34.391305	0	162.38608	43.511219	0
23	Optimized	328.2791	33.004175	0	162.49555	43.540552	0
24	Optimized	334.96125	31.64047	0	162.61286	43.571983	0
25	Optimized	341.5721	30.29131	0	162.72534	43.602122	0
26	Optimized	348.11175	28.95669	0	162.8452	43.634239	0
27	Optimized	354.6543	27.62148	0	162.97184	43.668174	0
28	Optimized	361.19965	26.285685	0	163.10657	43.704274	0
29	Optimized	367.74735	24.949415	0	163.22911	43.737109	0
30	Optimized	374.29745	23.612665	0	163.34878	43.769174	0
31	Optimized	381.00835	22.243095	0	163.47416	43.802768	0
32	Optimized	387.88005	20.840705	0	163.58822	43.833333	0
33	Optimized	394.75175	19.438315	0	163.70229	43.863897	0
34	Optimized	398.7786	18.616555	0	163.75437	43.877852	0
35	Optimized	400.1446	19.103275	0	294.73823	0	400

Slices of Slip Surface: 95

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	95	167.90755	66.49858	0	-249.52231	0	400
2	95	172.8923	64.71579	0	163.78871	43.887052	0
3	95	181.41085	62.97731	0	163.65068	43.850069	0
4	95	189.92935	61.238835	0	163.51266	43.813085	0
5	95	198.4479	59.50036	0	163.36313	43.77302	0
6	95	206.96645	57.76188	0	163.20211	43.729873	0
7	95	215.485	56.0234	0	163.04108	43.686725	0
8	95	224.00355	54.28492	0	162.88005	43.643578	0
9	95	232.5221	52.54644	0	162.73052	43.603512	0
10	95	241.04065	50.80796	0	162.581	43.563447	0
11	95	249.0499	49.17341	0	298.04332	79.860466	0
12	95	256.5499	47.642795	0	443.9688	118.96108	0
13	95	264.0499	46.112185	0	589.88121	158.05819	0
14	95	271.5499	44.58157	0	735.79363	197.15531	0
15	95	279.57255	42.944295	0	687.7666	184.2865	0
16	95	288.11785	41.20036	0	570.88194	152.96735	0
17	95	296.6631	39.45642	0	454.06607	121.66664	0
18	95	305.20835	37.712485	0	337.30753	90.381281	0
19	95	313.75365	35.96855	0	220.56046	59.098998	0
20	95	322.1075	34.26368	0	162.23167	43.469846	0
21	95	330.26995	32.597875	0	162.33971	43.498794	0
22	95	338.4324	30.93207	0	162.45975	43.530958	0
23	95	346.5948	29.26627	0	162.59179	43.566338	0
24	95	354.75725	27.600465	0	162.72383	43.601719	0
25	95	362.9197	25.93466	0	162.86788	43.640316	0
26	95	371.0821	24.268855	0	163.02393	43.682129	0
27	95	379.24455	22.60305	0	163.16797	43.720726	0
28	95	387.407	20.937245	0	163.31202	43.759323	0
29	95	395.5694	19.27144	0	163.45606	43.79792	0

30	95	403.73185	17.60564	0	163.60011	43.836517	0
31	95	411.8943	15.939835	0	163.72015	43.868681	0
32	95	417.0009	15.663165	0	229.91688	0	400


Tack-On Road Analysis
Without Protective Cover
1.313
150
140
130
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110
100
90
80
70
60
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30
20
10
0
-10
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100
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400
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460

Slope Stability

File Information

Title: Trench 23 - Final Stability
Created By: Gondhalekar, Rajendra S.
Revision Number: 67
Last Edited By: Gondhalekar, Rajendra S.
Date: 12/12/2014
Time: 1:17:57 PM
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Directory: N:\Projects\2014\EJ147410\Working Files\Calculations-Analyses\Stability\Tack on Road\
Last Solved Date: 12/12/2014
Last Solved Time: 1:18:04 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Slope Stability

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: (none)

Slip Surface
- Direction of movement: Left to Right
- Use Passive Mode: No
- Slip Surface Option: Auto-Search
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: Yes
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced
- Number of Slices: 30
- Optimization Tolerance: 0.01
- Minimum Slip Surface Depth: 5 ft
- Optimization Maximum Iterations: 20000
- Optimization Convergence Tolerance: 1e-007
- Starting Optimization Points: 8
- Ending Optimization Points: 16
- Complete Passes per Insertion: 1
- Driving Side Maximum Convex Angle: 5 °
- Resisting Side Maximum Convex Angle: 1 °

Materials

Liner Protective Soil

Model: Undrained (Phi=0)
Unit Weight: 110 pcf
Cohesion: 400 psf

Liner Interface

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 15 °
Phi-B: 0 °

Slip Surface Limits

Left Coordinate: (145.2999, 70.347) ft
Right Coordinate: (418.0263, 14.6885) ft

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 65 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	245.2999	51.4697
	245.2999	52.4697
	275.2999	51.8697
	275.2999	50.8697

Regions

	Material	Points	Area (ft²)
Region 1	Liner Protective Soil	1,2,3,4	322.88109
Region 2	Liner Interface	5,6,4,3,7,8	0.027255096

Points

	X (ft)	Y (ft)
Point 1	245.2999	51.4697
Point 2	275.2999	50.8697
Point 3	329.87079	32.67944
Point 4	243.1256	50.38255
Point 5	145.2999	70.3469
Point 6	145.2999	70.347
Point 7	418.0263	14.6885
Point 8	418.0263	14.6884

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.313	(264.198, 67.936)	67.89061	(163.446, 66.6438)	(329.894, 32.6748)
2	40	1.313	(264.198, 67.936)	86.11	(178.195, 63.6337)	(341.637, 30.2782)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	166.053	66.11166	0	0.00037259864	9.9837505e-005	0
2	Optimized	171.26785	65.047395	0	0.0011177959	0.00029951251	0
3	Optimized	176.48275	63.98313	0	0.0018629932	0.00049918752	0
4	Optimized	181.75425	62.907305	0	0.0029444963	0.0007889754	0
5	Optimized	187.08235	61.81992	0	0.0043621282	0.0011688287	0
6	Optimized	193.067	60.59854	0	0.0063945479	0.0017134139	0
7	Optimized	199.7082	59.24316	0	0.0090417429	0.0024227277	0
8	Optimized	203.2864	58.5129	0	0.01046812	0.0028049244	0
9	Optimized	206.0363	57.9517	0	0.01050239	0.002814107	0
10	Optimized	211.0209	56.93444	0	0.010365383	0.002777396	0
11	Optimized	216.0055	55.91718	0	0.010174703	0.0027263034	0
12	Optimized	220.99005	54.89992	0	0.0099301735	0.002660782	0
13	Optimized	226.4668	53.782205	0	0.0098303769	0.0026340415	0
14	Optimized	232.4358	52.56404	0	0.0098755178	0.002646137	0
15	Optimized	239.27295	51.16871	0	0.0099271587	0.0026599742	0
16	Optimized	244.21275	50.16059	0	80.842966	21.661807	0
17	Optimized	246.3291	49.728675	0	244.08471	65.402301	0
18	Optimized	249.7369	49.0332	0	310.32483	83.151289	0
19	Optimized	254.4936	48.062445	0	402.80183	107.93043	0
20	Optimized	259.19185	47.10362	0	494.1356	132.40323	0
21	Optimized	263.83215	46.15662	0	584.33931	156.57325	0

22	Optimized	268.47245	45.20962	0	674.54302	180.74326	0
23	Optimized	273.04625	44.27619	0	763.44922	204.5656	0
24	Optimized	277.15425	43.43783	0	719.55941	192.80536	0
25	Optimized	283.16415	42.211325	0	637.51771	170.82236	0
26	Optimized	290.6639	40.680755	0	535.15215	143.39359	0
27	Optimized	297.3523	39.31577	0	443.85795	118.93138	0
28	Optimized	304.15665	37.92713	0	350.98937	94.047318	0
29	Optimized	311.0769	36.51483	0	256.53797	68.739143	0
30	Optimized	318.66885	34.965445	0	152.90375	40.970436	0
31	Optimized	326.33575	33.400775	0	48.260895	12.931468	0
32	Optimized	329.88105	32.67725	0	0.010887685	0.0029173464	0
33	Optimized	329.8924	32.67498	0	0.0054927786	0.0014717856	0

Slices of Slip Surface: 40

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	40	180.90025	63.081565	0	0.0052154331	0.0013974711	0
2	40	186.31115	61.97725	0	0.010421678	0.0027924803	0
3	40	191.72205	60.872985	0	0.010403389	0.0027875798	0
4	40	197.13295	59.768715	0	0.010385281	0.0027827278	0
5	40	202.54385	58.66445	0	0.010366992	0.0027778272	0
6	40	207.95475	57.560185	0	0.010348703	0.0027729267	0
7	40	213.36565	56.45592	0	0.010330414	0.0027680262	0
8	40	218.77655	55.351655	0	0.010312125	0.0027631256	0
9	40	224.18745	54.247385	0	0.010293836	0.0027582251	0
10	40	229.59835	53.14312	0	0.010275547	0.0027533246	0
11	40	235.00925	52.038855	0	0.010257258	0.002748424	0
12	40	240.42015	50.934585	0	0.010238969	0.0027435235	0
13	40	244.21275	50.160585	0	80.842966	21.661807	0
14	40	247.7999	49.428515	0	272.67948	73.064245	0
15	40	252.7999	48.408105	0	369.87604	99.107987	0
16	40	257.7999	47.387695	0	467.07261	125.15173	0
17	40	262.7999	46.367285	0	564.26917	151.19547	0
18	40	267.7999	45.346875	0	661.46574	177.23921	0
19	40	272.7999	44.326465	0	758.6623	203.28295	0
20	40	278.02845	43.259415	0	707.61272	189.60426	0
21	40	283.48555	42.145725	0	633.13662	169.64845	0
22	40	288.94265	41.032035	0	558.64257	149.68782	0
23	40	294.39975	39.91834	0	484.16647	129.73201	0
24	40	299.8568	38.804645	0	409.67241	109.77139	0
25	40	305.31385	37.690955	0	335.19631	89.815581	0
26	40	310.77095	36.57726	0	260.70226	69.85496	0
27	40	316.22805	35.463565	0	186.22616	49.899149	0
28	40	321.68515	34.349875	0	111.73749	29.93997	0
29	40	327.14225	33.236185	0	37.252414	9.9817542	0
30	40	332.81235	32.07902	0	0.010876738	0.002914413	0
31	40	338.6955	30.87843	0	0.0054328492	0.0014557276	0

Terracon	Made by: RSG	Date: 1/29/15	Sheet No.: COVER
	Checked by: JCH	Date: 1/29/15	Job No.: EJ147410
	Calculations for:	Pressure Relief System Shutoff Analysis	
	Emelle Facility – Trench 23		

PRESSURE RELIEF SYSTEM SHUTOFF ANALYSIS

CALCULATION COVER SHEET

Calculations by:

Signature: [signature]

Name: Rajendra S. Gondhalekar, P.E.

Title: Project Engineer

1/29/2015
Date

Calculations Reviewed by:

Signature: [signature]

Name: J. Craig Hensley, E.I.T.

Title: Staff Engineer

1/29/2015
Date

Calculations Approved by:

Signature: [signature]

Name: Michael A. Kemp P.E.

Title: Department Manager

1/29/2015
Date

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	1/29/15	ALL	Initial Submittal

1.0 OBJECTIVE

Our objective is to evaluate the uplift pressure and compare it to the applied vertical load at Trench 23 of the Emelle Facility.

2.0 ASSUMPTIONS

Based on the Golder Associates site wide chalk water level data acquired May 30, 1983 to June 9, 1983, and shown on Figure 00-150-16, 7/29/1985 (part of Permit Application Revision 3.3), the groundwater level in the Selma Chalk in the vicinity of Trench 23 is estimated to range from elevations 210 to 250 ft MSL. This level ranges from about 0' to about 30' below ground surface, and averages about 10' below ground surface.

3.0 APPROACH

The applied load (calculated based on varying waste thicknesses) will be evaluated and compared against the uplift pressure to calculate a factor of safety against uplift and a minimum waste thickness at which the pressure relief system can be safely shut off.

3.1 Uplift Pressure

The uplift pressure U, after excavation below groundwater is calculated as:

$$U = \gamma_w H_w \quad (1)$$

Where:
γ_w = Unit weight of water; and
H_w = Depth of excavation below groundwater table

3.2 Applied Load

The applied load P. after waste placement in the landfill is calculated as:

$$P = \sum \gamma_i H_i \quad (2)$$

Where:
γ_i = Unit weight of each liner system component or waste layer in-place; and
H_i = Thickness of the liner system component or waste layer

3.3 Factor of Safety

The factor of safety against uplift P. after waste placement in the landfill is calculated as:

$$FS = \frac{P}{U} \quad (3)$$

4.0 ANALYSIS

The maximum excavation for Trench 23 is 81.4 ft below the estimated potentiometric surface in the Chalk and will occur in Cells 4 and 6, in the vicinity of the sump for these cells. Based on the Equation 1, the maximum uplift pressure, after the pressure relief system has been shut off is calculated as:

$$U = 62.4\text{ pcf} \times 81.4\text{ ft} = 5{,}079.4\text{ psf}$$

The applied load comprises of two components. The applied load due to the soil components of the liner system, and the applied load due to the waste in-place in the cell at the time the pressure relief system is shut off.

The soil components of the liner system, from the bottom up, are comprised of a 3 ft thick compacted chalk layer, a 1 ft thick drainage layer, and a 1.5 ft thick compacted chalk layer, which are estimated to have a unit weight of 130 pcf, 130 pcf, and 120 pcf respectively.

The waste in-place in the cell will have a thickness that will increase with time, and is estimated to have a unit weight of 110 pcf.

The applied downward vertical load required at the time of the pressure relief system shut-off is therefore calculated as:

$$P = 130\text{ pcf} \times 3\text{ ft} + 130\text{ pcf} \times 1\text{ ft} + 120\text{ pcf} \times 1.5\text{ ft} + 110\text{ pcf} \times H_{waste} = 700\text{ psf} + 110\text{ pcf} \times H_{waste}$$

To achieve an acceptable factor of safety of 1.3:

$$\frac{700\text{ psf} + 110\text{ pcf} \times H_{waste}}{5{,}079.4\text{ psf}} > 1.3$$

Therefore:

$$700\text{ psf} + 110\text{ pcf} \times H_{waste} > 6{,}603.2\text{ psf}$$

This is achievable when:

$$H_{waste} > \frac{(6{,}603.2\text{ psf} - 700\text{ psf})}{110\text{ pcf}} = 53.7\text{ ft} \approx 54\text{ ft}$$

5.0 RESULTS AND CONCLUSIONS

The pressure relief system for each cell of Trench 23 shall be maintained until there is at least 54 ft of waste in that cell. After this height of waste is reached, the system may be shut off, as an adequate factor of safety against uplift will be maintained.

Terracon	Made by:	JCH	Date:	1/30/15	Sheet No.:	COVER
	Checked by:	MAK	Date:	1/30/15	Job No.:	EJ147410
	Calculations for:	Leachate Collection Pipe Design				
	Emelle Facility Trench 23 Permit Application					

LEACHATE COLLECTION PIPE AND RISER PIPE CALCULATIONS

CALCULATION COVER SHEET

Calculations by:
Signature: [signature] — Date: 1-30-2015
Name: J. Craig Hensley, E.I.T.
Title: Staff Engineer

Calculations Reviewed by:
Signature: [signature] — Date: 1-30-2015
Name: Michael A. Kemp, P.E.
Title: Solid Waste Department Manager

Calculations Approved by:
Signature: [signature] — Date: 1-30-2015
Name: Rajendra S. Gondhalekar, P.E.
Title: Project Engineer

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	01/30/15	ALL	Initial Submittal

Reliable ■ Responsive ■ Resourceful

1.0 OBJECTIVE

Our objective is to design the following piped components of the leachate collection system to effectively convey liquid and withstand loading due to the overlying soils and waste.

2.0 LEACHATE COLLECTION PIPE DESIGN

Terracon proposes the following pipes for use in the leachate collection system in Trench 23:

- 8 inch HDPE collection pipe;
  - 5/8 inch diameter pipe perforations; and
  - Standard Dimension Ratio (SDR) of 9.
- 18 inch HDPE riser pipe;
  - 5/8 inch diameter pipe perforations; and
  - Standard Dimension Ratio (SDR) of 9.

We have evaluated the 8 inch leachate collection pipe (LCP) in terms of flow capacity, perforation sizing, and structural stability. We have evaluated the 18 inch riser pipe in terms of structural stability only.

2.1 Pipe Flow Capacity Design

We evaluated the flow capacity of the 8 inch leachate collection pipe located in the landfill floor in terms of the predicted worst case leachate generation rate from the Leachate Generation Analysis. This value was applied to the maximum tributary area of 8.1 acres for a single length of leachate collection pipe, which is found in Cell 1. The corresponding length of leachate collection pipe is sloped at 1.0% and is approximately 468 feet long.

Our calculations indicate that the 8 inch diameter HDPE leachate collection pipe will have sufficient capacity to handle to predicted peak leachate flow. The allowable capacity for the 8 inch pipe that is 80 percent full is more than 2.5 times greater than the predicted amount of leachate flow.

2.2 Pipe Perforation Sizing

The 5/8 inch perforations and spacing in the leachate collection pipe are sufficient in terms of the ability to prevent infiltration by the surrounding granular material layer. We have evaluated of the size and locations of the pipe perforations in terms of maximum allowable inflow. This value was calculated using the Orifice Equation. In calculating the amount of predicted inflow, we have used the same predicted leachate generation rate that was used in evaluating flow capacity performance. Our calculations indicate that the perforations are adequately sized and spaced to ensure that leachate flow into the pipe is not inhibited. The leachate inflow capacity is significantly greater than the predicted amount of inflow.

2.3 Pipe Structural Stability

Finally, Terracon has evaluated the structural stability of the 8 inch HDPE leachate collection pipe located in the cell floor area and the 18 inch HDPE leachate riser pipe located in the sump and adjacent side slope area. The following failure mechanisms were considered:

- Wall Crushing;
- Wall Buckling; and
- Ring Deflection.

The pipes were evaluated under worst case loading conditions. The worst case condition at the site is a pipe located on the landfill floor (not in a trench) under the post-closure condition. Pipe loads were calculated using three different methods. If a pipe were located at the invert of a trench, each method would yield a differing amount of load. However, since we have assumed that the pipe does not lie in a trench, all methods yielded an approximately equal amount of load.

Based on the results of the structural stability calculations, the currently permitted leachate collection pipe meets or exceeds recommended minimum design values. Calculated results for each failure mechanism are listed in Table 6.1 below.

Table 6.1: Pipe Structural Stability Results

Failure Mechanism	Post-Closure Applied Load (psf)	Result
8” Leachate Collection Pipe		
Wall Crushing	25,043	FS = 1.92
Wall Buckling	25,043	174 psi < 181 psi (Allowable)
Ring Deflection	25,043	6.99% < 7.5% (Allowable)
18” Riser Pipe		
Wall Crushing	25,214	FS = 1.90
Wall Buckling	25,214	175 psi < 181 psi (Allowable)
Ring Deflection	25,214	7.04% < 7.5% (Allowable)

Pipe wall crushing occurs when the compressive stress due to the applied load of the overlying soil and waste exceeds the compressive strength of the pipe. We assumed an allowable compressive stress of 1,500 psi, which is a typical value for HDPE type PE3408 pipe. Although crushing failures are more likely to occur with a brittle material such as PVC, we have addressed this failure mechanism for HDPE. We concluded that the predicted compressive stress was less than the allowable stress with an adequate factor of safety, which indicates that the leachate collection pipe and leachate riser pipe is adequate in resisting this mode of failure.

Pipe wall buckling occurs when the applied load exceeds the allowable constrained buckling pressure. This failure mechanism is a type of deflection that results in a large wrinkle or dimple in the pipe wall. Wall buckling is a ductile failure and is more likely to occur in HDPE material than a wall crushing failure. The amount of buckling pressure allowed in the pipe is a calculated value dependent upon pipe material and embedment specifications. We found that the predicted applied load was less than the allowable constrained buckling pressure. This indicates that the leachate collection pipe and leachate riser pipe is adequate in terms of resistance to wall buckling.

Small amounts of ring deflection are a desirable response to soil loading. This mobilizes supporting forces in the surrounding soil and promotes arching. However, excessive deflection may adversely affect flow capacity and pipe cleaning. The allowable ring deflection for HDPE pipe is 7.5 percent (Chevron, 2003 & Plastic Pipe Institute, 2009). The predicted amount of ring deflection was found to be less than the allowable 7.5 percent. This verifies that the specified leachate collection pipe and riser pipe is capable of maintaining sufficient hydraulic capacity and will likely remain accessible for pipe cleaning equipment.

Please refer to the attached calculations for pipe flow capacity and structural stability for more detailed information.

Landfill Profile

Pipe Type: 8 inch perforated HDPE, SDR 9

Final Cover
height = 4.0 ft. unit weight = 130 pcf

Intermediate Cover
height = 1.0 ft. unit weight = 130 pcf

Waste Layer
height = 222.0 ft. unit weight = 110 pcf

Protective Cover Layer
height = 1.5 ft. unit weight = 120 pcf

Drainage Layer
height = 1.0 ft unit weight = 120 pcf

Prism Pipe Loading

$$P_E = wH$$

Source: Eq. 7-1 from Performance Pipe, (2003).

where:

P_E = vertical soil pressure (psf)
w = unit weight of soil (pcf)
H = soil height above pipe crown

PE = (4. ft * 130 pcf) + (1. ft * 130 pcf) + (222. ft * 110 pcf) + (1.5 ft * 120 pcf) + (1. ft * 120 pcf)

P_E = 25,371 psf

Pipe Perforation Reduction

Diameter of perforation = 0.625 in
perforations per foot = 12
Perforated Area = 1.29%

Design Pipe Loading = (1 - 1.29 /100) x 25371 psf

Design Pipe Loading = 25,043 psf

Marston Pipe Loading

Pipe Type: 8 inch perforated HDPE, SDR 9

$$P_M = C_D w B_D$$

Source: Eq. 7-2 from Performance Pipe, (2003).

where:

P_m = vertical soil pressure (psf)

C_d = Load Coefficient

w = unit weight of soil (pcf) w = (25371 psf) / (228.5 ft) = 111 pcf

B_d = trench width at pipe crown (ft) B_d = 1E+07 ft *Note: Value for B_d assumes an infinitely wide trench.*

$C_D = [1-(e^{(-2K_{u'} *(H/B_D))})]/[2K_{u'}]$ *Source: Eq. 7-3 from Performance Pipe, (2003).*

e = natural log

$K_{u'}$ = Rankine earth pressure and frictic $K_{u'}$ = 0.192 *Source: Table 7-1 from Performance Pipe, (2003).*

H = soil height above pipe crown (ft) H= 4 ft + 1 ft + 222 ft + 1.5 ft = 228.5 ft

C_D = [1 - exp(-2 * 0.192 *(228.5 ft / 1.00E+07 ft))] / (2 * 0.192)

C_D = <u>2.3E-05</u>

P_M = (2.28E-05) * (111. pcf) * (1.00E+07 ft)

P_M = <u>25,371</u> psf

Pipe Perforation Reduction

Diameter of perforation = 0.625 in
perforations per foot = 12
Perforated Area = 1.29%

Design Pipe Loading = (1 - 1.29 /100) x 25371 psf

Design Pipe Loading = <u>25,043</u> psf

Modified Arching Load

Pipe Type: 8 inch perforated HDPE, SDR 9

$$P_c = FwH$$

Source: Eq. 7-6 from Performance Pipe, (2003).

where:

P_c = modified arching vertical pressure (psf)
F= arching coefficient
w = unit weight of the soil w = 111 pcf *Note: As calculated on sheet no. 2.*
H = soil height above the pipe H = 228.5 ft *Note: As calculated on sheet no. 2.*

F= [P_m + 0.4(P_E - P_m)]/P_E *Source: Eq. 7-7 from Performance Pipe, (2003).*

where:

P_m = Marston Load P_m = 25,371 psf *Note: As calculated on sheet no. 2.*
P_E = Prism Load P_E = 25,371 psf *Note: As calculated on sheet no. 2.*

F = [25371 psf + 0.4 * (25371 psf - 25371 psf)] / 25371 psf

F = 1

PC = (1.) * (111.03 pcf) * (25370.9 ft)

P_c = 25,371 psf

Pipe Perforation Reduction

Diameter of perforation = 0.625 in
perforations per foot = 12
Perforated Area = 1.29%

Design Pipe Loading = (1 - 1.29 /100) x 25371 psf

Design Pipe Loading = 25,043 psf

Made By: JCH	Date: 1/30/2015	Sheet No.: 4 of 7
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Calculations for: LCS Pipe Structural Stability - 8" Pipe		
Emelle Facility		

Wall Crushing Capacity

Pipe Type: 8 inch perforated HDPE, SDR 9

$$S = \left(\frac{P_T}{288}\right)\mathrm{SDR}$$

Source: Eq. 7-23 from Performance Pipe, (2003).

where:

S = pipe compressive stress (psi) — P_t = 25,043 psf

P_t = vertical load applied (psf) — SDR = 9

SDR = standard dimension ratio

S = (25043 psf / 288) * 9

S = 782.6 psi

$$FS = S_{yield} / S$$

where:

S_{yield} = yield stress on pipe (psi) — S_{yield} = 1500 psi — *Note: Typical yield strength of HDPE.*

FS = 1500 psi / 782.6 psi

FS = 1.92

Critical Pipe Wall Buckling

Pipe Type: 8 inch perforated HDPE, SDR 9

$$P_{wc} = \frac{5.65}{N}\sqrt{RB'E'\frac{E}{12(SDR-1)^3}}$$

Source: Eq. 7-32 from Performance Pipe, (2003).

where:

- P_{WC} = allowable constrained buckling pressure (psi)
- N = safety factor — N = 2
- R = bouyancy reduction factor
- B' = elastic support factor
- E' = soil reaction modulus (psi) — E' = 3,800 psi — *Source: Table 7-8 from Performance Pipe, (2003).*
- SDR = Standard Dimension Ratio — SDR = 9
- E = modulus elasticity of pipe — E = 13,000 psi — *Source: Table 1 from Performance Pipe, (2007).*

R = 1- (0.33*(H'/H)) — *Source: Eq. 7-34 from Performance Pipe, (2003).*

where

- H' = liquid height above pipe (ft) — H' = 0.3 ft
- H = cover height above pipe (ft) — H = 228.5 ft

R = 1 - (0.33 * (.3 ft / 228.5 ft))

R = 1

$B' = 1/(1+4e^{(-0.065H)})$ — *Source: Eq. 7-35 from Performance Pipe, (2003).*

B' = 1 / (1 + 4*exp(-0.065 * 228.5 ft))

B' = 1.000

Pwc = (5.65 / 2.) * {Sqrt [1. * 1. * 3800 psi *(13000 psi / (12 * (9 -1)^3))]}

Pwc = 181 psi

Applied Load = 25,043 psf = **174 psi** *Note: Previously calculated design pipe loading.*

Applied load is less than allowable constrained buckling pressure.

Ring Deflection

Pipe Type: 8 inch perforated HDPE, SDR 9

$$\frac{\Delta X}{D_i} = \frac{P_T}{144}\left[\frac{KL}{\frac{2E}{3}\left(\frac{1}{SDR-1}\right)^3 + 0.061E'}\right]$$

Source: Eq. 7-37 from Performance Pipe, (2003).

where:

ΔX = horizontal deflection (in)

Do = outside pipe diameter (in)	D_o =	7.551	in	
t = minimum wall thickness (in)	t =	0.958	in	
D_i = inside pipe diameter (in)	D_i =	6.593	in	
P_T = vertical pipe loading (psf)	P_T =	25,043	psf	
K = bedding factor	K =	0.1		*Note: Typical according to Performance Pipe, (2003).*
L = deflection lag factor	L =	1		*Source: Plastic Pipe Institute, (2009), pg. 216.*
E = elastic modulus (psi)	E =	13,000	psi	*Source: Table 1 from Performance Pipe, (2007).*
E' = soil reaction modulus (psi)	E' =	3,800	psi	*Source: Table 7-8 from Performance Pipe, (2003).*
SDR = standard dimension ratio	SDR =	9		

∆X/Di = (25043 psf / 144) * { (.1 * 1.) / [(2 * 13000 psi) / 3] * [1 / (9. - 1)^3 +(0.061 * 3800 psi)] }

$\Delta X/D_i$ = 0.0699

Ring Deflection = 6.99%

Allowable Ring Deflection = 7.5% *Source: Plastic Pipe Institute, (2009), pg. 218.*

References

Performance Pipe, (2003) "Book 2: Chapter 7 - Buried Pipe Design", *The Performance Pipe Engineering Manual*, Chevron Phillips Chemical Company, LP.

Performance Pipe, (2007) "Engineering Considerations for Temperature Change", *Technical Note 814-TN,* Chevron Phillips Chemical Company, LP.

Plastics Pipe Institute, (2009) "Chapter 6 - Design of PE Piping Systems", *Handbook of Polyethylene Pipe, Second Edition,* Plastic Pipe Institute, Inc.

Terracon	Made By: JCH	Date: 1/30/2015	Sheet No.: 1 of 7
	Checked By: MAK	Date: 1/30/2015	Job No.: EJ147410
	Calculations for: LCS Pipe Structural Stability - 18" Pipe		
	Emelle Facility		

Landfill Profile

Pipe Type: 18 inch perforated HDPE, SDR 9

Final Cover
height = 4.0 ft. unit weight = 130 pcf

Intermediate Cover
height = 1.0 ft. unit weight = 130 pcf

Waste Layer
height = 222.0 ft. unit weight = 110 pcf

Protective Cover Layer
height = 1.5 ft. unit weight = 120 pcf

Drainage Layer
height = 1.0 ft unit weight = 120 pcf

Prism Pipe Loading

$$P_E = wH$$

Source: Eq. 7-1 from Performance Pipe, (2003).

where:
- P_E = vertical soil pressure (psf)
- w = unit weight of soil (pcf)
- H = soil height above pipe crown

PE = (4. ft * 130 pcf) + (1. ft * 130 pcf) + (222. ft * 110 pcf) + (1.5 ft * 120 pcf) + (1. ft * 120 pcf)

P_E = 25,371 psf

Pipe Perforation Reduction

Diameter of perforation = 0.625 in
perforations per foot = 12
Perforated Area = 0.62%

Design Pipe Loading = (1 - 0.62 /100) x 25371 psf

Design Pipe Loading = 25,214 psf

Marston Pipe Loading

Pipe Type: 18 inch perforated HDPE, SDR 9

$$P_M = C_D w B_D$$

Source: Eq. 7-2 from Performance Pipe, (2003).

where:

P_m = vertical soil pressure (psf)

C_d = Load Coefficient

w = unit weight of soil (pcf) — w = (25371 psf) / (228.5 ft) = 111 pcf

B_d = trench width at pipe crown (ft) — B_d = 1E+07 ft *Note: Value for B_d assumes an infinitely wide trench.*

$C_D = [1-(e^{(-2K_{u'} *(H/B_D))})]/[2K_{u'}]$ *Source: Eq. 7-3 from Performance Pipe, (2003).*

e = natural log

$K_{u'}$ = Rankine earth pressure and frictic $K_{u'}$ = 0.192 *Source: Table 7-1 from Performance Pipe, (2003).*

H = soil height above pipe crown (ft) H= 4 ft + 1 ft + 222 ft + 1.5 ft = 228.5 ft

C_D = [1 - exp(-2 * 0.192 *(228.5 ft / 1.00E+07 ft))] / (2 * 0.192)

C_D = 2.3E-05

P_M = (2.28E-05) * (111. pcf) * (1.00E+07 ft)

P_M = 25,371 psf

Pipe Perforation Reduction

Diameter of perforation = 0.625 in
perforations per foot = 12
Perforated Area = 0.62%

Design Pipe Loading = (1 - 0.62 /100) x 25371 psf

Design Pipe Loading = 25,214 psf

Modified Arching Load

Pipe Type: 18 inch perforated HDPE, SDR 9

$$P_c = FwH$$

Source: Eq. 7-6 from Performance Pipe, (2003).

where:

P_c = modified arching vertical pressure (psf)
F= arching coefficient
w = unit weight of the soil — w = 111 pcf — *Note: As calculated on sheet no. 2.*
H = soil height above the pipe — H = 228.5 ft — *Note: As calculated on sheet no. 2.*

$F = [P_m + 0.4(P_E - P_m)]/P_E$ *Source: Eq. 7-7 from Performance Pipe, (2003).*

where:

P_m = Marston Load — P_m = 25,371 psf — *Note: As calculated on sheet no. 2.*
P_E = Prism Load — P_E = 25,371 psf — *Note: As calculated on sheet no. 2.*

F = [25371 psf + 0.4 * (25371 psf - 25371 psf)] / 25371 psf

F = 1

PC = (1.) * (111.03 pcf) * (25370.9 ft)

P_c = 25,371 psf

Pipe Perforation Reduction

Diameter of perforation = 0.625 in
perforations per foot = 12
Perforated Area = 0.62%

Design Pipe Loading = (1 - 0.62 /100) x 25371 psf

Design Pipe Loading = 25,214 psf

Wall Crushing Capacity **Pipe Type: 18 inch perforated HDPE, SDR 9**

$$S = \left(\frac{P_T}{288}\right)\text{SDR}$$

Source: Eq. 7-23 from Performance Pipe, (2003).

where:

S = pipe compressive stress (psi) P_t = 25,214 psf

P_t = vertical load applied (psf) SDR = 9

SDR = standard dimension ratio

S = (25214 psf / 288) * 9

S = 787.9 psi

$$FS = S_{yield} / S$$

where:

S_{yield} = yield stress on pipe (psi) S_{yield} = 1500 psi *Note: Typical yield strength of HDPE.*

FS = 1500 psi / 787.9 psi

FS = 1.90

Critical Pipe Wall Buckling

Pipe Type: 18 inch perforated HDPE, SDR 9

$$P_{wc} = \frac{5.65}{N}\sqrt{RB'E'\frac{E}{12(SDR-1)^3}}$$

Source: Eq. 7-32 from Performance Pipe, (2003).

where:

- Pwc = allowable constrained buckling pressure (psi)
- N = safety factor — N = 2
- R = bouyancy reduction factor
- B' = elastic support factor
- E' = soil reaction modulus (psi) — E' = 3,800 psi — *Source: Table 7-8 from Performance Pipe, (2003).*
- SDR = Standard Dimension Ratio — SDR = 9
- E = modulus elasticity of pipe — E = 13,000 psi — *Source: Table 1 from Performance Pipe, (2007).*

R = 1- (0.33*(H'/H)) — *Source: Eq. 7-34 from Performance Pipe, (2003).*

where

- H' = liquid height above pipe (ft) — H' = 0.0 ft
- H = cover height above pipe (ft) — H = 228.5 ft

R = 1 - (0.33 * (. ft / 228.5 ft))
R = 1.0

B' = 1/(1+4e$^{(-0.065H)}$) — *Source: Eq. 7-35 from Performance Pipe, (2003).*

B' = 1 / (1 + 4*exp(-0.065 * 228.5 ft))
B' = 1.000

Pwc = (5.65 / 2.) * {Sqrt [1. * 1. * 3800 psi *(13000 psi / (12 * (9 -1)^3))]}
Pwc = 181 psi

Applied Load = 25,214 psf = **175 psi** *Note: Previously calculated design pipe loading.*

Applied load is less than allowable constrained buckling pressure.

Ring Deflection

Pipe Type: 18 inch perforated HDPE, SDR 9

$$\frac{\Delta X}{D_i} = \frac{P_T}{144}\left[\frac{KL}{\frac{2E}{3}\left(\frac{1}{SDR-1}\right)^3 + 0.061E'}\right]$$

Source: Eq. 7-37 from Performance Pipe, (2003).

where:

ΔX = horizontal deflection (in)				
Do = outside pipe diameter (in)	D_o =	15.760	in	
t = minimum wall thickness (in)	t =	2.000	in	
D_i = inside pipe diameter (in)	D_i =	13.760	in	
P_T = vertical pipe loading (psf)	P_T =	25,214	psf	
K = bedding factor	K =	0.1		*Note: Typical according to Performance Pipe, (2003).*
L = deflection lag factor	L =	1		*Source: Plastic Pipe Institute, (2009), pg. 216.*
E = elastic modulus (psi)	E =	13,000	psi	*Source: Table 1 from Performance Pipe, (2007).*
E' = soil reaction modulus (psi)	E' =	3,800	psi	*Source: Table 7-8 from Performance Pipe, (2003).*
SDR = standard dimension ratio	SDR =	9		

ΔX/Di = (25214 psf / 144) * { (.1 * 1.) / [(2 * 13000 psi) / 3] * [1 / (9. - 1)^3 +(0.061 * 3800 psi)] }

$\Delta X/D_i$ = 0.0704

Ring Deflection = 7.04%

Allowable Ring Deflection = 7.5% *Source: Plastic Pipe Institute, (2009), pg. 218.*

References

Performance Pipe, (2003) "Book 2: Chapter 7 - Buried Pipe Design", *The Performance Pipe Engineering Manual*, Chevron Phillips Chemical Company, LP.

Performance Pipe, (2007) "Engineering Considerations for Temperature Change", *Technical Note 814-TN,* Chevron Phillips Chemical Company, LP.

Plastics Pipe Institute, (2009) "Chapter 6 - Design of PE Piping Systems", *Handbook of Polyethylene Pipe, Second Edition,* Plastic Pipe Institute, Inc.

Terracon	Made by: RSG	Date: 1/29/15	Sheet No.: COVER
	Checked by: JCH	Date: 1/29/15	Job No.: EJ147410
	Calculations for:	Structural Stability for Vertical Riser Pipes	
	Emelle Facility – Trench 23		

STRUCTURAL STABILITY FOR VERTICAL RISER PIPES

CALCULATION COVER SHEET

Calculations by:

Signature:

Name: Rajendra S. Gondhalekar, P.E.

Title: Project Engineer

1/29/2015
Date

Calculations Reviewed by:

Signature:

Name: J. Craig Hensley, E.I.T.

Title: Staff Engineer

1/29/2015
Date

Calculations Approved by:

Signature:

Name: Michael A. Kemp P.E.

Title: Department Manager

1/29/2015
Date

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	1/29/15	ALL	Initial Submittal

1.0 OBJECTIVE

Our objective is to determine the structural stability of the vertical riser pipes based on the proposed configuration of Trench 23.

2.0 METHOD

This vertical riser system over a majority of Emelle Trench 23 consists of a 48" diameter HDPE riser encased in a 60" diameter reinforced concrete riser. The outer concrete riser terminates at the surface of the granular material for the LCS sump, where it is supported by a 12' x 12' concrete base plate. The 48" HDPE riser within the LCS granular material is encased in a 54" diameter HDPE riser. Because of the greater thickness of waste in Trench 23 compared to Trench 22, larger wall thicknesses were selected for all of the riser components described above.

3.0 DESIGN DESCRIPTION

The proposed outer concrete riser will be subjected to downward force due to the surrounding Trench 23 waste, and the self-weight of the pipe. The base plate will be subjected to the same downward forces as well as additional downward force due to the weight of the soil above the base plate. The downward force at the base the pipe will result in compressive stress in the pipe wall. The concrete pipe will also be subjected to flexural and radial stress due to the lateral pressures at the base of the pipe (based on the downward force at the base). The base plate will be subjected to a bearing pressure due to the downward force.

The portion of the proposed composite HDPE 48" and 54" riser below the concrete encasing will be subjected to a downward force faced on the bearing pressure of the base plate. This downward force will result in lateral pressures at the base of the HDPE pipes, subjecting it to wall crushing, wall buckling, and causing a deflection of the pipe.

This analysis methodologies and associated assumptions are identical to those used by Golder Associates during the design of Trench 22. Differences in the Trench 23 analyses are a result of greater height of waste and larger pipe thicknesses to resist the increased associated forces.

3.1 Concrete Pipe Analysis

The analysis for the concrete pipe is provided in Exhibit 1, coded as a Microsoft Escel spreadsheet solution to the design equations. As indicated, the selected concrete pipe is of a sufficient thickness and strength and the selected base plate is sufficiently wide to resist the anticipated force (which neglects cohesion for the surrounding waste).

3.2 HDPE Pipe Analysis

The analysis for the HDPE pipe is provided in Exhibit 2, coded as a Microsoft Excel spreadsheet solution to the design equations. As indicated, the selected HDPE pipes are of a sufficient thickness and strength to anticpated force.

3.3 Conclusions

The proposed HDPE and concrete riser pipes and the concrete riser base pad are adequately sized to resist the anticipated loads.

EXHIBIT 1

Stability of Concrete Pipe

Structural Stability of Concrete Riser

The following calculations evaluate the structural stability of the concrete riser against crushing from downdrag forces, bending and radial stress due to lateral forces, and the bearing capacity of the reinforced concrete base plate.

Equations and Input Parameters:

The details of the vertical riser are shown on drawing 00-300-009. The height of the riser will vary with each cell. The following input parameters are assumed for the pipe:

d_i	(Inside diameter of pipe)	=	60	in
d_o	(outside diameter of pipe)	=	73.5	in
f'_c	(allowable compressive strength of concrete)	=	4000	psi
t	(wall thickness of pipe)	=	6.75	in
A	(cross sectional area of the pipe)	=	1415	in2
γ_c	(unit weight of concrete)	=	150	pcf
B	(width of base plate)	=	12	ft

The waste is assumed to have the following properties:

c	(waste cohesion)	=	650	psf
ϕ	(wastefriction angle)	=	15	degrees
μ	(coefficient of friction between waste and coated pipe)	=	0.2	
K_0	(coefficient of at rest lateral earth pressure)	=	0.74	
γ_w	(unit weight of waste)	=	110	pcf

The most conservative analysis location, with the tallest riser height is Trench 23, Cell 1, for which the following design elevations are obtained:

Final Cover Elevation	=	359.0	ft
Top of LCS Granular Material Elevation	=	179.1	ft
Top of Liner Elevation	=	172.2	ft
Thickness of Final Cover	=	4.1	ft
Required Spacing Below Final Cover	=	10.0	ft

Based on the thickness of final cover soil, the required spacing between bottom of final cover and top of

Top of Concrete Pipe Elevation	=	344.9	ft
H (Total Length of Riser)	=	179.9	ft
h (Length of HDPE segment above Concrete Pipe)	=	14.1	ft

Based on the design parameters above the horizontal pressre ancting on the pipe circumference is calculated

$$P_h = \frac{1}{2} \cdot [(K_0 \cdot \gamma_w \cdot H) + (K_0 \cdot \gamma_w \cdot h)] \cdot (H - h)$$

P_h (average horizontal pressure on concrete pipe) = 1311212.9 lb/ft

Total downdrag force acting on the pipe is calculated using the following equation:

$$P_d = P_h \cdot \mu \cdot \pi \cdot d_o$$

P_d (total downdrag force on concrete pipe) = 5046138.4 lb

The cocrete pipe will be subjected to additional downward force due to the weight of the pipe, while the base plate will be subjected to both the weight of the pipe and the weight of waste above base plate. The forces are calculated using the following equations:

$$W_p = \gamma_c \cdot A \cdot (H - h)$$

W_p	(weight of concrete pipe)	=	244465.9	lb

and:

$$W_s = \gamma_w \cdot \left(A_p - A_b\right) \cdot H$$

Where A_b = Area of base plate, and A_p = Exterior area of pipe

A_p	(external area of pipe)	=	29.5	ft^2
A_b	(area of base plate)	=	144.0	ft^2
W_s	(weight of waste above base plate)	=	2266539.0	lb

The total downward force on the vertical concrete riser is calculated as:

$$F_p = P_d + W_p \quad = \quad 5290604.3 \text{ lb}$$

Factor of Safety for pipe crushing

The compressive stress on the base of the pipe is calculated as:

$$\sigma_c = \frac{F_p}{A} \quad = \quad 3737.7 \text{ psi}$$

$$FS = \frac{f'_c}{\sigma_c} \quad = \quad 1.1$$

OK (as reduction in force due to coating of pipe is neglected)

Factor of Safety for pipe flexture

The vertical stress at the base of the riser is calculated as:

$$\sigma_v = H * \gamma_w \quad = \quad 19789.0 \text{ psf}$$

The horizontal stress at the base of the riser is calculated as:

$$\sigma_h = \sigma_v \cdot K_0 \quad = \quad 14667.2 \text{ psf}$$

The hoop stress at the base of the riser is calculated as:

$$\sigma_t = -\sigma_h \cdot \left(\frac{2 \cdot a^2}{a^2 - b^2}\right)$$

Where $a = d_o / 2$ and $b = d_i / 2$ = -87930.1 psf = -610.6 psi

assuming a 30% reduction in concrete strength to account for flexture

$$FS = 0.7 \cdot \frac{f'_c}{\sigma_t} \quad = \quad 4.6$$

OK

Factor of Safety for radial stress

The hoop stress at the base of the riser is calculated as:

$$\sigma_r = \frac{-\sigma_h \cdot a^2 \cdot (r^2 - b^2)}{r^2 \cdot (a^2 - b^2)}$$ Where a = d_o / 2, b = d_i / 2, and r = radius as which stress is calculated

Since maximum radial stress will occur at the exterior of the pipe r = a

By simplification:

$\sigma_r = -\sigma_h$	=	-14667.2	psf
	=	-101.9	psi
$FS = \frac{f'_c}{\sigma_h}$	=	39.3	OK

Factor of Safety for base bearing capacity

The total downward force on the base plate is calculated as:

$F_b = P_d + W_p + W_s$	=	7557143.3	lb

The base plate is underlain by chalk protective layer, LCS gravel, geoynthetics, and compacted chalk liner. The bearing capacity of the base plate is conservatively assumed to be based on the properties of compacted chalk (i.e., c = 600 psf, ϕ = 26°)

The bearing capacity is calculated using the following equation:

$$q_u = \frac{B \cdot \gamma}{2} \cdot N_\gamma + c \cdot N_c + q_q \cdot N_q$$

For ϕ = 26° and deep local shear failure: N_γ = 18, N_c = 26, and N_q = 18

Based on recommendations for pile bearing capacity, q_q will be limited to stress at a depth of 10 times d_o

$q_q = \gamma_w \cdot 10 \cdot d_o$	=	6737.5	psf
q_u = Ultimate bearing capacity of base plate	=	148755.0	psf

The applied bearing pressure at the base plate is calculated as:

$q_b = \frac{F_b}{B^2}$	=	52480.2	psf
$FS = \frac{q_u}{q_b}$	=	2.8	OK

EXHIBIT 2

Stability of HDPE Pipe

Structural Stability of HDPE Riser

The following calculations evaluate the structural stability of the HDPE riser against wall crushing, wall buckling, and ring deflection, based on the maximum applied vertical and horizontal pressure on the riser.

Equations and Input Parameters:

The details of the vertical riser are shown on drawing 00-300-009. The height of the riser will vary with each cell. The HDPE riser within the leachate collection system will consist of a 48 in diameter SDR 13.5 pipe with a supporting 54 inch diameter SDR 21 pipe. For the utlization as designed in the project, the two pipes will act together as a composite section. The following input parameters are assumed for the composite pipe:

d_{i1}	(Inside diameter of outer pipe)	=	48.55	in
t_1	(wall thickness of pipe)	=	2.077	in
d_{i2}	(Inside diameter of outer pipe)	=	40.46	in
t_2	(wall thickness of pipe)	=	3.556	in
d_o	(outside diameter of composite pipe)	=	52.70	in
d_i	(virtual Inside diameter of composite pipe)	=	41.44	in
t	(wall thickness of composite pipe)	=	5.633	in
SDR	(standard diameter ratio of composite pipe)	=	9.4	
T_{yeild}	(yield strength of HDPE material)	=	1500	psi
E_{pipe}	(elastic modulus of pipe material)	=	13000	psi

The maximum pressure acting on the HDPE pipe was based on the bearing pressure at the base plate of the concrete pipe

σ_v	(maximum vertical stress)	=	52480	psf
		=	364.4	psi

The backfill around the HDPE riser will consist of the LCS drainage layer granular material (i.e., gravel) and was assumed to have the follwing propeties:

ϕ	(friction angle of granular material)		=	30	degrees
E_{soil}	(elastic modulus of granular material at 85-95% std. Proctor)		=	2000	psi
$E_{r\text{-}sub}$	(subgrade reaction of soil = 2 * E_{soil})		=	4000	psi
K_0	(oefficient of at rest earth pressure)	$=1-\sin(\emptyset)$	=	0.5	

Based on the maximum vertical stress and the backfill properties, the maximum horizontal stress is calculated

σ_h (maximum horizontal stress) $= K_0 \cdot \sigma_v$ = 182.2 psi

Factor of Safety for wall crushing

The compressive stress in the pipe is calculated as follows:

$$S_A = \frac{(SDR-1)\cdot\sigma_h}{2}$$ = 761.3 psi

Therefore

$$FS = \frac{T_{yield}}{S_A}$$ = 2.0 > 2 OK

Factor of Safety for wall buckling

The critical hydrostatic collapse differential pressure for the pipe is calculated as follows:

$$P_c = \frac{2.32 \cdot E_{pipe}}{SDR^3}$$ = 36.83 psi

The critical buckling soil pressure is calculated as follows:

$$P_{cb} = 0.8 \cdot \sqrt{E_{soil} \cdot P_c}$$ = 217.1 psi

Therefore

$$FS = \frac{P_{cb}}{\sigma_h}$$ = 1.2 > 1 OK

Ring Deflection

The ring deflection for the pipe is calculated as follows:

$$\Delta y = \frac{D_l \cdot k \cdot \sigma_h \cdot d_o}{\left[\frac{2 \cdot E_{pipe}}{3 \cdot (SDR + 1)^3}\right] + 0.061 \cdot E_{r-sub}}$$

Where:

D_L (deflection lag factor)	=	1.0	(for load prism)
d (bedding constant)	=	0.1	

Therefore

Δy = 3.874 in

$$\text{Ring Deflection} = \frac{\Delta y}{d_o}$$ = 0.074 < 0.09 OK

Terracon	Made by:	RSG	Date:	1/29/15	Sheet No.:	COVER
	Checked by:	JCH	Date:	1/29/15	Job No.:	EJ147410
	Calculations for:	Final Cover Settlement Analysis				
	Emelle Facility – Trench 23					

FINAL COVER SETTLEMENT ANALYSIS

CALCULATION COVER SHEET

Calculations by:

Signature: [signature]

Name: Rajendra S. Gondhalekar, P.E.

Title: Project Engineer

1/29/2015
Date

Calculations Reviewed by:

Signature: [signature]

Name: J. Craig Hensley, E.I.T.

Title: Staff Engineer

1/29/2015
Date

Calculations Approved by:

Signature: [signature]

Name: Michael A. Kemp P.E.

Title: Department Manager

1/29/2015
Date

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	1/31/15	ALL	Initial Submittal

1.0 OBJECTIVE

Evaluate the settlement of the final cover as a result of change in stress in the upper 20 ft of waste below the cover due to construction of the final cover.

2.0 METHODOLOGY

The compression of the upper 20 ft waste as a result of placement of final cover soils (total thickness 4 ft) and the resulting impact on the landfill final cover system were evaluated. The first step in the evaluation was to input the geometry of the final cover and waste mass and the physical properties of the waste at discreet points along a selected cross section into a Microsoft Excel spreadsheet and perform a one-dimensional settlement analysis at each analysis location. This allows for an estimation of both post settlement final cover grades and the resulting tensile stresses in the final cover system.

3.0 SUBSURFACE CONDITIONS AND MATERIALS

Detailed description of the subsurface conditions is provided in various reports contained in Attachment E of the permit application. The information was previously compiled into engineering properties for settlement analyses by Golder Associates in the engineering calculation package for Trench 22, contained in Attachment D-6-1-7. A majority of the information remains relevant to the analysis of Trench 23 and has been utilized again.

Design drawings of the final cover grades of the landfill were used to identify a representative cross section for settlement analysis. The selected cross section location is shown in Figure 1 in relation to the proposed final cover system. The geometry of the landfill and along the analyzed cross section is shown in Figure 2.

<u>Soil Layer Data:</u>

Since the landfill waste placement will occur in phases, only the final 20 ft of waste in the landfill is assumed to consolidate after placement of the final cover system. This assumption is consistent with the final cover settlement analysis for Trench 22 by Golder Associates.

<u>Layer 1 – Compressible Waste</u>

This layer was modeled as an up to 20 ft thick normally consolidated soil layer with a Compression Index of 0.35 and an initial void ratio of 1.2, which were based on data presented by Golder Associates in the final cover settlement analysis of Trench 22. The layer was assumed to have a total unit weight of 110 psf. The secondary compression index for the waste was not provided in the Golder Associates analysis, therefore we conservatively selected a secondary compression index of 0.05 to model the effects of post closure secondary compression, which was calculated for a period of 30 years.

The placement of final cover soil (unit weight 130 pcf) was assumed to result in an increase in stress in the upper layer of waste. The change in stress was estimated at the midpoint of the compressible layer layer, and the resulting change in layer thickness was estimated using consolidation and secondary compression properties. The difference in settlement between two adjacent points was then used to compute the change is slope and any induced tensile stresses.

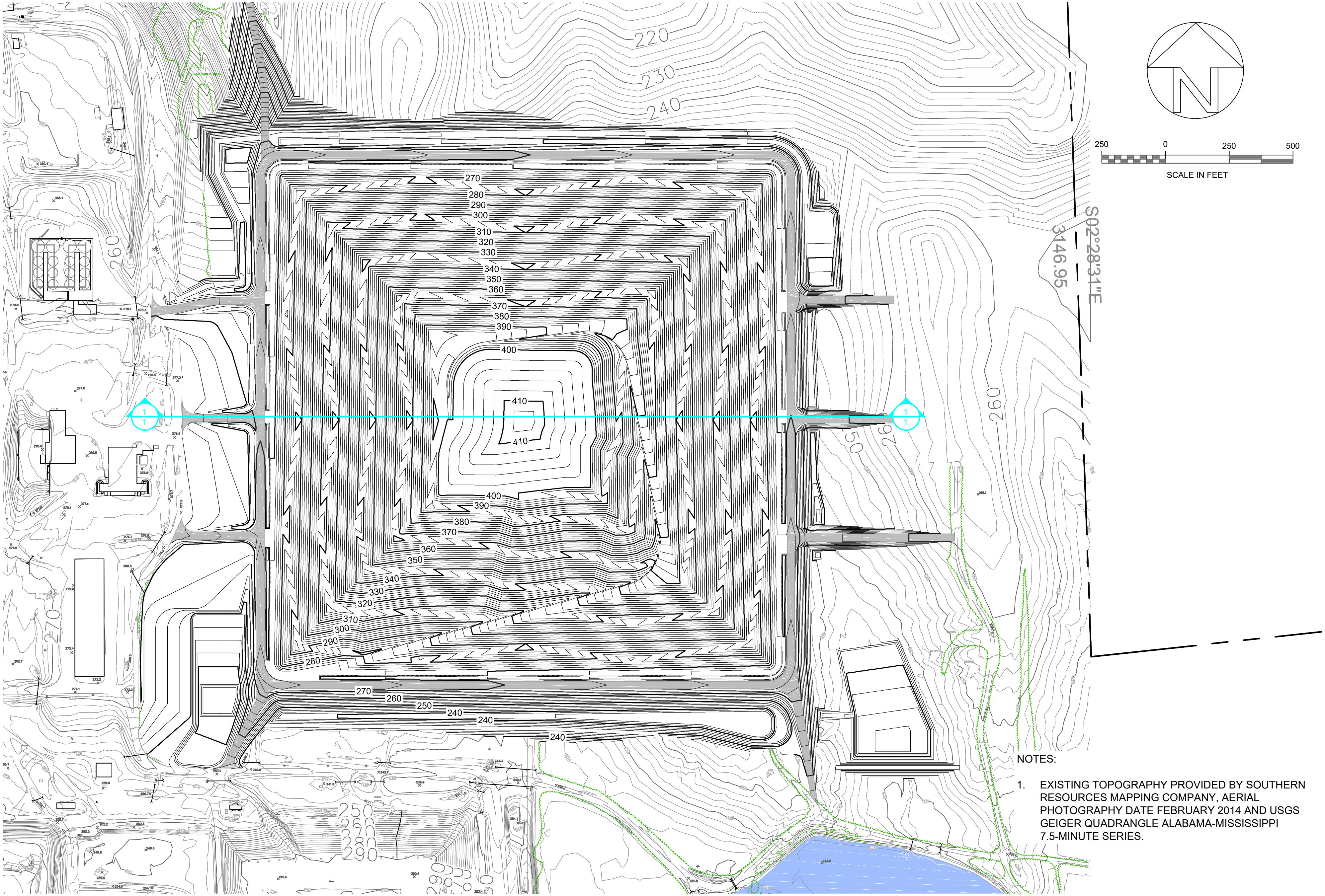
4.0 ANALYSIS RESULTS

The output for the spreadsheet computation of the base grade settlement analysis is attached. As indicated the subgrade settlement ranges from 0.88 to 2.01 ft under the landfill final cover. Based on this computed settlement, no tensile strains are calculated in the final cover system. The overall final cover system will continue to slope towards the exterior post closure with no localized reversals in slopes as a result of the anticipated settlement.

5.0 CONCLUSIONS

The analysis indicates that the proposed landfill geometry is adequately designed to accommodate the anticipated final cover settlements.

FIGURES



NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.

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Project Mngr: MAK	Project No. EJ147410		
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Checked By: JCH	File No. --		
Approved By: RSG	Date: 1/29/2015		

Terracon
Consulting Engineers and Scientists
240 HERITAGE WALK, SUITE 103 WOODSTOCK, GA 30188
PH. (770) 924-9799 FAX. (770) 924-7866

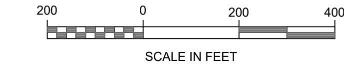
ANALYSIS CROSS SECTION LOCATION

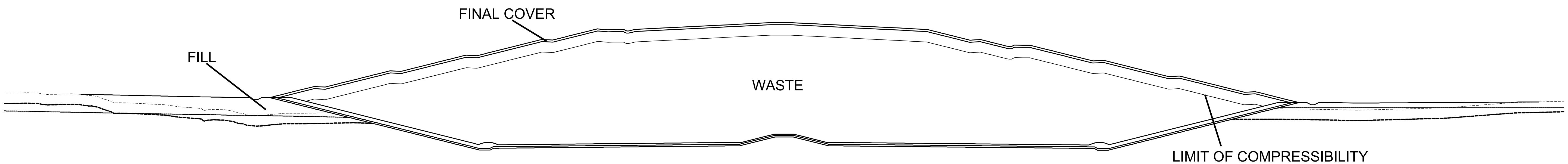
FINAL COVER SETTLEMENT ANALYSIS

EMELLE FACILITY

CHEMICAL WASTE MANAGEMENT

FIG. No. 1





Project Mngr: MAK	Project No. EJ147410	Terracon Consulting Engineers and Scientists	ANALYSIS PROFILE FINAL COVER SETTLEMENT ANALYSIS EMELLE FACILITY CHEMICAL WASTE MANAGEMENT
Drawn By: RSG	Scale: AS-SHOWN	240 HERITAGE WALK, SUITE 103 WOODSTOCK, GA 30188	
Checked By: JCH	File No. --	PH. (770) 924-9799 FAX. (770) 924-7866	
Approved By: RSG	Date: 1/29/2015		

FIG. No. 2

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ATTACHMENT 1

Final Cover Settlement Results

Final Cover Settlement Analysis

Point No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Horizontal Distance	468.00	508.76	549.30	639.27	729.23	819.19	909.15	935.60	1030.03	1124.46	1218.89	1313.32	1407.75	1475.20	1510.25	1577.74	1652.74	1739.11	1825.47	1911.8351	1998.20	2084.56	2113.62	2194.45	2275.27	2356.76	2436.93	2477.49	2516.87
Top of Final Cover Elevation (ft MSL)	269.22	269.60	279.73	296.00	318.41	334.61	350.81	357.42	380.77	398.34	400.58	405.30	410.02	413.00	412.76	409.39	405.65	401.34	385.16	369.81	361.01	339.63	338.50	318.30	304.37	284.17	270.23	260.10	246.85
Top of Waste Elevation (ft MSL)	269.22	269.60	275.61	291.80	314.12	334.61	346.69	353.37	376.77	394.22	396.57	401.29	406.01	409.00	408.76	405.39	401.65	397.34	381.03	365.69	356.90	335.62	334.38	314.17	300.25	280.04	266.11	260.10	246.85
Top of Liner Elevation (ft MSL)	269.22	269.60	269.19	246.70	224.22	201.73	179.99	182.47	179.86	180.81	181.75	182.70	183.64	199.50	200.04	183.65	182.90	182.03	181.17	180.30	179.44	181.73	179.89	199.08	219.28	239.49	259.69	260.10	246.85
Subgrade Elevation (ft MSL)	269.22	269.19	259.05	236.62	213.94	191.58	169.08	171.94	173.34	174.29	175.23	176.18	177.12	193.99	194.00	177.13	176.38	175.51	174.65	173.78	172.92	172.06	168.72	188.92	209.13	229.34	249.55	259.69	246.85
Final Cover Thickness (ft)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Final Cover Unit Weight (pcf)	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00	130.00
Change in Stress (psf)	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00	520.00
Compressible Waste Thickness (ft)		0.00	6.42	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	6.42	0.00	
Waste Unit Weight (pcf)		110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	
Initial Stress (psf)		0.00	353.10	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	1100.00	353.19	0.00	
Initial Void Ratio		1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	
Compression Index		0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	
Primary Settlement (ft)		0.00	0.40	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.40	0.00	
Secondary Comression Index		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
Start of Secondary Compression (years)		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
End of Secondary Compression (years)		30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	
Secondary Compression (ft)		0.00	0.47	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	0.47	0.00	

Total Settlement		0.00	0.88	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	0.88	0.00	
Initial Slope of Final Cover (ft/ft)			0.25	0.18	0.25	0.18	0.18	0.25	0.25	0.19	0.02	0.05	0.05	0.04	-0.01	-0.05	-0.05	-0.05	-0.19	-0.18	-0.10	-0.25	-0.04	-0.25	-0.17	-0.25	-0.17	-0.25	
Final Slope of Final Cover (ft/ft)			0.23	0.17	0.25	0.18	0.18	0.25	0.25	0.19	0.02	0.05	0.05	0.04	-0.01	-0.05	-0.05	-0.05	-0.19	-0.18	-0.10	-0.25	-0.04	-0.25	-0.17	-0.25	-0.16	-0.23	
Initial Segment Length (ft)			41.34	91.42	92.70	91.81	91.07	27.28	97.28	96.04	94.46	94.55	94.55	67.52	35.05	67.58	75.09	86.47	87.88	87.72	86.81	88.96	29.08	83.31	82.02	83.96	81.37	41.35	
Final Segment Length (ft)			41.17	91.22	92.70	91.81	91.07	27.28	97.28	96.04	94.46	94.55	94.55	67.52	35.05	67.58	75.09	86.47	87.88	87.72	86.81	88.96	29.08	83.31	82.02	83.96	81.18	41.19	
Strain (%, Tensile Negative)			0.39	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.39	

Terracon	Made by:	RSG	Date:	1/29/15	Sheet No.:	COVER
	Checked by:	JCH	Date:	1/29/15	Job No.:	EJ147410
	Calculations for:	Liner System Settlement Analysis				
	Emelle Facility – Trench 23					

LINER SYSTEM SETTLEMENT ANALYSIS

CALCULATION COVER SHEET

Calculations by:

Signature: [signature]
Name: Rajendra S. Gondhalekar, P.E.
Title: Project Engineer

1/29/2015
Date

Calculations Reviewed by:

Signature: [signature]
Name: J. Craig Hensley, E.I.T.
Title: Staff Engineer

1/29/2015
Date

Calculations Approved by:

Signature: [signature]
Name: Michael A. Kemp P.E.
Title: Department Manager

1/29/2015
Date

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	1/29/15	ALL	Initial Submittal

1.0 OBJECTIVE

Evaluate the base grade settlements as a result of the change in stress in the soils and chalk below the subgrade level due to construction of Trench 23 and placement of waste in the landfill.

2.0 METHODOLOGY

The compression of the subgrade soil and chalk as a result of placement of waste in Trench 23 and the resulting impact on the landfill liner system were evaluated. The first step in the evaluation was to input the geometry of the soil/chalk and waste mass and the physical properties of the soil/chalk and waste at discreet points along a selected cross section into a Microsoft Excel spreadsheet and perform a one-dimensional settlement analysis at each analysis location. This allows for an estimation of both post settlement base grades and the resulting tensile stresses in the liner system.

3.0 SUBSURFACE CONDITIONS AND MATERIALS

Detailed description of the subsurface conditions is provided in various reports contained in Attachment E of the permit application. The information was previously compiled into engineering properties for settlement analyses by Golder Associates in the engineering calculation package for Trench 22, contained in Attachment D-6-1-7. A majority of the information remains relevant to the analysis of Trench 23 and has been utilized again.

Design drawings of the liner system and final cover grades of the landfill were used to identify a representative cross section for settlement analysis. The selected cross section location is shown in Figure 1 and 2 in relation to the proposed liner system and final cover system respectively. The geometry of the landfill and subsurface soils along the analyzed cross section is shown in Figure 3.

Soil Layer Data:

The subgrade soil was divided in 4 different layers at each analysis location to represent distinct strata of the underlying soil and chalk. The following subgrade soil material properties were used for each layer based on experience and the references cited above.

Layer 1 – Recompacted Chalk Layer

This layer was modeled as an a 3 ft thick overconsolidated soil layer with a Compression Index of 0.25 and an initial void ratio of 0.84, which were based on data presented by Golder Associates during settlement analysis of Trench 22. The preconsolidation pressure was typically assumed to be equal to 4000 psf, except at analysis locations near the edge where the final stress at the subgrade level was smaller than 4,000 psf. The layer was assumed to have a total unit weight of 120 psf.

Layer 2 – Fill

This layer was modeled as a normally consolidated soil layer with a Compression Index of 0.25 and an initial void ratio of 0.84, which were based on previous data from Golder associates. The layer was only modeled to be present at the analysis locations near the exterior, where the subgrade proposed elevations were higher than existing ground elevations. This layer was also assumed to have a total unit weight of 120 psf. The thickness of this layer ranged from 0 ft to 33.07 ft.

Layer 3 – Weathered Chalk

The stratum between the existing ground surface and an elevation of 20 ft below was assumed to be a zone of weathered chalk, and was modeled as an overconsolidated soil layer with a Compression Index of 0.25 and an initial void ratio of 0.84, which were based on data presented by Golder Associates during settlement analysis of Trench 22 for a recompacted chalk layer. The preconsolidation pressure was assumed to be equal to 4000 psf. The layer was assumed to have a total unit weight of 110 psf. The thickness of these layers ranged was assumed to be a maximum of 20 ft. Since in the central portion of Trench 23, the proposed excavation will exceed 20 ft in depth, this layer was assumed to be removed during excavation, and was not modeled.

Layer 4 – Intact Chalk

The stratum below the bottom of weathered chalk was assumed to consist of a zone of intact chalk and was modeled as an elastic soil with a modulus of 16,000,000 psf, which was identical to that used by Golder Associates during settlement analysis of Trench 22. Based on previous assumption by Golder, that the upper 100 ft of chalk below the landfill excavation is compressible, the rest is not compressible; the base of this layer was assumed to be at an elevation of 71.4 ft MSL, marking the limit of all compressible strata.

The placement of engineered fill (unit weight 120 pcf), liner soil (unit weight 120 pcf), waste (unit weight 110 pcf), and the final cover soil (unit weight 120 psf) were assumed to result in an increase in stress in the layers 3 and 4, whereas only the increase in stress due to liner soil, waste, and final cover soil were considered for layers 1 and 2, because these layers are located above the base of the engineered fill. The change in stress was estimated at the midpoint of each layer, and the resulting change in layer thickness was estimated using either elastic or consolidation properties. The difference in settlement between two adjacent points was used to compute the change is slope and, any induced tensile stresses.

4.0 ANALYSIS RESULTS

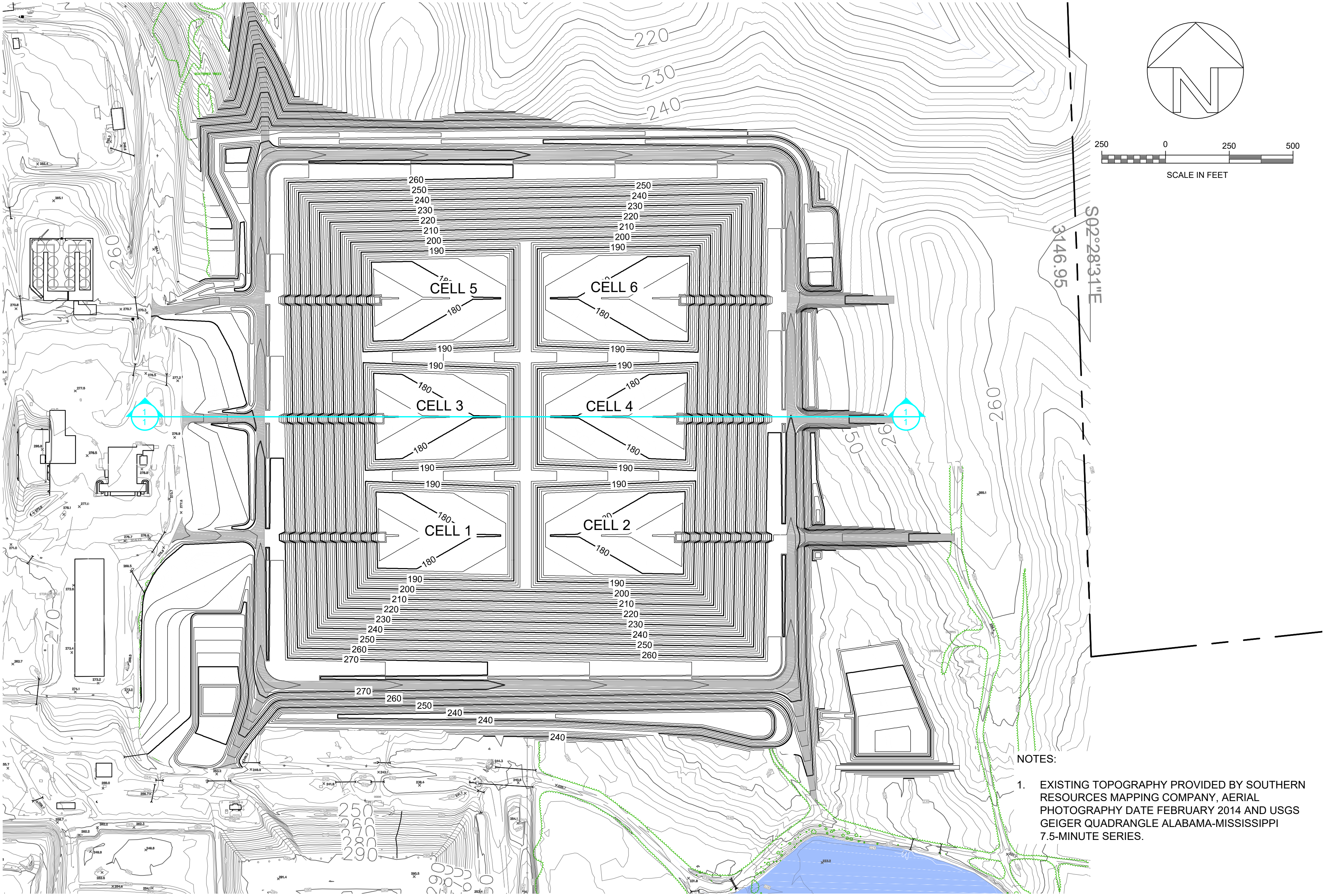
The output for the spreadsheet computation of the base grade settlement analysis is attached. As indicated the subgrade settlement ranges from 0.041 to 0.382 ft (i.e., 0.49 to 4.58 inches) under the landfill liner. Based on this computed settlement, the maximum tensile strain in the liner system is anticipated to be 0.012% (which is significantly less than the typically acceptable value of 5%). The overall landfill

Leachate Collection System slope towards the sumps is maintained with no localized reversals in slopes as a result of the anticipated settlement.

5.0 CONCLUSIONS

The analysis indicates that the proposed landfill geometry is adequately designed to accommodate the anticipated base grade settlements.

FIGURES



NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.

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Project Mngr:	MAK	Project No.	EJ147410
Drawn By:	RSG	Scale:	AS-SHOWN
Checked By:	JCH	File No.	--
Approved By:	RSG	Date:	1/29/2015

Terracon
Consulting Engineers and Scientists
240 HERITAGE WALK, SUITE 103 WOODSTOCK, GA 30188
PH. (770) 924-9799 FAX. (770) 924-7866

ANALYSIS CROSS SECTION LOCATION
LINER SETTLEMENT ANALYSIS
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIG. No. 1

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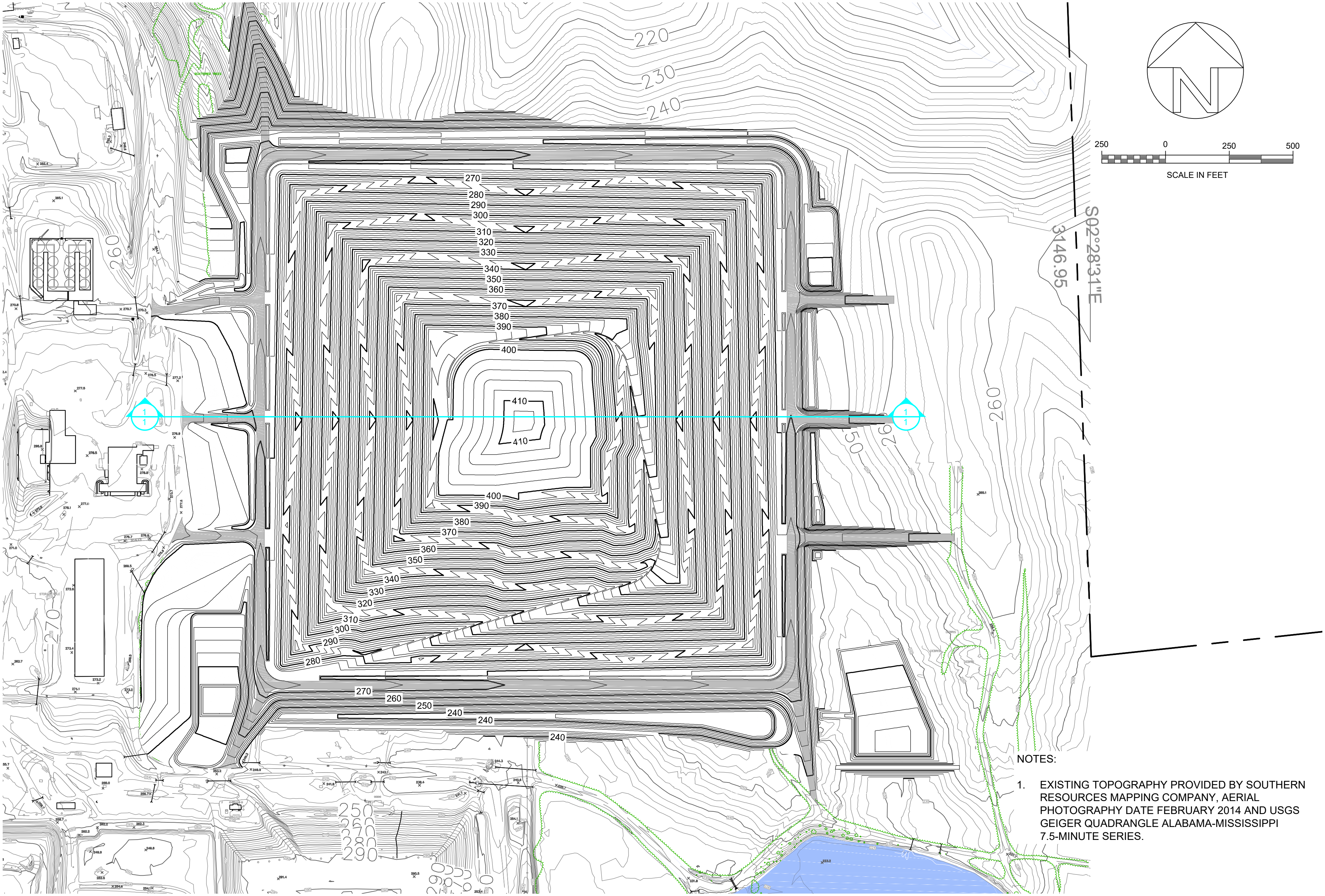

NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.

Project Mngr: MAK	Project No. EJ147410		
Drawn By: RSG	Scale: AS-SHOWN		
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Terracon
Consulting Engineers and Scientists
240 HERITAGE WALK, SUITE 103 WOODSTOCK, GA 30188
PH. (770) 924-9799 FAX. (770) 924-7866

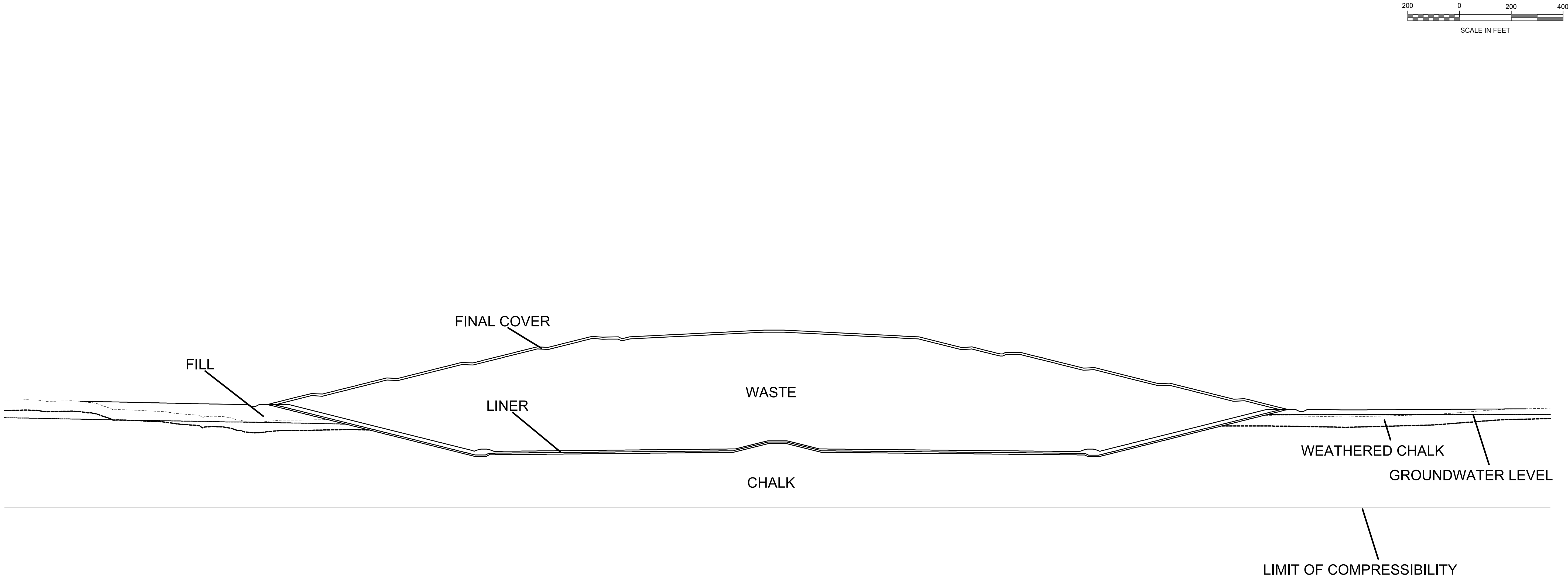
ANALYSIS CROSS SECTION LOCATION

LINER SETTLEMENT ANALYSIS

EMELLE FACILITY

CHEMICAL WASTE MANAGEMENT

FIG. No. 2



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Project Mngr:	MAK	Project No.	EJ147410
Drawn By:	RSG	Scale:	AS-SHOWN
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Terracon
Consulting Engineers and Scientists
240 HERITAGE WALK, SUITE 103 WOODSTOCK, GA 30188
PH. (770) 924-9799 FAX. (770) 924-7866

ANALYSIS PROFILE
LINER SETTLEMENT ANALYSIS
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIG. No.
3

ATTACHMENT 1

Liner System Settlement Results

Point No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Horizontal Distance	468.00	508.76	549.30	639.27	729.23	819.19	909.15	935.60	1030.03	1124.46	1218.89	1313.32	1407.75	1475.20	1510.25	1577.74	1652.74	1739.11	1825.47	1911.8351	1998.20	2084.56	2113.62	2194.45	2275.27	2356.76	2436.93	2477.49	2516.87
Top of Final Cover Elevation (ft MSL)	269.22	269.60	279.73	296.00	318.41	334.61	350.81	357.42	380.77	398.34	400.58	405.30	410.02	413.00	412.76	409.39	405.65	401.34	385.16	369.81	361.01	339.63	338.50	318.30	304.37	284.17	270.23	260.10	246.85
Top of Waste Elevation (ft MSL)	269.22	269.60	275.61	291.80	314.12	334.61	346.69	353.37	376.77	394.22	396.57	401.29	406.01	409.00	408.76	405.39	401.65	397.34	381.03	365.69	356.90	335.62	334.38	314.17	300.25	280.04	266.11	260.10	246.85
Top of Liner Elevation (ft MSL)	269.22	269.60	269.19	246.70	224.22	201.73	179.99	182.47	179.86	180.81	181.75	182.70	183.64	199.50	200.04	183.65	182.90	182.03	181.17	180.30	179.44	181.73	179.89	199.08	219.28	239.49	259.69	260.10	246.85
Subgrade Elevation (ft MSL)	269.22	269.19	259.05	236.62	213.94	191.58	169.08	171.94	173.34	174.29	175.23	176.18	177.12	193.99	194.00	177.13	176.38	175.51	174.65	173.78	172.92	172.06	168.72	188.92	209.13	229.34	249.55	259.69	246.85
Existing Ground Elevation (ft MSL)	236.15	236.95	239.40	240.68	239.94	236.90	232.69	230.98	227.05	235.93	243.52	250.89	260.00	264.49	267.04	272.64	278.32	281.96	278.24	273.09	267.76	262.17	260.30	254.41	249.63	248.15	247.89	247.61	246.85
Groundwater Elevation (ft MSL)	235.44	234.65	233.94	232.04	230.01	230.01	230.01	230.01	230.01	230.01	230.01	235.22	242.57	249.19	250.01	250.01	250.01	250.01	250.01	250.01	250.01	250.01	250.01	250.01	250.01	250.01	250.01	250.01	250.01
Cut (ft)	0.00	0.00	0.00	4.06	26.00	45.32	63.60	59.04	53.70	61.64	68.28	74.71	82.88	70.51	73.04	95.52	101.95	106.45	103.59	99.30	94.83	90.11	91.58	65.48	40.50	18.81	0.00	0.00	0.00
Fill (ft)	33.07	32.24	19.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.66	12.08	0.00
Fill Soil Density (pcf)	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0
Liner Soil Thickness (ft)	0.00	0.41	10.14	10.08	10.27	10.15	10.90	10.54	6.52	6.52	6.52	6.52	6.52	5.51	6.04	6.52	6.52	6.52	6.52	6.52	6.52	9.67	11.17	10.16	10.15	10.15	10.14	0.41	0.00
Liner Soil Density (pcf)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
Cover Soil Thickness (ft)	0.00	0.00	4.12	4.20	4.29	0.00	4.12	4.05	4.01	4.12	4.01	4.01	4.01	4.00	4.01	4.00	4.00	4.01	4.12	4.12	4.11	4.01	4.12	4.12	4.12	4.12	4.12	0.00	0.00
Cover Soil Density (pcf)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
Waste Thickness (ft)	0.00	0.00	6.42	45.09	89.90	132.88	166.70	170.90	196.91	213.42	214.82	218.59	222.36	209.50	208.72	221.74	218.75	215.30	199.87	185.39	177.46	153.90	154.49	115.09	80.96	40.56	6.42	0.00	0.00
Waste Density (pcf)	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
Change in Stress (psf)	3968.40	3917.86	4775.40	6227.57	8776.40	10849.81	13143.74	14054.83	17015.01	17971.21	17381.77	17090.60	16607.31	16430.74	16129.65	15147.95	14111.56	13236.98	11867.05	10746.61	10364.51	8657.87	8755.00	7170.45	6164.16	4104.56	2617.17	1497.94	0.00
Change in Stress at Subgrade Level (psf)	0.00	49.06	2417.40	6227.57	8776.40	10849.81	13143.74	14054.83	17015.01	17971.21	17381.77	17090.60	16607.31	16430.74	16129.65	15147.95	14111.56	13236.98	11867.05	10746.61	10364.51	8657.87	8755.00	7170.45	6164.16	4104.56	2417.92	48.84	0.00
Layer 1 (Recompacted Chalk)																													
Layer Thickness (ft)			3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00		
Initial Stress (psf)			2417.40	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	2417.92		
Initial Void Ratio			0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84		
Compression Index			0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25		
Layer Settlement (ft)			0.000	0.078	0.139	0.177	0.211	0.222	0.256	0.266	0.260	0.257	0.252	0.250	0.247	0.236	0.223	0.212	0.193	0.175	0.169	0.137	0.139	0.103	0.077	0.005	0.000		
Layer 2 (Fill)																													
Layer Thickness (ft)	33.07	32.24	19.65																								1.66	12.08	0.00
Initial Stress (psf)	0.00	49.06	2417.40																								2417.92	48.84	0.00
Initial Void Ratio	0.84	0.84	0.84																								0.84	0.84	0.84
Compression Index	0.25	0.25	0.25																								0.25	0.25	0.25
Layer Settlement (ft)		0.000	0.000																								0.000	0.000	
Layer 3 (Weathered Chalk)																													
Top Elevation (ft MSL)	236.15	236.95	239.40	236.62	213.94	191.58	169.08	171.94	173.34	174.29	175.23	176.18	177.12	193.99	194.00	177.13	176.38	175.51	174.65	173.78	172.92	172.06	168.72	188.92	209.13	229.34	247.89	247.61	246.85
Botton Elevation (ft MSL)	216.15	216.95	219.40	220.68	213.94	191.58	169.08	171.94	173.34	174.29	175.23	176.18	177.12	193.99	194.00	177.13	176.38	175.51	174.65	173.78	172.92	172.06	168.72	188.92	209.13	228.15	227.89	227.61	226.85
Mid Point Elevation (ft MSL)	226.150	226.950	229.400	228.654	213.942	191.576	169.084	171.937	173.344	174.289	175.234	176.180	177.125	193.988	194.000	177.125	176.375	175.512	174.648	173.785	172.921	172.057	168.717	188.925	209.133	228.745	237.889	237.613	236.845
Soil Density (pcf)	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
Layer Thickness (ft)	20.00	20.00	20.00	15.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.19	20.00	20.00	20.00
Initial Stress (psf)	596.000	596.000	714.656	620.464																						267.126	714.742	596.000	596.000
Initial Void Ratio	0.84	0.84	0.84	0.84																						0.84	0.84	0.84	0.84
Compression Index	0.25	0.25	0.25	0.25																						0.25	0.25	0.25	0.25
Recompression Index	0.025	0.025	0.025	0.025																						0.025	0.025	0.025	0.025
Preconsolidation Pressure (psf)	4000	4000	4000	4000																						4000	4000	4000	4000
Layer Settlement (ft)	0.039	0.040	0.034	0.031																						0.005	0.035	0.041	0.041
Layer 4 (Intact Chalk)																													
Top Elevation (ft MSL)	216.15	216.95	219.40	220.68	213.94	191.58	169.08	171.94	173.34	174.29	175.23	176.18	177.12	193.99	194.00	177.13	176.38	175.51	174.65	173.78	172.92	172.06	168.72	188.92	209.13	228.15	227.89	227.61	226.85
Botton Elevation (ft MSL)	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40
Layer Thickness (ft)	144.75	145.55	148.00	149.28	142.54	120.17	97.68	100.53	101.94	102.88	103.83	104.78	105.72	122.58	122.60	105.72	104.97	104.11	103.24	102.38	101.52	100.65	97.31	117.52	137.73	156.74	156.48	156.21	155.44
Elastic Modulus E (psf)	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000	16000000
Layer Settlement (ft)	0.036	0.036	0.044	0.058	0.078	0.081	0.080	0.088	0.108	0.116	0.113	0.112	0.110	0.126	0.124	0.100	0.093	0.086	0.077	0.069	0.066	0.054	0.053	0.053	0.053	0.040	0.026	0.015	0.000
Total Settlement (ft)	0.075	0.075	0.078	0.167	0.217	0.258	0.291	0.311	0.365	0.382	0.373	0.369	0.362	0.376	0.370	0.336	0.316	0.298	0.269	0.244	0.234	0.191	0.192	0.156	0.130	0.049	0.061	0.056	0.041
Initial Length of Liner Segment (ft)		40.76	40.88	92.73	92.75	92.71	92.64	26.59	94.43	94.43	94.43	94.43	94.43	69.41	35.05	69.52	75.00	86.37	86.37	86.37	86.37	86.37	29.17	83.19	83.31	83.96	82.67	40.90	41.49
Final Length of Liner Segment (ft)		40.76	40.88	92.70	92.74	92.70	92.63	26.59	94.43	94.43	94.43	94.43	94.43	69.41	35.05	69.53	75.00	86.37	86.37	86.37	86.37	86.37	29.17	83.18	83.31	83.94	82.68	40.90	41.49
Strain (%, Tensile Negative)		0.00	0.00	0.02	0.01	0.01	0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	-0.01
Initial Liner Slope (ft/f)		0.00	-0.13	-0.25	-0.25	-0.25	-0.246	0.101	-0.006	0.010	0.010	0.010	0.010	0.243	0.008	-0.246	-0.010	-0.010	-0.010	-0.010	-0.010	0.008	-0.089	0.244	0.250	0.248	0.252	0.130	-0.331
Final Liner Slope (ft/ft)		0.00	-0.13	-0.25	-0.25	-0.25	-0.246	0.100	-0.007	0.010	0.010	0.010	0.010	0.242	0.008	-0.246	-0.010	-0.010	-0.010	-0.010	-0.010	0.009	-0.089	0.244	0.250	0.249	0.252	0.130	-0.331

Terracon	Made by:	JCH	Date:	1/30/15	Sheet No.:	COVER
	Checked by:	MAK	Date:	1/30/15	Job No.:	EJ147410
	Calculations for:	Stormwater Management Calculations				
	Emelle Facility Trench 23 Permit Application					

STORMWATER MANAGEMENT CALCULATIONS

CALCULATION COVER SHEET

Calculations by:

Signature: J. Craig Hensley

Name: J. Craig Hensley, E.I.T.

Title: Staff Engineer

1/30/2015
Date

Calculations Reviewed by:

Signature: Michael A. Kemp

Name: Michael A. Kemp, P.E.

Title: Solid Waste Dept. Manager

1/30/2015
Date

Calculations Approved by:

Signature: Rajendra S. Gondhalekar

Name: Rajendra S. Gondhalekar, P.E.

Title: Project Engineer

1/30/2015
Date

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	01/30/15	ALL	Initial Submittal

TABLE OF CONTENTS

1.0 OVERVIEW

In order to control the stormwater runoff quantity and quality, a Hydrology Study (Study) has been developed for Trench 23 of the Emelle Facility (the “Facility” or “Site”). This Study presents a discussion of the methods used to analyze the site hydrology and design the stormwater conveyance and control system for the facility. The proposed stormwater conveyance features route approximately 34.9 ft^3/sec of stormwater runoff from the Trench 23 area to Sediment Basin No. 6.

2.0 METHODOLOGY

The study is composed of the following three sections:

1) Hydrologic Analysis and Hydraulic Design – Conveyance Features;
2) Hydrologic Analysis and Hydraulic Design – Sediment Traps; and
3) References.

The hydrologic analysis of the conveyance features section includes an estimation of the anticipated peak 25-year, 24-hour storm flow rates for various stormwater management features. The features include stormwater diversion terraces, stormwater downdrains, channels, ditches, and culverts. Design flows were developed using the SCS Method. The section includes a discussion of the hydraulic design of the stormwater management features using the anticipated peak flow rates.

The *Hydrologic Analysis and Hydraulic Design – Sediment Traps* section includes an estimation of the anticipated peak 25-year, 24-hour storm flow rate for the proposed sediment traps that are located inline with the exterior stormwater channel. The design flow was developed using results from the SCS routing method. The section includes a discussion of the hydraulic design of the sediment traps using the anticipated peak flow rates.

The *References* section includes a brief discussion of the technical references used in the design and analysis of the stormwater management features.

2.1 Hydrologic Analysis and Hydraulic Design – Conveyance Features

This section includes an estimation of the peak flow rates during the 25-year, 24-hour design storm. The peak flow rates for critical stormwater management features were determined using the SCS Method. Relatively short times of concentration were selected in order to provide conservative estimates of peak runoff rates.

The largest contributing area for each stormwater management feature was determined using AutoCAD software. The rainfall data and time of concentration data were determined using computer software (Hydraflow Hydrographs Extension for AutoCAD Civil 3D 2014) and various references that are discussed in Section 2.3.

The second step in the design was to determine the hydraulic performance of the conveyance features. Peak flow rates developed in the first part of the analysis were used to determine the required size and geometry of the features. Input parameters used to design the berms, ditches, channels, culverts, and downdrains were obtained from various technical references presented in Section 2.3. Computer software (Hydraflow Express Extension for AutoCAD Civil 3D 2014) was also used in analyzing the stormwater management features. Results of the design and analysis are presented in the attached Exhibits H-1 through H-4.

2.1.1 Final Cover Terraces

For hydraulic design of final cover terraces, the largest contributing area for any of the terraces was determined using AutoCAD software. As shown in Figure A-1 in Exhibit H-1, the largest contributing area to any final cover terrace is 4.2 acres. The SCS Method was then used to determine the peak flow rate during a 25-year, 24-hour design storm. A conservative runoff curve number of 80 was selected based on our experience with similar project conditions. Rainfall data for Sumter County was interpolated based on data from the Rainfall Frequency Atlas of the United States (NOAA T.P. 40) and a Type III storm distribution. The peak flow rate was computed to be 11.4 ft^3/sec.

The next step in designing the terraces was to check the hydraulic performance of the critical terrace during the design storm event. A Manning roughness coefficient of 0.030 was selected for the terrace channel. Final cover terrace geometry as shown in the Permit Drawing details was also used to analyze the hydraulic performance of the terrace. Hydraflow Express, software that utilizes the Manning Equation to analyze open channel flow, was used to determine the maximum depth of water in the critical terrace. As shown in the calculations in Exhibit H-1, the maximum flow depth in the critical channel is 0.73 ft., which is less than the design terrace depth of 1 foot.

2.1.2 Final Cover Downdrain Inlets

For hydraulic design of the final cover downdrain inlets, the largest contributing area for any of the inlets was determined using AutoCAD software. As shown in Figure B-1 in Exhibit H-2, the largest contributing area to any final cover terrace inlet is 12.5 acres for the critical 4' x 4' inlet and 2.8 acres for the critical 6' x 6' inlet. The SCS Method was then used to determine the peak flow rate during a 25-year, 24-hour design storm. A conservative runoff curve number of 80 was selected based on our experience with similar project conditions. Rainfall data for Sumter County was interpolated based on data from the Rainfall Frequency Atlas of the United States (NOAA T.P. 40) and a Type III storm distribution. The peak flow rate during the design storm event was computed to be 67.5 ft^3/sec for the 4' x 4' inlet and 15.0 ft^3/sec for the 6' x 6' inlet.

The next step in designing the downdrain inlets was to check the hydraulic performance of the critical downdrain inlets during the design storm event. Final cover downdrain inlet geometry as shown in the Permit Drawing details was also used to analyze the hydraulic performance of each inlet. Hydraflow Express was used to determine the maximum depth of water at the critical downdrain inlets. As shown in the calculations in Exhibit H-2, the maximum flow depth at the critical 4' x 4' inlet is approximately 1.7 ft., and the maximum flow depth at the critical 6' x 6' inlet is approximately 0.4 ft. The calculated depth for the 4' x 4' inlet is less than the design final cover roadside ditch depth of 3 feet, and the calculated depth for the 6' x 6' inlet is less than the design final cover terrace depth of 1 foot.

2.1.3 Final Cover Downdrains

For hydraulic design of final cover downdrain pipe, the largest contributing area for any of the downdrains was determined using AutoCAD software. As shown in Figure C-1 in Exhibit H-2, the largest contributing area to any side slope downdrain pipe is 19.2 acres. The SCS Method was then used to determine the peak flow rate during a 25-year, 24-hour design storm. A conservative runoff curve number of 80 was selected based on our experience with similar project conditions. Rainfall data for Sumter County was interpolated based on data from the Rainfall Frequency Atlas of the United States (NOAA T.P. 40) and a Type III storm distribution. The peak flow rate was computed to be 103.5 ft^3/sec.

The next step in designing the downdrain pipes was to check the hydraulic performance of the critical downdrain during the design storm event. A Manning roughness coefficient of 0.012 was selected for the downdrain material. Final cover downdrain geometry as shown in the Permit Drawing details was also used to analyze the hydraulic performance of the downdrain. Hydraflow Express, which is a software that utilizes the Manning Equation to analyze open channel flow, was used to determine the maximum depth of water in the critical downdrain. As shown in the calculations in Exhibit H-2, the maximum flow depth in the critical downdrain is 2.5 ft., which is less than the design downdrain diameter of 3 feet.

2.1.4 Final Cover Downdrain Pipe at Road Crossings

For hydraulic design of final cover downdrain pipe at road crossings, the contributing area for each of the downdrain road crossings was determined using AutoCAD software. These contributing areas are shown in Figure C-2 in Exhibit H-2. The SCS Method was then used to determine the peak flow rate during a 25-year, 24-hour design storm. A conservative runoff curve number of 80 was selected based on our experience with similar project conditions. Rainfall data for Sumter County was interpolated based on data from the Rainfall Frequency Atlas of the United States (NOAA T.P. 40) and a Type III storm distribution. The peak flow rates were calculated and are shown in Exhibit H-2.

The next step in designing the downdrain road crossing pipes was to check the hydraulic performance of the pipes during the design storm event. A Manning roughness coefficient of 0.012 was selected for the downdrain material. Final cover downdrain geometry as shown in the Permit Drawing details was also used to analyze the hydraulic performance of the pipe. Hydraflow Express, which is a software that utilizes the Manning Equation to analyze open channel flow, was used to determine the maximum depth of water in the critical downdrain. As shown in the calculations in Exhibit H-2, the downdrain road crossing pipes are designed to contain and convey the 25-year, 24-hour storm event.

2.1.5 Perimeter Channels

For hydraulic design of perimeter channels, the largest contributing area for each of the channels was determined using AutoCAD software. Figures D-0 through D-26 in Exhibit H-3 show the contributing area for each section of the perimeter channel. The SCS Method was then used to determine the peak flow rate during a 25-year, 24-hour design storm. A conservative runoff curve number of 80 was selected based on our experience with similar project conditions. Rainfall data for Sumter County was interpolated based on data from the Rainfall Frequency Atlas of the United States (NOAA T.P. 40) and a Type III storm distribution. The peak flow rates were calculated for each section of ditch and are shown in Exhibit H-3.

The next step in designing the ditches is to check the hydraulic performance of each section of ditch during the design storm event. A Manning roughness coefficient of 0.030 was selected for the channels. Channel geometry as shown in the Permit Drawing details was also used to analyze the hydraulic performance of the ditches. Hydraflow Express, which is a software that utilizes the Manning Equation to analyze open channel flow, was used to determine the maximum depth of water in each section of the channel. As shown in the calculations in Exhibit H-3, the channels are designed to contain and convey the 25-year, 24-hour storm event with adequate freeboard. The channel lining requirements were determined using Erosion Control Materials Design software by Tensar Corporation. The results of the analysis are provided in Exhibit H-3 and are also indicated on the Permit Drawings.

2.1.6 Stormwater Conveyance Culverts

For hydraulic design of stormwater conveyance culverts (pipes), the contributing area for each pipe was determined using AutoCAD software. Figures G-1 and G-2 presented in Exhibit H-4 shows the drainage area for each section of pipe. The SCS Method was then used to determine the peak flow rate during a 25-year, 24-hour design storm. A conservative runoff curve number of 80 was selected based on our experience with similar project conditions. Rainfall data for Sumter County was interpolated based on data from the Rainfall Frequency Atlas of the United States (NOAA T.P. 40) and a Type III storm distribution. The peak flow rates were calculated for each culvert and are shown in Exhibit H-4.

The next step in designing the culverts was to check the hydraulic performance of each pipe. A Manning roughness coefficient of 0.012 was selected for the pipes. Culvert geometry as shown in the Permit Drawing details was also used to analyze the hydraulic performance of the culverts. Hydraflow Express was used to determine the flow rate and the headwater conditions for each pipe. The hydraulic analysis results for each pipe are presented in Exhibit H-4. As indicated, the culverts are designed to contain and convey the 25-year, 24-hour storm event.

2.2 Hydrologic Analysis and Hydraulic Design – Sediment Traps

A total of six (6) sediment traps were designed and are located inline with the perimeter ditch located on the exterior of the Trench 23 access road. The intent of these traps is to improve water quality and reduce erosion in the stormwater channels by slowing the velocity of runoff and gradually discharging stormwater from the sediment trap outlets to downstream channels. For the sediment traps, the contributing area for each was determined using AutoCAD software. They were analyzed using hydrographs developed in Hydraflow Hydrographs Extension for AutoCAD Civil 3D 2014. The results of the analysis are presented in Exhibit H-5. As indicated, the currently designed sediment traps effectively store and release stormwater runoff up to a 100-year, 24-hour storm without overtopping.

2.3 References

Various references were used to determine the values used in the design and analysis of the stormwater conveyance and control system. The following references are presented in Exhibit P-7:

Web based results of Soil Survey, Sumter County, Alabama Natural Resource Conservation Service.

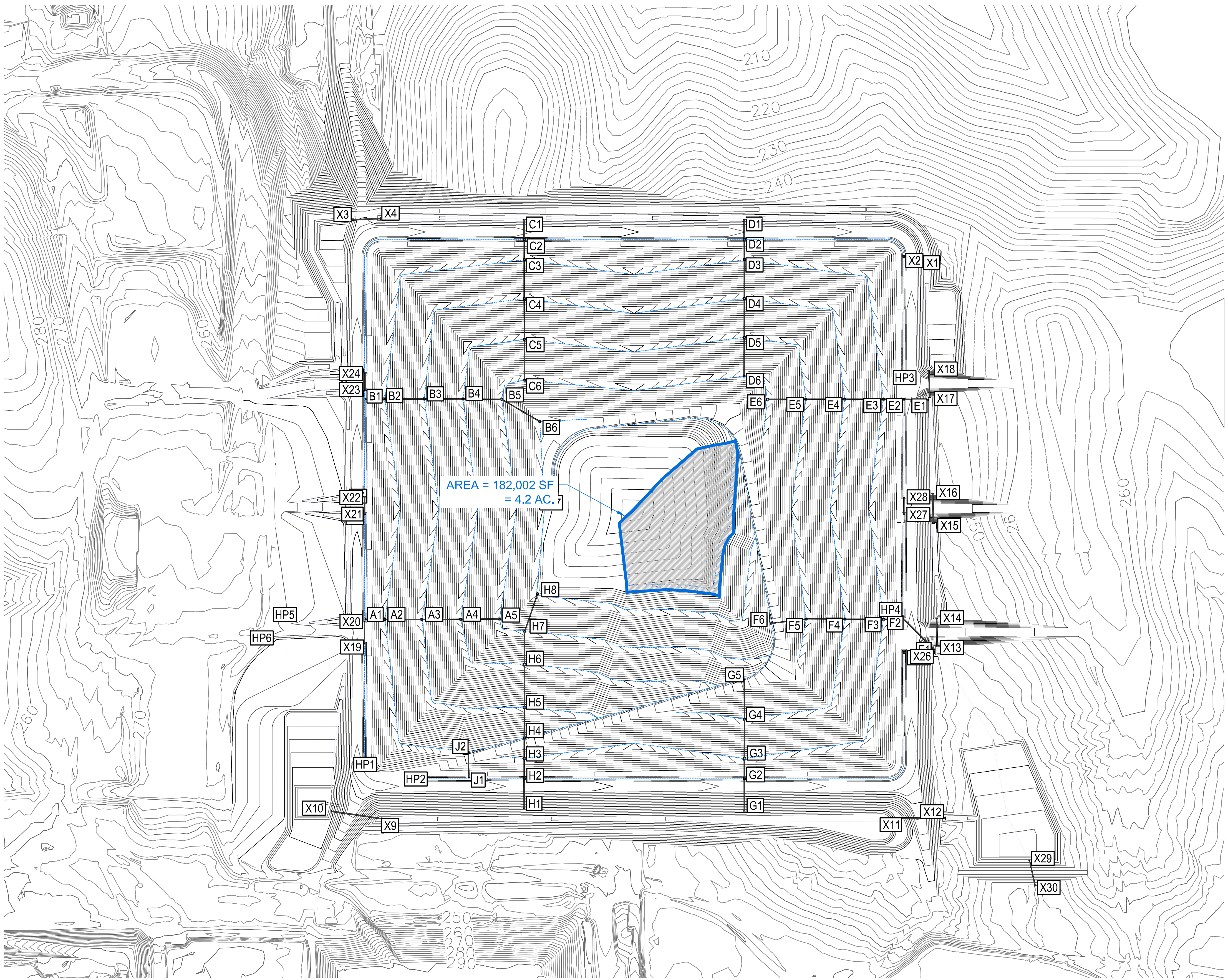
National Oceanic and Atmospheric Administration, 1961, Rainfall Frequency Atlas of the United States, Technical Paper No. 40, Washington, D.C.

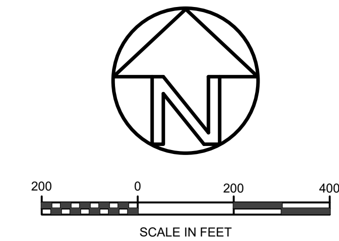
Federal Highway Administration, 2009. Urban Drainage Design Manual, Hydraulic Engineering Circular 22, Third Edition, FHWA-NHI-10-009, Washington, D.C.

United States Department of Agriculture, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, Second Edition, Washington, D.C.

EXHIBIT H-1

Hydrologic and Hydraulic Calculations – Final Cover Terraces





PEAK FLOW FOR CRITICAL FINAL COVER TERRACE

Q_{PEAK} = 22.6 cfs
25 YR 24 HR STORM EVENT

LEGEND

(light line)	2-FT FINAL COVER CTR
(line)	10-FT FINAL COVER CTR
(dark line)	DOWNDRAIN / CULVERT
(blue line)	WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

EMELLE FACILITY

Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

CRITICAL FINAL COVER TERRACE WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
A-1

Channel Report

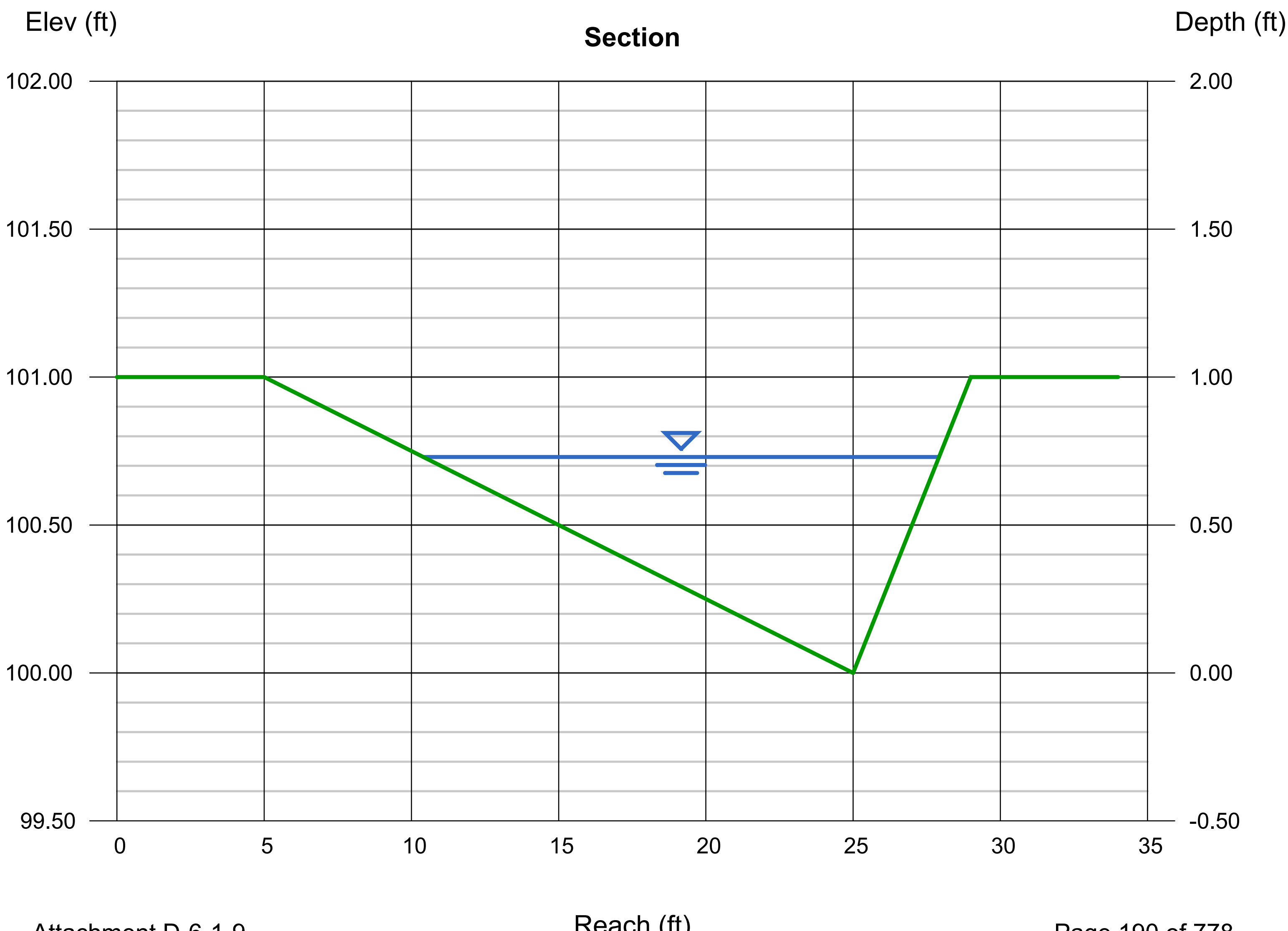
CRITICAL FINAL COVER TERRACE - 2%

Triangular
Side Slopes (z:1) = 20.00, 4.00
Total Depth (ft) = 1.00

Invert Elev (ft) = 100.00
Slope (%) = 2.00
N-Value = 0.030

Calculations
Compute by: Known Q
Known Q (cfs) = 22.60

Highlighted
Depth (ft) = 0.73
Q (cfs) = 22.60
Area (sqft) = 6.39
Velocity (ft/s) = 3.53
Wetted Perim (ft) = 17.63
Crit Depth, Yc (ft) = 0.74
Top Width (ft) = 17.52
EGL (ft) = 0.92



Channel Report

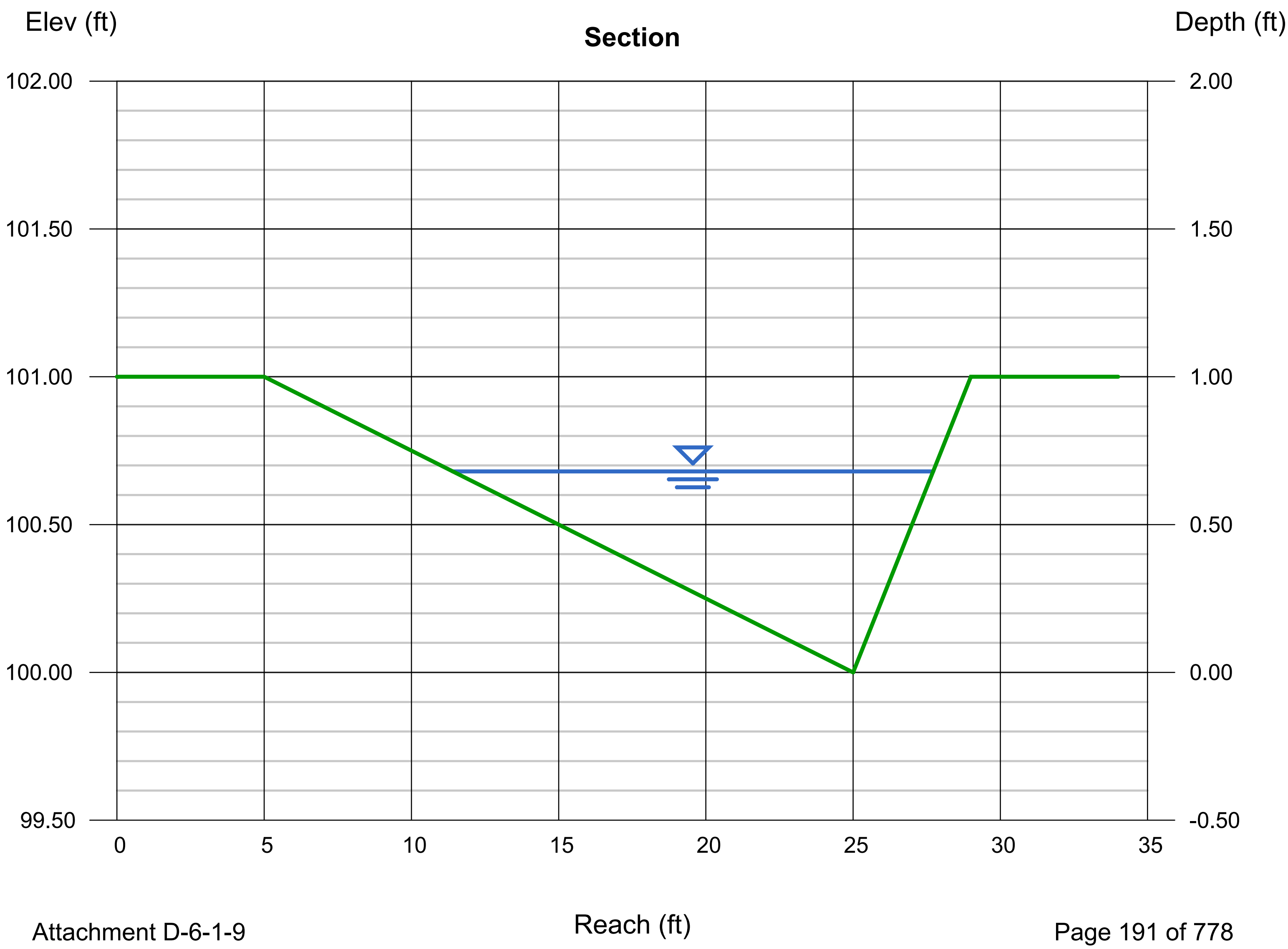
CRITICAL FINAL COVER TERRACE - 3%

Triangular
Side Slopes (z:1) = 20.00, 4.00
Total Depth (ft) = 1.00

Invert Elev (ft) = 100.00
Slope (%) = 3.00
N-Value = 0.030

Calculations
Compute by: Known Q
Known Q (cfs) = 22.60

Highlighted
Depth (ft) = 0.68
Q (cfs) = 22.60
Area (sqft) = 5.55
Velocity (ft/s) = 4.07
Wetted Perim (ft) = 16.42
Crit Depth, Yc (ft) = 0.74
Top Width (ft) = 16.32
EGL (ft) = 0.94



Watershed Model Schematic

1

Legend

Hyd.	Origin	Description
1	SCS Runoff	<no description>

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	8.161	1	727	28,006	------	------	------	Critical Diversion Terrace

Q-Critical Terrace.gpw	Return Period: 1 Year	Thursday, 01 / 29 / 2015

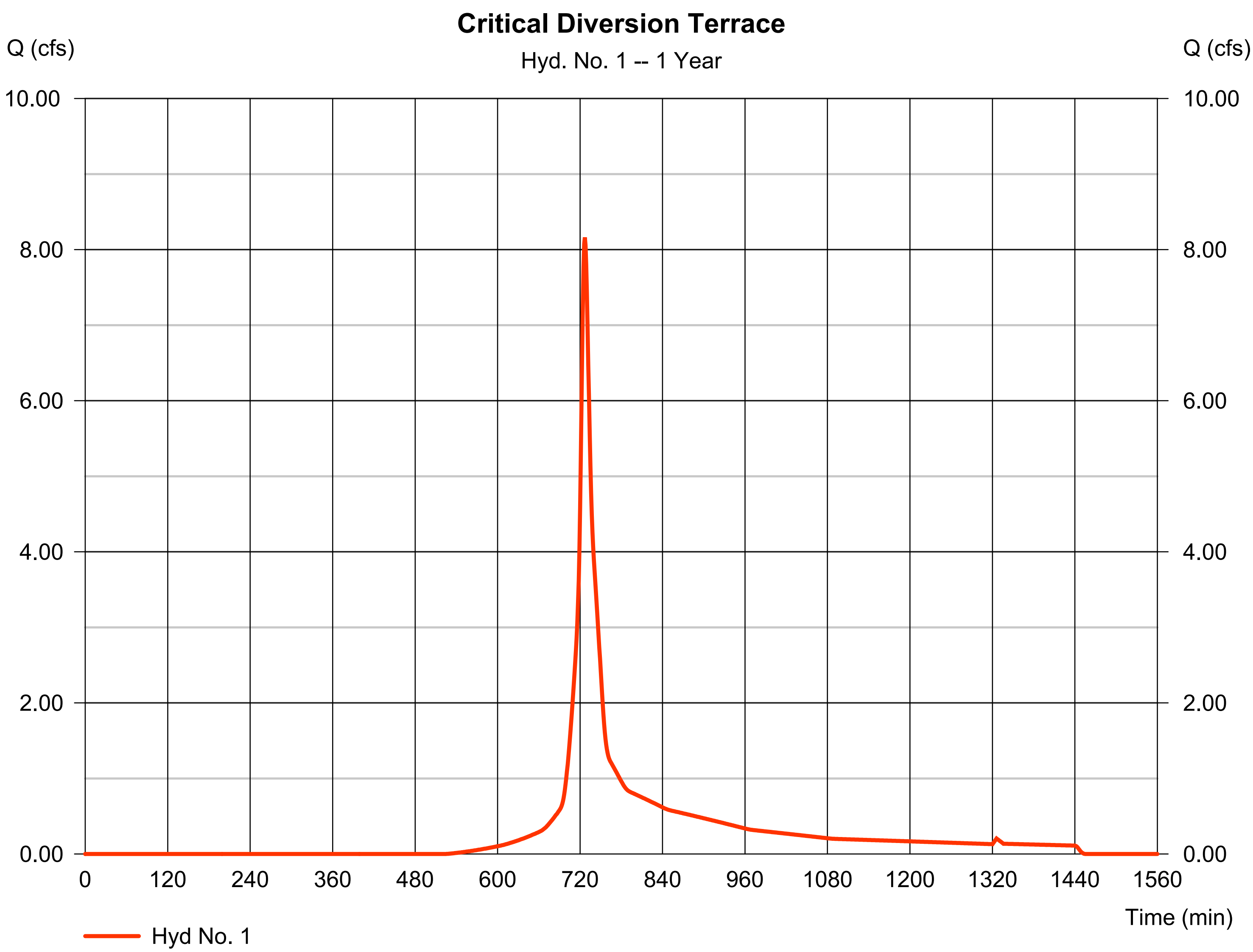
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Thursday, 01 / 29 / 2015

Hyd. No. 1

Critical Diversion Terrace

Hydrograph type	= SCS Runoff	Peak discharge	= 8.161 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 28,006 cuft
Drainage area	= 4.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.50 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	10.97	1	727	37,529	------	------	------	Critical Diversion Terrace

Q-Critical Terrace.gpw | Return Period: 2 Year | Thursday, 01 / 29 / 2015

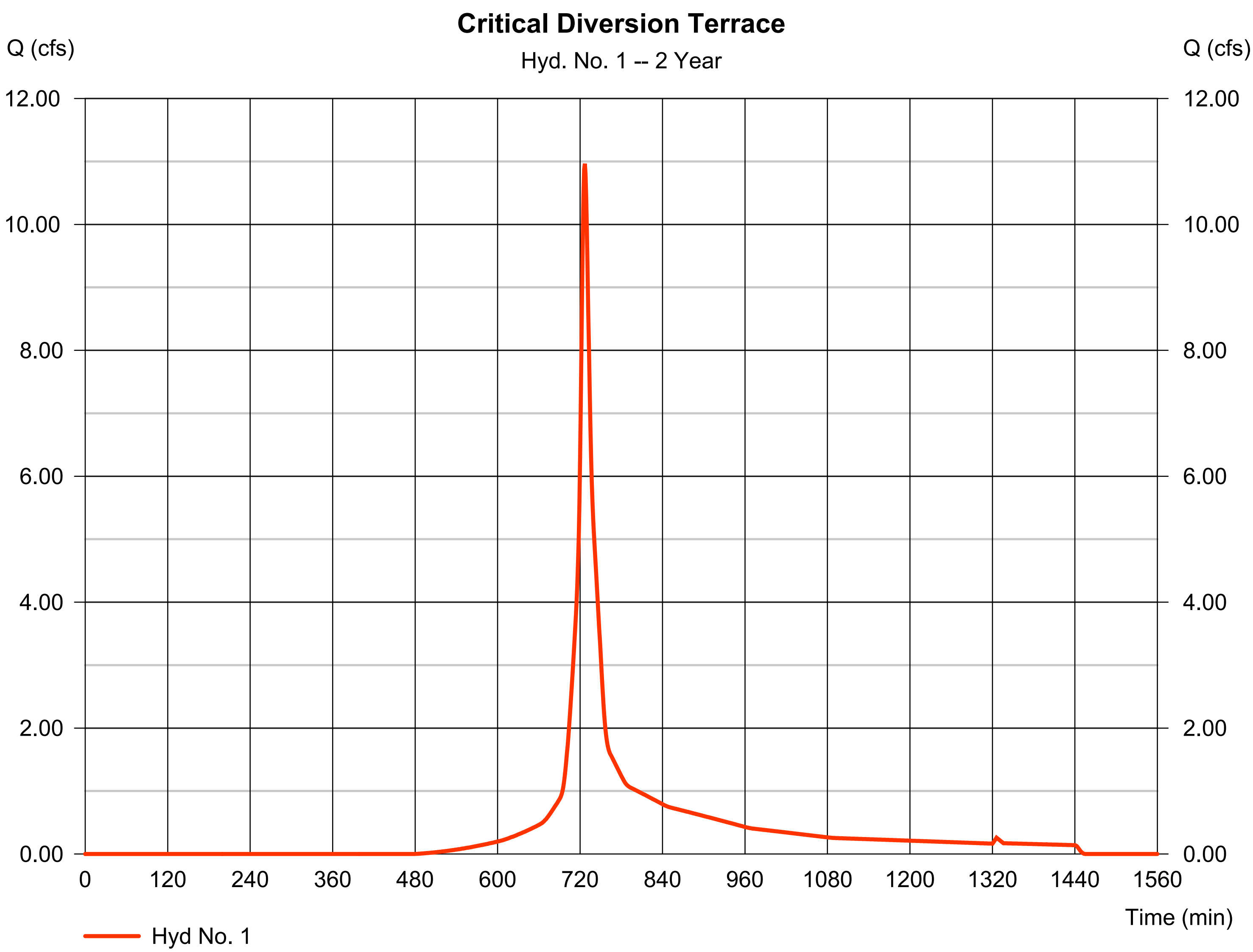
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Thursday, 01 / 29 / 2015

Hyd. No. 1

Critical Diversion Terrace

Hydrograph type	= SCS Runoff	Peak discharge	= 10.97 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 37,529 cuft
Drainage area	= 4.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.50 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	15.39	1	727	52,858	------	------	------	Critical Diversion Terrace

Q-Critical Terrace.gpw | Return Period: 5 Year | Thursday, 01 / 29 / 2015

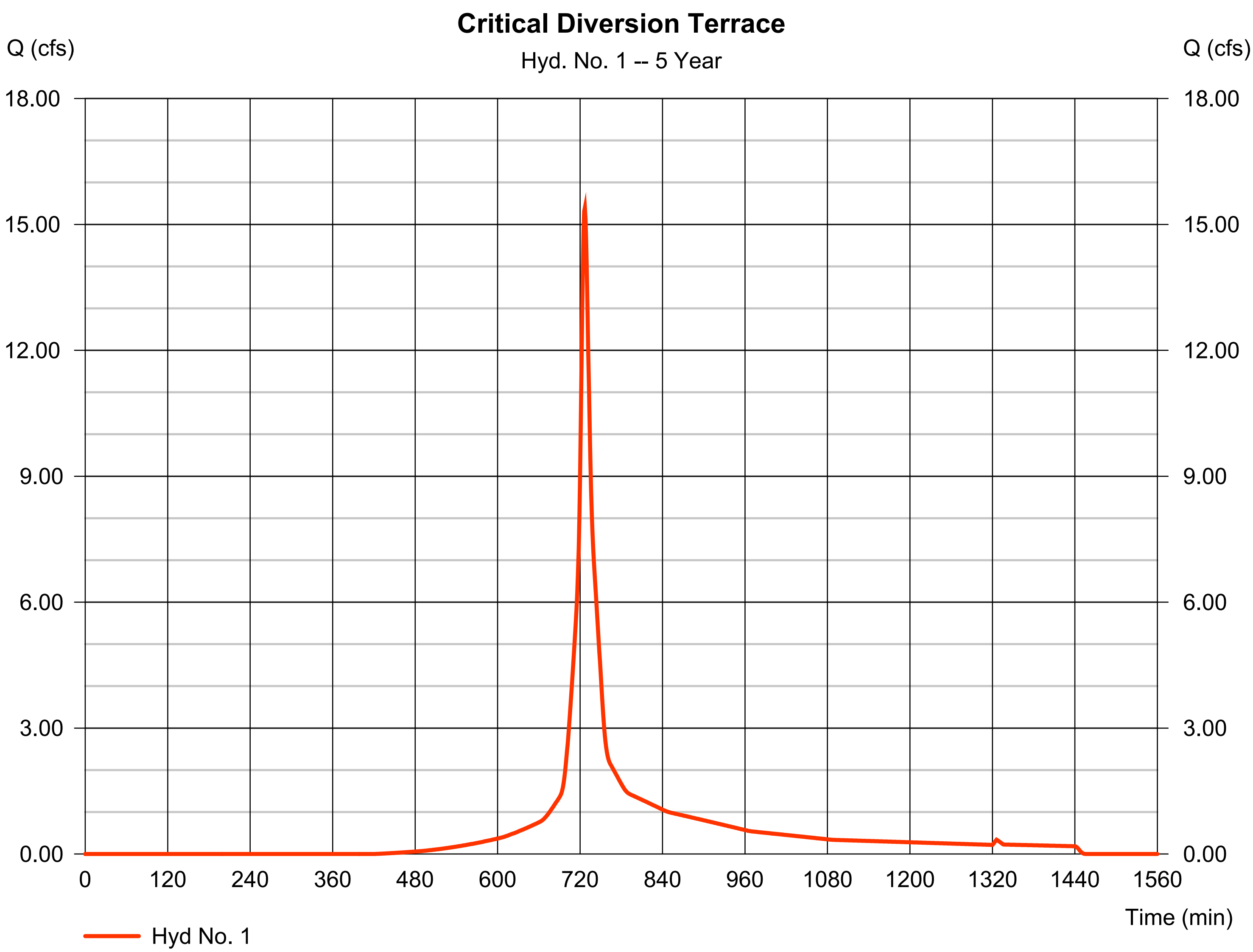
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Thursday, 01 / 29 / 2015

Hyd. No. 1

Critical Diversion Terrace

Hydrograph type	= SCS Runoff	Peak discharge	= 15.39 cfs
Storm frequency	= 5 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 52,858 cuft
Drainage area	= 4.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.50 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	18.71	1	727	64,571	------	------	------	Critical Diversion Terrace

Q-Critical Terrace.gpw	Return Period: 10 Year	Thursday, 01 / 29 / 2015

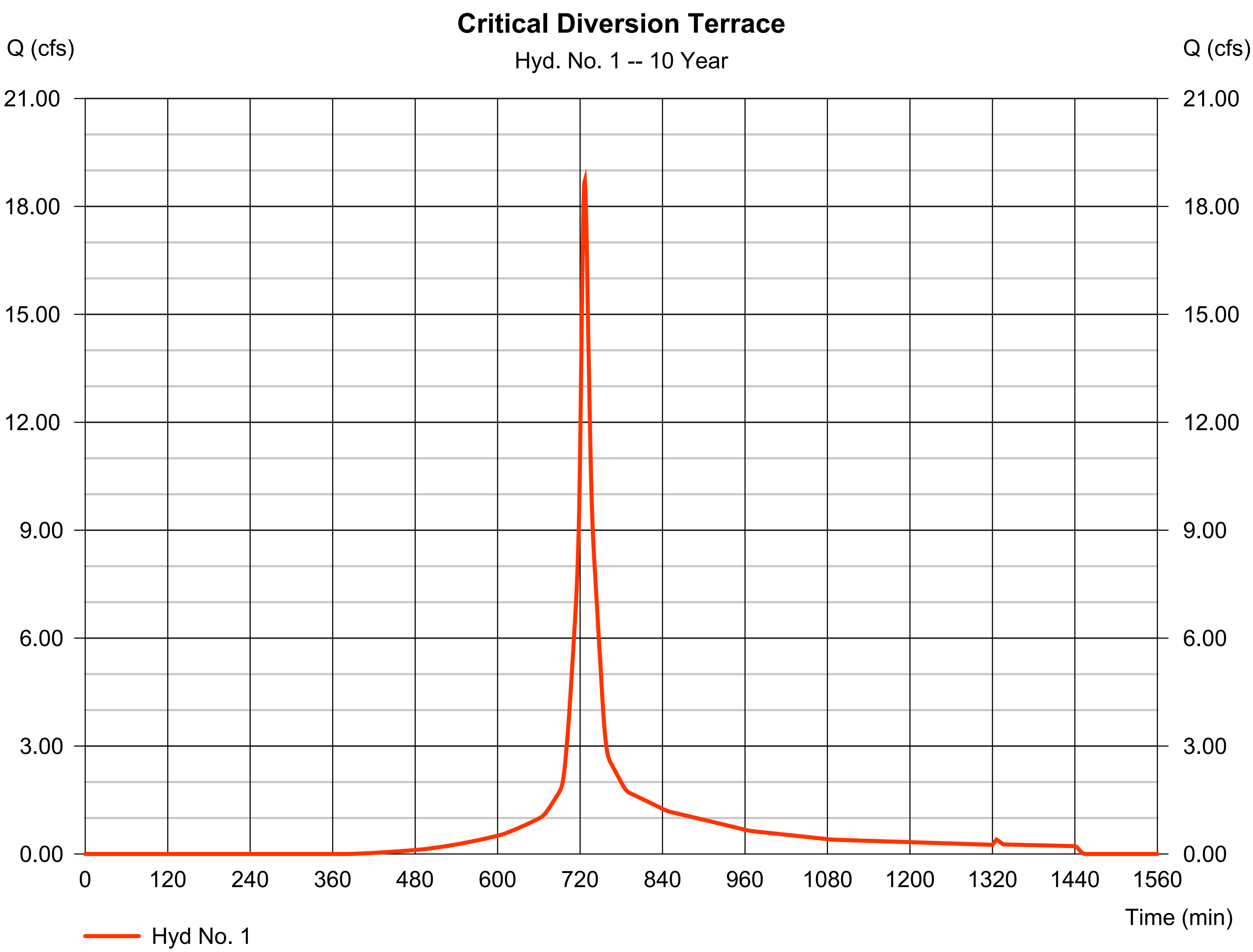
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Thursday, 01 / 29 / 2015

Hyd. No. 1

Critical Diversion Terrace

Hydrograph type	= SCS Runoff	Peak discharge	= 18.71 cfs
Storm frequency	= 10 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 64,571 cuft
Drainage area	= 4.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.50 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	22.64	1	727	78,637	------	------	------	Critical Diversion Terrace

Q-Critical Terrace.gpw	Return Period: 25 Year	Thursday, 01 / 29 / 2015

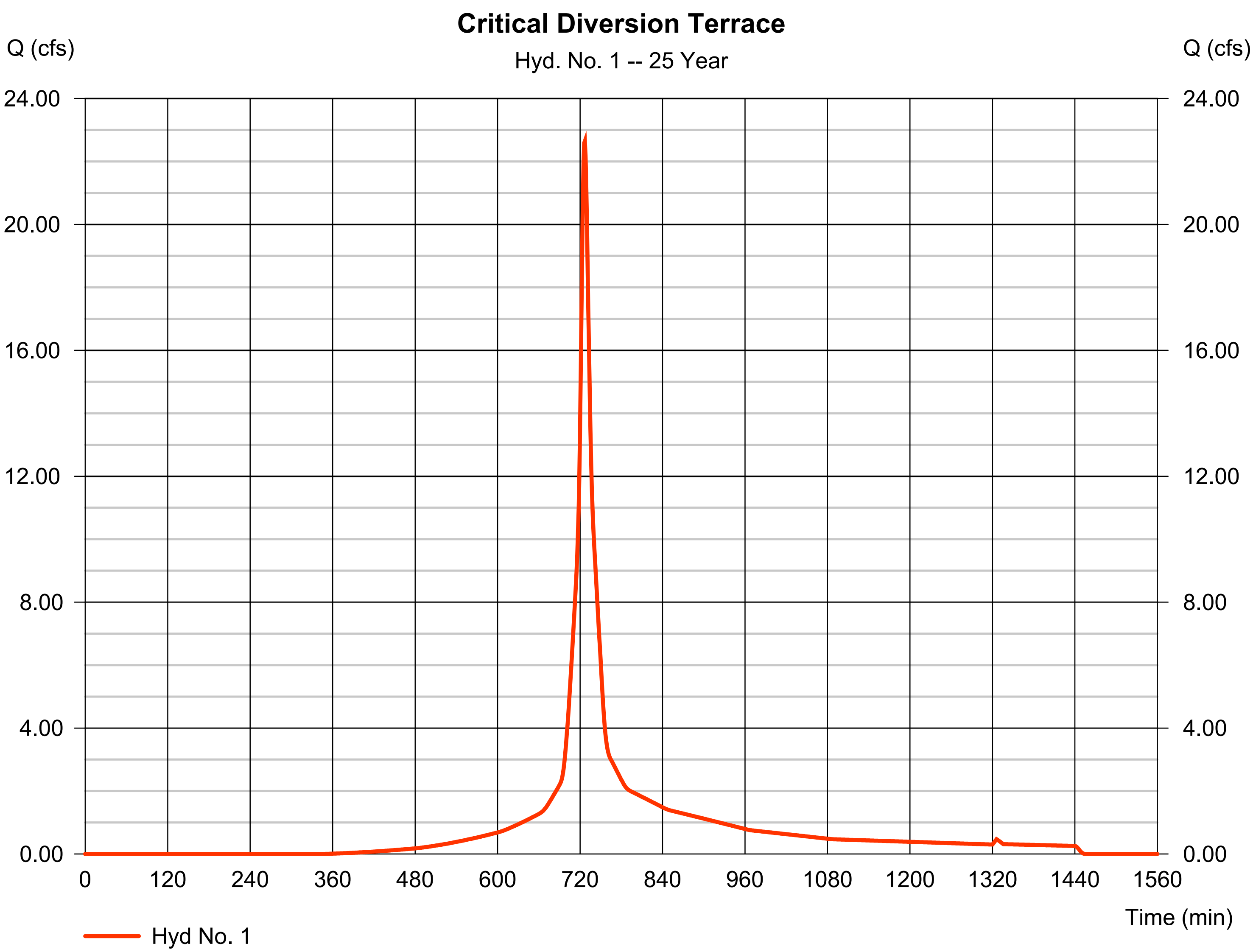
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Thursday, 01 / 29 / 2015

Hyd. No. 1

Critical Diversion Terrace

Hydrograph type	= SCS Runoff	Peak discharge	= 22.64 cfs
Storm frequency	= 25 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 78,637 cuft
Drainage area	= 4.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.50 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	26.19	1	727	91,491	------	------	------	Critical Diversion Terrace

Q-Critical Terrace.gpw | Return Period: 50 Year | Thursday, 01 / 29 / 2015

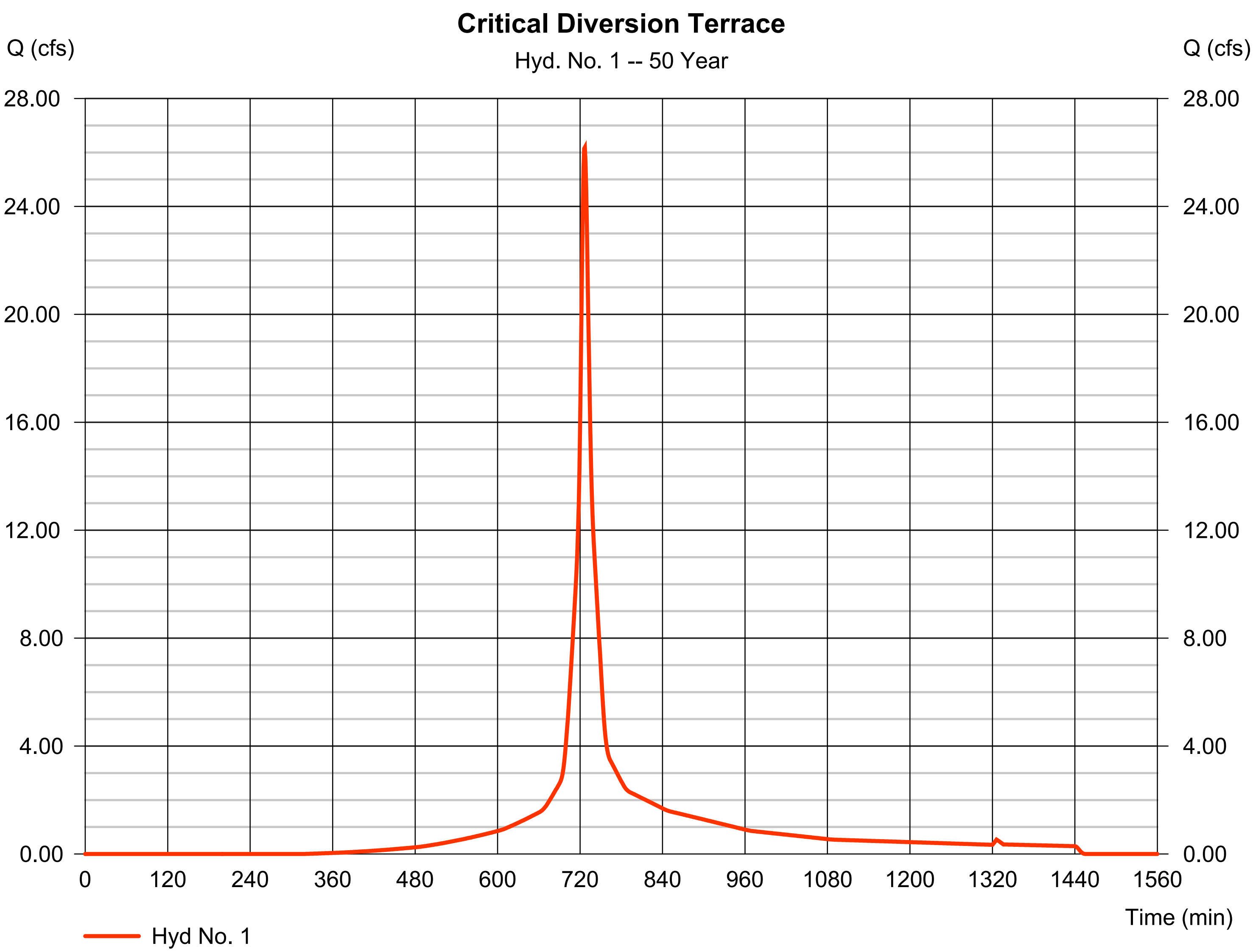
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Thursday, 01 / 29 / 2015

Hyd. No. 1

Critical Diversion Terrace

Hydrograph type	= SCS Runoff	Peak discharge	= 26.19 cfs
Storm frequency	= 50 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 91,491 cuft
Drainage area	= 4.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.50 min
Total precip.	= 8.40 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	29.33	1	727	103,033	------	------	------	Critical Diversion Terrace

Q-Critical Terrace.gpw | Return Period: 100 Year | Thursday, 01 / 29 / 2015

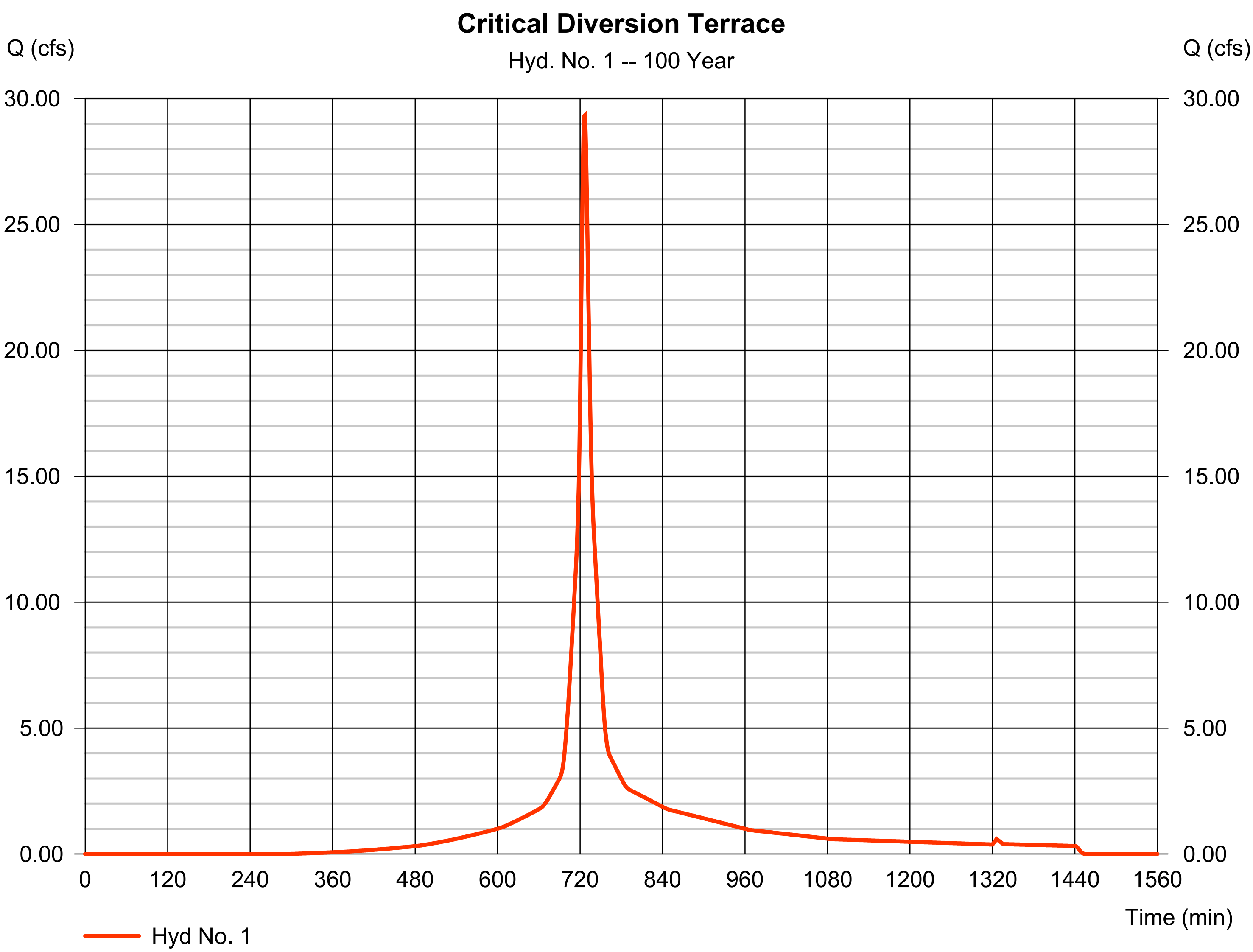
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Thursday, 01 / 29 / 2015

Hyd. No. 1

Critical Diversion Terrace

Hydrograph type	= SCS Runoff	Peak discharge	= 29.33 cfs
Storm frequency	= 100 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 103,033 cuft
Drainage area	= 4.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.50 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Thursday, 01 / 29 / 2015

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	0.0000	0.0000	0.0000	--------
3	0.0000	0.0000	0.0000	--------
5	0.0000	0.0000	0.0000	--------
10	0.0000	0.0000	0.0000	--------
25	0.0000	0.0000	0.0000	--------
50	0.0000	0.0000	0.0000	--------
100	0.0000	0.0000	0.0000	--------

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

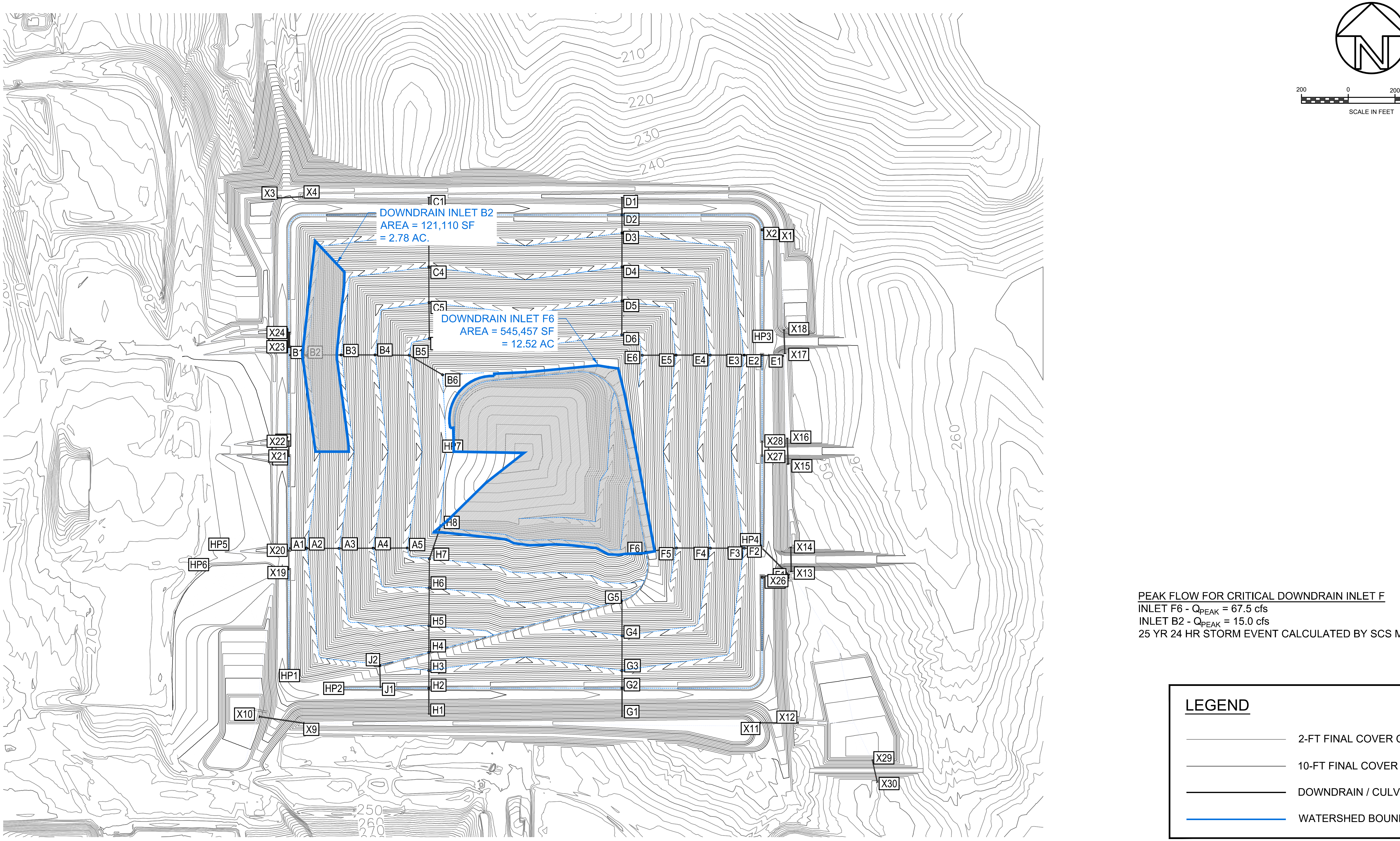
Tc = time in minutes. Values may exceed 60.

ojects\2014\EJ147461\Working Files\Calculations-Analyses\SCS METHOD\Peachtree City (24 hr GA Green Book).pcp

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.75	4.50	0.00	5.65	6.50	7.50	8.40	9.20
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

EXHIBIT H-2

Hydrologic and Hydraulic Calculations – Final Cover Downdrains



PEAK FLOW FOR CRITICAL DOWNDRAIN INLET F

INLET F6 - Q_{PEAK} = 67.5 cfs

INLET B2 - Q_{PEAK} = 15.0 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

EMELLE FACILITY

Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

CRITICAL FINAL COVER DOWNDRAIN INLET WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

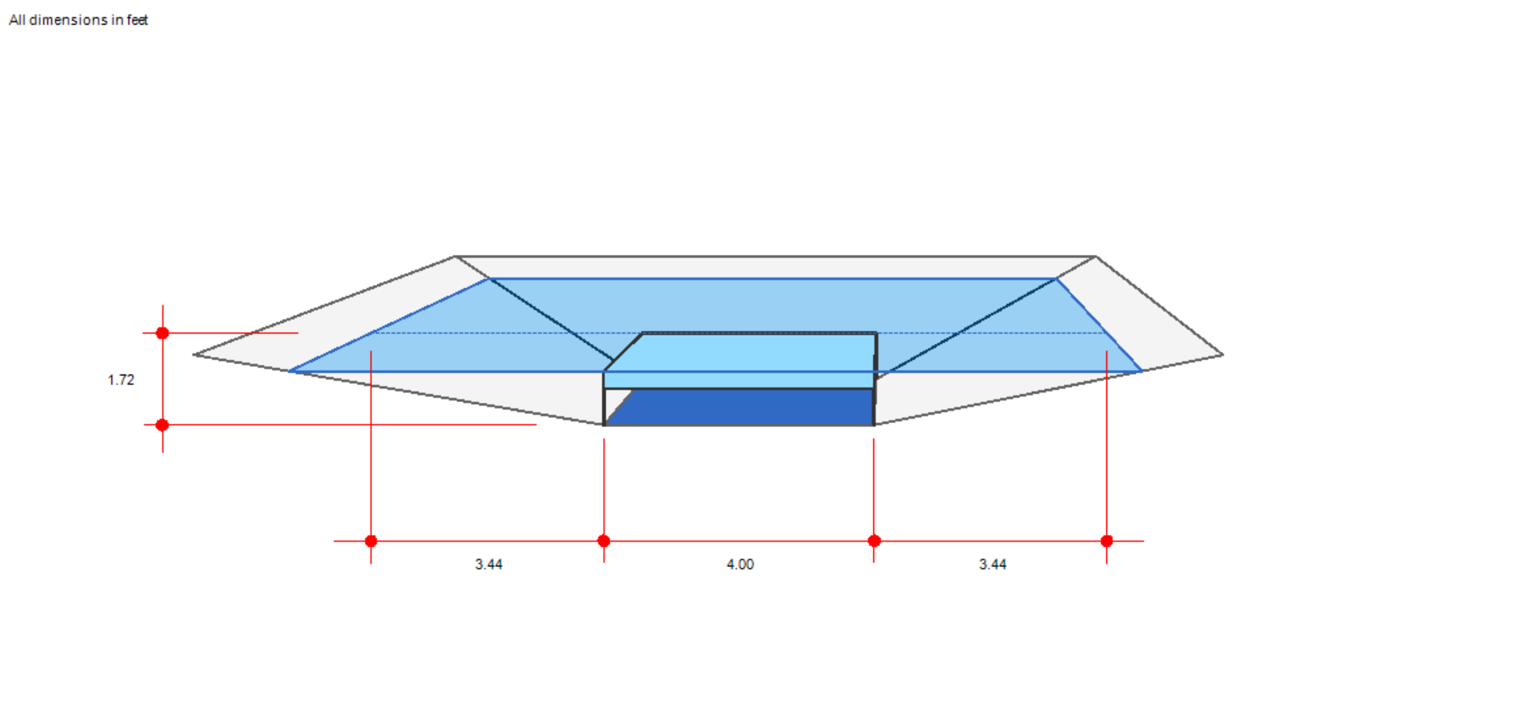
FIGURE
B-1

Last Saved By: JCHENSLEY Date: 1/29/2015 3:56 PM File Path: N:\PROJECTS\2014\EJ147410\WORKING FILES\CALCULATIONS-ANALYSES\HYDROLOGY\FIGURE-HYDROLOGY\EJ147410-HYDRO-EMELLE TRENCH 23.DWG

Inlet Report

Critical Final Cover Downdrain Drop Inlet - F6 (4' x 4')

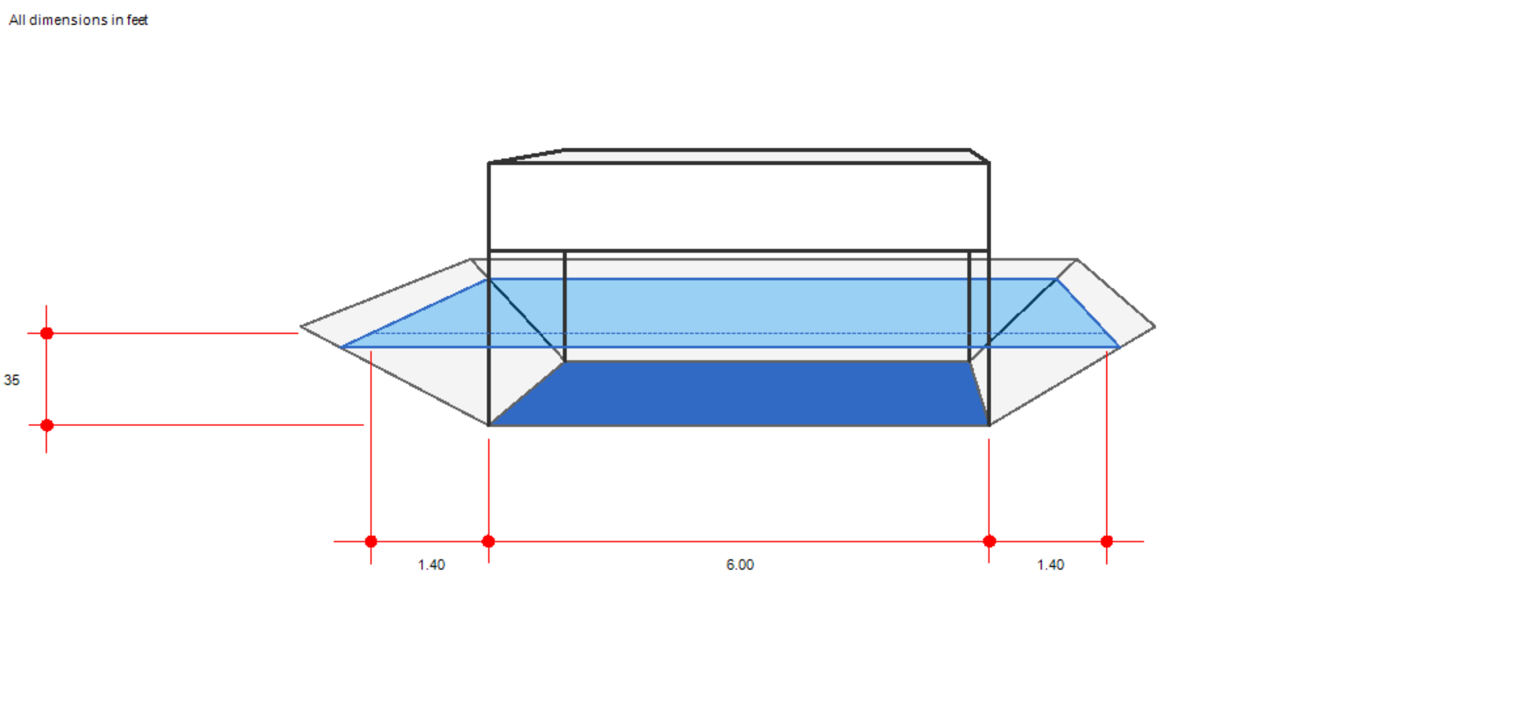
Drop Curb Inlet		**Calculations**	
Location	= Sag	Compute by:	Known Q
Curb Length (ft)	= 16.00	Q (cfs)	= 67.50
Throat Height (in)	= 8.00		
Grate Area (sqft)	= -0-	**Highlighted**	
Grate Width (ft)	= -0-	Q Total (cfs)	= 67.50
Grate Length (ft)	= -0-	Q Capt (cfs)	= 67.50
		Q Bypass (cfs)	= -0-
Gutter		Depth at Inlet (in)	= 20.64
Slope, Sw (ft/ft)	= 0.500	Efficiency (%)	= 100
Slope, Sx (ft/ft)	= 0.500	Gutter Spread (ft)	= 3.44
Local Depr (in)	= -0-	Gutter Vel (ft/s)	= -0-
Gutter Width (ft)	= -0-	Bypass Spread (ft)	= -0-
Gutter Slope (%)	= -0-	Bypass Depth (in)	= -0-
Gutter n-value	= -0-		



Inlet Report

Critical Final Cover Downdrain Drop Inlet - B2 (6'x6')

Drop Curb Inlet		**Calculations**	
Location	= Sag	Compute by:	Known Q
Curb Length (ft)	= 24.00	Q (cfs)	= 15.00
Throat Height (in)	= 8.00		
Grate Area (sqft)	= -0-	**Highlighted**	
Grate Width (ft)	= -0-	Q Total (cfs)	= 15.00
Grate Length (ft)	= -0-	Q Capt (cfs)	= 15.00
		Q Bypass (cfs)	= -0-
Gutter		Depth at Inlet (in)	= 4.21
Slope, Sw (ft/ft)	= 0.250	Efficiency (%)	= 100
Slope, Sx (ft/ft)	= 0.250	Gutter Spread (ft)	= 1.40
Local Depr (in)	= -0-	Gutter Vel (ft/s)	= -0-
Gutter Width (ft)	= -0-	Bypass Spread (ft)	= -0-
Gutter Slope (%)	= -0-	Bypass Depth (in)	= -0-
Gutter n-value	= -0-		



Watershed Model Schematic

Legend

Hyd.	Origin	Description
1	SCS Runoff	CRITICAL DD INLET F6 (4'X4' INLET)
2	SCS Runoff	CRITICAL DD INLET B2 (6'X6' INLET)

Project: Q-Critical DD Inlets.gpw

Friday, 01 / 30 / 2015

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	24.33	1	727	83,485	------	------	------	CRITICAL DD INLET F6 (4'X4' INLET
2	SCS Runoff	5.402	1	727	18,537	------	------	------	CRITICAL DD INLET B2 (6'X6' INLET

Q-Critical DD Inlet F6.gpw | Return Period: 1 Year | Thursday, 01 / 29 / 2015

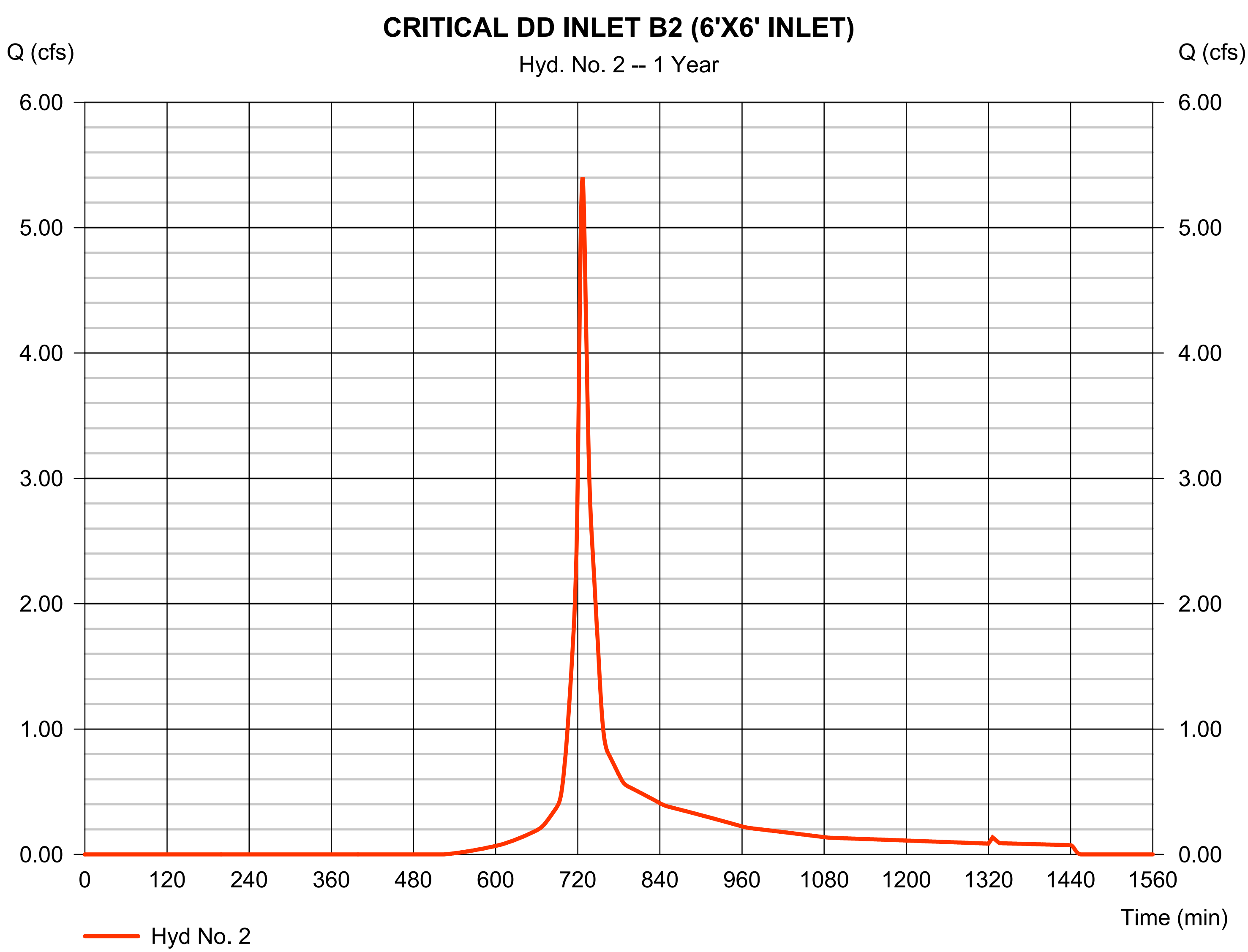
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Thursday, 01 / 29 / 2015

Hyd. No. 2

CRITICAL DD INLET B2 (6'X6' INLET)

Hydrograph type	= SCS Runoff	Peak discharge	= 5.402 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 18,537 cuft
Drainage area	= 2.780 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	32.69	1	727	111,871	------	------	------	CRITICAL DD INLET F6 (4'X4' INLET
2	SCS Runoff	7.258	1	727	24,840	------	------	------	CRITICAL DD INLET B2 (6'X6' INLET

Q-Critical DD Inlet F6.gpw | Return Period: 2 Year | Thursday, 01 / 29 / 2015

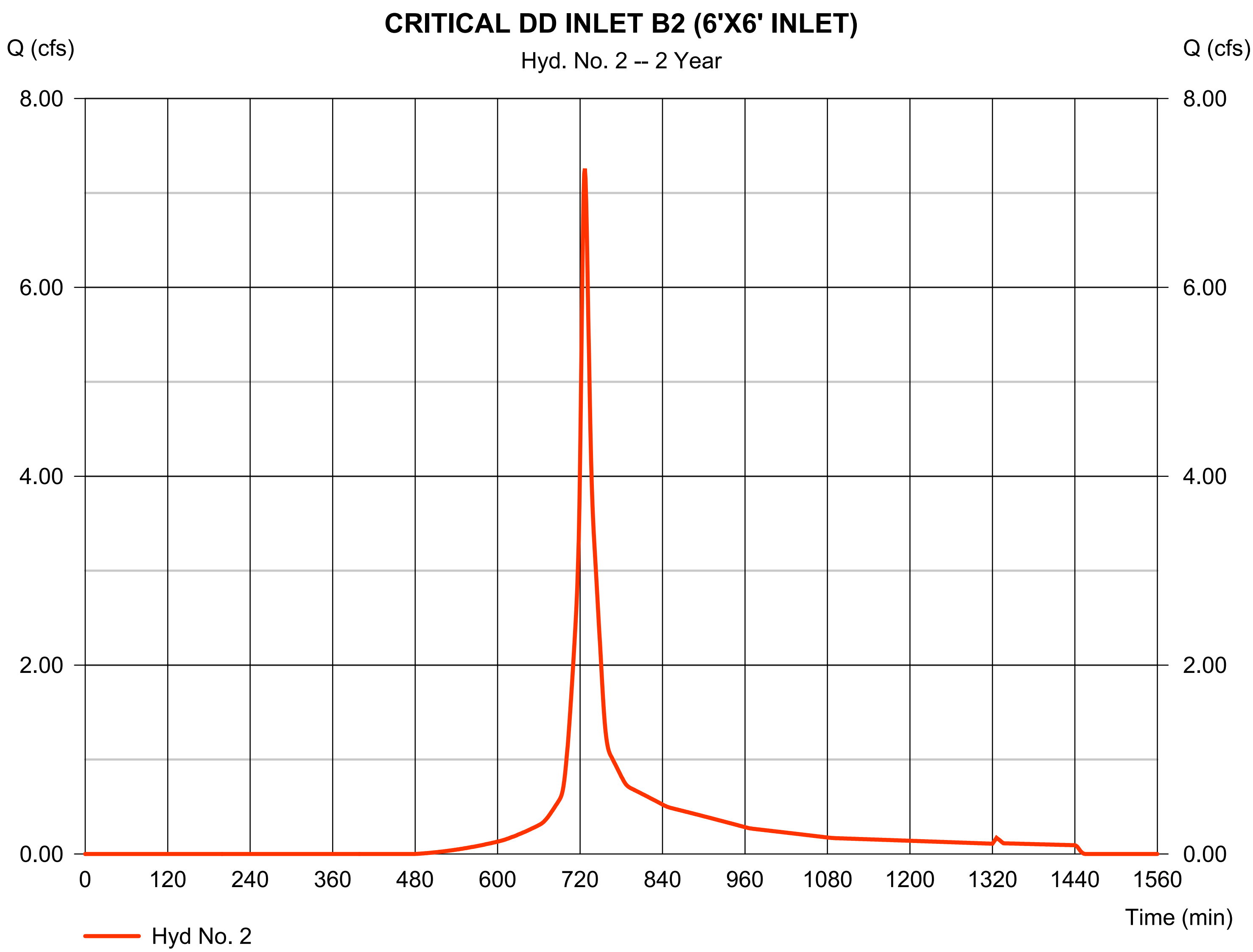
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Thursday, 01 / 29 / 2015

Hyd. No. 2

CRITICAL DD INLET B2 (6'X6' INLET)

Hydrograph type	= SCS Runoff	Peak discharge	= 7.258 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 24,840 cuft
Drainage area	= 2.780 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	45.89	1	727	157,567	------	------	------	CRITICAL DD INLET F6 (4'X4' INLET
2	SCS Runoff	10.19	1	727	34,987	------	------	------	CRITICAL DD INLET B2 (6'X6' INLET

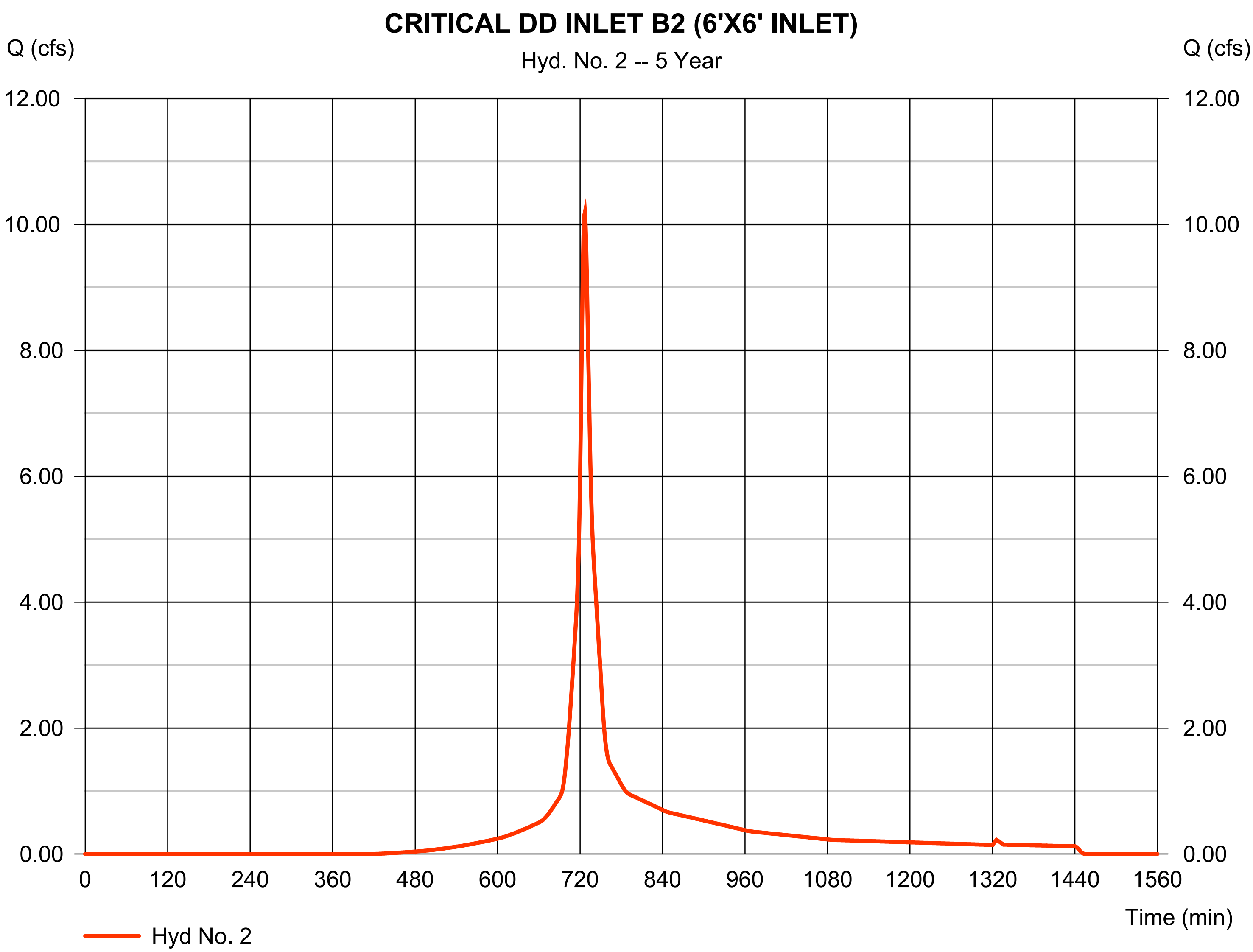
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Thursday, 01 / 29 / 2015

Hyd. No. 2

CRITICAL DD INLET B2 (6'X6' INLET)

Hydrograph type	= SCS Runoff	Peak discharge	= 10.19 cfs
Storm frequency	= 5 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 34,987 cuft
Drainage area	= 2.780 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	55.79	1	727	192,484	------	------	------	CRITICAL DD INLET F6 (4'X4' INLET
2	SCS Runoff	12.39	1	727	42,740	------	------	------	CRITICAL DD INLET B2 (6'X6' INLET

Q-Critical DD Inlet F6.gpw | Return Period: 10 Year | Thursday, 01 / 29 / 2015

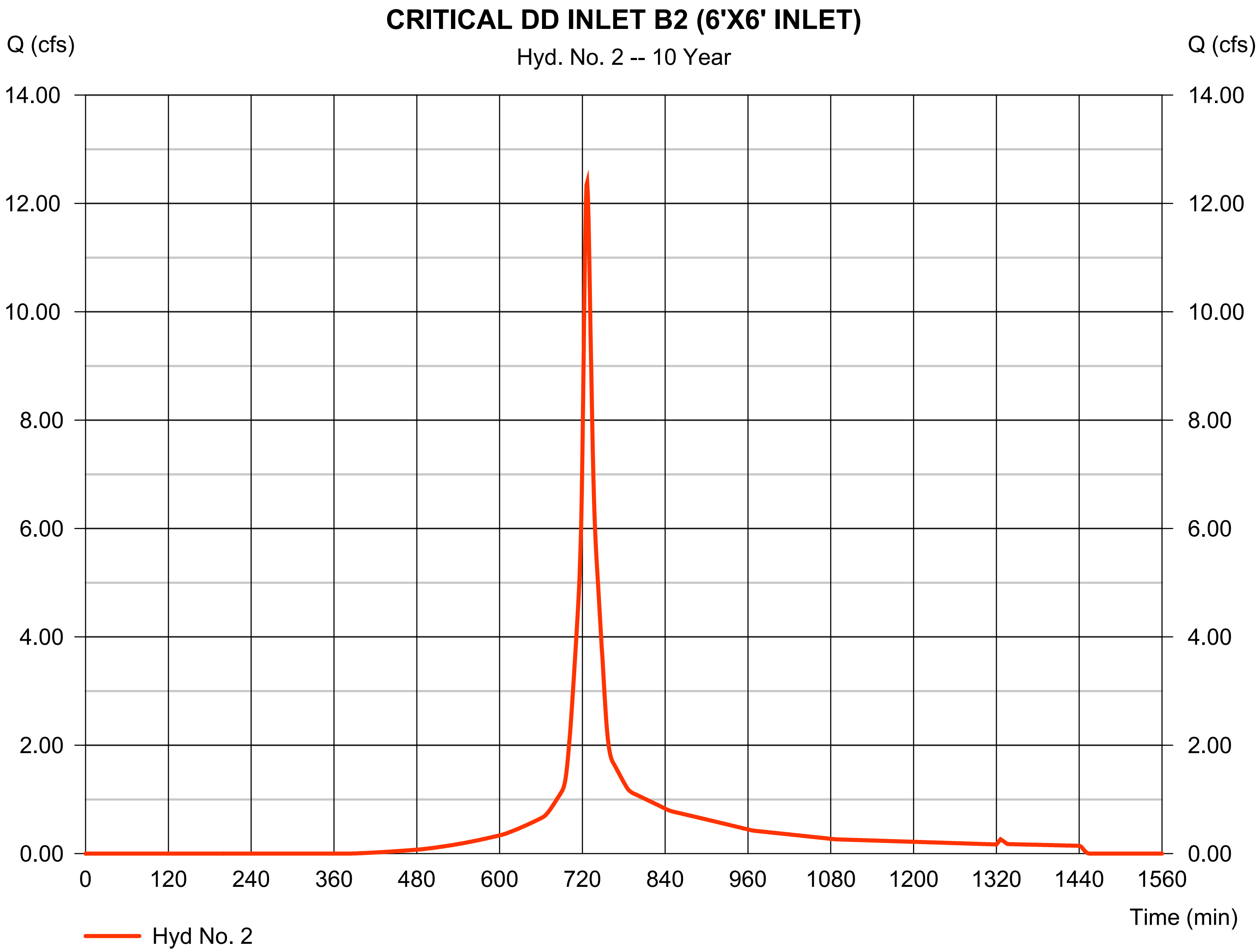
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Thursday, 01 / 29 / 2015

Hyd. No. 2

CRITICAL DD INLET B2 (6'X6' INLET)

Hydrograph type	= SCS Runoff	Peak discharge	= 12.39 cfs
Storm frequency	= 10 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 42,740 cuft
Drainage area	= 2.780 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

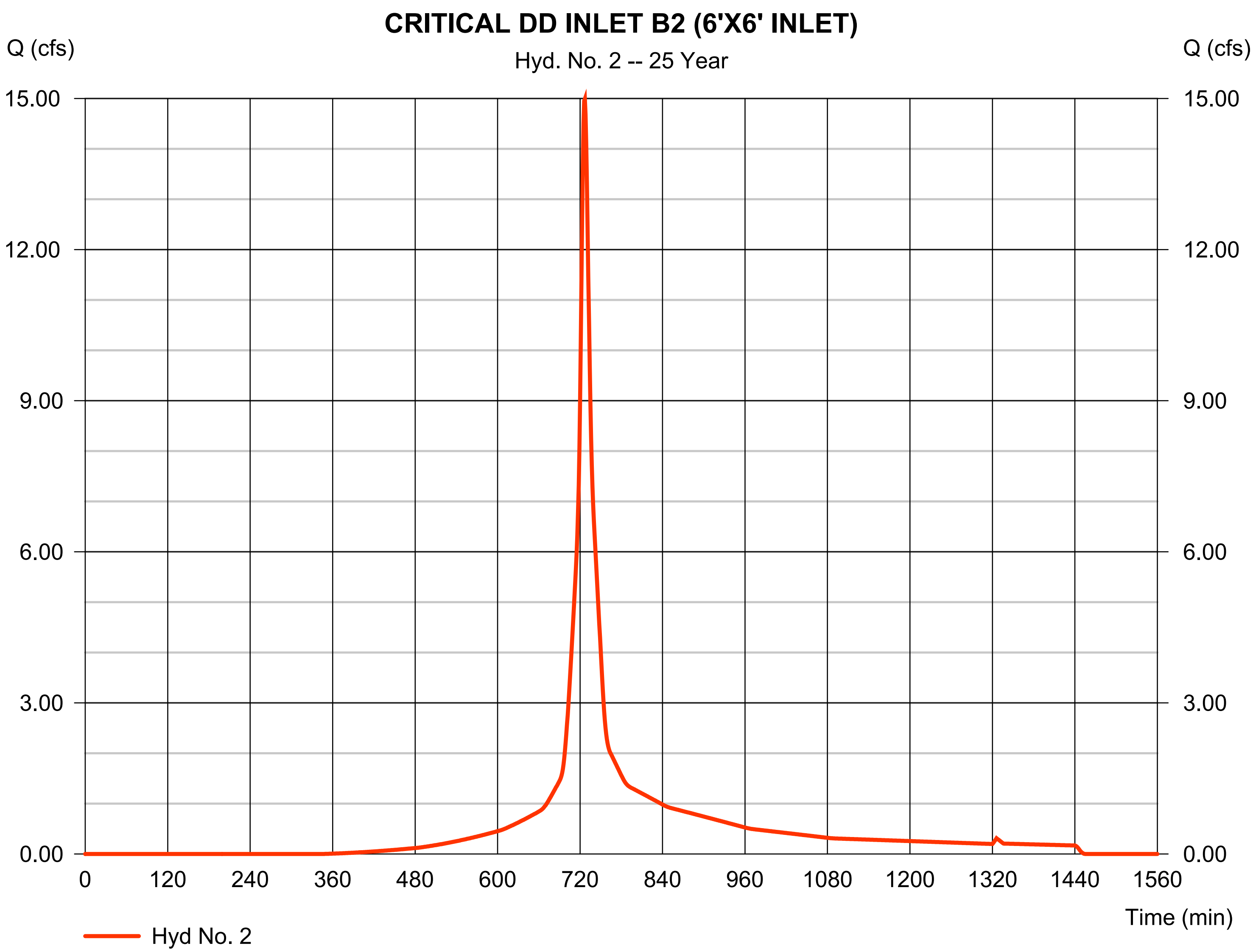
Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	67.50	1	727	234,414	------	------	------	CRITICAL DD INLET F6 (4'X4' INLET
2	SCS Runoff	14.99	1	727	52,050	------	------	------	CRITICAL DD INLET B2 (6'X6' INLET

Hydrograph Report

Hyd. No. 2

CRITICAL DD INLET B2 (6'X6' INLET)

Hydrograph type	= SCS Runoff	Peak discharge	= 14.99 cfs
Storm frequency	= 25 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 52,050 cuft
Drainage area	= 2.780 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	78.06	1	727	272,729	------	------	------	CRITICAL DD INLET F6 (4'X4' INLET
2	SCS Runoff	17.33	1	727	60,558	------	------	------	CRITICAL DD INLET B2 (6'X6' INLET

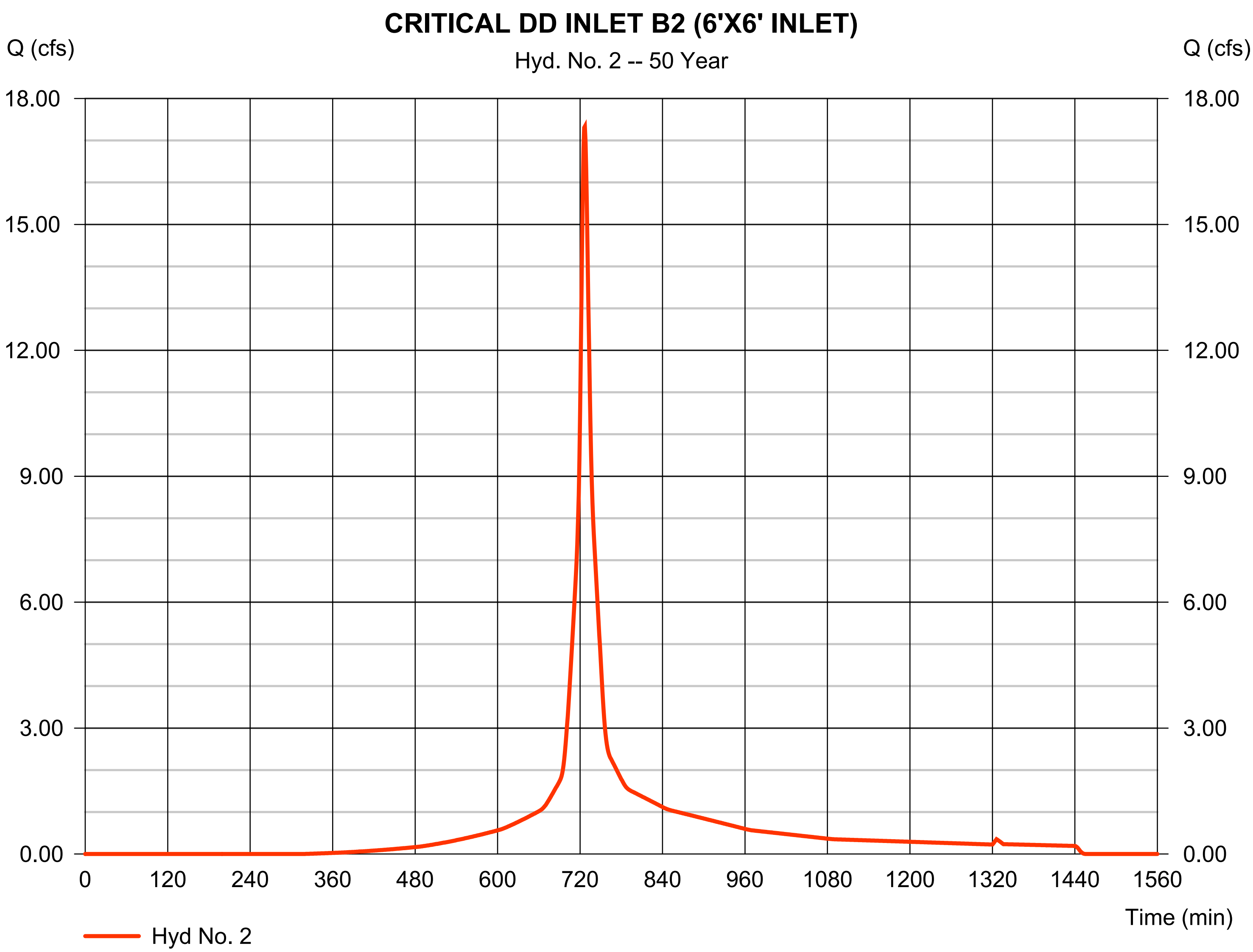
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Thursday, 01 / 29 / 2015

Hyd. No. 2

CRITICAL DD INLET B2 (6'X6' INLET)

Hydrograph type	= SCS Runoff	Peak discharge	= 17.33 cfs
Storm frequency	= 50 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 60,558 cuft
Drainage area	= 2.780 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 8.40 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	87.44	1	727	307,137	------	------	------	CRITICAL DD INLET F6 (4'X4' INLET
2	SCS Runoff	19.42	1	727	68,198	------	------	------	CRITICAL DD INLET B2 (6'X6' INLET

Q-Critical DD Inlet F6.gpw | Return Period: 100 Year | Thursday, 01 / 29 / 2015

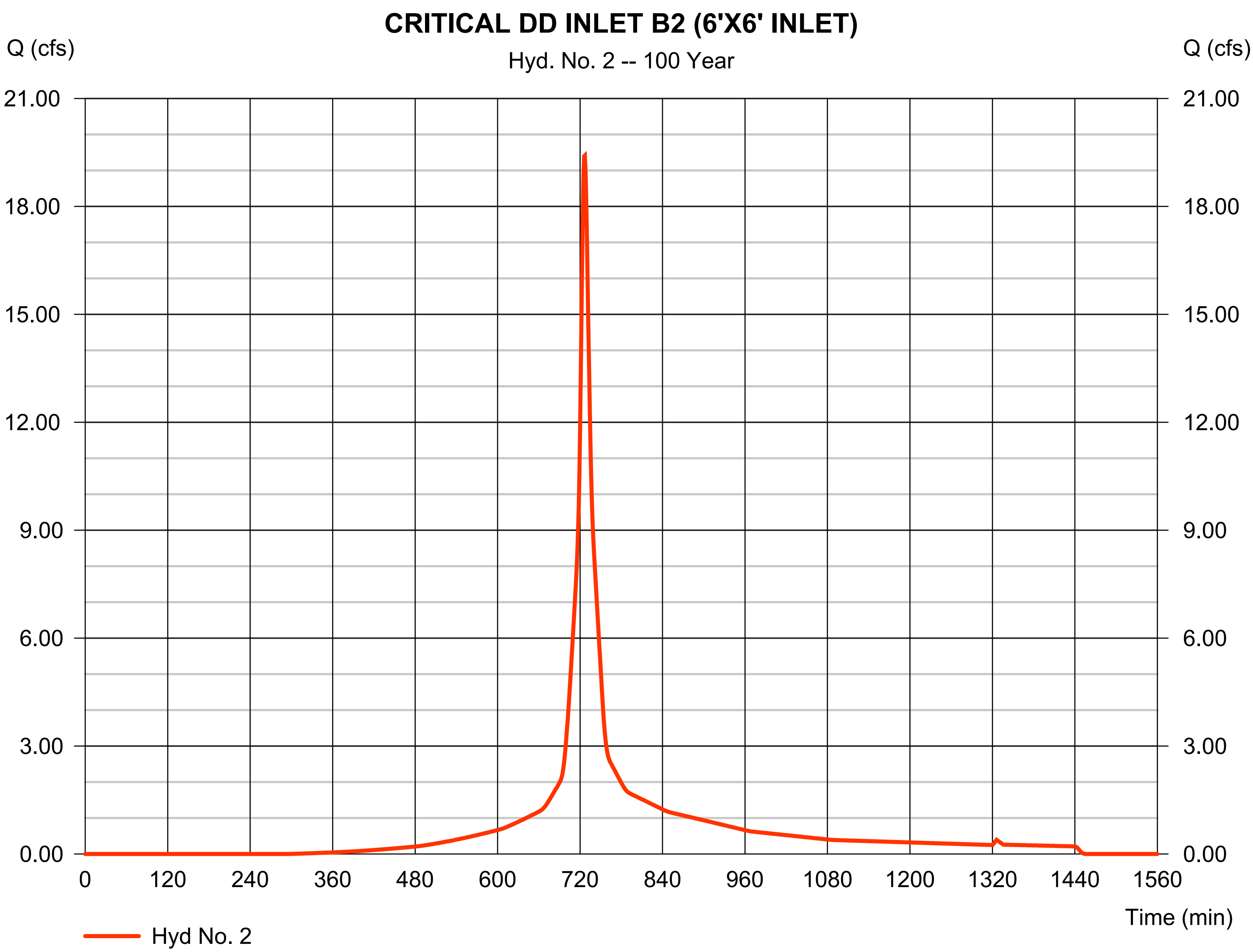
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Thursday, 01 / 29 / 2015

Hyd. No. 2

CRITICAL DD INLET B2 (6'X6' INLET)

Hydrograph type	= SCS Runoff	Peak discharge	= 19.42 cfs
Storm frequency	= 100 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 68,198 cuft
Drainage area	= 2.780 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Thursday, 01 / 29 / 2015

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	0.0000	0.0000	0.0000	--------
3	0.0000	0.0000	0.0000	--------
5	0.0000	0.0000	0.0000	--------
10	0.0000	0.0000	0.0000	--------
25	0.0000	0.0000	0.0000	--------
50	0.0000	0.0000	0.0000	--------
100	0.0000	0.0000	0.0000	--------

File name: SampleFHA.idf

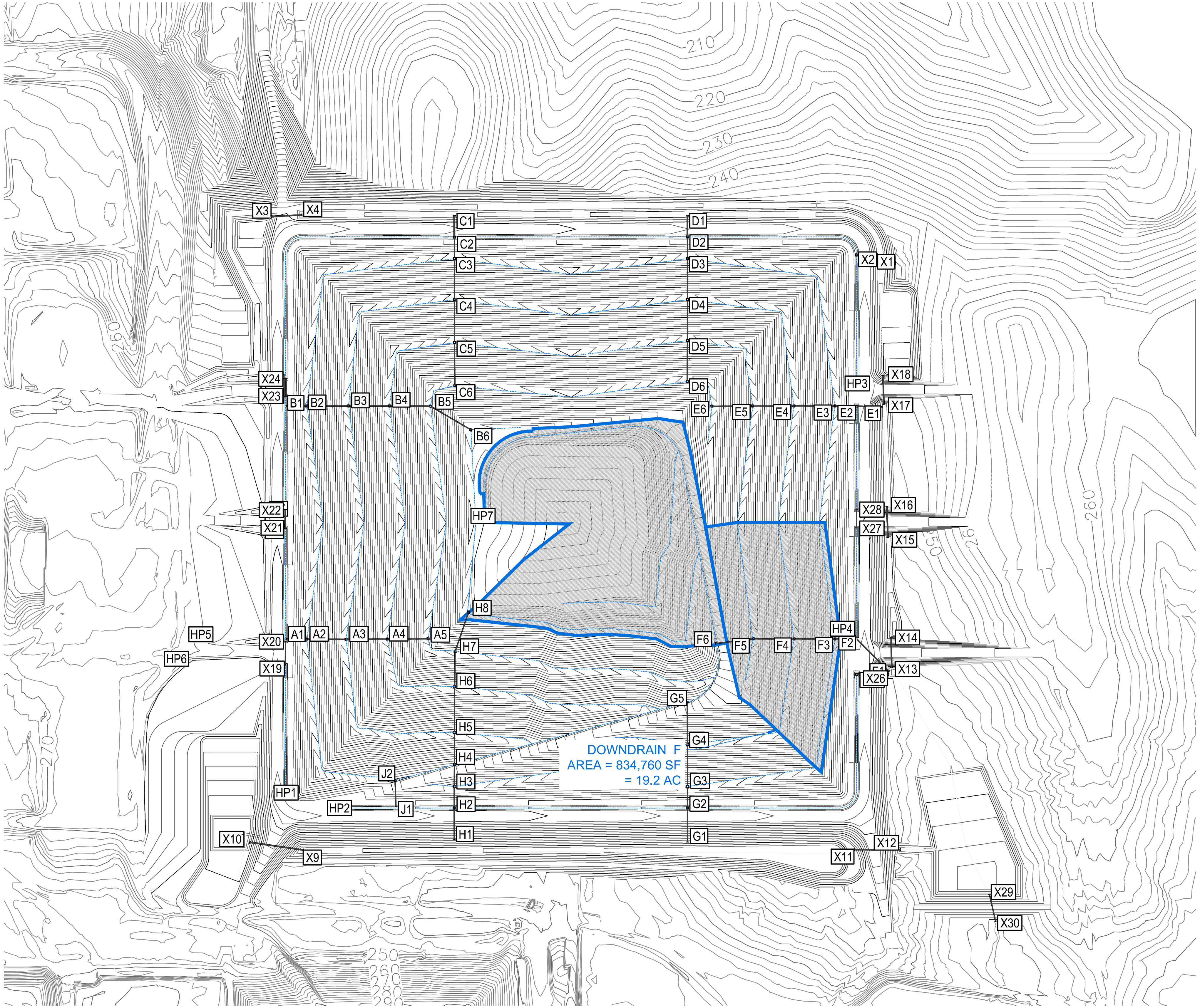
Intensity = B / (Tc + D)^E

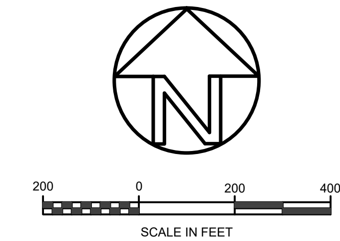
Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Tc = time in minutes. Values may exceed 60.

ojects\2014\EJ147461\Working Files\Calculations-Analyses\SCS METHOD\Peachtree City (24 hr GA Green Book).pcp

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.75	4.50	0.00	5.65	6.50	7.50	8.40	9.20
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00





PEAK FLOW FOR CRITICAL DOWNDRAIN F

Q_{PEAK} = 103.5 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

EMELLE FACILITY

Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

CRITICAL FINAL COVER DOWNDRAIN PIPE WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
C-1

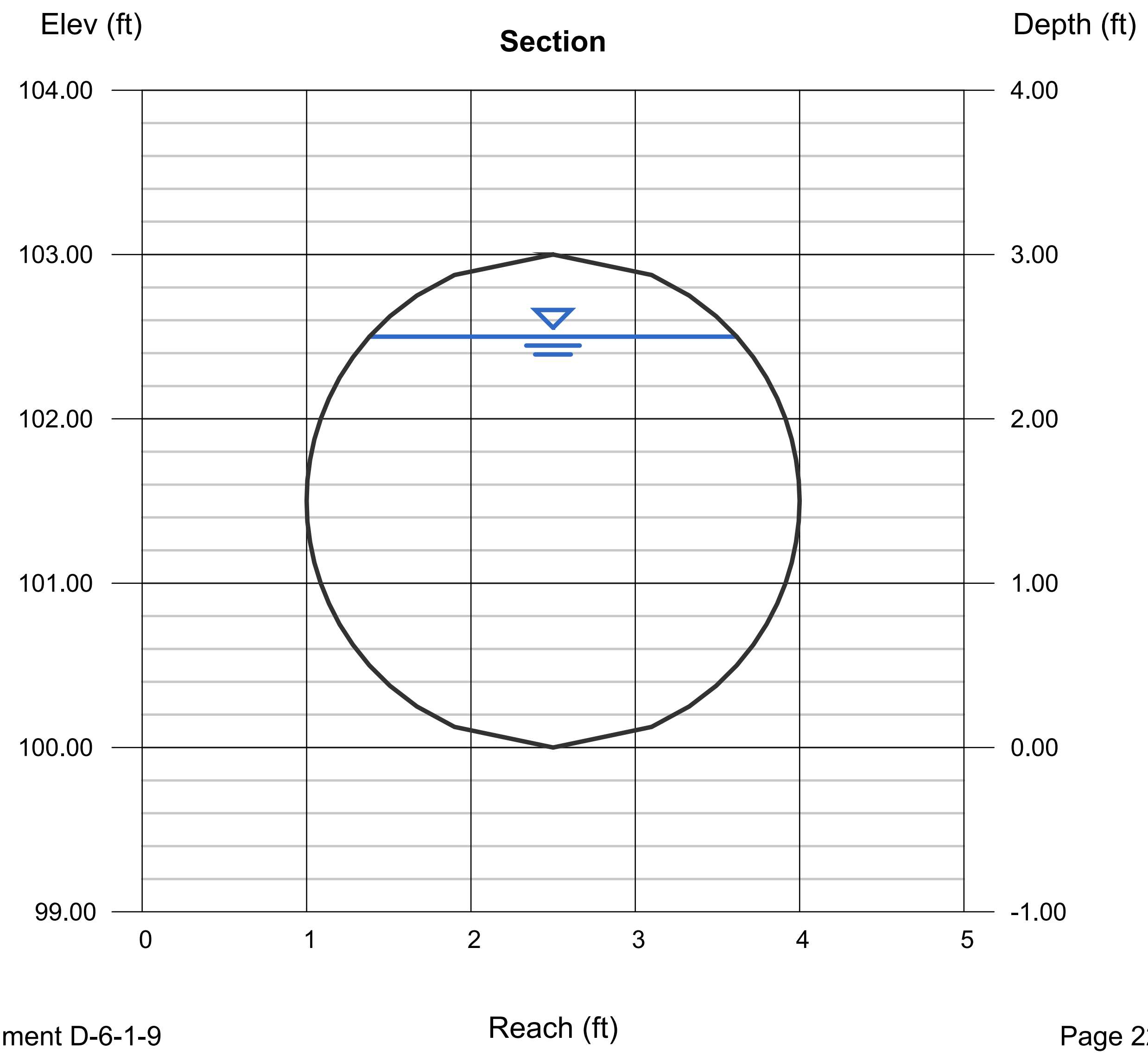
Last Saved By: JCHENSLEY Date: 1/30/2015 8:47 AM File Path: N:\PROJECTS\2014\EJ147410\WORKING FILES\CALCULATIONS-ANALYSES\HYDROLOGY\FIGURE-HYDROLOGY\EJ147410-HYDRO-EMELLE TRENCH 23.DWG

Channel Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Friday, Jan 30 2015

Critical Downdrawin F

Circular			**Highlighted**		
Diameter (ft)	=	3.00	Depth (ft)	=	2.50
			Q (cfs)	=	103.52
			Area (sqft)	=	6.31
Invert Elev (ft)	=	100.00	Velocity (ft/s)	=	16.42
Slope (%)	=	2.00	Wetted Perim (ft)	=	6.92
N-Value	=	0.012	Crit Depth, Yc (ft)	=	2.91
			Top Width (ft)	=	2.23
Calculations			EGL (ft)	=	6.69
Compute by:		Known Q			
Known Q (cfs)	=	103.52			



Watershed Model Schematic

Legend

Hyd.	Origin	Description
1	SCS Runoff	Critical DD - F

Project: Q-Critical DD Pipe.gpw

Friday, 01 / 30 / 2015

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	37.31	1	727	128,029	------	------	------	Critical DD - F

Q-Critical DD.gpw | Return Period: 1 Year | Friday, 01 / 30 / 2015

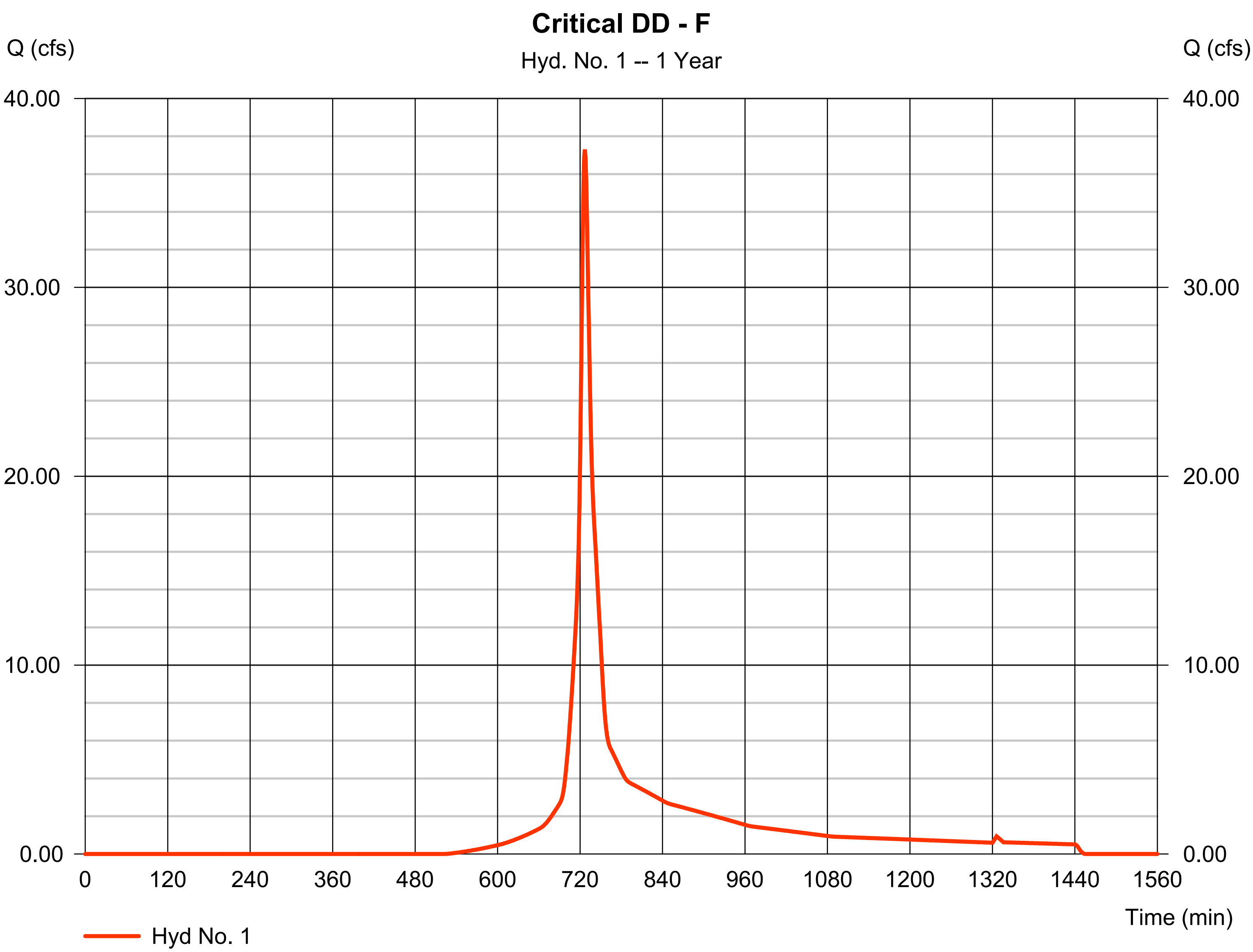
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

Critical DD - F

Hydrograph type	= SCS Runoff	Peak discharge	= 37.31 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 128,029 cuft
Drainage area	= 19.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	50.13	1	727	171,559	------	------	------	Critical DD - F

Q-Critical DD.gpw	Return Period: 2 Year	Friday, 01 / 30 / 2015

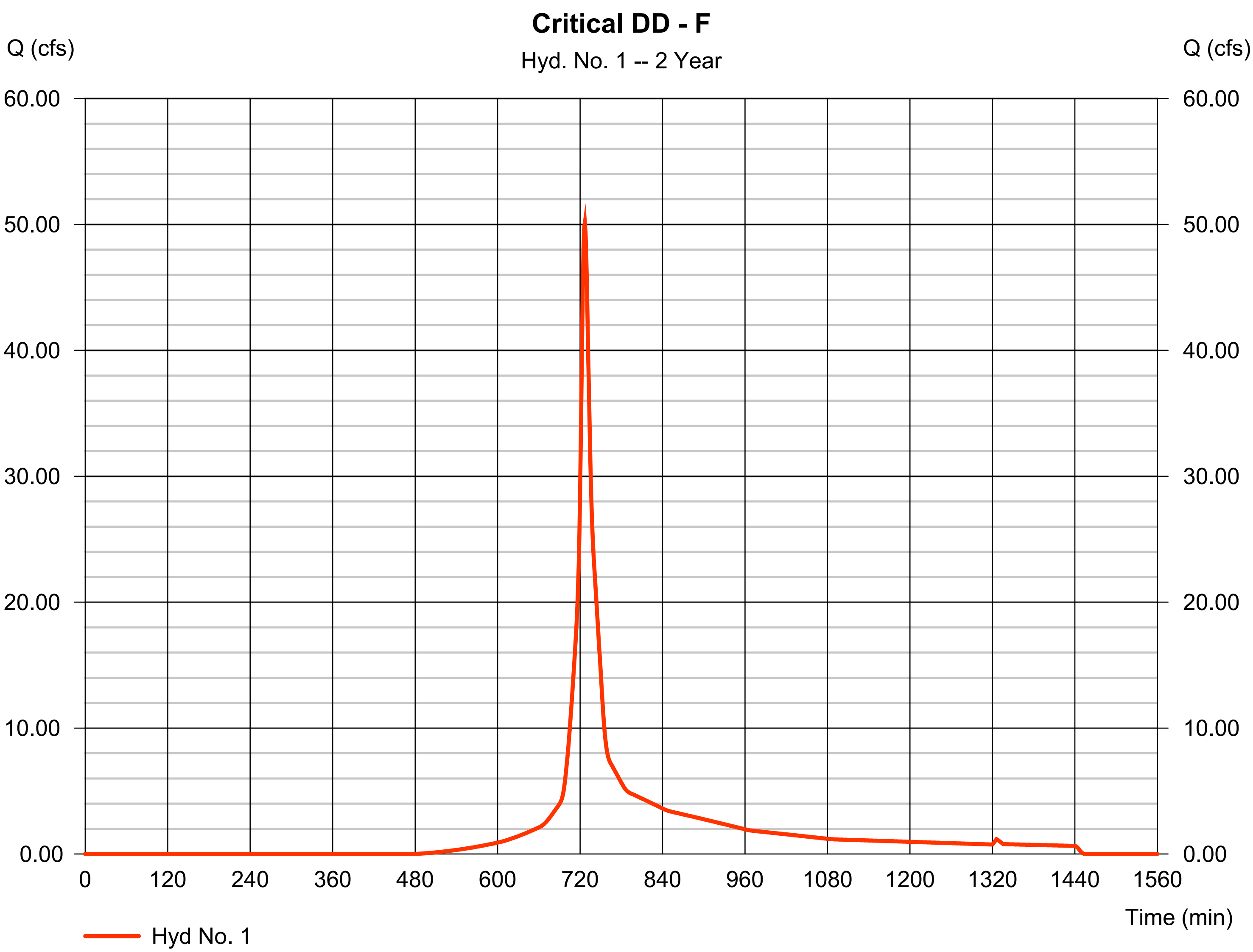
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 1

Critical DD - F

Hydrograph type	= SCS Runoff	Peak discharge	= 50.13 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 171,559 cuft
Drainage area	= 19.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	70.37	1	727	241,636	------	------	------	Critical DD - F

Q-Critical DD.gpw	Return Period: 5 Year	Friday, 01 / 30 / 2015

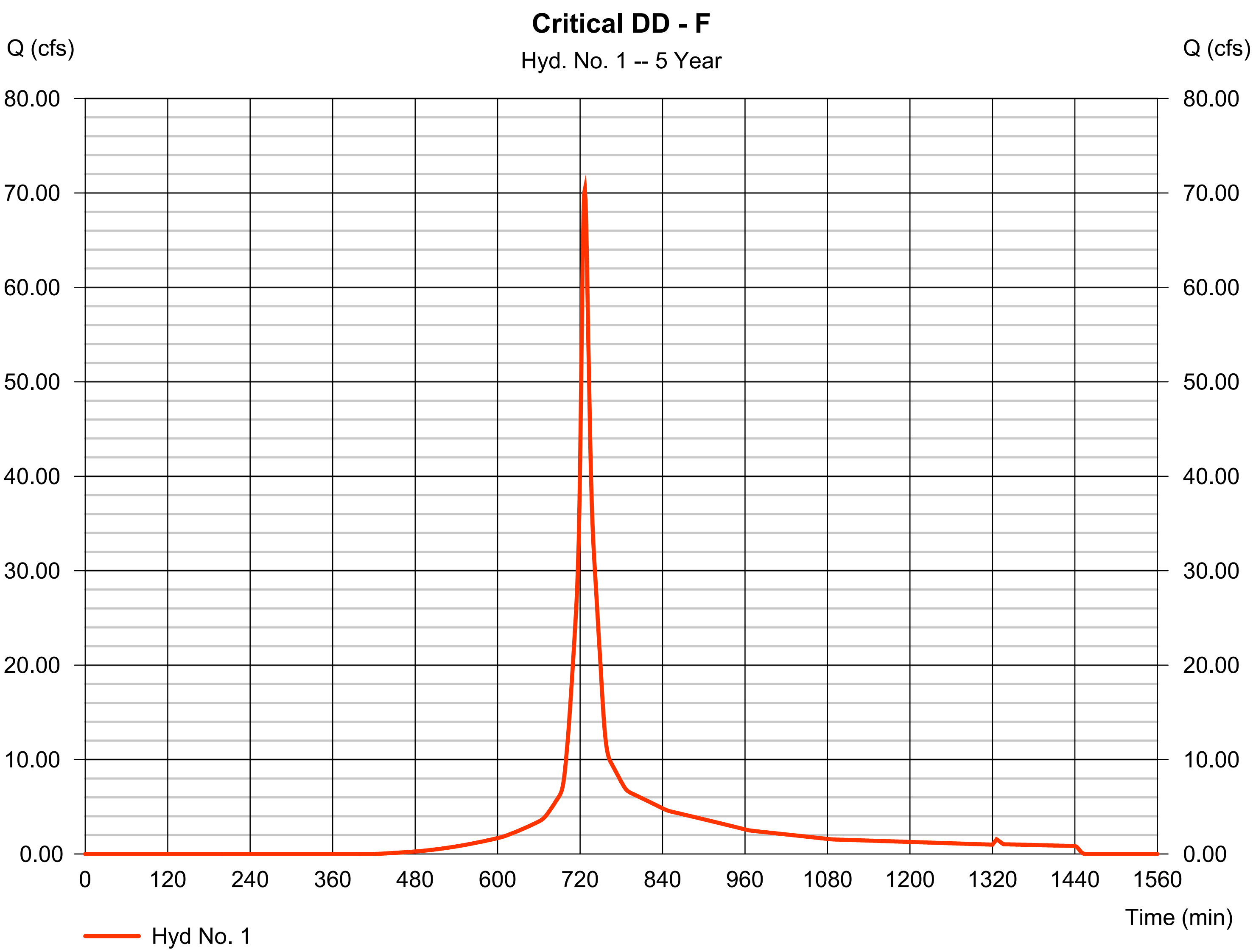
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

Critical DD - F

Hydrograph type	= SCS Runoff	Peak discharge	= 70.37 cfs
Storm frequency	= 5 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 241,636 cuft
Drainage area	= 19.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	85.55	1	727	295,183	------	------	------	Critical DD - F

Q-Critical DD.gpw	Return Period: 10 Year	Friday, 01 / 30 / 2015

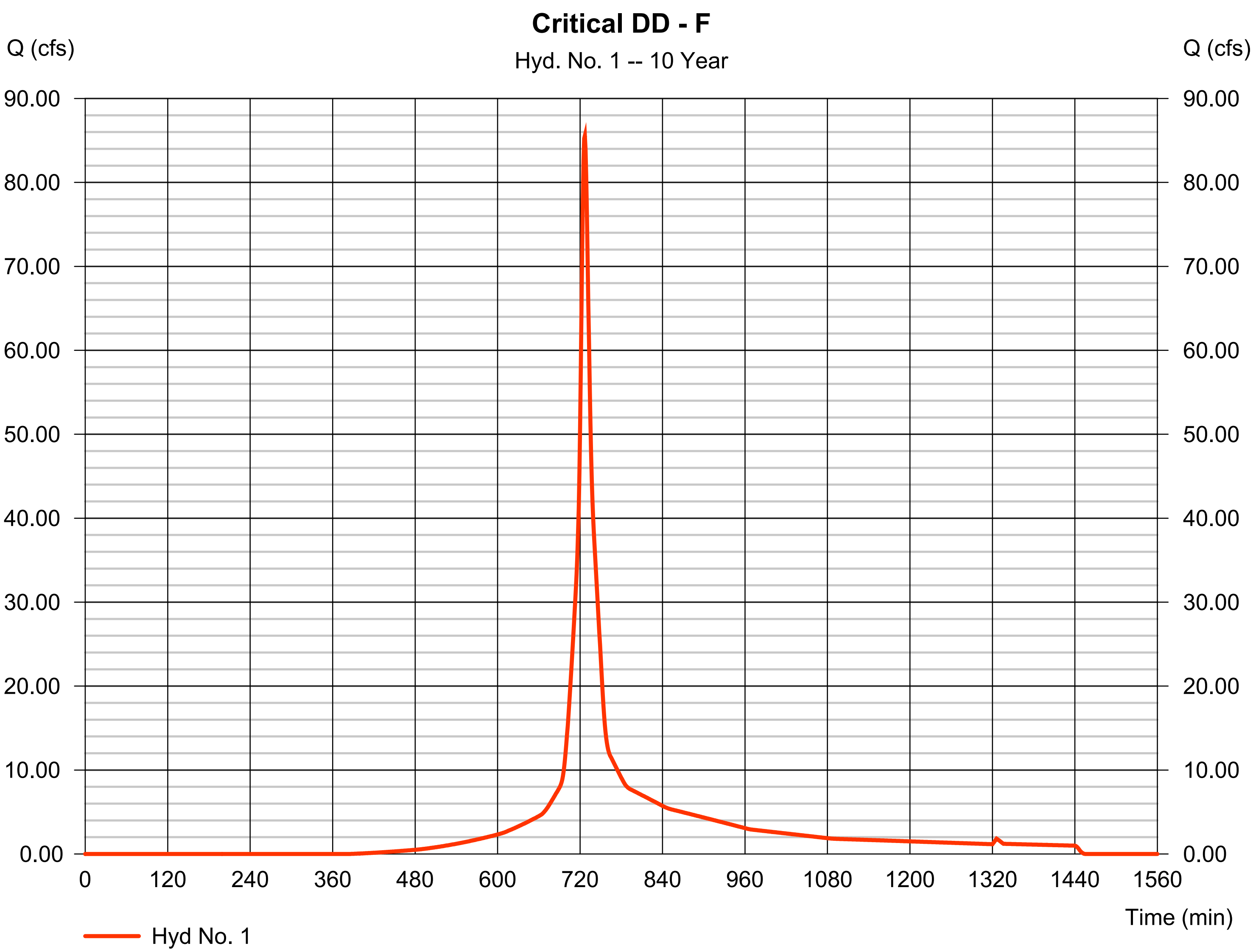
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

Critical DD - F

Hydrograph type	= SCS Runoff	Peak discharge	= 85.55 cfs
Storm frequency	= 10 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 295,183 cuft
Drainage area	= 19.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	103.52	1	727	359,485	------	------	------	Critical DD - F

Q-Critical DD.gpw	Return Period: 25 Year	Friday, 01 / 30 / 2015

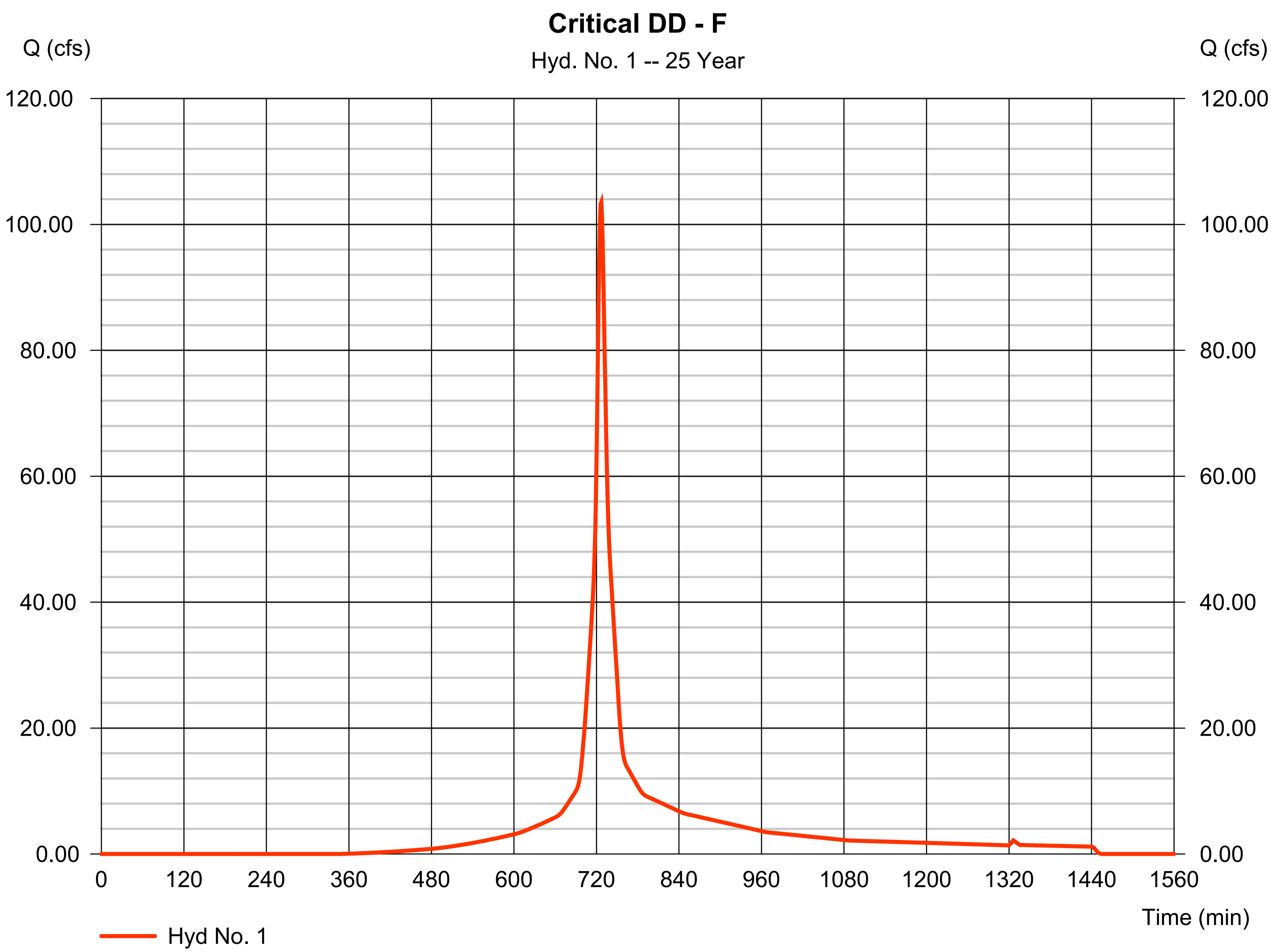
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 1

Critical DD - F

Hydrograph type	= SCS Runoff	Peak discharge	= 103.52 cfs
Storm frequency	= 25 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 359,485 cuft
Drainage area	= 19.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	119.71	1	727	418,243	------	------	------	Critical DD - F

Q-Critical DD.gpw	Return Period: 50 Year	Friday, 01 / 30 / 2015

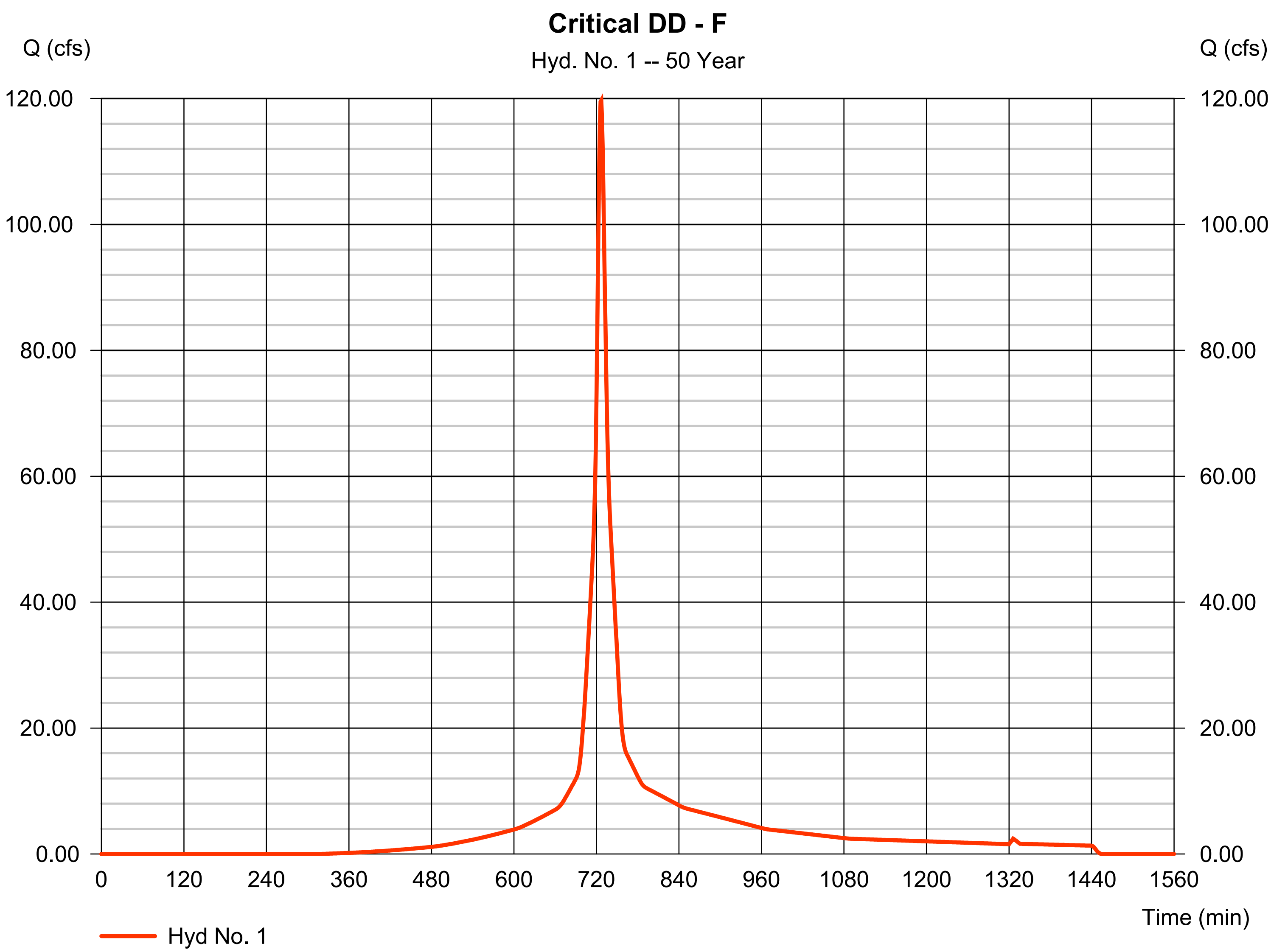
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

Critical DD - F

Hydrograph type	= SCS Runoff	Peak discharge	= 119.71 cfs
Storm frequency	= 50 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 418,243 cuft
Drainage area	= 19.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 8.40 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	134.10	1	727	471,008	------	------	------	Critical DD - F

Q-Critical DD.gpw	Return Period: 100 Year	Friday, 01 / 30 / 2015

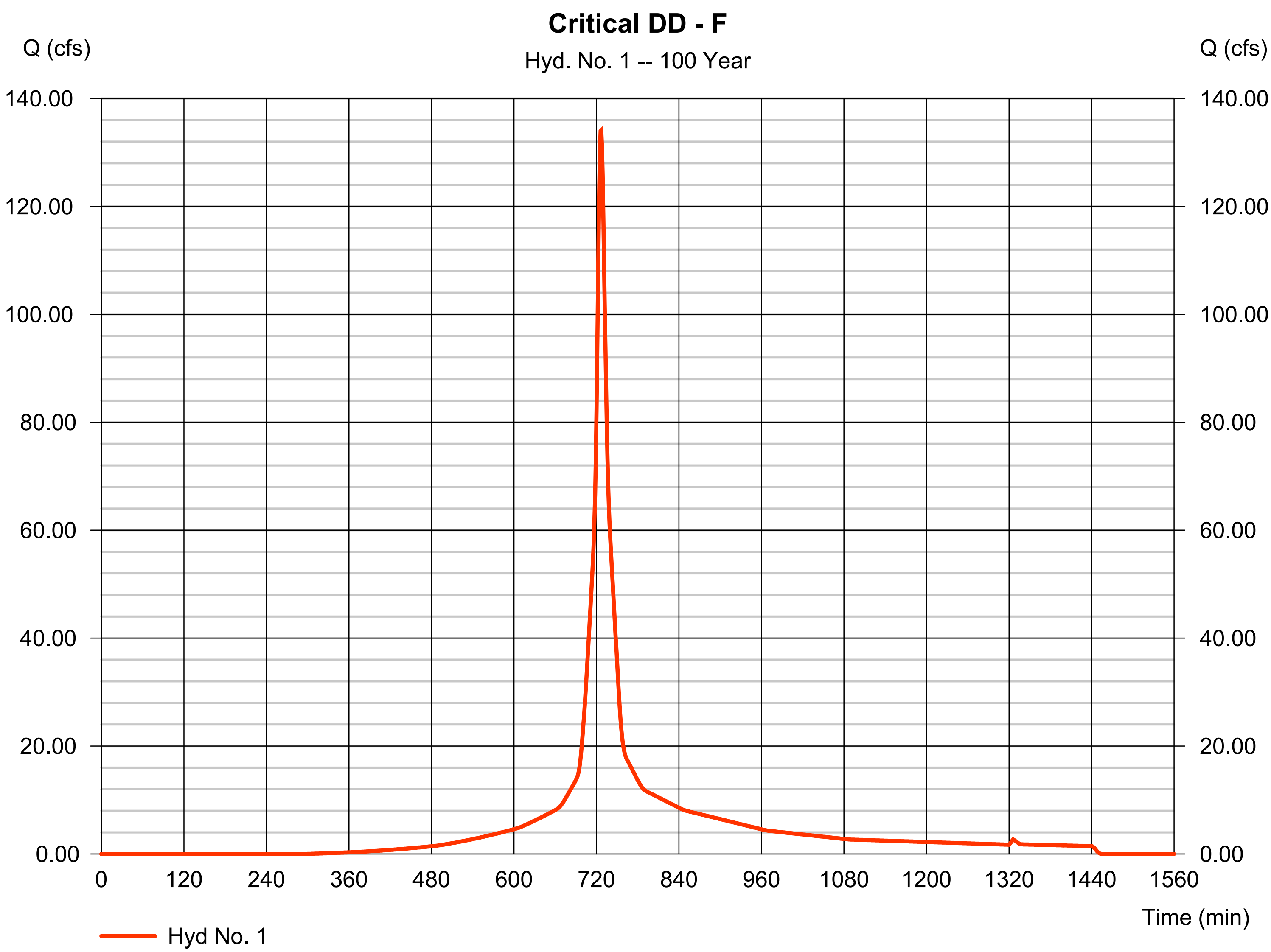
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 1

Critical DD - F

Hydrograph type	= SCS Runoff	Peak discharge	= 134.10 cfs
Storm frequency	= 100 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 471,008 cuft
Drainage area	= 19.200 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	0.0000	0.0000	0.0000	--------
3	0.0000	0.0000	0.0000	--------
5	0.0000	0.0000	0.0000	--------
10	0.0000	0.0000	0.0000	--------
25	0.0000	0.0000	0.0000	--------
50	0.0000	0.0000	0.0000	--------
100	0.0000	0.0000	0.0000	--------

File name: SampleFHA.idf

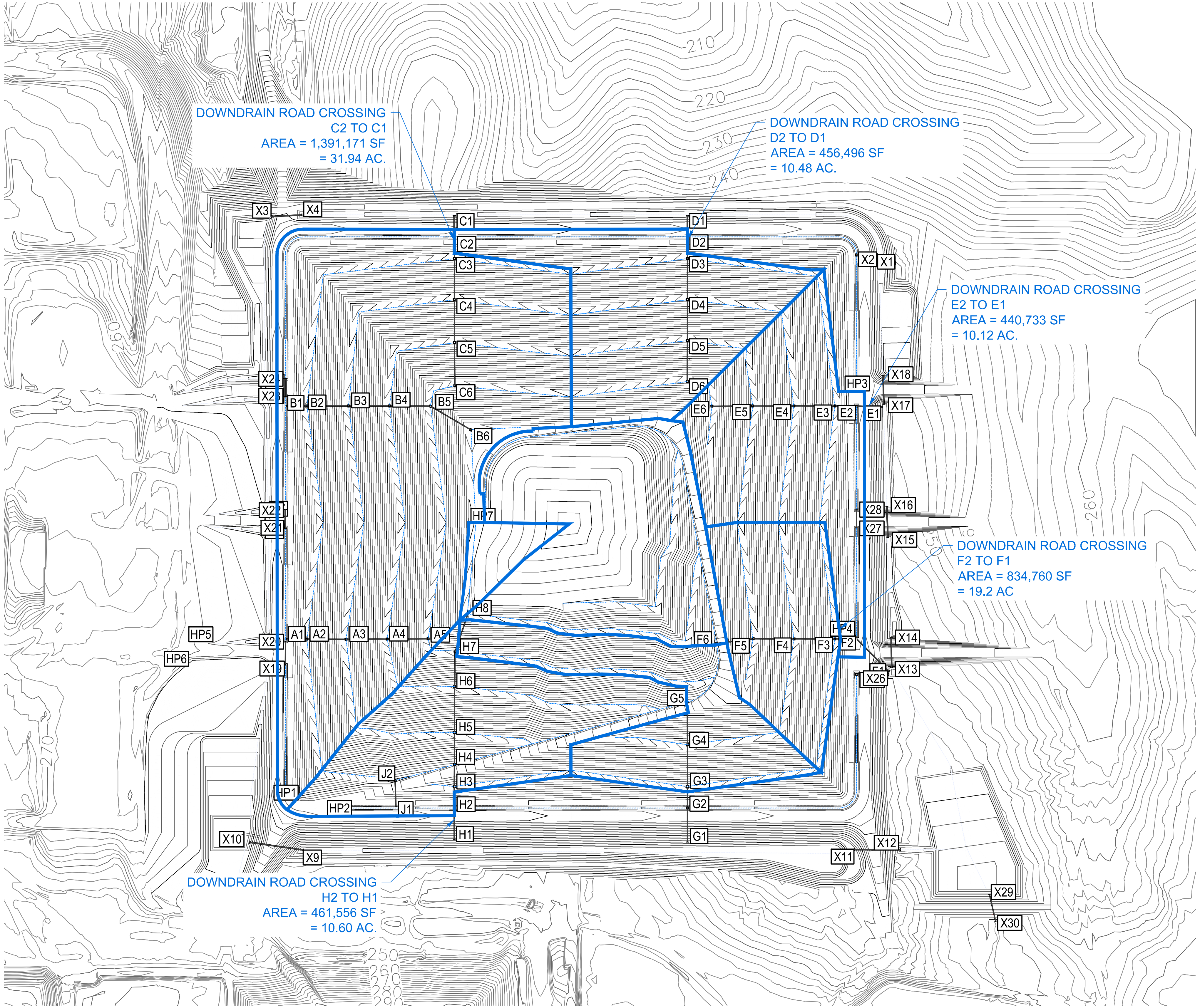
Intensity = B / (Tc + D)^E

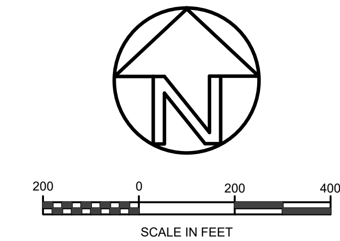
Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Tc = time in minutes. Values may exceed 60.

ojects\2014\EJ147461\Working Files\Calculations-Analyses\SCS METHOD\Peachtree City (24 hr GA Green Book).pcp

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.75	4.50	0.00	5.65	6.50	7.50	8.40	9.20
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00





PEAK FLOW FOR DOWNDRAIN ROAD CROSSINGS

C2-C1 -- Q_{PEAK} = 163.4 cfs
D2-D1 -- Q_{PEAK} = 62.3 cfs
E2-E1 -- Q_{PEAK} = 49.3 cfs
F2-F1 -- Q_{PEAK} = 103.5 cfs
G2-G1 -- Q_{PEAK} = 69.8 cfs
H2-H1 -- Q_{PEAK} = 67.5 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

EMELLE FACILITY

Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

FINAL COVER DOWNDRAIN AND DOWNDRAIN ROAD CROSSING WATERSHEDS

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
C-2

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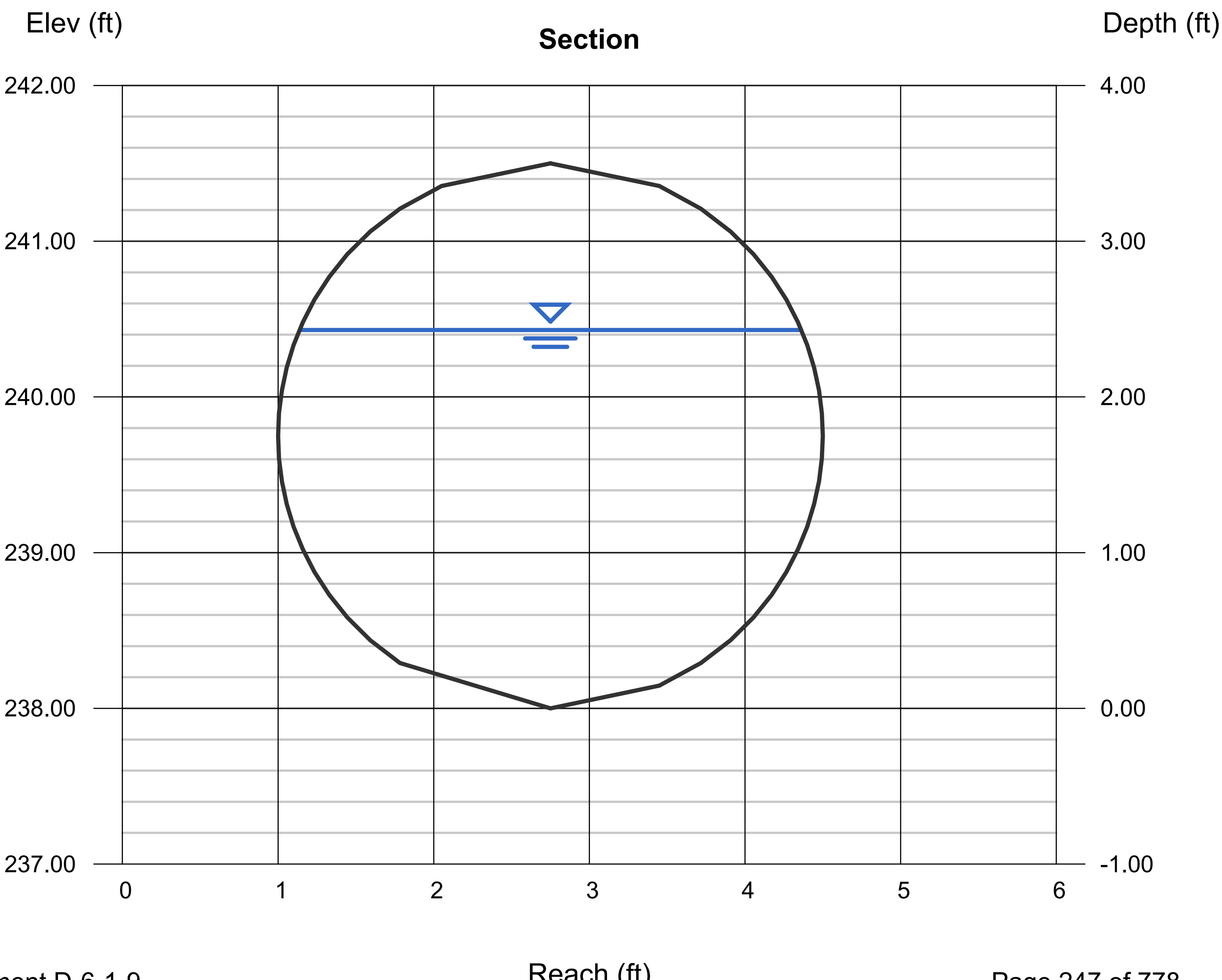
Channel Report

Downdrain Road Crossing -- C2 - C1

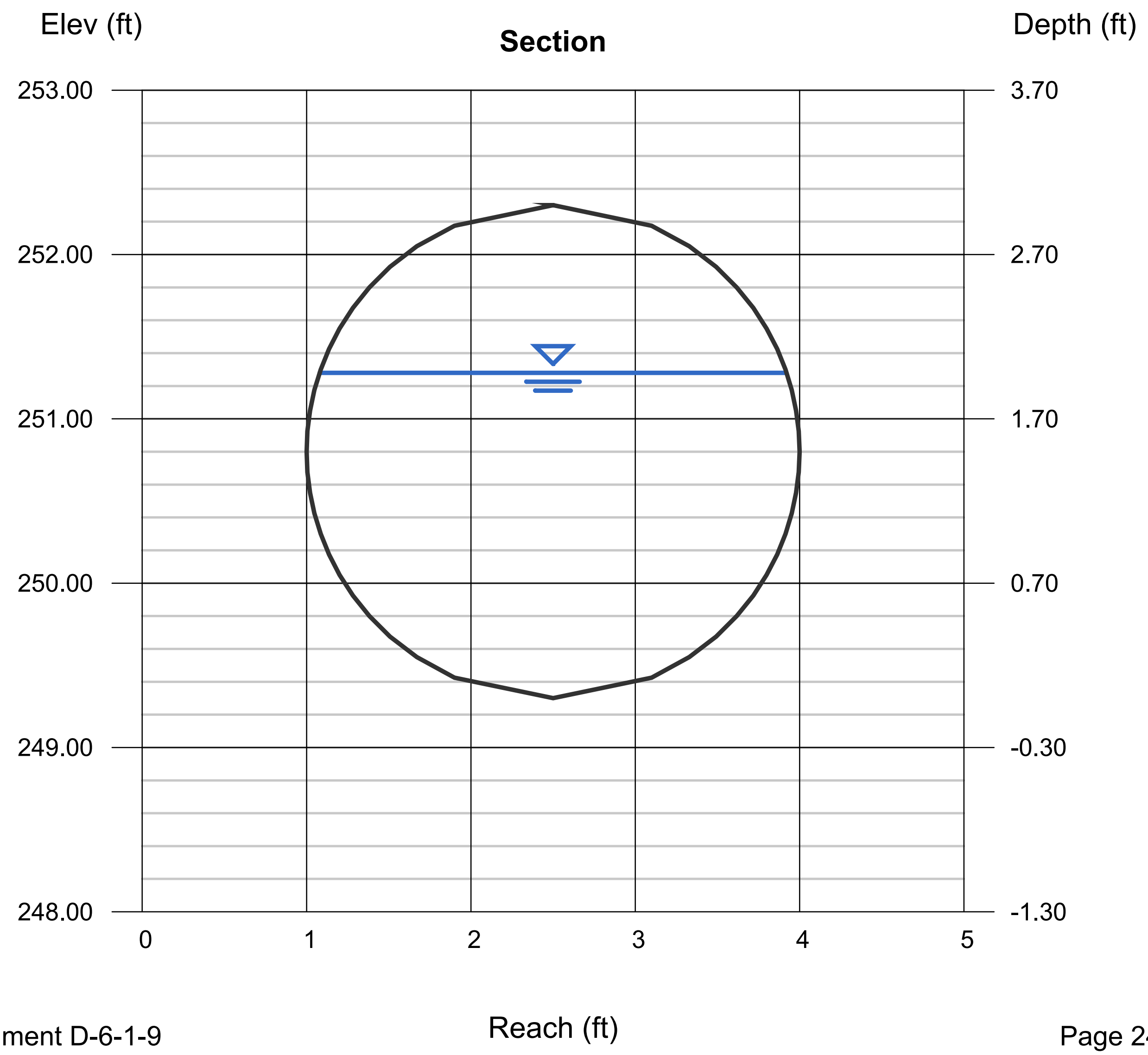
Circular		**Highlighted**	
Diameter (ft)	= 3.50	Depth (ft)	= 2.43
		Q (cfs)	= 163.40
		Area (sqft)	= 7.13
Invert Elev (ft)	= 238.00	Velocity (ft/s)	= 22.92
Slope (%)	= 3.30	Wetted Perim (ft)	= 6.89
N-Value	= 0.012	Crit Depth, Yc (ft)	= 3.42
		Top Width (ft)	= 3.22
Calculations		EGL (ft)	= 10.60
Compute by:	Known Q		
Known Q (cfs)	= 163.40		



Channel Report

Downdrawin Road Crossing -- D2 - D1

Circular		**Highlighted**	
Diameter (ft)	= 3.00	Depth (ft)	= 1.98
		Q (cfs)	= 66.30
		Area (sqft)	= 4.96
Invert Elev (ft)	= 249.30	Velocity (ft/s)	= 13.36
Slope (%)	= 1.40	Wetted Perim (ft)	= 5.70
N-Value	= 0.012	Crit Depth, Yc (ft)	= 2.61
		Top Width (ft)	= 2.84
Calculations		EGL (ft)	= 4.75
Compute by:	Known Q		
Known Q (cfs)	= 66.30		

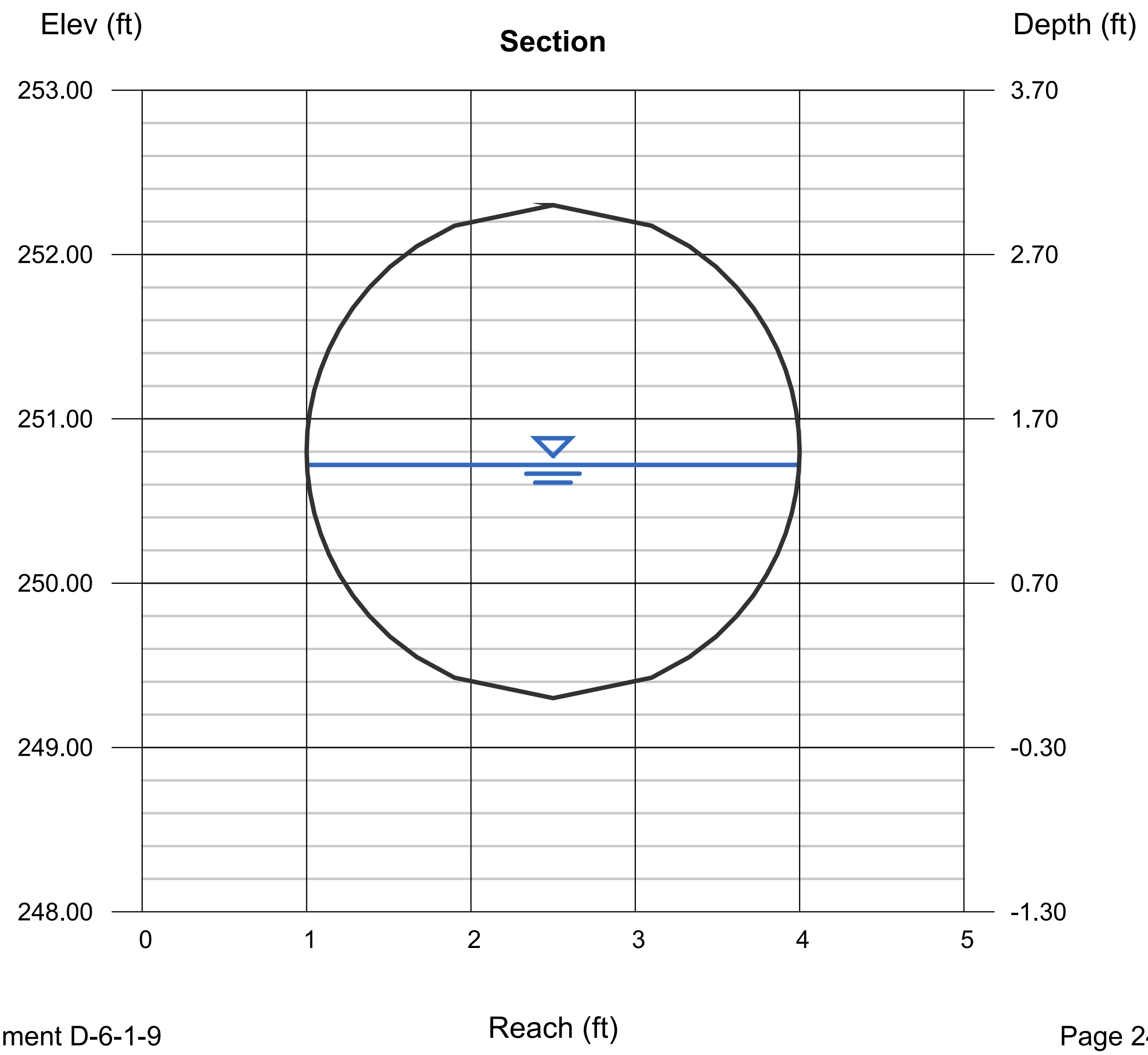


Channel Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Friday, Jan 30 2015

Downdrawin Road Crossing -- E2 - E1

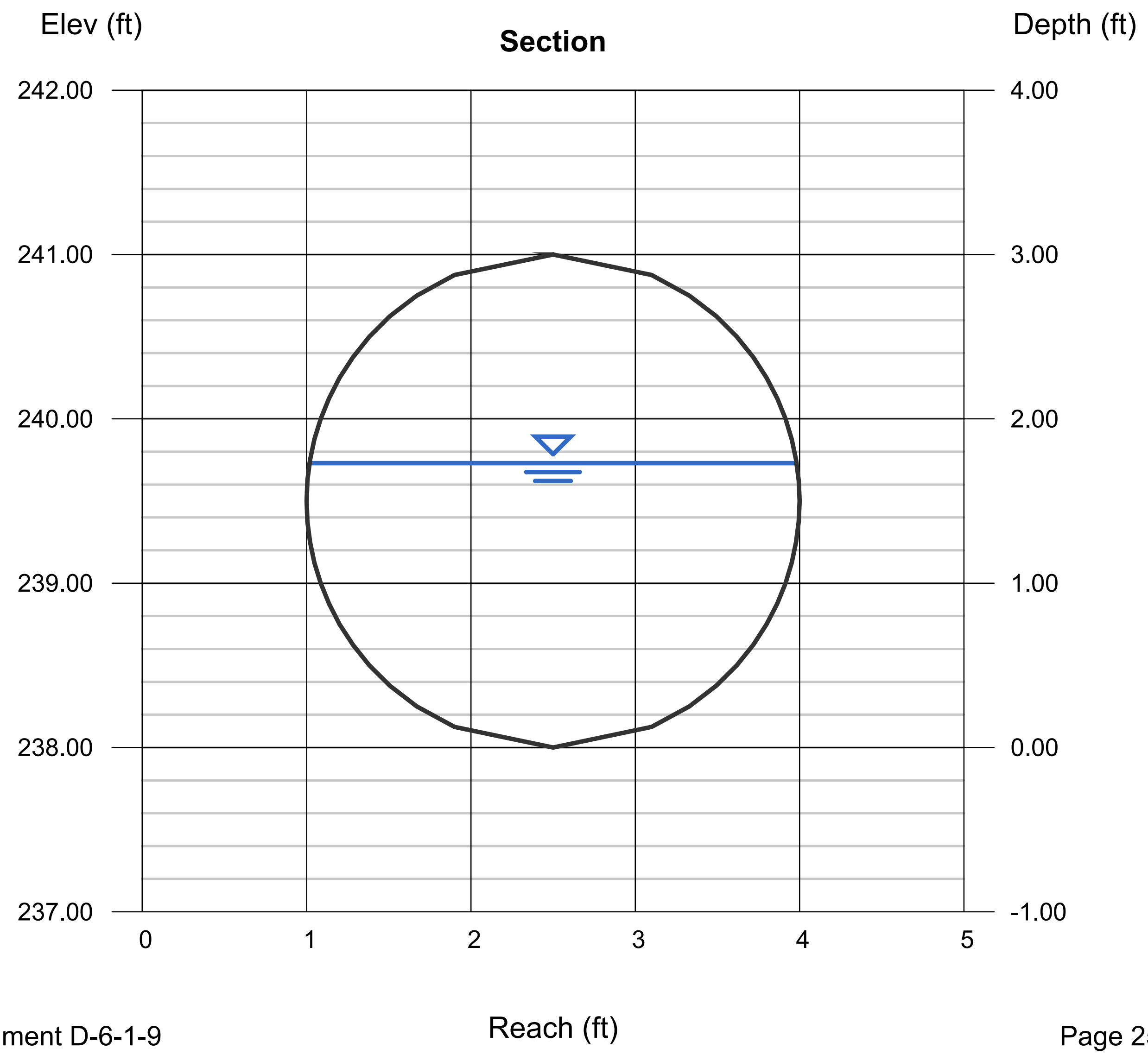
Circular		**Highlighted**	
Diameter (ft)	= 3.00	Depth (ft)	= 1.42
		Q (cfs)	= 63.90
		Area (sqft)	= 3.31
Invert Elev (ft)	= 249.30	Velocity (ft/s)	= 19.33
Slope (%)	= 3.80	Wetted Perim (ft)	= 4.56
N-Value	= 0.012	Crit Depth, Yc (ft)	= 2.57
		Top Width (ft)	= 3.00
Calculations		EGL (ft)	= 7.23
Compute by:	Known Q		
Known Q (cfs)	= 63.90		



Channel Report

Downdrawin Road Crossing -- F2 - F1

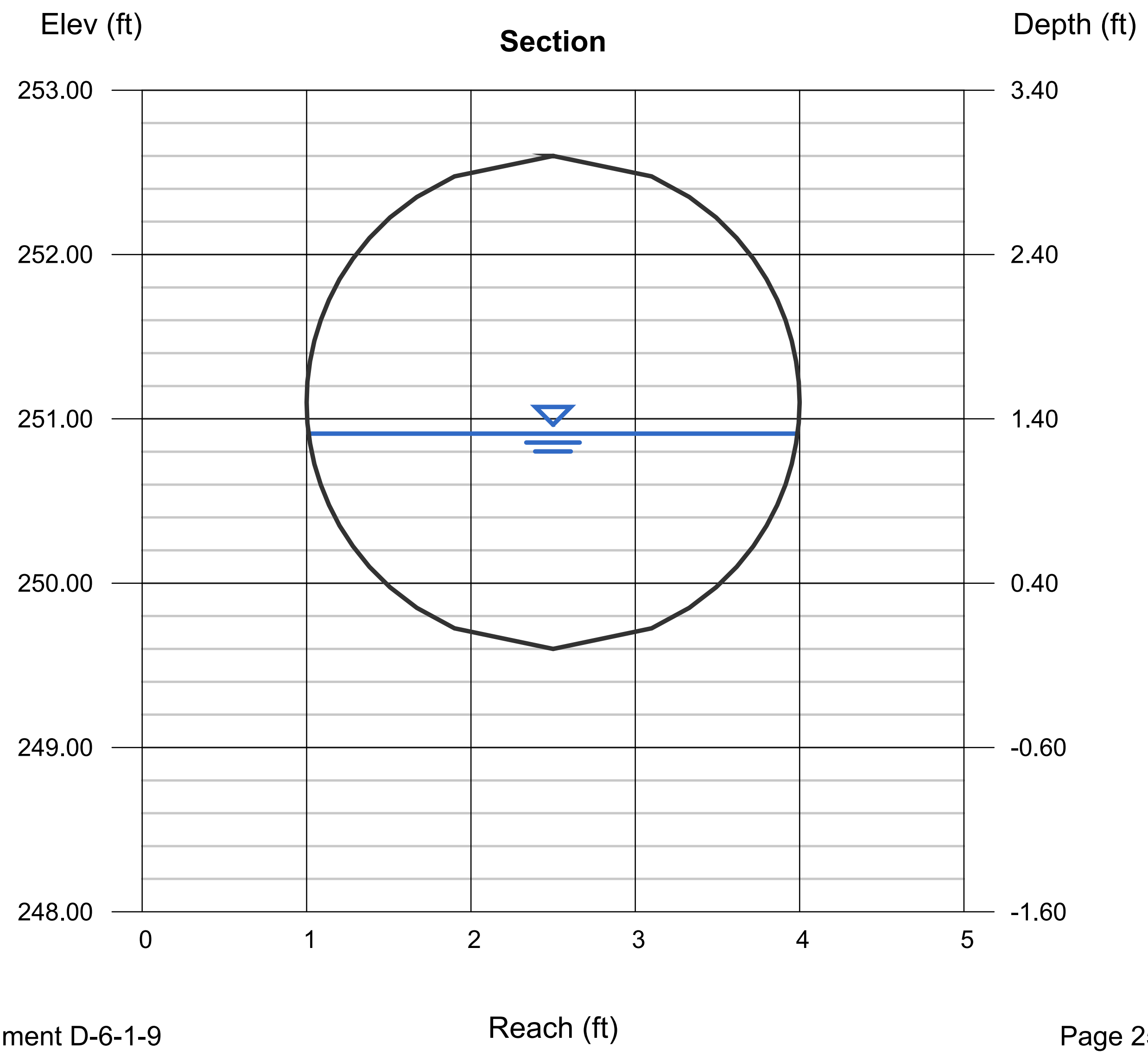
Circular		**Highlighted**	
Diameter (ft)	= 3.00	Depth (ft)	= 1.73
		Q (cfs)	= 103.52
		Area (sqft)	= 4.22
Invert Elev (ft)	= 238.00	Velocity (ft/s)	= 24.51
Slope (%)	= 5.20	Wetted Perim (ft)	= 5.17
N-Value	= 0.012	Crit Depth, Yc (ft)	= 2.91
		Top Width (ft)	= 2.96
Calculations		EGL (ft)	= 11.07
Compute by:	Known Q		
Known Q (cfs)	= 103.52		



Channel Report

Downdrawin Road Crossing -- G2 - G1

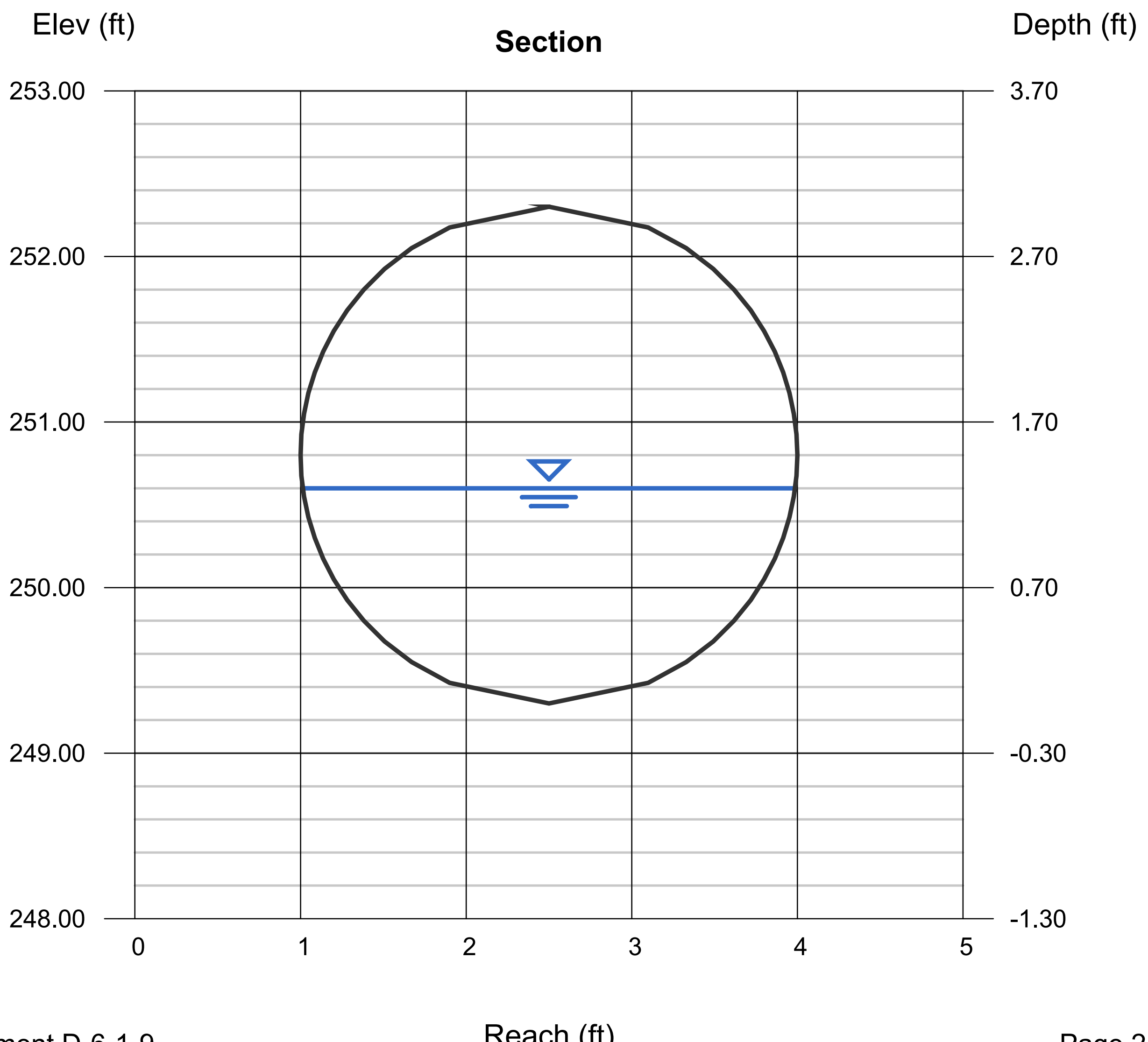
Circular		**Highlighted**	
Diameter (ft)	= 3.00	Depth (ft)	= 1.31
		Q (cfs)	= 69.80
		Area (sqft)	= 2.97
Invert Elev (ft)	= 249.60	Velocity (ft/s)	= 23.49
Slope (%)	= 6.00	Wetted Perim (ft)	= 4.33
N-Value	= 0.012	Crit Depth, Yc (ft)	= 2.66
		Top Width (ft)	= 2.98
Calculations		EGL (ft)	= 9.89
Compute by:	Known Q		
Known Q (cfs)	= 69.80		



Channel Report

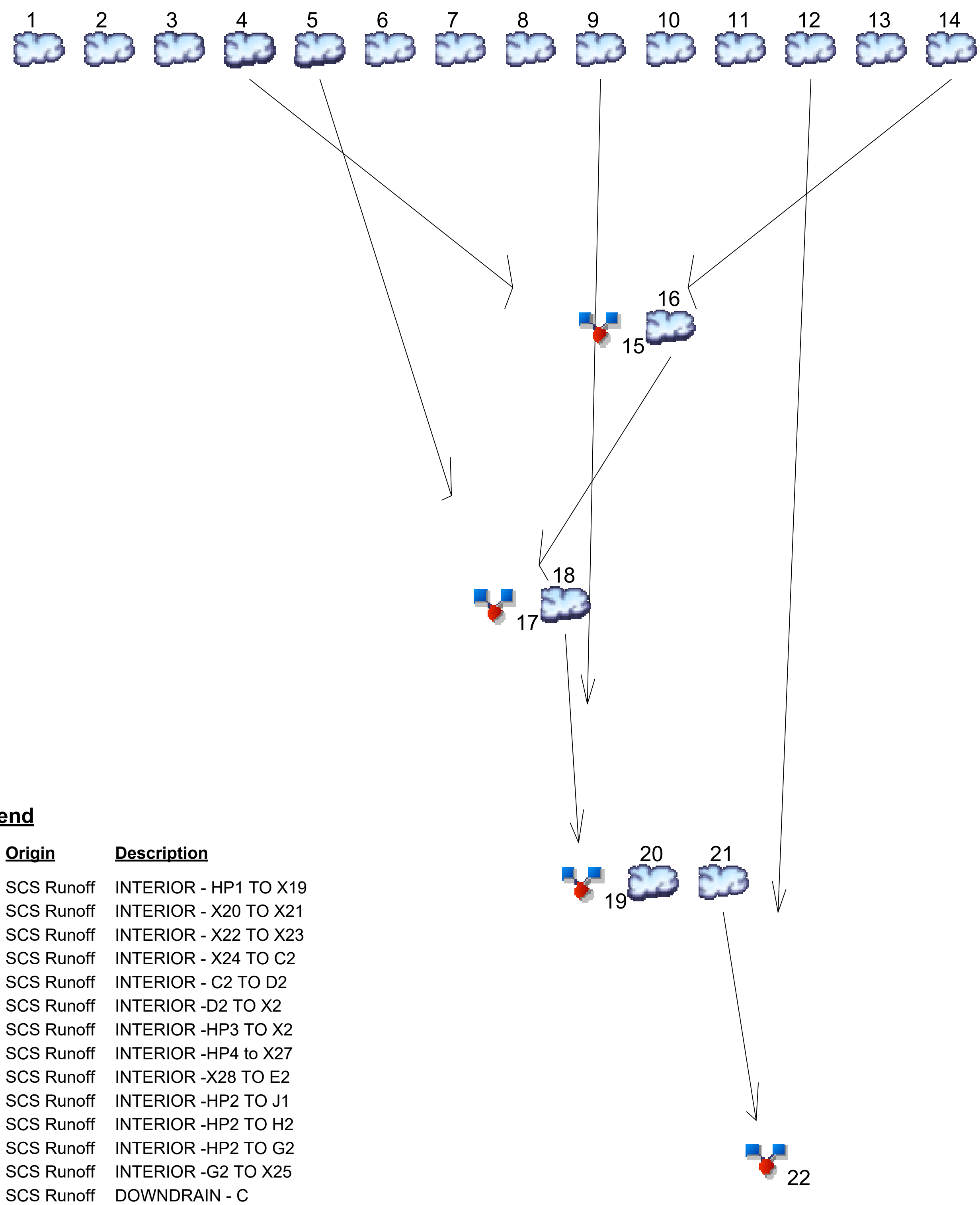
Downdrawin Road Crossing -- H2 - H1

Circular		**Highlighted**	
Diameter (ft)	= 3.00	Depth (ft)	= 1.30
		Q (cfs)	= 67.50
		Area (sqft)	= 2.95
Invert Elev (ft)	= 249.30	Velocity (ft/s)	= 22.89
Slope (%)	= 5.80	Wetted Perim (ft)	= 4.32
N-Value	= 0.012	Crit Depth, Yc (ft)	= 2.63
		Top Width (ft)	= 2.97
Calculations		EGL (ft)	= 9.45
Compute by:	Known Q		
Known Q (cfs)	= 67.50		



Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3



Legend

Hyd.	**Origin**	**Description**
1	SCS Runoff	INTERIOR - HP1 TO X19
2	SCS Runoff	INTERIOR - X20 TO X21
3	SCS Runoff	INTERIOR - X22 TO X23
4	SCS Runoff	INTERIOR - X24 TO C2
5	SCS Runoff	INTERIOR - C2 TO D2
6	SCS Runoff	INTERIOR -D2 TO X2
7	SCS Runoff	INTERIOR -HP3 TO X2
8	SCS Runoff	INTERIOR -HP4 to X27
9	SCS Runoff	INTERIOR -X28 TO E2
10	SCS Runoff	INTERIOR -HP2 TO J1
11	SCS Runoff	INTERIOR -HP2 TO H2
12	SCS Runoff	INTERIOR -HP2 TO G2
13	SCS Runoff	INTERIOR -G2 TO X25
14	SCS Runoff	DOWNDRAIN - C
15	Combine	DD RD X-ING @ C2-C1
16	SCS Runoff	DOWNDRAIN - D
17	Combine	DD ROAD X-ING @ D2-D1
18	SCS Runoff	DOWNDRAIN - E
19	Combine	DD ROAD X-ING @ E2-E1
20	SCS Runoff	DD RD X-ING @ H2-H1
21	SCS Runoff	DOWNDRAIN - G
22	Combine	DD ROAD XING @ G2-G1

Project: Q-DD Rd X-ings.gpw

Friday, 01 / 30 / 2015

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	3.168	1	723	9,202	------	------	------	INTERIOR - HP1 TO X19
2	SCS Runoff	23.24	1	725	71,722	------	------	------	INTERIOR - X20 TO X21
3	SCS Runoff	41.20	1	726	132,630	------	------	------	INTERIOR - X22 TO X23
4	SCS Runoff	45.16	1	727	154,968	------	------	------	INTERIOR - X24 TO C2
5	SCS Runoff	4.913	1	723	14,270	------	------	------	INTERIOR - C2 TO D2
6	SCS Runoff	3.650	1	723	10,602	------	------	------	INTERIOR -D2 TO X2
7	SCS Runoff	3.008	1	723	8,735	------	------	------	INTERIOR -HP3 TO X2
8	SCS Runoff	2.870	1	722	7,814	------	------	------	INTERIOR -HP4 to X27
9	SCS Runoff	5.464	1	723	15,870	------	------	------	INTERIOR -X28 TO E2
10	SCS Runoff	1.999	1	726	6,436	------	------	------	INTERIOR -HP2 TO J1
11	SCS Runoff	6.180	1	726	19,894	------	------	------	INTERIOR -HP2 TO H2
12	SCS Runoff	10.14	1	727	34,808	------	------	------	INTERIOR -HP2 TO G2
13	SCS Runoff	14.22	1	729	53,628	------	------	------	INTERIOR -G2 TO X25
14	SCS Runoff	19.95	1	722	54,325	------	------	------	DOWNDRAIN - C
15	Combine	58.68	1	725	209,292	4, 14	------	------	DD RD X-ING @ C2-C1
16	SCS Runoff	19.15	1	722	52,137	------	------	------	DOWNDRAIN - D
17	Combine	23.82	1	722	66,406	5, 16	------	------	DD ROAD X-ING @ D2-D1
18	SCS Runoff	17.77	1	722	48,386	------	------	------	DOWNDRAIN - E
19	Combine	22.97	1	722	64,256	9, 18	------	------	DD ROAD X-ING @ E2-E1
20	SCS Runoff	24.34	1	722	66,265	------	------	------	DD RD X-ING @ H2-H1
21	SCS Runoff	17.38	1	722	47,323	------	------	------	DOWNDRAIN - G
22	Combine	25.08	1	723	82,131	12, 21	------	------	DD ROAD XING @ G2-G1

Q-DD Rd X-ings.gpw	Return Period: 1 Year	Friday, 01 / 30 / 2015

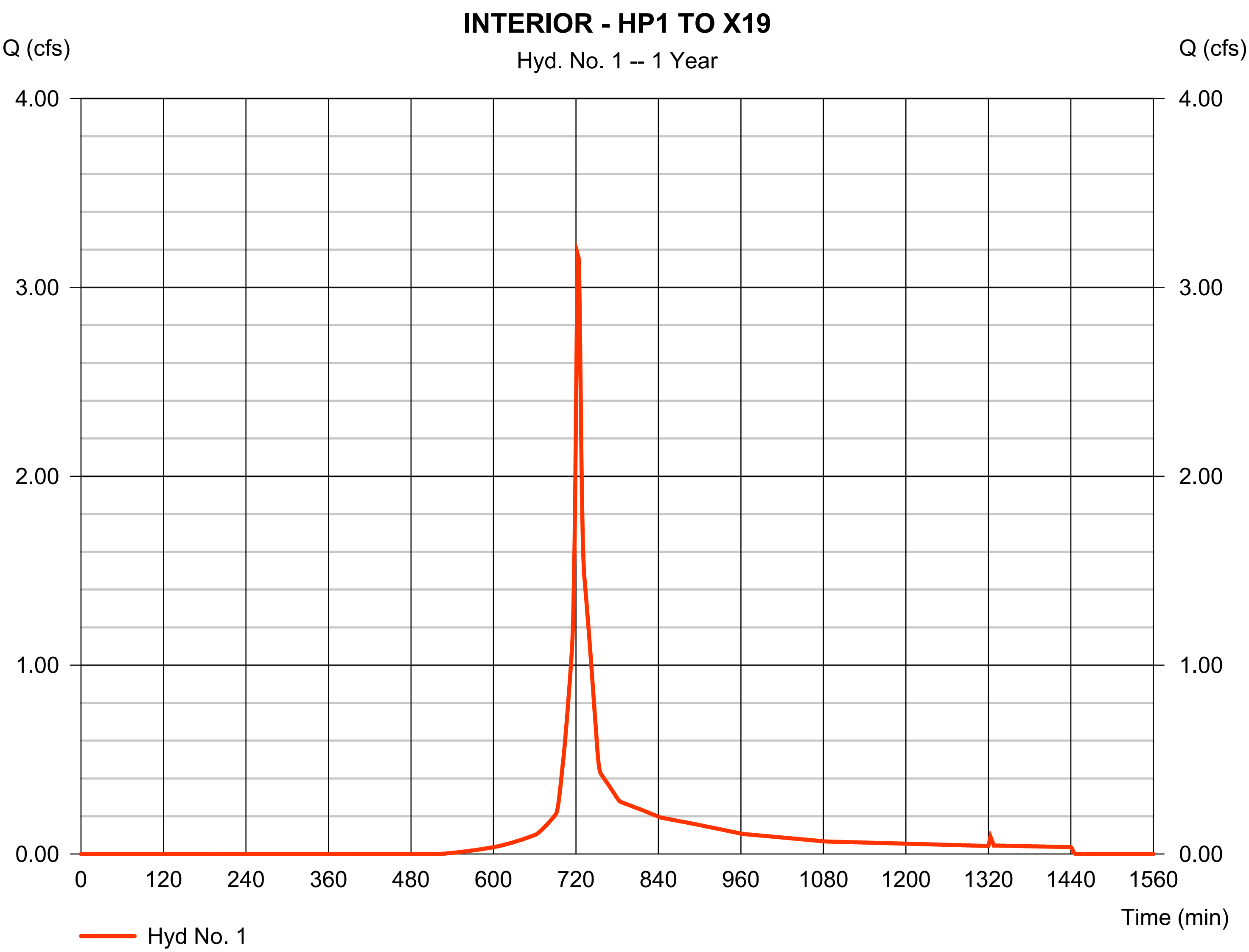
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

INTERIOR - HP1 TO X19

Hydrograph type	= SCS Runoff	Peak discharge	= 3.168 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 9,202 cuft
Drainage area	= 1.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	4.262	1	723	12,331	------	------	------	INTERIOR - HP1 TO X19
2	SCS Runoff	31.20	1	725	96,108	------	------	------	INTERIOR - X20 TO X21
3	SCS Runoff	55.30	1	726	177,725	------	------	------	INTERIOR - X22 TO X23
4	SCS Runoff	60.67	1	727	207,658	------	------	------	INTERIOR - X24 TO C2
5	SCS Runoff	6.609	1	723	19,122	------	------	------	INTERIOR - C2 TO D2
6	SCS Runoff	4.910	1	723	14,207	------	------	------	INTERIOR -D2 TO X2
7	SCS Runoff	4.046	1	723	11,705	------	------	------	INTERIOR -HP3 TO X2
8	SCS Runoff	3.856	1	722	10,471	------	------	------	INTERIOR -HP4 to X27
9	SCS Runoff	7.350	1	723	21,266	------	------	------	INTERIOR -X28 TO E2
10	SCS Runoff	2.684	1	726	8,625	------	------	------	INTERIOR -HP2 TO J1
11	SCS Runoff	8.295	1	726	26,659	------	------	------	INTERIOR -HP2 TO H2
12	SCS Runoff	13.63	1	727	46,643	------	------	------	INTERIOR -HP2 TO G2
13	SCS Runoff	19.12	1	729	71,861	------	------	------	INTERIOR -G2 TO X25
14	SCS Runoff	26.81	1	722	72,795	------	------	------	DOWNDRAIN - C
15	Combine	78.93	1	725	280,454	4, 14	------	------	DD RD X-ING @ C2-C1
16	SCS Runoff	25.73	1	722	69,864	------	------	------	DOWNDRAIN - D
17	Combine	32.04	1	722	88,985	5, 16	------	------	DD ROAD X-ING @ D2-D1
18	SCS Runoff	23.88	1	722	64,837	------	------	------	DOWNDRAIN - E
19	Combine	30.89	1	722	86,104	9, 18	------	------	DD ROAD X-ING @ E2-E1
20	SCS Runoff	32.70	1	722	88,795	------	------	------	DD RD X-ING @ H2-H1
21	SCS Runoff	23.35	1	722	63,413	------	------	------	DOWNDRAIN - G
22	Combine	33.74	1	723	110,056	12, 21	------	------	DD ROAD XING @ G2-G1

Q-DD Rd X-ings.gpw | Return Period: 2 Year | Friday, 01 / 30 / 2015

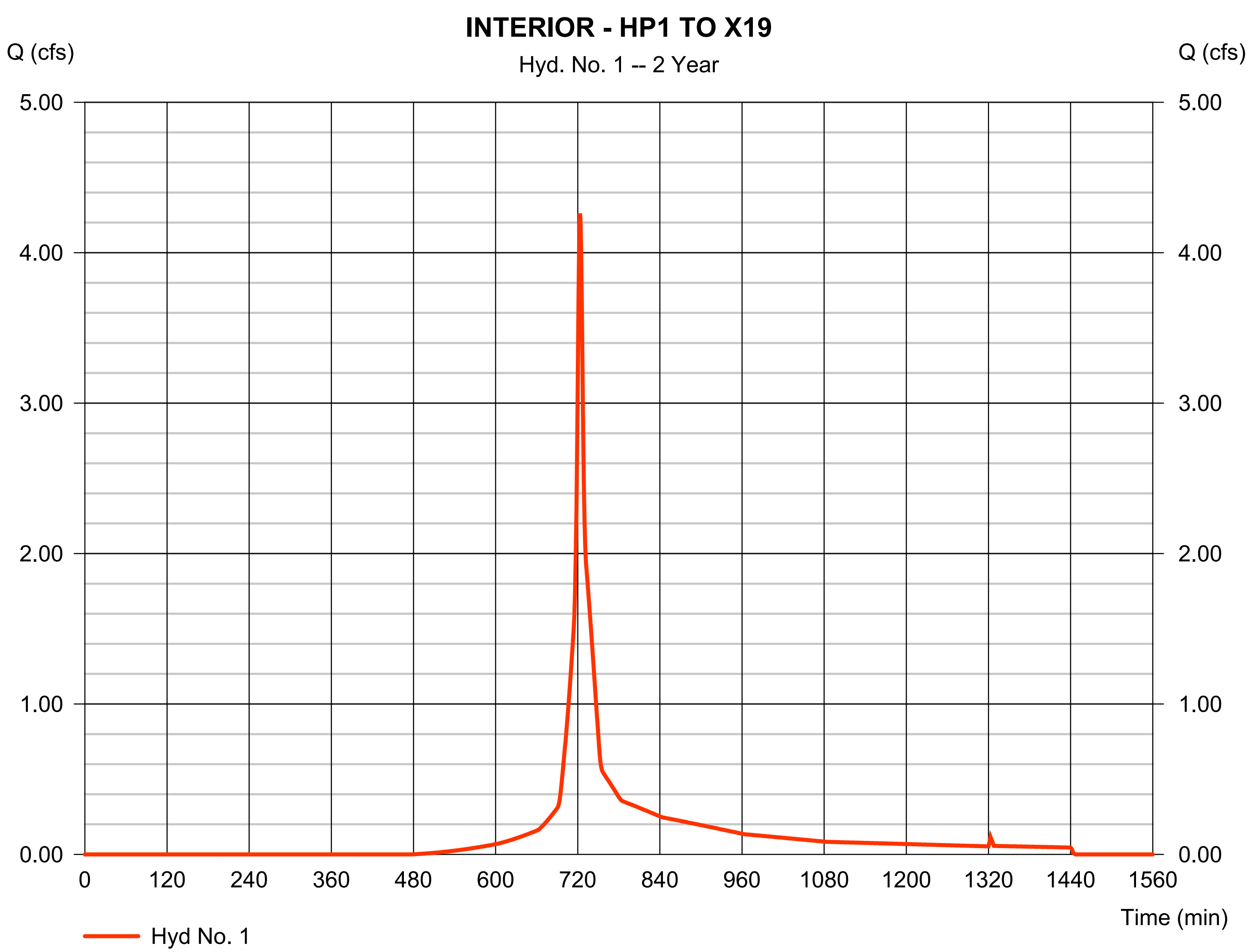
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

INTERIOR - HP1 TO X19

Hydrograph type	= SCS Runoff	Peak discharge	= 4.262 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 12,331 cuft
Drainage area	= 1.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	5.990	1	723	17,368	------	------	------	INTERIOR - HP1 TO X19
2	SCS Runoff	43.74	1	725	135,366	------	------	------	INTERIOR - X20 TO X21
3	SCS Runoff	77.55	1	726	250,319	------	------	------	INTERIOR - X22 TO X23
4	SCS Runoff	85.17	1	727	292,480	------	------	------	INTERIOR - X24 TO C2
5	SCS Runoff	9.288	1	723	26,932	------	------	------	INTERIOR - C2 TO D2
6	SCS Runoff	6.901	1	723	20,010	------	------	------	INTERIOR -D2 TO X2
7	SCS Runoff	5.686	1	723	16,487	------	------	------	INTERIOR -HP3 TO X2
8	SCS Runoff	5.412	1	722	14,748	------	------	------	INTERIOR -HP4 to X27
9	SCS Runoff	10.33	1	723	29,953	------	------	------	INTERIOR -X28 TO E2
10	SCS Runoff	3.764	1	726	12,148	------	------	------	INTERIOR -HP2 TO J1
11	SCS Runoff	11.63	1	726	37,548	------	------	------	INTERIOR -HP2 TO H2
12	SCS Runoff	19.13	1	727	65,695	------	------	------	INTERIOR -HP2 TO G2
13	SCS Runoff	26.87	1	729	101,214	------	------	------	INTERIOR -G2 TO X25
14	SCS Runoff	37.62	1	722	102,530	------	------	------	DOWNDRAIN - C
15	Combine	110.94	1	725	395,010	4, 14	------	------	DD RD X-ING @ C2-C1
16	SCS Runoff	36.11	1	722	98,400	------	------	------	DOWNDRAIN - D
17	Combine	45.01	1	722	125,333	5, 16	------	------	DD ROAD X-ING @ D2-D1
18	SCS Runoff	33.51	1	722	91,321	------	------	------	DOWNDRAIN - E
19	Combine	43.41	1	722	121,274	9, 18	------	------	DD ROAD X-ING @ E2-E1
20	SCS Runoff	45.89	1	722	125,065	------	------	------	DD RD X-ING @ H2-H1
21	SCS Runoff	32.77	1	722	89,316	------	------	------	DOWNDRAIN - G
22	Combine	47.42	1	723	155,010	12, 21	------	------	DD ROAD XING @ G2-G1

Q-DD Rd X-ings.gpw	Return Period: 5 Year	Friday, 01 / 30 / 2015

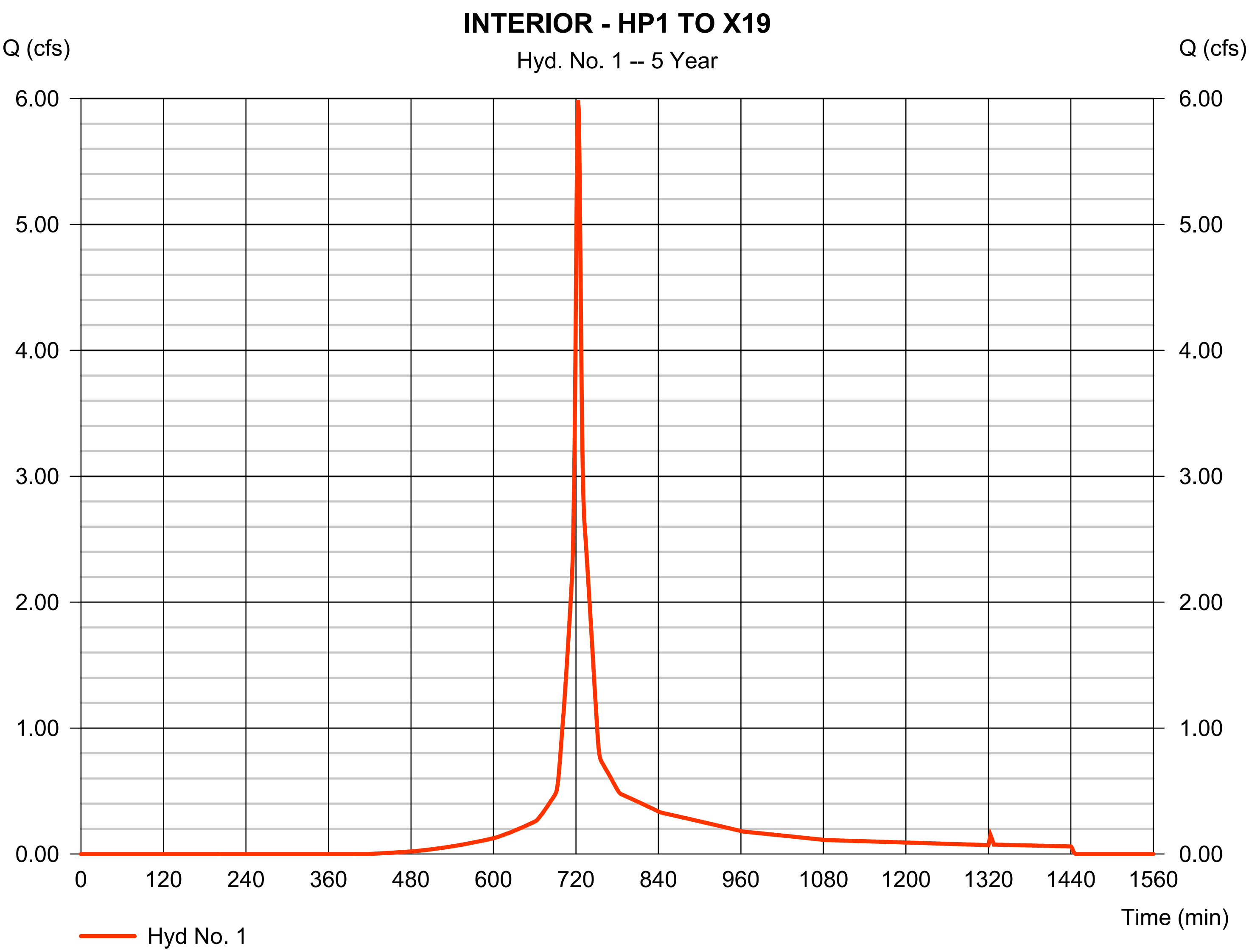
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 1

INTERIOR - HP1 TO X19

Hydrograph type	= SCS Runoff	Peak discharge	= 5.990 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 17,368 cuft
Drainage area	= 1.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	7.286	1	723	21,216	------	------	------	INTERIOR - HP1 TO X19
2	SCS Runoff	53.15	1	725	165,363	------	------	------	INTERIOR - X20 TO X21
3	SCS Runoff	94.26	1	725	305,791	------	------	------	INTERIOR - X22 TO X23
4	SCS Runoff	103.55	1	727	357,295	------	------	------	INTERIOR - X24 TO C2
5	SCS Runoff	11.30	1	723	32,901	------	------	------	INTERIOR - C2 TO D2
6	SCS Runoff	8.395	1	723	24,445	------	------	------	INTERIOR -D2 TO X2
7	SCS Runoff	6.917	1	723	20,140	------	------	------	INTERIOR -HP3 TO X2
8	SCS Runoff	6.578	1	722	18,017	------	------	------	INTERIOR -HP4 to X27
9	SCS Runoff	12.57	1	723	36,590	------	------	------	INTERIOR -X28 TO E2
10	SCS Runoff	4.574	1	725	14,840	------	------	------	INTERIOR -HP2 TO J1
11	SCS Runoff	14.14	1	725	45,869	------	------	------	INTERIOR -HP2 TO H2
12	SCS Runoff	23.26	1	727	80,253	------	------	------	INTERIOR -HP2 TO G2
13	SCS Runoff	32.68	1	729	123,644	------	------	------	INTERIOR -G2 TO X25
14	SCS Runoff	45.73	1	722	125,251	------	------	------	DOWNDRAIN - C
15	Combine	134.97	1	725	482,546	4, 14	------	------	DD RD X-ING @ C2-C1
16	SCS Runoff	43.89	1	722	120,206	------	------	------	DOWNDRAIN - D
17	Combine	54.74	1	722	153,107	5, 16	------	------	DD ROAD X-ING @ D2-D1
18	SCS Runoff	40.73	1	722	111,559	------	------	------	DOWNDRAIN - E
19	Combine	52.80	1	722	148,149	9, 18	------	------	DD ROAD X-ING @ E2-E1
20	SCS Runoff	55.79	1	722	152,780	------	------	------	DD RD X-ING @ H2-H1
21	SCS Runoff	39.84	1	722	109,108	------	------	------	DOWNDRAIN - G
22	Combine	57.69	1	723	189,361	12, 21	------	------	DD ROAD XING @ G2-G1

Q-DD Rd X-ings.gpw | Return Period: 10 Year | Friday, 01 / 30 / 2015

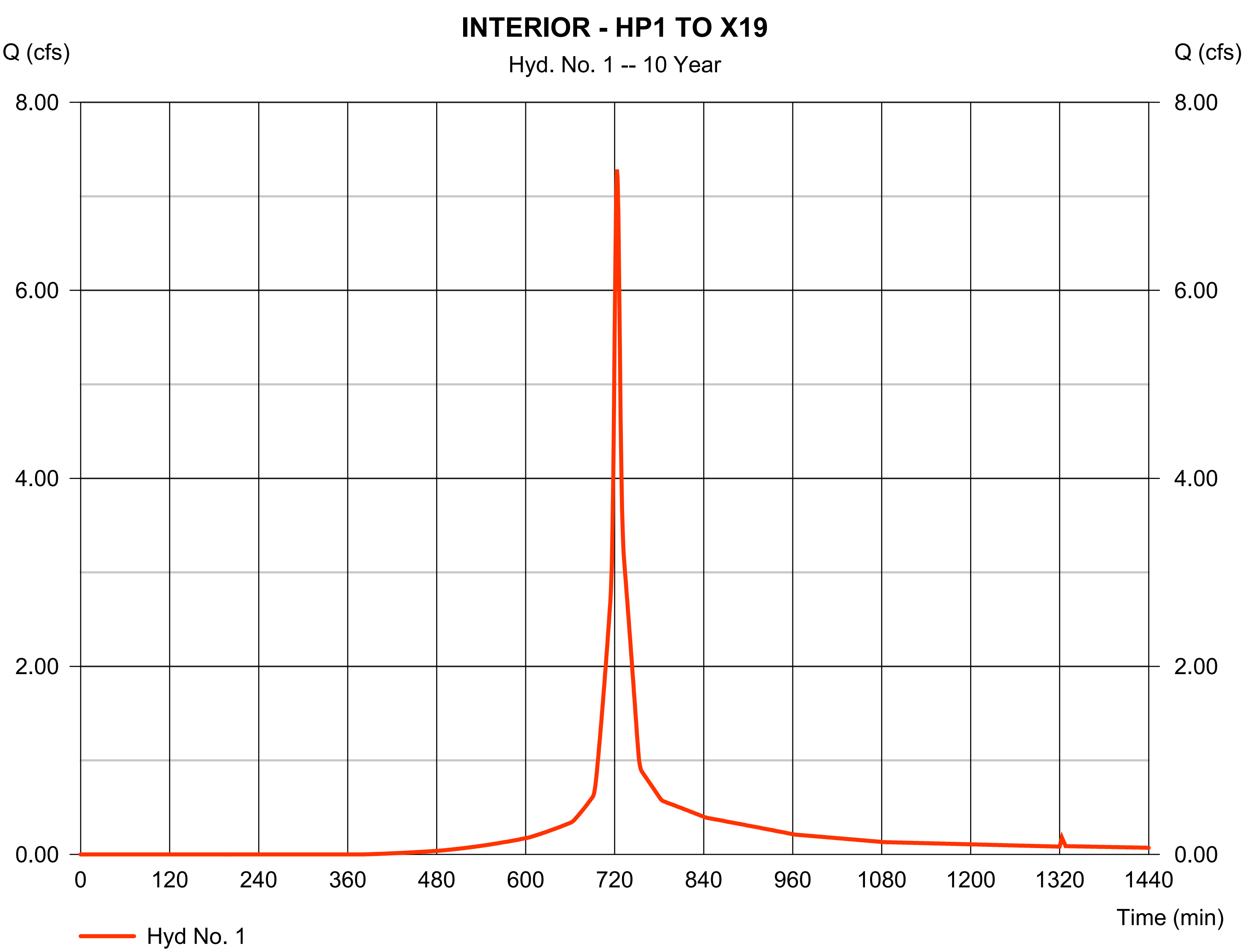
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

INTERIOR - HP1 TO X19

Hydrograph type	= SCS Runoff	Peak discharge	= 7.286 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 21,216 cuft
Drainage area	= 1.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	8.820	1	723	25,838	------	------	------	INTERIOR - HP1 TO X19
2	SCS Runoff	64.29	1	724	201,385	------	------	------	INTERIOR - X20 TO X21
3	SCS Runoff	114.15	1	725	372,403	------	------	------	INTERIOR - X22 TO X23
4	SCS Runoff	125.30	1	727	435,126	------	------	------	INTERIOR - X24 TO C2
5	SCS Runoff	13.68	1	723	40,068	------	------	------	INTERIOR - C2 TO D2
6	SCS Runoff	10.16	1	723	29,770	------	------	------	INTERIOR -D2 TO X2
7	SCS Runoff	8.373	1	723	24,527	------	------	------	INTERIOR -HP3 TO X2
8	SCS Runoff	7.958	1	722	21,941	------	------	------	INTERIOR -HP4 to X27
9	SCS Runoff	15.21	1	723	44,561	------	------	------	INTERIOR -X28 TO E2
10	SCS Runoff	5.540	1	725	18,073	------	------	------	INTERIOR -HP2 TO J1
11	SCS Runoff	17.12	1	725	55,861	------	------	------	INTERIOR -HP2 TO H2
12	SCS Runoff	28.14	1	727	97,735	------	------	------	INTERIOR -HP2 TO G2
13	SCS Runoff	39.56	1	729	150,578	------	------	------	INTERIOR -G2 TO X25
14	SCS Runoff	55.33	1	722	152,535	------	------	------	DOWNDRAIN - C
15	Combine	163.40	1	725	587,661	4, 14	------	------	DD RD X-ING @ C2-C1
16	SCS Runoff	53.10	1	722	146,392	------	------	------	DOWNDRAIN - D
17	Combine	66.26	1	722	186,459	5, 16	------	------	DD ROAD X-ING @ D2-D1
18	SCS Runoff	49.28	1	722	135,860	------	------	------	DOWNDRAIN - E
19	Combine	63.91	1	722	180,421	9, 18	------	------	DD ROAD X-ING @ E2-E1
20	SCS Runoff	67.49	1	722	186,061	------	------	------	DD RD X-ING @ H2-H1
21	SCS Runoff	48.20	1	722	132,876	------	------	------	DOWNDRAIN - G
22	Combine	69.84	1	723	230,611	12, 21	------	------	DD ROAD XING @ G2-G1

Q-DD Rd X-ings.gpw	Return Period: 25 Year	Friday, 01 / 30 / 2015

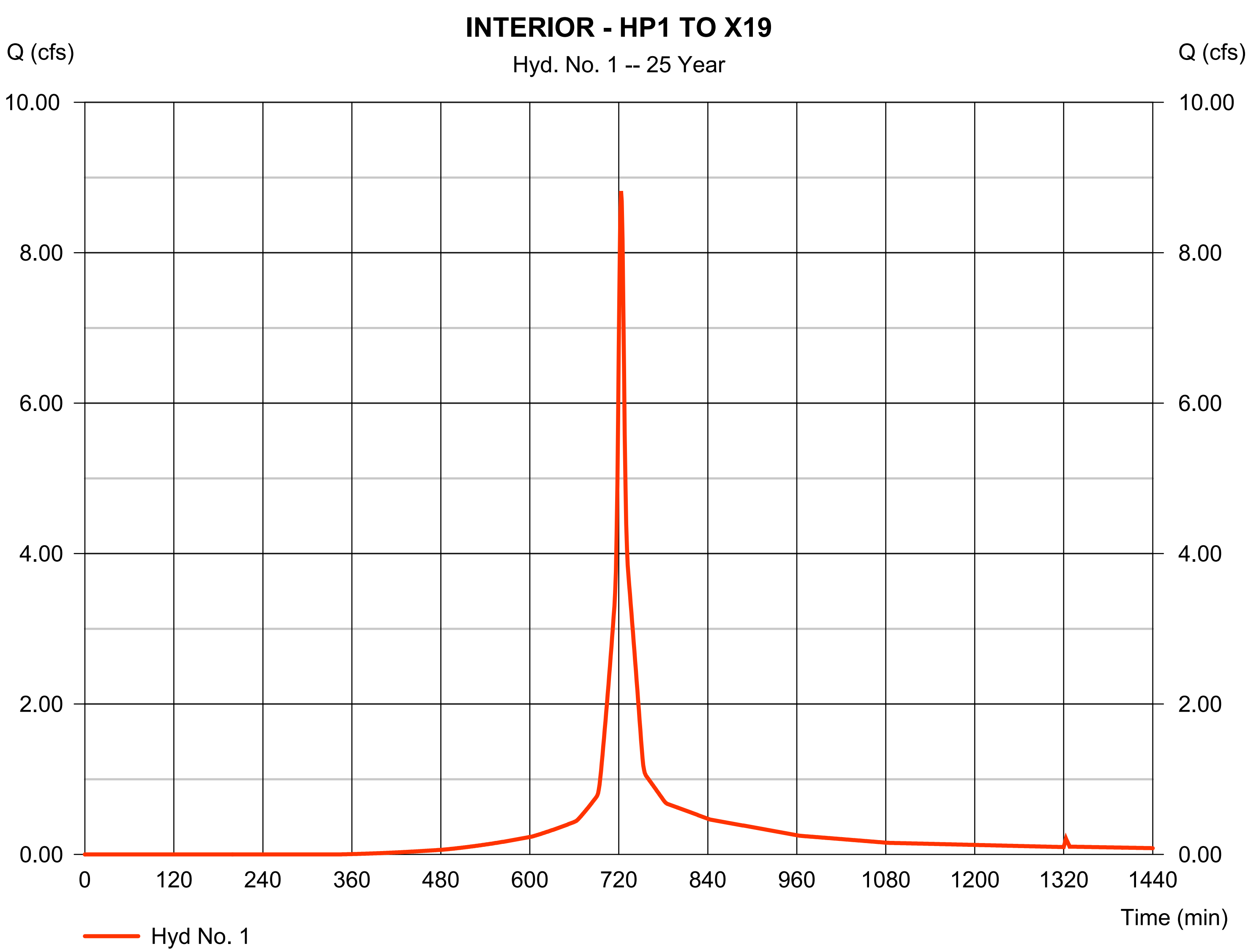
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

INTERIOR - HP1 TO X19

Hydrograph type	= SCS Runoff	Peak discharge	= 8.820 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 25,838 cuft
Drainage area	= 1.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	10.20	1	723	30,061	------	------	------	INTERIOR - HP1 TO X19
2	SCS Runoff	74.40	1	724	234,302	------	------	------	INTERIOR - X20 TO X21
3	SCS Runoff	132.09	1	725	433,274	------	------	------	INTERIOR - X22 TO X23
4	SCS Runoff	144.90	1	727	506,248	------	------	------	INTERIOR - X24 TO C2
5	SCS Runoff	15.82	1	723	46,617	------	------	------	INTERIOR - C2 TO D2
6	SCS Runoff	11.76	1	723	34,636	------	------	------	INTERIOR -D2 TO X2
7	SCS Runoff	9.686	1	723	28,536	------	------	------	INTERIOR -HP3 TO X2
8	SCS Runoff	9.202	1	722	25,528	------	------	------	INTERIOR -HP4 to X27
9	SCS Runoff	17.60	1	723	51,845	------	------	------	INTERIOR -X28 TO E2
10	SCS Runoff	6.410	1	725	21,027	------	------	------	INTERIOR -HP2 TO J1
11	SCS Runoff	19.81	1	725	64,991	------	------	------	INTERIOR -HP2 TO H2
12	SCS Runoff	32.55	1	727	113,710	------	------	------	INTERIOR -HP2 TO G2
13	SCS Runoff	45.77	1	729	175,190	------	------	------	INTERIOR -G2 TO X25
14	SCS Runoff	63.97	1	722	177,467	------	------	------	DOWNDRAIN - C
15	Combine	189.03	1	725	683,715	4, 14	------	------	DD RD X-ING @ C2-C1
16	SCS Runoff	61.40	1	722	170,319	------	------	------	DOWNDRAIN - D
17	Combine	76.64	1	722	216,936	5, 16	------	------	DD ROAD X-ING @ D2-D1
18	SCS Runoff	56.98	1	722	158,066	------	------	------	DOWNDRAIN - E
19	Combine	73.93	1	722	209,911	9, 18	------	------	DD ROAD X-ING @ E2-E1
20	SCS Runoff	78.03	1	722	216,473	------	------	------	DD RD X-ING @ H2-H1
21	SCS Runoff	55.73	1	722	154,595	------	------	------	DOWNDRAIN - G
22	Combine	80.79	1	723	268,305	12, 21	------	------	DD ROAD XING @ G2-G1

Q-DD Rd X-ings.gpw | Return Period: 50 Year | Friday, 01 / 30 / 2015

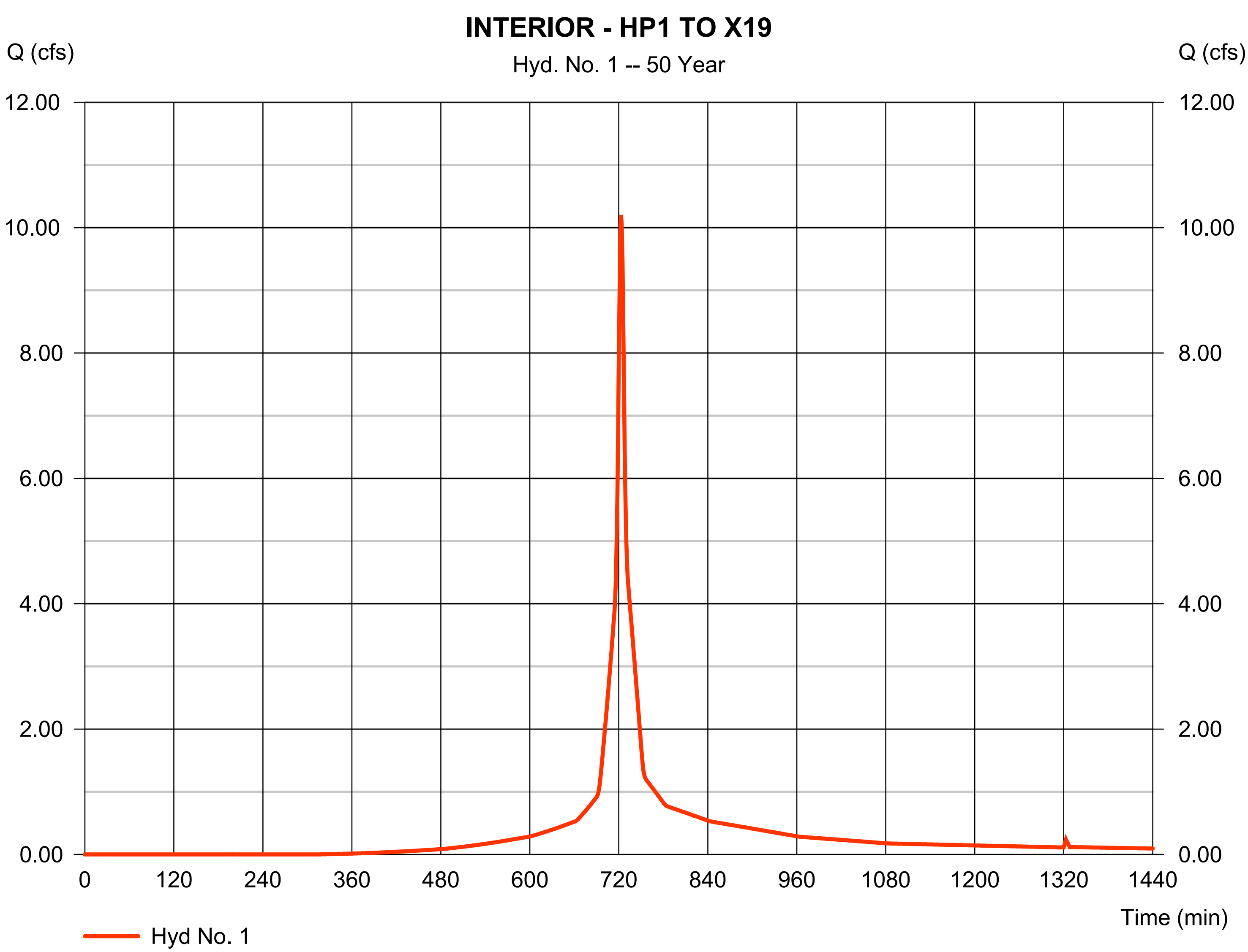
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

INTERIOR - HP1 TO X19

Hydrograph type	= SCS Runoff	Peak discharge	= 10.20 cfs
Storm frequency	= 50 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 30,061 cuft
Drainage area	= 1.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 8.40 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	11.43	1	723	33,854	------	------	------	INTERIOR - HP1 TO X19
2	SCS Runoff	83.38	1	724	263,861	------	------	------	INTERIOR - X20 TO X21
3	SCS Runoff	148.03	1	725	487,935	------	------	------	INTERIOR - X22 TO X23
4	SCS Runoff	162.31	1	727	570,116	------	------	------	INTERIOR - X24 TO C2
5	SCS Runoff	17.73	1	723	52,498	------	------	------	INTERIOR - C2 TO D2
6	SCS Runoff	13.17	1	723	39,005	------	------	------	INTERIOR -D2 TO X2
7	SCS Runoff	10.85	1	723	32,137	------	------	------	INTERIOR -HP3 TO X2
8	SCS Runoff	10.31	1	722	28,748	------	------	------	INTERIOR -HP4 to X27
9	SCS Runoff	19.72	1	723	58,385	------	------	------	INTERIOR -X28 TO E2
10	SCS Runoff	7.184	1	725	23,679	------	------	------	INTERIOR -HP2 TO J1
11	SCS Runoff	22.20	1	725	73,190	------	------	------	INTERIOR -HP2 TO H2
12	SCS Runoff	36.46	1	727	128,055	------	------	------	INTERIOR -HP2 TO G2
13	SCS Runoff	51.28	1	729	197,292	------	------	------	INTERIOR -G2 TO X25
14	SCS Runoff	71.65	1	722	199,857	------	------	------	DOWNDRAIN - C
15	Combine	211.81	1	725	769,972	4, 14	------	------	DD RD X-ING @ C2-C1
16	SCS Runoff	68.77	1	722	191,807	------	------	------	DOWNDRAIN - D
17	Combine	85.86	1	722	244,305	5, 16	------	------	DD ROAD X-ING @ D2-D1
18	SCS Runoff	63.82	1	722	178,008	------	------	------	DOWNDRAIN - E
19	Combine	82.83	1	722	236,393	9, 18	------	------	DD ROAD X-ING @ E2-E1
20	SCS Runoff	87.40	1	722	243,783	------	------	------	DD RD X-ING @ H2-H1
21	SCS Runoff	62.42	1	722	174,098	------	------	------	DOWNDRAIN - G
22	Combine	90.53	1	723	302,153	12, 21	------	------	DD ROAD XING @ G2-G1

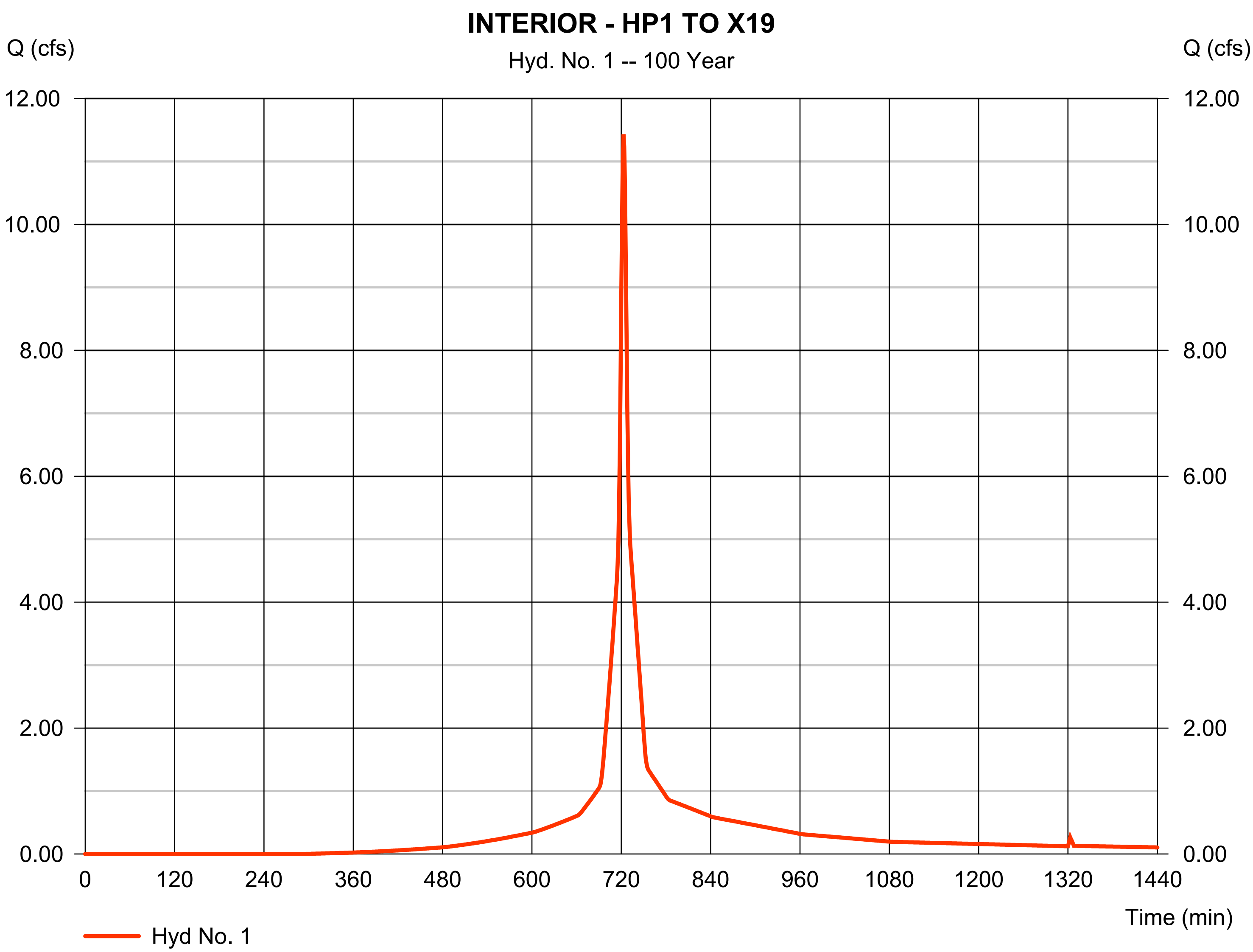
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 1

INTERIOR - HP1 TO X19

Hydrograph type	= SCS Runoff	Peak discharge	= 11.43 cfs
Storm frequency	= 100 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 33,854 cuft
Drainage area	= 1.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	0.0000	0.0000	0.0000	--------
3	0.0000	0.0000	0.0000	--------
5	0.0000	0.0000	0.0000	--------
10	0.0000	0.0000	0.0000	--------
25	0.0000	0.0000	0.0000	--------
50	0.0000	0.0000	0.0000	--------
100	0.0000	0.0000	0.0000	--------

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

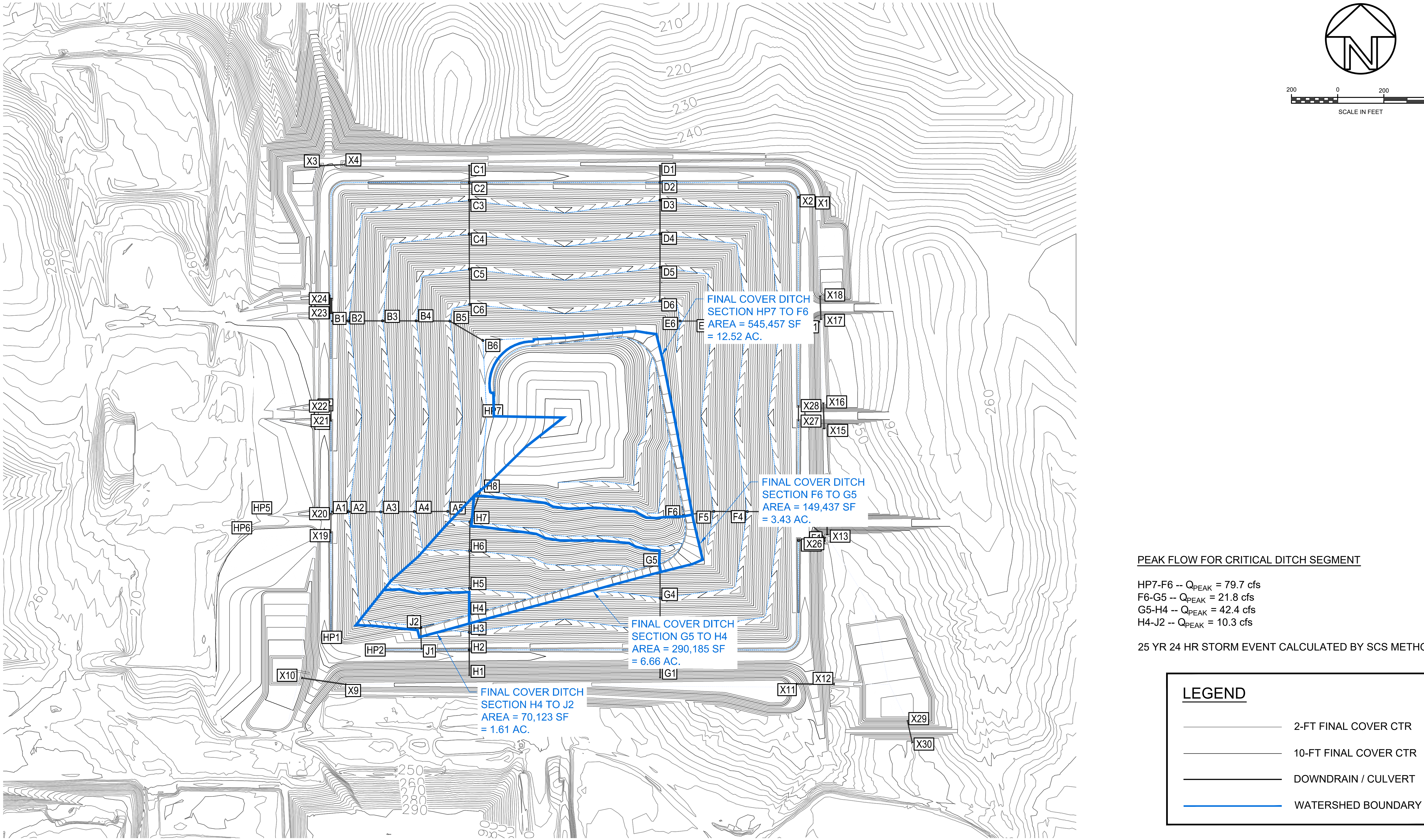
Tc = time in minutes. Values may exceed 60.

ojects\2014\EJ147461\Working Files\Calculations-Analyses\SCS METHOD\Peachtree City (24 hr GA Green Book).pcp

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.75	4.50	0.00	5.65	6.50	7.50	8.40	9.20
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

EXHIBIT H-3

Hydrologic and Hydraulic Calculations – Perimeter Channels



PEAK FLOW FOR CRITICAL DITCH SEGMENT

HP7-F6 -- Q_{PEAK} = 79.7 cfs
F6-G5 -- Q_{PEAK} = 21.8 cfs
G5-H4 -- Q_{PEAK} = 42.4 cfs
H4-J2 -- Q_{PEAK} = 10.3 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

Last Saved By: JCHENSLEY Date: 1/30/2015 9:43 AM File Path: N:\PROJECTS\2014\EJ147410\WORKING FILES\CALCULATIONS-ANALYSES\HYDROLOGY\FIGURE-HYDROLOGY\EJ147410-HYDRO-EMELLE TRENCH 23.DWG

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

EMELLE FACILITY

Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

FINAL COVER DITCH, SECTION HP7 TO J2 WATERSHED

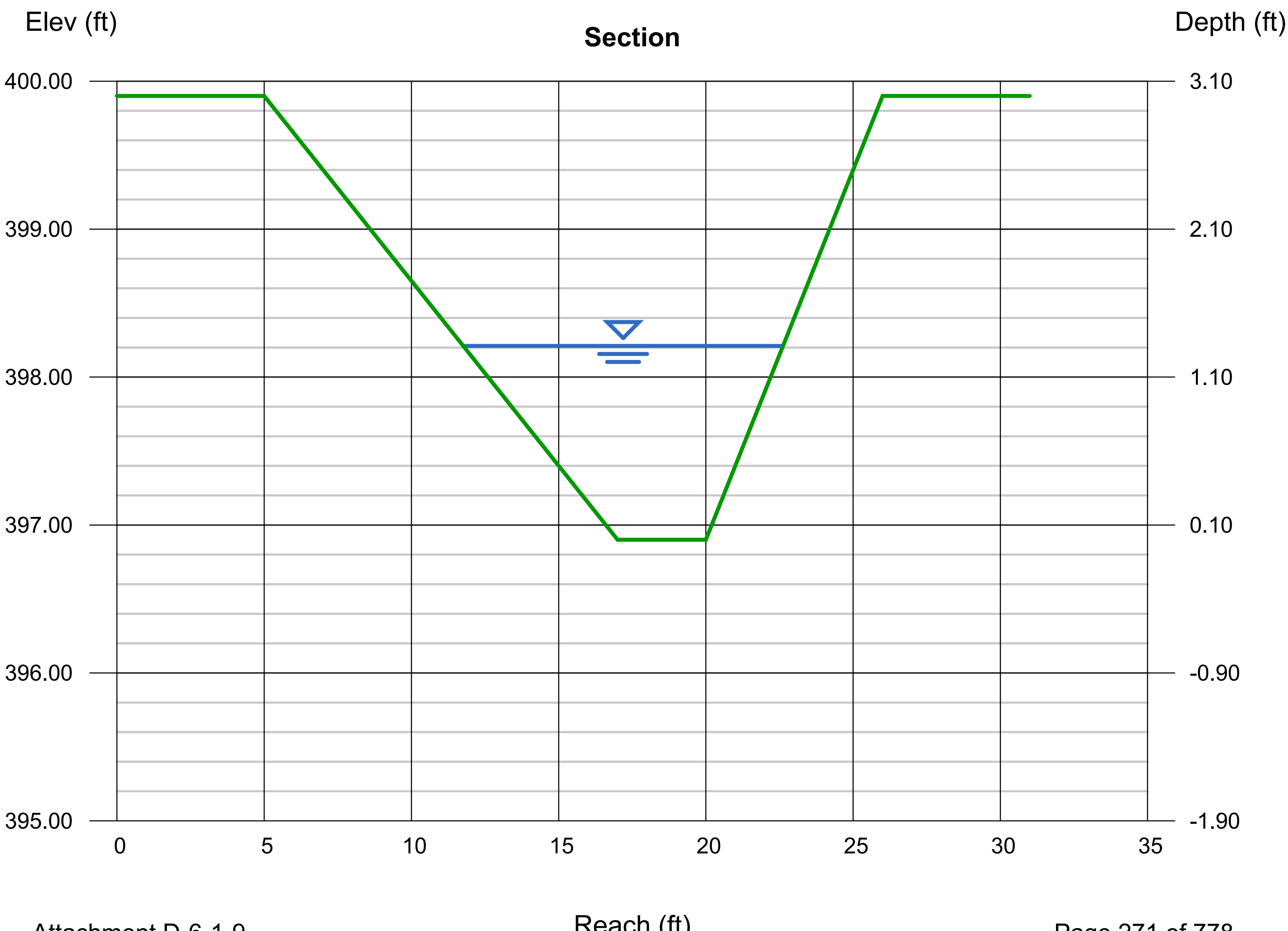
HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE D-0

Channel Report

FINAL COVER DITCH - HP7 TO F6 (4.3% SLOPE)

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 3.00	Depth (ft)	= 1.31
Side Slopes (z:1)	= 4.00, 2.00	Q (cfs)	= 79.70
Total Depth (ft)	= 3.00	Area (sqft)	= 9.08
Invert Elev (ft)	= 396.90	Velocity (ft/s)	= 8.78
Slope (%)	= 4.30	Wetted Perim (ft)	= 11.33
N-Value	= 0.030	Crit Depth, Yc (ft)	= 1.70
		Top Width (ft)	= 10.86
Calculations		EGL (ft)	= 2.51
Compute by:	Known Q		
Known Q (cfs)	= 79.70		



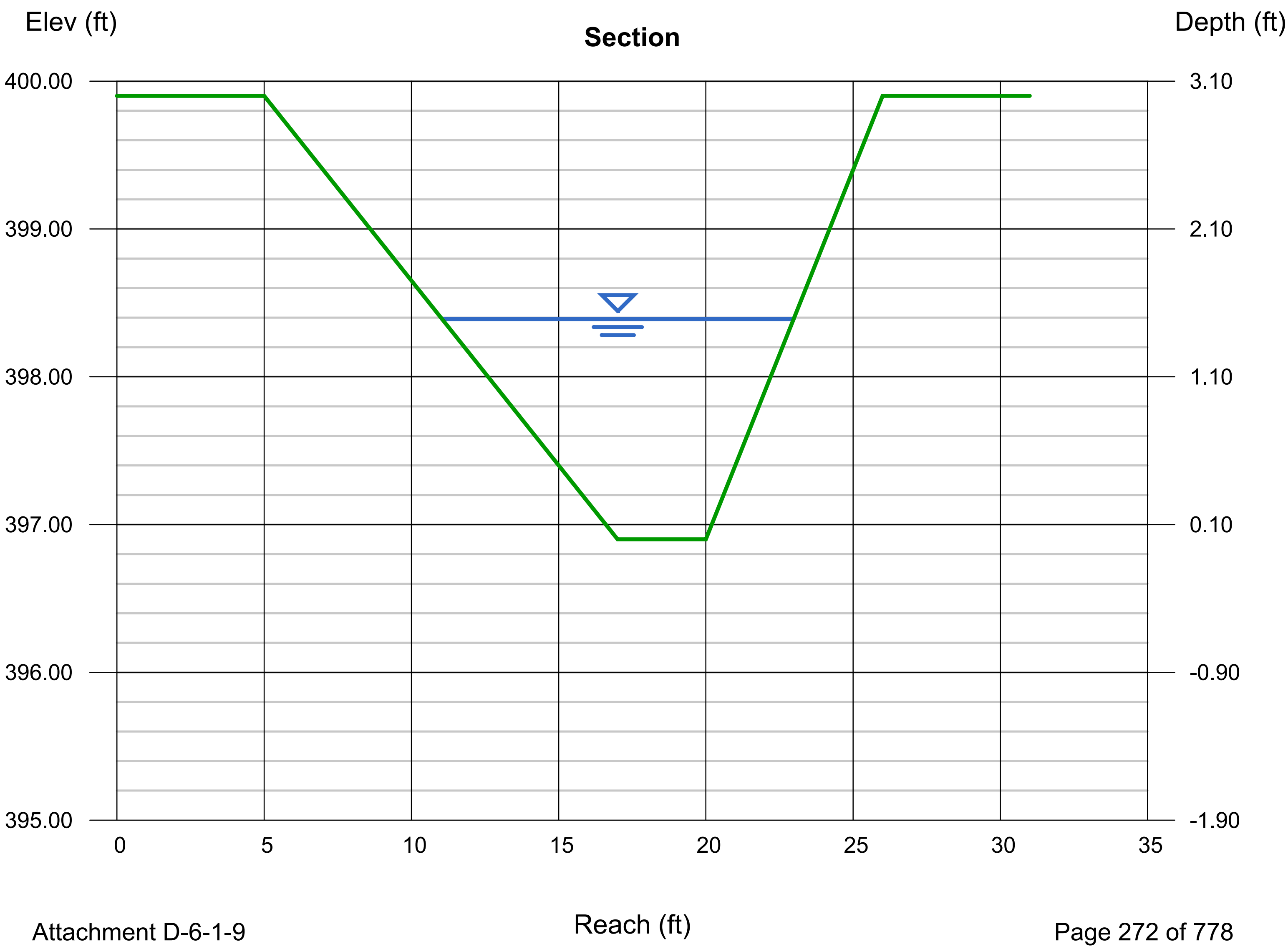
Channel Report

FINAL COVER DITCH - HP7 TO F6 (2.5% SLOPE)

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 3.00	Depth (ft)	= 1.49
Side Slopes (z:1)	= 4.00, 2.00	Q (cfs)	= 79.70
Total Depth (ft)	= 3.00	Area (sqft)	= 11.13
Invert Elev (ft)	= 396.90	Velocity (ft/s)	= 7.16
Slope (%)	= 2.50	Wetted Perim (ft)	= 12.48
N-Value	= 0.030	Crit Depth, Yc (ft)	= 1.70
		Top Width (ft)	= 11.94
		EGL (ft)	= 2.29

Calculations

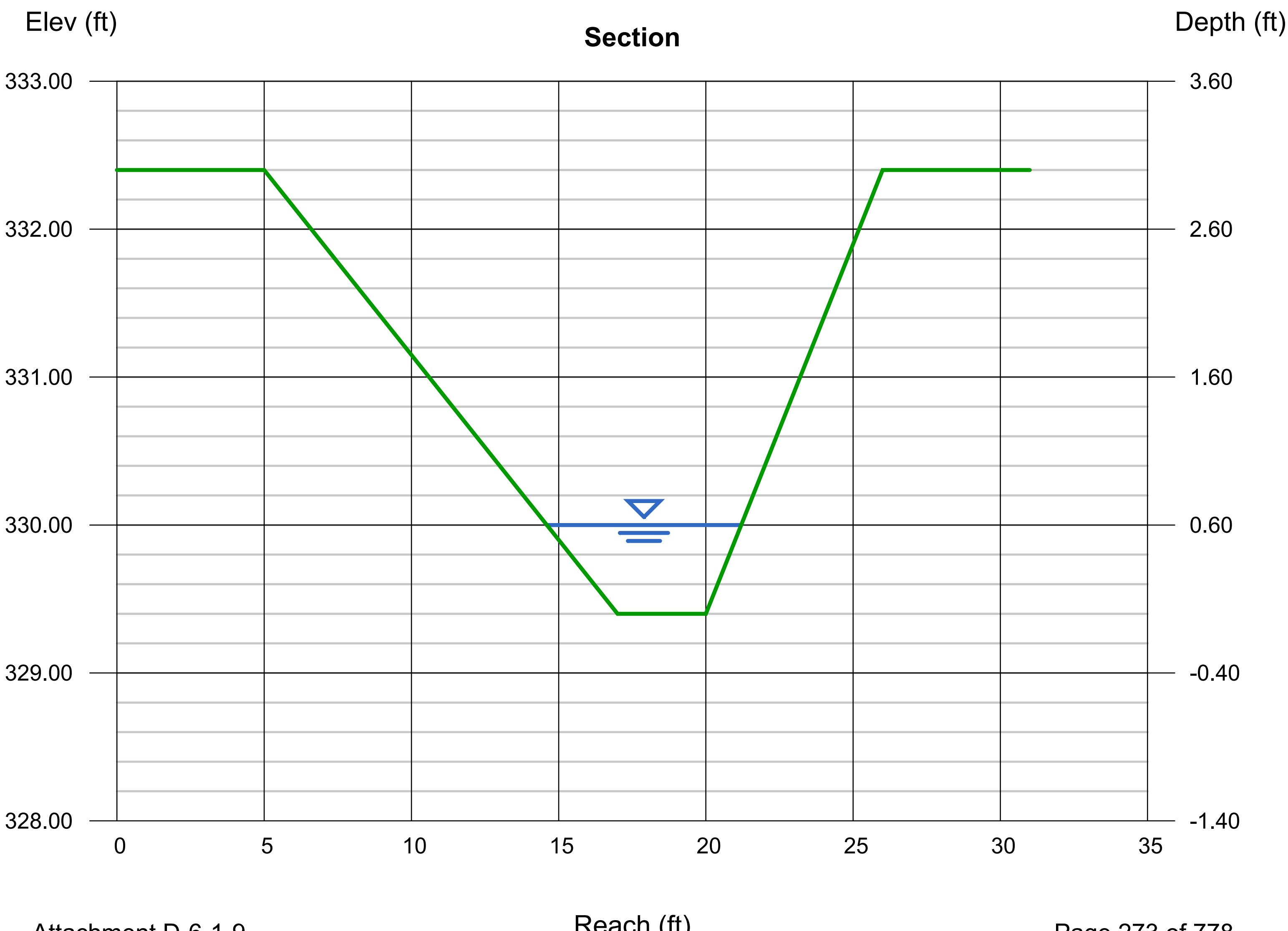
Compute by:	Known Q
Known Q (cfs)	= 79.70



Channel Report

FINAL COVER DITCH - F6 TO G5 (7.7% SLOPE)

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 3.00	Depth (ft)	= 0.60
Side Slopes (z:1)	= 4.00, 2.00	Q (cfs)	= 21.80
Total Depth (ft)	= 3.00	Area (sqft)	= 2.88
Invert Elev (ft)	= 329.40	Velocity (ft/s)	= 7.57
Slope (%)	= 7.70	Wetted Perim (ft)	= 6.82
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.89
		Top Width (ft)	= 6.60
Calculations		EGL (ft)	= 1.49
Compute by:	Known Q		
Known Q (cfs)	= 21.80		



Channel Report

FINAL COVER DITCH - F6 TO G5 (2.9% SLOPE)

Trapezoidal

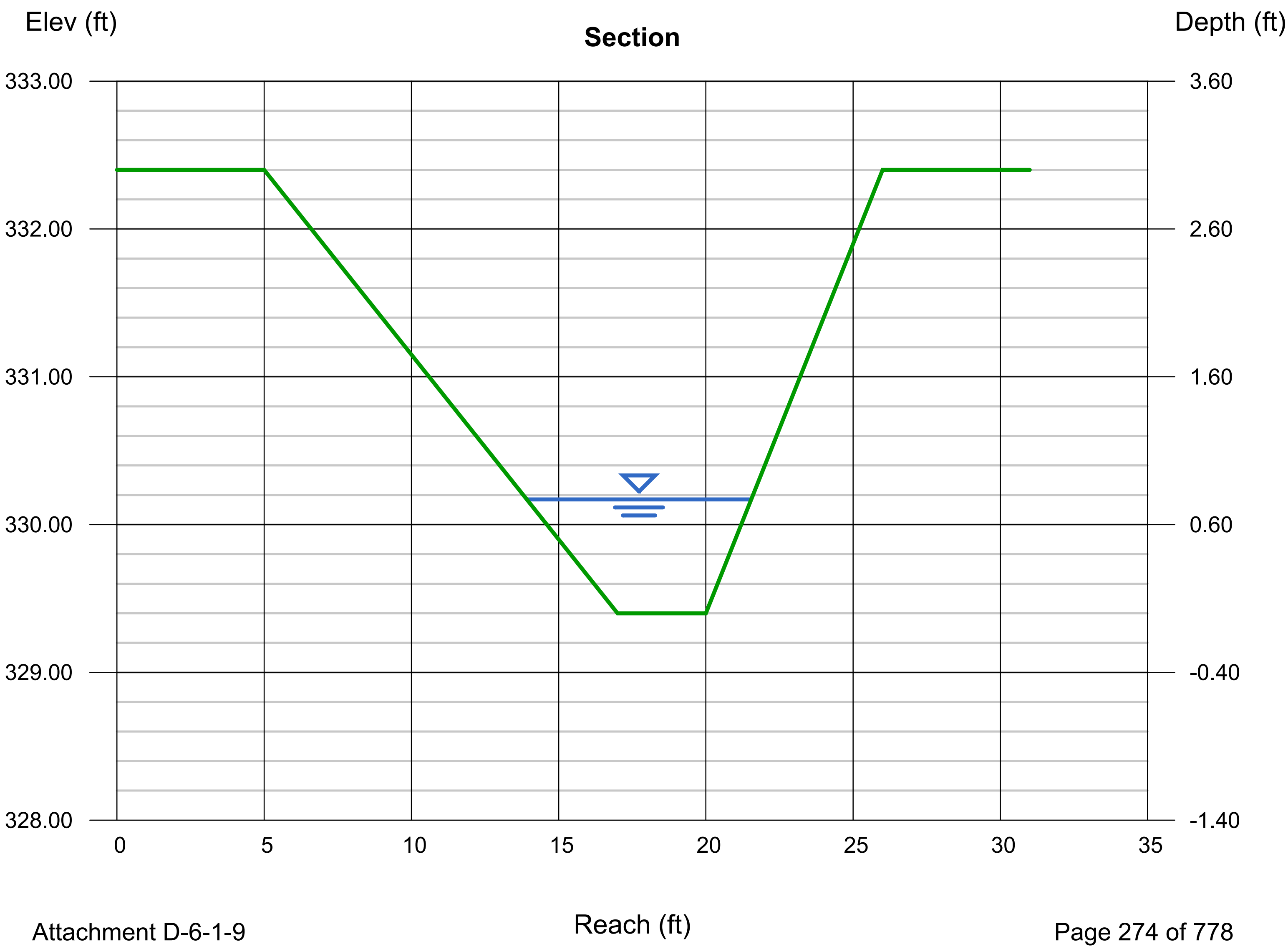
Bottom Width (ft)	= 3.00
Side Slopes (z:1)	= 4.00, 2.00
Total Depth (ft)	= 3.00
Invert Elev (ft)	= 329.40
Slope (%)	= 2.90
N-Value	= 0.030

Calculations

Compute by:	Known Q
Known Q (cfs)	= 21.80

Highlighted

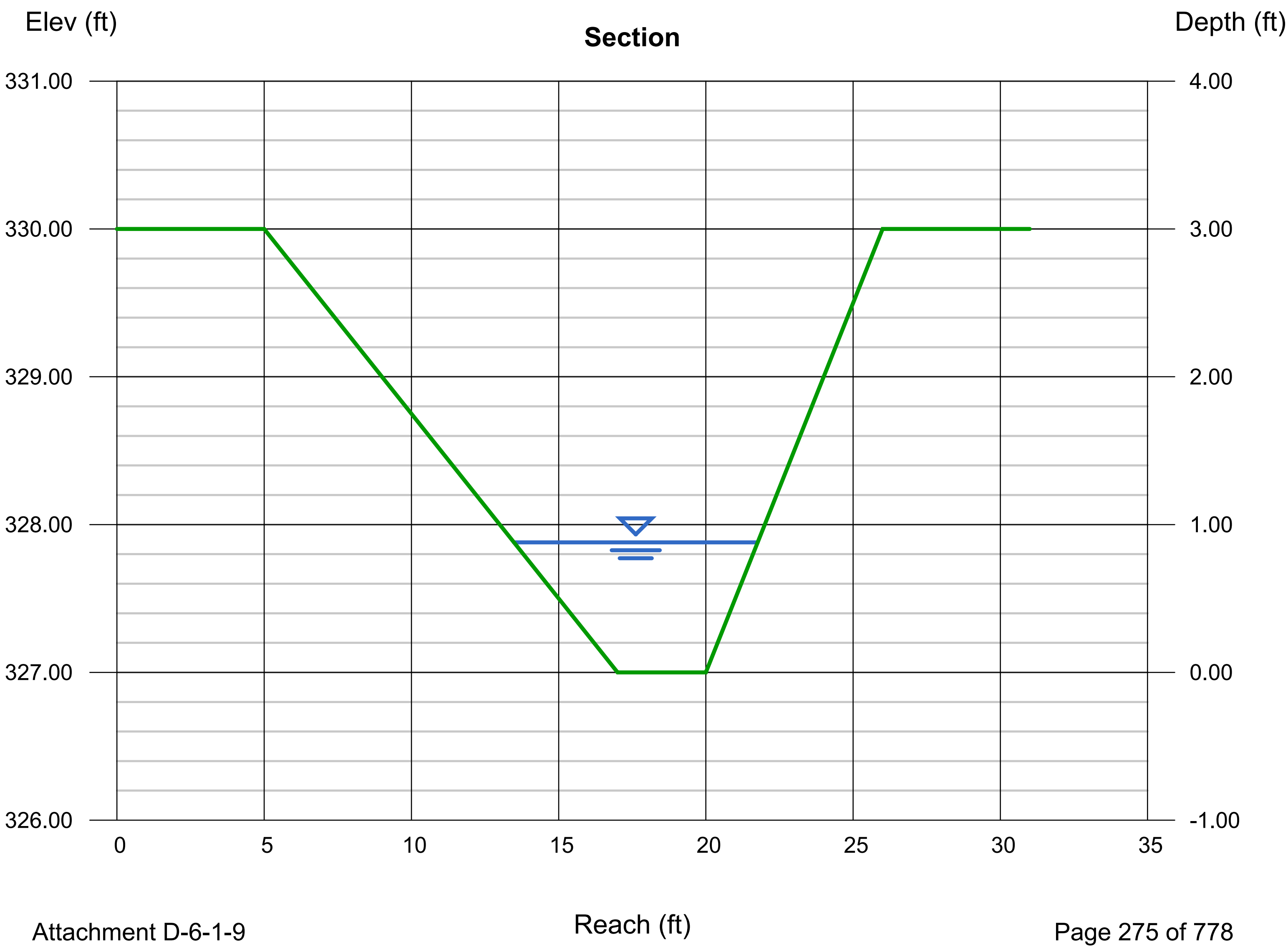
Depth (ft)	= 0.77
Q (cfs)	= 21.80
Area (sqft)	= 4.09
Velocity (ft/s)	= 5.33
Wetted Perim (ft)	= 7.90
Crit Depth, Yc (ft)	= 0.89
Top Width (ft)	= 7.62
EGL (ft)	= 1.21



Channel Report

FINAL COVER DITCH - G5 TO H4 (6.2% SLOPE)

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 3.00	Depth (ft)	= 0.88
Side Slopes (z:1)	= 4.00, 2.00	Q (cfs)	= 42.40
Total Depth (ft)	= 3.00	Area (sqft)	= 4.96
Invert Elev (ft)	= 327.00	Velocity (ft/s)	= 8.54
Slope (%)	= 6.20	Wetted Perim (ft)	= 8.60
N-Value	= 0.030	Crit Depth, Yc (ft)	= 1.25
		Top Width (ft)	= 8.28
Calculations		EGL (ft)	= 2.01
Compute by:	Known Q		
Known Q (cfs)	= 42.40		



Channel Report

FINAL COVER DITCH - G5 TO H4 (3.0% SLOPE)

Trapezoidal

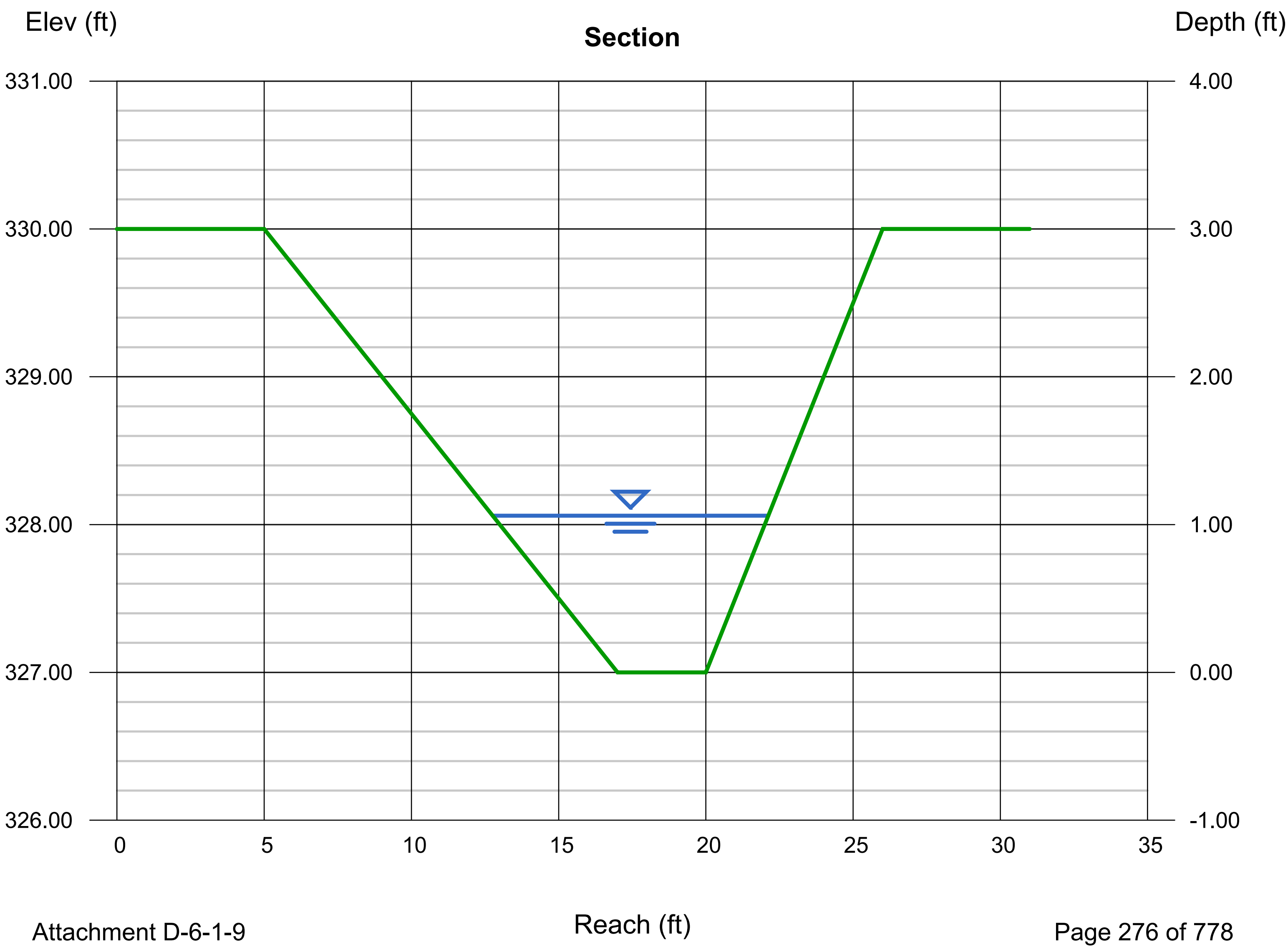
Bottom Width (ft)	= 3.00
Side Slopes (z:1)	= 4.00, 2.00
Total Depth (ft)	= 3.00
Invert Elev (ft)	= 327.00
Slope (%)	= 3.00
N-Value	= 0.030

Calculations

Compute by:	Known Q
Known Q (cfs)	= 42.40

Highlighted

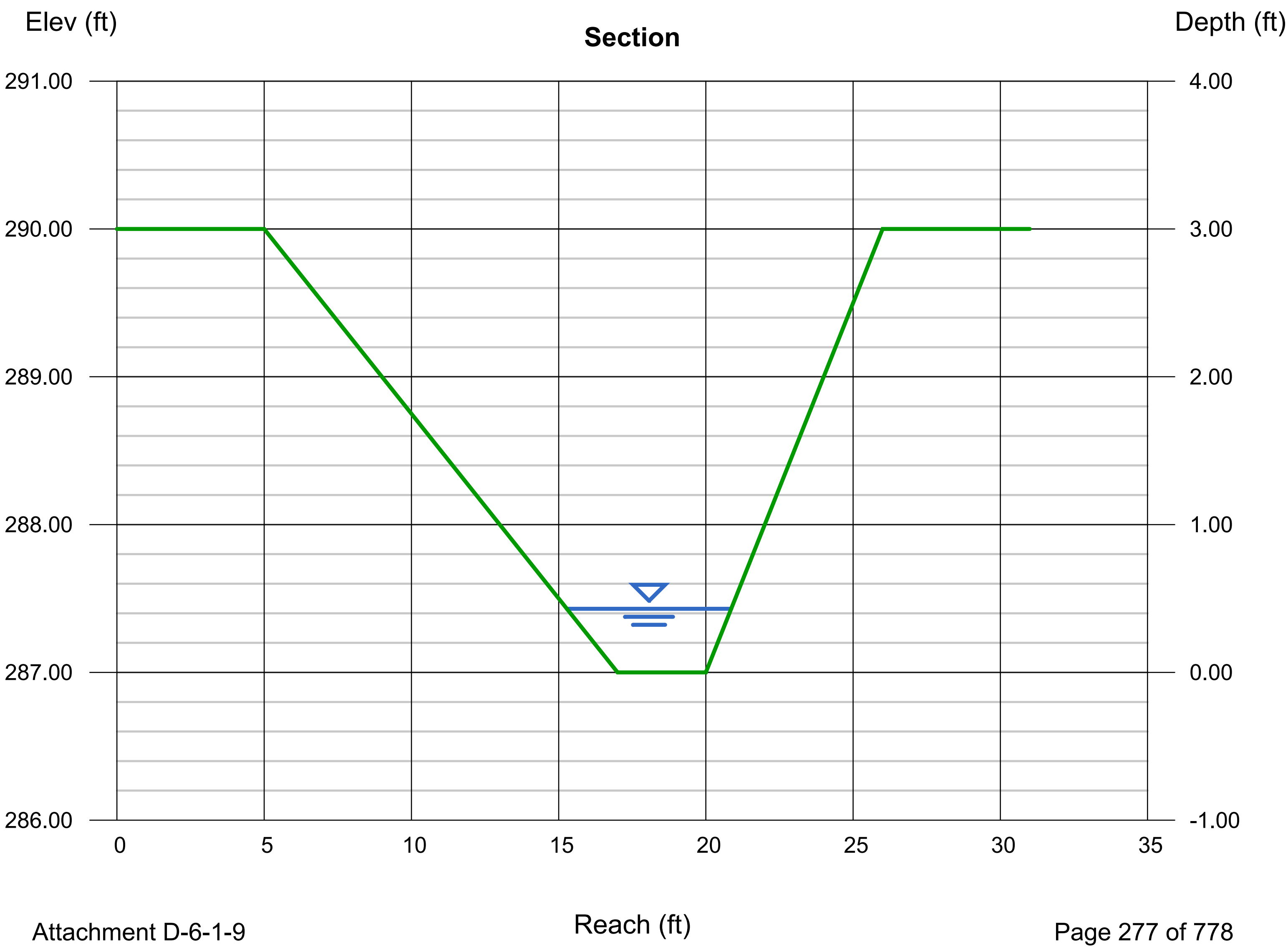
Depth (ft)	= 1.06
Q (cfs)	= 42.40
Area (sqft)	= 6.55
Velocity (ft/s)	= 6.47
Wetted Perim (ft)	= 9.74
Crit Depth, Yc (ft)	= 1.25
Top Width (ft)	= 9.36
EGL (ft)	= 1.71



Channel Report

FINAL COVER DITCH - H4 TO J2 (6.1% SLOPE)

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 3.00	Depth (ft)	= 0.43
Side Slopes (z:1)	= 4.00, 2.00	Q (cfs)	= 10.30
Total Depth (ft)	= 3.00	Area (sqft)	= 1.84
Invert Elev (ft)	= 287.00	Velocity (ft/s)	= 5.58
Slope (%)	= 6.10	Wetted Perim (ft)	= 5.73
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.59
		Top Width (ft)	= 5.58
Calculations		EGL (ft)	= 0.91
Compute by:	Known Q		
Known Q (cfs)	= 10.30		

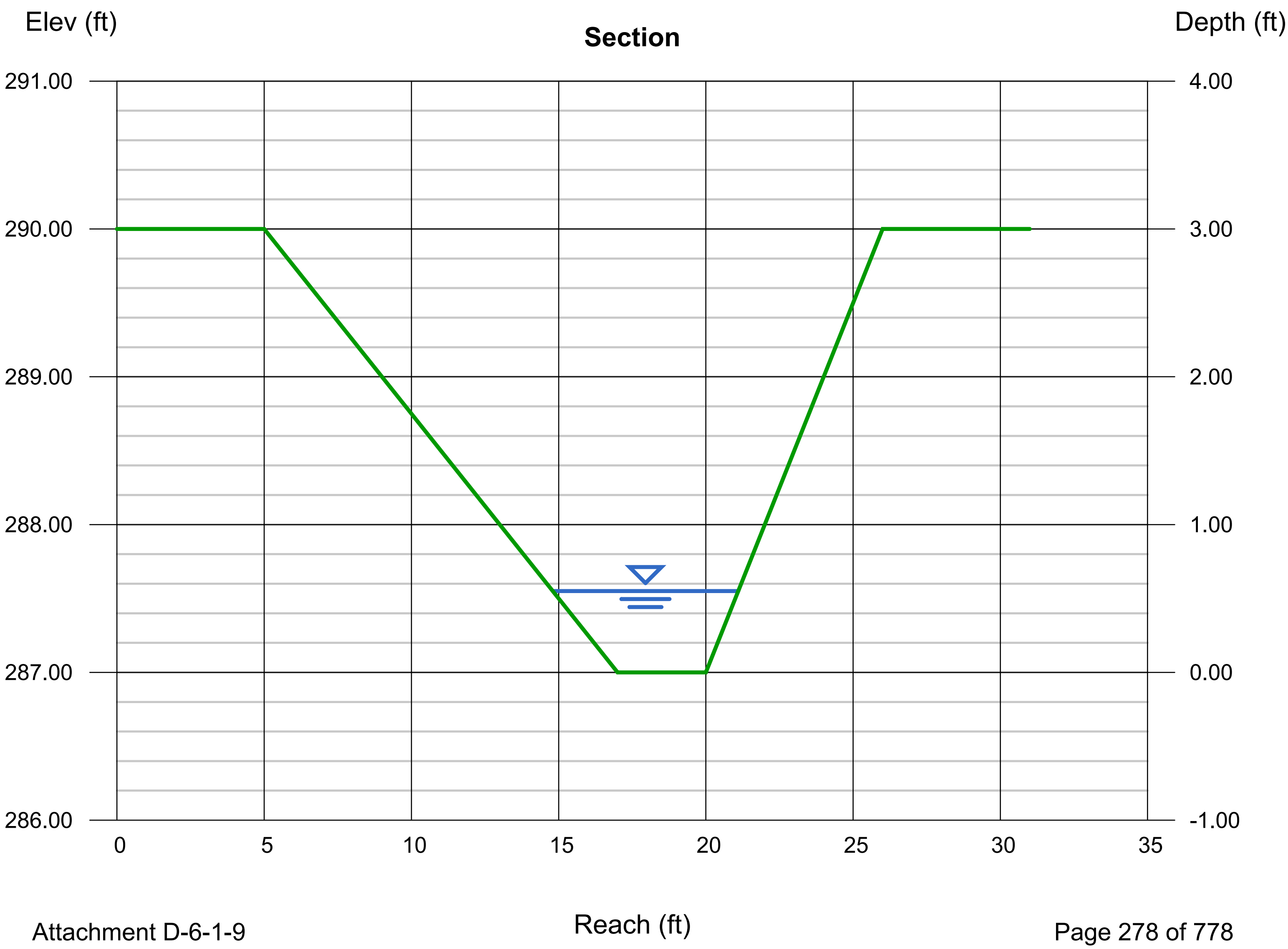


Channel Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. — Friday, Jan 30 2015

FINAL COVER DITCH - H4 TO J2 (2.4% SLOPE)

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 3.00	Depth (ft)	= 0.55
Side Slopes (z:1)	= 4.00, 2.00	Q (cfs)	= 10.30
Total Depth (ft)	= 3.00	Area (sqft)	= 2.56
Invert Elev (ft)	= 287.00	Velocity (ft/s)	= 4.03
Slope (%)	= 2.40	Wetted Perim (ft)	= 6.50
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.59
		Top Width (ft)	= 6.30
Calculations		EGL (ft)	= 0.80
Compute by:	Known Q		
Known Q (cfs)	= 10.30		



Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Legend

Hyd.	Origin	Description
1	SCS Runoff	FINAL COVER - HP7 TO F6
2	SCS Runoff	FINAL COVER - F6 TO G5
3	SCS Runoff	FINAL COVER - G5 TO H4
4	SCS Runoff	FINAL COVER - H4 TO J2

Project: Q-Final Cover Ditch.gpw

Friday, 01 / 30 / 2015

Hydrograph Summary Report

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	79.71	1	722	219,763	------	------	------	FINAL COVER - HP7 TO F6
2	SCS Runoff	21.84	1	722	60,207	------	------	------	FINAL COVER - F6 TO G5
3	SCS Runoff	42.40	1	722	116,903	------	------	------	FINAL COVER - G5 TO H4
4	SCS Runoff	10.25	1	722	28,260	------	------	------	FINAL COVER - H4 TO J2

Q-Final Cover Ditch.gpw	Return Period: 25 Year	Friday, 01 / 30 / 2015

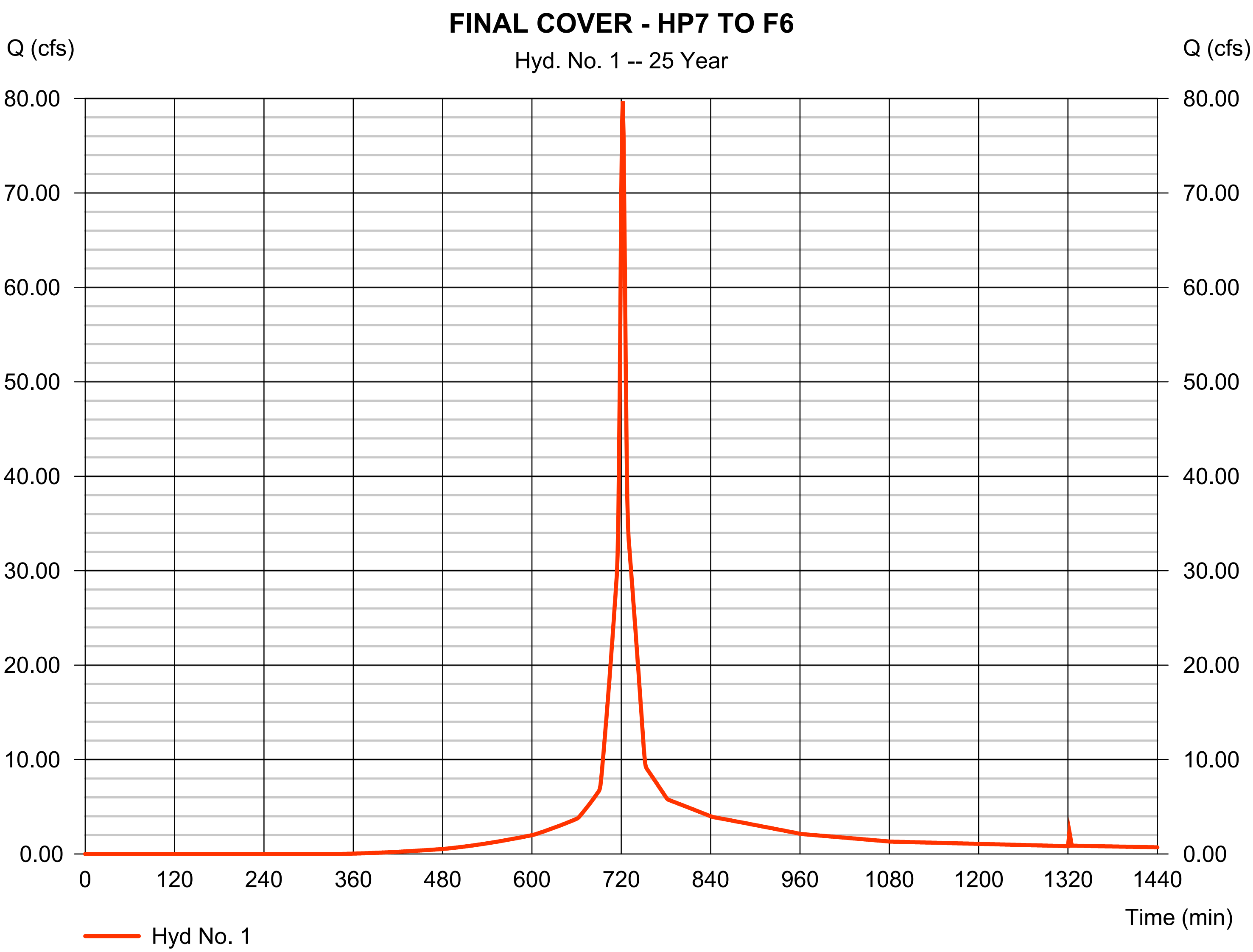
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 1

FINAL COVER - HP7 TO F6

Hydrograph type	= SCS Runoff	Peak discharge	= 79.71 cfs
Storm frequency	= 25 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 219,763 cuft
Drainage area	= 12.520 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 2.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



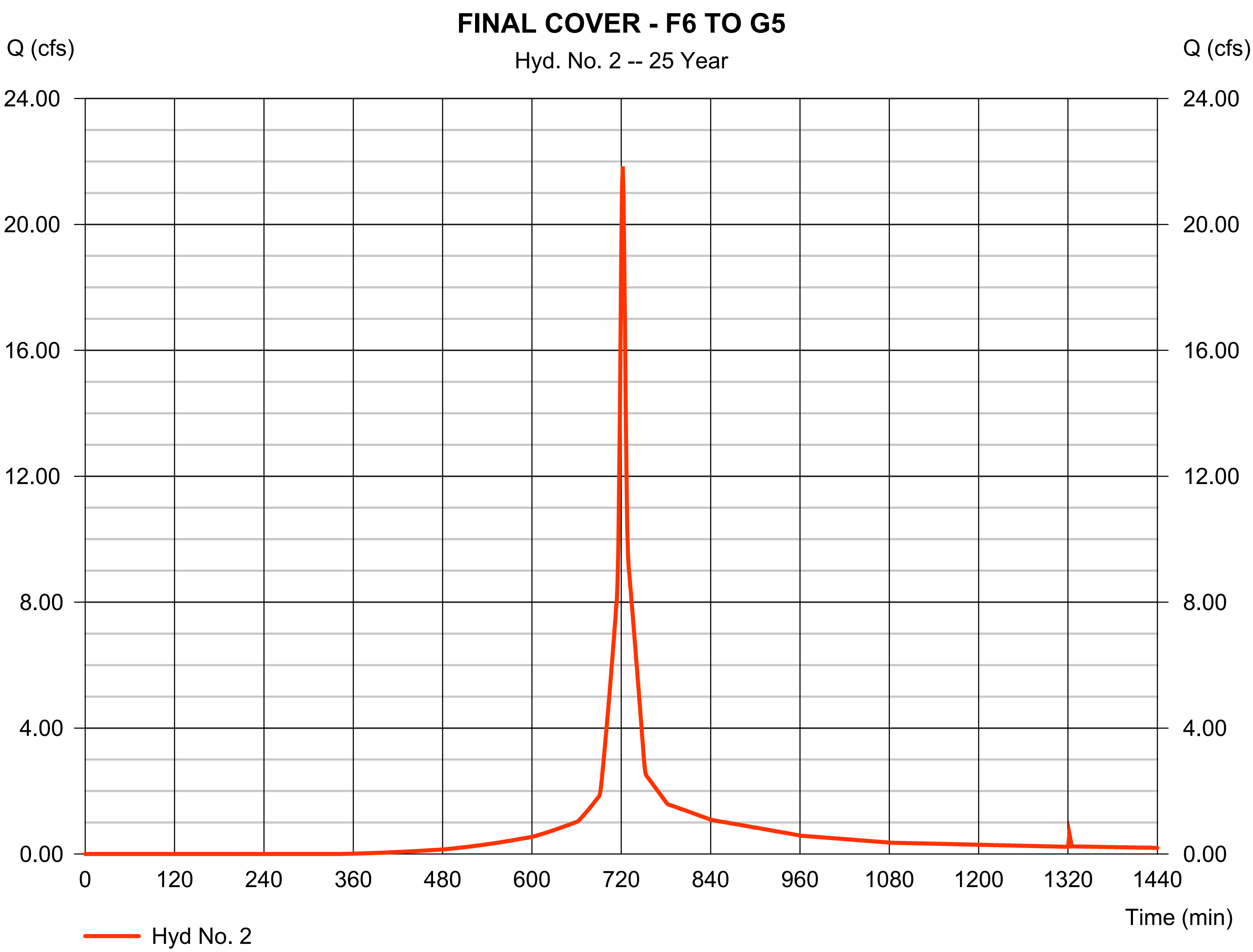
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 2

FINAL COVER - F6 TO G5

Hydrograph type	=	SCS Runoff	Peak discharge	=	21.84 cfs
Storm frequency	=	25 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	60,207 cuft
Drainage area	=	3.430 ac	Curve number	=	80
Basin Slope	=	25.0 %	Hydraulic length	=	0 ft
Tc method	=	User	Time of conc. (Tc)	=	2.00 min
Total precip.	=	7.50 in	Distribution	=	Type III
Storm duration	=	24 hrs	Shape factor	=	484

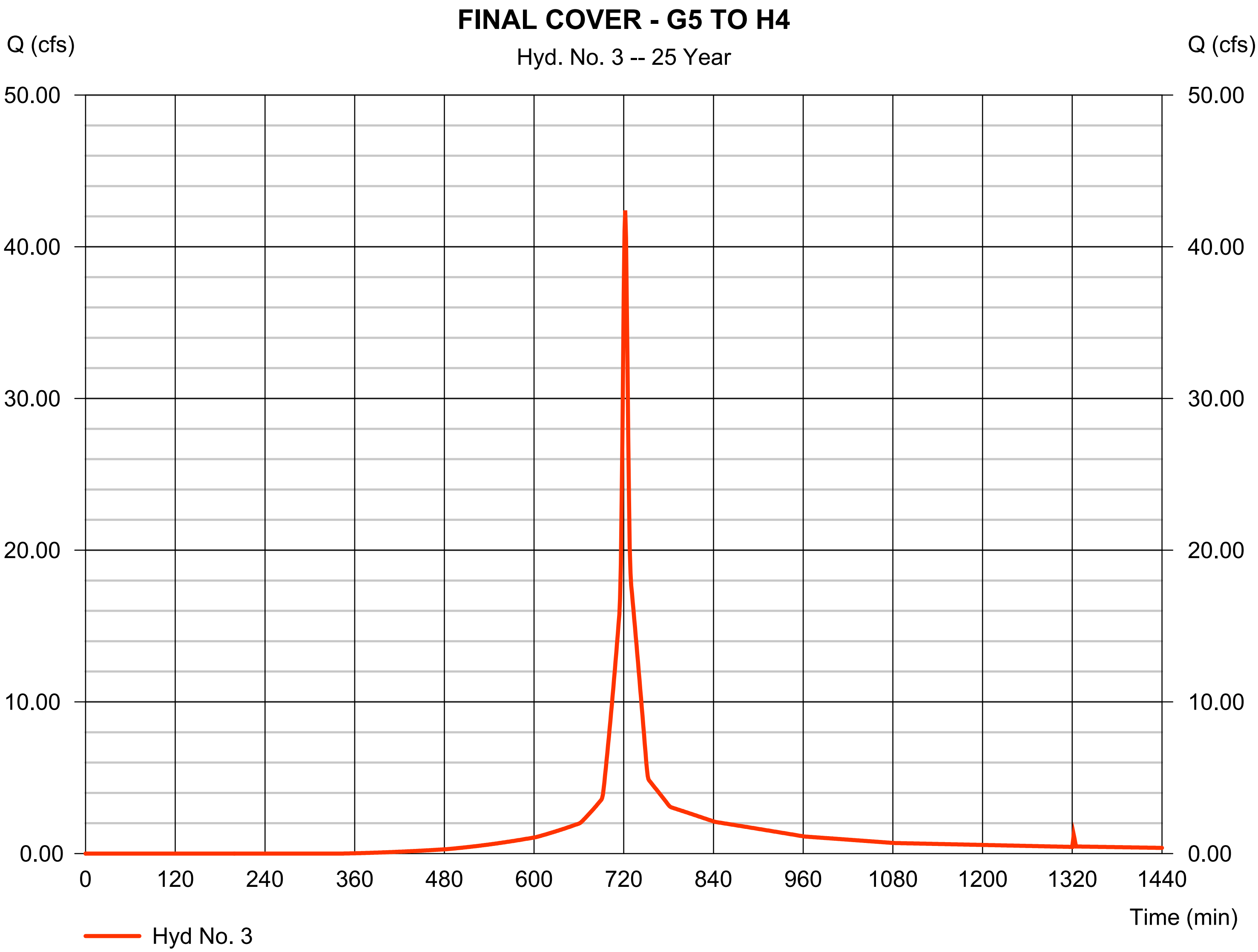


Hydrograph Report

Hyd. No. 3

FINAL COVER - G5 TO H4

Hydrograph type	= SCS Runoff	Peak discharge	= 42.40 cfs
Storm frequency	= 25 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 116,903 cuft
Drainage area	= 6.660 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 2.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

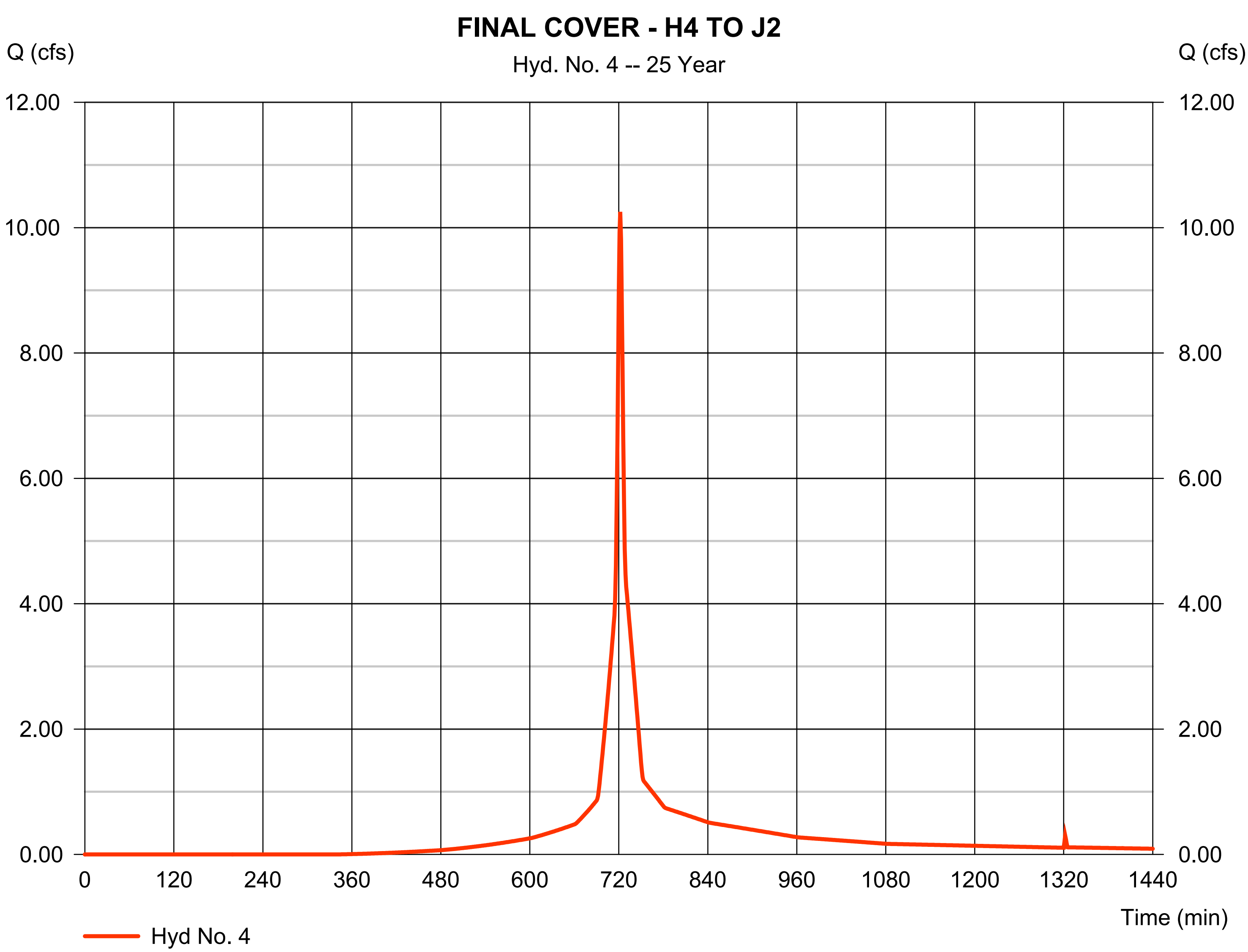


Hydrograph Report

Hyd. No. 4

FINAL COVER - H4 TO J2

Hydrograph type	= SCS Runoff	Peak discharge	= 10.25 cfs
Storm frequency	= 25 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 28,260 cuft
Drainage area	= 1.610 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 2.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	0.0000	0.0000	0.0000	--------
3	0.0000	0.0000	0.0000	--------
5	0.0000	0.0000	0.0000	--------
10	0.0000	0.0000	0.0000	--------
25	0.0000	0.0000	0.0000	--------
50	0.0000	0.0000	0.0000	--------
100	0.0000	0.0000	0.0000	--------

File name: SampleFHA.idf

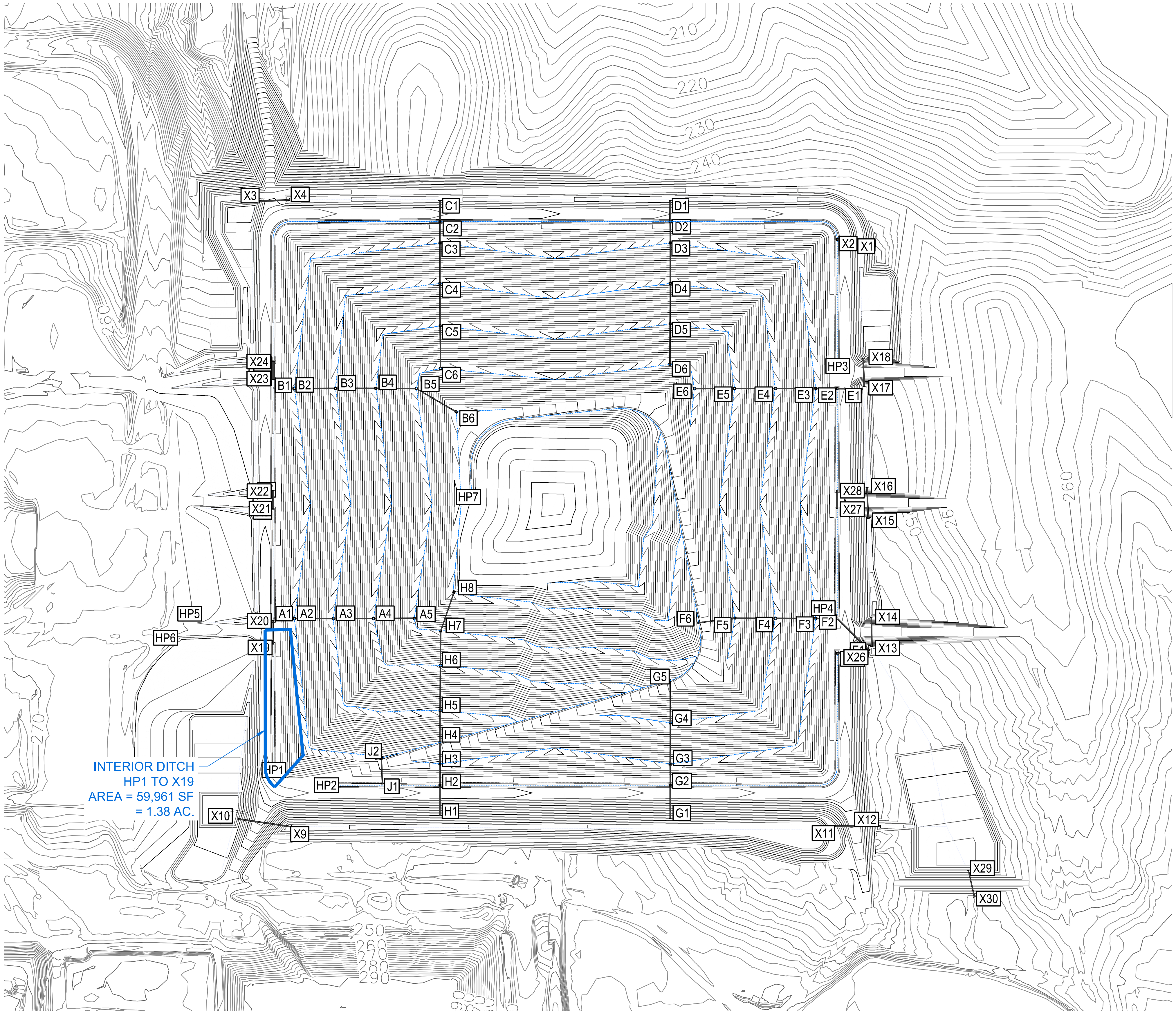
Intensity = B / (Tc + D)^E

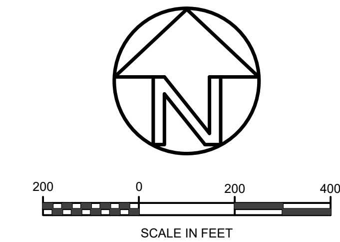
Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Tc = time in minutes. Values may exceed 60.

ojects\2014\EJ147461\Working Files\Calculations-Analyses\SCS METHOD\Peachtree City (24 hr GA Green Book).pcp

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.75	4.50	0.00	5.65	6.50	7.50	8.40	9.20
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00





PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 8.8 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

2-FT FINAL COVER CTR	
10-FT FINAL COVER CTR	
DOWNDRAIN / CULVERT	
WATERSHED BOUNDARY	

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DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

EMELLE FACILITY

Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

INTERIOR DITCH, SECTION HP1 TO X19 WATERSHED

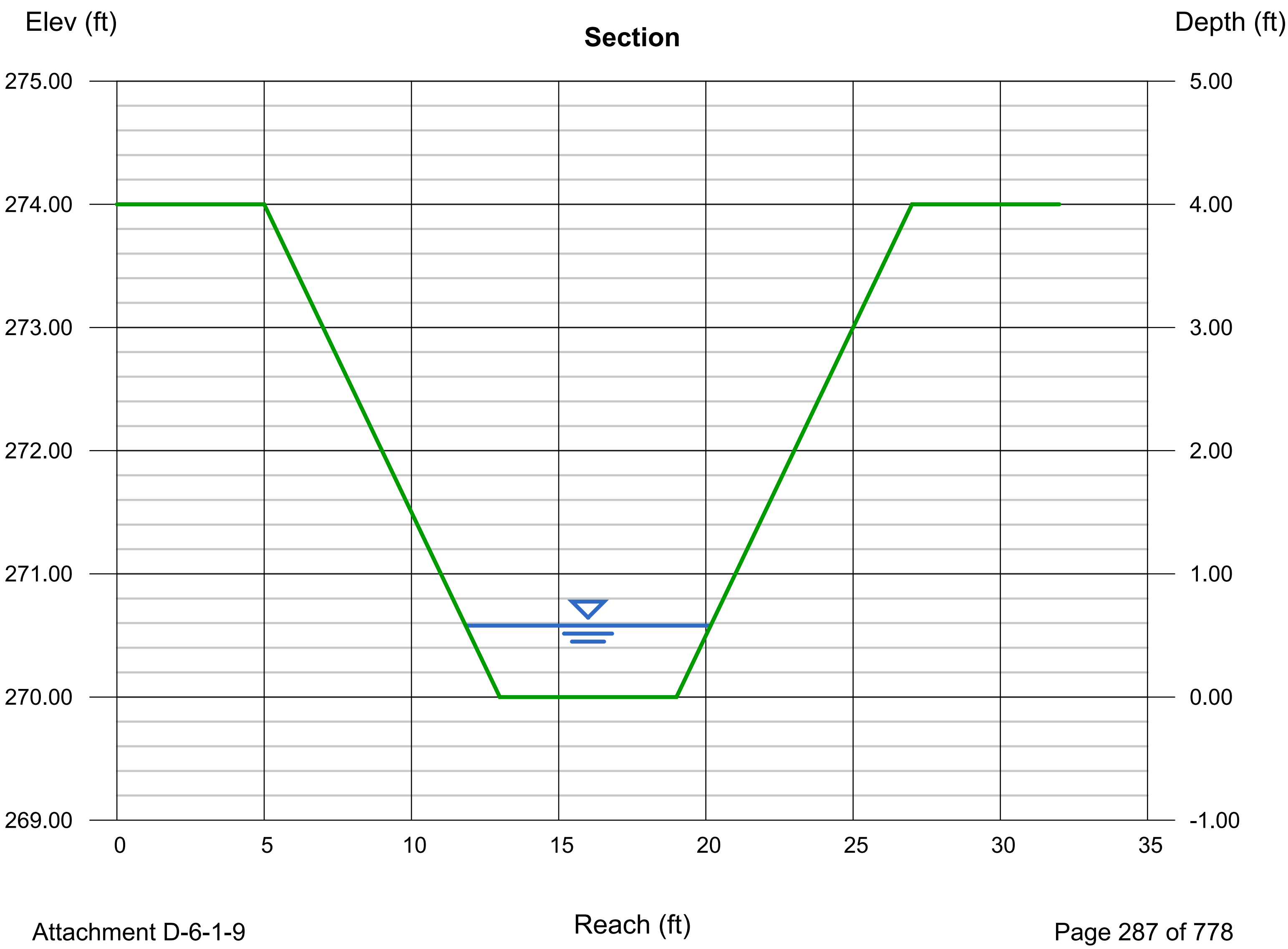
HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

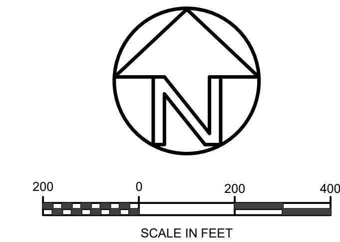
FIGURE
D-1

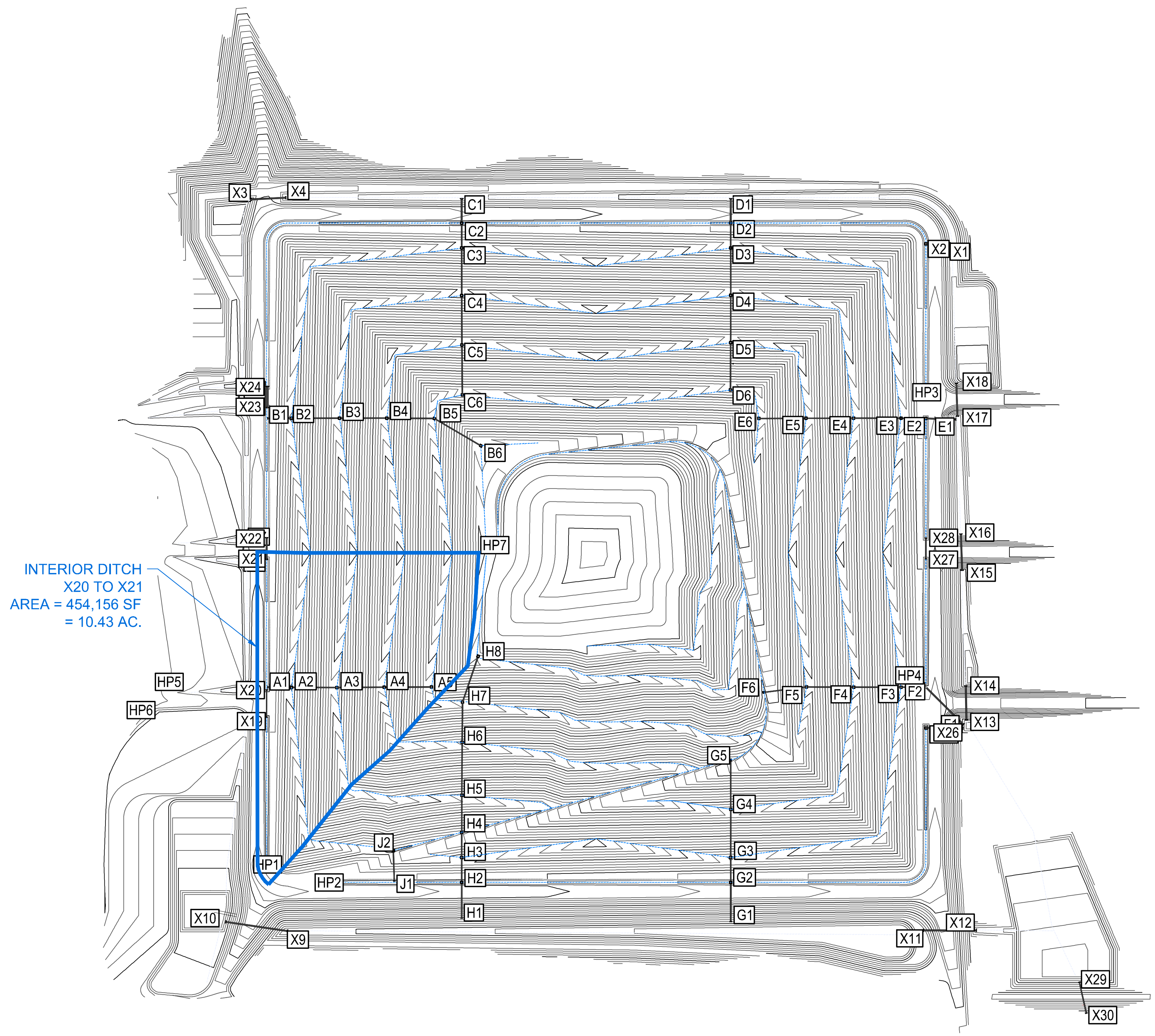
Channel Report

INTERIOR DITCH - HP1 TO X19

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 6.00	Depth (ft)	= 0.58
Side Slopes (z:1)	= 2.00, 2.00	Q (cfs)	= 8.800
Total Depth (ft)	= 4.00	Area (sqft)	= 4.15
Invert Elev (ft)	= 270.00	Velocity (ft/s)	= 2.12
Slope (%)	= 0.50	Wetted Perim (ft)	= 8.59
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.39
		Top Width (ft)	= 8.32
Calculations		EGL (ft)	= 0.65
Compute by:	Known Q		
Known Q (cfs)	= 8.80		







PEAK FLOW FOR CRITICAL DITCH SEGMENT
Q_{PEAK} = 64.3 cfs
25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

(line)	2-FT FINAL COVER CTR
(line)	10-FT FINAL COVER CTR
(line)	DOWNDRAIN / CULVERT
(line)	WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

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Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

INTERIOR DITCH, SECTION X20 TO X21 WATERSHED

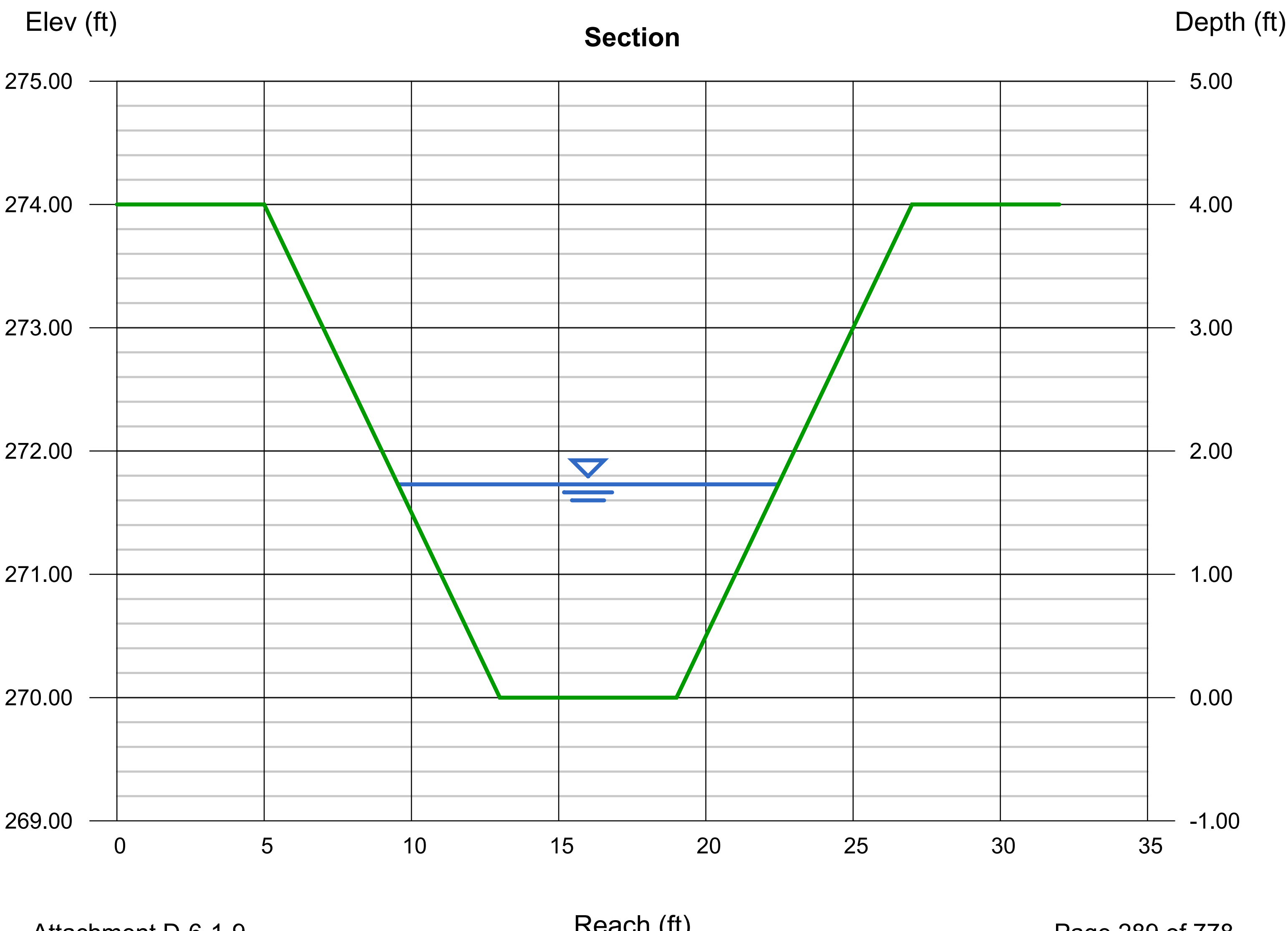
HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

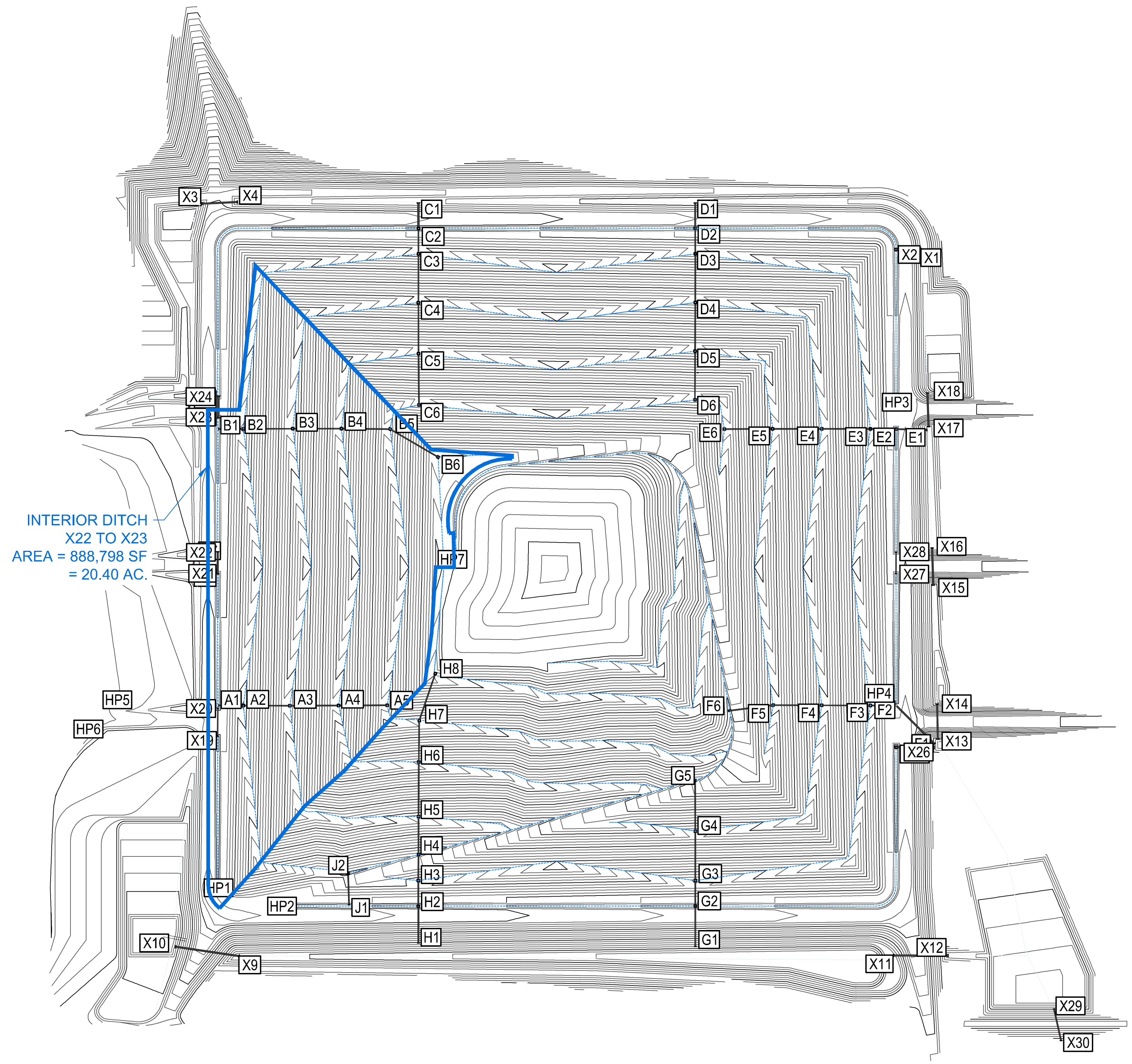
FIGURE
D-2

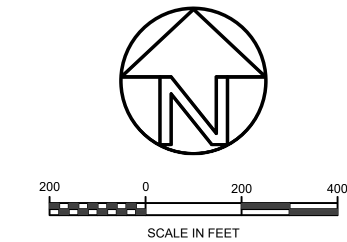
Channel Report

INTERIOR DITCH - X20 TO X21

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 6.00	Depth (ft)	= 1.73
Side Slopes (z:1)	= 2.00, 2.00	Q (cfs)	= 64.30
Total Depth (ft)	= 4.00	Area (sqft)	= 16.37
Invert Elev (ft)	= 270.00	Velocity (ft/s)	= 3.93
Slope (%)	= 0.50	Wetted Perim (ft)	= 13.74
N-Value	= 0.030	Crit Depth, Yc (ft)	= 1.32
		Top Width (ft)	= 12.92
Calculations		EGL (ft)	= 1.97
Compute by:	Known Q		
Known Q (cfs)	= 64.30		







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 114.2 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

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CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

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PH. (770) 924-9799 FAX. (770) 924-7866

INTERIOR DITCH, SECTION X22 TO X23 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
D-3

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Channel Report

INTERIOR DITCH - X22 TO X23

Trapezoidal

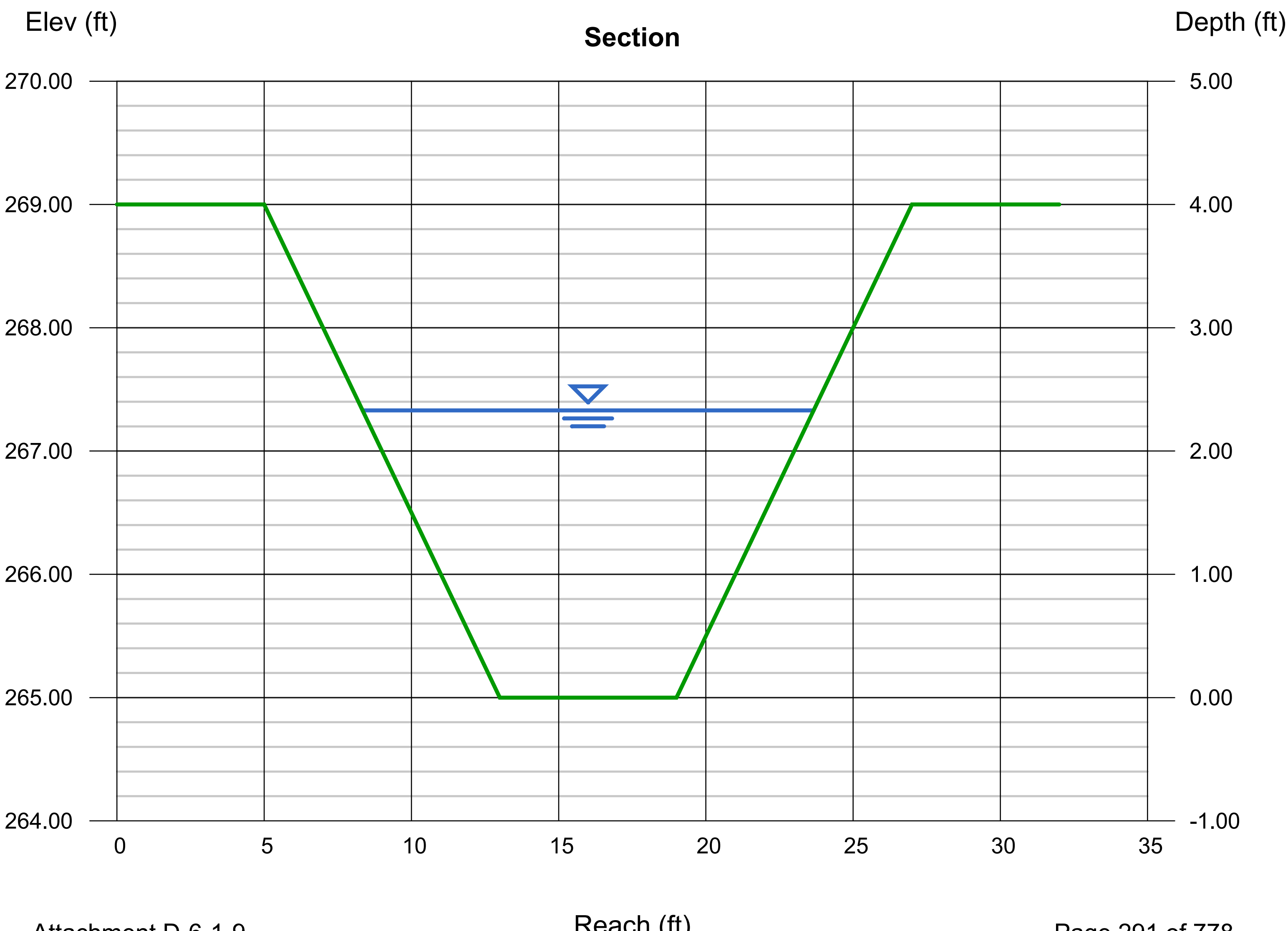
Bottom Width (ft)	= 6.00
Side Slopes (z:1)	= 2.00, 2.00
Total Depth (ft)	= 4.00
Invert Elev (ft)	= 265.00
Slope (%)	= 0.50
N-Value	= 0.030

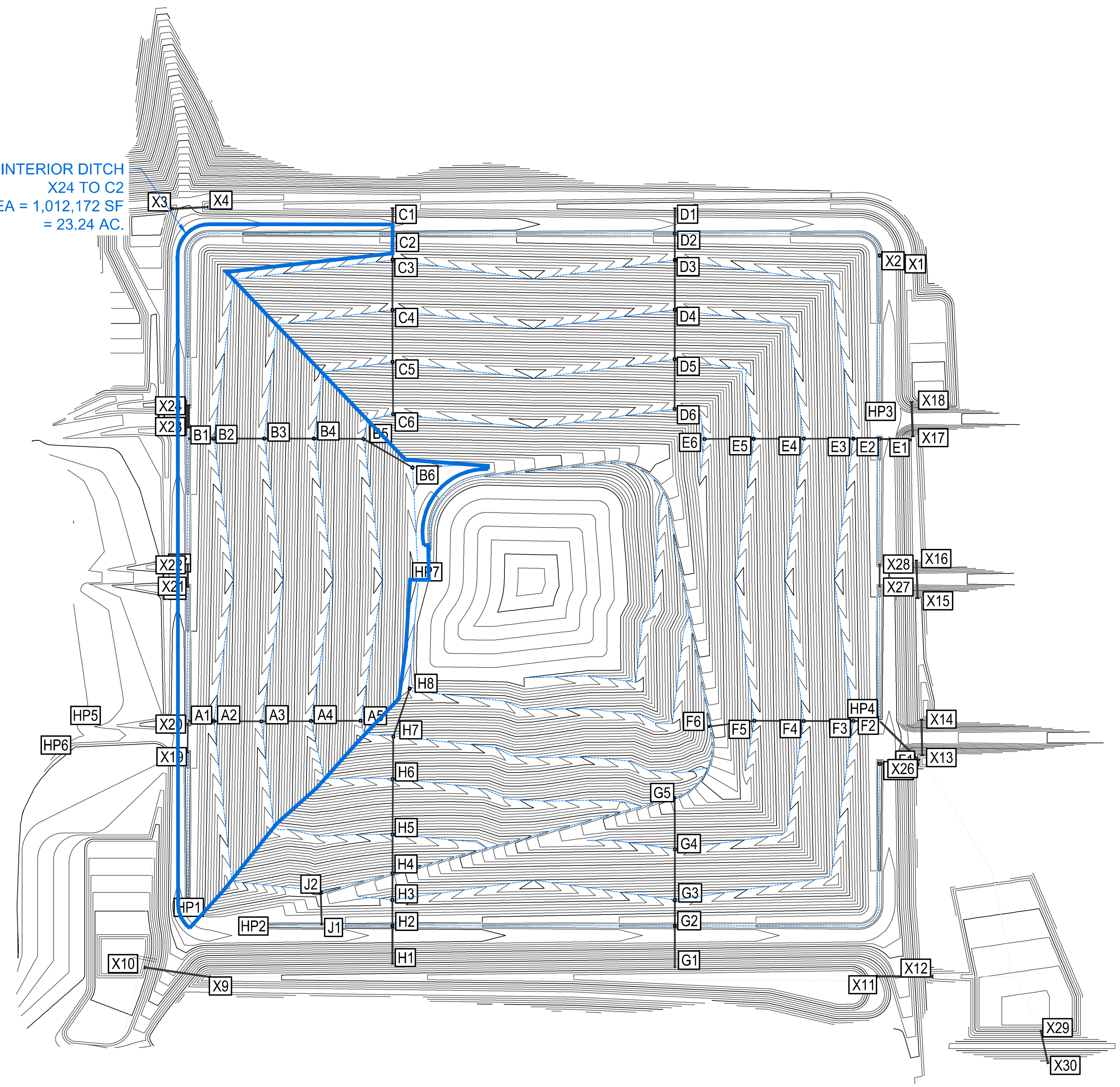
Calculations

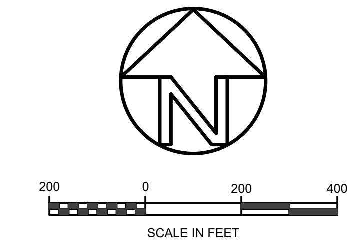
Compute by:	Known Q
Known Q (cfs)	= 114.20

Highlighted

Depth (ft)	= 2.33
Q (cfs)	= 114.20
Area (sqft)	= 24.84
Velocity (ft/s)	= 4.60
Wetted Perim (ft)	= 16.42
Crit Depth, Yc (ft)	= 1.82
Top Width (ft)	= 15.32
EGL (ft)	= 2.66







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 125.3 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

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CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

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4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

INTERIOR DITCH, SECTION X24 TO C2 WATERSHED

HYDROLOGY STUDY
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FIGURE
D-4

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Channel Report

INTERIOR DITCH - X24 TO C2

Trapezoidal

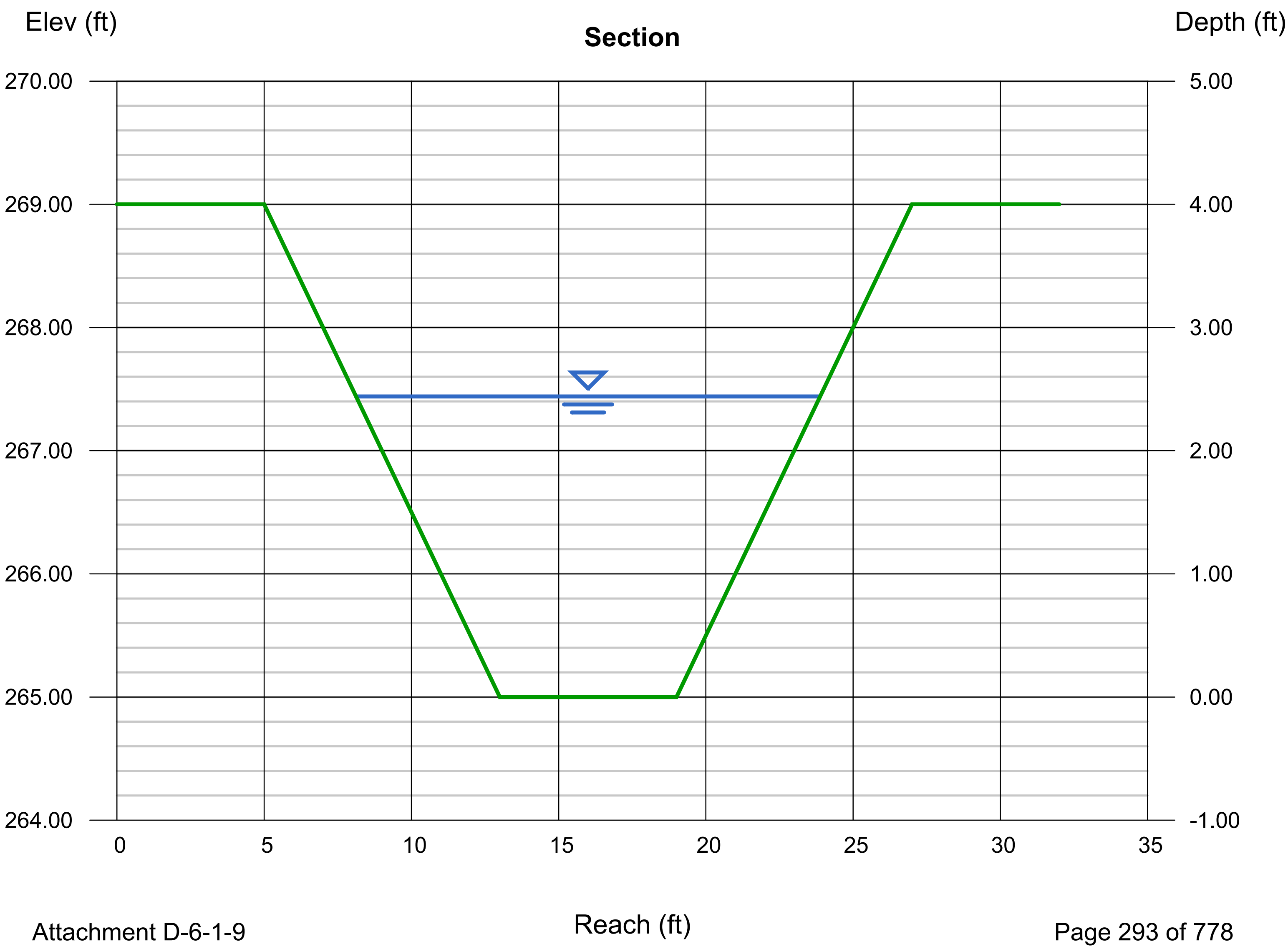
Bottom Width (ft)	= 6.00
Side Slopes (z:1)	= 2.00, 2.00
Total Depth (ft)	= 4.00
Invert Elev (ft)	= 265.00
Slope (%)	= 0.50
N-Value	= 0.030

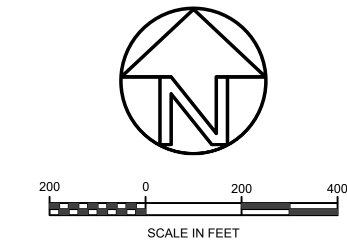
Calculations

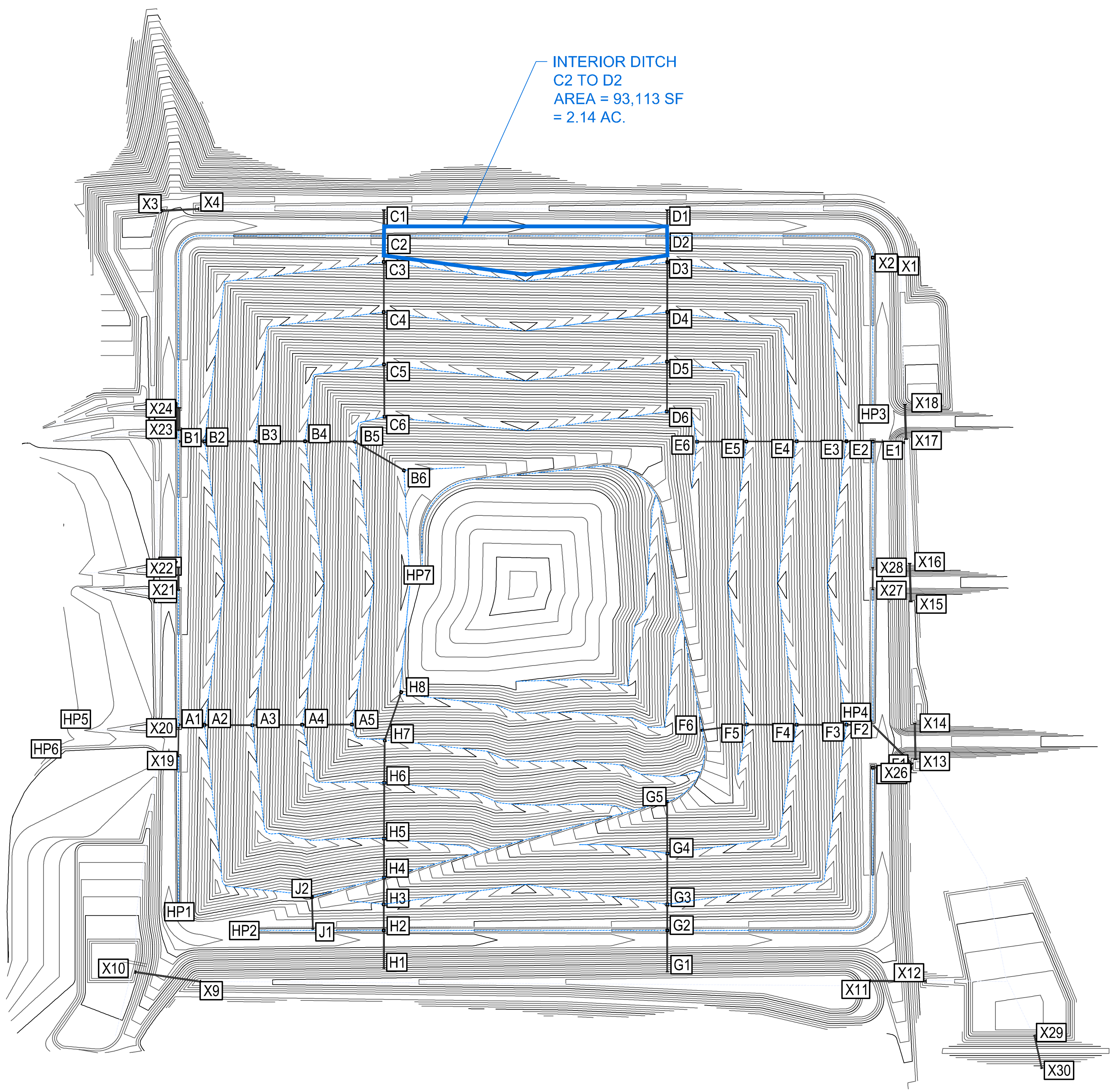
Compute by:	Known Q
Known Q (cfs)	= 125.30

Highlighted

Depth (ft)	= 2.44
Q (cfs)	= 125.30
Area (sqft)	= 26.55
Velocity (ft/s)	= 4.72
Wetted Perim (ft)	= 16.91
Crit Depth, Yc (ft)	= 1.92
Top Width (ft)	= 15.76
EGL (ft)	= 2.79







PEAK FLOW FOR CRITICAL DITCH SEGMENT
Q_{PEAK} = 13.7 cfs
25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

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4040 Royal Drive, Suite 100 Kennesaw, GA 30144
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INTERIOR DITCH, SECTION C2 TO D2 WATERSHED

HYDROLOGY STUDY
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CHEMICAL WASTE MANAGEMENT

FIGURE
D-5

Channel Report

INTERIOR DITCH - C2 TO D2

Trapezoidal

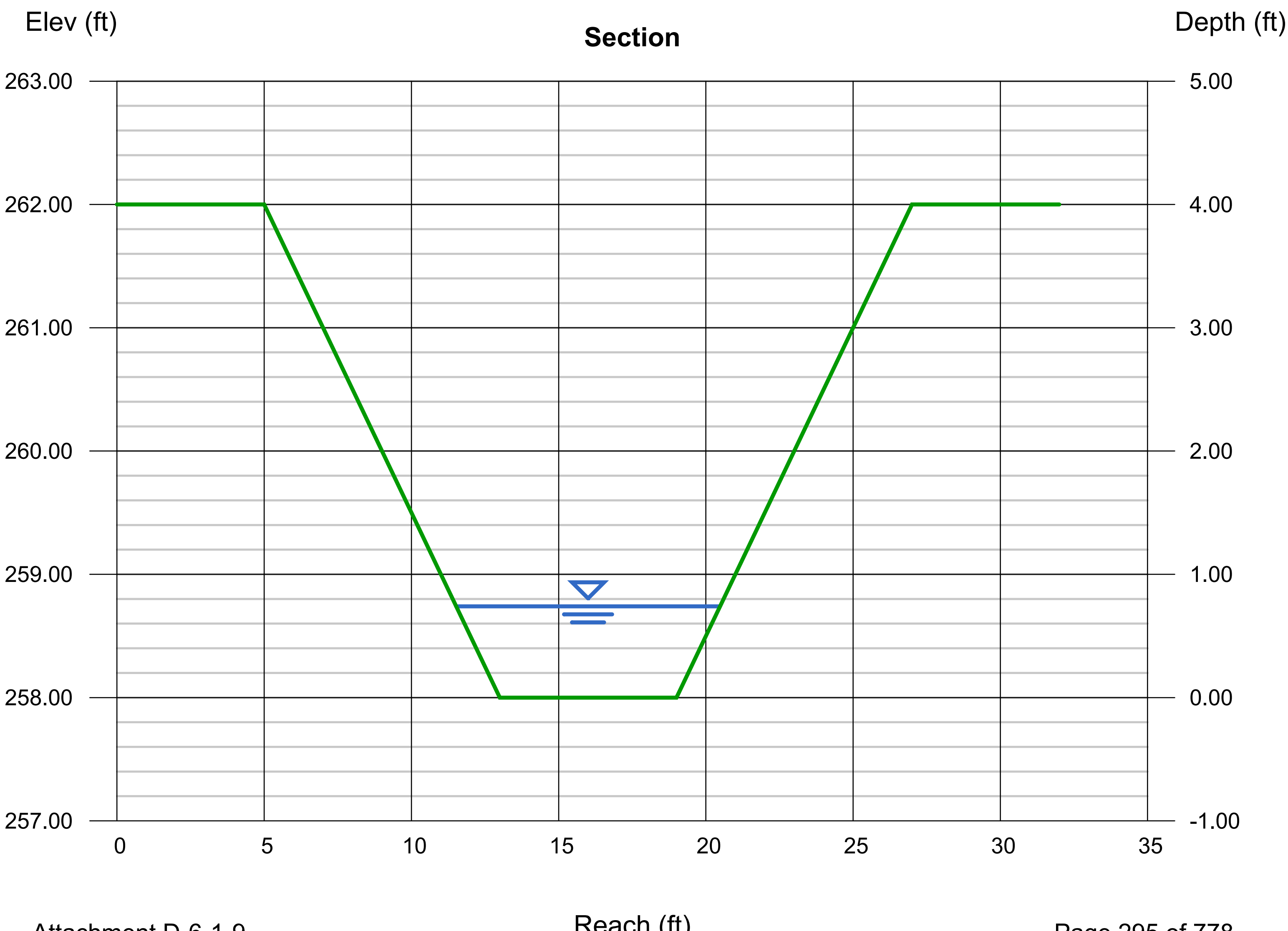
Bottom Width (ft)	= 6.00
Side Slopes (z:1)	= 2.00, 2.00
Total Depth (ft)	= 4.00
Invert Elev (ft)	= 258.00
Slope (%)	= 0.50
N-Value	= 0.030

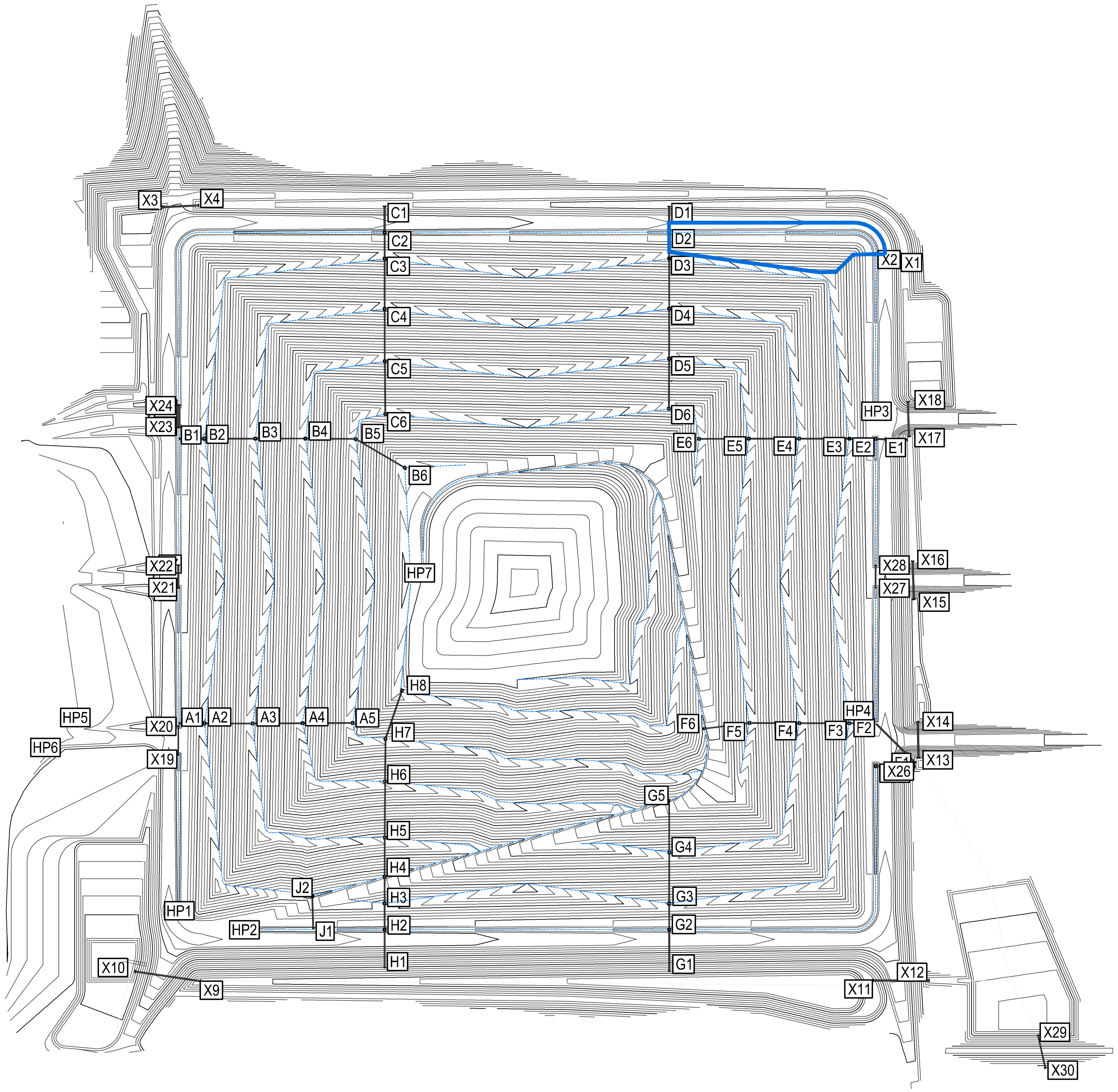
Calculations

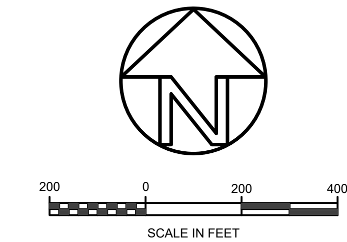
Compute by:	Known Q
Known Q (cfs)	= 13.70

Highlighted

Depth (ft)	= 0.74
Q (cfs)	= 13.70
Area (sqft)	= 5.54
Velocity (ft/s)	= 2.48
Wetted Perim (ft)	= 9.31
Crit Depth, Yc (ft)	= 0.52
Top Width (ft)	= 8.96
EGL (ft)	= 0.84







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 10.2 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

(thin line)	2-FT FINAL COVER CTR
(medium line)	10-FT FINAL COVER CTR
(black line)	DOWNDRAIN / CULVERT
(blue line)	WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

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PH. (770) 924-9799 FAX. (770) 924-7866

INTERIOR DITCH , SECTION D2 TO X2 WATERSHED

HYDROLOGY STUDY

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CHEMICAL WASTE MANAGEMENT

FIGURE

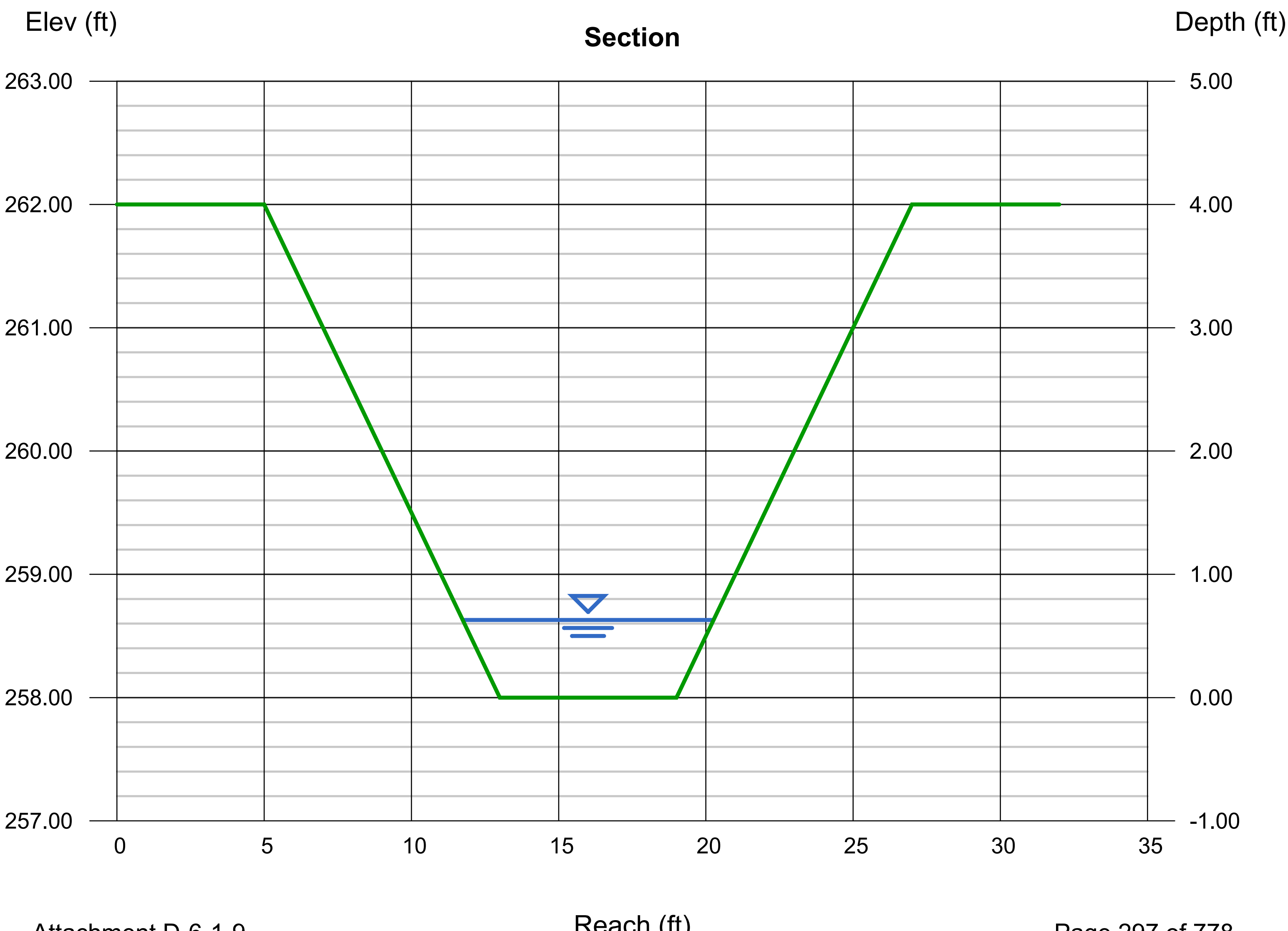
D-6

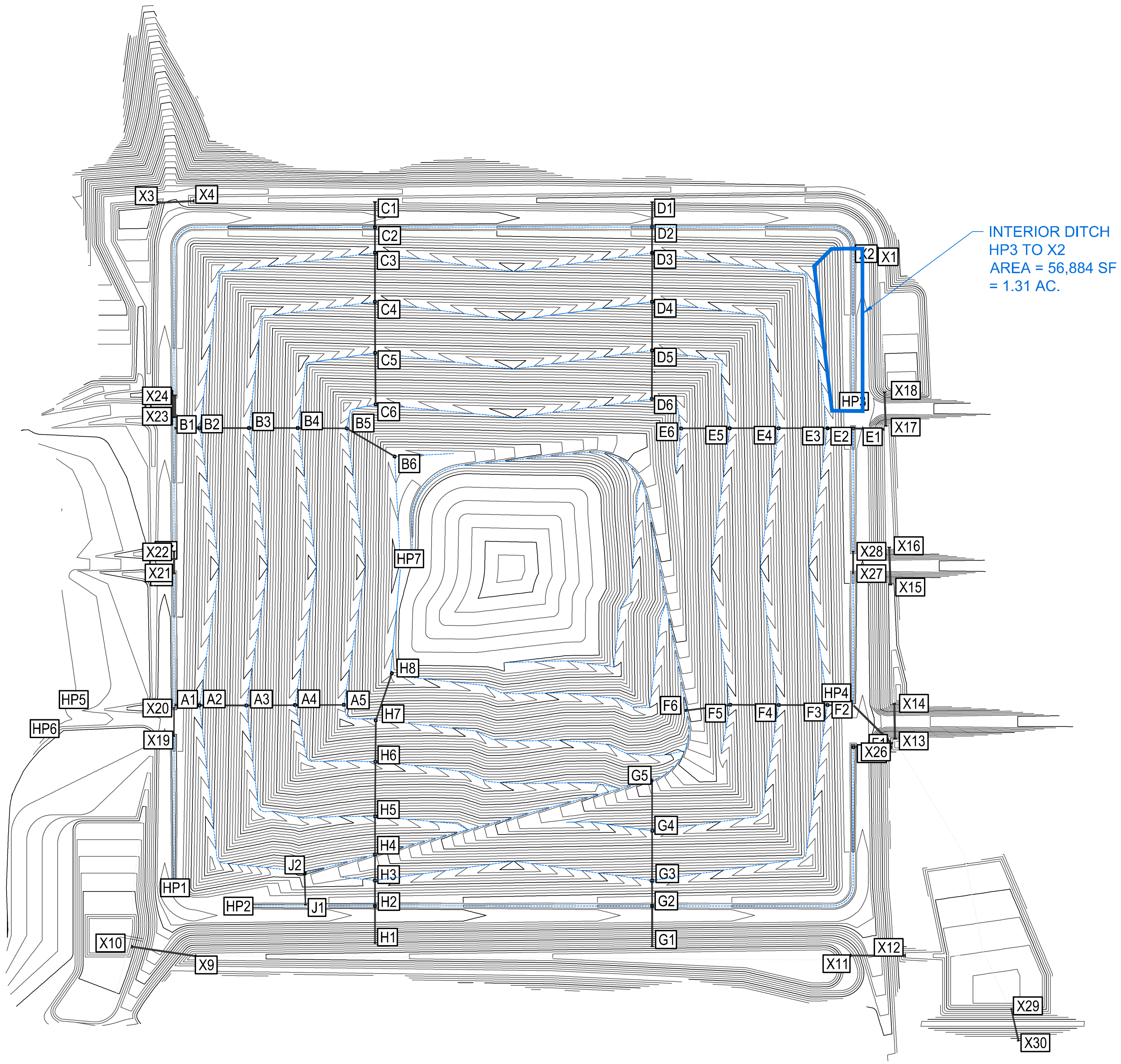
Channel Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Friday, Jan 30 2015

INTERIOR DITCH - D2 TO X2

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 6.00	Depth (ft)	= 0.63
Side Slopes (z:1)	= 2.00, 2.00	Q (cfs)	= 10.20
Total Depth (ft)	= 4.00	Area (sqft)	= 4.57
Invert Elev (ft)	= 258.00	Velocity (ft/s)	= 2.23
Slope (%)	= 0.50	Wetted Perim (ft)	= 8.82
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.43
		Top Width (ft)	= 8.52
Calculations		EGL (ft)	= 0.71
Compute by:	Known Q		
Known Q (cfs)	= 10.20		





200 0 200 400
SCALE IN FEET

PEAK FLOW FOR CRITICAL DITCH SEGMENT
Q_{PEAK} = 8.4 cfs
25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

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Consulting Engineers and Scientists
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PH. (770) 924-9799 FAX. (770) 924-7866

INTERIOR DITCH - SECTION HP3 TO X2 WATERSHED

HYDROLOGY STUDY
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CHEMICAL WASTE MANAGEMENT

FIGURE
D-7

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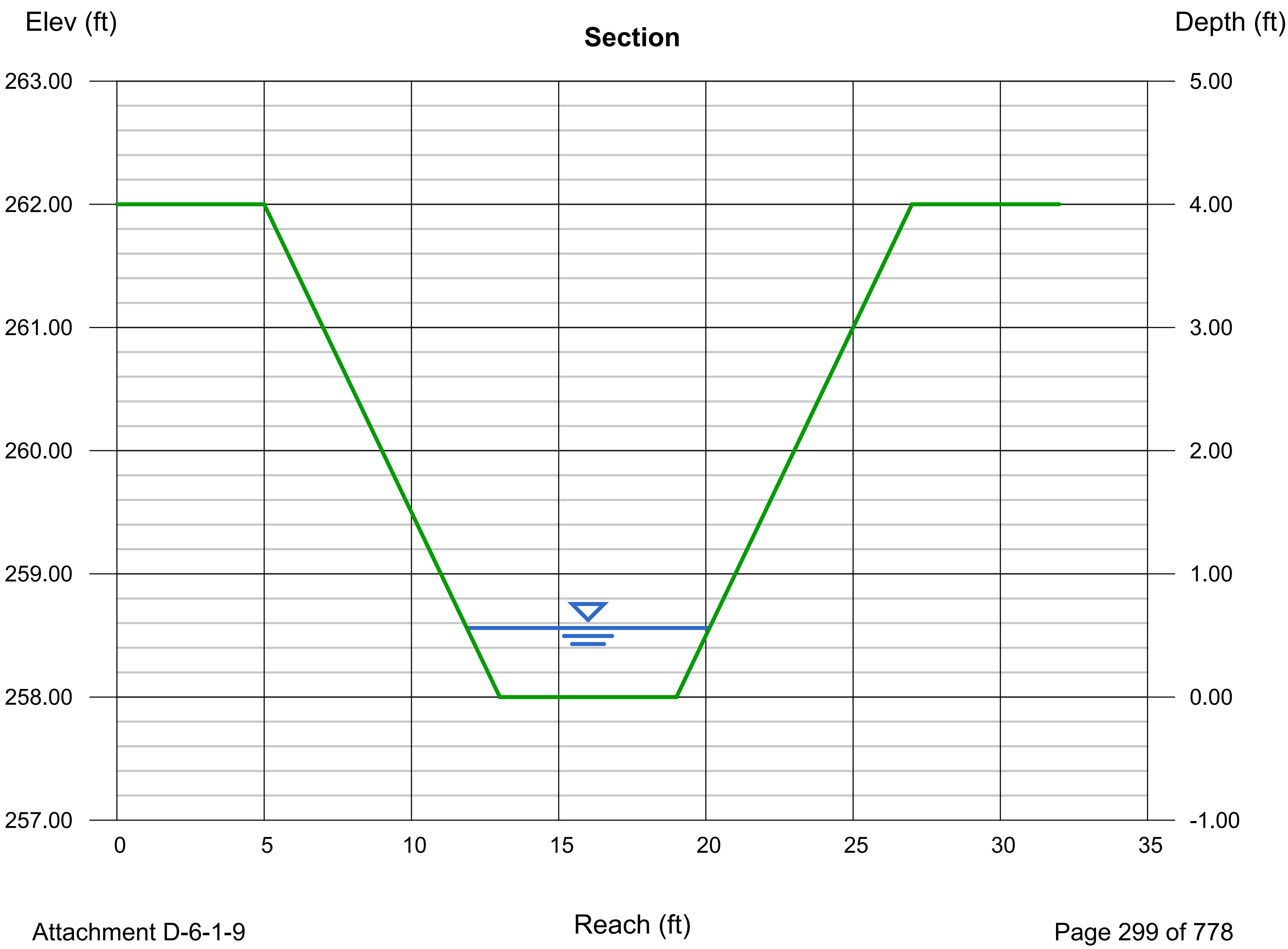
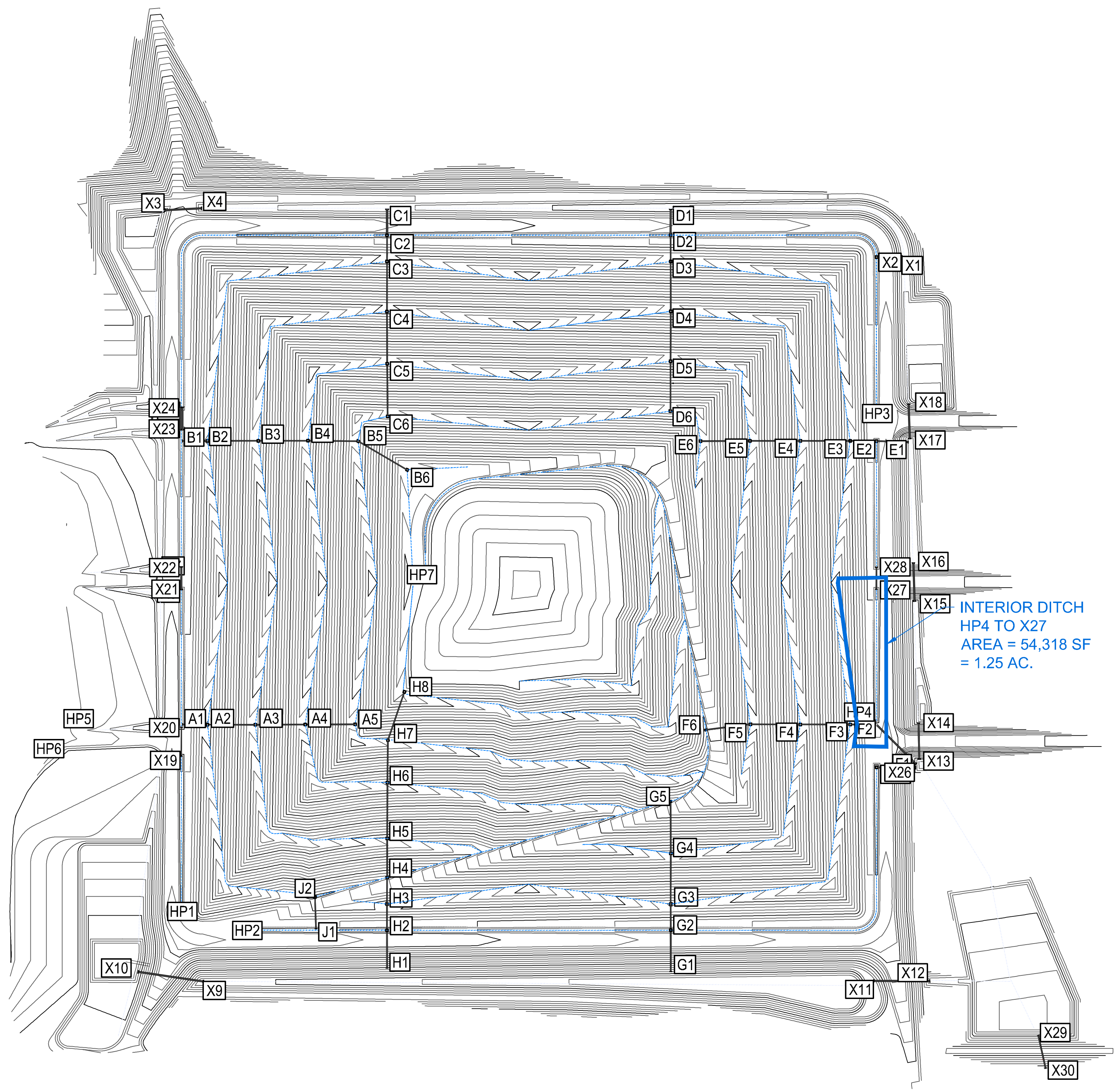
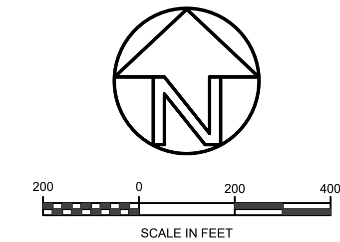
Channel Report

INTERIOR DITCH - HP3 TO X2

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 6.00	Depth (ft)	= 0.56
Side Slopes (z:1)	= 2.00, 2.00	Q (cfs)	= 8.400
Total Depth (ft)	= 4.00	Area (sqft)	= 3.99
Invert Elev (ft)	= 258.00	Velocity (ft/s)	= 2.11
Slope (%)	= 0.50	Wetted Perim (ft)	= 8.50
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.38
		Top Width (ft)	= 8.24
Calculations		EGL (ft)	= 0.63
Compute by:	Known Q		
Known Q (cfs)	= 8.40		







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 8.0 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

(thin line)	2-FT FINAL COVER CTR
(line)	10-FT FINAL COVER CTR
(heavy line)	DOWNDRAIN / CULVERT
(blue line)	WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

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Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

INTERIOR DITCH, SECTION HP4 TO X27 WATERSHED

HYDROLOGY STUDY
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CHEMICAL WASTE MANAGEMENT

FIGURE
D-8

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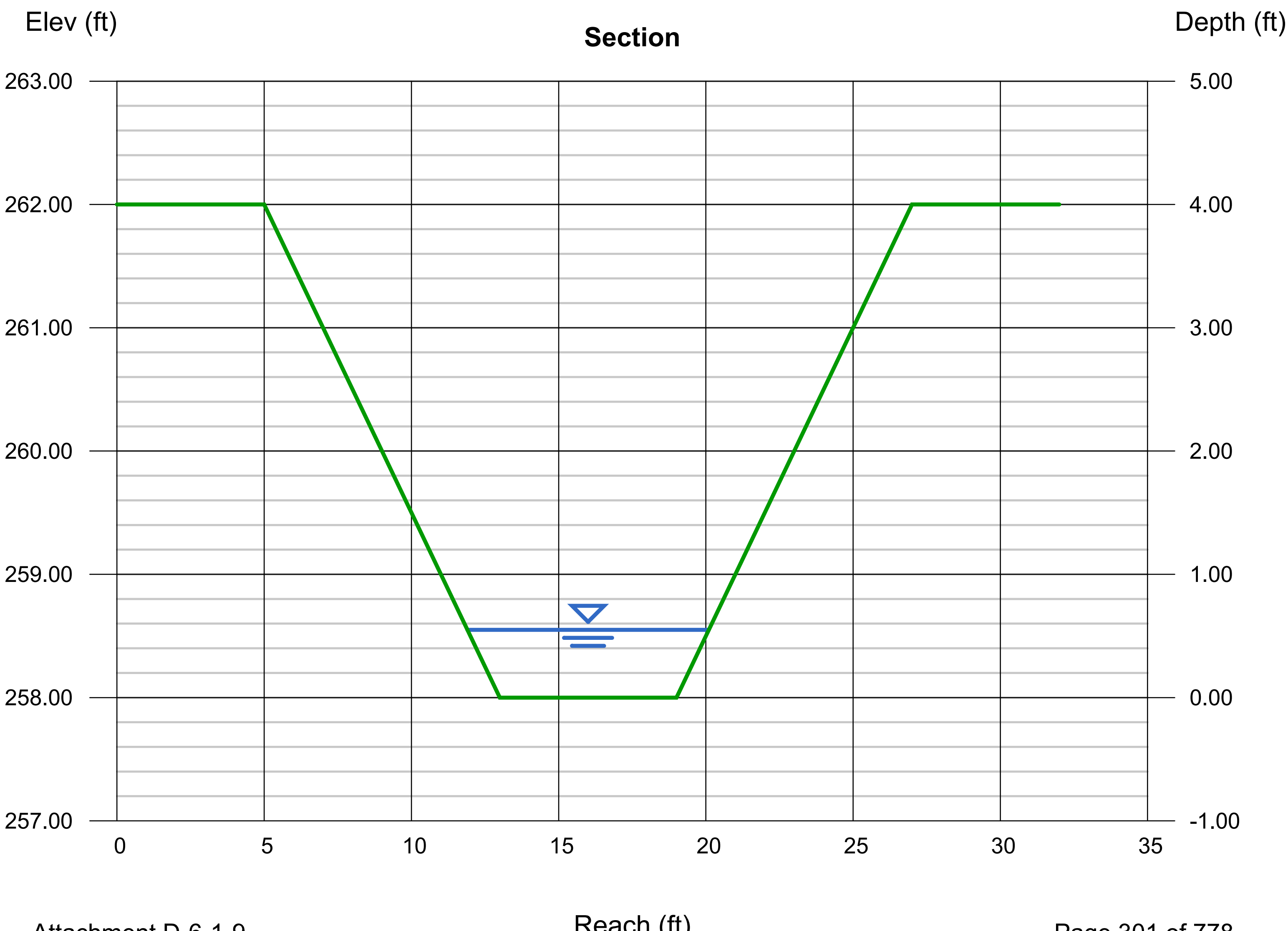
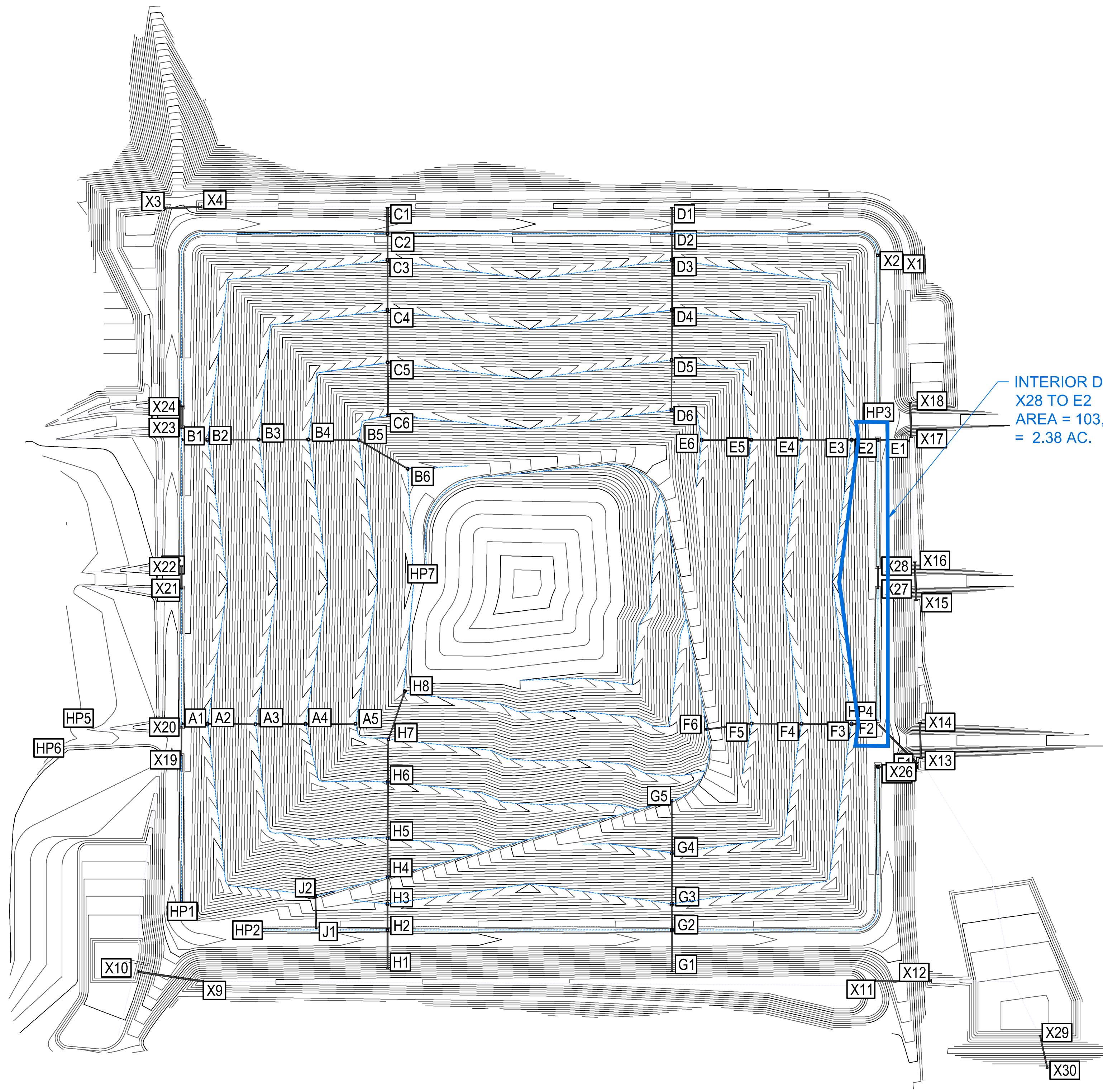
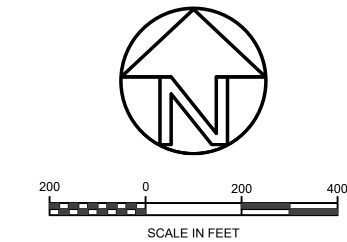
Channel Report

INTERIOR DITCH - HP4 TO X27

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 6.00	Depth (ft)	= 0.55
Side Slopes (z:1)	= 2.00, 2.00	Q (cfs)	= 8.000
Total Depth (ft)	= 4.00	Area (sqft)	= 3.90
Invert Elev (ft)	= 258.00	Velocity (ft/s)	= 2.05
Slope (%)	= 0.50	Wetted Perim (ft)	= 8.46
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.37
		Top Width (ft)	= 8.20
Calculations		EGL (ft)	= 0.62
Compute by:	Known Q		
Known Q (cfs)	= 8.00		







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 15.2 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

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INTERIOR DITCH, SECTION X28 TO E2 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
D-9

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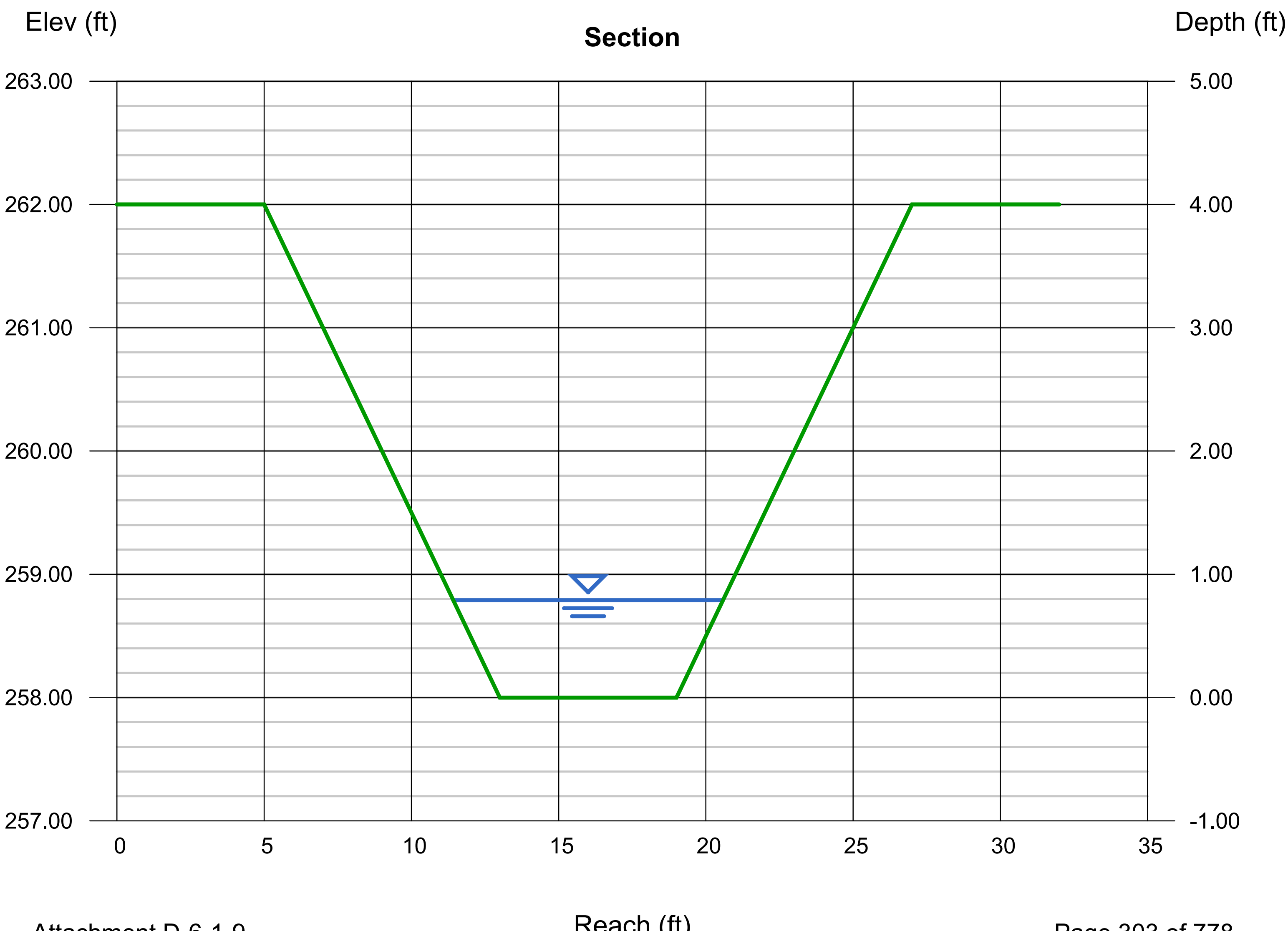
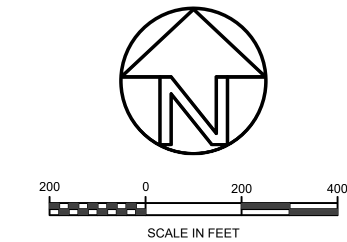
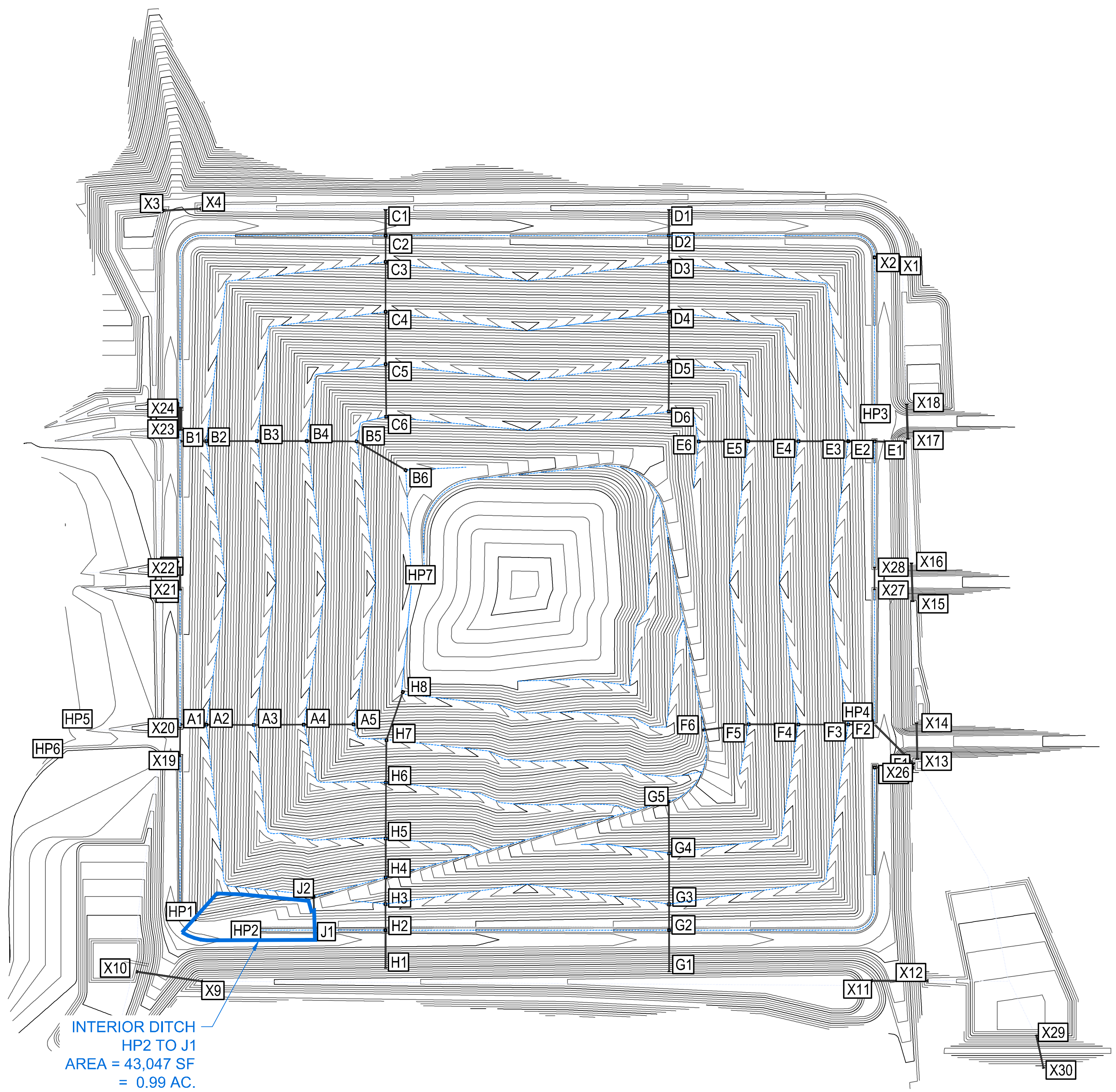
Channel Report

INTERIOR DITCH - X28 TO E2

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 6.00	Depth (ft)	= 0.79
Side Slopes (z:1)	= 2.00, 2.00	Q (cfs)	= 15.20
Total Depth (ft)	= 4.00	Area (sqft)	= 5.99
Invert Elev (ft)	= 258.00	Velocity (ft/s)	= 2.54
Slope (%)	= 0.50	Wetted Perim (ft)	= 9.53
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.55
		Top Width (ft)	= 9.16
Calculations		EGL (ft)	= 0.89
Compute by:	Known Q		
Known Q (cfs)	= 15.20		







PEAK FLOW FOR CRITICAL DITCH SEGMENT
Q_{PEAK} = 5.5 cfs
25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

——	2-FT FINAL COVER CTR
——	10-FT FINAL COVER CTR
——	DOWNDRAIN / CULVERT
——	WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

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Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

INTERIOR DITCH, SECTION HP2 TO J1 WATERSHED

HYDROLOGY STUDY
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CHEMICAL WASTE MANAGEMENT

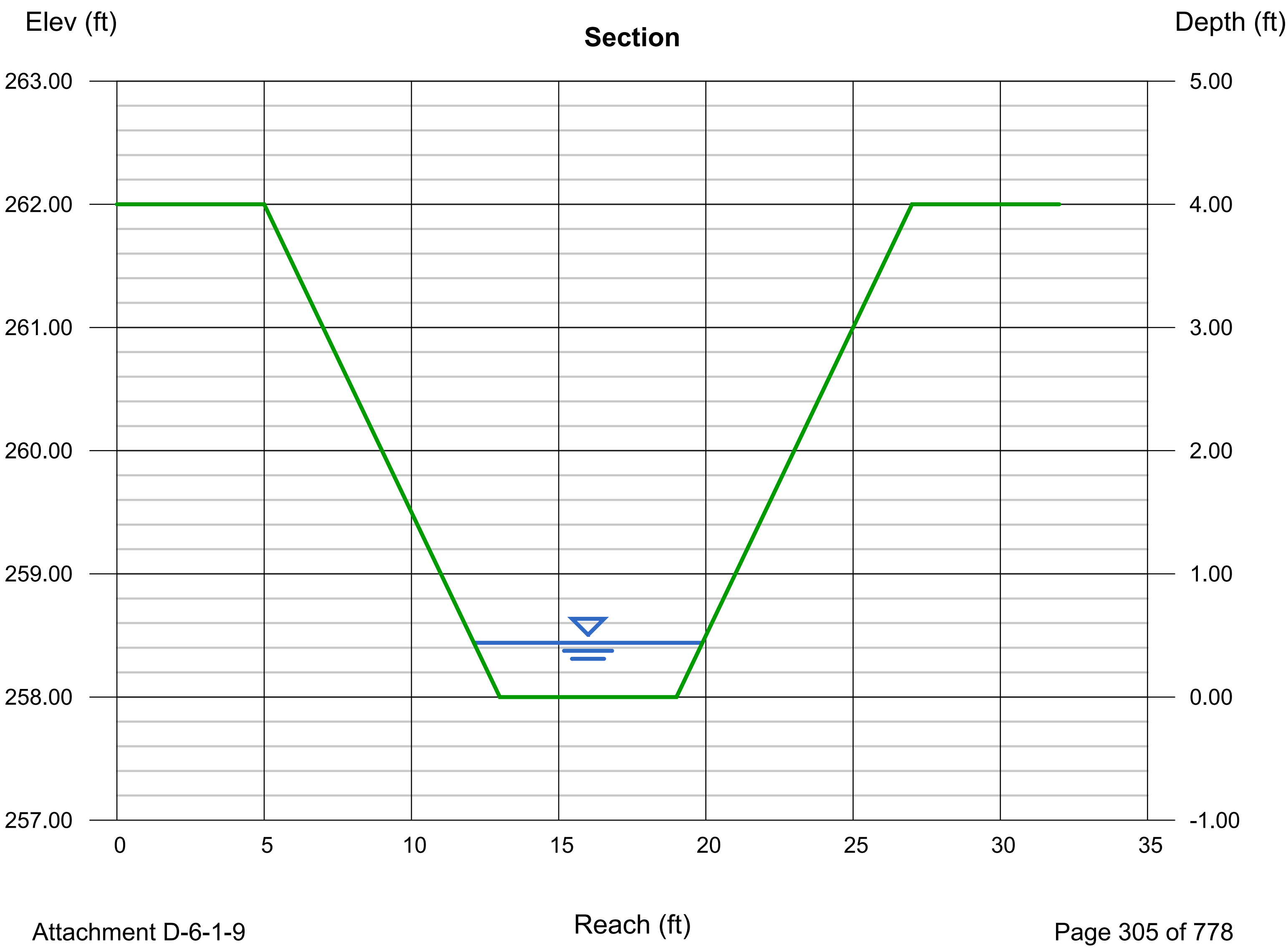
FIGURE
D-10

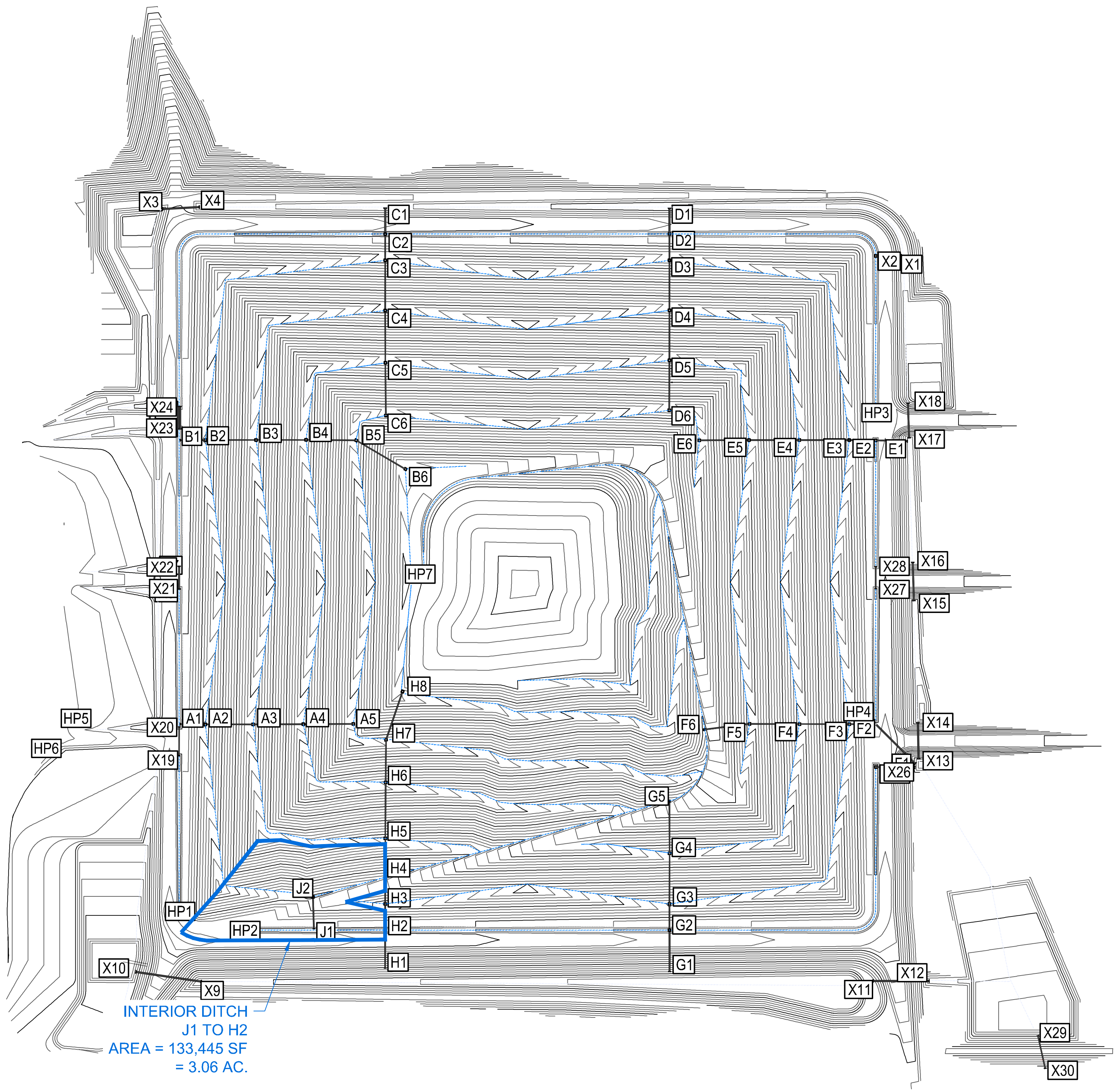
Channel Report

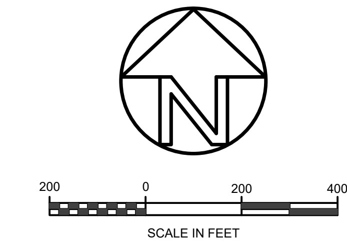
Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. — Friday, Jan 30 2015

INTERIOR DITCH - HP2 TO J1

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 6.00	Depth (ft)	= 0.44
Side Slopes (z:1)	= 2.00, 2.00	Q (cfs)	= 5.500
Total Depth (ft)	= 4.00	Area (sqft)	= 3.03
Invert Elev (ft)	= 258.00	Velocity (ft/s)	= 1.82
Slope (%)	= 0.50	Wetted Perim (ft)	= 7.97
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.29
		Top Width (ft)	= 7.76
Calculations		EGL (ft)	= 0.49
Compute by:	Known Q		
Known Q (cfs)	= 5.50		







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 17.1 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

EMELLE FACILITY

Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

INTERIOR DITCH, SECTION J1 TO H2 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE

D-11

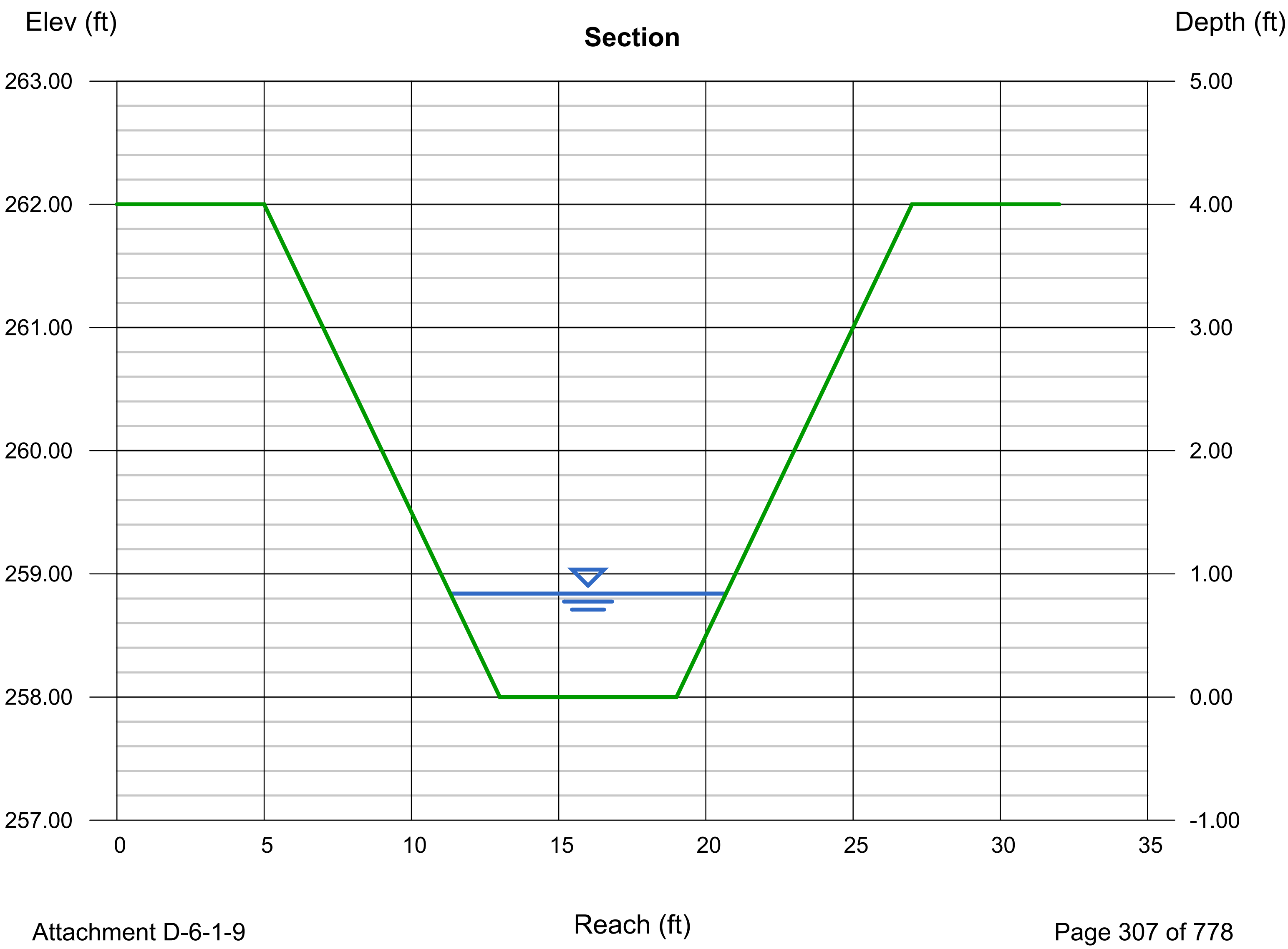
Last Saved By: JCHENSLEY Date: 1/30/2015 10:05 AM File Path: N:\PROJECTS\2014\EJ147410\WORKING FILES\CALCULATIONS-ANALYSES\HYDROLOGY\FIGURE-HYDROLOGY\EJ147410-HYDRO-EMELLE TRENCH 23.DWG

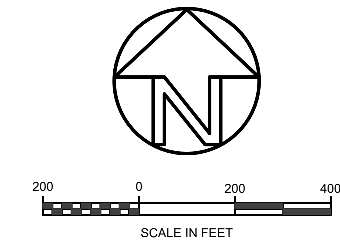
Channel Report

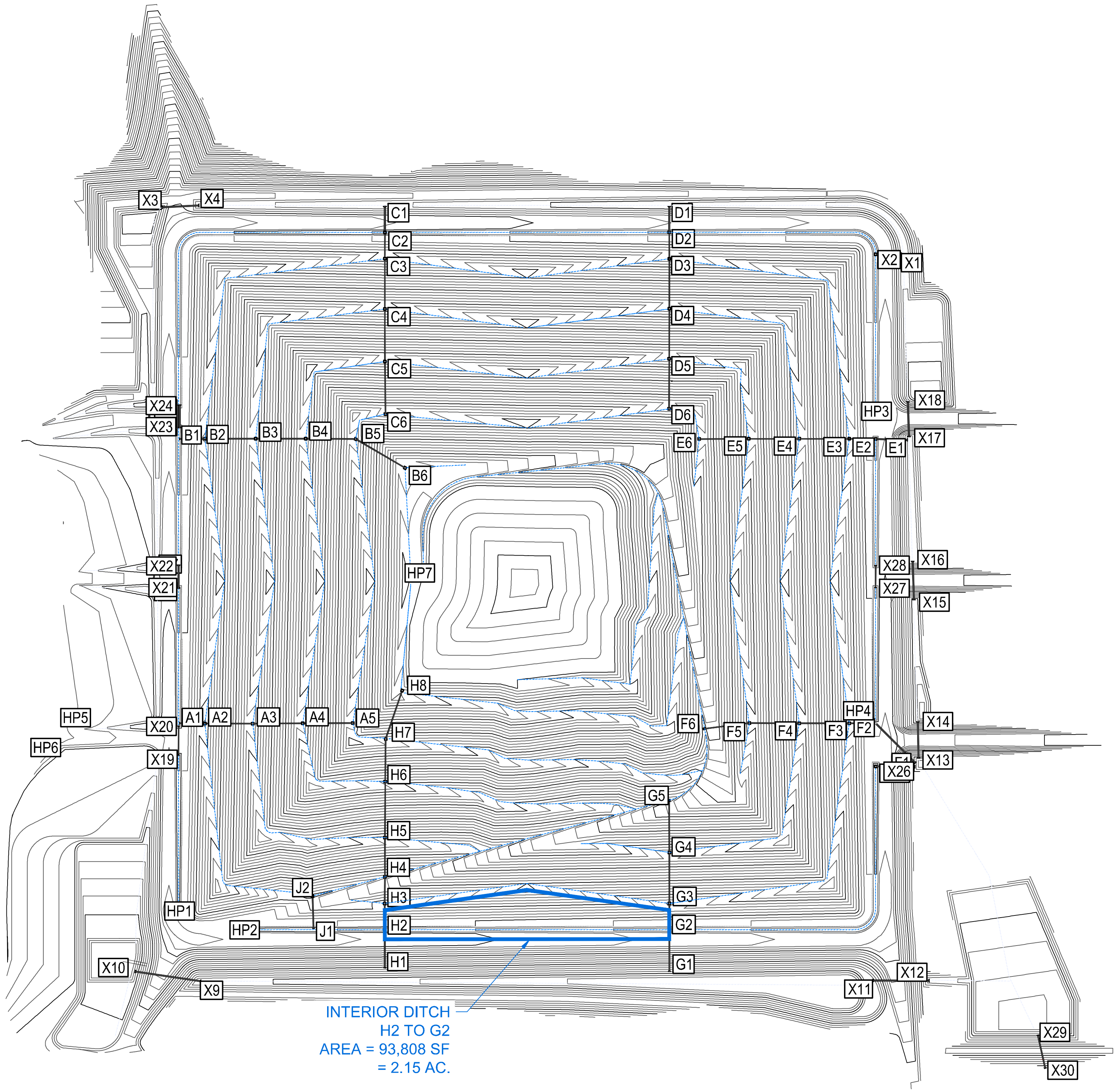
Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Friday, Jan 30 2015

INTERIOR DITCH - J1 TO H2

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 6.00	Depth (ft)	= 0.84
Side Slopes (z:1)	= 2.00, 2.00	Q (cfs)	= 17.10
Total Depth (ft)	= 4.00	Area (sqft)	= 6.45
Invert Elev (ft)	= 258.00	Velocity (ft/s)	= 2.65
Slope (%)	= 0.50	Wetted Perim (ft)	= 9.76
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.59
		Top Width (ft)	= 9.36
Calculations		EGL (ft)	= 0.95
Compute by:	Known Q		
Known Q (cfs)	= 17.10		







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 11.6 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

(thin line)	2-FT FINAL COVER CTR
(line)	10-FT FINAL COVER CTR
(dark line)	DOWNDRAIN / CULVERT
(blue line)	WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

EMELLE FACILITY

Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

INTERIOR DITCH, SECTION H2 TO G2 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
D-12

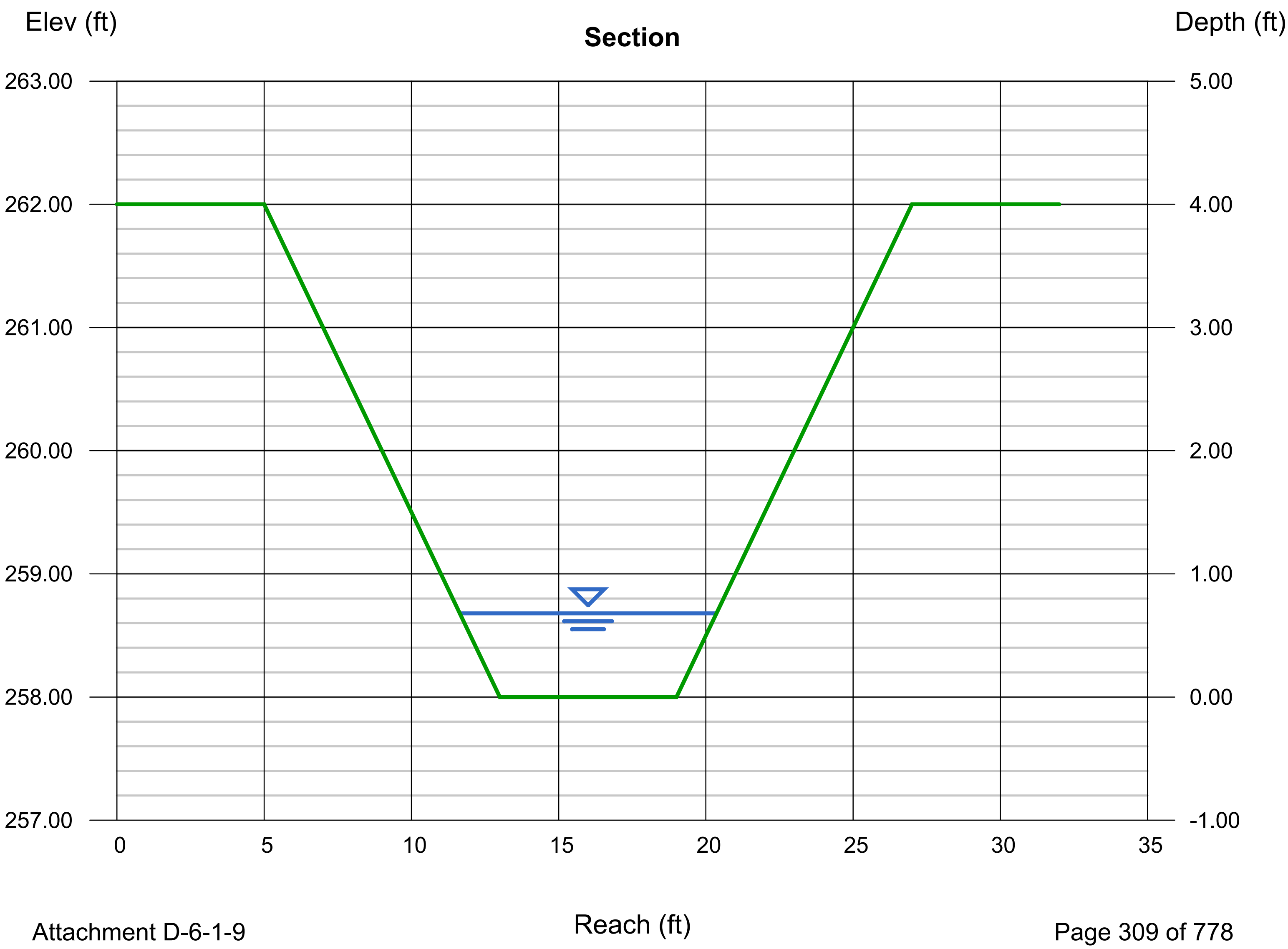
Last Saved By: JCHENSLEY Date: 1/30/2015 4:29 PM File Path: N:\PROJECTS\2014\EJ147410\WORKING FILES\CALCULATIONS-ANALYSES\HYDROLOGY\FIGURE-HYDROLOGY\EJ147410-HYDRO-EMELLE TRENCH 23.DWG

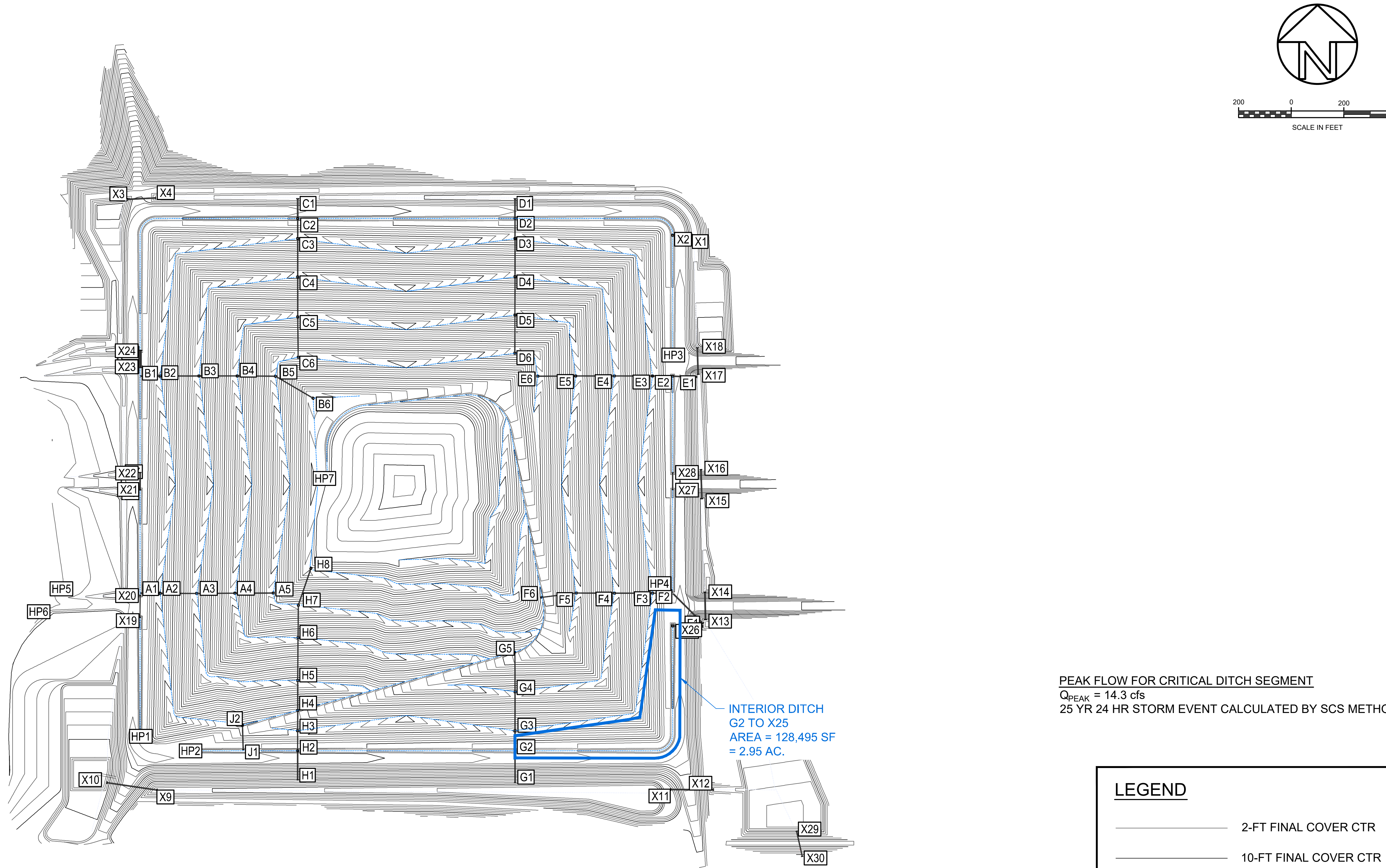
Channel Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Friday, Jan 30 2015

INTERIOR DITCH - H2 TO G2

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 6.00	Depth (ft)	= 0.68
Side Slopes (z:1)	= 2.00, 2.00	Q (cfs)	= 11.60
Total Depth (ft)	= 4.00	Area (sqft)	= 5.00
Invert Elev (ft)	= 258.00	Velocity (ft/s)	= 2.32
Slope (%)	= 0.50	Wetted Perim (ft)	= 9.04
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.47
		Top Width (ft)	= 8.72
Calculations		EGL (ft)	= 0.76
Compute by:	Known Q		
Known Q (cfs)	= 11.60		





PEAK FLOW FOR CRITICAL DITCH SEGMENT
Q_{PEAK} = 14.3 cfs
25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

2-FT FINAL COVER CTR
10-FT FINAL COVER CTR
DOWNDRAIN / CULVERT
WATERSHED BOUNDARY

Last Saved By: JCHENSLEY Date: 1/30/2015 4:33 PM File Path: N:\PROJECTS\2014\EJ147410\WORKING FILES\CALCULATIONS-ANALYSES\HYDROLOGY\FIGURE-HYDROLOGY\EJ147410-HYDRO-EMELLE TRENCH 23.DWG

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

EMELLE FACILITY

Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

INTERIOR DITCH, SECTION G2 TO X25 WATERSHED

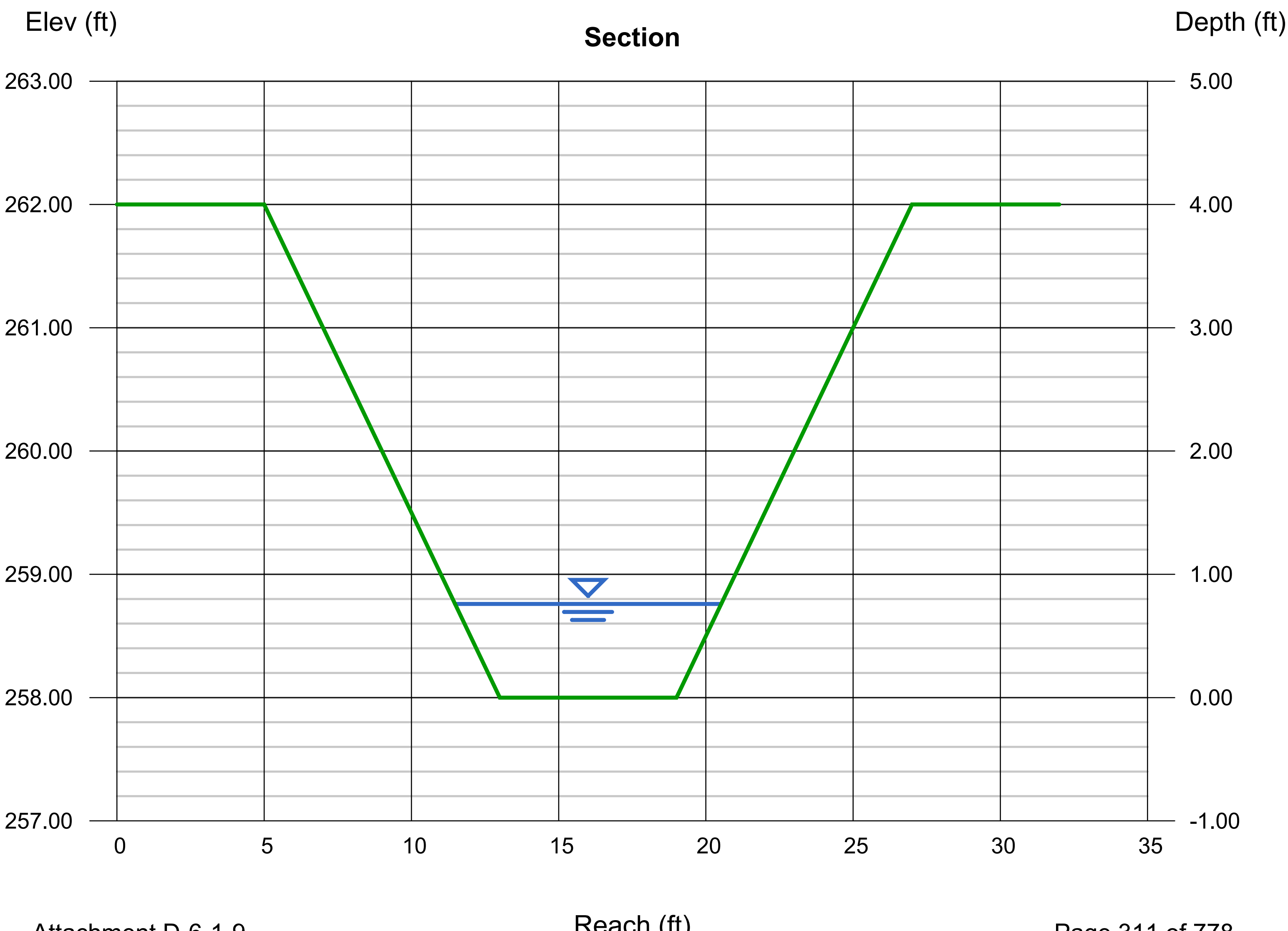
HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
D-13

Channel Report

INTERIOR DITCH - HP2 TO X25

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 6.00	Depth (ft)	= 0.76
Side Slopes (z:1)	= 2.00, 2.00	Q (cfs)	= 14.30
Total Depth (ft)	= 4.00	Area (sqft)	= 5.72
Invert Elev (ft)	= 258.00	Velocity (ft/s)	= 2.50
Slope (%)	= 0.50	Wetted Perim (ft)	= 9.40
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.53
		Top Width (ft)	= 9.04
Calculations		EGL (ft)	= 0.86
Compute by:	Known Q		
Known Q (cfs)	= 14.30		



Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Legend

Hyd.	Origin	Description
1	SCS Runoff	INTERIOR - HP1 TO X19
2	SCS Runoff	INTERIOR - X20 TO X21
3	SCS Runoff	INTERIOR - X22 TO X23
4	SCS Runoff	INTERIOR - X24 TO C2
5	SCS Runoff	INTERIOR - C2 TO D2
6	SCS Runoff	INTERIOR -D2 TO X2
7	SCS Runoff	INTERIOR -HP3 TO X2
8	SCS Runoff	INTERIOR -HP4 to X27
9	SCS Runoff	INTERIOR -X28 TO E2
10	SCS Runoff	INTERIOR -HP2 TO J1
11	SCS Runoff	INTERIOR -J1 TO H2
12	SCS Runoff	INTERIOR -H2 TO G2
13	SCS Runoff	INTERIOR - G2 TO X25

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)								Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	-------	-------	-------	-------	-------	8.820	-------	-------	INTERIOR - HP1 TO X19
2	SCS Runoff	------	-------	-------	-------	-------	-------	64.29	-------	-------	INTERIOR - X20 TO X21
3	SCS Runoff	------	-------	-------	-------	-------	-------	114.15	-------	-------	INTERIOR - X22 TO X23
4	SCS Runoff	------	-------	-------	-------	-------	-------	125.30	-------	-------	INTERIOR - X24 TO C2
5	SCS Runoff	------	-------	-------	-------	-------	-------	13.68	-------	-------	INTERIOR - C2 TO D2
6	SCS Runoff	------	-------	-------	-------	-------	-------	10.16	-------	-------	INTERIOR -D2 TO X2
7	SCS Runoff	------	-------	-------	-------	-------	-------	8.373	-------	-------	INTERIOR -HP3 TO X2
8	SCS Runoff	------	-------	-------	-------	-------	-------	7.958	-------	-------	INTERIOR -HP4 to X27
9	SCS Runoff	------	-------	-------	-------	-------	-------	15.21	-------	-------	INTERIOR -X28 TO E2
10	SCS Runoff	------	-------	-------	-------	-------	-------	5.540	-------	-------	INTERIOR -HP2 TO J1
11	SCS Runoff	------	-------	-------	-------	-------	-------	17.12	-------	-------	INTERIOR -J1 TO H2
12	SCS Runoff	------	-------	-------	-------	-------	-------	11.59	-------	-------	INTERIOR -H2 TO G2
13	SCS Runoff	------	-------	-------	-------	-------	-------	14.28	-------	-------	INTERIOR - G2 TO X25

Proj. file: Q-Interior Ditch.gpw

Friday, 01 / 30 / 2015

Hydrograph Summary Report

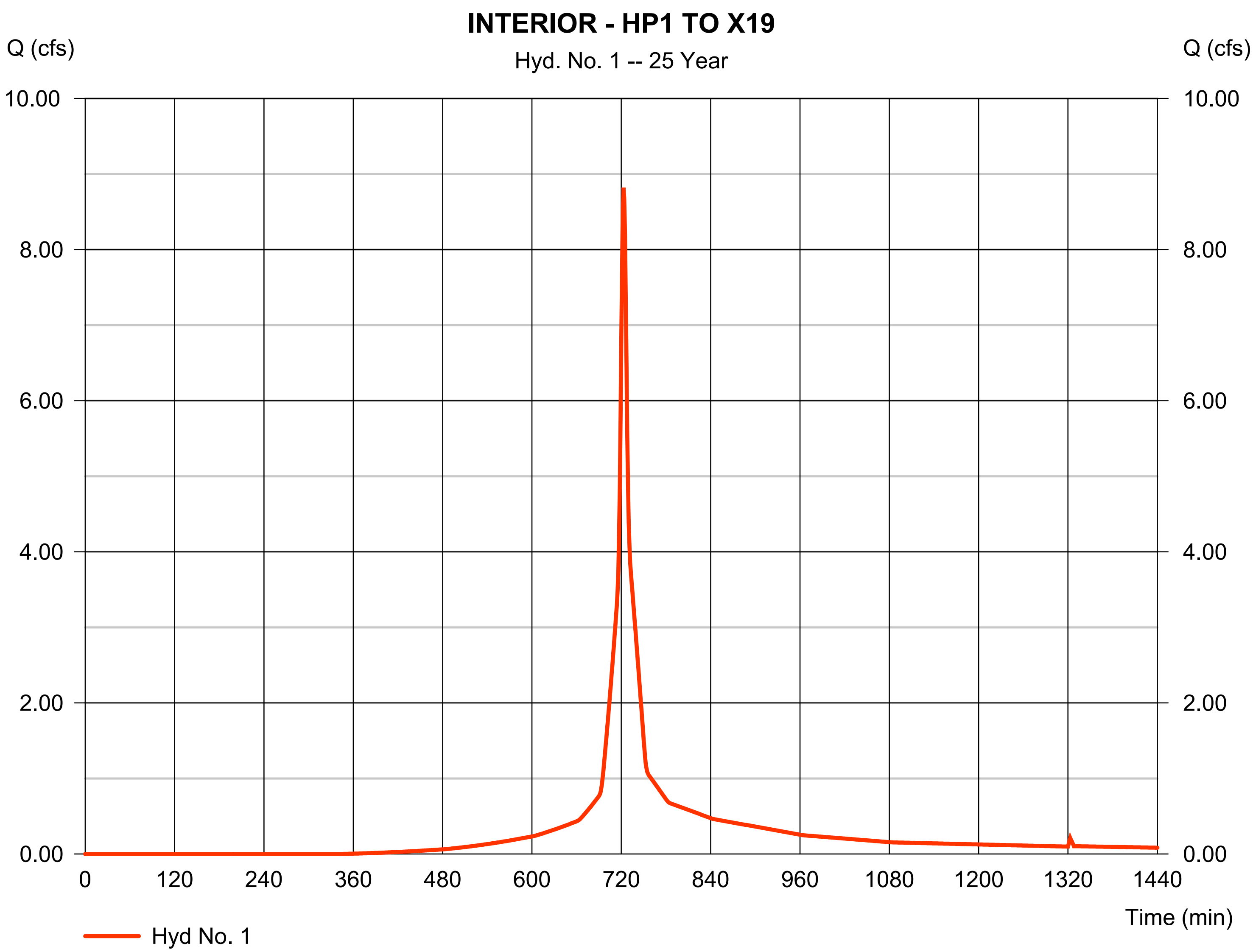
Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	8.820	1	723	25,838	------	------	------	INTERIOR - HP1 TO X19
2	SCS Runoff	64.29	1	724	201,385	------	------	------	INTERIOR - X20 TO X21
3	SCS Runoff	114.15	1	725	372,403	------	------	------	INTERIOR - X22 TO X23
4	SCS Runoff	125.30	1	727	435,126	------	------	------	INTERIOR - X24 TO C2
5	SCS Runoff	13.68	1	723	40,068	------	------	------	INTERIOR - C2 TO D2
6	SCS Runoff	10.16	1	723	29,770	------	------	------	INTERIOR -D2 TO X2
7	SCS Runoff	8.373	1	723	24,527	------	------	------	INTERIOR -HP3 TO X2
8	SCS Runoff	7.958	1	722	21,941	------	------	------	INTERIOR -HP4 to X27
9	SCS Runoff	15.21	1	723	44,561	------	------	------	INTERIOR -X28 TO E2
10	SCS Runoff	5.540	1	725	18,073	------	------	------	INTERIOR -HP2 TO J1
11	SCS Runoff	17.12	1	725	55,861	------	------	------	INTERIOR -J1 TO H2
12	SCS Runoff	11.59	1	727	40,255	------	------	------	INTERIOR -H2 TO G2
13	SCS Runoff	14.28	1	729	54,370	------	------	------	INTERIOR - G2 TO X25

Hydrograph Report

Hyd. No. 1

INTERIOR - HP1 TO X19

Hydrograph type	= SCS Runoff	Peak discharge	= 8.820 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 25,838 cuft
Drainage area	= 1.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

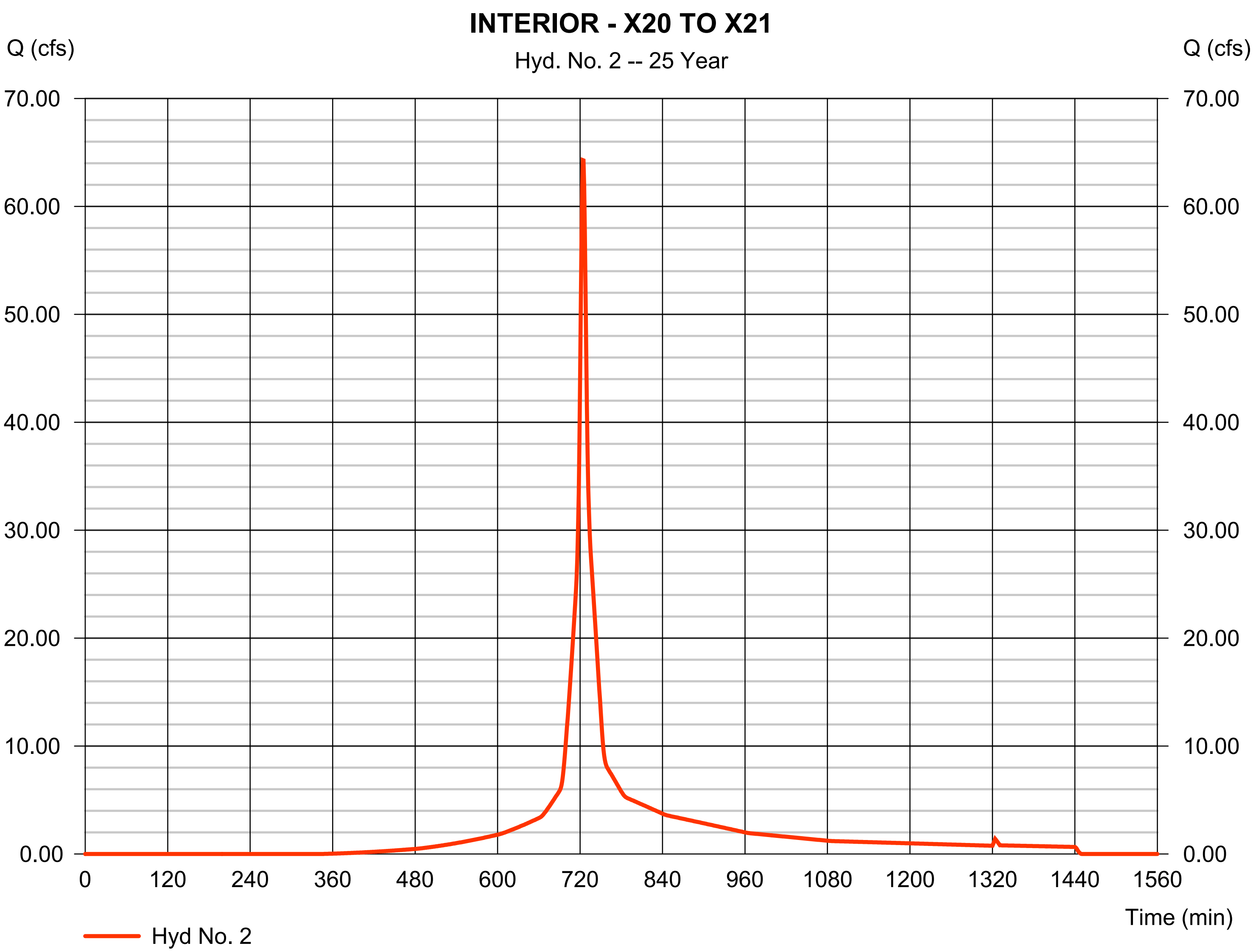


Hydrograph Report

Hyd. No. 2

INTERIOR - X20 TO X21

Hydrograph type	= SCS Runoff	Peak discharge	= 64.29 cfs
Storm frequency	= 25 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 201,385 cuft
Drainage area	= 10.430 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.50 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

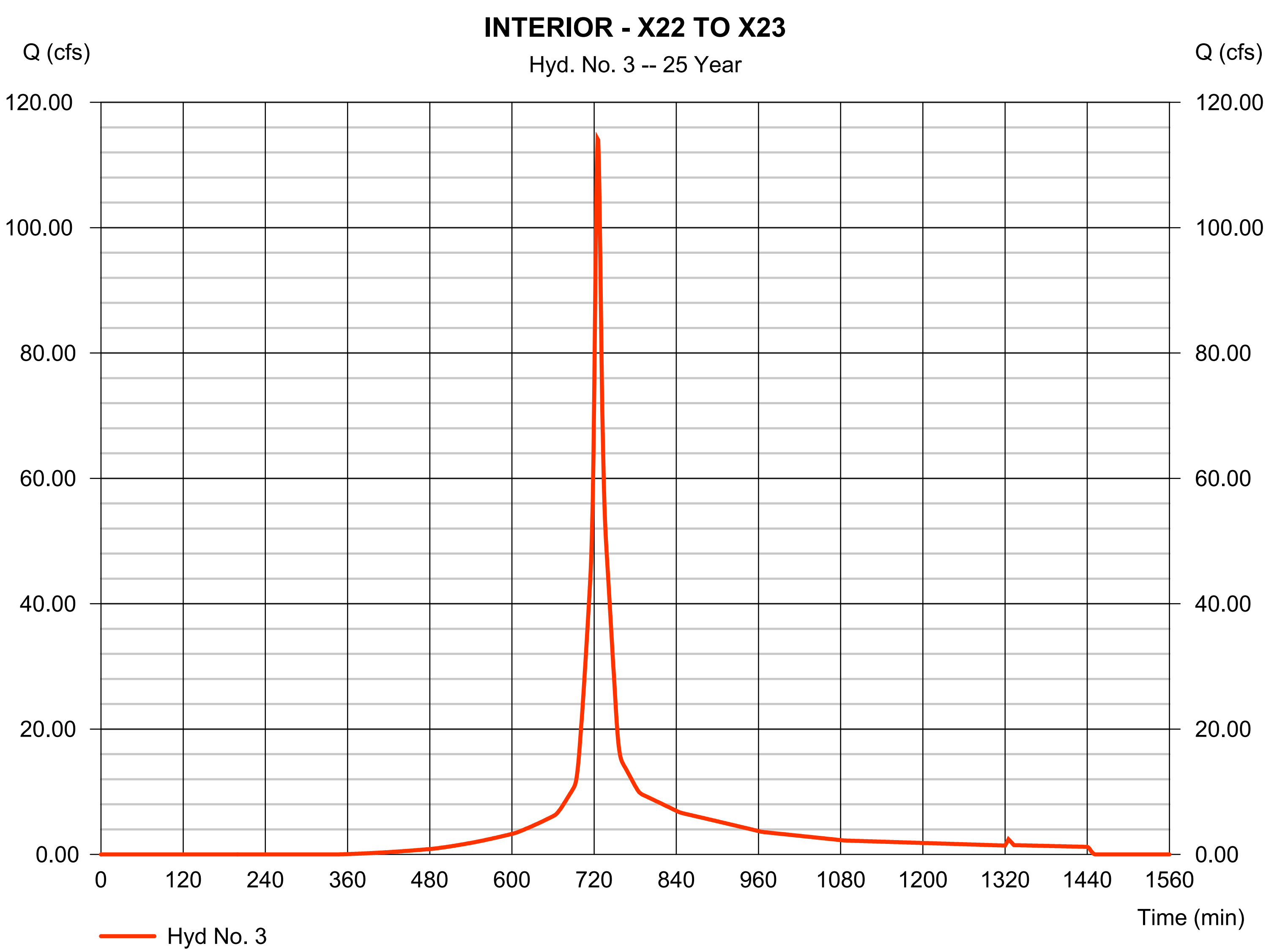


Hydrograph Report

Hyd. No. 3

INTERIOR - X22 TO X23

Hydrograph type	= SCS Runoff	Peak discharge	= 114.15 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 372,403 cuft
Drainage area	= 20.400 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 6.80 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

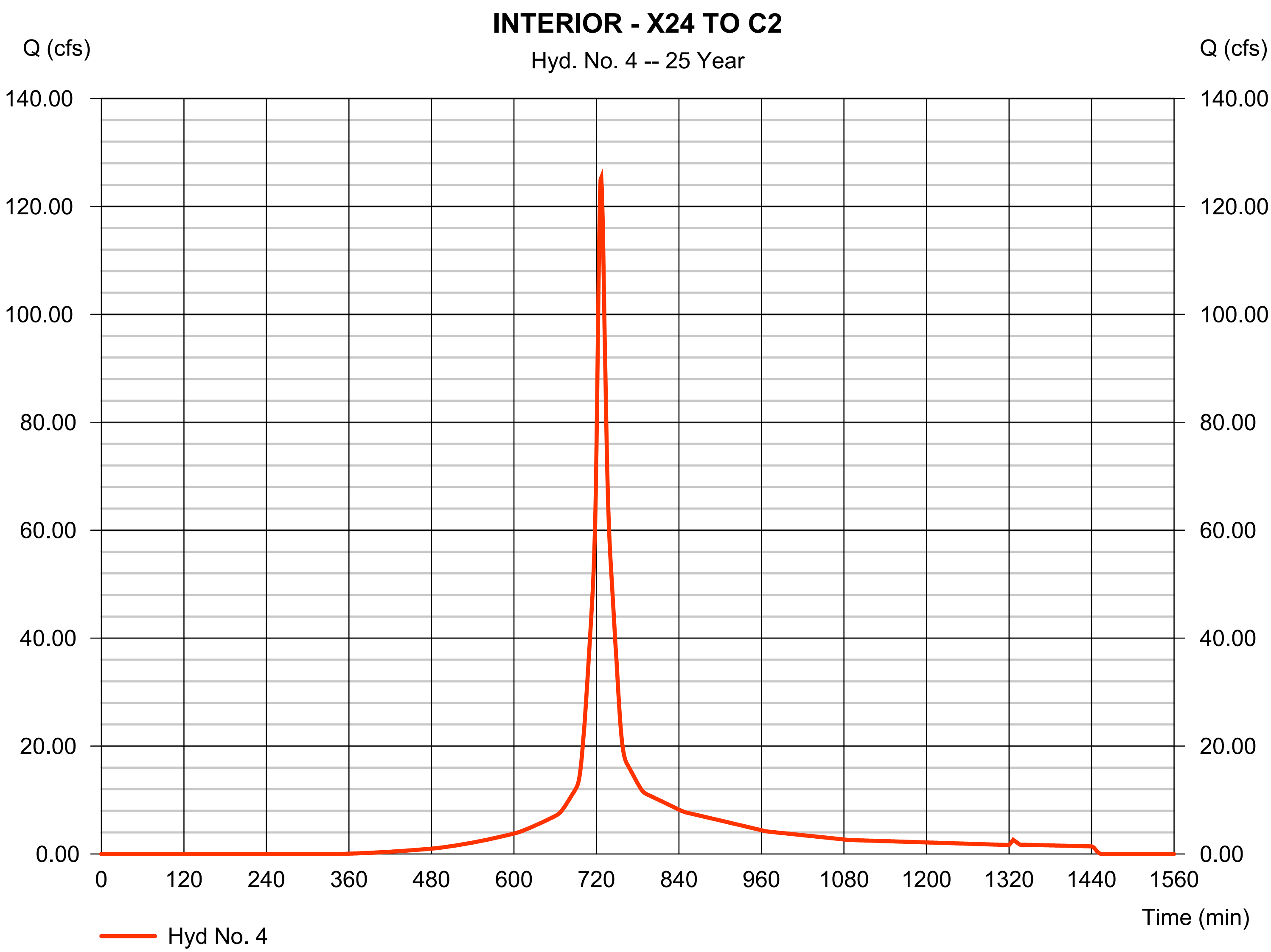


Hydrograph Report

Hyd. No. 4

INTERIOR - X24 TO C2

Hydrograph type	= SCS Runoff	Peak discharge	= 125.30 cfs
Storm frequency	= 25 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 435,126 cuft
Drainage area	= 23.240 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 9.80 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

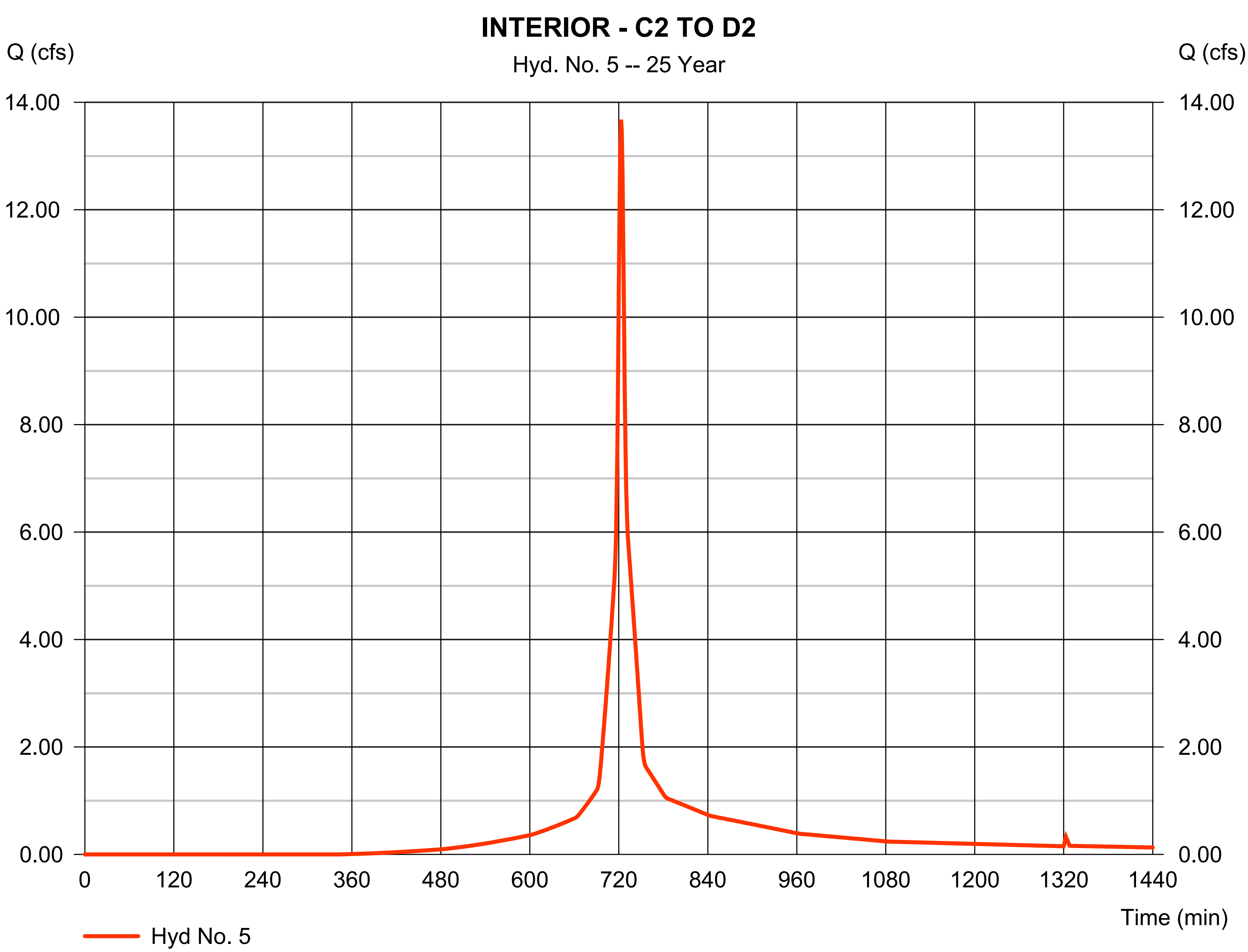


Hydrograph Report

Hyd. No. 5

INTERIOR - C2 TO D2

Hydrograph type	= SCS Runoff	Peak discharge	= 13.68 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 40,068 cuft
Drainage area	= 2.140 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.10 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

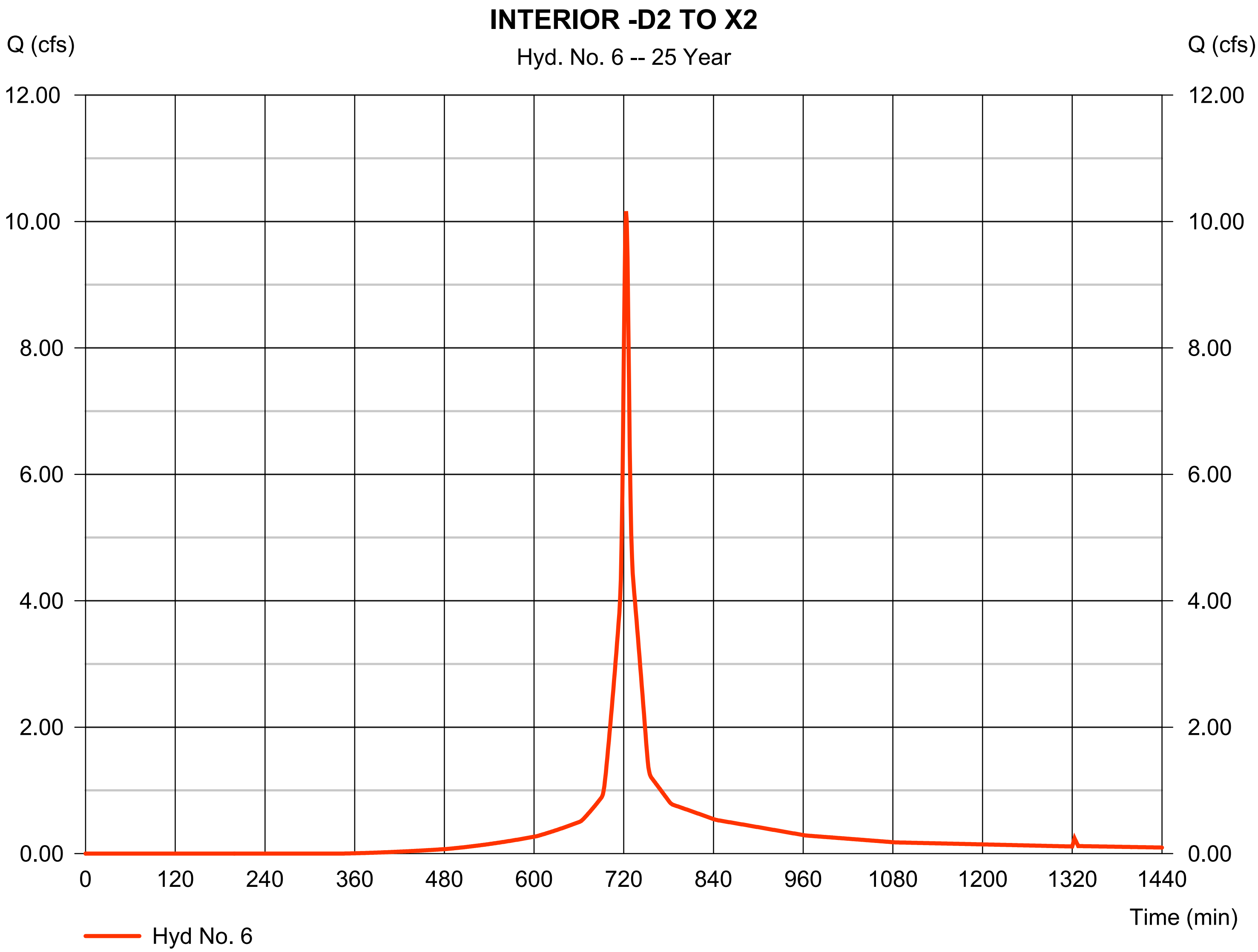


Hydrograph Report

Hyd. No. 6

INTERIOR -D2 TO X2

Hydrograph type	= SCS Runoff	Peak discharge	= 10.16 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 29,770 cuft
Drainage area	= 1.590 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.60 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

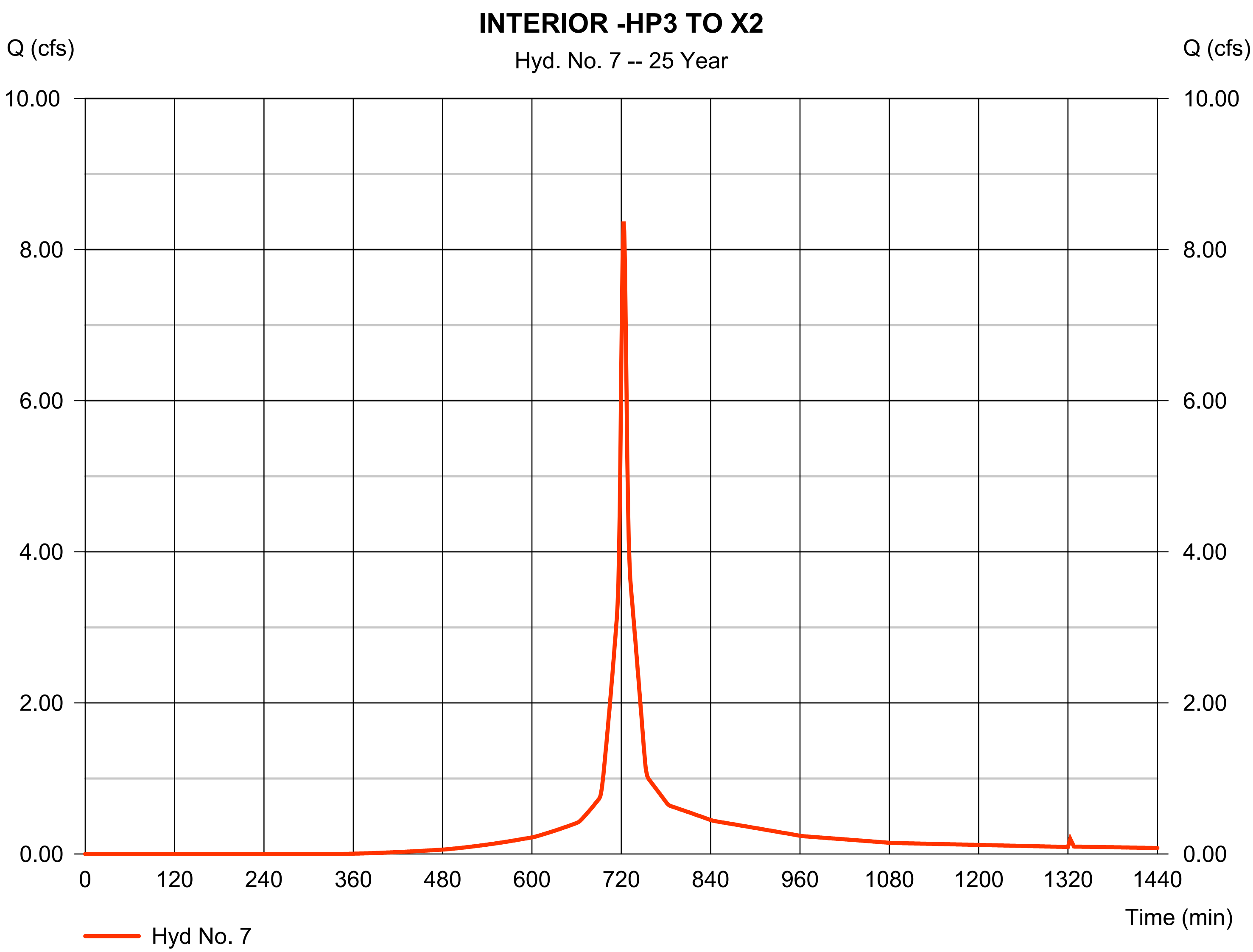


Hydrograph Report

Hyd. No. 7

INTERIOR -HP3 TO X2

Hydrograph type	= SCS Runoff	Peak discharge	= 8.373 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 24,527 cuft
Drainage area	= 1.310 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.40 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

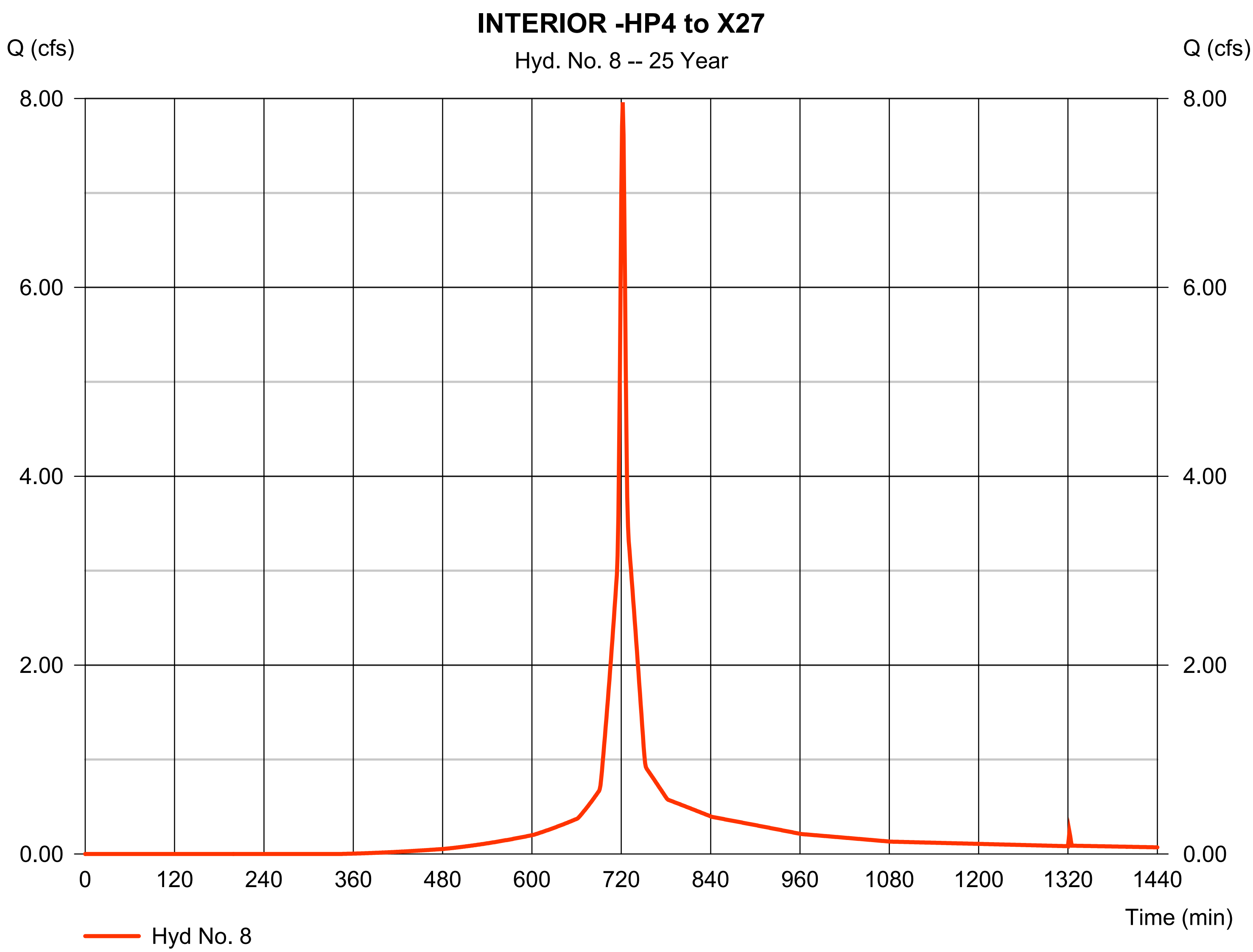


Hydrograph Report

Hyd. No. 8

INTERIOR -HP4 to X27

Hydrograph type	= SCS Runoff	Peak discharge	= 7.958 cfs
Storm frequency	= 25 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 21,941 cuft
Drainage area	= 1.250 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

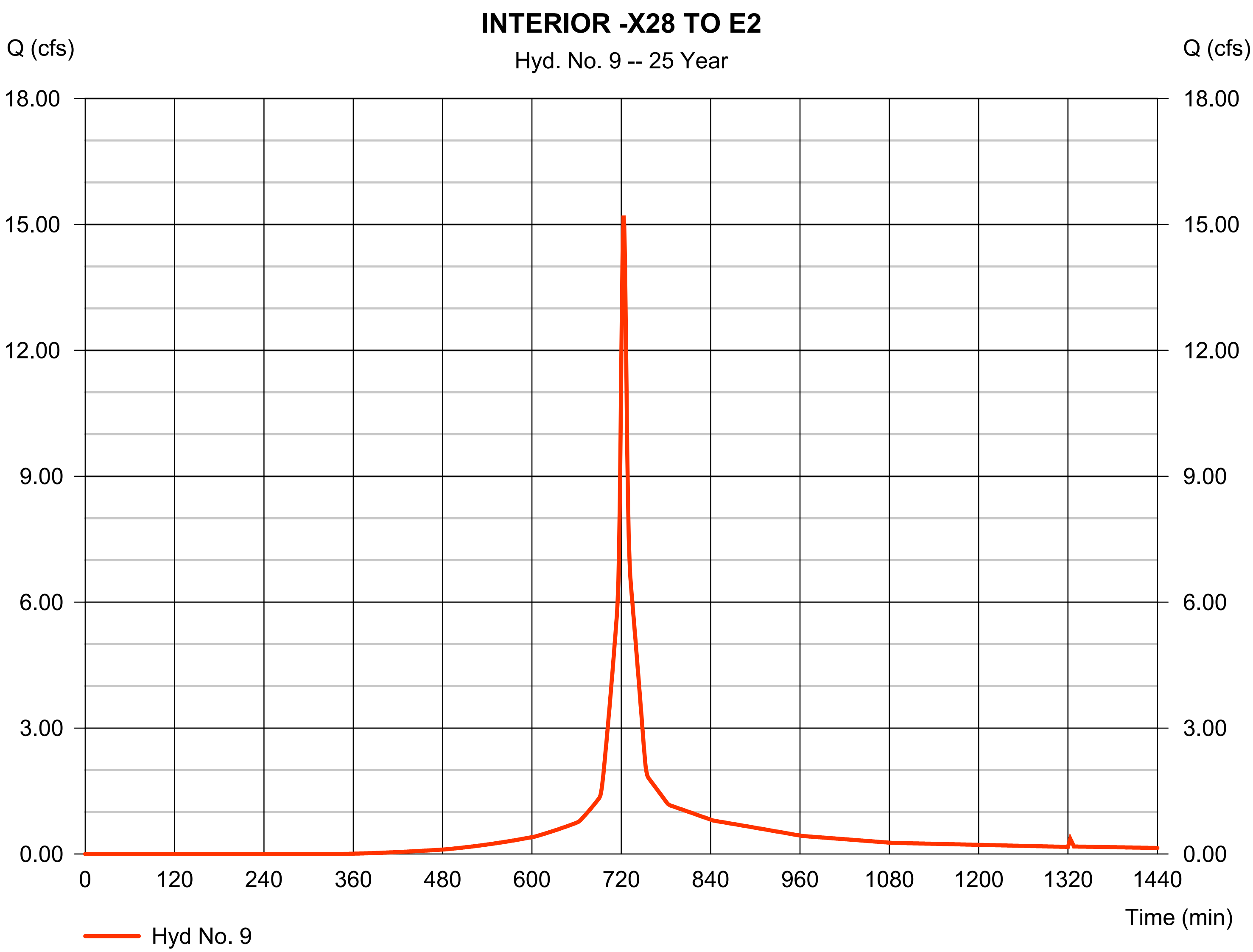


Hydrograph Report

Hyd. No. 9

INTERIOR -X28 TO E2

Hydrograph type	= SCS Runoff	Peak discharge	= 15.21 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 44,561 cuft
Drainage area	= 2.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.10 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

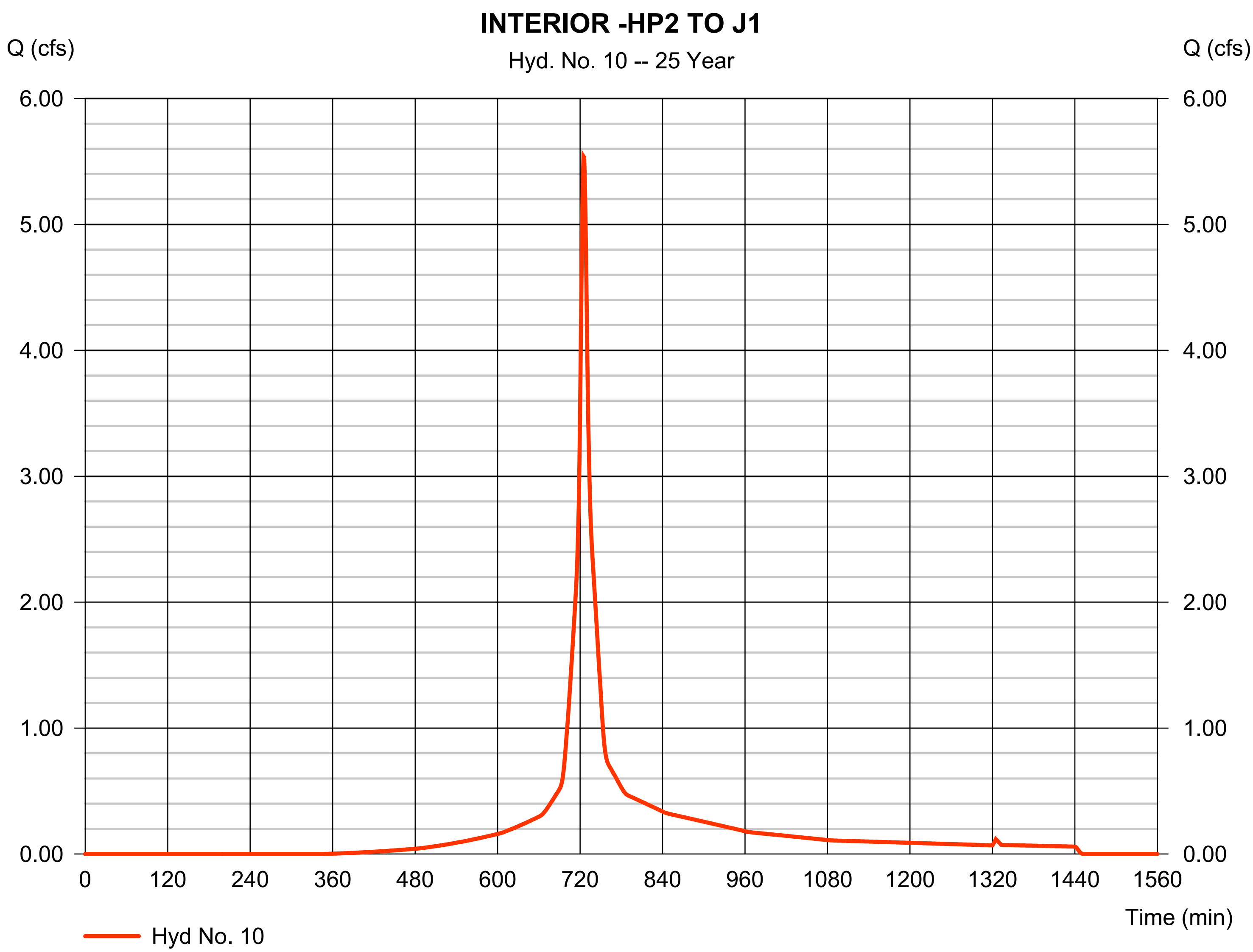


Hydrograph Report

Hyd. No. 10

INTERIOR -HP2 TO J1

Hydrograph type	= SCS Runoff	Peak discharge	= 5.540 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 18,073 cuft
Drainage area	= 0.990 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 6.90 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

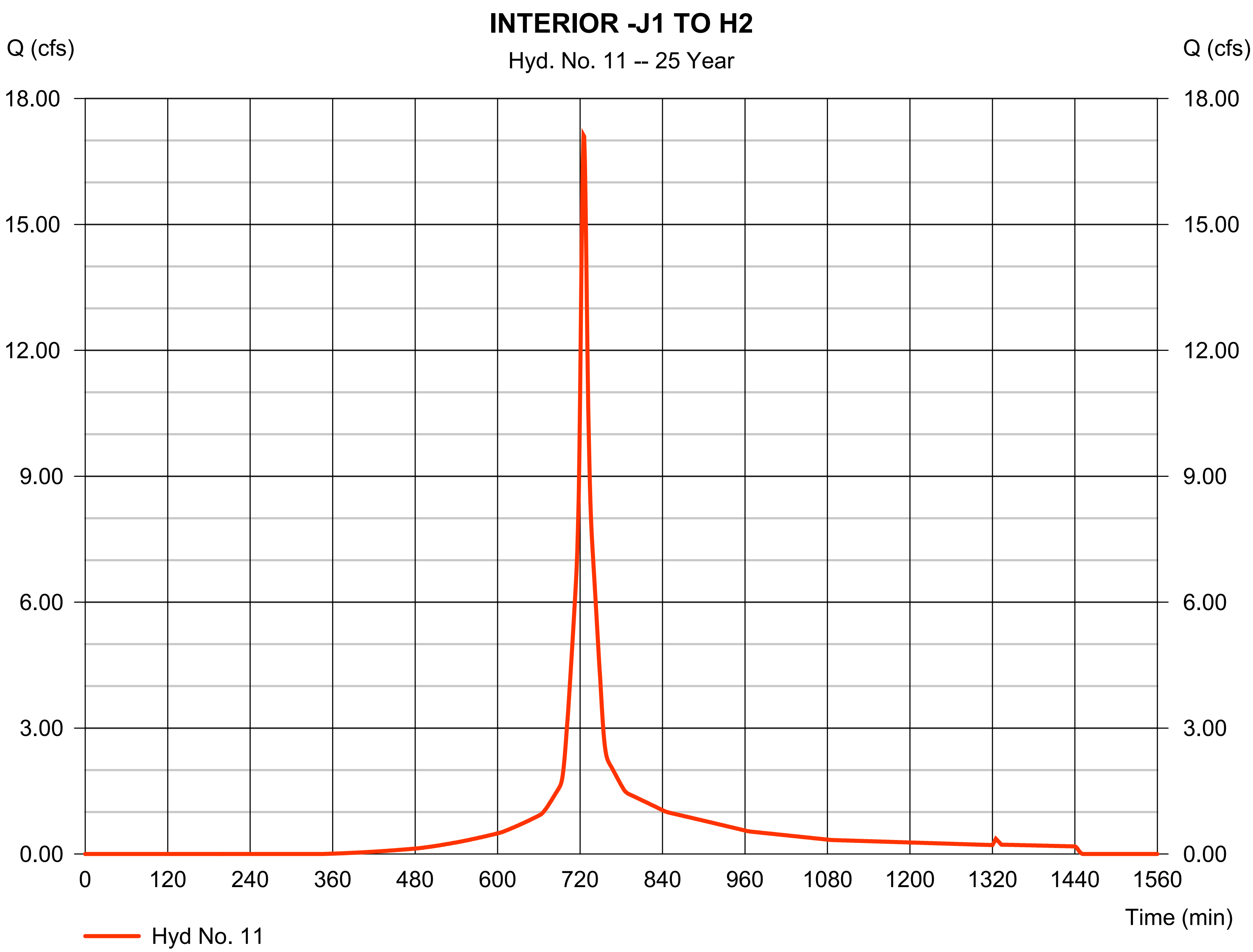


Hydrograph Report

Hyd. No. 11

INTERIOR -J1 TO H2

Hydrograph type	= SCS Runoff	Peak discharge	= 17.12 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 55,861 cuft
Drainage area	= 3.060 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.40 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



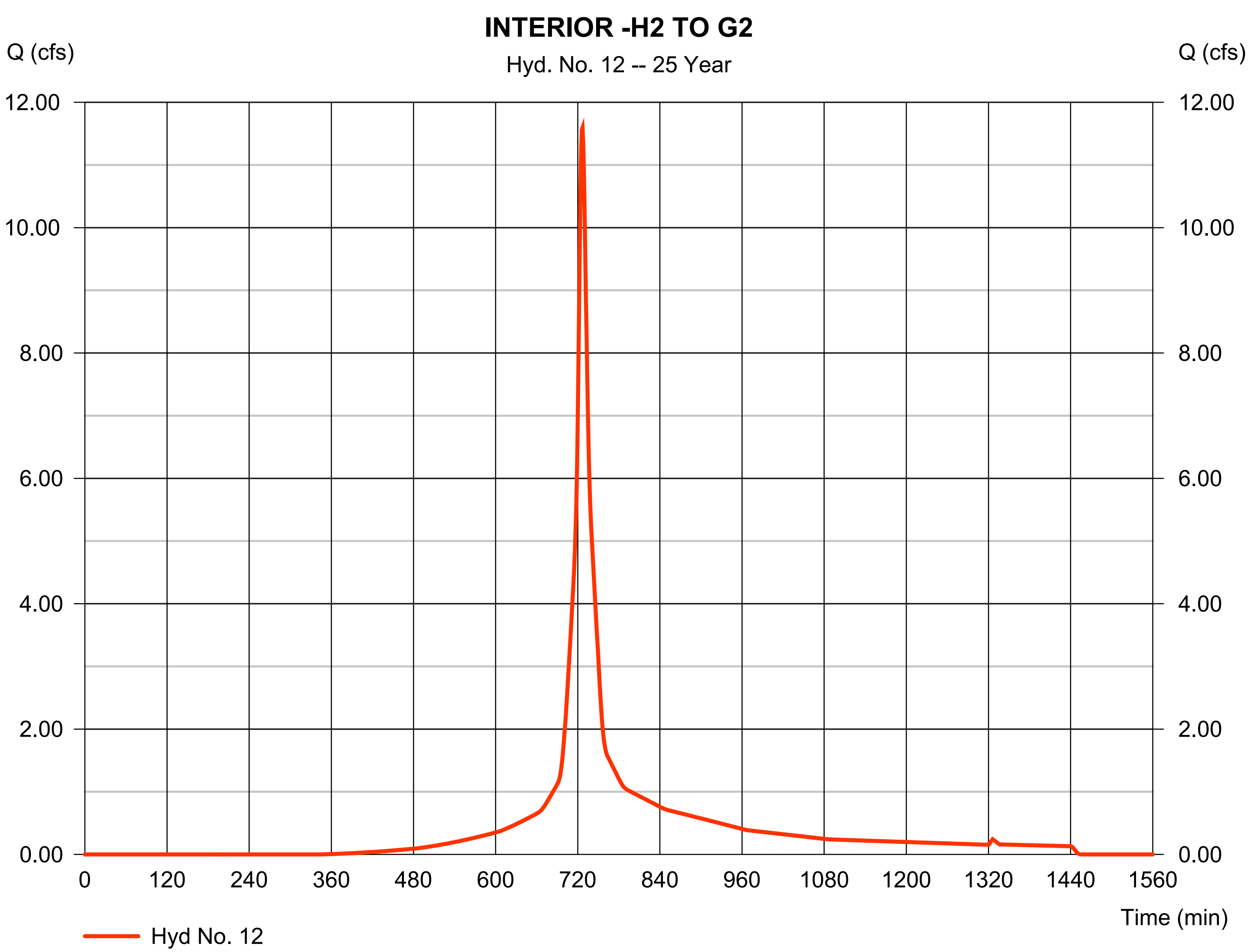
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 12

INTERIOR -H2 TO G2

Hydrograph type	= SCS Runoff	Peak discharge	= 11.59 cfs
Storm frequency	= 25 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 40,255 cuft
Drainage area	= 2.150 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 9.70 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



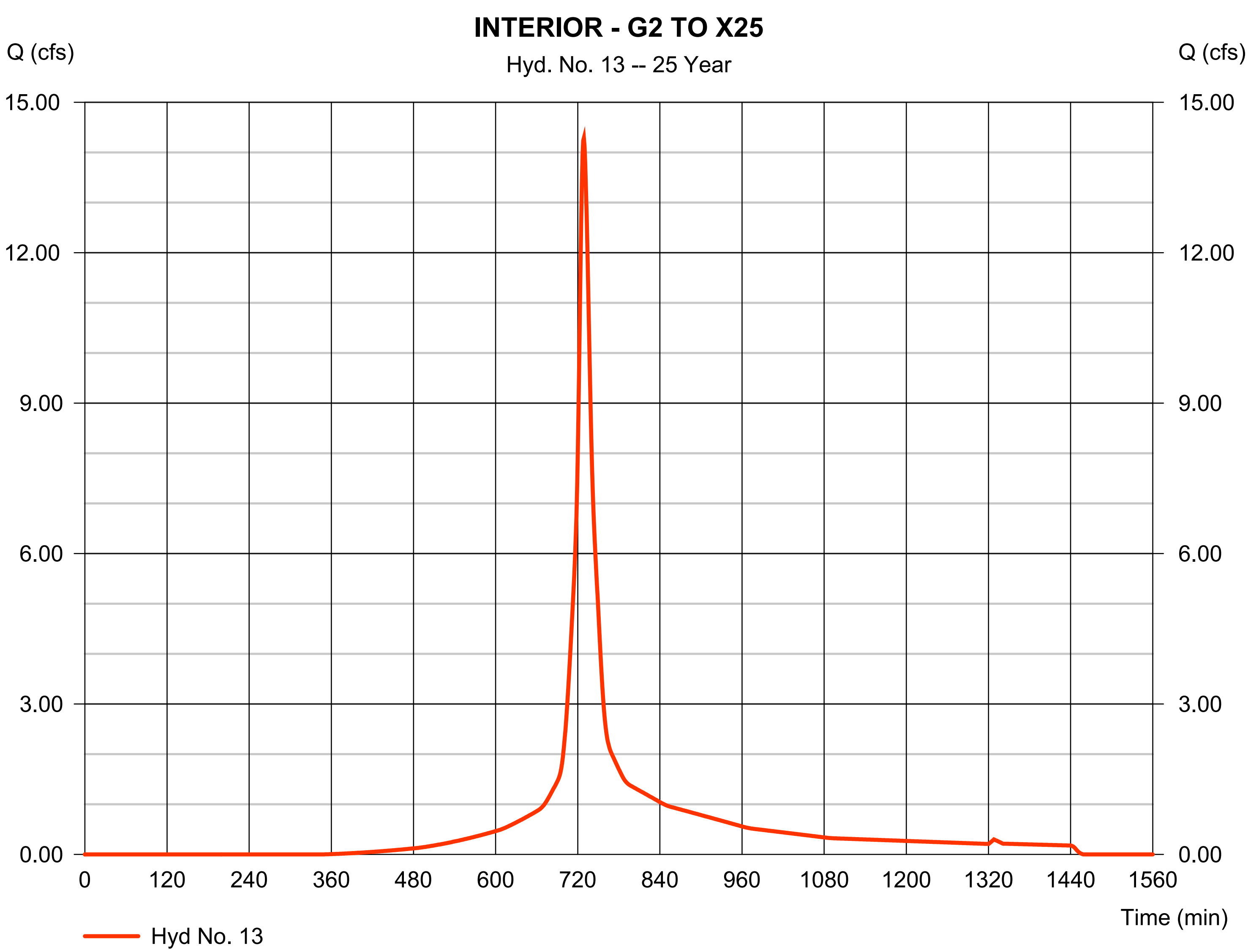
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 13

INTERIOR - G2 TO X25

Hydrograph type	= SCS Runoff	Peak discharge	= 14.28 cfs
Storm frequency	= 25 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 54,370 cuft
Drainage area	= 2.950 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.40 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	0.0000	0.0000	0.0000	--------
3	0.0000	0.0000	0.0000	--------
5	0.0000	0.0000	0.0000	--------
10	0.0000	0.0000	0.0000	--------
25	0.0000	0.0000	0.0000	--------
50	0.0000	0.0000	0.0000	--------
100	0.0000	0.0000	0.0000	--------

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Tc = time in minutes. Values may exceed 60.

ojects\2014\EJ147461\Working Files\Calculations-Analyses\SCS METHOD\Peachtree City (24 hr GA Green Book).pcp

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.75	4.50	0.00	5.65	6.50	7.50	8.40	9.20
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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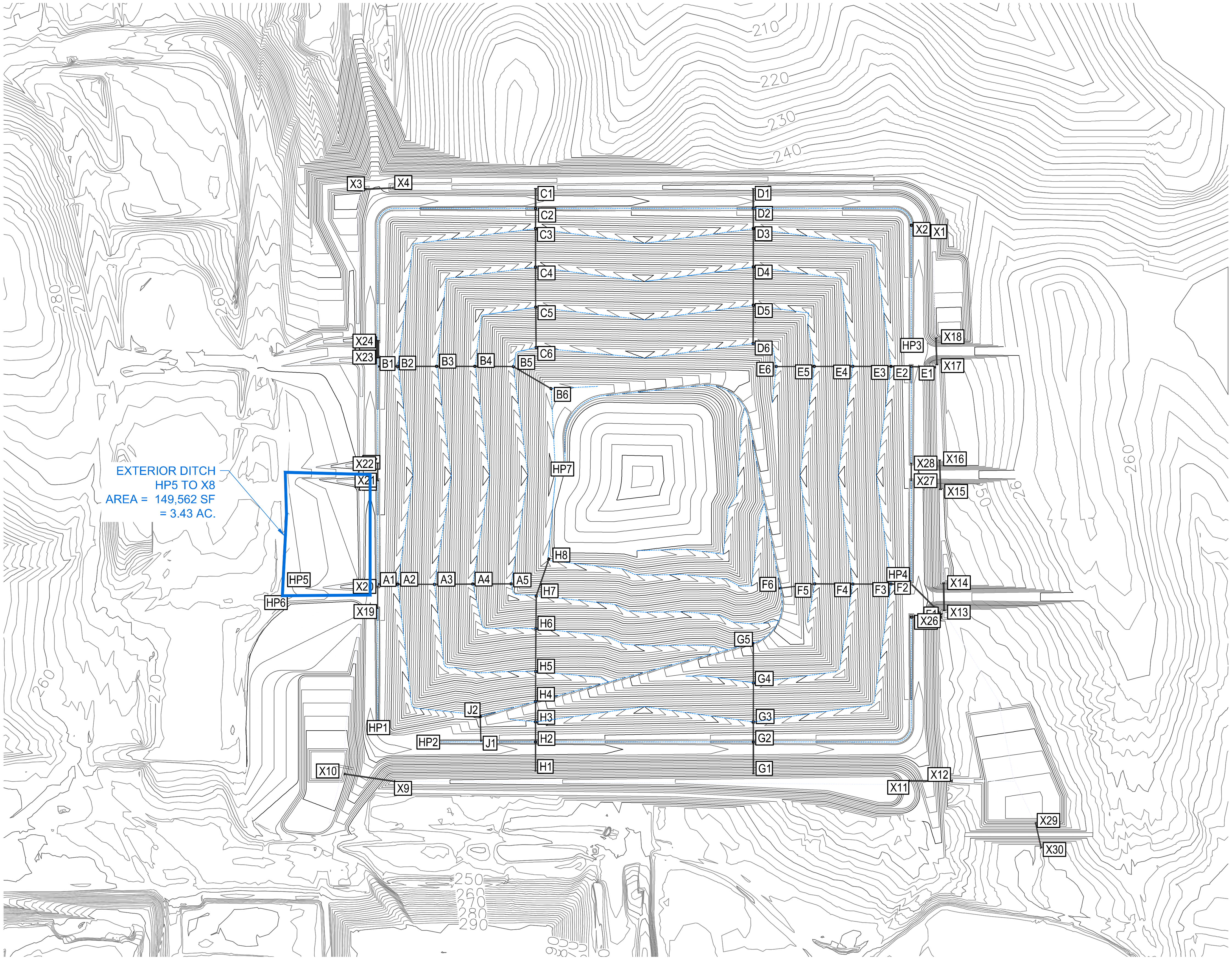

200 0 200 400

SCALE IN FEET

PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 19.2 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

———	2-FT FINAL COVER CTR
———	10-FT FINAL COVER CTR
———	DOWNDRAIN / CULVERT
———	WATERSHED BOUNDARY

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CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
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Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

EXTERIOR DITCH, SECTION HP5 TO X8 WATERSHED

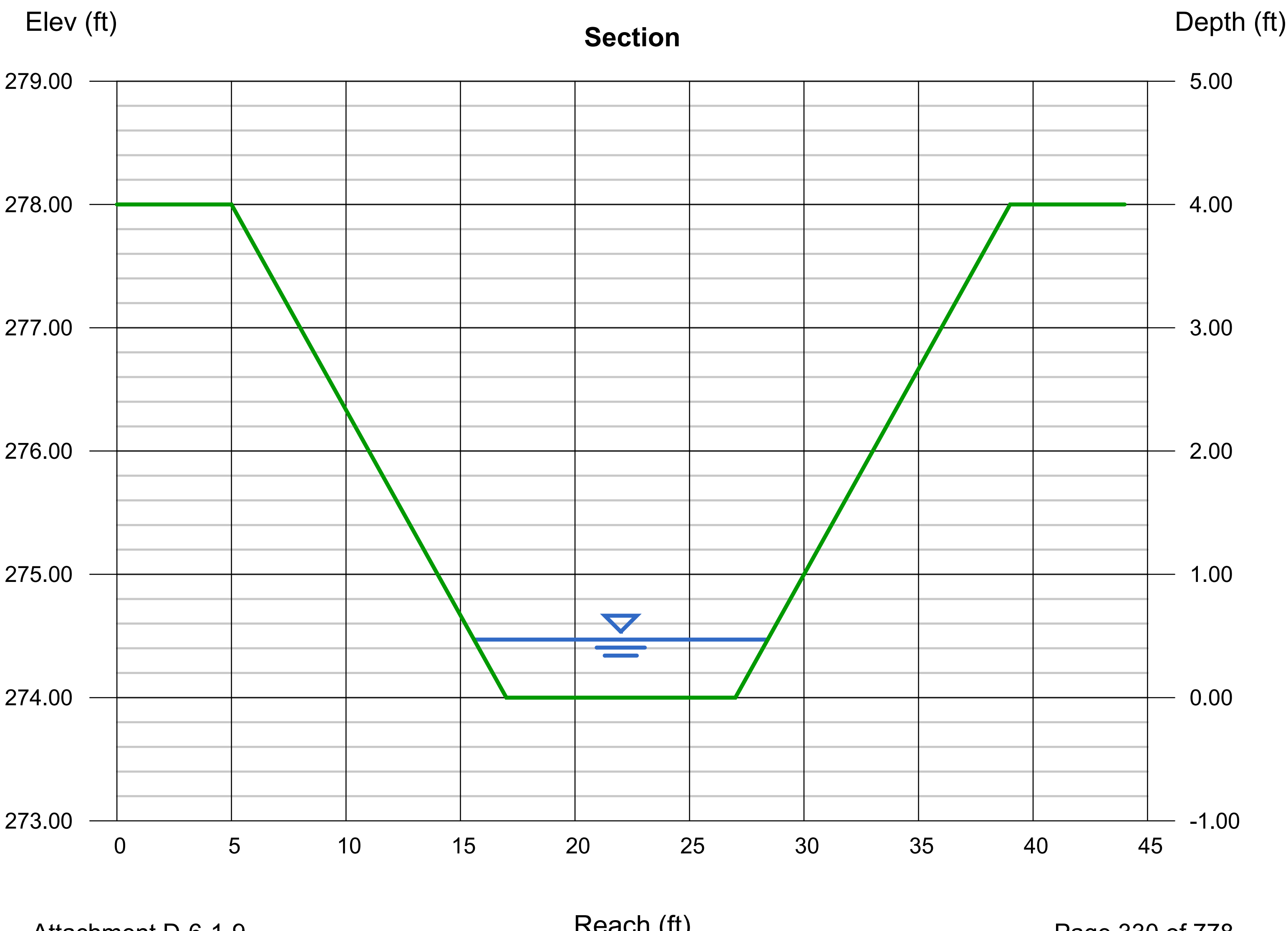
HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

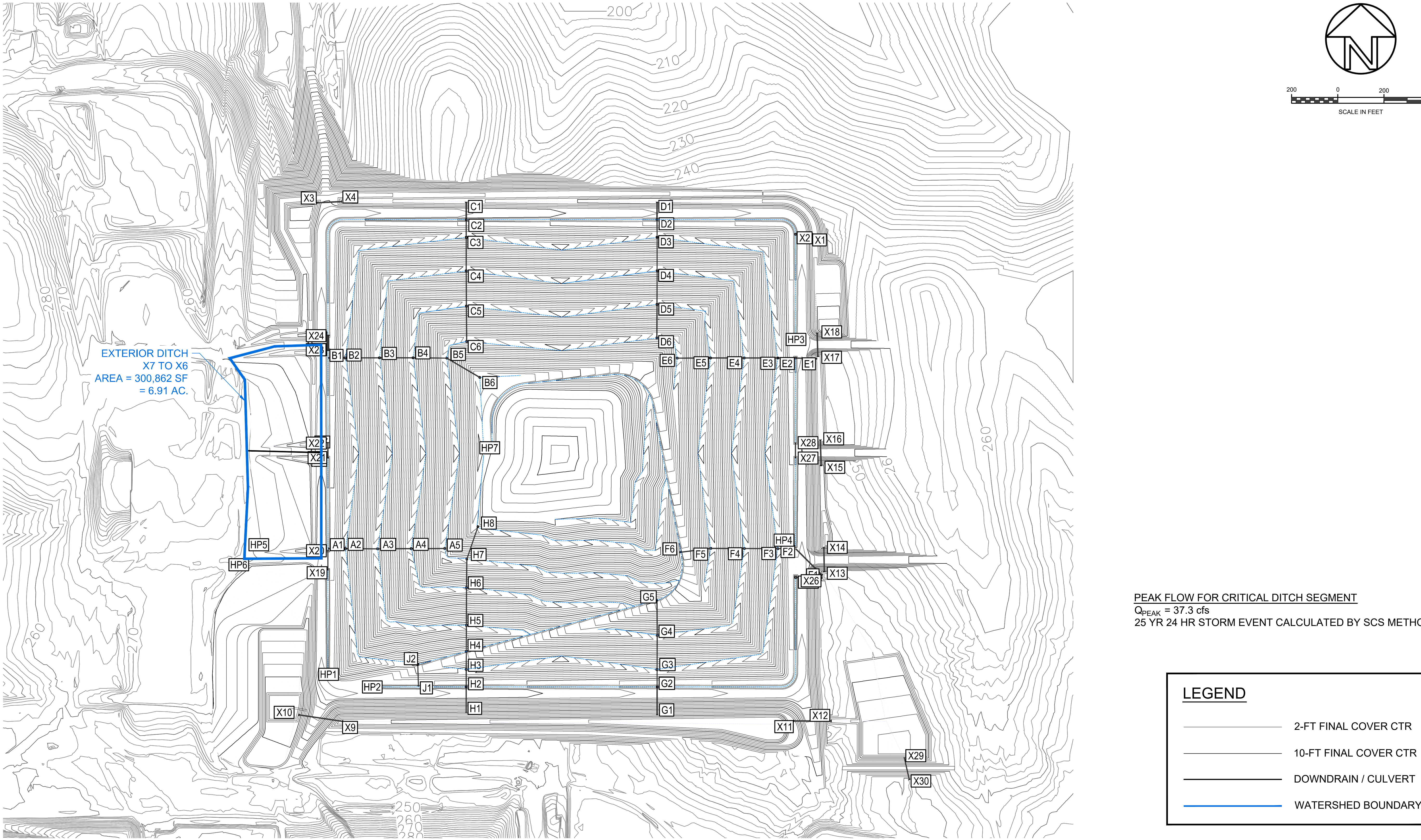
FIGURE
D-14

Channel Report

EXTERIOR DITCH - HP5 TO X8

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 10.00	Depth (ft)	= 0.47
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 19.20
Total Depth (ft)	= 4.00	Area (sqft)	= 5.36
Invert Elev (ft)	= 274.00	Velocity (ft/s)	= 3.58
Slope (%)	= 1.70	Wetted Perim (ft)	= 12.97
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.47
		Top Width (ft)	= 12.82
Calculations		EGL (ft)	= 0.67
Compute by:	Known Q		
Known Q (cfs)	= 19.20		





PEAK FLOW FOR CRITICAL DITCH SEGMENT
Q_{PEAK} = 37.3 cfs
25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

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PH. (770) 924-9799 FAX. (770) 924-7866

EXTERIOR DITCH, SECTION X7 TO X6 WATERSHED

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CHEMICAL WASTE MANAGEMENT

FIGURE
D-15

Channel Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Friday, Jan 30 2015

EXTERIOR DITCH - X7 TO X6

Trapezoidal

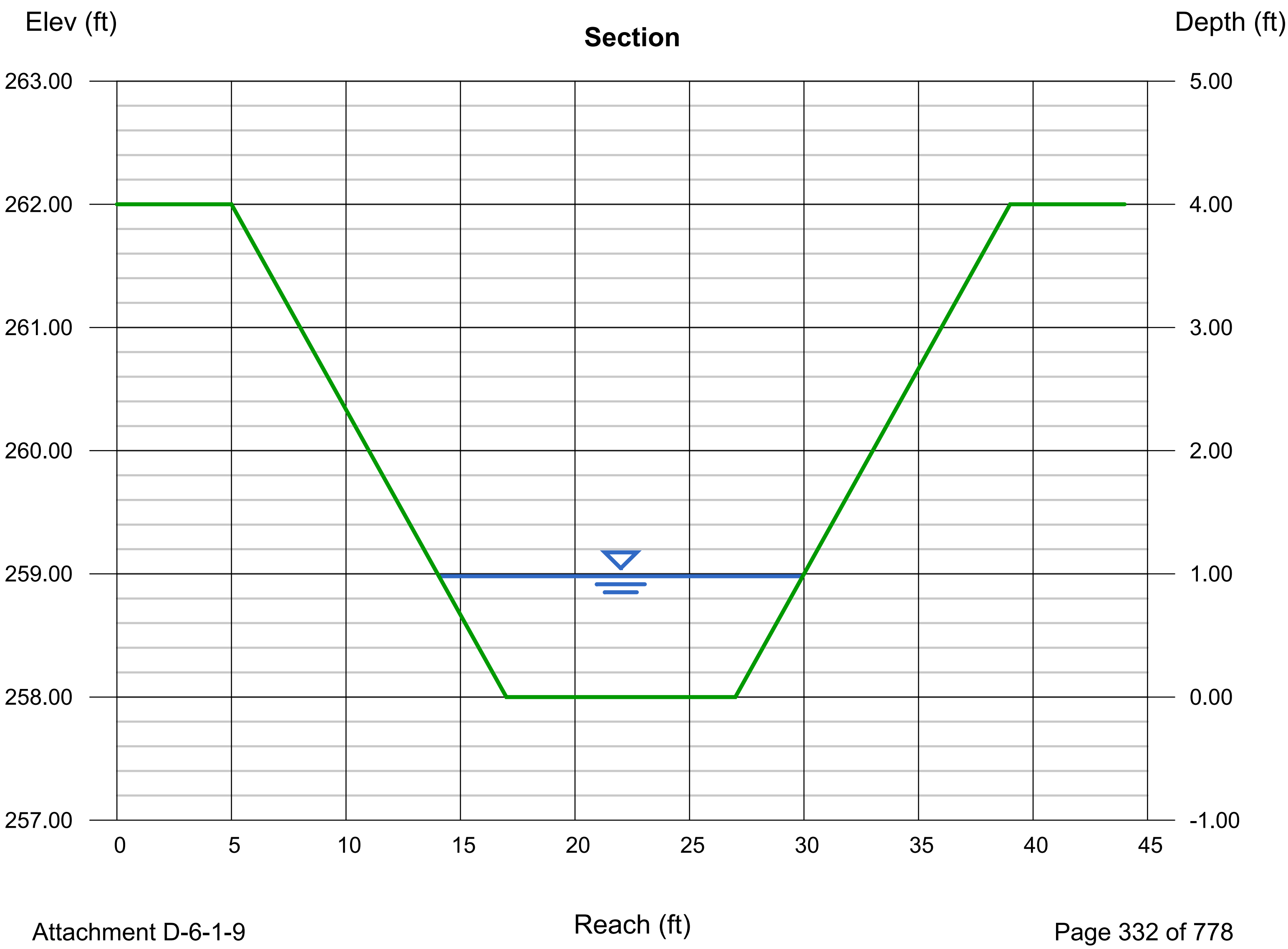
Bottom Width (ft)	= 10.00
Side Slopes (z:1)	= 3.00, 3.00
Total Depth (ft)	= 4.00
Invert Elev (ft)	= 258.00
Slope (%)	= 0.50
N-Value	= 0.030

Calculations

Compute by:	Known Q
Known Q (cfs)	= 37.30

Highlighted

Depth (ft)	= 0.98
Q (cfs)	= 37.30
Area (sqft)	= 12.68
Velocity (ft/s)	= 2.94
Wetted Perim (ft)	= 16.20
Crit Depth, Yc (ft)	= 0.71
Top Width (ft)	= 15.88
EGL (ft)	= 1.11



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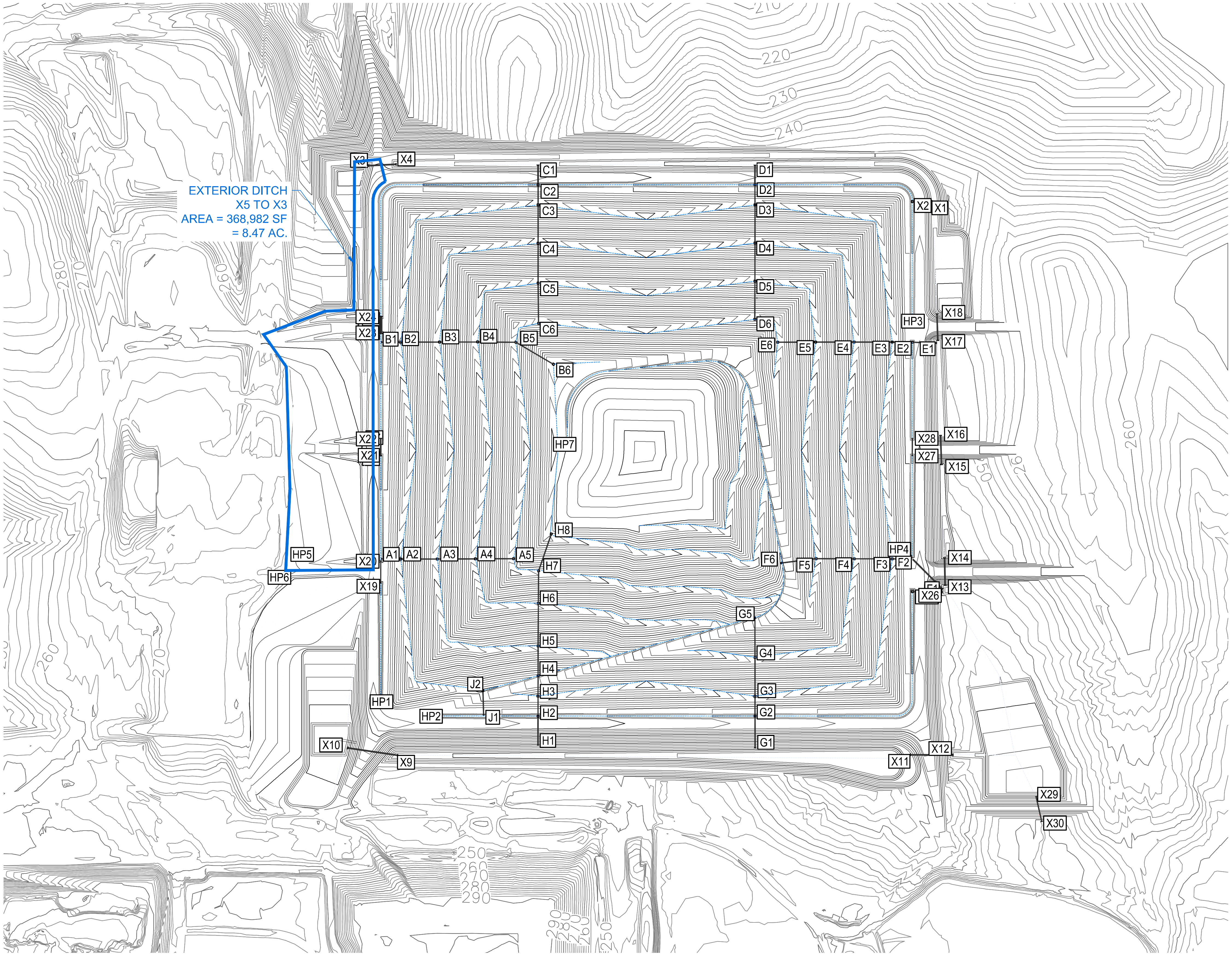

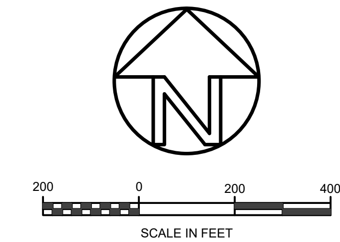

PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 48.2 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

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CHECKED BY:	RSG
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Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

INTERIOR DITCH, SECTION X5 TO X3 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
D-16

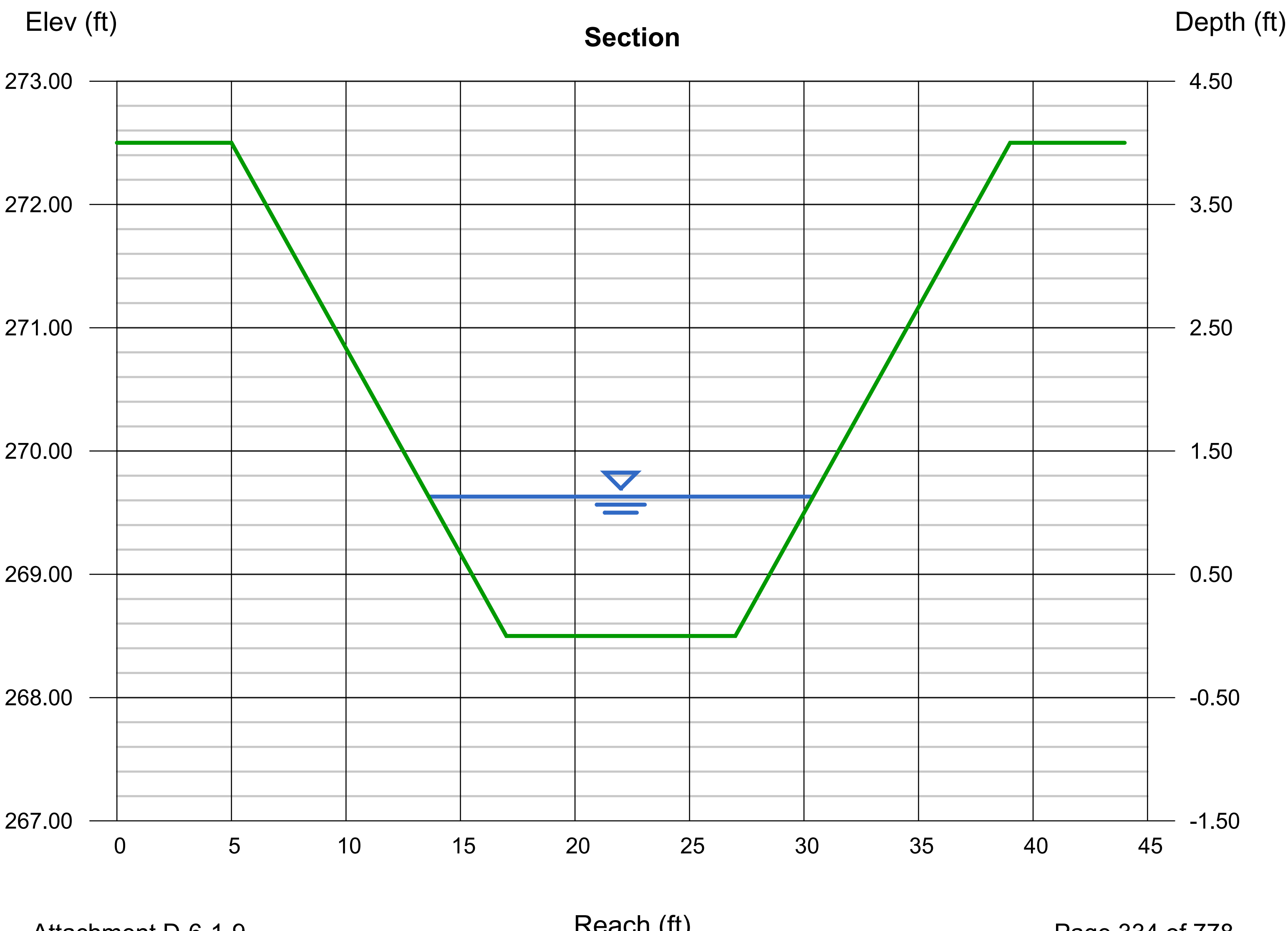
Channel Report

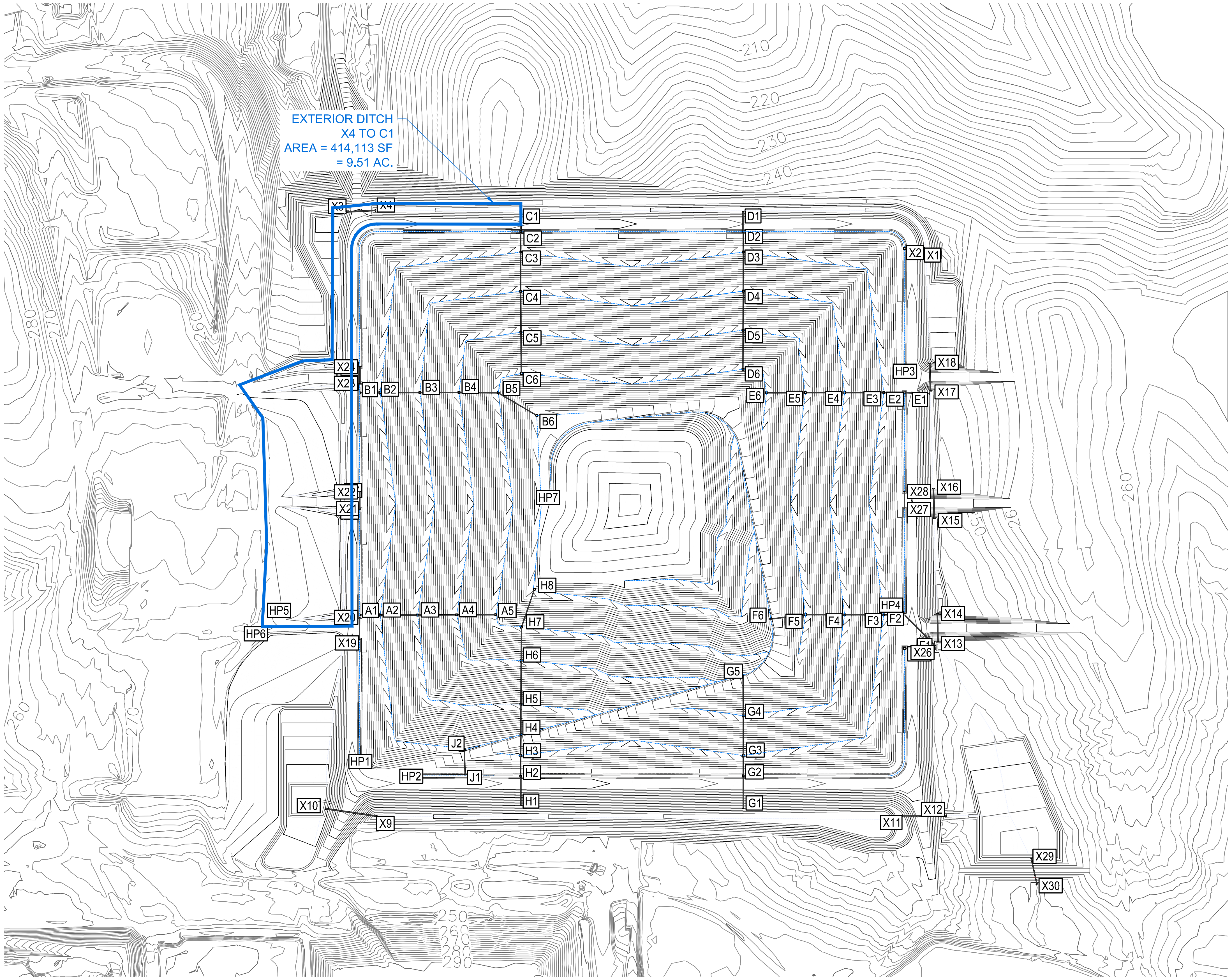
EXTERIOR DITCH - X5 TO X3

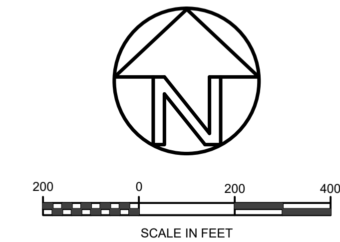
Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 10.00	Depth (ft)	= 1.13
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 48.20
Total Depth (ft)	= 4.00	Area (sqft)	= 15.13
Invert Elev (ft)	= 268.50	Velocity (ft/s)	= 3.19
Slope (%)	= 0.50	Wetted Perim (ft)	= 17.15
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.83
		Top Width (ft)	= 16.78
		EGL (ft)	= 1.29

Calculations

Compute by:	Known Q
Known Q (cfs)	= 48.20







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 7.1 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

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PH. (770) 924-9799 FAX. (770) 924-7866

EXTERIOR DITCH, SECTION X4 TO C1 WATERSHED

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FIGURE
D-17

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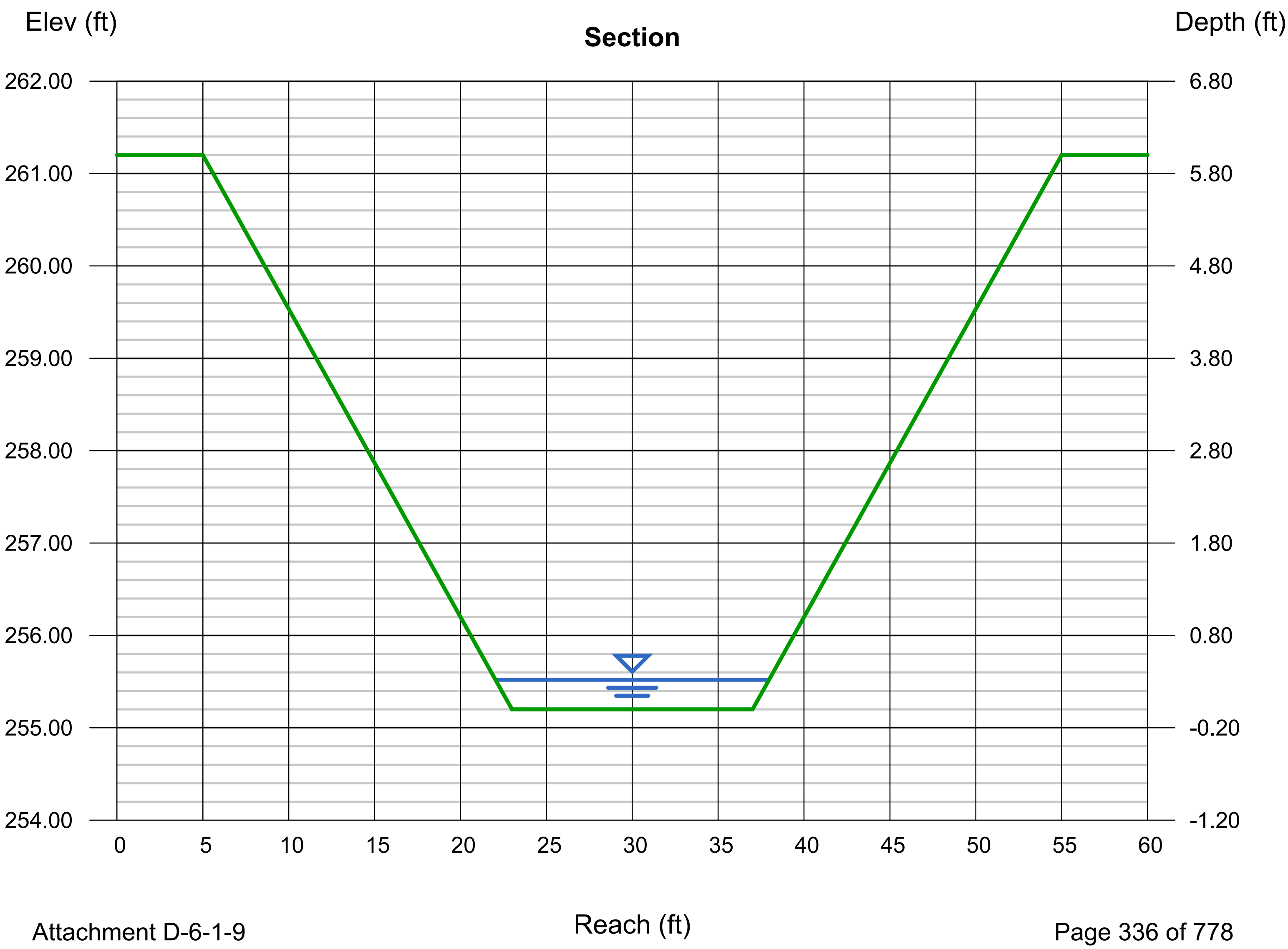
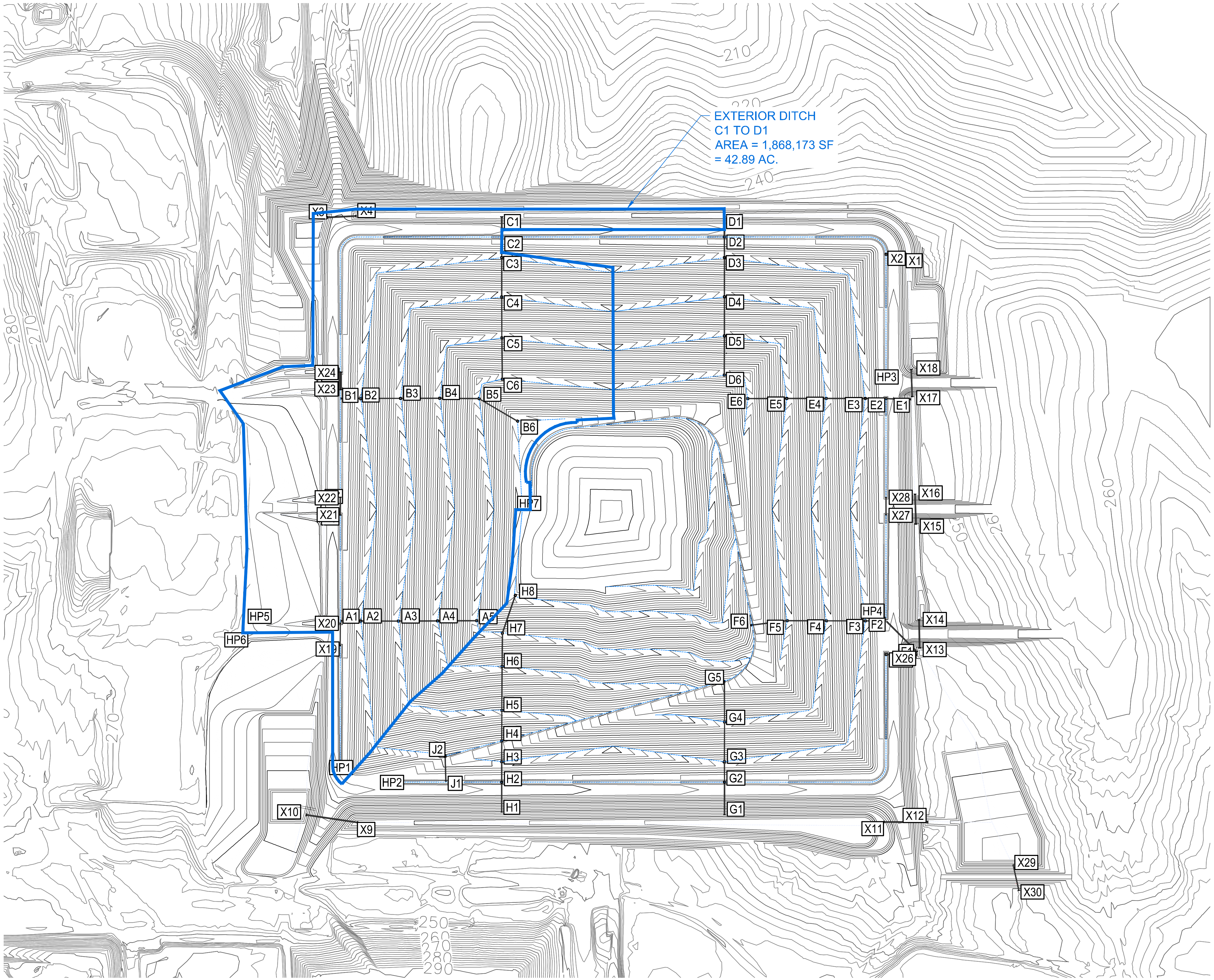
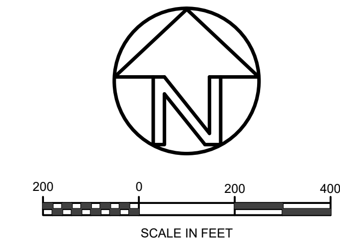
Channel Report

EXTERIOR DITCH - X4 TO C1

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 14.00	Depth (ft)	= 0.32
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 7.100
Total Depth (ft)	= 6.00	Area (sqft)	= 4.79
Invert Elev (ft)	= 255.20	Velocity (ft/s)	= 1.48
Slope (%)	= 0.50	Wetted Perim (ft)	= 16.02
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.20
		Top Width (ft)	= 15.92
Calculations		EGL (ft)	= 0.35
Compute by:	Known Q		
Known Q (cfs)	= 7.10		







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 178.1 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

———	2-FT FINAL COVER CTR
———	10-FT FINAL COVER CTR
———	DOWNDRAIN / CULVERT
———	WATERSHED BOUNDARY

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PH. (770) 924-9799 FAX. (770) 924-7866

EXTERIOR DITCH SECTION C1 TO D1 WATERSHED

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CHEMICAL WASTE MANAGEMENT

FIGURE
D-18

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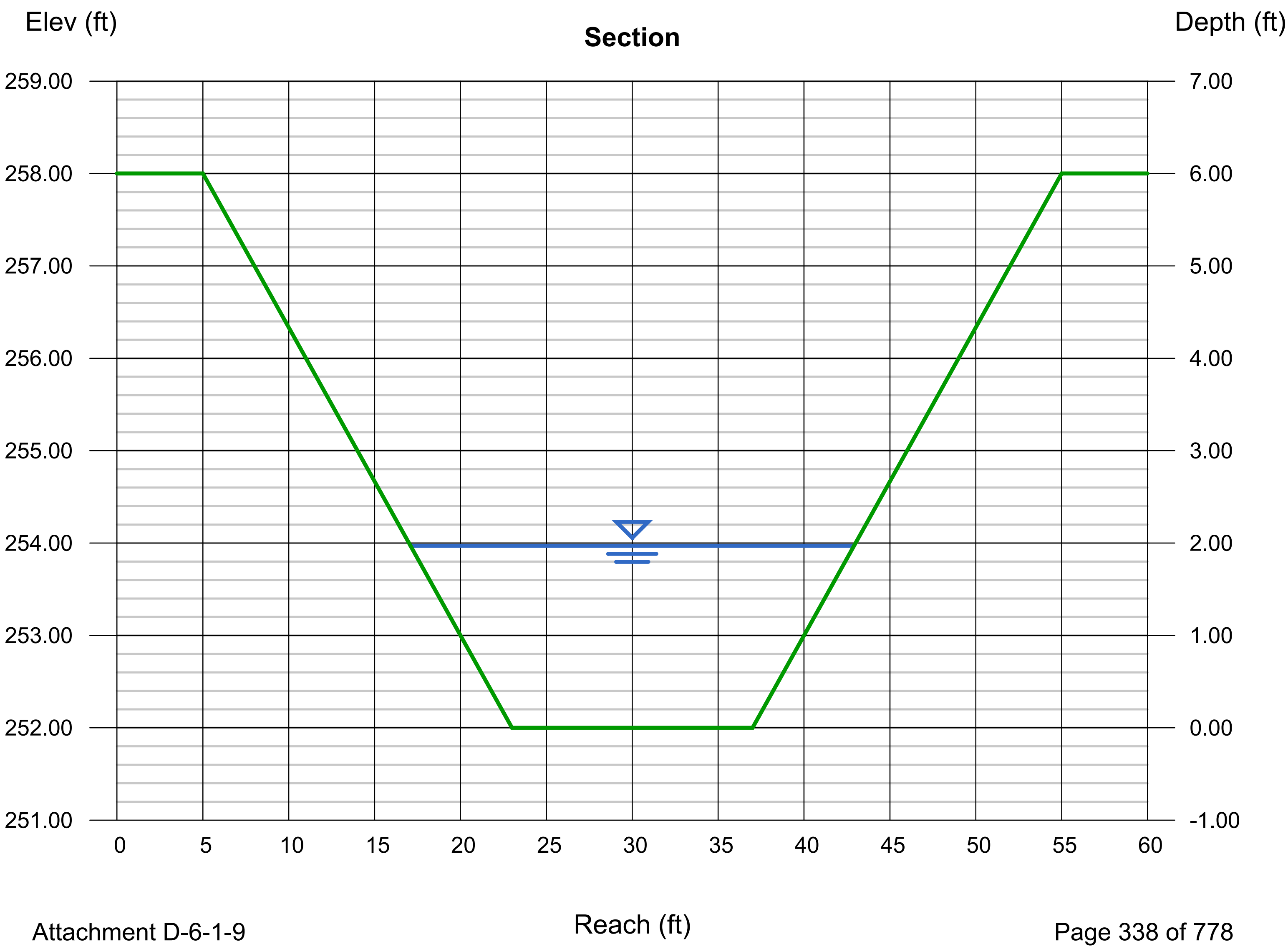
Channel Report

EXTERIOR DITCH - C1 TO D1

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 14.00	Depth (ft)	= 1.97
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 178.10
Total Depth (ft)	= 6.00	Area (sqft)	= 39.22
Invert Elev (ft)	= 252.00	Velocity (ft/s)	= 4.54
Slope (%)	= 0.50	Wetted Perim (ft)	= 26.46
N-Value	= 0.030	Crit Depth, Yc (ft)	= 1.53
		Top Width (ft)	= 25.82
Calculations		EGL (ft)	= 2.29
Compute by:	Known Q		
Known Q (cfs)	= 178.10		



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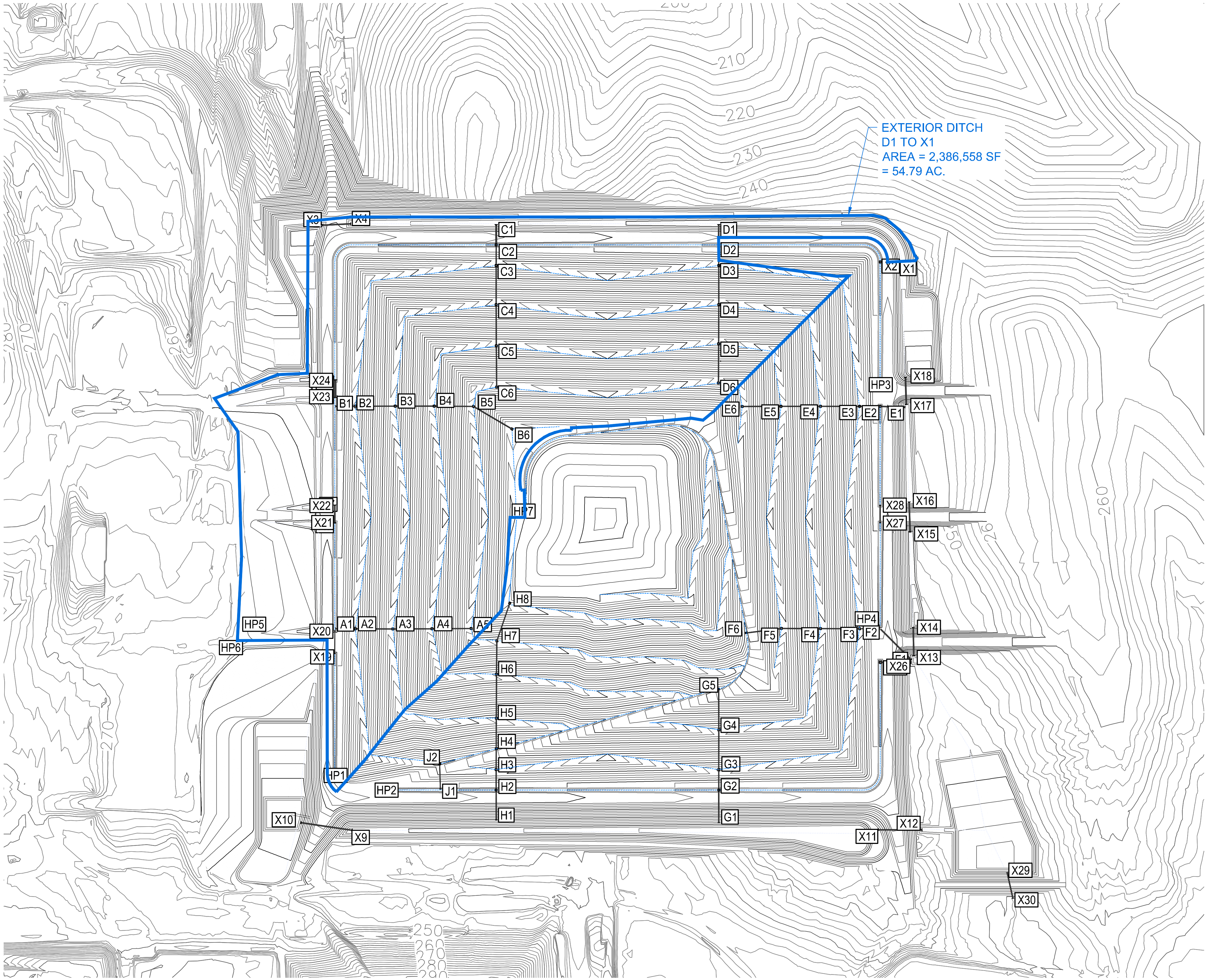

N

200 0 200 400

SCALE IN FEET

PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 244.6 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

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EXTERIOR DITCH, SECTION D1 TO X1 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

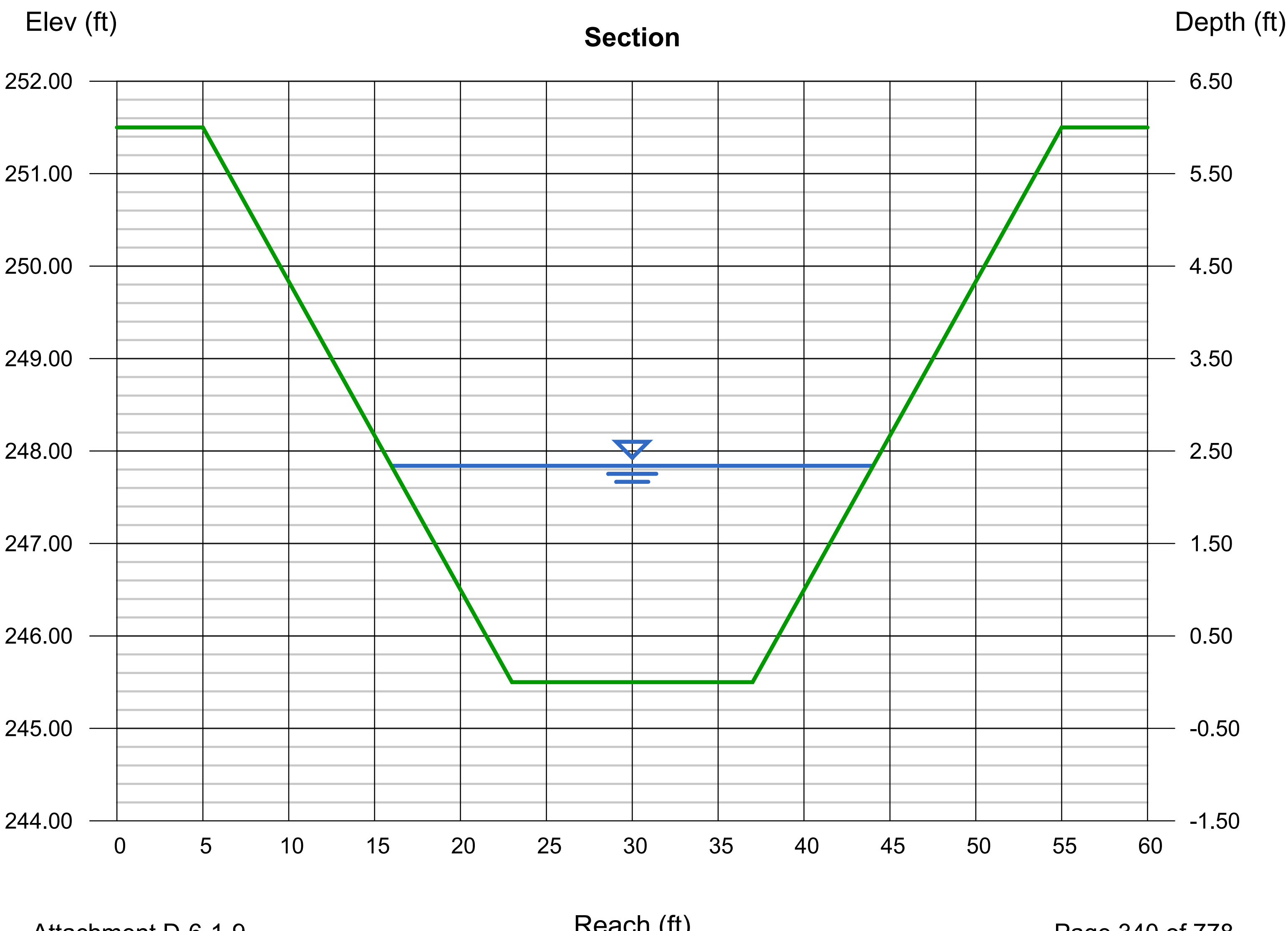
FIGURE

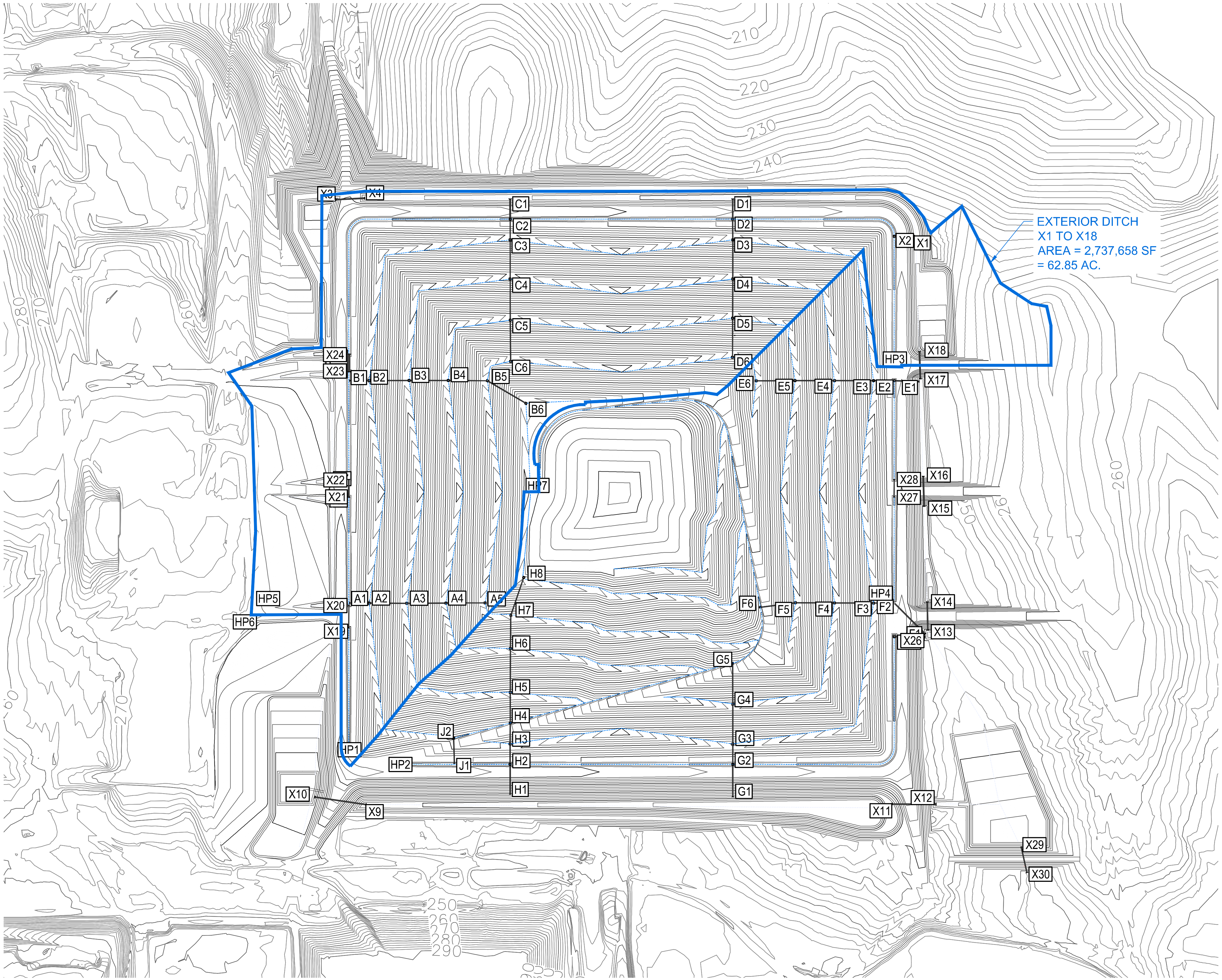
D-19

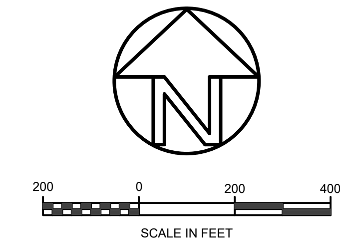
Channel Report

EXTERIOR DITCH - D1 TO X1

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 14.00	Depth (ft)	= 2.34
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 244.60
Total Depth (ft)	= 6.00	Area (sqft)	= 49.19
Invert Elev (ft)	= 245.50	Velocity (ft/s)	= 4.97
Slope (%)	= 0.50	Wetted Perim (ft)	= 28.80
N-Value	= 0.030	Crit Depth, Yc (ft)	= 1.85
		Top Width (ft)	= 28.04
Calculations		EGL (ft)	= 2.72
Compute by:	Known Q		
Known Q (cfs)	= 244.60		







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 287.8 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

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PH. (770) 924-9799 FAX. (770) 924-7866

EXTERIOR DITCH, SECTION X1 TO X18 WATERSHED

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CHEMICAL WASTE MANAGEMENT

FIGURE
D-20

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Channel Report

EXTERIOR DITCH - X1 TO X18

Trapezoidal

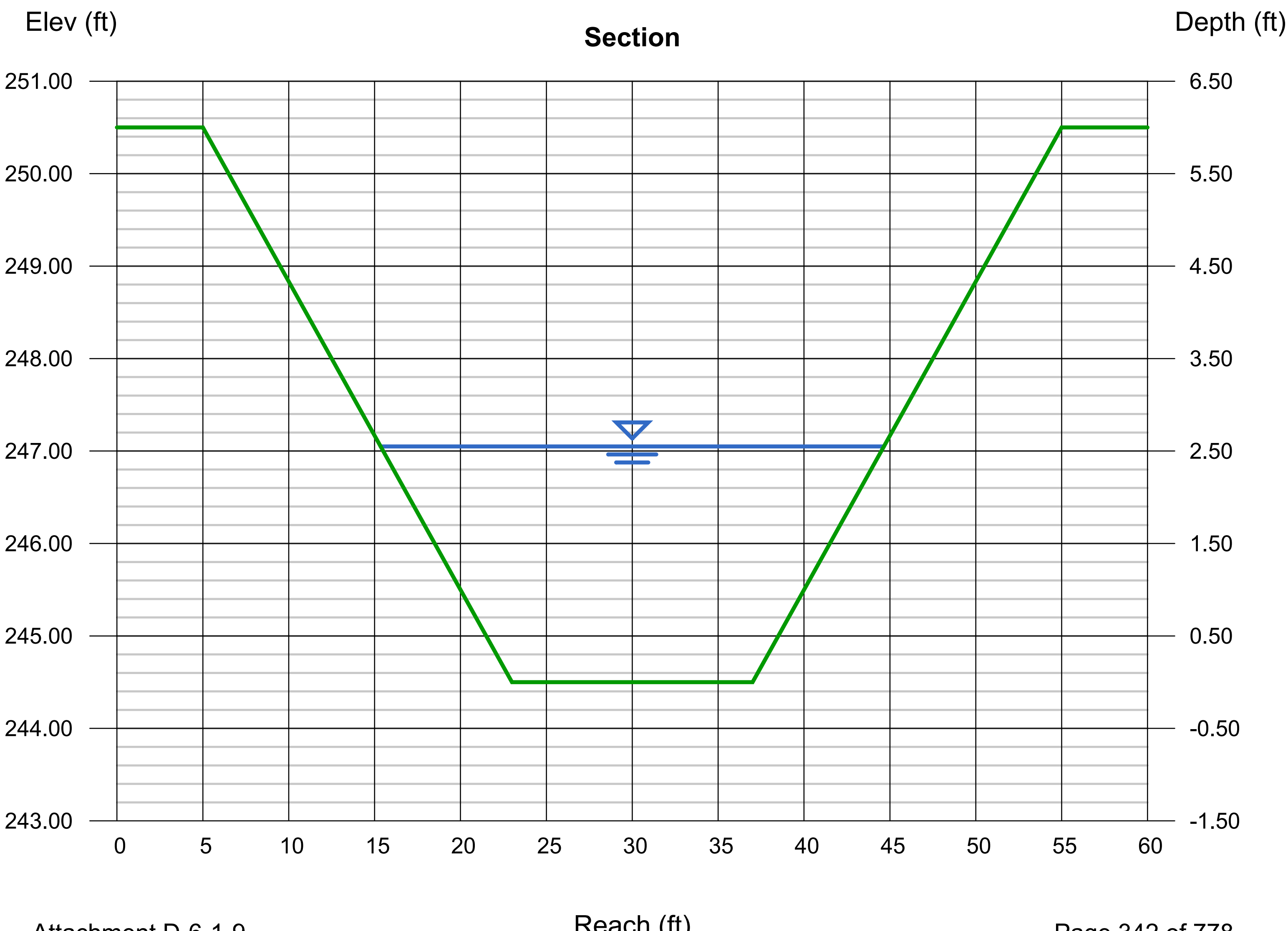
Bottom Width (ft)	= 14.00
Side Slopes (z:1)	= 3.00, 3.00
Total Depth (ft)	= 6.00
Invert Elev (ft)	= 244.50
Slope (%)	= 0.50
N-Value	= 0.030

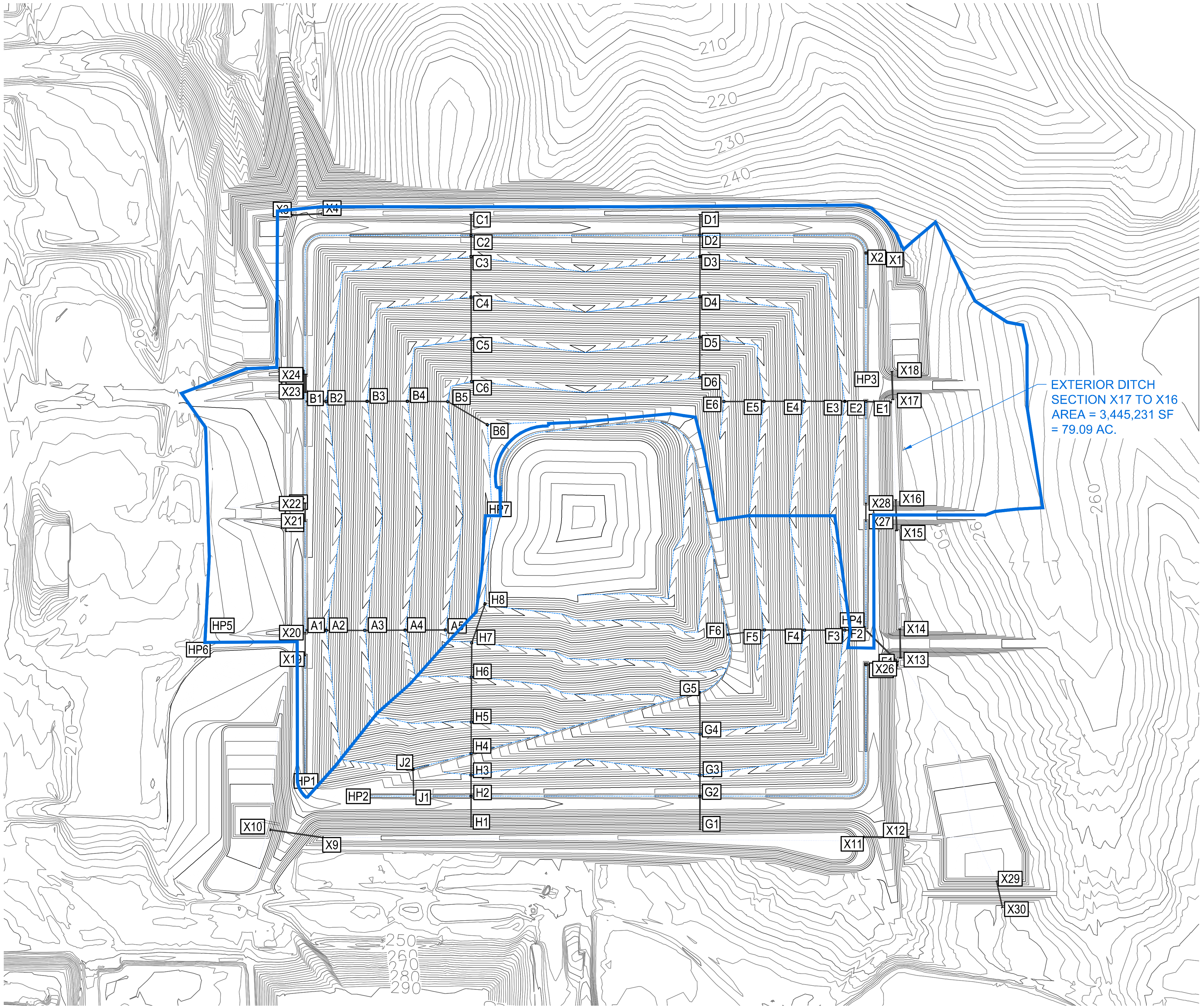
Calculations

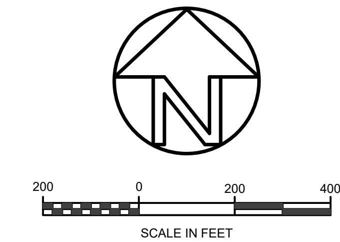
Compute by:	Known Q
Known Q (cfs)	= 287.80

Highlighted

Depth (ft)	= 2.55
Q (cfs)	= 287.80
Area (sqft)	= 55.21
Velocity (ft/s)	= 5.21
Wetted Perim (ft)	= 30.13
Crit Depth, Yc (ft)	= 2.03
Top Width (ft)	= 29.30
EGL (ft)	= 2.97







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 122.4 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

———	2-FT FINAL COVER CTR
———	10-FT FINAL COVER CTR
———	DOWNDRAIN / CULVERT
———	WATERSHED BOUNDARY

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Terracon
Consulting Engineers and Scientists
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PH. (770) 924-9799 FAX. (770) 924-7866

EXTERIOR DITCH, SECTION X17 TO X16 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
D-21

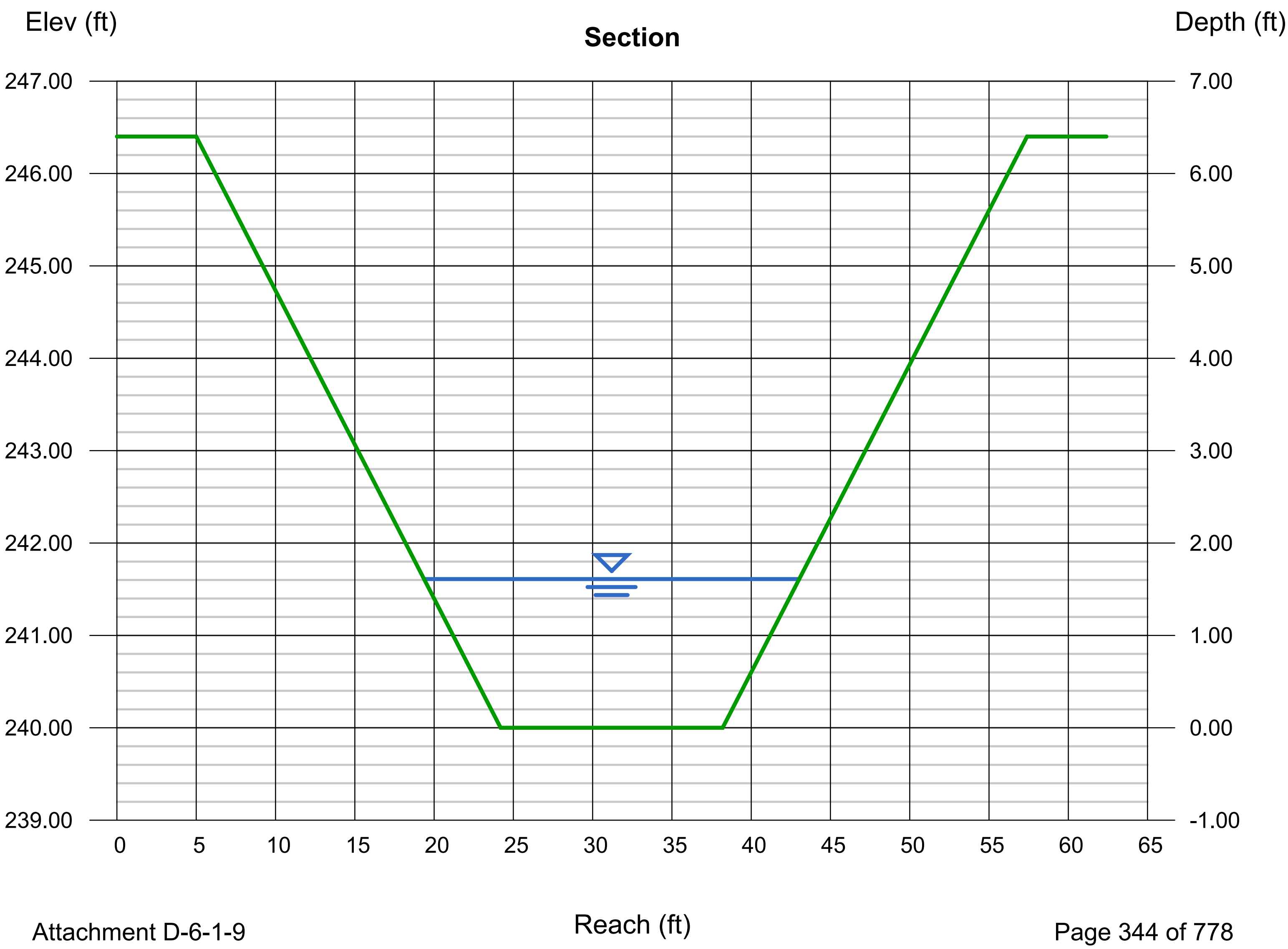
Channel Report

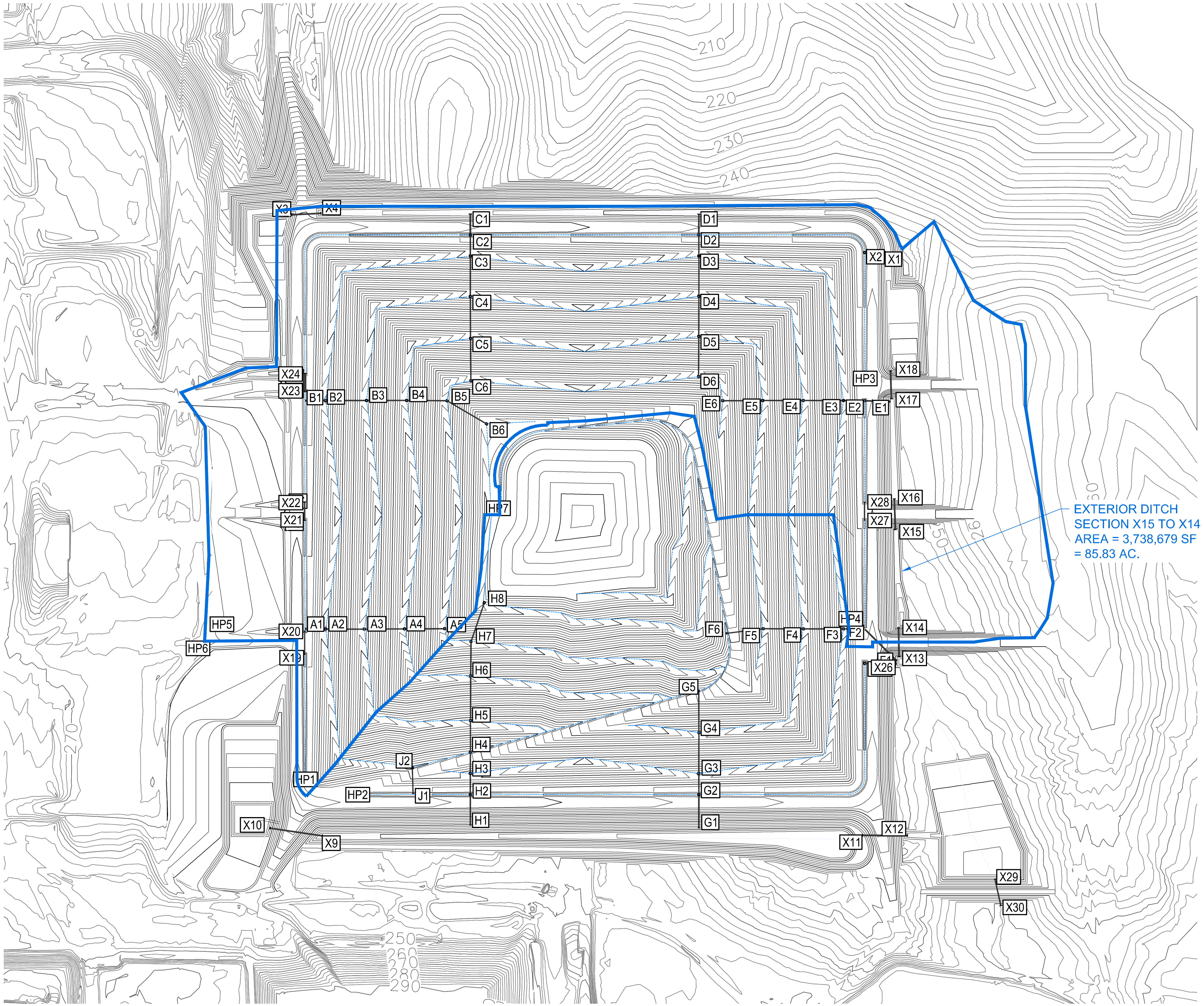
EXTERIOR DITCH - X17 TO X16

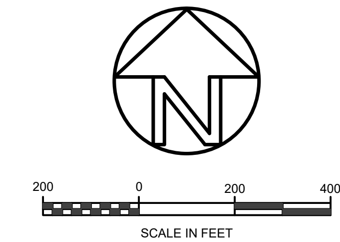
Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 14.00	Depth (ft)	= 1.61
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 122.40
Total Depth (ft)	= 6.40	Area (sqft)	= 30.32
Invert Elev (ft)	= 240.00	Velocity (ft/s)	= 4.04
Slope (%)	= 0.50	Wetted Perim (ft)	= 24.18
N-Value	= 0.030	Crit Depth, Yc (ft)	= 1.22
		Top Width (ft)	= 23.66
		EGL (ft)	= 1.86

Calculations

Compute by:	Known Q
Known Q (cfs)	= 122.40







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 163.5 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

——	2-FT FINAL COVER CTR
——	10-FT FINAL COVER CTR
——	DOWNDRAIN / CULVERT
——	WATERSHED BOUNDARY

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PH. (770) 924-9799 FAX. (770) 924-7866

EXTERIOR DITCH, SECTION X15 TO X14 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
D-22

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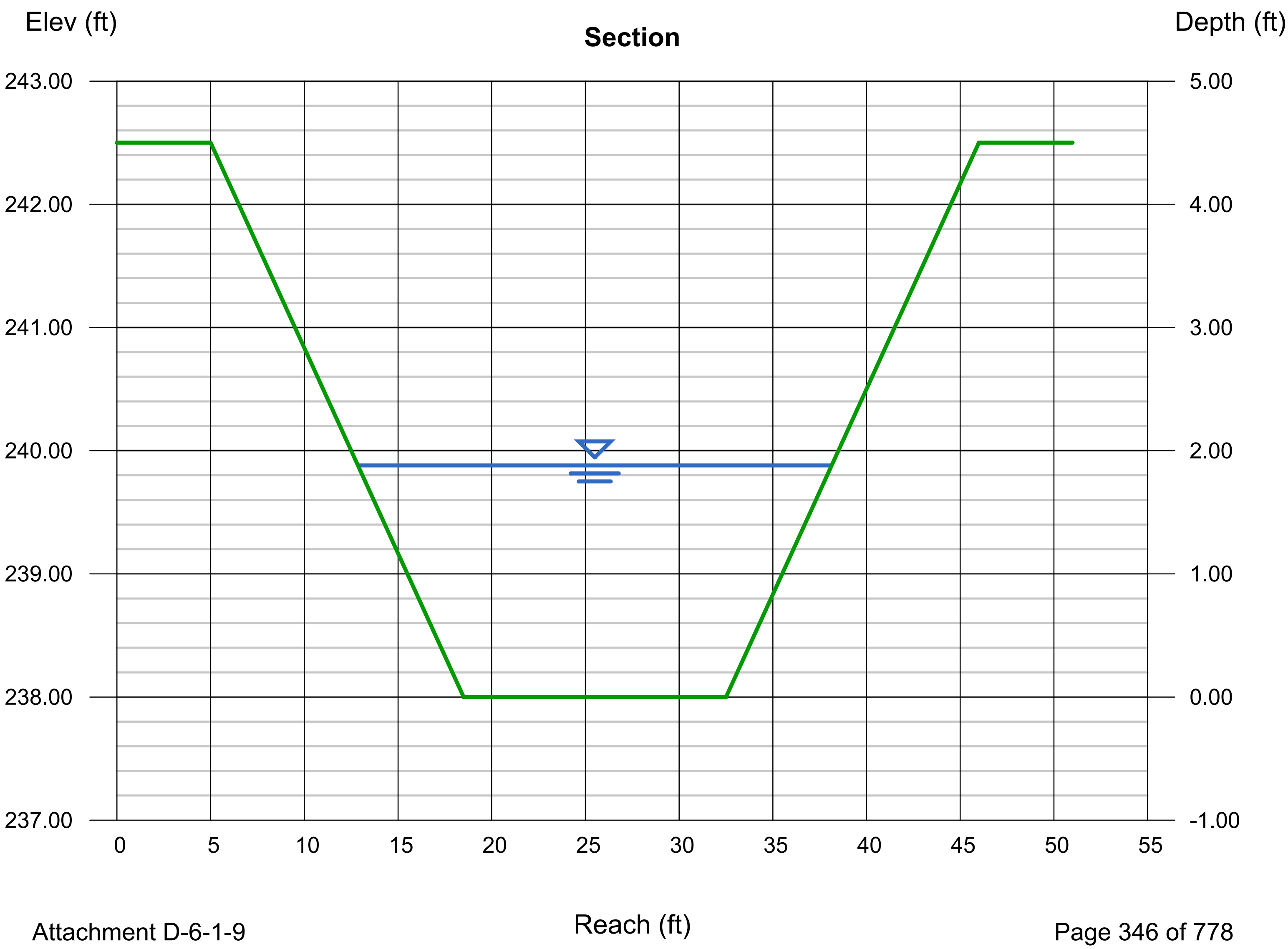
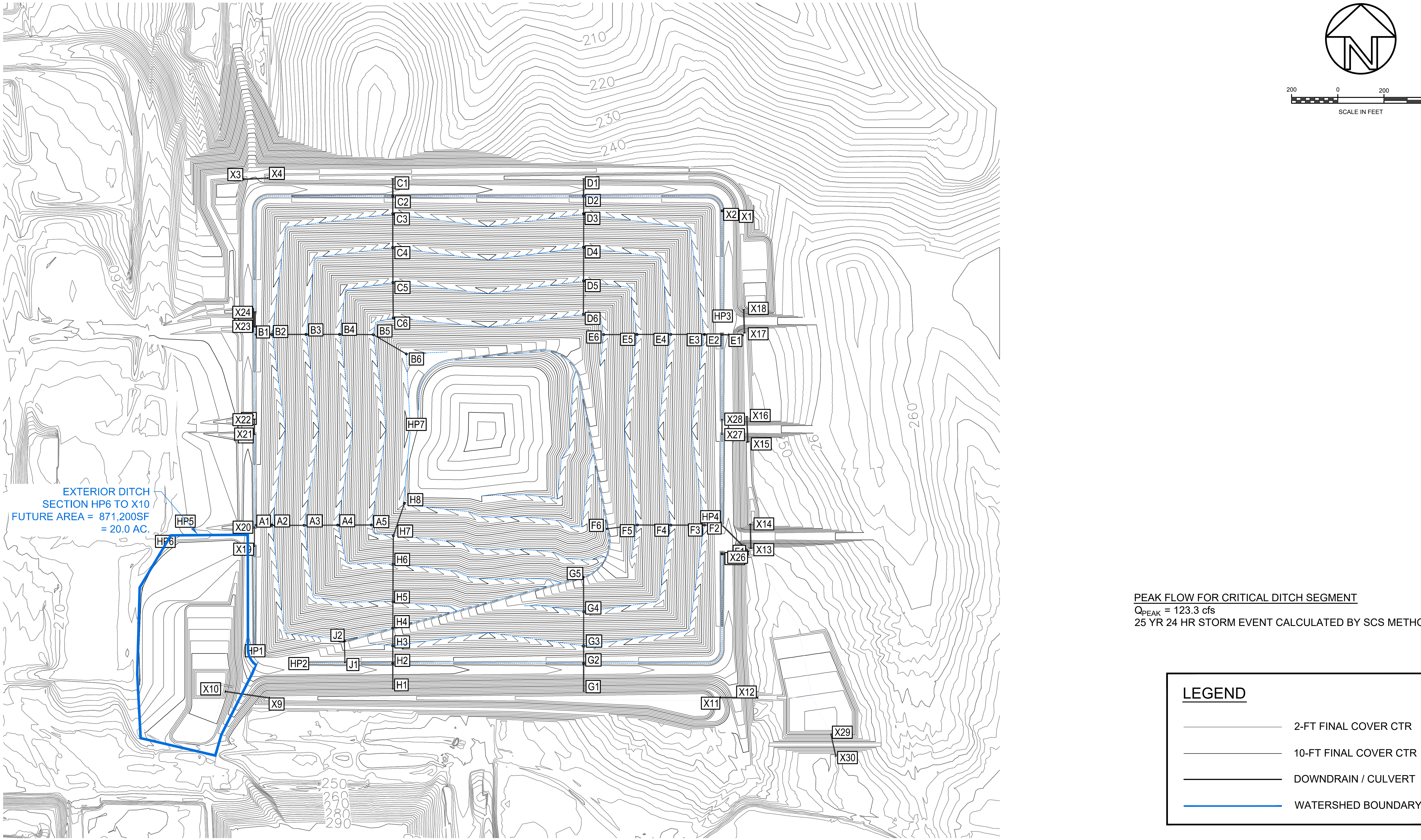
Channel Report

EXTERIOR DITCH - X15 TO X14

Trapezoidal	
Bottom Width (ft)	= 14.00
Side Slopes (z:1)	= 3.00, 3.00
Total Depth (ft)	= 4.50
Invert Elev (ft)	= 238.00
Slope (%)	= 0.50
N-Value	= 0.030
Calculations	
Compute by:	Known Q
Known Q (cfs)	= 163.50

Highlighted	
Depth (ft)	= 1.88
Q (cfs)	= 163.50
Area (sqft)	= 36.92
Velocity (ft/s)	= 4.43
Wetted Perim (ft)	= 25.89
Crit Depth, Yc (ft)	= 1.46
Top Width (ft)	= 25.28
EGL (ft)	= 2.18





PEAK FLOW FOR CRITICAL DITCH SEGMENT
Q_{PEAK} = 123.3 cfs
25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

EMELLE FACILITY

Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

EXTERIOR DITCH, SECTION HP6 TO X10 WATERSHED

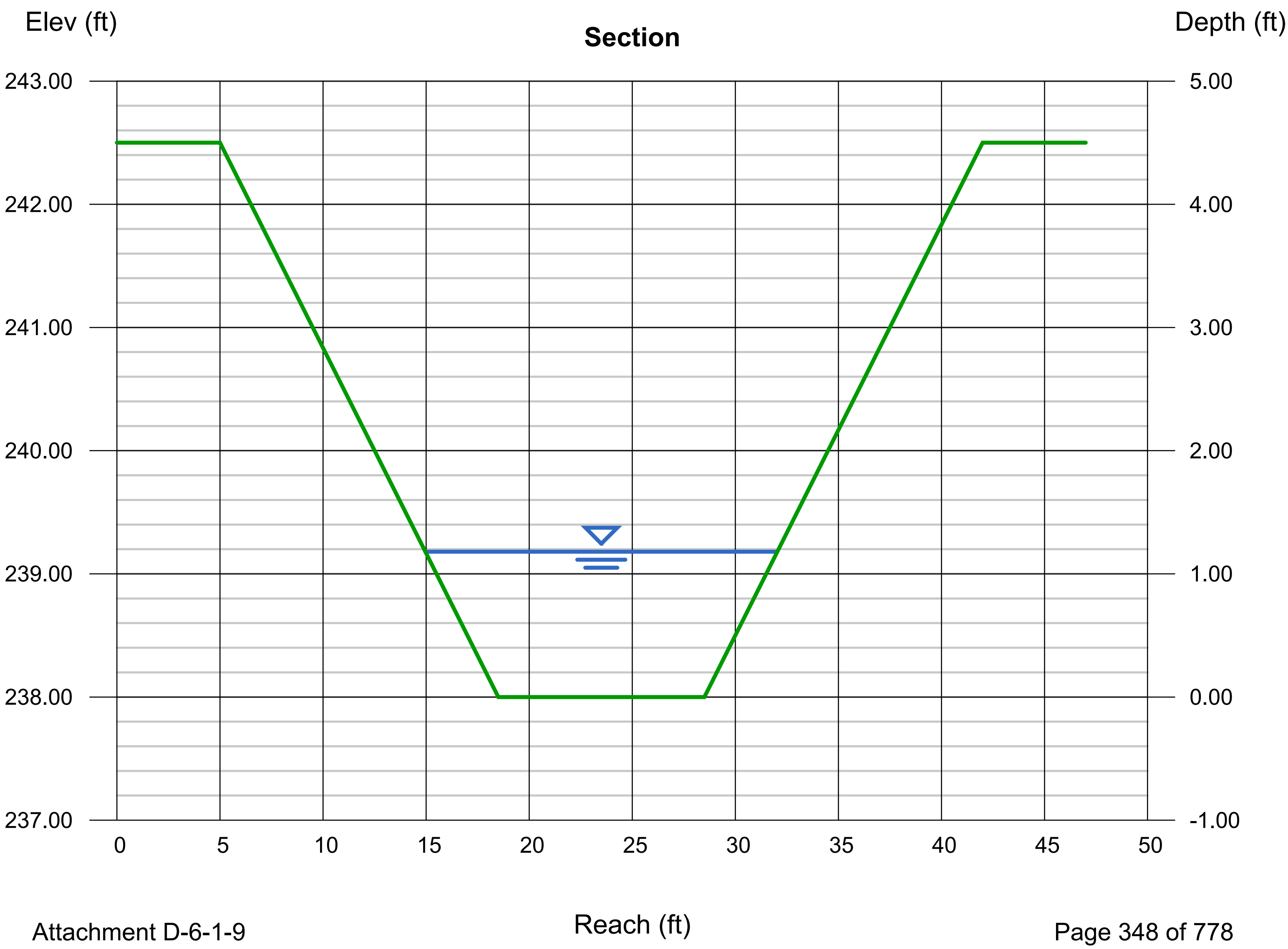
HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

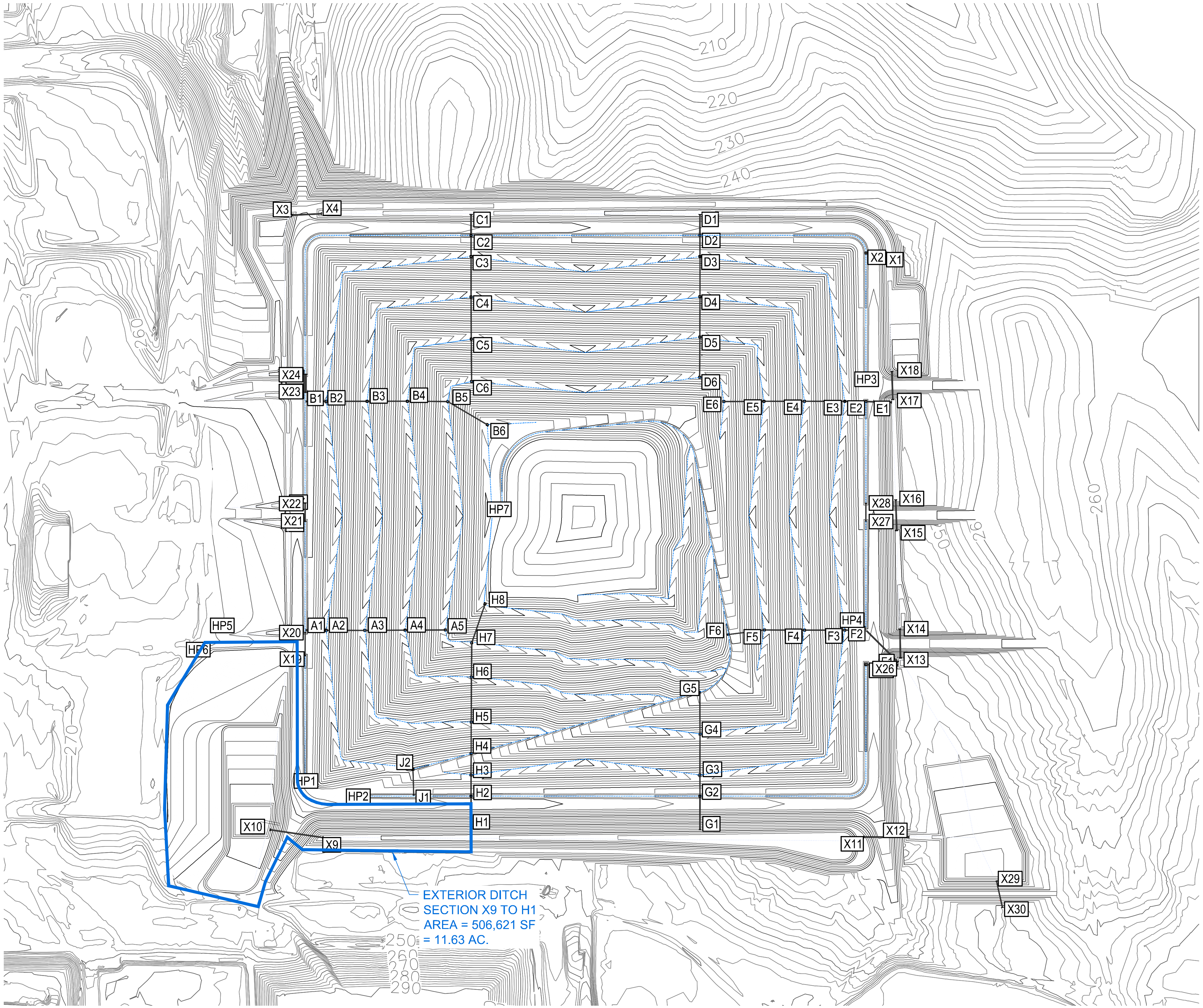
FIGURE
D-23

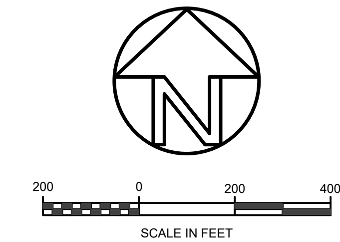
Channel Report

EXTERIOR DITCH - HP6 TO X10

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 10.00	Depth (ft)	= 1.18
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 123.30
Total Depth (ft)	= 4.50	Area (sqft)	= 15.98
Invert Elev (ft)	= 238.00	Velocity (ft/s)	= 7.72
Slope (%)	= 2.78	Wetted Perim (ft)	= 17.46
N-Value	= 0.030	Crit Depth, Yc (ft)	= 1.45
		Top Width (ft)	= 17.08
Calculations		EGL (ft)	= 2.11
Compute by:	Known Q		
Known Q (cfs)	= 123.30		







PEAK FLOW FOR CRITICAL DITCH SEGMENT

Q_{PEAK} = 23.9 cfs

25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

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EXTERIOR DITCH, SECTION X9 TO H1 WATERSHED

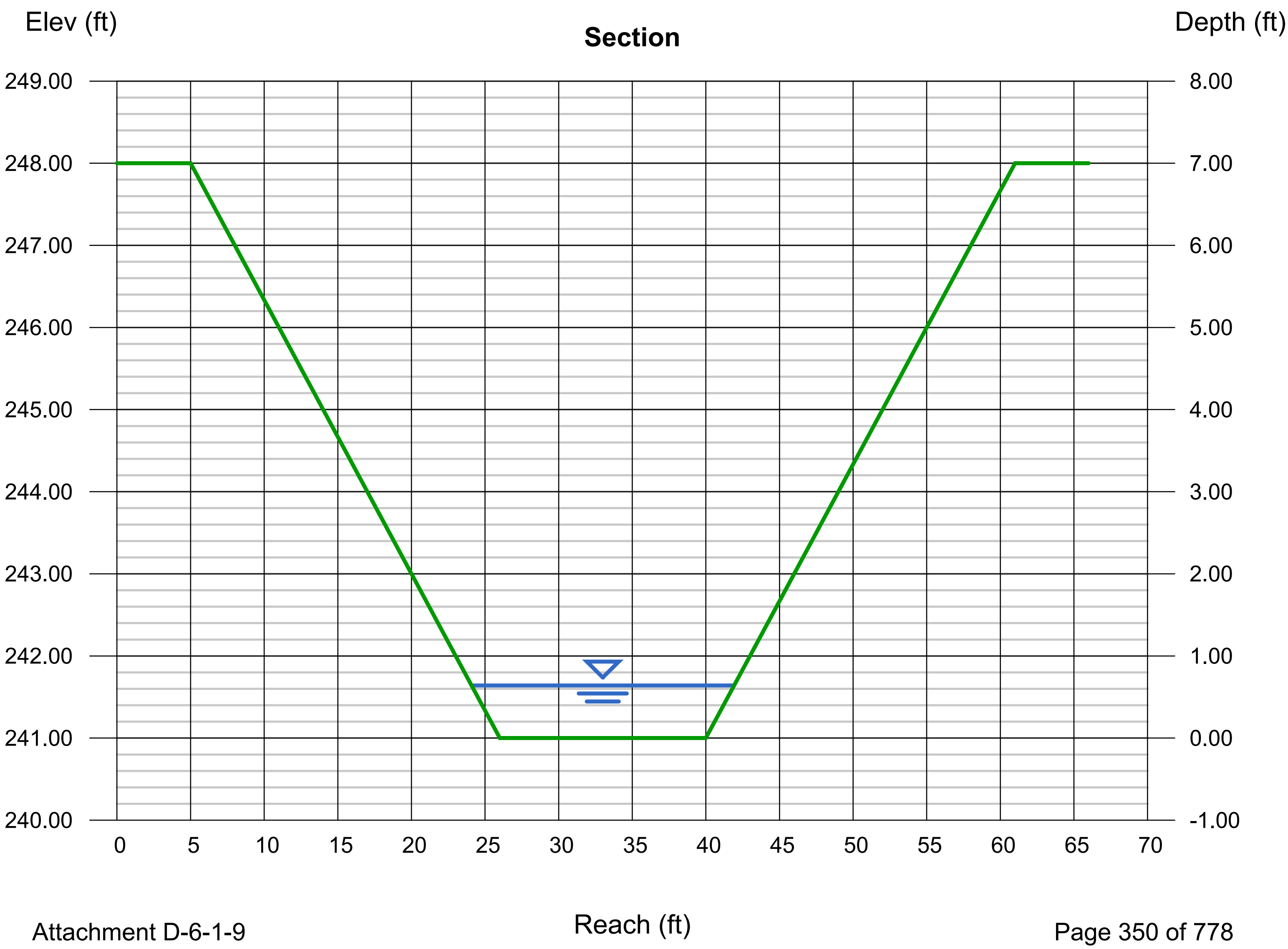
HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

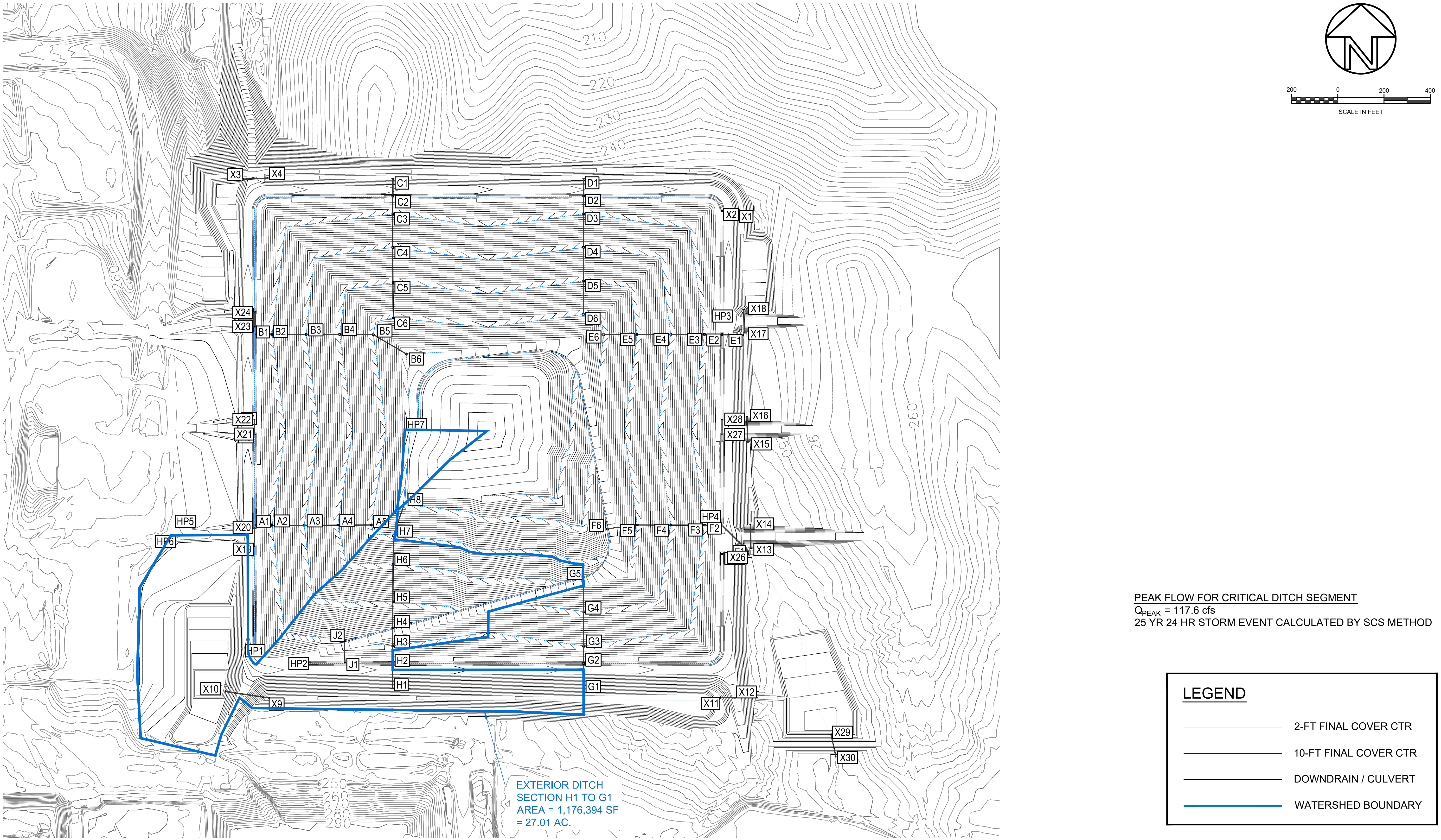
FIGURE
D-24

Channel Report

EXTERIOR DITCH - X9 TO H1

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 14.00	Depth (ft)	= 0.64
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 23.90
Total Depth (ft)	= 7.00	Area (sqft)	= 10.19
Invert Elev (ft)	= 241.00	Velocity (ft/s)	= 2.35
Slope (%)	= 0.50	Wetted Perim (ft)	= 18.05
N-Value	= 0.030	Crit Depth, Yc (ft)	= 0.44
		Top Width (ft)	= 17.84
Calculations		EGL (ft)	= 0.73
Compute by:	Known Q		
Known Q (cfs)	= 23.90		





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EXTERIOR DITCH, SECTION H1 TO G1 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
D-25

Channel Report

EXTERIOR DITCH - H1 TO G1

Trapezoidal

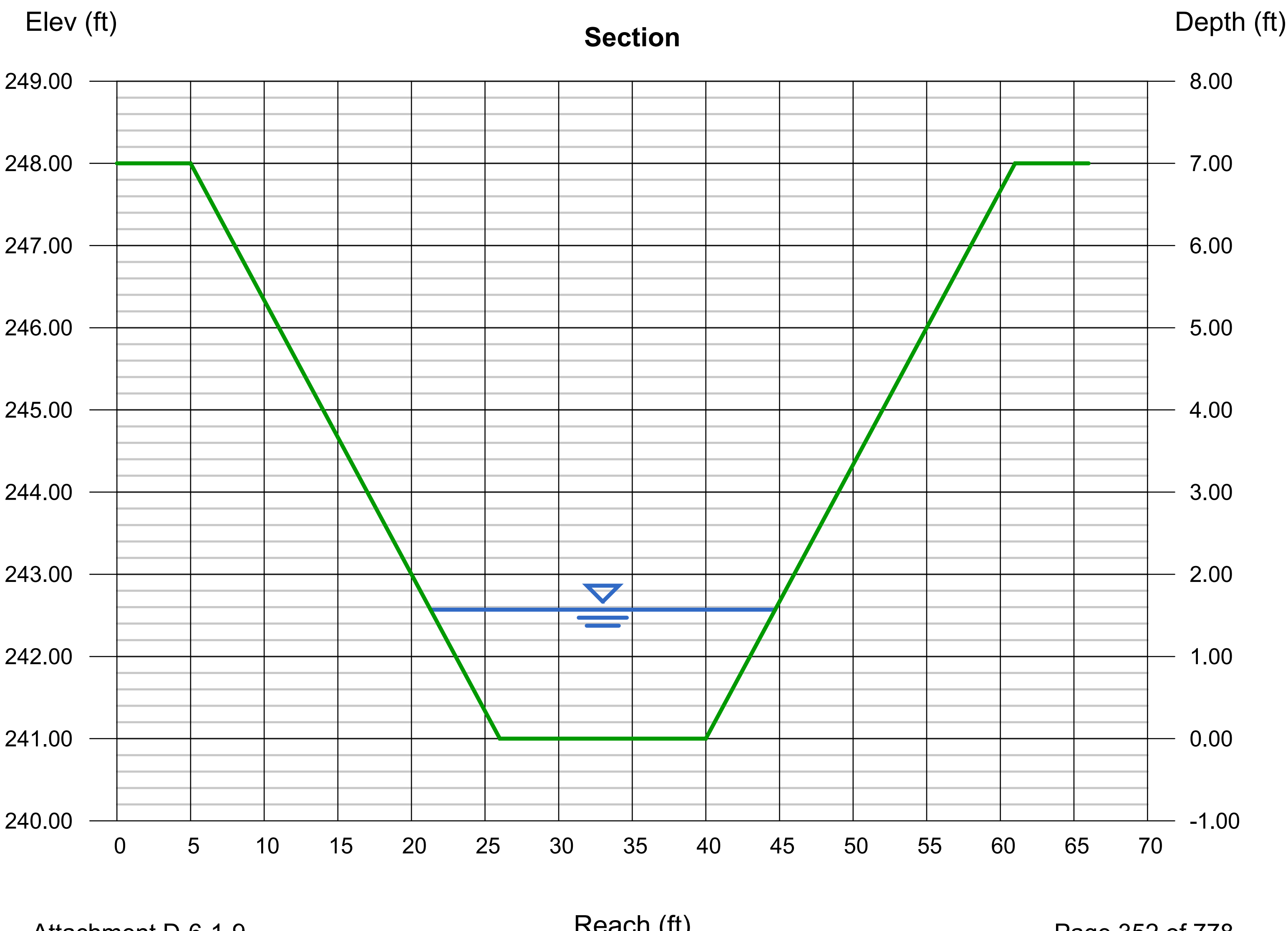
Bottom Width (ft)	= 14.00
Side Slopes (z:1)	= 3.00, 3.00
Total Depth (ft)	= 7.00
Invert Elev (ft)	= 241.00
Slope (%)	= 0.50
N-Value	= 0.030

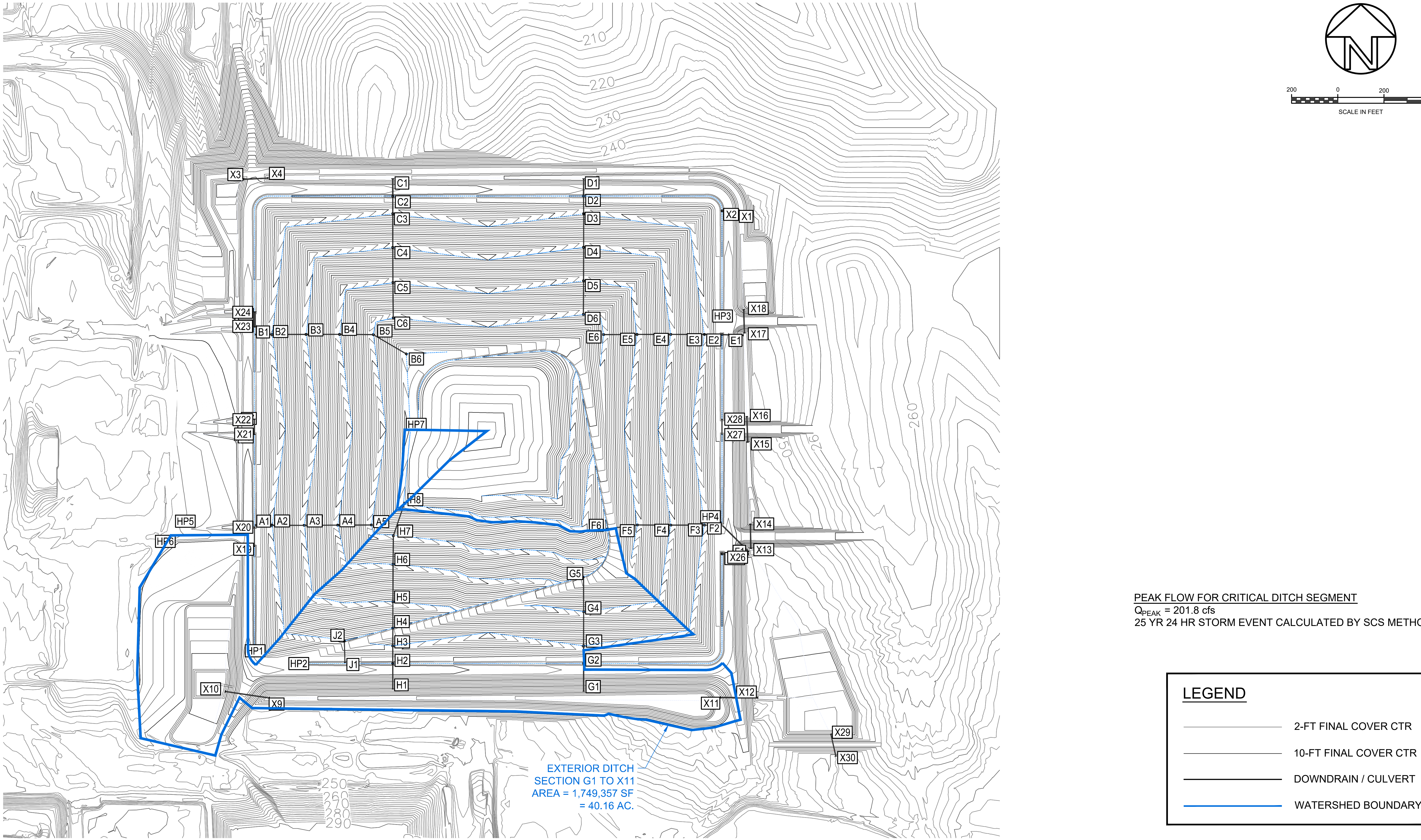
Calculations

Compute by:	Known Q
Known Q (cfs)	= 117.60

Highlighted

Depth (ft)	= 1.57
Q (cfs)	= 117.60
Area (sqft)	= 29.37
Velocity (ft/s)	= 4.00
Wetted Perim (ft)	= 23.93
Crit Depth, Yc (ft)	= 1.19
Top Width (ft)	= 23.42
EGL (ft)	= 1.82





PEAK FLOW FOR CRITICAL DITCH SEGMENT
Q_{PEAK} = 201.8 cfs
25 YR 24 HR STORM EVENT CALCULATED BY SCS METHOD

LEGEND

	2-FT FINAL COVER CTR
	10-FT FINAL COVER CTR
	DOWNDRAIN / CULVERT
	WATERSHED BOUNDARY

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PH. (770) 924-9799 FAX. (770) 924-7866

EXTERIOR DITCH, SECTION G1 TO X11 WATERSHED

HYDROLOGY STUDY
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CHEMICAL WASTE MANAGEMENT

FIGURE
D-26

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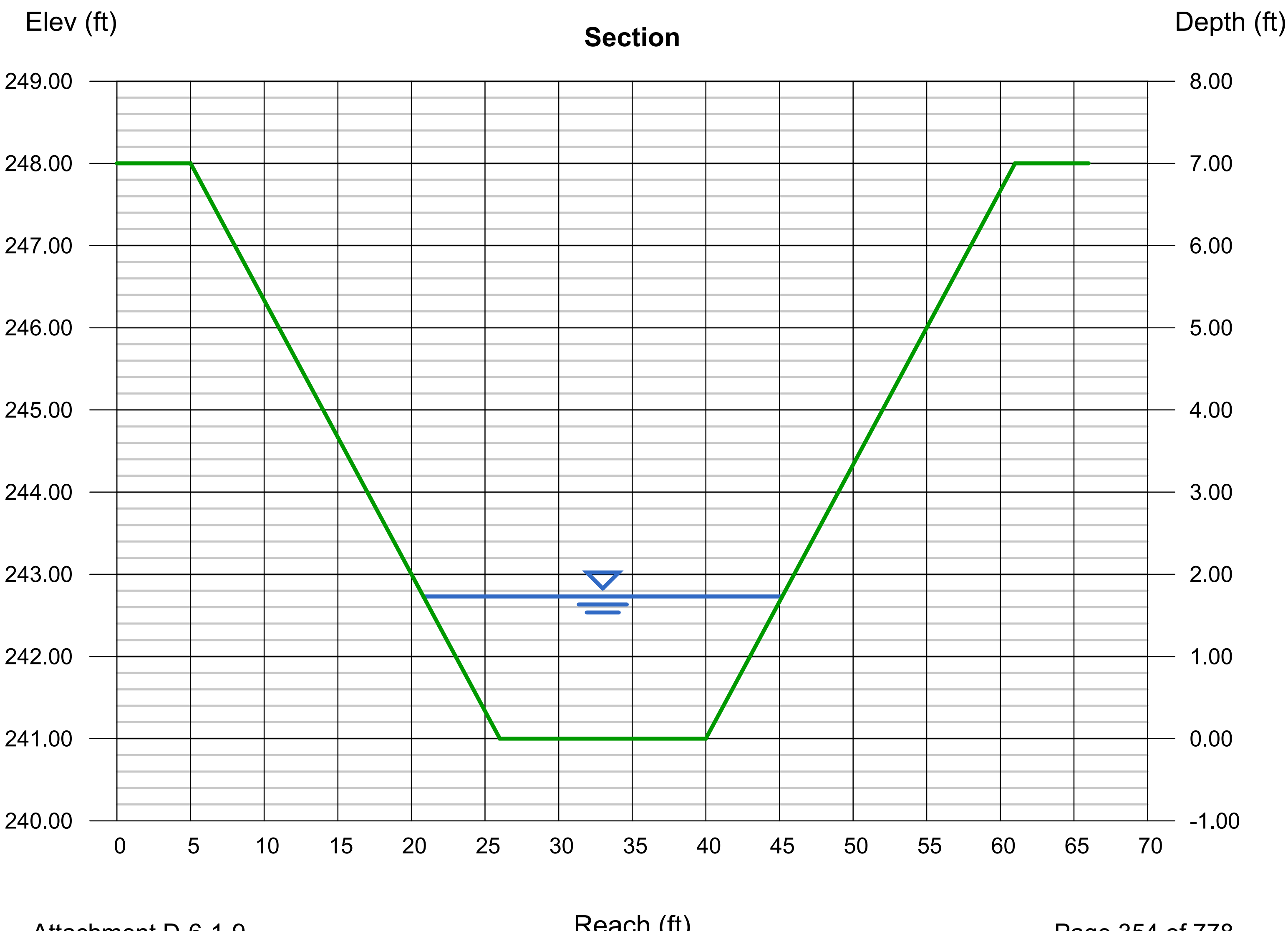
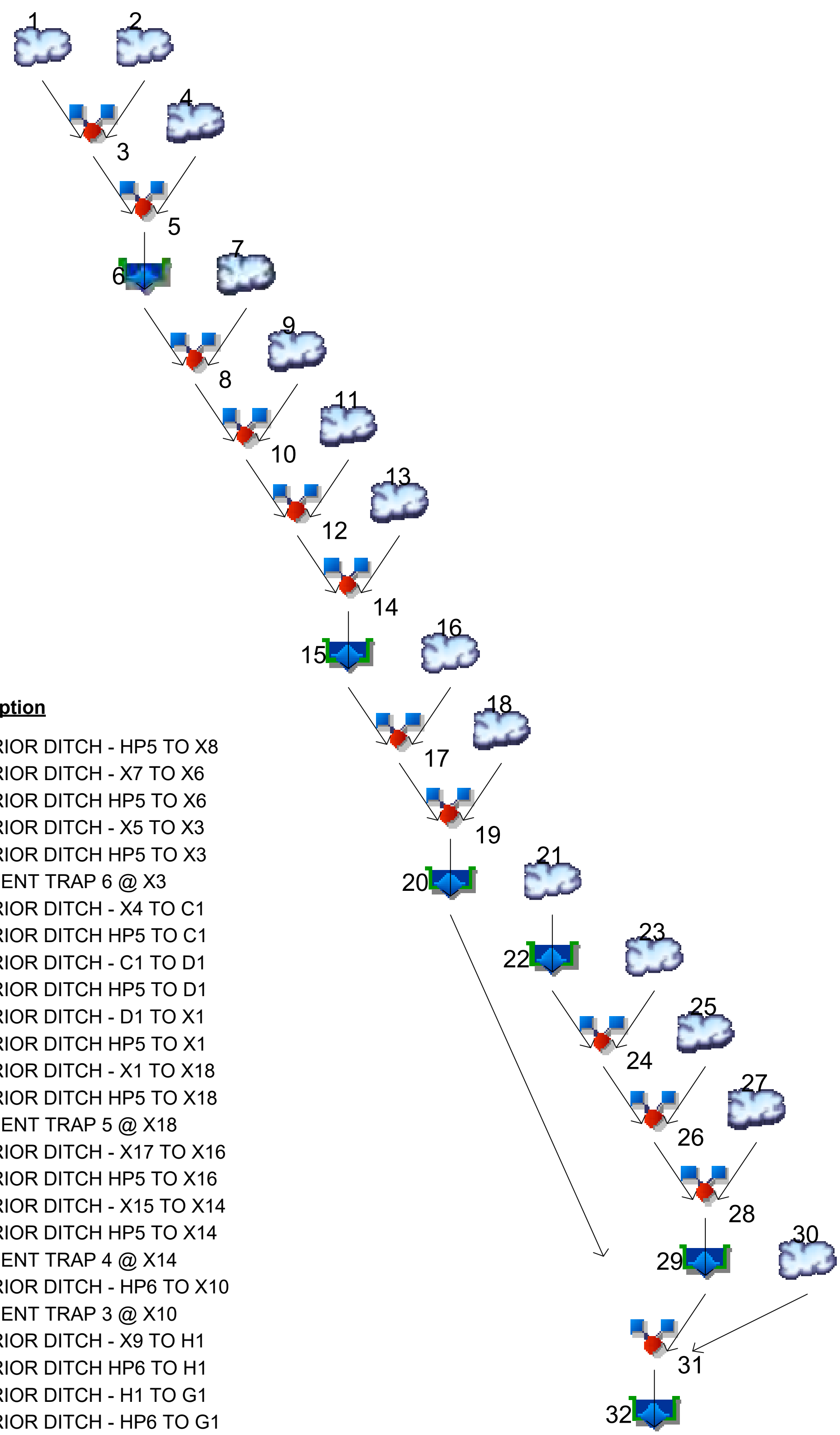
Channel Report

EXTERIOR DITCH - G1 TO X11

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 14.00	Depth (ft)	= 1.73
Side Slopes (z:1)	= 3.00, 3.00	Q (cfs)	= 201.80
Total Depth (ft)	= 7.00	Area (sqft)	= 33.20
Invert Elev (ft)	= 241.00	Velocity (ft/s)	= 6.08
Slope (%)	= 1.04	Wetted Perim (ft)	= 24.94
N-Value	= 0.030	Crit Depth, Yc (ft)	= 1.65
		Top Width (ft)	= 24.38
Calculations		EGL (ft)	= 2.30
Compute by:	Known Q		
Known Q (cfs)	= 201.80		



Watershed Model Schematic



Legend

Hyd.	**Origin**	**Description**
1	SCS Runoff	EXTERIOR DITCH - HP5 TO X8
2	SCS Runoff	EXTERIOR DITCH - X7 TO X6
3	Combine	EXTERIOR DITCH HP5 TO X6
4	SCS Runoff	EXTERIOR DITCH - X5 TO X3
5	Combine	EXTERIOR DITCH HP5 TO X3
6	Reservoir	SEDIMENT TRAP 6 @ X3
7	SCS Runoff	EXTERIOR DITCH - X4 TO C1
8	Combine	EXTERIOR DITCH HP5 TO C1
9	SCS Runoff	EXTERIOR DITCH - C1 TO D1
10	Combine	EXTERIOR DITCH HP5 TO D1
11	SCS Runoff	EXTERIOR DITCH - D1 TO X1
12	Combine	EXTERIOR DITCH HP5 TO X1
13	SCS Runoff	EXTERIOR DITCH - X1 TO X18
14	Combine	EXTERIOR DITCH HP5 TO X18
15	Reservoir	SEDIMENT TRAP 5 @ X18
16	SCS Runoff	EXTERIOR DITCH - X17 TO X16
17	Combine	EXTERIOR DITCH HP5 TO X16
18	SCS Runoff	EXTERIOR DITCH - X15 TO X14
19	Combine	EXTERIOR DITCH HP5 TO X14
20	Reservoir	SEDIMENT TRAP 4 @ X14
21	SCS Runoff	EXTERIOR DITCH - HP6 TO X10
22	Reservoir	SEDIMENT TRAP 3 @ X10
23	SCS Runoff	EXTERIOR DITCH - X9 TO H1
24	Combine	EXTERIOR DITCH HP6 TO H1
25	SCS Runoff	EXTERIOR DITCH - H1 TO G1
26	Combine	EXTERIOR DITCH - HP6 TO G1
27	SCS Runoff	EXTERIOR DITCH - G1 TO X11
28	Combine	EXTERIOR DITCH - HP6 TO X11
29	Reservoir	SEDIMENT TRAP 2 @ X11
30	SCS Runoff	WATERSHED - TOP DECK TO OC1
31	Combine	INLET TO SED TRAP @ OC1
32	Reservoir	SEDIMENT TRAP 1 @ OC1

Project: Exterior Ditch [with ponds].gpw

Friday, 01 / 30 / 2015

Hydrograph Summary Report

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	19.19	1	725	62,615	------	------	------	EXTERIOR DITCH - HP5 TO X8
2	SCS Runoff	19.42	1	725	63,345	------	------	------	EXTERIOR DITCH - X7 TO X6
3	Combine	38.61	1	725	125,960	1, 2	------	------	EXTERIOR DITCH HP5 TO X6
4	SCS Runoff	9.616	1	724	30,121	------	------	------	EXTERIOR DITCH - X5 TO X3
5	Combine	48.22	1	725	156,081	3, 4	------	------	EXTERIOR DITCH HP5 TO X3
6	Reservoir	5.078	1	774	119,277	5	257.81	125,160	SEDIMENT TRAP 6 @ X3
7	SCS Runoff	6.647	1	723	19,472	------	------	------	EXTERIOR DITCH - X4 TO C1
8	Combine	7.058	1	723	138,749	6, 7	------	------	EXTERIOR DITCH HP5 TO C1
9	SCS Runoff	173.02	1	728	636,139	------	------	------	EXTERIOR DITCH - C1 TO D1
10	Combine	178.09	1	728	774,889	8, 9	------	------	EXTERIOR DITCH HP5 TO D1
11	SCS Runoff	73.36	1	724	229,768	------	------	------	EXTERIOR DITCH - D1 TO X1
12	Combine	244.64	1	726	1,004,657	10, 11	------	------	EXTERIOR DITCH HP5 TO X1
13	SCS Runoff	51.51	1	723	150,909	------	------	------	EXTERIOR DITCH - X1 TO X18
14	Combine	287.80	1	726	1,155,566	12, 13	------	------	EXTERIOR DITCH HP5 TO X18
15	Reservoir	27.84	1	813	1,122,583	14	250.33	620,543	SEDIMENT TRAP 5 @ X18
16	SCS Runoff	103.80	1	723	304,064	------	------	------	EXTERIOR DITCH - X17 TO X16
17	Combine	122.43	1	723	1,426,648	15, 16	------	------	EXTERIOR DITCH HP5 TO X16
18	SCS Runoff	42.91	1	722	118,307	------	------	------	EXTERIOR DITCH - X15 TO X14
19	Combine	163.48	1	723	1,544,954	17, 18	------	------	EXTERIOR DITCH HP5 TO X14
20	Reservoir	31.19	1	968	1,537,197	19	247.61	328,229	SEDIMENT TRAP 4 @ X14
21	SCS Runoff	123.29	1	724	386,165	------	------	------	EXTERIOR DITCH - HP6 TO X10
22	Reservoir	17.56	1	755	369,897	21	252.28	260,417	SEDIMENT TRAP 3 @ X10
23	SCS Runoff	15.72	1	723	46,059	------	------	------	EXTERIOR DITCH - X9 TO H1
24	Combine	23.94	1	731	415,956	22, 23	------	------	EXTERIOR DITCH HP6 TO H1
25	SCS Runoff	98.36	1	723	288,149	------	------	------	EXTERIOR DITCH - H1 TO G1
26	Combine	117.63	1	723	704,106	24, 25	------	------	EXTERIOR DITCH - HP6 TO G1
27	SCS Runoff	84.17	1	723	246,584	------	------	------	EXTERIOR DITCH - G1 TO X11
28	Combine	201.80	1	723	950,689	26, 27	------	------	EXTERIOR DITCH - HP6 TO X11
29	Reservoir	14.72	1	925	577,516	28	246.77	1,129,301	SEDIMENT TRAP 2 @ X11
30	SCS Runoff	235.48	1	724	737,576	------	------	------	WATERSHED - TOP DECK TO OC1
31	Combine	254.87	1	725	2,852,292	20, 29, 30	------	------	INLET TO SED TRAP @ OC1
32	Reservoir	34.89	1	1291	2,438,157	31	237.64	1,382,721	SEDIMENT TRAP 1 @ OC1

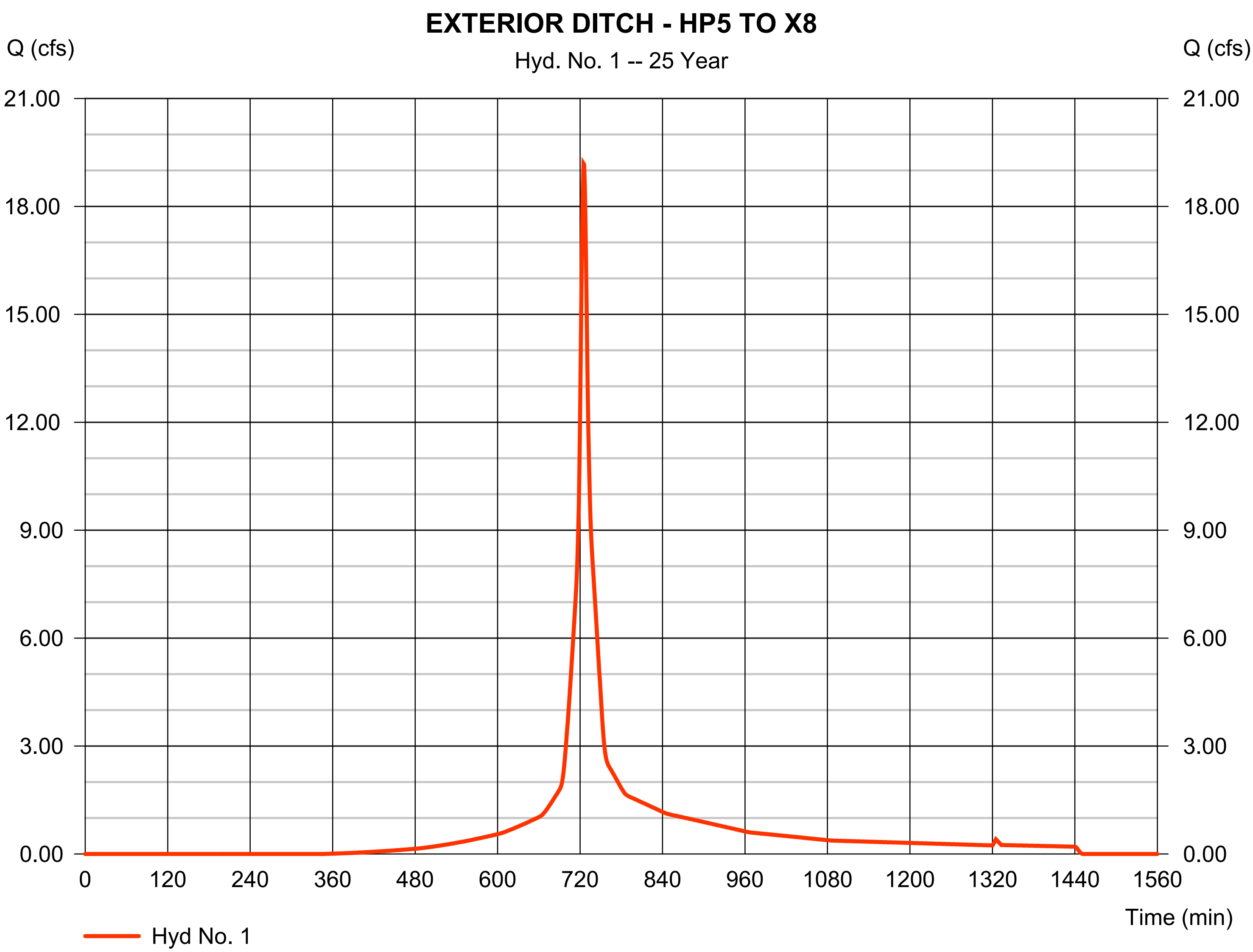
Exterior Ditch [with ponds].gpw	Return Period: 25 Year	Friday, 01 / 30 / 2015

Hydrograph Report

Hyd. No. 1

EXTERIOR DITCH - HP5 TO X8

Hydrograph type	= SCS Runoff	Peak discharge	= 19.19 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 62,615 cuft
Drainage area	= 3.430 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.30 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

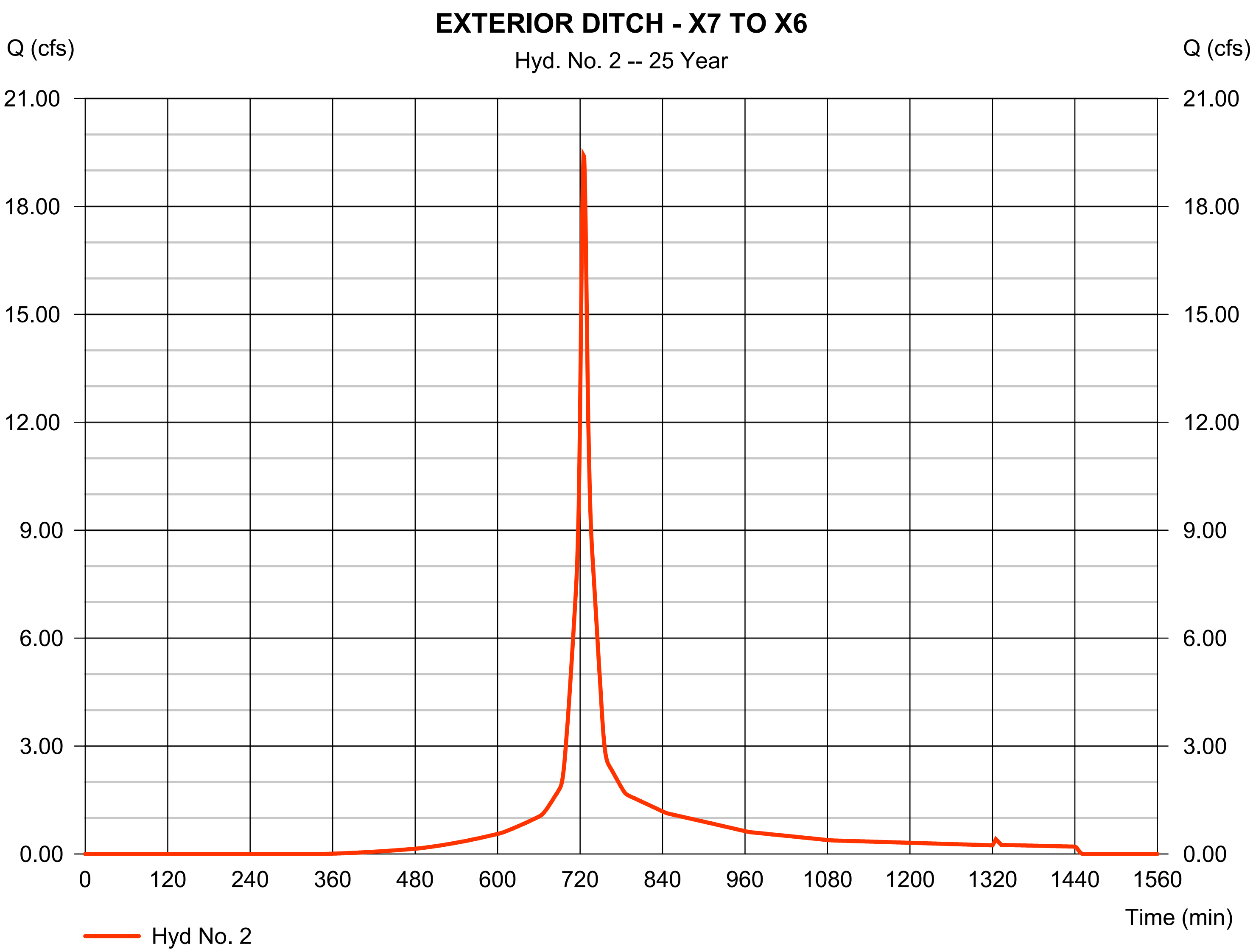


Hydrograph Report

Hyd. No. 2

EXTERIOR DITCH - X7 TO X6

Hydrograph type	= SCS Runoff	Peak discharge	= 19.42 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 63,345 cuft
Drainage area	= 3.470 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.70 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

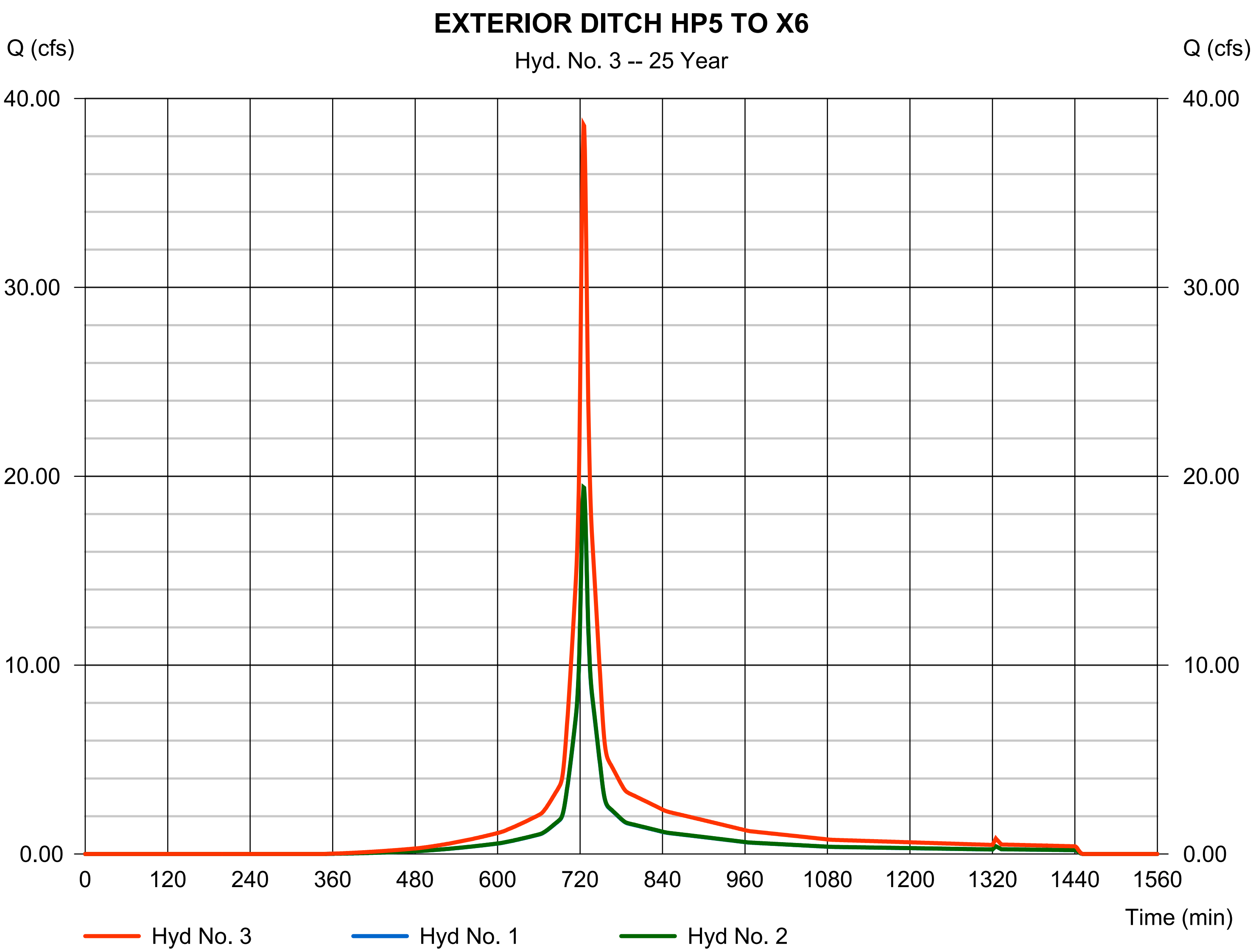


Hydrograph Report

Hyd. No. 3

EXTERIOR DITCH HP5 TO X6

Hydrograph type	= Combine	Peak discharge	= 38.61 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 125,960 cuft
Inflow hyds.	= 1, 2	Contrib. drain. area	= 6.900 ac

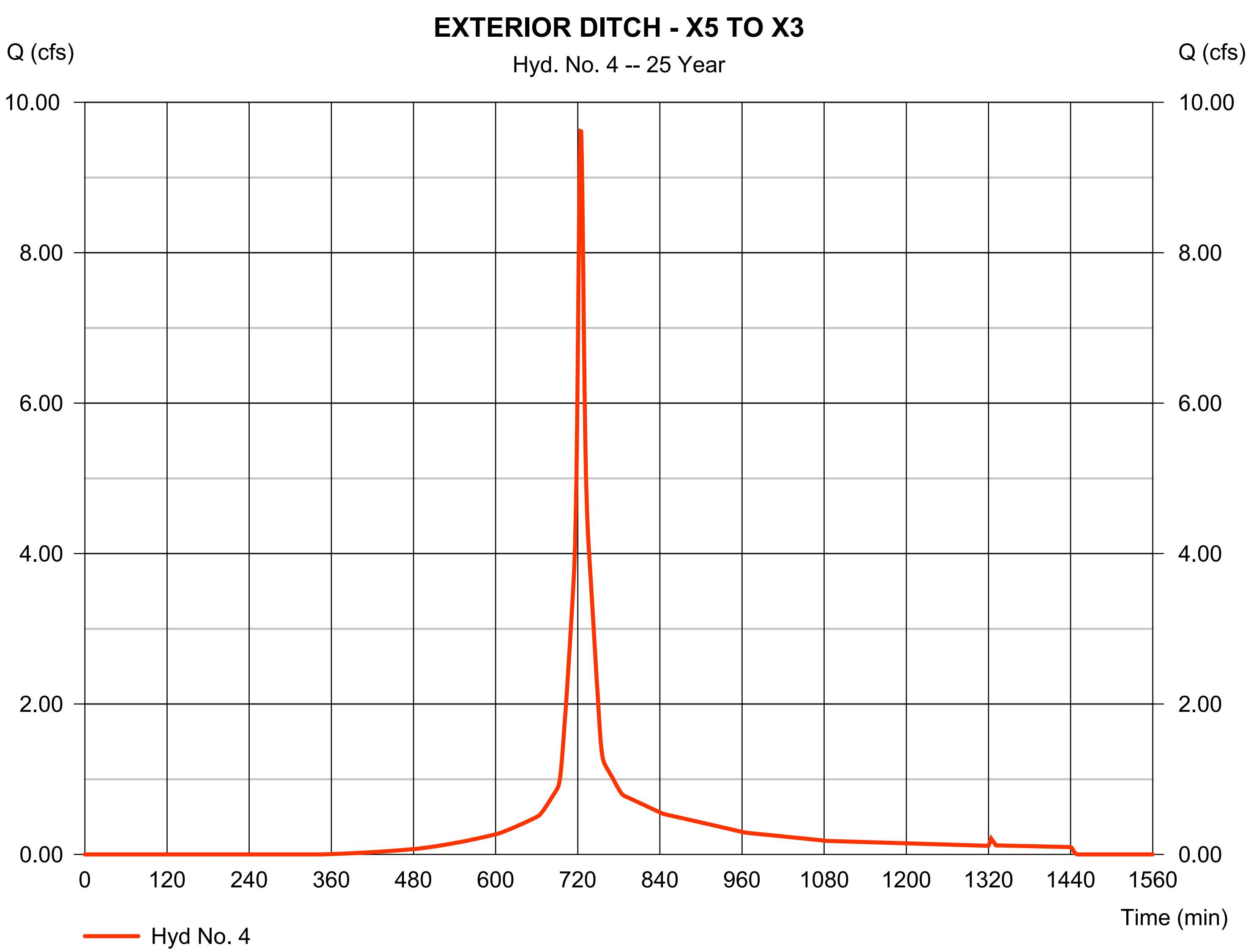


Hydrograph Report

Hyd. No. 4

EXTERIOR DITCH - X5 TO X3

Hydrograph type	= SCS Runoff	Peak discharge	= 9.616 cfs
Storm frequency	= 25 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 30,121 cuft
Drainage area	= 1.560 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.90 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

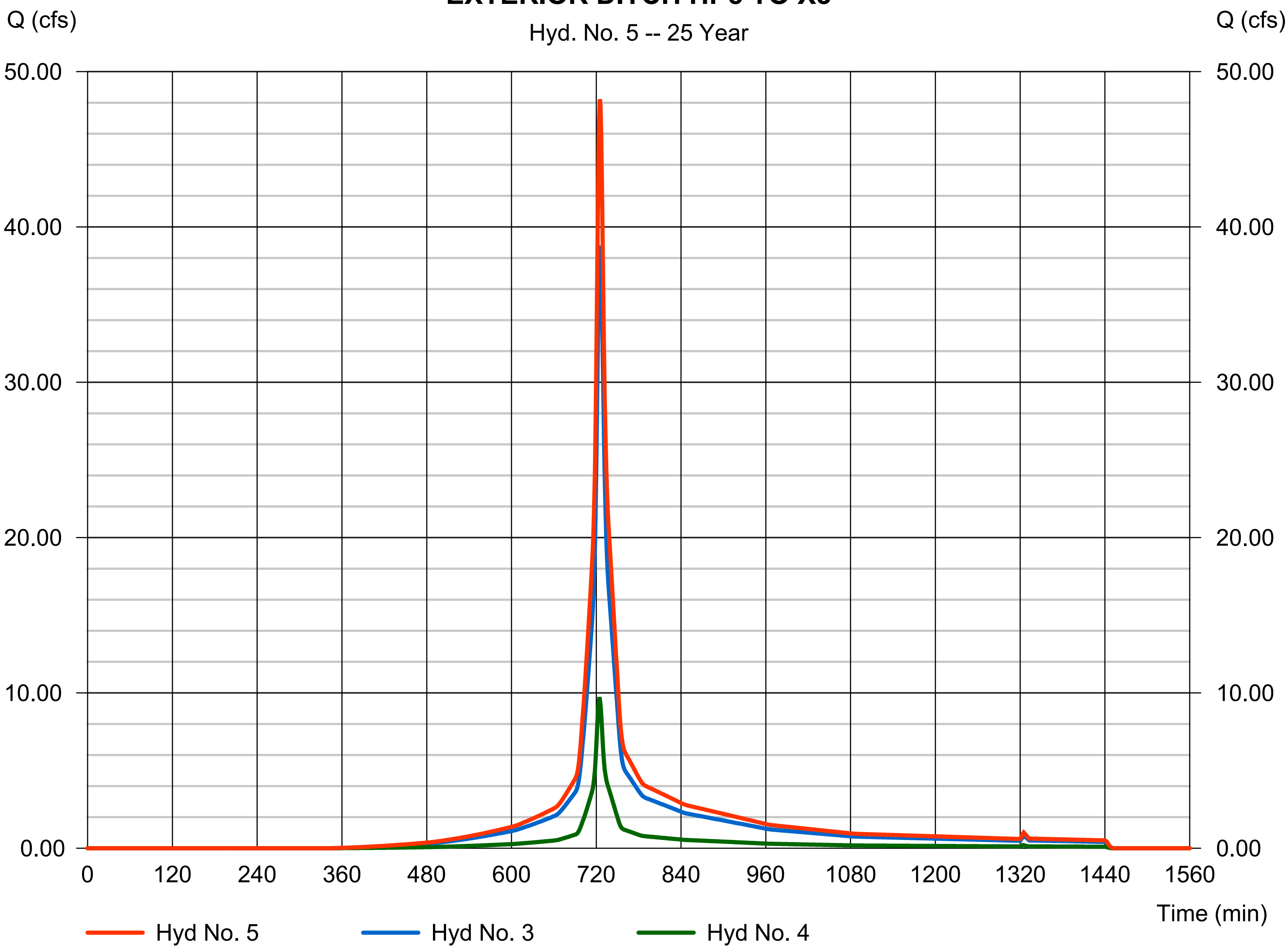
Hyd. No. 5

EXTERIOR DITCH HP5 TO X3

Hydrograph type	= Combine	Peak discharge	= 48.22 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 156,081 cuft
Inflow hyds.	= 3, 4	Contrib. drain. area	= 1.560 ac

EXTERIOR DITCH HP5 TO X3

Hyd. No. 5 -- 25 Year



Hydrograph Report

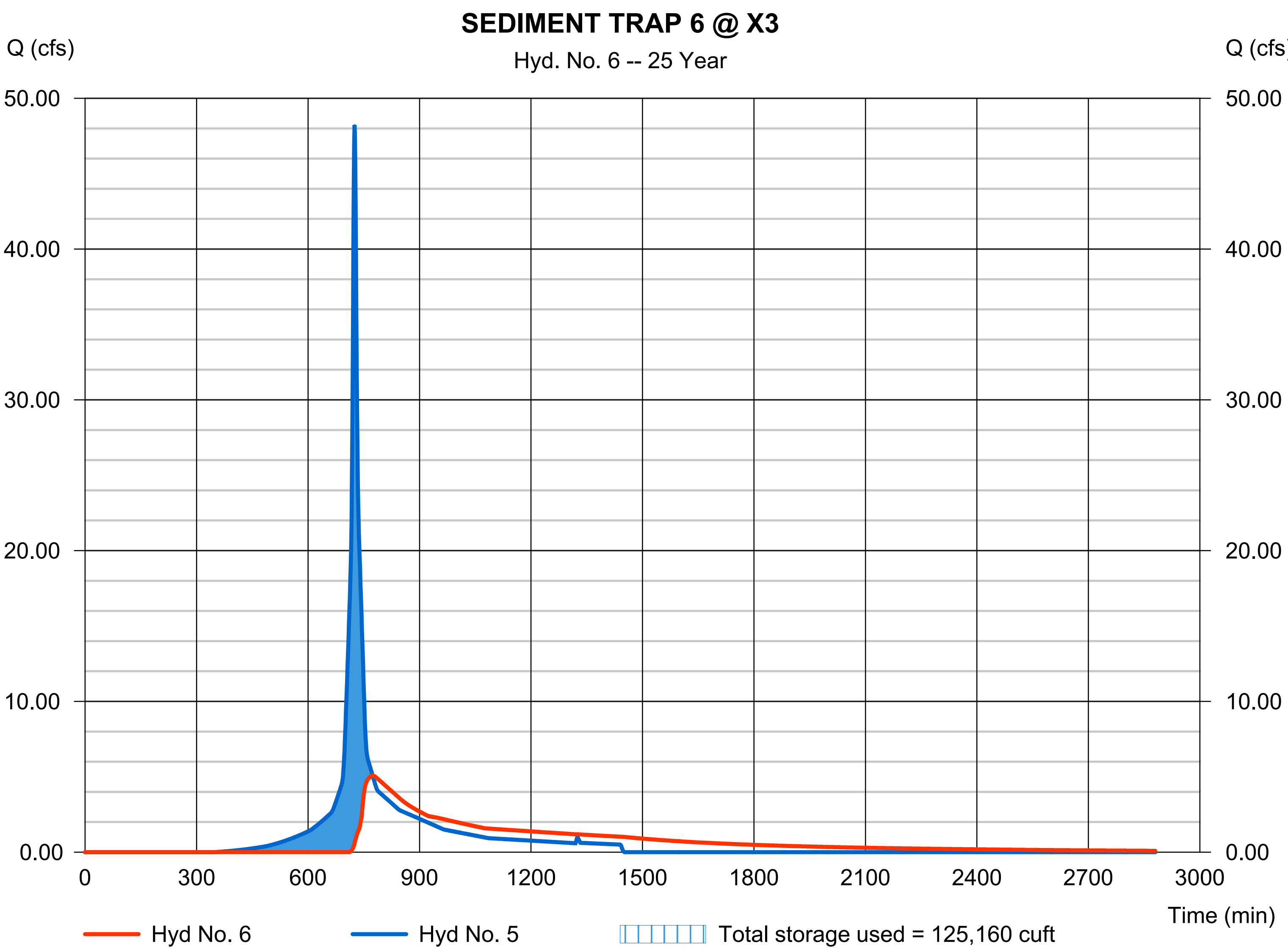
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 6

SEDIMENT TRAP 6 @ X3

Hydrograph type	= Reservoir	Peak discharge	= 5.078 cfs
Storm frequency	= 25 yrs	Time to peak	= 774 min
Time interval	= 1 min	Hyd. volume	= 119,277 cuft
Inflow hyd. No.	= 5 - EXTERIOR DITCH HP5 TO X3	Max. Elevation	= 257.81 ft
Reservoir name	= SEDIMENT TRAP 6 @ X3	Max. Storage	= 125,160 cuft

Storage Indication method used. Wet pond routing start elevation = 254.00 ft.

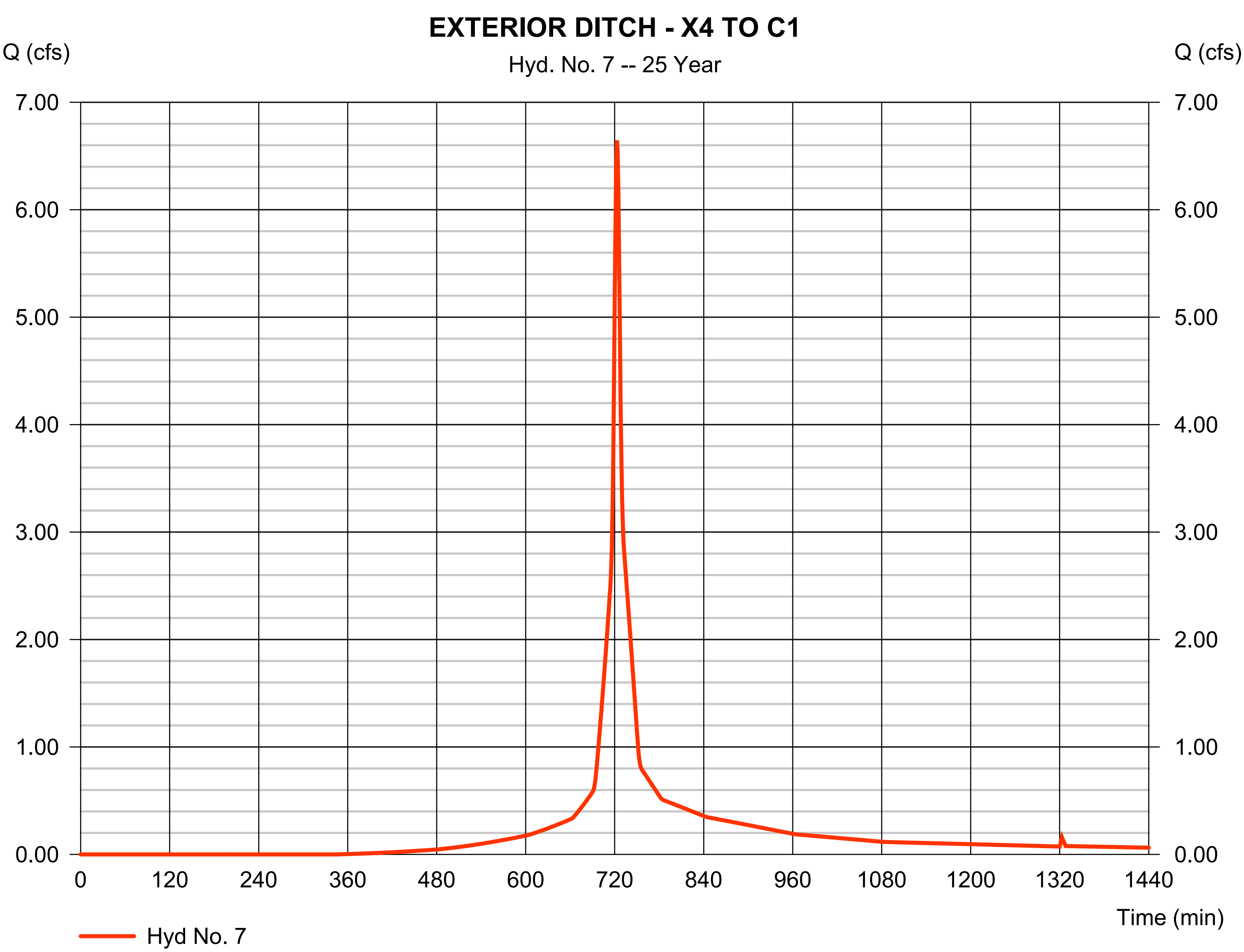


Hydrograph Report

Hyd. No. 7

EXTERIOR DITCH - X4 TO C1

Hydrograph type	= SCS Runoff	Peak discharge	= 6.647 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 19,472 cuft
Drainage area	= 1.040 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.70 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

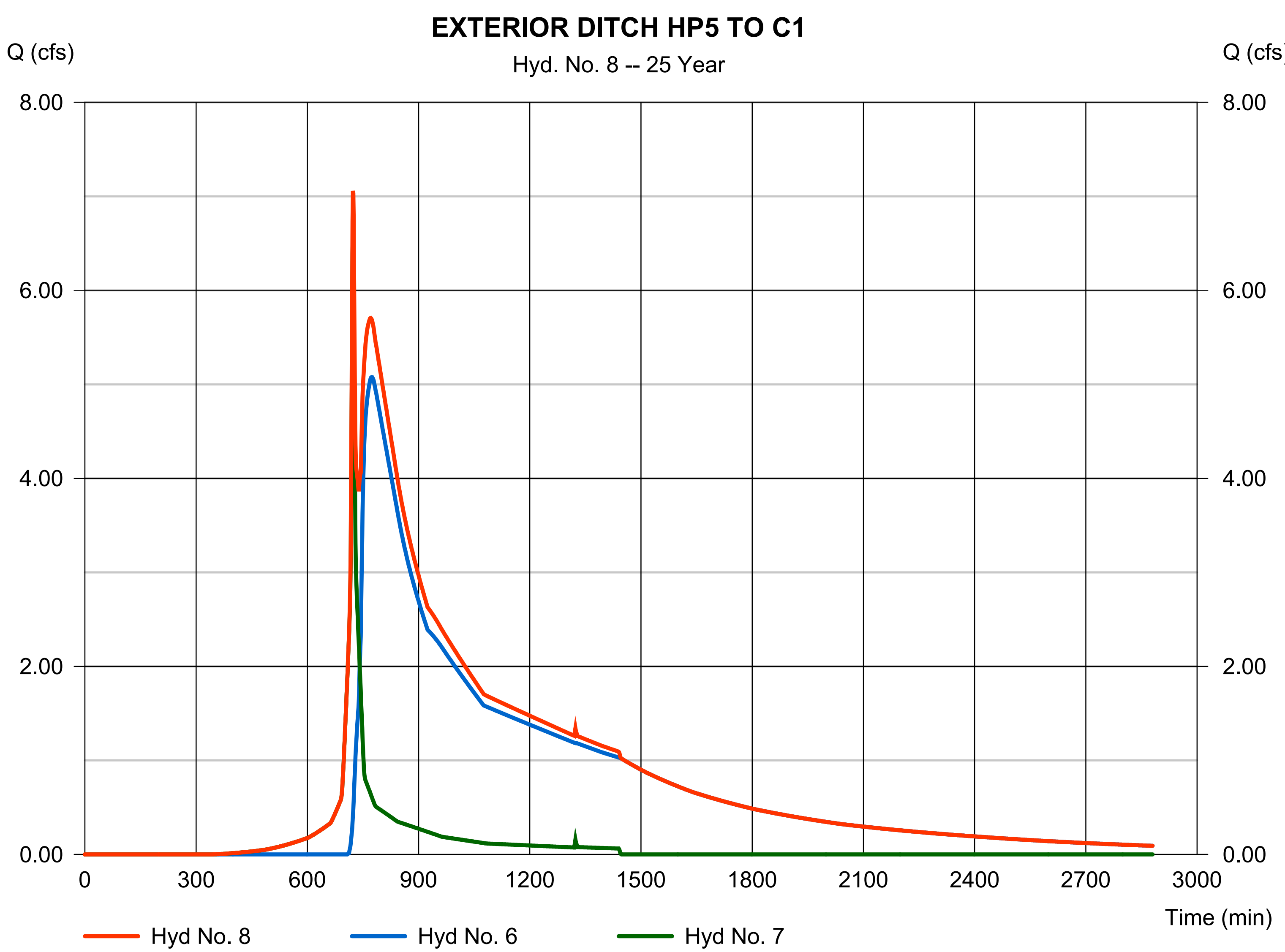


Hydrograph Report

Hyd. No. 8

EXTERIOR DITCH HP5 TO C1

Hydrograph type	= Combine	Peak discharge	= 7.058 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 138,749 cuft
Inflow hyds.	= 6, 7	Contrib. drain. area	= 1.040 ac

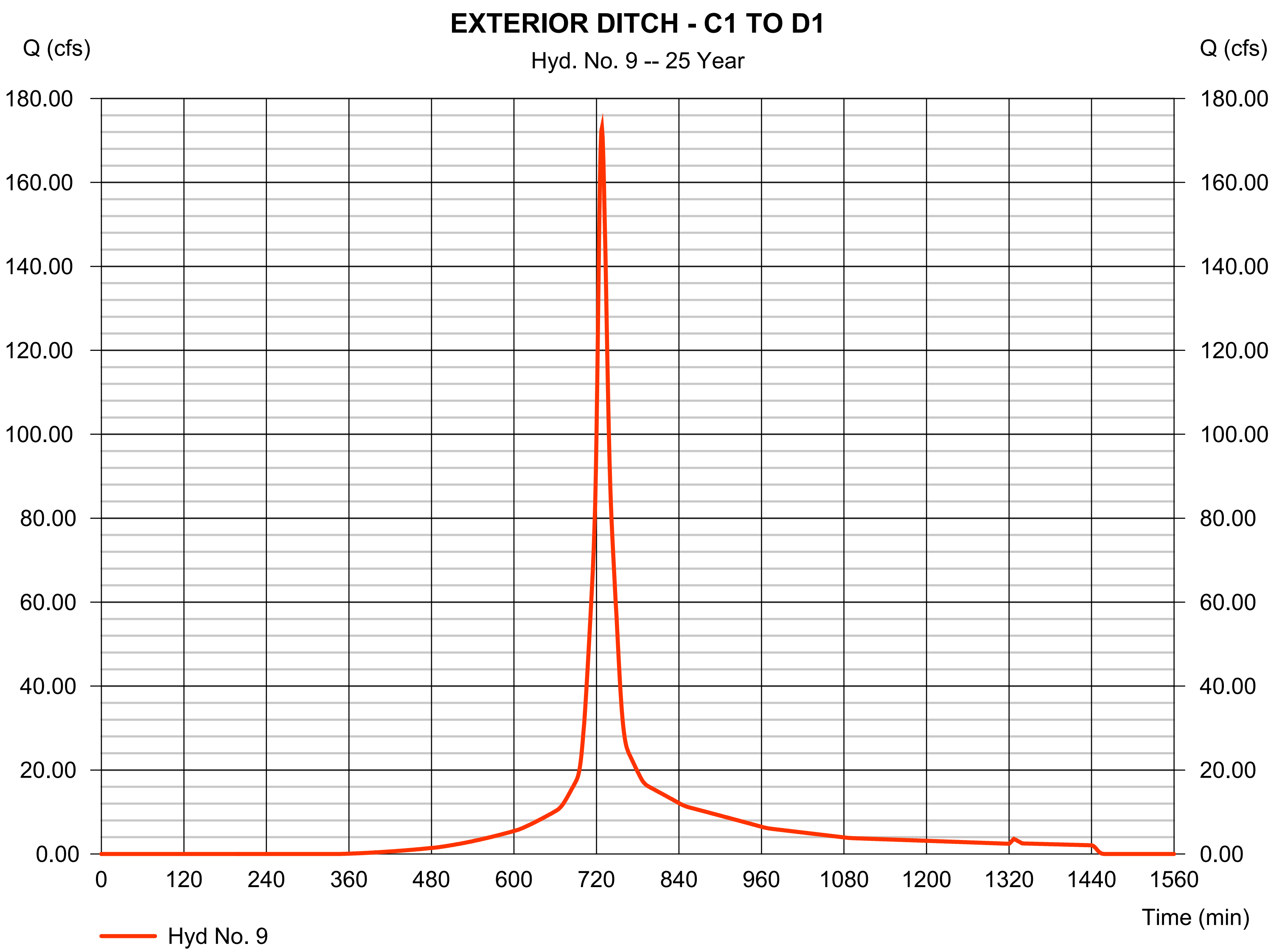


Hydrograph Report

Hyd. No. 9

EXTERIOR DITCH - C1 TO D1

Hydrograph type	= SCS Runoff	Peak discharge	= 173.02 cfs
Storm frequency	= 25 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 636,139 cuft
Drainage area	= 33.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

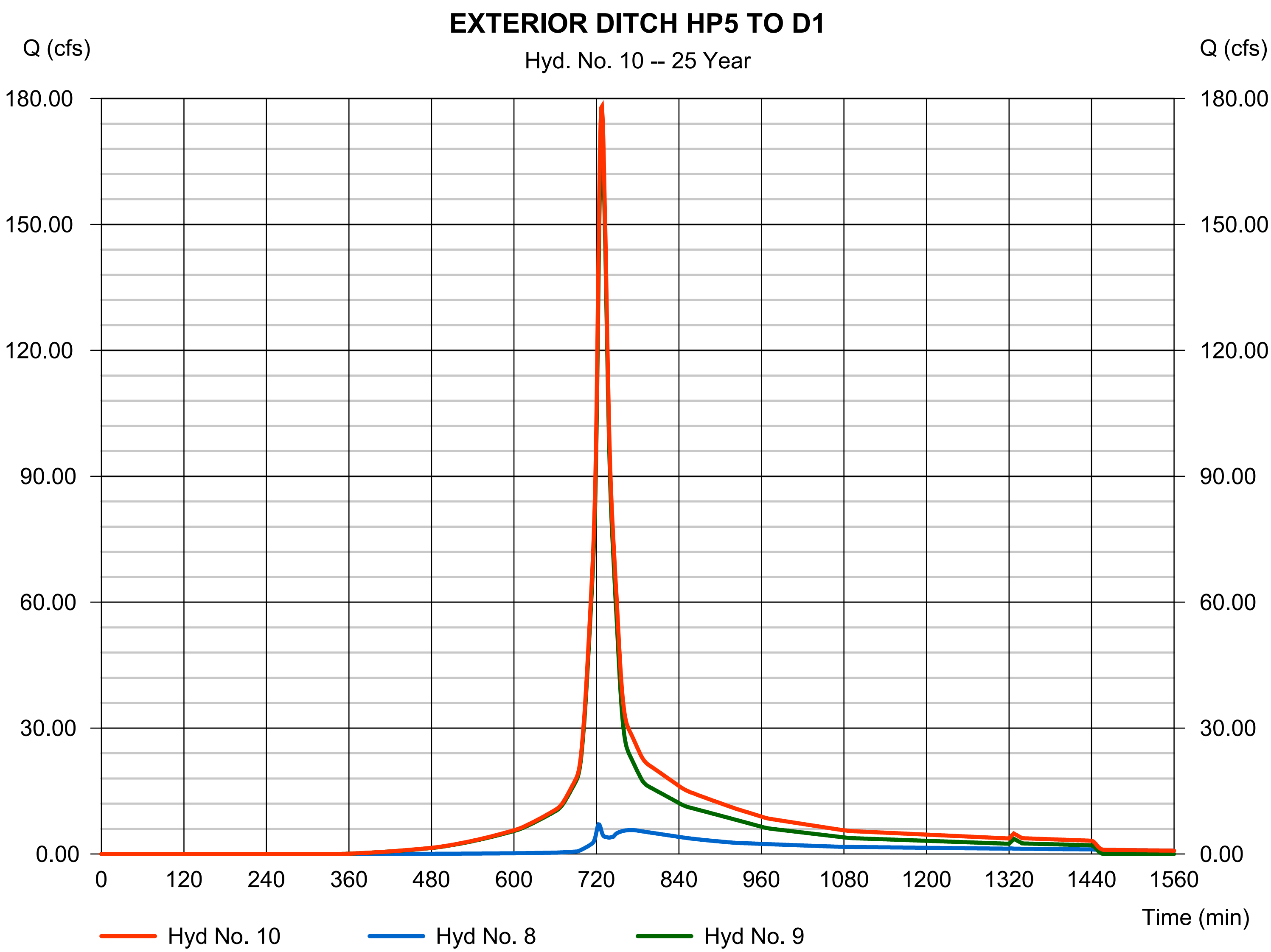


Hydrograph Report

Hyd. No. 10

EXTERIOR DITCH HP5 TO D1

Hydrograph type	= Combine	Peak discharge	= 178.09 cfs
Storm frequency	= 25 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 774,889 cuft
Inflow hyds.	= 8, 9	Contrib. drain. area	= 33.380 ac

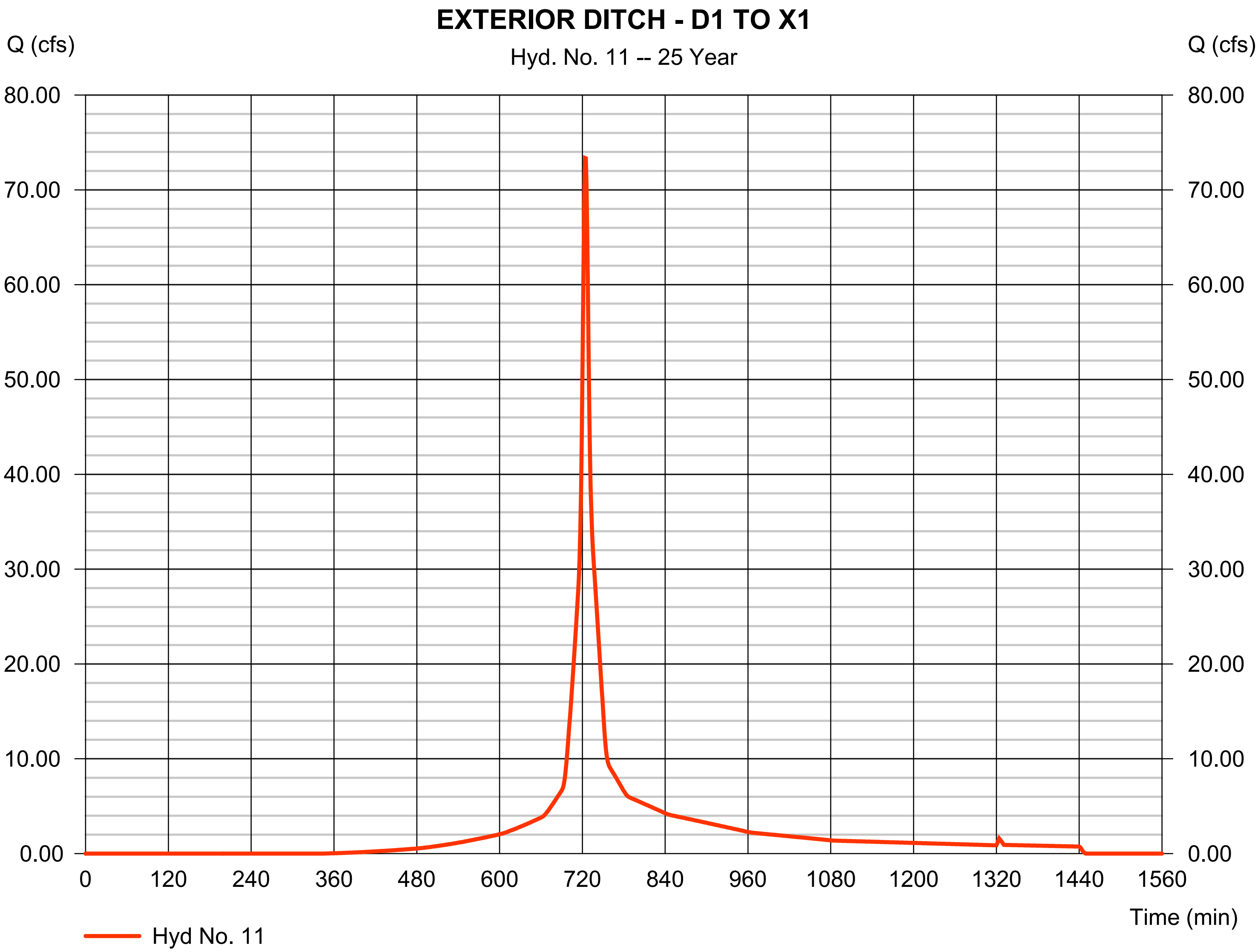


Hydrograph Report

Hyd. No. 11

EXTERIOR DITCH - D1 TO X1

Hydrograph type	= SCS Runoff	Peak discharge	= 73.36 cfs
Storm frequency	= 25 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 229,768 cuft
Drainage area	= 11.900 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.20 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



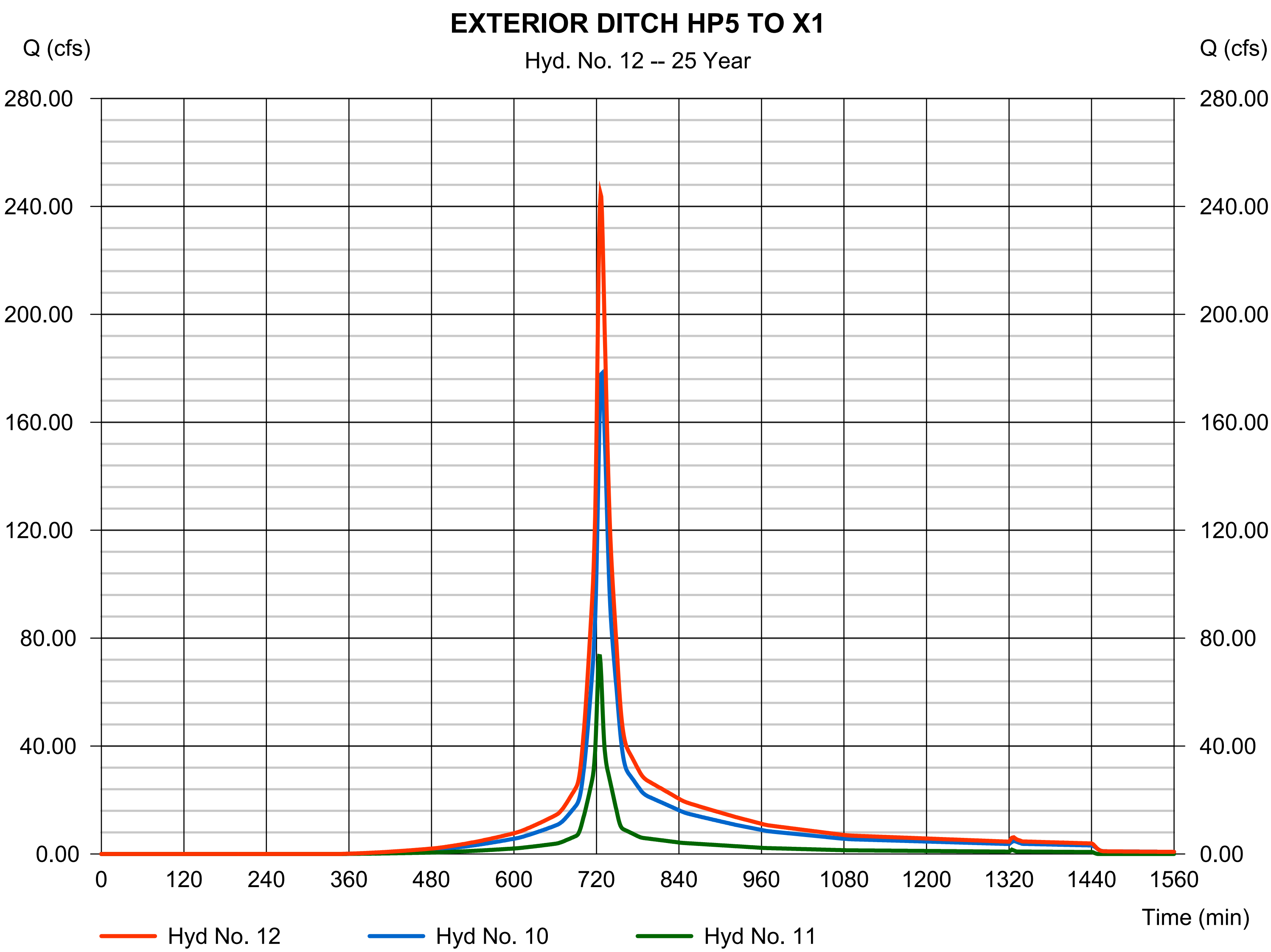
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 | Friday, 01 / 30 / 2015

Hyd. No. 12

EXTERIOR DITCH HP5 TO X1

Hydrograph type	= Combine	Peak discharge	= 244.64 cfs
Storm frequency	= 25 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,004,657 cuft
Inflow hyds.	= 10, 11	Contrib. drain. area	= 11.900 ac

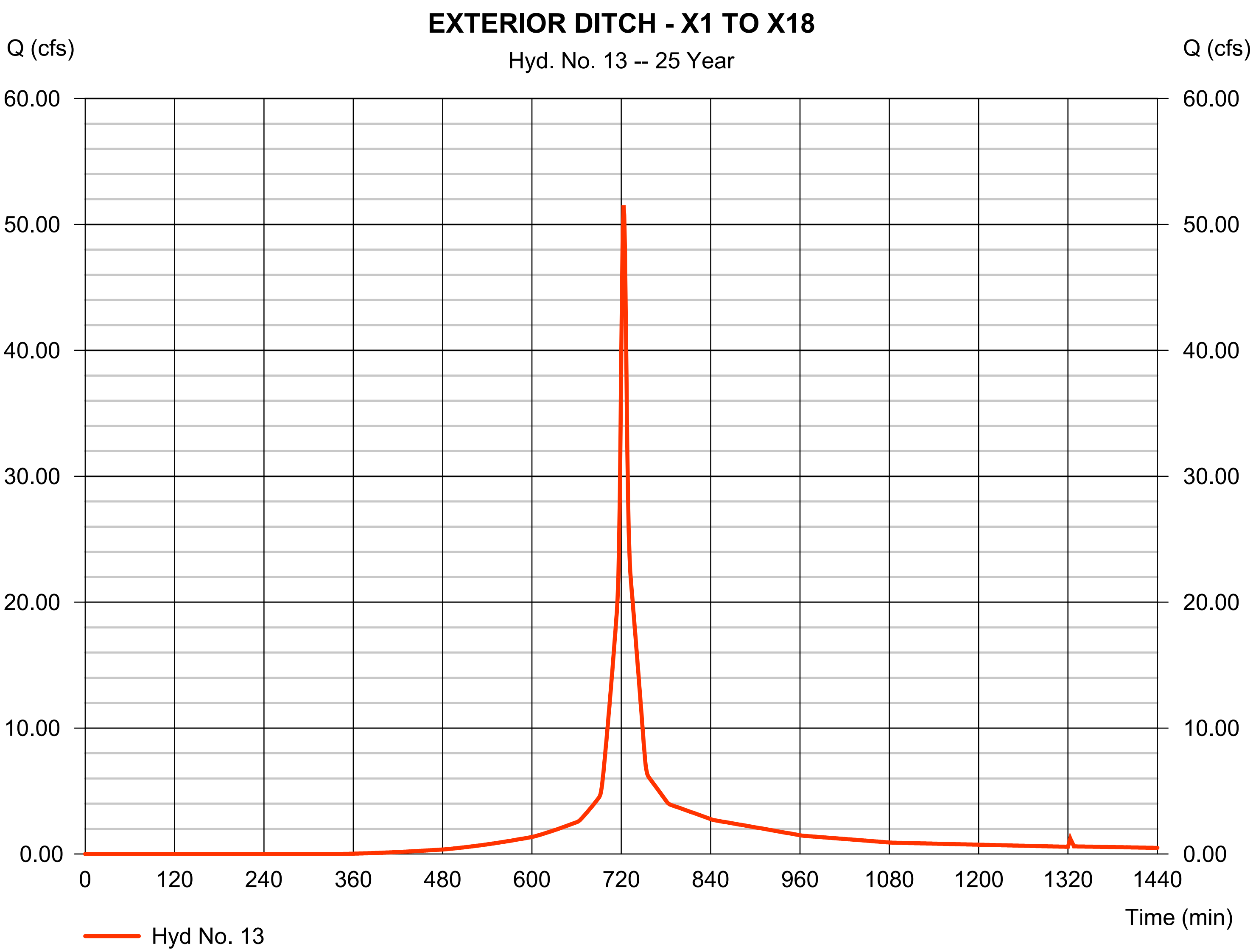


Hydrograph Report

Hyd. No. 13

EXTERIOR DITCH - X1 TO X18

Hydrograph type	= SCS Runoff	Peak discharge	= 51.51 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 150,909 cuft
Drainage area	= 8.060 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.80 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

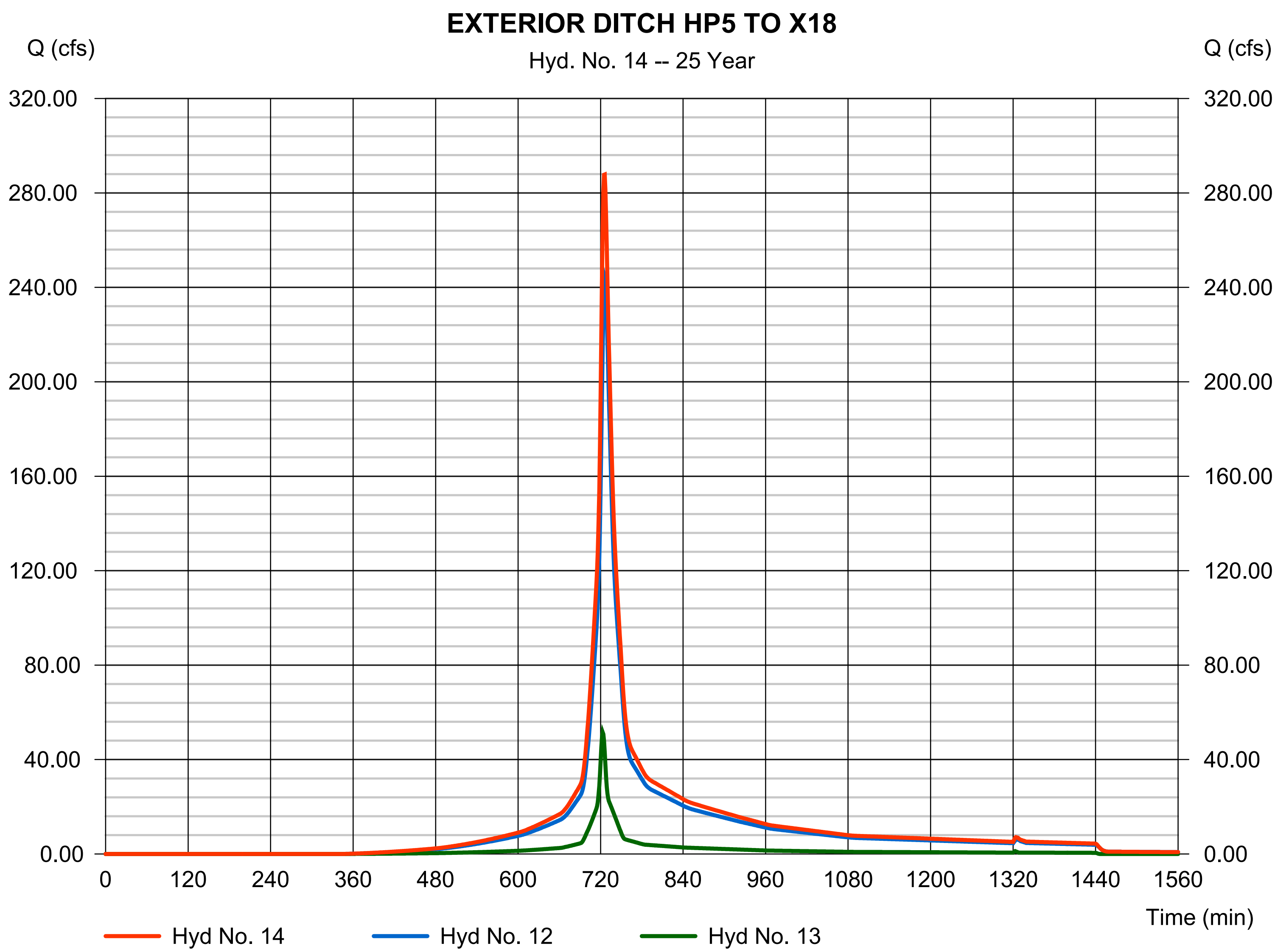


Hydrograph Report

Hyd. No. 14

EXTERIOR DITCH HP5 TO X18

Hydrograph type	= Combine	Peak discharge	= 287.80 cfs
Storm frequency	= 25 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,155,566 cuft
Inflow hyds.	= 12, 13	Contrib. drain. area	= 8.060 ac



Hydrograph Report

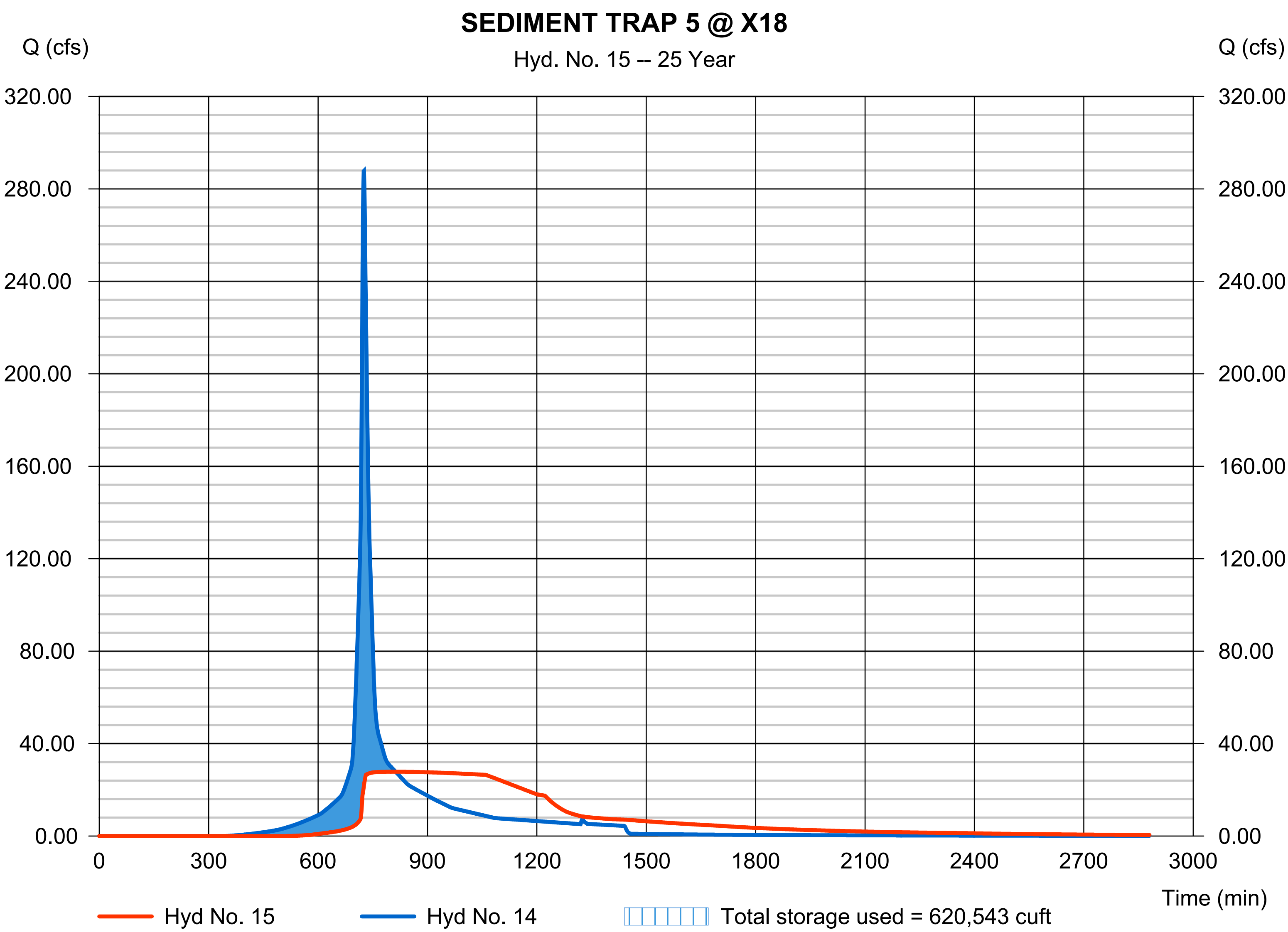
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 15

SEDIMENT TRAP 5 @ X18

Hydrograph type	= Reservoir	Peak discharge	= 27.84 cfs
Storm frequency	= 25 yrs	Time to peak	= 813 min
Time interval	= 1 min	Hyd. volume	= 1,122,583 cuft
Inflow hyd. No.	= 14 - EXTERIOR DITCH HP5 TO X18	Max. Elevation	= 250.33 ft
Reservoir name	= SEDIMENT TRAP 5 @ X18	Max. Storage	= 620,543 cuft

Storage Indication method used. Wet pond routing start elevation = 242.00 ft.

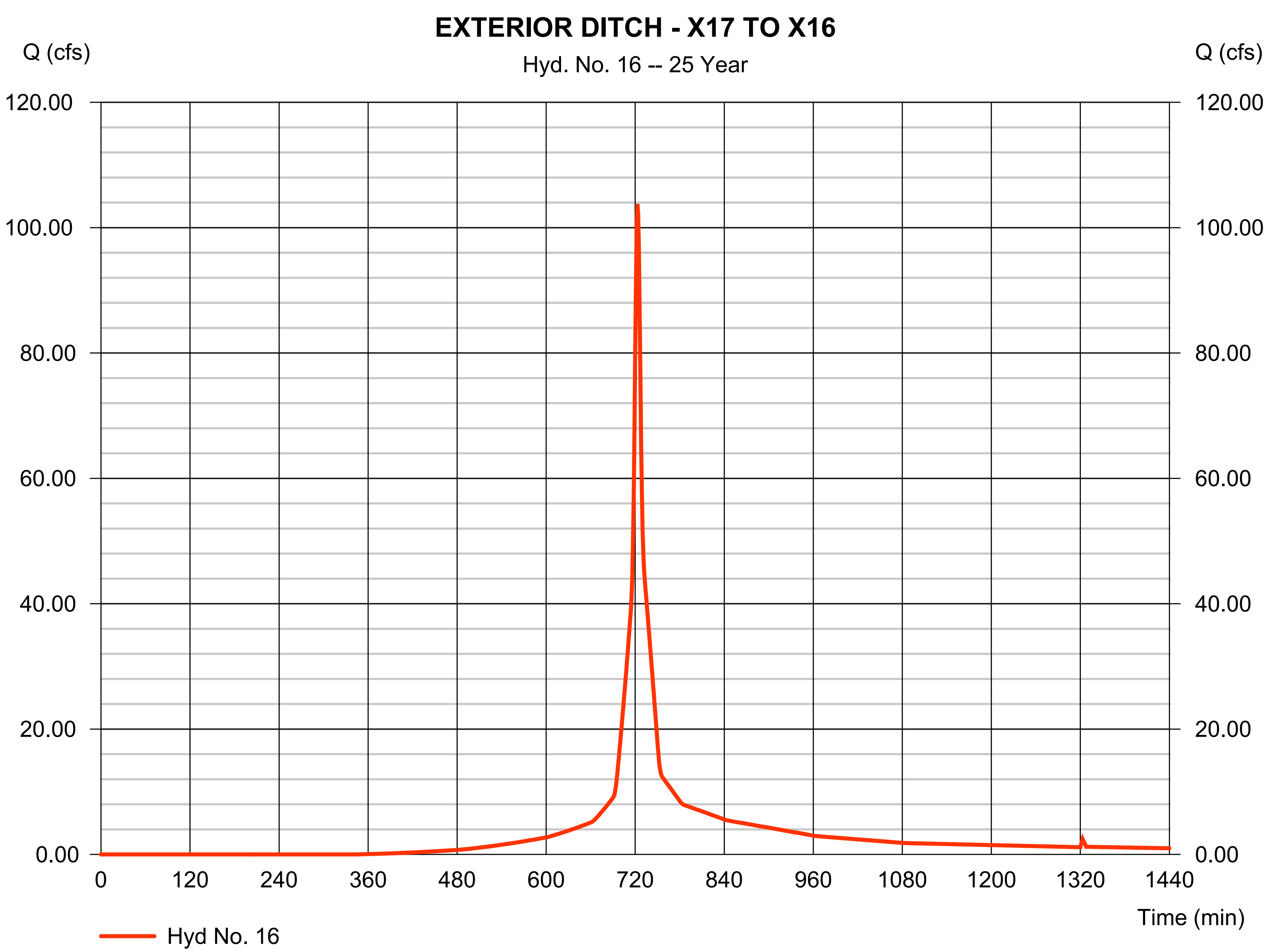


Hydrograph Report

Hyd. No. 16

EXTERIOR DITCH - X17 TO X16

Hydrograph type	= SCS Runoff	Peak discharge	= 103.80 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 304,064 cuft
Drainage area	= 16.240 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



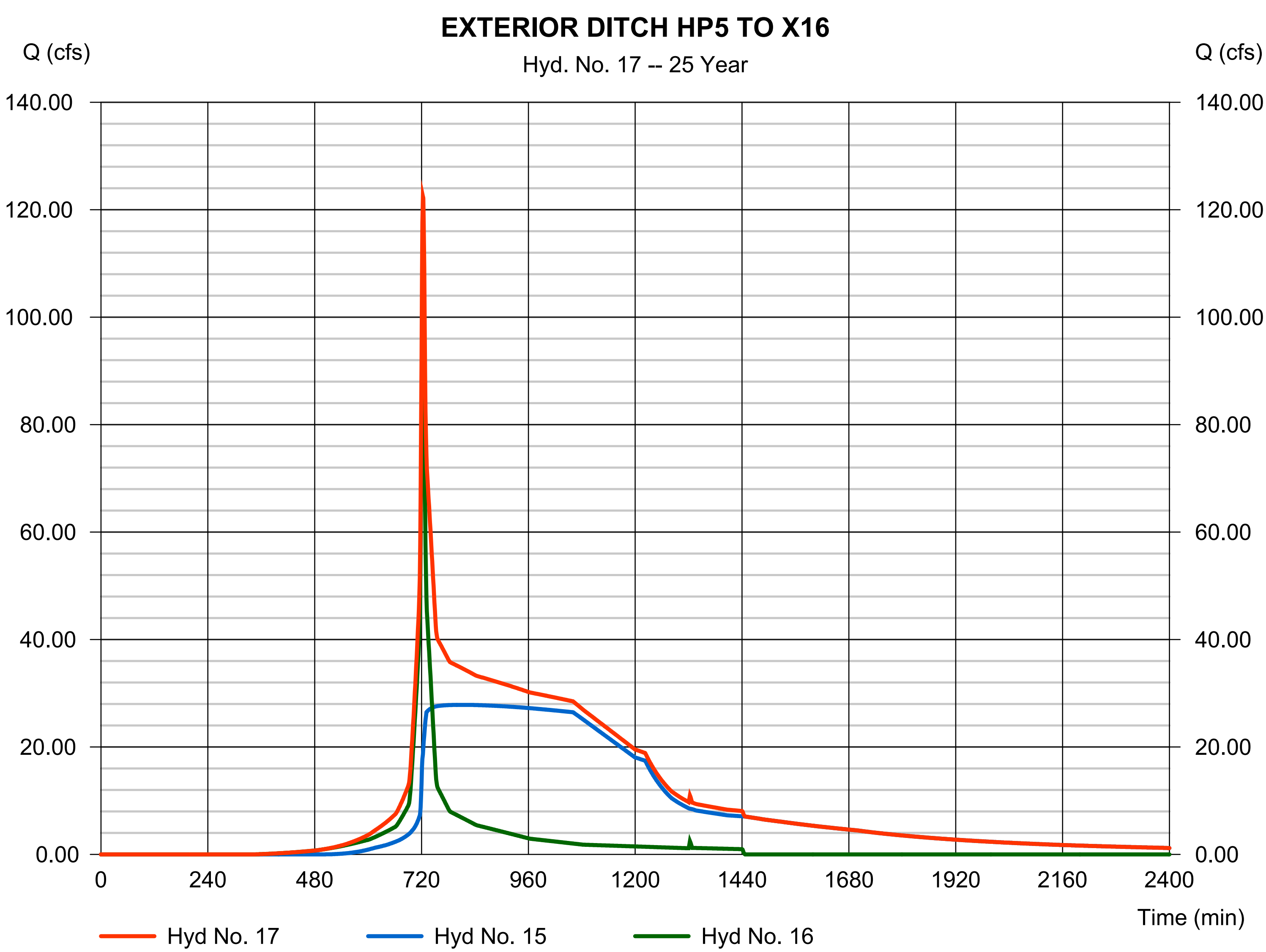
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 17

EXTERIOR DITCH HP5 TO X16

Hydrograph type	= Combine	Peak discharge	= 122.43 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 1,426,648 cuft
Inflow hyds.	= 15, 16	Contrib. drain. area	= 16.240 ac

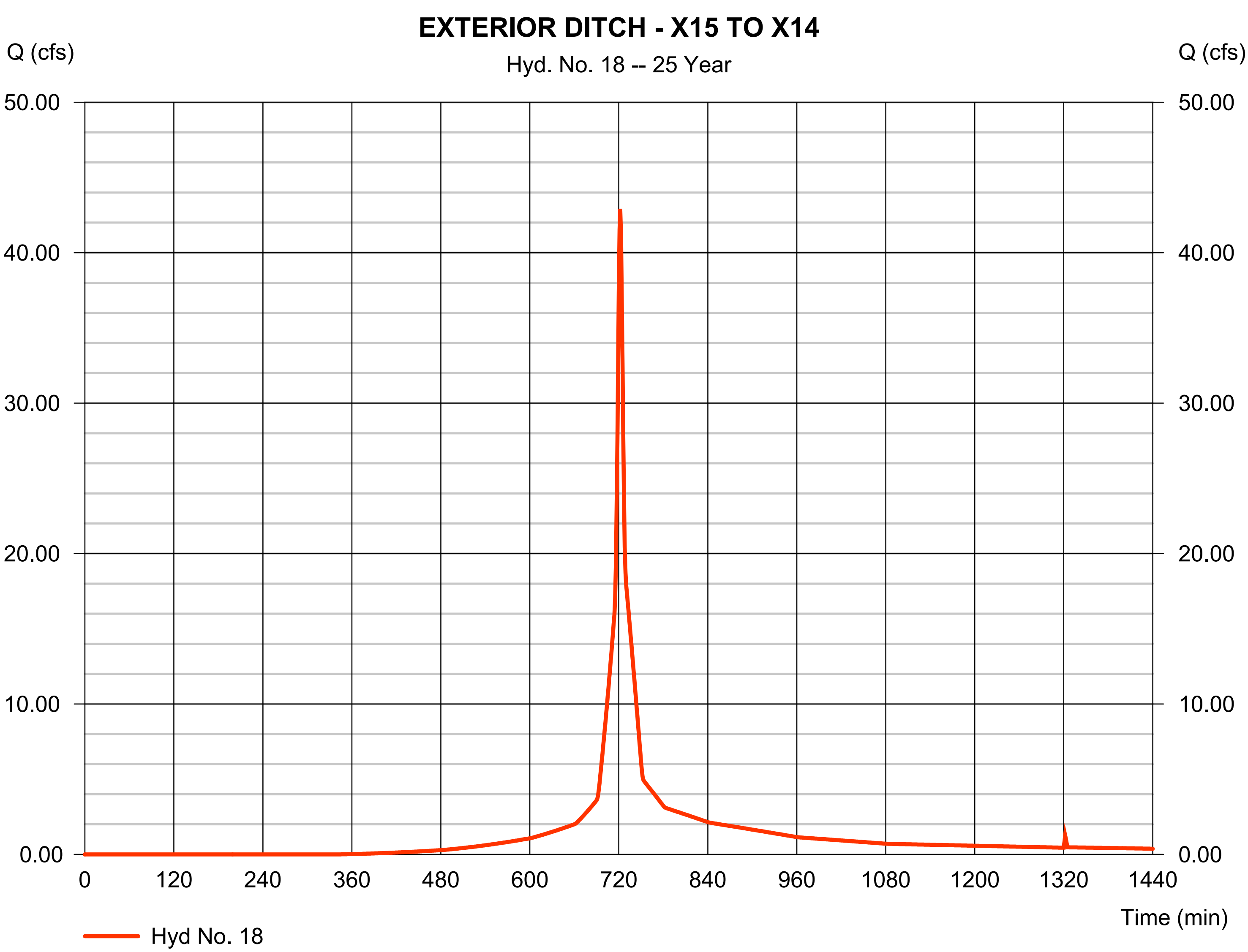


Hydrograph Report

Hyd. No. 18

EXTERIOR DITCH - X15 TO X14

Hydrograph type	= SCS Runoff	Peak discharge	= 42.91 cfs
Storm frequency	= 25 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 118,307 cuft
Drainage area	= 6.740 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 2.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



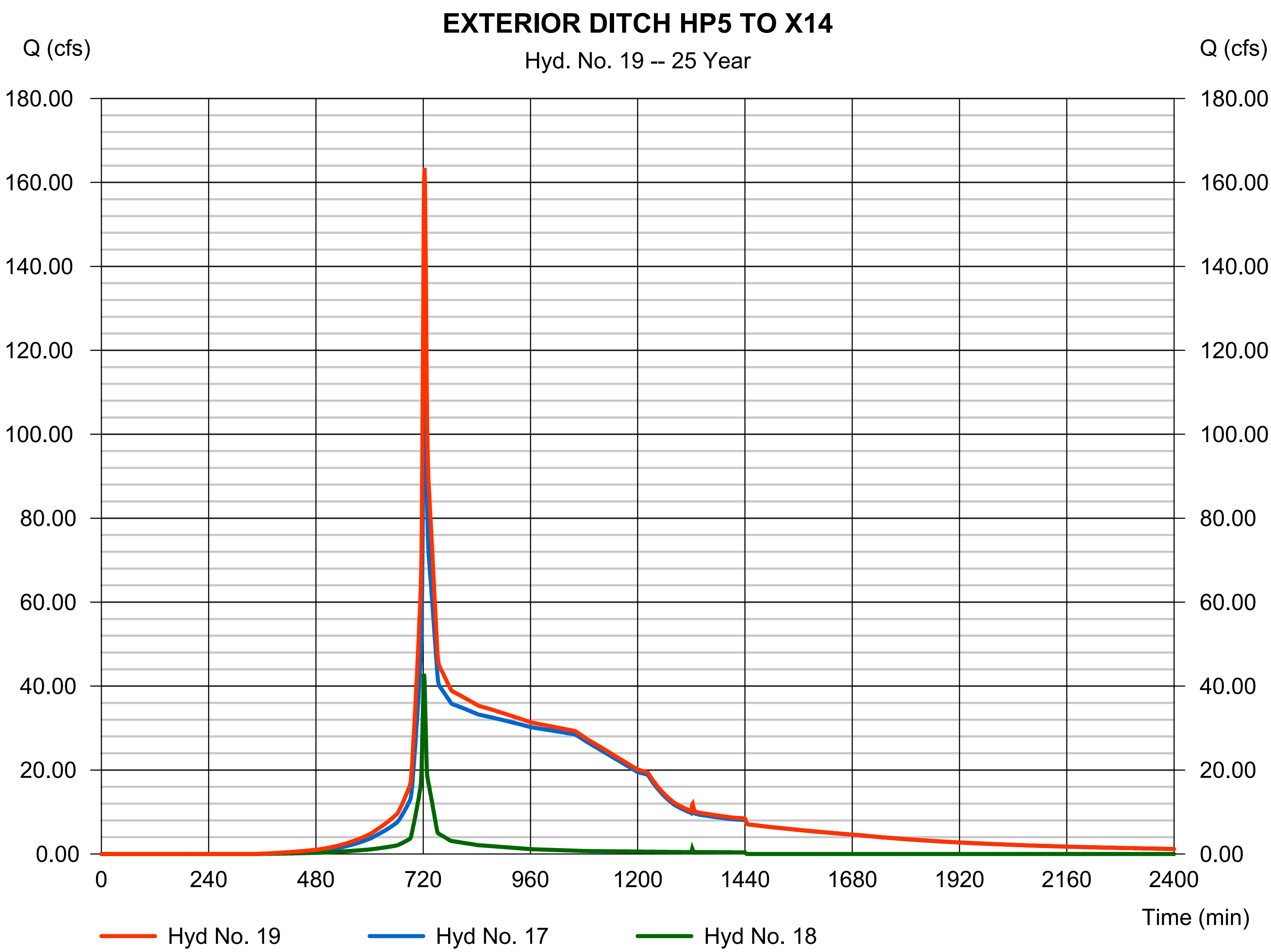
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 19

EXTERIOR DITCH HP5 TO X14

Hydrograph type	= Combine	Peak discharge	= 163.48 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 1,544,954 cuft
Inflow hyds.	= 17, 18	Contrib. drain. area	= 6.740 ac



Hydrograph Report

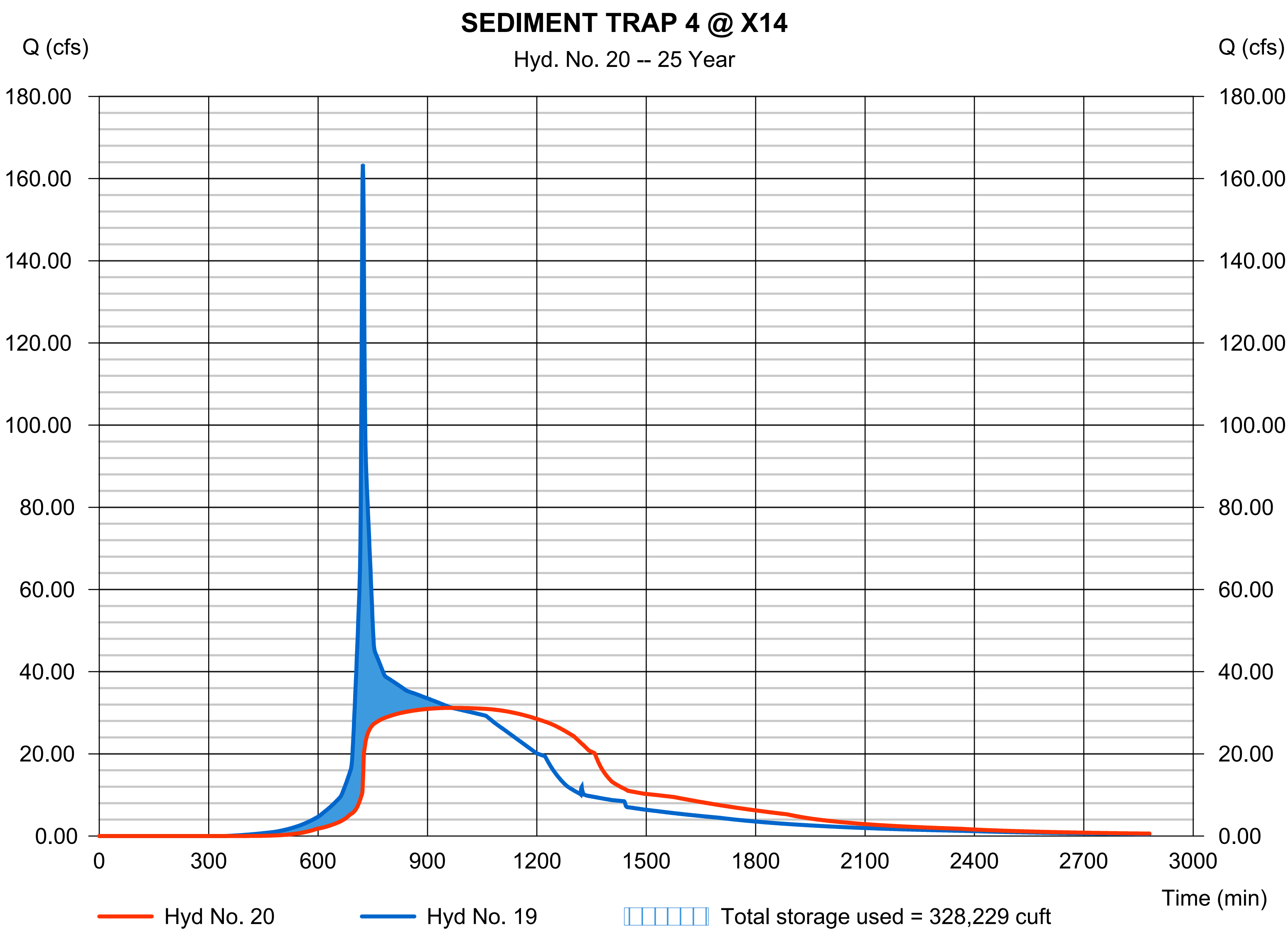
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 20

SEDIMENT TRAP 4 @ X14

Hydrograph type	= Reservoir	Peak discharge	= 31.19 cfs
Storm frequency	= 25 yrs	Time to peak	= 968 min
Time interval	= 1 min	Hyd. volume	= 1,537,197 cuft
Inflow hyd. No.	= 19 - EXTERIOR DITCH HP5 TO X14	Max. Elevation	= 247.61 ft
Reservoir name	= SEDIMENT TRAP 4 @ X14	Max. Storage	= 328,229 cuft

Storage Indication method used. Wet pond routing start elevation = 238.00 ft.

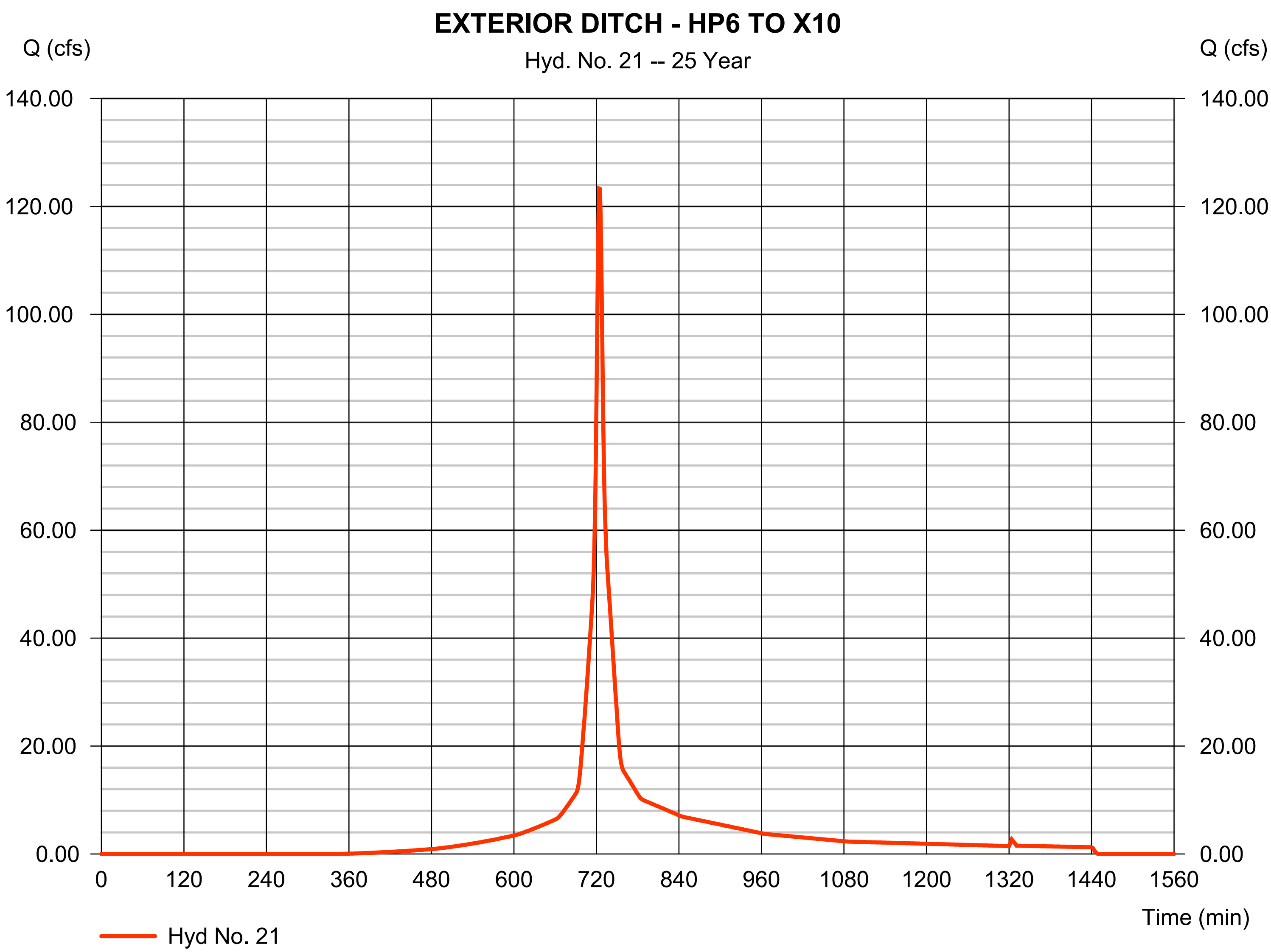


Hydrograph Report

Hyd. No. 21

EXTERIOR DITCH - HP6 TO X10

Hydrograph type	= SCS Runoff	Peak discharge	= 123.29 cfs
Storm frequency	= 25 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 386,165 cuft
Drainage area	= 20.000 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

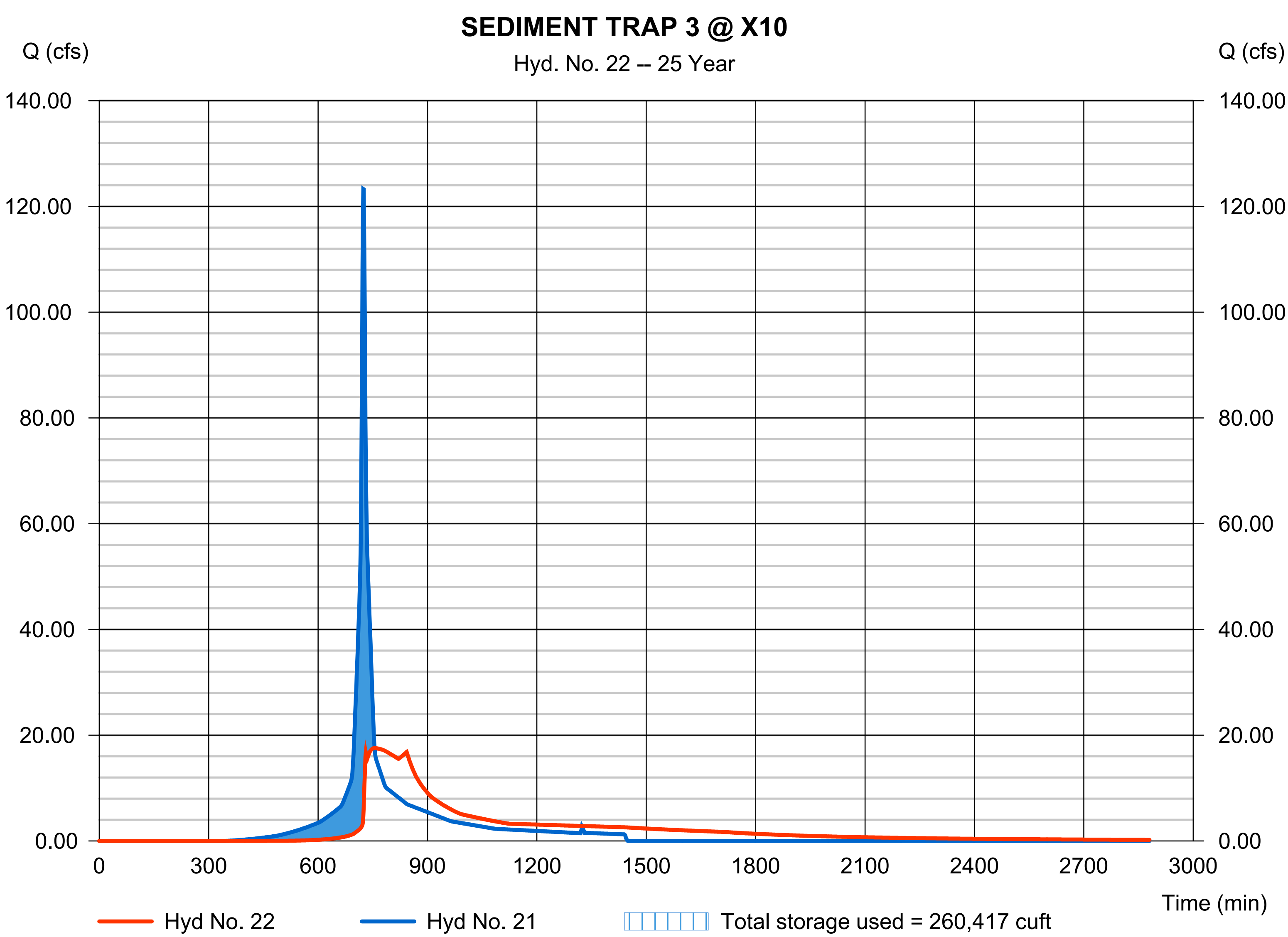
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 22

SEDIMENT TRAP 3 @ X10

Hydrograph type	= Reservoir	Peak discharge	= 17.56 cfs
Storm frequency	= 25 yrs	Time to peak	= 755 min
Time interval	= 1 min	Hyd. volume	= 369,897 cuft
Inflow hyd. No.	= 21 - EXTERIOR DITCH - HP6 TO X10	Max. Elevation	= 252.28 ft
Reservoir name	= SEDIMENT TRAP 3 @ X10	Max. Storage	= 260,417 cuft

Storage Indication method used. Wet pond routing start elevation = 248.00 ft.

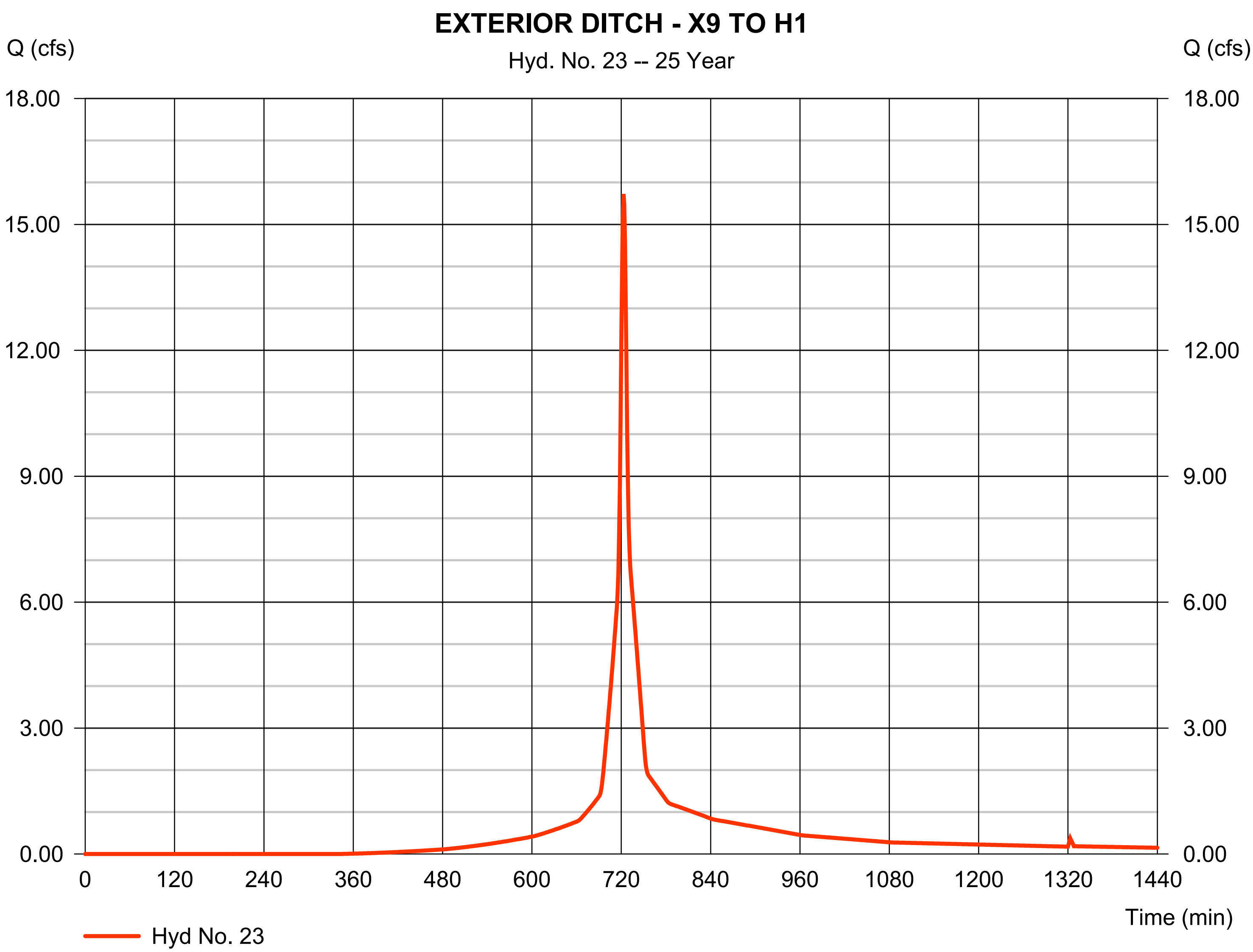


Hydrograph Report

Hyd. No. 23

EXTERIOR DITCH - X9 TO H1

Hydrograph type	= SCS Runoff	Peak discharge	= 15.72 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 46,059 cuft
Drainage area	= 2.460 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

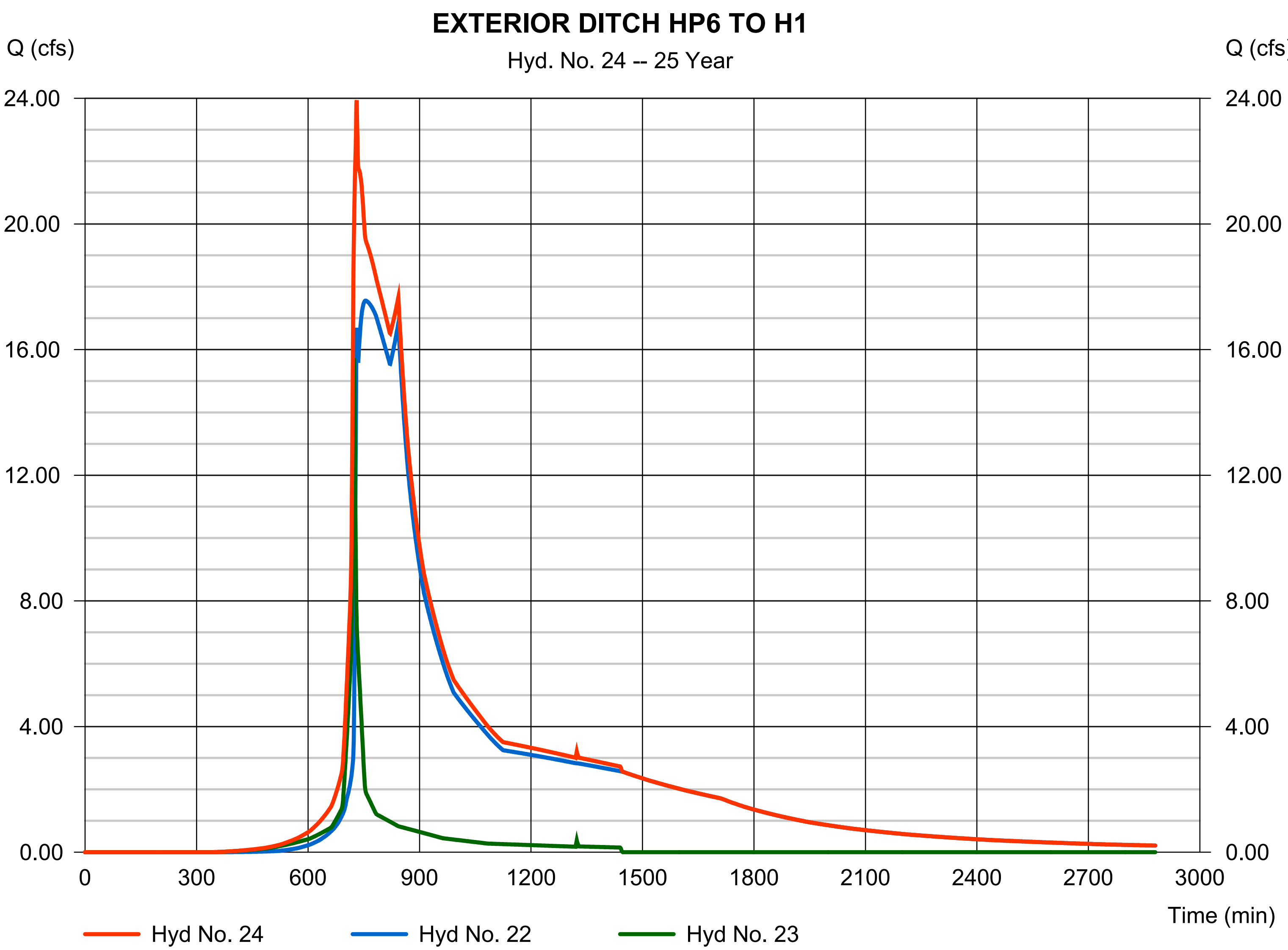


Hydrograph Report

Hyd. No. 24

EXTERIOR DITCH HP6 TO H1

Hydrograph type	= Combine	Peak discharge	= 23.94 cfs
Storm frequency	= 25 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 415,956 cuft
Inflow hyds.	= 22, 23	Contrib. drain. area	= 2.460 ac

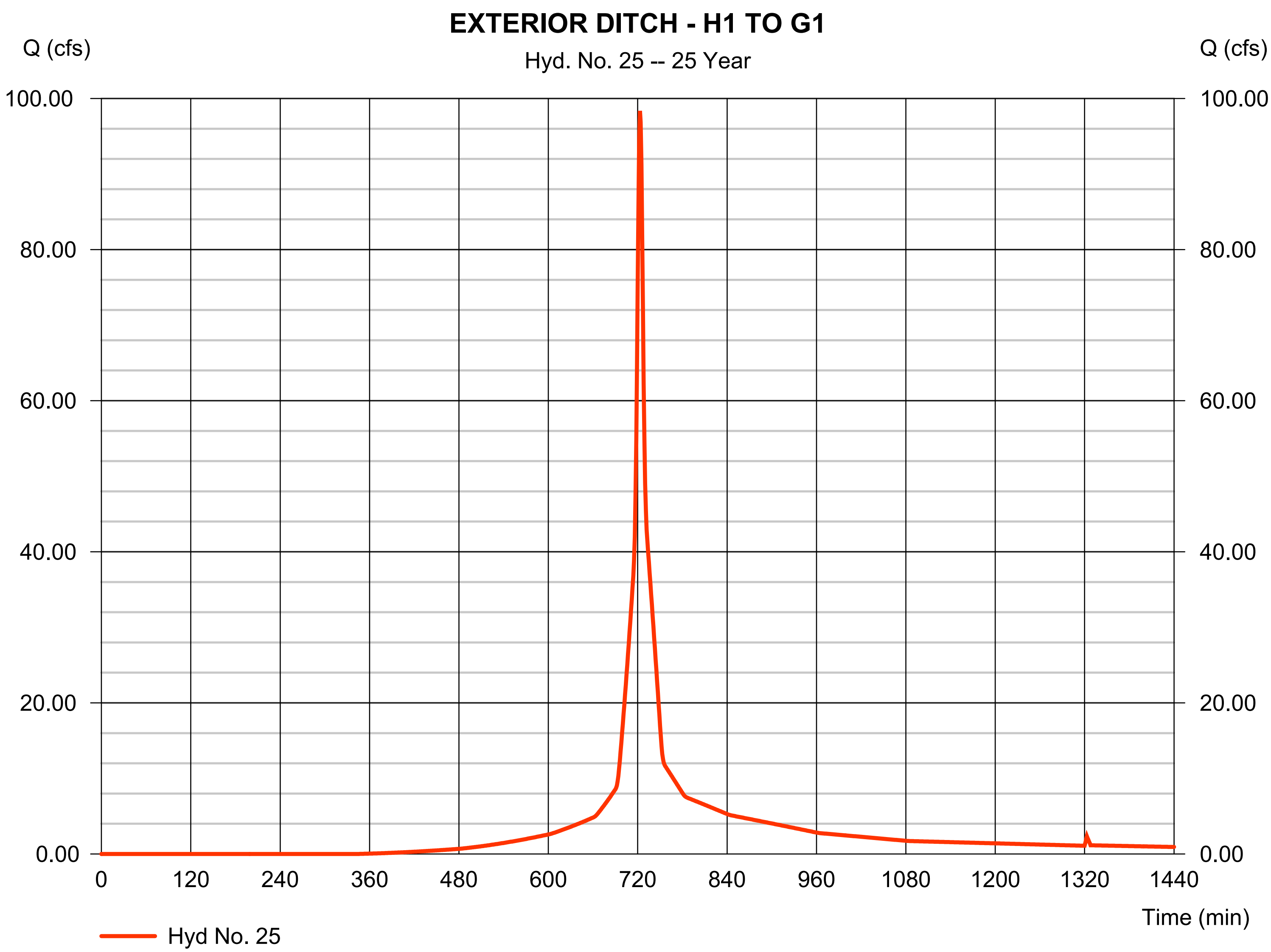


Hydrograph Report

Hyd. No. 25

EXTERIOR DITCH - H1 TO G1

Hydrograph type	= SCS Runoff	Peak discharge	= 98.36 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 288,149 cuft
Drainage area	= 15.390 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

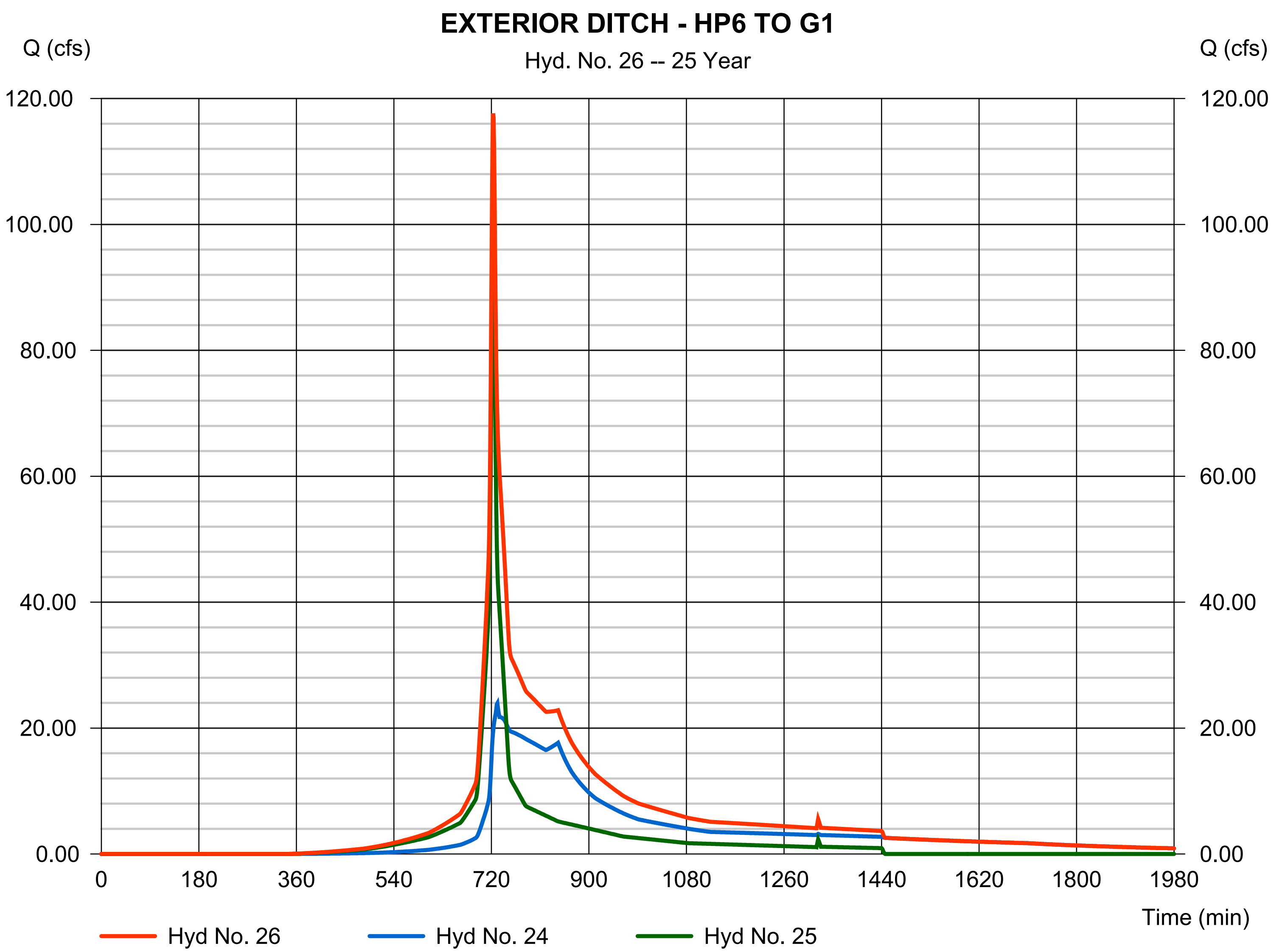


Hydrograph Report

Hyd. No. 26

EXTERIOR DITCH - HP6 TO G1

Hydrograph type	= Combine	Peak discharge	= 117.63 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 704,106 cuft
Inflow hyds.	= 24, 25	Contrib. drain. area	= 15.390 ac

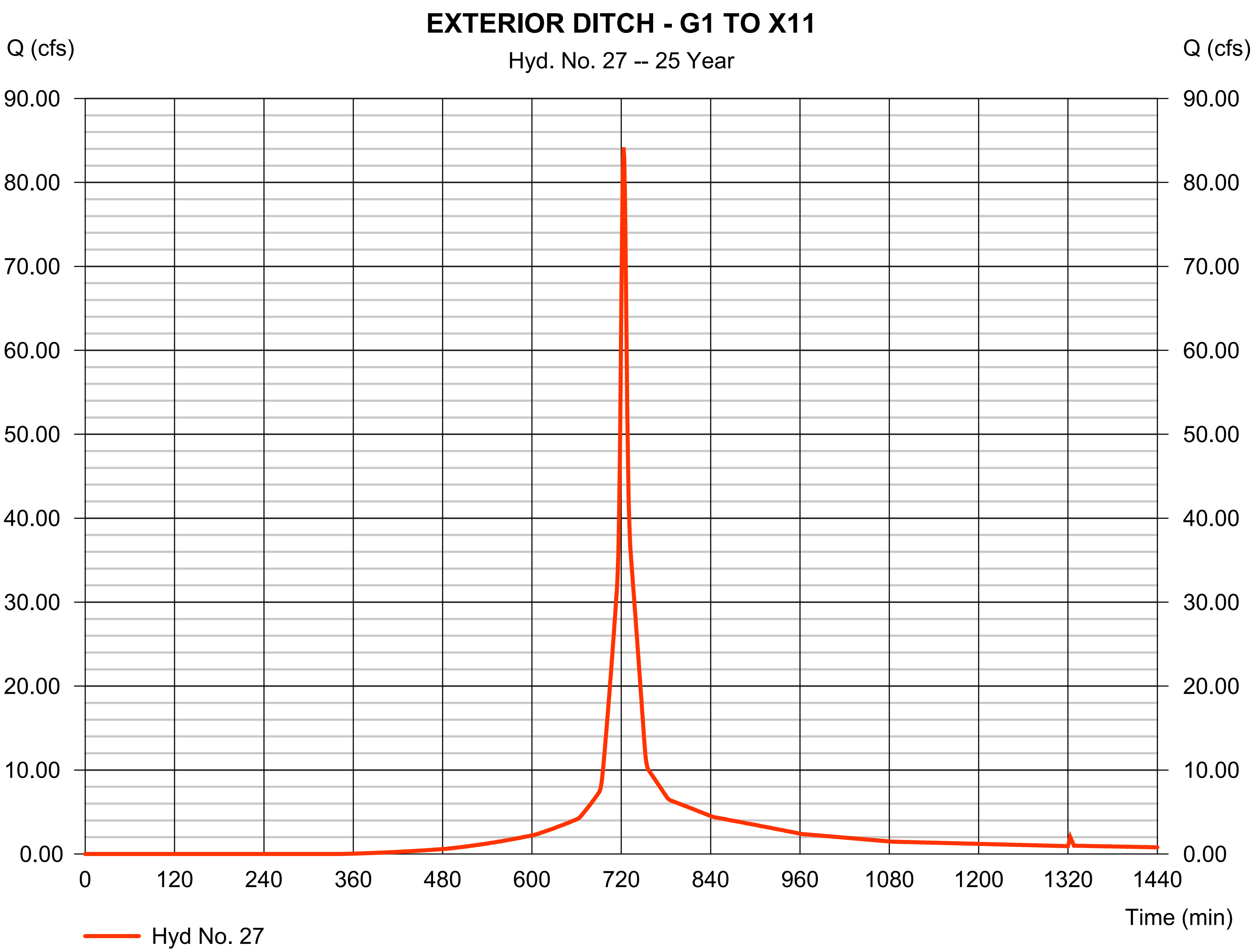


Hydrograph Report

Hyd. No. 27

EXTERIOR DITCH - G1 TO X11

Hydrograph type	= SCS Runoff	Peak discharge	= 84.17 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 246,584 cuft
Drainage area	= 13.170 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



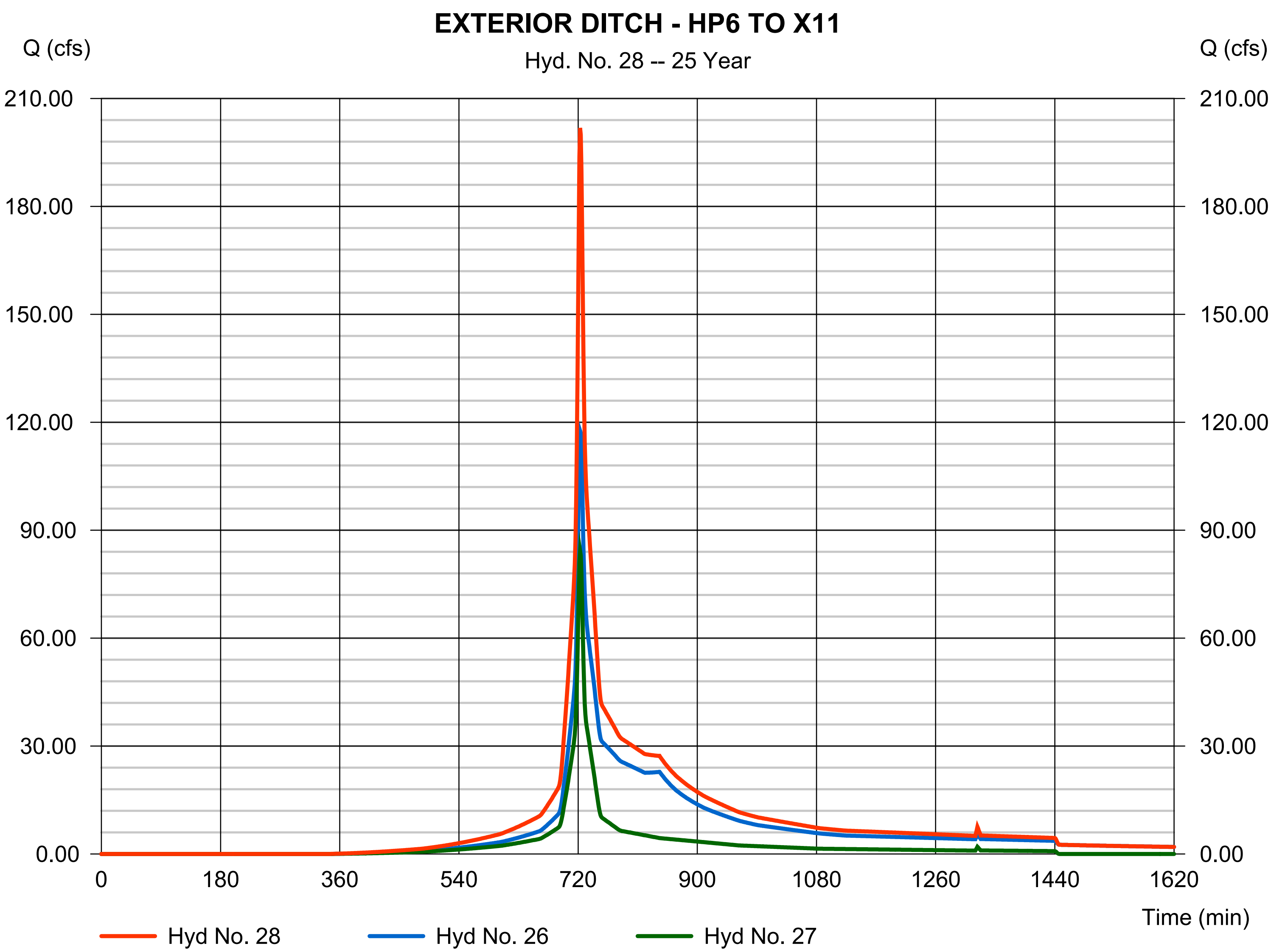
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 28

EXTERIOR DITCH - HP6 TO X11

Hydrograph type	= Combine	Peak discharge	= 201.80 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 950,689 cuft
Inflow hyds.	= 26, 27	Contrib. drain. area	= 13.170 ac



Hydrograph Report

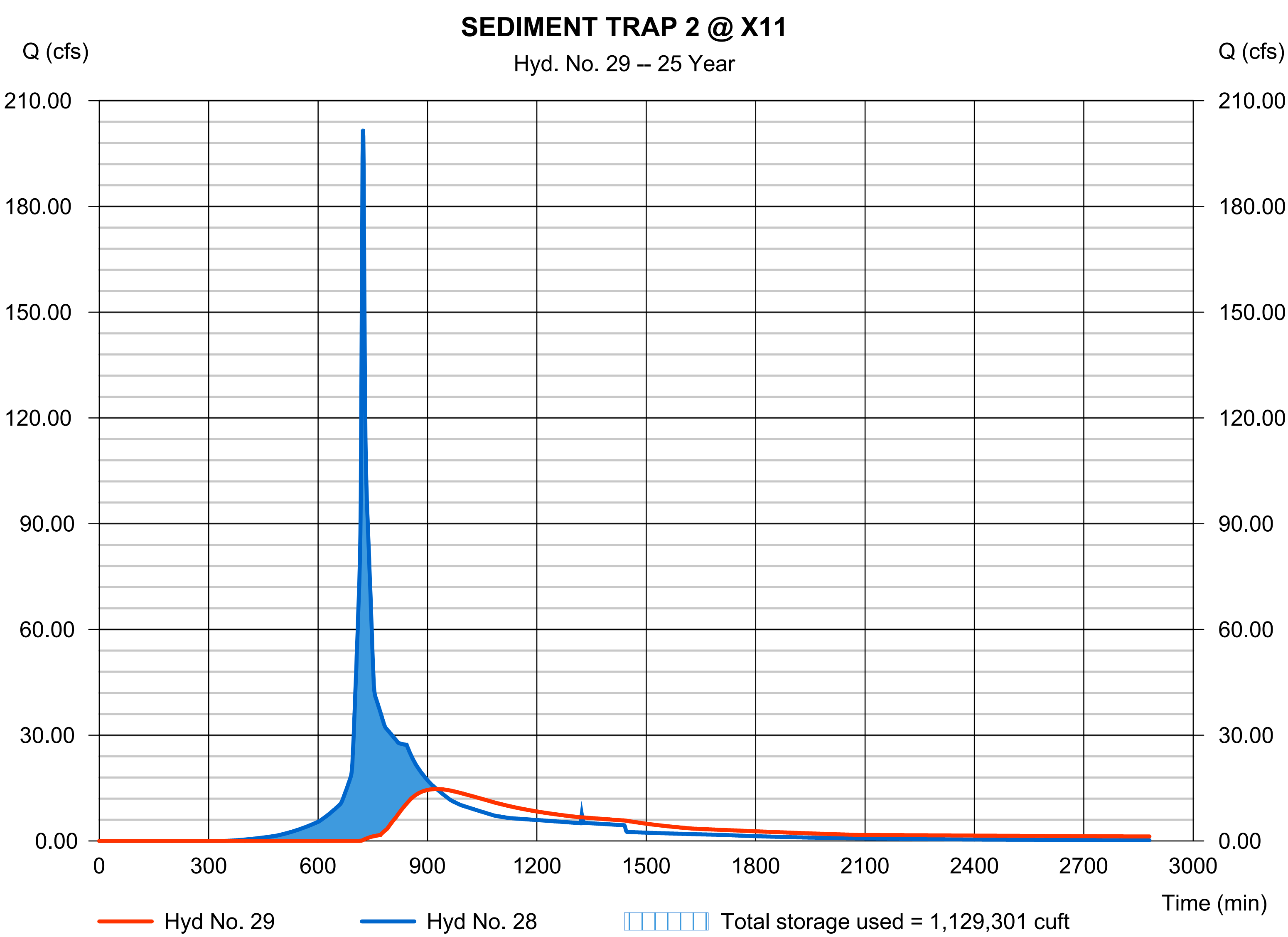
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 29

SEDIMENT TRAP 2 @ X11

Hydrograph type	= Reservoir	Peak discharge	= 14.72 cfs
Storm frequency	= 25 yrs	Time to peak	= 925 min
Time interval	= 1 min	Hyd. volume	= 577,516 cuft
Inflow hyd. No.	= 28 - EXTERIOR DITCH - HP6 TO X11	Max. Elevation	= 246.77 ft
Reservoir name	= SEDIMENT TRAP 2 @ X11	Max. Storage	= 1,129,301 cuft

Storage Indication method used. Wet pond routing start elevation = 243.00 ft.

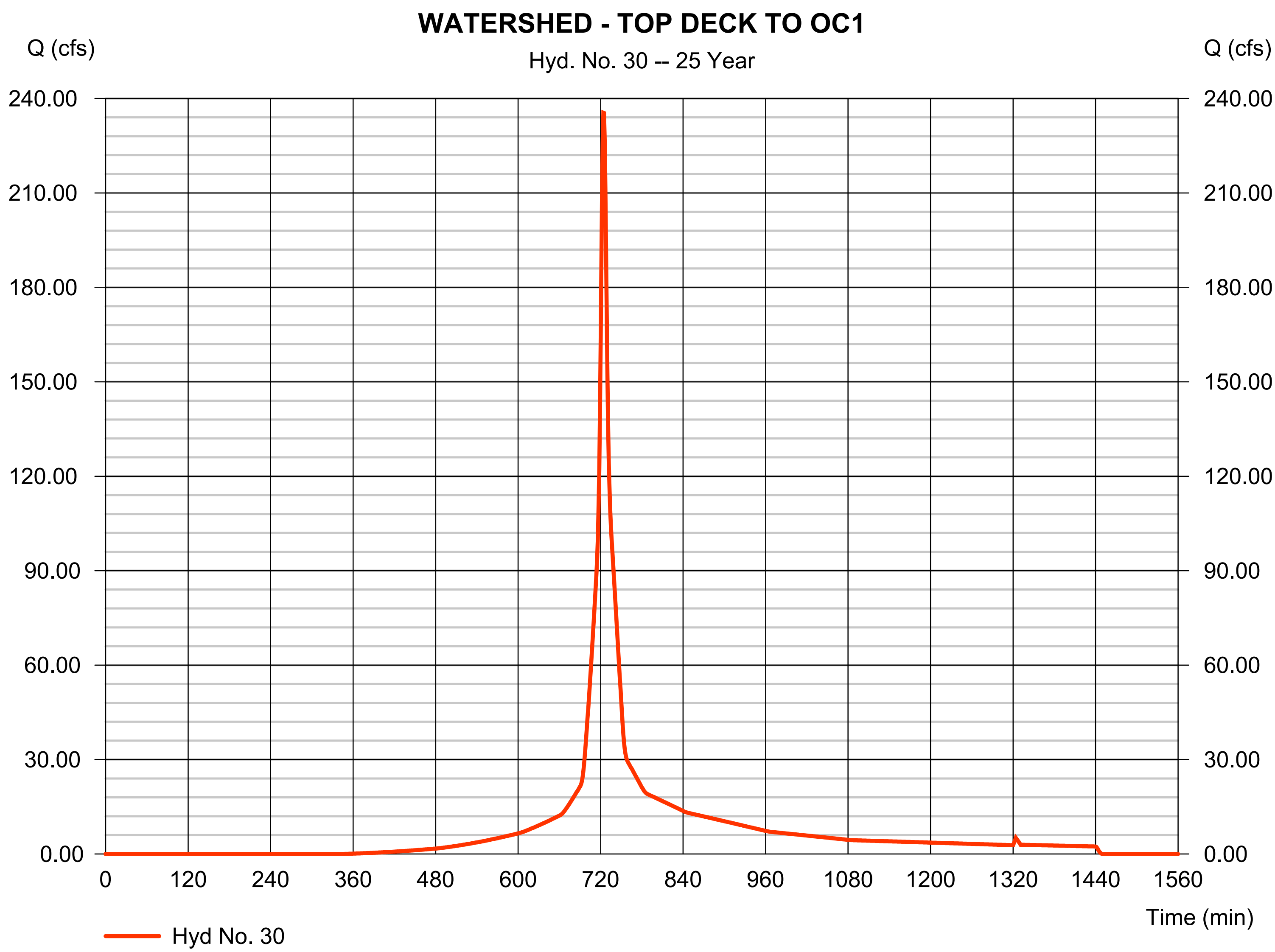


Hydrograph Report

Hyd. No. 30

WATERSHED - TOP DECK TO OC1

Hydrograph type	= SCS Runoff	Peak discharge	= 235.48 cfs
Storm frequency	= 25 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 737,576 cuft
Drainage area	= 38.200 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



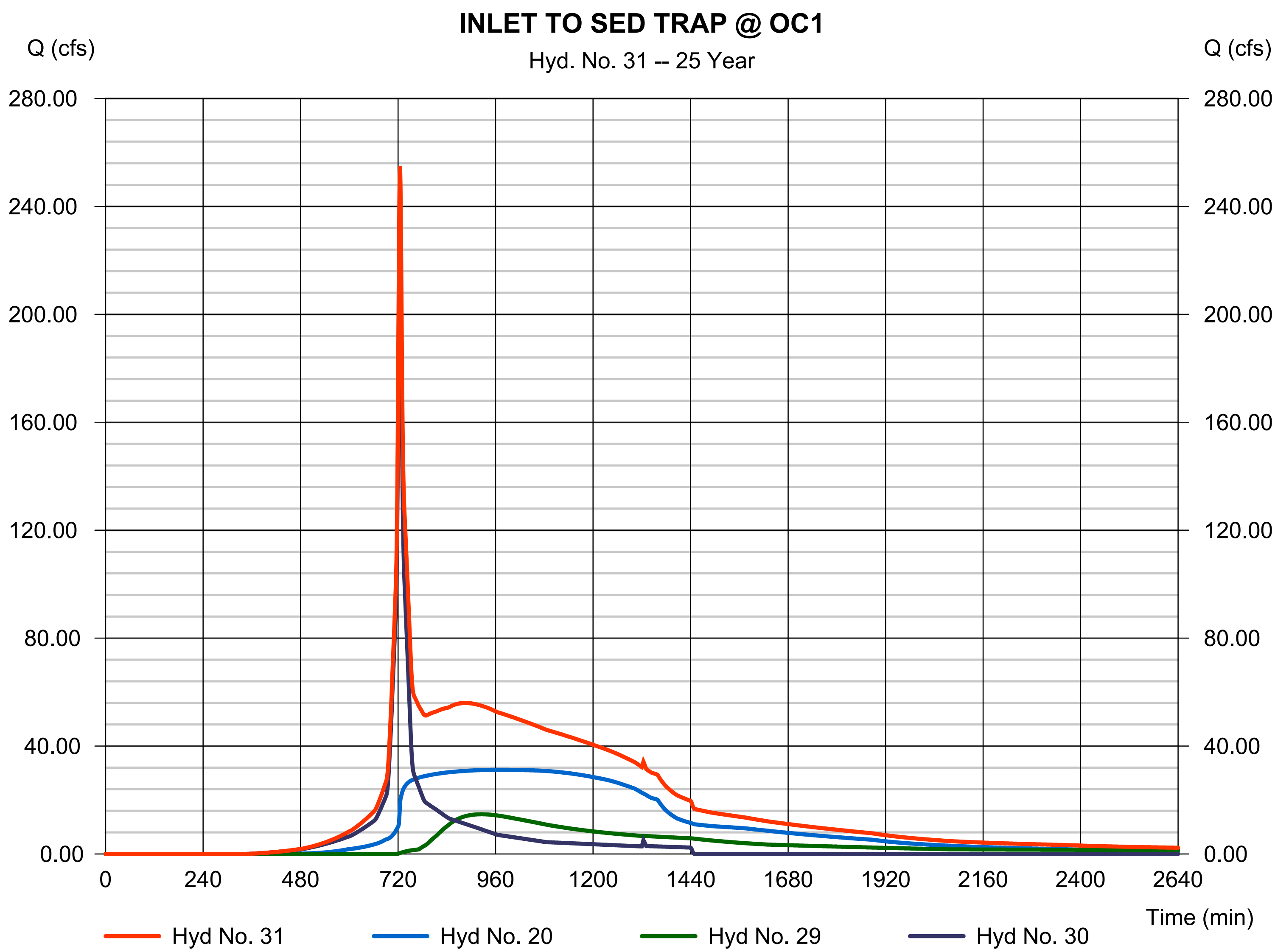
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 31

INLET TO SED TRAP @ OC1

Hydrograph type	= Combine	Peak discharge	= 254.87 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 2,852,292 cuft
Inflow hyds.	= 20, 29, 30	Contrib. drain. area	= 38.200 ac



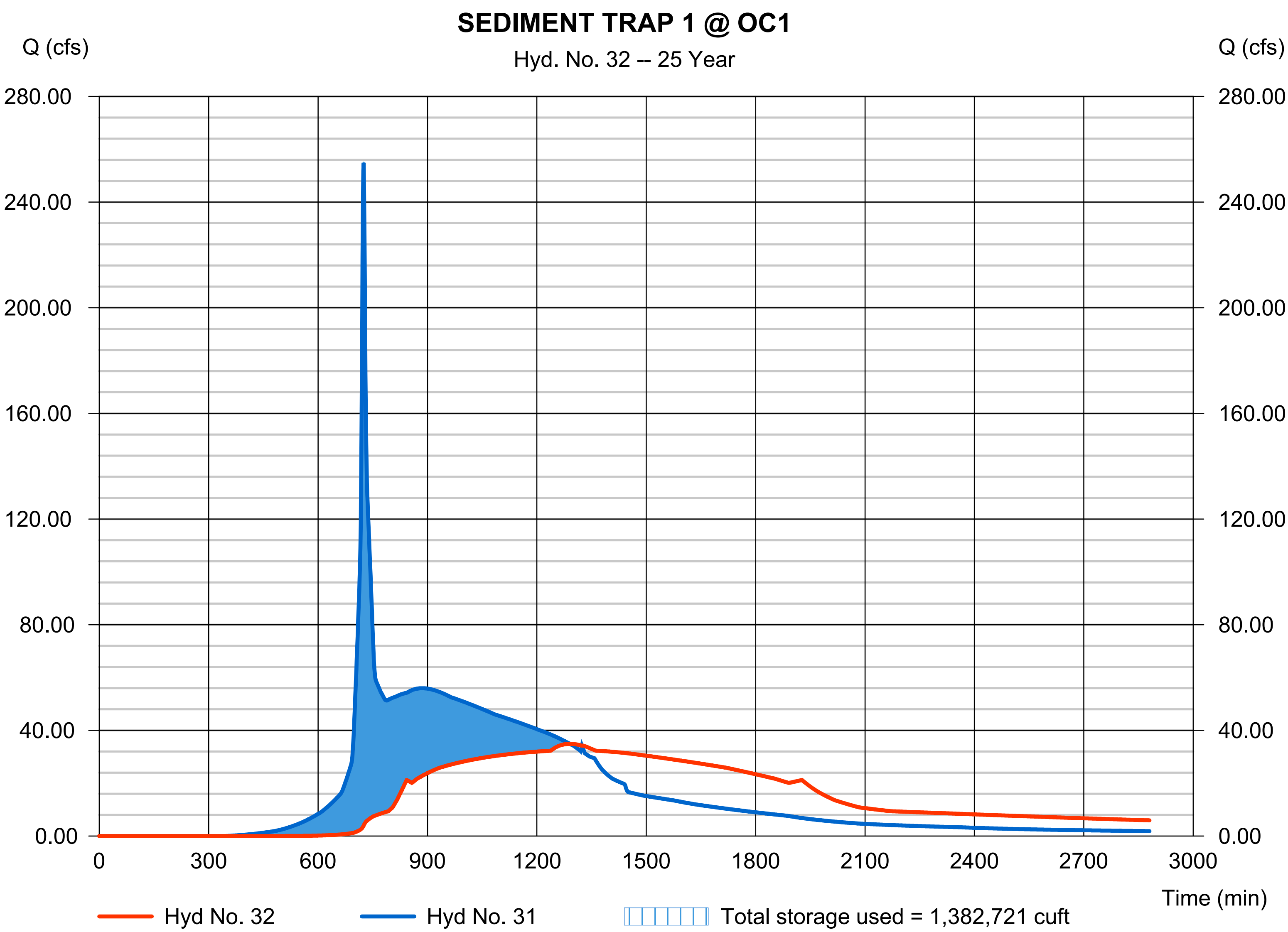
Hydrograph Report

Hyd. No. 32

SEDIMENT TRAP 1 @ OC1

Hydrograph type	= Reservoir	Peak discharge	= 34.89 cfs
Storm frequency	= 25 yrs	Time to peak	= 1291 min
Time interval	= 1 min	Hyd. volume	= 2,438,157 cuft
Inflow hyd. No.	= 31 - INLET TO SED TRAP @ OC1	Max. Elevation	= 237.64 ft
Reservoir name	= SEDIMENT TRAP 1 @ OC1	Max. Storage	= 1,382,721 cuft

Storage Indication method used. Wet pond routing start elevation = 228.00 ft.



Hydraflow Rainfall Report

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	0.0000	0.0000	0.0000	--------
3	0.0000	0.0000	0.0000	--------
5	0.0000	0.0000	0.0000	--------
10	0.0000	0.0000	0.0000	--------
25	0.0000	0.0000	0.0000	--------
50	0.0000	0.0000	0.0000	--------
100	0.0000	0.0000	0.0000	--------

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Tc = time in minutes. Values may exceed 60.

ojects\2014\EJ147461\Working Files\Calculations-Analyses\SCS METHOD\Peachtree City (24 hr GA Green Book).pcp

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.75	4.50	0.00	5.65	6.50	7.50	8.40	9.20
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

Erosion Control Materials Design Software
Version 5.0

Project Summary Page

Project Name:	Emelle Facility
Project Number:	Project
File Number:	
Project Type:	Landfill
Estimate Start Date:	
Project Stage:	
Active:	
Units:	English
Project Address:	, ,
Project Notes:	

Project Components

Channel Analysis
-- CHANNEL REACH H4 - J2
-- Final Cover Terrace
-- CHANNEL REACH HP1 - X19
-- CHANNEL REACH X17 - X16
-- CHANNEL REACH X20 - X21
-- CHANNEL REACH X22 - X23

-- CHANNEL REACH X24 - C2
-- CHANNEL REACH C2 - D2
-- CHANNEL REACH D2 - X2
-- CHANNEL REACH HP3 - X2
-- CHANNEL REACH HP4 - X27
-- CHANNEL REACH X28 - E2
-- CHANNEL REACH HP2 - J1
-- CHANNEL REACH J1 - H2
-- CHANNEL REACH H2 - G2
-- CHANNEL REACH G2 - X25
-- CHANNEL REACH F6 - G5
-- CHANNEL REACH HP7 - F6
-- CHANNEL REACH G5 - H4
-- CHANNEL REACH HP5 - X8
-- CHANNEL REACH X7 - X6
-- CHANNEL REACH X5 - X3
-- CHANNEL REACH X4 - C1
-- CHANNEL REACH C1 - D1
-- CHANNEL REACH X1 - X18
-- CHANNEL REACH D1 - X1
-- CHANNEL REACH X15 - X14
-- CHANNEL REACH X9 - H1
-- CHANNEL REACH HP6 - X10
-- CHANNEL REACH H1 - G1
-- CHANNEL REACH G1 - X11

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

Erosion Control Materials Design Software
Version 5.0

Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH H4 - J2

Discharge	10.3
Peak Flow Period	2.4
Channel Slope	0.061
Channel Bottom Width	3
Left Side Slope	4
Right Side Slope	2
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

Rock Riprap - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
Rock Riprap Unvegetated	Straight	10.3 cfs	5.7 ft/s	0.42 ft	0.03	4 lbs/ft2	1.61 lbs/ft2	2.48	STABLE	--

P550 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
P550 Unvegetated	Straight	10.3 cfs	5.7 ft/s	0.42 ft	0.03	3.25 lbs/ft2	1.61 lbs/ft2	2.02	STABLE	E
P550 Reinforced Vegetation	Straight	10.3 cfs	5.7 ft/s	0.42 ft	0.03	12 lbs/ft2	1.61 lbs/ft2	7.44	STABLE	E
Underlying Substrate	Straight	10.3 cfs	5.7 ft/s	0.42 ft	--	3.25 lbs/ft2	1.807 lbs/ft2	1.8	STABLE	--

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	10.3
Peak Flow Period:	2.4
Channel Slope:	0.061
Bottom Width:	3
Left Side Slope:	4
Right Side Slope:	2
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type	
Matting Type	Rock Riprap
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	1.81
AL = (1/2) * Depth2 * ZL =	0.36
AB = Bottom Width * Depth =	1.27
AR = (1/2) * Depth2 * ZR =	0.18
Wetted Perimeter (P)	
P = PL + PB + PR =	5.69

PL = Depth * (ZL2 + 1)0.5 =	1.75
PB = Channel Bottom Width =	3
PR = Depth * (ZR2 + 1)0.5	0.95
Hydraulic Radius (R)	
R = A / P =	0.32
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	10.3
Velocity (V)	
V = Q / A =	5.7
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	1.61
Channel Safety Factor = (Tp / Td)	2.48
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0
CF =	0
ns =	0
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	

Material Type	
Matting Type	P550
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	1.81
AL = (1/2) * Depth2 * ZL =	0.36
AB = Bottom Width * Depth =	1.27
AR = (1/2) * Depth2 * ZR =	0.18
Wetted Perimeter (P)	
P = PL + PB + PR =	5.69
PL = Depth * (ZL2 + 1)0.5 =	1.75
PB = Channel Bottom Width =	3
PR = Depth * (ZR2 + 1)0.5	0.95
Hydraulic Radius (R)	
R = A / P =	0.32

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	10.3
Velocity (V)	
V = Q / A =	5.7
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	1.61
Channel Safety Factor = (Tp / Td)	2.02
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	3.01
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	P550
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	1.81
AL = (1/2) * Depth2 * ZL =	0.36
AB = Bottom Width * Depth =	1.27
AR = (1/2) * Depth2 * ZR =	0.18
Wetted Perimeter (P)	
P = PL + PB + PR =	5.69
PL = Depth * (ZL2 + 1)0.5 =	1.75
PB = Channel Bottom Width =	3
PR = Depth * (ZR2 + 1)0.5	0.95
Hydraulic Radius (R)	
R = A / P =	0.32
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	10.3
Velocity (V)	
V = Q / A =	5.7

Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	1.61
Channel Safety Factor = (Tp / Td)	7.44
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	1.81
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	3.25
Soil Safety Factor = Ta / Te =	1.8
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

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5401 St. Wendel-Cynthiana Road
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: Final Cover Terrace

Discharge	22.6
Peak Flow Period	1
Channel Slope	0.03
Channel Bottom Width	0
Left Side Slope	20
Right Side Slope	4
Existing Bend Radius	20
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Good 75-95%
Soil Type	Clay

P300 - Class D - Bunch Type - Good 75-95%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
P300 Unvegetated	Straight	22.6 cfs	4.14 ft/s	0.67 ft	0.03	3 lbs/ft2	1.26 lbs/ft2	2.38	STABLE	E
P300 Reinforced Vegetation	Straight	22.6 cfs	4.14 ft/s	0.67 ft	0.03	8 lbs/ft2	1.26 lbs/ft2	6.34	STABLE	E
Underlying Substrate	Straight	22.6 cfs	4.14 ft/s	0.67 ft	--	2 lbs/ft2	0.735 lbs/ft2	2.72	STABLE	--
P300 Unvegetated	Bend	22.6 cfs	4.14 ft/s	0.67 ft	0.03	3 lbs/ft2	2.53 lbs/ft2	1.19	STABLE	E
P300 Reinforced Vegetation	Bend	22.6 cfs	4.14 ft/s	0.67 ft	0.03	8 lbs/ft2	2.53 lbs/ft2	3.17	STABLE	E
Underlying Substrate	Bend	22.6 cfs	4.14 ft/s	0.67 ft	--	2 lbs/ft2	0.735 lbs/ft2	2.72	STABLE	--

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Poseyville, Indiana 47633
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Channel Computations

Project Parameters	
Specify Manning's n:	0.03
Discharge:	22.6
Peak Flow Period:	1
Channel Slope:	0.03
Bottom Width:	0
Left Side Slope:	20
Right Side Slope:	4
Existing Channel Bend:	1
Bend Coefficient (Kb):	
Channel Radius :	20
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Good 75-95%
Soil Type:	Clay
Channel Lining Options	
Protection Type	Permanent

Material Type	
Matting Type	P300
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	5.46
AL = (1/2) * Depth2 * ZL =	4.55
AB = Bottom Width * Depth =	0
AR = (1/2) * Depth2 * ZR =	0.91
Wetted Perimeter (P)	

P = PL + PB + PR =	16.29
PL = Depth * (ZL2 + 1)0.5 =	13.51
PB = Channel Bottom Width =	0
PR = Depth * (ZR2 + 1)0.5	2.78
Hydraulic Radius (R)	
R = A / P =	0.34
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	22.6
Velocity (V)	
V = Q / A =	4.14
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	1.26
Channel Safety Factor = (Tp / Td)	2.38
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	1.47
CF =	0
ns =	0.03
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Bend Shear Stress (Tdb)	
Tdb =	2.53
Bend Safety Factor	
Tdb =	1.19
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	2.94
Soil Safety Factor in Bend	
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Material Type	
Matting Type	P300

Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	5.46
AL = (1/2) * Depth2 * ZL =	4.55
AB = Bottom Width * Depth =	0
AR = (1/2) * Depth2 * ZR =	0.91
Wetted Perimeter (P)	
P = PL + PB + PR =	16.29
PL = Depth * (ZL2 + 1)0.5 =	13.51
PB = Channel Bottom Width =	0
PR = Depth * (ZR2 + 1)0.5	2.78
Hydraulic Radius (R)	
R = A / P =	0.34
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	22.6
Velocity (V)	
V = Q / A =	4.14
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	1.26
Channel Safety Factor = (Tp / Td)	6.34
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.74
CF =	0.5
ns =	0.03
Soil Safety Factor	
Allowable Soil Shear (Ta) =	2
Soil Safety Factor = Ta / Te =	2.72
Bend Shear Stress (Tdb)	
Tdb =	2.53
Bend Safety Factor	
Tdb =	3.17
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	1.47
Soil Safety Factor in Bend	

Soil Safety Factor = Ta / Te =	0.68
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Side Slope Liner Results

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5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH HP1 - X19

Discharge	8.8
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	6
Left Side Slope	2
Right Side Slope	2
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	8.8 cfs	2.14 ft/s	0.57 ft	0.03	2.5 lbs/ft2	0.18 lbs/ft2	13.95	STABLE	E
SC250 Reinforced Vegetation	Straight	8.8 cfs	2.14 ft/s	0.57 ft	0.03	8 lbs/ft2	0.18 lbs/ft2	44.66	STABLE	E
Underlying Substrate	Straight	8.8 cfs	2.14 ft/s	0.57 ft	--	0.8 lbs/ft2	0.178 lbs/ft2	4.5	STABLE	--

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Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	8.8
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	4.1
AL = (1/2) * Depth2 * ZL =	0.33
AB = Bottom Width * Depth =	3.45
AR = (1/2) * Depth2 * ZR =	0.33

Wetted Perimeter (P)

P = PL + PB + PR =	8.57

PL = Depth * (ZL2 + 1)0.5 =	1.28
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.28
Hydraulic Radius (R)	
R = A / P =	0.48
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	8.8
Velocity (V)	
V = Q / A =	2.14
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.18
Channel Safety Factor = (Tp / Td)	13.95
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.3
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	4.1
AL = (1/2) * Depth2 * ZL =	0.33
AB = Bottom Width * Depth =	3.45
AR = (1/2) * Depth2 * ZR =	0.33
Wetted Perimeter (P)	
P = PL + PB + PR =	8.57
PL = Depth * (ZL2 + 1)0.5 =	1.28
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.28
Hydraulic Radius (R)	
R = A / P =	0.48

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	8.8
Velocity (V)	
V = Q / A =	2.14
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.18
Channel Safety Factor = (Tp / Td)	44.66
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.18
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	4.5
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
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Fax 812.867.0247
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH X17 - X16

Discharge	122.4
Peak Flow Period	2.4
Channel Slope	.005
Channel Bottom Width	14
Left Side Slope	3
Right Side Slope	3
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	122.4 cfs	4.06 ft/s	1.6 ft	0.03	2.5 lbs/ft2	0.5 lbs/ft2	5	STABLE	E
SC250 Reinforced Vegetation	Straight	122.4 cfs	4.06 ft/s	1.6 ft	0.03	8 lbs/ft2	0.5 lbs/ft2	16	STABLE	E
Underlying Substrate	Straight	122.4 cfs	4.06 ft/s	1.6 ft	--	0.8 lbs/ft2	0.116 lbs/ft2	6.87	STABLE	--

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Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	122.4
Peak Flow Period:	2.4
Channel Slope:	.005
Bottom Width:	14
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	30.14
AL = (1/2) * Depth2 * ZL =	3.85
AB = Bottom Width * Depth =	22.43
AR = (1/2) * Depth2 * ZR =	3.85

Wetted Perimeter (P)

P = PL + PB + PR =	24.13

PL = Depth * (ZL2 + 1)0.5 =	5.07
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	5.07
Hydraulic Radius (R)	
R = A / P =	1.25
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	122.4
Velocity (V)	
V = Q / A =	4.06
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.5
Channel Safety Factor = (Tp / Td)	5
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.19
CF =	0
ns =	0.02
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	30.14
AL = (1/2) * Depth2 * ZL =	3.85
AB = Bottom Width * Depth =	22.43
AR = (1/2) * Depth2 * ZR =	3.85
Wetted Perimeter (P)	
P = PL + PB + PR =	24.13
PL = Depth * (ZL2 + 1)0.5 =	5.07
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	5.07
Hydraulic Radius (R)	
R = A / P =	1.25

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	122.4
Velocity (V)	
V = Q / A =	4.06
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.5
Channel Safety Factor = (Tp / Td)	16
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.12
CF =	0.4
ns =	0.02
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	6.87
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH X20 - X21

Discharge	64.3
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	6
Left Side Slope	2
Right Side Slope	2
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	64.3 cfs	3.93 ft/s	1.73 ft	0.03	2.5 lbs/ft2	0.54 lbs/ft2	4.64	STABLE	E
SC250 Reinforced Vegetation	Straight	64.3 cfs	3.93 ft/s	1.73 ft	0.03	8 lbs/ft2	0.54 lbs/ft2	14.84	STABLE	E
Underlying Substrate	Straight	64.3 cfs	3.93 ft/s	1.73 ft	--	0.8 lbs/ft2	0.095 lbs/ft2	8.43	STABLE	--

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Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	64.3
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	16.35
AL = (1/2) * Depth2 * ZL =	2.99
AB = Bottom Width * Depth =	10.37
AR = (1/2) * Depth2 * ZR =	2.99

Wetted Perimeter (P)

P = PL + PB + PR =	13.73

PL = Depth * (ZL2 + 1)0.5 =	3.86
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	3.86
Hydraulic Radius (R)	
R = A / P =	1.19
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	64.31
Velocity (V)	
V = Q / A =	3.93
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.54
Channel Safety Factor = (Tp / Td)	4.64
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.16
CF =	0
ns =	0.02
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	16.35
AL = (1/2) * Depth2 * ZL =	2.99
AB = Bottom Width * Depth =	10.37
AR = (1/2) * Depth2 * ZR =	2.99
Wetted Perimeter (P)	
P = PL + PB + PR =	13.73
PL = Depth * (ZL2 + 1)0.5 =	3.86
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	3.86
Hydraulic Radius (R)	
R = A / P =	1.19

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	64.31
Velocity (V)	
V = Q / A =	3.93
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.54
Channel Safety Factor = (Tp / Td)	14.84
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.09
CF =	0.4
ns =	0.02
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	8.43
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

Erosion Control Materials Design Software
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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	114.2
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	24.77
AL = (1/2) * Depth2 * ZL =	5.41
AB = Bottom Width * Depth =	13.95
AR = (1/2) * Depth2 * ZR =	5.41
Wetted Perimeter (P)	
P = PL + PB + PR =	16.4

PL = Depth * (ZL2 + 1)0.5 =	5.2
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	5.2

Hydraulic Radius (R)

R = A / P =	1.51

Flow (Q)

Q = 1.486 / n * A * R2/3 * S1/2 =	114.21

Velocity (V)

V = Q / A =	4.61

Channel Shear Stress (Te)

Td = 62.4 * Depth * Slope =	0.73
Channel Safety Factor = (Tp / Td)	3.45

Effective Stress on Blanket(Tdb)

Te = Td * (1-CF) * (ns/n)2 =	0.1
CF =	0
ns =	0.01

Soil Safety Factor

Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	24.77
AL = (1/2) * Depth2 * ZL =	5.41
AB = Bottom Width * Depth =	13.95
AR = (1/2) * Depth2 * ZR =	5.41

Wetted Perimeter (P)

P = PL + PB + PR =	16.4
PL = Depth * (ZL2 + 1)0.5 =	5.2
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	5.2

Hydraulic Radius (R)

R = A / P =	1.51

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	114.21
Velocity (V)	
V = Q / A =	4.61
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.73
Channel Safety Factor = (Tp / Td)	11.03
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.06
CF =	0.4
ns =	0.01
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	13.67
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH X24 - C2

Discharge	125.3
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	6
Left Side Slope	2
Right Side Slope	2
Existing Bend Radius	59
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	125.3 cfs	4.73 ft/s	2.44 ft	0.03	2.5 lbs/ft2	0.76 lbs/ft2	3.29	STABLE	E
SC250 Reinforced Vegetation	Straight	125.3 cfs	4.73 ft/s	2.44 ft	0.03	8 lbs/ft2	0.76 lbs/ft2	10.52	STABLE	E
Underlying Substrate	Straight	125.3 cfs	4.73 ft/s	2.44 ft	--	0.8 lbs/ft2	0.061 lbs/ft2	13.04	STABLE	--
SC250 Unvegetated	Bend	125.3 cfs	4.73 ft/s	2.44 ft	0.03	2.5 lbs/ft2	0.79 lbs/ft2	3.16	STABLE	E
SC250 Reinforced Vegetation	Bend	125.3 cfs	4.73 ft/s	2.44 ft	0.03	8 lbs/ft2	0.79 lbs/ft2	10.1	STABLE	E
Underlying Substrate	Bend	125.3 cfs	4.73 ft/s	2.44 ft	--	0.8 lbs/ft2	0.061 lbs/ft2	13.04	STABLE	--

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	125.3
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	1
Bend Coefficient (Kb):	
Channel Radius :	59
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	26.5
AL = (1/2) * Depth2 * ZL =	5.94
AB = Bottom Width * Depth =	14.62
AR = (1/2) * Depth2 * ZR =	5.94

Wetted Perimeter (P)

P = PL + PB + PR =	16.9
PL = Depth * (ZL2 + 1)0.5 =	5.45
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	5.45
Hydraulic Radius (R)	
R = A / P =	1.57
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	125.3
Velocity (V)	
V = Q / A =	4.73
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.76
Channel Safety Factor = (Tp / Td)	3.29
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.1
CF =	0
ns =	0.01
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Bend Shear Stress (Tdb)	
Tdb =	0.79
Bend Safety Factor	
Tdb =	3.16
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	0.11
Soil Safety Factor in Bend	
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Material Type	
Matting Type	SC250

Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	26.5
AL = (1/2) * Depth2 * ZL =	5.94
AB = Bottom Width * Depth =	14.62
AR = (1/2) * Depth2 * ZR =	5.94
Wetted Perimeter (P)	
P = PL + PB + PR =	16.9
PL = Depth * (ZL2 + 1)0.5 =	5.45
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	5.45
Hydraulic Radius (R)	
R = A / P =	1.57
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	125.3
Velocity (V)	
V = Q / A =	4.73
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.76
Channel Safety Factor = (Tp / Td)	10.52
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.06
CF =	0.4
ns =	0.01
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	13.04
Bend Shear Stress (Tdb)	
Tdb =	0.79
Bend Safety Factor	
Tdb =	10.1
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	0.06
Soil Safety Factor in Bend	

Soil Safety Factor = Ta / Te =	7.52
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Side Slope Liner Results

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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH C2 - D2

Discharge	13.7
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	6
Left Side Slope	2
Right Side Slope	2
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	13.7 cfs	2.48 ft/s	0.74 ft	0.03	2.5 lbs/ft2	0.23 lbs/ft2	10.83	STABLE	E
SC250 Reinforced Vegetation	Straight	13.7 cfs	2.48 ft/s	0.74 ft	0.03	8 lbs/ft2	0.23 lbs/ft2	34.66	STABLE	E
Underlying Substrate	Straight	13.7 cfs	2.48 ft/s	0.74 ft	--	0.8 lbs/ft2	0.192 lbs/ft2	4.16	STABLE	--

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	13.7
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	5.53
AL = (1/2) * Depth2 * ZL =	0.55
AB = Bottom Width * Depth =	4.44
AR = (1/2) * Depth2 * ZR =	0.55
Wetted Perimeter (P)	
P = PL + PB + PR =	9.31

PL = Depth * (ZL2 + 1)0.5 =	1.65
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.65
Hydraulic Radius (R)	
R = A / P =	0.59
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	13.7
Velocity (V)	
V = Q / A =	2.48
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.23
Channel Safety Factor = (Tp / Td)	10.83
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.32
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	5.53
AL = (1/2) * Depth2 * ZL =	0.55
AB = Bottom Width * Depth =	4.44
AR = (1/2) * Depth2 * ZR =	0.55
Wetted Perimeter (P)	
P = PL + PB + PR =	9.31
PL = Depth * (ZL2 + 1)0.5 =	1.65
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.65
Hydraulic Radius (R)	
R = A / P =	0.59

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	13.7
Velocity (V)	
V = Q / A =	2.48
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.23
Channel Safety Factor = (Tp / Td)	34.66
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.19
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	4.16
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH D2 - X2

Discharge	10.2
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	6
Left Side Slope	2
Right Side Slope	2
Existing Bend Radius	59
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	10.2 cfs	2.25 ft/s	0.63 ft	0.03	2.5 lbs/ft2	0.2 lbs/ft2	12.82	STABLE	E
SC250 Reinforced Vegetation	Straight	10.2 cfs	2.25 ft/s	0.63 ft	0.03	8 lbs/ft2	0.2 lbs/ft2	41.02	STABLE	E
Underlying Substrate	Straight	10.2 cfs	2.25 ft/s	0.63 ft	--	0.8 lbs/ft2	0.184 lbs/ft2	4.36	STABLE	--
SC250 Unvegetated	Bend	10.2 cfs	2.25 ft/s	0.63 ft	0.03	2.5 lbs/ft2	0.2 lbs/ft2	12.31	STABLE	E
SC250 Reinforced Vegetation	Bend	10.2 cfs	2.25 ft/s	0.63 ft	0.03	8 lbs/ft2	0.2 lbs/ft2	39.39	STABLE	E
Underlying Substrate	Bend	10.2 cfs	2.25 ft/s	0.63 ft	--	0.8 lbs/ft2	0.184 lbs/ft2	4.36	STABLE	--

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	10.2
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	1
Bend Coefficient (Kb):	
Channel Radius :	59
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	4.53
AL = (1/2) * Depth2 * ZL =	0.39
AB = Bottom Width * Depth =	3.75
AR = (1/2) * Depth2 * ZR =	0.39

Wetted Perimeter (P)

P = PL + PB + PR =	8.8
PL = Depth * (ZL2 + 1)0.5 =	1.4
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.4
Hydraulic Radius (R)	
R = A / P =	0.52
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	10.2
Velocity (V)	
V = Q / A =	2.25
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.2
Channel Safety Factor = (Tp / Td)	12.82
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.31
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Bend Shear Stress (Tdb)	
Tdb =	0.2
Bend Safety Factor	
Tdb =	12.31
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	0.32
Soil Safety Factor in Bend	
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Material Type	
Matting Type	SC250

Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	4.53
AL = (1/2) * Depth2 * ZL =	0.39
AB = Bottom Width * Depth =	3.75
AR = (1/2) * Depth2 * ZR =	0.39
Wetted Perimeter (P)	
P = PL + PB + PR =	8.8
PL = Depth * (ZL2 + 1)0.5 =	1.4
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.4
Hydraulic Radius (R)	
R = A / P =	0.52
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	10.2
Velocity (V)	
V = Q / A =	2.25
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.2
Channel Safety Factor = (Tp / Td)	41.02
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.18
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	4.36
Bend Shear Stress (Tdb)	
Tdb =	0.2
Bend Safety Factor	
Tdb =	39.39
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	0.19
Soil Safety Factor in Bend	

Soil Safety Factor = Ta / Te =	2.51
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Side Slope Liner Results

Tensar International Corporation
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH HP3 - X2

Discharge	8.4
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	6
Left Side Slope	2
Right Side Slope	2
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	8.4 cfs	2.11 ft/s	0.56 ft	0.03	2.5 lbs/ft2	0.17 lbs/ft2	14.33	STABLE	E
SC250 Reinforced Vegetation	Straight	8.4 cfs	2.11 ft/s	0.56 ft	0.03	8 lbs/ft2	0.17 lbs/ft2	45.87	STABLE	E
Underlying Substrate	Straight	8.4 cfs	2.11 ft/s	0.56 ft	--	0.8 lbs/ft2	0.176 lbs/ft2	4.56	STABLE	--

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	8.4
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	3.98
AL = (1/2) * Depth2 * ZL =	0.31
AB = Bottom Width * Depth =	3.35
AR = (1/2) * Depth2 * ZR =	0.31

Wetted Perimeter (P)

P = PL + PB + PR =	8.5

PL = Depth * (ZL2 + 1)0.5 =	1.25
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.25
Hydraulic Radius (R)	
R = A / P =	0.47
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	8.4
Velocity (V)	
V = Q / A =	2.11
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.17
Channel Safety Factor = (Tp / Td)	14.33
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.29
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	3.98
AL = (1/2) * Depth2 * ZL =	0.31
AB = Bottom Width * Depth =	3.35
AR = (1/2) * Depth2 * ZR =	0.31
Wetted Perimeter (P)	
P = PL + PB + PR =	8.5
PL = Depth * (ZL2 + 1)0.5 =	1.25
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.25
Hydraulic Radius (R)	
R = A / P =	0.47

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	8.4
Velocity (V)	
V = Q / A =	2.11
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.17
Channel Safety Factor = (Tp / Td)	45.87
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.18
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	4.56
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH HP4 - X27

Discharge	8
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	6
Left Side Slope	2
Right Side Slope	2
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	8 cfs	2.08 ft/s	0.54 ft	0.03	2.5 lbs/ft2	0.17 lbs/ft2	14.75	STABLE	E
SC250 Reinforced Vegetation	Straight	8 cfs	2.08 ft/s	0.54 ft	0.03	8 lbs/ft2	0.17 lbs/ft2	47.19	STABLE	E
Underlying Substrate	Straight	8 cfs	2.08 ft/s	0.54 ft	--	0.8 lbs/ft2	0.173 lbs/ft2	4.62	STABLE	--

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	8
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	3.85
AL = (1/2) * Depth2 * ZL =	0.3
AB = Bottom Width * Depth =	3.26
AR = (1/2) * Depth2 * ZR =	0.3

Wetted Perimeter (P)

P = PL + PB + PR =	8.43

PL = Depth * (ZL2 + 1)0.5 =	1.22
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.22
Hydraulic Radius (R)	
R = A / P =	0.46
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	8
Velocity (V)	
V = Q / A =	2.08
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.17
Channel Safety Factor = (Tp / Td)	14.75
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.29
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	3.85
AL = (1/2) * Depth2 * ZL =	0.3
AB = Bottom Width * Depth =	3.26
AR = (1/2) * Depth2 * ZR =	0.3
Wetted Perimeter (P)	
P = PL + PB + PR =	8.43
PL = Depth * (ZL2 + 1)0.5 =	1.22
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.22
Hydraulic Radius (R)	
R = A / P =	0.46

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	8
Velocity (V)	
V = Q / A =	2.08
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.17
Channel Safety Factor = (Tp / Td)	47.19
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.17
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	4.62
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH X28 - E2

Discharge	15.2
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	6
Left Side Slope	2
Right Side Slope	2
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	15.2 cfs	2.56 ft/s	0.78 ft	0.03	2.5 lbs/ft2	0.24 lbs/ft2	10.21	STABLE	E
SC250 Reinforced Vegetation	Straight	15.2 cfs	2.56 ft/s	0.78 ft	0.03	8 lbs/ft2	0.24 lbs/ft2	32.68	STABLE	E
Underlying Substrate	Straight	15.2 cfs	2.56 ft/s	0.78 ft	--	0.8 lbs/ft2	0.194 lbs/ft2	4.12	STABLE	--

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Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	15.2
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	5.94
AL = (1/2) * Depth2 * ZL =	0.62
AB = Bottom Width * Depth =	4.71
AR = (1/2) * Depth2 * ZR =	0.62
Wetted Perimeter (P)	
P = PL + PB + PR =	9.51

PL = Depth * (ZL2 + 1)0.5 =	1.75
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.75
Hydraulic Radius (R)	
R = A / P =	0.62
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	15.2
Velocity (V)	
V = Q / A =	2.56
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.24
Channel Safety Factor = (Tp / Td)	10.21
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.32
CF =	0
ns =	0.03
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	5.94
AL = (1/2) * Depth2 * ZL =	0.62
AB = Bottom Width * Depth =	4.71
AR = (1/2) * Depth2 * ZR =	0.62
Wetted Perimeter (P)	
P = PL + PB + PR =	9.51
PL = Depth * (ZL2 + 1)0.5 =	1.75
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.75
Hydraulic Radius (R)	
R = A / P =	0.62

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	15.2
Velocity (V)	
V = Q / A =	2.56
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.24
Channel Safety Factor = (Tp / Td)	32.68
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.19
CF =	0.4
ns =	0.03
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	4.12
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH HP2 - J1

Discharge	5.2
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	6
Left Side Slope	2
Right Side Slope	2
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	5.2 cfs	1.8 ft/s	0.42 ft	0.03	2.5 lbs/ft2	0.13 lbs/ft2	18.94	STABLE	E
SC250 Reinforced Vegetation	Straight	5.2 cfs	1.8 ft/s	0.42 ft	0.03	8 lbs/ft2	0.13 lbs/ft2	60.6	STABLE	E
Underlying Substrate	Straight	5.2 cfs	1.8 ft/s	0.42 ft	--	0.8 lbs/ft2	0.141 lbs/ft2	5.68	STABLE	--

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Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	5.2
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	2.9
AL = (1/2) * Depth2 * ZL =	0.18
AB = Bottom Width * Depth =	2.54
AR = (1/2) * Depth2 * ZR =	0.18
Wetted Perimeter (P)	
P = PL + PB + PR =	7.89

PL = Depth * (ZL2 + 1)0.5 =	0.95
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	0.95
Hydraulic Radius (R)	
R = A / P =	0.37
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	5.2
Velocity (V)	
V = Q / A =	1.8
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.13
Channel Safety Factor = (Tp / Td)	18.94
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.23
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	2.9
AL = (1/2) * Depth2 * ZL =	0.18
AB = Bottom Width * Depth =	2.54
AR = (1/2) * Depth2 * ZR =	0.18
Wetted Perimeter (P)	
P = PL + PB + PR =	7.89
PL = Depth * (ZL2 + 1)0.5 =	0.95
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	0.95
Hydraulic Radius (R)	
R = A / P =	0.37

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	5.2
Velocity (V)	
V = Q / A =	1.8
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.13
Channel Safety Factor = (Tp / Td)	60.6
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.14
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	5.68
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

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5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
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Fax 812.867.0247
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH J1 - H2

Discharge	17.1
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	6
Left Side Slope	2
Right Side Slope	2
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	17.1 cfs	2.66 ft/s	0.84 ft	0.03	2.5 lbs/ft2	0.26 lbs/ft2	9.55	STABLE	E
SC250 Reinforced Vegetation	Straight	17.1 cfs	2.66 ft/s	0.84 ft	0.03	8 lbs/ft2	0.26 lbs/ft2	30.57	STABLE	E
Underlying Substrate	Straight	17.1 cfs	2.66 ft/s	0.84 ft	--	0.8 lbs/ft2	0.195 lbs/ft2	4.1	STABLE	--

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5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	17.1
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	6.44
AL = (1/2) * Depth2 * ZL =	0.7
AB = Bottom Width * Depth =	5.03
AR = (1/2) * Depth2 * ZR =	0.7

Wetted Perimeter (P)

P = PL + PB + PR =	9.75

PL = Depth * (ZL2 + 1)0.5 =	1.88
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.88
Hydraulic Radius (R)	
R = A / P =	0.66
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	17.1
Velocity (V)	
V = Q / A =	2.66
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.26
Channel Safety Factor = (Tp / Td)	9.55
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.33
CF =	0
ns =	0.03
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	6.44
AL = (1/2) * Depth2 * ZL =	0.7
AB = Bottom Width * Depth =	5.03
AR = (1/2) * Depth2 * ZR =	0.7
Wetted Perimeter (P)	
P = PL + PB + PR =	9.75
PL = Depth * (ZL2 + 1)0.5 =	1.88
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.88
Hydraulic Radius (R)	
R = A / P =	0.66

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	17.1
Velocity (V)	
V = Q / A =	2.66
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.26
Channel Safety Factor = (Tp / Td)	30.57
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.2
CF =	0.4
ns =	0.03
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	4.1
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH H2 - G2

Discharge	11.6
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	6
Left Side Slope	2
Right Side Slope	2
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	11.6 cfs	2.35 ft/s	0.67 ft	0.03	2.5 lbs/ft2	0.21 lbs/ft2	11.91	STABLE	E
SC250 Reinforced Vegetation	Straight	11.6 cfs	2.35 ft/s	0.67 ft	0.03	8 lbs/ft2	0.21 lbs/ft2	38.11	STABLE	E
Underlying Substrate	Straight	11.6 cfs	2.35 ft/s	0.67 ft	--	0.8 lbs/ft2	0.188 lbs/ft2	4.25	STABLE	--

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Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	11.6
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	4.94
AL = (1/2) * Depth2 * ZL =	0.45
AB = Bottom Width * Depth =	4.04
AR = (1/2) * Depth2 * ZR =	0.45
Wetted Perimeter (P)	
P = PL + PB + PR =	9.01

PL = Depth * (ZL2 + 1)0.5 =	1.5
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.5
Hydraulic Radius (R)	
R = A / P =	0.55
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	11.6
Velocity (V)	
V = Q / A =	2.35
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.21
Channel Safety Factor = (Tp / Td)	11.91
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.31
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	4.94
AL = (1/2) * Depth2 * ZL =	0.45
AB = Bottom Width * Depth =	4.04
AR = (1/2) * Depth2 * ZR =	0.45
Wetted Perimeter (P)	
P = PL + PB + PR =	9.01
PL = Depth * (ZL2 + 1)0.5 =	1.5
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.5
Hydraulic Radius (R)	
R = A / P =	0.55

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	11.6
Velocity (V)	
V = Q / A =	2.35
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.21
Channel Safety Factor = (Tp / Td)	38.11
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.19
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	4.25
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH G2 - X25

Discharge	14.3
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	6
Left Side Slope	2
Right Side Slope	2
Existing Bend Radius	59
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	14.3 cfs	2.51 ft/s	0.76 ft	0.03	2.5 lbs/ft2	0.24 lbs/ft2	10.57	STABLE	E
SC250 Reinforced Vegetation	Straight	14.3 cfs	2.51 ft/s	0.76 ft	0.03	8 lbs/ft2	0.24 lbs/ft2	33.83	STABLE	E
Underlying Substrate	Straight	14.3 cfs	2.51 ft/s	0.76 ft	--	0.8 lbs/ft2	0.193 lbs/ft2	4.14	STABLE	--
SC250 Unvegetated	Bend	14.3 cfs	2.51 ft/s	0.76 ft	0.03	2.5 lbs/ft2	0.25 lbs/ft2	10.15	STABLE	E
SC250 Reinforced Vegetation	Bend	14.3 cfs	2.51 ft/s	0.76 ft	0.03	8 lbs/ft2	0.25 lbs/ft2	32.49	STABLE	E
Underlying Substrate	Bend	14.3 cfs	2.51 ft/s	0.76 ft	--	0.8 lbs/ft2	0.193 lbs/ft2	4.14	STABLE	--

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Poseyville, Indiana 47633
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Fax 812.867.0247
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Channel Computations

Project Parameters	
Specify Manning's n:	0.03
Discharge:	14.3
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	6
Left Side Slope:	2
Right Side Slope:	2
Existing Channel Bend:	1
Bend Coefficient (Kb):	
Channel Radius :	59
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam
Channel Lining Options	
Protection Type	Permanent

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	5.7
AL = (1/2) * Depth2 * ZL =	0.57
AB = Bottom Width * Depth =	4.55
AR = (1/2) * Depth2 * ZR =	0.57
Wetted Perimeter (P)	

P = PL + PB + PR =	9.39
PL = Depth * (ZL2 + 1)0.5 =	1.69
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.69
Hydraulic Radius (R)	
R = A / P =	0.61
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	14.3
Velocity (V)	
V = Q / A =	2.51
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.24
Channel Safety Factor = (Tp / Td)	10.57
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.32
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Bend Shear Stress (Tdb)	
Tdb =	0.25
Bend Safety Factor	
Tdb =	10.15
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	0.34
Soil Safety Factor in Bend	
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Material Type	
Matting Type	SC250

Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	5.7
AL = (1/2) * Depth2 * ZL =	0.57
AB = Bottom Width * Depth =	4.55
AR = (1/2) * Depth2 * ZR =	0.57
Wetted Perimeter (P)	
P = PL + PB + PR =	9.39
PL = Depth * (ZL2 + 1)0.5 =	1.69
PB = Channel Bottom Width =	6
PR = Depth * (ZR2 + 1)0.5	1.69
Hydraulic Radius (R)	
R = A / P =	0.61
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	14.3
Velocity (V)	
V = Q / A =	2.51
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.24
Channel Safety Factor = (Tp / Td)	33.83
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.19
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	4.14
Bend Shear Stress (Tdb)	
Tdb =	0.25
Bend Safety Factor	
Tdb =	32.49
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	0.2
Soil Safety Factor in Bend	

Soil Safety Factor = Ta / Te =	2.39
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

Erosion Control Materials Design Software
Version 5.0

Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH F6 - G5

Discharge	21.8
Peak Flow Period	2.4
Channel Slope	0.077
Channel Bottom Width	3
Left Side Slope	4
Right Side Slope	2
Existing Bend Radius	161
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

Rock Riprap - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
Rock Riprap Unvegetated	Straight	21.8 cfs	7.69 ft/s	0.59 ft	0.03	4 lbs/ft2	2.85 lbs/ft2	1.4	STABLE	--
Rock Riprap Unvegetated	Bend	21.8 cfs	7.69 ft/s	0.59 ft	0.03	4 lbs/ft2	2.85 lbs/ft2	1.4	STABLE	--

W3000 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern

W3000 Reinforced Vegetation	Straight	21.8 cfs	7.69 ft/s	0.59 ft	0.03	16 lbs/ft2	2.85 lbs/ft2	5.61	STABLE	
Underlying Substrate	Straight	21.8 cfs	7.69 ft/s	0.59 ft	--	3.25 lbs/ft2	2.929 lbs/ft2	1.11	STABLE	--
W3000 Reinforced Vegetation	Bend	21.8 cfs	7.69 ft/s	0.59 ft	0.03	16 lbs/ft2	2.85 lbs/ft2	5.61	STABLE	
Underlying Substrate	Bend	21.8 cfs	7.69 ft/s	0.59 ft	--	3.25 lbs/ft2	2.929 lbs/ft2	1.11	STABLE	--

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Poseyville, Indiana 47633
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Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	21.8
Peak Flow Period:	2.4
Channel Slope:	0.077
Bottom Width:	3
Left Side Slope:	4
Right Side Slope:	2
Existing Channel Bend:	1
Bend Coefficient (Kb):	
Channel Radius :	161
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type	
Matting Type	Rock Riprap
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	2.83
AL = (1/2) * Depth2 * ZL =	0.7
AB = Bottom Width * Depth =	1.78
AR = (1/2) * Depth2 * ZR =	0.35
Wetted Perimeter (P)	

P = PL + PB + PR =	6.77
PL = Depth * (ZL2 + 1)0.5 =	2.45
PB = Channel Bottom Width =	3
PR = Depth * (ZR2 + 1)0.5	1.33
Hydraulic Radius (R)	
R = A / P =	0.42
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	21.8
Velocity (V)	
V = Q / A =	7.69
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	2.85
Channel Safety Factor = (Tp / Td)	1.4
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0
CF =	0
ns =	0
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Bend Shear Stress (Tdb)	
Tdb =	2.85
Bend Safety Factor	
Tdb =	1.4
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	0
Soil Safety Factor in Bend	
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Material Type	
Matting Type	W3000

Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	2.83
AL = (1/2) * Depth2 * ZL =	0.7
AB = Bottom Width * Depth =	1.78
AR = (1/2) * Depth2 * ZR =	0.35
Wetted Perimeter (P)	
P = PL + PB + PR =	6.77
PL = Depth * (ZL2 + 1)0.5 =	2.45
PB = Channel Bottom Width =	3
PR = Depth * (ZR2 + 1)0.5	1.33
Hydraulic Radius (R)	
R = A / P =	0.42
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	21.8
Velocity (V)	
V = Q / A =	7.69
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	2.85
Channel Safety Factor = (Tp / Td)	5.61
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	2.93
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	3.25
Soil Safety Factor = Ta / Te =	1.11
Bend Shear Stress (Tdb)	
Tdb =	2.85
Bend Safety Factor	
Tdb =	5.61
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	2.93
Soil Safety Factor in Bend	

Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
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Fax 812.867.0247
www.nagreen.com

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Version 5.0

Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH HP7 - F6

Discharge	79.7
Peak Flow Period	2.4
Channel Slope	0.043
Channel Bottom Width	3
Left Side Slope	4
Right Side Slope	2
Existing Bend Radius	161
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

Rock Riprap - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
Rock Riprap Unvegetated	Straight	79.7 cfs	8.84 ft/s	1.3 ft	0.03	4 lbs/ft2	3.5 lbs/ft2	1.14	STABLE	--
Rock Riprap Unvegetated	Bend	79.7 cfs	8.84 ft/s	1.3 ft	0.03	4 lbs/ft2	3.5 lbs/ft2	1.14	STABLE	--

W3000 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern

W3000 Reinforced Vegetation	Straight	79.7 cfs	8.84 ft/s	1.3 ft	0.03	16 lbs/ft2	3.5 lbs/ft2	4.57	STABLE	
Underlying Substrate	Straight	79.7 cfs	8.84 ft/s	1.3 ft	--	3.25 lbs/ft2	1.575 lbs/ft2	2.06	STABLE	--
W3000 Reinforced Vegetation	Bend	79.7 cfs	8.84 ft/s	1.3 ft	0.03	16 lbs/ft2	3.5 lbs/ft2	4.57	STABLE	
Underlying Substrate	Bend	79.7 cfs	8.84 ft/s	1.3 ft	--	3.25 lbs/ft2	1.575 lbs/ft2	2.06	STABLE	--

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Poseyville, Indiana 47633
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Channel Computations

Project Parameters	
Specify Manning's n:	0.03
Discharge:	79.7
Peak Flow Period:	2.4
Channel Slope:	0.043
Bottom Width:	3
Left Side Slope:	4
Right Side Slope:	2
Existing Channel Bend:	1
Bend Coefficient (Kb):	
Channel Radius :	161
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam
Channel Lining Options	
Protection Type	Permanent

Material Type	
Matting Type	Rock Riprap
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	9.02
AL = (1/2) * Depth2 * ZL =	3.4
AB = Bottom Width * Depth =	3.91
AR = (1/2) * Depth2 * ZR =	1.7
Wetted Perimeter (P)	

P = PL + PB + PR =	11.29
PL = Depth * (ZL2 + 1)0.5 =	5.38
PB = Channel Bottom Width =	3
PR = Depth * (ZR2 + 1)0.5	2.92
Hydraulic Radius (R)	
R = A / P =	0.8
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	79.71
Velocity (V)	
V = Q / A =	8.84
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	3.5
Channel Safety Factor = (Tp / Td)	1.14
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0
CF =	0
ns =	0
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Bend Shear Stress (Tdb)	
Tdb =	3.5
Bend Safety Factor	
Tdb =	1.14
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	0
Soil Safety Factor in Bend	
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Material Type	
Matting Type	W3000

Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	9.02
AL = (1/2) * Depth2 * ZL =	3.4
AB = Bottom Width * Depth =	3.91
AR = (1/2) * Depth2 * ZR =	1.7
Wetted Perimeter (P)	
P = PL + PB + PR =	11.29
PL = Depth * (ZL2 + 1)0.5 =	5.38
PB = Channel Bottom Width =	3
PR = Depth * (ZR2 + 1)0.5	2.92
Hydraulic Radius (R)	
R = A / P =	0.8
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	79.71
Velocity (V)	
V = Q / A =	8.84
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	3.5
Channel Safety Factor = (Tp / Td)	4.57
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	1.58
CF =	0.4
ns =	0.03
Soil Safety Factor	
Allowable Soil Shear (Ta) =	3.25
Soil Safety Factor = Ta / Te =	2.06
Bend Shear Stress (Tdb)	
Tdb =	3.5
Bend Safety Factor	
Tdb =	4.57
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	1.58
Soil Safety Factor in Bend	

Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
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Fax 812.867.0247
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Erosion Control Materials Design Software
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH G5 - H4

Discharge	42.4
Peak Flow Period	2.4
Channel Slope	0.062
Channel Bottom Width	3
Left Side Slope	4
Right Side Slope	2
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

Rock Riprap - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
Rock Riprap Unvegetated	Straight	42.4 cfs	8.55 ft/s	0.88 ft	0.03	4 lbs/ft2	3.4 lbs/ft2	1.18	STABLE	--

W3000 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
W3000 Reinforced Vegetation	Straight	42.4 cfs	8.55 ft/s	0.88 ft	0.03	16 lbs/ft2	3.4 lbs/ft2	4.7	STABLE	
Underlying Substrate	Straight	42.4 cfs	8.55 ft/s	0.88 ft	--	3.25 lbs/ft2	2.609 lbs/ft2	1.25	STABLE	--

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5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	42.4
Peak Flow Period:	2.4
Channel Slope:	0.062
Bottom Width:	3
Left Side Slope:	4
Right Side Slope:	2
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type	
Matting Type	Rock Riprap
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	4.96
AL = (1/2) * Depth2 * ZL =	1.55
AB = Bottom Width * Depth =	2.64
AR = (1/2) * Depth2 * ZR =	0.77
Wetted Perimeter (P)	
P = PL + PB + PR =	8.59

PL = Depth * (ZL2 + 1)0.5 =	3.63
PB = Channel Bottom Width =	3
PR = Depth * (ZR2 + 1)0.5	1.97
Hydraulic Radius (R)	
R = A / P =	0.58
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	42.41
Velocity (V)	
V = Q / A =	8.55
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	3.4
Channel Safety Factor = (Tp / Td)	1.18
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0
CF =	0
ns =	0
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	

Material Type	
Matting Type	W3000
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	4.96
AL = (1/2) * Depth2 * ZL =	1.55
AB = Bottom Width * Depth =	2.64
AR = (1/2) * Depth2 * ZR =	0.77
Wetted Perimeter (P)	
P = PL + PB + PR =	8.59
PL = Depth * (ZL2 + 1)0.5 =	3.63
PB = Channel Bottom Width =	3
PR = Depth * (ZR2 + 1)0.5	1.97
Hydraulic Radius (R)	
R = A / P =	0.58

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	42.41
Velocity (V)	
V = Q / A =	8.55
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	3.4
Channel Safety Factor = (Tp / Td)	4.7
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	2.61
CF =	0.4
ns =	0.03
Soil Safety Factor	
Allowable Soil Shear (Ta) =	3.25
Soil Safety Factor = Ta / Te =	1.25
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

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Poseyville, Indiana 47633
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Fax 812.867.0247
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Erosion Control Materials Design Software
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH HP5 - X8

Discharge	19.2
Peak Flow Period	2.4
Channel Slope	0.03
Channel Bottom Width	10
Left Side Slope	3
Right Side Slope	3
Existing Bend Radius	33
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	19.2 cfs	4.31 ft/s	0.4 ft	0.03	2.5 lbs/ft2	0.75 lbs/ft2	3.35	STABLE	E
SC250 Reinforced Vegetation	Straight	19.2 cfs	4.31 ft/s	0.4 ft	0.03	8 lbs/ft2	0.75 lbs/ft2	10.73	STABLE	E
Underlying Substrate	Straight	19.2 cfs	4.31 ft/s	0.4 ft	--	0.8 lbs/ft2	0.795 lbs/ft2	1.01	STABLE	--
SC250 Unvegetated	Bend	19.2 cfs	4.31 ft/s	0.4 ft	0.03	2.5 lbs/ft2	1.34 lbs/ft2	1.87	STABLE	E
SC250 Reinforced Vegetation	Bend	19.2 cfs	4.31 ft/s	0.4 ft	0.03	8 lbs/ft2	1.34 lbs/ft2	5.98	STABLE	E
Underlying Substrate	Bend	19.2 cfs	4.31 ft/s	0.4 ft	--	0.8 lbs/ft2	0.795 lbs/ft2	1.01	STABLE	--

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Poseyville, Indiana 47633
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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	19.2
Peak Flow Period:	2.4
Channel Slope:	0.03
Bottom Width:	10
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	1
Bend Coefficient (Kb):	
Channel Radius :	33
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	4.46
AL = (1/2) * Depth2 * ZL =	0.24
AB = Bottom Width * Depth =	3.98
AR = (1/2) * Depth2 * ZR =	0.24

Wetted Perimeter (P)

P = PL + PB + PR =	12.52
PL = Depth * (ZL2 + 1)0.5 =	1.26
PB = Channel Bottom Width =	10
PR = Depth * (ZR2 + 1)0.5	1.26
Hydraulic Radius (R)	
R = A / P =	0.36
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	19.21
Velocity (V)	
V = Q / A =	4.31
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.75
Channel Safety Factor = (Tp / Td)	3.35
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	1.32
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Bend Shear Stress (Tdb)	
Tdb =	1.34
Bend Safety Factor	
Tdb =	1.87
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	2.38
Soil Safety Factor in Bend	
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Material Type	
Matting Type	SC250

Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	4.46
AL = (1/2) * Depth2 * ZL =	0.24
AB = Bottom Width * Depth =	3.98
AR = (1/2) * Depth2 * ZR =	0.24
Wetted Perimeter (P)	
P = PL + PB + PR =	12.52
PL = Depth * (ZL2 + 1)0.5 =	1.26
PB = Channel Bottom Width =	10
PR = Depth * (ZR2 + 1)0.5	1.26
Hydraulic Radius (R)	
R = A / P =	0.36
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	19.21
Velocity (V)	
V = Q / A =	4.31
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.75
Channel Safety Factor = (Tp / Td)	10.73
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.79
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	1.01
Bend Shear Stress (Tdb)	
Tdb =	1.34
Bend Safety Factor	
Tdb =	5.98
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	1.43
Soil Safety Factor in Bend	

Soil Safety Factor = Ta / Te =	0.34
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH X7 - X6

Discharge	38.6
Peak Flow Period	2.4
Channel Slope	0.038
Channel Bottom Width	10
Left Side Slope	3
Right Side Slope	3
Existing Bend Radius	33
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

P550 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
P550 Unvegetated	Straight	38.6 cfs	5.93 ft/s	0.56 ft	0.03	3.25 lbs/ft2	1.32 lbs/ft2	2.46	STABLE	E
P550 Reinforced Vegetation	Straight	38.6 cfs	5.93 ft/s	0.56 ft	0.03	12 lbs/ft2	1.32 lbs/ft2	9.07	STABLE	E
Underlying Substrate	Straight	38.6 cfs	5.93 ft/s	0.56 ft	--	3.25 lbs/ft2	1.405 lbs/ft2	2.31	STABLE	--
P550 Unvegetated	Bend	38.6 cfs	5.93 ft/s	0.56 ft	0.03	3.25 lbs/ft2	2.38 lbs/ft2	1.37	STABLE	E
P550 Reinforced Vegetation	Bend	38.6 cfs	5.93 ft/s	0.56 ft	0.03	12 lbs/ft2	2.38 lbs/ft2	5.05	STABLE	E
Underlying Substrate	Bend	38.6 cfs	5.93 ft/s	0.56 ft	--	3.25 lbs/ft2	1.405 lbs/ft2	2.31	STABLE	--

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	38.6
Peak Flow Period:	2.4
Channel Slope:	0.038
Bottom Width:	10
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	1
Bend Coefficient (Kb):	
Channel Radius :	33
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	P550
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	6.51
AL = (1/2) * Depth2 * ZL =	0.47
AB = Bottom Width * Depth =	5.58
AR = (1/2) * Depth2 * ZR =	0.47

Wetted Perimeter (P)

P = PL + PB + PR =	13.53
PL = Depth * (ZL2 + 1)0.5 =	1.76
PB = Channel Bottom Width =	10
PR = Depth * (ZR2 + 1)0.5	1.76
Hydraulic Radius (R)	
R = A / P =	0.48
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	38.6
Velocity (V)	
V = Q / A =	5.93
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	1.32
Channel Safety Factor = (Tp / Td)	2.46
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	2.34
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Bend Shear Stress (Tdb)	
Tdb =	2.38
Bend Safety Factor	
Tdb =	1.37
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	4.21
Soil Safety Factor in Bend	
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Material Type	
Matting Type	P550

Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	6.51
AL = (1/2) * Depth2 * ZL =	0.47
AB = Bottom Width * Depth =	5.58
AR = (1/2) * Depth2 * ZR =	0.47
Wetted Perimeter (P)	
P = PL + PB + PR =	13.53
PL = Depth * (ZL2 + 1)0.5 =	1.76
PB = Channel Bottom Width =	10
PR = Depth * (ZR2 + 1)0.5	1.76
Hydraulic Radius (R)	
R = A / P =	0.48
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	38.6
Velocity (V)	
V = Q / A =	5.93
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	1.32
Channel Safety Factor = (Tp / Td)	9.07
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	1.41
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	3.25
Soil Safety Factor = Ta / Te =	2.31
Bend Shear Stress (Tdb)	
Tdb =	2.38
Bend Safety Factor	
Tdb =	5.05
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	2.52
Soil Safety Factor in Bend	

Soil Safety Factor = Ta / Te =	0.77
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Side Slope Liner Results

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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH X5 - X3

Discharge	28.2
Peak Flow Period	2.4
Channel Slope	0.032
Channel Bottom Width	10
Left Side Slope	3
Right Side Slope	3
Existing Bend Radius	34
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

C350 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
C350 Unvegetated	Straight	28.2 cfs	5.03 ft/s	0.49 ft	0.03	3 lbs/ft2	0.98 lbs/ft2	3.07	STABLE	E
C350 Reinforced Vegetation	Straight	28.2 cfs	5.03 ft/s	0.49 ft	0.03	10 lbs/ft2	0.98 lbs/ft2	10.25	STABLE	E
Underlying Substrate	Straight	28.2 cfs	5.03 ft/s	0.49 ft	--	1.2 lbs/ft2	1.094 lbs/ft2	1.1	STABLE	--
C350 Unvegetated	Bend	28.2 cfs	5.03 ft/s	0.49 ft	0.03	3 lbs/ft2	1.74 lbs/ft2	1.73	STABLE	E
C350 Reinforced Vegetation	Bend	28.2 cfs	5.03 ft/s	0.49 ft	0.03	10 lbs/ft2	1.74 lbs/ft2	5.75	STABLE	E
Underlying Substrate	Bend	28.2 cfs	5.03 ft/s	0.49 ft	--	1.2 lbs/ft2	1.094 lbs/ft2	1.1	STABLE	--

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Poseyville, Indiana 47633
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Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	28.2
Peak Flow Period:	2.4
Channel Slope:	0.032
Bottom Width:	10
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	1
Bend Coefficient (Kb):	
Channel Radius :	34
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	C350
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	5.6
AL = (1/2) * Depth2 * ZL =	0.36
AB = Bottom Width * Depth =	4.89
AR = (1/2) * Depth2 * ZR =	0.36

Wetted Perimeter (P)

P = PL + PB + PR =	13.09
PL = Depth * (ZL2 + 1)0.5 =	1.55
PB = Channel Bottom Width =	10
PR = Depth * (ZR2 + 1)0.5	1.55
Hydraulic Radius (R)	
R = A / P =	0.43
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	28.2
Velocity (V)	
V = Q / A =	5.03
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.98
Channel Safety Factor = (Tp / Td)	3.07
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	1.82
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Bend Shear Stress (Tdb)	
Tdb =	1.74
Bend Safety Factor	
Tdb =	1.73
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	3.25
Soil Safety Factor in Bend	
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Material Type	
Matting Type	C350

Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	5.6
AL = (1/2) * Depth2 * ZL =	0.36
AB = Bottom Width * Depth =	4.89
AR = (1/2) * Depth2 * ZR =	0.36
Wetted Perimeter (P)	
P = PL + PB + PR =	13.09
PL = Depth * (ZL2 + 1)0.5 =	1.55
PB = Channel Bottom Width =	10
PR = Depth * (ZR2 + 1)0.5	1.55
Hydraulic Radius (R)	
R = A / P =	0.43
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	28.2
Velocity (V)	
V = Q / A =	5.03
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.98
Channel Safety Factor = (Tp / Td)	10.25
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	1.09
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	1.2
Soil Safety Factor = Ta / Te =	1.1
Bend Shear Stress (Tdb)	
Tdb =	1.74
Bend Safety Factor	
Tdb =	5.75
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	1.95
Soil Safety Factor in Bend	

Soil Safety Factor = Ta / Te =	0.37
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Side Slope Liner Results

Tensar International Corporation
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH X4 - C1

Discharge	7.1
Peak Flow Period	2.4
Channel Slope	.005
Channel Bottom Width	14
Left Side Slope	3
Right Side Slope	3
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	7.1 cfs	1.53 ft/s	0.31 ft	0.03	2.5 lbs/ft2	0.1 lbs/ft2	25.85	STABLE	E
SC250 Reinforced Vegetation	Straight	7.1 cfs	1.53 ft/s	0.31 ft	0.03	8 lbs/ft2	0.1 lbs/ft2	82.71	STABLE	E
Underlying Substrate	Straight	7.1 cfs	1.53 ft/s	0.31 ft	--	0.8 lbs/ft2	0.103 lbs/ft2	7.75	STABLE	--

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Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters	
Specify Manning's n:	0.03
Discharge:	7.1
Peak Flow Period:	2.4
Channel Slope:	.005
Bottom Width:	14
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam
Channel Lining Options	
Protection Type	Permanent

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	4.63
AL = (1/2) * Depth2 * ZL =	0.14
AB = Bottom Width * Depth =	4.34
AR = (1/2) * Depth2 * ZR =	0.14
Wetted Perimeter (P)	
P = PL + PB + PR =	15.96

PL = Depth * (ZL2 + 1)0.5 =	0.98
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	0.98
Hydraulic Radius (R)	
R = A / P =	0.29
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	7.1
Velocity (V)	
V = Q / A =	1.53
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.1
Channel Safety Factor = (Tp / Td)	25.85
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.17
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	4.63
AL = (1/2) * Depth2 * ZL =	0.14
AB = Bottom Width * Depth =	4.34
AR = (1/2) * Depth2 * ZR =	0.14
Wetted Perimeter (P)	
P = PL + PB + PR =	15.96
PL = Depth * (ZL2 + 1)0.5 =	0.98
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	0.98
Hydraulic Radius (R)	
R = A / P =	0.29

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	7.1
Velocity (V)	
V = Q / A =	1.53
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.1
Channel Safety Factor = (Tp / Td)	82.71
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.1
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	7.75
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH C1 - D1

Discharge	178.1
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	14
Left Side Slope	3
Right Side Slope	3
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	178.1 cfs	4.55 ft/s	1.97 ft	0.03	2.5 lbs/ft2	0.61 lbs/ft2	4.07	STABLE	E
SC250 Reinforced Vegetation	Straight	178.1 cfs	4.55 ft/s	1.97 ft	0.03	8 lbs/ft2	0.61 lbs/ft2	13.04	STABLE	E
Underlying Substrate	Straight	178.1 cfs	4.55 ft/s	1.97 ft	--	0.8 lbs/ft2	0.055 lbs/ft2	14.44	STABLE	--

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Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	178.1
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	14
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	39.15
AL = (1/2) * Depth2 * ZL =	5.8
AB = Bottom Width * Depth =	27.54
AR = (1/2) * Depth2 * ZR =	5.8
Wetted Perimeter (P)	
P = PL + PB + PR =	26.44

PL = Depth * (ZL2 + 1)0.5 =	6.22
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	6.22
Hydraulic Radius (R)	
R = A / P =	1.48
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	178.1
Velocity (V)	
V = Q / A =	4.55
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.61
Channel Safety Factor = (Tp / Td)	4.07
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.09
CF =	0
ns =	0.01
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	39.15
AL = (1/2) * Depth2 * ZL =	5.8
AB = Bottom Width * Depth =	27.54
AR = (1/2) * Depth2 * ZR =	5.8
Wetted Perimeter (P)	
P = PL + PB + PR =	26.44
PL = Depth * (ZL2 + 1)0.5 =	6.22
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	6.22
Hydraulic Radius (R)	
R = A / P =	1.48

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	178.1
Velocity (V)	
V = Q / A =	4.55
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.61
Channel Safety Factor = (Tp / Td)	13.04
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.06
CF =	0.4
ns =	0.01
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	14.44
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

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Poseyville, Indiana 47633
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Fax 812.867.0247
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH X1 - X18

Discharge	287.8
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	14
Left Side Slope	3
Right Side Slope	3
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	287.8 cfs	5.24 ft/s	2.54 ft	0.03	2.5 lbs/ft2	0.79 lbs/ft2	3.15	STABLE	E
SC250 Reinforced Vegetation	Straight	287.8 cfs	5.24 ft/s	2.54 ft	0.03	8 lbs/ft2	0.79 lbs/ft2	10.09	STABLE	E
Underlying Substrate	Straight	287.8 cfs	5.24 ft/s	2.54 ft	--	0.8 lbs/ft2	0.064 lbs/ft2	12.5	STABLE	--

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Version 5.0

Channel Computations

Project Parameters	
Specify Manning's n:	0.03
Discharge:	287.8
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	14
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam
Channel Lining Options	
Protection Type	Permanent

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	54.97
AL = (1/2) * Depth2 * ZL =	9.69
AB = Bottom Width * Depth =	35.59
AR = (1/2) * Depth2 * ZR =	9.69
Wetted Perimeter (P)	
P = PL + PB + PR =	30.08

PL = Depth * (ZL2 + 1)0.5 =	8.04
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	8.04
Hydraulic Radius (R)	
R = A / P =	1.83
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	287.81
Velocity (V)	
V = Q / A =	5.24
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.79
Channel Safety Factor = (Tp / Td)	3.15
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.11
CF =	0
ns =	0.01
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	54.97
AL = (1/2) * Depth2 * ZL =	9.69
AB = Bottom Width * Depth =	35.59
AR = (1/2) * Depth2 * ZR =	9.69
Wetted Perimeter (P)	
P = PL + PB + PR =	30.08
PL = Depth * (ZL2 + 1)0.5 =	8.04
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	8.04
Hydraulic Radius (R)	
R = A / P =	1.83

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	287.81
Velocity (V)	
V = Q / A =	5.24
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.79
Channel Safety Factor = (Tp / Td)	10.09
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.06
CF =	0.4
ns =	0.01
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	12.5
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH D1 - X1

Discharge	244.6
Peak Flow Period	2.4
Channel Slope	0.005
Channel Bottom Width	14
Left Side Slope	3
Right Side Slope	3
Existing Bend Radius	137
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	244.6 cfs	5 ft/s	2.33 ft	0.03	2.5 lbs/ft2	0.73 lbs/ft2	3.44	STABLE	E
SC250 Reinforced Vegetation	Straight	244.6 cfs	5 ft/s	2.33 ft	0.03	8 lbs/ft2	0.73 lbs/ft2	10.99	STABLE	E
Underlying Substrate	Straight	244.6 cfs	5 ft/s	2.33 ft	--	0.8 lbs/ft2	0.059 lbs/ft2	13.63	STABLE	--
SC250 Unvegetated	Bend	244.6 cfs	5 ft/s	2.33 ft	0.03	2.5 lbs/ft2	0.76 lbs/ft2	3.29	STABLE	E
SC250 Reinforced Vegetation	Bend	244.6 cfs	5 ft/s	2.33 ft	0.03	8 lbs/ft2	0.76 lbs/ft2	10.52	STABLE	E
Underlying Substrate	Bend	244.6 cfs	5 ft/s	2.33 ft	--	0.8 lbs/ft2	0.059 lbs/ft2	13.63	STABLE	--

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Poseyville, Indiana 47633
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Erosion Control Materials Design Software
Version 5.0

Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	244.6
Peak Flow Period:	2.4
Channel Slope:	0.005
Bottom Width:	14
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	1
Bend Coefficient (Kb):	
Channel Radius :	137
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	48.97
AL = (1/2) * Depth2 * ZL =	8.16
AB = Bottom Width * Depth =	32.65
AR = (1/2) * Depth2 * ZR =	8.16

Wetted Perimeter (P)

P = PL + PB + PR =	28.75
PL = Depth * (ZL2 + 1)0.5 =	7.38
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	7.38
Hydraulic Radius (R)	
R = A / P =	1.7
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	244.61
Velocity (V)	
V = Q / A =	5
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.73
Channel Safety Factor = (Tp / Td)	3.44
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.1
CF =	0
ns =	0.01
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Bend Shear Stress (Tdb)	
Tdb =	0.76
Bend Safety Factor	
Tdb =	3.29
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	0.1
Soil Safety Factor in Bend	
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Material Type	
Matting Type	SC250

Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	48.97
AL = (1/2) * Depth2 * ZL =	8.16
AB = Bottom Width * Depth =	32.65
AR = (1/2) * Depth2 * ZR =	8.16
Wetted Perimeter (P)	
P = PL + PB + PR =	28.75
PL = Depth * (ZL2 + 1)0.5 =	7.38
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	7.38
Hydraulic Radius (R)	
R = A / P =	1.7
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	244.61
Velocity (V)	
V = Q / A =	5
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.73
Channel Safety Factor = (Tp / Td)	10.99
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.06
CF =	0.4
ns =	0.01
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	13.63
Bend Shear Stress (Tdb)	
Tdb =	0.76
Bend Safety Factor	
Tdb =	10.52
Effective Stress on Blanket in Bend T(eb)	
Teb = Tdb * (1-CF) * (ns / n)2 =	0.06
Soil Safety Factor in Bend	

Soil Safety Factor = Ta / Te =	7.82
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE
Conclusion: Stability of Mat (Bend)	STABLE
Conclusion: Stability of Underlying Soil (Bend)	

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH X15 - X14

Discharge	163.5
Peak Flow Period	2.4
Channel Slope	.005
Channel Bottom Width	14
Left Side Slope	3
Right Side Slope	3
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	163.5 cfs	4.43 ft/s	1.88 ft	0.03	2.5 lbs/ft2	0.59 lbs/ft2	4.27	STABLE	E
SC250 Reinforced Vegetation	Straight	163.5 cfs	4.43 ft/s	1.88 ft	0.03	8 lbs/ft2	0.59 lbs/ft2	13.65	STABLE	E
Underlying Substrate	Straight	163.5 cfs	4.43 ft/s	1.88 ft	--	0.8 lbs/ft2	0.07 lbs/ft2	11.47	STABLE	--

Tensar International Corporation
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Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	163.5
Peak Flow Period:	2.4
Channel Slope:	.005
Bottom Width:	14
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	36.87
AL = (1/2) * Depth2 * ZL =	5.29
AB = Bottom Width * Depth =	26.29
AR = (1/2) * Depth2 * ZR =	5.29

Wetted Perimeter (P)

P = PL + PB + PR =	25.88

PL = Depth * (ZL2 + 1)0.5 =	5.94
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	5.94
Hydraulic Radius (R)	
R = A / P =	1.42
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	163.5
Velocity (V)	
V = Q / A =	4.43
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.59
Channel Safety Factor = (Tp / Td)	4.27
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.12
CF =	0
ns =	0.01
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	36.87
AL = (1/2) * Depth2 * ZL =	5.29
AB = Bottom Width * Depth =	26.29
AR = (1/2) * Depth2 * ZR =	5.29
Wetted Perimeter (P)	
P = PL + PB + PR =	25.88
PL = Depth * (ZL2 + 1)0.5 =	5.94
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	5.94
Hydraulic Radius (R)	
R = A / P =	1.42

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	163.5
Velocity (V)	
V = Q / A =	4.43
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.59
Channel Safety Factor = (Tp / Td)	13.65
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.07
CF =	0.4
ns =	0.01
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	11.47
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH X9 - H1

Discharge	23.9
Peak Flow Period	2.4
Channel Slope	.005
Channel Bottom Width	14
Left Side Slope	3
Right Side Slope	3
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	23.9 cfs	2.38 ft/s	0.63 ft	0.03	2.5 lbs/ft2	0.2 lbs/ft2	12.66	STABLE	E
SC250 Reinforced Vegetation	Straight	23.9 cfs	2.38 ft/s	0.63 ft	0.03	8 lbs/ft2	0.2 lbs/ft2	40.53	STABLE	E
Underlying Substrate	Straight	23.9 cfs	2.38 ft/s	0.63 ft	--	0.8 lbs/ft2	0.184 lbs/ft2	4.34	STABLE	--

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	23.9
Peak Flow Period:	2.4
Channel Slope:	.005
Bottom Width:	14
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	10.06
AL = (1/2) * Depth2 * ZL =	0.6
AB = Bottom Width * Depth =	8.86
AR = (1/2) * Depth2 * ZR =	0.6

Wetted Perimeter (P)

P = PL + PB + PR =	18

PL = Depth * (ZL2 + 1)0.5 =	2
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	2
Hydraulic Radius (R)	
R = A / P =	0.56
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	23.9
Velocity (V)	
V = Q / A =	2.38
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.2
Channel Safety Factor = (Tp / Td)	12.66
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.31
CF =	0
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	10.06
AL = (1/2) * Depth2 * ZL =	0.6
AB = Bottom Width * Depth =	8.86
AR = (1/2) * Depth2 * ZR =	0.6
Wetted Perimeter (P)	
P = PL + PB + PR =	18
PL = Depth * (ZL2 + 1)0.5 =	2
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	2
Hydraulic Radius (R)	
R = A / P =	0.56

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	23.9
Velocity (V)	
V = Q / A =	2.38
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.2
Channel Safety Factor = (Tp / Td)	40.53
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.18
CF =	0.4
ns =	0.04
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	4.34
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH HP6 - X10

Discharge	123.3
Peak Flow Period	2.4
Channel Slope	0.04
Channel Bottom Width	10
Left Side Slope	3
Right Side Slope	3
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

P550 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
P550 Unvegetated	Straight	123.3 cfs	8.8 ft/s	1.06 ft	0.03	3.25 lbs/ft2	2.65 lbs/ft2	1.23	STABLE	E
P550 Reinforced Vegetation	Straight	123.3 cfs	8.8 ft/s	1.06 ft	0.03	12 lbs/ft2	2.65 lbs/ft2	4.53	STABLE	E
Underlying Substrate	Straight	123.3 cfs	8.8 ft/s	1.06 ft	--	3.25 lbs/ft2	1.645 lbs/ft2	1.98	STABLE	--

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

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Channel Computations

Project Parameters	
Specify Manning's n:	0.03
Discharge:	123.3
Peak Flow Period:	2.4
Channel Slope:	0.04
Bottom Width:	10
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam
Channel Lining Options	
Protection Type	Permanent

Material Type	
Matting Type	P550
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	14.01
AL = (1/2) * Depth2 * ZL =	1.69
AB = Bottom Width * Depth =	10.62
AR = (1/2) * Depth2 * ZR =	1.69
Wetted Perimeter (P)	
P = PL + PB + PR =	16.72

PL = Depth * (ZL2 + 1)0.5 =	3.36
PB = Channel Bottom Width =	10
PR = Depth * (ZR2 + 1)0.5	3.36
Hydraulic Radius (R)	
R = A / P =	0.84
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	123.3
Velocity (V)	
V = Q / A =	8.8
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	2.65
Channel Safety Factor = (Tp / Td)	1.23
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	2.74
CF =	0
ns =	0.03
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	P550
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	14.01
AL = (1/2) * Depth2 * ZL =	1.69
AB = Bottom Width * Depth =	10.62
AR = (1/2) * Depth2 * ZR =	1.69
Wetted Perimeter (P)	
P = PL + PB + PR =	16.72
PL = Depth * (ZL2 + 1)0.5 =	3.36
PB = Channel Bottom Width =	10
PR = Depth * (ZR2 + 1)0.5	3.36
Hydraulic Radius (R)	
R = A / P =	0.84

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	123.3
Velocity (V)	
V = Q / A =	8.8
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	2.65
Channel Safety Factor = (Tp / Td)	4.53
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	1.64
CF =	0.4
ns =	0.03
Soil Safety Factor	
Allowable Soil Shear (Ta) =	3.25
Soil Safety Factor = Ta / Te =	1.98
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

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Poseyville, Indiana 47633
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Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH H1 - G1

Discharge	117.6
Peak Flow Period	2.4
Channel Slope	.005
Channel Bottom Width	14
Left Side Slope	3
Right Side Slope	3
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	117.6 cfs	4.01 ft/s	1.57 ft	0.03	2.5 lbs/ft2	0.49 lbs/ft2	5.11	STABLE	E
SC250 Reinforced Vegetation	Straight	117.6 cfs	4.01 ft/s	1.57 ft	0.03	8 lbs/ft2	0.49 lbs/ft2	16.36	STABLE	E
Underlying Substrate	Straight	117.6 cfs	4.01 ft/s	1.57 ft	--	0.8 lbs/ft2	0.122 lbs/ft2	6.54	STABLE	--

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Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
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Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	117.6
Peak Flow Period:	2.4
Channel Slope:	.005
Bottom Width:	14
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	29.31
AL = (1/2) * Depth2 * ZL =	3.69
AB = Bottom Width * Depth =	21.94
AR = (1/2) * Depth2 * ZR =	3.69

Wetted Perimeter (P)

P = PL + PB + PR =	23.91

PL = Depth * (ZL2 + 1)0.5 =	4.96
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	4.96
Hydraulic Radius (R)	
R = A / P =	1.23
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	117.6
Velocity (V)	
V = Q / A =	4.01
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.49
Channel Safety Factor = (Tp / Td)	5.11
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.2
CF =	0
ns =	0.02
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	29.31
AL = (1/2) * Depth2 * ZL =	3.69
AB = Bottom Width * Depth =	21.94
AR = (1/2) * Depth2 * ZR =	3.69
Wetted Perimeter (P)	
P = PL + PB + PR =	23.91
PL = Depth * (ZL2 + 1)0.5 =	4.96
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	4.96
Hydraulic Radius (R)	
R = A / P =	1.23

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	117.6
Velocity (V)	
V = Q / A =	4.01
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	0.49
Channel Safety Factor = (Tp / Td)	16.36
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.12
CF =	0.4
ns =	0.02
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	6.54
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

Tensar International Corporation
5401 St. Wendel-Cynthiana Road
Poseyville, Indiana 47633
Tel. 800.772.2040
Fax 812.867.0247
www.nagreen.com

Erosion Control Materials Design Software
Version 5.0

Project Name: Emelle Facility
Project Number: 57919
Channel Name: CHANNEL REACH G1 - X11

Discharge	201.8
Peak Flow Period	2.4
Channel Slope	0.01
Channel Bottom Width	14
Left Side Slope	3
Right Side Slope	3
Low Flow Liner	
Retardance Class	D
Vegtation Type	Bunch Type
Vegetation Density	Fair 50-75%
Soil Type	Clay Loam

SC250 - Class D - Bunch Type - Fair 50-75%

Phase	Reach	Discharge	Velocity	Normal Depth	Mannings N	Permissible Shear Stress	Calculated Shear Stress	Safety Factor	Remarks	Staple Pattern
SC250 Unvegetated	Straight	201.8 cfs	6.02 ft/s	1.74 ft	0.03	2.5 lbs/ft2	1.09 lbs/ft2	2.3	STABLE	E
SC250 Reinforced Vegetation	Straight	201.8 cfs	6.02 ft/s	1.74 ft	0.03	8 lbs/ft2	1.09 lbs/ft2	7.35	STABLE	E
Underlying Substrate	Straight	201.8 cfs	6.02 ft/s	1.74 ft	--	0.8 lbs/ft2	0.185 lbs/ft2	4.33	STABLE	--

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Version 5.0

Channel Computations

Project Parameters

Specify Manning's n:	0.03
Discharge:	201.8
Peak Flow Period:	2.4
Channel Slope:	0.01
Bottom Width:	14
Left Side Slope:	3
Right Side Slope:	3
Existing Channel Bend:	0
Bend Coefficient (Kb):	1.00
Retardance Class (A - E):	D
Vegetation Type:	Bunch Type
Vegetation Density:	Fair 50-75%
Soil Type:	Clay Loam

Channel Lining Options

Protection Type	Permanent

Material Type

Matting Type	SC250
Manning's N value for selected Product	0.03

Cross-Sectional Area (A)

A = AL + AB + AR =	33.53
AL = (1/2) * Depth2 * ZL =	4.56
AB = Bottom Width * Depth =	24.41
AR = (1/2) * Depth2 * ZR =	4.56

Wetted Perimeter (P)

P = PL + PB + PR =	25.03

PL = Depth * (ZL2 + 1)0.5 =	5.51
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	5.51
Hydraulic Radius (R)	
R = A / P =	1.34
Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	201.81
Velocity (V)	
V = Q / A =	6.02
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	1.09
Channel Safety Factor = (Tp / Td)	2.3
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.31
CF =	0
ns =	0.02
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0
Soil Safety Factor = Ta / Te =	0
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

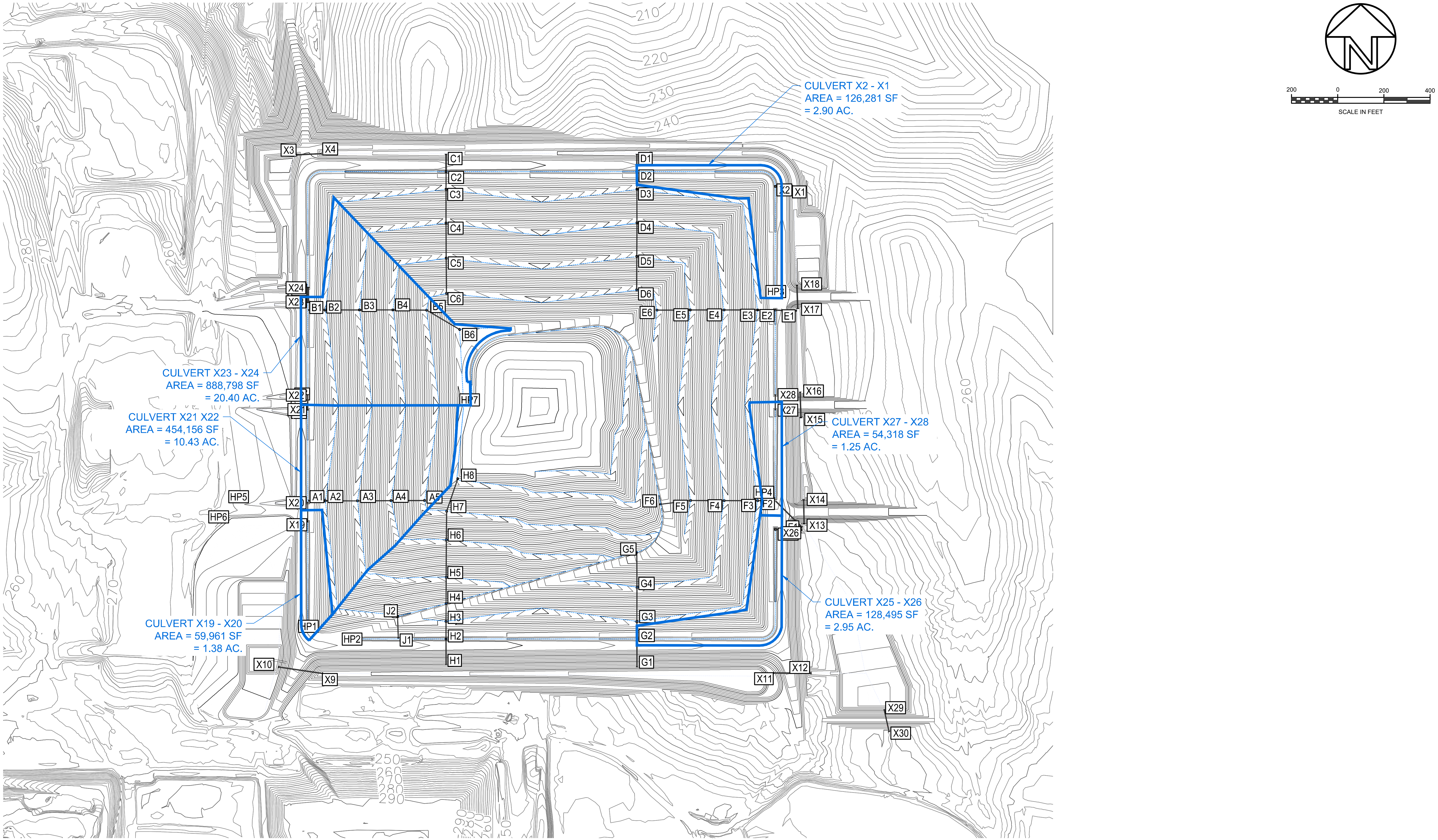
Material Type	
Matting Type	SC250
Manning's N value for selected Product	0.03
Cross-Sectional Area (A)	
A = AL + AB + AR =	33.53
AL = (1/2) * Depth2 * ZL =	4.56
AB = Bottom Width * Depth =	24.41
AR = (1/2) * Depth2 * ZR =	4.56
Wetted Perimeter (P)	
P = PL + PB + PR =	25.03
PL = Depth * (ZL2 + 1)0.5 =	5.51
PB = Channel Bottom Width =	14
PR = Depth * (ZR2 + 1)0.5	5.51
Hydraulic Radius (R)	
R = A / P =	1.34

Flow (Q)	
Q = 1.486 / n * A * R2/3 * S1/2 =	201.81
Velocity (V)	
V = Q / A =	6.02
Channel Shear Stress (Te)	
Td = 62.4 * Depth * Slope =	1.09
Channel Safety Factor = (Tp / Td)	7.35
Effective Stress on Blanket(Tdb)	
Te = Td * (1-CF) * (ns/n)2 =	0.18
CF =	0.4
ns =	0.02
Soil Safety Factor	
Allowable Soil Shear (Ta) =	0.8
Soil Safety Factor = Ta / Te =	4.33
Conclusion: Stability of Mat	STABLE
Conclusion: Stability of Underlying soil	STABLE

Side Slope Liner Results

EXHIBIT H-4

Hydrologic and Hydraulic Calculations – Stormwater Conveyance Culverts



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DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

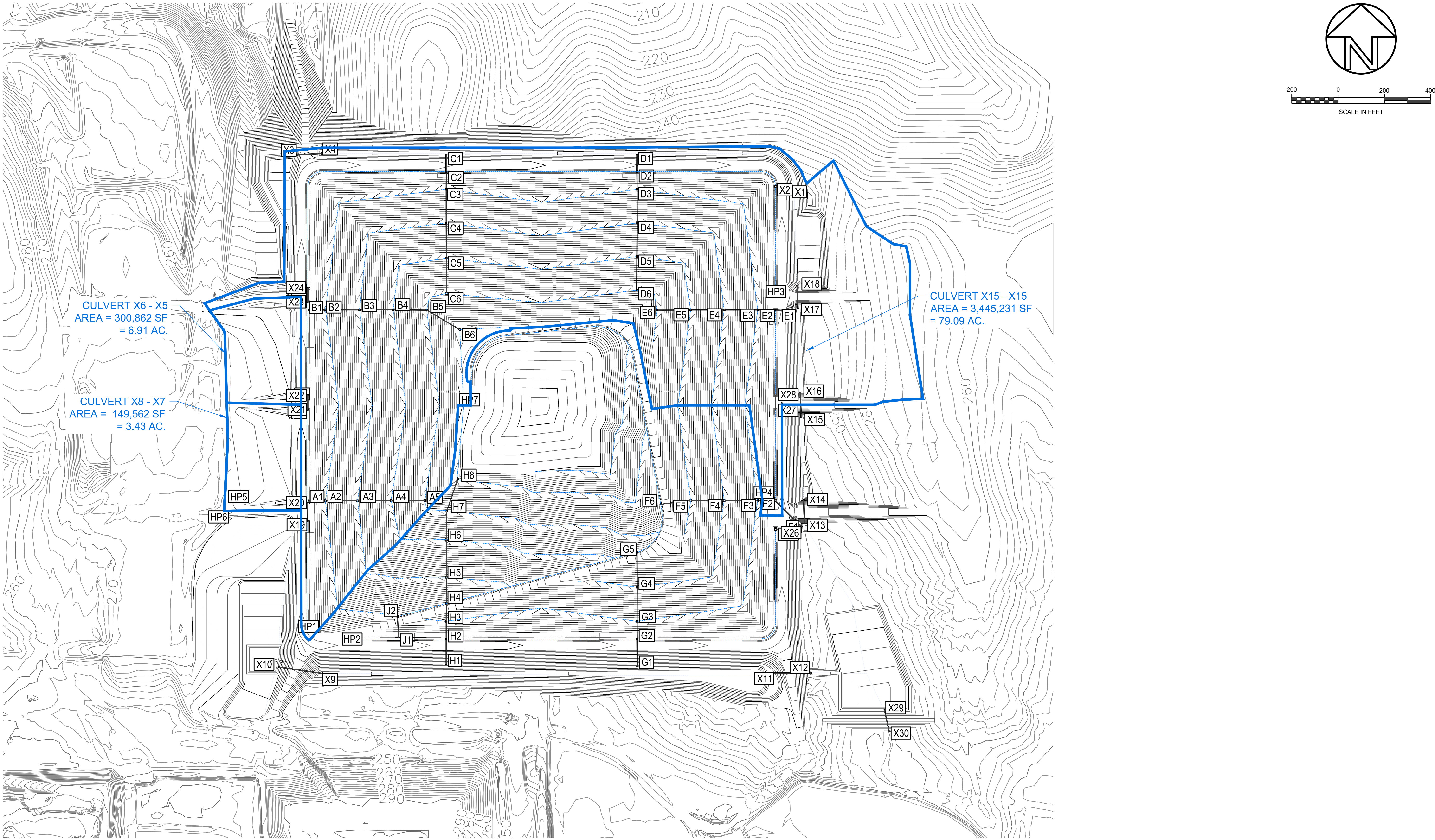
EMELLE FACILITY

Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

STORM WATER CONVEYANCE PIPES

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
G-1



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DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

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STORM WATER CONVEYANCE PIPES

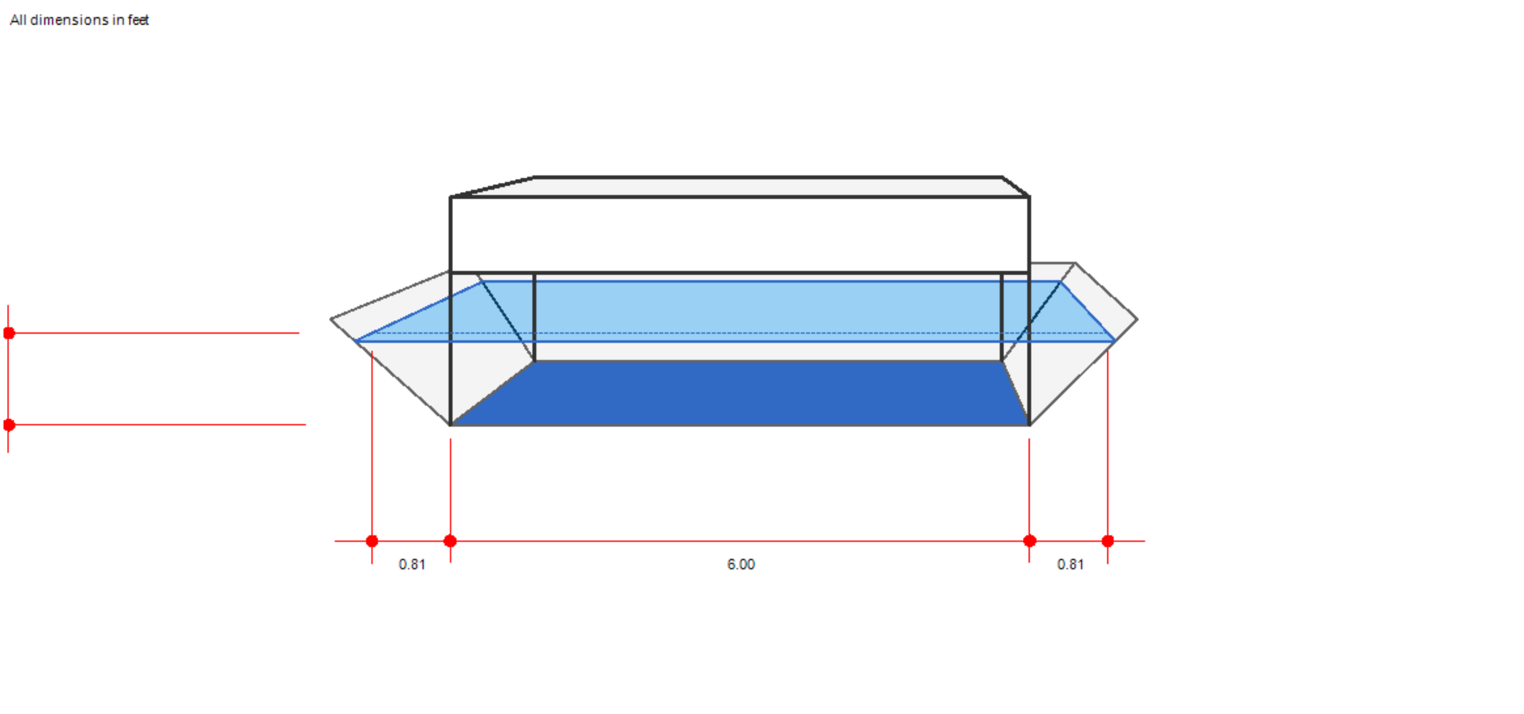
HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
G-2

Inlet Report

INLET @ CULVERT X2 - X1

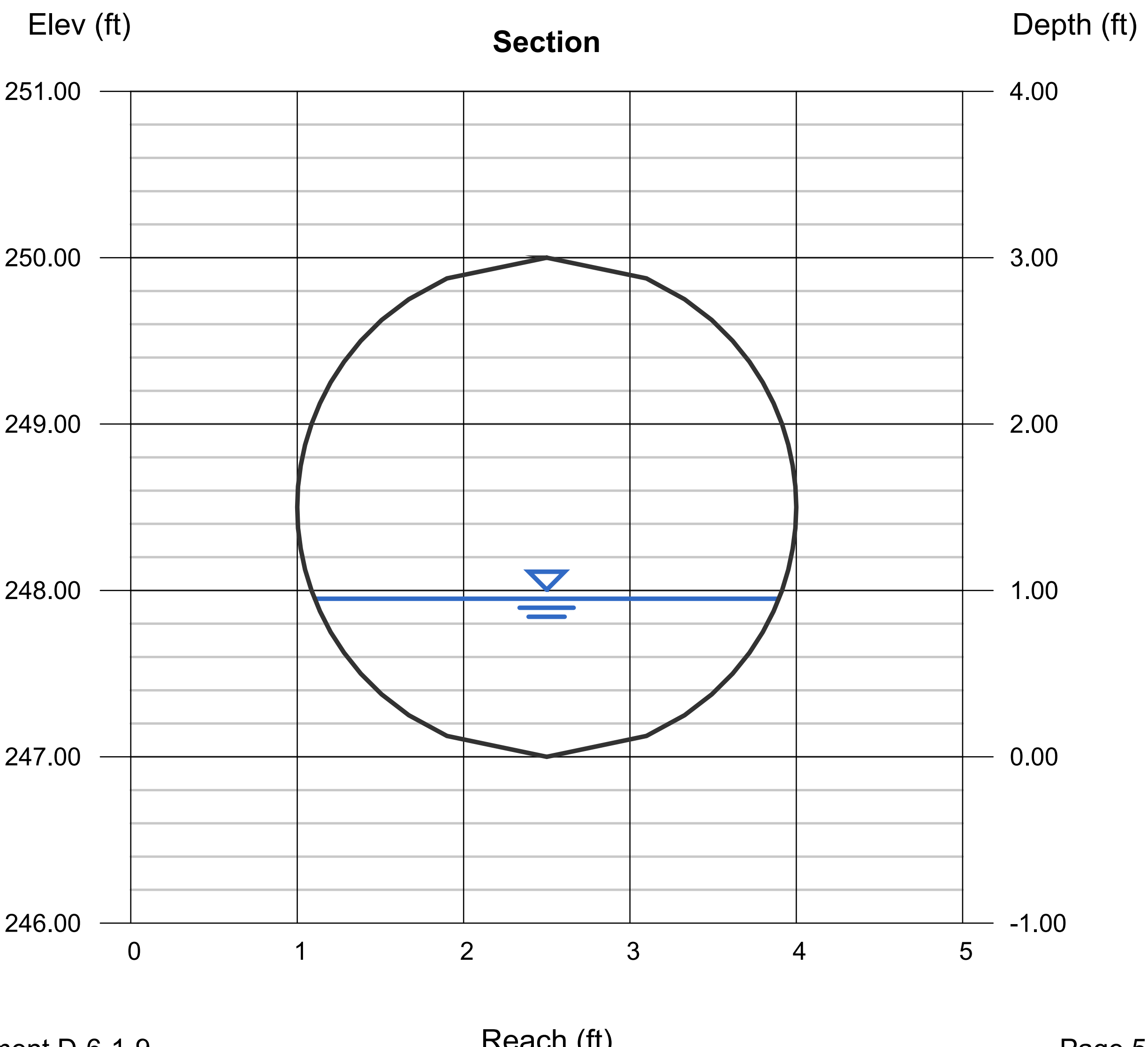
Drop Curb Inlet		**Calculations**	
Location	= Sag	Compute by:	Known Q
Curb Length (ft)	= 24.00	Q (cfs)	= 18.50
Throat Height (in)	= 8.00		
Grate Area (sqft)	= -0-	**Highlighted**	
Grate Width (ft)	= -0-	Q Total (cfs)	= 18.50
Grate Length (ft)	= -0-	Q Capt (cfs)	= 18.50
		Q Bypass (cfs)	= -0-
Gutter		Depth at Inlet (in)	= 4.85
Slope, Sw (ft/ft)	= 0.500	Efficiency (%)	= 100
Slope, Sx (ft/ft)	= 0.500	Gutter Spread (ft)	= 0.81
Local Depr (in)	= -0-	Gutter Vel (ft/s)	= -0-
Gutter Width (ft)	= -0-	Bypass Spread (ft)	= -0-
Gutter Slope (%)	= -0-	Bypass Depth (in)	= -0-
Gutter n-value	= -0-		



Channel Report

CULVERT X2 - X1

Circular		**Highlighted**	
Diameter (ft)	= 3.00	Depth (ft)	= 0.95
		Q (cfs)	= 18.50
		Area (sqft)	= 1.94
Invert Elev (ft)	= 247.00	Velocity (ft/s)	= 9.54
Slope (%)	= 1.40	Wetted Perim (ft)	= 3.60
N-Value	= 0.012	Crit Depth, Yc (ft)	= 1.38
		Top Width (ft)	= 2.80
Calculations		EGL (ft)	= 2.36
Compute by:	Known Q		
Known Q (cfs)	= 18.50		



Culvert Report

CULVERT X6 TO X5

Invert Elev Dn (ft)	=	258.90
Pipe Length (ft)	=	67.00
Slope (%)	=	6.42
Invert Elev Up (ft)	=	263.20
Rise (in)	=	36.0
Shape	=	Circular
Span (in)	=	36.0
No. Barrels	=	1
n-Value	=	0.012
Culvert Type	=	Circular Corrugate Metal Pipe
Culvert Entrance	=	Headwall
Coeff. K,M,c,Y,k	=	0.0078, 2, 0.0379, 0.69, 0.5

Embankment

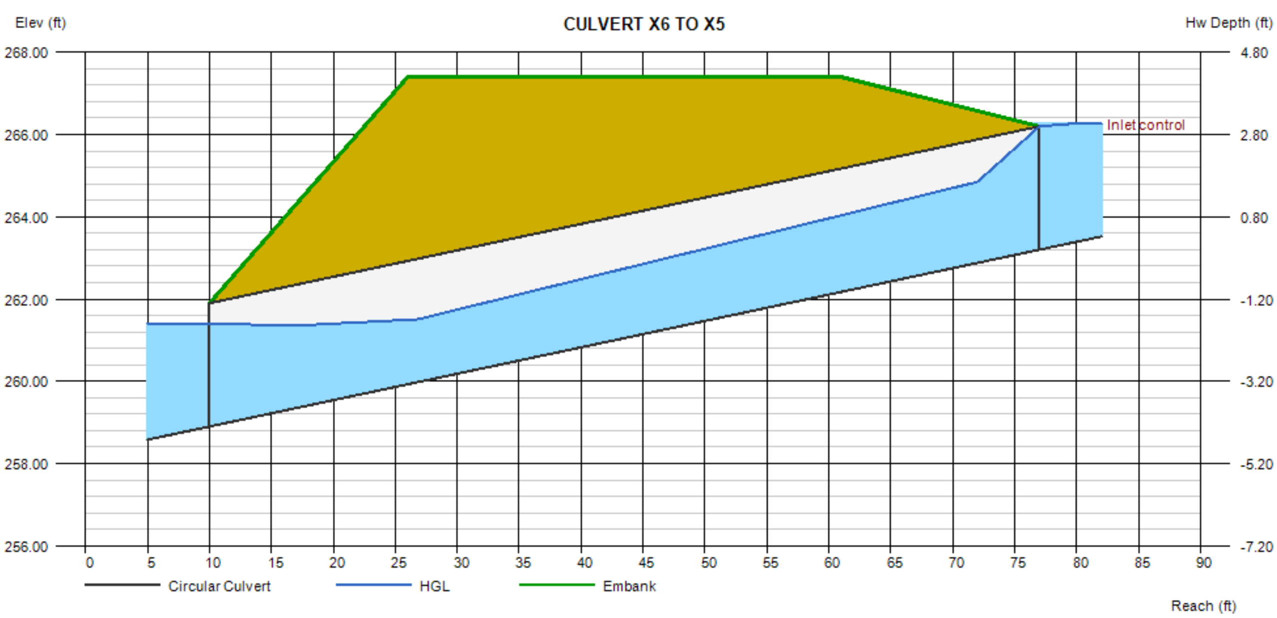
Top Elevation (ft)	=	267.40
Top Width (ft)	=	35.00
Crest Width (ft)	=	50.00

Calculations

Qmin (cfs)	=	38.60
Qmax (cfs)	=	38.60
Tailwater Elev (ft)	=	(dc+D)/2

Highlighted

Qtotal (cfs)	=	38.60
Qpipe (cfs)	=	38.60
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	6.11
Veloc Up (ft/s)	=	7.62
HGL Dn (ft)	=	261.41
HGL Up (ft)	=	265.22
Hw Elev (ft)	=	266.26
Hw/D (ft)	=	1.02
Flow Regime	=	Inlet Control



Culvert Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. — Friday, Jan 30 2015

CULVERT X8 TO X7

Invert Elev Dn (ft)	=	266.00
Pipe Length (ft)	=	73.90
Slope (%)	=	0.68
Invert Elev Up (ft)	=	266.50
Rise (in)	=	24.0
Shape	=	Circular
Span (in)	=	24.0
No. Barrels	=	1
n-Value	=	0.012
Culvert Type	=	Circular Corrugate Metal Pipe
Culvert Entrance	=	Headwall
Coeff. K,M,c,Y,k	=	0.0078, 2, 0.0379, 0.69, 0.5

Embankment

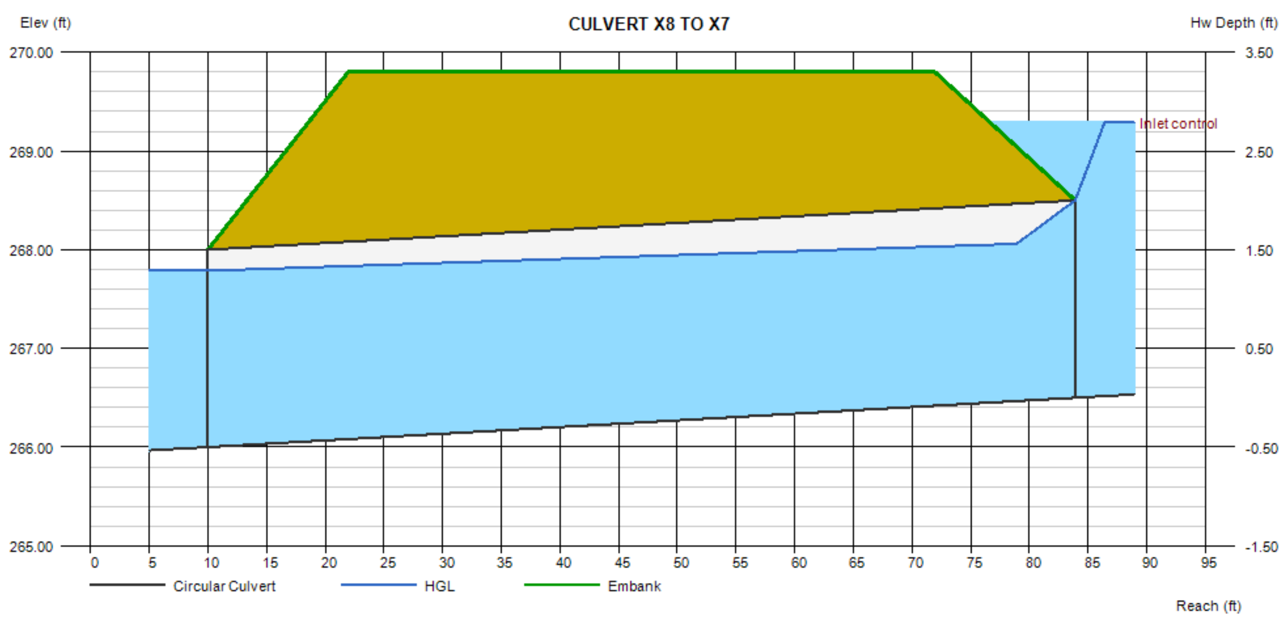
Top Elevation (ft)	=	269.80
Top Width (ft)	=	50.00
Crest Width (ft)	=	50.00

Calculations

Qmin (cfs)	=	19.20
Qmax (cfs)	=	19.20
Tailwater Elev (ft)	=	(dc+D)/2

Highlighted

Qtotal (cfs)	=	19.20
Qpipe (cfs)	=	19.20
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	6.48
Veloc Up (ft/s)	=	7.22
HGL Dn (ft)	=	267.79
HGL Up (ft)	=	268.08
Hw Elev (ft)	=	269.29
Hw/D (ft)	=	1.39
Flow Regime	=	Inlet Control



Culvert Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Friday, Jan 30 2015

CULVERT X16 TO X15

Invert Elev Dn (ft)	=	240.10
Pipe Length (ft)	=	107.00
Slope (%)	=	1.59
Invert Elev Up (ft)	=	241.80
Rise (in)	=	36.0
Shape	=	Circular
Span (in)	=	36.0
No. Barrels	=	1
n-Value	=	0.012
Culvert Type	=	Circular Corrugate Metal Pipe
Culvert Entrance	=	Headwall
Coeff. K,M,c,Y,k	=	0.0078, 2, 0.0379, 0.69, 0.5

Embankment

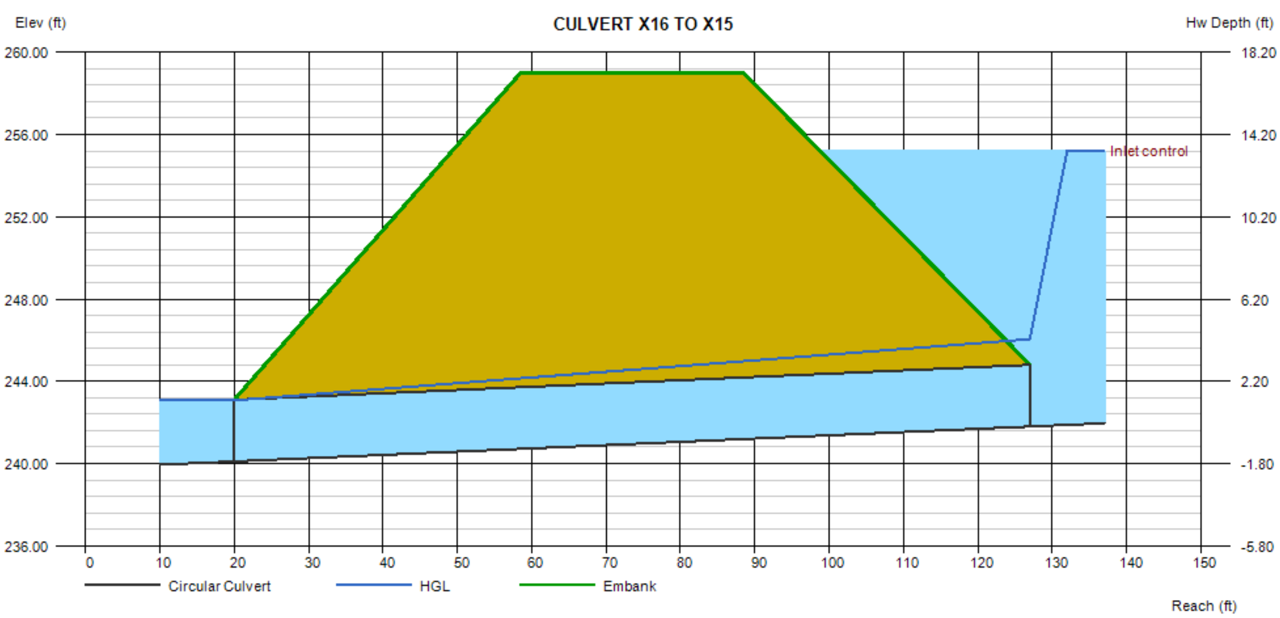
Top Elevation (ft)	=	259.00
Top Width (ft)	=	30.00
Crest Width (ft)	=	50.00

Calculations

Qmin (cfs)	=	122.40
Qmax (cfs)	=	122.40
Tailwater Elev (ft)	=	(dc+D)/2

Highlighted

Qtotal (cfs)	=	122.40
Qpipe (cfs)	=	122.40
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	17.34
Veloc Up (ft/s)	=	17.32
HGL Dn (ft)	=	243.08
HGL Up (ft)	=	246.05
Hw Elev (ft)	=	255.21
Hw/D (ft)	=	4.47
Flow Regime	=	Inlet Control



Culvert Report

CULVERT X19 TO X20

Invert Elev Dn (ft)	=	267.40
Pipe Length (ft)	=	83.00
Slope (%)	=	0.36
Invert Elev Up (ft)	=	267.70
Rise (in)	=	24.0
Shape	=	Circular
Span (in)	=	24.0
No. Barrels	=	1
n-Value	=	0.012
Culvert Type	=	Circular Corrugate Metal Pipe
Culvert Entrance	=	Headwall
Coeff. K,M,c,Y,k	=	0.0078, 2, 0.0379, 0.69, 0.5

Embankment

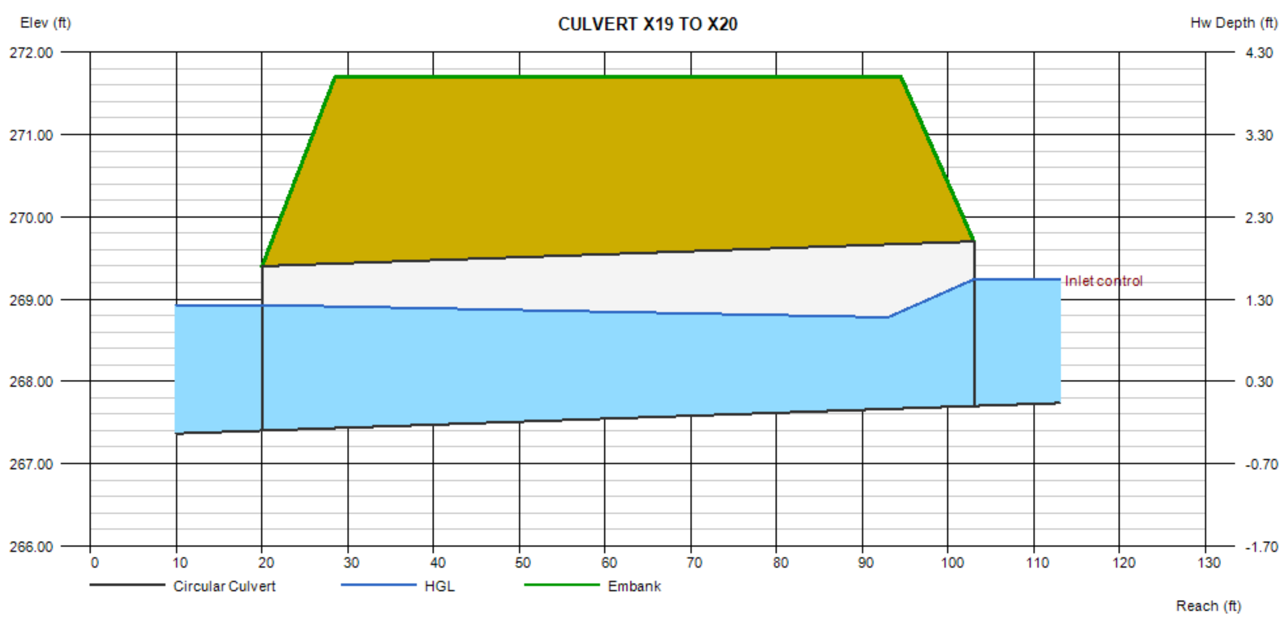
Top Elevation (ft)	=	271.70
Top Width (ft)	=	66.00
Crest Width (ft)	=	22.00

Calculations

Qmin (cfs)	=	8.80
Qmax (cfs)	=	8.80
Tailwater Elev (ft)	=	(dc+D)/2

Highlighted

Qtotal (cfs)	=	8.80
Qpipe (cfs)	=	8.80
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	3.42
Veloc Up (ft/s)	=	5.22
HGL Dn (ft)	=	268.93
HGL Up (ft)	=	268.76
Hw Elev (ft)	=	269.24
Hw/D (ft)	=	0.77
Flow Regime	=	Inlet Control



Culvert Report

CULVERT X21 TO X22

Invert Elev Dn (ft)	=	258.70
Pipe Length (ft)	=	62.00
Slope (%)	=	0.48
Invert Elev Up (ft)	=	259.00
Rise (in)	=	36.0
Shape	=	Circular
Span (in)	=	36.0
No. Barrels	=	1
n-Value	=	0.012
Culvert Type	=	Circular Corrugate Metal Pipe
Culvert Entrance	=	Headwall
Coeff. K,M,c,Y,k	=	0.0078, 2, 0.0379, 0.69, 0.5

Embankment

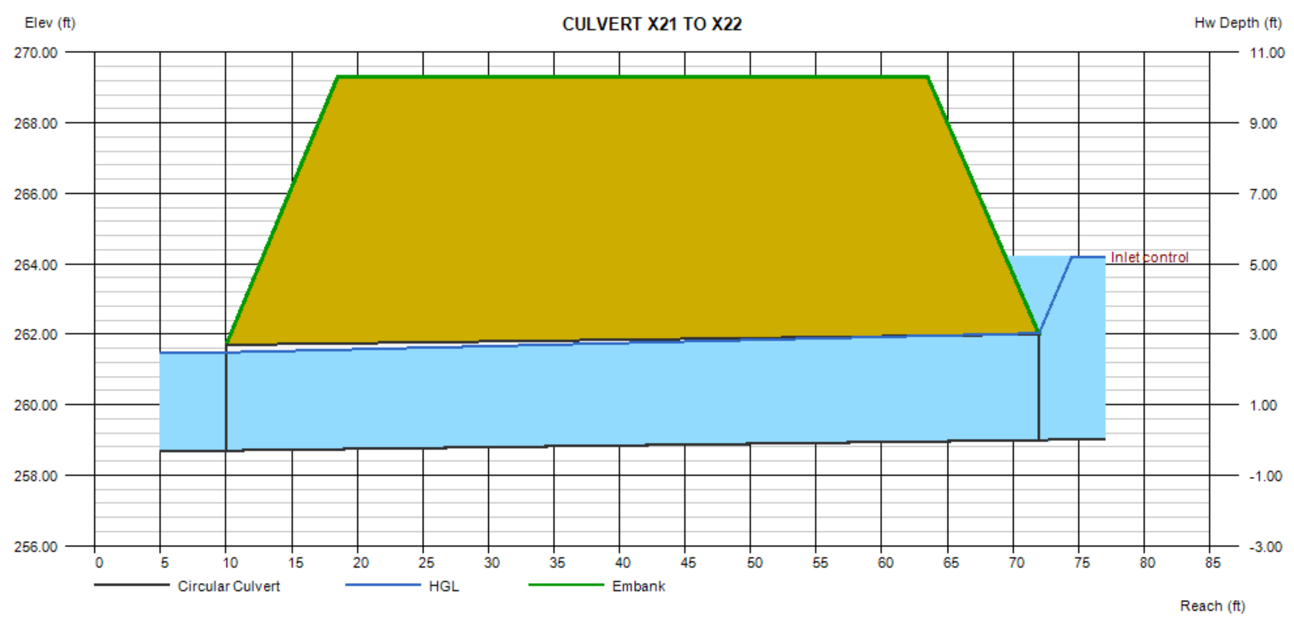
Top Elevation (ft)	=	269.30
Top Width (ft)	=	45.00
Crest Width (ft)	=	22.00

Calculations

Qmin (cfs)	=	64.30
Qmax (cfs)	=	64.30
Tailwater Elev (ft)	=	(dc+D)/2

Highlighted

Qtotal (cfs)	=	64.30
Qpipe (cfs)	=	64.30
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	9.39
Veloc Up (ft/s)	=	9.10
HGL Dn (ft)	=	261.49
HGL Up (ft)	=	262.03
Hw Elev (ft)	=	264.20
Hw/D (ft)	=	1.73
Flow Regime	=	Inlet Control



Culvert Report

CULVERT X23 TO X24

Invert Elev Dn (ft)	=	261.20
Pipe Length (ft)	=	62.00
Slope (%)	=	0.48
Invert Elev Up (ft)	=	261.50
Rise (in)	=	36.0
Shape	=	Circular
Span (in)	=	36.0
No. Barrels	=	2
n-Value	=	0.012
Culvert Type	=	Circular Corrugate Metal Pipe
Culvert Entrance	=	Headwall
Coeff. K,M,c,Y,k	=	0.0078, 2, 0.0379, 0.69, 0.5

Embankment

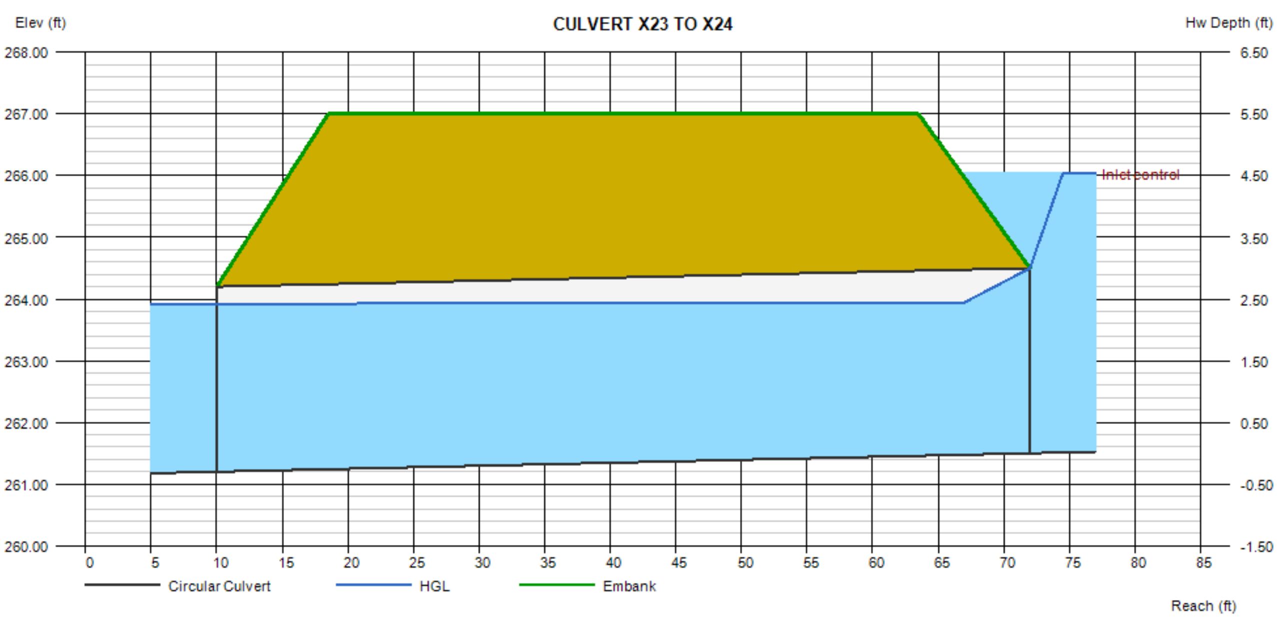
Top Elevation (ft)	=	267.00
Top Width (ft)	=	45.00
Crest Width (ft)	=	22.00

Calculations

Qmin (cfs)	=	114.20
Qmax (cfs)	=	114.20
Tailwater Elev (ft)	=	(dc+D)/2

Highlighted

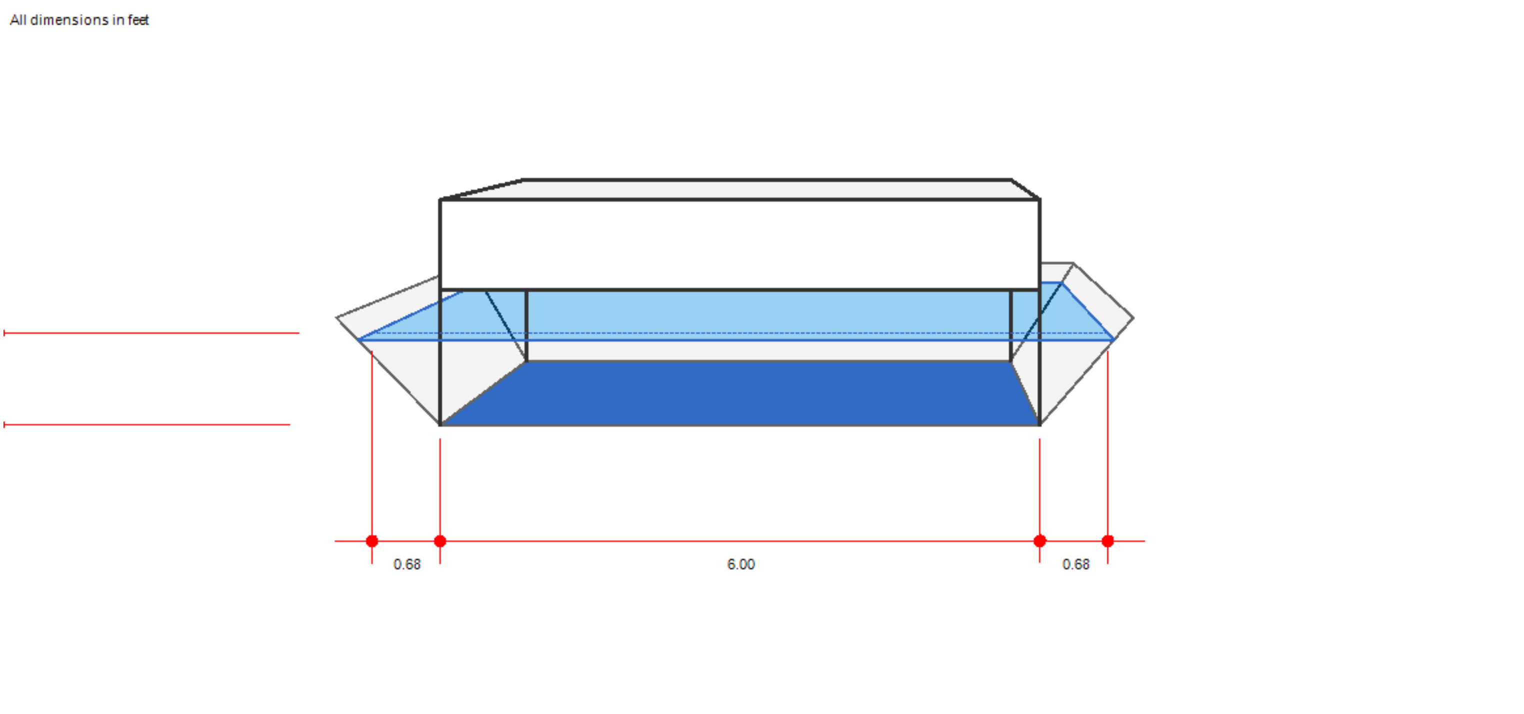
Qtotal (cfs)	=	114.20
Qpipe (cfs)	=	114.20
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	8.47
Veloc Up (ft/s)	=	9.25
HGL Dn (ft)	=	263.92
HGL Up (ft)	=	263.95
Hw Elev (ft)	=	266.04
Hw/D (ft)	=	1.51
Flow Regime	=	Inlet Control



Inlet Report

INLET @ CULVERT X25 - X26

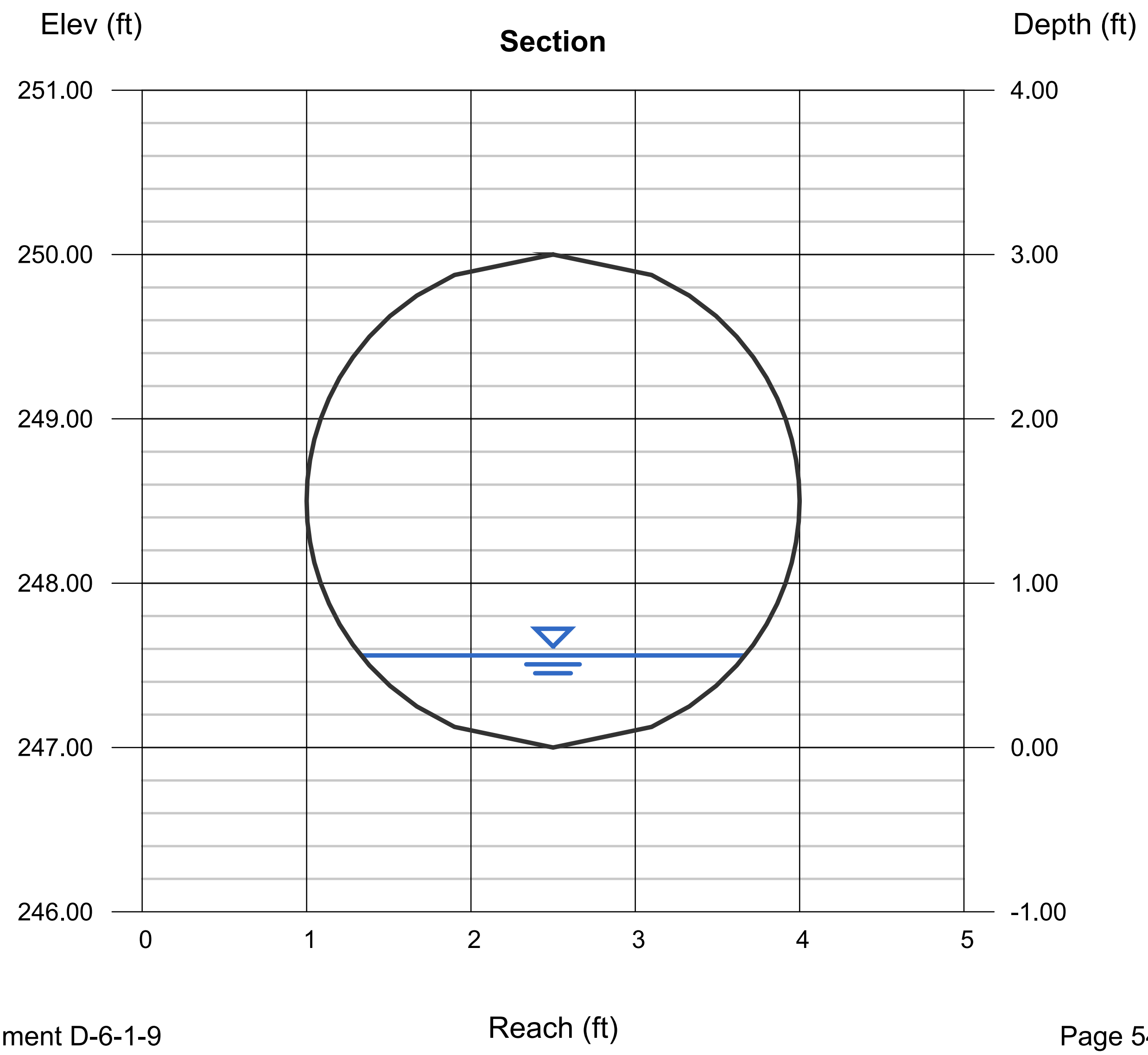
Drop Curb Inlet		**Calculations**	
Location	= Sag	Compute by:	Known Q
Curb Length (ft)	= 24.00	Q (cfs)	= 14.30
Throat Height (in)	= 6.00		
Grate Area (sqft)	= -0-	**Highlighted**	
Grate Width (ft)	= -0-	Q Total (cfs)	= 14.30
Grate Length (ft)	= -0-	Q Capt (cfs)	= 14.30
		Q Bypass (cfs)	= -0-
Gutter		Depth at Inlet (in)	= 4.08
Slope, Sw (ft/ft)	= 0.500	Efficiency (%)	= 100
Slope, Sx (ft/ft)	= 0.500	Gutter Spread (ft)	= 0.68
Local Depr (in)	= -0-	Gutter Vel (ft/s)	= -0-
Gutter Width (ft)	= -0-	Bypass Spread (ft)	= -0-
Gutter Slope (%)	= -0-	Bypass Depth (in)	= -0-
Gutter n-value	= -0-		



Channel Report

CULVERT X25 - X26

Circular		**Highlighted**	
Diameter (ft)	= 3.00	Depth (ft)	= 0.56
		Q (cfs)	= 14.30
		Area (sqft)	= 0.92
Invert Elev (ft)	= 247.00	Velocity (ft/s)	= 15.62
Slope (%)	= 7.10	Wetted Perim (ft)	= 2.68
N-Value	= 0.012	Crit Depth, Yc (ft)	= 1.21
		Top Width (ft)	= 2.34
Calculations		EGL (ft)	= 4.35
Compute by:	Known Q		
Known Q (cfs)	= 14.30		



Culvert Report

CULVERT X27 TO X28

Invert Elev Dn (ft)	=	249.20
Pipe Length (ft)	=	62.00
Slope (%)	=	0.48
Invert Elev Up (ft)	=	249.50
Rise (in)	=	24.0
Shape	=	Circular
Span (in)	=	24.0
No. Barrels	=	1
n-Value	=	0.012
Culvert Type	=	Circular Corrugate Metal Pipe
Culvert Entrance	=	Headwall
Coeff. K,M,c,Y,k	=	0.0078, 2, 0.0379, 0.69, 0.5

Embankment

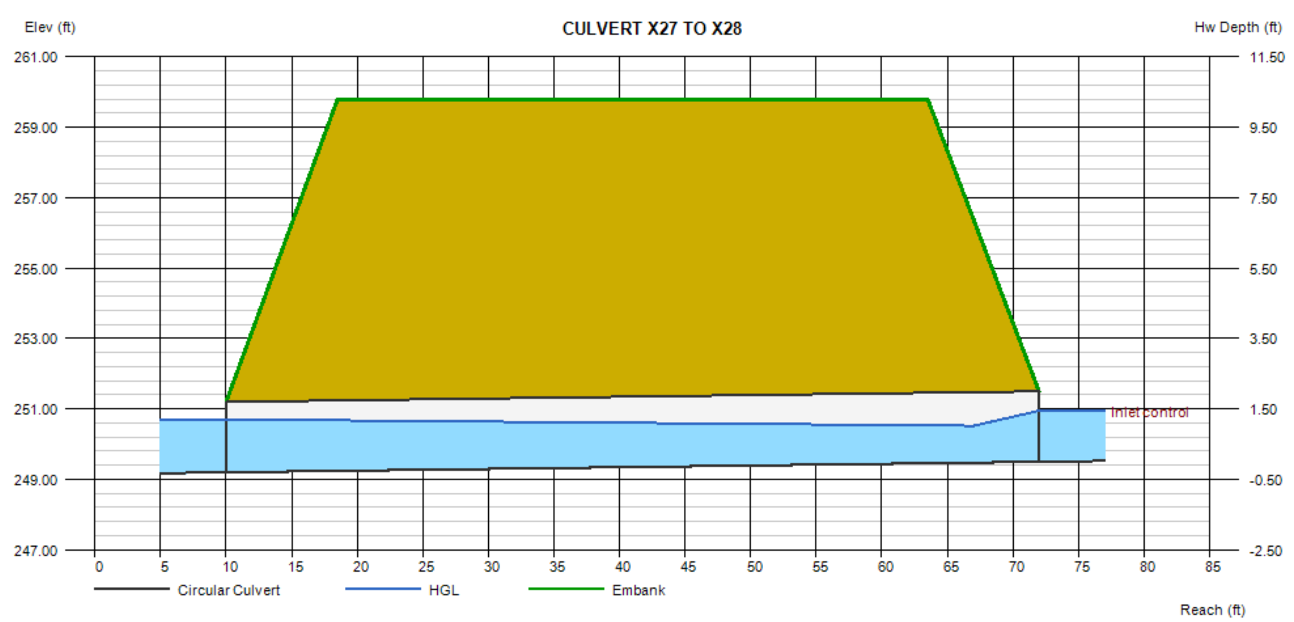
Top Elevation (ft)	=	259.80
Top Width (ft)	=	45.00
Crest Width (ft)	=	22.00

Calculations

Qmin (cfs)	=	8.00
Qmax (cfs)	=	8.00
Tailwater Elev (ft)	=	(dc+D)/2

Highlighted

Qtotal (cfs)	=	8.00
Qpipe (cfs)	=	8.00
Qovertop (cfs)	=	0.00
Veloc Dn (ft/s)	=	3.16
Veloc Up (ft/s)	=	5.06
HGL Dn (ft)	=	250.70
HGL Up (ft)	=	250.51
Hw Elev (ft)	=	250.95
Hw/D (ft)	=	0.72
Flow Regime	=	Inlet Control



Watershed Model Schematic

Legend

Hyd.	Origin	Description
1	SCS Runoff	CULVERT X19 - X20
2	SCS Runoff	CULVERT X21 - X22
3	SCS Runoff	CULVERT X23 - X24
4	SCS Runoff	CULVERT X2 - X1
5	SCS Runoff	CULVERT X27 X28
6	SCS Runoff	CULVERT X25-X26

Hydrograph Summary Report

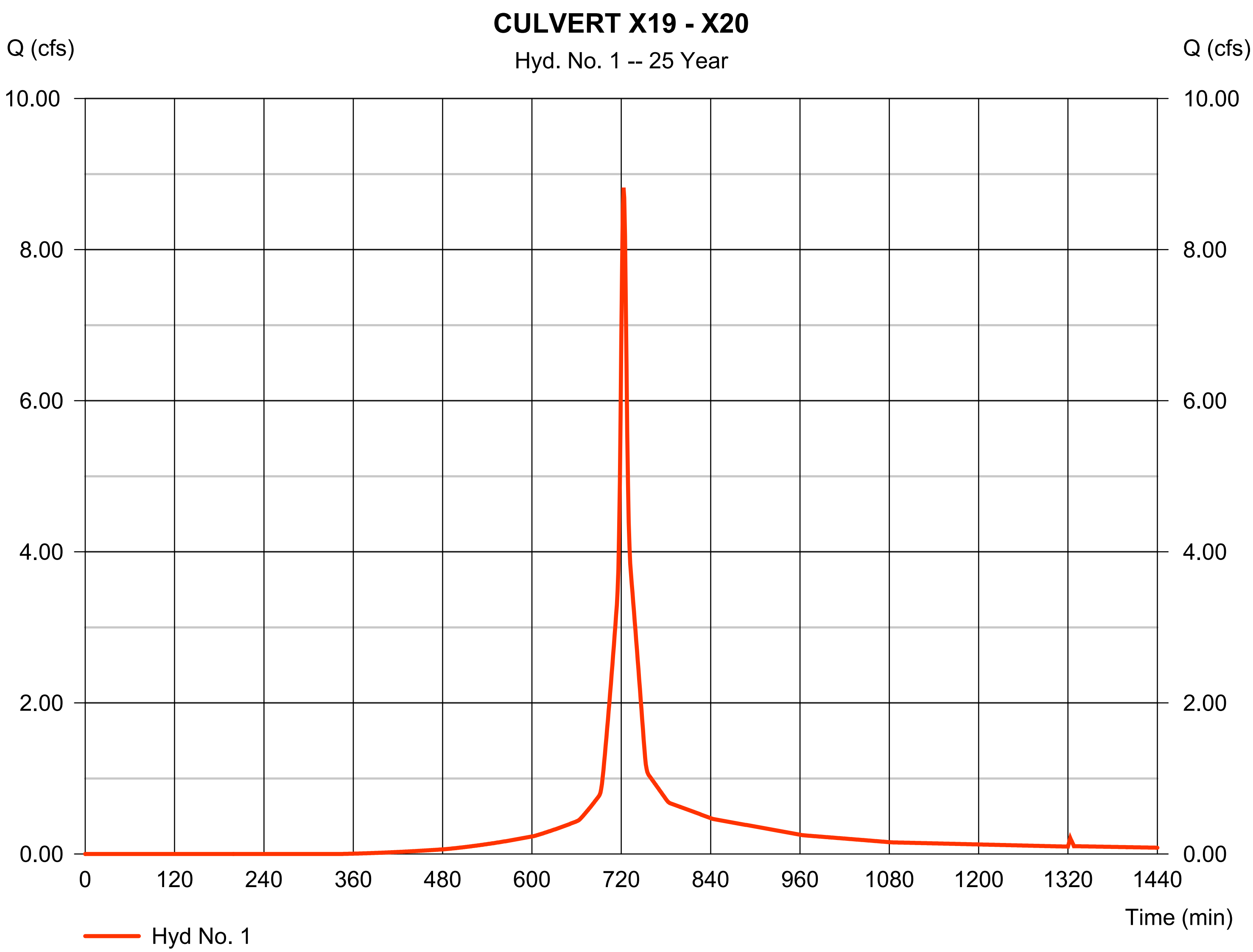
Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	8.820	1	723	25,838	------	------	------	CULVERT X19 - X20
2	SCS Runoff	64.29	1	724	201,385	------	------	------	CULVERT X21 - X22
3	SCS Runoff	114.15	1	725	372,403	------	------	------	CULVERT X23 - X24
4	SCS Runoff	18.54	1	723	54,297	------	------	------	CULVERT X2 - X1
5	SCS Runoff	7.958	1	722	21,941	------	------	------	CULVERT X27 X28
6	SCS Runoff	14.28	1	729	54,370	------	------	------	CULVERT X25-X26

Hydrograph Report

Hyd. No. 1

CULVERT X19 - X20

Hydrograph type	= SCS Runoff	Peak discharge	= 8.820 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 25,838 cuft
Drainage area	= 1.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

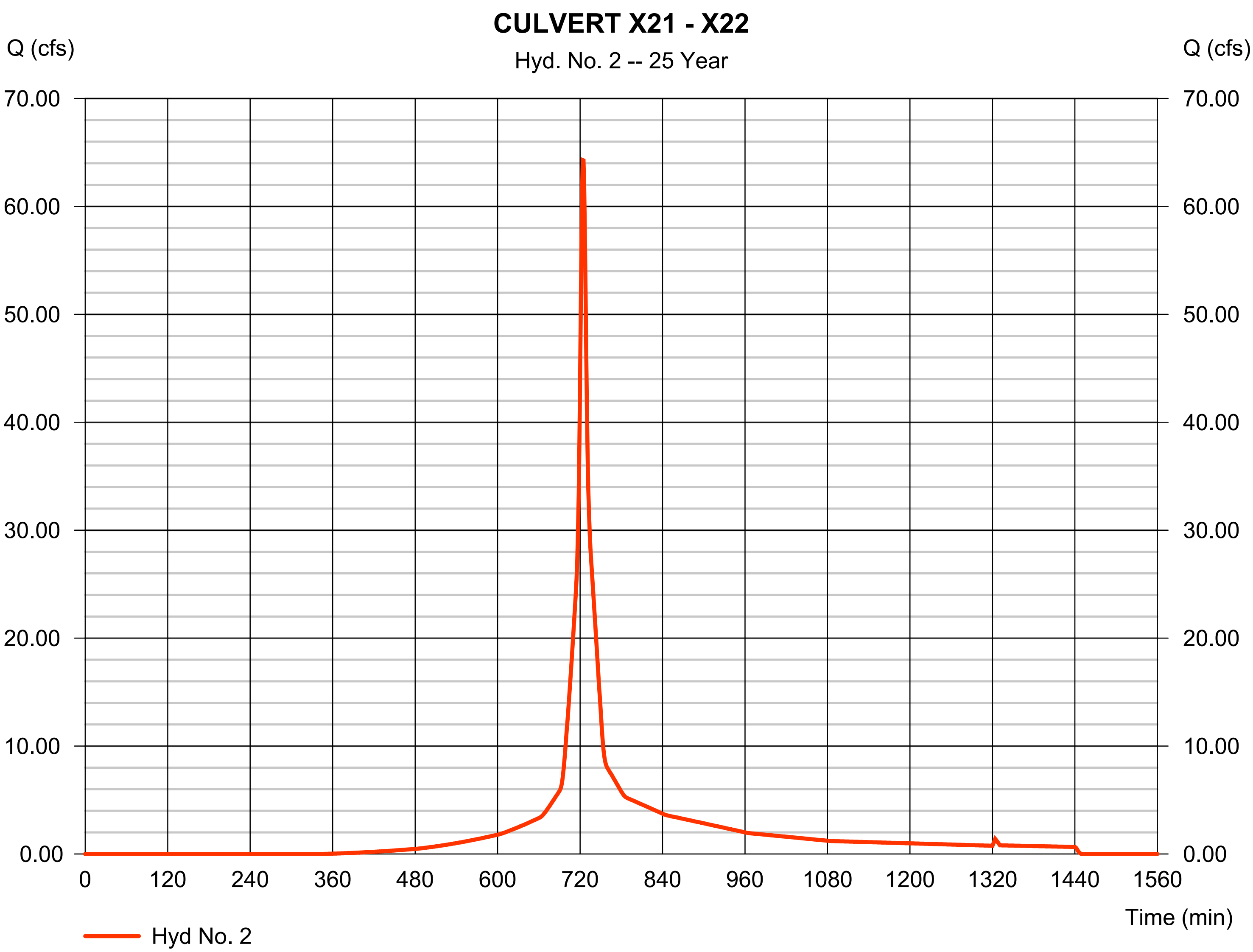


Hydrograph Report

Hyd. No. 2

CULVERT X21 - X22

Hydrograph type	= SCS Runoff	Peak discharge	= 64.29 cfs
Storm frequency	= 25 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 201,385 cuft
Drainage area	= 10.430 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.50 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

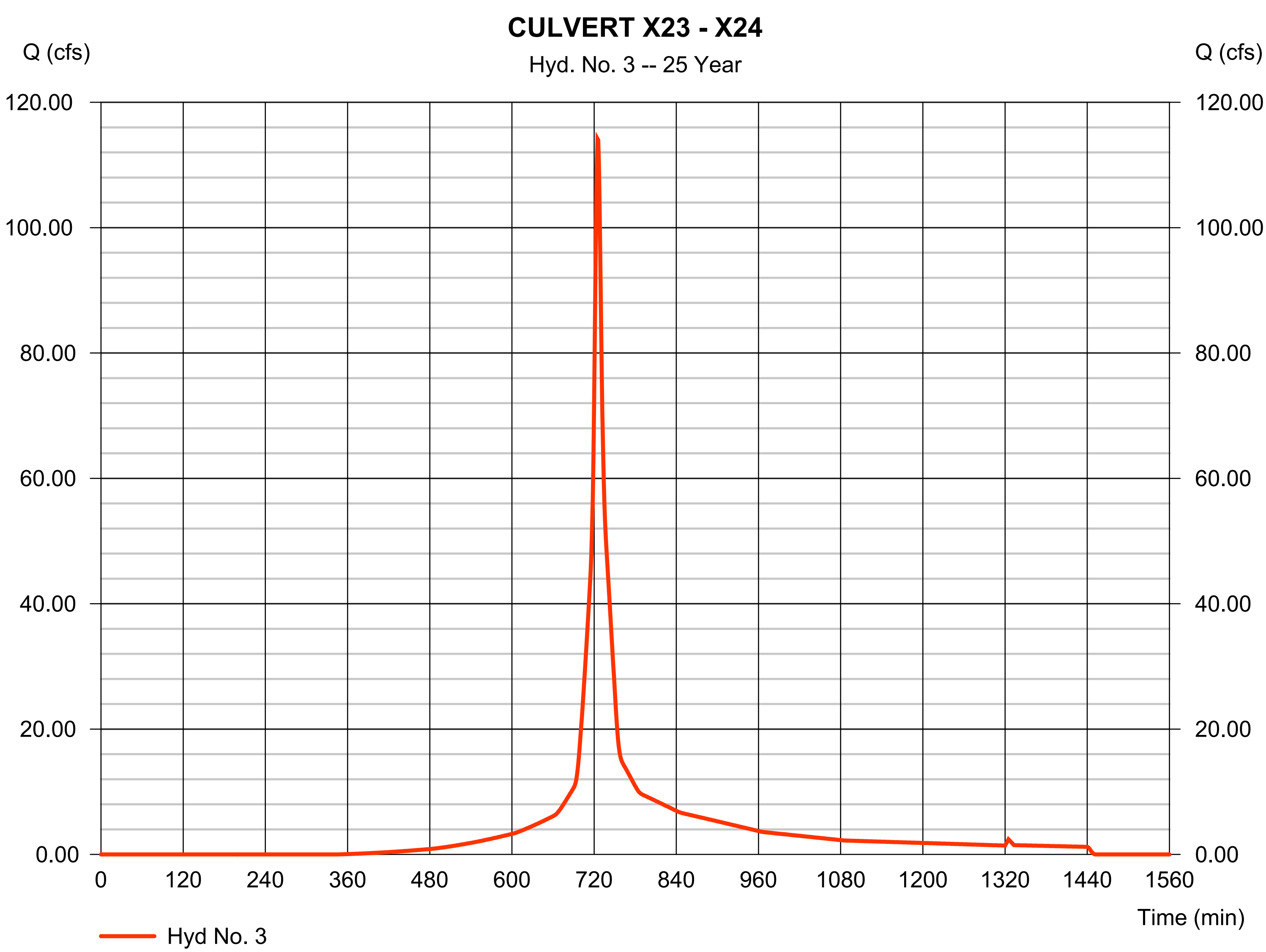


Hydrograph Report

Hyd. No. 3

CULVERT X23 - X24

Hydrograph type	= SCS Runoff	Peak discharge	= 114.15 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 372,403 cuft
Drainage area	= 20.400 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 6.80 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

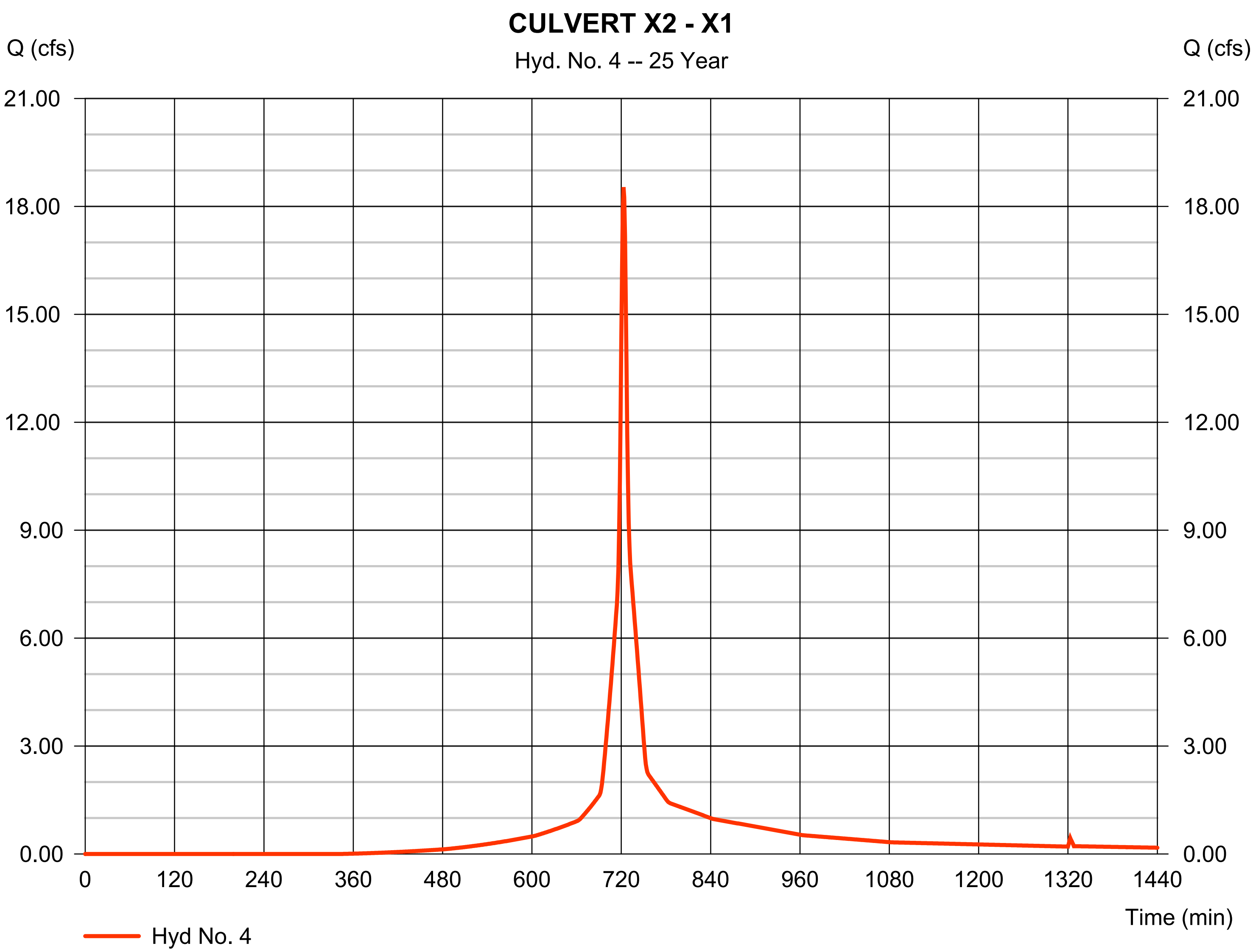


Hydrograph Report

Hyd. No. 4

CULVERT X2 - X1

Hydrograph type	= SCS Runoff	Peak discharge	= 18.54 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 54,297 cuft
Drainage area	= 2.900 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.60 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

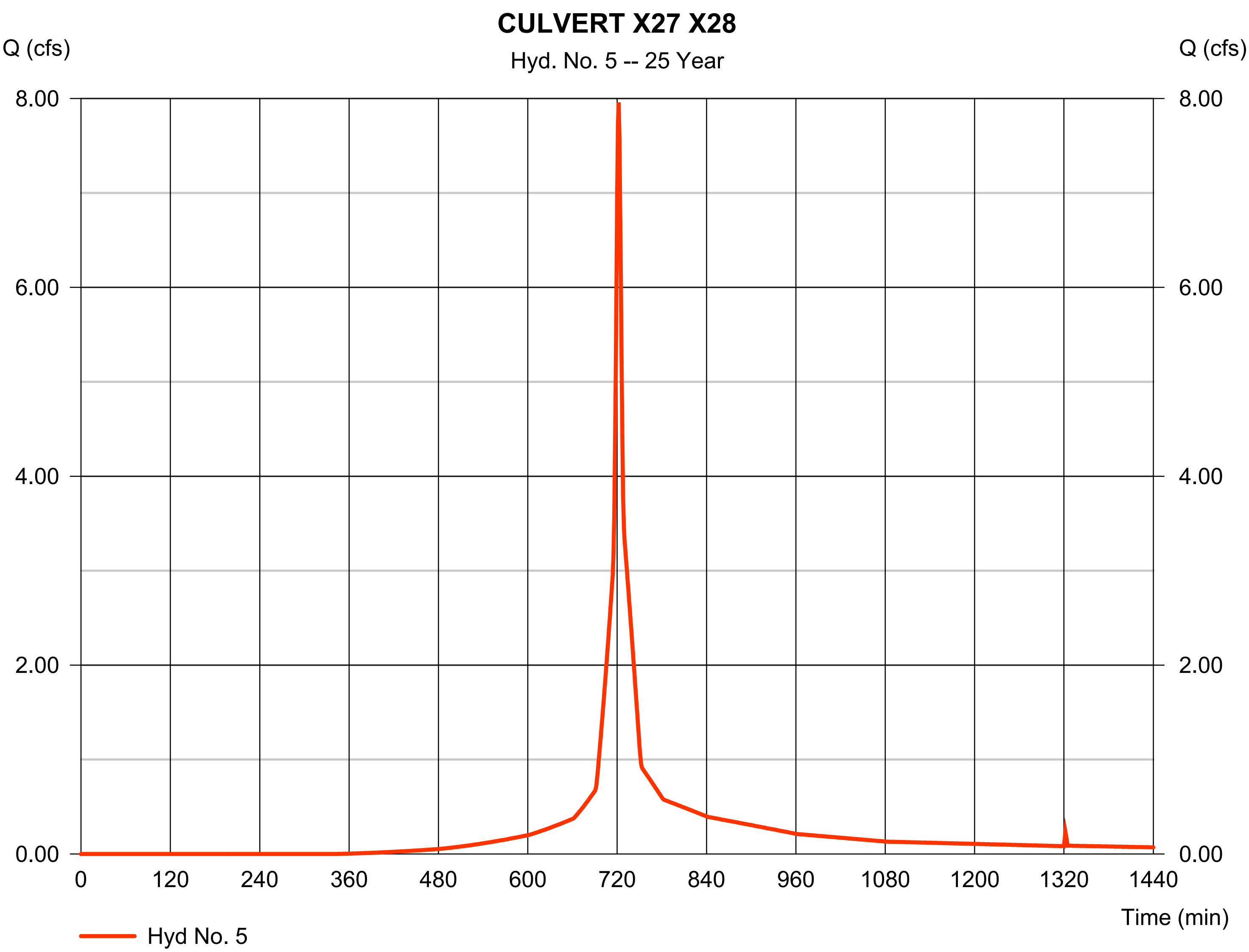


Hydrograph Report

Hyd. No. 5

CULVERT X27 X28

Hydrograph type	= SCS Runoff	Peak discharge	= 7.958 cfs
Storm frequency	= 25 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 21,941 cuft
Drainage area	= 1.250 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484

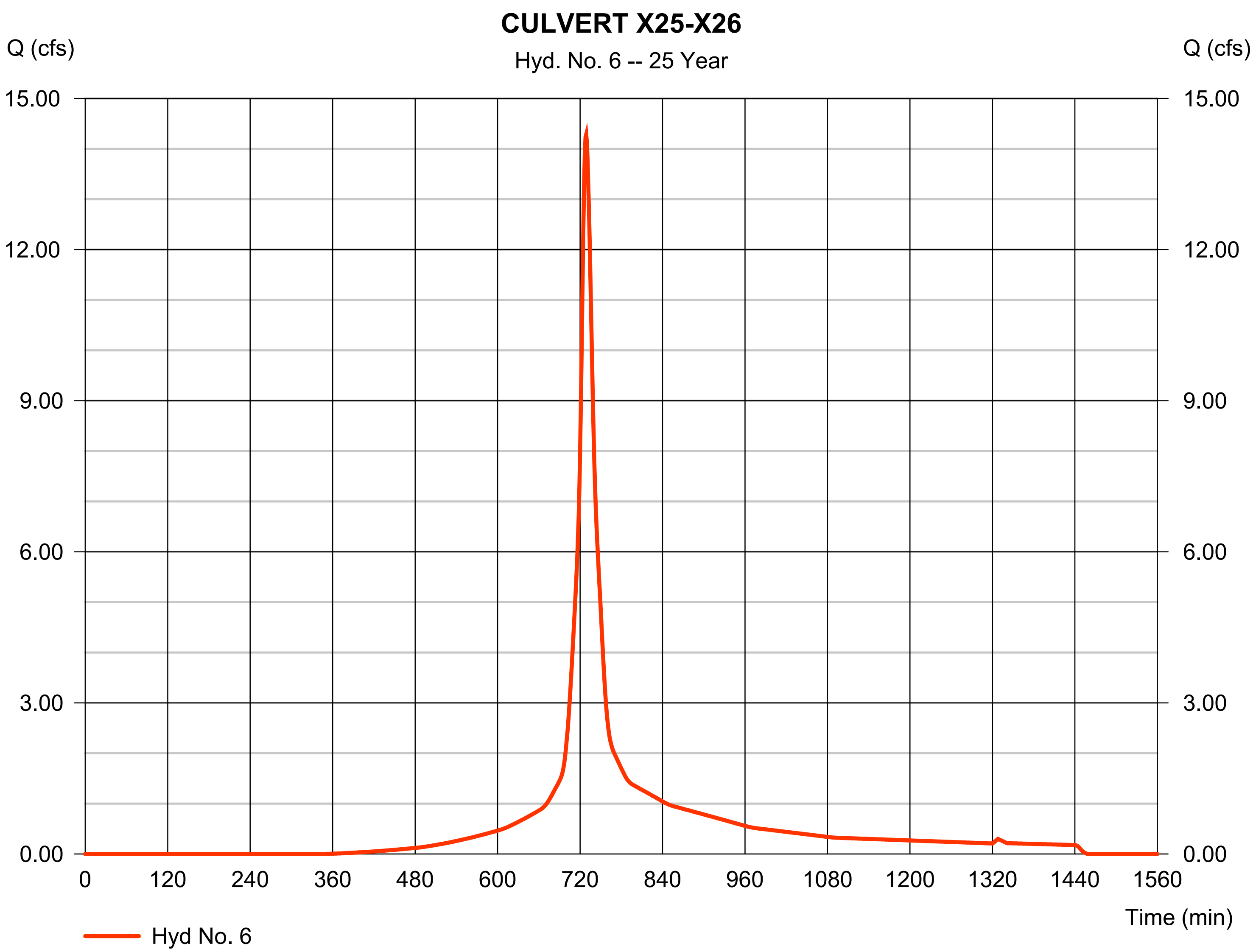


Hydrograph Report

Hyd. No. 6

CULVERT X25-X26

Hydrograph type	= SCS Runoff	Peak discharge	= 14.28 cfs
Storm frequency	= 25 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 54,370 cuft
Drainage area	= 2.950 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.40 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	0.0000	0.0000	0.0000	--------
3	0.0000	0.0000	0.0000	--------
5	0.0000	0.0000	0.0000	--------
10	0.0000	0.0000	0.0000	--------
25	0.0000	0.0000	0.0000	--------
50	0.0000	0.0000	0.0000	--------
100	0.0000	0.0000	0.0000	--------

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

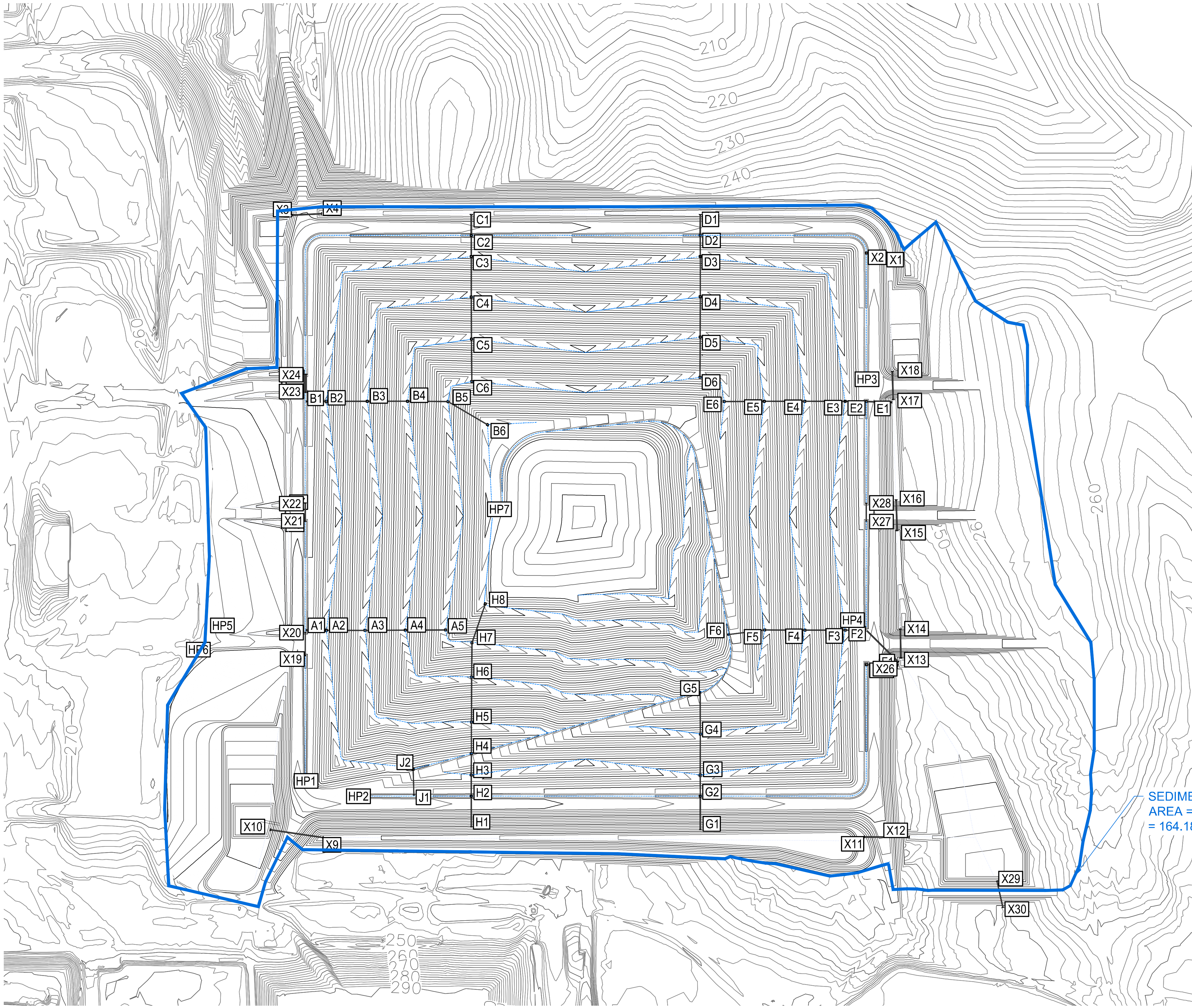
Tc = time in minutes. Values may exceed 60.

ojects\2014\EJ147461\Working Files\Calculations-Analyses\SCS METHOD\Peachtree City (24 hr GA Green Book).pcp

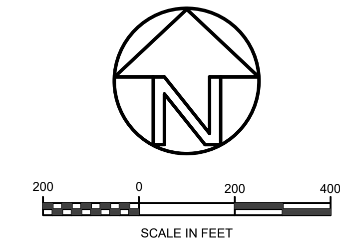
Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.75	4.50	0.00	5.65	6.50	7.50	8.40	9.20
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

EXHIBIT H-5

Hydrologic and Hydraulic Calculations – Sediment Traps



SEDIMENT TRAP 1 AT X29
AREA = 7,151,658 SF
= 164.18 AC.



LEGEND

———	2-FT FINAL COVER CTR
———	10-FT FINAL COVER CTR
———	DOWNDRAIN / CULVERT
———	WATERSHED BOUNDARY

DRAWN BY:	JCH
CHECKED BY:	RSG
APPROVED BY:	RSG
DATE:	12/31/2014
PROJECT #:	EJ147410

EMELLE FACILITY

Terracon
Consulting Engineers and Scientists
4040 Royal Drive, Suite 100 Kennesaw, GA 30144
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SEDIMENT TRAP 1 AT X29 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
ST-1

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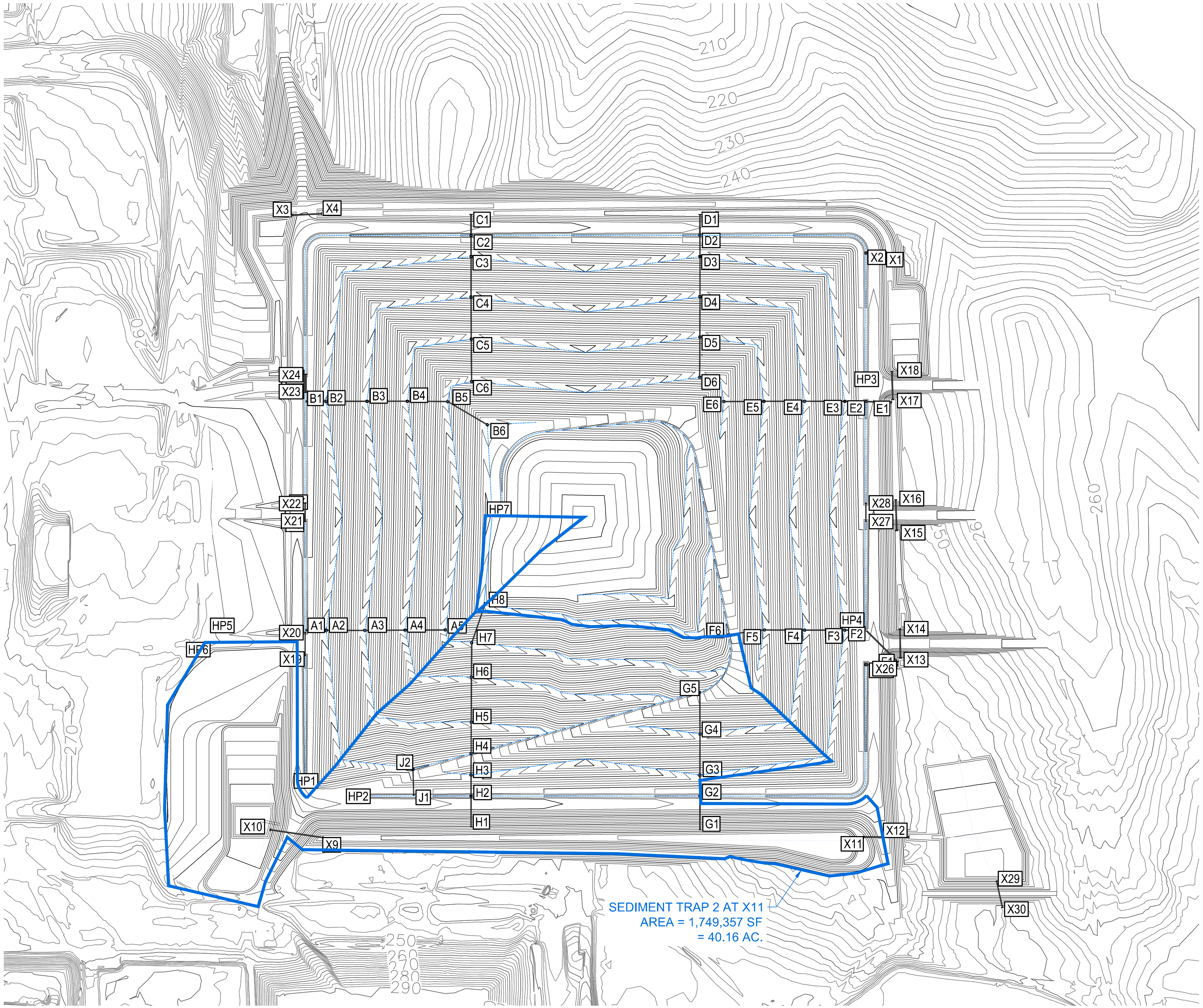

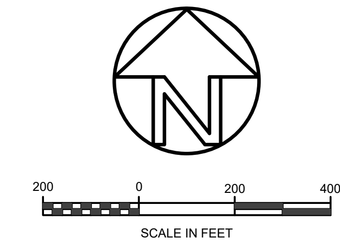

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

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SEDIMENT TRAP 2 AT X11 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
ST-2

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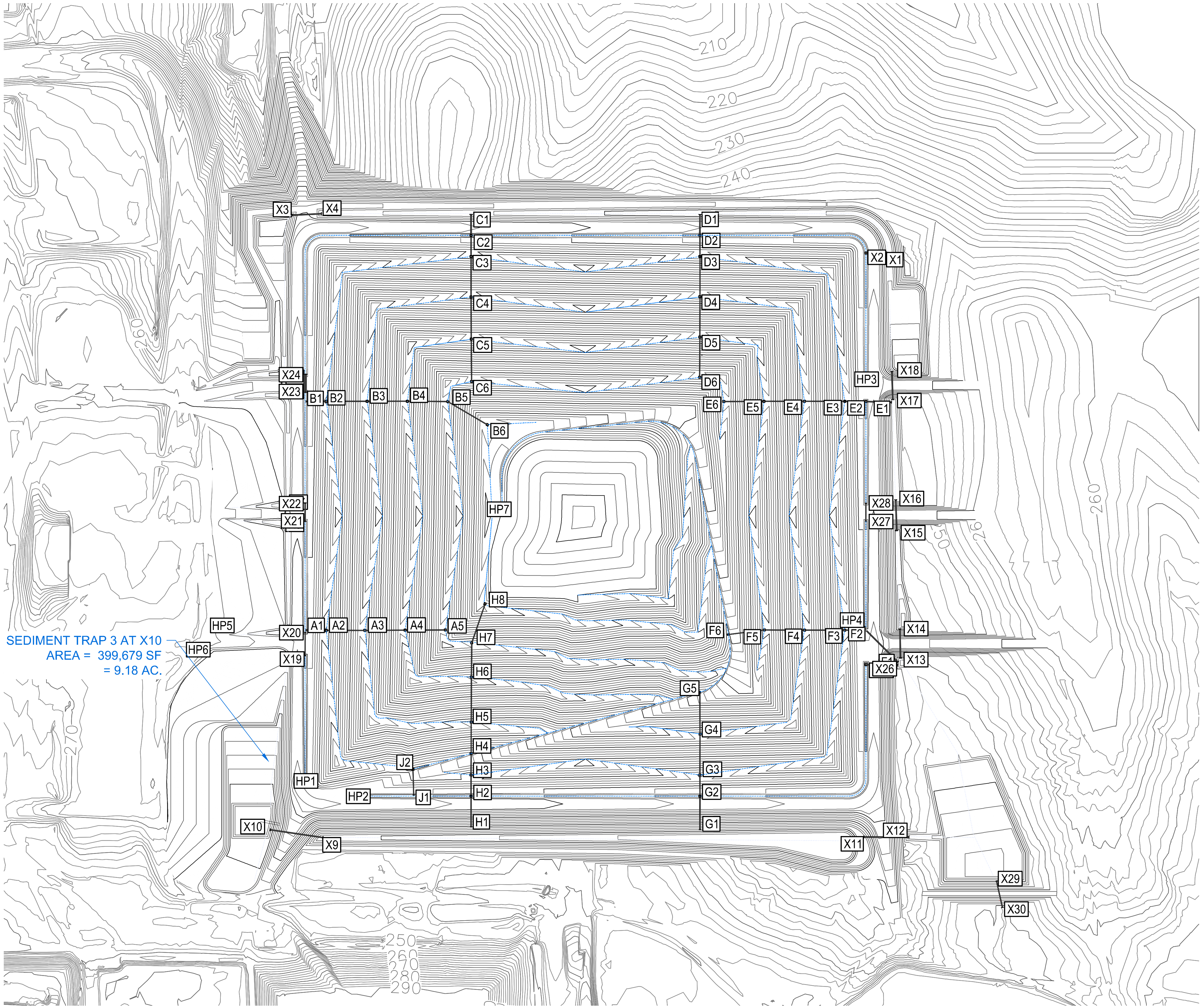

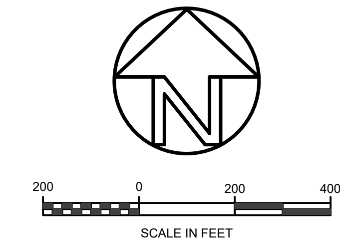

LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

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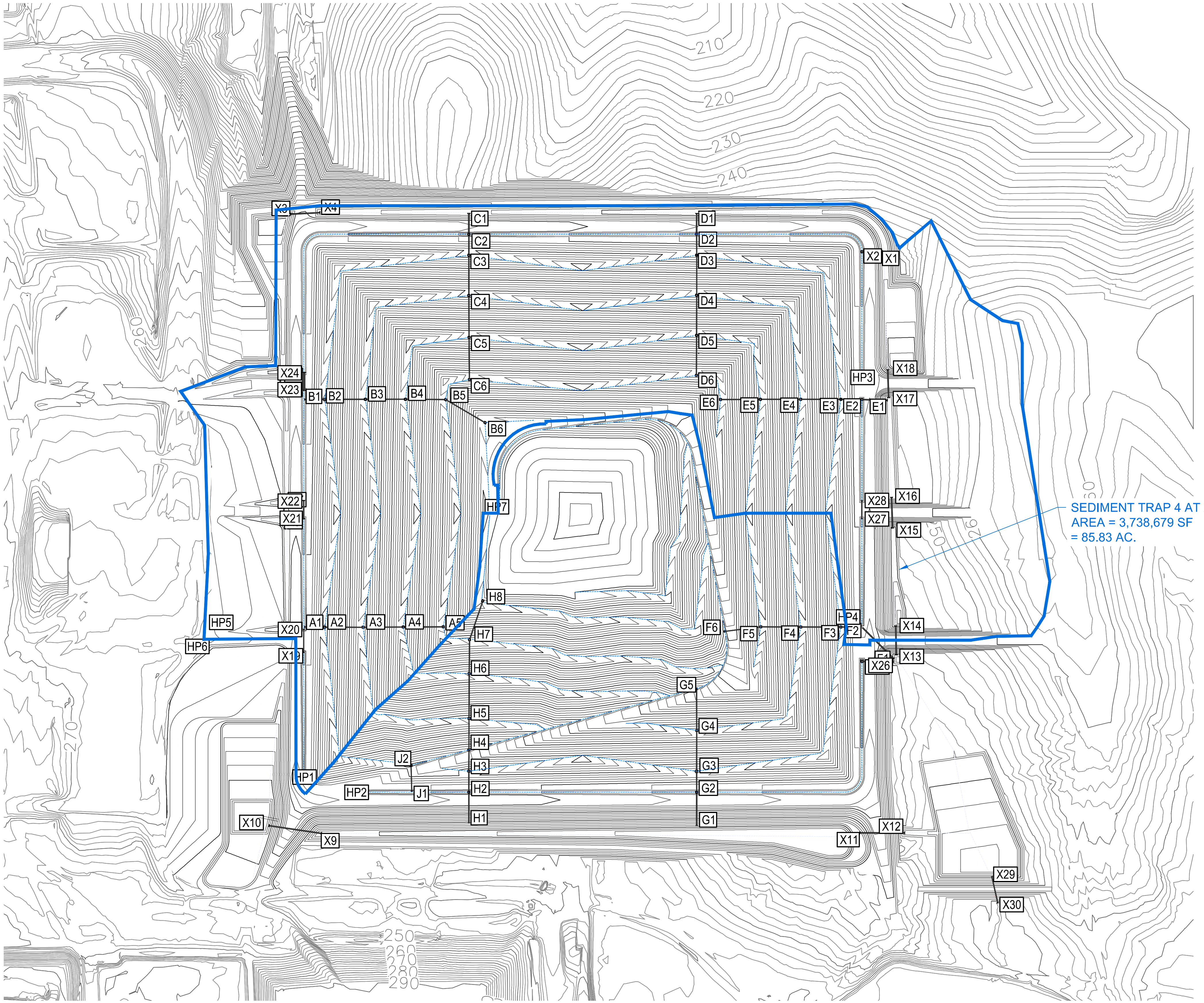
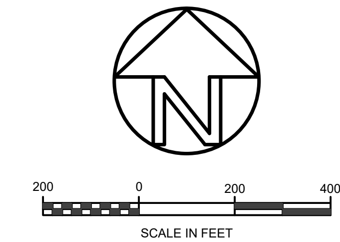
SEDIMENT TRAP 3 AT X10 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
ST-3





LEGEND

- 2-FT FINAL COVER CTR
- 10-FT FINAL COVER CTR
- DOWNDRAIN / CULVERT
- WATERSHED BOUNDARY

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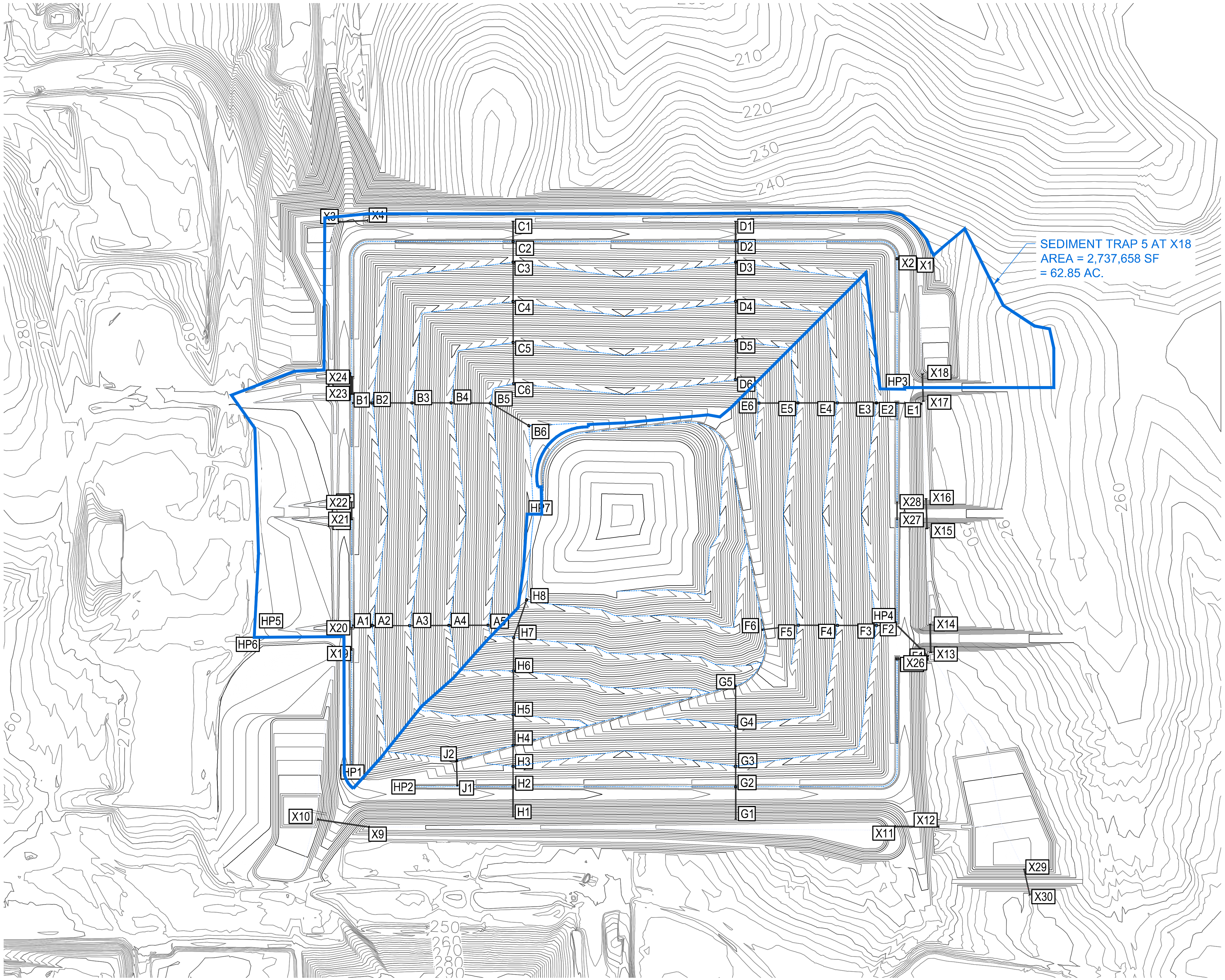
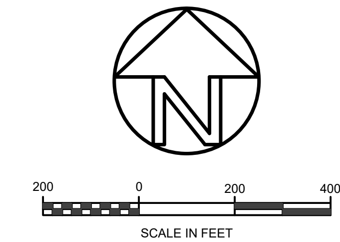
SEDIMENT TRAP 4 AT X14 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
ST-4





LEGEND

——	2-FT FINAL COVER CTR
——	10-FT FINAL COVER CTR
——	DOWNDRAIN / CULVERT
——	WATERSHED BOUNDARY

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PROJECT #:	EJ147410

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SEDIMENT TRAP 5 AT X18 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
ST-5

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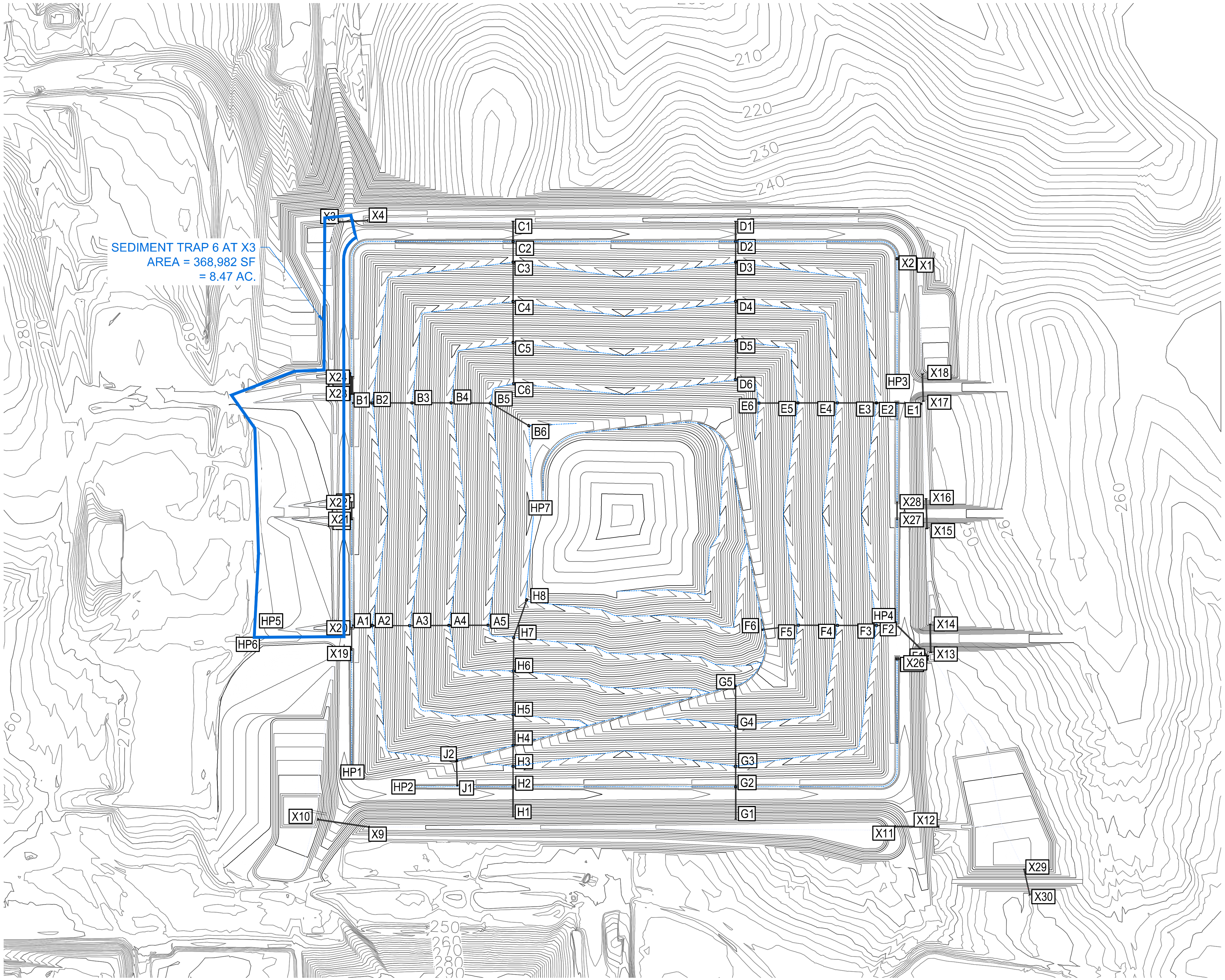

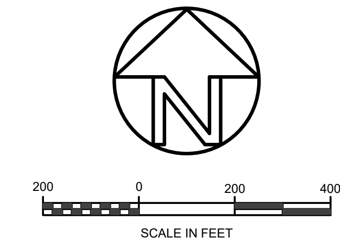

LEGEND

2-FT FINAL COVER CTR	
10-FT FINAL COVER CTR	
DOWNDRAIN / CULVERT	
WATERSHED BOUNDARY	

DRAWN BY:	JCH
CHECKED BY:	RSG
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DATE:	12/31/2014
PROJECT #:	EJ147410

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SEDIMENT TRAP 6 AT X3 WATERSHED

HYDROLOGY STUDY
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIGURE
ST-6

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Hydraflow Table of Contents

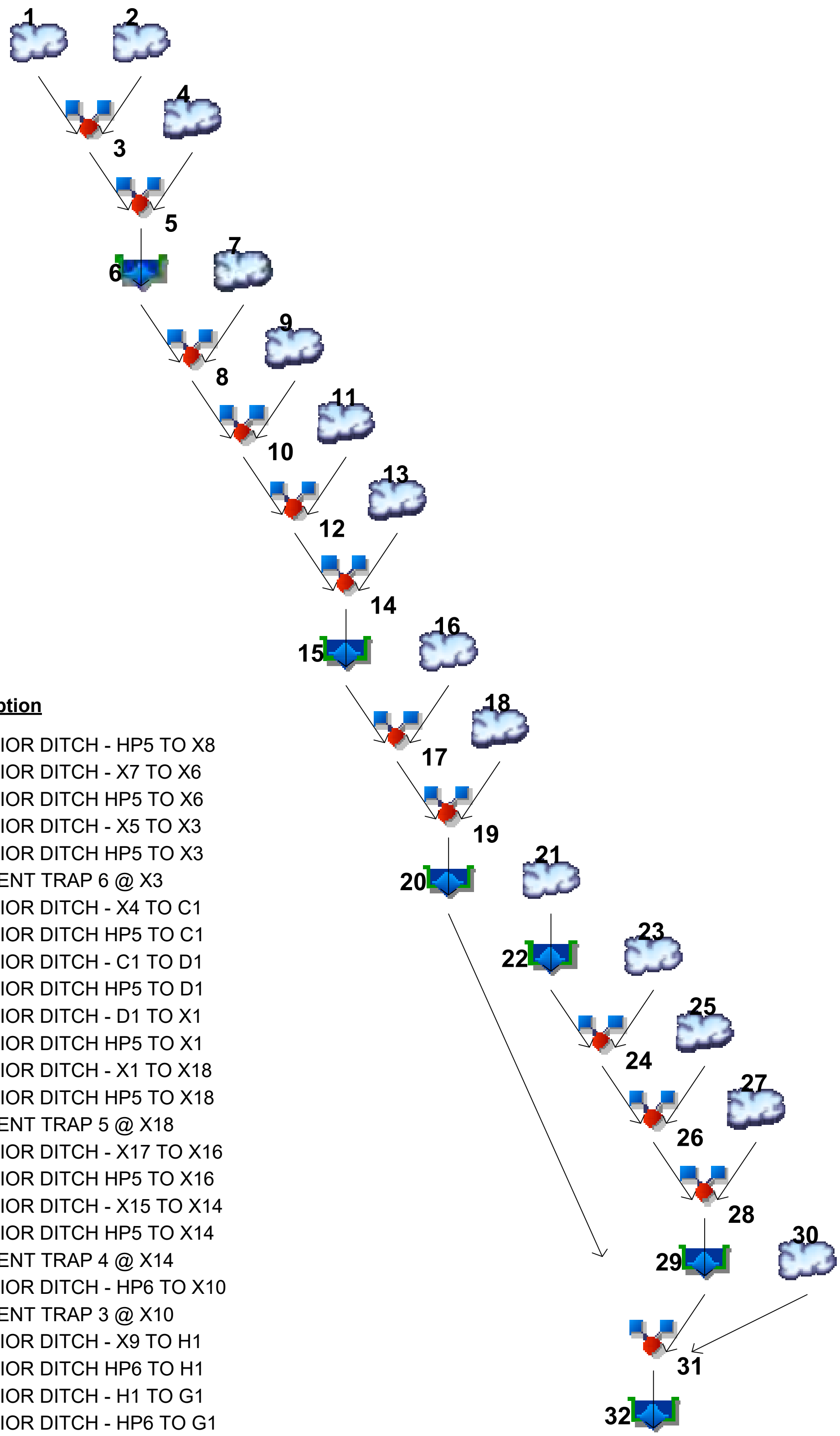
5 - Year

25 - Year

100 - Year

Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3



Legend

Hyd.	Origin	Description
1	SCS Runoff	EXTERIOR DITCH - HP5 TO X8
2	SCS Runoff	EXTERIOR DITCH - X7 TO X6
3	Combine	EXTERIOR DITCH HP5 TO X6
4	SCS Runoff	EXTERIOR DITCH - X5 TO X3
5	Combine	EXTERIOR DITCH HP5 TO X3
6	Reservoir	SEDIMENT TRAP 6 @ X3
7	SCS Runoff	EXTERIOR DITCH - X4 TO C1
8	Combine	EXTERIOR DITCH HP5 TO C1
9	SCS Runoff	EXTERIOR DITCH - C1 TO D1
10	Combine	EXTERIOR DITCH HP5 TO D1
11	SCS Runoff	EXTERIOR DITCH - D1 TO X1
12	Combine	EXTERIOR DITCH HP5 TO X1
13	SCS Runoff	EXTERIOR DITCH - X1 TO X18
14	Combine	EXTERIOR DITCH HP5 TO X18
15	Reservoir	SEDIMENT TRAP 5 @ X18
16	SCS Runoff	EXTERIOR DITCH - X17 TO X16
17	Combine	EXTERIOR DITCH HP5 TO X16
18	SCS Runoff	EXTERIOR DITCH - X15 TO X14
19	Combine	EXTERIOR DITCH HP5 TO X14
20	Reservoir	SEDIMENT TRAP 4 @ X14
21	SCS Runoff	EXTERIOR DITCH - HP6 TO X10
22	Reservoir	SEDIMENT TRAP 3 @ X10
23	SCS Runoff	EXTERIOR DITCH - X9 TO H1
24	Combine	EXTERIOR DITCH HP6 TO H1
25	SCS Runoff	EXTERIOR DITCH - H1 TO G1
26	Combine	EXTERIOR DITCH - HP6 TO G1
27	SCS Runoff	EXTERIOR DITCH - G1 TO X11
28	Combine	EXTERIOR DITCH - HP6 TO X11
29	Reservoir	SEDIMENT TRAP 2 @ X11
30	SCS Runoff	WATERSHED - TOP DECK TO OC1
31	Combine	INLET TO SED TRAP @ OC1
32	Reservoir	SEDIMENT TRAP 1 @ OC1

Hydrograph Return Period Recap

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)								Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	6.927	9.298	-------	13.04	15.85	19.19	-------	24.89	EXTERIOR DITCH - HP5 TO X8
2	SCS Runoff	------	7.008	9.406	-------	13.19	16.03	19.42	-------	25.18	EXTERIOR DITCH - X7 TO X6
3	Combine	1, 2	13.93	18.70	-------	26.23	31.88	38.61	-------	50.07	EXTERIOR DITCH HP5 TO X6
4	SCS Runoff	------	3.477	4.666	-------	6.542	7.949	9.616	-------	12.47	EXTERIOR DITCH - X5 TO X3
5	Combine	3, 4	17.31	23.29	-------	32.74	39.83	48.22	-------	62.51	EXTERIOR DITCH HP5 TO X3
6	Reservoir	5	0.310	0.617	-------	1.264	2.124	5.078	-------	14.10	SEDIMENT TRAP 6 @ X3
7	SCS Runoff	------	2.388	3.212	-------	4.514	5.491	6.647	-------	8.615	EXTERIOR DITCH - X4 TO C1
8	Combine	6, 7	2.388	3.212	-------	4.518	5.624	7.058	-------	15.88	EXTERIOR DITCH HP5 TO C1
9	SCS Runoff	------	62.20	83.64	-------	117.51	142.93	173.02	-------	224.24	EXTERIOR DITCH - C1 TO D1
10	Combine	8, 9	63.78	85.73	-------	120.57	146.87	178.09	-------	232.22	EXTERIOR DITCH HP5 TO D1
11	SCS Runoff	------	26.52	35.59	-------	49.91	60.64	73.36	-------	95.13	EXTERIOR DITCH - D1 TO X1
12	Combine	10, 11	87.47	117.54	-------	165.46	201.68	244.64	-------	318.07	EXTERIOR DITCH HP5 TO X1
13	SCS Runoff	------	18.50	24.89	-------	34.98	42.56	51.51	-------	66.77	EXTERIOR DITCH - X1 TO X18
14	Combine	12, 13	103.20	138.78	-------	195.07	237.50	287.80	-------	374.09	EXTERIOR DITCH HP5 TO X18
15	Reservoir	14	7.101	16.10	-------	23.97	26.83	27.84	-------	37.06	SEDIMENT TRAP 5 @ X18
16	SCS Runoff	------	37.28	50.15	-------	70.49	85.74	103.80	-------	134.53	EXTERIOR DITCH - X17 TO X16
17	Combine	15, 16	39.41	53.70	-------	76.45	95.74	122.43	-------	160.17	EXTERIOR DITCH HP5 TO X16
18	SCS Runoff	------	15.48	20.79	-------	29.18	35.47	42.91	-------	55.58	EXTERIOR DITCH - X15 TO X14
19	Combine	17, 18	54.35	73.76	-------	104.48	128.18	163.48	-------	213.22	EXTERIOR DITCH HP5 TO X14
20	Reservoir	19	9.011	16.76	-------	25.11	28.67	31.19	-------	44.67	SEDIMENT TRAP 4 @ X14
21	SCS Runoff	------	44.57	59.82	-------	83.87	101.91	123.29	-------	159.89	EXTERIOR DITCH - HP6 TO X10
22	Reservoir	21	2.255	3.059	-------	8.463	16.46	17.56	-------	29.41	SEDIMENT TRAP 3 @ X10
23	SCS Runoff	------	5.648	7.597	-------	10.68	12.99	15.72	-------	20.38	EXTERIOR DITCH - X9 TO H1
24	Combine	22, 23	6.336	8.854	-------	12.72	18.64	23.94	-------	36.63	EXTERIOR DITCH HP6 TO H1
25	SCS Runoff	------	35.33	47.53	-------	66.80	81.26	98.36	-------	127.49	EXTERIOR DITCH - H1 TO G1
26	Combine	24, 25	41.61	56.31	-------	79.52	96.83	117.63	-------	164.12	EXTERIOR DITCH - HP6 TO G1
27	SCS Runoff	------	30.24	40.67	-------	57.16	69.54	84.17	-------	109.10	EXTERIOR DITCH - G1 TO X11
28	Combine	26, 27	71.85	96.98	-------	136.68	166.36	201.80	-------	273.22	EXTERIOR DITCH - HP6 TO X11
29	Reservoir	28	0.634	1.218	-------	3.909	7.469	14.72	-------	22.21	SEDIMENT TRAP 2 @ X11
30	SCS Runoff	------	85.13	114.25	-------	160.20	194.65	235.48	-------	305.38	WATERSHED - TOP DECK TO OC1
31	Combine	20, 29, 30	90.18	120.82	-------	169.28	205.22	254.87	-------	331.29	INLET TO SED TRAP @ OC1
32	Reservoir	31	6.202	8.792	-------	21.22	27.06	34.89	-------	46.75	SEDIMENT TRAP 1 @ OC1

Proj. file: Exterior Ditch [with ponds].gpw | Friday, 01 / 30 / 2015

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	6.927	1	726	22,300	------	------	------	EXTERIOR DITCH - HP5 TO X8
2	SCS Runoff	7.008	1	726	22,560	------	------	------	EXTERIOR DITCH - X7 TO X6
3	Combine	13.93	1	726	44,860	1, 2	------	------	EXTERIOR DITCH HP5 TO X6
4	SCS Runoff	3.477	1	725	10,727	------	------	------	EXTERIOR DITCH - X5 TO X3
5	Combine	17.31	1	726	55,587	3, 4	------	------	EXTERIOR DITCH HP5 TO X3
6	Reservoir	0.310	1	1234	21,301	5	256.18	79,373	SEDIMENT TRAP 6 @ X3
7	SCS Runoff	2.388	1	723	6,935	------	------	------	EXTERIOR DITCH - X4 TO C1
8	Combine	2.388	1	723	28,236	6, 7	------	------	EXTERIOR DITCH HP5 TO C1
9	SCS Runoff	62.20	1	728	226,558	------	------	------	EXTERIOR DITCH - C1 TO D1
10	Combine	63.78	1	728	254,794	8, 9	------	------	EXTERIOR DITCH HP5 TO D1
11	SCS Runoff	26.52	1	725	81,831	------	------	------	EXTERIOR DITCH - D1 TO X1
12	Combine	87.47	1	727	336,625	10, 11	------	------	EXTERIOR DITCH HP5 TO X1
13	SCS Runoff	18.50	1	723	53,745	------	------	------	EXTERIOR DITCH - X1 TO X18
14	Combine	103.20	1	726	390,370	12, 13	------	------	EXTERIOR DITCH HP5 TO X18
15	Reservoir	7.101	1	876	364,136	14	247.31	250,452	SEDIMENT TRAP 5 @ X18
16	SCS Runoff	37.28	1	723	108,291	------	------	------	EXTERIOR DITCH - X17 TO X16
17	Combine	39.41	1	724	472,426	15, 16	------	------	EXTERIOR DITCH HP5 TO X16
18	SCS Runoff	15.48	1	722	42,134	------	------	------	EXTERIOR DITCH - X15 TO X14
19	Combine	54.35	1	723	514,561	17, 18	------	------	EXTERIOR DITCH HP5 TO X14
20	Reservoir	9.011	1	939	509,105	19	243.77	105,090	SEDIMENT TRAP 4 @ X14
21	SCS Runoff	44.57	1	725	137,531	------	------	------	EXTERIOR DITCH - HP6 TO X10
22	Reservoir	2.255	1	904	124,864	21	250.38	144,730	SEDIMENT TRAP 3 @ X10
23	SCS Runoff	5.648	1	723	16,404	------	------	------	EXTERIOR DITCH - X9 TO H1
24	Combine	6.336	1	724	141,268	22, 23	------	------	EXTERIOR DITCH HP6 TO H1
25	SCS Runoff	35.33	1	723	102,623	------	------	------	EXTERIOR DITCH - H1 TO G1
26	Combine	41.61	1	723	243,891	24, 25	------	------	EXTERIOR DITCH - HP6 TO G1
27	SCS Runoff	30.24	1	723	87,820	------	------	------	EXTERIOR DITCH - G1 TO X11
28	Combine	71.85	1	723	331,710	26, 27	------	------	EXTERIOR DITCH - HP6 TO X11
29	Reservoir	0.634	1	1806	64,071	28	245.07	854,984	SEDIMENT TRAP 2 @ X11
30	SCS Runoff	85.13	1	725	262,683	------	------	------	WATERSHED - TOP DECK TO OC1
31	Combine	90.18	1	725	835,858	20, 29, 30	------	------	INLET TO SED TRAP @ OC1
32	Reservoir	6.202	1	1502	600,070	31	232.47	592,213	SEDIMENT TRAP 1 @ OC1

Exterior Ditch [with ponds].gpw	Return Period: 1 Year	Friday, 01 / 30 / 2015

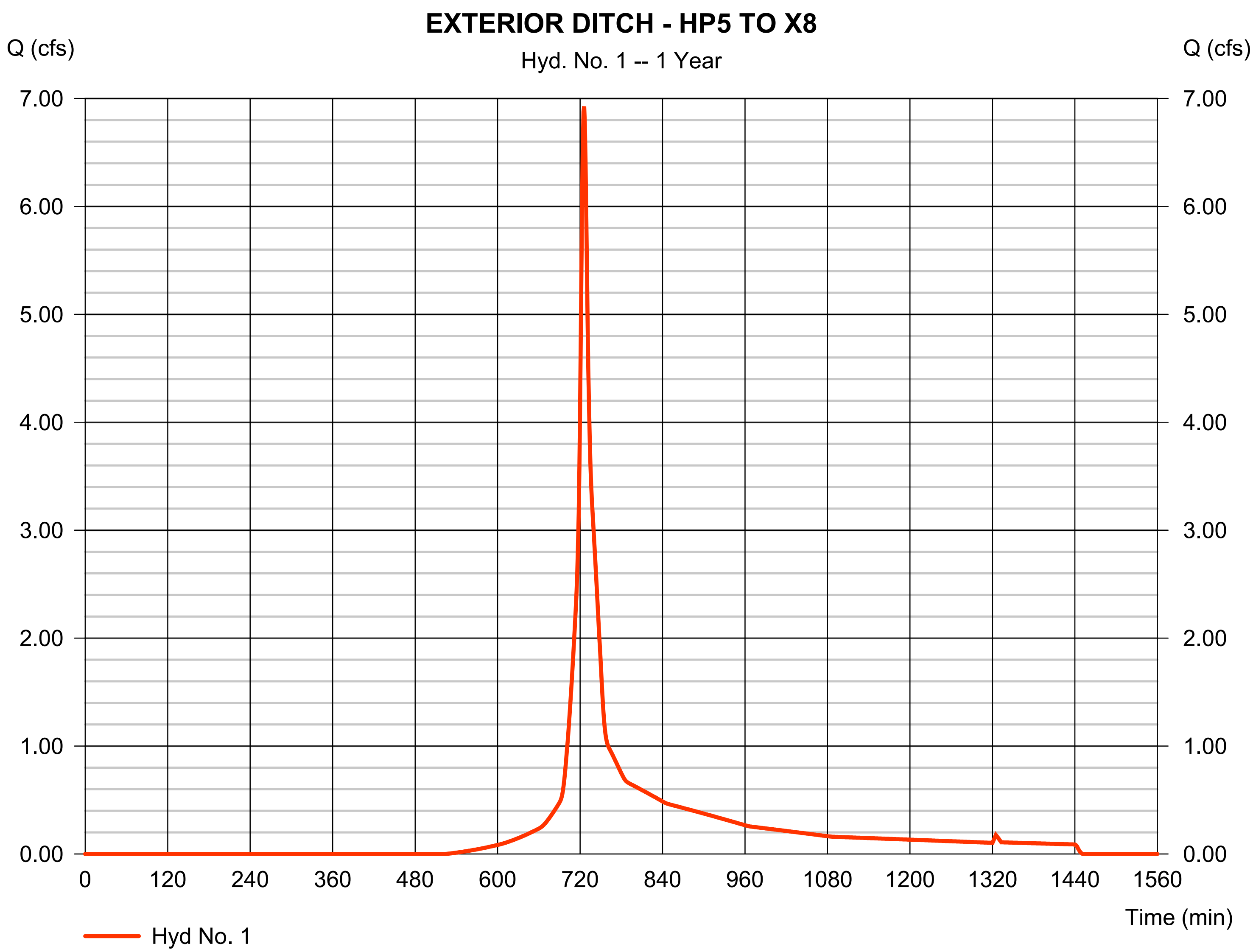
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 1

EXTERIOR DITCH - HP5 TO X8

Hydrograph type	= SCS Runoff	Peak discharge	= 6.927 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 22,300 cuft
Drainage area	= 3.430 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.30 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



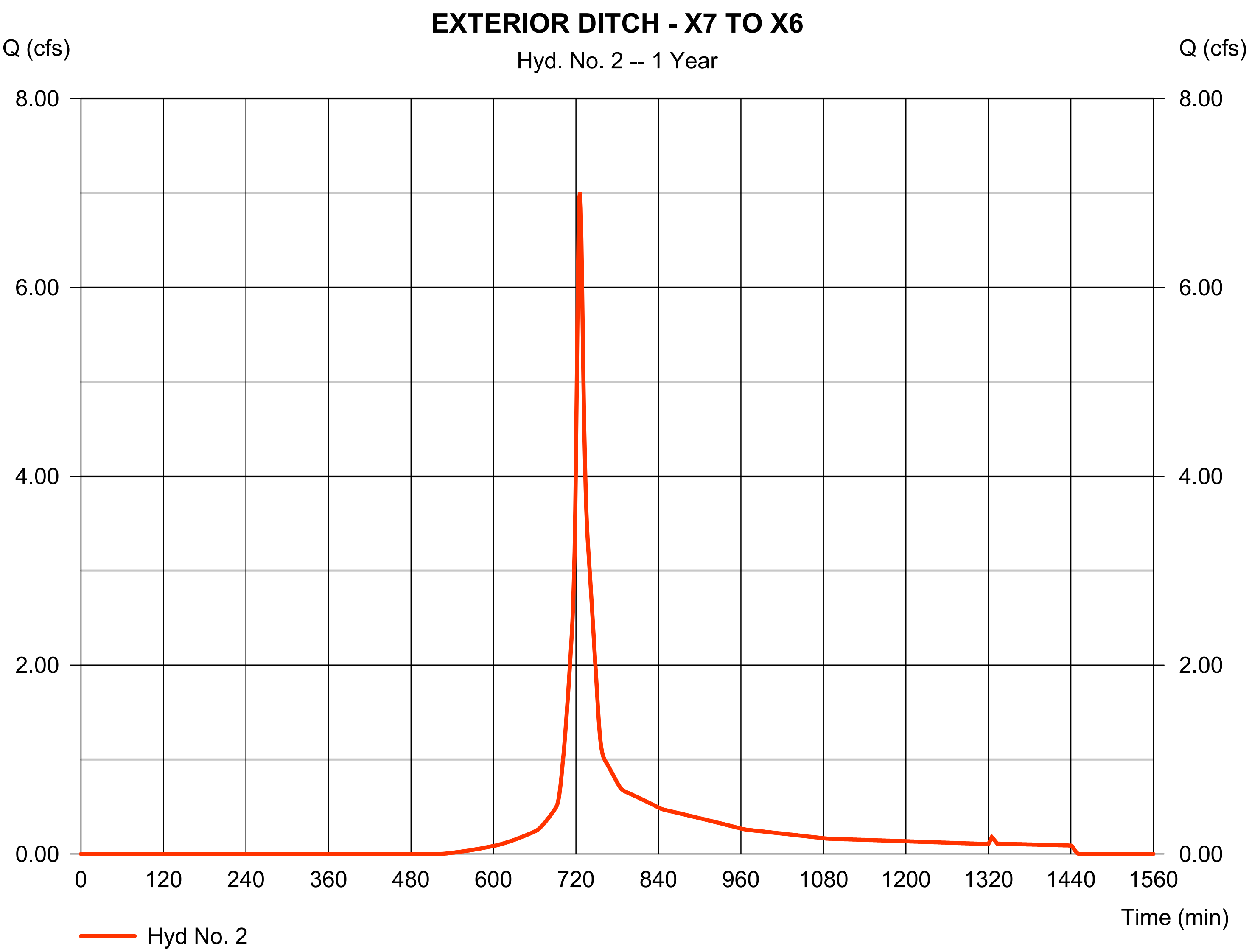
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 2

EXTERIOR DITCH - X7 TO X6

Hydrograph type	=	SCS Runoff	Peak discharge	=	7.008 cfs
Storm frequency	=	1 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	22,560 cuft
Drainage area	=	3.470 ac	Curve number	=	80
Basin Slope	=	25.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	7.70 min
Total precip.	=	3.75 in	Distribution	=	Type III
Storm duration	=	24 hrs	Shape factor	=	484



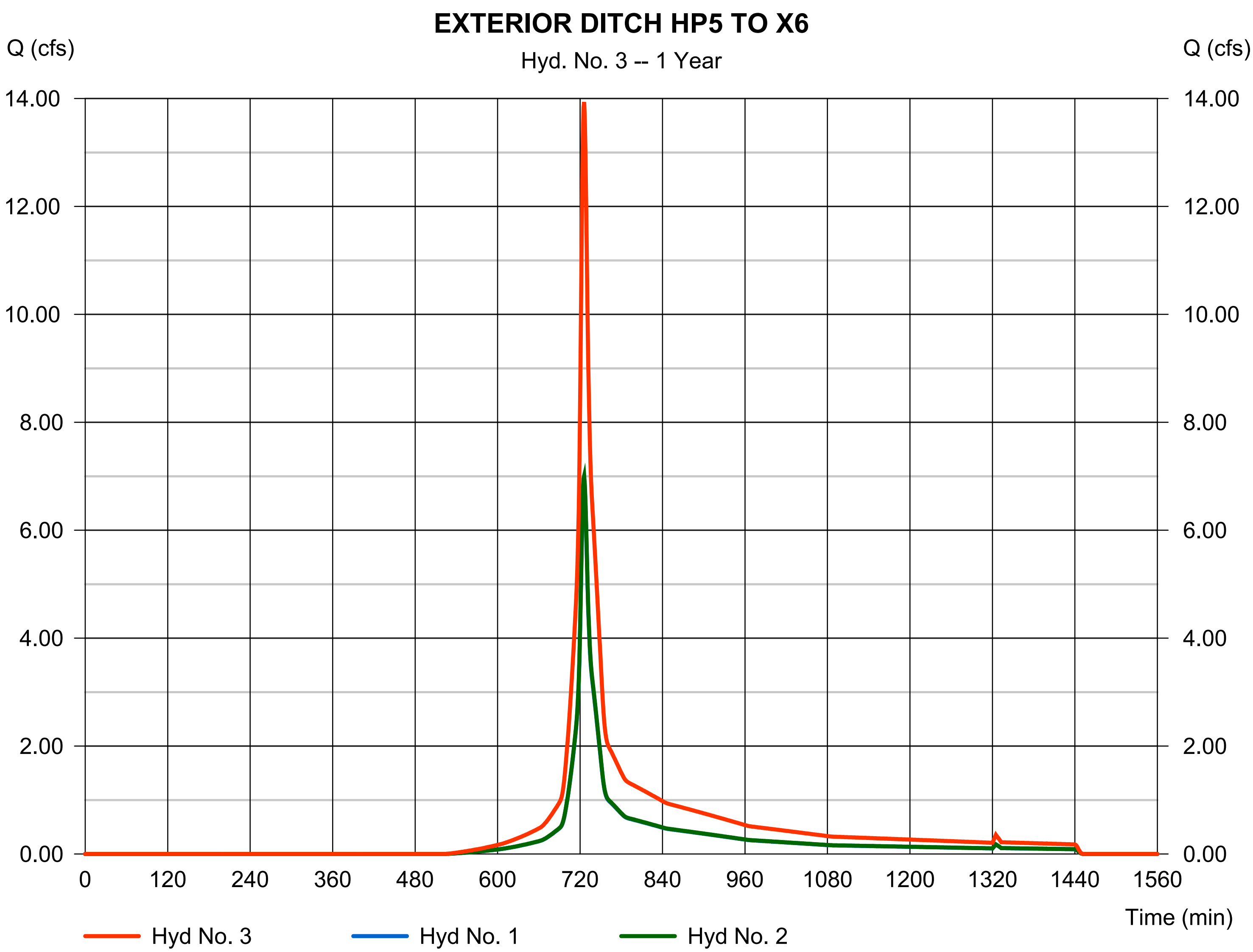
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 3

EXTERIOR DITCH HP5 TO X6

Hydrograph type	= Combine	Peak discharge	= 13.93 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 44,860 cuft
Inflow hyds.	= 1, 2	Contrib. drain. area	= 6.900 ac



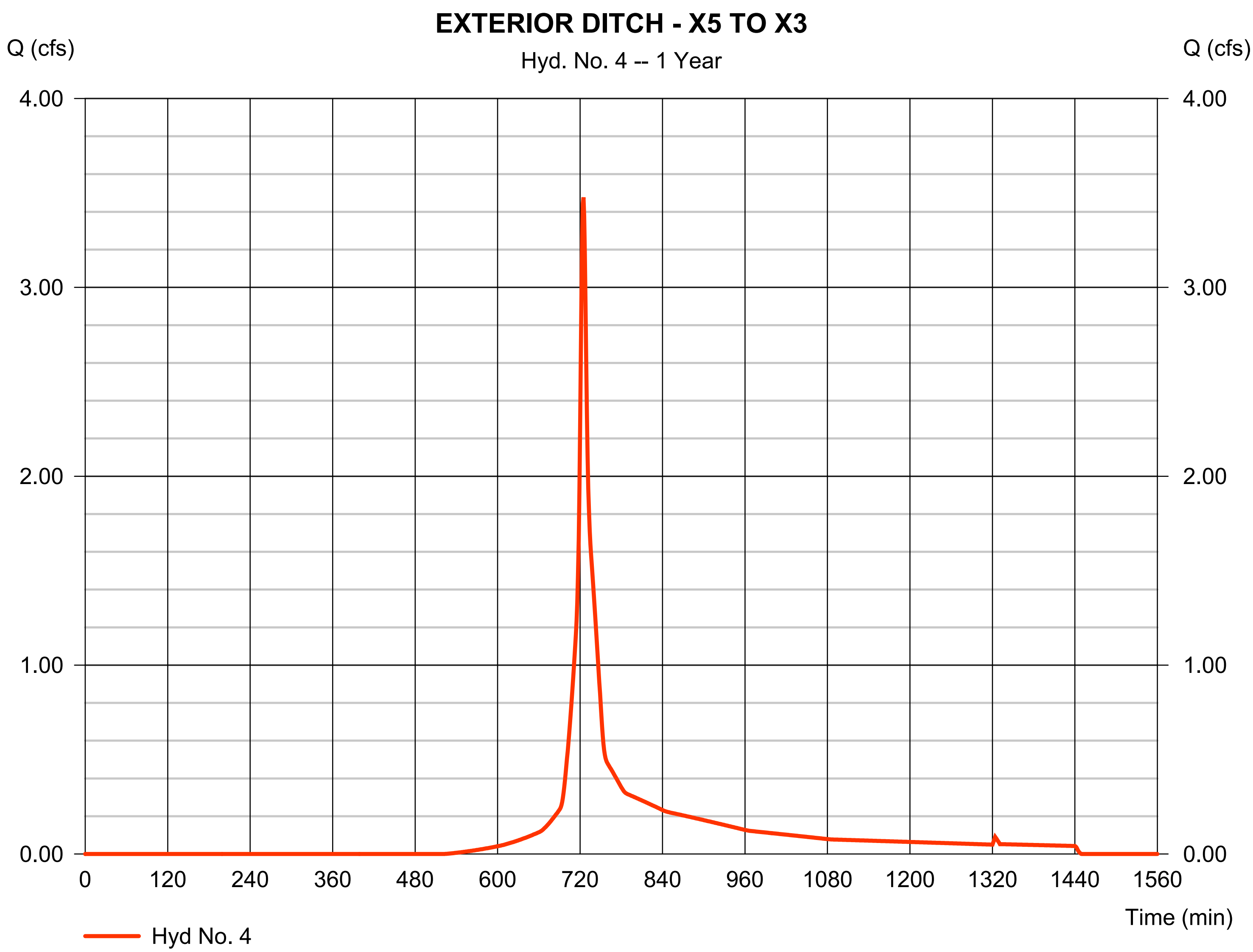
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 4

EXTERIOR DITCH - X5 TO X3

Hydrograph type	= SCS Runoff	Peak discharge	= 3.477 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 10,727 cuft
Drainage area	= 1.560 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.90 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



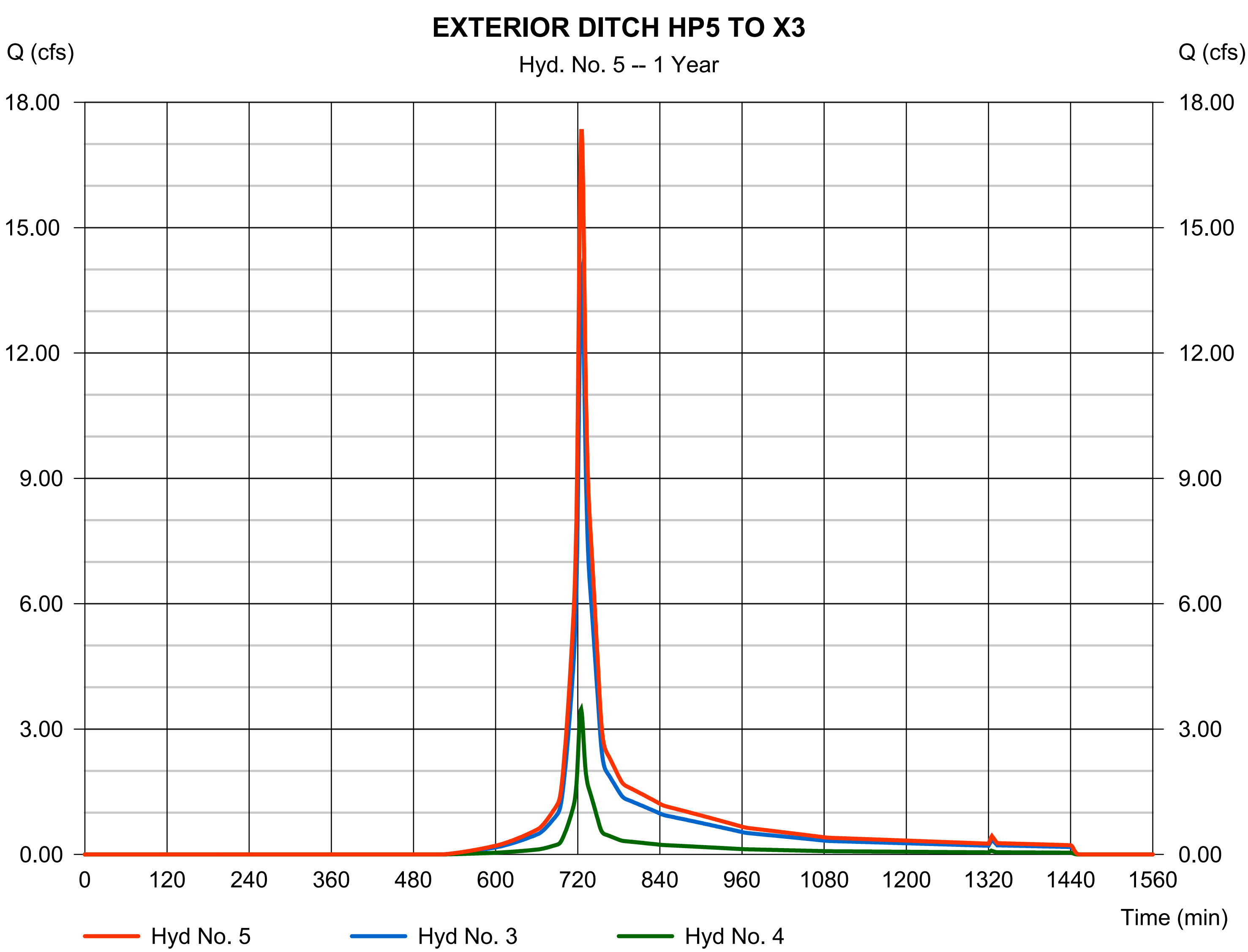
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 5

EXTERIOR DITCH HP5 TO X3

Hydrograph type	= Combine	Peak discharge	= 17.31 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 55,587 cuft
Inflow hyds.	= 3, 4	Contrib. drain. area	= 1.560 ac



Hydrograph Report

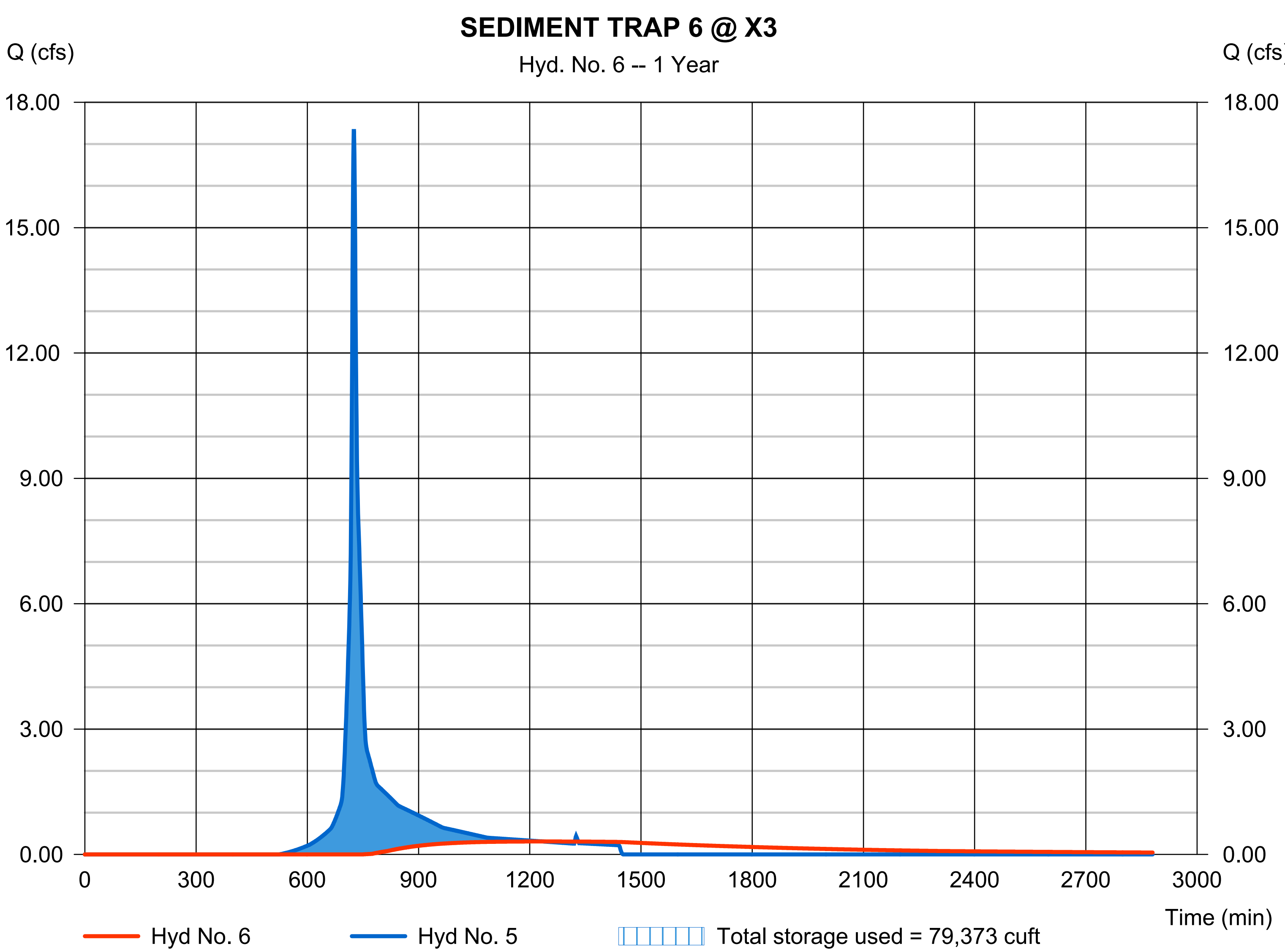
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 6

SEDIMENT TRAP 6 @ X3

Hydrograph type	= Reservoir	Peak discharge	= 0.310 cfs
Storm frequency	= 1 yrs	Time to peak	= 1234 min
Time interval	= 1 min	Hyd. volume	= 21,301 cuft
Inflow hyd. No.	= 5 - EXTERIOR DITCH HP5 TO X3	Max. Elevation	= 256.18 ft
Reservoir name	= SEDIMENT TRAP 6 @ X3	Max. Storage	= 79,373 cuft

Storage Indication method used. Wet pond routing start elevation = 254.00 ft.



Pond Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 | Friday, 01 / 30 / 2015

Pond No. 1 - SEDIMENT TRAP 6 @ X3

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 250.00 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	250.00	5,302	0	0
1.00	252.00	9,746	7,411	7,411
3.00	254.00	16,924	26,339	33,751
5.00	256.00	23,720	40,449	74,200
7.00	258.00	32,962	56,424	130,624
8.00	259.00	37,526	35,216	165,839

Culvert / Orifice Structures

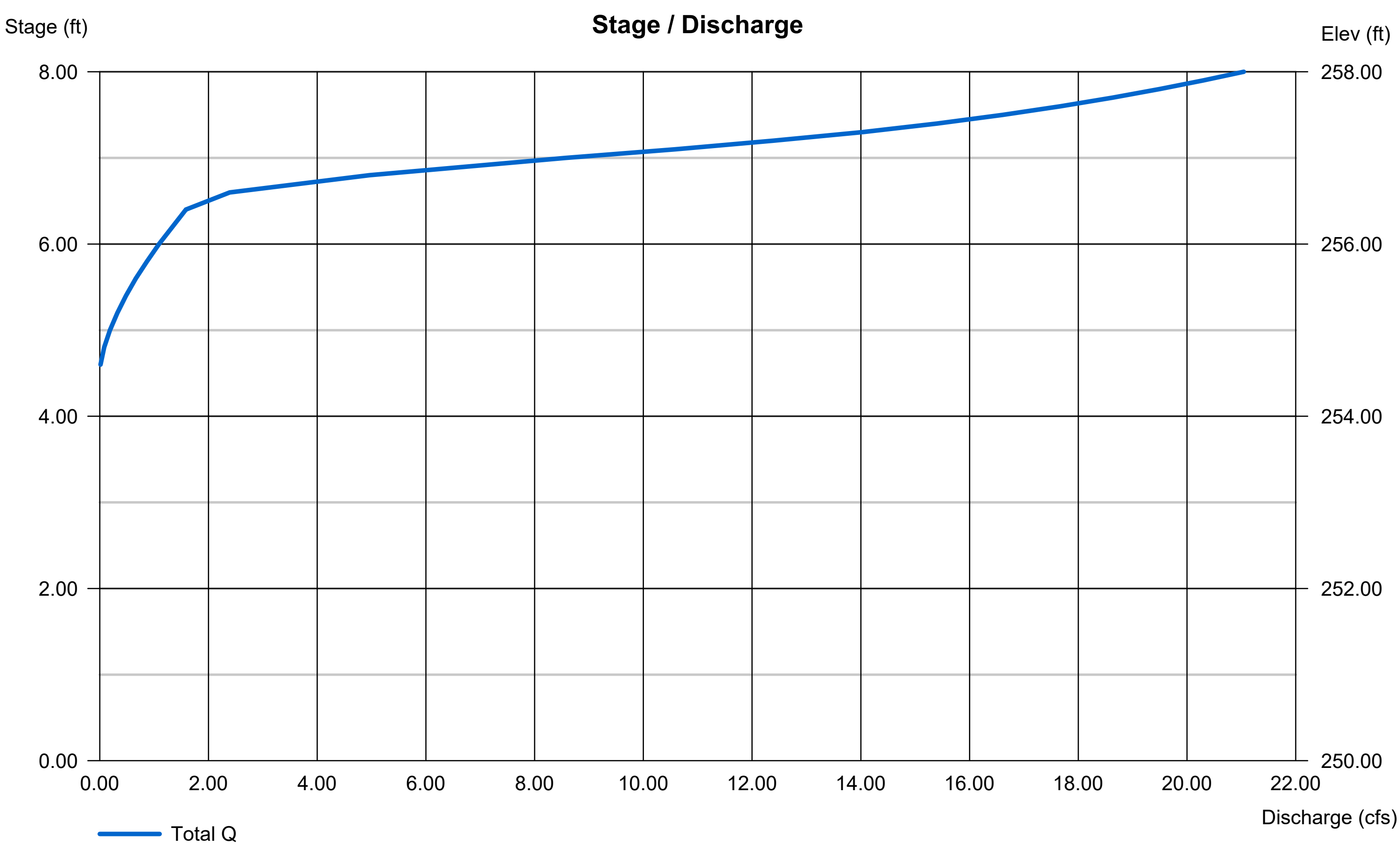
	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 24.00	0.00	0.00	1.00
Span (in)	= 24.00	0.00	0.00	1.00
No. Barrels	= 1	0	0	195
Invert El. (ft)	= 255.50	0.00	0.00	254.00
Length (ft)	= 103.00	0.00	0.00	3.50
Slope (%)	= 0.50	0.00	0.00	n/a
N-Value	= .012	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	Yes

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 6.28	0.00	0.00	0.00
Crest El. (ft)	= 257.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= 1	---	---	---
Multi-Stage	= Yes	No	No	No

Exfil.(in/hr) = 0.000 (by Wet area)
TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).



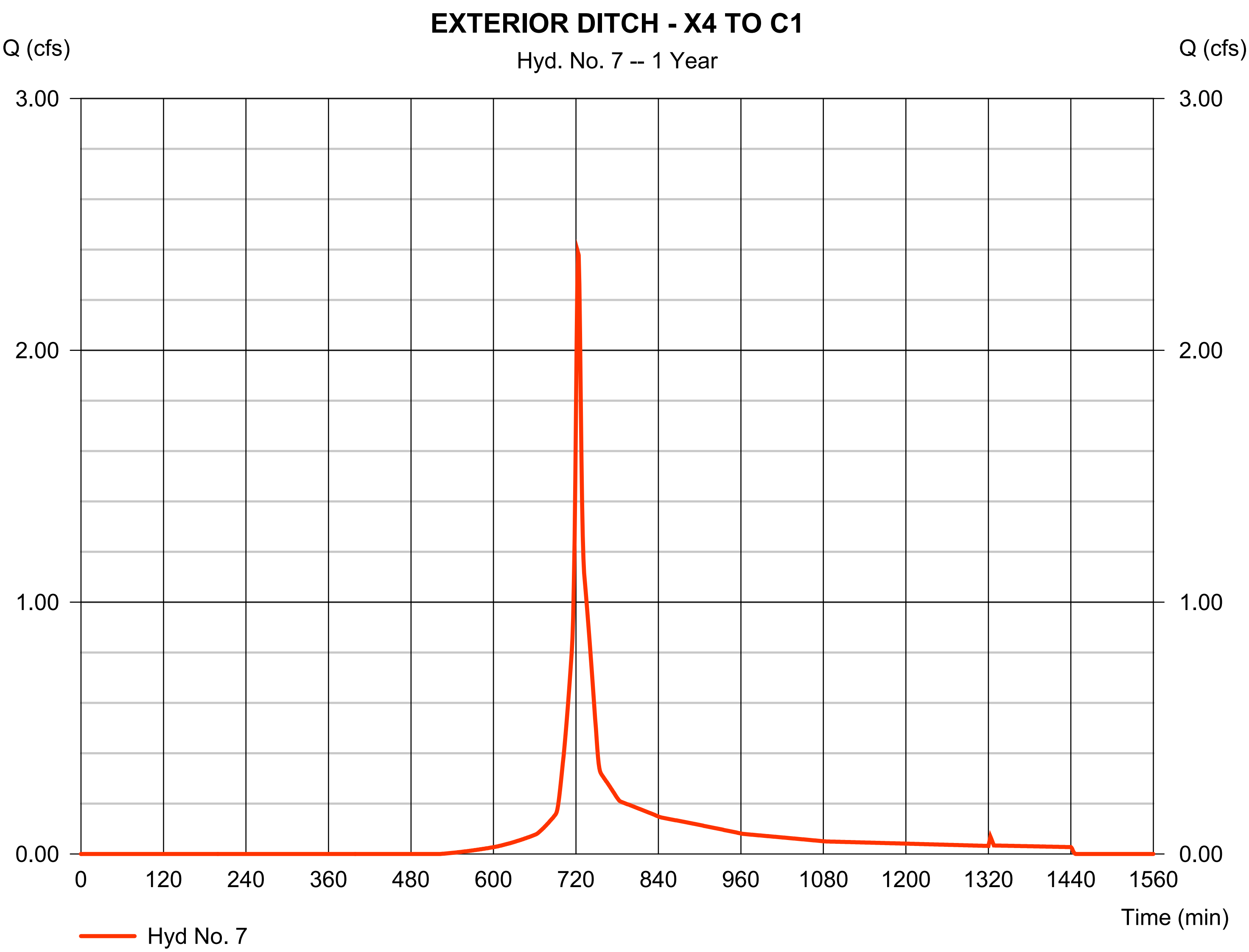
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 7

EXTERIOR DITCH - X4 TO C1

Hydrograph type	= SCS Runoff	Peak discharge	= 2.388 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 6,935 cuft
Drainage area	= 1.040 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.70 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



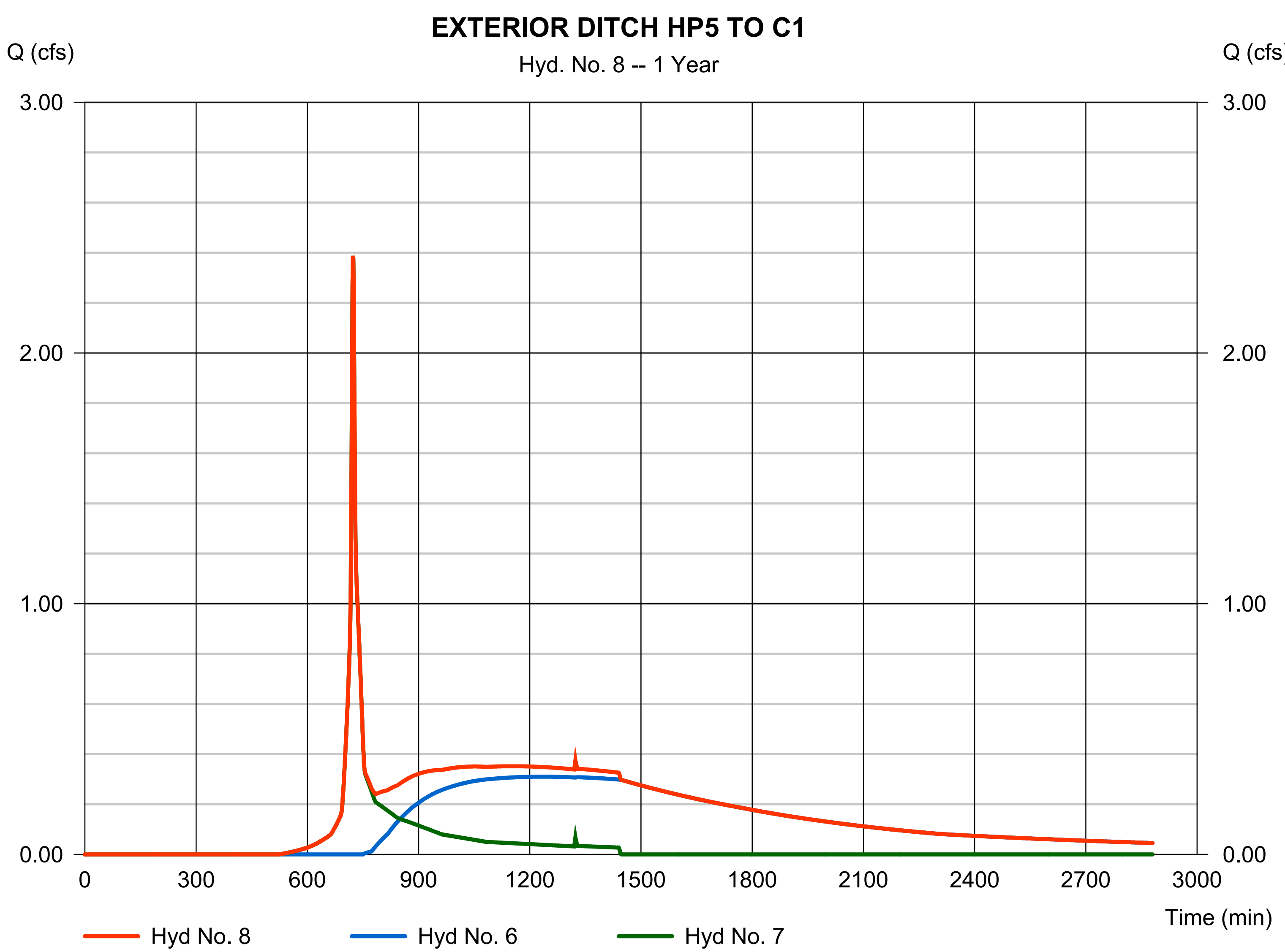
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 8

EXTERIOR DITCH HP5 TO C1

Hydrograph type	= Combine	Peak discharge	= 2.388 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 28,236 cuft
Inflow hyds.	= 6, 7	Contrib. drain. area	= 1.040 ac



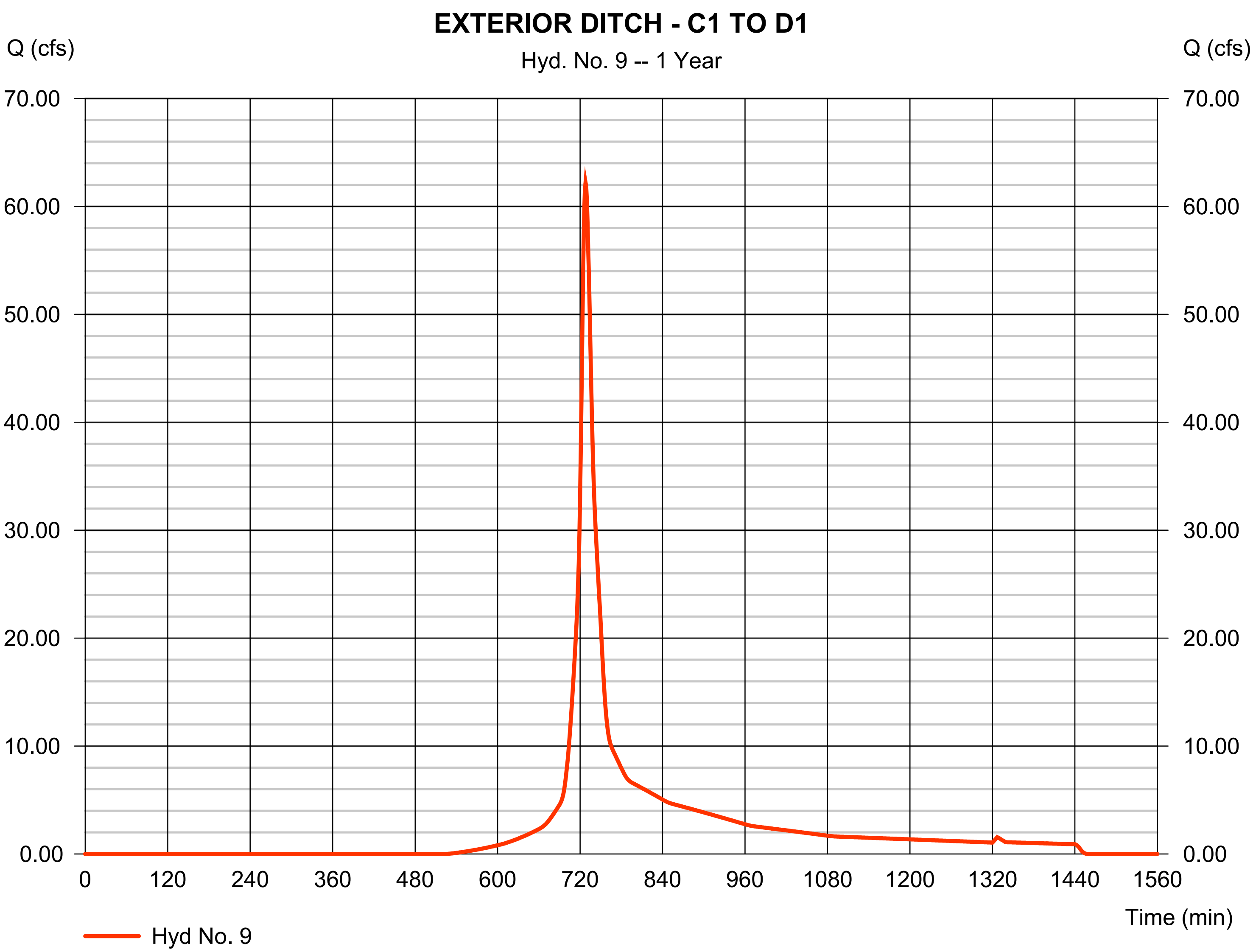
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 9

EXTERIOR DITCH - C1 TO D1

Hydrograph type	= SCS Runoff	Peak discharge	= 62.20 cfs
Storm frequency	= 1 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 226,558 cuft
Drainage area	= 33.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.00 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



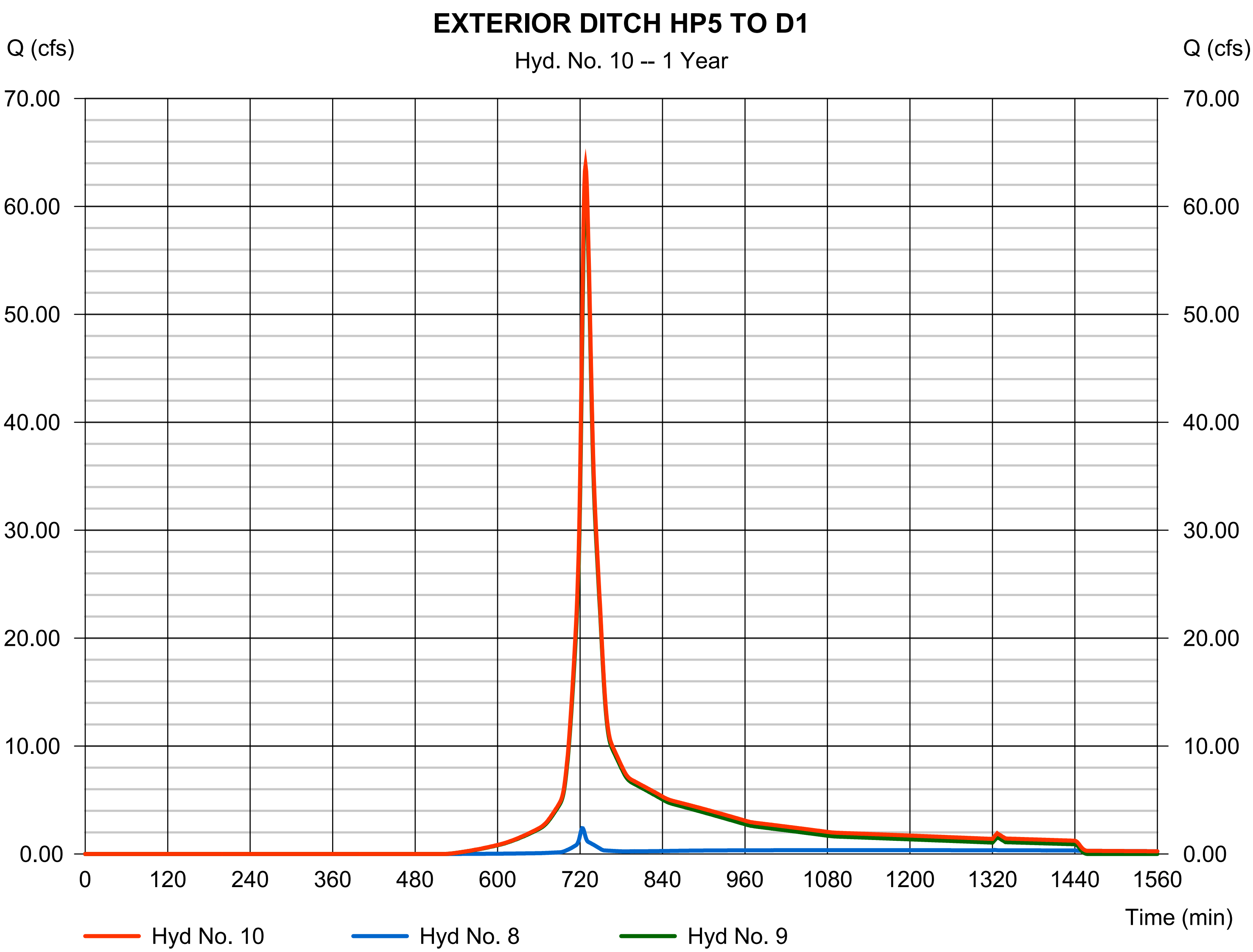
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 | Friday, 01 / 30 / 2015

Hyd. No. 10

EXTERIOR DITCH HP5 TO D1

Hydrograph type	= Combine	Peak discharge	= 63.78 cfs
Storm frequency	= 1 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 254,794 cuft
Inflow hyds.	= 8, 9	Contrib. drain. area	= 33.380 ac



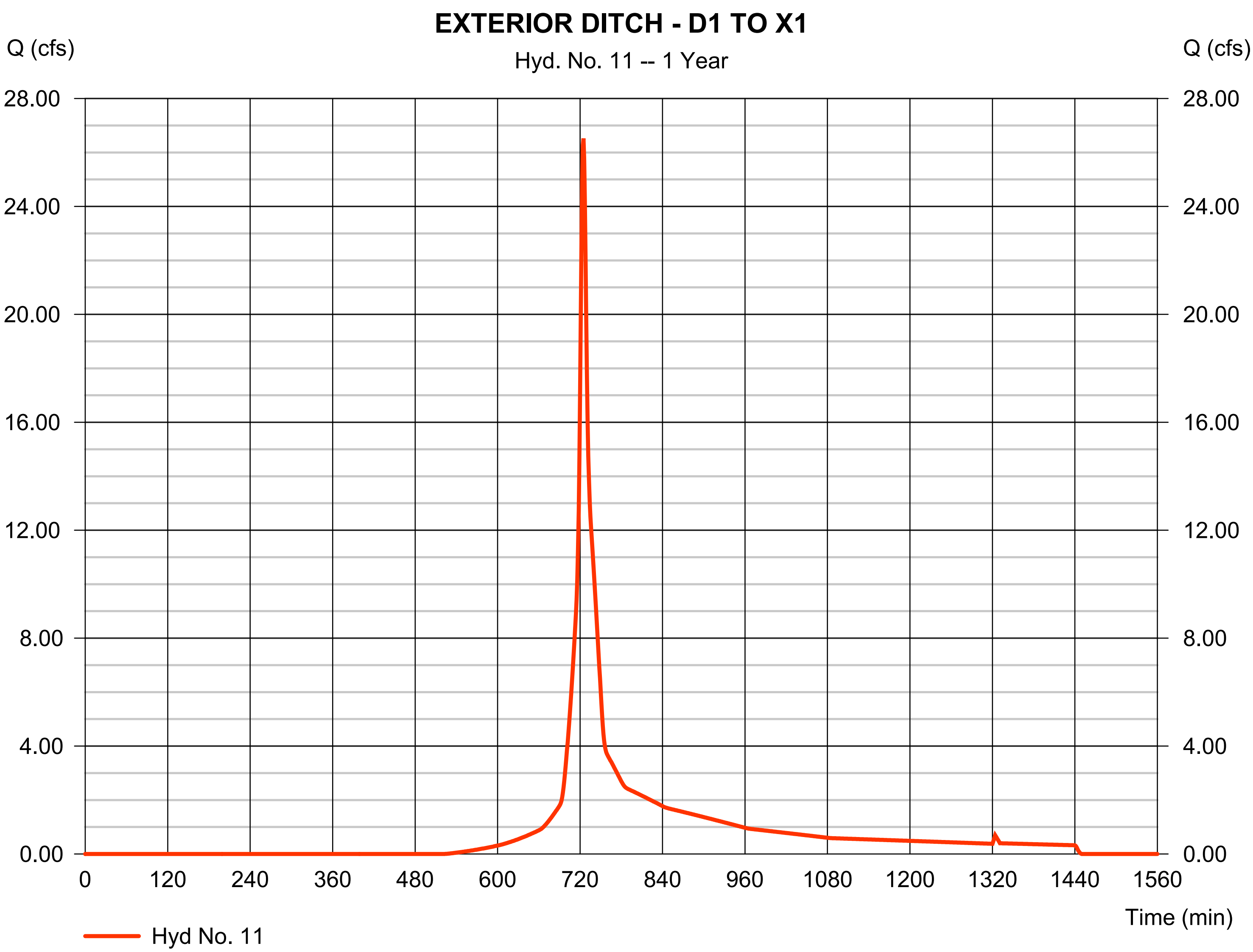
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 11

EXTERIOR DITCH - D1 TO X1

Hydrograph type	= SCS Runoff	Peak discharge	= 26.52 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 81,831 cuft
Drainage area	= 11.900 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.20 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



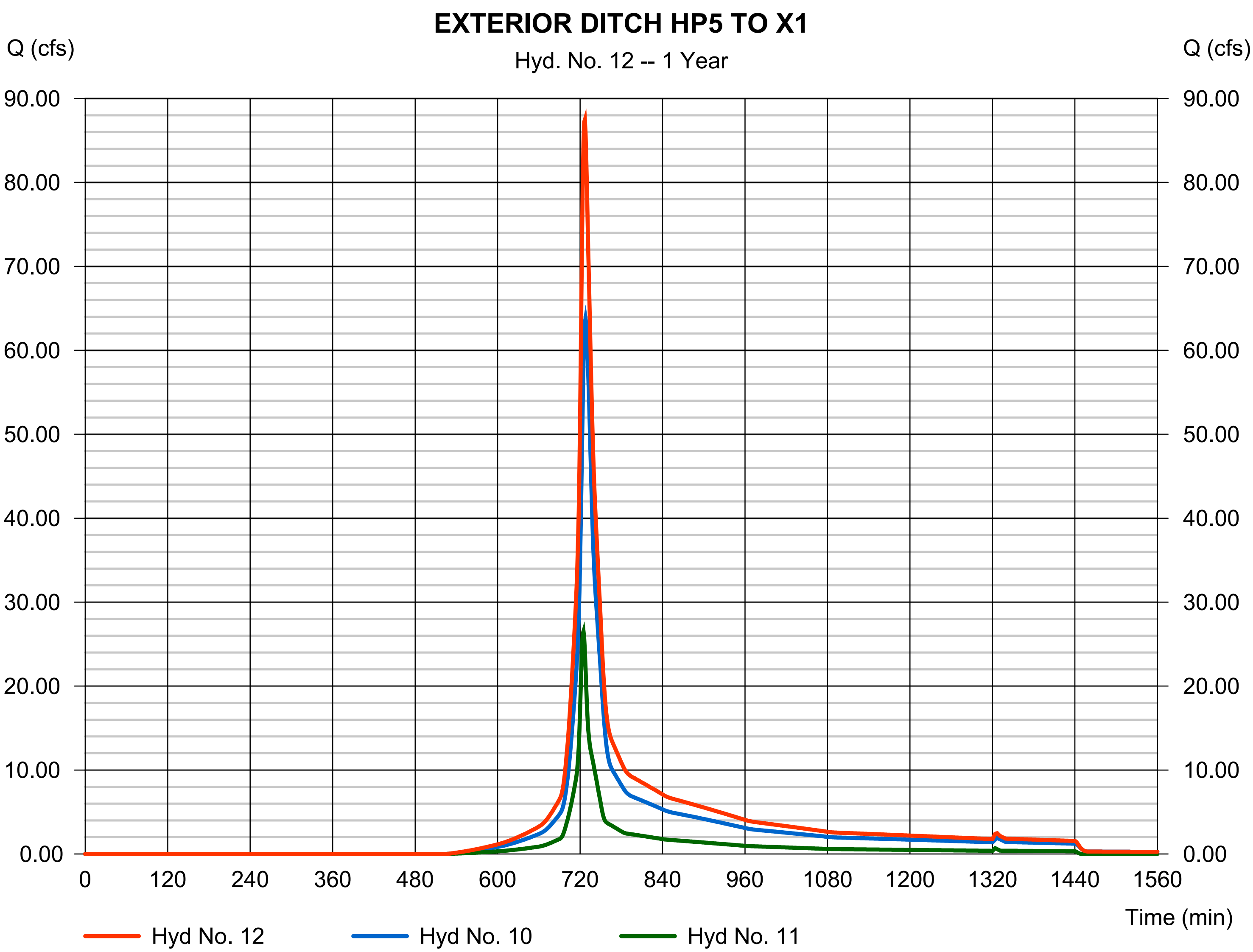
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 12

EXTERIOR DITCH HP5 TO X1

Hydrograph type	= Combine	Peak discharge	= 87.47 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 336,625 cuft
Inflow hyds.	= 10, 11	Contrib. drain. area	= 11.900 ac



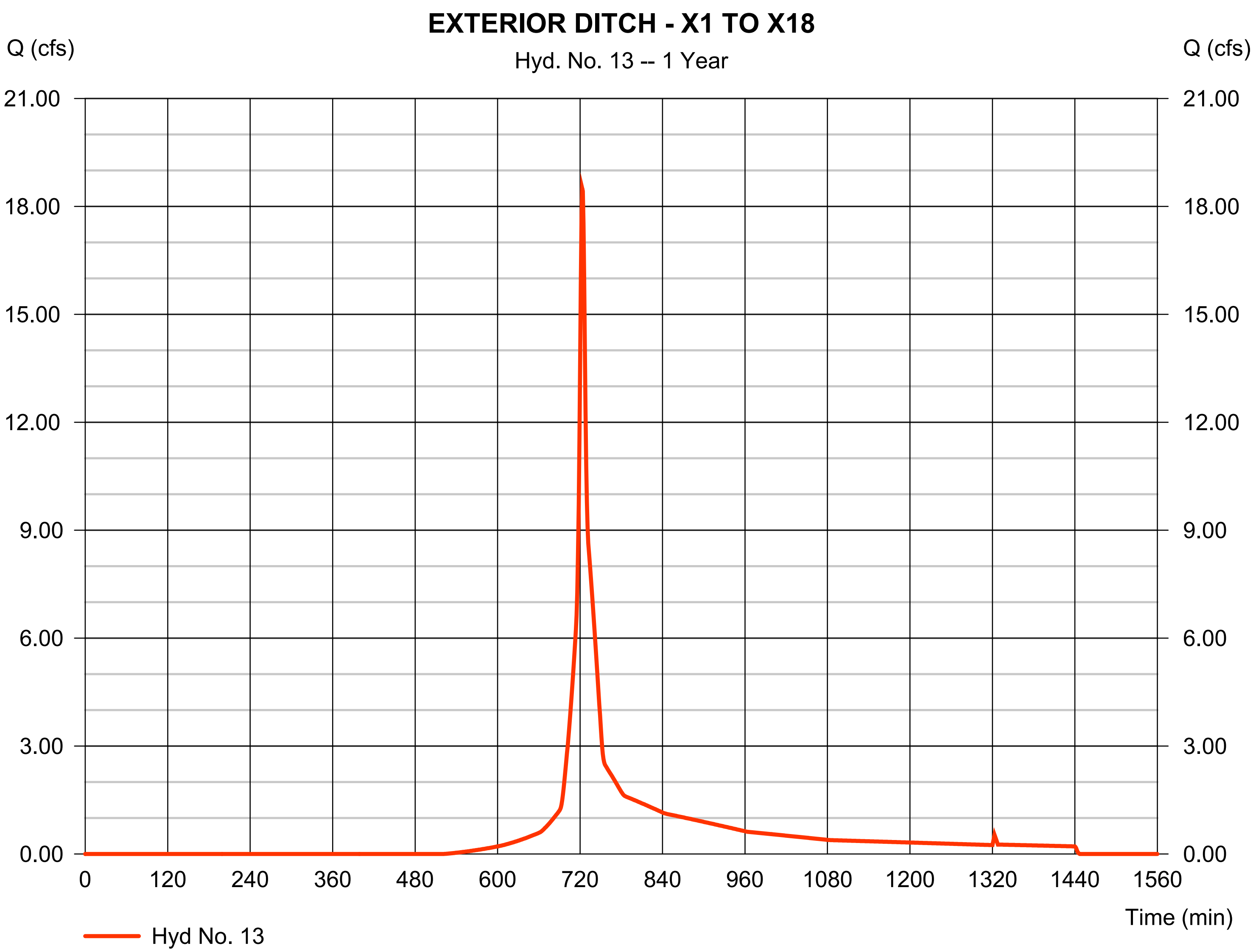
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 13

EXTERIOR DITCH - X1 TO X18

Hydrograph type	= SCS Runoff	Peak discharge	= 18.50 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 53,745 cuft
Drainage area	= 8.060 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.80 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



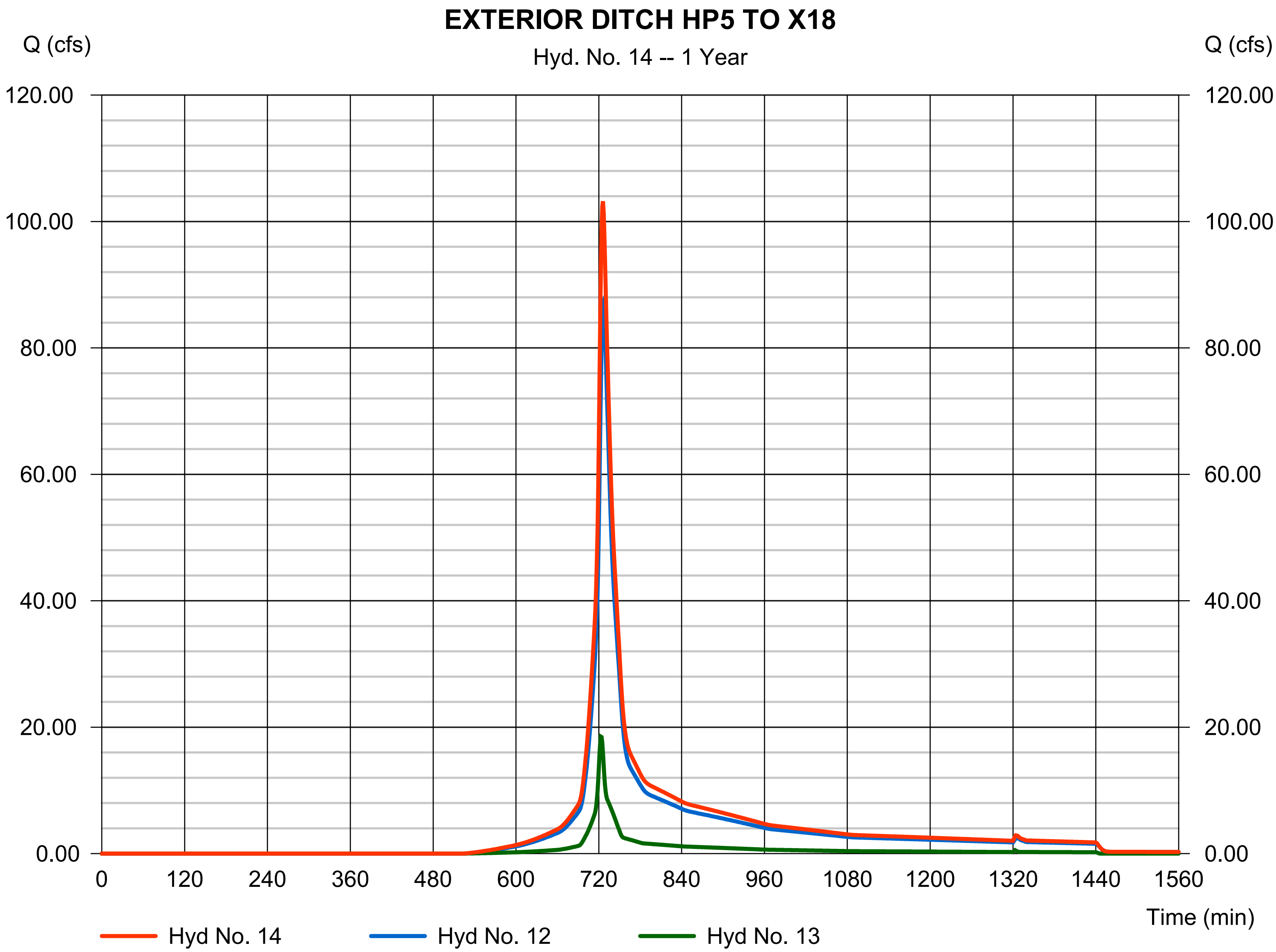
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 14

EXTERIOR DITCH HP5 TO X18

Hydrograph type	= Combine	Peak discharge	= 103.20 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 390,370 cuft
Inflow hyds.	= 12, 13	Contrib. drain. area	= 8.060 ac



Hydrograph Report

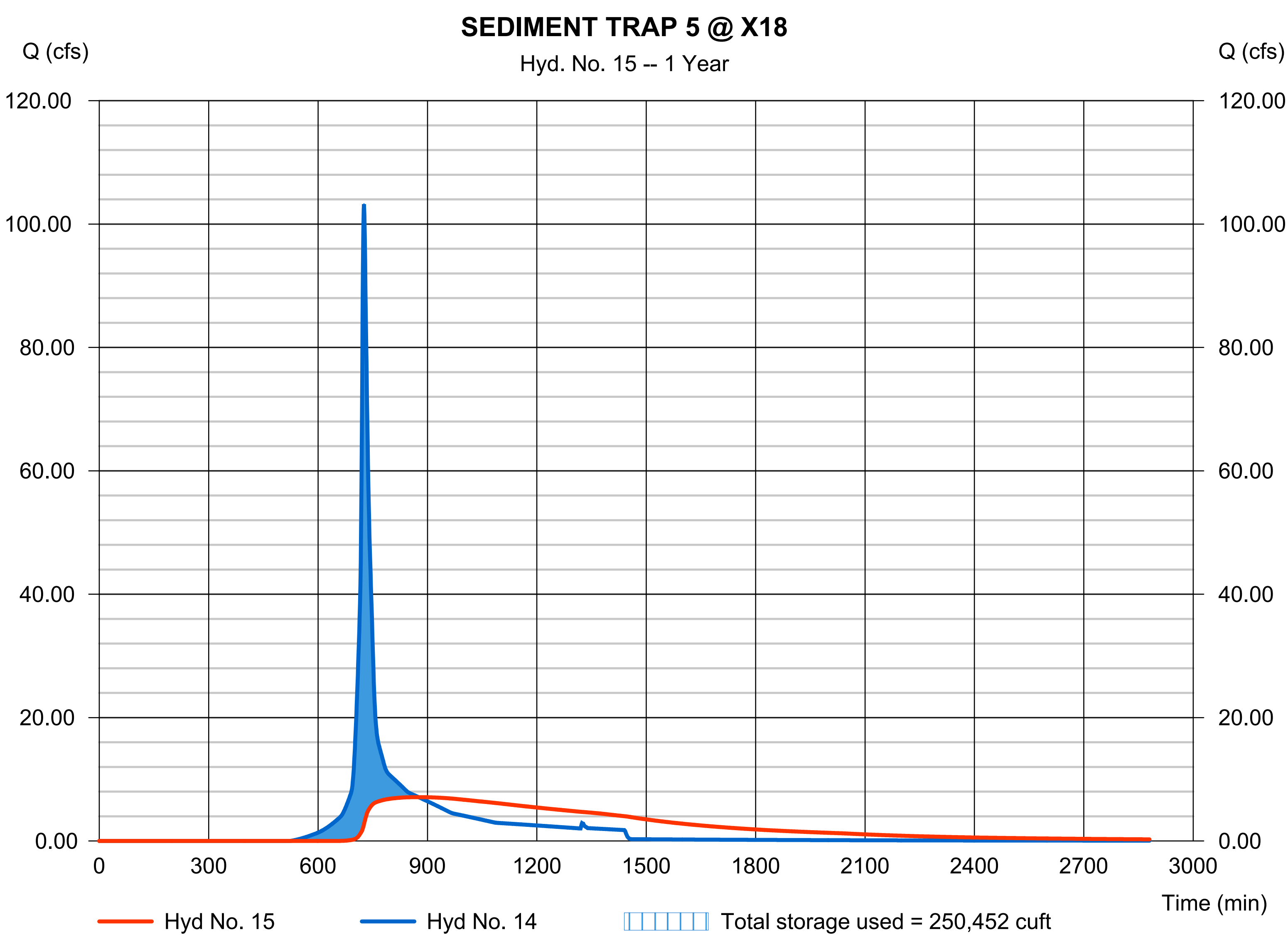
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 15

SEDIMENT TRAP 5 @ X18

Hydrograph type	= Reservoir	Peak discharge	= 7.101 cfs
Storm frequency	= 1 yrs	Time to peak	= 876 min
Time interval	= 1 min	Hyd. volume	= 364,136 cuft
Inflow hyd. No.	= 14 - EXTERIOR DITCH HP5 TO X18	Max. Elevation	= 247.31 ft
Reservoir name	= SEDIMENT TRAP 5 @ X18	Max. Storage	= 250,452 cuft

Storage Indication method used. Wet pond routing start elevation = 242.00 ft.



Pond Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Pond No. 2 - SEDIMENT TRAP 5 @ X18

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 238.00 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	238.00	3,446	0	0
2.00	240.00	9,883	12,775	12,775
4.00	242.00	17,696	27,200	39,975
6.00	244.00	35,177	51,877	91,852
8.00	246.00	48,600	83,408	175,260
10.00	248.00	66,828	114,934	290,193
12.00	250.00	89,898	156,141	446,335
14.00	252.00	1,171,487	1,057,166	1,503,500

Culvert / Orifice Structures

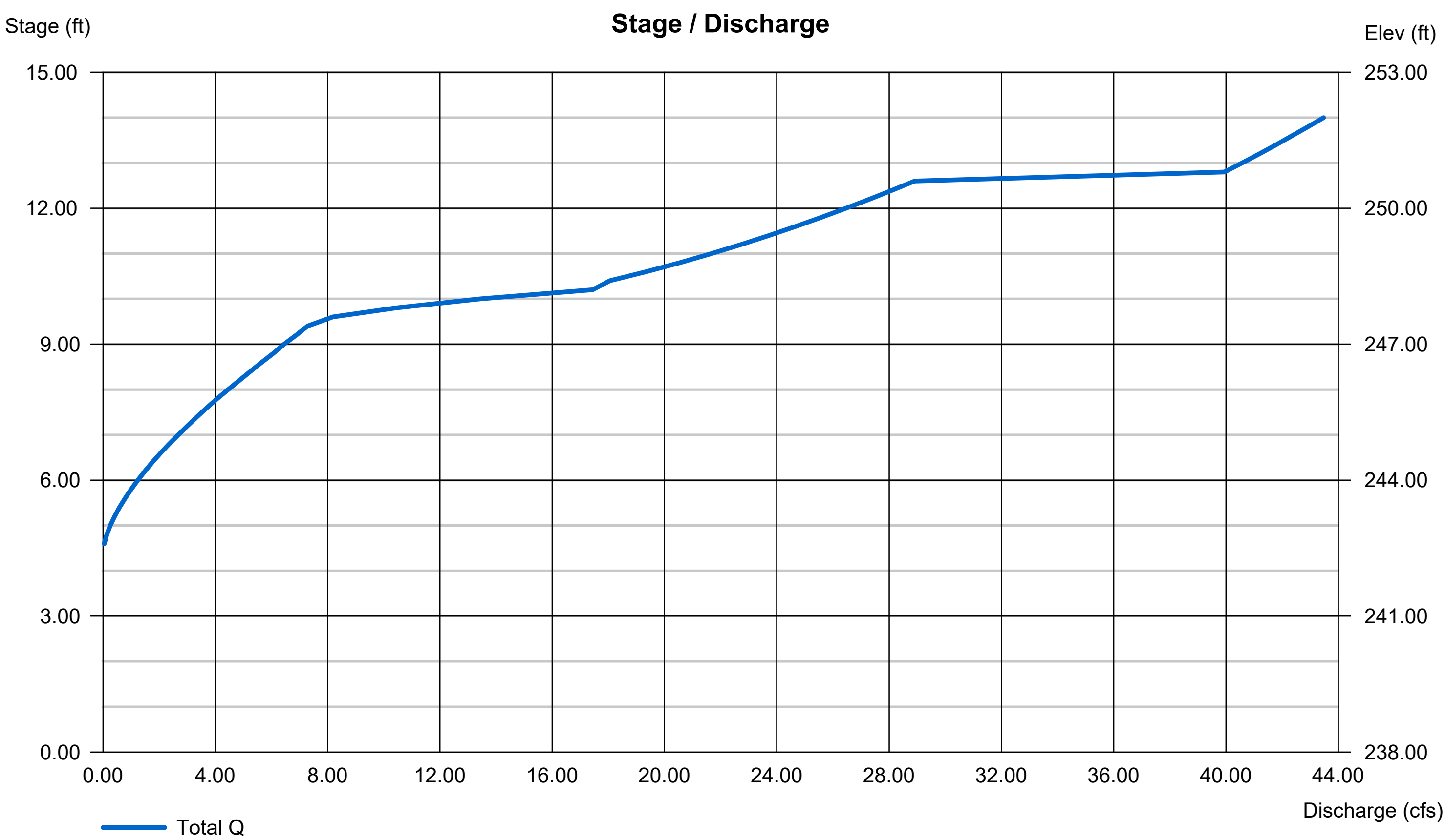
	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 24.00	0.00	0.00	1.00
Span (in)	= 24.00	0.00	0.00	1.00
No. Barrels	= 1	0	0	315
Invert El. (ft)	= 242.40	0.00	0.00	242.00
Length (ft)	= 97.00	0.00	0.00	5.50
Slope (%)	= 0.50	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	Yes

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 6.28	0.00	0.00	0.00
Crest El. (ft)	= 247.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= 1	---	---	---
Multi-Stage	= Yes	No	No	No

Exfil.(in/hr) = 0.000 (by Wet area)
TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).



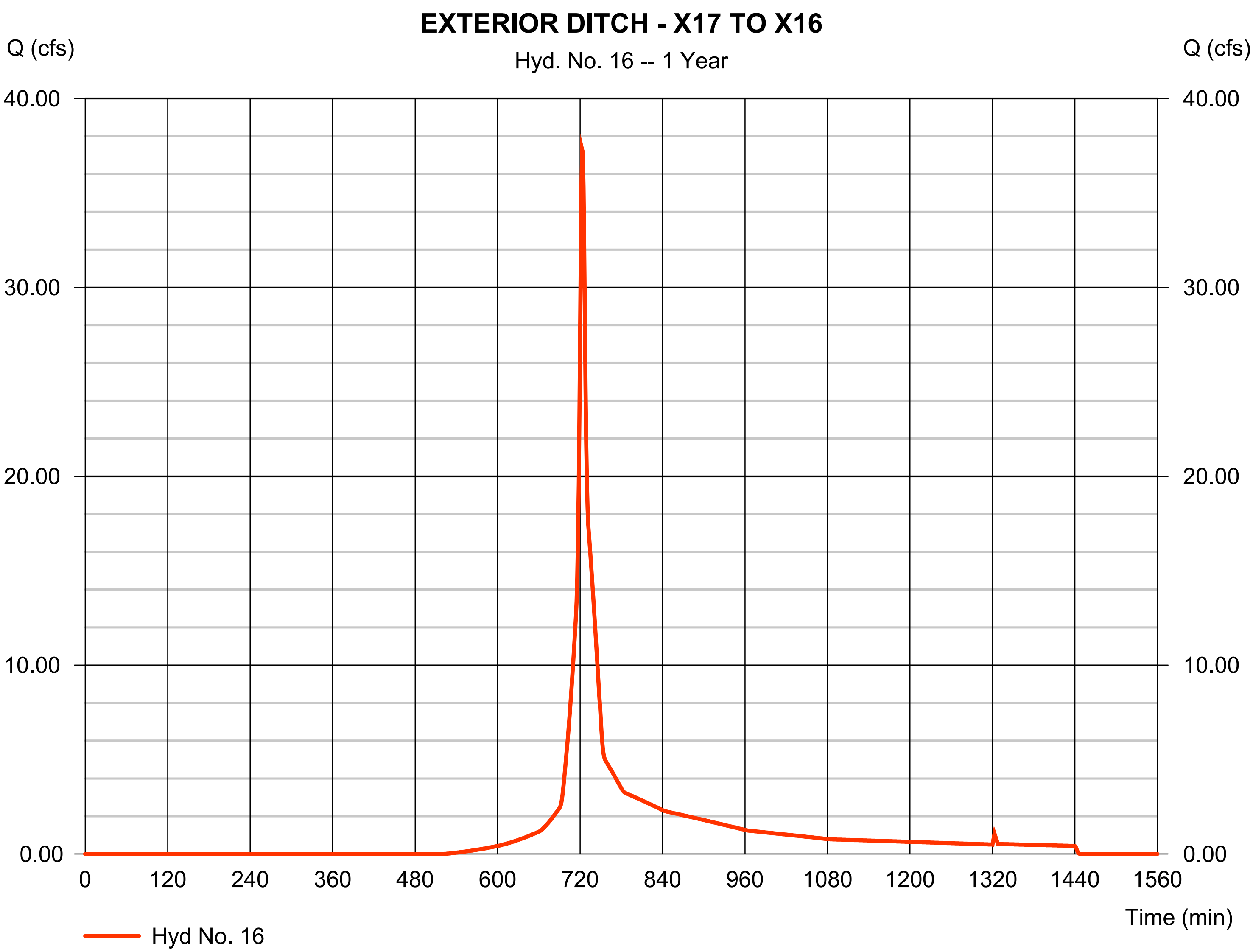
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 16

EXTERIOR DITCH - X17 TO X16

Hydrograph type	= SCS Runoff	Peak discharge	= 37.28 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 108,291 cuft
Drainage area	= 16.240 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



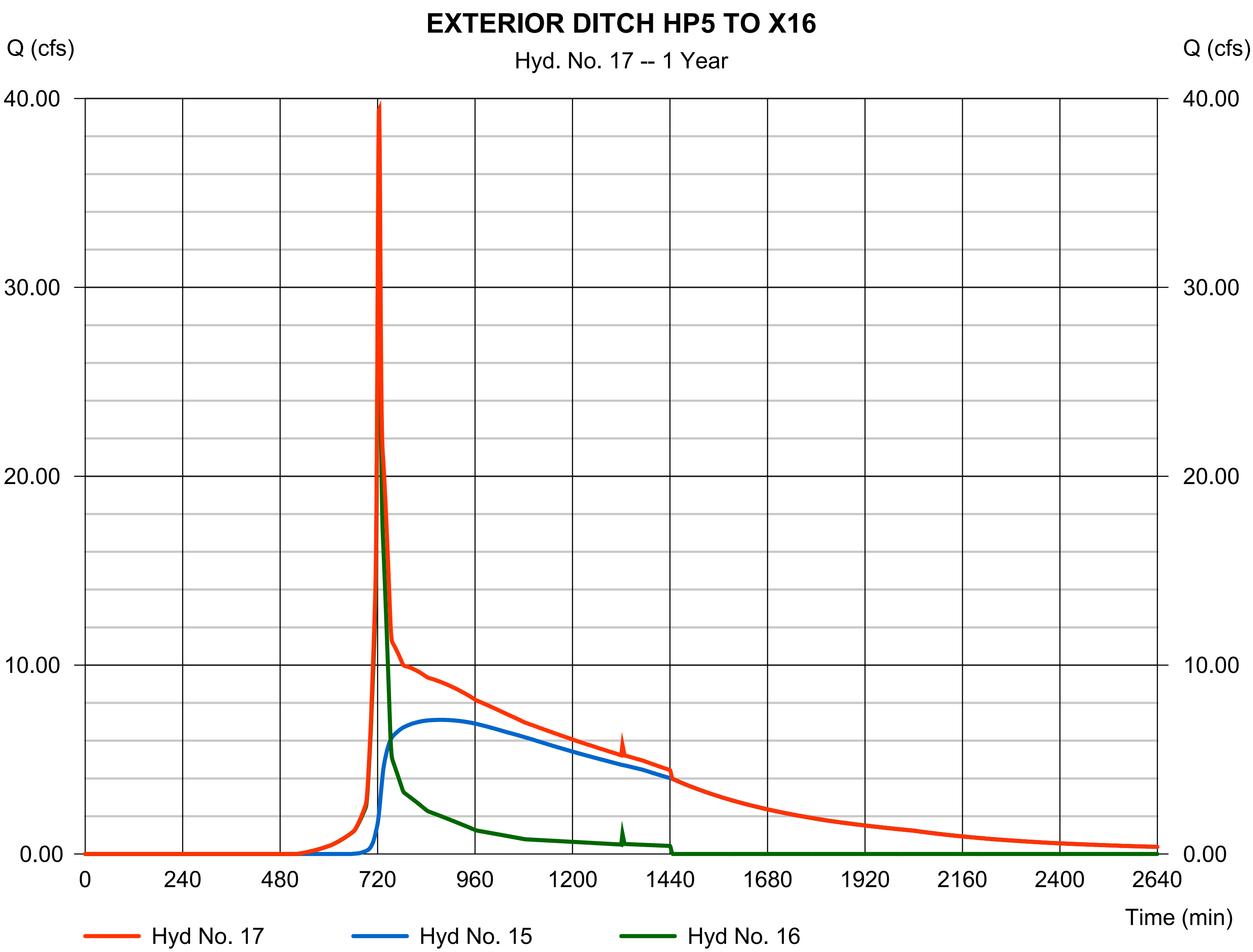
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 17

EXTERIOR DITCH HP5 TO X16

Hydrograph type	= Combine	Peak discharge	= 39.41 cfs
Storm frequency	= 1 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 472,426 cuft
Inflow hyds.	= 15, 16	Contrib. drain. area	= 16.240 ac



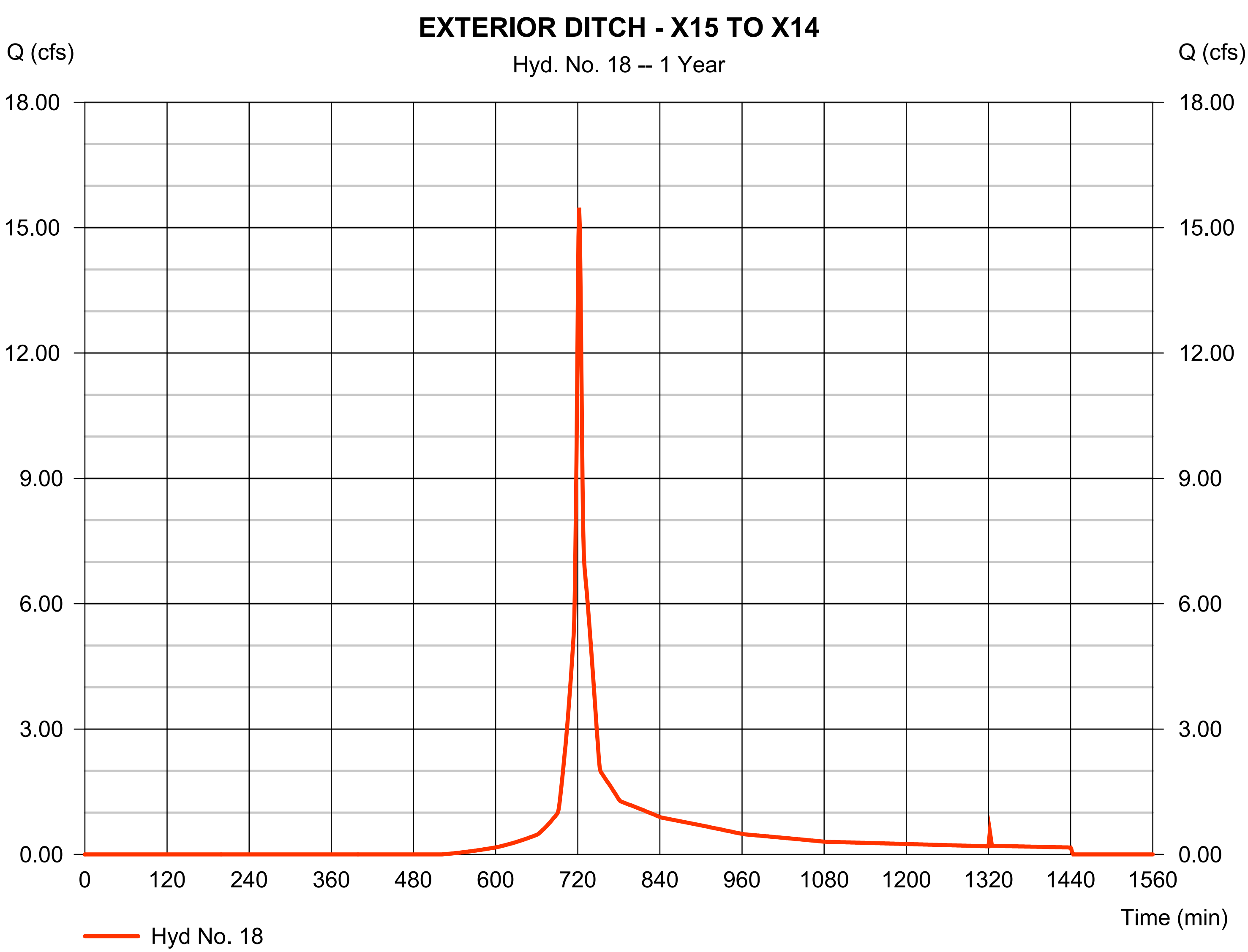
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 18

EXTERIOR DITCH - X15 TO X14

Hydrograph type	= SCS Runoff	Peak discharge	= 15.48 cfs
Storm frequency	= 1 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 42,134 cuft
Drainage area	= 6.740 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 2.00 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



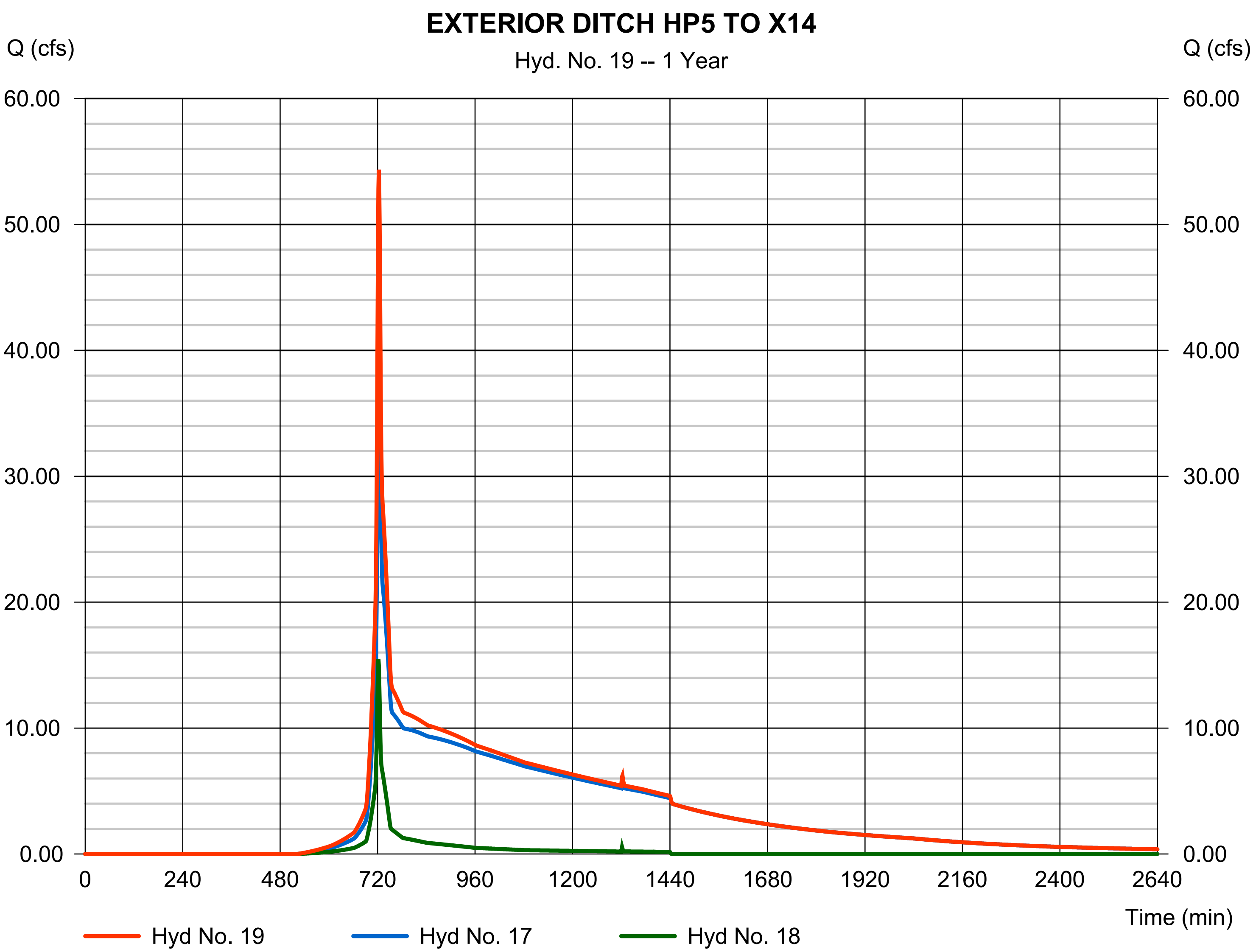
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 19

EXTERIOR DITCH HP5 TO X14

Hydrograph type	= Combine	Peak discharge	= 54.35 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 514,561 cuft
Inflow hyds.	= 17, 18	Contrib. drain. area	= 6.740 ac



Hydrograph Report

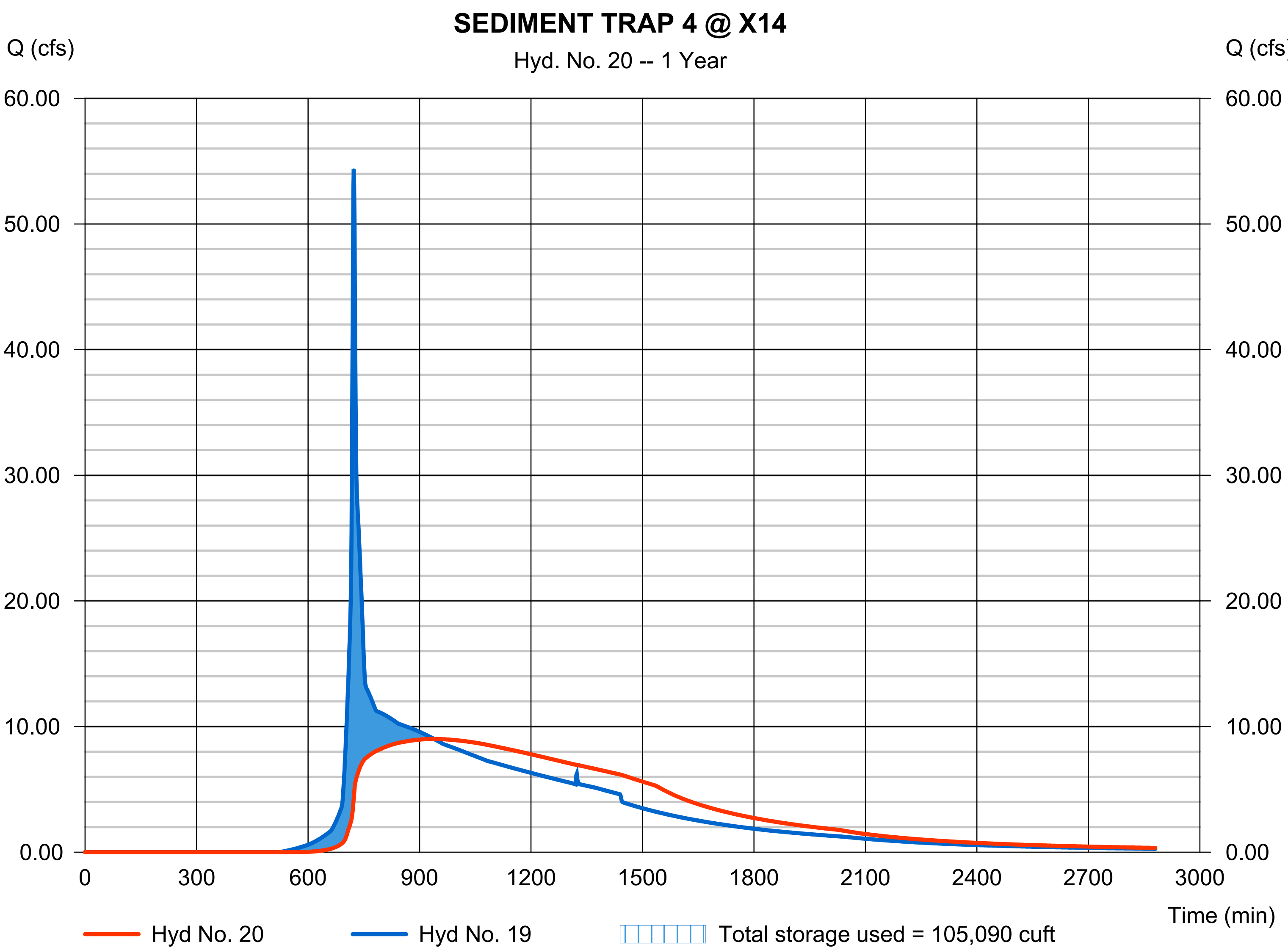
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 20

SEDIMENT TRAP 4 @ X14

Hydrograph type	= Reservoir	Peak discharge	= 9.011 cfs
Storm frequency	= 1 yrs	Time to peak	= 939 min
Time interval	= 1 min	Hyd. volume	= 509,105 cuft
Inflow hyd. No.	= 19 - EXTERIOR DITCH HP5 TO X14	Max. Elevation	= 243.77 ft
Reservoir name	= SEDIMENT TRAP 4 @ X14	Max. Storage	= 105,090 cuft

Storage Indication method used. Wet pond routing start elevation = 238.00 ft.



Pond Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Pond No. 3 - SEDIMENT TRAP 4 @ X14

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 234.00 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	234.00	666	0	0
2.00	236.00	2,385	2,874	2,874
4.00	238.00	4,814	7,058	9,932
6.00	240.00	10,906	15,309	25,241
8.00	242.00	19,227	29,739	54,980
10.00	244.00	38,334	56,467	111,447
12.00	246.00	61,499	98,915	210,362
14.00	248.00	85,531	146,356	356,719
16.00	250.00	108,342	193,405	550,123
18.00	252.00	126,305	234,394	784,517
20.00	254.00	143,959	270,045	1,054,562
22.00	256.00	161,782	305,537	1,360,099

Culvert / Orifice Structures

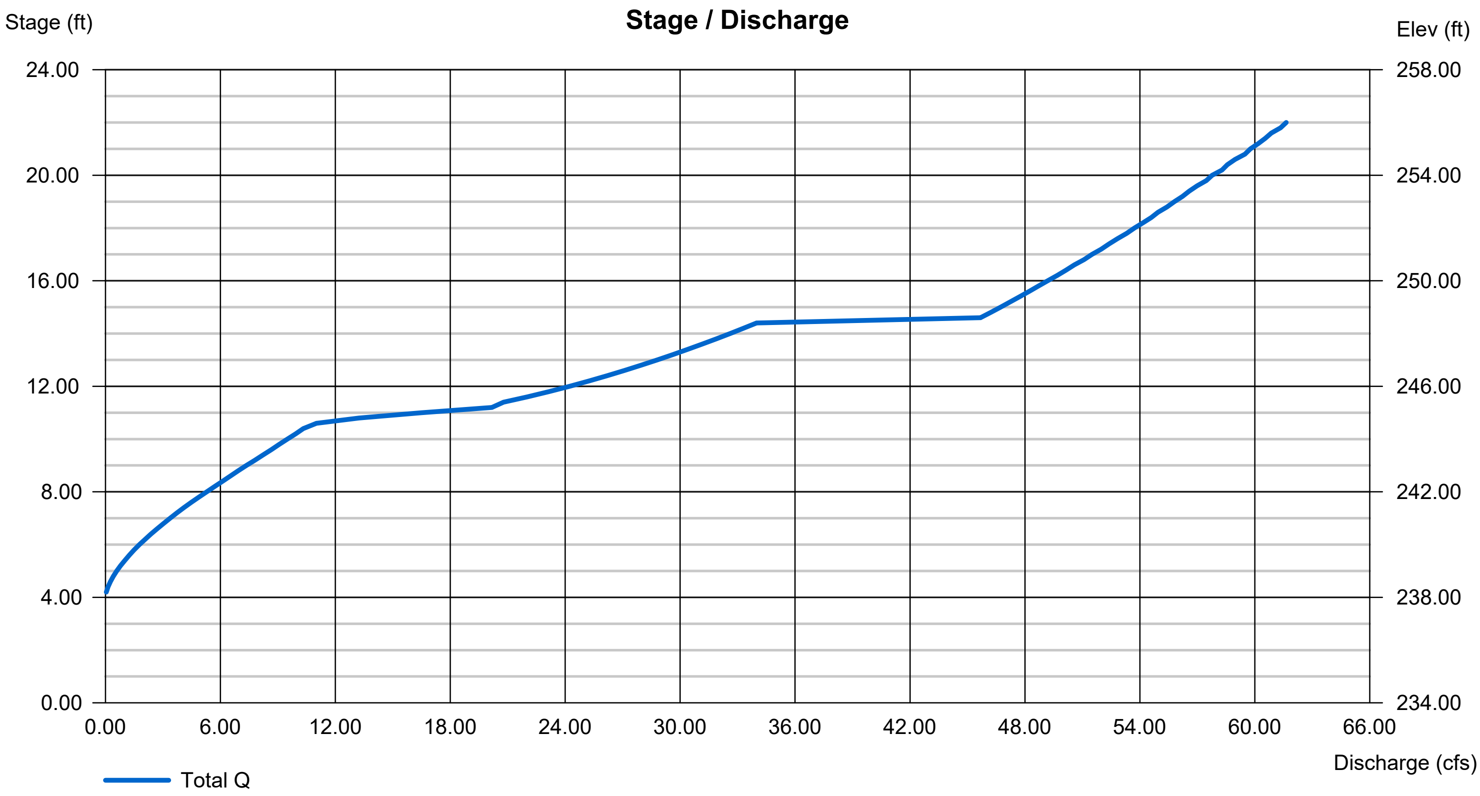
	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 24.00	0.00	0.00	1.00
Span (in)	= 24.00	0.00	0.00	1.00
No. Barrels	= 1	0	0	375
Invert El. (ft)	= 238.00	0.00	0.00	238.00
Length (ft)	= 101.00	0.00	0.00	6.50
Slope (%)	= 0.50	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	Yes

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 6.28	0.00	0.00	0.00
Crest El. (ft)	= 244.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= 1	---	---	---
Multi-Stage	= Yes	No	No	No

Exfil.(in/hr) = 0.000 (by Wet area)
TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).



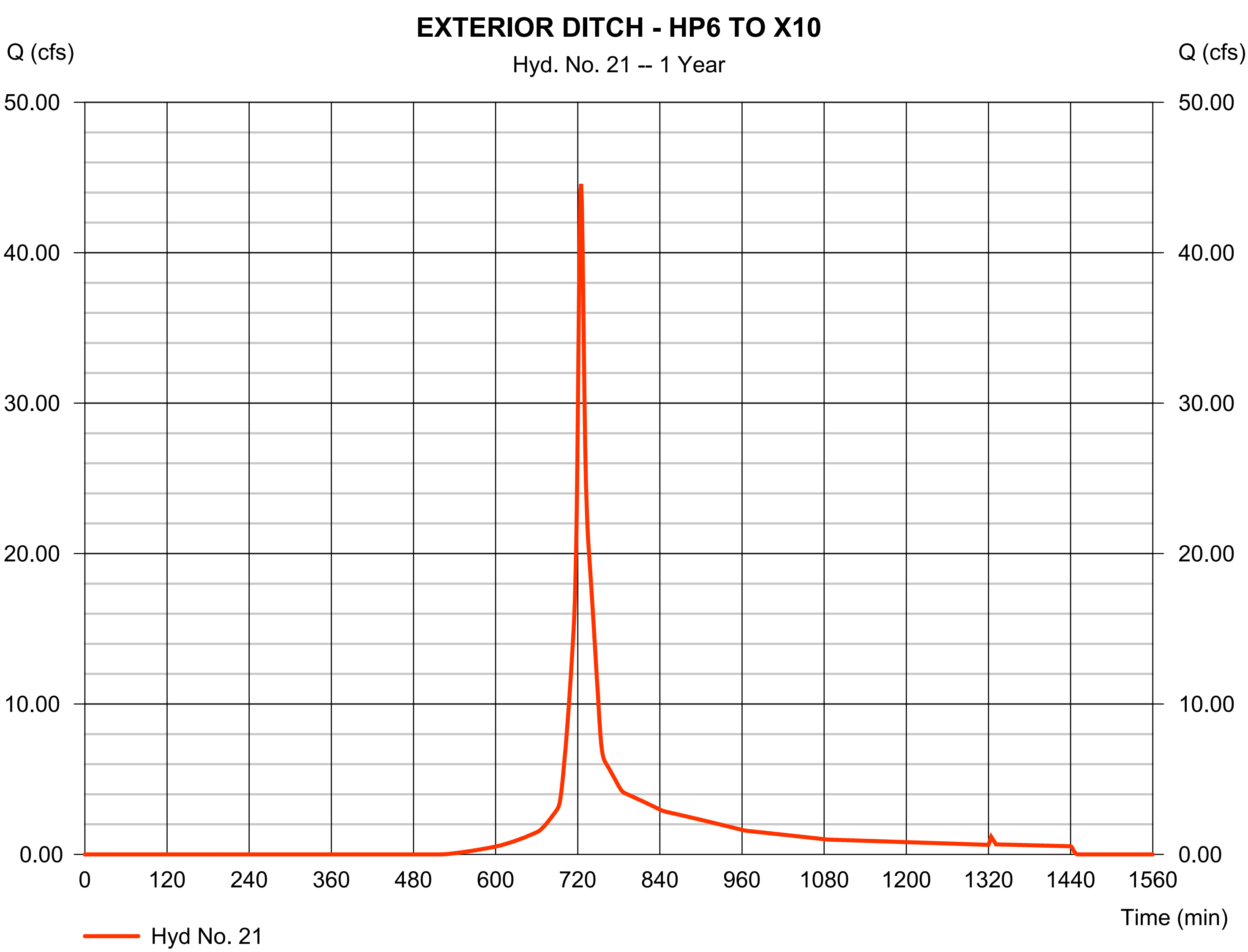
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 21

EXTERIOR DITCH - HP6 TO X10

Hydrograph type	= SCS Runoff	Peak discharge	= 44.57 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 137,531 cuft
Drainage area	= 20.000 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

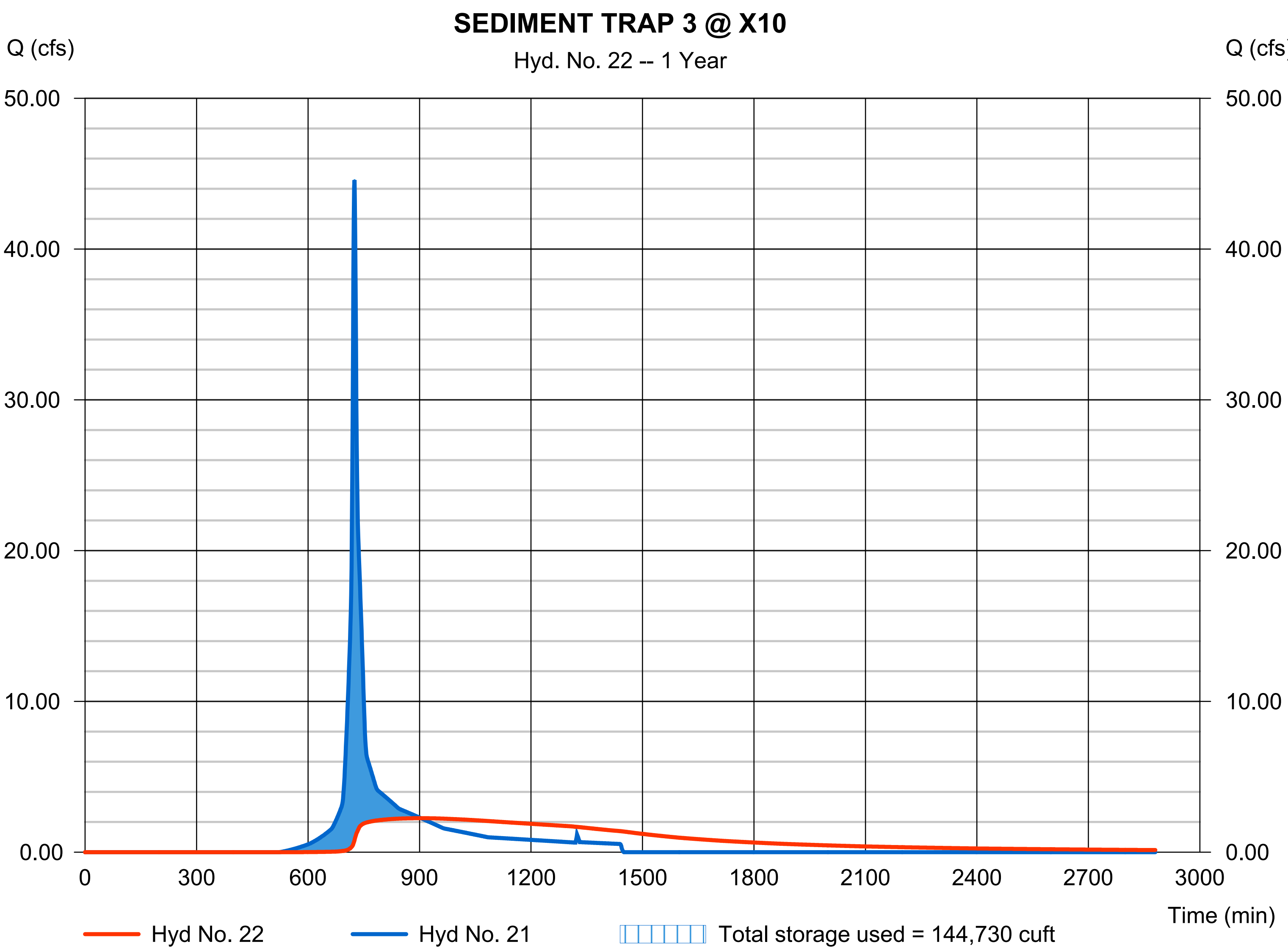
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 22

SEDIMENT TRAP 3 @ X10

Hydrograph type	= Reservoir	Peak discharge	= 2.255 cfs
Storm frequency	= 1 yrs	Time to peak	= 904 min
Time interval	= 1 min	Hyd. volume	= 124,864 cuft
Inflow hyd. No.	= 21 - EXTERIOR DITCH - HP6 TO X10	Max. Elevation	= 250.38 ft
Reservoir name	= SEDIMENT TRAP 3 @ X10	Max. Storage	= 144,730 cuft

Storage Indication method used. Wet pond routing start elevation = 248.00 ft.



Pond Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Pond No. 4 - SEDIMENT TRAP 3 @ X10

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 244.00 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	244.00	12,774	0	0
2.00	246.00	15,609	28,333	28,333
4.00	248.00	18,722	34,280	62,613
6.00	250.00	43,254	60,283	122,896
8.00	252.00	73,084	115,030	237,926
10.00	254.00	88,482	161,305	399,231

Culvert / Orifice Structures

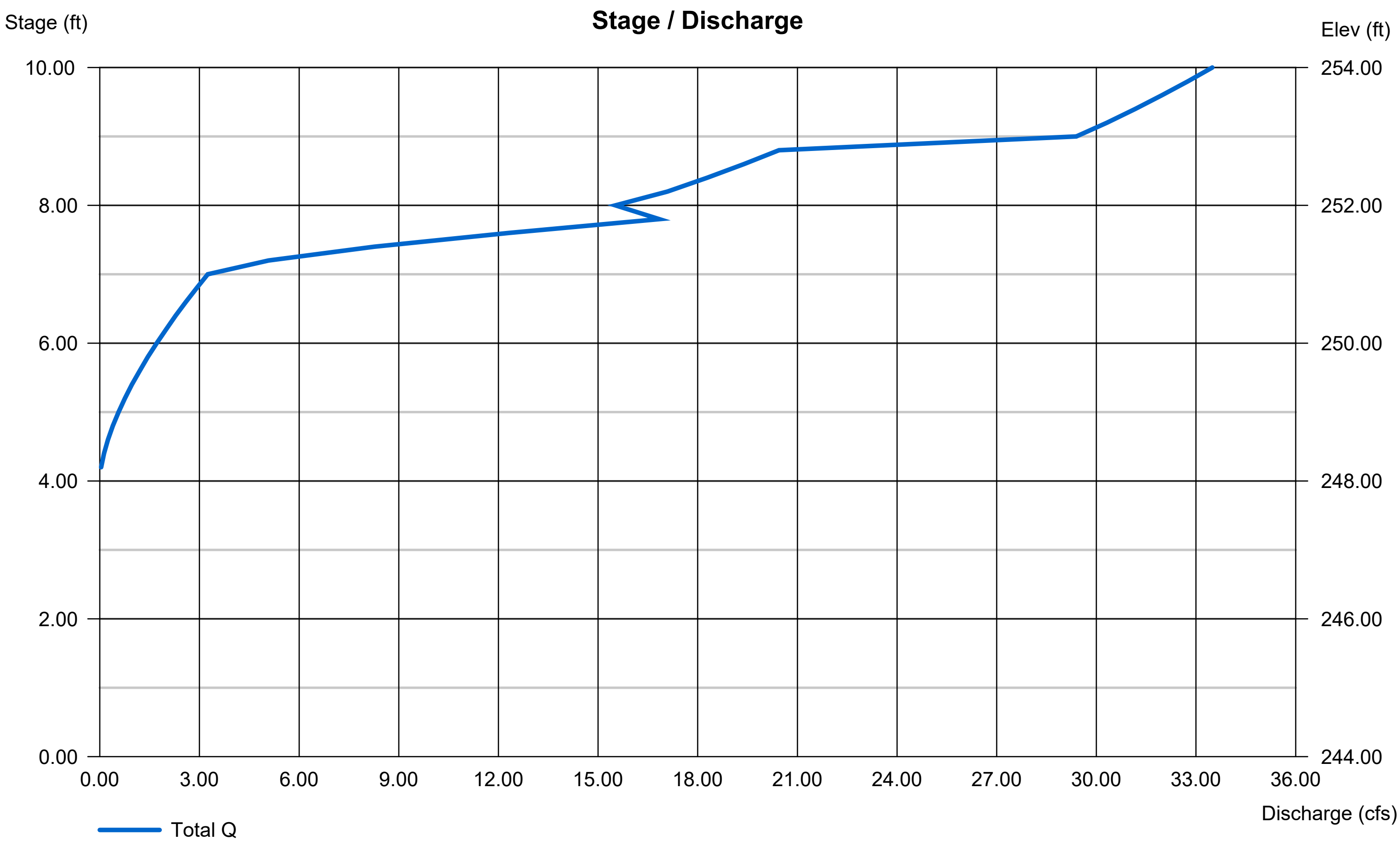
	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 24.00	0.00	0.00	1.00
Span (in)	= 24.00	0.00	0.00	1.00
No. Barrels	= 1	0	0	165
Invert El. (ft)	= 248.00	0.00	0.00	248.00
Length (ft)	= 188.00	0.00	0.00	3.00
Slope (%)	= 3.30	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	Yes

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 6.28	0.00	0.00	0.00
Crest El. (ft)	= 251.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= 1	---	---	---
Multi-Stage	= Yes	No	No	No

Exfil.(in/hr) = 0.000 (by Wet area)
TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).



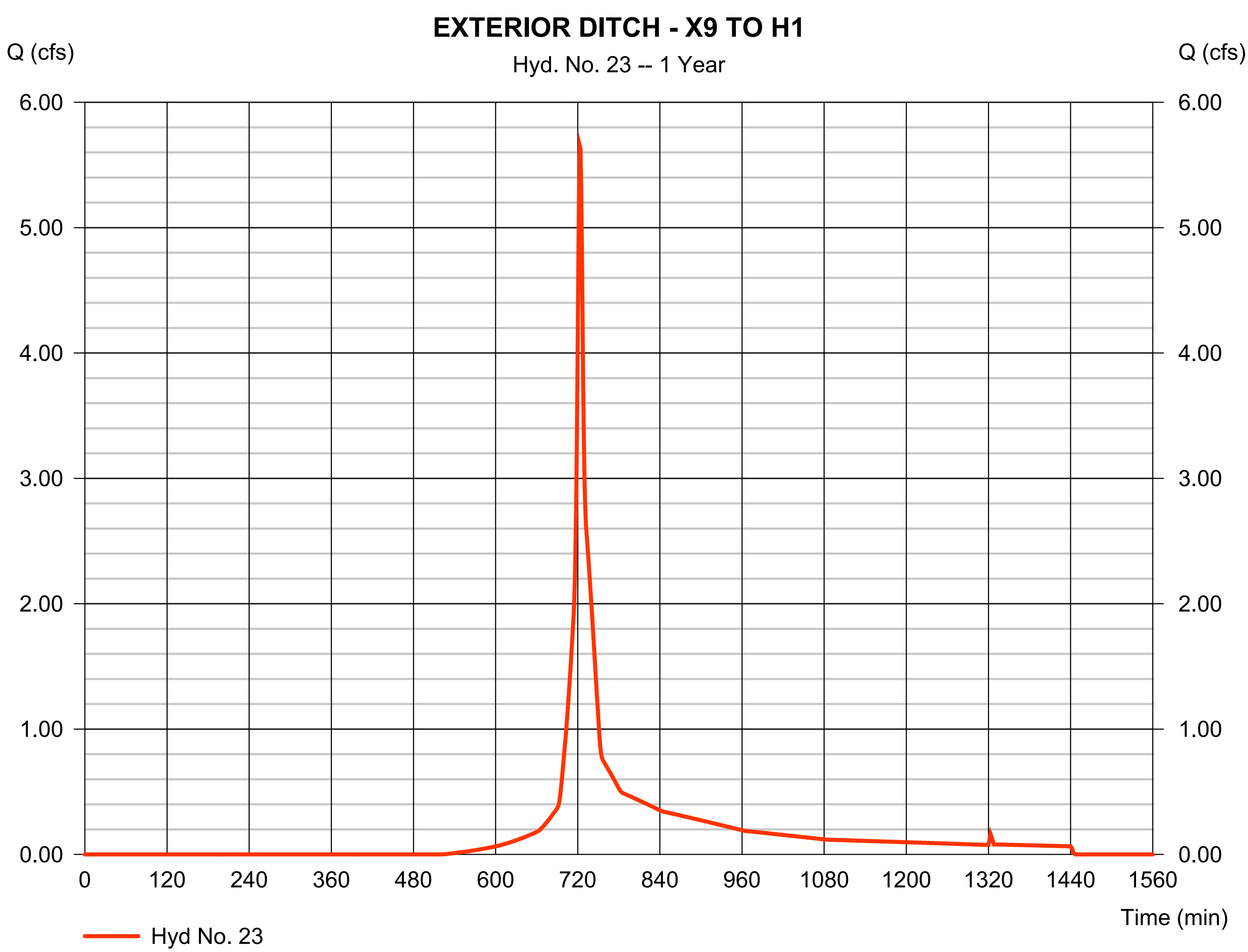
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 23

EXTERIOR DITCH - X9 TO H1

Hydrograph type	= SCS Runoff	Peak discharge	= 5.648 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 16,404 cuft
Drainage area	= 2.460 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



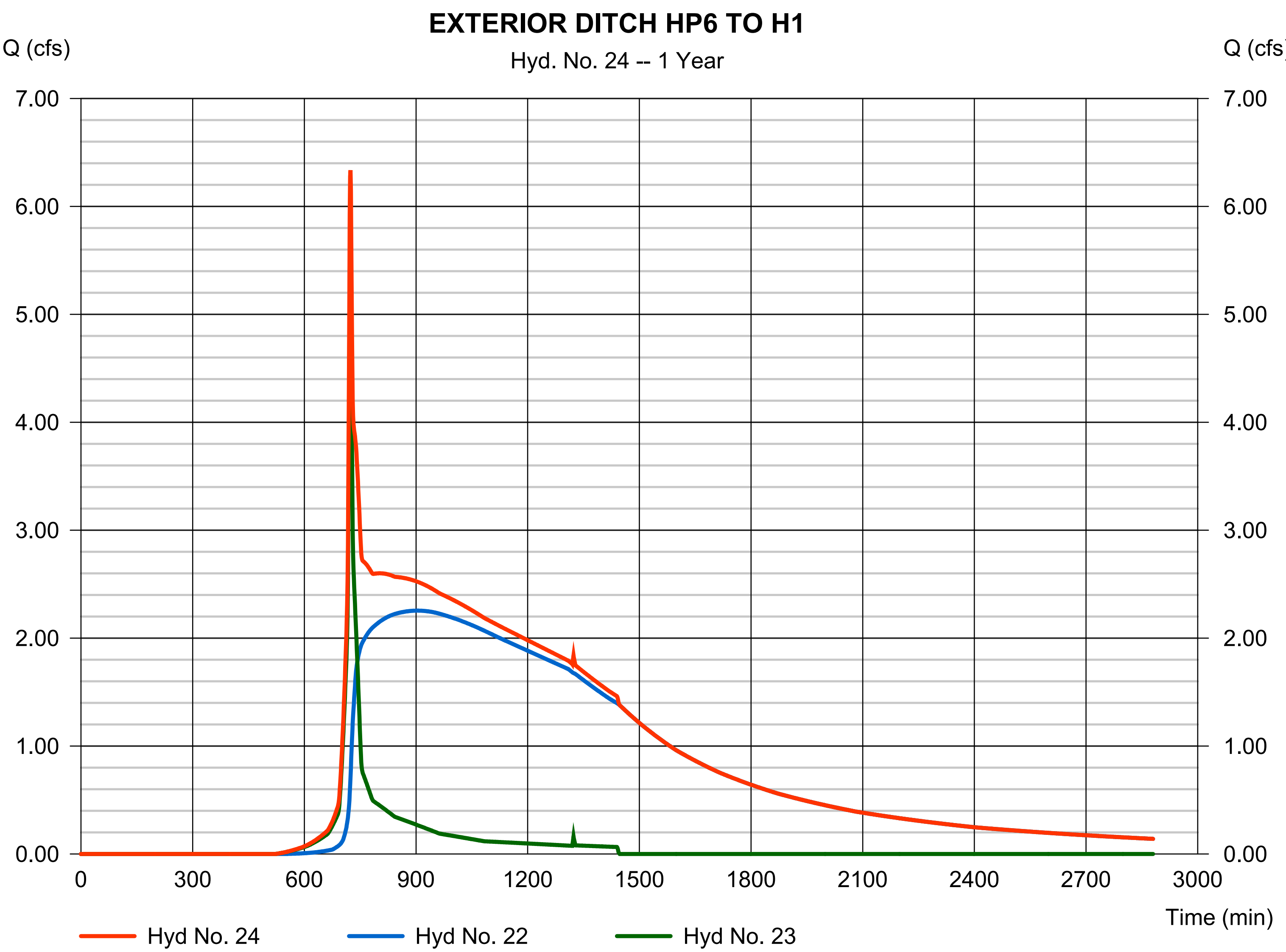
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 | Friday, 01 / 30 / 2015

Hyd. No. 24

EXTERIOR DITCH HP6 TO H1

Hydrograph type	= Combine	Peak discharge	= 6.336 cfs
Storm frequency	= 1 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 141,268 cuft
Inflow hyds.	= 22, 23	Contrib. drain. area	= 2.460 ac



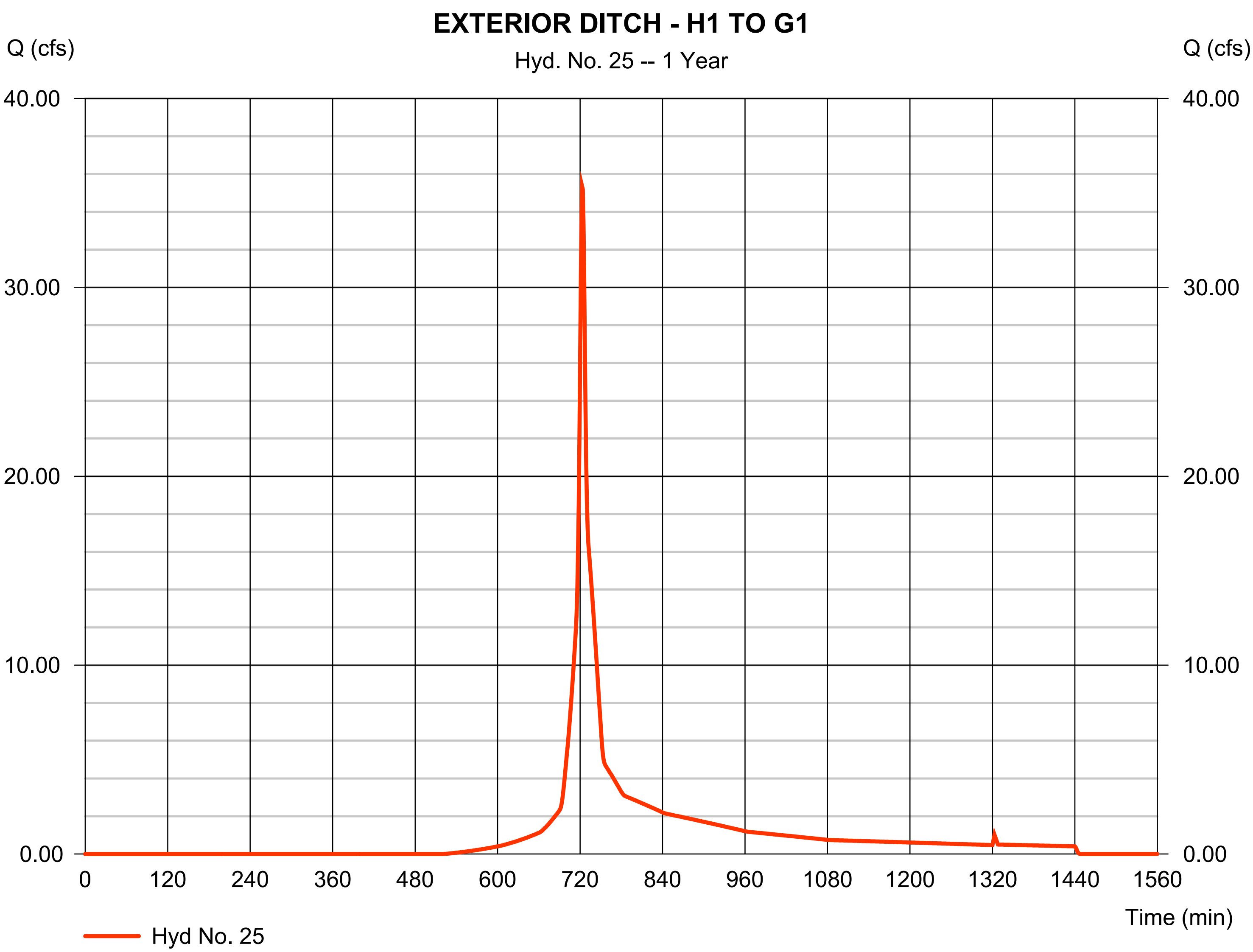
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 25

EXTERIOR DITCH - H1 TO G1

Hydrograph type	=	SCS Runoff	Peak discharge	=	35.33 cfs
Storm frequency	=	1 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	102,623 cuft
Drainage area	=	15.390 ac	Curve number	=	80
Basin Slope	=	10.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	4.30 min
Total precip.	=	3.75 in	Distribution	=	Type III
Storm duration	=	24 hrs	Shape factor	=	484



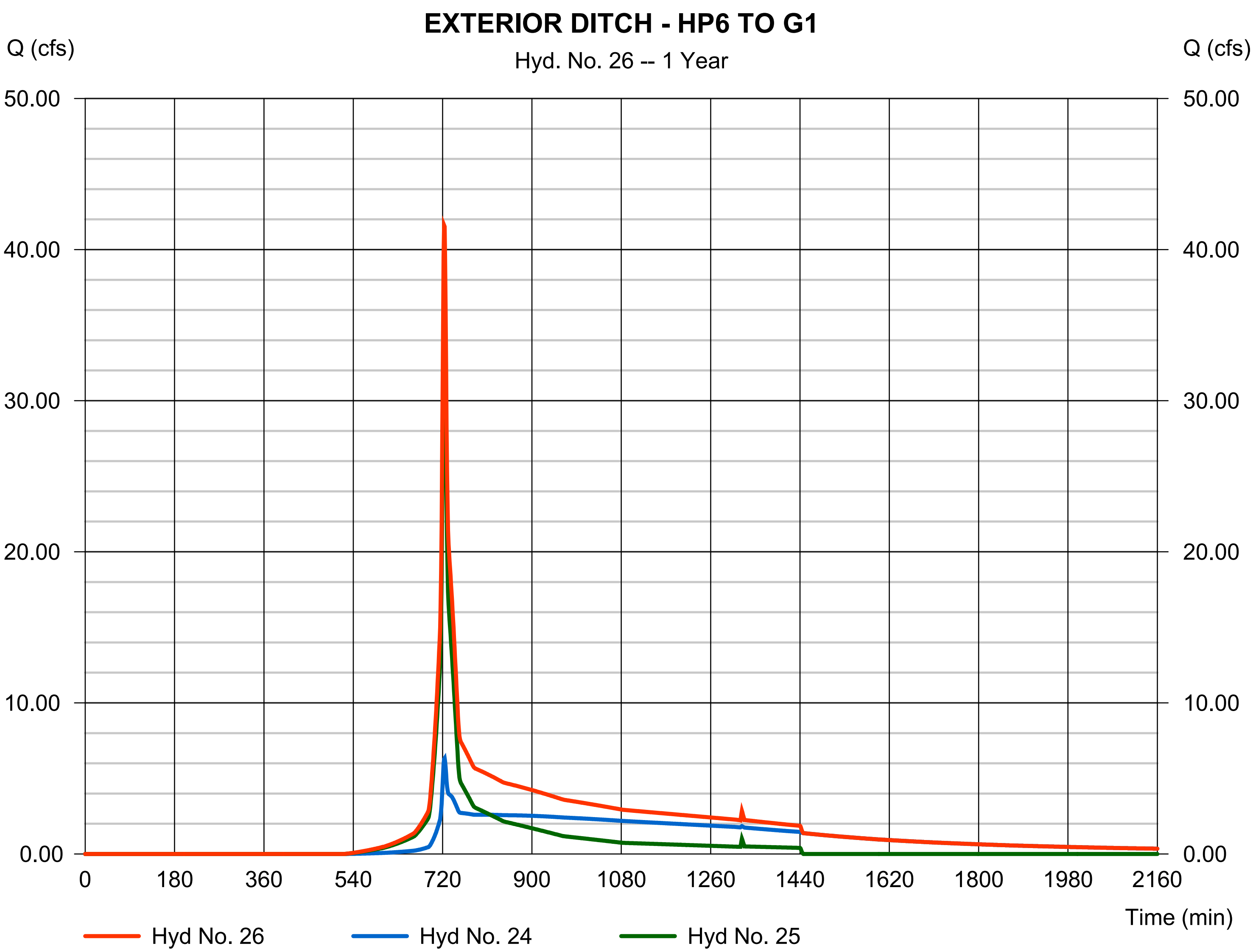
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 26

EXTERIOR DITCH - HP6 TO G1

Hydrograph type	= Combine	Peak discharge	= 41.61 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 243,891 cuft
Inflow hyds.	= 24, 25	Contrib. drain. area	= 15.390 ac



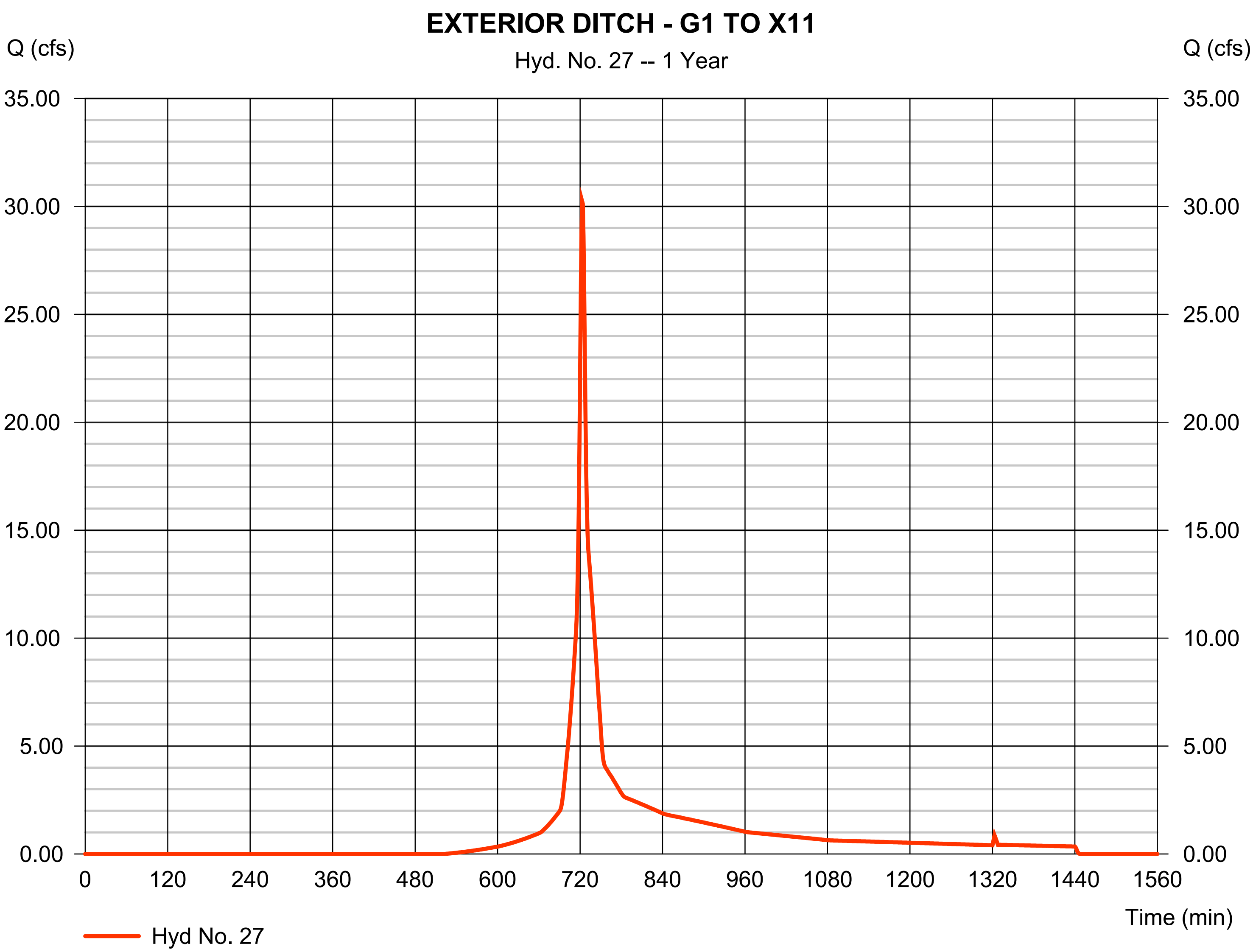
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 27

EXTERIOR DITCH - G1 TO X11

Hydrograph type	= SCS Runoff	Peak discharge	= 30.24 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 87,820 cuft
Drainage area	= 13.170 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.00 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



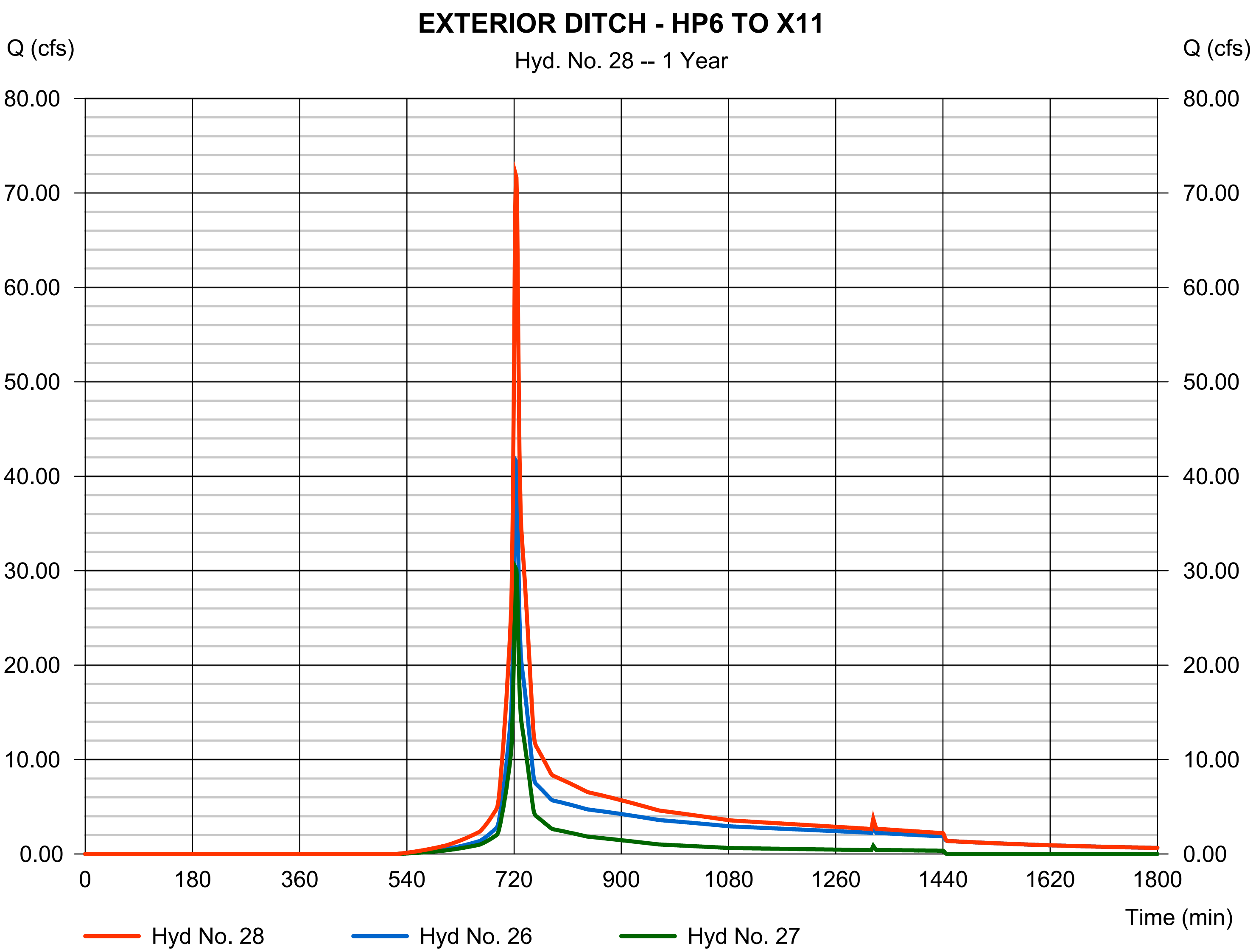
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 28

EXTERIOR DITCH - HP6 TO X11

Hydrograph type	= Combine	Peak discharge	= 71.85 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 331,710 cuft
Inflow hyds.	= 26, 27	Contrib. drain. area	= 13.170 ac



Hydrograph Report

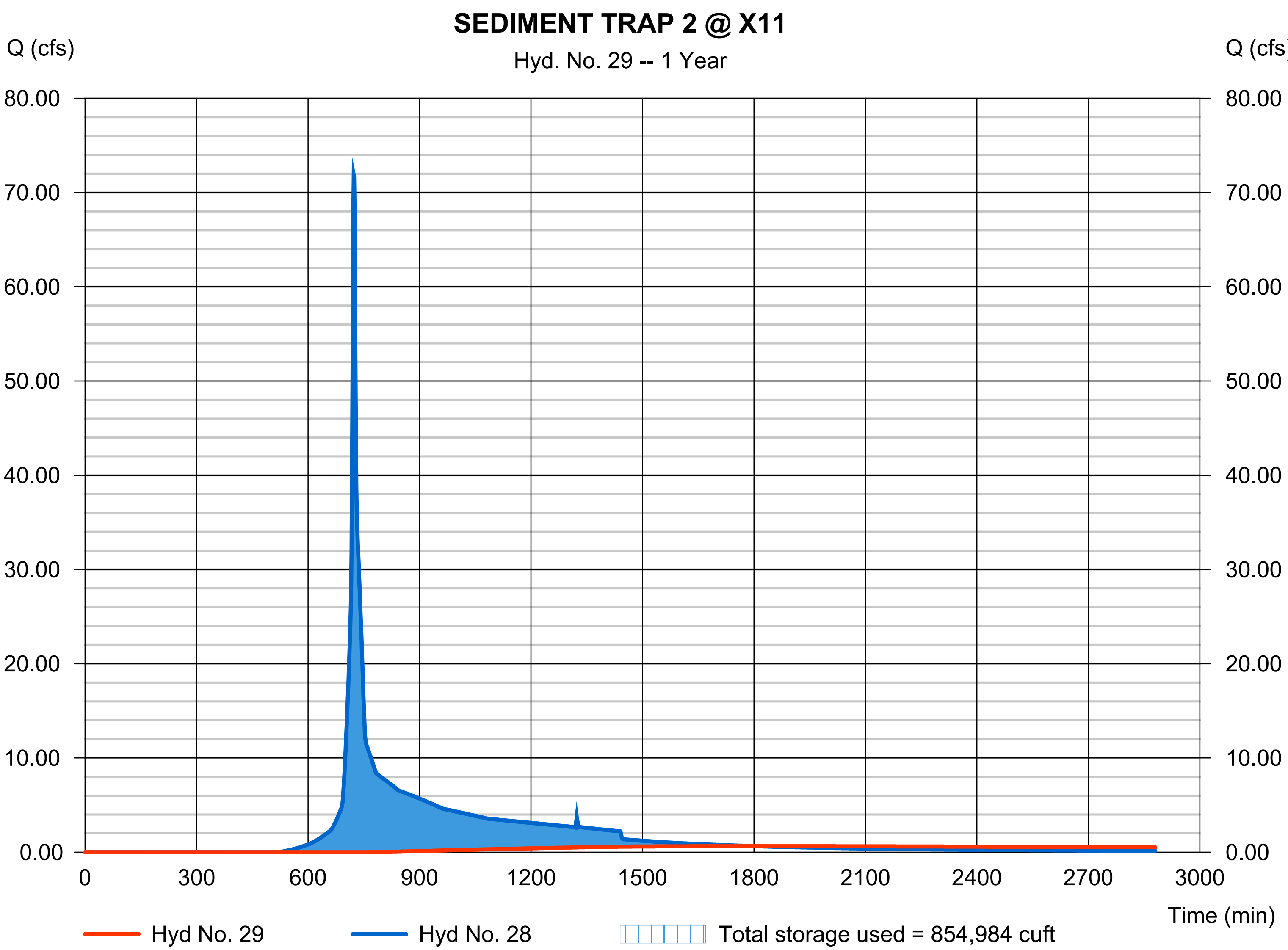
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 29

SEDIMENT TRAP 2 @ X11

Hydrograph type	= Reservoir	Peak discharge	= 0.634 cfs
Storm frequency	= 1 yrs	Time to peak	= 1806 min
Time interval	= 1 min	Hyd. volume	= 64,071 cuft
Inflow hyd. No.	= 28 - EXTERIOR DITCH - HP6 TO X11	Max. Elevation	= 245.07 ft
Reservoir name	= SEDIMENT TRAP 2 @ X11	Max. Storage	= 854,984 cuft

Storage Indication method used. Wet pond routing start elevation = 243.00 ft.



Pond Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Pond No. 5 - SEDIMENT TRAP 2 @ X11

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 235.00 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	235.00	00	0	0
1.00	236.00	39,713	13,236	13,236
3.00	238.00	58,935	98,008	111,244
5.00	240.00	83,387	141,602	252,847
7.00	242.00	109,728	192,494	445,341
9.00	244.00	138,467	247,614	692,955
11.00	246.00	163,371	301,465	994,419
13.00	248.00	188,693	351,725	1,346,144

Culvert / Orifice Structures

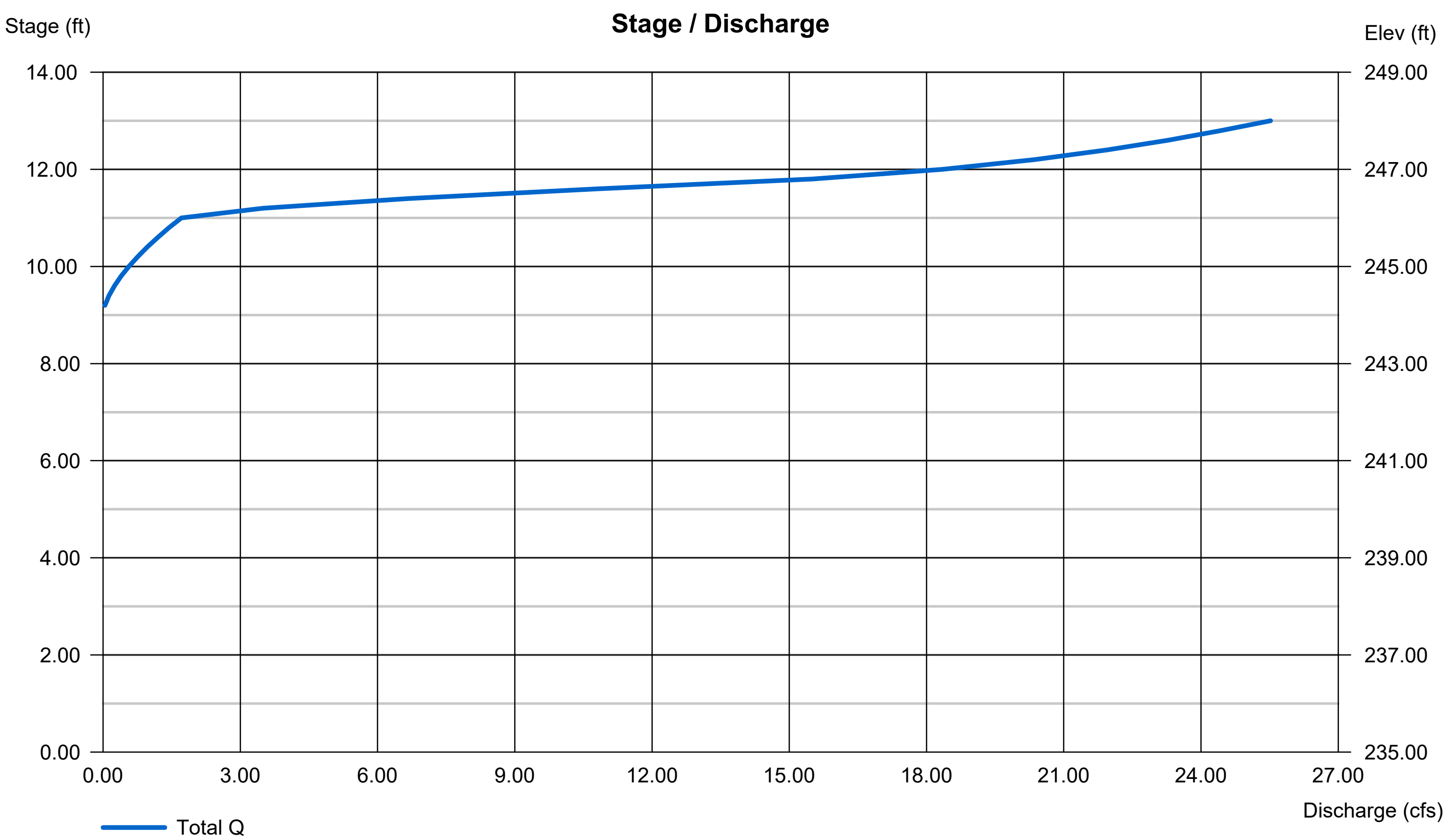
	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 24.00	0.00	0.00	1.00
Span (in)	= 24.00	0.00	0.00	1.00
No. Barrels	= 1	0	0	165
Invert El. (ft)	= 244.00	0.00	0.00	243.00
Length (ft)	= 159.00	0.00	0.00	3.00
Slope (%)	= 7.00	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	Yes

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 6.28	0.00	0.00	0.00
Crest El. (ft)	= 246.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= 1	---	---	---
Multi-Stage	= Yes	No	No	No

Exfil.(in/hr) = 0.000 (by Wet area)
TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).



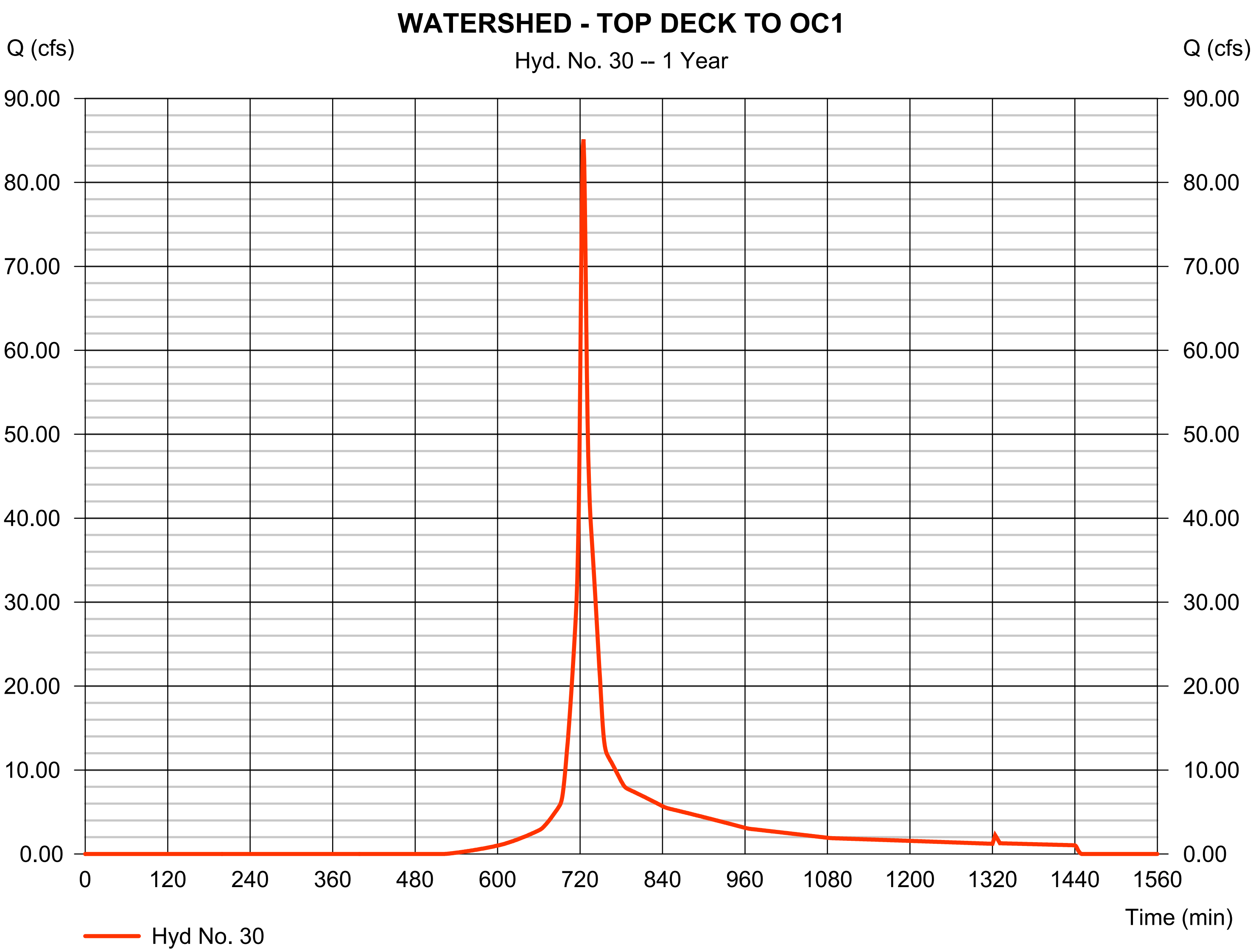
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 30

WATERSHED - TOP DECK TO OC1

Hydrograph type	= SCS Runoff	Peak discharge	= 85.13 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 262,683 cuft
Drainage area	= 38.200 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 3.75 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



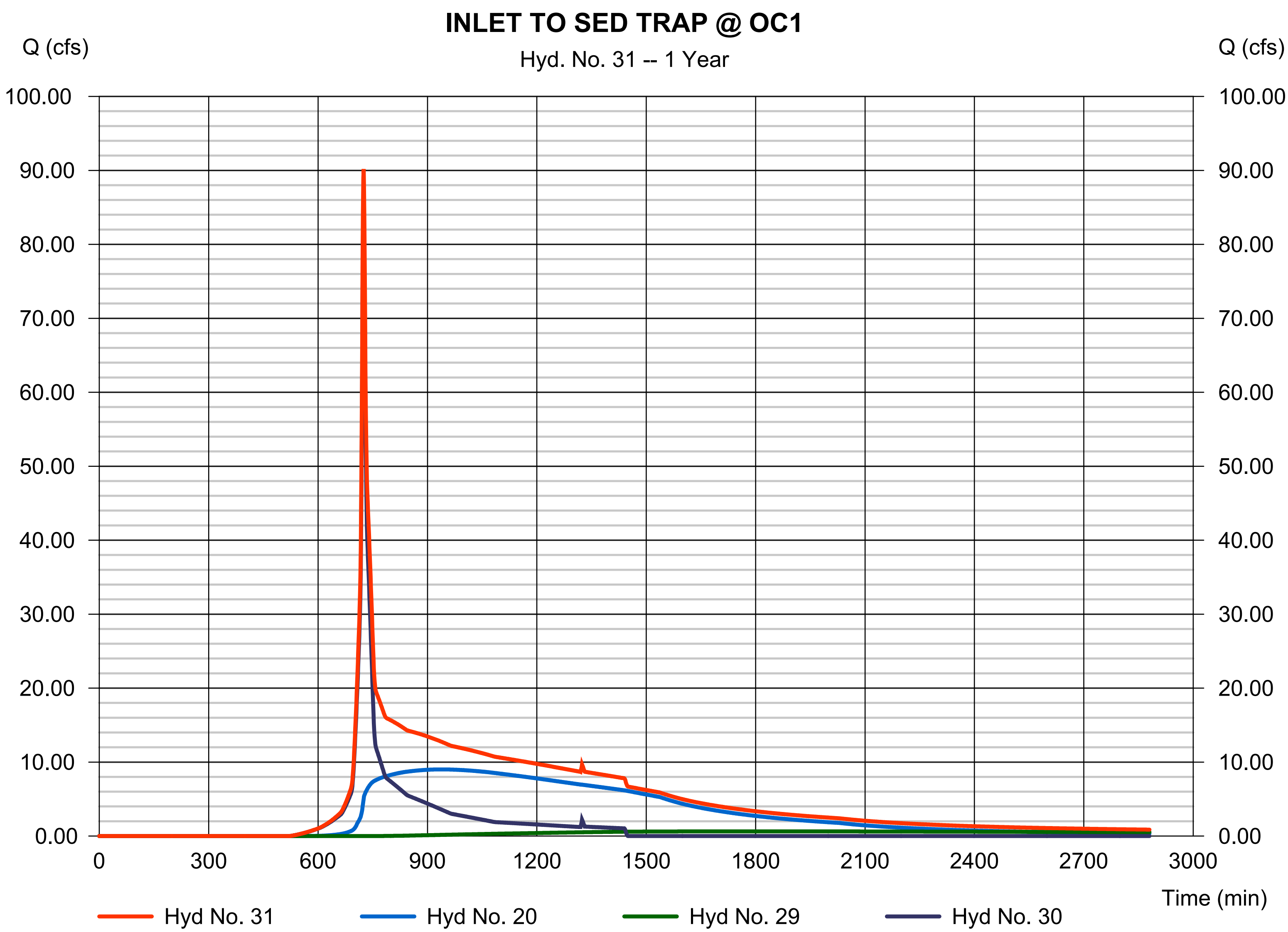
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 31

INLET TO SED TRAP @ OC1

Hydrograph type	= Combine	Peak discharge	= 90.18 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 835,858 cuft
Inflow hyds.	= 20, 29, 30	Contrib. drain. area	= 38.200 ac



Hydrograph Report

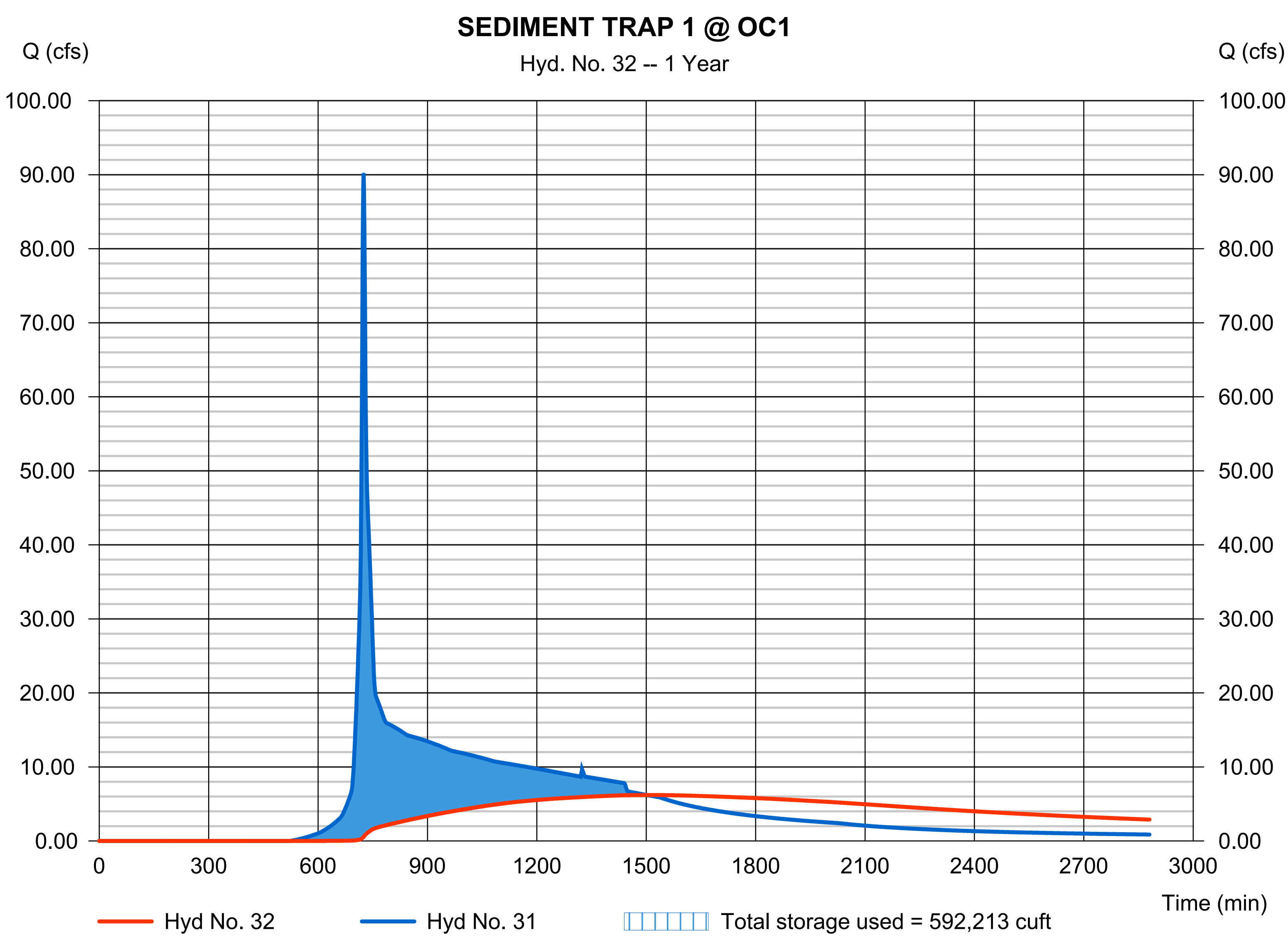
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 32

SEDIMENT TRAP 1 @ OC1

Hydrograph type	= Reservoir	Peak discharge	= 6.202 cfs
Storm frequency	= 1 yrs	Time to peak	= 1502 min
Time interval	= 1 min	Hyd. volume	= 600,070 cuft
Inflow hyd. No.	= 31 - INLET TO SED TRAP @ OC1	Max. Elevation	= 232.47 ft
Reservoir name	= SEDIMENT TRAP 1 @ OC1	Max. Storage	= 592,213 cuft

Storage Indication method used. Wet pond routing start elevation = 228.00 ft.



Pond Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Pond No. 6 - SEDIMENT TRAP 1 @ OC1

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 224.00 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	224.00	12,770	0	0
2.00	226.00	43,095	52,877	52,877
4.00	228.00	67,568	109,739	162,616
6.00	230.00	92,769	159,657	322,273
8.00	232.00	119,094	211,295	533,567
10.00	234.00	129,832	248,824	782,391
12.00	236.00	161,699	290,920	1,073,311
14.00	238.00	216,045	376,396	1,449,707
16.00	240.00	288,173	502,440	1,952,147
18.00	242.00	349,765	636,881	2,589,028

Culvert / Orifice Structures

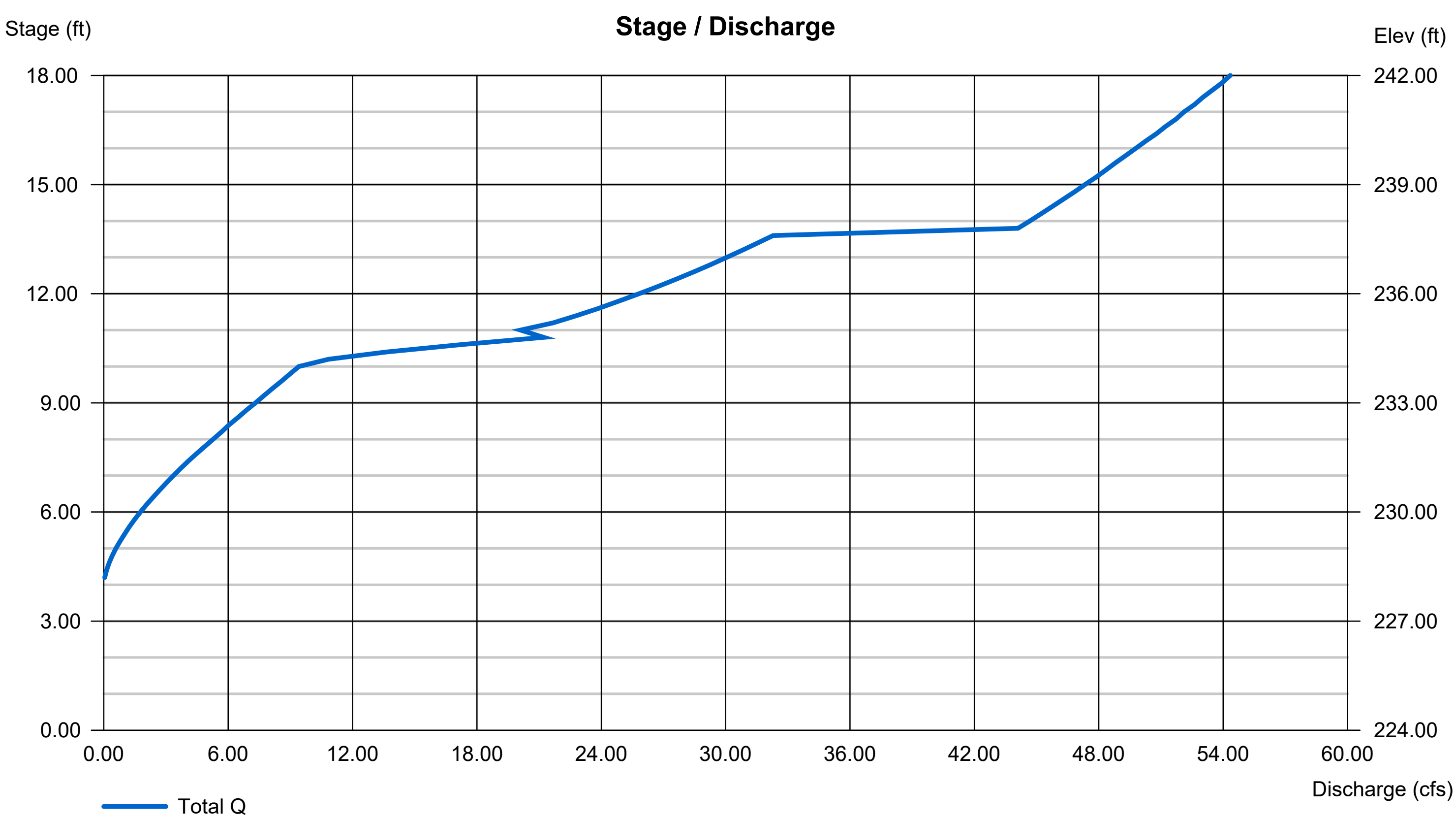
	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 24.00	0.00	0.00	1.00
Span (in)	= 24.00	0.00	0.00	1.00
No. Barrels	= 1	0	0	345
Invert El. (ft)	= 228.00	0.00	0.00	228.00
Length (ft)	= 95.00	0.00	0.00	6.00
Slope (%)	= 0.50	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	Yes

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 6.28	0.00	0.00	0.00
Crest El. (ft)	= 234.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= 1	---	---	---
Multi-Stage	= Yes	No	No	No

Exfil.(in/hr) = 0.000 (by Wet area)
TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	9.298	1	726	29,882	------	------	------	EXTERIOR DITCH - HP5 TO X8
2	SCS Runoff	9.406	1	726	30,231	------	------	------	EXTERIOR DITCH - X7 TO X6
3	Combine	18.70	1	726	60,113	1, 2	------	------	EXTERIOR DITCH HP5 TO X6
4	SCS Runoff	4.666	1	725	14,375	------	------	------	EXTERIOR DITCH - X5 TO X3
5	Combine	23.29	1	725	74,488	3, 4	------	------	EXTERIOR DITCH HP5 TO X3
6	Reservoir	0.617	1	1042	39,246	5	256.55	89,693	SEDIMENT TRAP 6 @ X3
7	SCS Runoff	3.212	1	723	9,293	------	------	------	EXTERIOR DITCH - X4 TO C1
8	Combine	3.212	1	723	48,539	6, 7	------	------	EXTERIOR DITCH HP5 TO C1
9	SCS Runoff	83.64	1	728	303,589	------	------	------	EXTERIOR DITCH - C1 TO D1
10	Combine	85.73	1	728	352,128	8, 9	------	------	EXTERIOR DITCH HP5 TO D1
11	SCS Runoff	35.59	1	725	109,654	------	------	------	EXTERIOR DITCH - D1 TO X1
12	Combine	117.54	1	727	461,781	10, 11	------	------	EXTERIOR DITCH HP5 TO X1
13	SCS Runoff	24.89	1	723	72,019	------	------	------	EXTERIOR DITCH - X1 TO X18
14	Combine	138.78	1	726	533,801	12, 13	------	------	EXTERIOR DITCH HP5 TO X18
15	Reservoir	16.10	1	782	505,453	14	248.13	300,566	SEDIMENT TRAP 5 @ X18
16	SCS Runoff	50.15	1	723	145,111	------	------	------	EXTERIOR DITCH - X17 TO X16
17	Combine	53.70	1	723	650,563	15, 16	------	------	EXTERIOR DITCH HP5 TO X16
18	SCS Runoff	20.79	1	722	56,460	------	------	------	EXTERIOR DITCH - X15 TO X14
19	Combine	73.76	1	723	707,024	17, 18	------	------	EXTERIOR DITCH HP5 TO X14
20	Reservoir	16.76	1	862	700,842	19	245.01	161,620	SEDIMENT TRAP 4 @ X14
21	SCS Runoff	59.82	1	725	184,292	------	------	------	EXTERIOR DITCH - HP6 TO X10
22	Reservoir	3.059	1	891	170,036	21	250.89	173,859	SEDIMENT TRAP 3 @ X10
23	SCS Runoff	7.597	1	723	21,981	------	------	------	EXTERIOR DITCH - X9 TO H1
24	Combine	8.854	1	724	192,017	22, 23	------	------	EXTERIOR DITCH HP6 TO H1
25	SCS Runoff	47.53	1	723	137,516	------	------	------	EXTERIOR DITCH - H1 TO G1
26	Combine	56.31	1	723	329,534	24, 25	------	------	EXTERIOR DITCH - HP6 TO G1
27	SCS Runoff	40.67	1	723	117,679	------	------	------	EXTERIOR DITCH - G1 TO X11
28	Combine	96.98	1	723	447,212	26, 27	------	------	EXTERIOR DITCH - HP6 TO X11
29	Reservoir	1.218	1	1669	123,642	28	245.61	936,256	SEDIMENT TRAP 2 @ X11
30	SCS Runoff	114.25	1	725	351,998	------	------	------	WATERSHED - TOP DECK TO OC1
31	Combine	120.82	1	725	1,176,480	20, 29, 30	------	------	INLET TO SED TRAP @ OC1
32	Reservoir	8.792	1	1450	867,638	31	233.70	745,371	SEDIMENT TRAP 1 @ OC1

Exterior Ditch [with ponds].gpw	Return Period: 2 Year	Friday, 01 / 30 / 2015

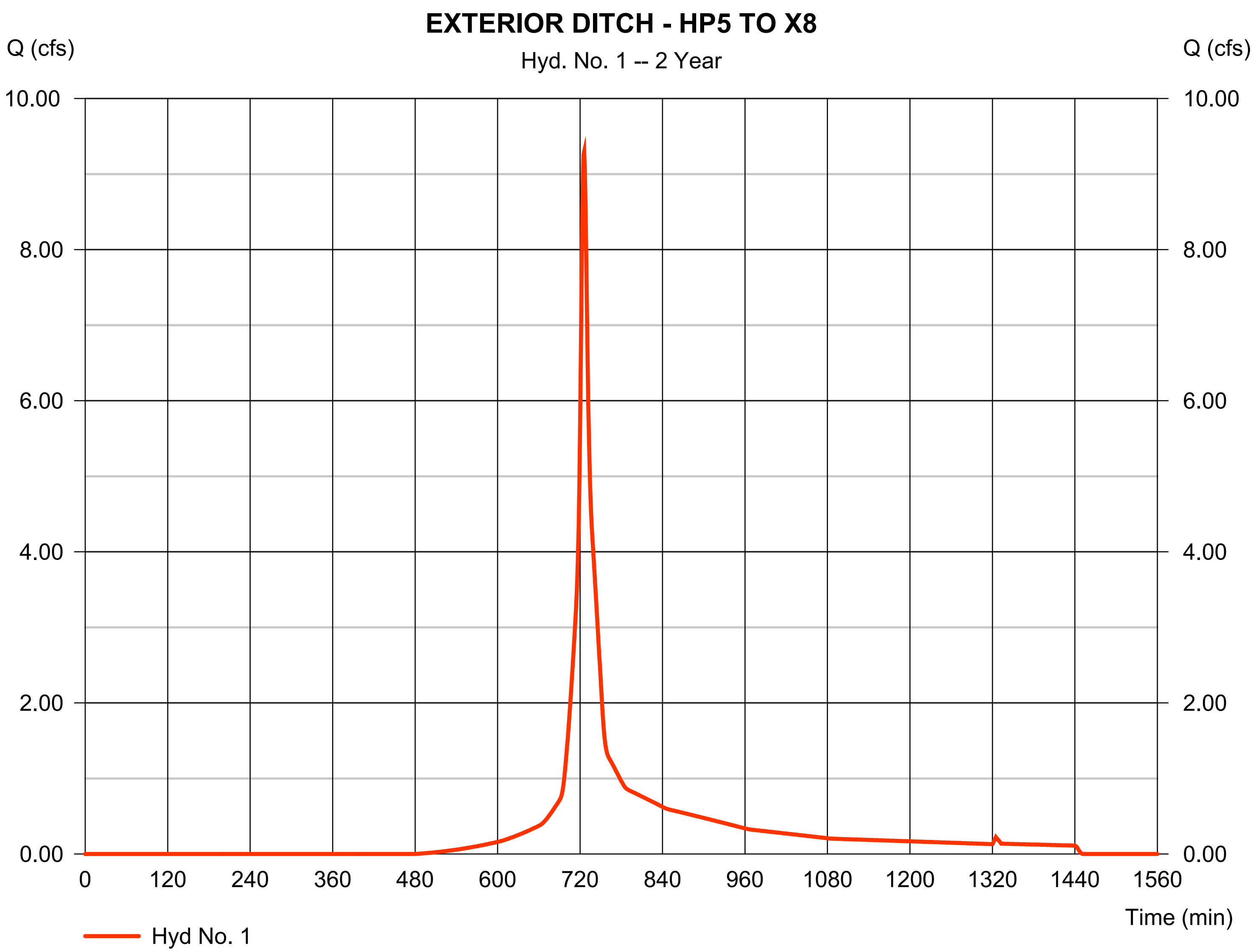
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

EXTERIOR DITCH - HP5 TO X8

Hydrograph type	= SCS Runoff	Peak discharge	= 9.298 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 29,882 cuft
Drainage area	= 3.430 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.30 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



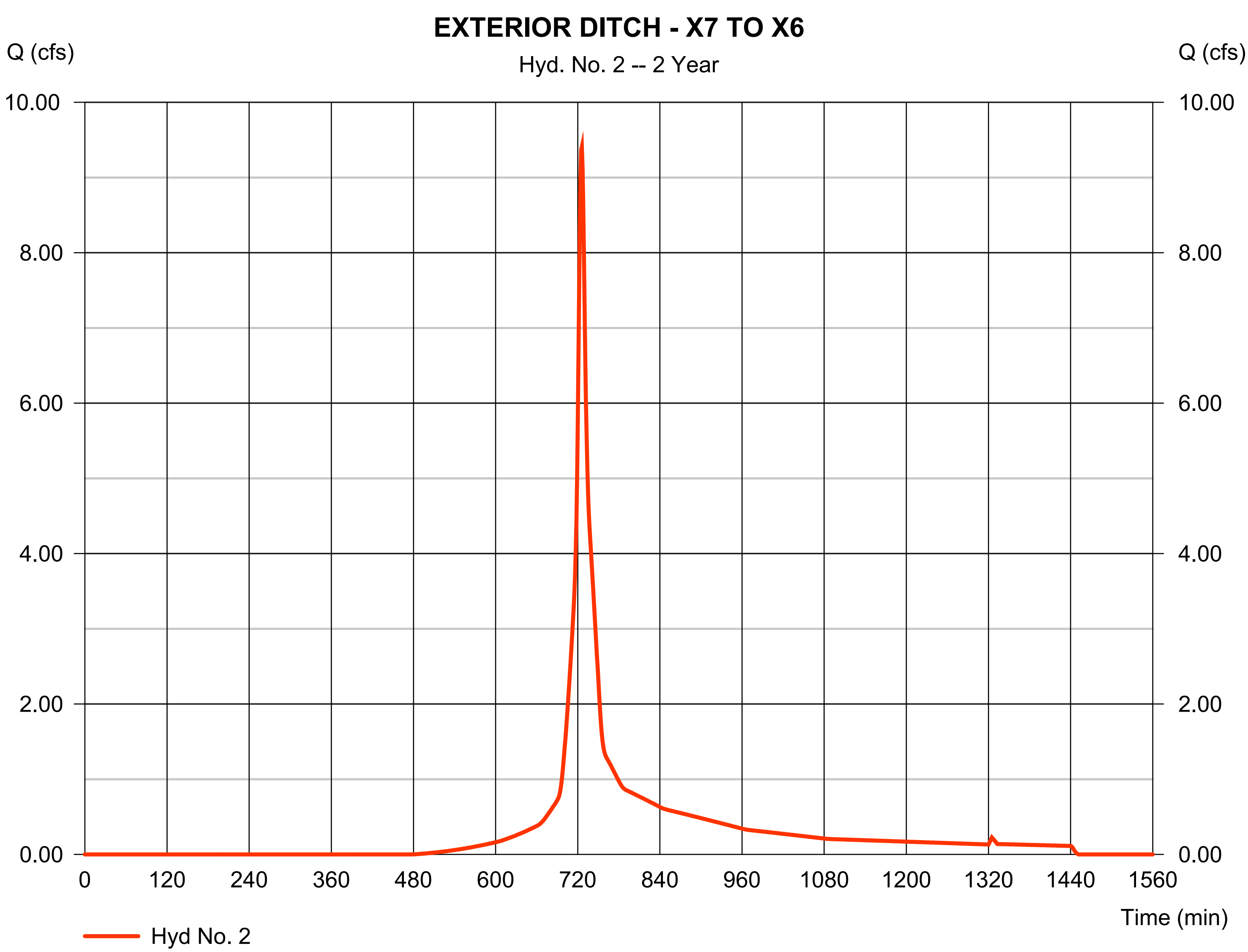
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 2

EXTERIOR DITCH - X7 TO X6

Hydrograph type	= SCS Runoff	Peak discharge	= 9.406 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 30,231 cuft
Drainage area	= 3.470 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.70 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



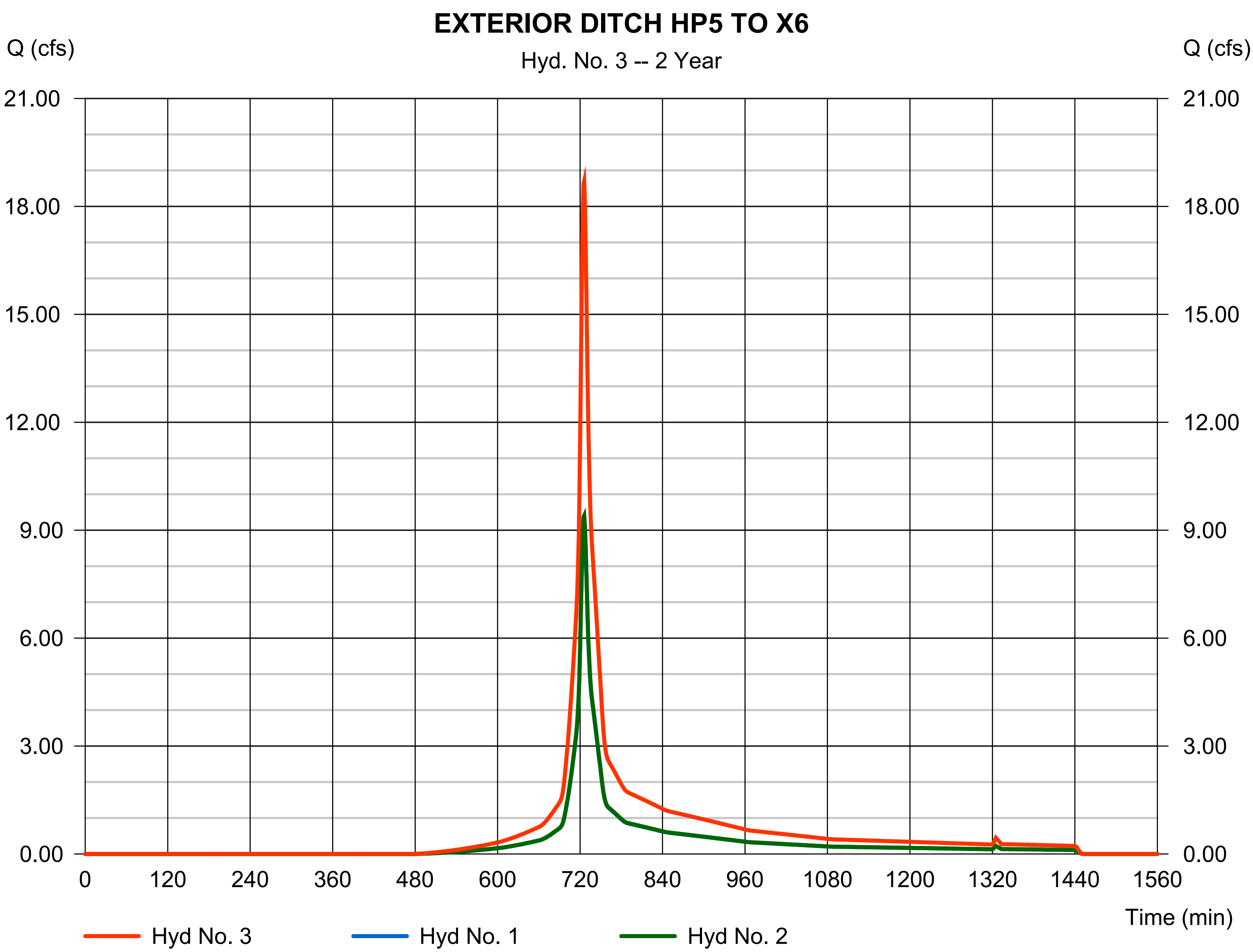
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 3

EXTERIOR DITCH HP5 TO X6

Hydrograph type	= Combine	Peak discharge	= 18.70 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 60,113 cuft
Inflow hyds.	= 1, 2	Contrib. drain. area	= 6.900 ac



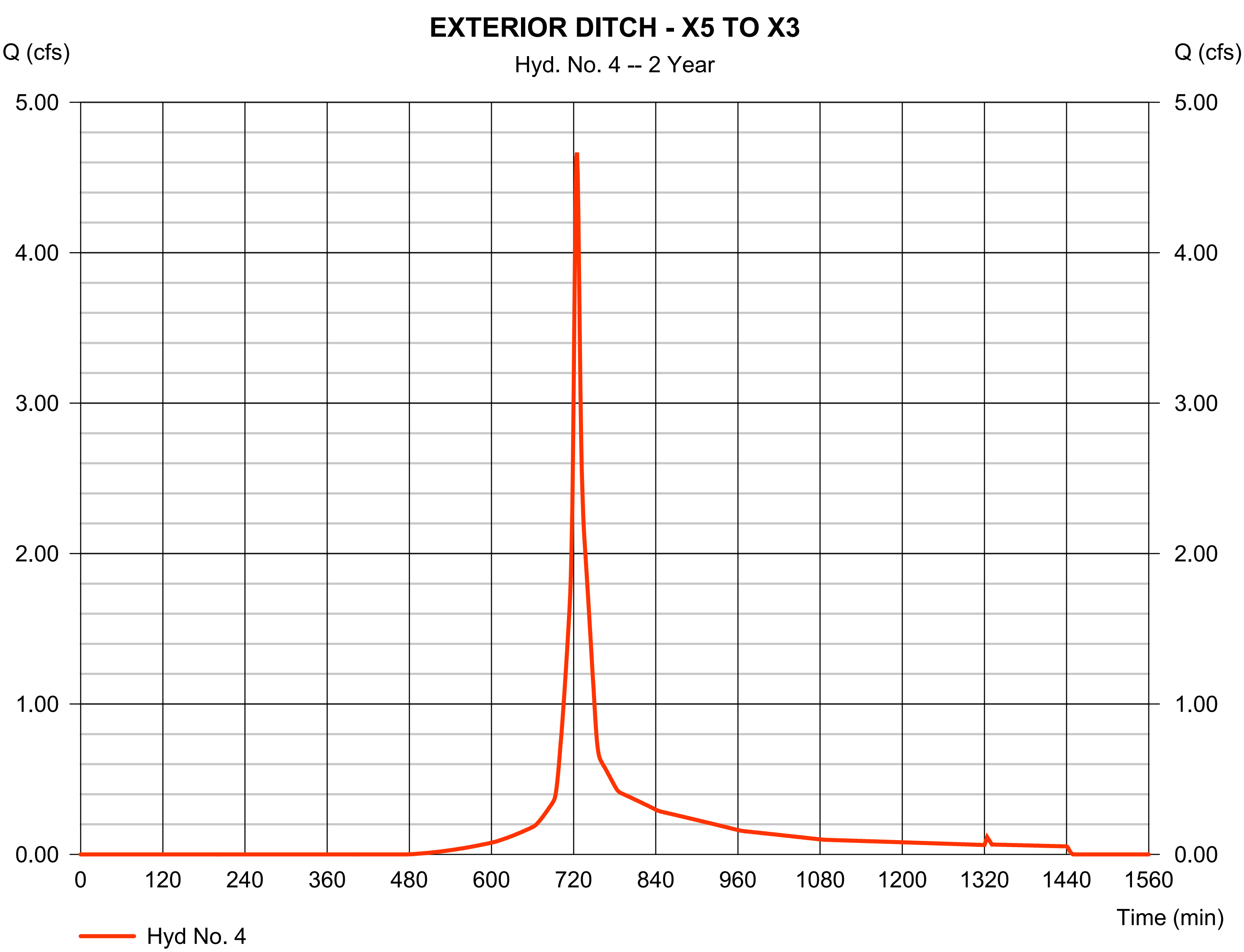
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 4

EXTERIOR DITCH - X5 TO X3

Hydrograph type	= SCS Runoff	Peak discharge	= 4.666 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 14,375 cuft
Drainage area	= 1.560 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.90 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



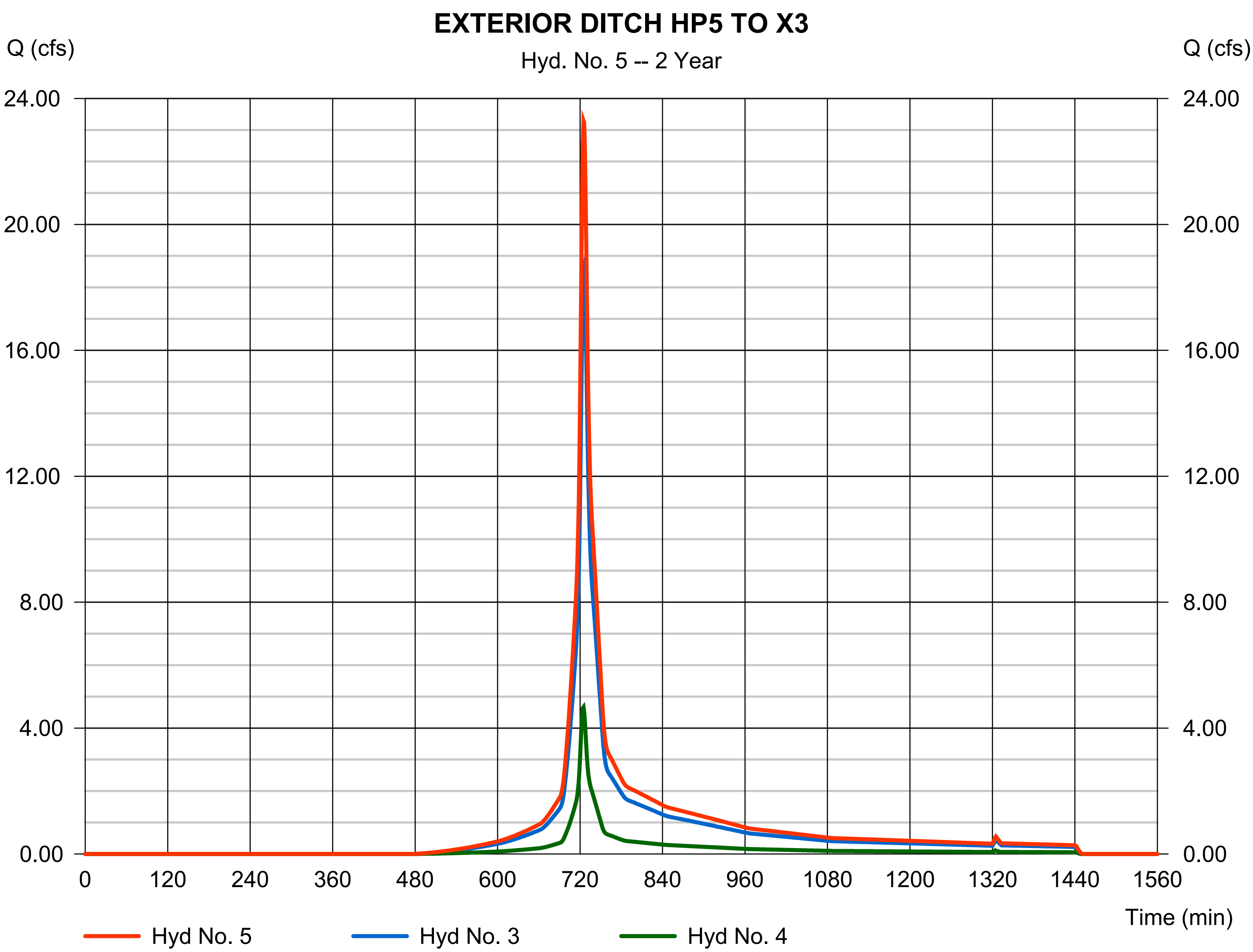
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 5

EXTERIOR DITCH HP5 TO X3

Hydrograph type	= Combine	Peak discharge	= 23.29 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 74,488 cuft
Inflow hyds.	= 3, 4	Contrib. drain. area	= 1.560 ac



Hydrograph Report

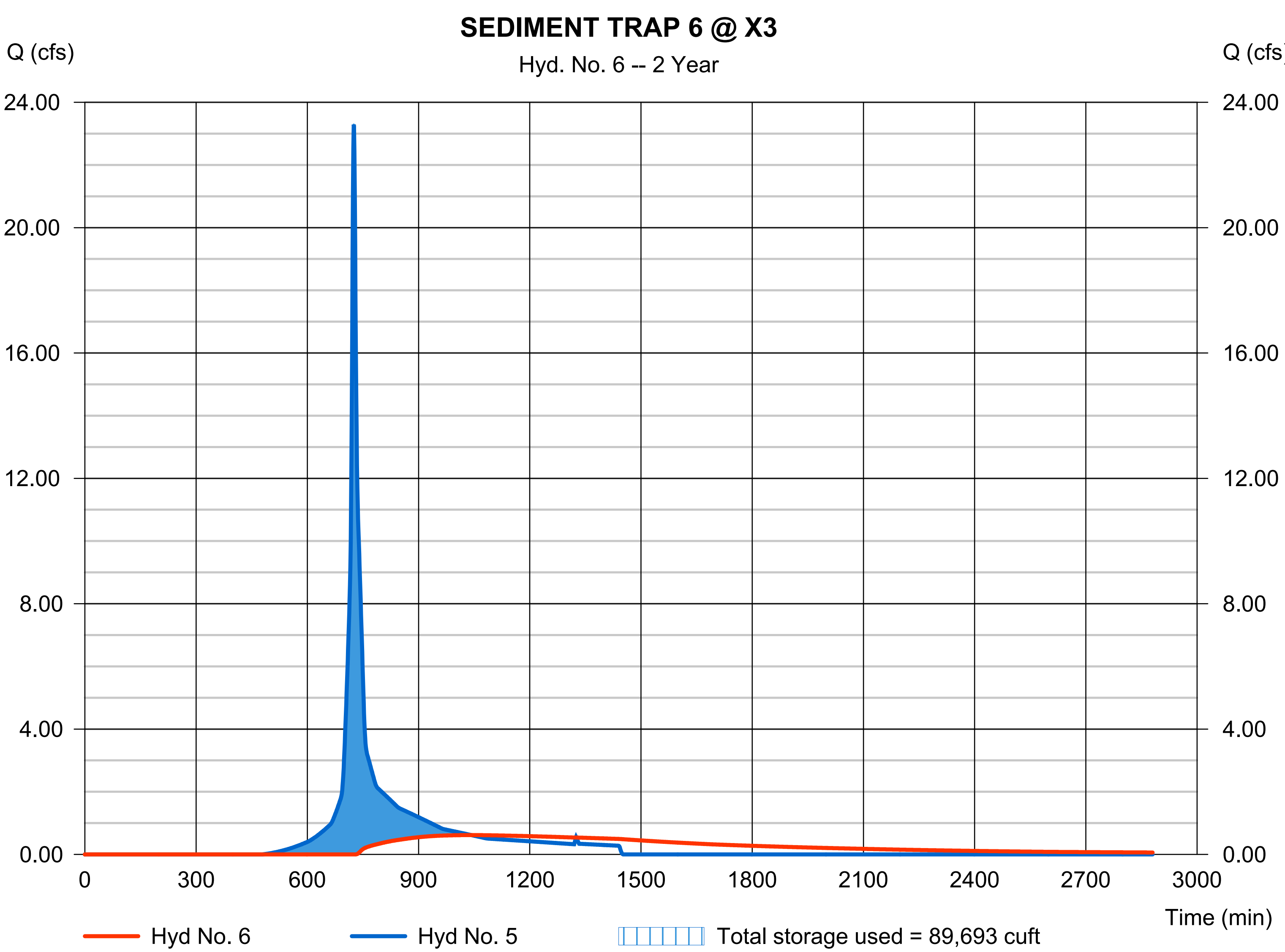
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 6

SEDIMENT TRAP 6 @ X3

Hydrograph type	= Reservoir	Peak discharge	= 0.617 cfs
Storm frequency	= 2 yrs	Time to peak	= 1042 min
Time interval	= 1 min	Hyd. volume	= 39,246 cuft
Inflow hyd. No.	= 5 - EXTERIOR DITCH HP5 TO X3	Max. Elevation	= 256.55 ft
Reservoir name	= SEDIMENT TRAP 6 @ X3	Max. Storage	= 89,693 cuft

Storage Indication method used. Wet pond routing start elevation = 254.00 ft.



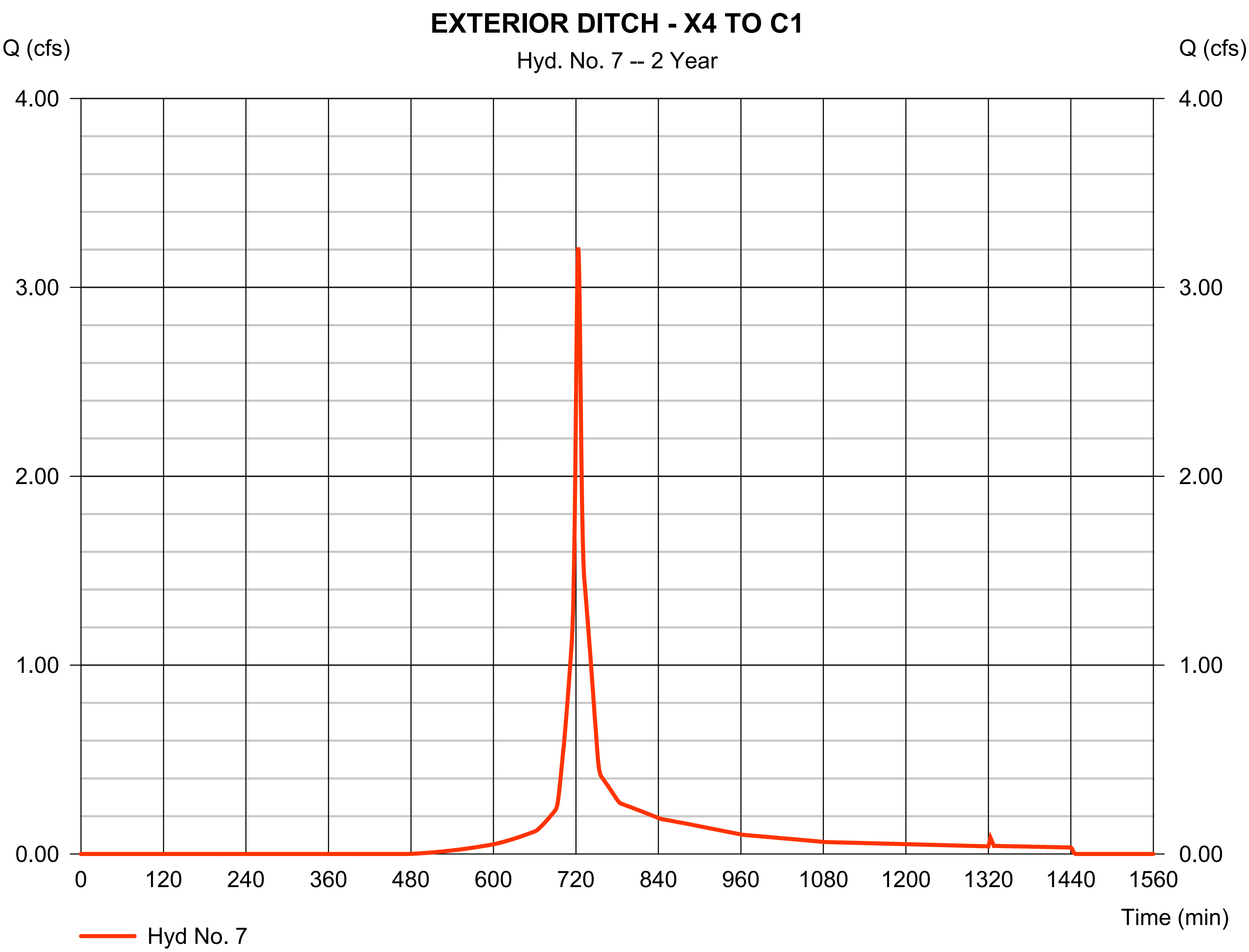
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 7

EXTERIOR DITCH - X4 TO C1

Hydrograph type	= SCS Runoff	Peak discharge	= 3.212 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 9,293 cuft
Drainage area	= 1.040 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.70 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



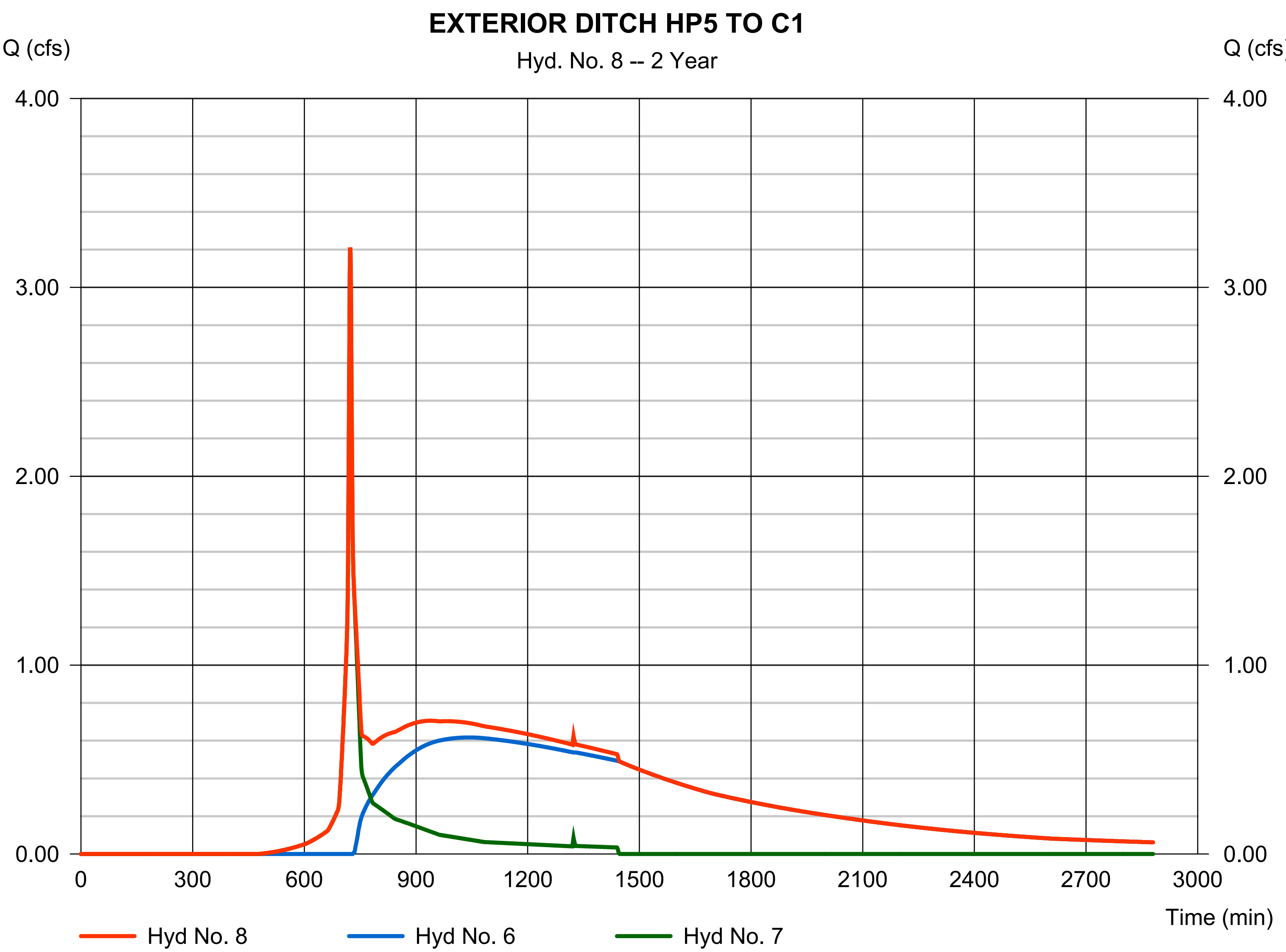
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 8

EXTERIOR DITCH HP5 TO C1

Hydrograph type	= Combine	Peak discharge	= 3.212 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 48,539 cuft
Inflow hyds.	= 6, 7	Contrib. drain. area	= 1.040 ac



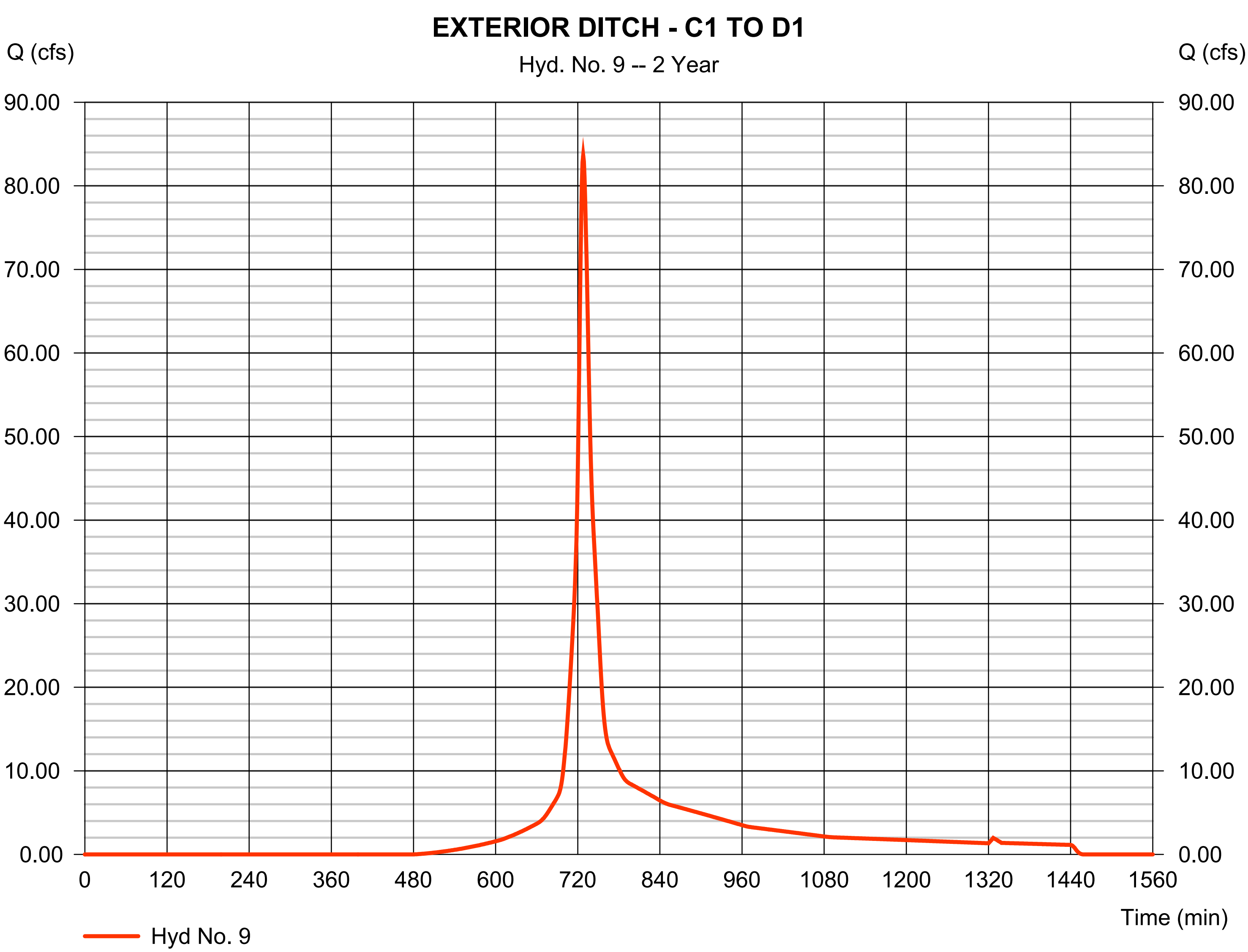
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 | Friday, 01 / 30 / 2015

Hyd. No. 9

EXTERIOR DITCH - C1 TO D1

Hydrograph type	= SCS Runoff	Peak discharge	= 83.64 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 303,589 cuft
Drainage area	= 33.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.00 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



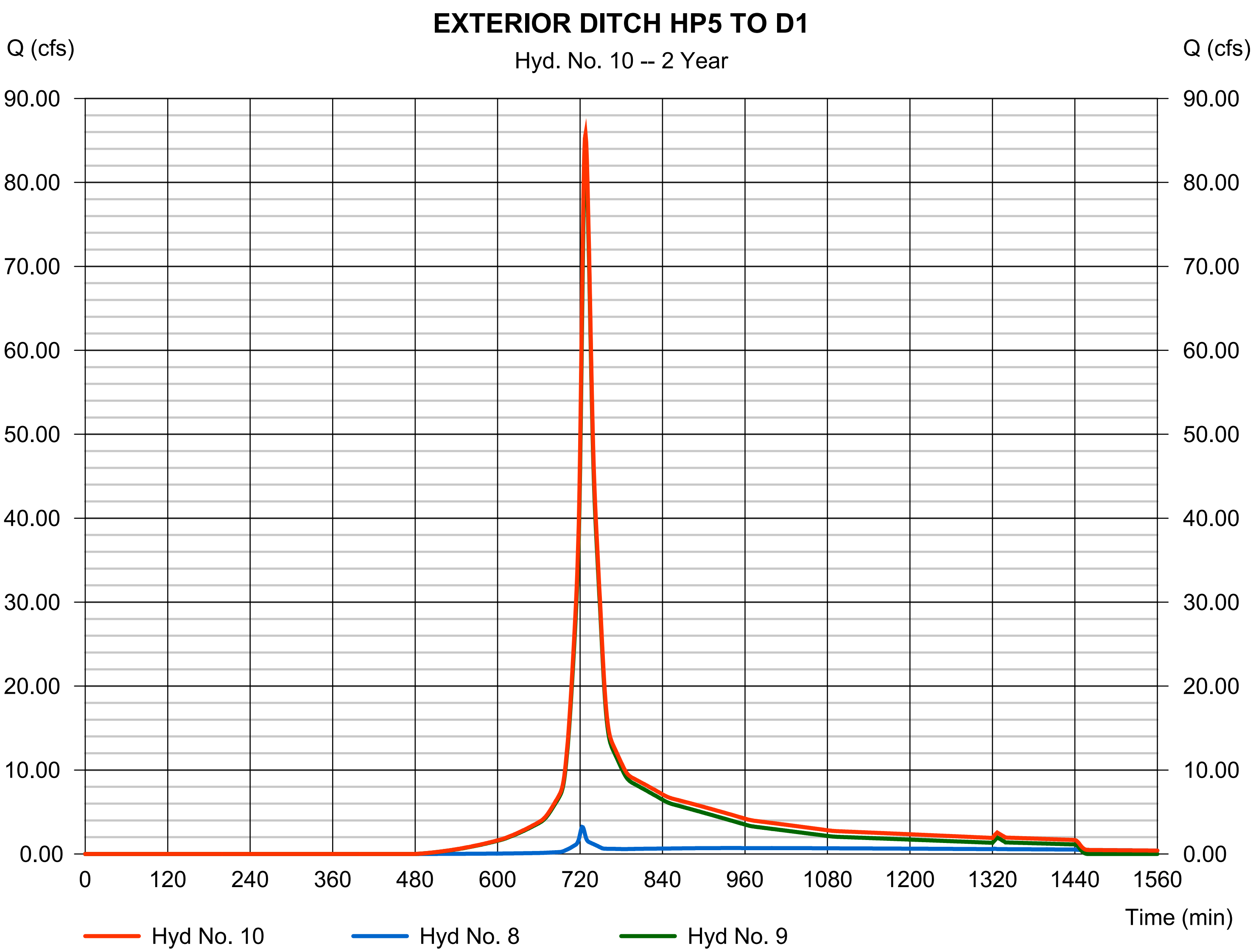
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 10

EXTERIOR DITCH HP5 TO D1

Hydrograph type	= Combine	Peak discharge	= 85.73 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 352,128 cuft
Inflow hyds.	= 8, 9	Contrib. drain. area	= 33.380 ac



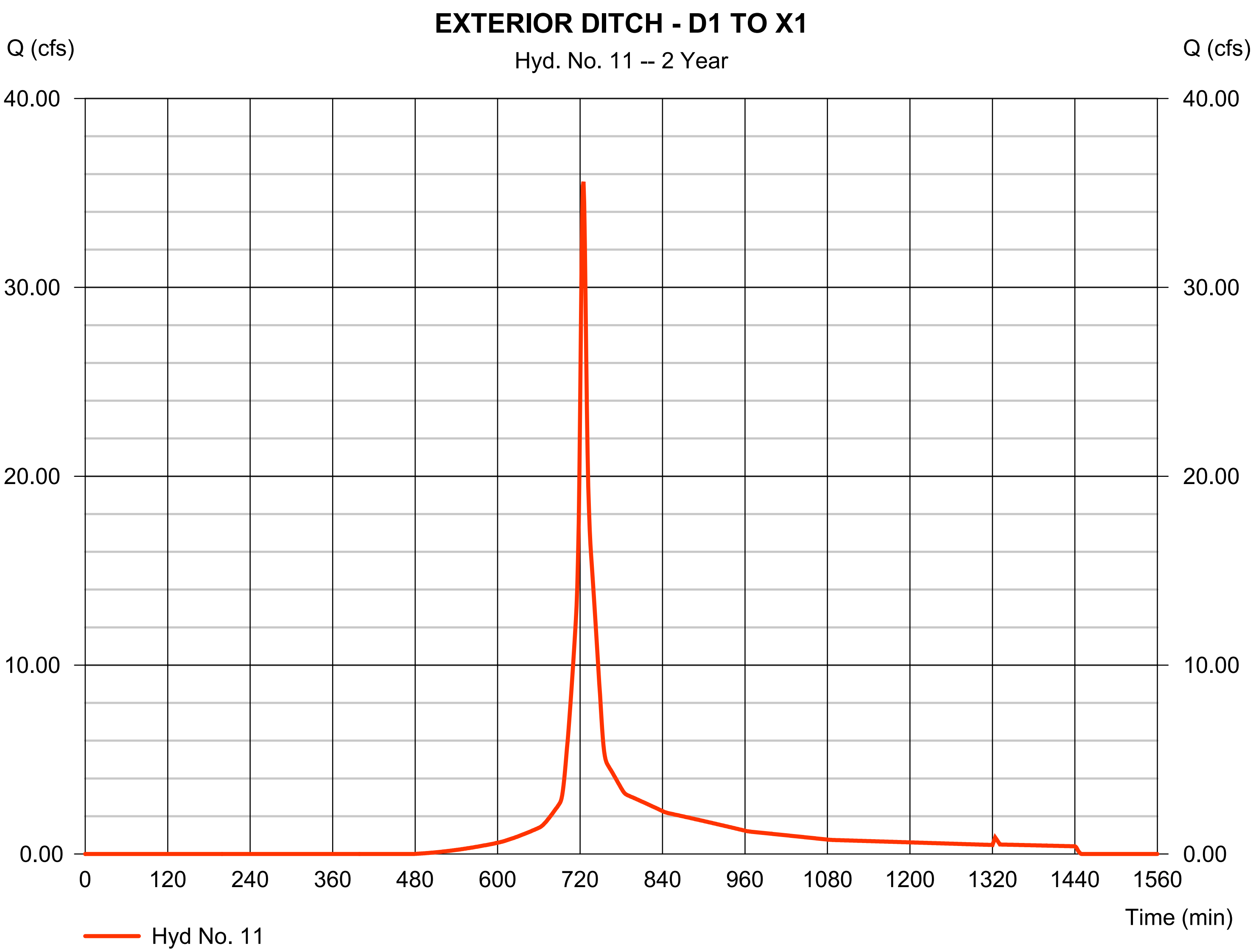
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 11

EXTERIOR DITCH - D1 TO X1

Hydrograph type	= SCS Runoff	Peak discharge	= 35.59 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 109,654 cuft
Drainage area	= 11.900 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.20 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



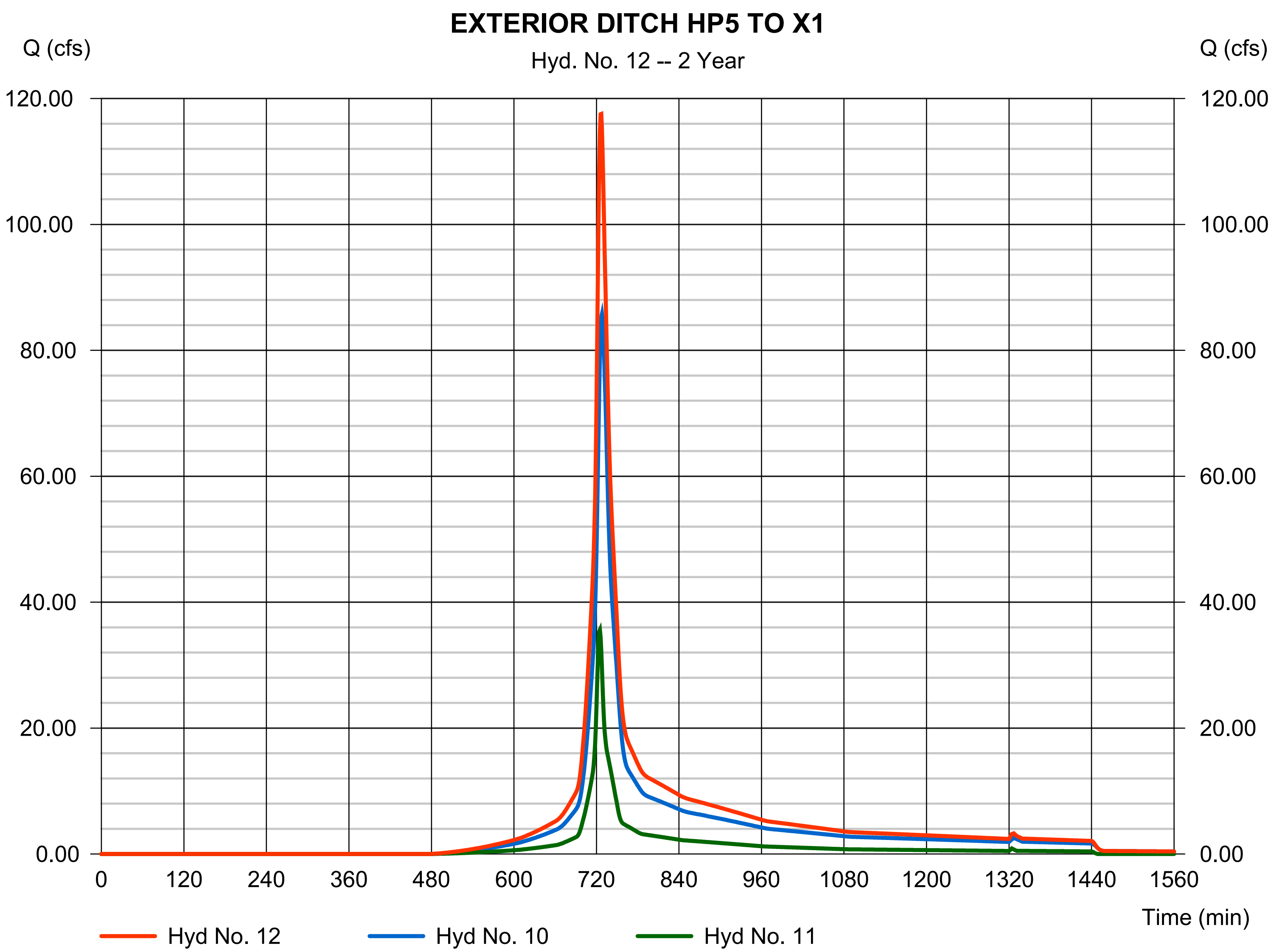
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 12

EXTERIOR DITCH HP5 TO X1

Hydrograph type	= Combine	Peak discharge	= 117.54 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 461,781 cuft
Inflow hyds.	= 10, 11	Contrib. drain. area	= 11.900 ac



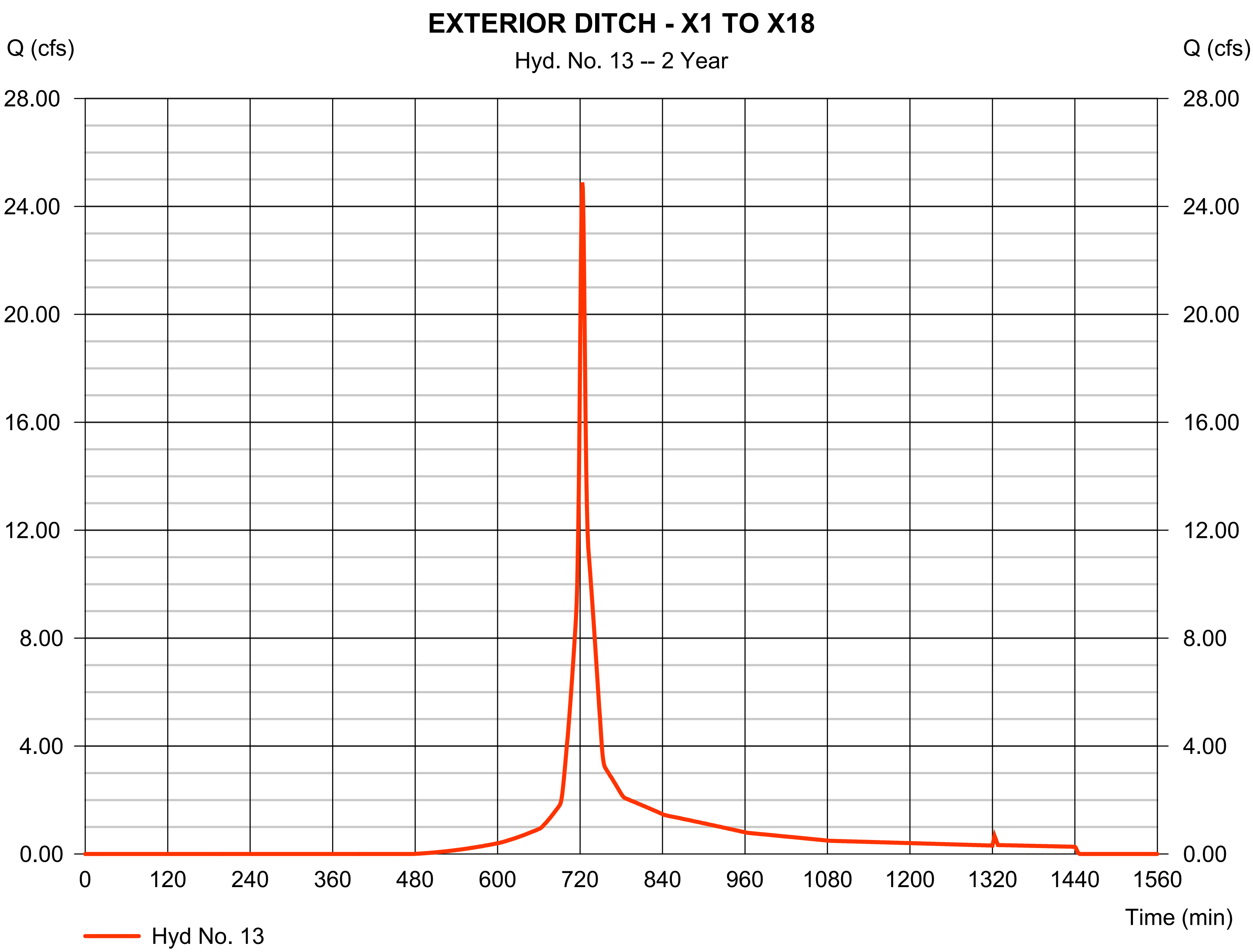
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 13

EXTERIOR DITCH - X1 TO X18

Hydrograph type	= SCS Runoff	Peak discharge	= 24.89 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 72,019 cuft
Drainage area	= 8.060 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.80 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



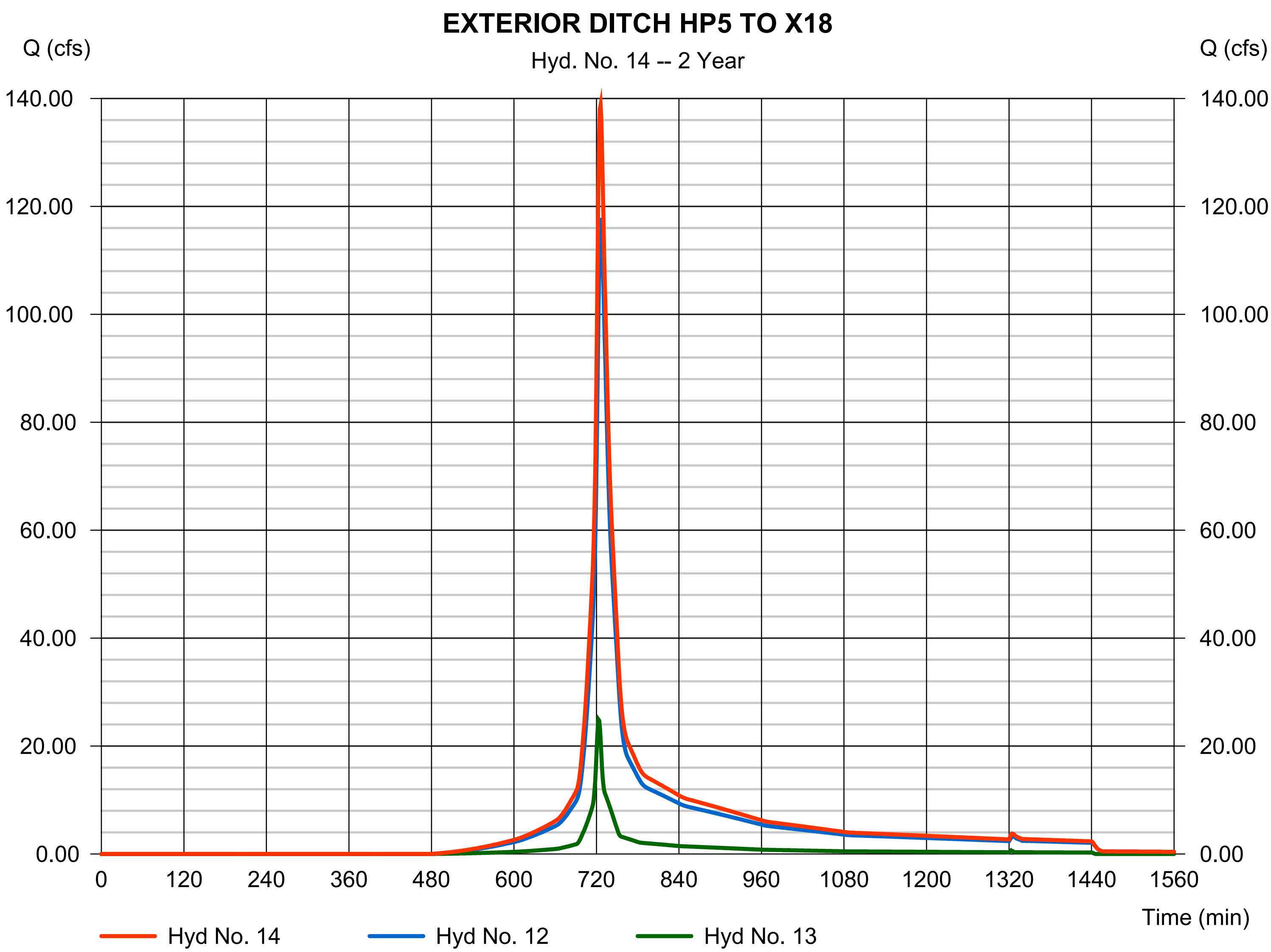
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 14

EXTERIOR DITCH HP5 TO X18

Hydrograph type	= Combine	Peak discharge	= 138.78 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 533,801 cuft
Inflow hyds.	= 12, 13	Contrib. drain. area	= 8.060 ac



Hydrograph Report

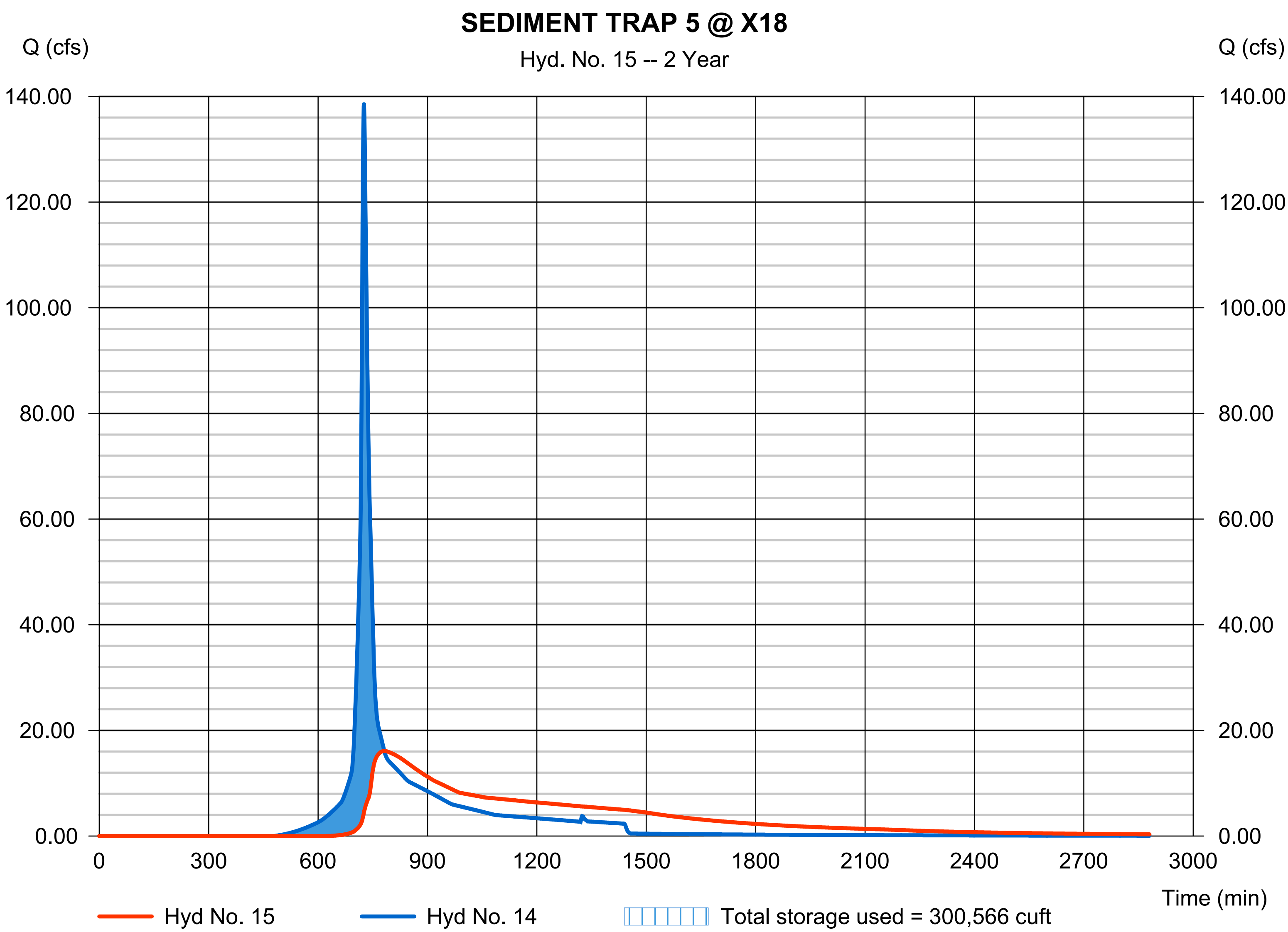
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 15

SEDIMENT TRAP 5 @ X18

Hydrograph type	= Reservoir	Peak discharge	= 16.10 cfs
Storm frequency	= 2 yrs	Time to peak	= 782 min
Time interval	= 1 min	Hyd. volume	= 505,453 cuft
Inflow hyd. No.	= 14 - EXTERIOR DITCH HP5 TO X18	Max. Elevation	= 248.13 ft
Reservoir name	= SEDIMENT TRAP 5 @ X18	Max. Storage	= 300,566 cuft

Storage Indication method used. Wet pond routing start elevation = 242.00 ft.



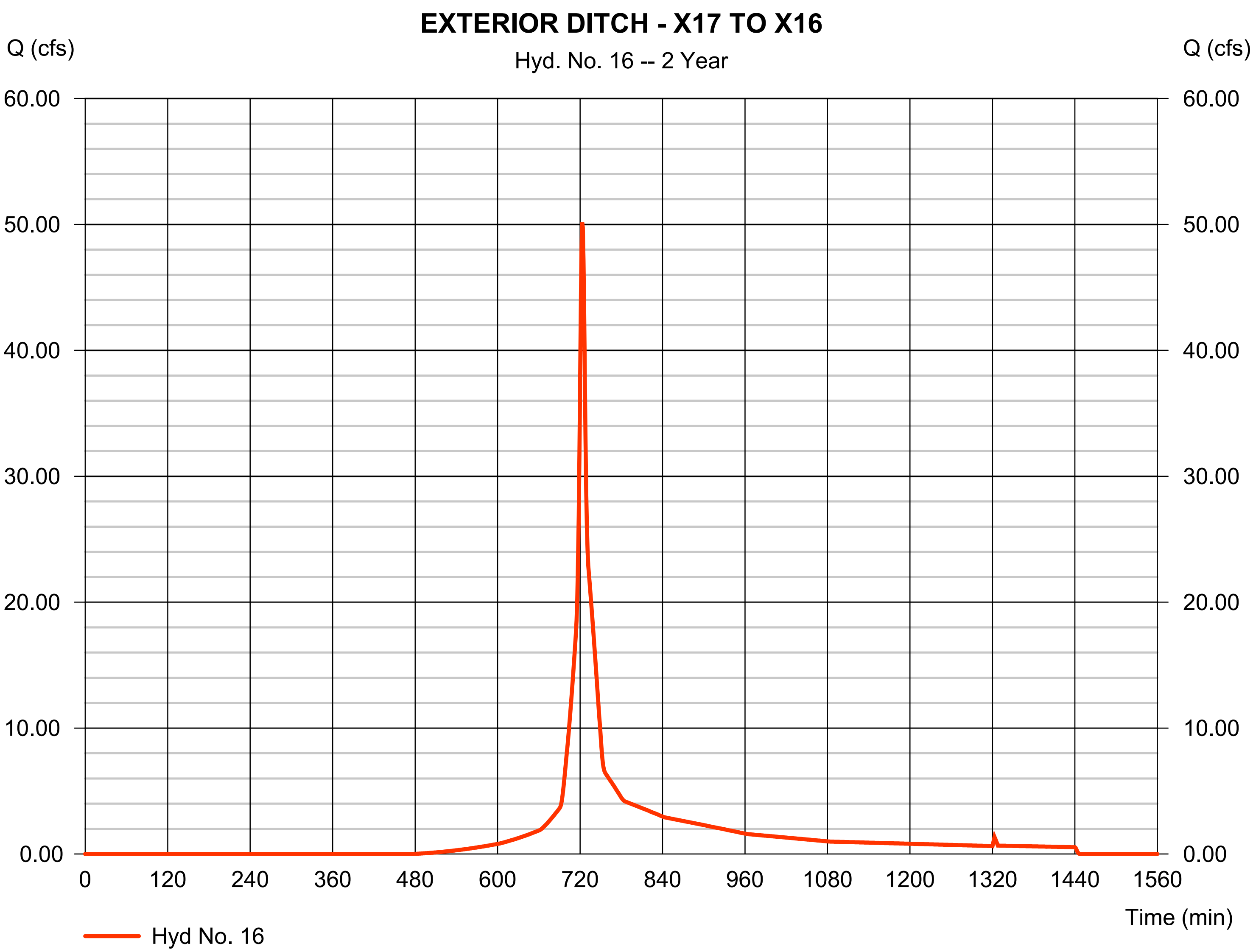
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 16

EXTERIOR DITCH - X17 TO X16

Hydrograph type	= SCS Runoff	Peak discharge	= 50.15 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 145,111 cuft
Drainage area	= 16.240 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



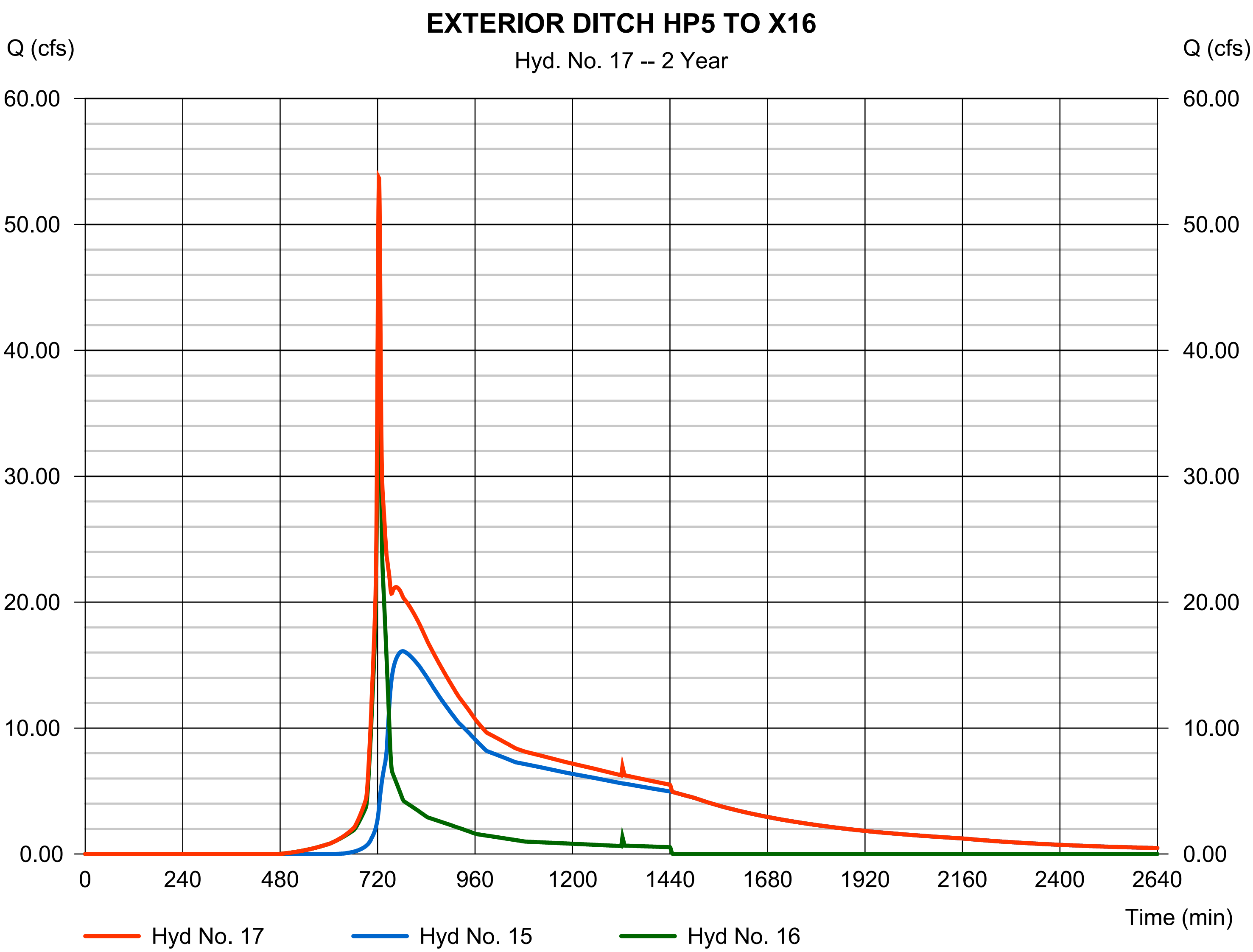
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 17

EXTERIOR DITCH HP5 TO X16

Hydrograph type	= Combine	Peak discharge	= 53.70 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 650,563 cuft
Inflow hyds.	= 15, 16	Contrib. drain. area	= 16.240 ac



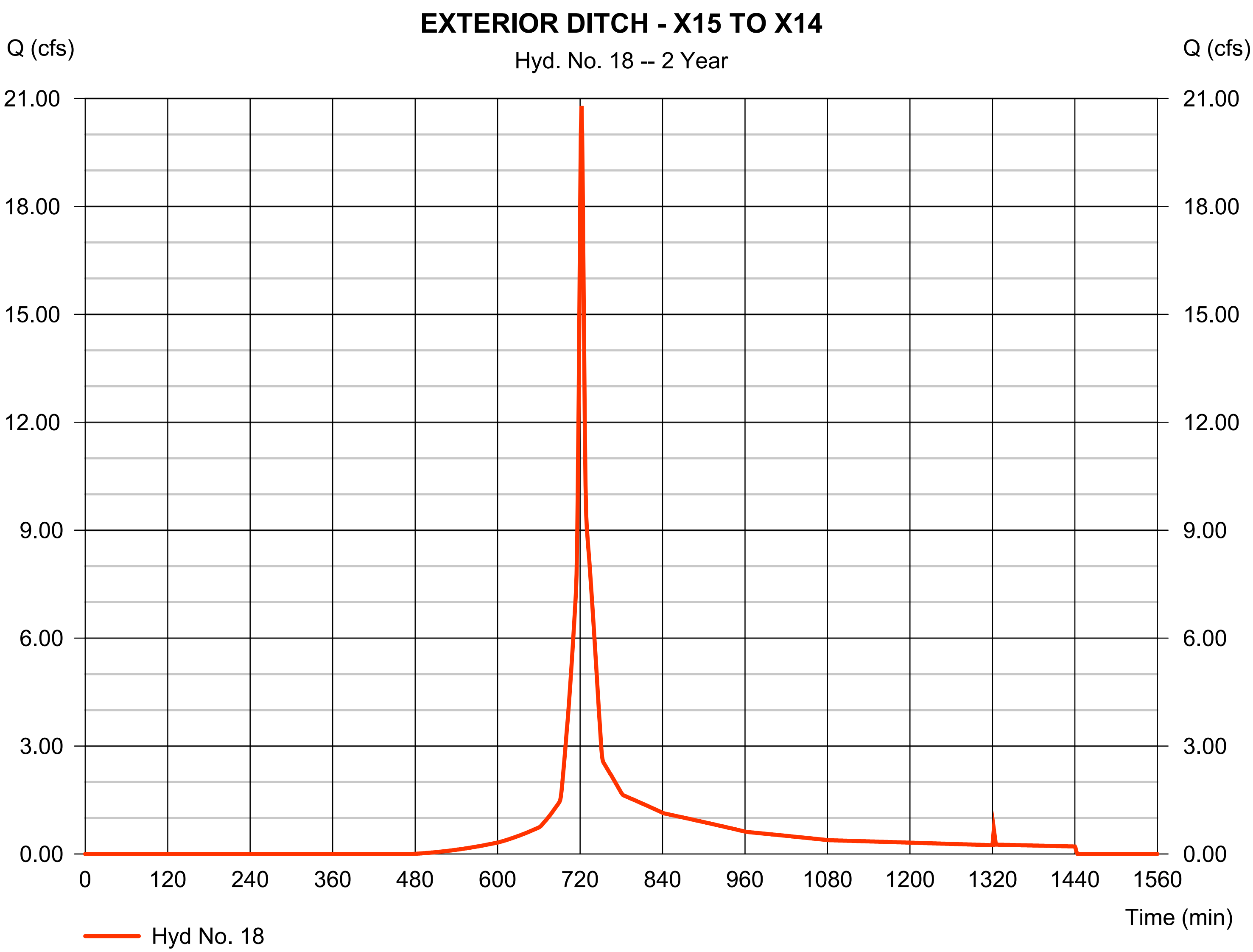
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 18

EXTERIOR DITCH - X15 TO X14

Hydrograph type	= SCS Runoff	Peak discharge	= 20.79 cfs
Storm frequency	= 2 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 56,460 cuft
Drainage area	= 6.740 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 2.00 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



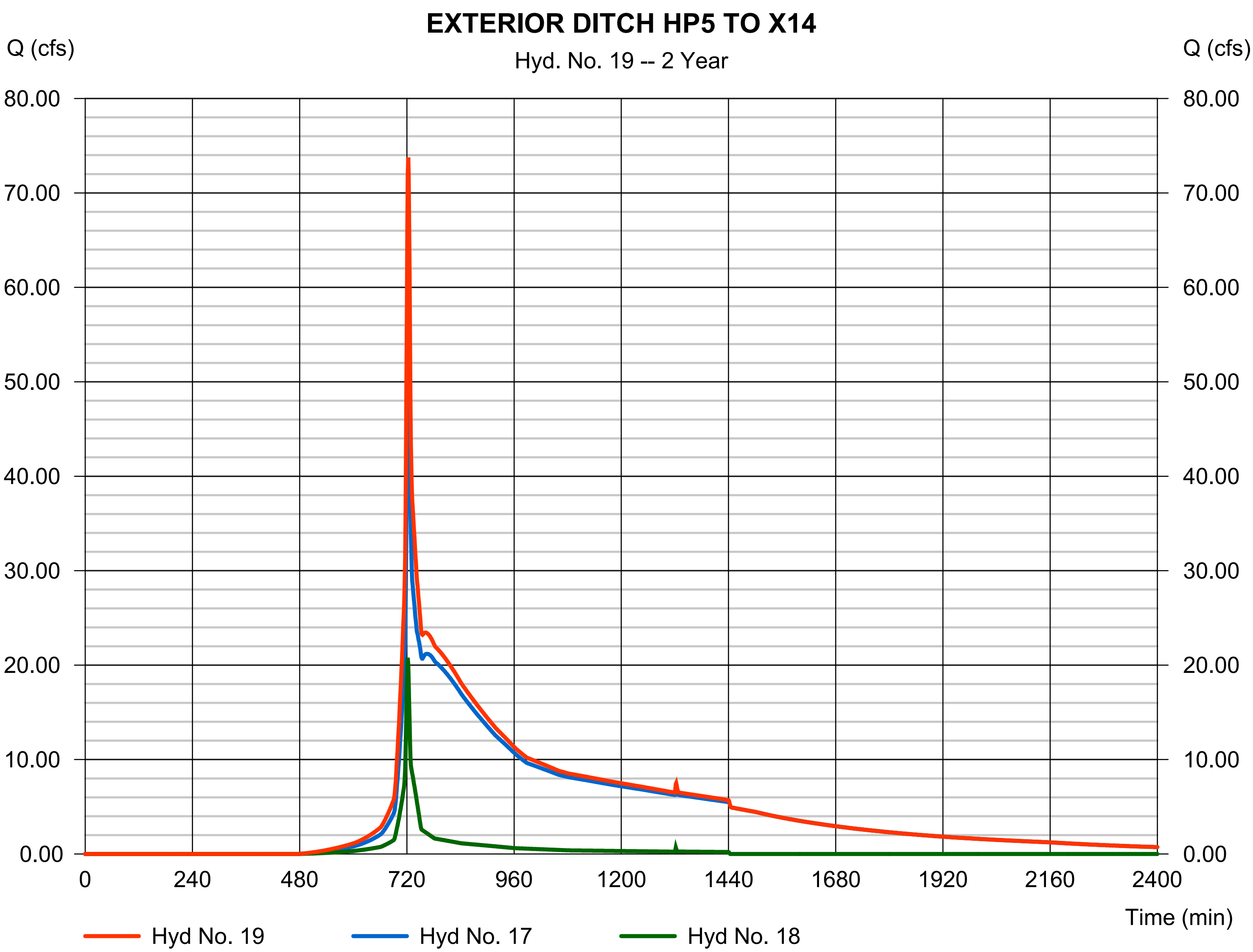
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 19

EXTERIOR DITCH HP5 TO X14

Hydrograph type	= Combine	Peak discharge	= 73.76 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 707,024 cuft
Inflow hyds.	= 17, 18	Contrib. drain. area	= 6.740 ac



Hydrograph Report

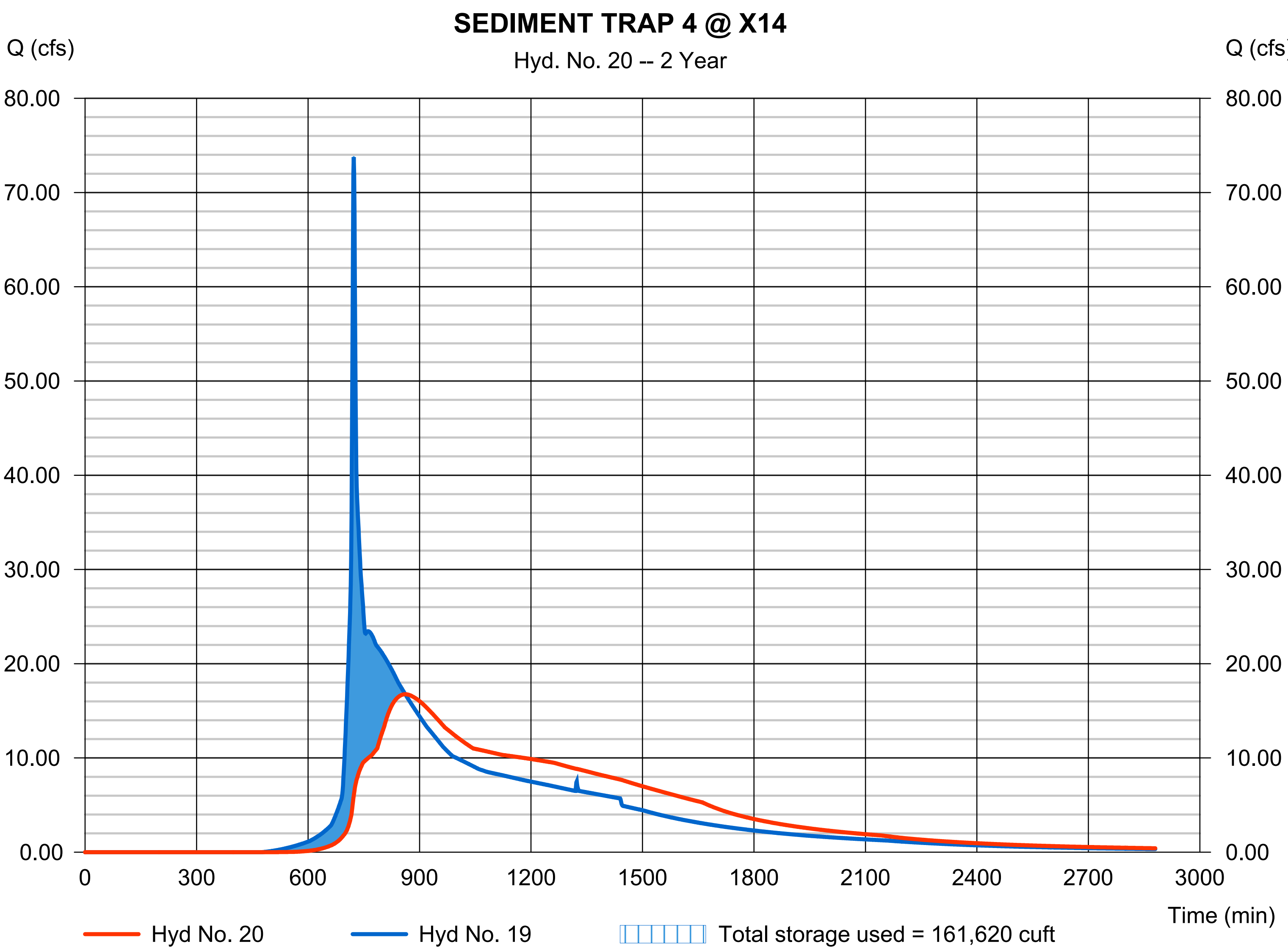
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 20

SEDIMENT TRAP 4 @ X14

Hydrograph type	= Reservoir	Peak discharge	= 16.76 cfs
Storm frequency	= 2 yrs	Time to peak	= 862 min
Time interval	= 1 min	Hyd. volume	= 700,842 cuft
Inflow hyd. No.	= 19 - EXTERIOR DITCH HP5 TO X14	Max. Elevation	= 245.01 ft
Reservoir name	= SEDIMENT TRAP 4 @ X14	Max. Storage	= 161,620 cuft

Storage Indication method used. Wet pond routing start elevation = 238.00 ft.



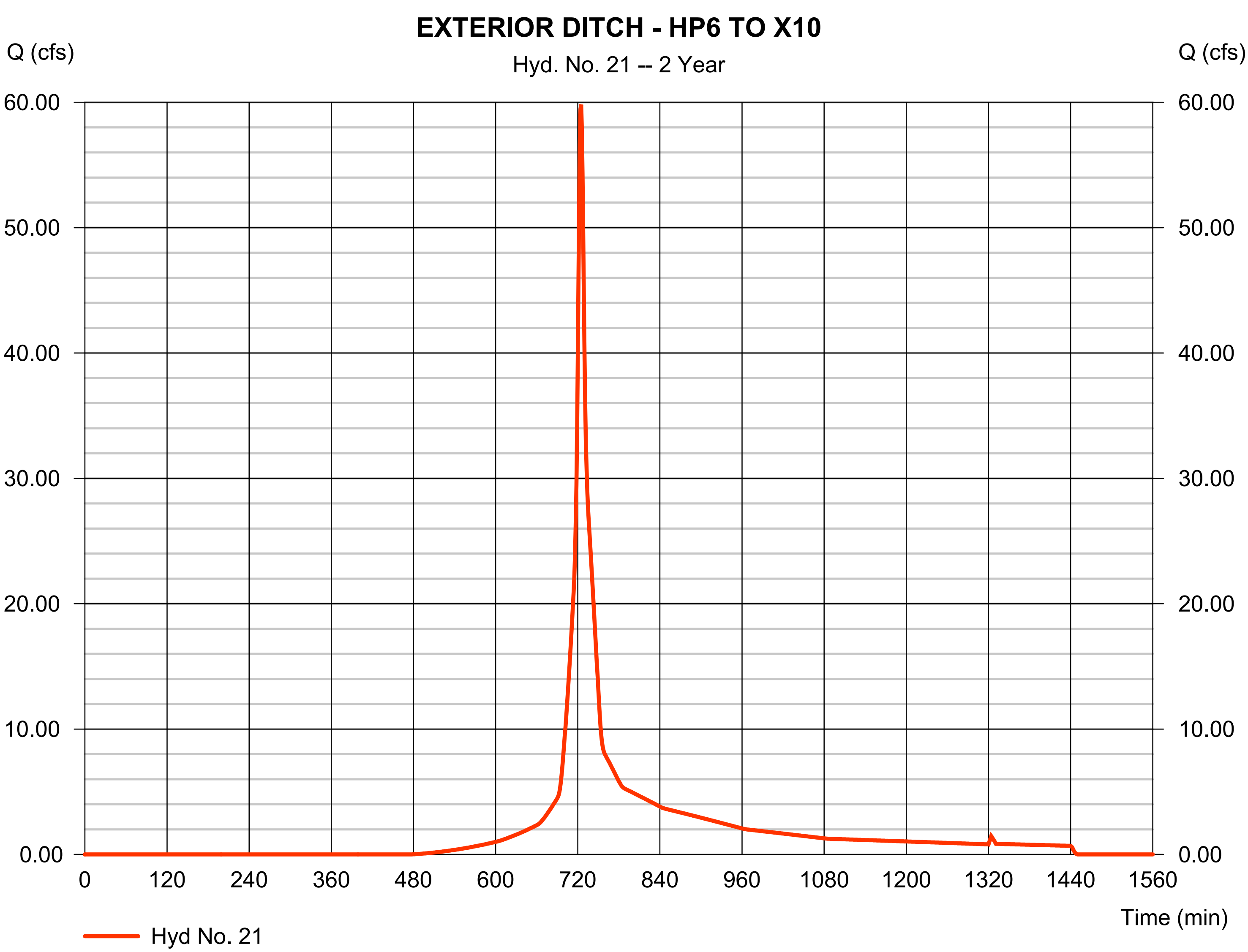
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 21

EXTERIOR DITCH - HP6 TO X10

Hydrograph type	= SCS Runoff	Peak discharge	= 59.82 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 184,292 cuft
Drainage area	= 20.000 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

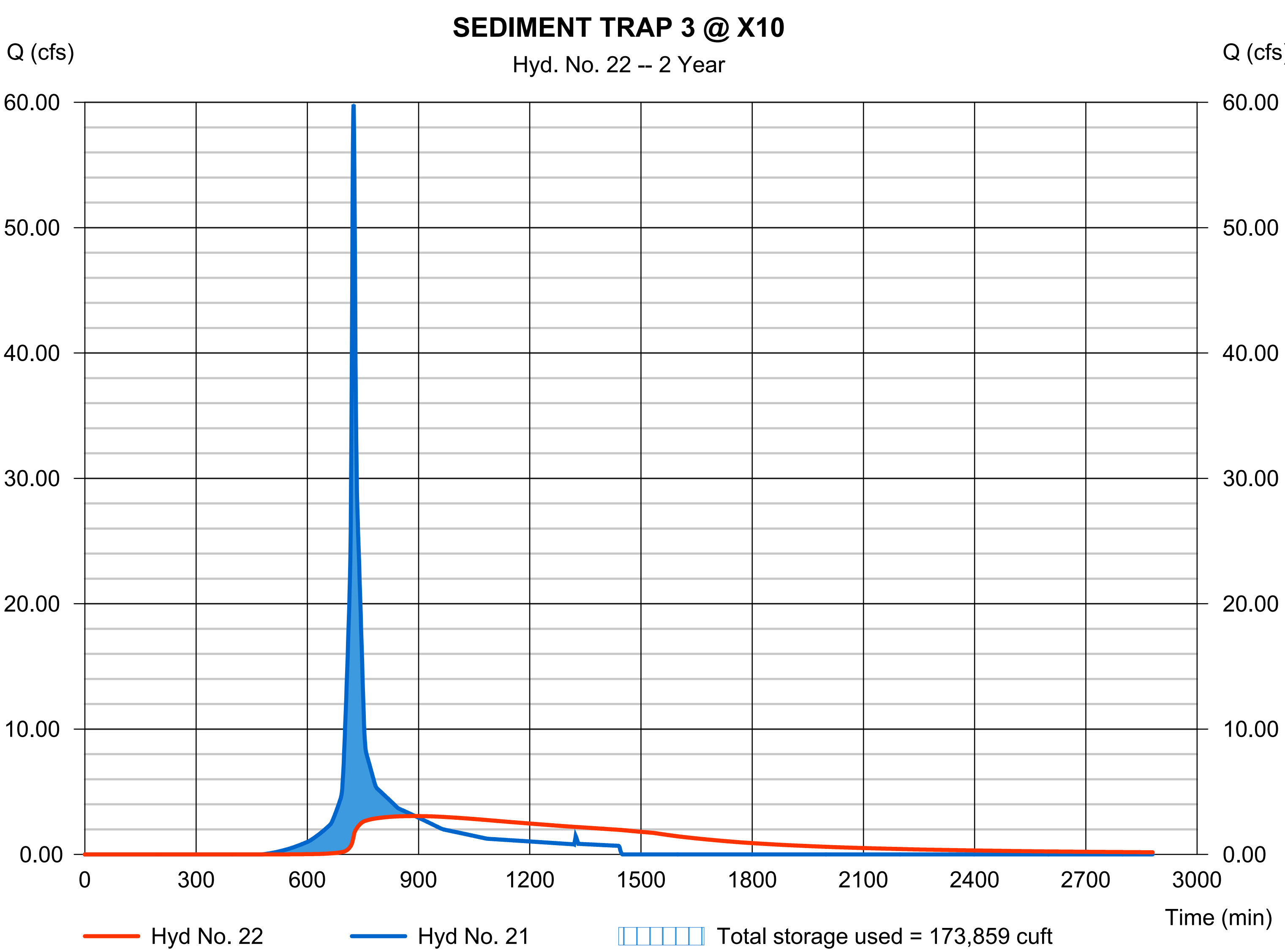
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 22

SEDIMENT TRAP 3 @ X10

Hydrograph type	= Reservoir	Peak discharge	= 3.059 cfs
Storm frequency	= 2 yrs	Time to peak	= 891 min
Time interval	= 1 min	Hyd. volume	= 170,036 cuft
Inflow hyd. No.	= 21 - EXTERIOR DITCH - HP6 TO X10	Max. Elevation	= 250.89 ft
Reservoir name	= SEDIMENT TRAP 3 @ X10	Max. Storage	= 173,859 cuft

Storage Indication method used. Wet pond routing start elevation = 248.00 ft.



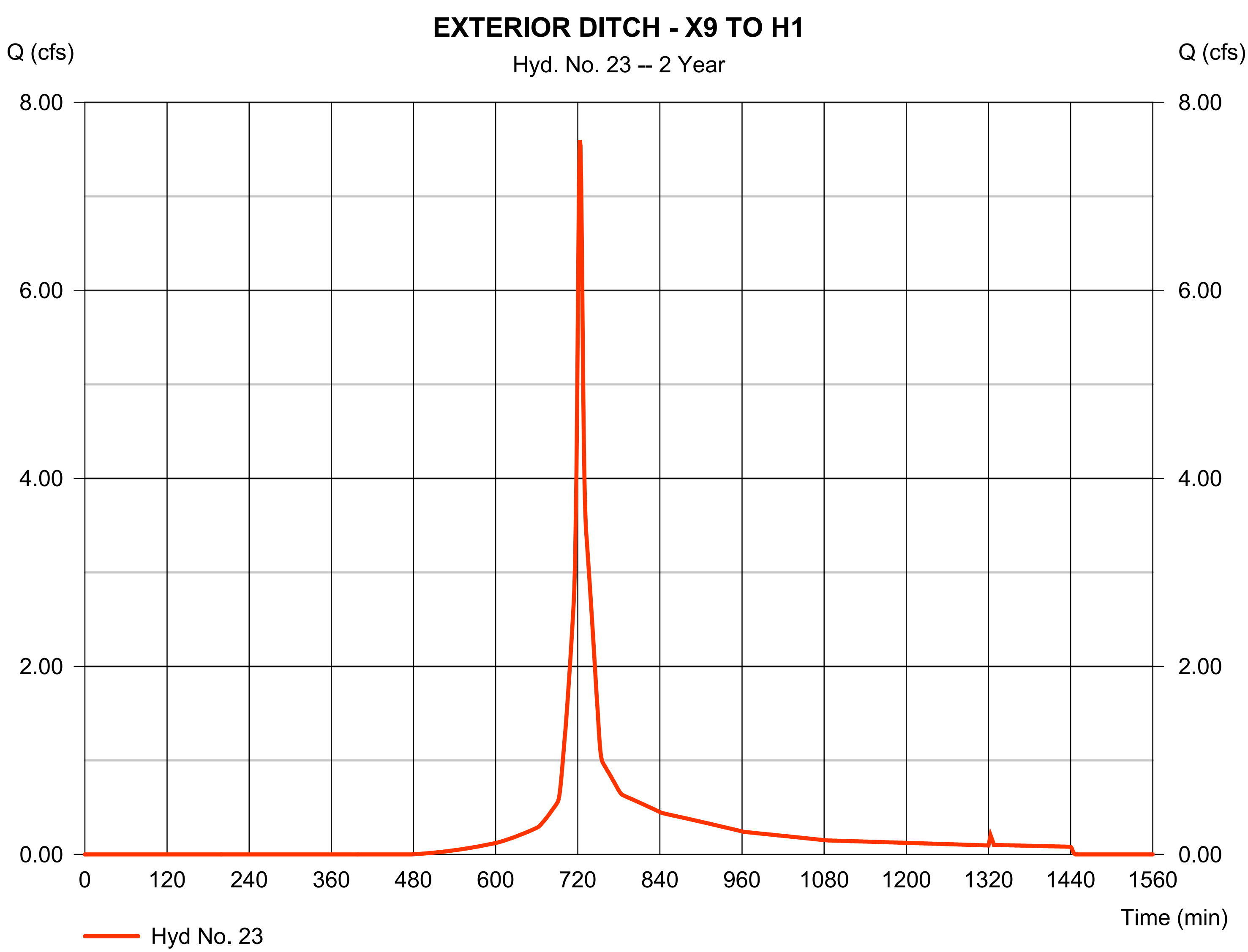
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 23

EXTERIOR DITCH - X9 TO H1

Hydrograph type	= SCS Runoff	Peak discharge	= 7.597 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 21,981 cuft
Drainage area	= 2.460 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



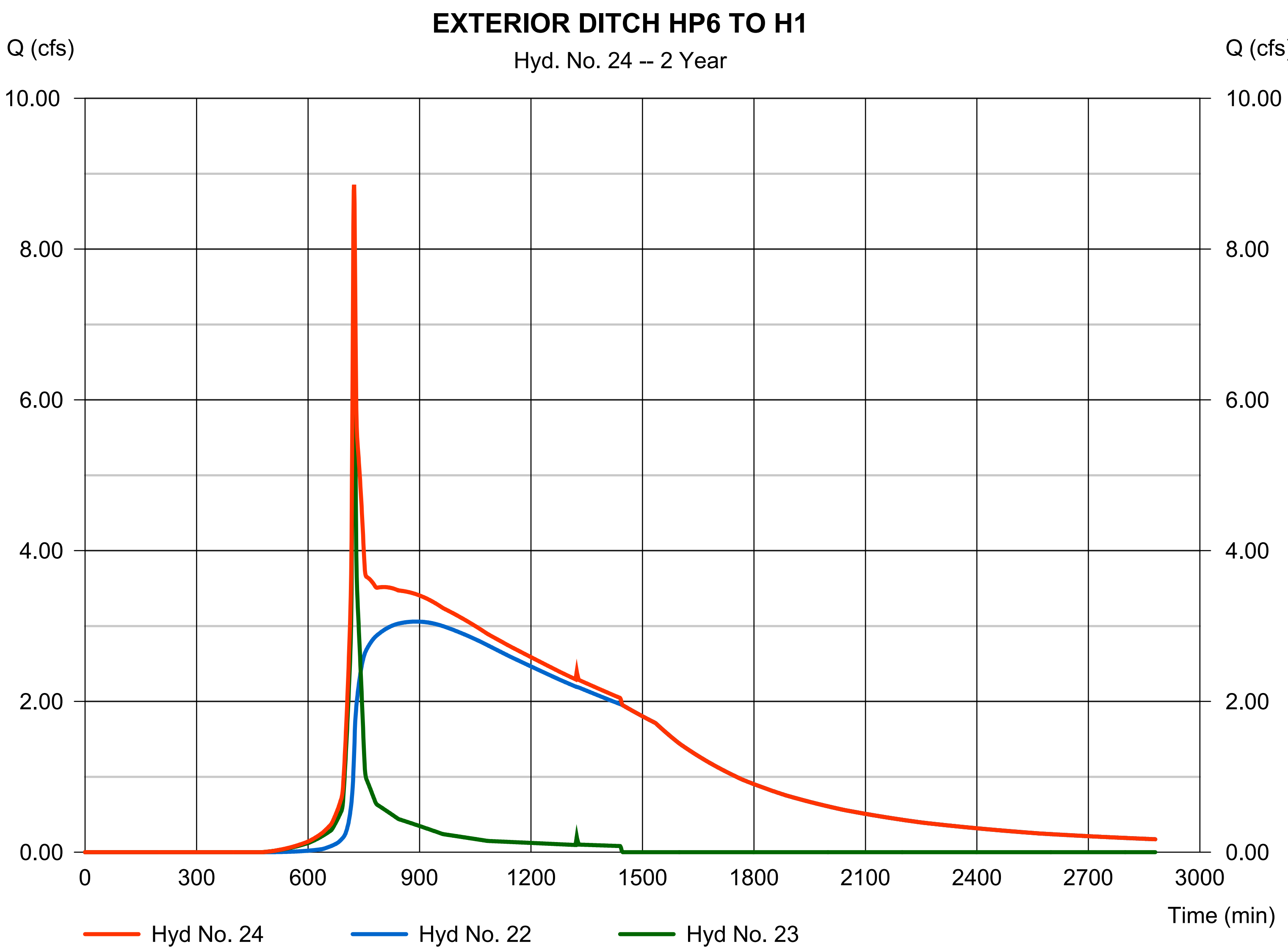
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 24

EXTERIOR DITCH HP6 TO H1

Hydrograph type	= Combine	Peak discharge	= 8.854 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 192,017 cuft
Inflow hyds.	= 22, 23	Contrib. drain. area	= 2.460 ac



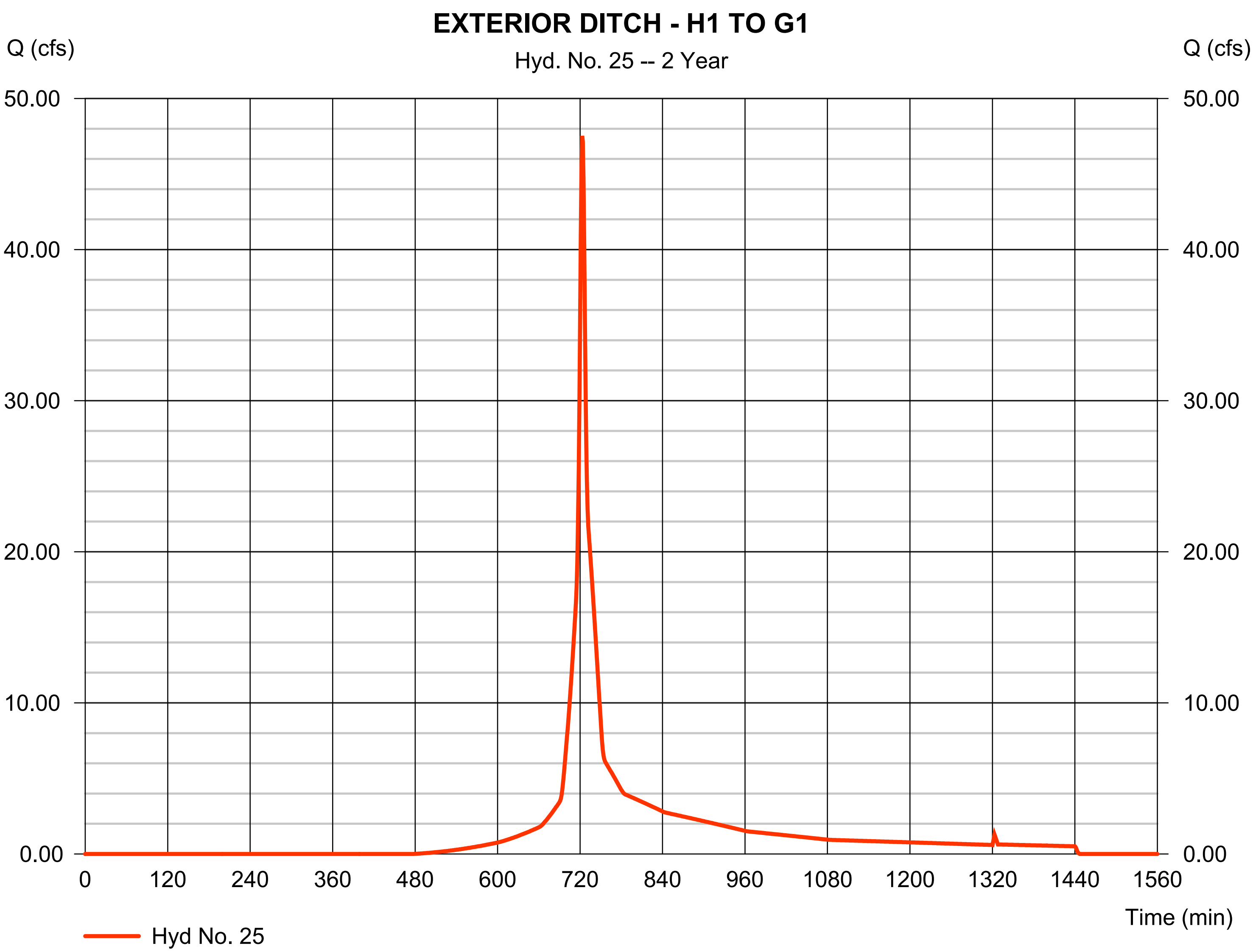
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 25

EXTERIOR DITCH - H1 TO G1

Hydrograph type	= SCS Runoff	Peak discharge	= 47.53 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 137,516 cuft
Drainage area	= 15.390 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



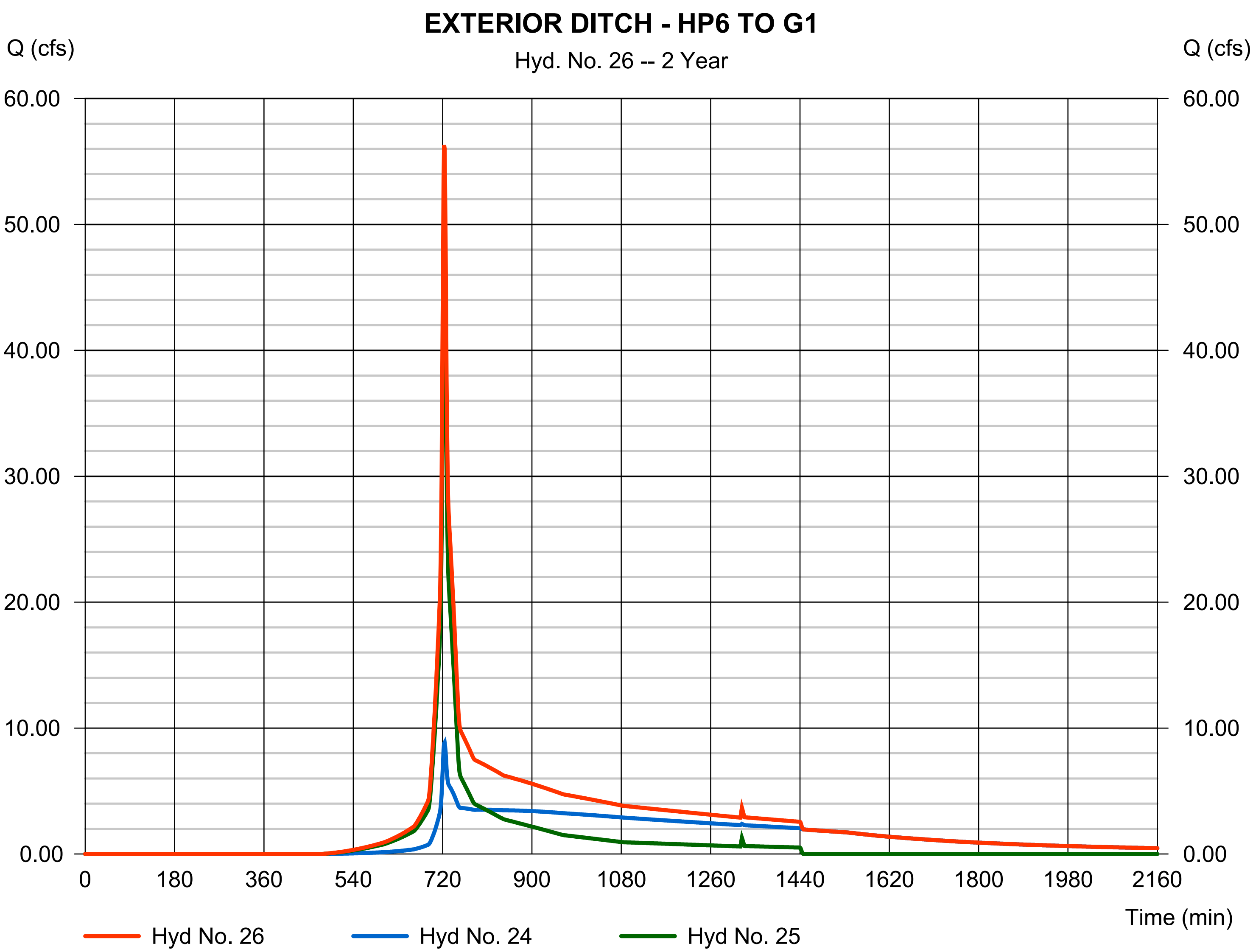
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 26

EXTERIOR DITCH - HP6 TO G1

Hydrograph type	= Combine	Peak discharge	= 56.31 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 329,534 cuft
Inflow hyds.	= 24, 25	Contrib. drain. area	= 15.390 ac



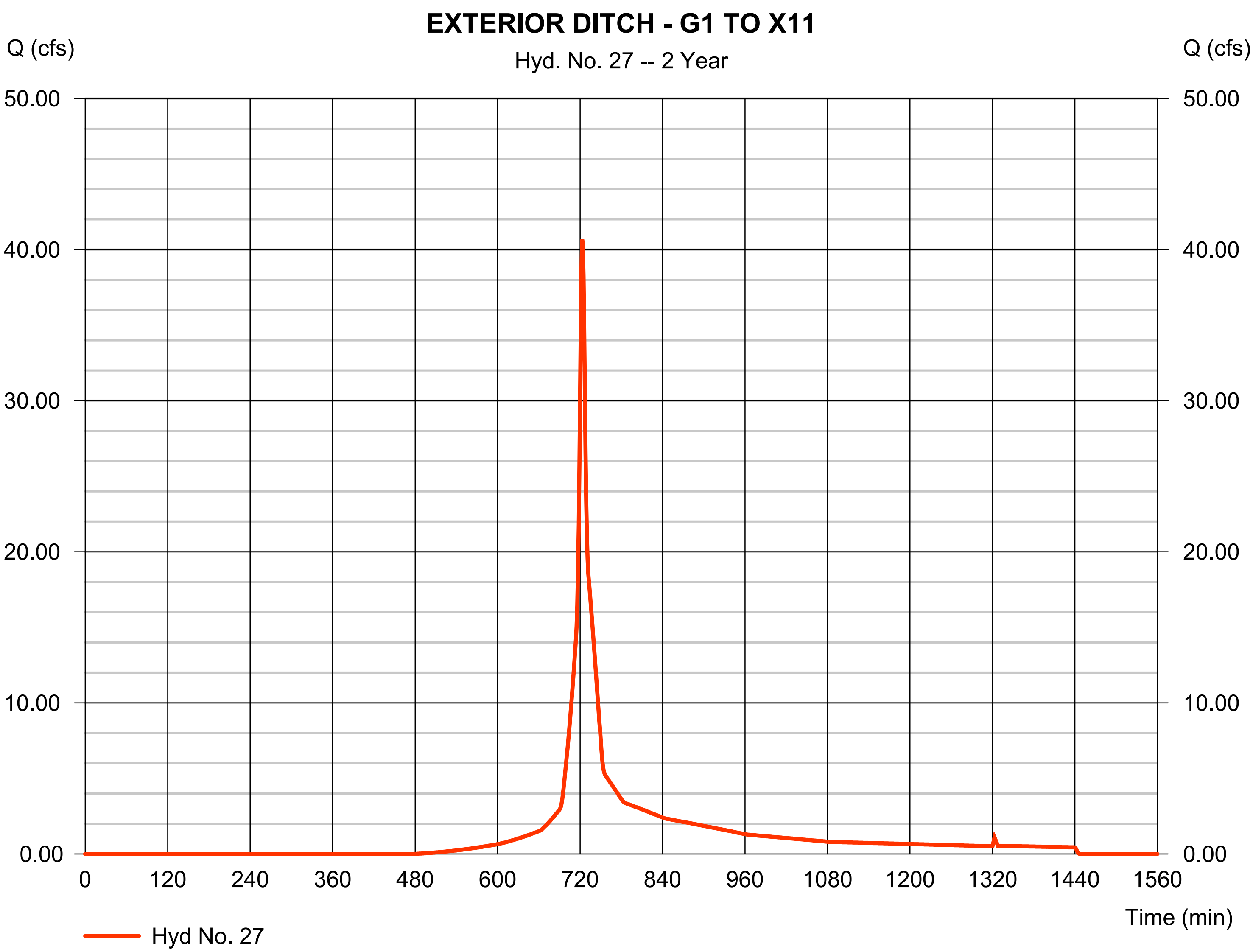
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 27

EXTERIOR DITCH - G1 TO X11

Hydrograph type	= SCS Runoff	Peak discharge	= 40.67 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 117,679 cuft
Drainage area	= 13.170 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.00 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



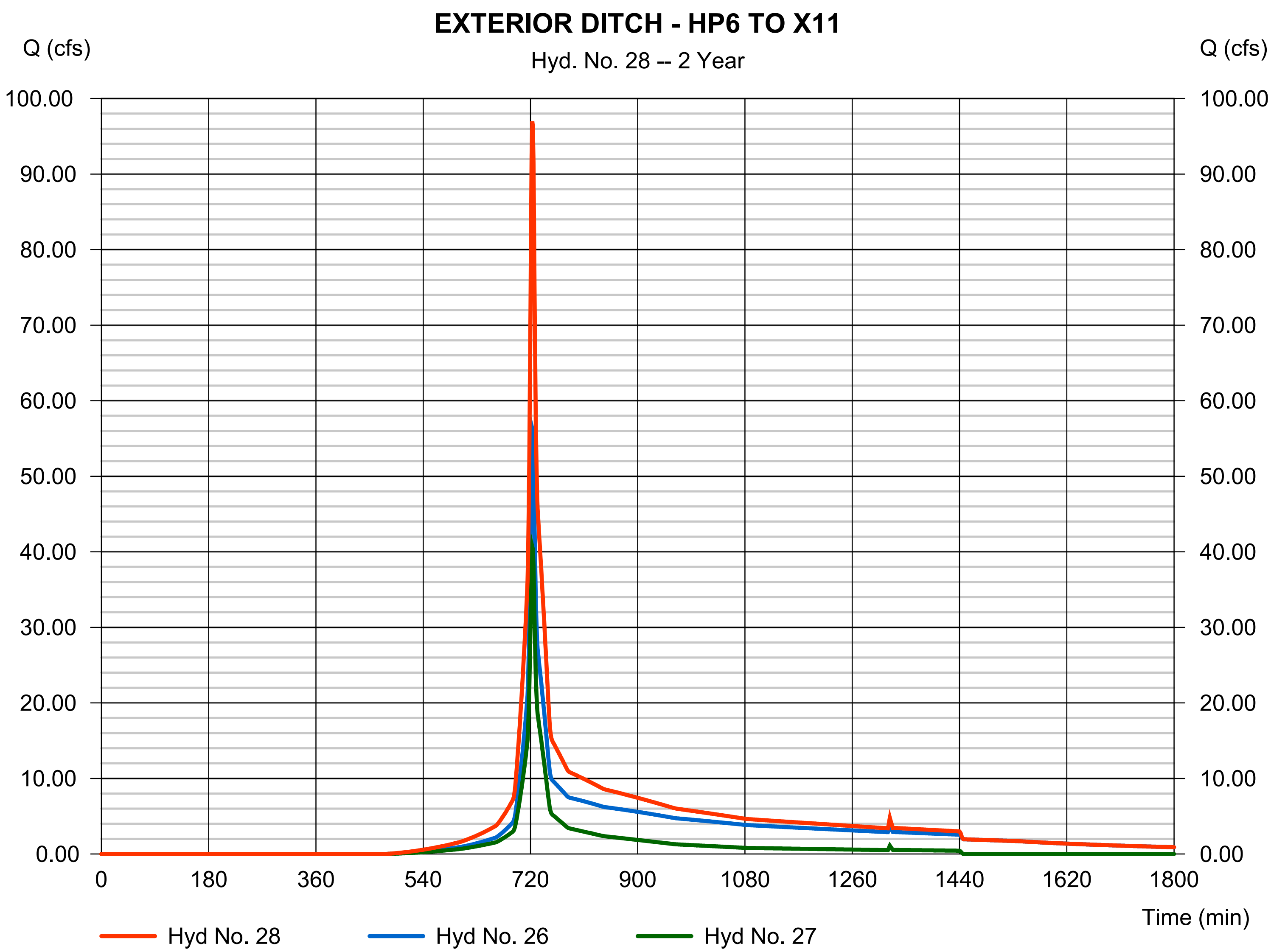
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 28

EXTERIOR DITCH - HP6 TO X11

Hydrograph type	= Combine	Peak discharge	= 96.98 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 447,212 cuft
Inflow hyds.	= 26, 27	Contrib. drain. area	= 13.170 ac



Hydrograph Report

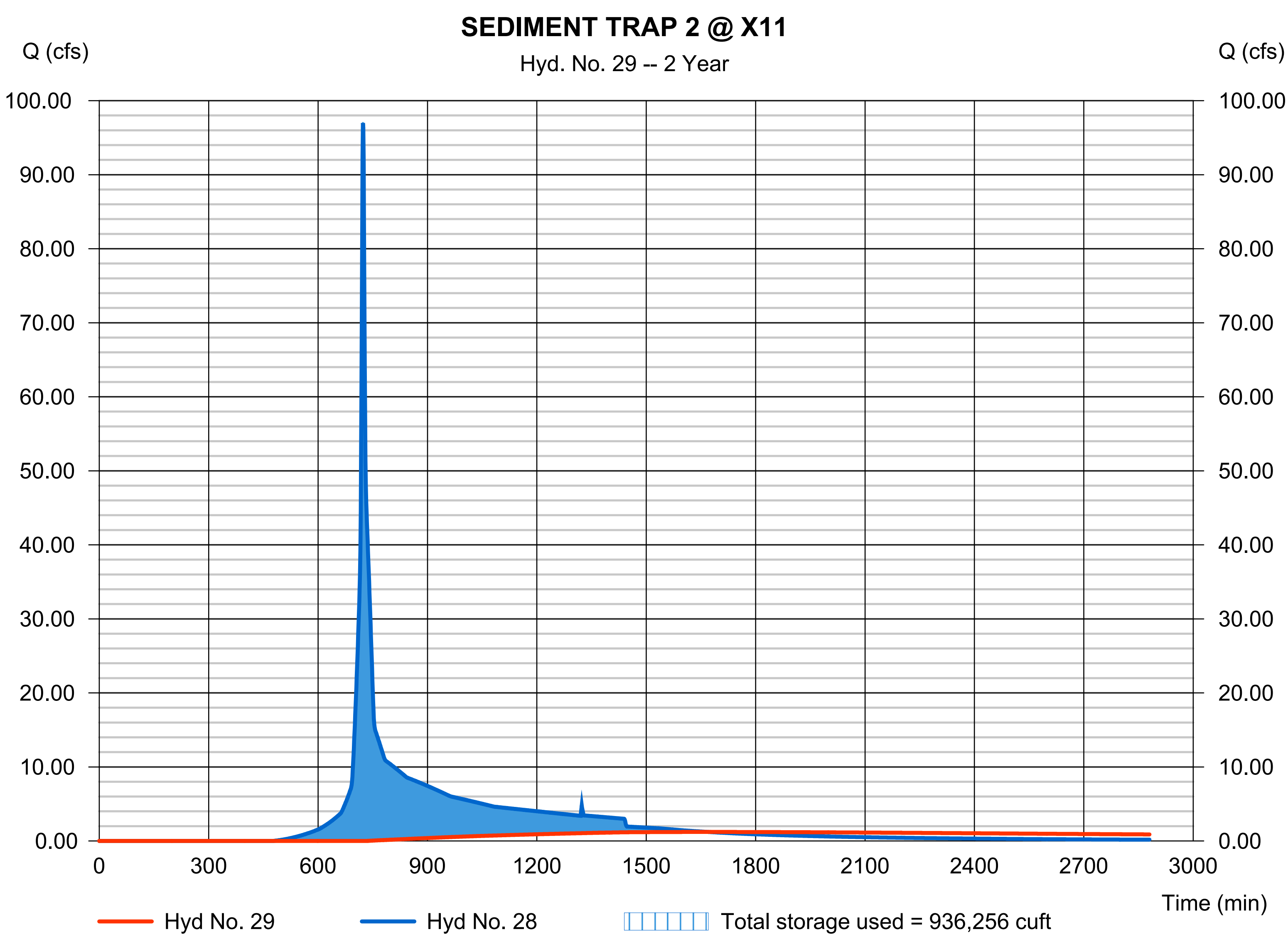
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 29

SEDIMENT TRAP 2 @ X11

Hydrograph type	= Reservoir	Peak discharge	= 1.218 cfs
Storm frequency	= 2 yrs	Time to peak	= 1669 min
Time interval	= 1 min	Hyd. volume	= 123,642 cuft
Inflow hyd. No.	= 28 - EXTERIOR DITCH - HP6 TO X11	Max. Elevation	= 245.61 ft
Reservoir name	= SEDIMENT TRAP 2 @ X11	Max. Storage	= 936,256 cuft

Storage Indication method used. Wet pond routing start elevation = 243.00 ft.



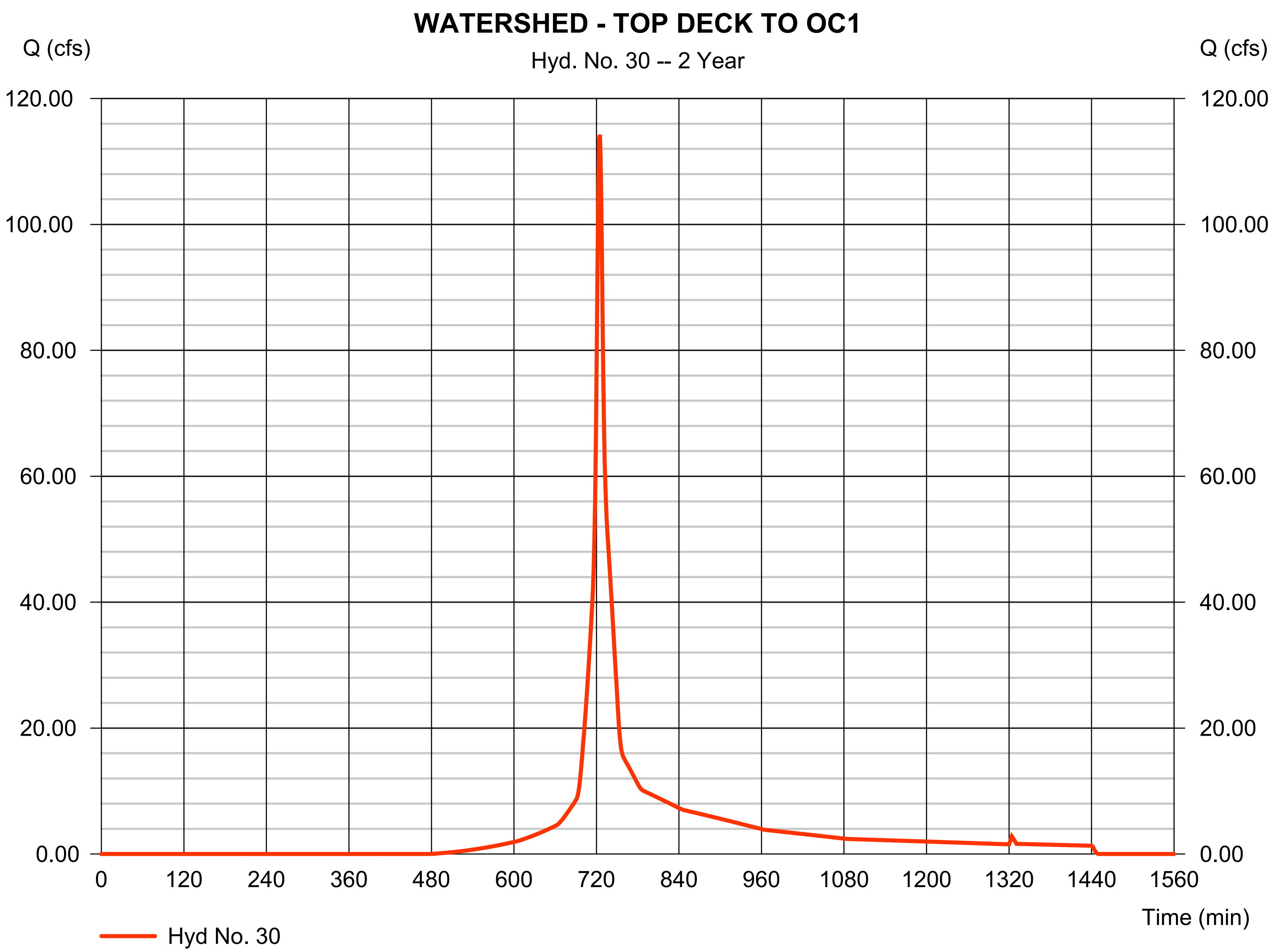
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 30

WATERSHED - TOP DECK TO OC1

Hydrograph type	= SCS Runoff	Peak discharge	= 114.25 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 351,998 cuft
Drainage area	= 38.200 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 4.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



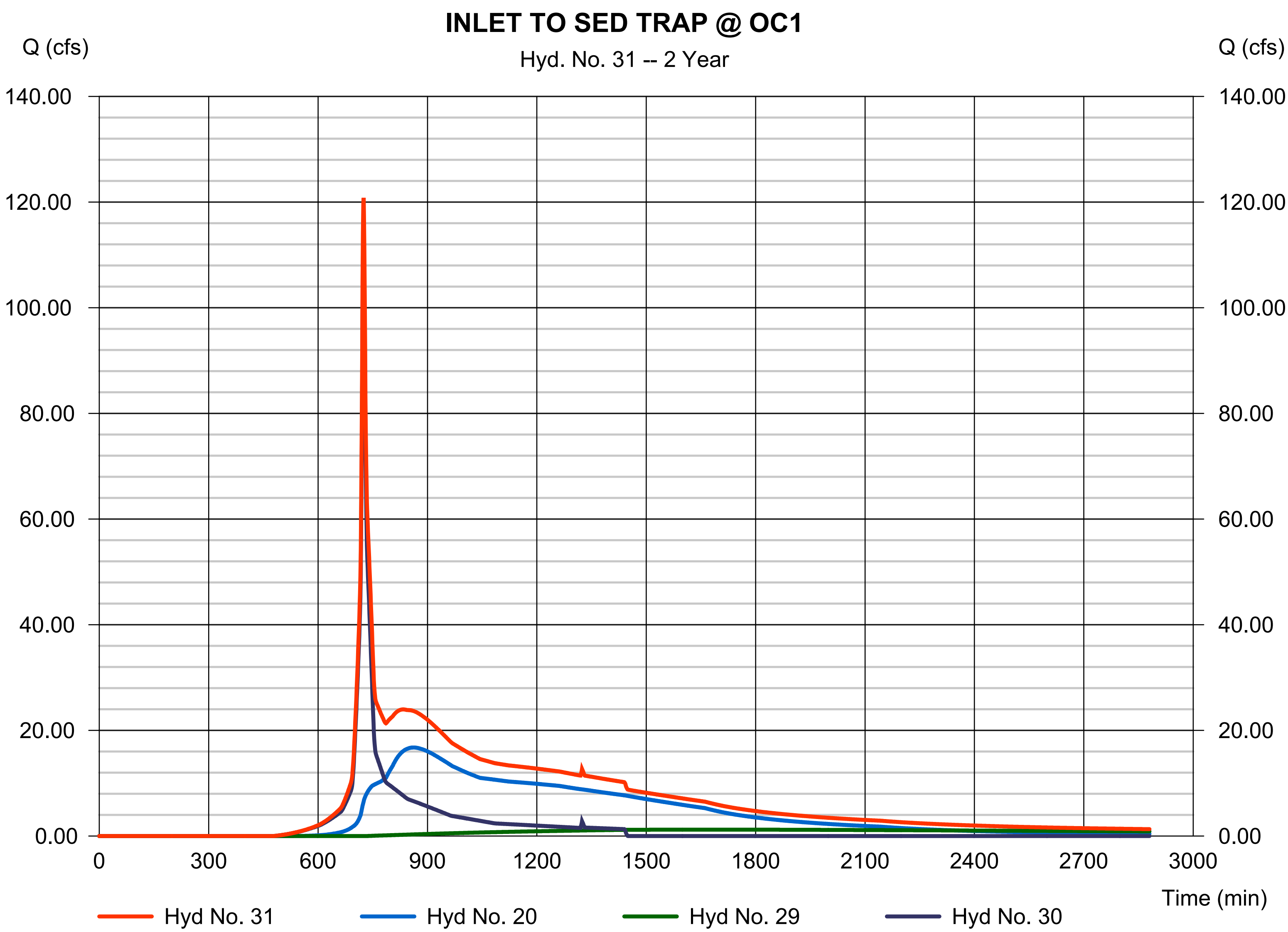
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 31

INLET TO SED TRAP @ OC1

Hydrograph type	= Combine	Peak discharge	= 120.82 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,176,480 cuft
Inflow hyds.	= 20, 29, 30	Contrib. drain. area	= 38.200 ac



Hydrograph Report

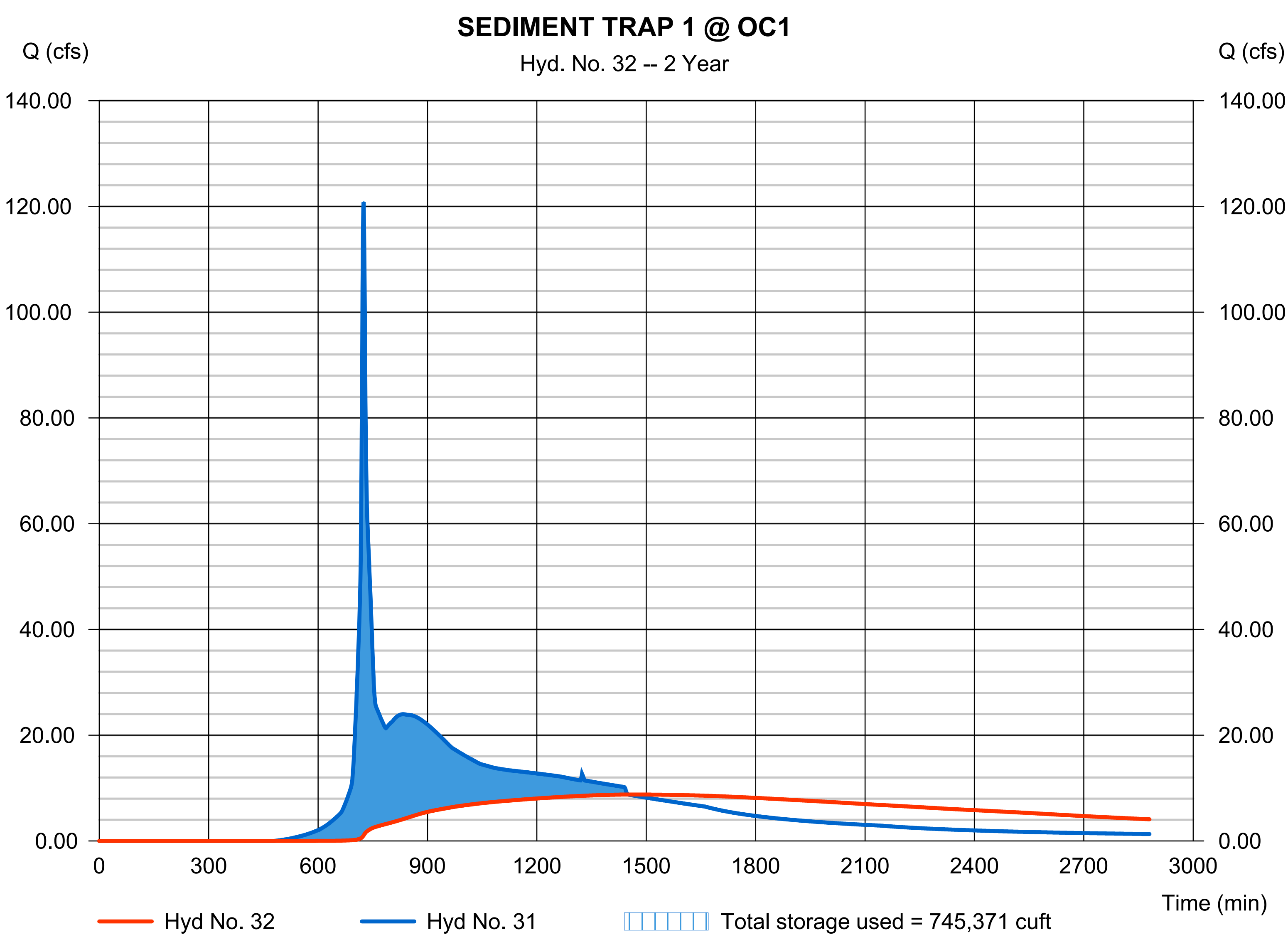
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 32

SEDIMENT TRAP 1 @ OC1

Hydrograph type	= Reservoir	Peak discharge	= 8.792 cfs
Storm frequency	= 2 yrs	Time to peak	= 1450 min
Time interval	= 1 min	Hyd. volume	= 867,638 cuft
Inflow hyd. No.	= 31 - INLET TO SED TRAP @ OC1	Max. Elevation	= 233.70 ft
Reservoir name	= SEDIMENT TRAP 1 @ OC1	Max. Storage	= 745,371 cuft

Storage Indication method used. Wet pond routing start elevation = 228.00 ft.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	13.04	1	726	42,088	------	------	------	EXTERIOR DITCH - HP5 TO X8
2	SCS Runoff	13.19	1	726	42,579	------	------	------	EXTERIOR DITCH - X7 TO X6
3	Combine	26.23	1	726	84,667	1, 2	------	------	EXTERIOR DITCH HP5 TO X6
4	SCS Runoff	6.542	1	725	20,246	------	------	------	EXTERIOR DITCH - X5 TO X3
5	Combine	32.74	1	725	104,913	3, 4	------	------	EXTERIOR DITCH HP5 TO X3
6	Reservoir	1.264	1	941	68,728	5	257.14	106,395	SEDIMENT TRAP 6 @ X3
7	SCS Runoff	4.514	1	723	13,089	------	------	------	EXTERIOR DITCH - X4 TO C1
8	Combine	4.518	1	723	81,816	6, 7	------	------	EXTERIOR DITCH HP5 TO C1
9	SCS Runoff	117.51	1	728	427,595	------	------	------	EXTERIOR DITCH - C1 TO D1
10	Combine	120.57	1	728	509,411	8, 9	------	------	EXTERIOR DITCH HP5 TO D1
11	SCS Runoff	49.91	1	725	154,444	------	------	------	EXTERIOR DITCH - D1 TO X1
12	Combine	165.46	1	726	663,856	10, 11	------	------	EXTERIOR DITCH HP5 TO X1
13	SCS Runoff	34.98	1	723	101,437	------	------	------	EXTERIOR DITCH - X1 TO X18
14	Combine	195.07	1	726	765,293	12, 13	------	------	EXTERIOR DITCH HP5 TO X18
15	Reservoir	23.97	1	777	734,608	14	249.45	403,352	SEDIMENT TRAP 5 @ X18
16	SCS Runoff	70.49	1	723	204,383	------	------	------	EXTERIOR DITCH - X17 TO X16
17	Combine	76.45	1	723	938,992	15, 16	------	------	EXTERIOR DITCH HP5 TO X16
18	SCS Runoff	29.18	1	722	79,523	------	------	------	EXTERIOR DITCH - X15 TO X14
19	Combine	104.48	1	723	1,018,515	17, 18	------	------	EXTERIOR DITCH HP5 TO X14
20	Reservoir	25.11	1	896	1,011,545	19	246.18	223,360	SEDIMENT TRAP 4 @ X14
21	SCS Runoff	83.87	1	725	259,569	------	------	------	EXTERIOR DITCH - HP6 TO X10
22	Reservoir	8.463	1	776	244,209	21	251.41	203,980	SEDIMENT TRAP 3 @ X10
23	SCS Runoff	10.68	1	723	30,960	------	------	------	EXTERIOR DITCH - X9 TO H1
24	Combine	12.72	1	723	275,169	22, 23	------	------	EXTERIOR DITCH HP6 TO H1
25	SCS Runoff	66.80	1	723	193,686	------	------	------	EXTERIOR DITCH - H1 TO G1
26	Combine	79.52	1	723	468,855	24, 25	------	------	EXTERIOR DITCH - HP6 TO G1
27	SCS Runoff	57.16	1	723	165,747	------	------	------	EXTERIOR DITCH - G1 TO X11
28	Combine	136.68	1	723	634,601	26, 27	------	------	EXTERIOR DITCH - HP6 TO X11
29	Reservoir	3.909	1	1388	266,973	28	246.23	1,034,152	SEDIMENT TRAP 2 @ X11
30	SCS Runoff	160.20	1	725	495,778	------	------	------	WATERSHED - TOP DECK TO OC1
31	Combine	169.28	1	725	1,774,297	20, 29, 30	------	------	INLET TO SED TRAP @ OC1
32	Reservoir	21.22	1	1060	1,405,866	31	234.87	908,738	SEDIMENT TRAP 1 @ OC1

Exterior Ditch [with ponds].gpw	Return Period: 5 Year	Friday, 01 / 30 / 2015

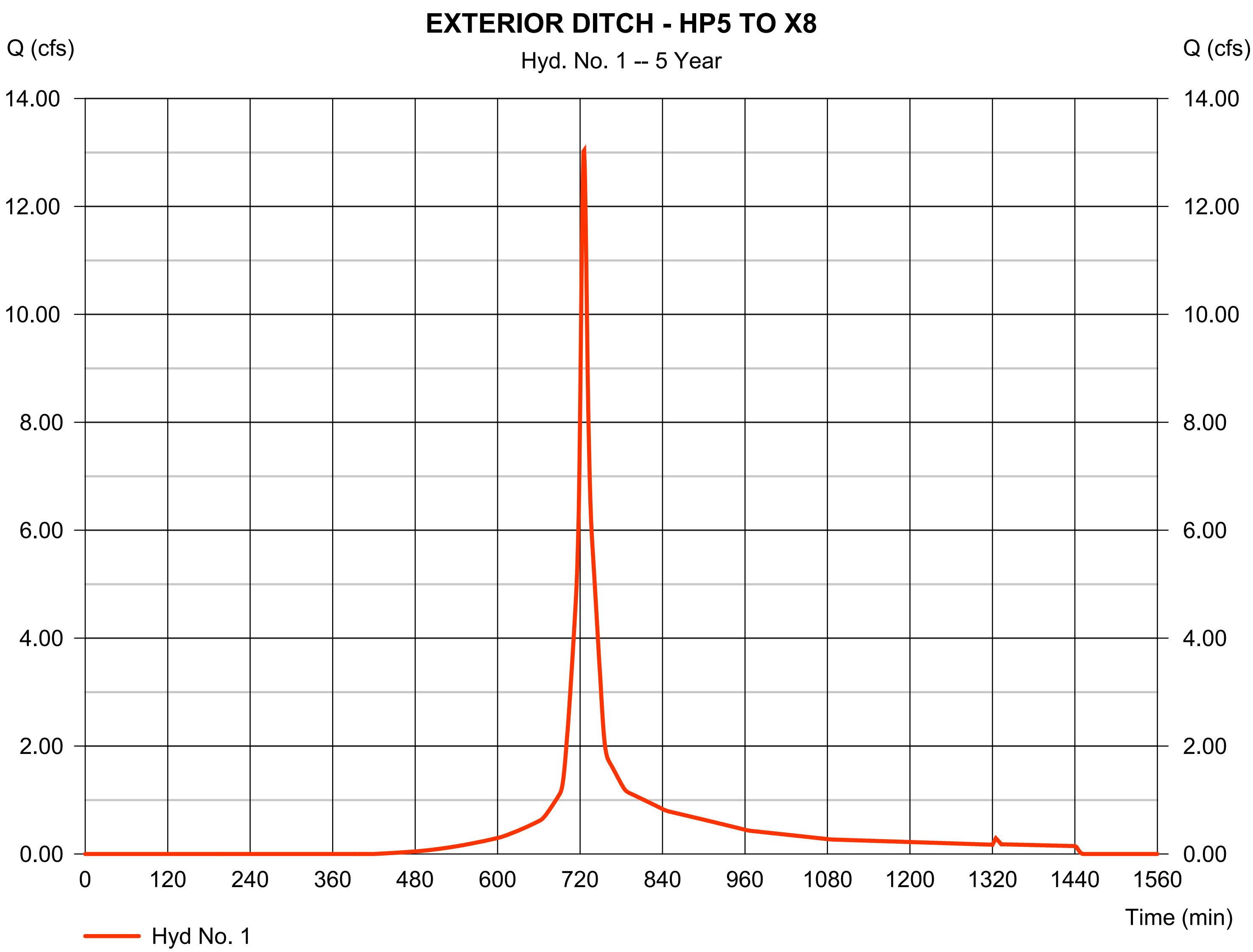
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

EXTERIOR DITCH - HP5 TO X8

Hydrograph type	= SCS Runoff	Peak discharge	= 13.04 cfs
Storm frequency	= 5 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 42,088 cuft
Drainage area	= 3.430 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.30 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



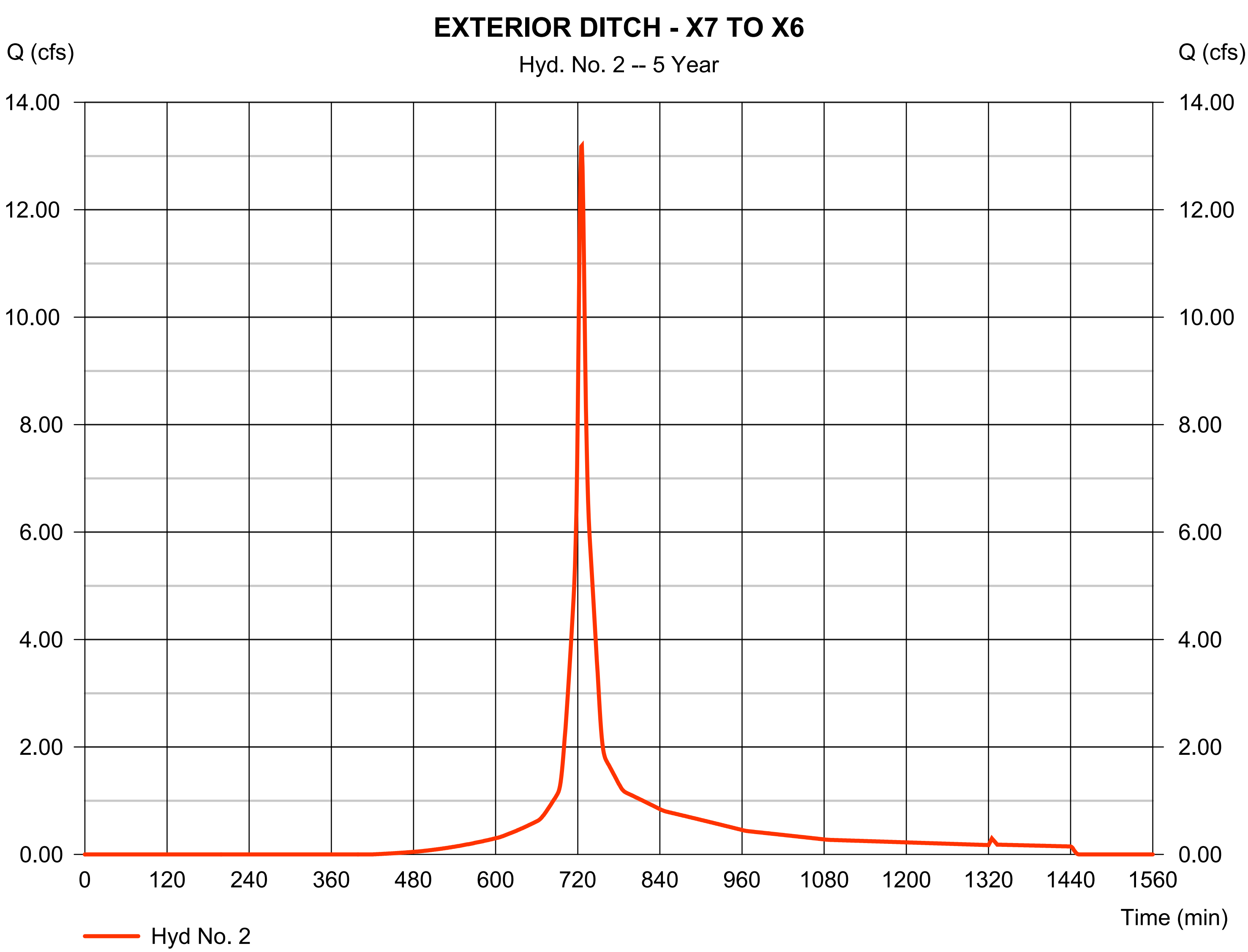
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 2

EXTERIOR DITCH - X7 TO X6

Hydrograph type	= SCS Runoff	Peak discharge	= 13.19 cfs
Storm frequency	= 5 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 42,579 cuft
Drainage area	= 3.470 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.70 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



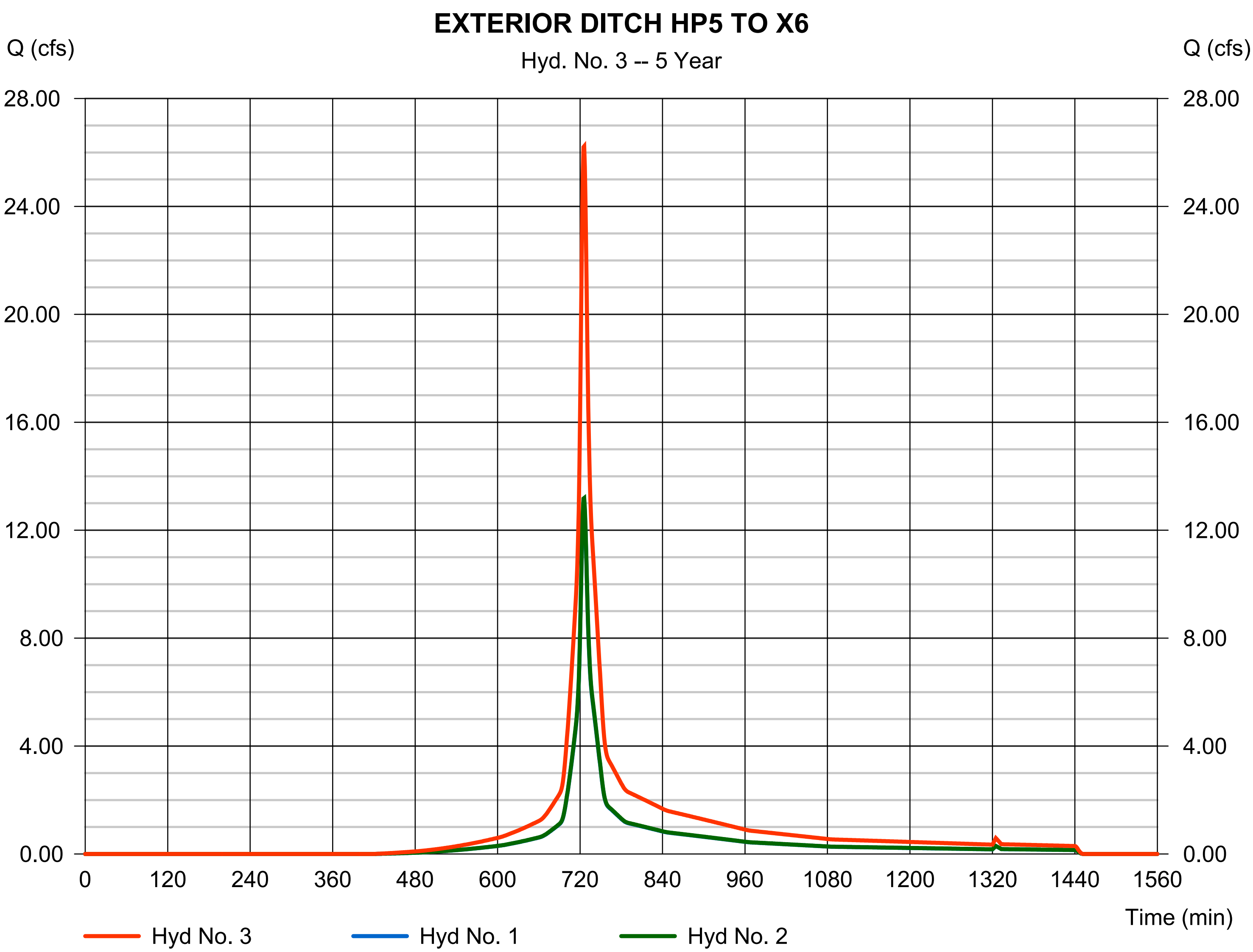
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 3

EXTERIOR DITCH HP5 TO X6

Hydrograph type	= Combine	Peak discharge	= 26.23 cfs
Storm frequency	= 5 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 84,667 cuft
Inflow hyds.	= 1, 2	Contrib. drain. area	= 6.900 ac



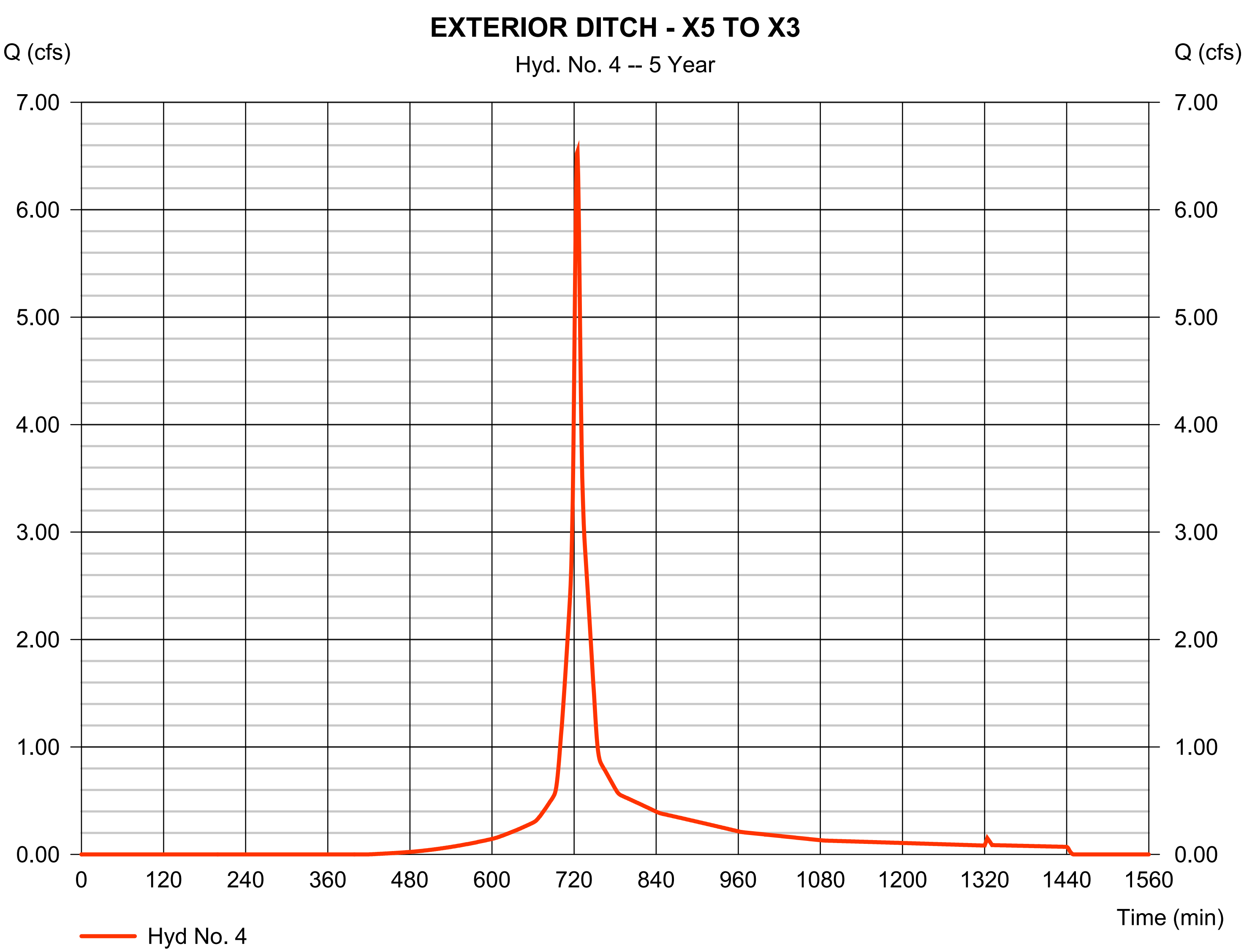
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 4

EXTERIOR DITCH - X5 TO X3

Hydrograph type	= SCS Runoff	Peak discharge	= 6.542 cfs
Storm frequency	= 5 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 20,246 cuft
Drainage area	= 1.560 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.90 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



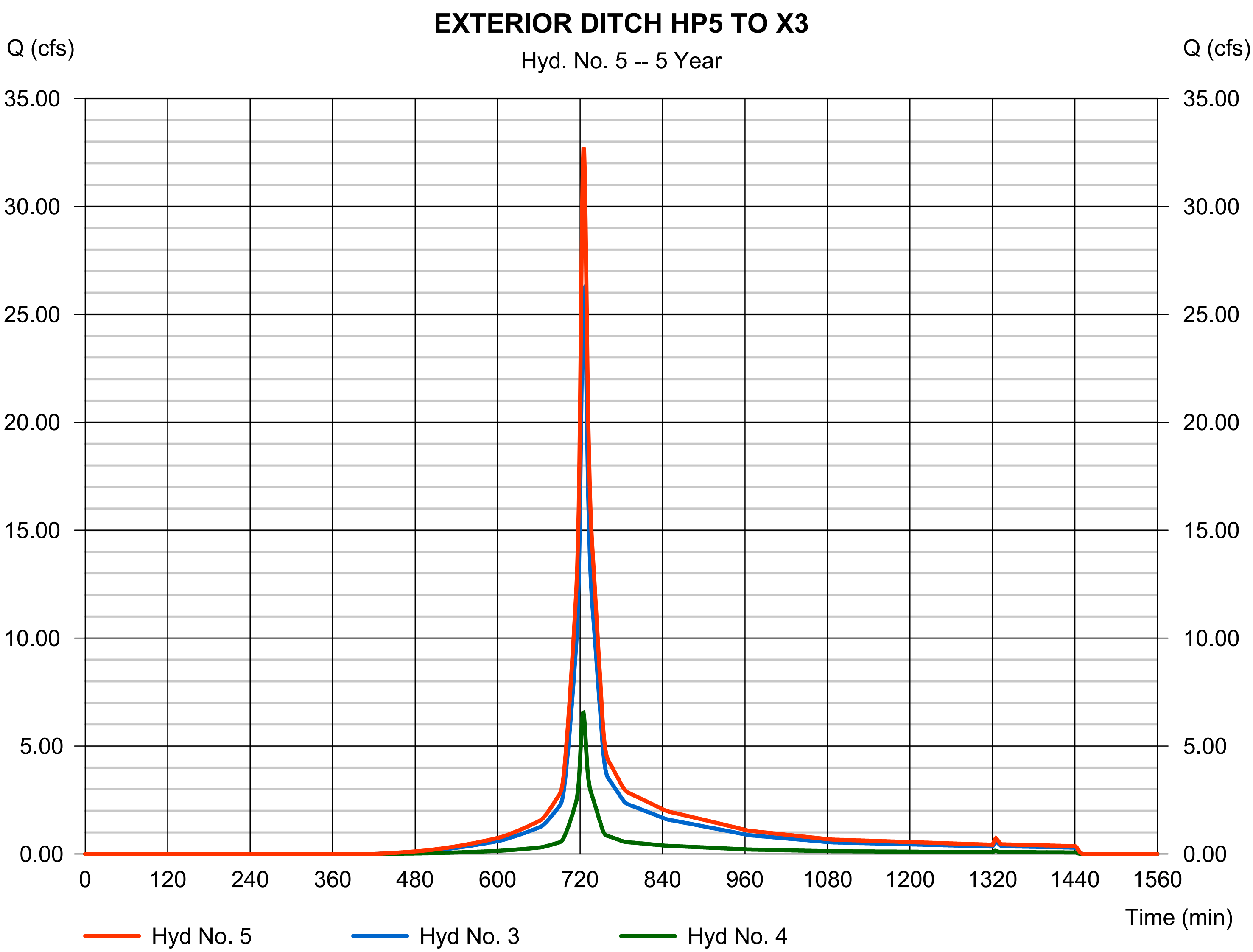
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 5

EXTERIOR DITCH HP5 TO X3

Hydrograph type	= Combine	Peak discharge	= 32.74 cfs
Storm frequency	= 5 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 104,913 cuft
Inflow hyds.	= 3, 4	Contrib. drain. area	= 1.560 ac



Hydrograph Report

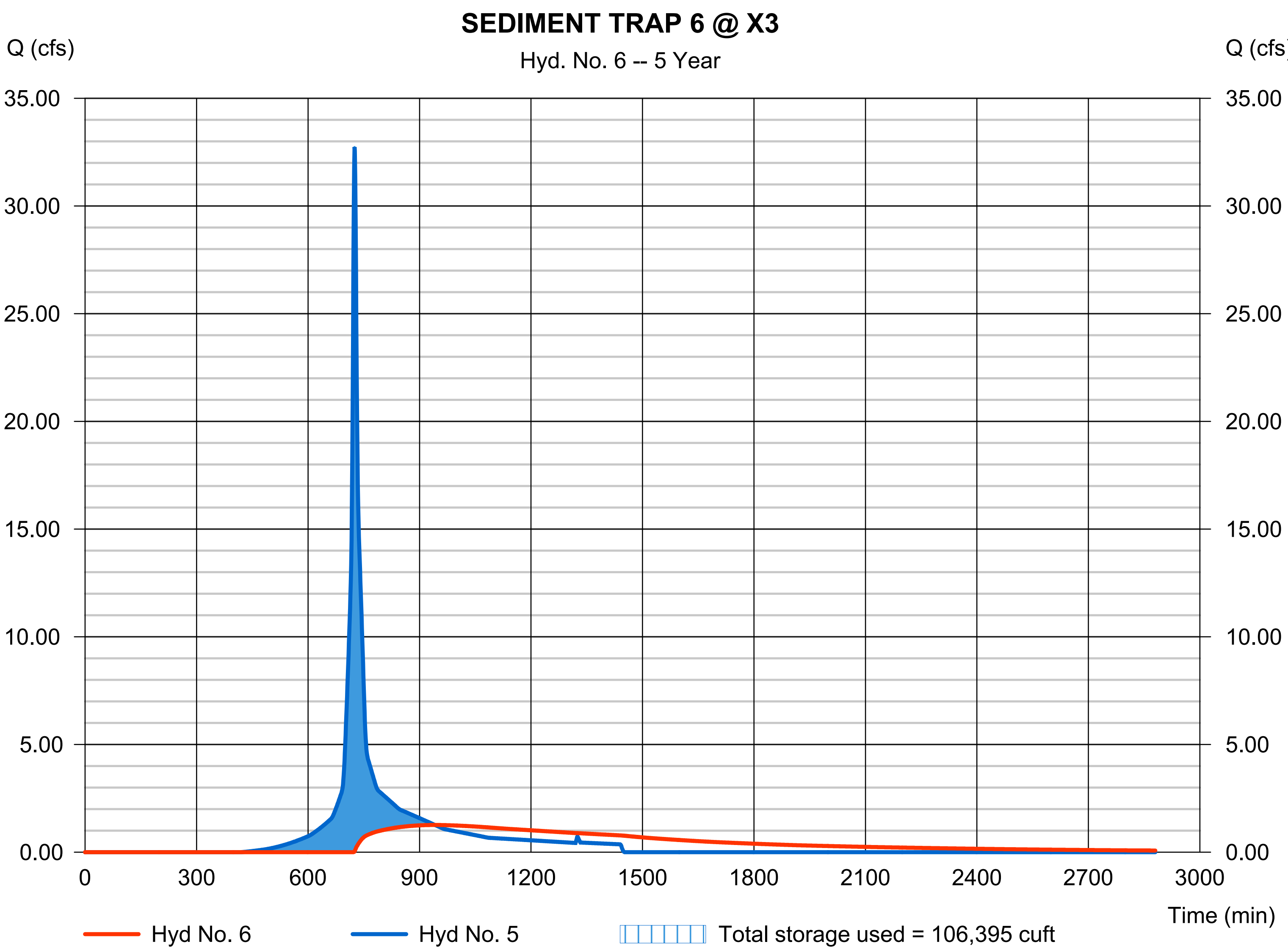
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 6

SEDIMENT TRAP 6 @ X3

Hydrograph type	= Reservoir	Peak discharge	= 1.264 cfs
Storm frequency	= 5 yrs	Time to peak	= 941 min
Time interval	= 1 min	Hyd. volume	= 68,728 cuft
Inflow hyd. No.	= 5 - EXTERIOR DITCH HP5 TO X3	Max. Elevation	= 257.14 ft
Reservoir name	= SEDIMENT TRAP 6 @ X3	Max. Storage	= 106,395 cuft

Storage Indication method used. Wet pond routing start elevation = 254.00 ft.



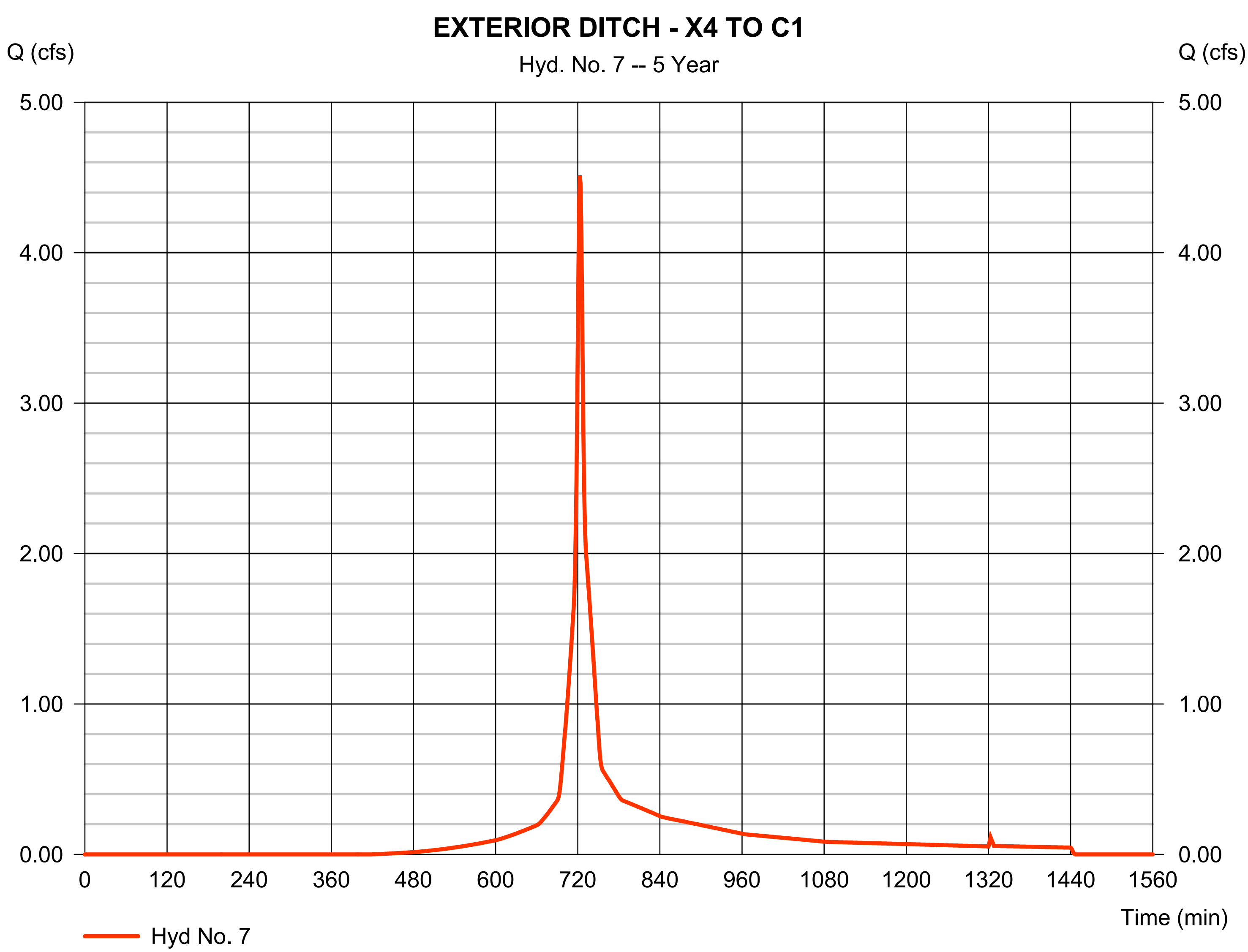
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 7

EXTERIOR DITCH - X4 TO C1

Hydrograph type	= SCS Runoff	Peak discharge	= 4.514 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 13,089 cuft
Drainage area	= 1.040 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.70 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



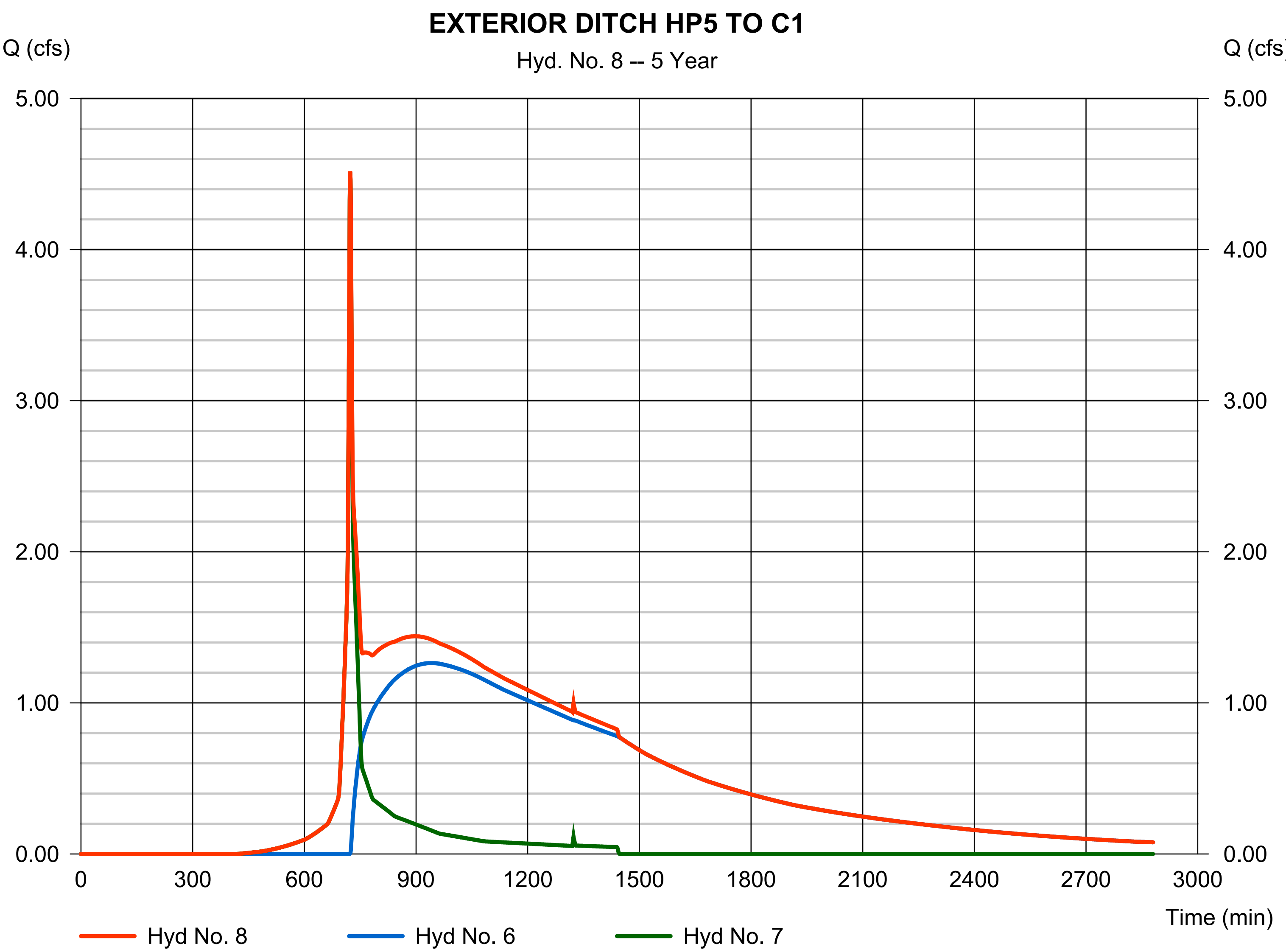
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 8

EXTERIOR DITCH HP5 TO C1

Hydrograph type	= Combine	Peak discharge	= 4.518 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 81,816 cuft
Inflow hyds.	= 6, 7	Contrib. drain. area	= 1.040 ac



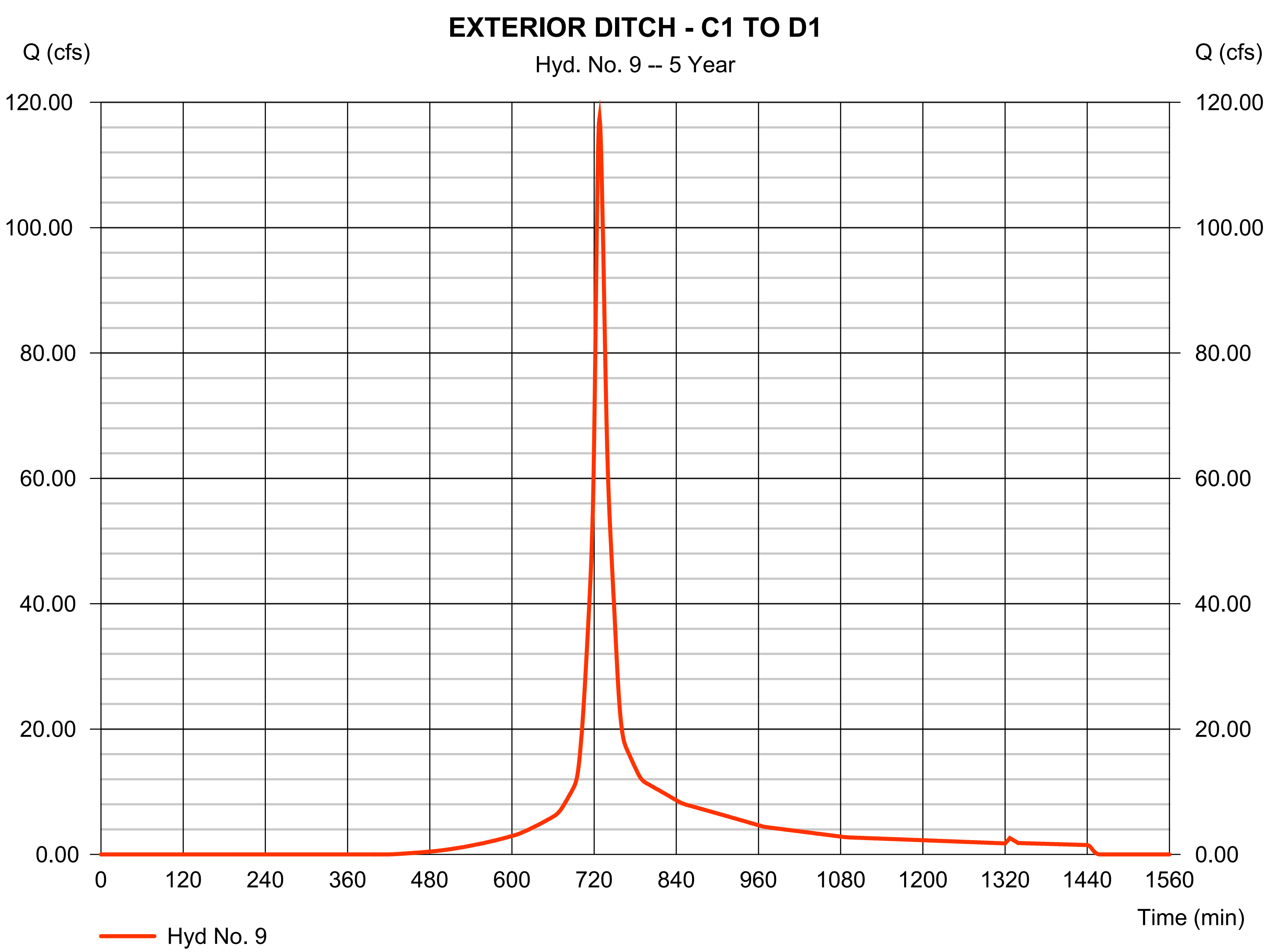
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 9

EXTERIOR DITCH - C1 TO D1

Hydrograph type	= SCS Runoff	Peak discharge	= 117.51 cfs
Storm frequency	= 5 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 427,595 cuft
Drainage area	= 33.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.00 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



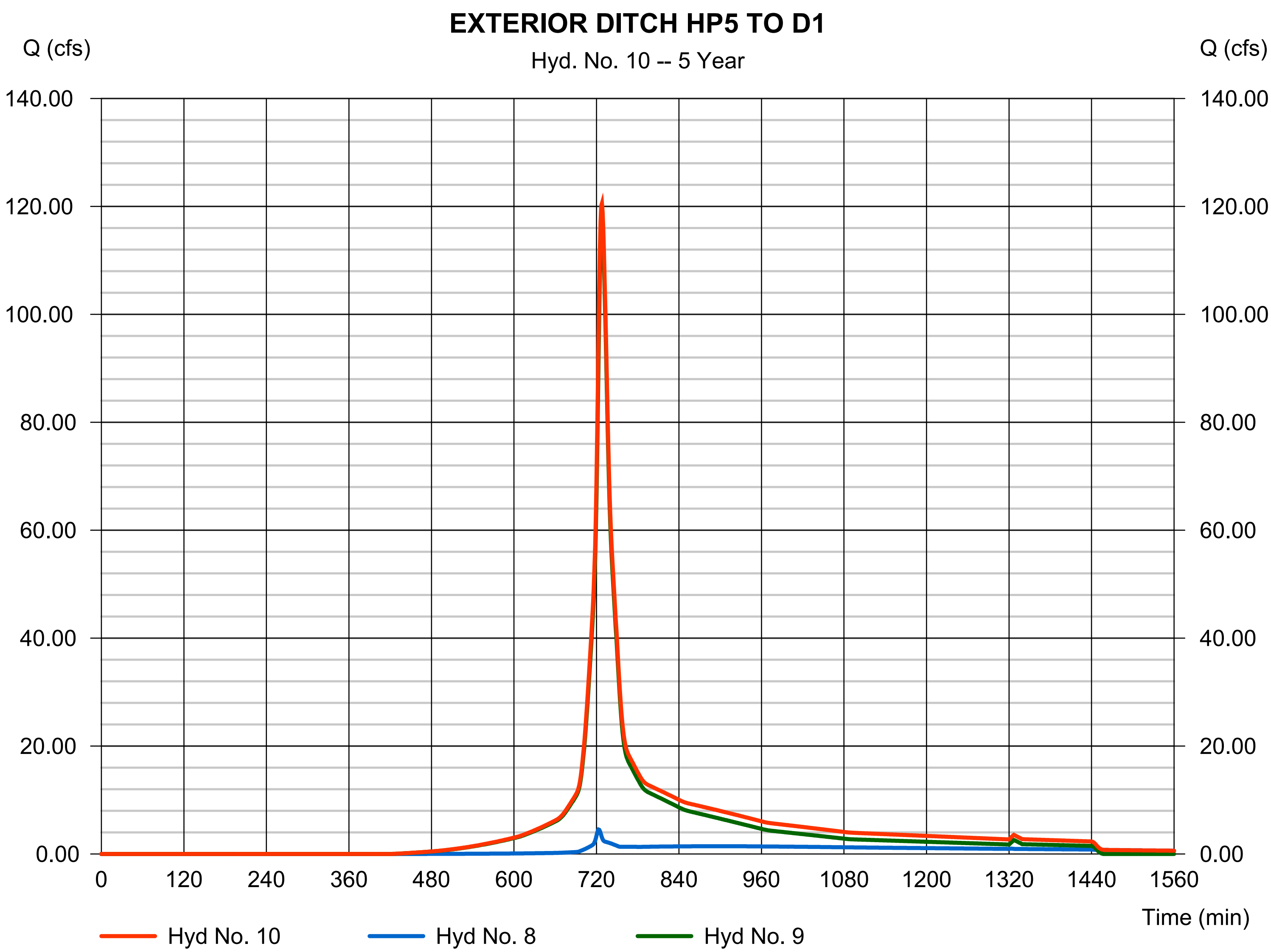
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 10

EXTERIOR DITCH HP5 TO D1

Hydrograph type	= Combine	Peak discharge	= 120.57 cfs
Storm frequency	= 5 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 509,411 cuft
Inflow hyds.	= 8, 9	Contrib. drain. area	= 33.380 ac



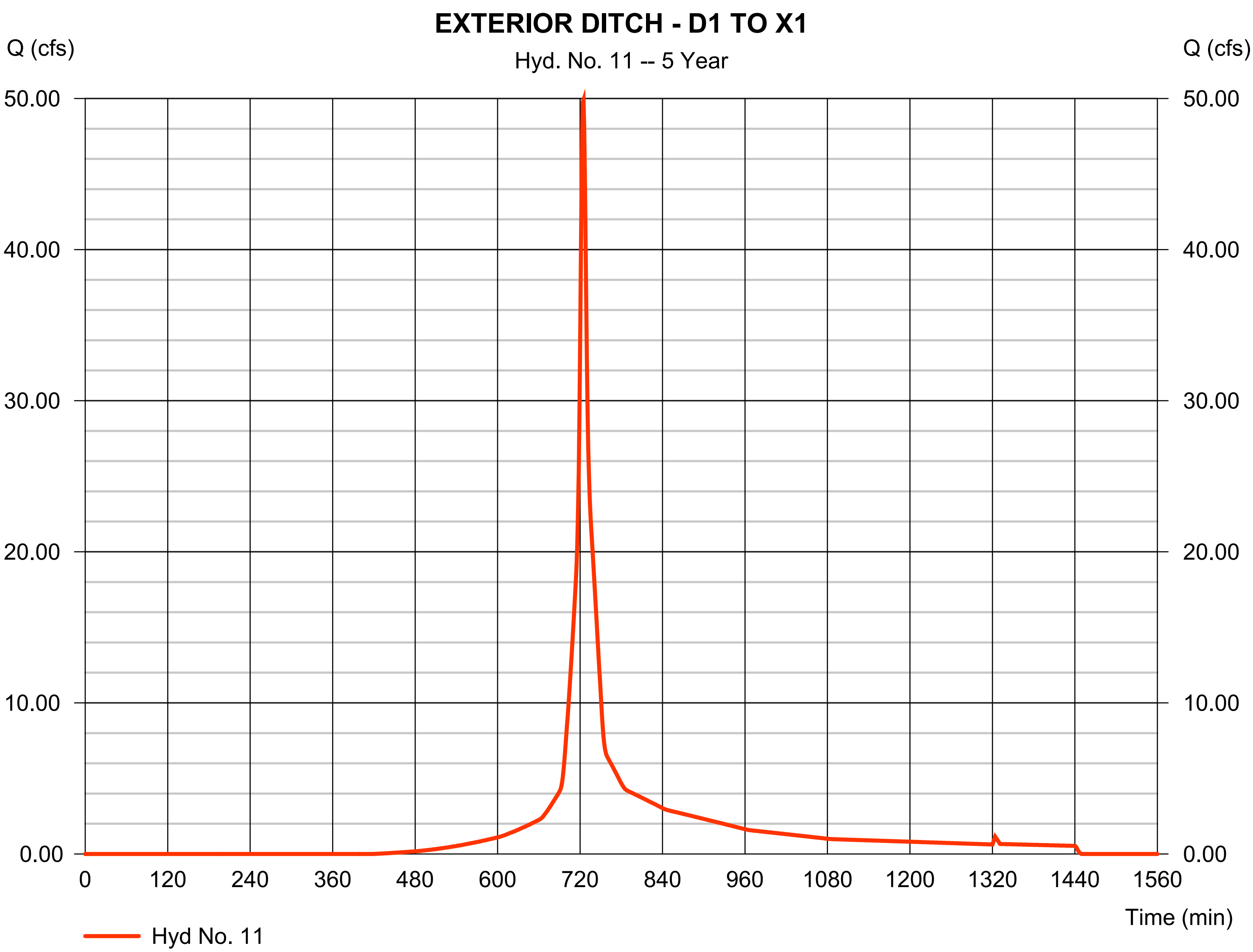
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 11

EXTERIOR DITCH - D1 TO X1

Hydrograph type	= SCS Runoff	Peak discharge	= 49.91 cfs
Storm frequency	= 5 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 154,444 cuft
Drainage area	= 11.900 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.20 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



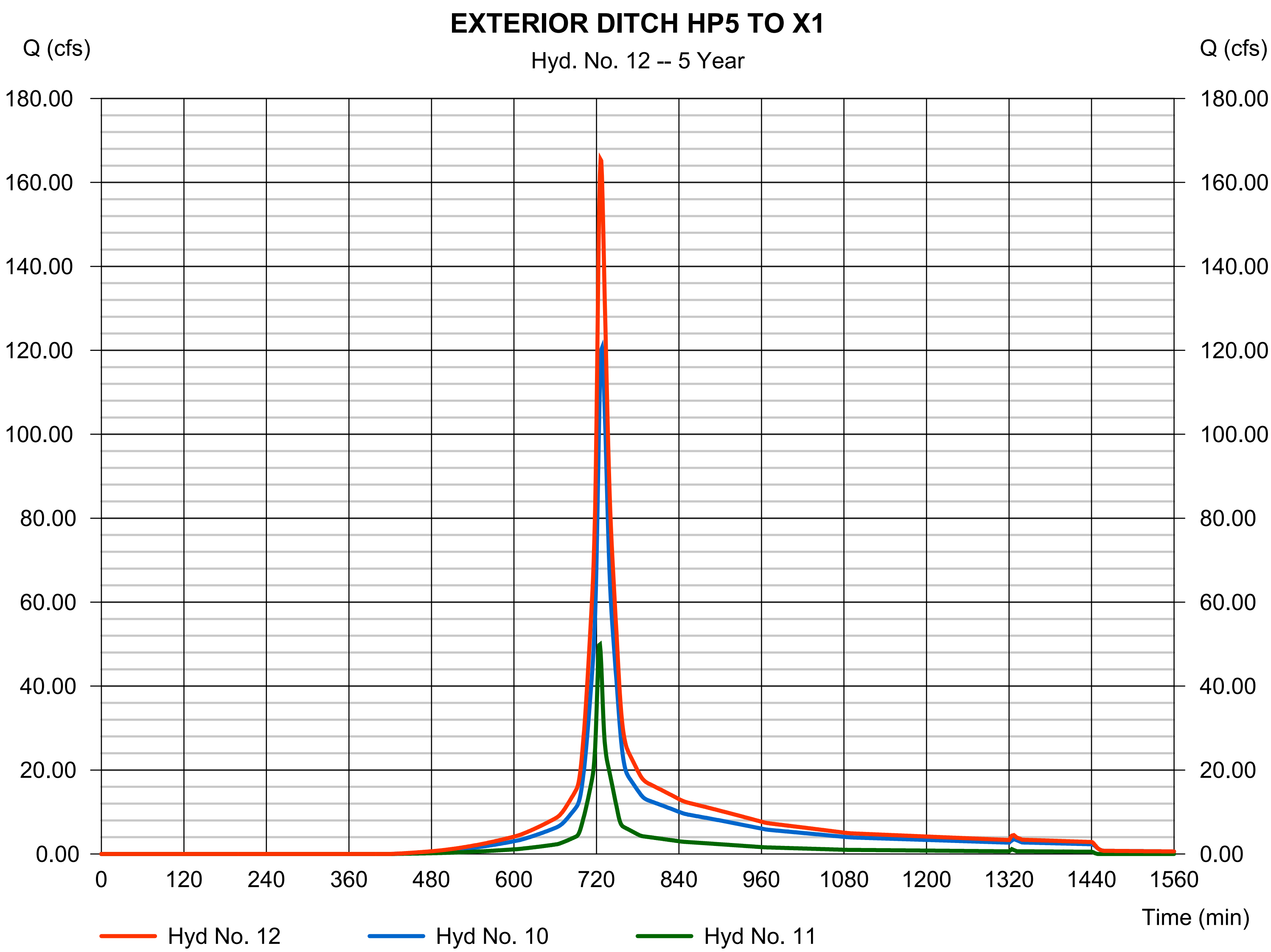
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 12

EXTERIOR DITCH HP5 TO X1

Hydrograph type	= Combine	Peak discharge	= 165.46 cfs
Storm frequency	= 5 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 663,856 cuft
Inflow hyds.	= 10, 11	Contrib. drain. area	= 11.900 ac



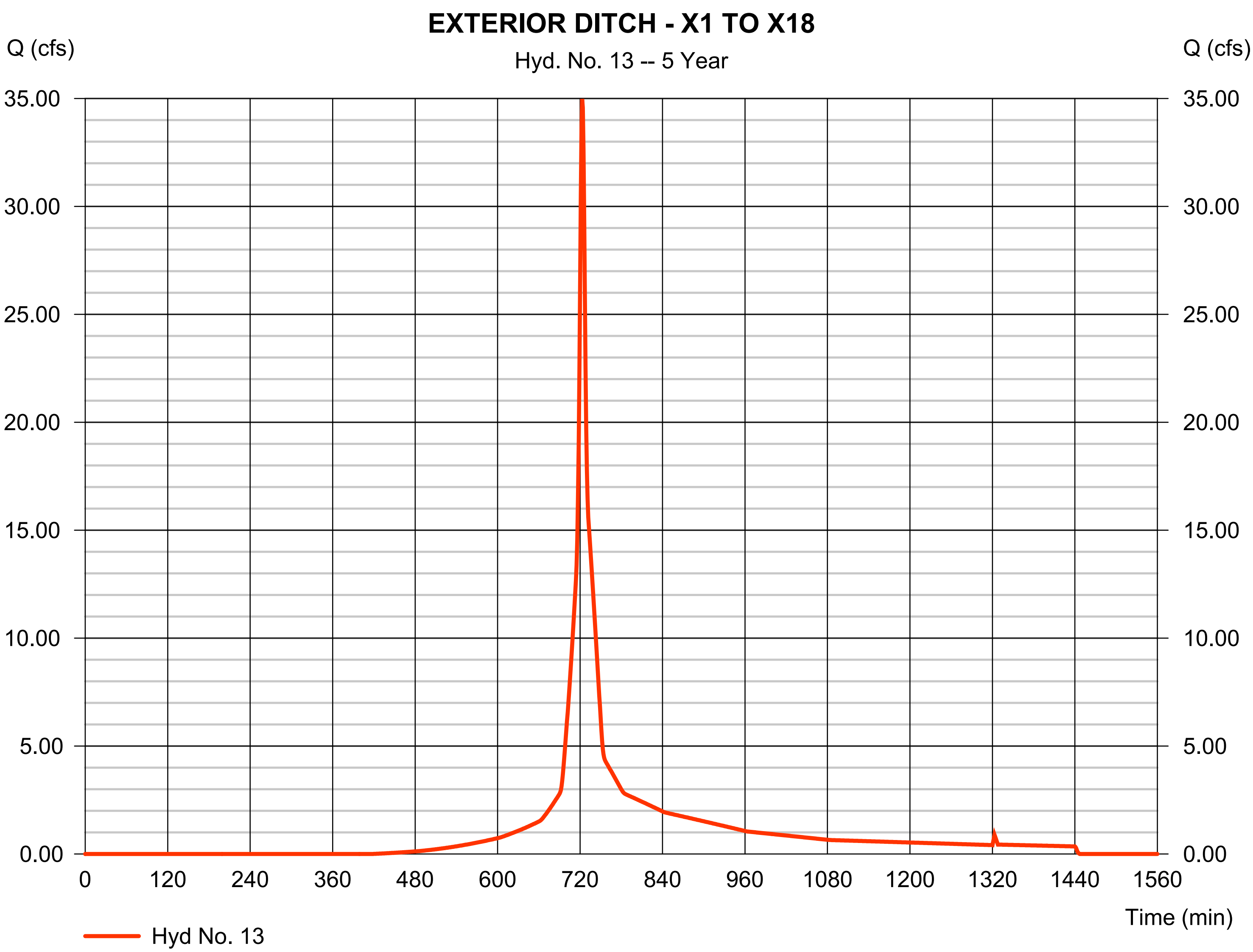
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 | Friday, 01 / 30 / 2015

Hyd. No. 13

EXTERIOR DITCH - X1 TO X18

Hydrograph type	= SCS Runoff	Peak discharge	= 34.98 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 101,437 cuft
Drainage area	= 8.060 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.80 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



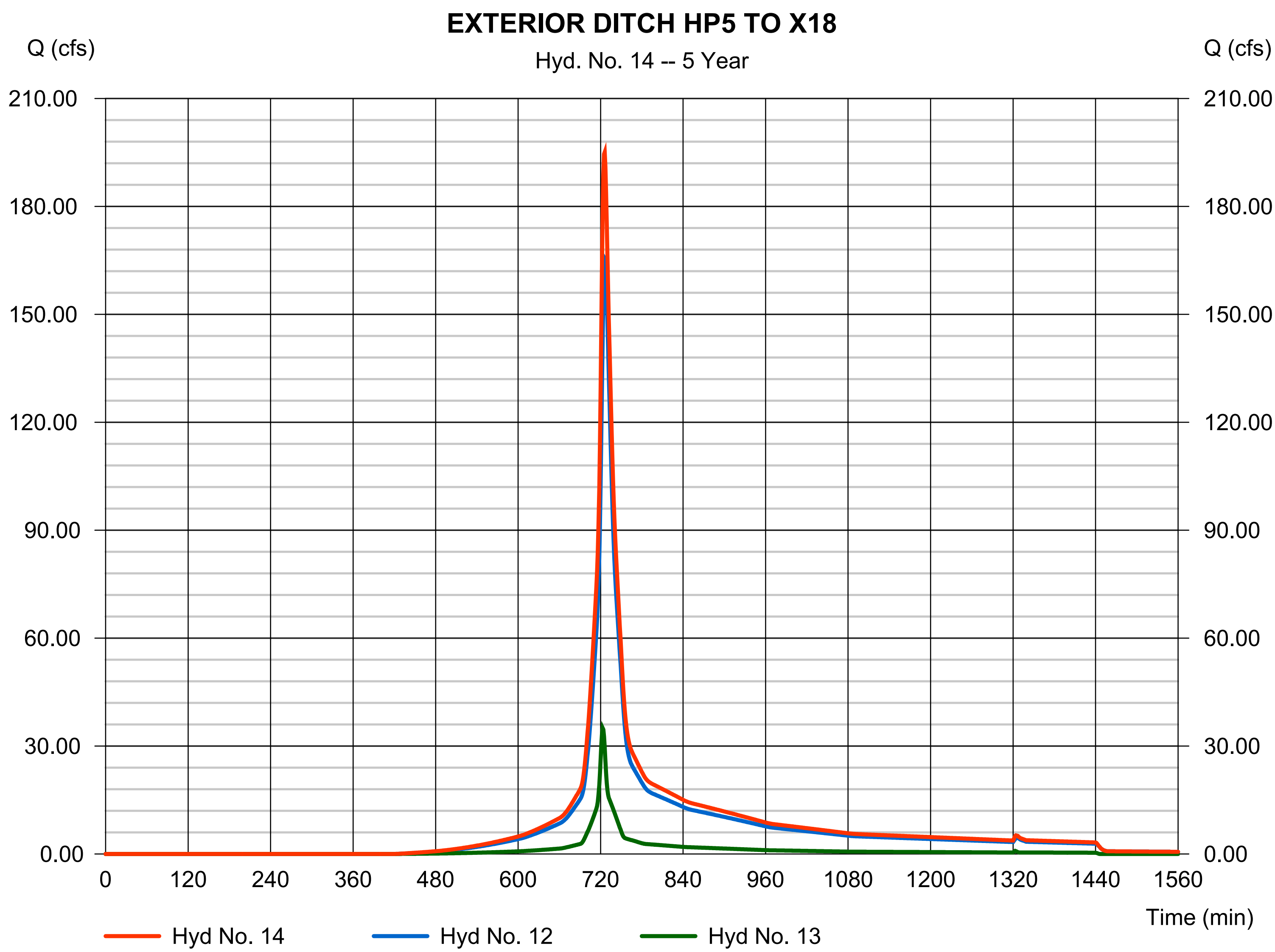
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 14

EXTERIOR DITCH HP5 TO X18

Hydrograph type	= Combine	Peak discharge	= 195.07 cfs
Storm frequency	= 5 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 765,293 cuft
Inflow hyds.	= 12, 13	Contrib. drain. area	= 8.060 ac



Hydrograph Report

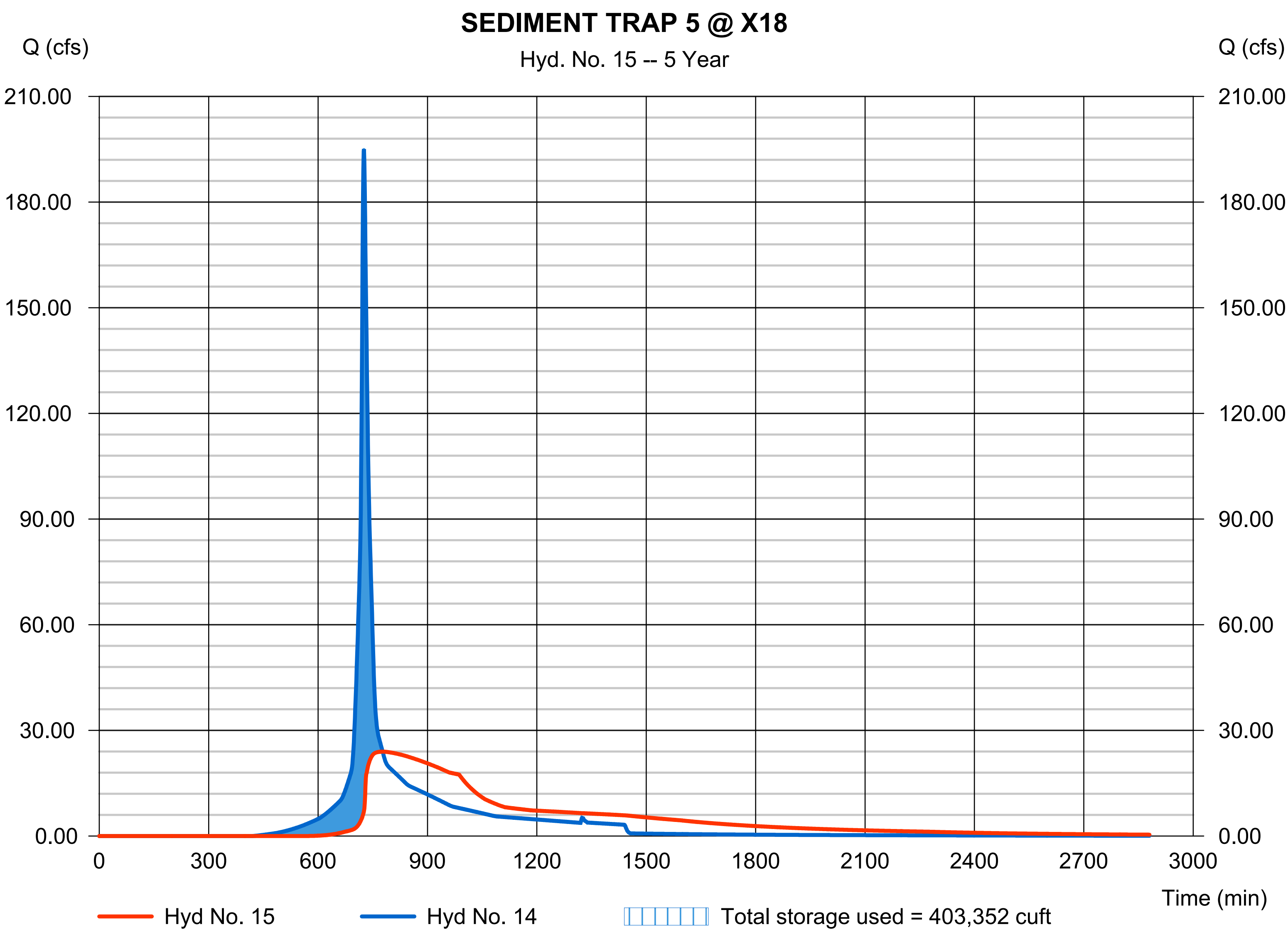
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 15

SEDIMENT TRAP 5 @ X18

Hydrograph type	= Reservoir	Peak discharge	= 23.97 cfs
Storm frequency	= 5 yrs	Time to peak	= 777 min
Time interval	= 1 min	Hyd. volume	= 734,608 cuft
Inflow hyd. No.	= 14 - EXTERIOR DITCH HP5 TO X18	Max. Elevation	= 249.45 ft
Reservoir name	= SEDIMENT TRAP 5 @ X18	Max. Storage	= 403,352 cuft

Storage Indication method used. Wet pond routing start elevation = 242.00 ft.



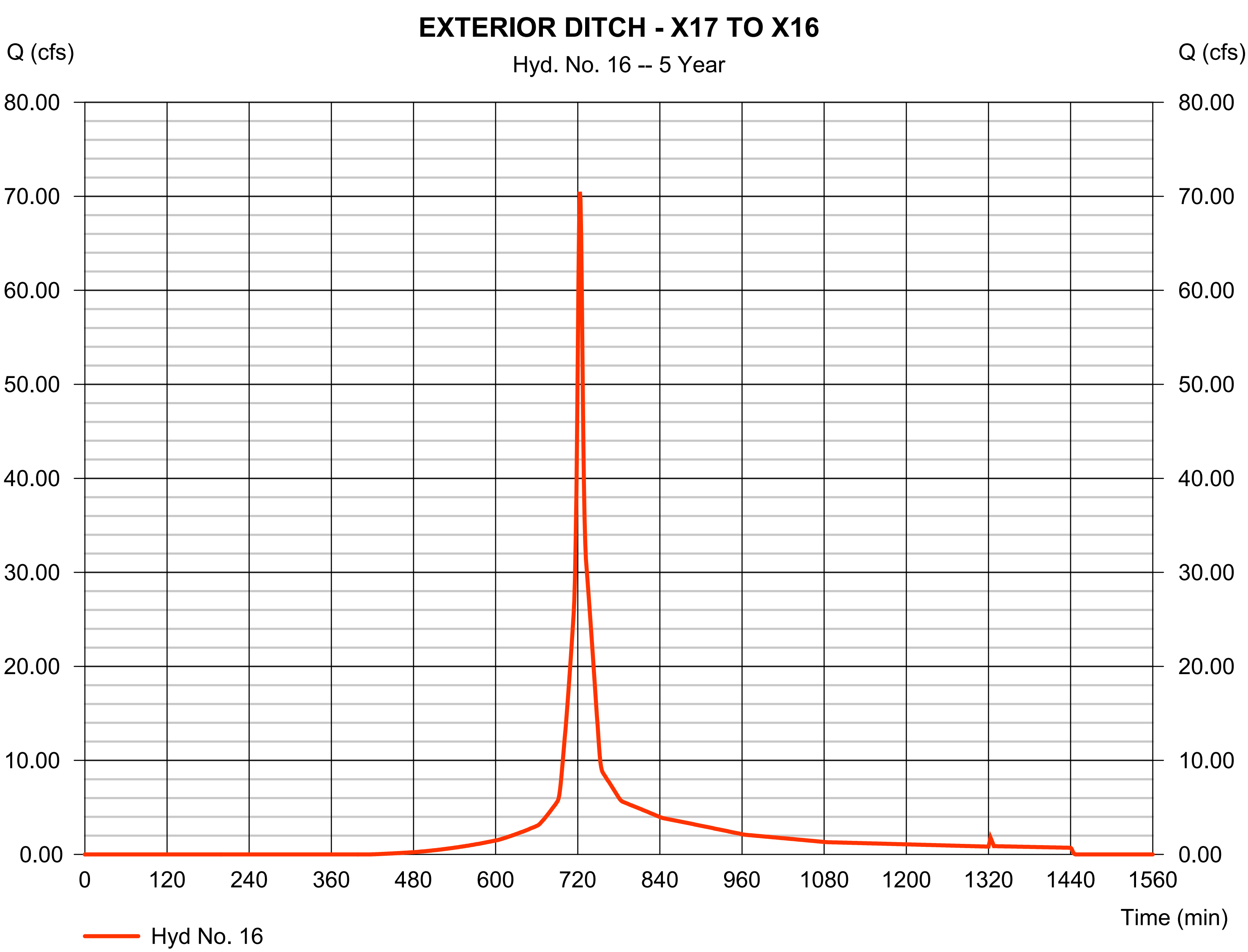
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 16

EXTERIOR DITCH - X17 TO X16

Hydrograph type	= SCS Runoff	Peak discharge	= 70.49 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 204,383 cuft
Drainage area	= 16.240 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



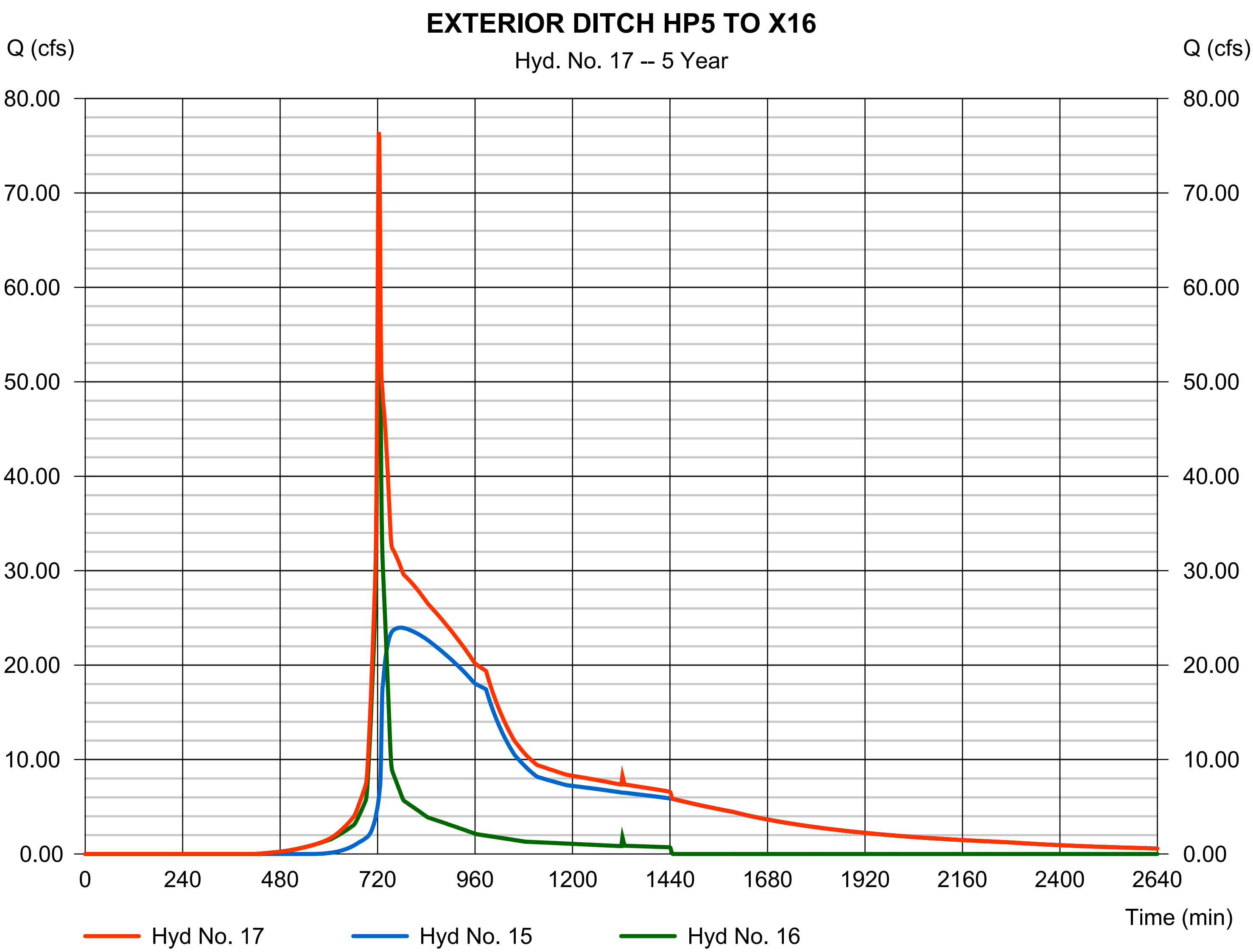
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 17

EXTERIOR DITCH HP5 TO X16

Hydrograph type	= Combine	Peak discharge	= 76.45 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 938,992 cuft
Inflow hyds.	= 15, 16	Contrib. drain. area	= 16.240 ac



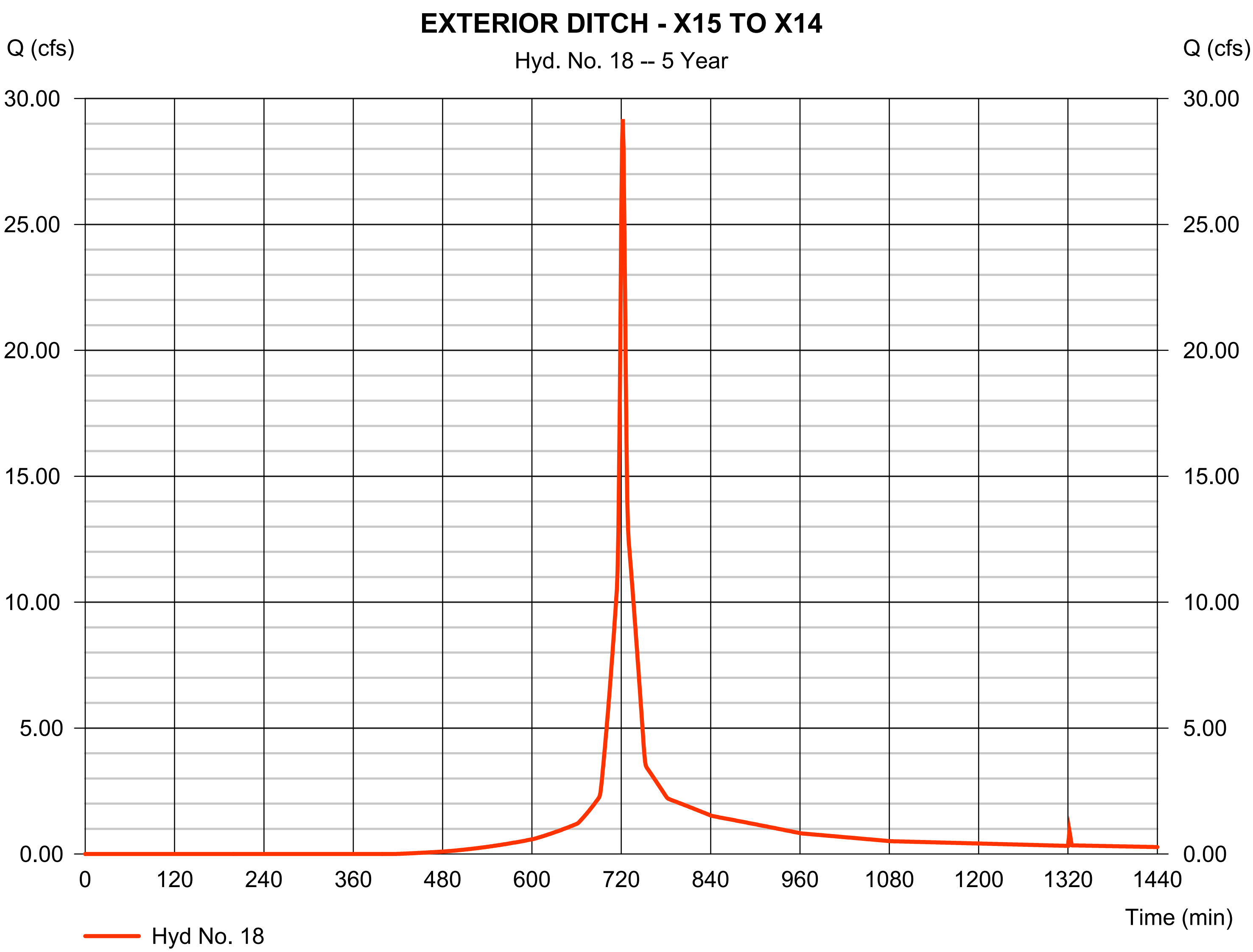
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 18

EXTERIOR DITCH - X15 TO X14

Hydrograph type	= SCS Runoff	Peak discharge	= 29.18 cfs
Storm frequency	= 5 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 79,523 cuft
Drainage area	= 6.740 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 2.00 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



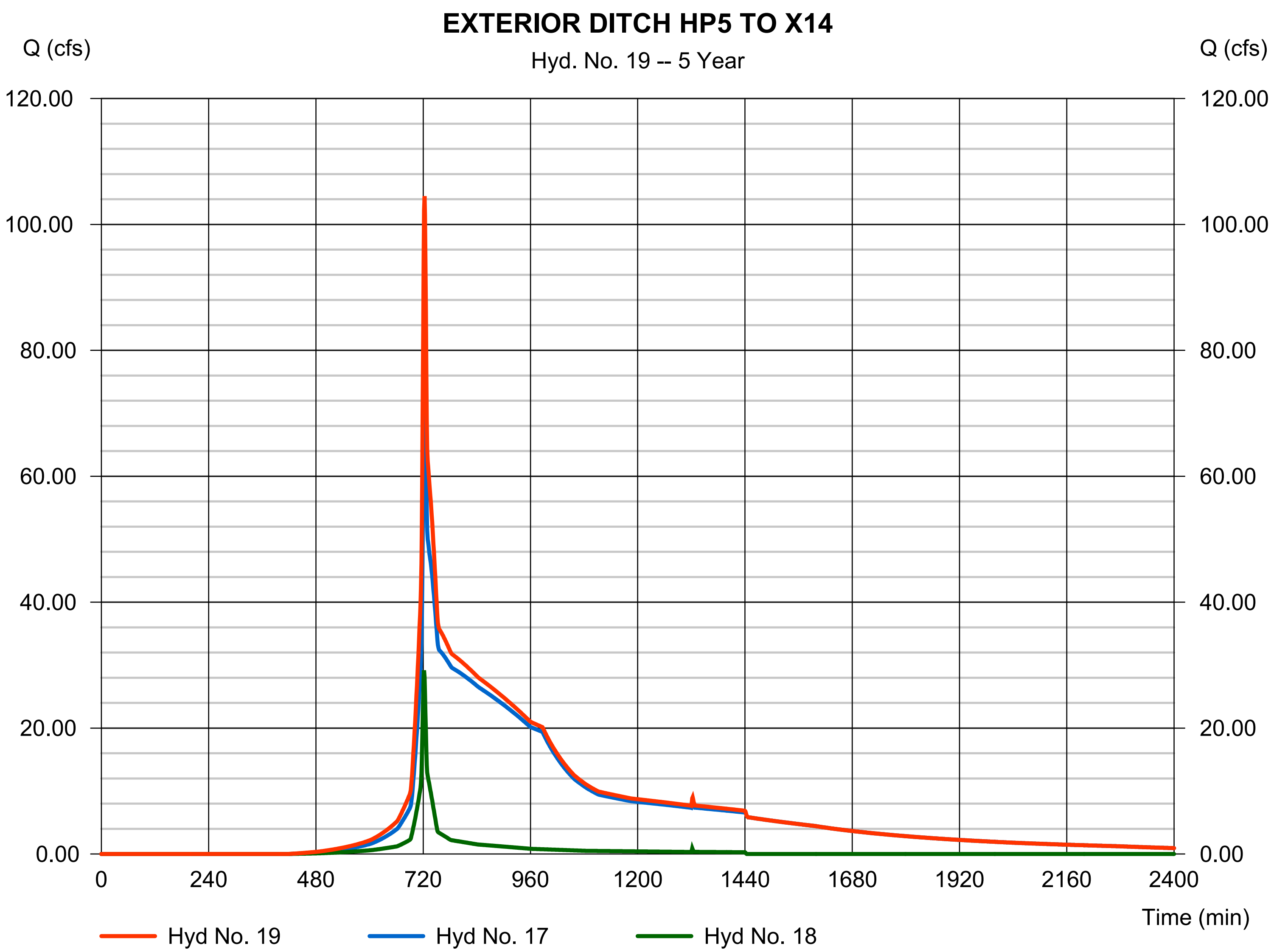
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 19

EXTERIOR DITCH HP5 TO X14

Hydrograph type	= Combine	Peak discharge	= 104.48 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 1,018,515 cuft
Inflow hyds.	= 17, 18	Contrib. drain. area	= 6.740 ac



Hydrograph Report

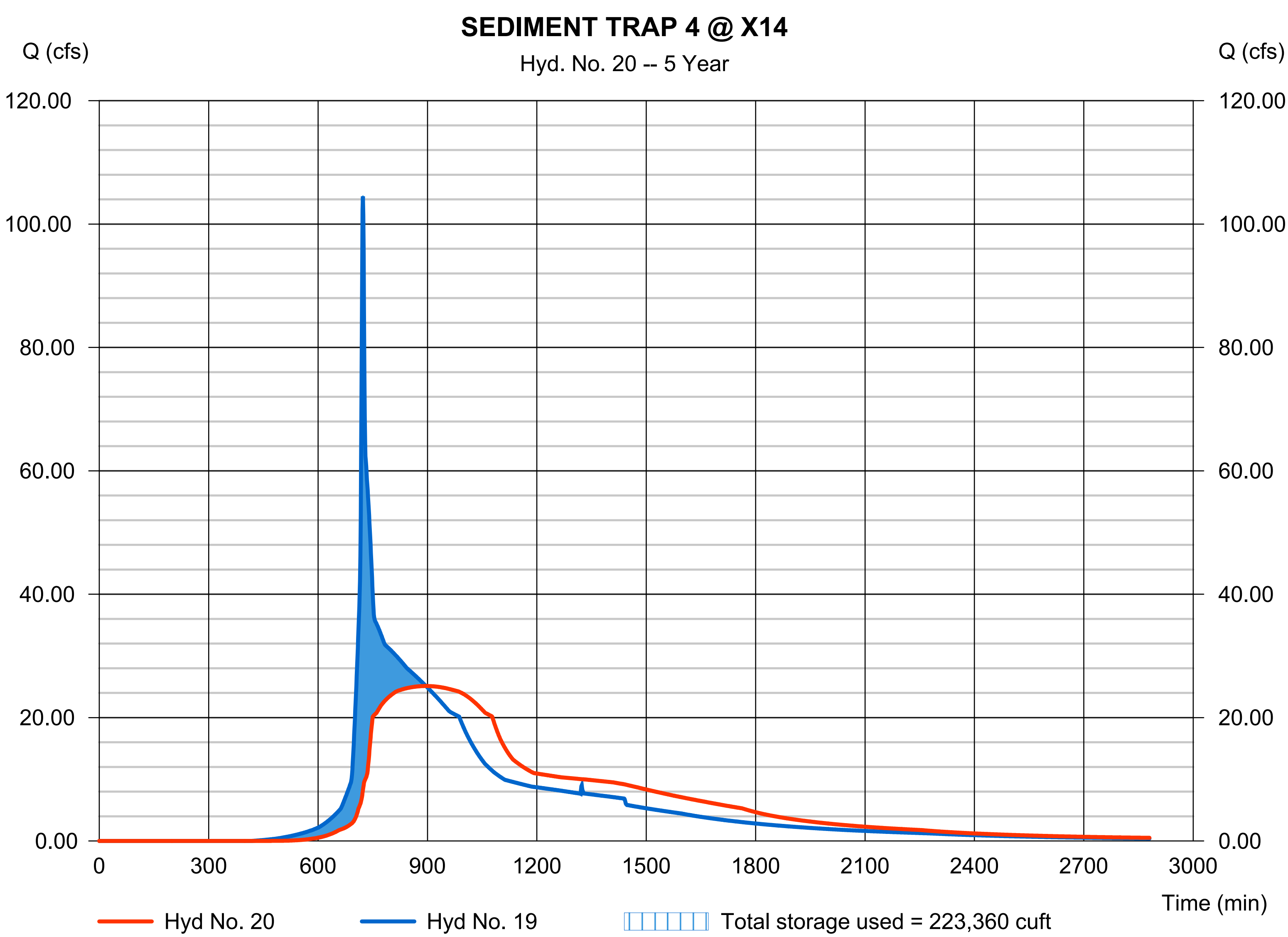
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 20

SEDIMENT TRAP 4 @ X14

Hydrograph type	= Reservoir	Peak discharge	= 25.11 cfs
Storm frequency	= 5 yrs	Time to peak	= 896 min
Time interval	= 1 min	Hyd. volume	= 1,011,545 cuft
Inflow hyd. No.	= 19 - EXTERIOR DITCH HP5 TO X14	Max. Elevation	= 246.18 ft
Reservoir name	= SEDIMENT TRAP 4 @ X14	Max. Storage	= 223,360 cuft

Storage Indication method used. Wet pond routing start elevation = 238.00 ft.



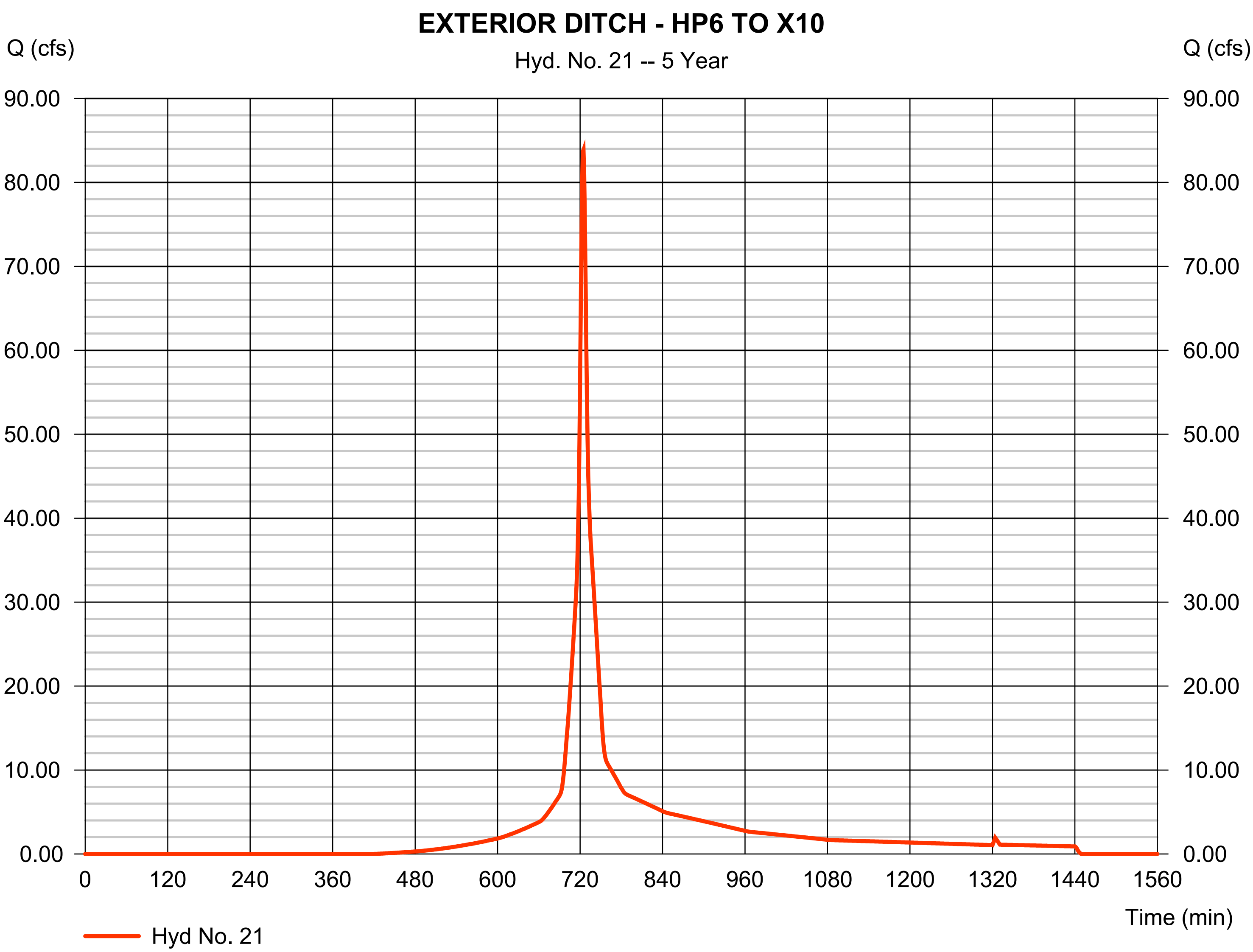
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 21

EXTERIOR DITCH - HP6 TO X10

Hydrograph type	= SCS Runoff	Peak discharge	= 83.87 cfs
Storm frequency	= 5 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 259,569 cuft
Drainage area	= 20.000 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

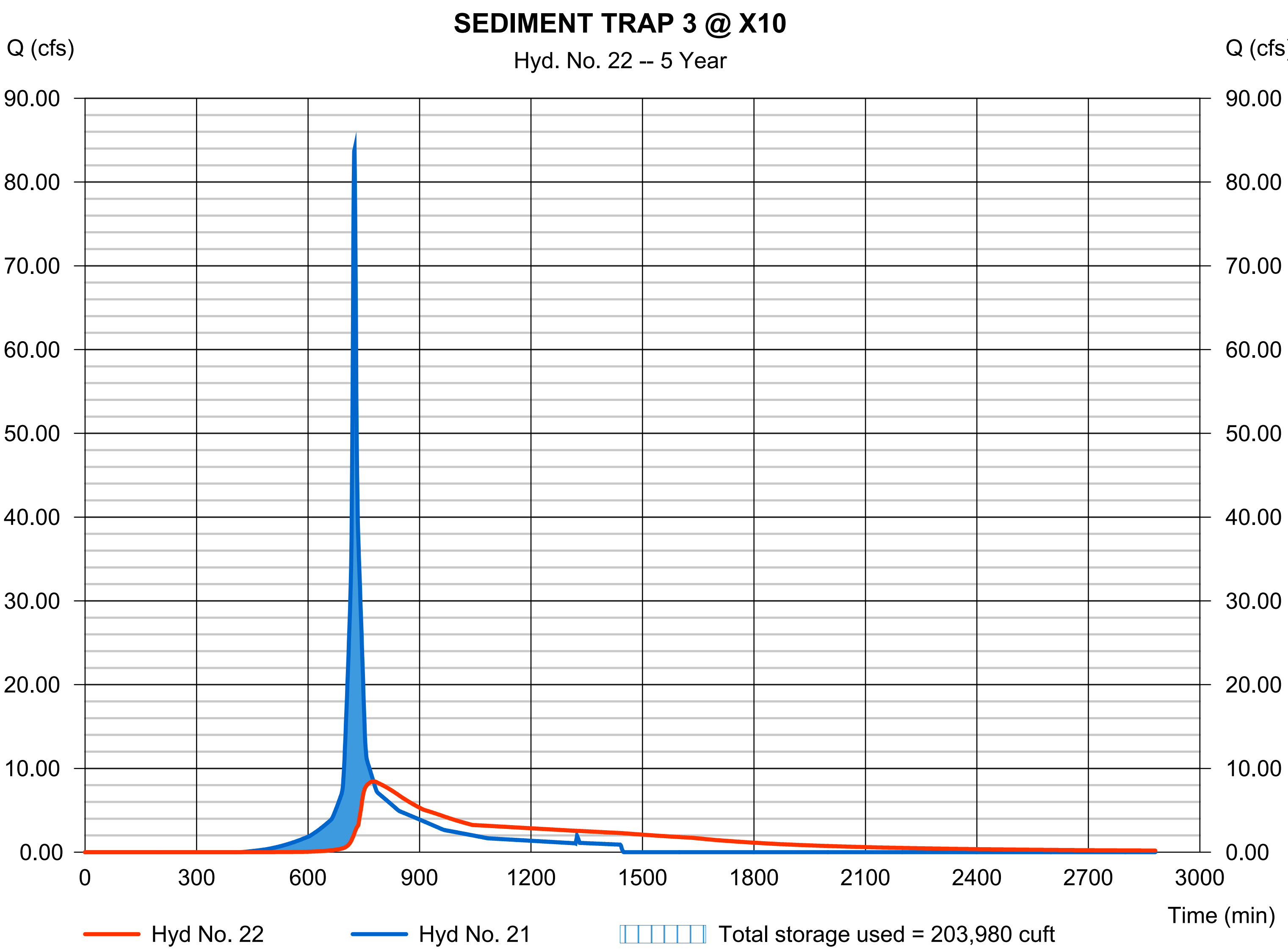
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 22

SEDIMENT TRAP 3 @ X10

Hydrograph type	= Reservoir	Peak discharge	= 8.463 cfs
Storm frequency	= 5 yrs	Time to peak	= 776 min
Time interval	= 1 min	Hyd. volume	= 244,209 cuft
Inflow hyd. No.	= 21 - EXTERIOR DITCH - HP6 TO X10	Max. Elevation	= 251.41 ft
Reservoir name	= SEDIMENT TRAP 3 @ X10	Max. Storage	= 203,980 cuft

Storage Indication method used. Wet pond routing start elevation = 248.00 ft.



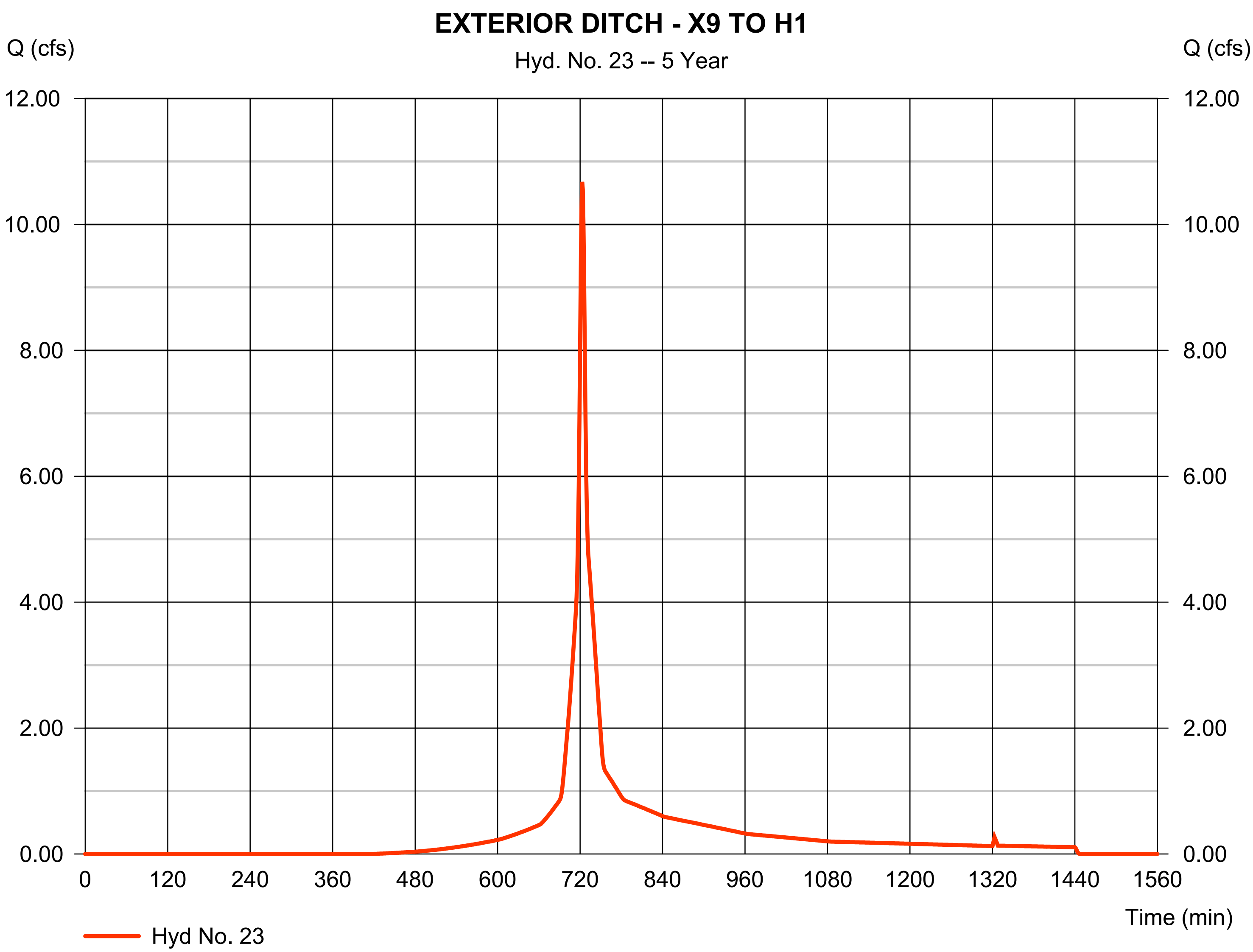
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 23

EXTERIOR DITCH - X9 TO H1

Hydrograph type	= SCS Runoff	Peak discharge	= 10.68 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 30,960 cuft
Drainage area	= 2.460 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



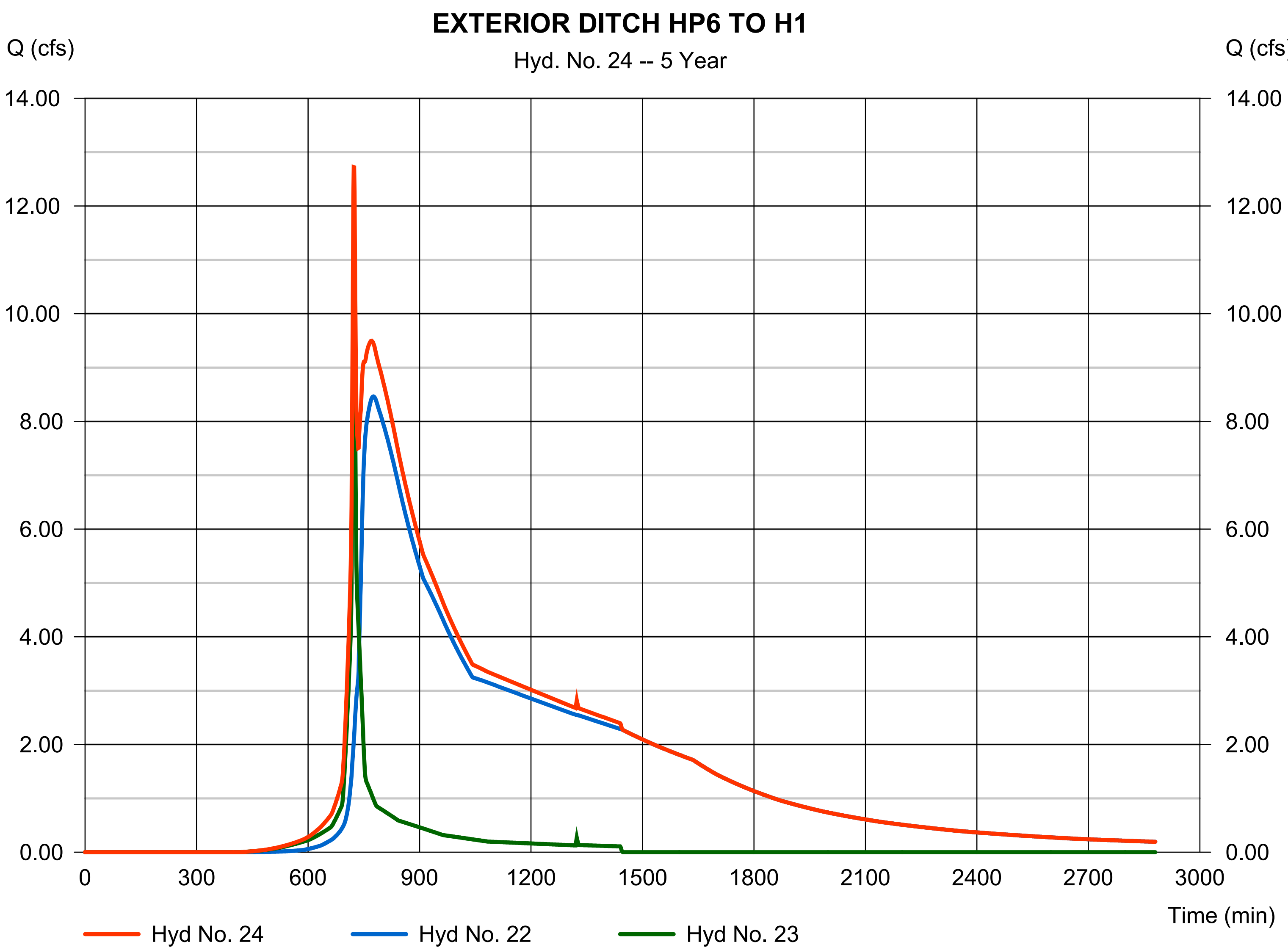
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 24

EXTERIOR DITCH HP6 TO H1

Hydrograph type	= Combine	Peak discharge	= 12.72 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 275,169 cuft
Inflow hyds.	= 22, 23	Contrib. drain. area	= 2.460 ac



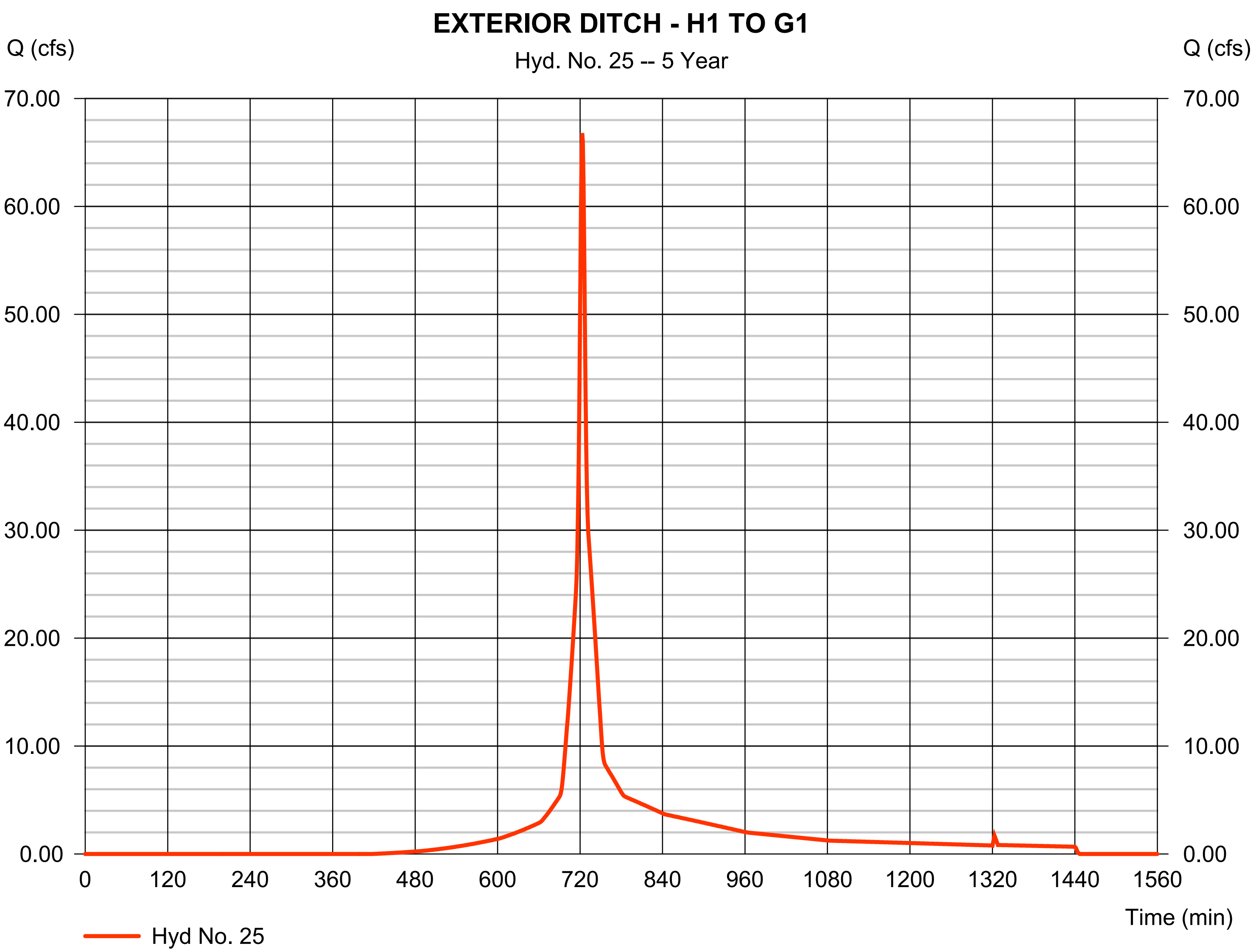
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 25

EXTERIOR DITCH - H1 TO G1

Hydrograph type	= SCS Runoff	Peak discharge	= 66.80 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 193,686 cuft
Drainage area	= 15.390 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



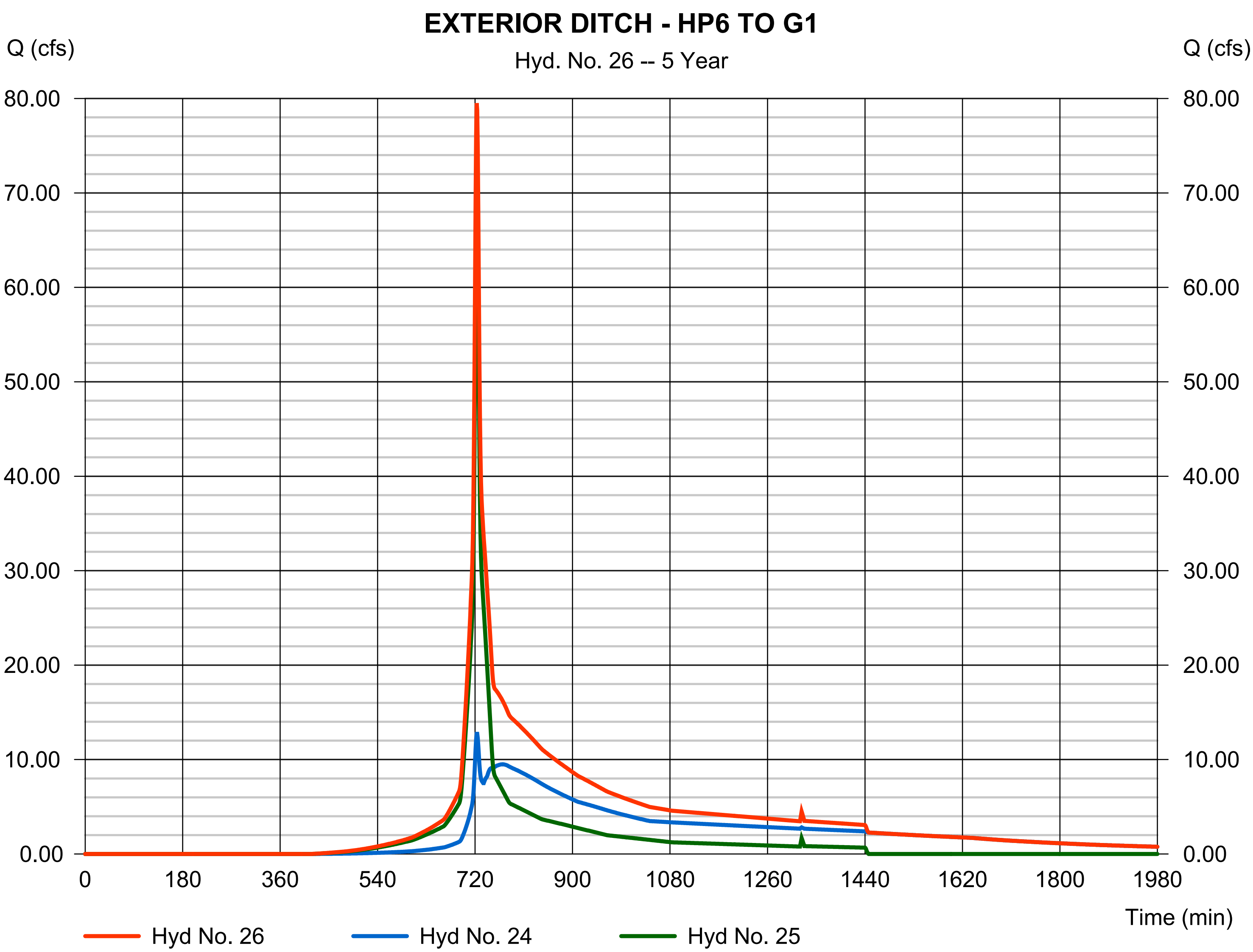
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 26

EXTERIOR DITCH - HP6 TO G1

Hydrograph type	= Combine	Peak discharge	= 79.52 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 468,855 cuft
Inflow hyds.	= 24, 25	Contrib. drain. area	= 15.390 ac



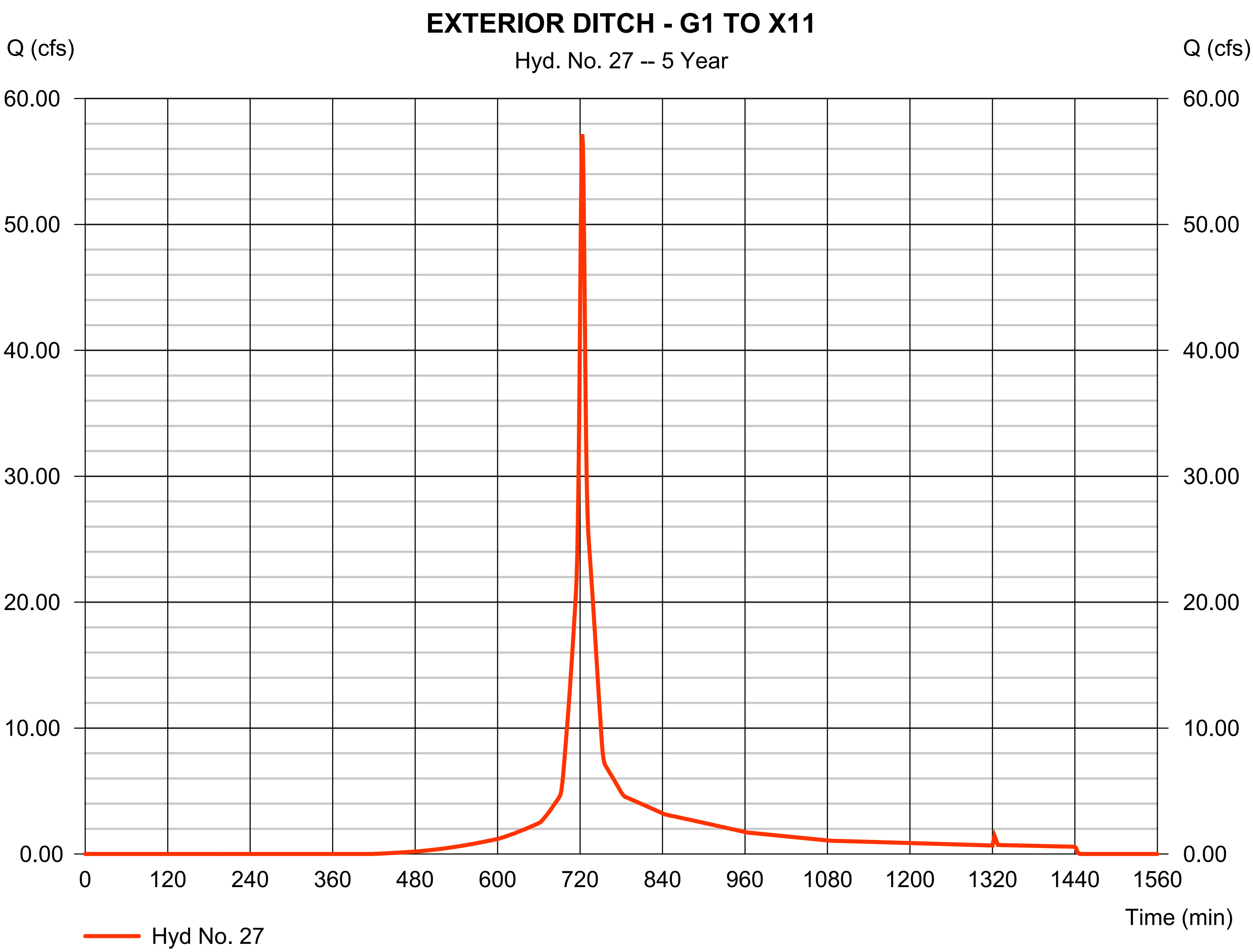
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 27

EXTERIOR DITCH - G1 TO X11

Hydrograph type	= SCS Runoff	Peak discharge	= 57.16 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 165,747 cuft
Drainage area	= 13.170 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.00 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



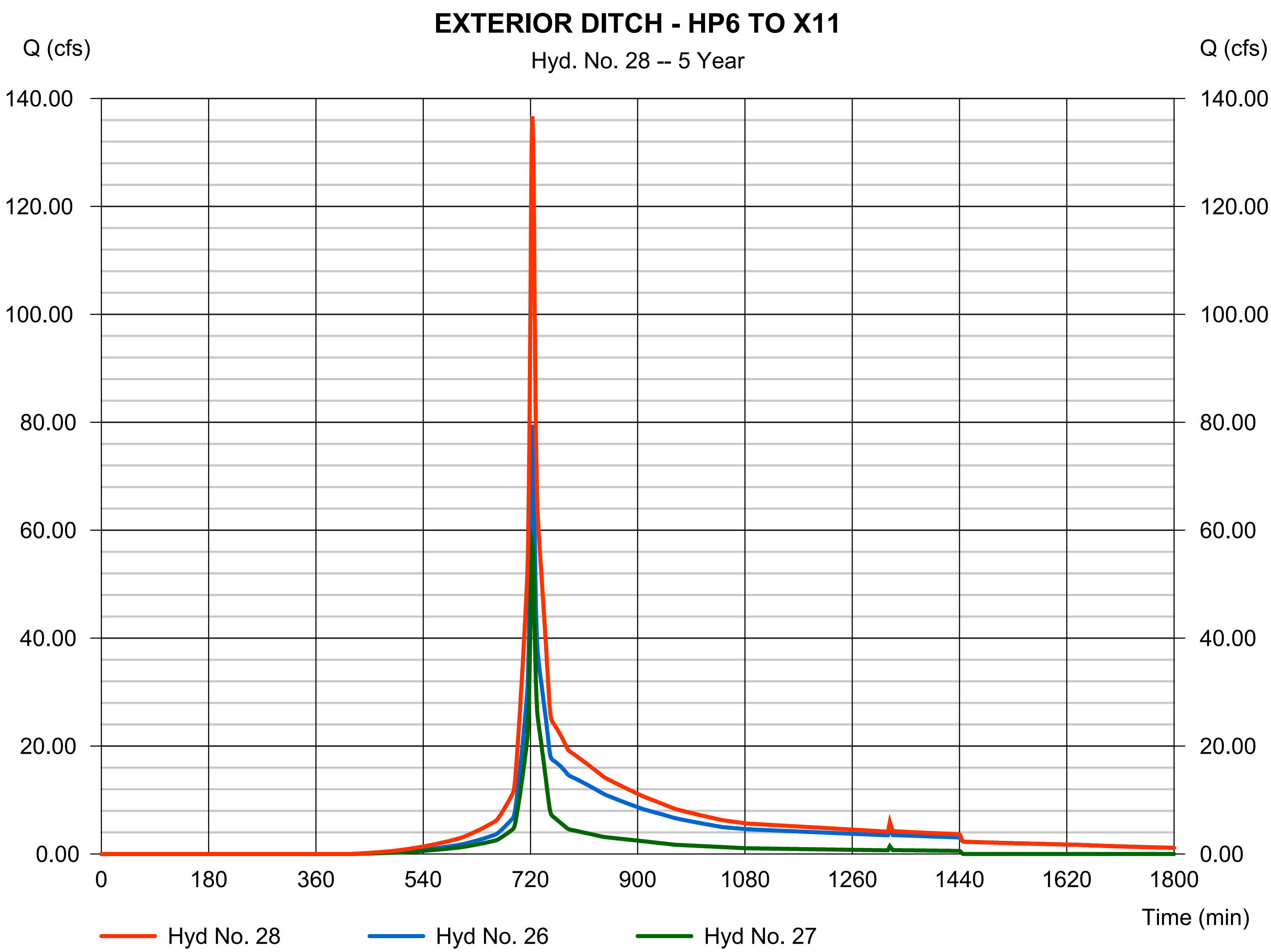
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 28

EXTERIOR DITCH - HP6 TO X11

Hydrograph type	= Combine	Peak discharge	= 136.68 cfs
Storm frequency	= 5 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 634,601 cuft
Inflow hyds.	= 26, 27	Contrib. drain. area	= 13.170 ac



Hydrograph Report

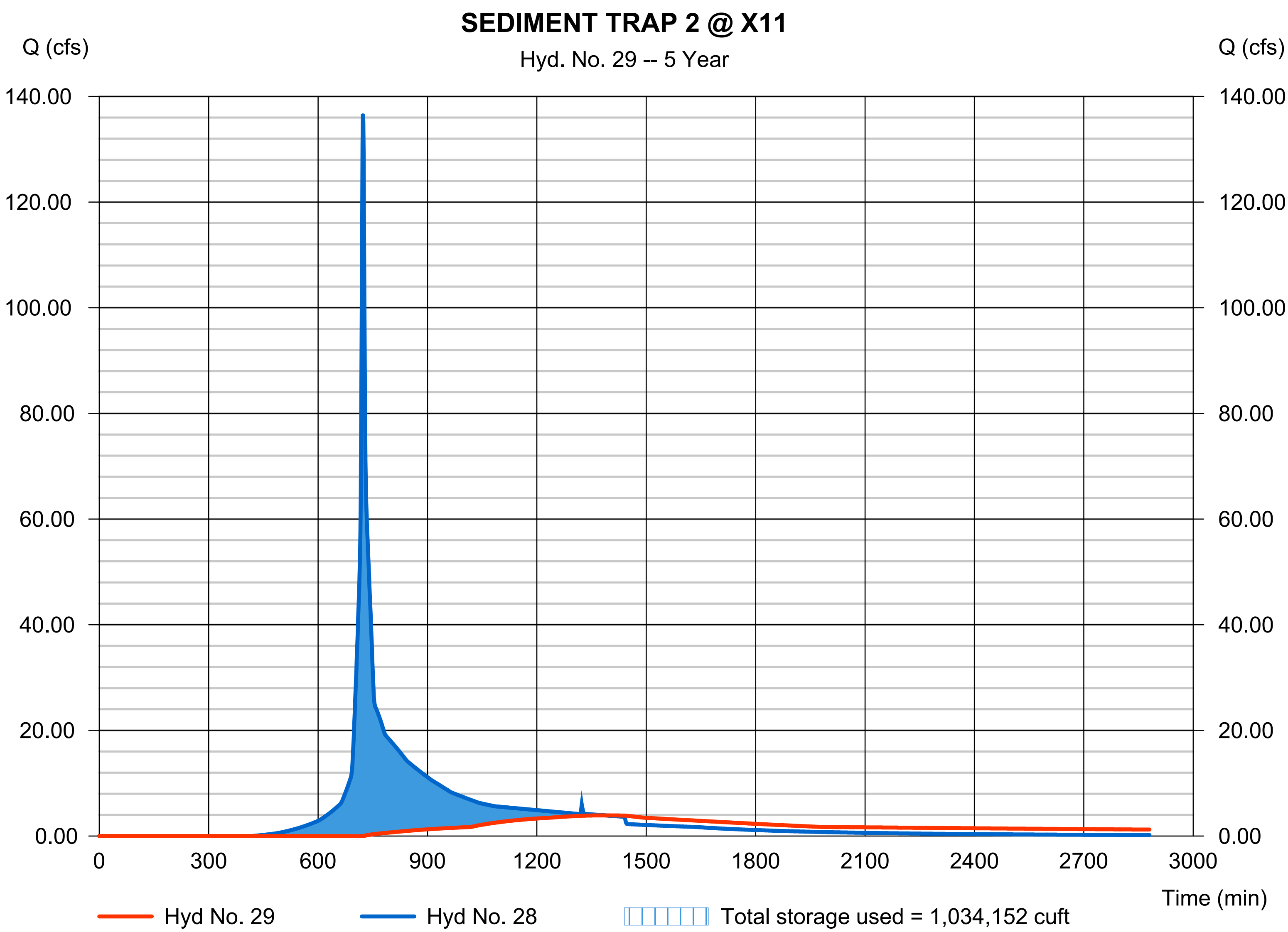
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 29

SEDIMENT TRAP 2 @ X11

Hydrograph type	= Reservoir	Peak discharge	= 3.909 cfs
Storm frequency	= 5 yrs	Time to peak	= 1388 min
Time interval	= 1 min	Hyd. volume	= 266,973 cuft
Inflow hyd. No.	= 28 - EXTERIOR DITCH - HP6 TO X11	Max. Elevation	= 246.23 ft
Reservoir name	= SEDIMENT TRAP 2 @ X11	Max. Storage	= 1,034,152 cuft

Storage Indication method used. Wet pond routing start elevation = 243.00 ft.



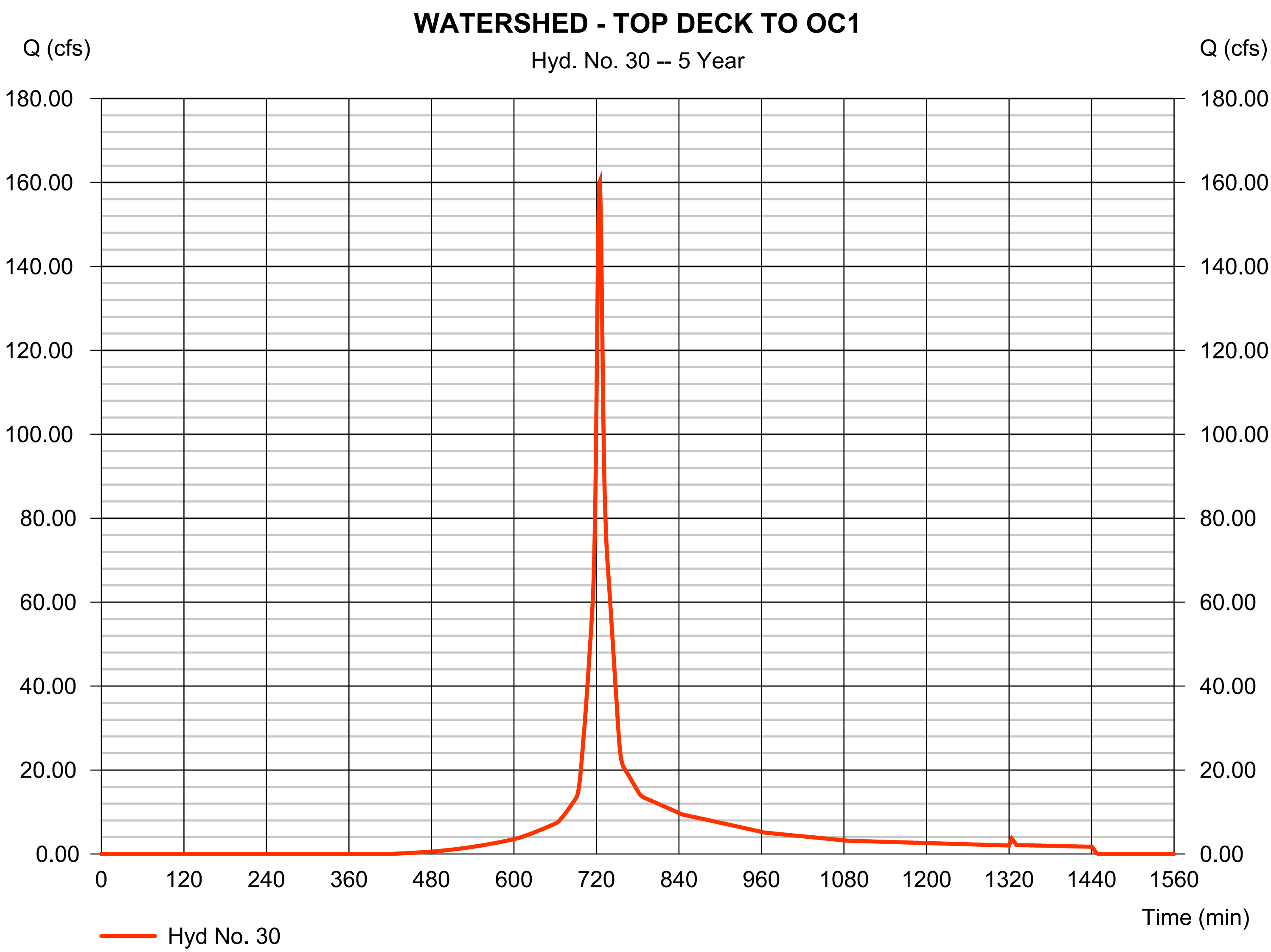
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 30

WATERSHED - TOP DECK TO OC1

Hydrograph type	= SCS Runoff	Peak discharge	= 160.20 cfs
Storm frequency	= 5 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 495,778 cuft
Drainage area	= 38.200 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 5.65 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



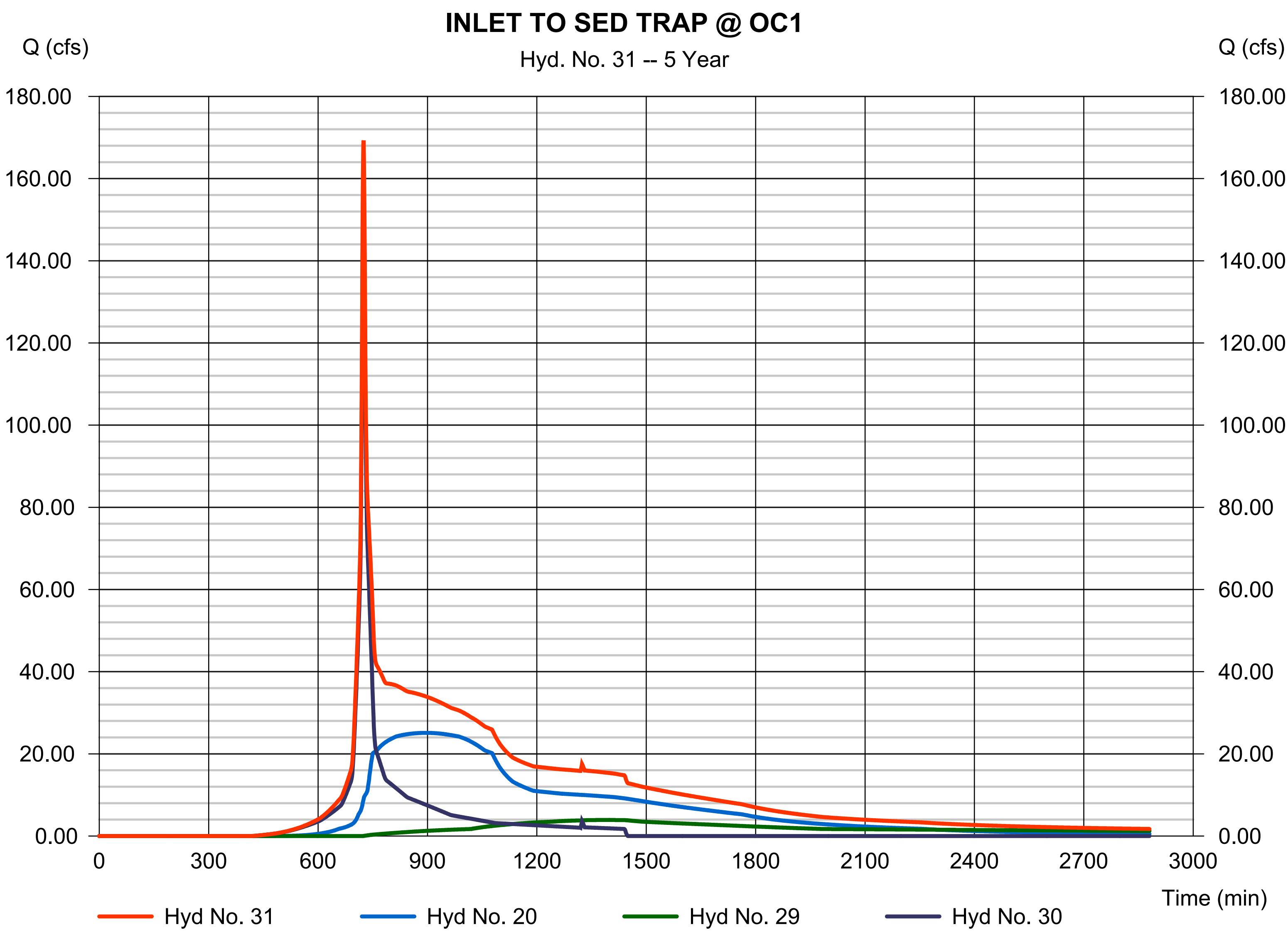
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 31

INLET TO SED TRAP @ OC1

Hydrograph type	= Combine	Peak discharge	= 169.28 cfs
Storm frequency	= 5 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,774,297 cuft
Inflow hyds.	= 20, 29, 30	Contrib. drain. area	= 38.200 ac



Hydrograph Report

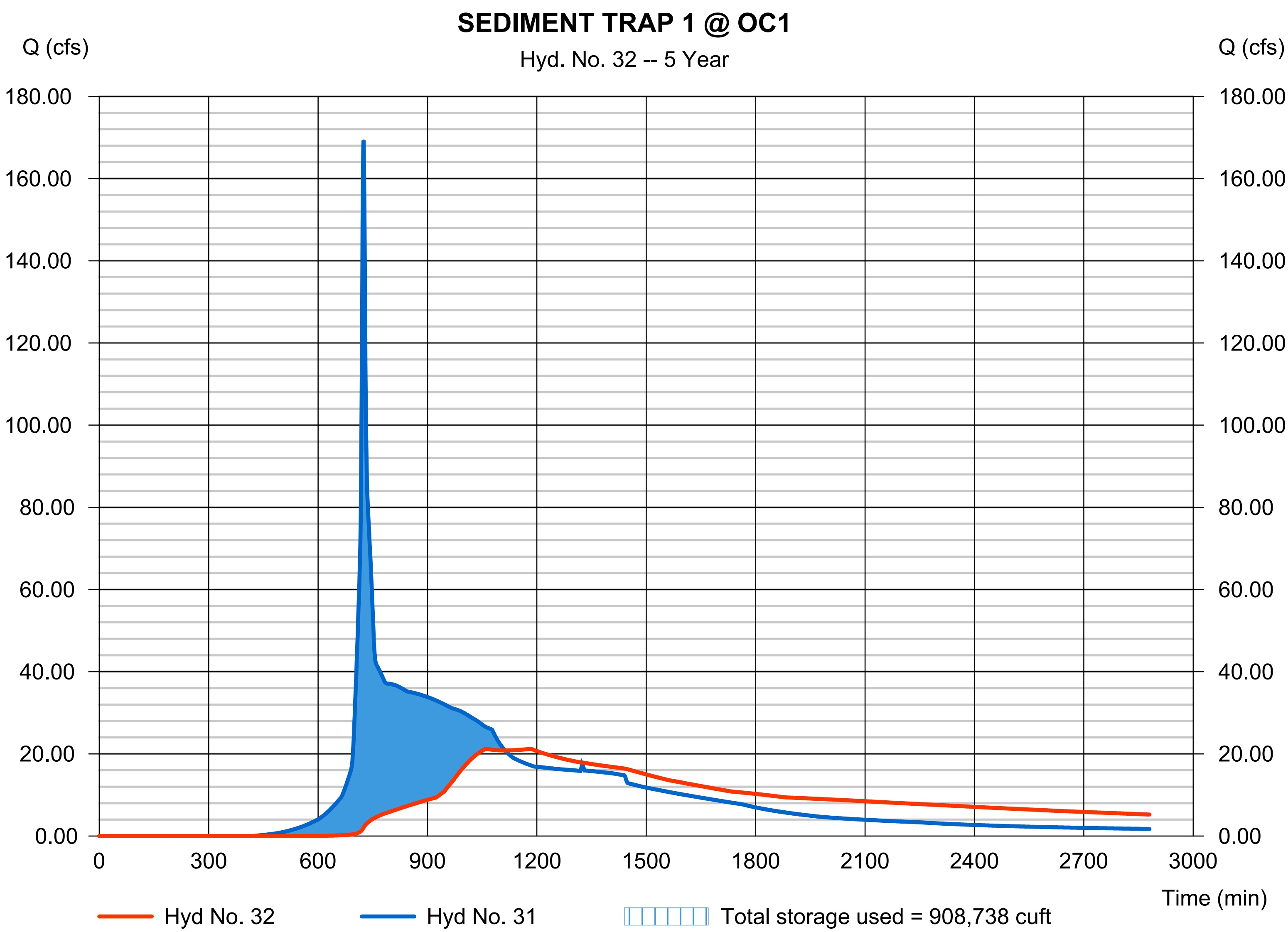
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 32

SEDIMENT TRAP 1 @ OC1

Hydrograph type	= Reservoir	Peak discharge	= 21.22 cfs
Storm frequency	= 5 yrs	Time to peak	= 1060 min
Time interval	= 1 min	Hyd. volume	= 1,405,866 cuft
Inflow hyd. No.	= 31 - INLET TO SED TRAP @ OC1	Max. Elevation	= 234.87 ft
Reservoir name	= SEDIMENT TRAP 1 @ OC1	Max. Storage	= 908,738 cuft

Storage Indication method used. Wet pond routing start elevation = 228.00 ft.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	15.85	1	725	51,415	------	------	------	EXTERIOR DITCH - HP5 TO X8
2	SCS Runoff	16.03	1	725	52,014	------	------	------	EXTERIOR DITCH - X7 TO X6
3	Combine	31.88	1	725	103,429	1, 2	------	------	EXTERIOR DITCH HP5 TO X6
4	SCS Runoff	7.949	1	725	24,733	------	------	------	EXTERIOR DITCH - X5 TO X3
5	Combine	39.83	1	725	128,162	3, 4	------	------	EXTERIOR DITCH HP5 TO X3
6	Reservoir	2.124	1	872	91,559	5	257.53	117,486	SEDIMENT TRAP 6 @ X3
7	SCS Runoff	5.491	1	723	15,989	------	------	------	EXTERIOR DITCH - X4 TO C1
8	Combine	5.624	1	723	107,548	6, 7	------	------	EXTERIOR DITCH HP5 TO C1
9	SCS Runoff	142.93	1	728	522,352	------	------	------	EXTERIOR DITCH - C1 TO D1
10	Combine	146.87	1	728	629,900	8, 9	------	------	EXTERIOR DITCH HP5 TO D1
11	SCS Runoff	60.64	1	725	188,669	------	------	------	EXTERIOR DITCH - D1 TO X1
12	Combine	201.68	1	726	818,569	10, 11	------	------	EXTERIOR DITCH HP5 TO X1
13	SCS Runoff	42.56	1	723	123,915	------	------	------	EXTERIOR DITCH - X1 TO X18
14	Combine	237.50	1	726	942,485	12, 13	------	------	EXTERIOR DITCH HP5 TO X18
15	Reservoir	26.83	1	782	910,518	14	250.09	492,538	SEDIMENT TRAP 5 @ X18
16	SCS Runoff	85.74	1	723	249,676	------	------	------	EXTERIOR DITCH - X17 TO X16
17	Combine	95.74	1	724	1,160,195	15, 16	------	------	EXTERIOR DITCH HP5 TO X16
18	SCS Runoff	35.47	1	722	97,145	------	------	------	EXTERIOR DITCH - X15 TO X14
19	Combine	128.18	1	723	1,257,340	17, 18	------	------	EXTERIOR DITCH HP5 TO X14
20	Reservoir	28.67	1	937	1,249,933	19	246.97	281,352	SEDIMENT TRAP 4 @ X14
21	SCS Runoff	101.91	1	725	317,091	------	------	------	EXTERIOR DITCH - HP6 TO X10
22	Reservoir	16.46	1	753	301,288	21	251.78	225,465	SEDIMENT TRAP 3 @ X10
23	SCS Runoff	12.99	1	723	37,820	------	------	------	EXTERIOR DITCH - X9 TO H1
24	Combine	18.64	1	748	339,108	22, 23	------	------	EXTERIOR DITCH HP6 TO H1
25	SCS Runoff	81.26	1	723	236,608	------	------	------	EXTERIOR DITCH - H1 TO G1
26	Combine	96.83	1	723	575,716	24, 25	------	------	EXTERIOR DITCH - HP6 TO G1
27	SCS Runoff	69.54	1	723	202,477	------	------	------	EXTERIOR DITCH - G1 TO X11
28	Combine	166.36	1	723	778,193	26, 27	------	------	EXTERIOR DITCH - HP6 TO X11
29	Reservoir	7.469	1	1036	407,475	28	246.44	1,071,538	SEDIMENT TRAP 2 @ X11
30	SCS Runoff	194.65	1	725	605,644	------	------	------	WATERSHED - TOP DECK TO OC1
31	Combine	205.22	1	725	2,263,053	20, 29, 30	------	------	INLET TO SED TRAP @ OC1
32	Reservoir	27.06	1	1219	1,875,470	31	236.27	1,124,844	SEDIMENT TRAP 1 @ OC1

Exterior Ditch [with ponds].gpw	Return Period: 10 Year	Friday, 01 / 30 / 2015

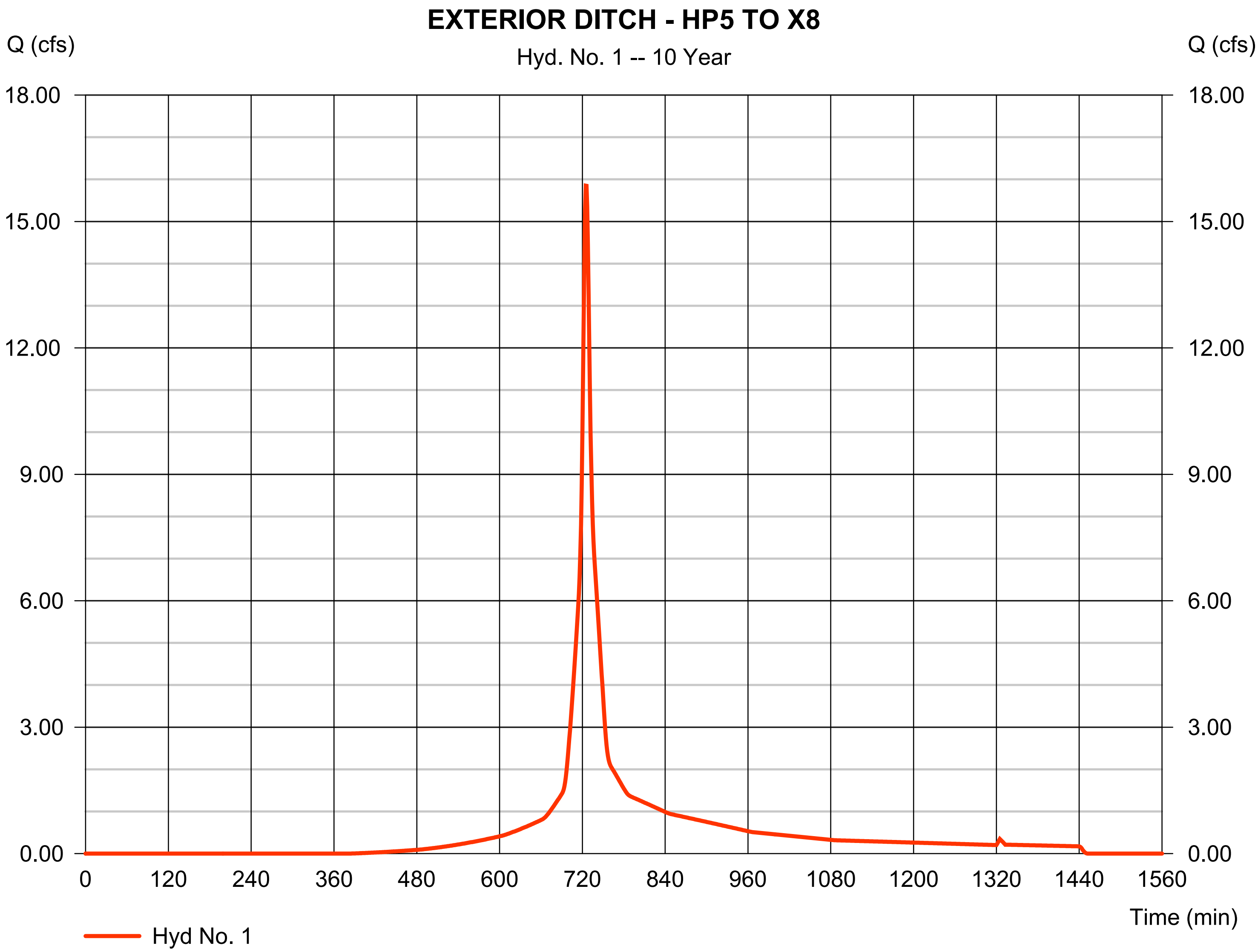
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

EXTERIOR DITCH - HP5 TO X8

Hydrograph type	= SCS Runoff	Peak discharge	= 15.85 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 51,415 cuft
Drainage area	= 3.430 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.30 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



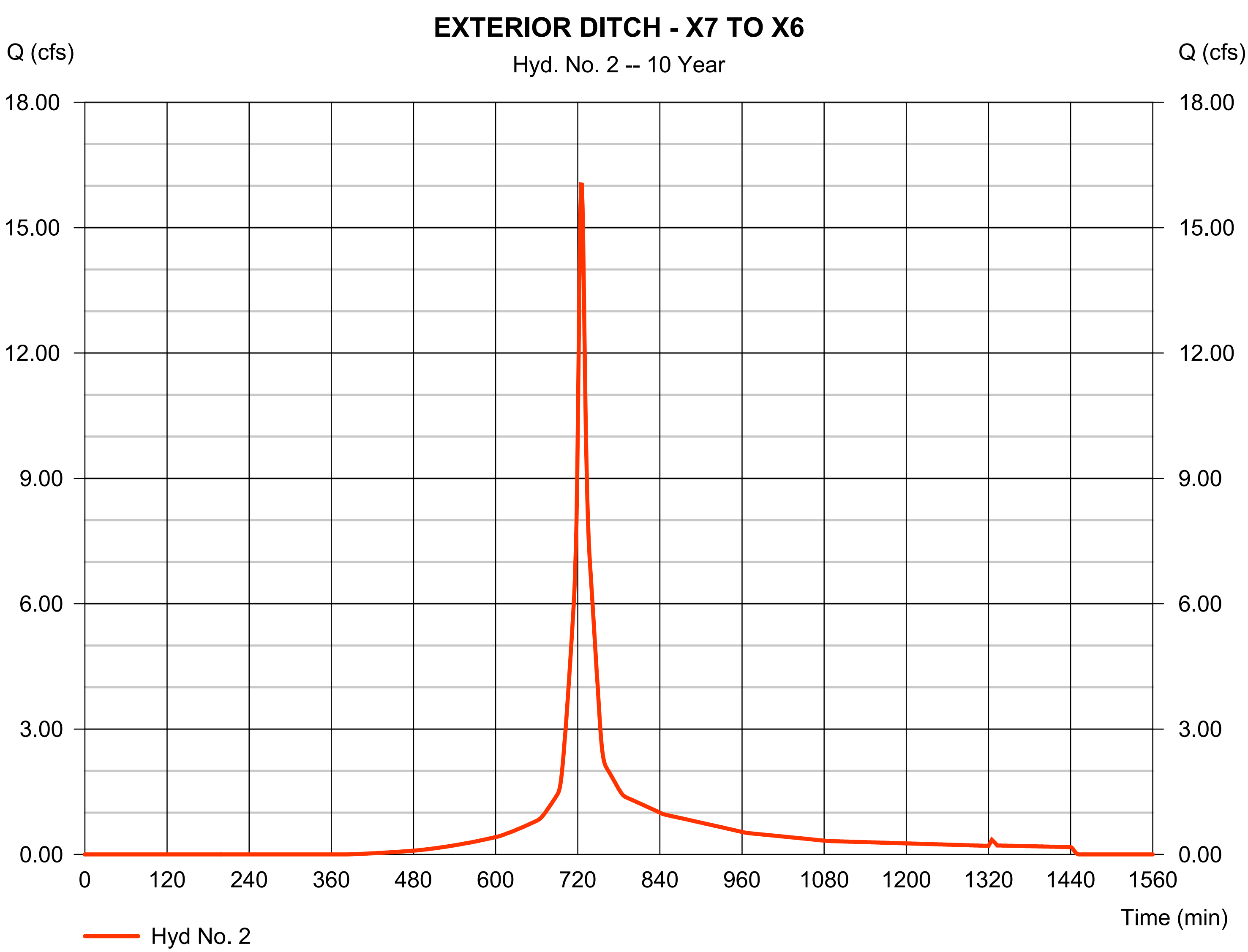
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 2

EXTERIOR DITCH - X7 TO X6

Hydrograph type	= SCS Runoff	Peak discharge	= 16.03 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 52,014 cuft
Drainage area	= 3.470 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.70 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



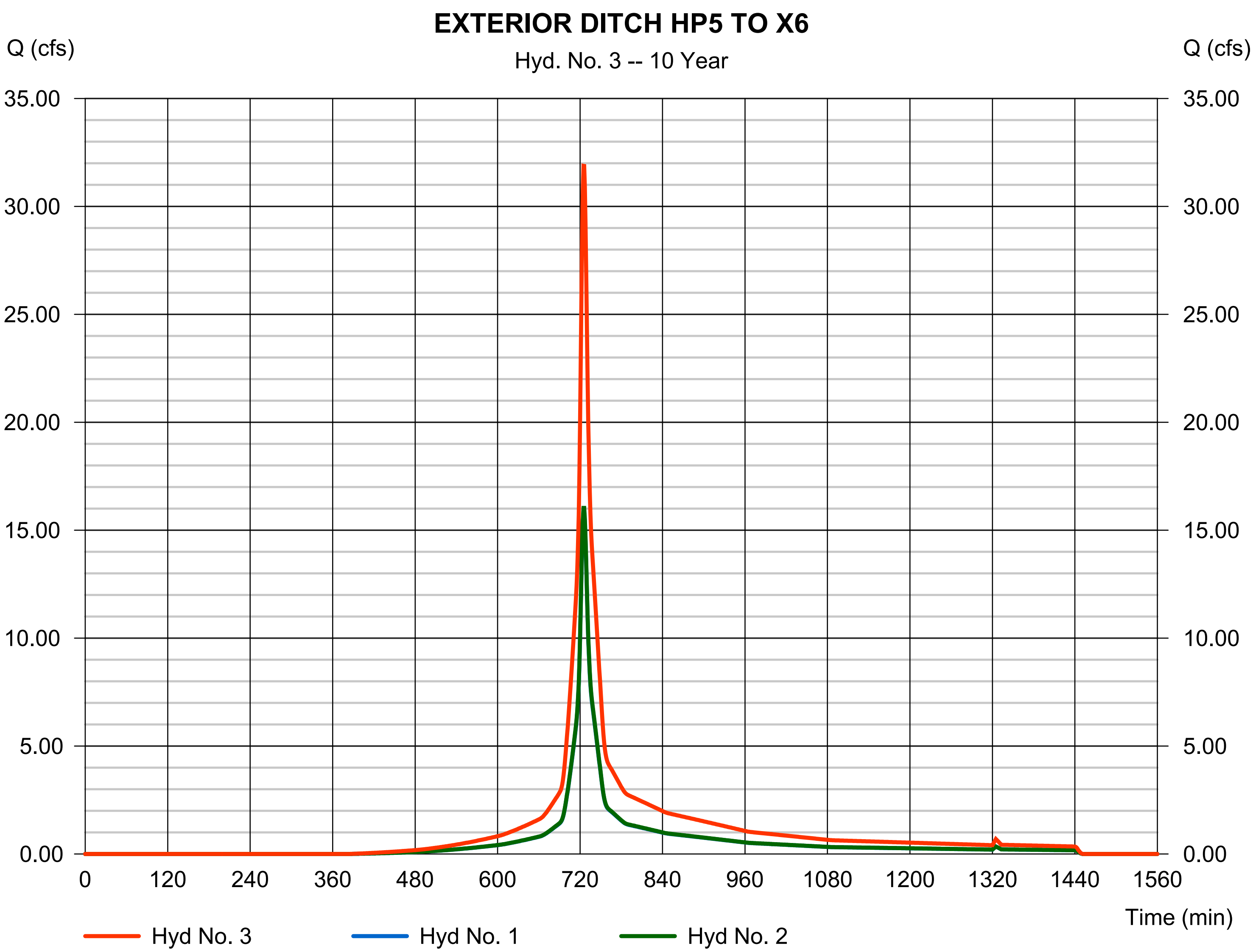
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 3

EXTERIOR DITCH HP5 TO X6

Hydrograph type	= Combine	Peak discharge	= 31.88 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 103,429 cuft
Inflow hyds.	= 1, 2	Contrib. drain. area	= 6.900 ac



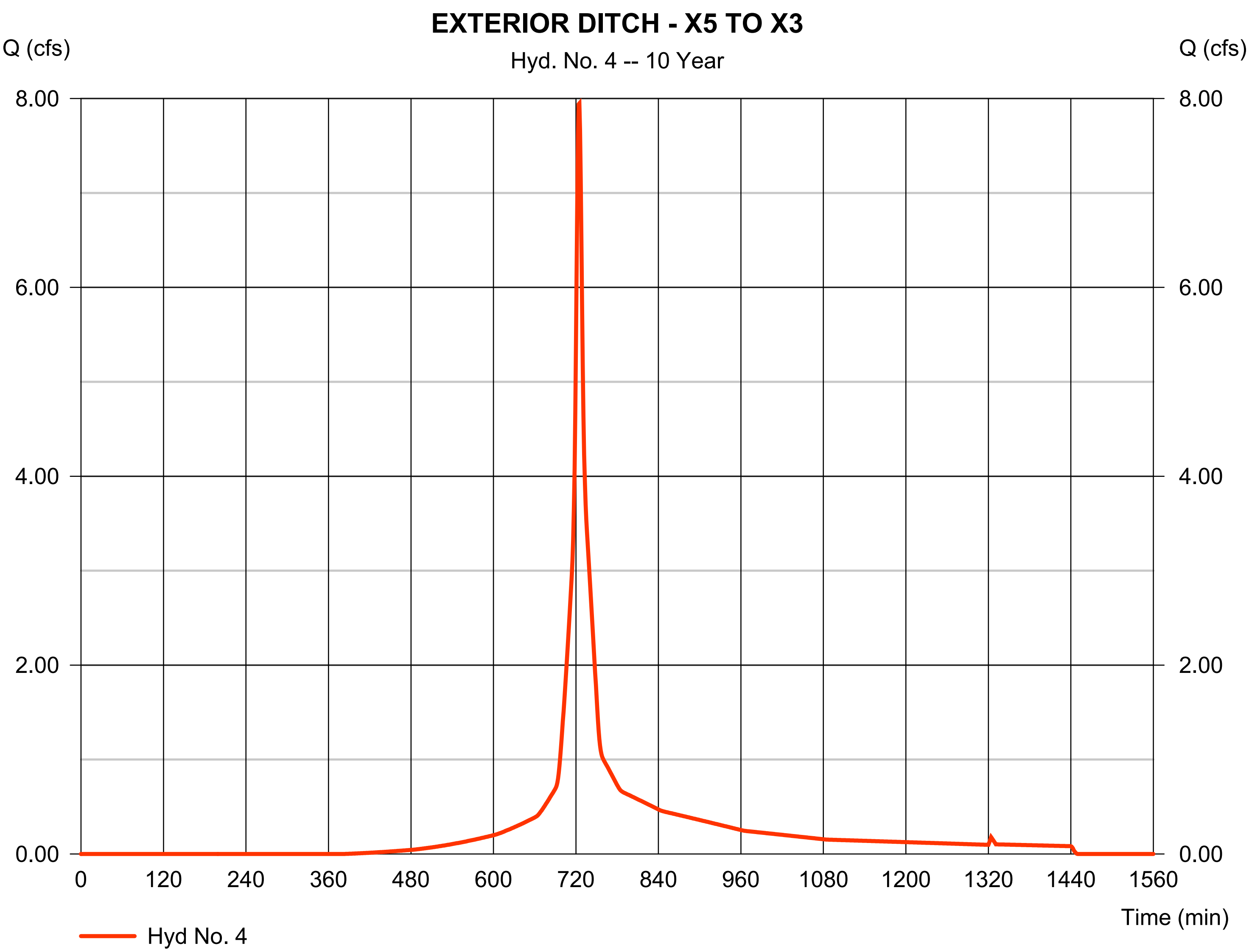
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 4

EXTERIOR DITCH - X5 TO X3

Hydrograph type	= SCS Runoff	Peak discharge	= 7.949 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 24,733 cuft
Drainage area	= 1.560 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.90 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



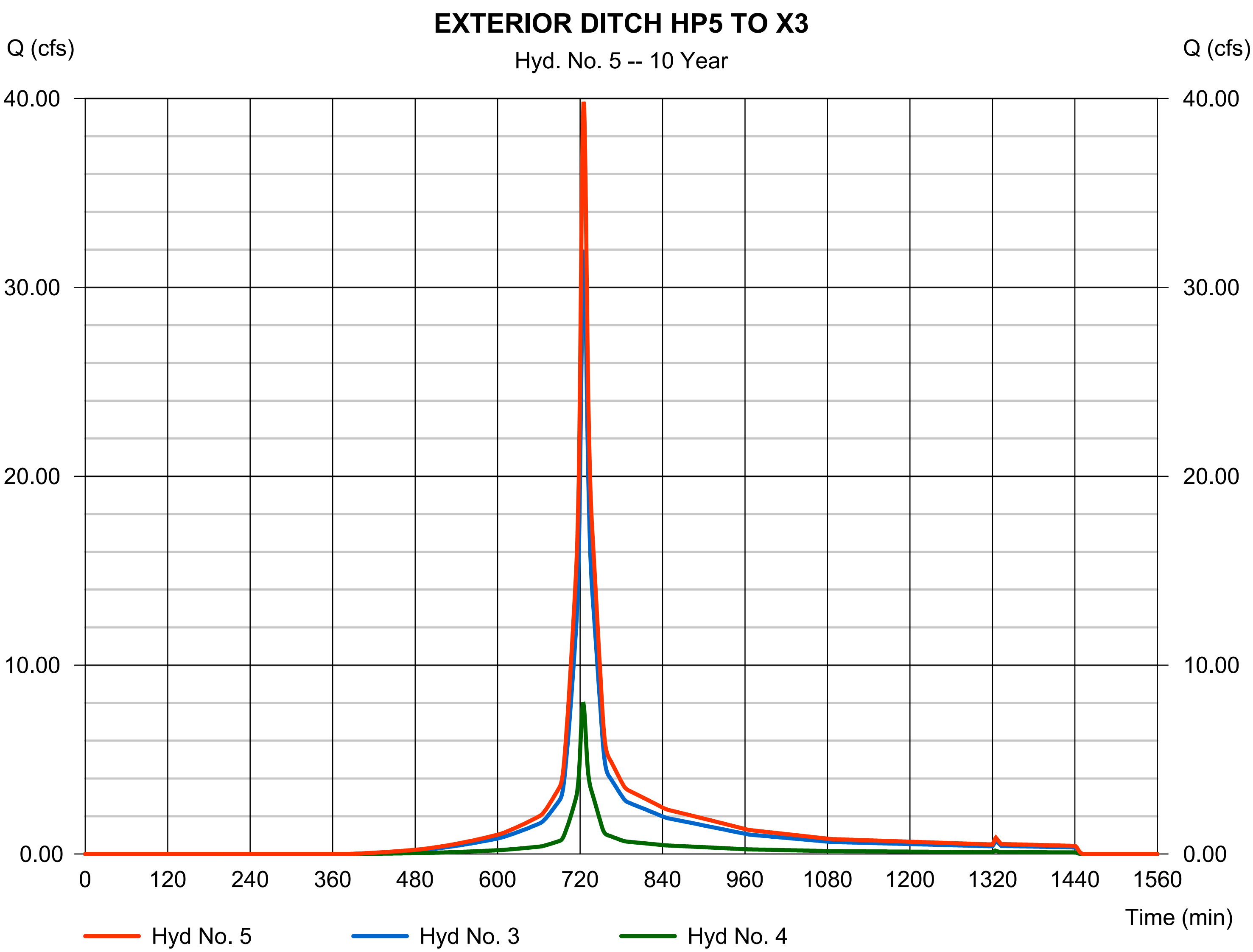
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 5

EXTERIOR DITCH HP5 TO X3

Hydrograph type	= Combine	Peak discharge	= 39.83 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 128,162 cuft
Inflow hyds.	= 3, 4	Contrib. drain. area	= 1.560 ac



Hydrograph Report

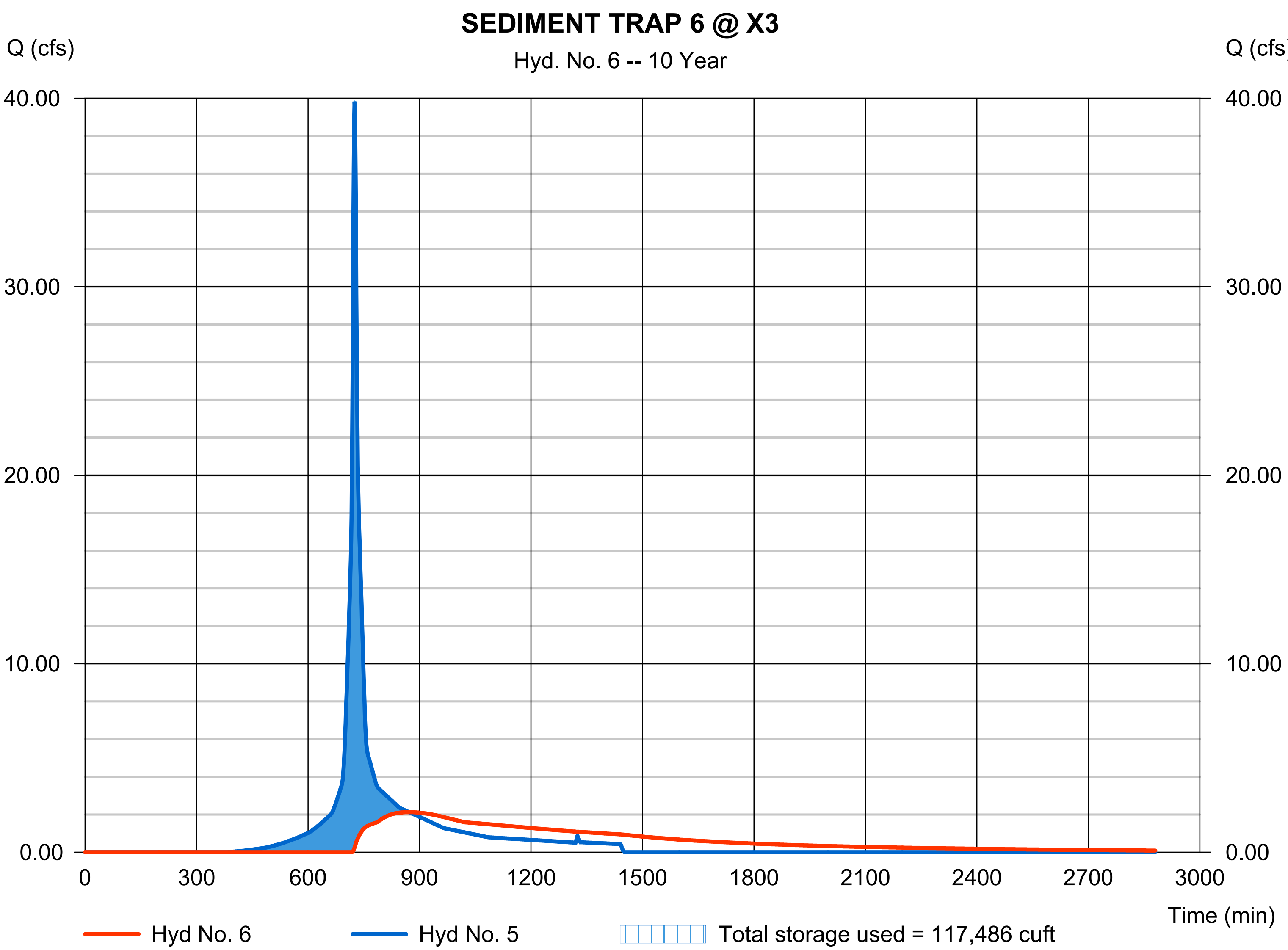
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 6

SEDIMENT TRAP 6 @ X3

Hydrograph type	= Reservoir	Peak discharge	= 2.124 cfs
Storm frequency	= 10 yrs	Time to peak	= 872 min
Time interval	= 1 min	Hyd. volume	= 91,559 cuft
Inflow hyd. No.	= 5 - EXTERIOR DITCH HP5 TO X3	Max. Elevation	= 257.53 ft
Reservoir name	= SEDIMENT TRAP 6 @ X3	Max. Storage	= 117,486 cuft

Storage Indication method used. Wet pond routing start elevation = 254.00 ft.



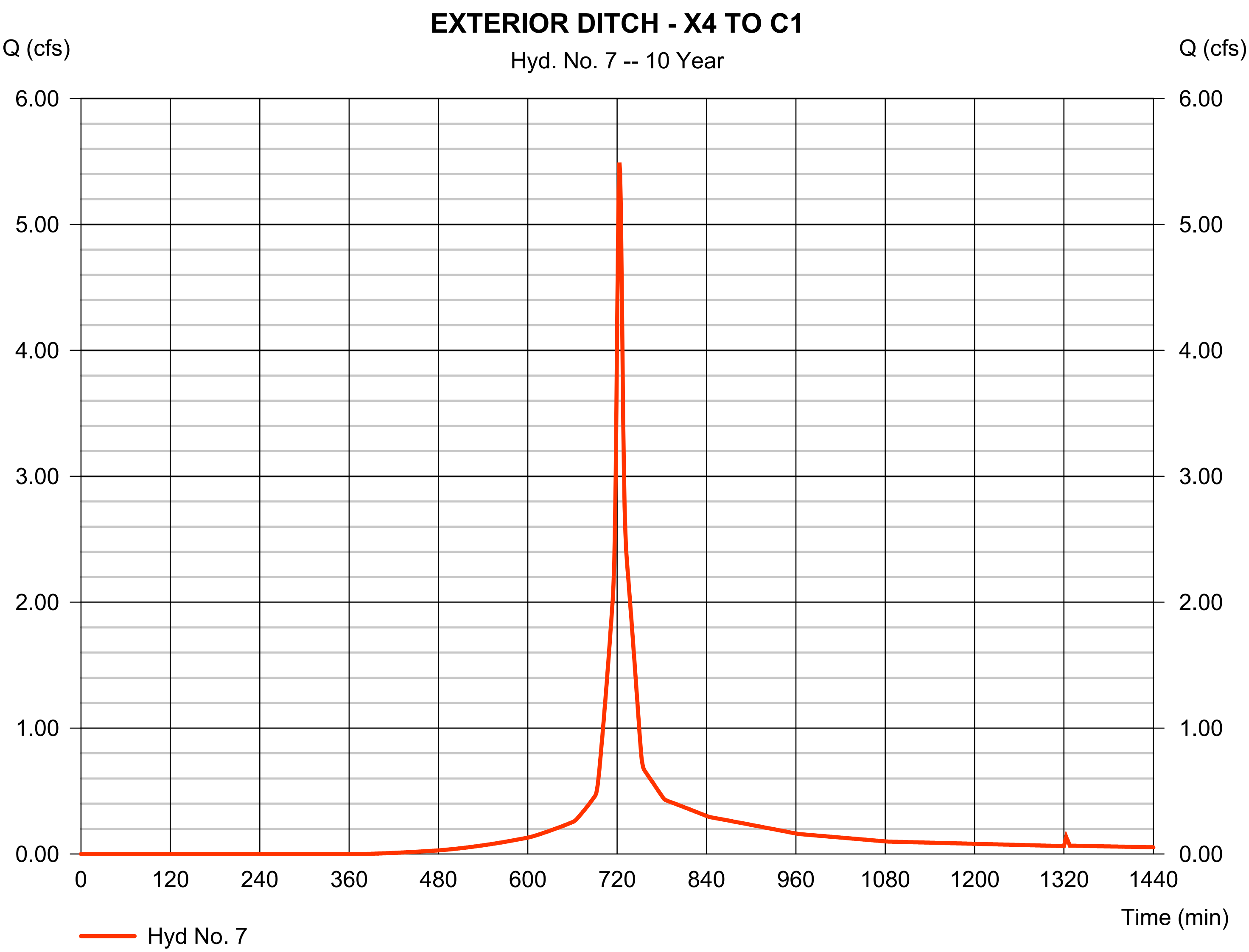
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 7

EXTERIOR DITCH - X4 TO C1

Hydrograph type	= SCS Runoff	Peak discharge	= 5.491 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 15,989 cuft
Drainage area	= 1.040 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.70 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



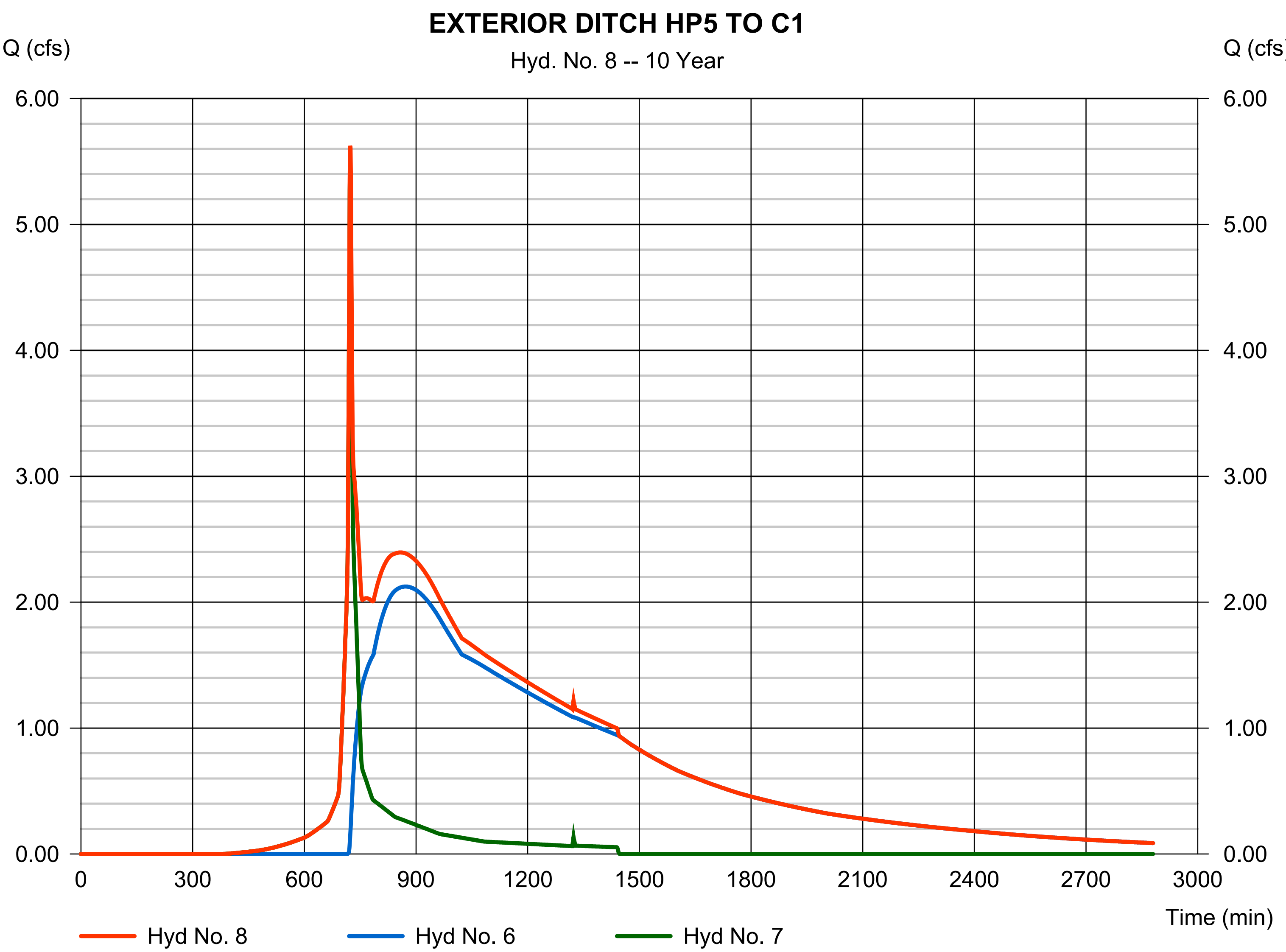
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 8

EXTERIOR DITCH HP5 TO C1

Hydrograph type	= Combine	Peak discharge	= 5.624 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 107,548 cuft
Inflow hyds.	= 6, 7	Contrib. drain. area	= 1.040 ac



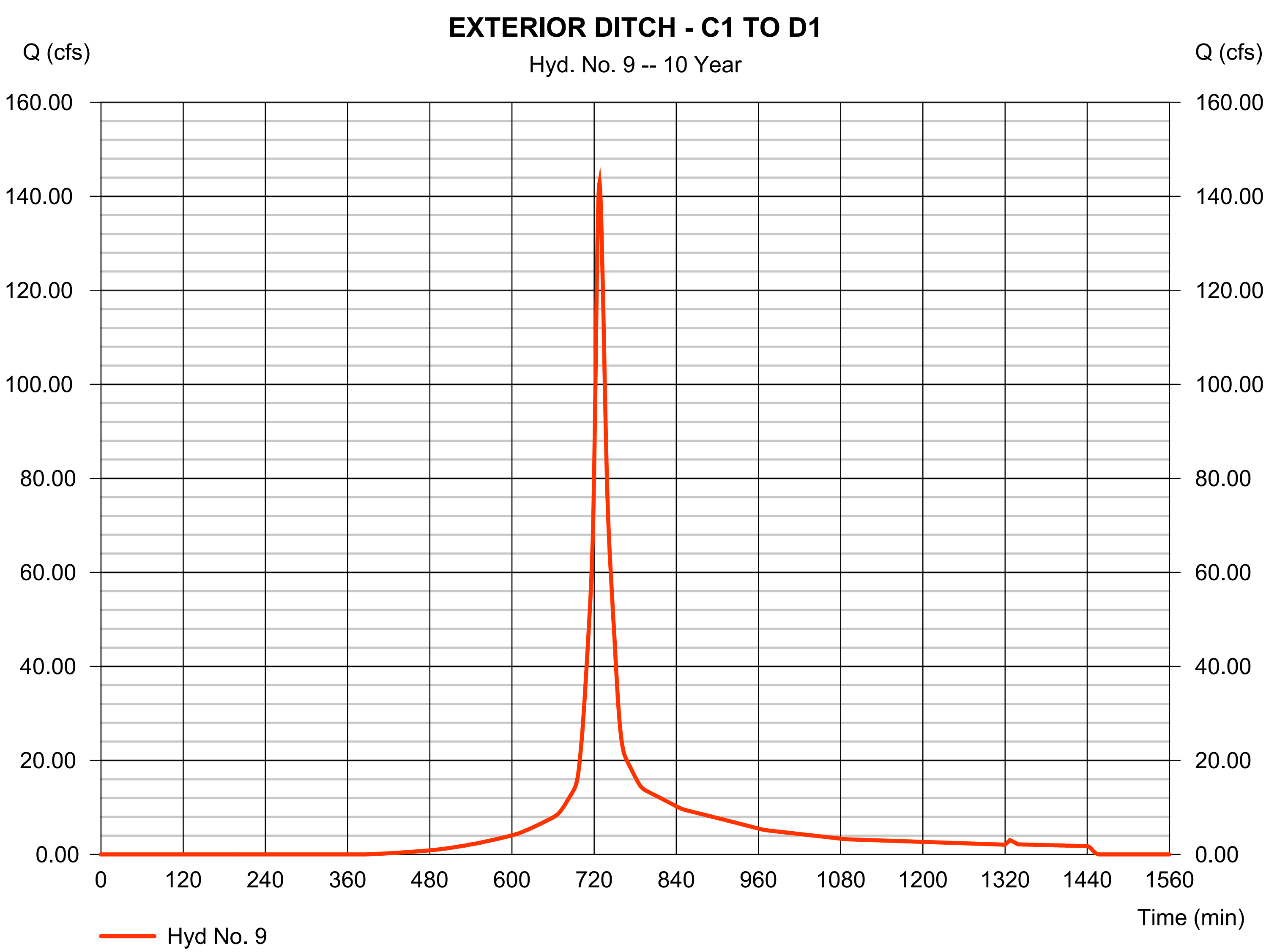
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 9

EXTERIOR DITCH - C1 TO D1

Hydrograph type	= SCS Runoff	Peak discharge	= 142.93 cfs
Storm frequency	= 10 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 522,352 cuft
Drainage area	= 33.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.00 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



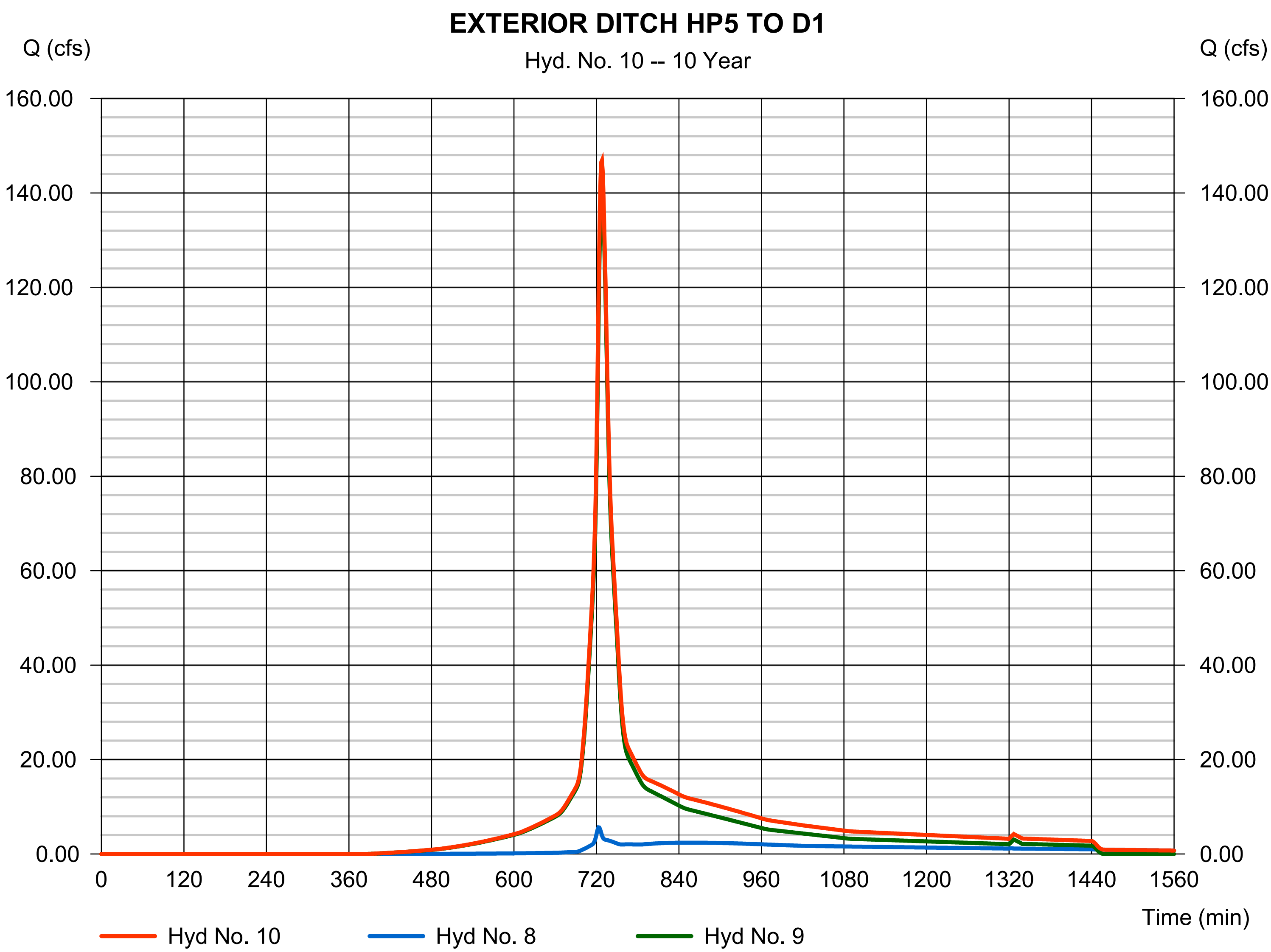
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 10

EXTERIOR DITCH HP5 TO D1

Hydrograph type	= Combine	Peak discharge	= 146.87 cfs
Storm frequency	= 10 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 629,900 cuft
Inflow hyds.	= 8, 9	Contrib. drain. area	= 33.380 ac



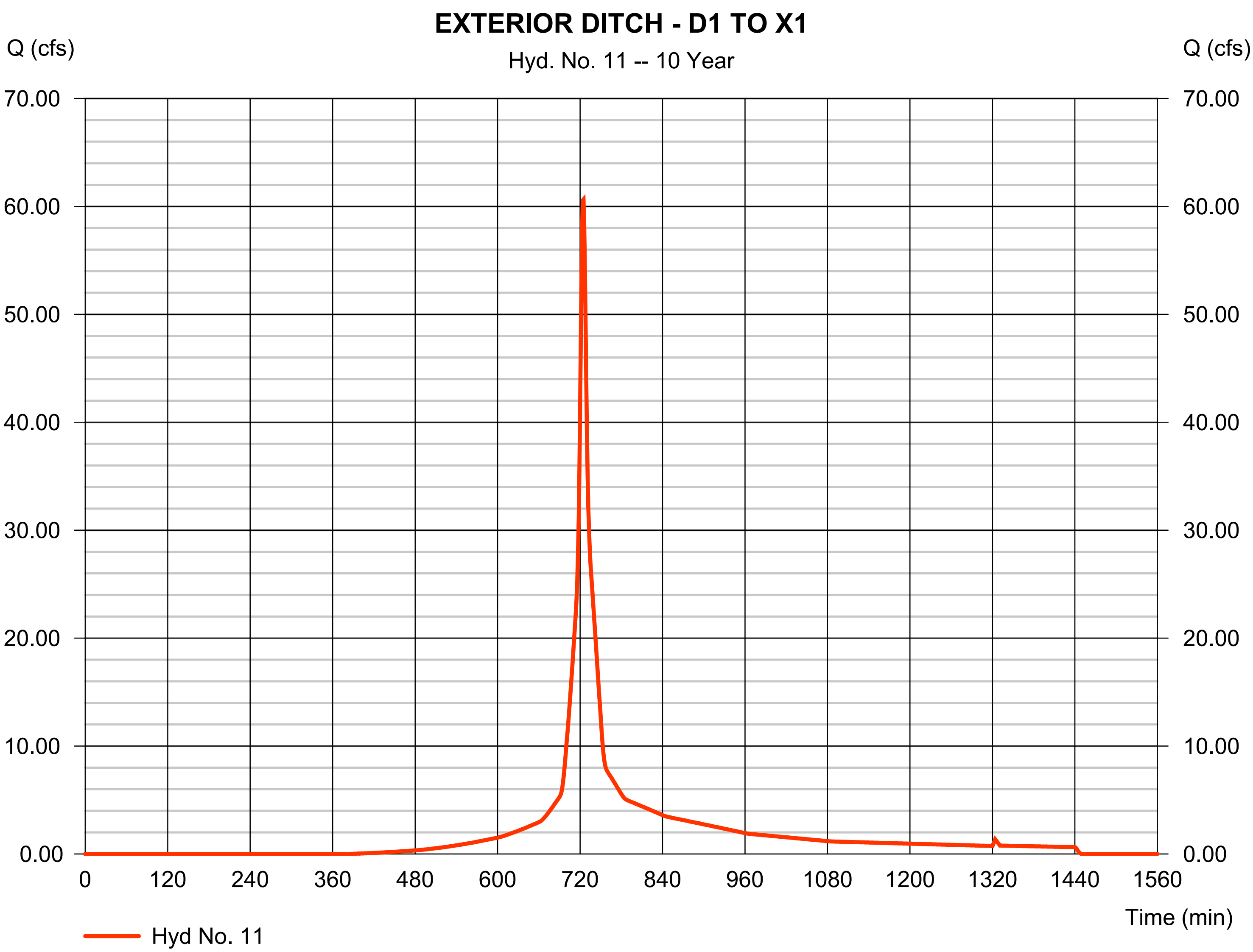
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 11

EXTERIOR DITCH - D1 TO X1

Hydrograph type	= SCS Runoff	Peak discharge	= 60.64 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 188,669 cuft
Drainage area	= 11.900 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.20 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



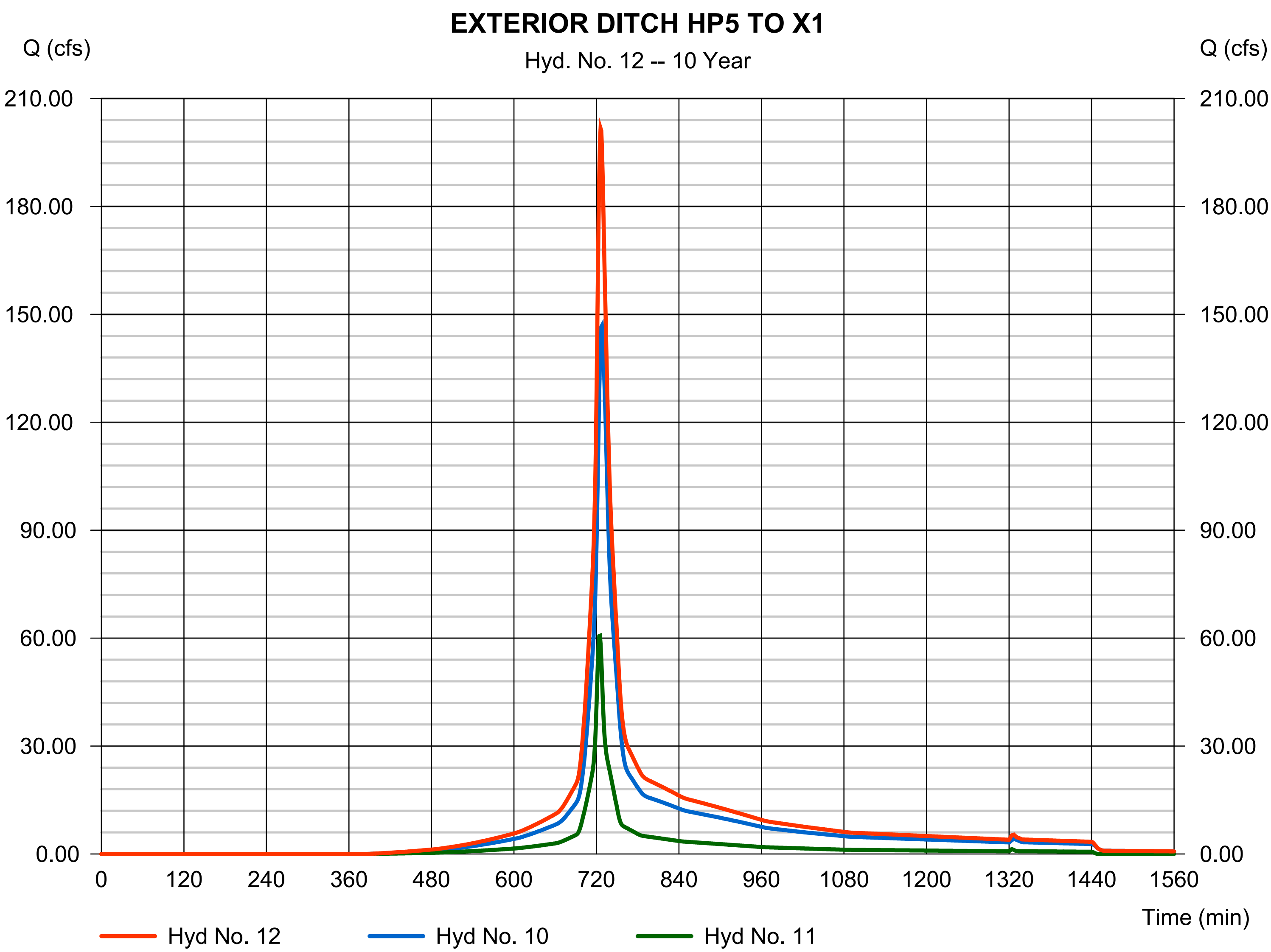
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 12

EXTERIOR DITCH HP5 TO X1

Hydrograph type	= Combine	Peak discharge	= 201.68 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 818,569 cuft
Inflow hyds.	= 10, 11	Contrib. drain. area	= 11.900 ac



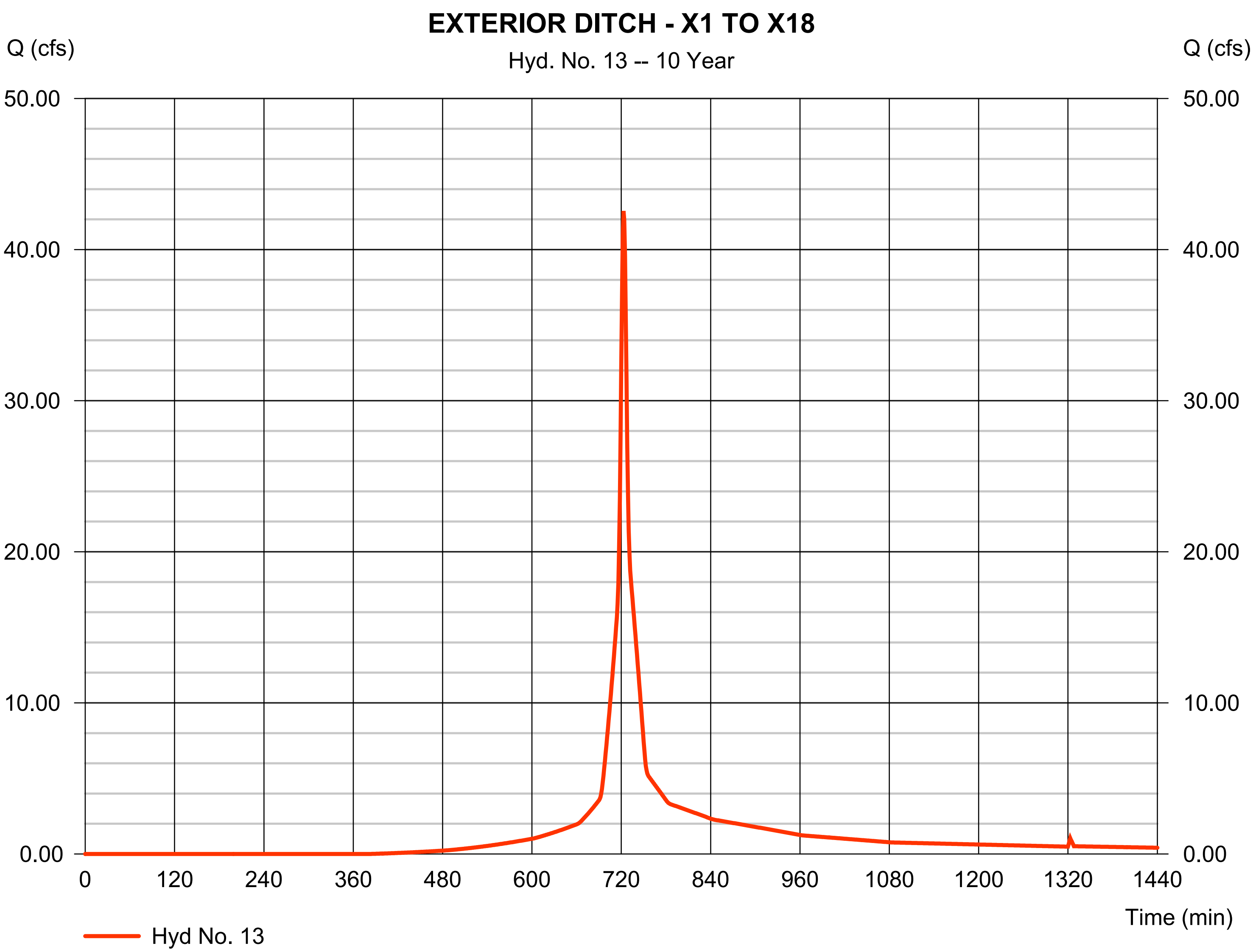
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 13

EXTERIOR DITCH - X1 TO X18

Hydrograph type	= SCS Runoff	Peak discharge	= 42.56 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 123,915 cuft
Drainage area	= 8.060 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.80 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



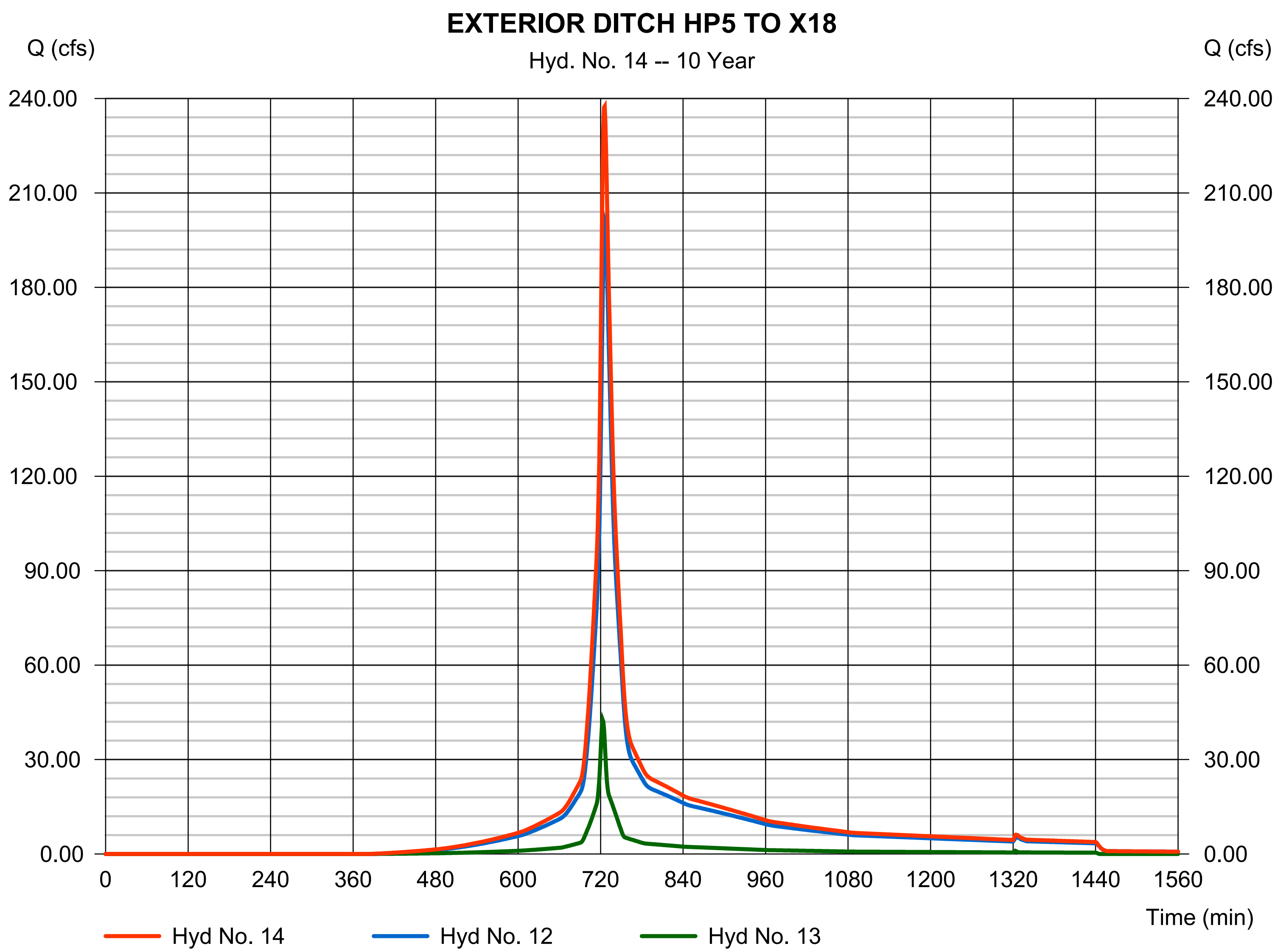
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 14

EXTERIOR DITCH HP5 TO X18

Hydrograph type	= Combine	Peak discharge	= 237.50 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 942,485 cuft
Inflow hyds.	= 12, 13	Contrib. drain. area	= 8.060 ac



Hydrograph Report

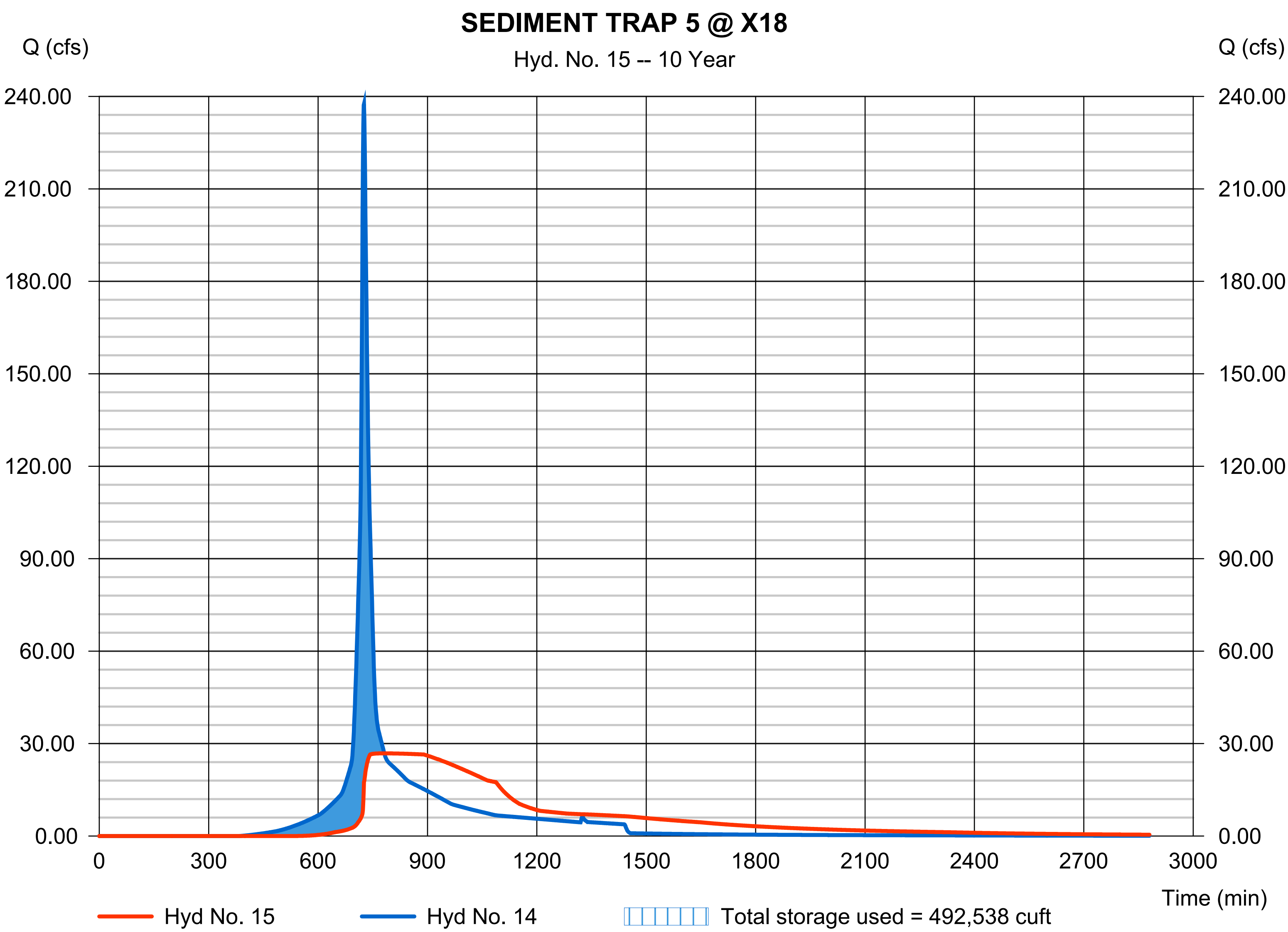
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 15

SEDIMENT TRAP 5 @ X18

Hydrograph type	= Reservoir	Peak discharge	= 26.83 cfs
Storm frequency	= 10 yrs	Time to peak	= 782 min
Time interval	= 1 min	Hyd. volume	= 910,518 cuft
Inflow hyd. No.	= 14 - EXTERIOR DITCH HP5 TO X18	Max. Elevation	= 250.09 ft
Reservoir name	= SEDIMENT TRAP 5 @ X18	Max. Storage	= 492,538 cuft

Storage Indication method used. Wet pond routing start elevation = 242.00 ft.



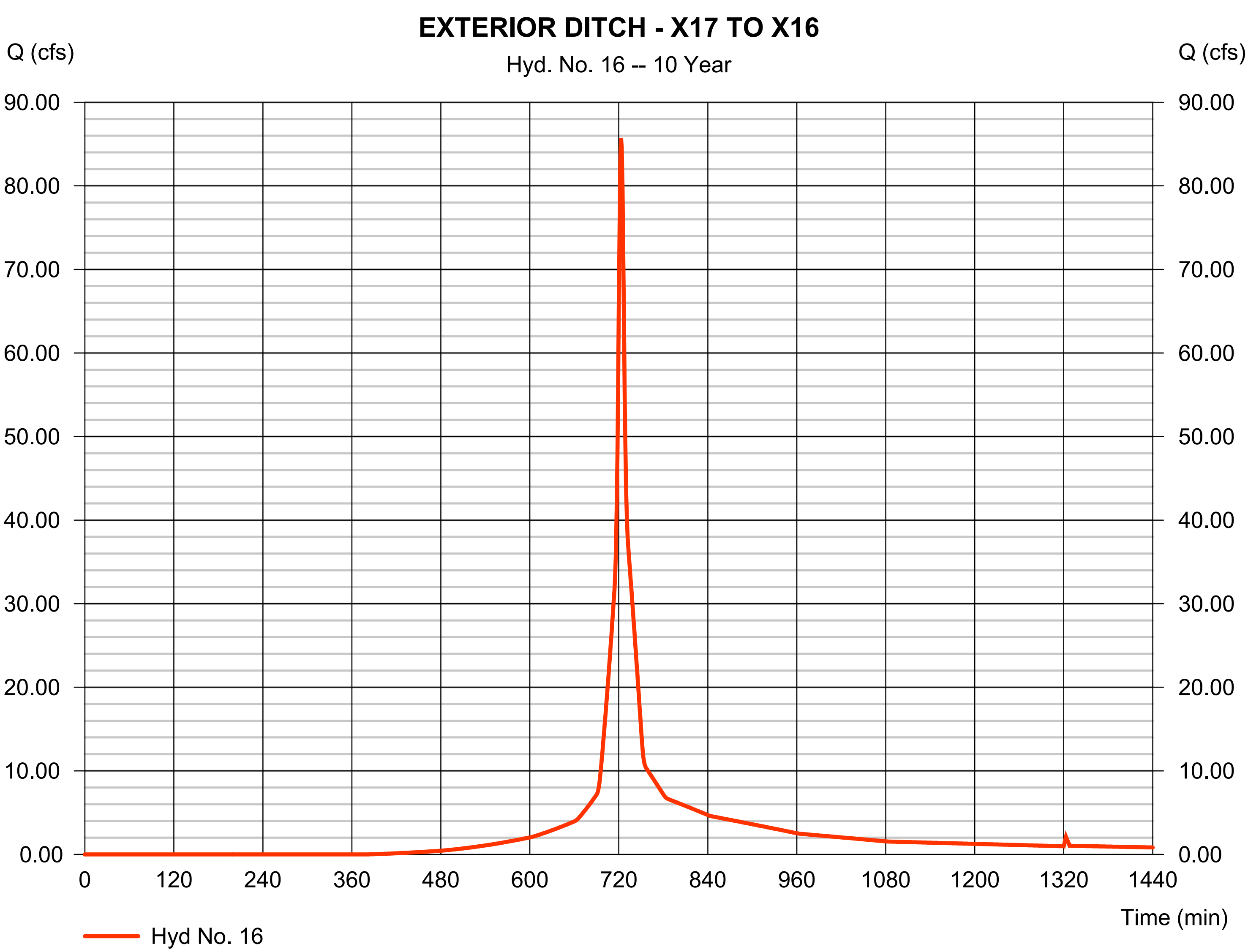
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 16

EXTERIOR DITCH - X17 TO X16

Hydrograph type	= SCS Runoff	Peak discharge	= 85.74 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 249,676 cuft
Drainage area	= 16.240 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



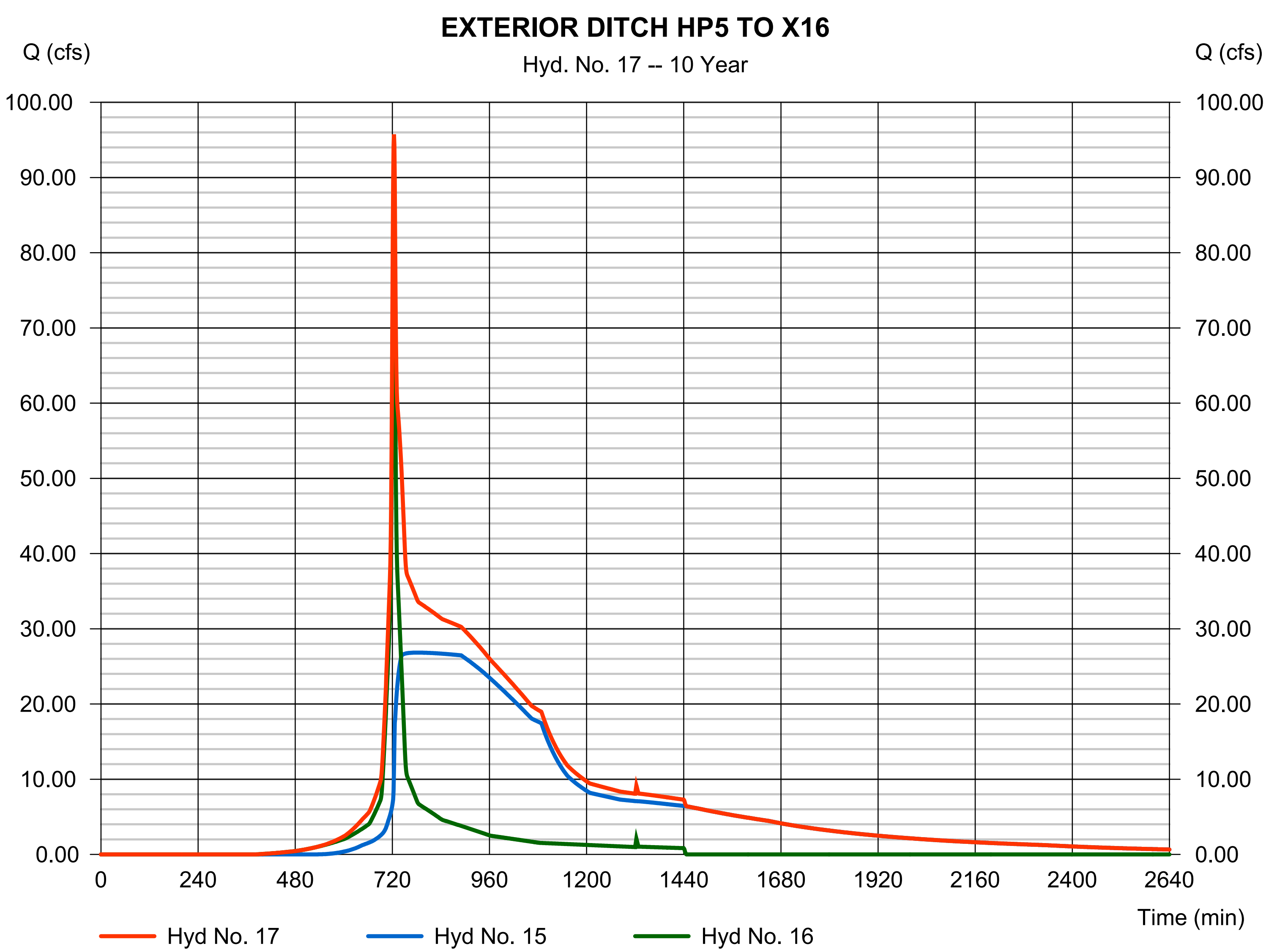
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 17

EXTERIOR DITCH HP5 TO X16

Hydrograph type	= Combine	Peak discharge	= 95.74 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 1,160,195 cuft
Inflow hyds.	= 15, 16	Contrib. drain. area	= 16.240 ac



Hydrograph Report

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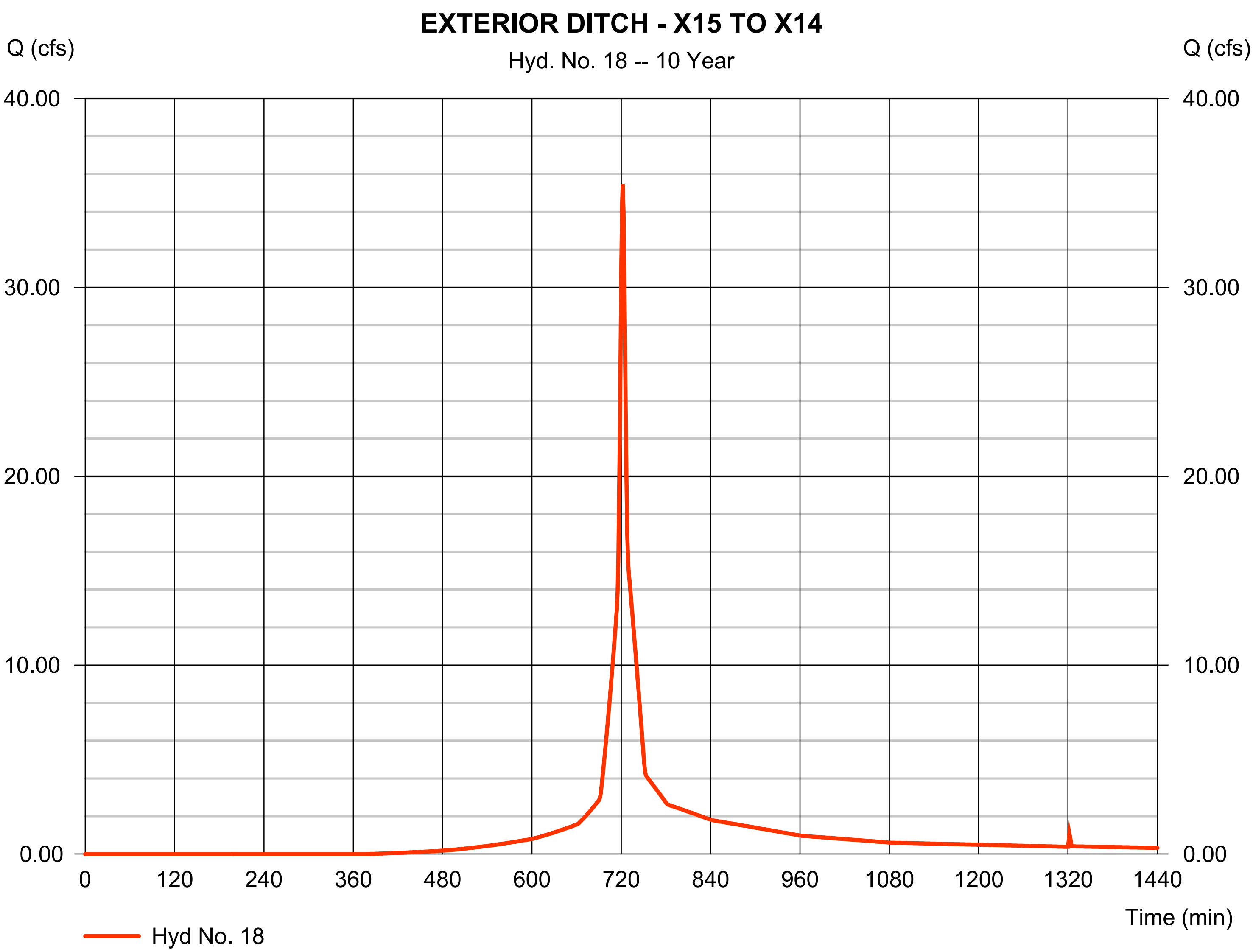
Hyd. No. 18

EXTERIOR DITCH - X15 TO X14

Hydrograph type	= SCS Runoff	Peak discharge	= 35.47 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 97,145 cuft
Drainage area	= 6.740 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 2.00 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



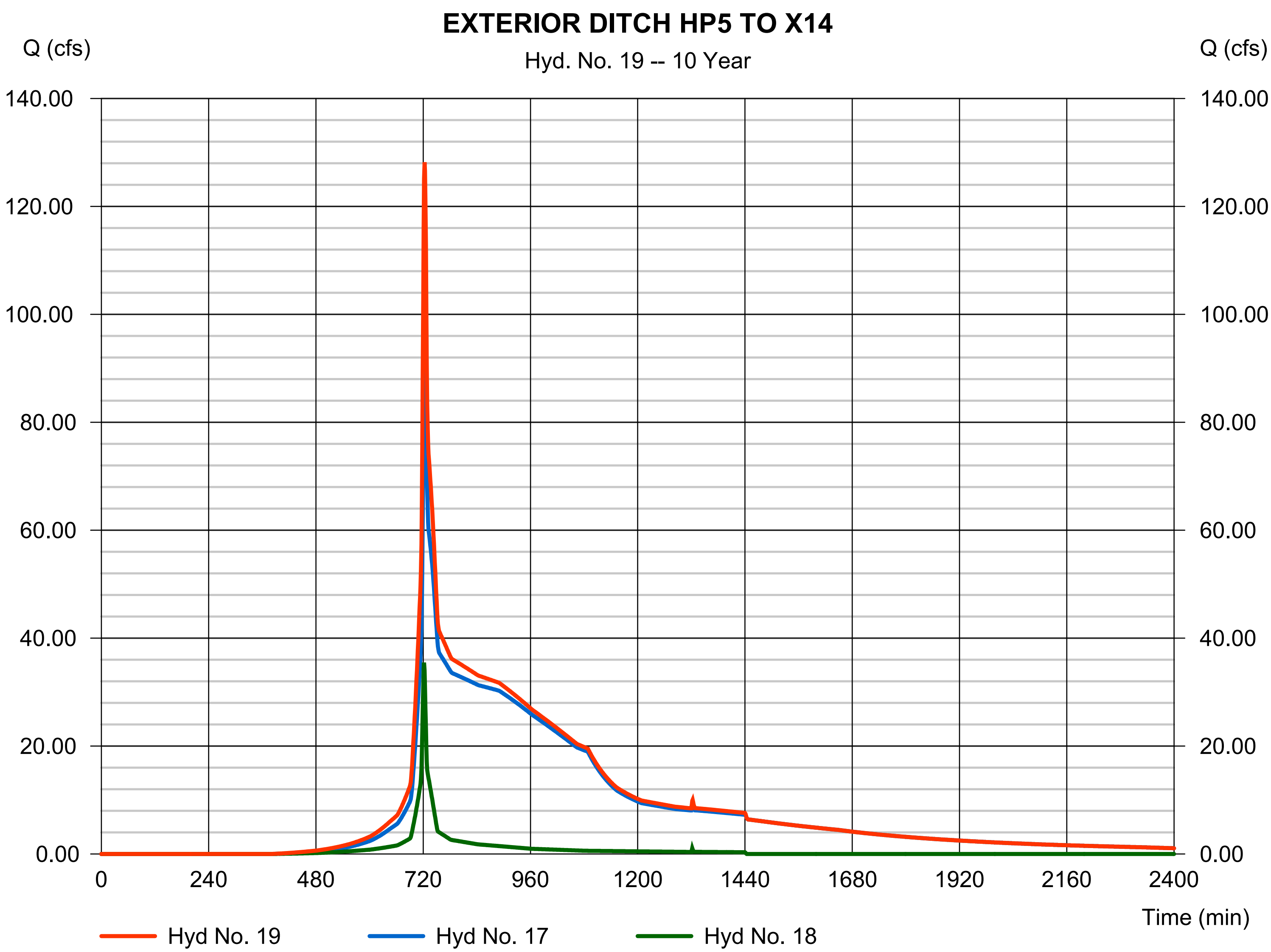
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 19

EXTERIOR DITCH HP5 TO X14

Hydrograph type	= Combine	Peak discharge	= 128.18 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 1,257,340 cuft
Inflow hyds.	= 17, 18	Contrib. drain. area	= 6.740 ac



Hydrograph Report

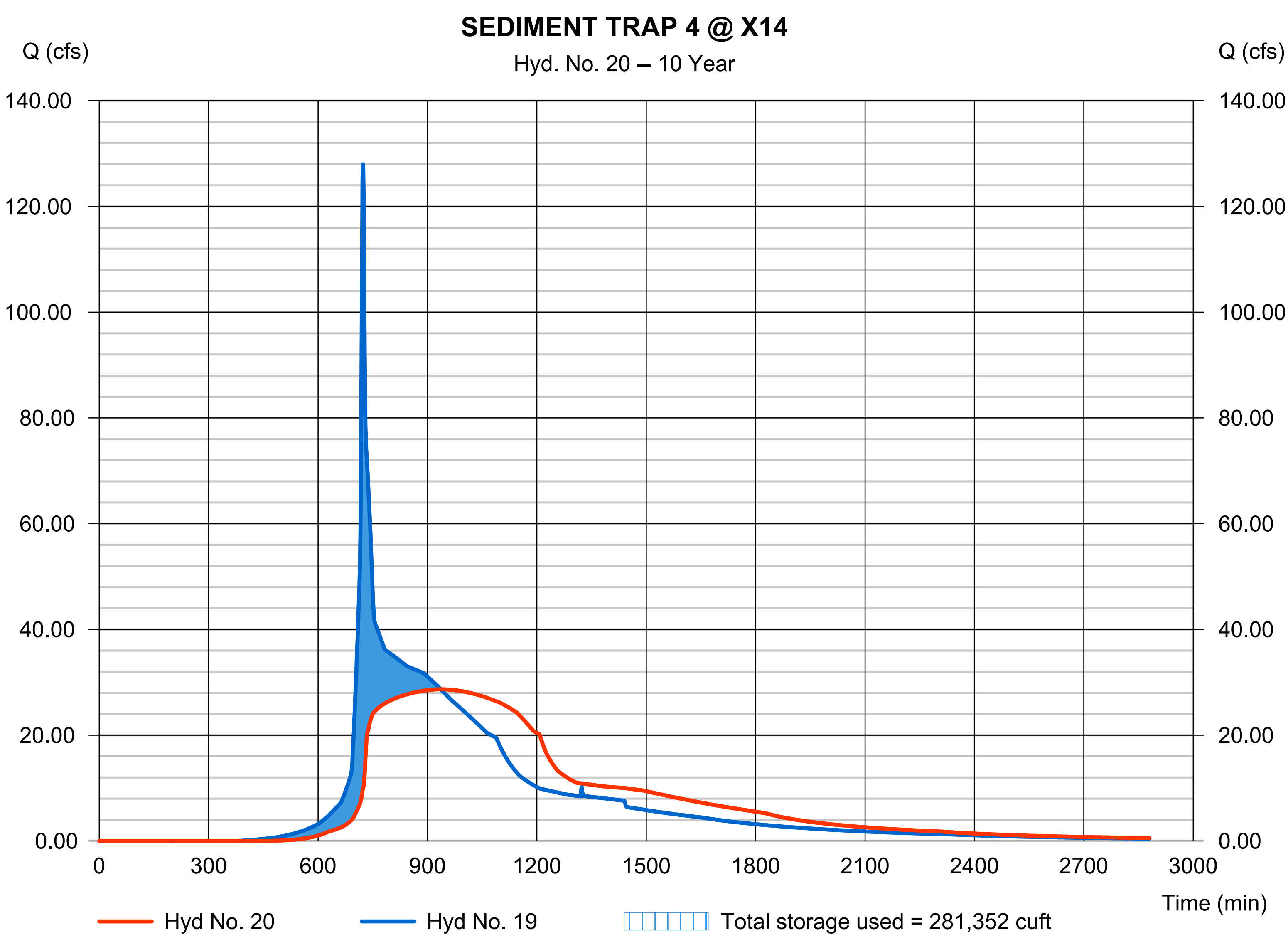
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 20

SEDIMENT TRAP 4 @ X14

Hydrograph type	= Reservoir	Peak discharge	= 28.67 cfs
Storm frequency	= 10 yrs	Time to peak	= 937 min
Time interval	= 1 min	Hyd. volume	= 1,249,933 cuft
Inflow hyd. No.	= 19 - EXTERIOR DITCH HP5 TO X14	Max. Elevation	= 246.97 ft
Reservoir name	= SEDIMENT TRAP 4 @ X14	Max. Storage	= 281,352 cuft

Storage Indication method used. Wet pond routing start elevation = 238.00 ft.



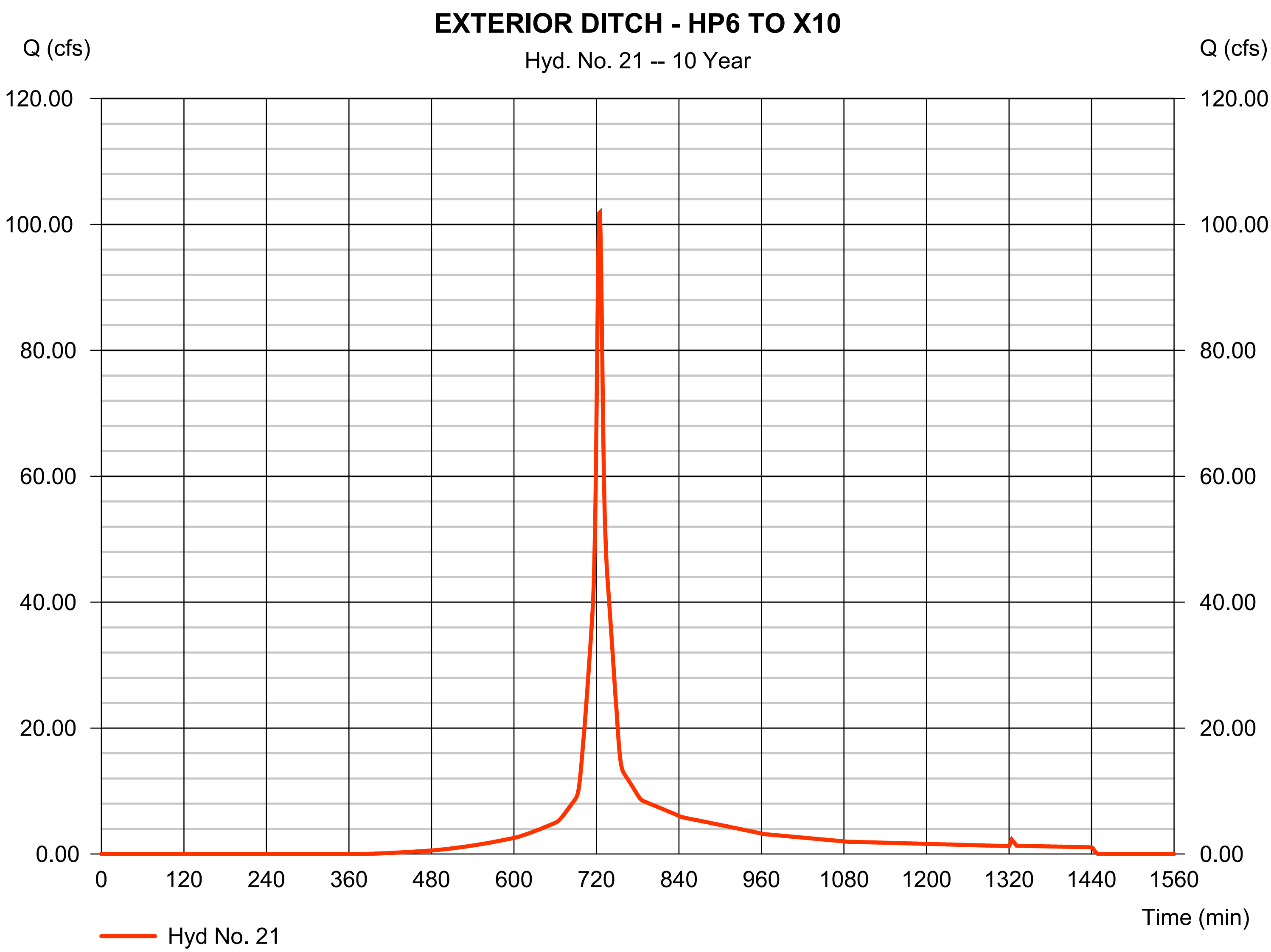
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 21

EXTERIOR DITCH - HP6 TO X10

Hydrograph type	= SCS Runoff	Peak discharge	= 101.91 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 317,091 cuft
Drainage area	= 20.000 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

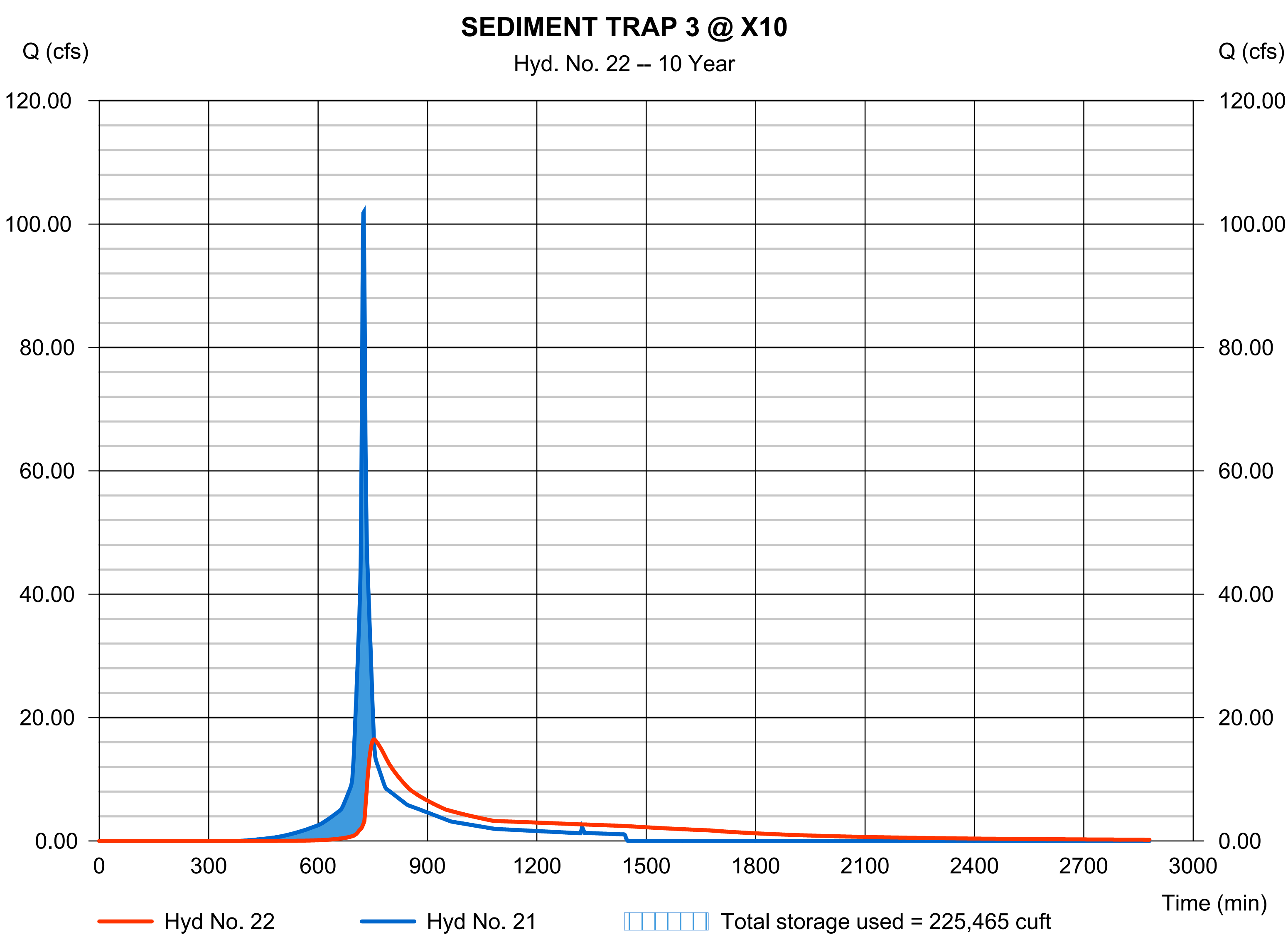
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 22

SEDIMENT TRAP 3 @ X10

Hydrograph type	= Reservoir	Peak discharge	= 16.46 cfs
Storm frequency	= 10 yrs	Time to peak	= 753 min
Time interval	= 1 min	Hyd. volume	= 301,288 cuft
Inflow hyd. No.	= 21 - EXTERIOR DITCH - HP6 TO X10	Max. Elevation	= 251.78 ft
Reservoir name	= SEDIMENT TRAP 3 @ X10	Max. Storage	= 225,465 cuft

Storage Indication method used. Wet pond routing start elevation = 248.00 ft.



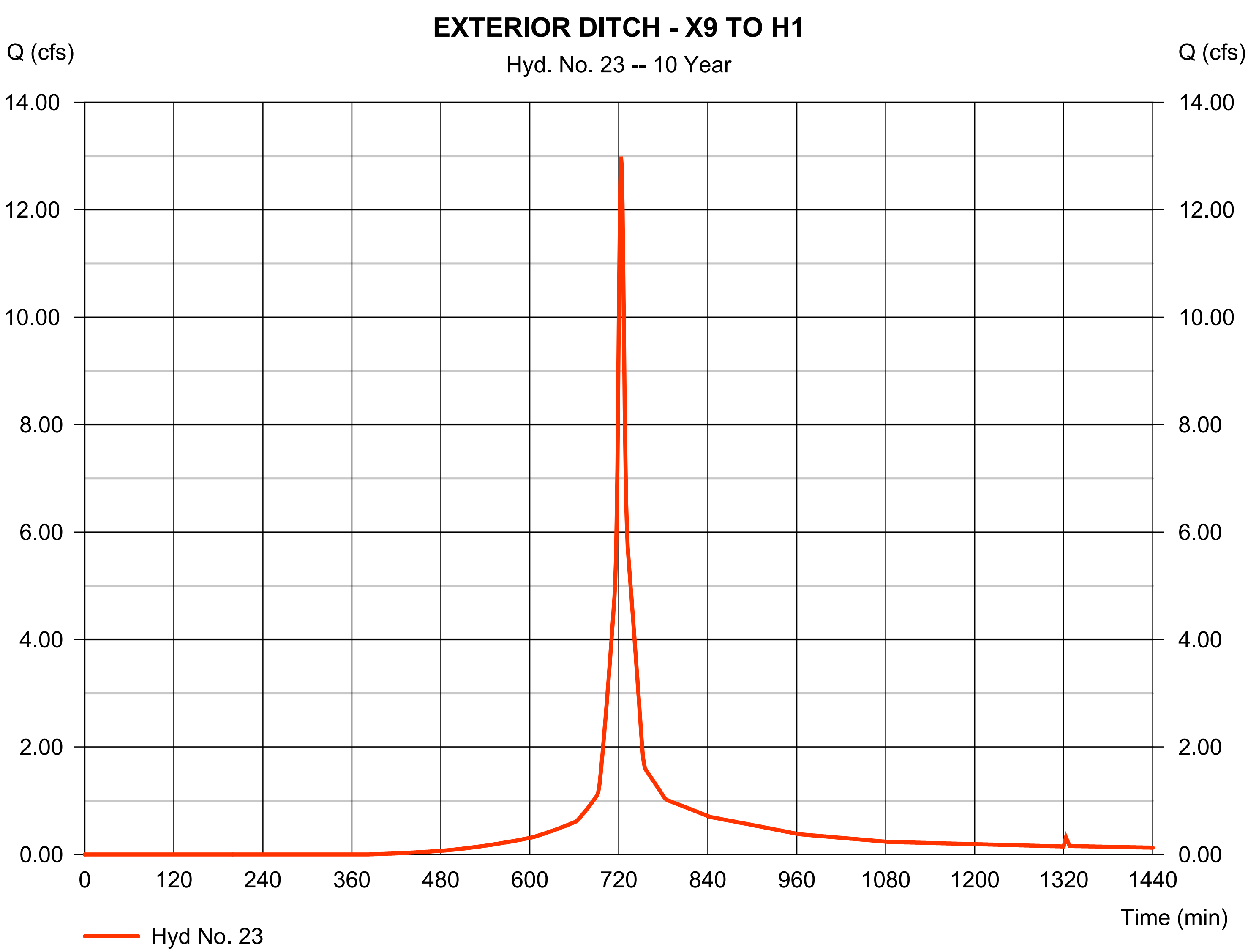
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 23

EXTERIOR DITCH - X9 TO H1

Hydrograph type	= SCS Runoff	Peak discharge	= 12.99 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 37,820 cuft
Drainage area	= 2.460 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



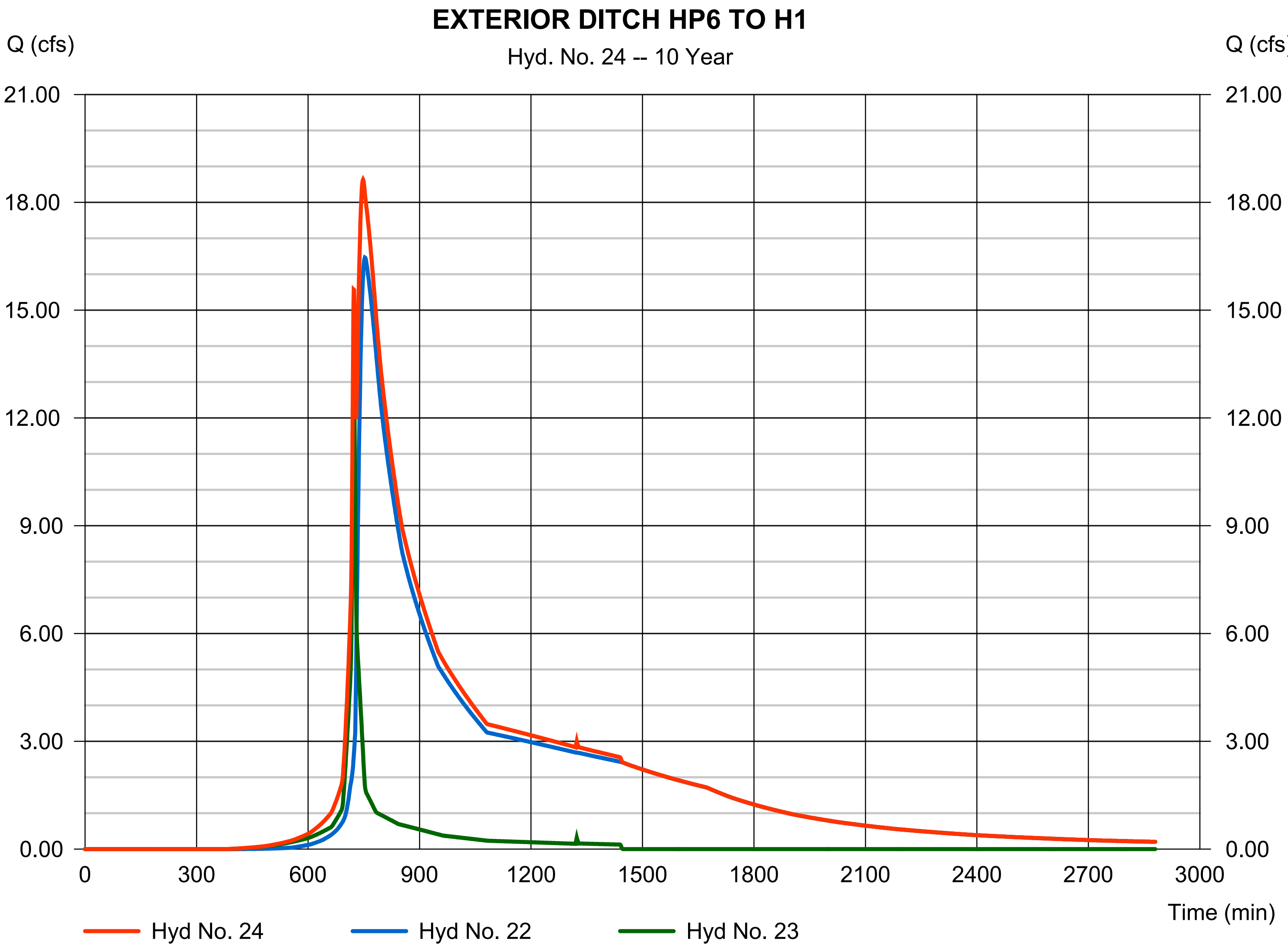
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 24

EXTERIOR DITCH HP6 TO H1

Hydrograph type	= Combine	Peak discharge	= 18.64 cfs
Storm frequency	= 10 yrs	Time to peak	= 748 min
Time interval	= 1 min	Hyd. volume	= 339,108 cuft
Inflow hyds.	= 22, 23	Contrib. drain. area	= 2.460 ac



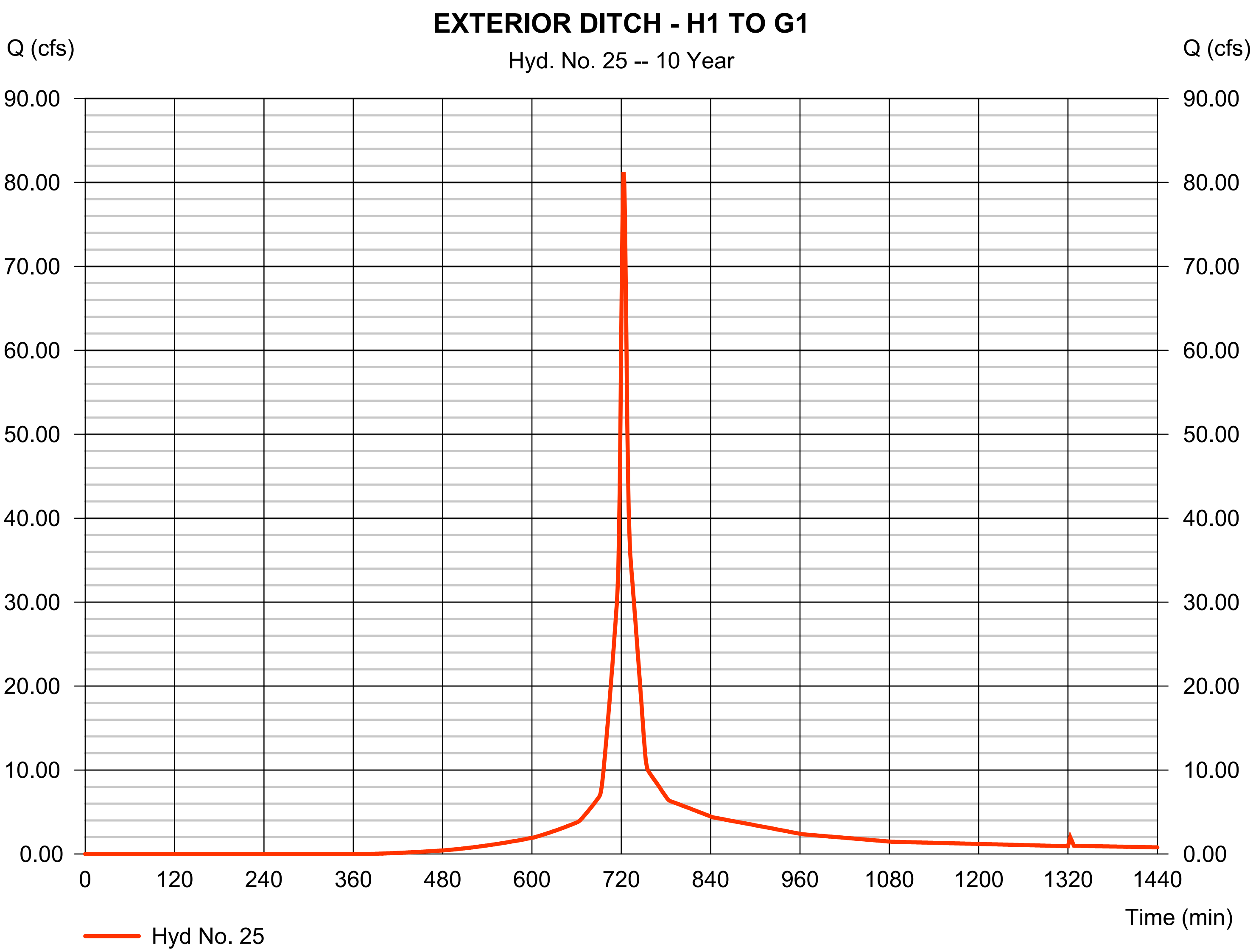
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 25

EXTERIOR DITCH - H1 TO G1

Hydrograph type	= SCS Runoff	Peak discharge	= 81.26 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 236,608 cuft
Drainage area	= 15.390 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



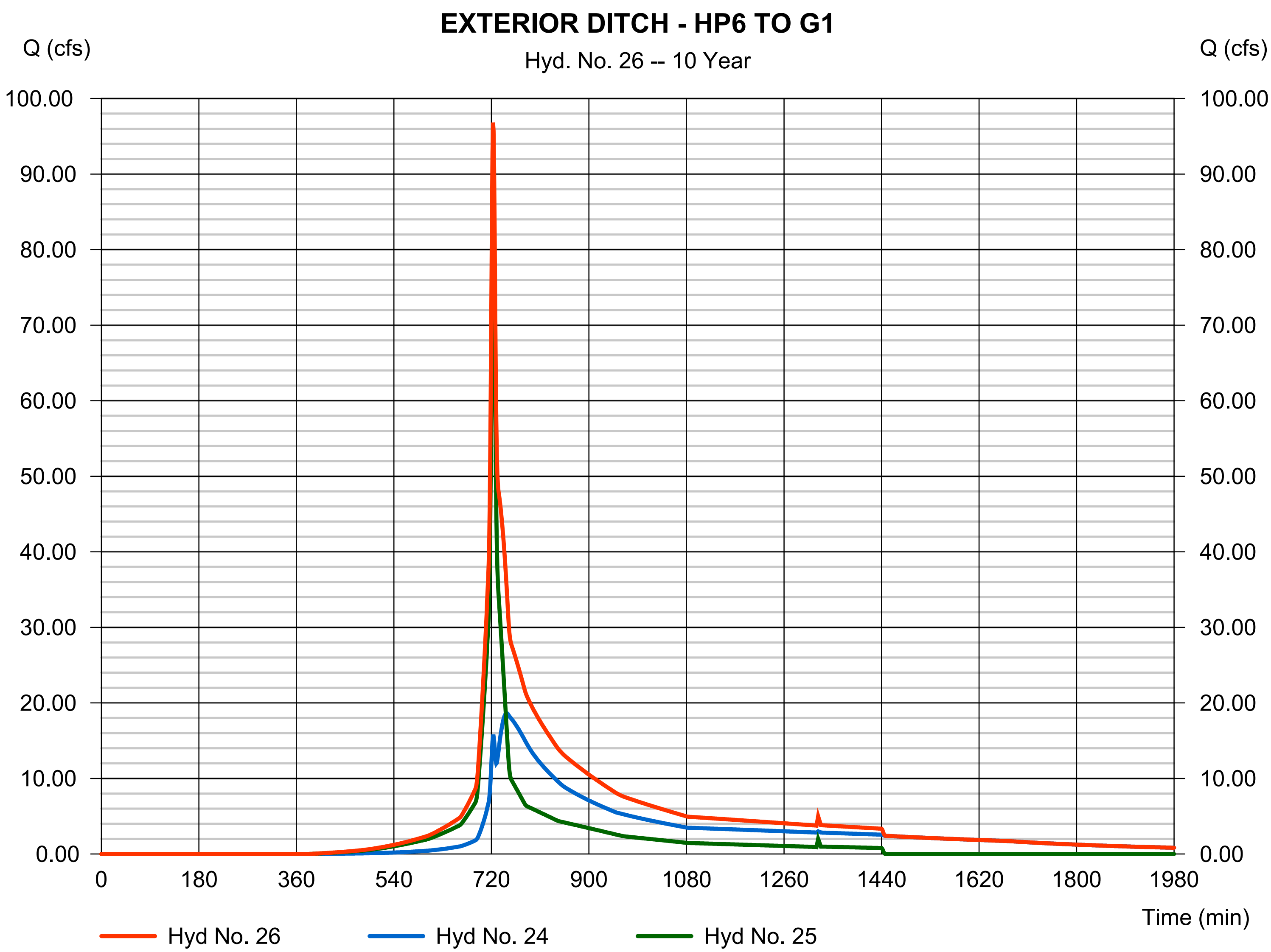
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 26

EXTERIOR DITCH - HP6 TO G1

Hydrograph type	= Combine	Peak discharge	= 96.83 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 575,716 cuft
Inflow hyds.	= 24, 25	Contrib. drain. area	= 15.390 ac



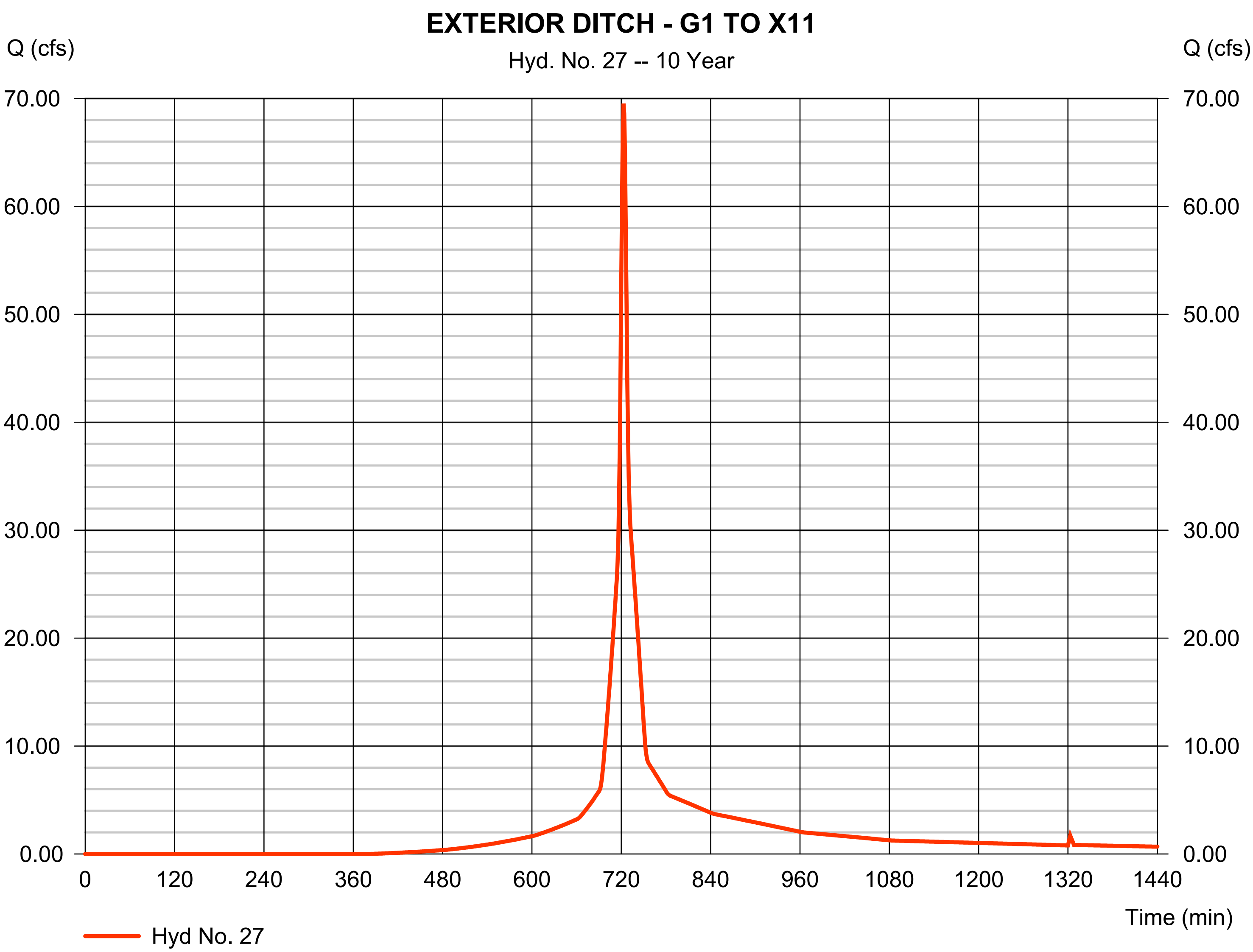
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 27

EXTERIOR DITCH - G1 TO X11

Hydrograph type	= SCS Runoff	Peak discharge	= 69.54 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 202,477 cuft
Drainage area	= 13.170 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.00 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

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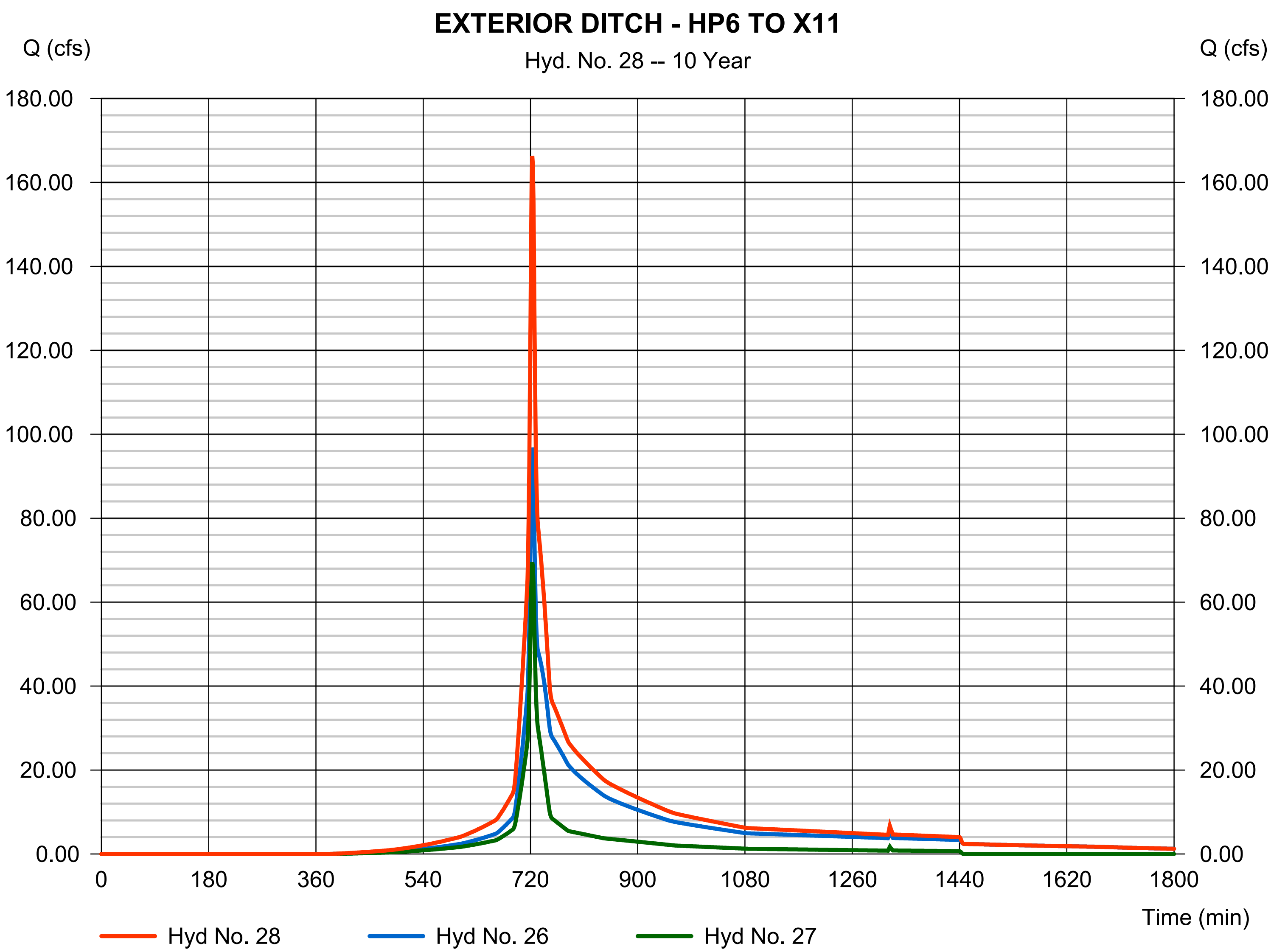
Hyd. No. 28

EXTERIOR DITCH - HP6 TO X11

Hydrograph type	= Combine	Peak discharge	= 166.36 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 778,193 cuft
Inflow hyds.	= 26, 27	Contrib. drain. area	= 13.170 ac



Hydrograph Report

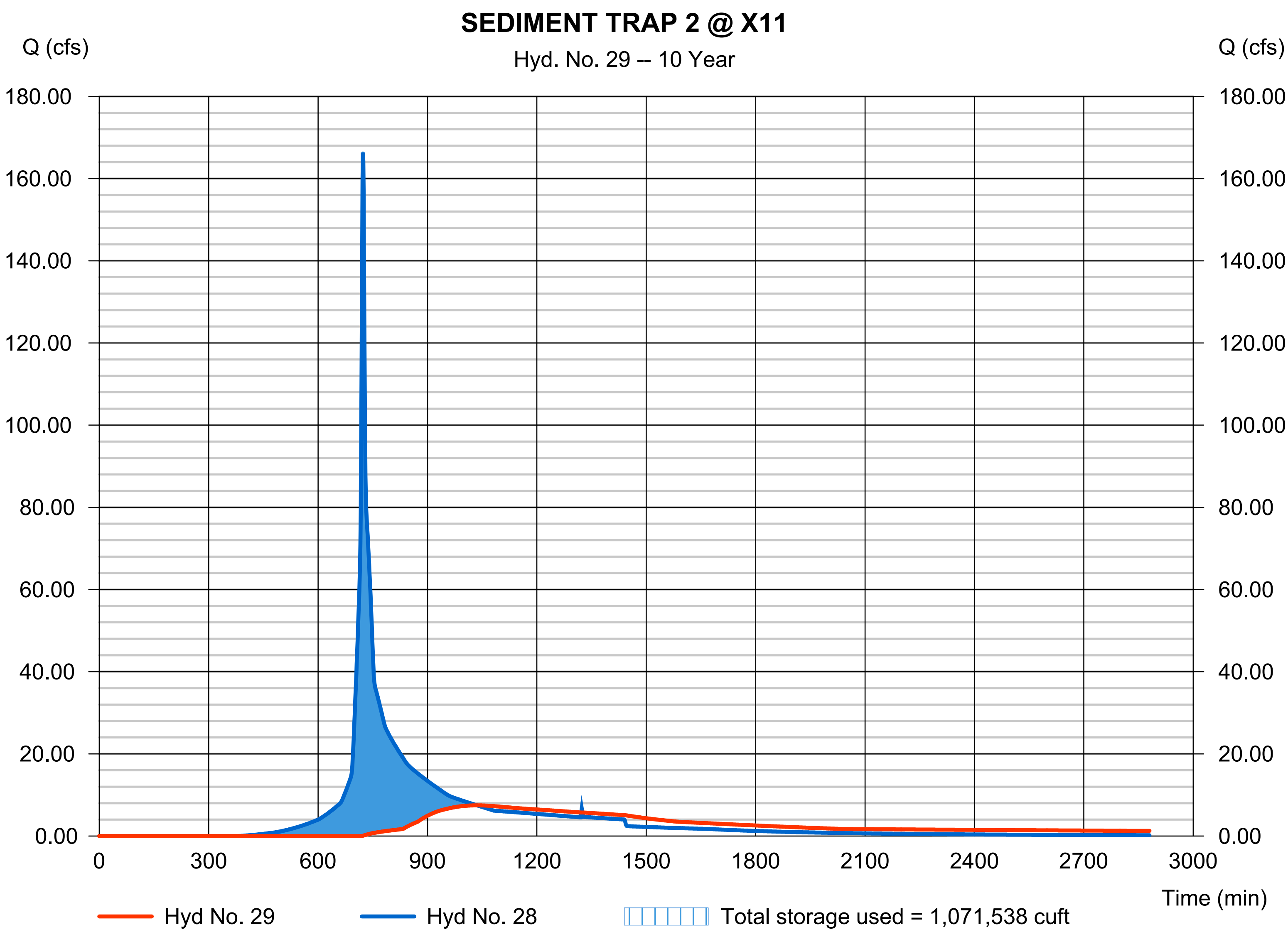
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 29

SEDIMENT TRAP 2 @ X11

Hydrograph type	= Reservoir	Peak discharge	= 7.469 cfs
Storm frequency	= 10 yrs	Time to peak	= 1036 min
Time interval	= 1 min	Hyd. volume	= 407,475 cuft
Inflow hyd. No.	= 28 - EXTERIOR DITCH - HP6 TO X11	Max. Elevation	= 246.44 ft
Reservoir name	= SEDIMENT TRAP 2 @ X11	Max. Storage	= 1,071,538 cuft

Storage Indication method used. Wet pond routing start elevation = 243.00 ft.



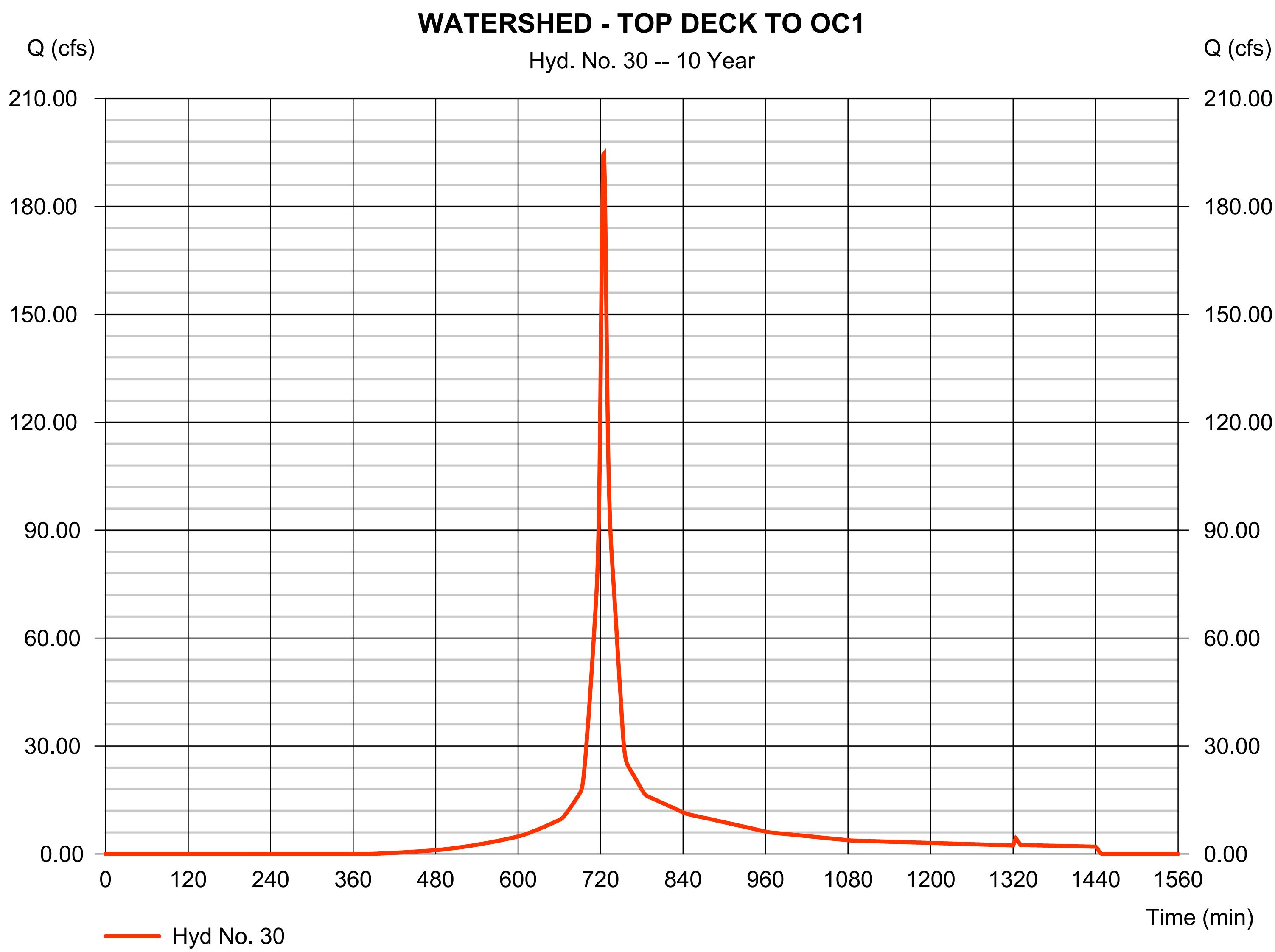
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 30

WATERSHED - TOP DECK TO OC1

Hydrograph type	= SCS Runoff	Peak discharge	= 194.65 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 605,644 cuft
Drainage area	= 38.200 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 6.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

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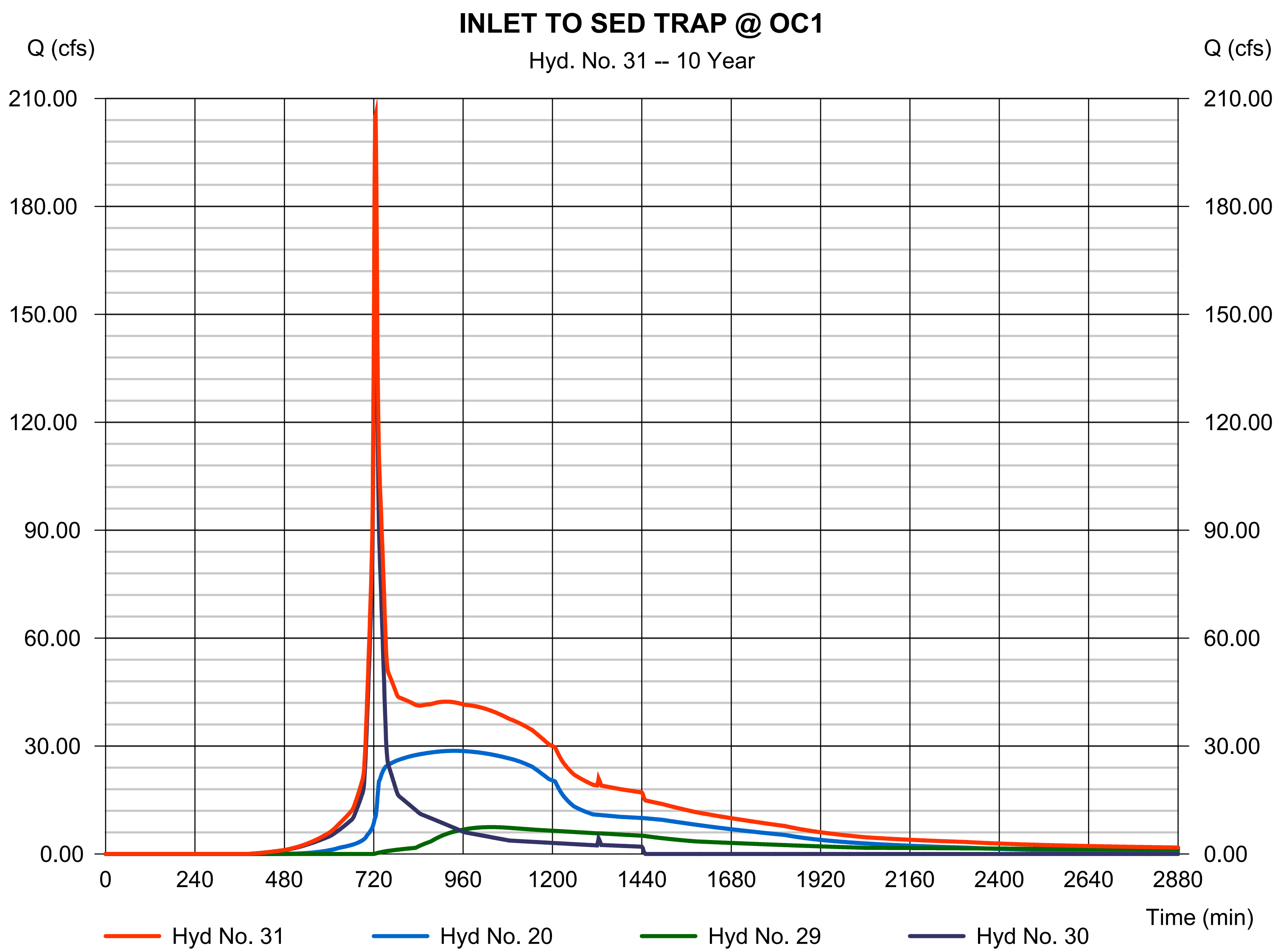
Hyd. No. 31

INLET TO SED TRAP @ OC1

Hydrograph type	= Combine	Peak discharge	= 205.22 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 2,263,053 cuft
Inflow hyds.	= 20, 29, 30	Contrib. drain. area	= 38.200 ac



Hydrograph Report

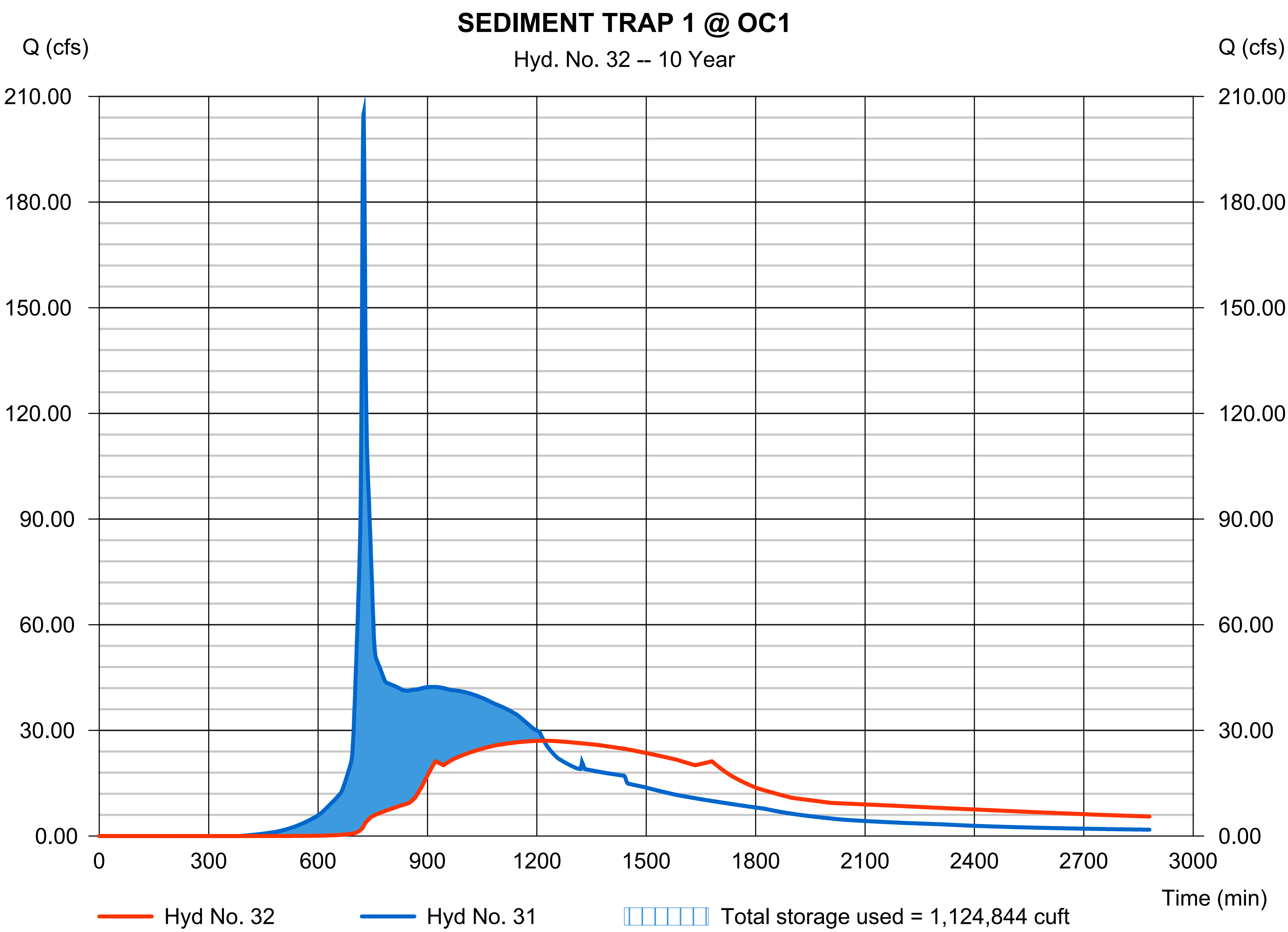
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 32

SEDIMENT TRAP 1 @ OC1

Hydrograph type	= Reservoir	Peak discharge	= 27.06 cfs
Storm frequency	= 10 yrs	Time to peak	= 1219 min
Time interval	= 1 min	Hyd. volume	= 1,875,470 cuft
Inflow hyd. No.	= 31 - INLET TO SED TRAP @ OC1	Max. Elevation	= 236.27 ft
Reservoir name	= SEDIMENT TRAP 1 @ OC1	Max. Storage	= 1,124,844 cuft

Storage Indication method used. Wet pond routing start elevation = 228.00 ft.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	19.19	1	725	62,615	------	------	------	EXTERIOR DITCH - HP5 TO X8
2	SCS Runoff	19.42	1	725	63,345	------	------	------	EXTERIOR DITCH - X7 TO X6
3	Combine	38.61	1	725	125,960	1, 2	------	------	EXTERIOR DITCH HP5 TO X6
4	SCS Runoff	9.616	1	724	30,121	------	------	------	EXTERIOR DITCH - X5 TO X3
5	Combine	48.22	1	725	156,081	3, 4	------	------	EXTERIOR DITCH HP5 TO X3
6	Reservoir	5.078	1	774	119,277	5	257.81	125,160	SEDIMENT TRAP 6 @ X3
7	SCS Runoff	6.647	1	723	19,472	------	------	------	EXTERIOR DITCH - X4 TO C1
8	Combine	7.058	1	723	138,749	6, 7	------	------	EXTERIOR DITCH HP5 TO C1
9	SCS Runoff	173.02	1	728	636,139	------	------	------	EXTERIOR DITCH - C1 TO D1
10	Combine	178.09	1	728	774,889	8, 9	------	------	EXTERIOR DITCH HP5 TO D1
11	SCS Runoff	73.36	1	724	229,768	------	------	------	EXTERIOR DITCH - D1 TO X1
12	Combine	244.64	1	726	1,004,657	10, 11	------	------	EXTERIOR DITCH HP5 TO X1
13	SCS Runoff	51.51	1	723	150,909	------	------	------	EXTERIOR DITCH - X1 TO X18
14	Combine	287.80	1	726	1,155,566	12, 13	------	------	EXTERIOR DITCH HP5 TO X18
15	Reservoir	27.84	1	813	1,122,583	14	250.33	620,543	SEDIMENT TRAP 5 @ X18
16	SCS Runoff	103.80	1	723	304,064	------	------	------	EXTERIOR DITCH - X17 TO X16
17	Combine	122.43	1	723	1,426,648	15, 16	------	------	EXTERIOR DITCH HP5 TO X16
18	SCS Runoff	42.91	1	722	118,307	------	------	------	EXTERIOR DITCH - X15 TO X14
19	Combine	163.48	1	723	1,544,954	17, 18	------	------	EXTERIOR DITCH HP5 TO X14
20	Reservoir	31.19	1	968	1,537,197	19	247.61	328,229	SEDIMENT TRAP 4 @ X14
21	SCS Runoff	123.29	1	724	386,165	------	------	------	EXTERIOR DITCH - HP6 TO X10
22	Reservoir	17.56	1	755	369,897	21	252.28	260,417	SEDIMENT TRAP 3 @ X10
23	SCS Runoff	15.72	1	723	46,059	------	------	------	EXTERIOR DITCH - X9 TO H1
24	Combine	23.94	1	731	415,956	22, 23	------	------	EXTERIOR DITCH HP6 TO H1
25	SCS Runoff	98.36	1	723	288,149	------	------	------	EXTERIOR DITCH - H1 TO G1
26	Combine	117.63	1	723	704,106	24, 25	------	------	EXTERIOR DITCH - HP6 TO G1
27	SCS Runoff	84.17	1	723	246,584	------	------	------	EXTERIOR DITCH - G1 TO X11
28	Combine	201.80	1	723	950,689	26, 27	------	------	EXTERIOR DITCH - HP6 TO X11
29	Reservoir	14.72	1	925	577,516	28	246.77	1,129,301	SEDIMENT TRAP 2 @ X11
30	SCS Runoff	235.48	1	724	737,576	------	------	------	WATERSHED - TOP DECK TO OC1
31	Combine	254.87	1	725	2,852,292	20, 29, 30	------	------	INLET TO SED TRAP @ OC1
32	Reservoir	34.89	1	1291	2,438,157	31	237.64	1,382,721	SEDIMENT TRAP 1 @ OC1

Exterior Ditch [with ponds].gpw	Return Period: 25 Year	Friday, 01 / 30 / 2015

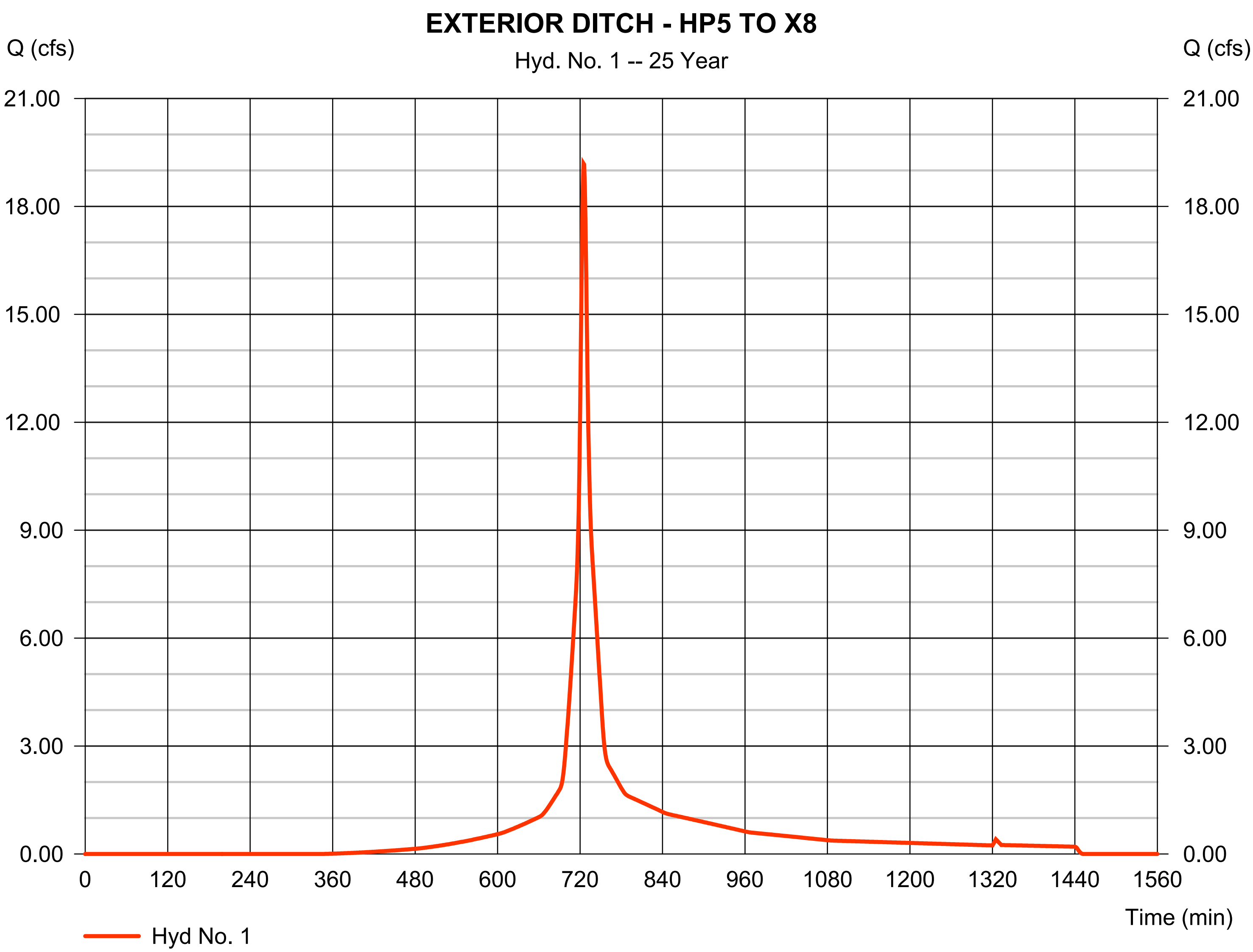
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

EXTERIOR DITCH - HP5 TO X8

Hydrograph type	= SCS Runoff	Peak discharge	= 19.19 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 62,615 cuft
Drainage area	= 3.430 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.30 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



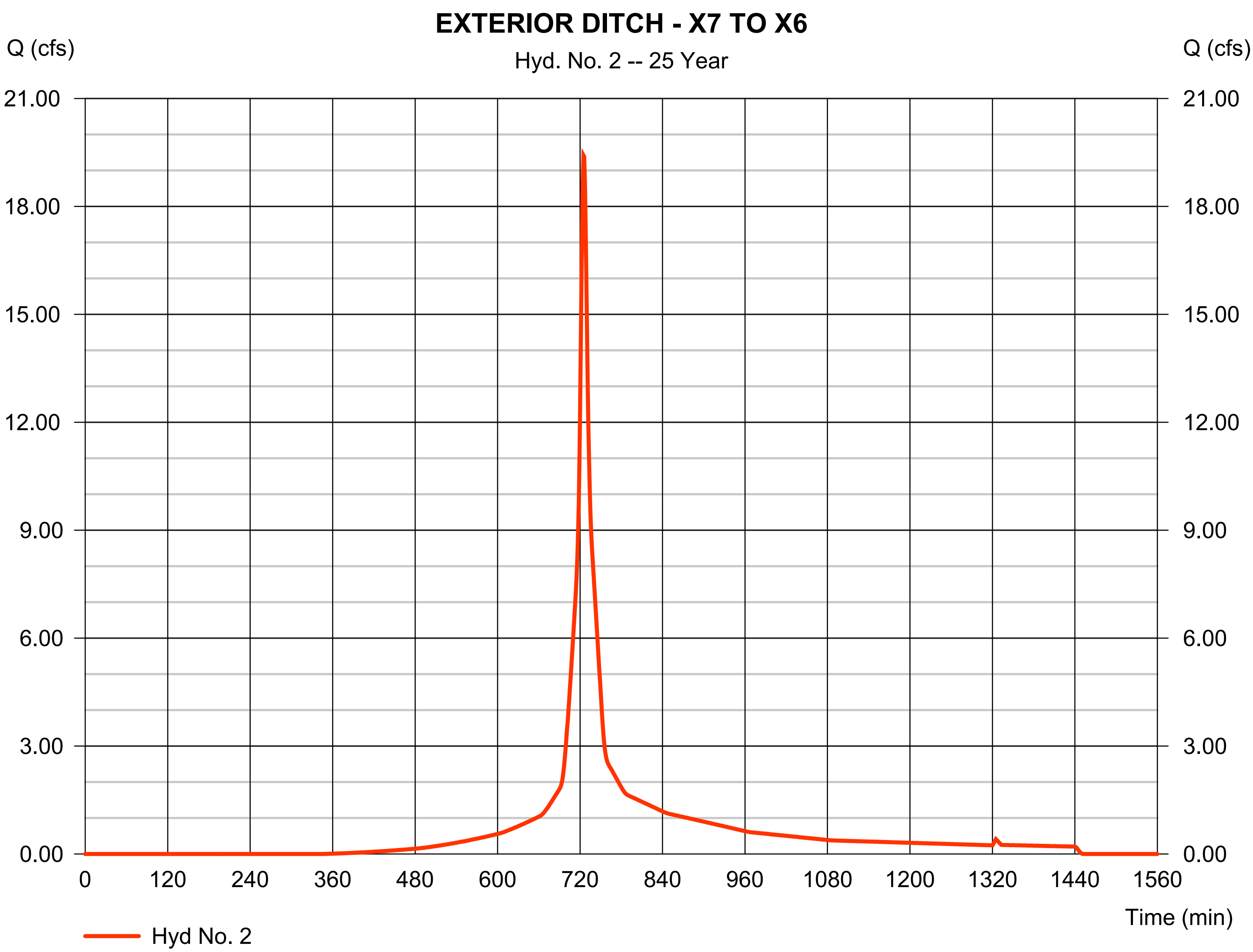
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 2

EXTERIOR DITCH - X7 TO X6

Hydrograph type	= SCS Runoff	Peak discharge	= 19.42 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 63,345 cuft
Drainage area	= 3.470 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.70 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



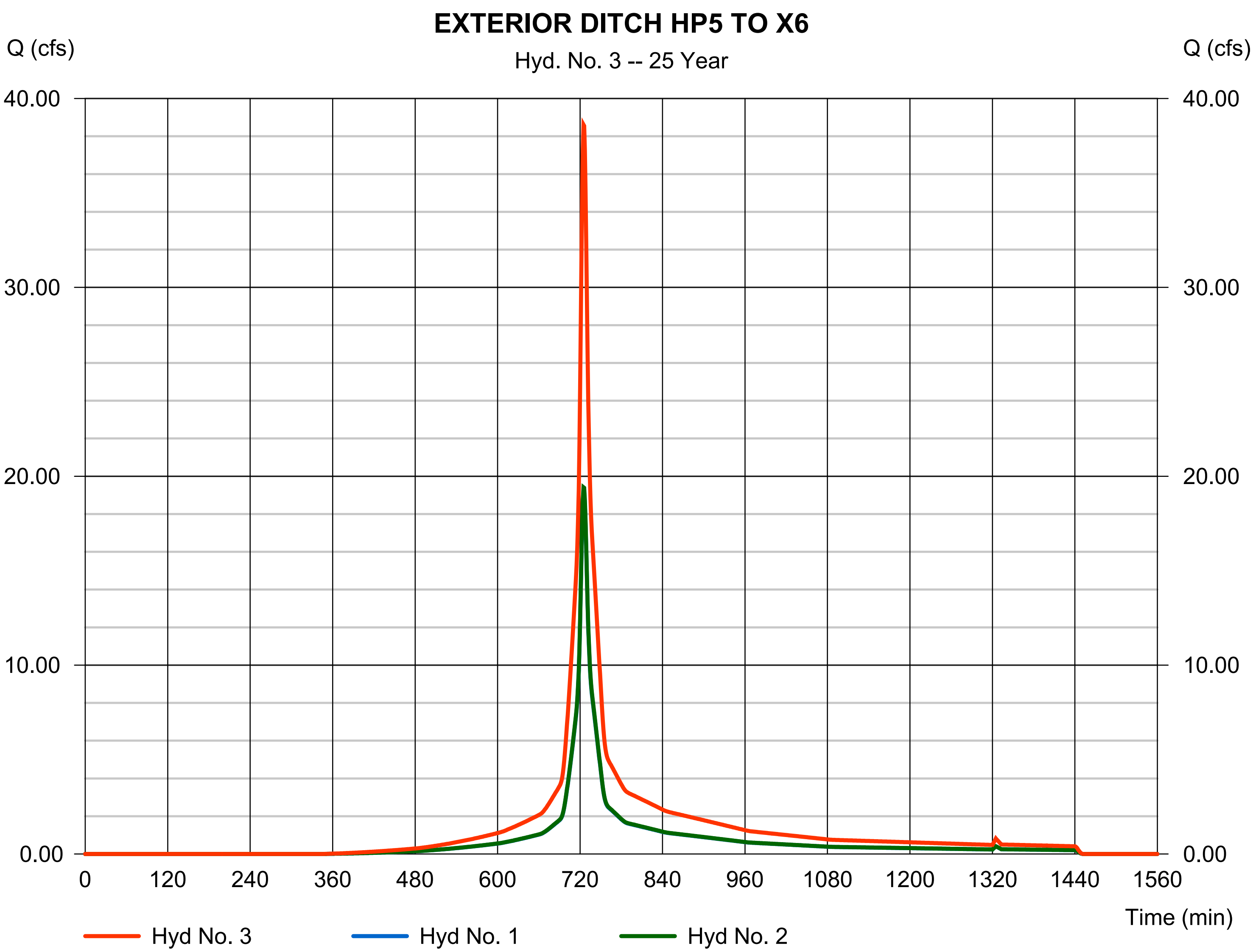
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 3

EXTERIOR DITCH HP5 TO X6

Hydrograph type	= Combine	Peak discharge	= 38.61 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 125,960 cuft
Inflow hyds.	= 1, 2	Contrib. drain. area	= 6.900 ac



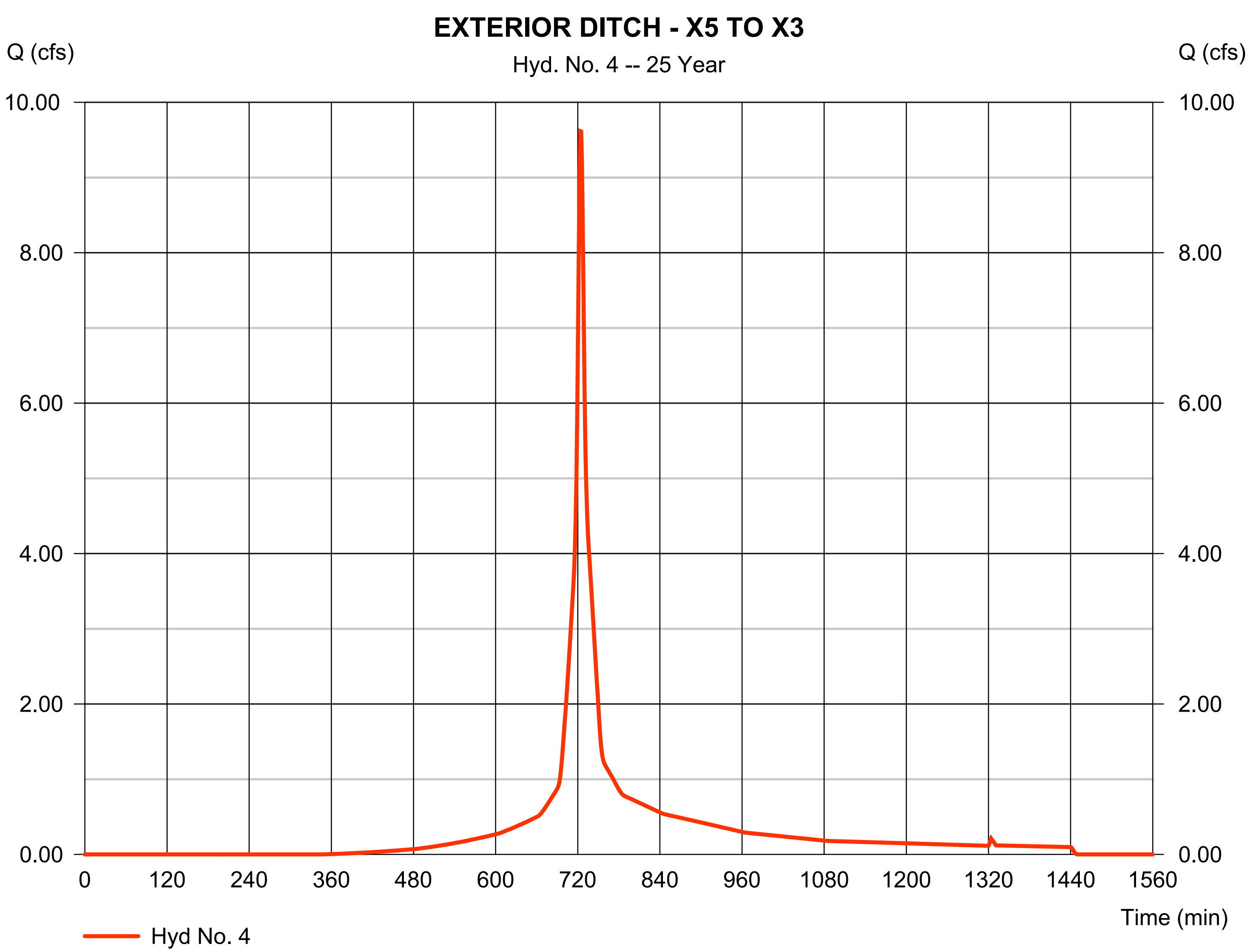
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 4

EXTERIOR DITCH - X5 TO X3

Hydrograph type	= SCS Runoff	Peak discharge	= 9.616 cfs
Storm frequency	= 25 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 30,121 cuft
Drainage area	= 1.560 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.90 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



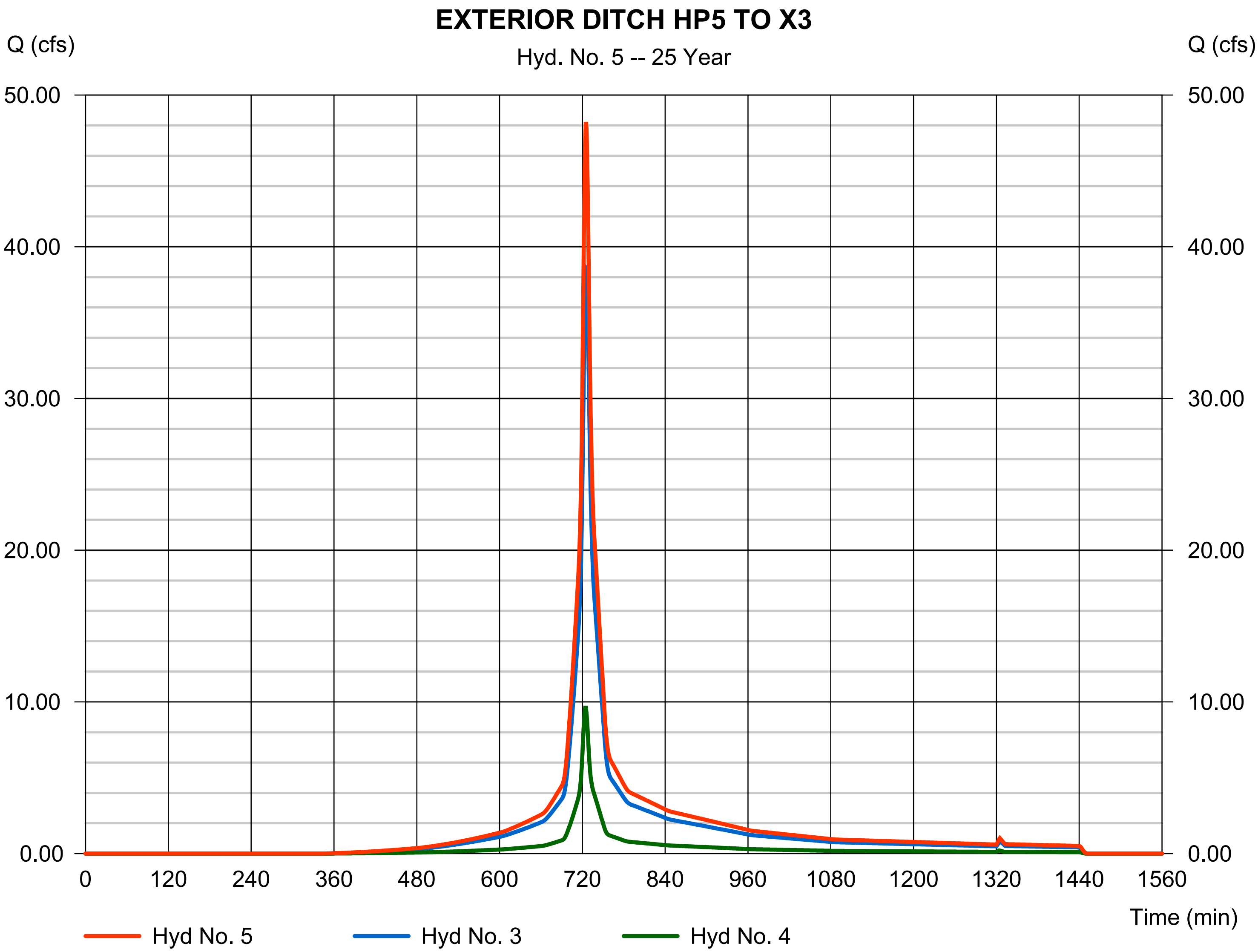
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 5

EXTERIOR DITCH HP5 TO X3

Hydrograph type	= Combine	Peak discharge	= 48.22 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 156,081 cuft
Inflow hyds.	= 3, 4	Contrib. drain. area	= 1.560 ac



Hydrograph Report

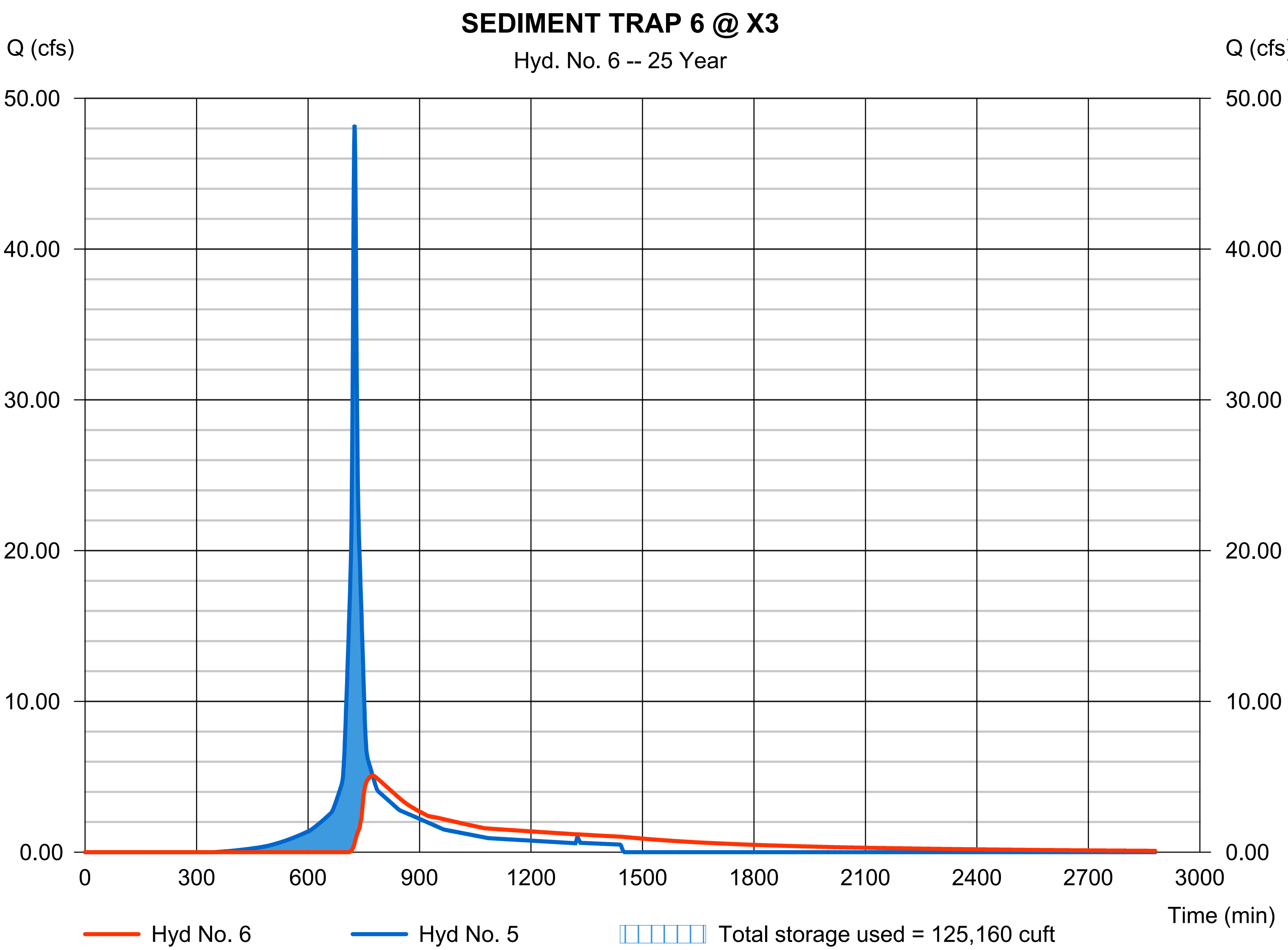
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 6

SEDIMENT TRAP 6 @ X3

Hydrograph type	= Reservoir	Peak discharge	= 5.078 cfs
Storm frequency	= 25 yrs	Time to peak	= 774 min
Time interval	= 1 min	Hyd. volume	= 119,277 cuft
Inflow hyd. No.	= 5 - EXTERIOR DITCH HP5 TO X3	Max. Elevation	= 257.81 ft
Reservoir name	= SEDIMENT TRAP 6 @ X3	Max. Storage	= 125,160 cuft

Storage Indication method used. Wet pond routing start elevation = 254.00 ft.



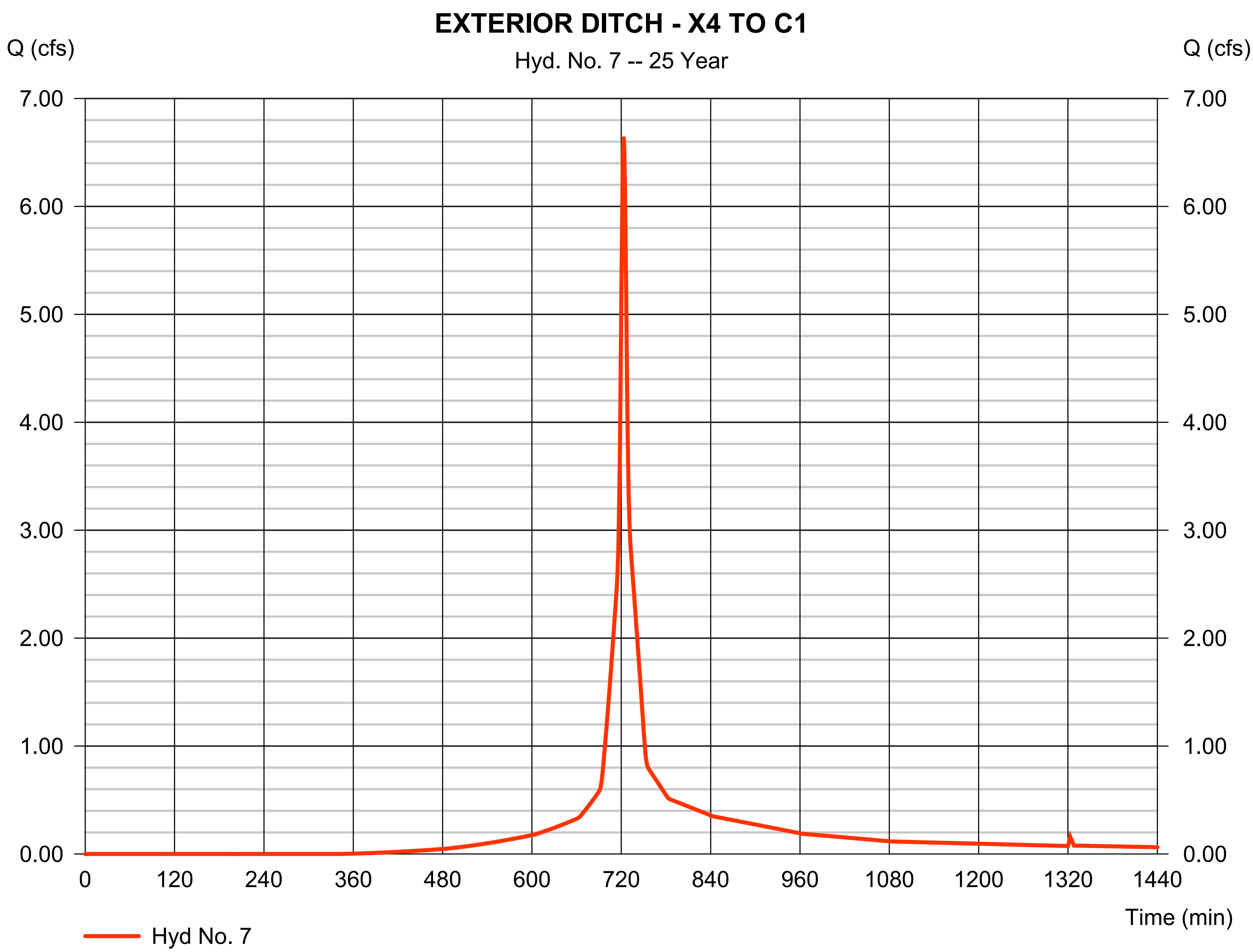
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 7

EXTERIOR DITCH - X4 TO C1

Hydrograph type	= SCS Runoff	Peak discharge	= 6.647 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 19,472 cuft
Drainage area	= 1.040 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.70 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



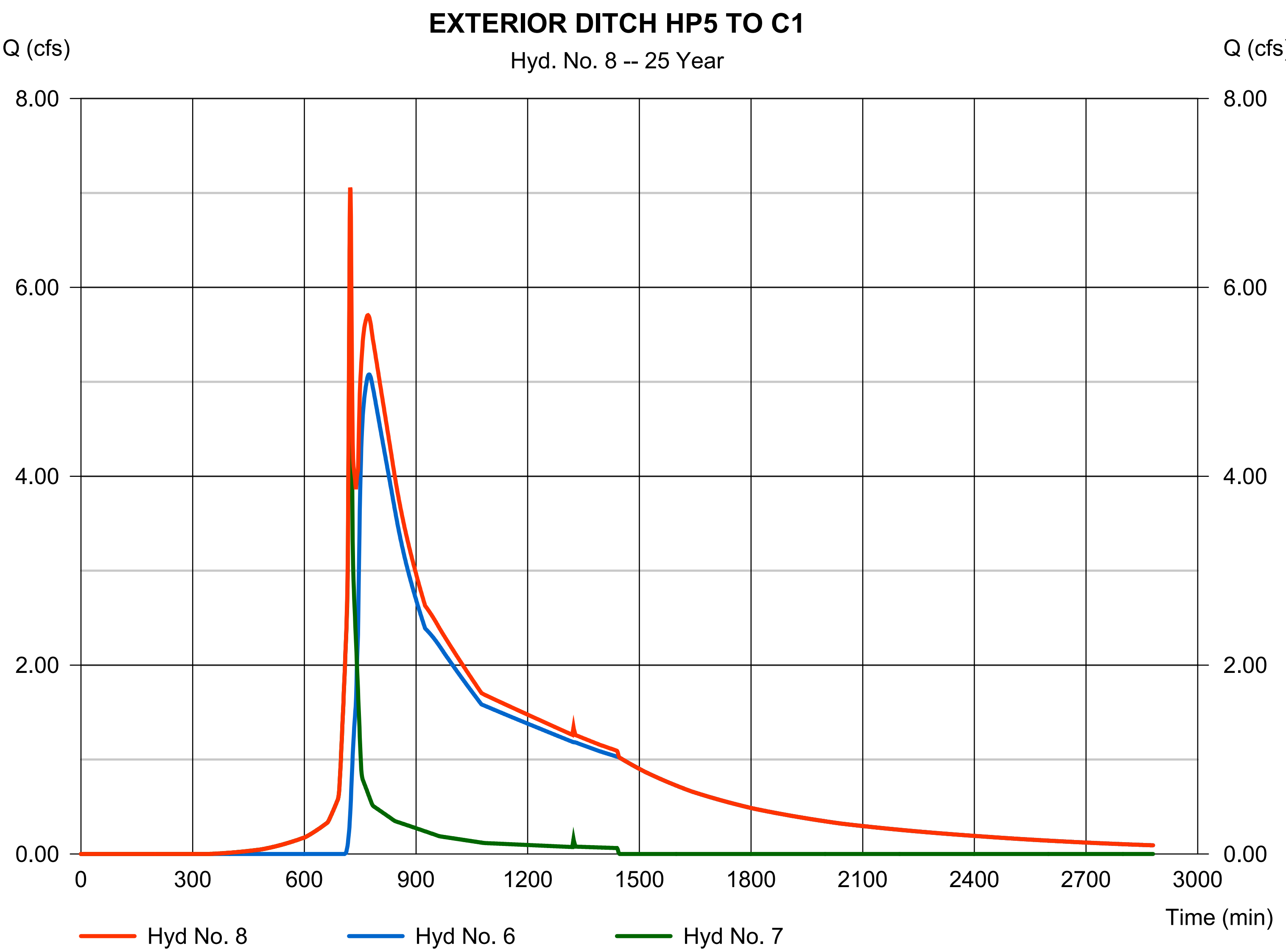
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 8

EXTERIOR DITCH HP5 TO C1

Hydrograph type	= Combine	Peak discharge	= 7.058 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 138,749 cuft
Inflow hyds.	= 6, 7	Contrib. drain. area	= 1.040 ac



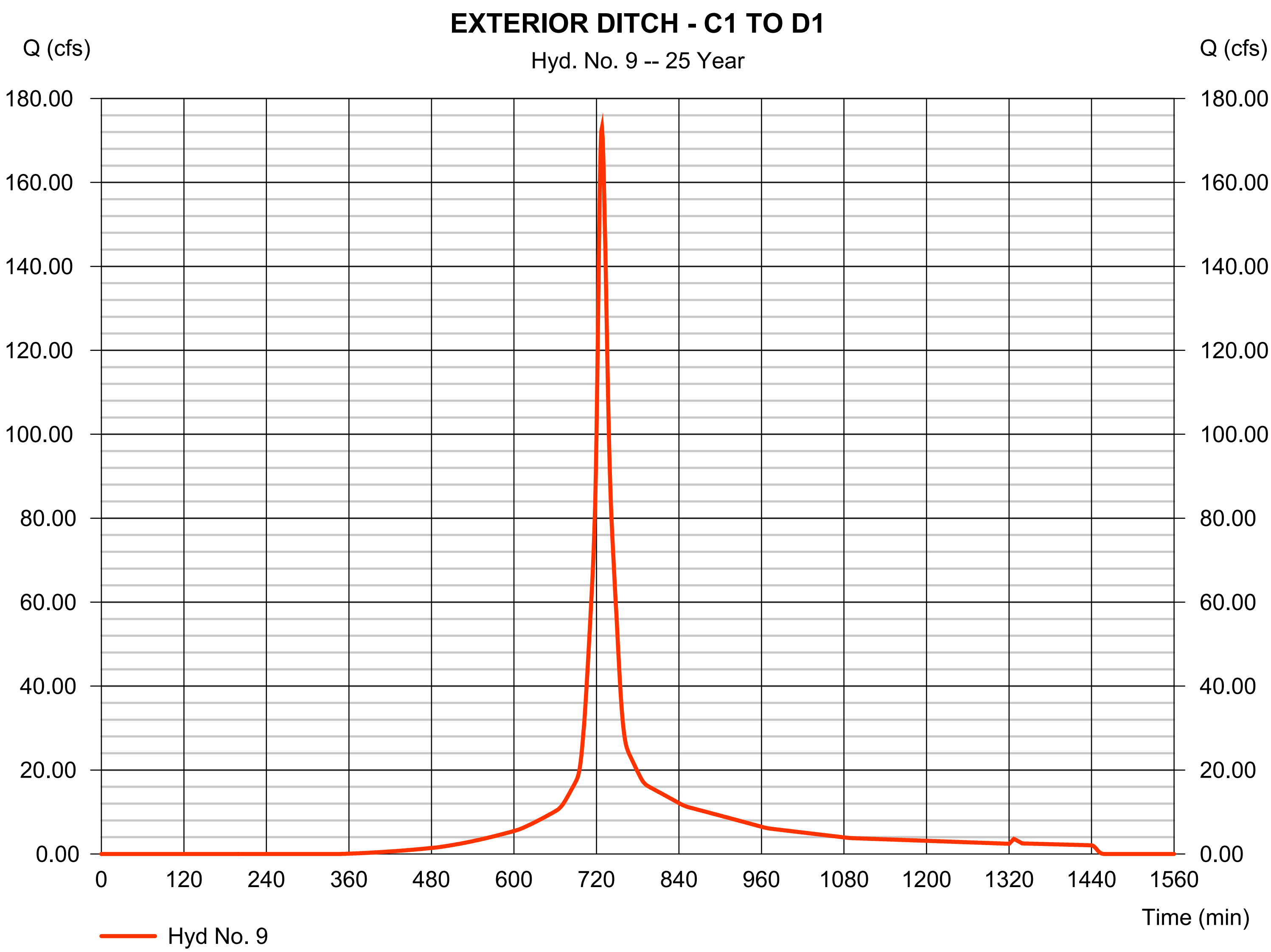
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 9

EXTERIOR DITCH - C1 TO D1

Hydrograph type	= SCS Runoff	Peak discharge	= 173.02 cfs
Storm frequency	= 25 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 636,139 cuft
Drainage area	= 33.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



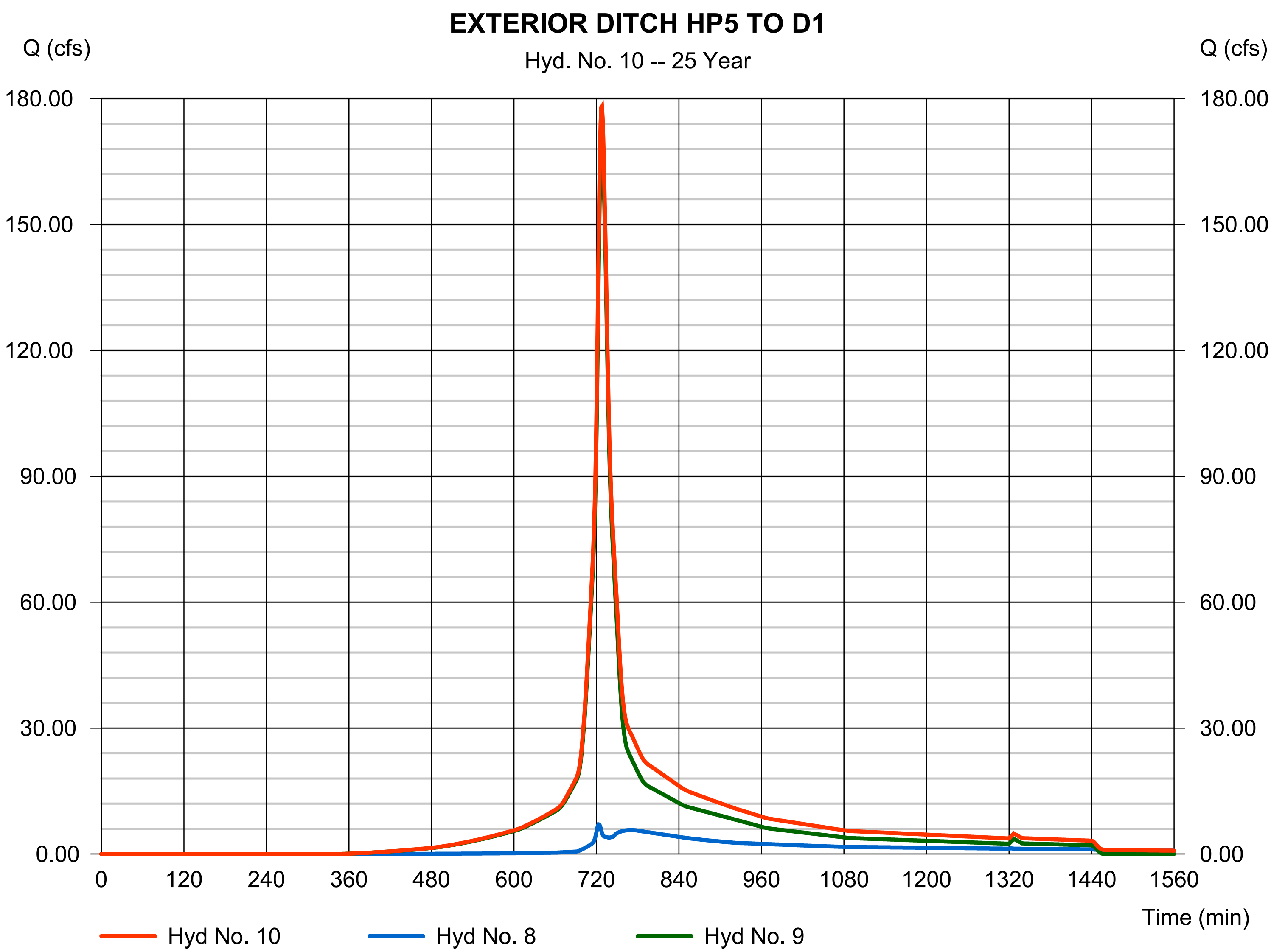
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 10

EXTERIOR DITCH HP5 TO D1

Hydrograph type	= Combine	Peak discharge	= 178.09 cfs
Storm frequency	= 25 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 774,889 cuft
Inflow hyds.	= 8, 9	Contrib. drain. area	= 33.380 ac



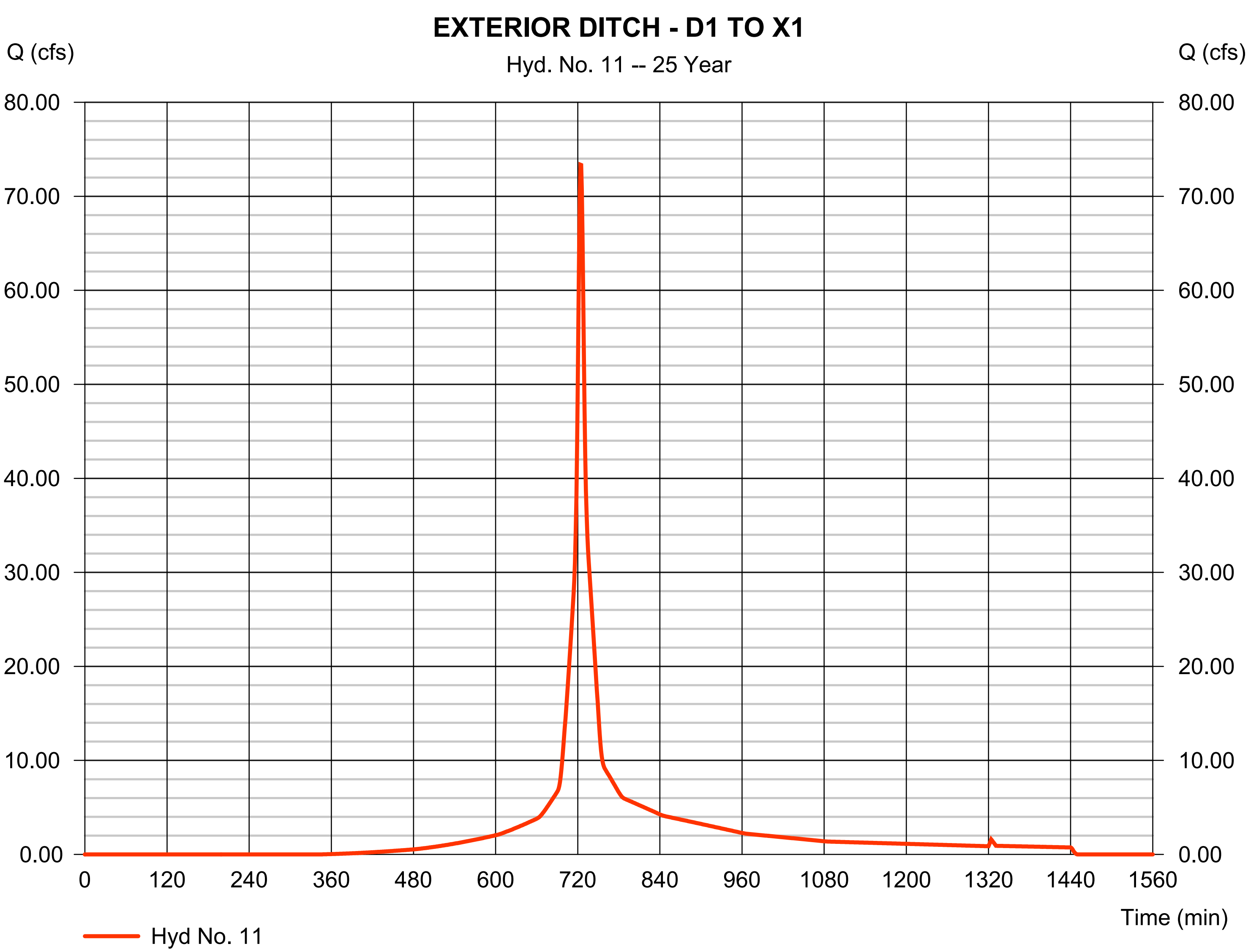
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 11

EXTERIOR DITCH - D1 TO X1

Hydrograph type	= SCS Runoff	Peak discharge	= 73.36 cfs
Storm frequency	= 25 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 229,768 cuft
Drainage area	= 11.900 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.20 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



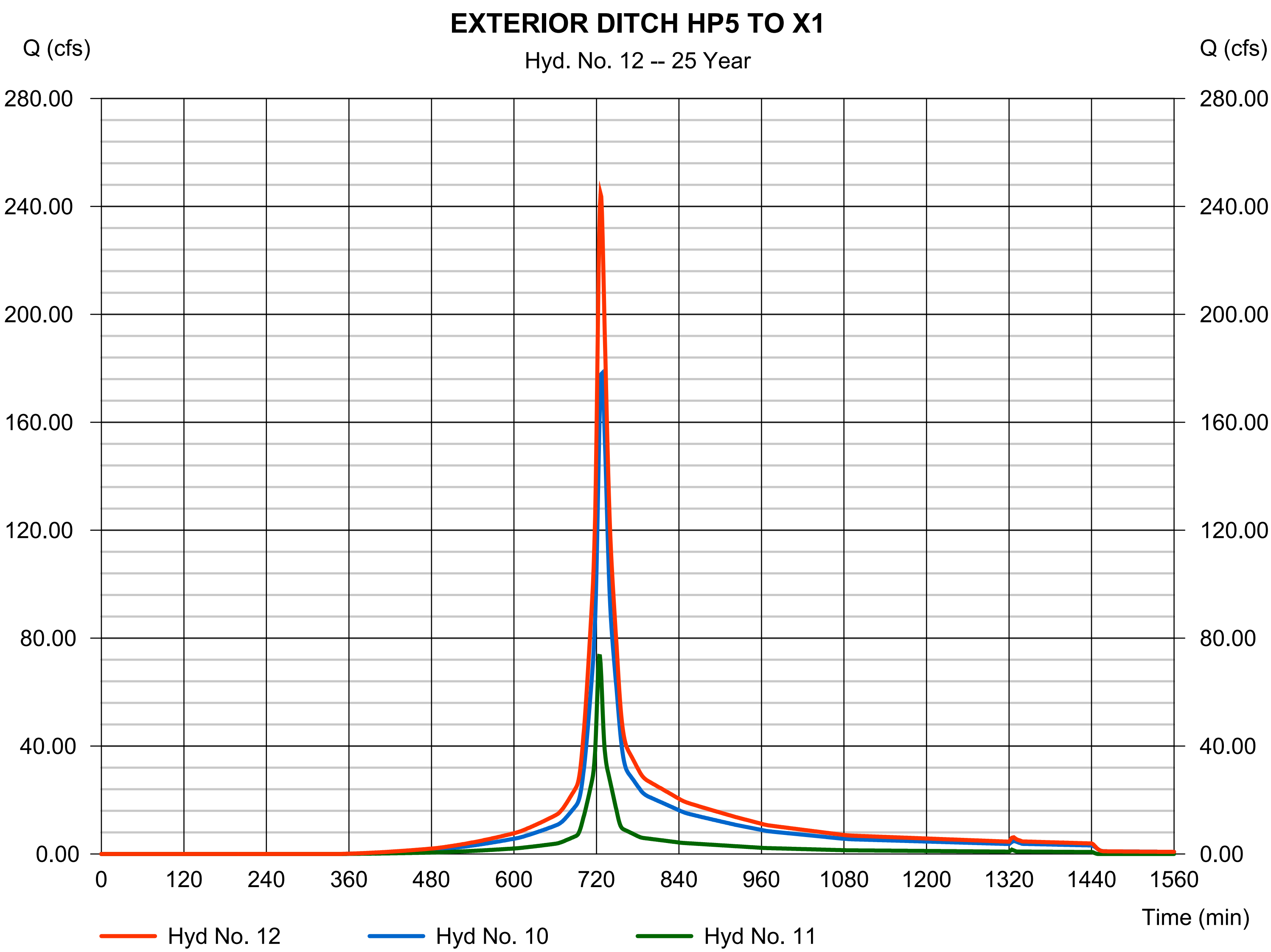
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 12

EXTERIOR DITCH HP5 TO X1

Hydrograph type	= Combine	Peak discharge	= 244.64 cfs
Storm frequency	= 25 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,004,657 cuft
Inflow hyds.	= 10, 11	Contrib. drain. area	= 11.900 ac



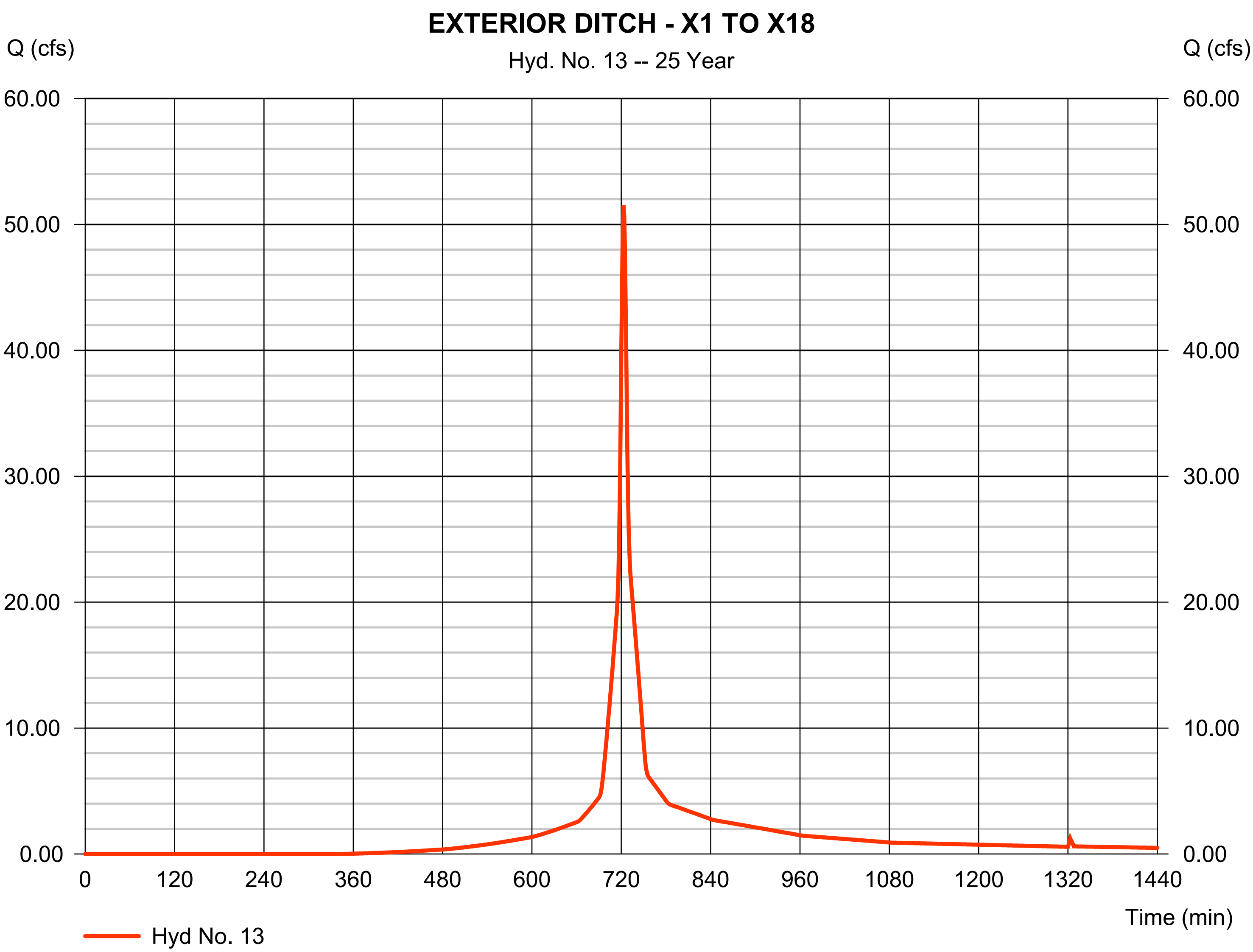
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 13

EXTERIOR DITCH - X1 TO X18

Hydrograph type	= SCS Runoff	Peak discharge	= 51.51 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 150,909 cuft
Drainage area	= 8.060 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.80 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



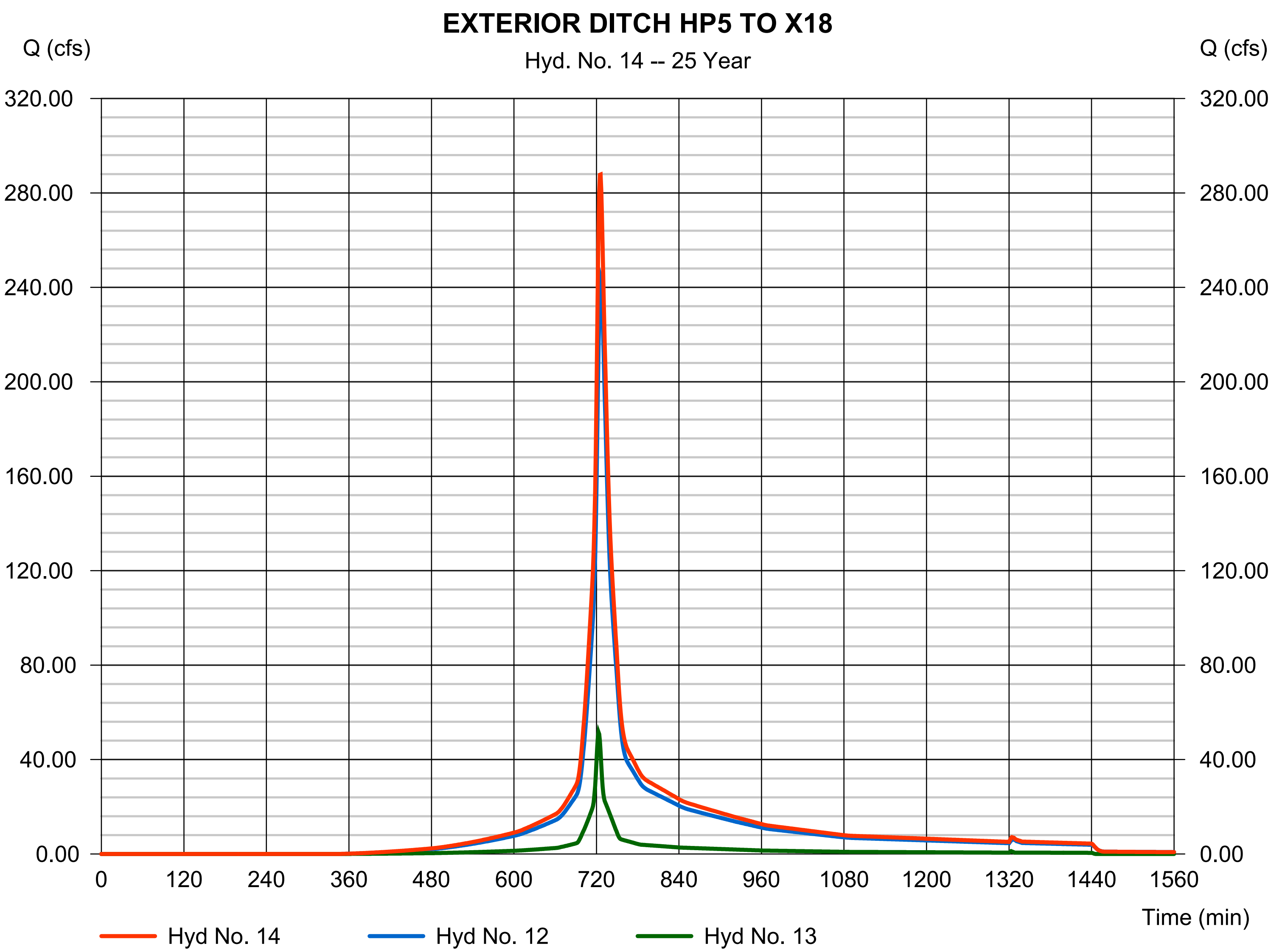
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 14

EXTERIOR DITCH HP5 TO X18

Hydrograph type	= Combine	Peak discharge	= 287.80 cfs
Storm frequency	= 25 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,155,566 cuft
Inflow hyds.	= 12, 13	Contrib. drain. area	= 8.060 ac



Hydrograph Report

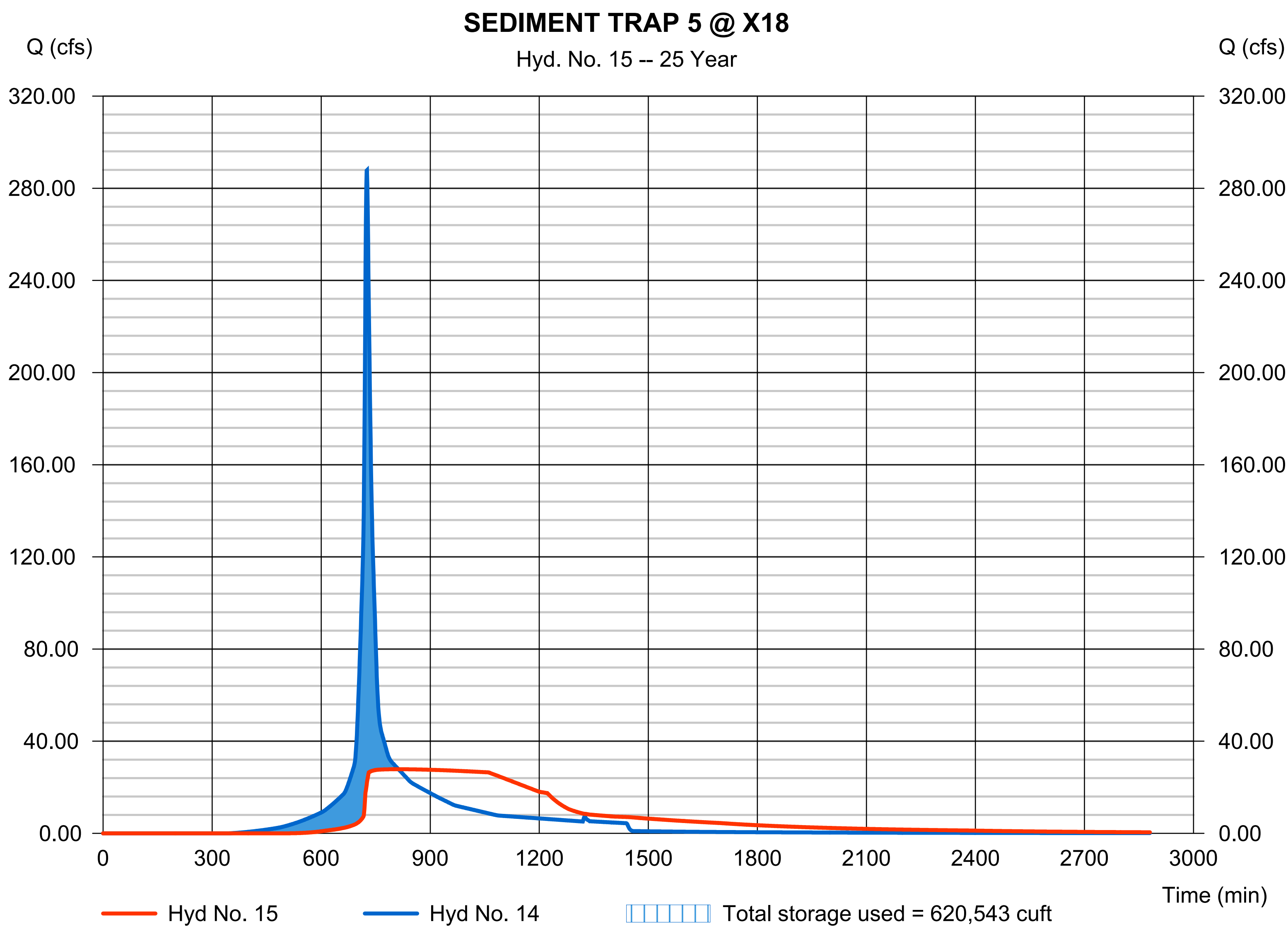
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 15

SEDIMENT TRAP 5 @ X18

Hydrograph type	= Reservoir	Peak discharge	= 27.84 cfs
Storm frequency	= 25 yrs	Time to peak	= 813 min
Time interval	= 1 min	Hyd. volume	= 1,122,583 cuft
Inflow hyd. No.	= 14 - EXTERIOR DITCH HP5 TO X18	Max. Elevation	= 250.33 ft
Reservoir name	= SEDIMENT TRAP 5 @ X18	Max. Storage	= 620,543 cuft

Storage Indication method used. Wet pond routing start elevation = 242.00 ft.



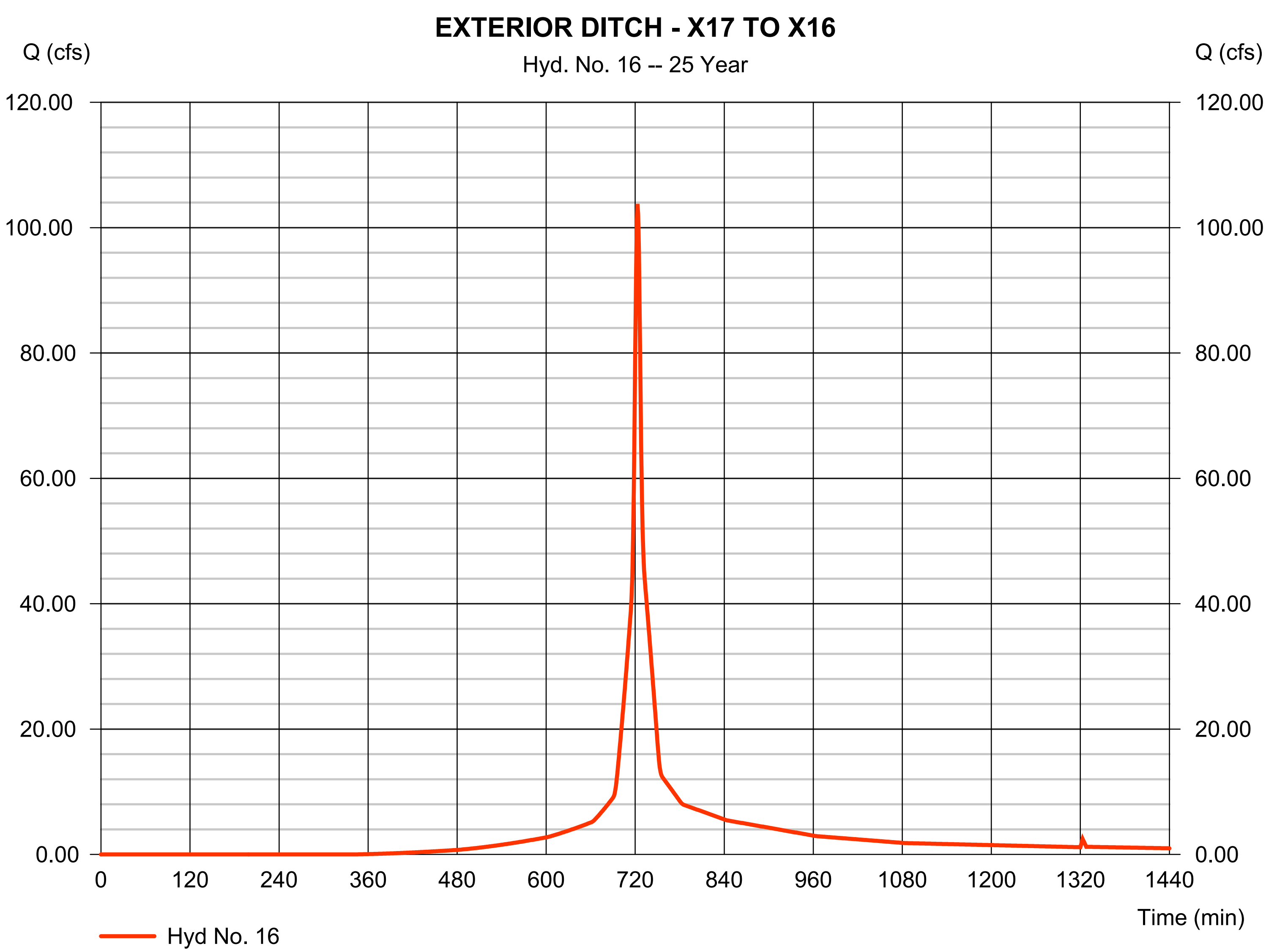
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 16

EXTERIOR DITCH - X17 TO X16

Hydrograph type	= SCS Runoff	Peak discharge	= 103.80 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 304,064 cuft
Drainage area	= 16.240 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



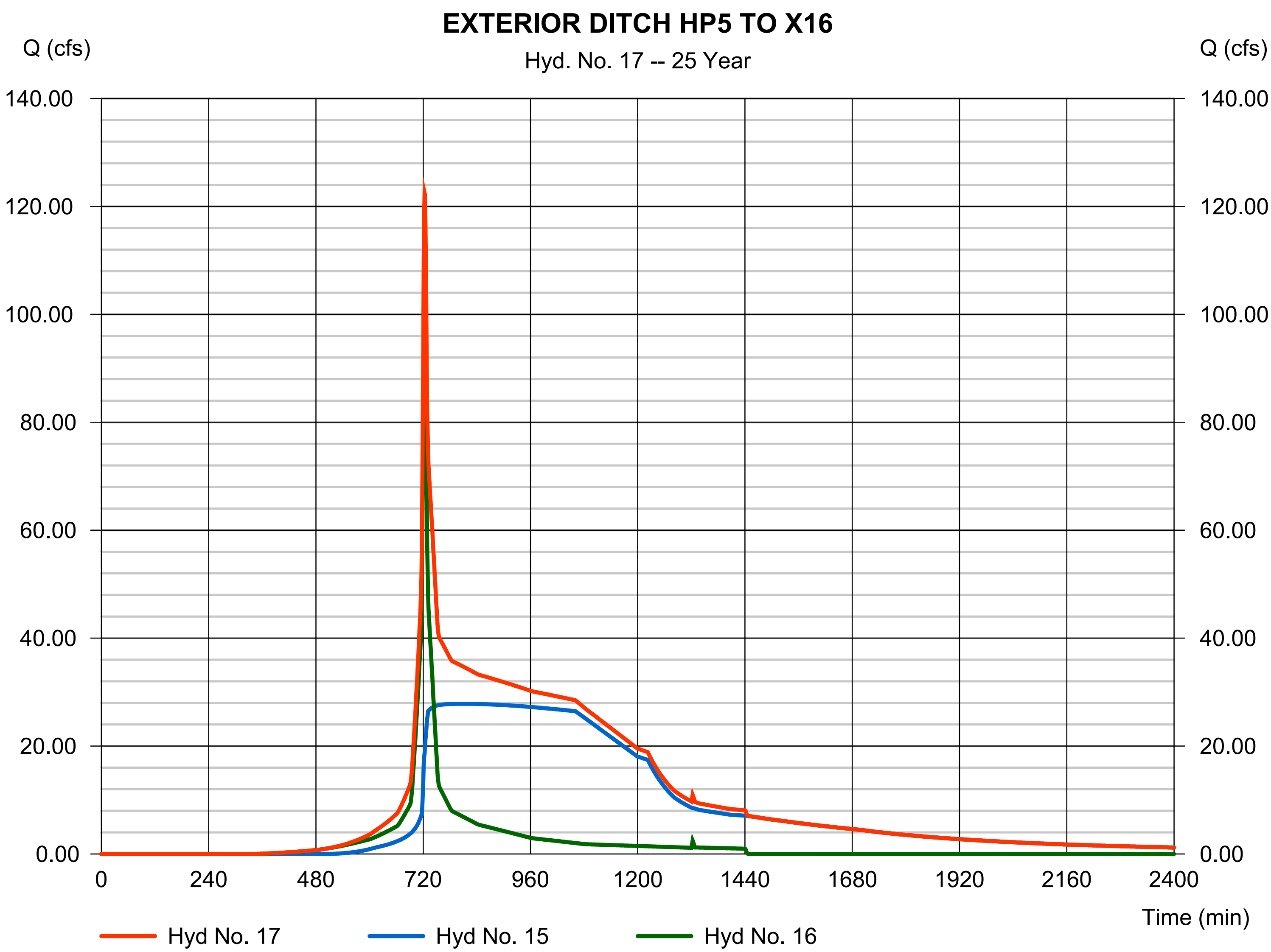
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 17

EXTERIOR DITCH HP5 TO X16

Hydrograph type	= Combine	Peak discharge	= 122.43 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 1,426,648 cuft
Inflow hyds.	= 15, 16	Contrib. drain. area	= 16.240 ac



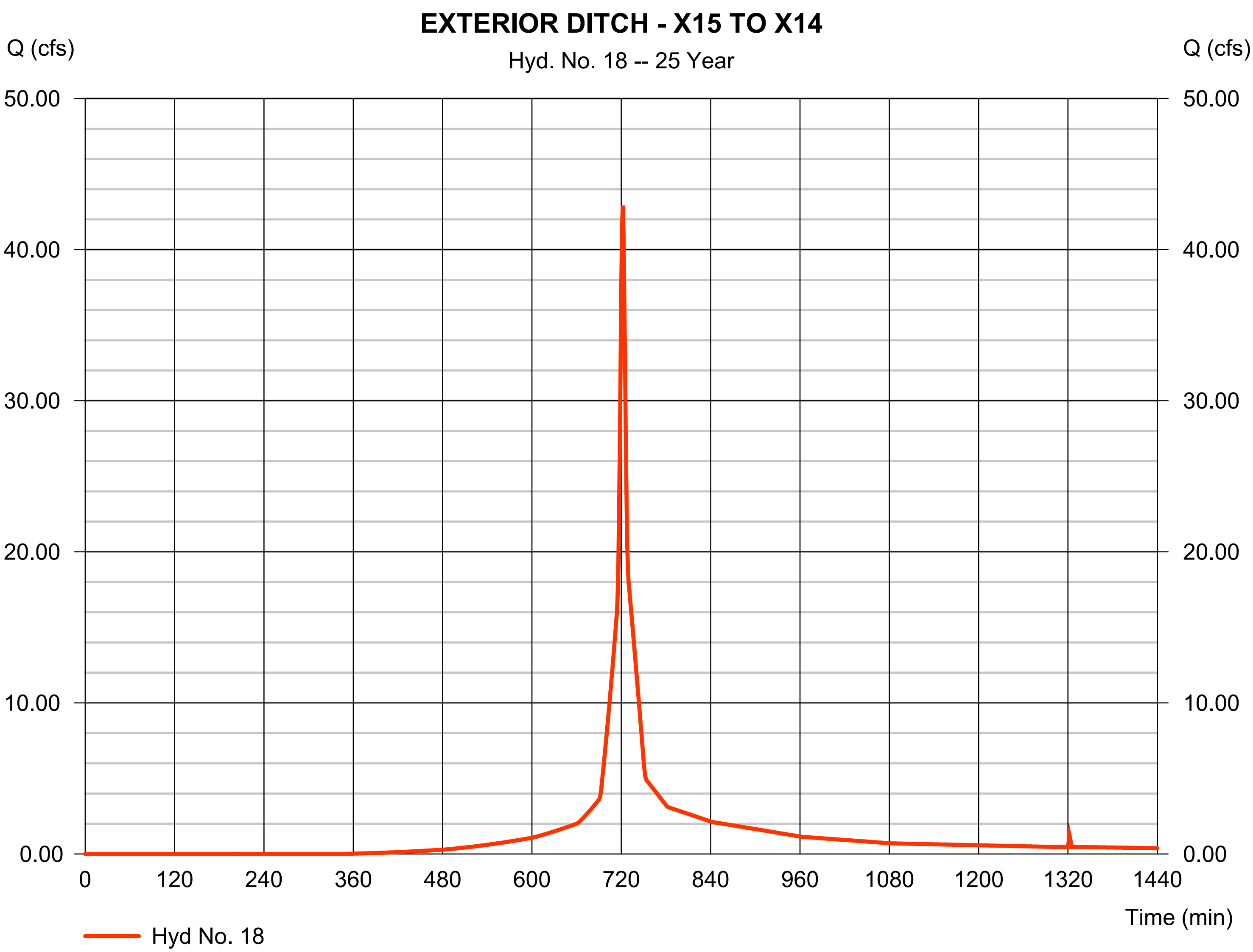
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 | Friday, 01 / 30 / 2015

Hyd. No. 18

EXTERIOR DITCH - X15 TO X14

Hydrograph type	= SCS Runoff	Peak discharge	= 42.91 cfs
Storm frequency	= 25 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 118,307 cuft
Drainage area	= 6.740 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 2.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



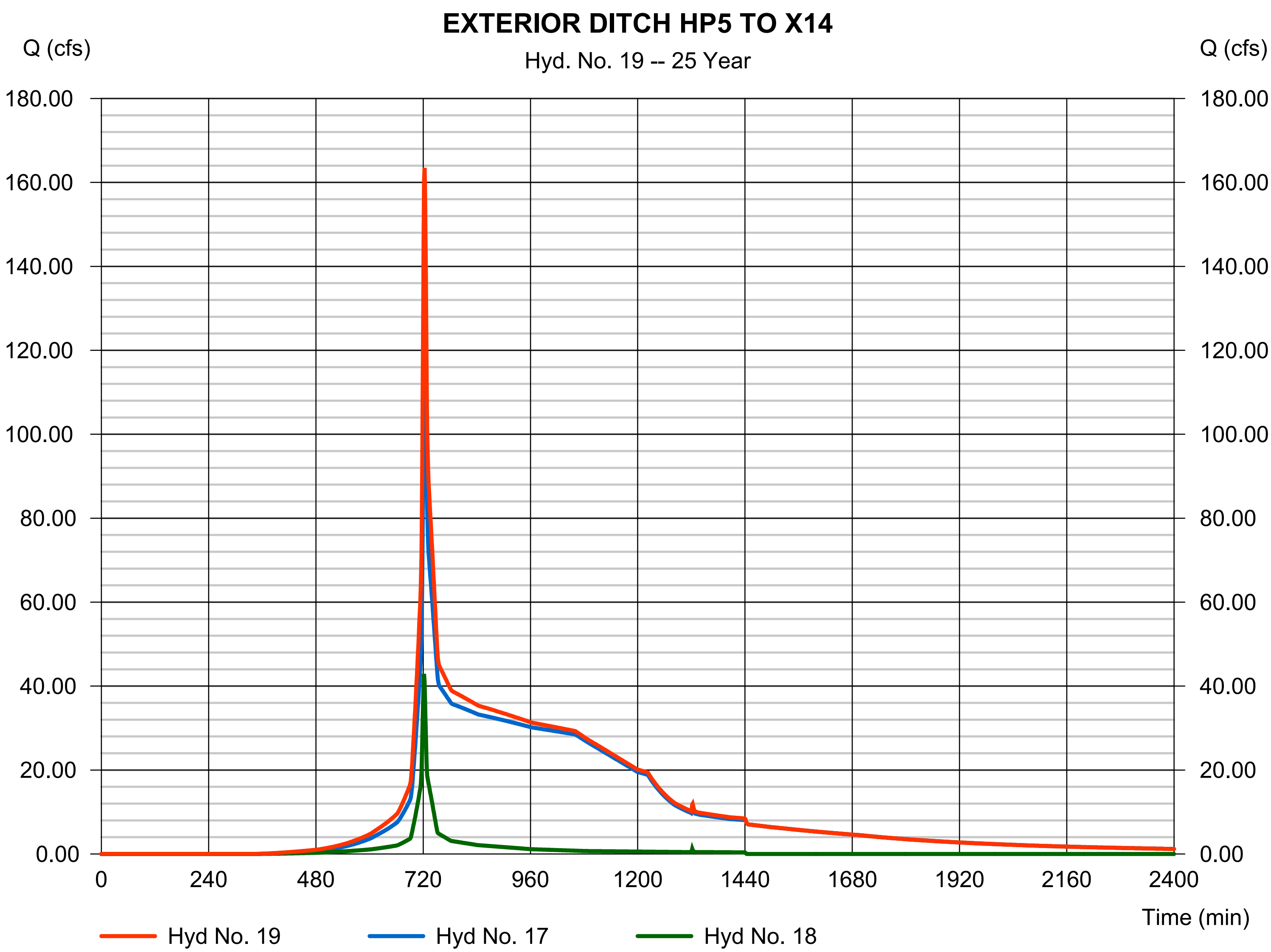
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 19

EXTERIOR DITCH HP5 TO X14

Hydrograph type	= Combine	Peak discharge	= 163.48 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 1,544,954 cuft
Inflow hyds.	= 17, 18	Contrib. drain. area	= 6.740 ac



Hydrograph Report

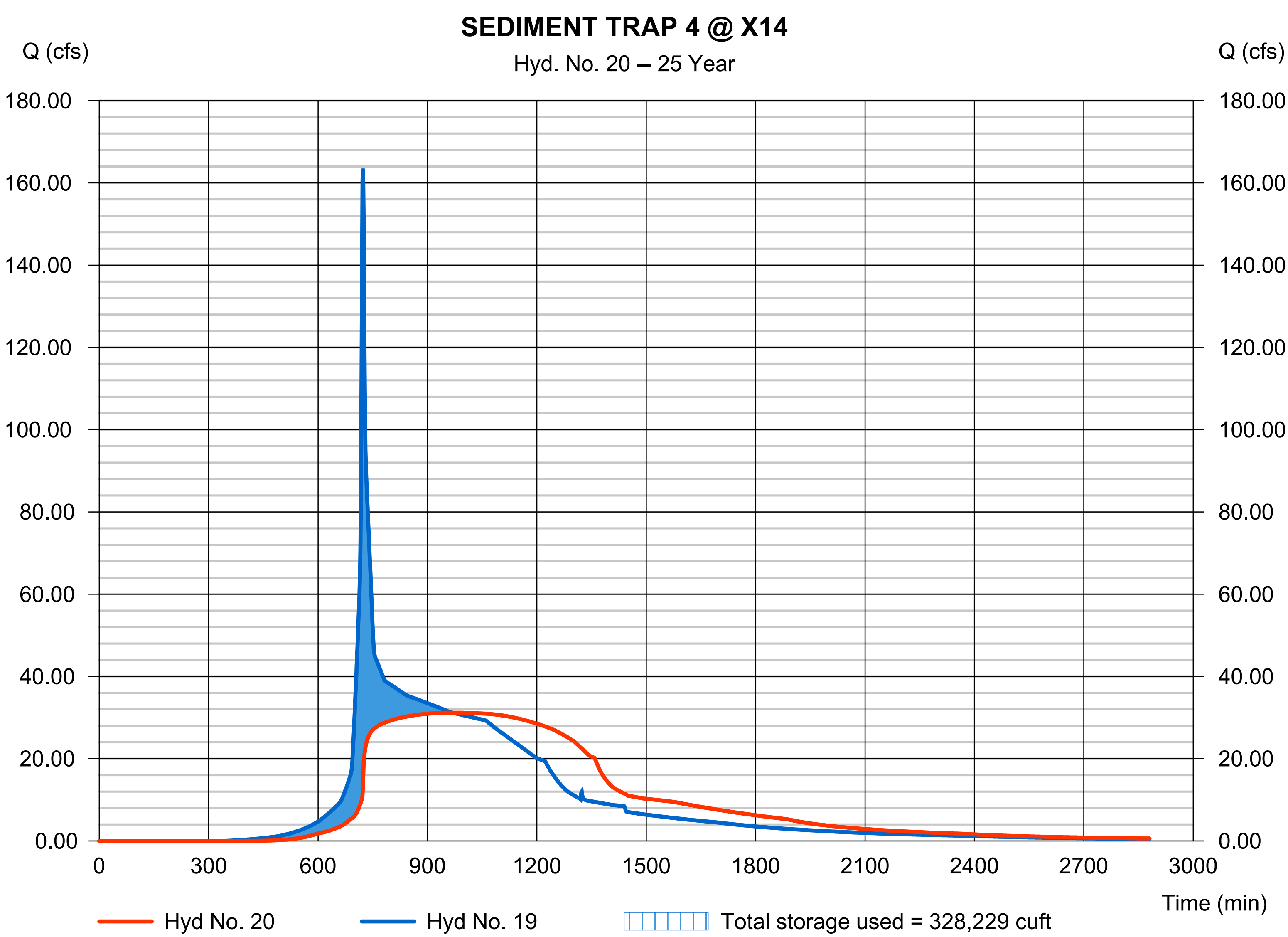
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 20

SEDIMENT TRAP 4 @ X14

Hydrograph type	= Reservoir	Peak discharge	= 31.19 cfs
Storm frequency	= 25 yrs	Time to peak	= 968 min
Time interval	= 1 min	Hyd. volume	= 1,537,197 cuft
Inflow hyd. No.	= 19 - EXTERIOR DITCH HP5 TO X14	Max. Elevation	= 247.61 ft
Reservoir name	= SEDIMENT TRAP 4 @ X14	Max. Storage	= 328,229 cuft

Storage Indication method used. Wet pond routing start elevation = 238.00 ft.



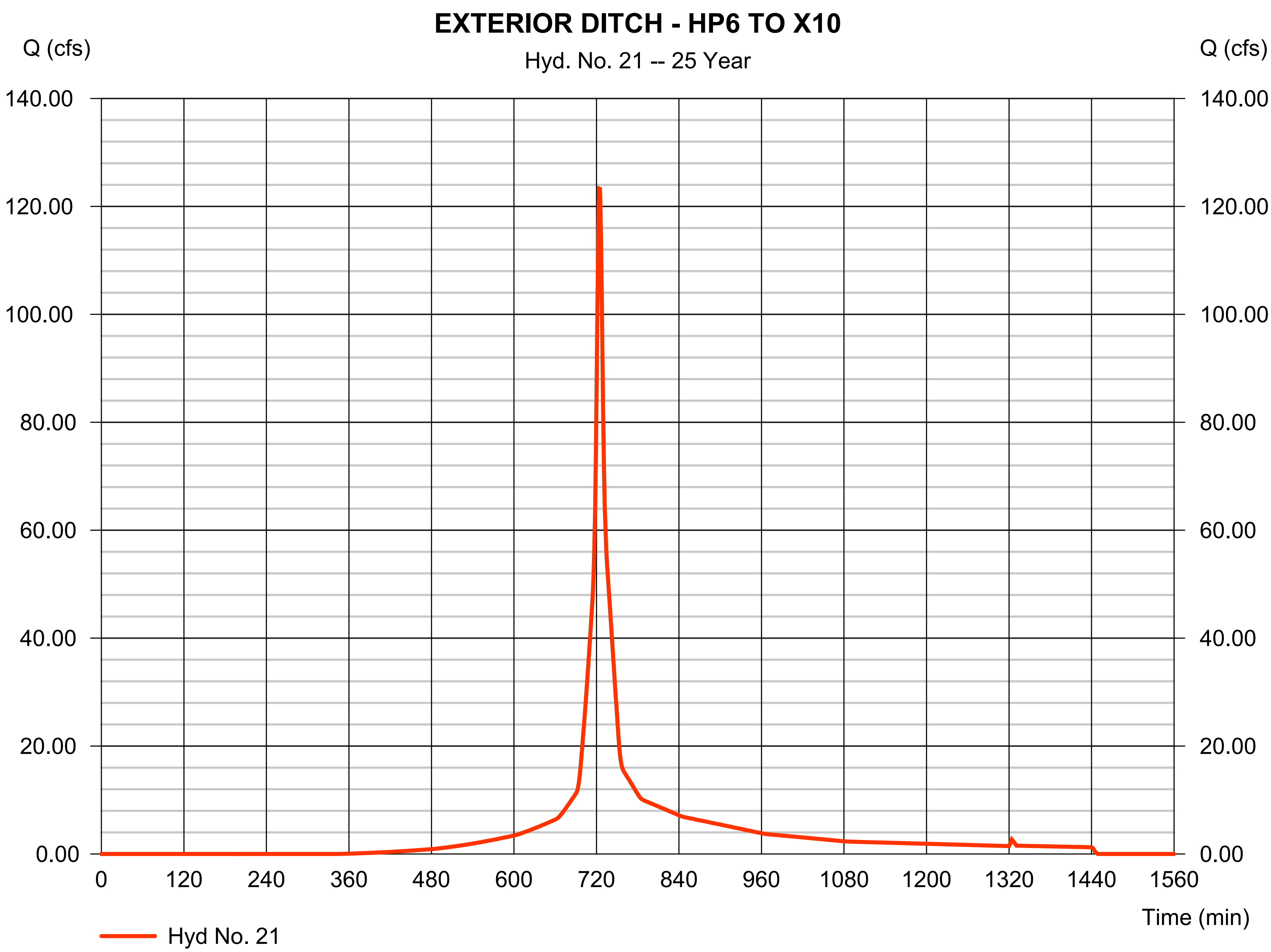
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 21

EXTERIOR DITCH - HP6 TO X10

Hydrograph type	= SCS Runoff	Peak discharge	= 123.29 cfs
Storm frequency	= 25 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 386,165 cuft
Drainage area	= 20.000 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

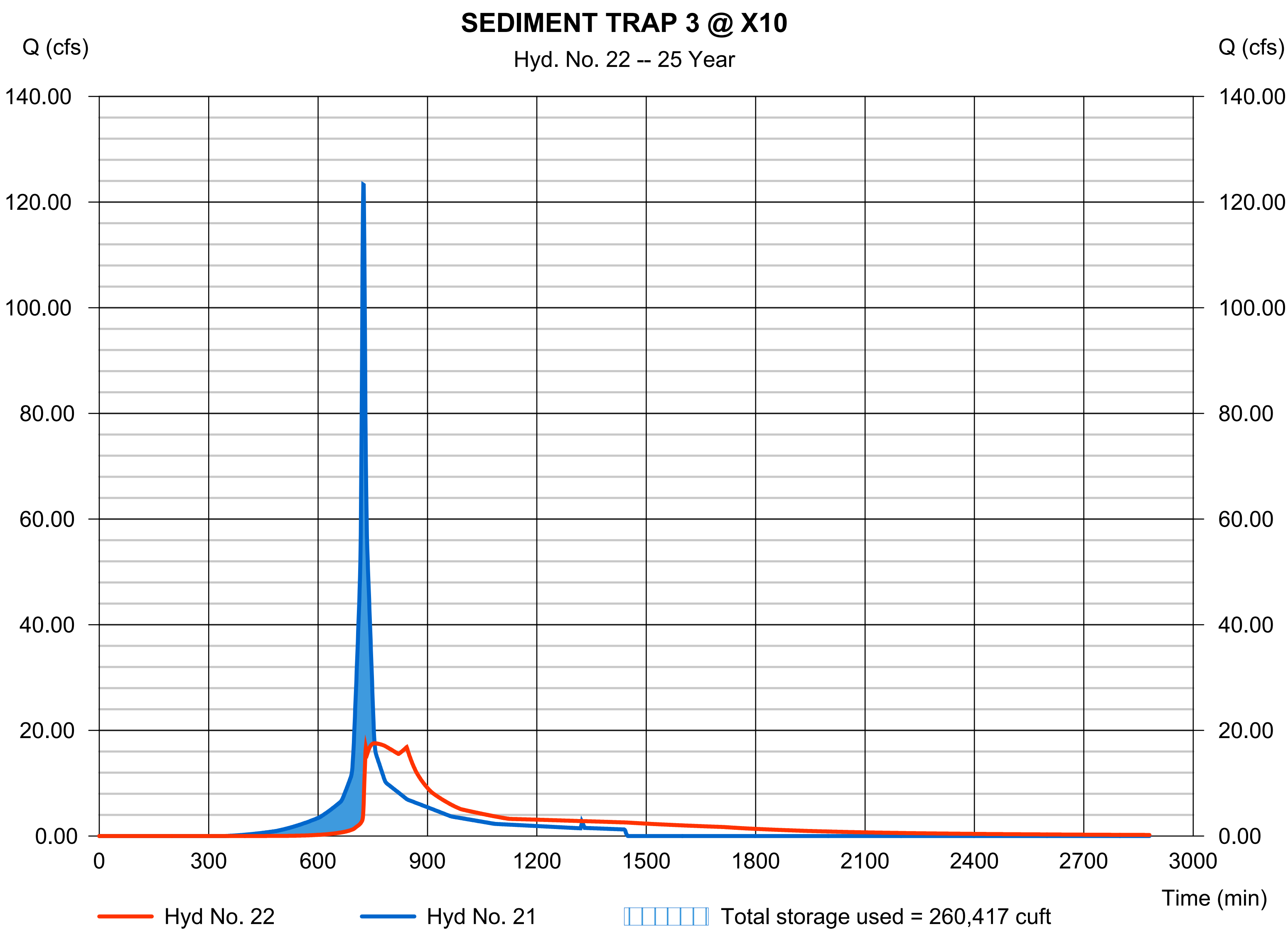
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 | Friday, 01 / 30 / 2015

Hyd. No. 22

SEDIMENT TRAP 3 @ X10

Hydrograph type	= Reservoir	Peak discharge	= 17.56 cfs
Storm frequency	= 25 yrs	Time to peak	= 755 min
Time interval	= 1 min	Hyd. volume	= 369,897 cuft
Inflow hyd. No.	= 21 - EXTERIOR DITCH - HP6 TO X10	Max. Elevation	= 252.28 ft
Reservoir name	= SEDIMENT TRAP 3 @ X10	Max. Storage	= 260,417 cuft

Storage Indication method used. Wet pond routing start elevation = 248.00 ft.



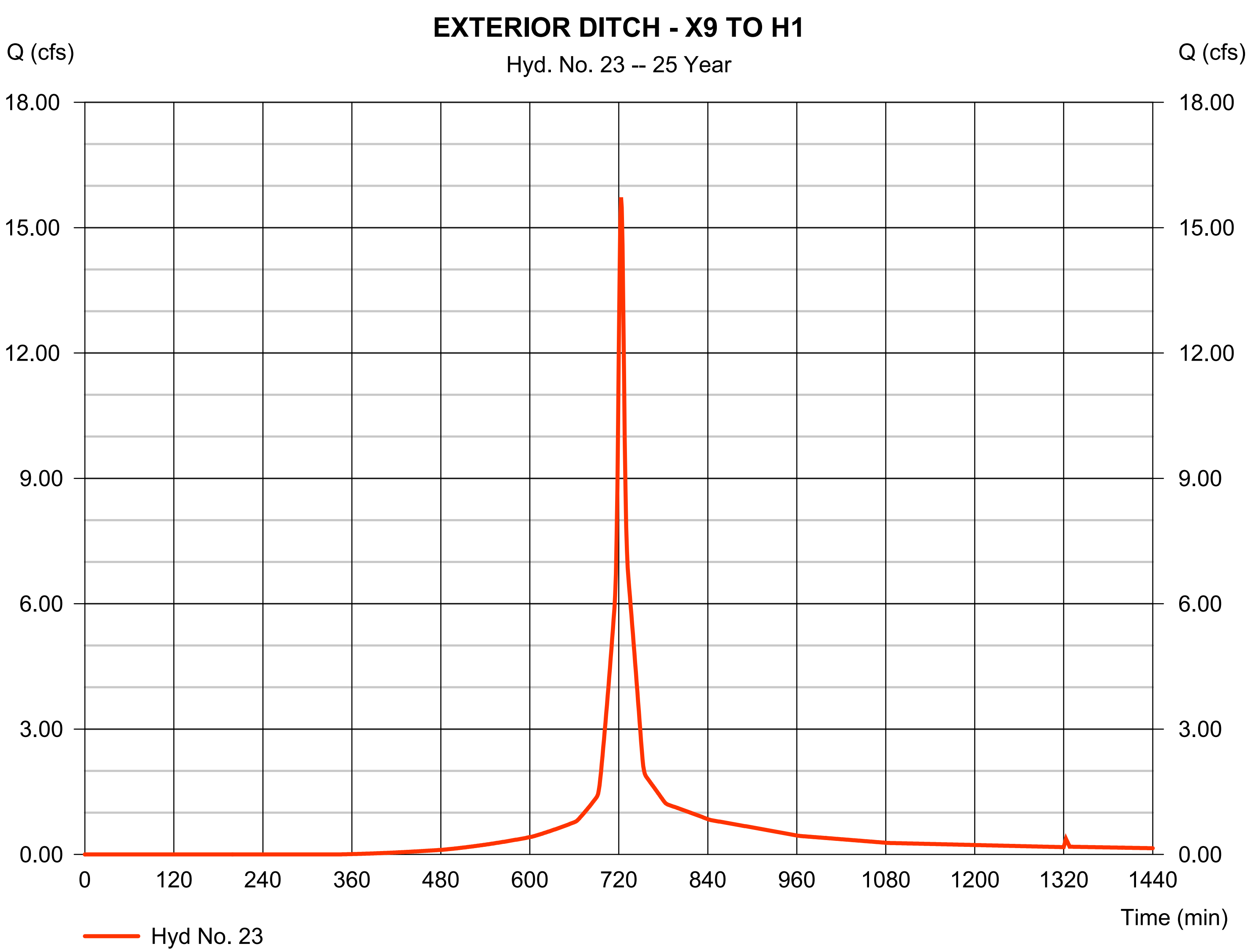
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 23

EXTERIOR DITCH - X9 TO H1

Hydrograph type	= SCS Runoff	Peak discharge	= 15.72 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 46,059 cuft
Drainage area	= 2.460 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



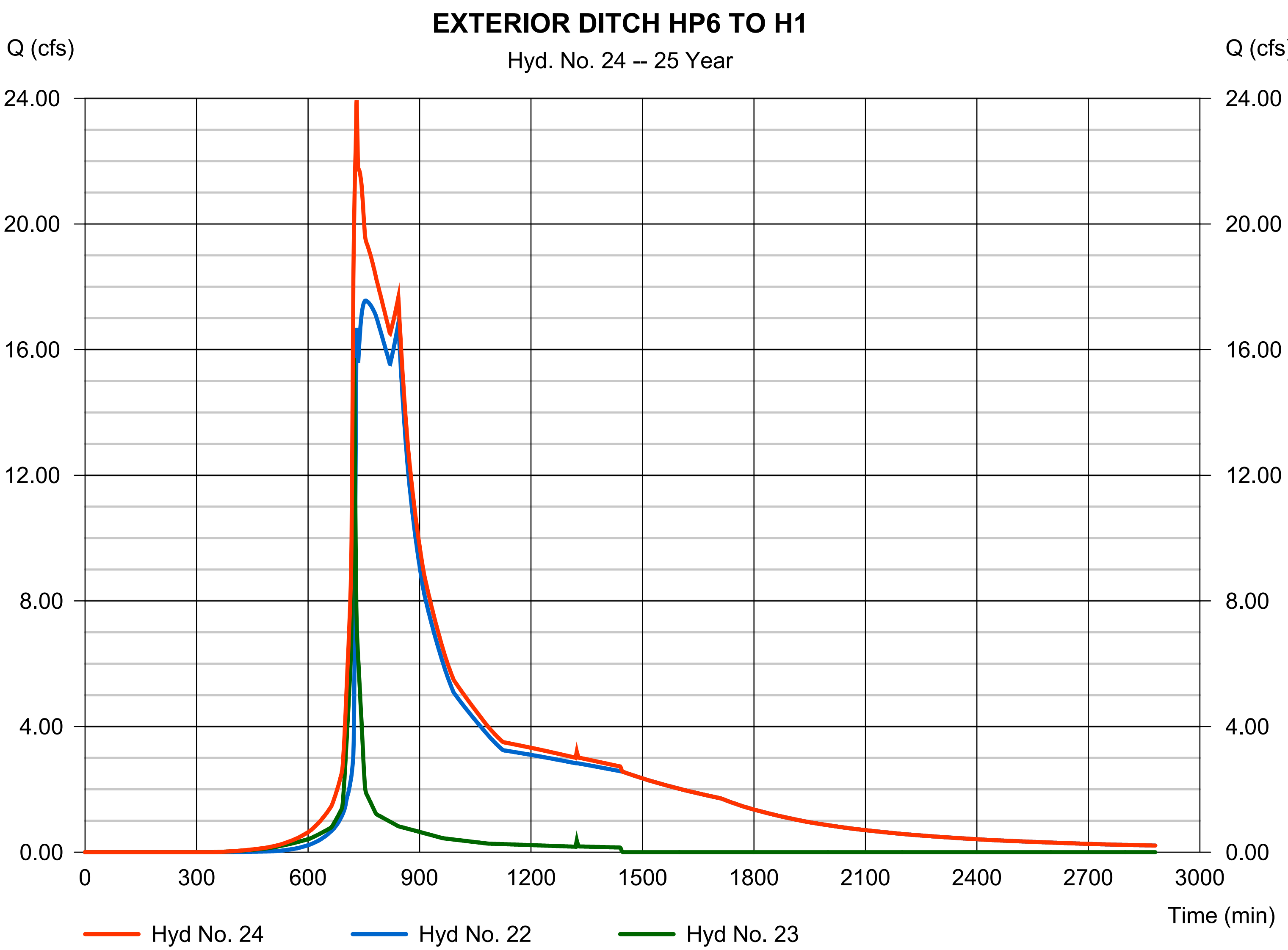
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 24

EXTERIOR DITCH HP6 TO H1

Hydrograph type	= Combine	Peak discharge	= 23.94 cfs
Storm frequency	= 25 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 415,956 cuft
Inflow hyds.	= 22, 23	Contrib. drain. area	= 2.460 ac



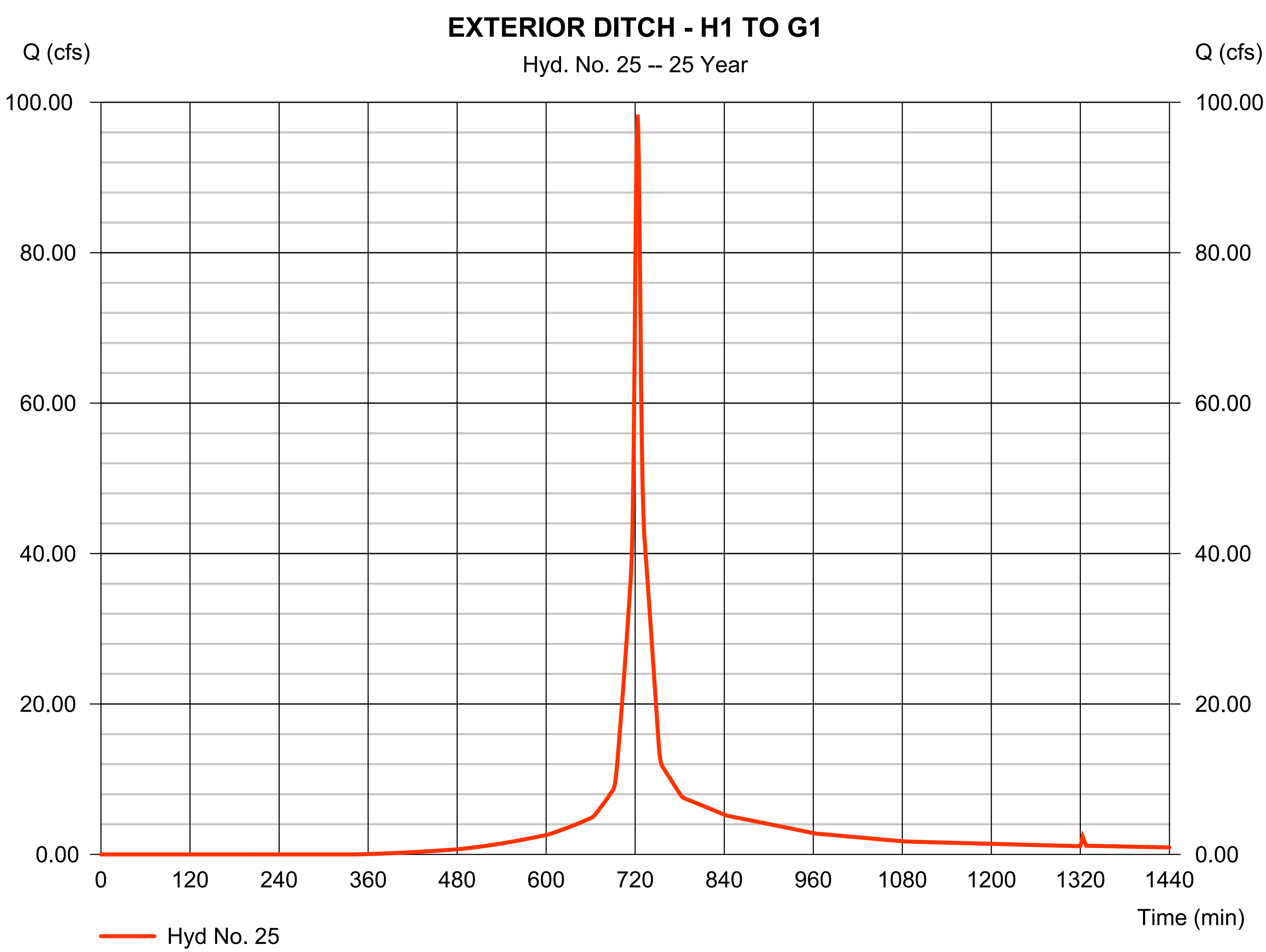
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 25

EXTERIOR DITCH - H1 TO G1

Hydrograph type	= SCS Runoff	Peak discharge	= 98.36 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 288,149 cuft
Drainage area	= 15.390 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



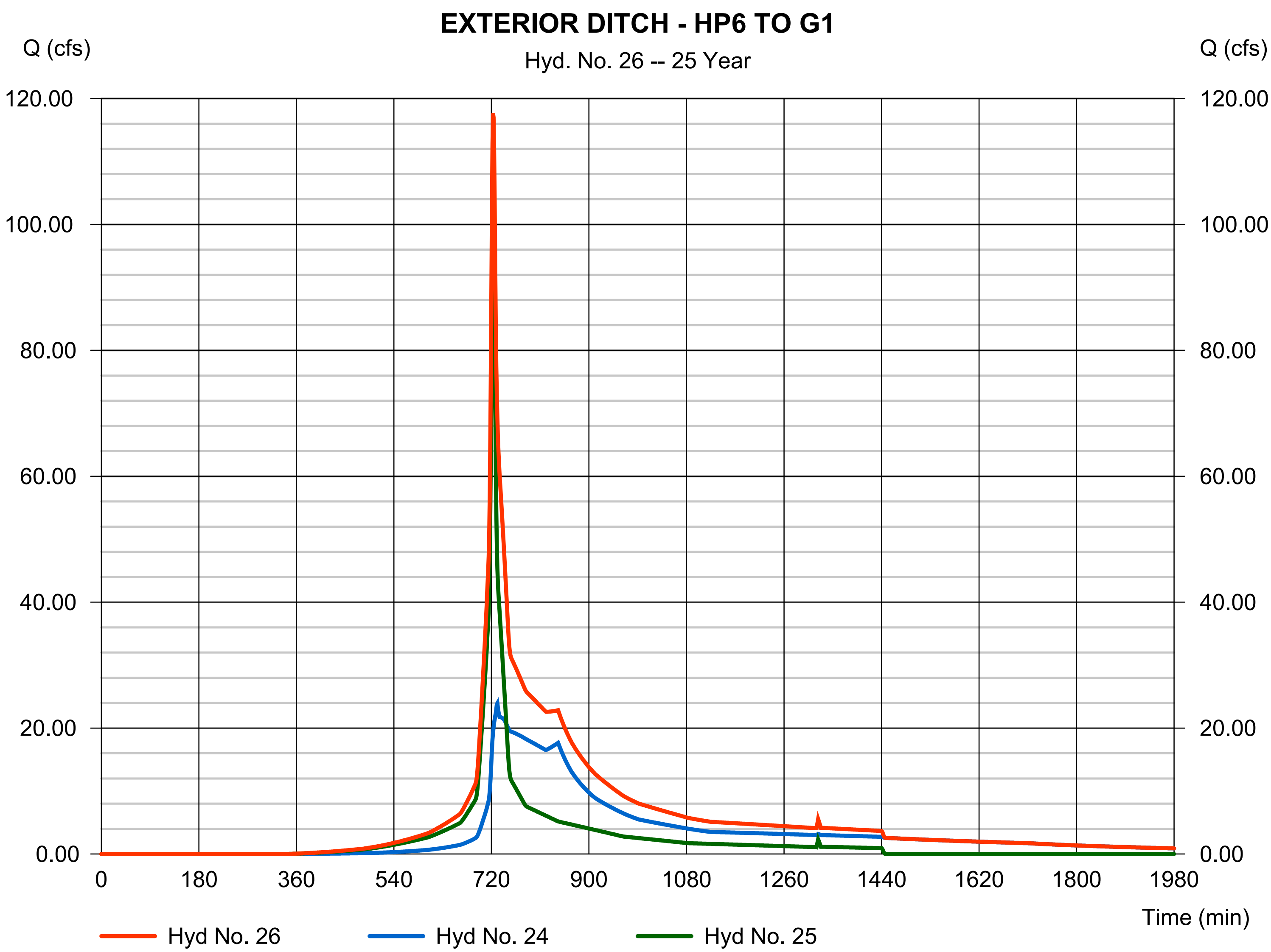
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 26

EXTERIOR DITCH - HP6 TO G1

Hydrograph type	= Combine	Peak discharge	= 117.63 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 704,106 cuft
Inflow hyds.	= 24, 25	Contrib. drain. area	= 15.390 ac



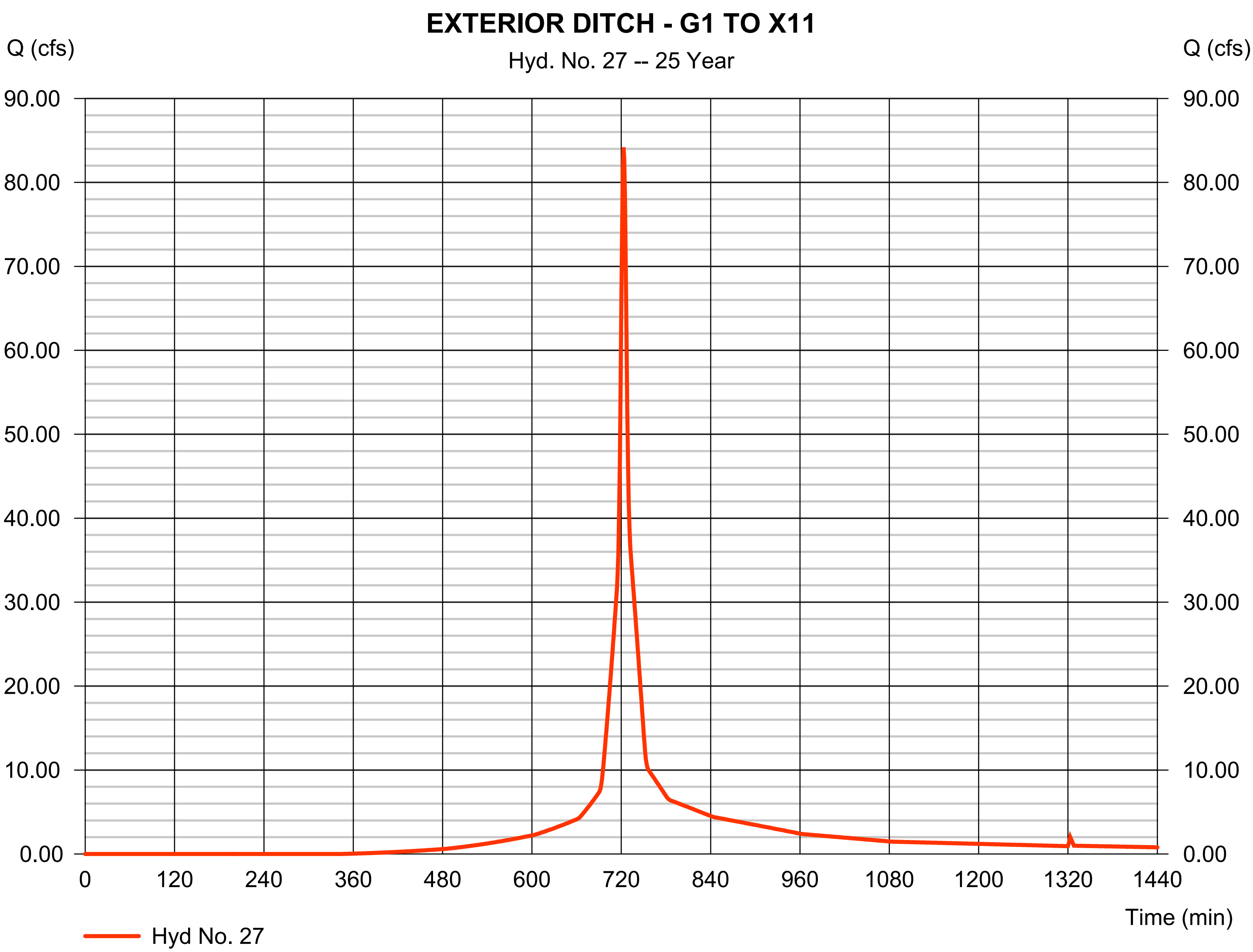
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 27

EXTERIOR DITCH - G1 TO X11

Hydrograph type	= SCS Runoff	Peak discharge	= 84.17 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 246,584 cuft
Drainage area	= 13.170 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



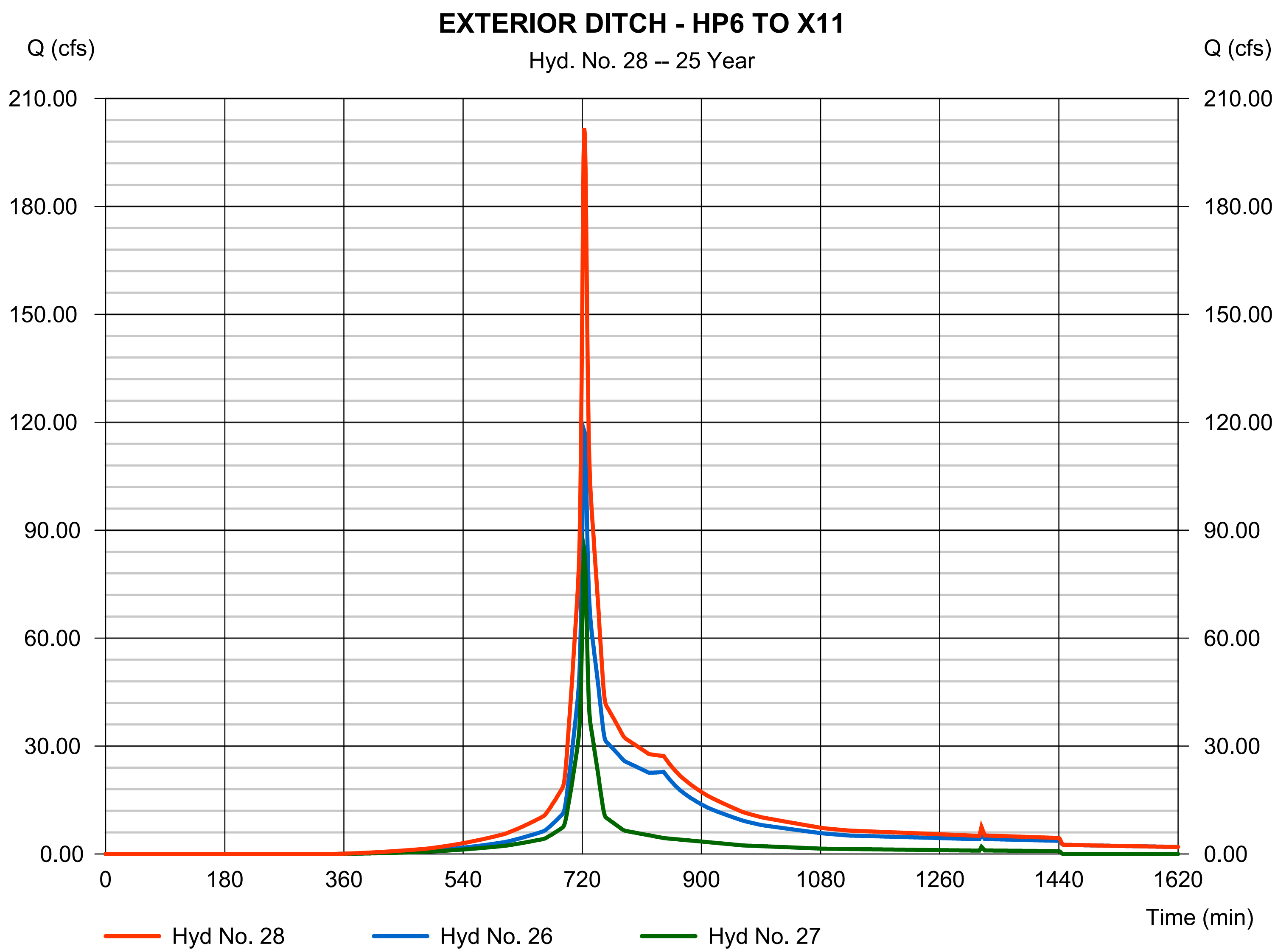
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 28

EXTERIOR DITCH - HP6 TO X11

Hydrograph type	= Combine	Peak discharge	= 201.80 cfs
Storm frequency	= 25 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 950,689 cuft
Inflow hyds.	= 26, 27	Contrib. drain. area	= 13.170 ac



Hydrograph Report

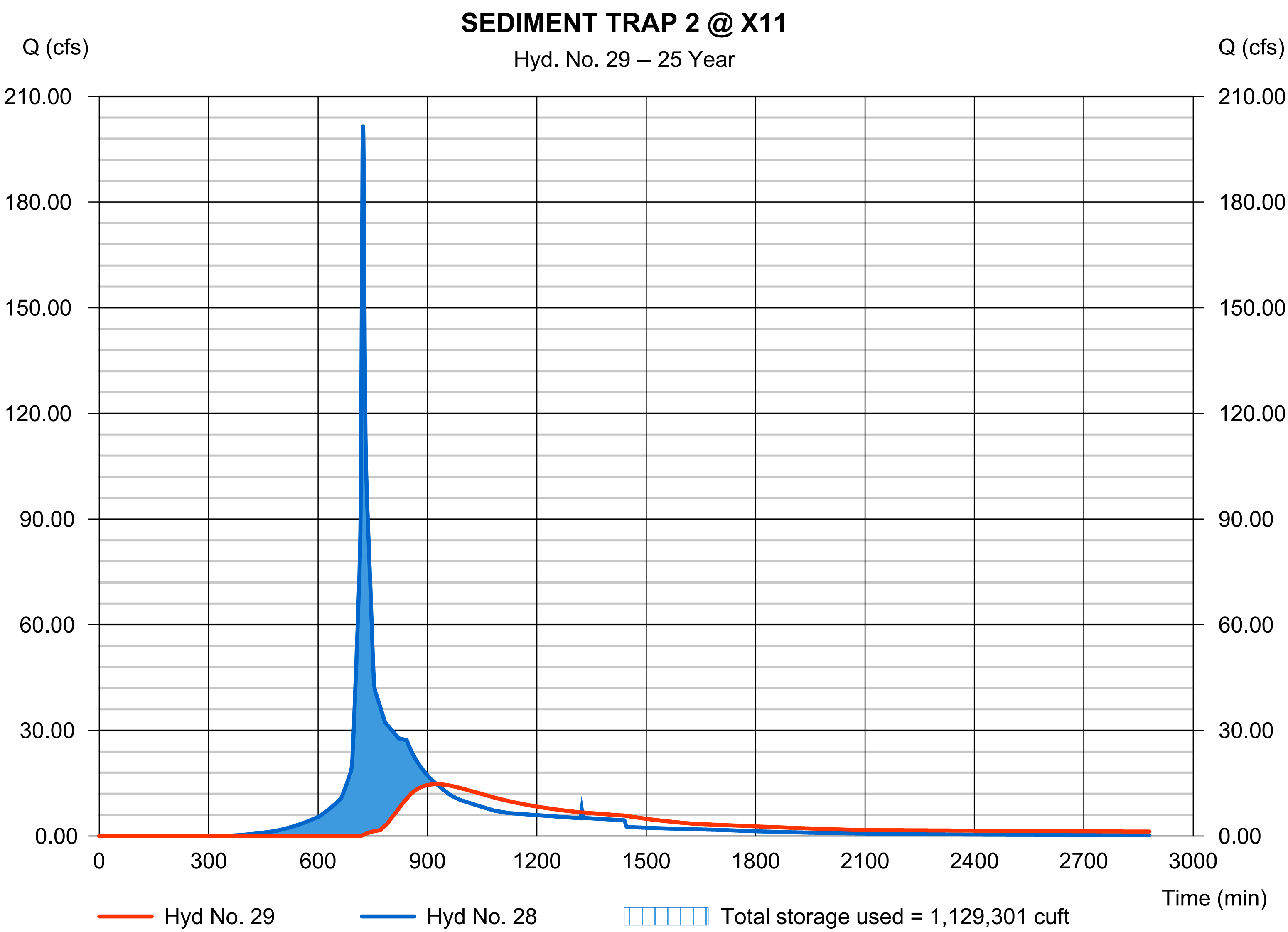
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 29

SEDIMENT TRAP 2 @ X11

Hydrograph type	= Reservoir	Peak discharge	= 14.72 cfs
Storm frequency	= 25 yrs	Time to peak	= 925 min
Time interval	= 1 min	Hyd. volume	= 577,516 cuft
Inflow hyd. No.	= 28 - EXTERIOR DITCH - HP6 TO X11	Max. Elevation	= 246.77 ft
Reservoir name	= SEDIMENT TRAP 2 @ X11	Max. Storage	= 1,129,301 cuft

Storage Indication method used. Wet pond routing start elevation = 243.00 ft.



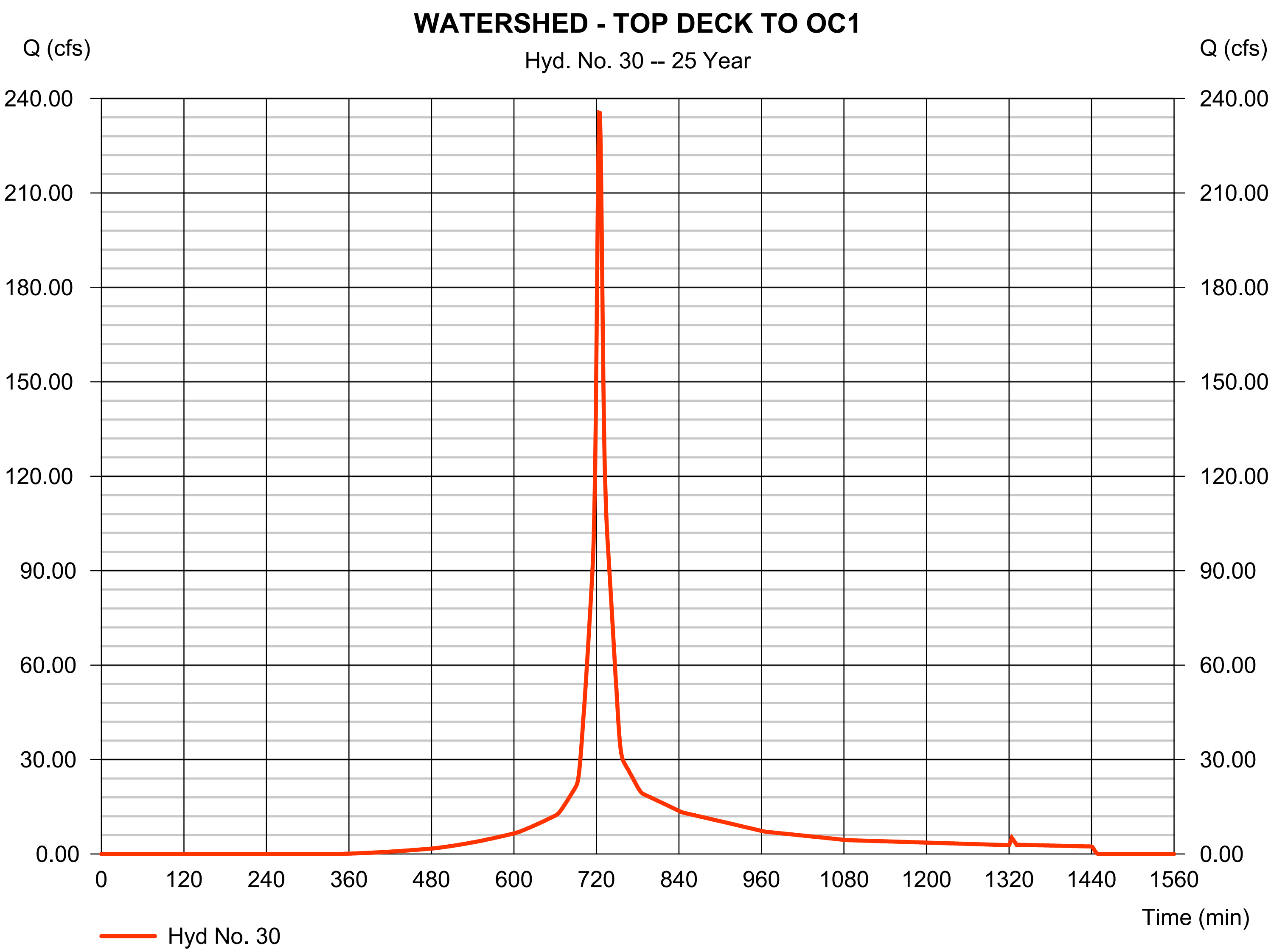
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 30

WATERSHED - TOP DECK TO OC1

Hydrograph type	= SCS Runoff	Peak discharge	= 235.48 cfs
Storm frequency	= 25 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 737,576 cuft
Drainage area	= 38.200 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 7.50 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



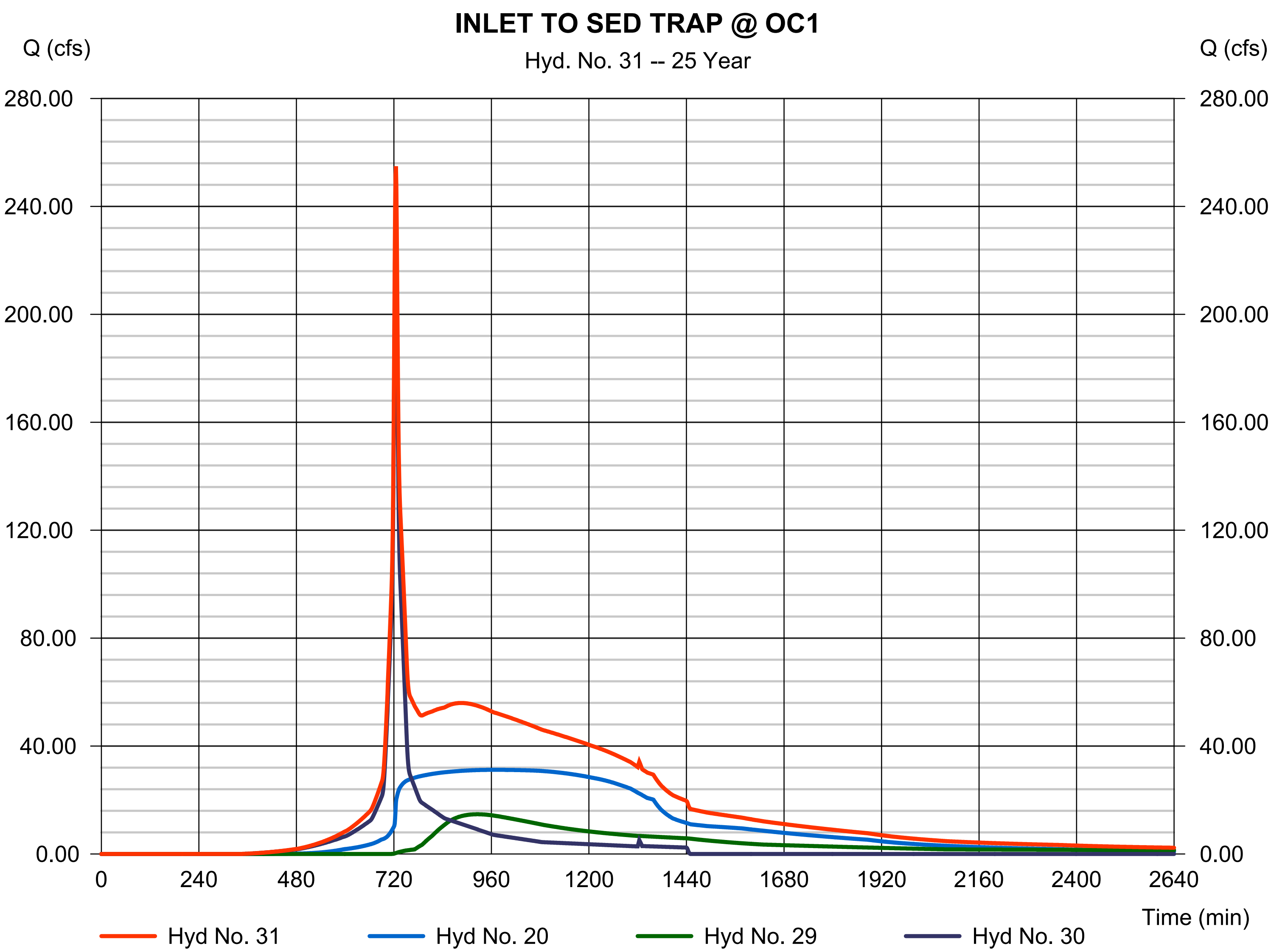
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 31

INLET TO SED TRAP @ OC1

Hydrograph type	= Combine	Peak discharge	= 254.87 cfs
Storm frequency	= 25 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 2,852,292 cuft
Inflow hyds.	= 20, 29, 30	Contrib. drain. area	= 38.200 ac



Hydrograph Report

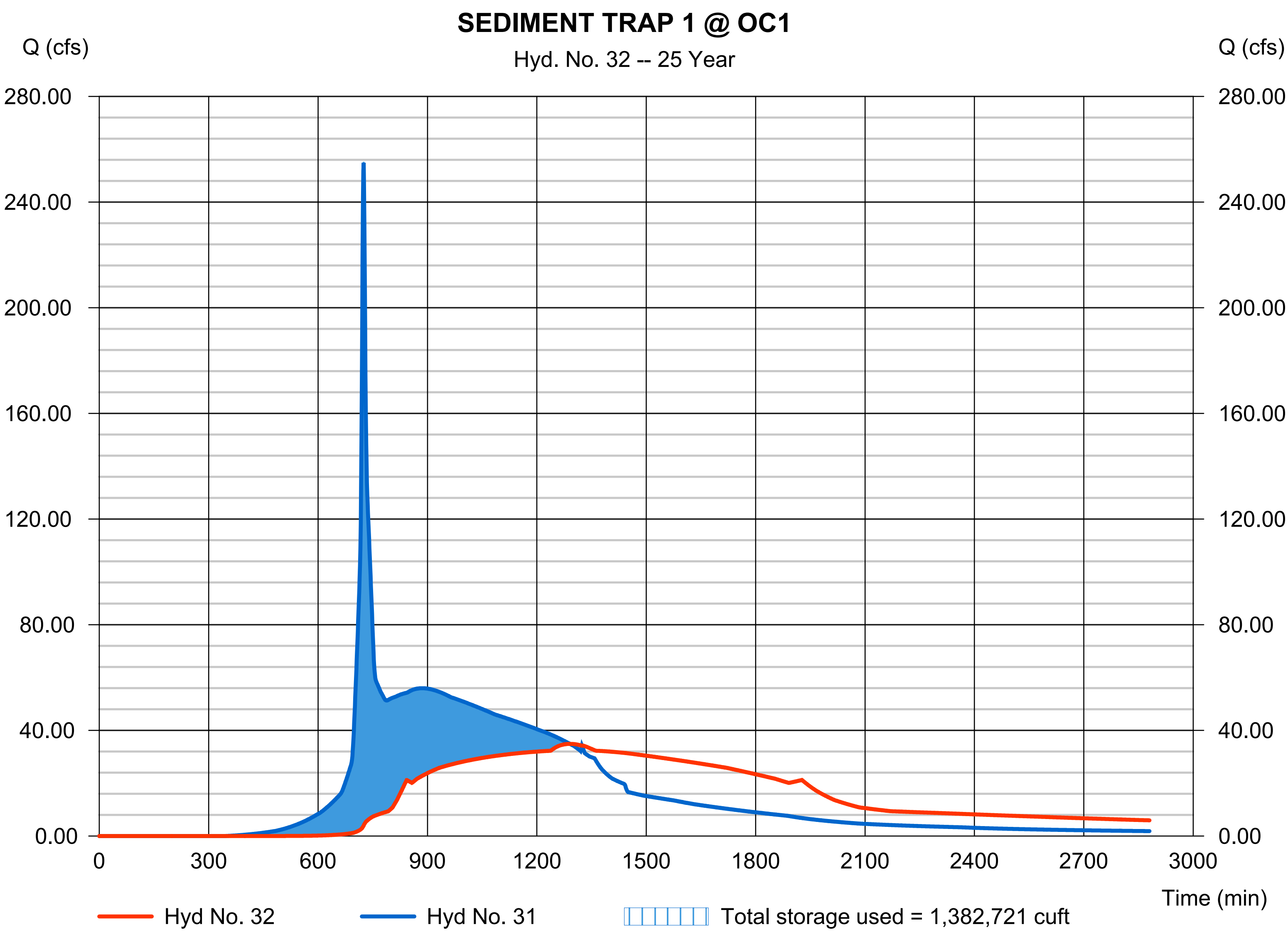
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 32

SEDIMENT TRAP 1 @ OC1

Hydrograph type	= Reservoir	Peak discharge	= 34.89 cfs
Storm frequency	= 25 yrs	Time to peak	= 1291 min
Time interval	= 1 min	Hyd. volume	= 2,438,157 cuft
Inflow hyd. No.	= 31 - INLET TO SED TRAP @ OC1	Max. Elevation	= 237.64 ft
Reservoir name	= SEDIMENT TRAP 1 @ OC1	Max. Storage	= 1,382,721 cuft

Storage Indication method used. Wet pond routing start elevation = 228.00 ft.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	24.89	1	725	82,040	------	------	------	EXTERIOR DITCH - HP5 TO X8
2	SCS Runoff	25.18	1	725	82,997	------	------	------	EXTERIOR DITCH - X7 TO X6
3	Combine	50.07	1	725	165,037	1, 2	------	------	EXTERIOR DITCH HP5 TO X6
4	SCS Runoff	12.47	1	724	39,465	------	------	------	EXTERIOR DITCH - X5 TO X3
5	Combine	62.51	1	725	204,502	3, 4	------	------	EXTERIOR DITCH HP5 TO X3
6	Reservoir	14.10	1	750	167,433	5	258.31	141,393	SEDIMENT TRAP 6 @ X3
7	SCS Runoff	8.615	1	723	25,513	------	------	------	EXTERIOR DITCH - X4 TO C1
8	Combine	15.88	1	745	192,946	6, 7	------	------	EXTERIOR DITCH HP5 TO C1
9	SCS Runoff	224.24	1	728	833,490	------	------	------	EXTERIOR DITCH - C1 TO D1
10	Combine	232.22	1	728	1,026,435	8, 9	------	------	EXTERIOR DITCH HP5 TO D1
11	SCS Runoff	95.13	1	724	301,050	------	------	------	EXTERIOR DITCH - D1 TO X1
12	Combine	318.07	1	726	1,327,486	10, 11	------	------	EXTERIOR DITCH HP5 TO X1
13	SCS Runoff	66.77	1	723	197,725	------	------	------	EXTERIOR DITCH - X1 TO X18
14	Combine	374.09	1	725	1,525,212	12, 13	------	------	EXTERIOR DITCH HP5 TO X18
15	Reservoir	37.06	1	809	1,490,566	14	250.75	841,525	SEDIMENT TRAP 5 @ X18
16	SCS Runoff	134.53	1	723	398,394	------	------	------	EXTERIOR DITCH - X17 TO X16
17	Combine	160.17	1	723	1,888,960	15, 16	------	------	EXTERIOR DITCH HP5 TO X16
18	SCS Runoff	55.58	1	722	155,009	------	------	------	EXTERIOR DITCH - X15 TO X14
19	Combine	213.22	1	723	2,043,970	17, 18	------	------	EXTERIOR DITCH HP5 TO X14
20	Reservoir	44.67	1	855	2,035,627	19	248.58	413,069	SEDIMENT TRAP 4 @ X14
21	SCS Runoff	159.89	1	724	505,966	------	------	------	EXTERIOR DITCH - HP6 TO X10
22	Reservoir	29.41	1	751	489,037	21	253.00	318,866	SEDIMENT TRAP 3 @ X10
23	SCS Runoff	20.38	1	723	60,348	------	------	------	EXTERIOR DITCH - X9 TO H1
24	Combine	36.63	1	723	549,385	22, 23	------	------	EXTERIOR DITCH HP6 TO H1
25	SCS Runoff	127.49	1	723	377,542	------	------	------	EXTERIOR DITCH - H1 TO G1
26	Combine	164.12	1	723	926,927	24, 25	------	------	EXTERIOR DITCH - HP6 TO G1
27	SCS Runoff	109.10	1	723	323,082	------	------	------	EXTERIOR DITCH - G1 TO X11
28	Combine	273.22	1	723	1,250,010	26, 27	------	------	EXTERIOR DITCH - HP6 TO X11
29	Reservoir	22.21	1	938	873,487	28	247.44	1,247,744	SEDIMENT TRAP 2 @ X11
30	SCS Runoff	305.38	1	724	966,395	------	------	------	WATERSHED - TOP DECK TO OC1
31	Combine	331.29	1	725	3,875,507	20, 29, 30	------	------	INLET TO SED TRAP @ OC1
32	Reservoir	46.75	1	1271	3,428,631	31	238.77	1,643,778	SEDIMENT TRAP 1 @ OC1

Exterior Ditch [with ponds].gpw	Return Period: 100 Year	Friday, 01 / 30 / 2015

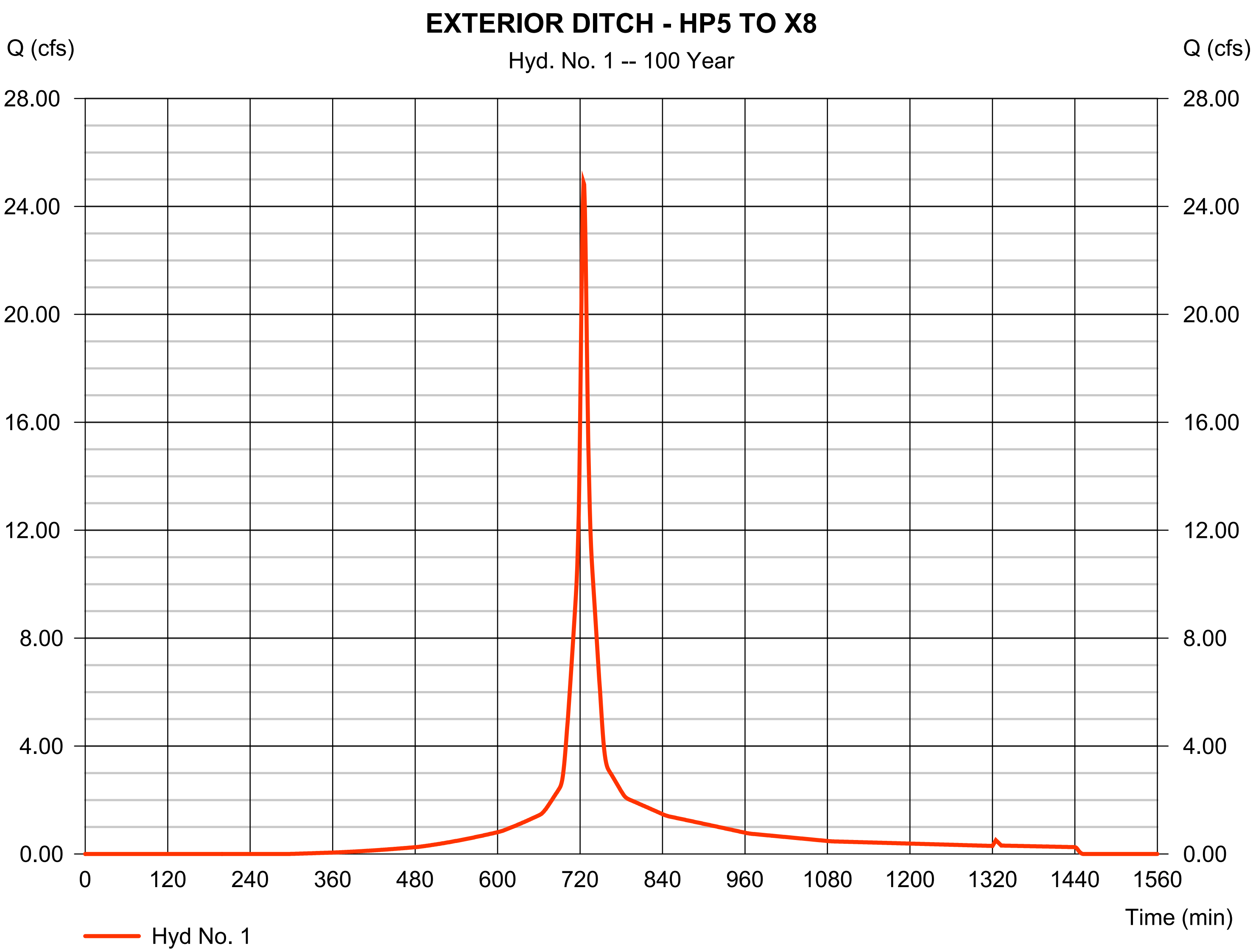
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 1

EXTERIOR DITCH - HP5 TO X8

Hydrograph type	= SCS Runoff	Peak discharge	= 24.89 cfs
Storm frequency	= 100 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 82,040 cuft
Drainage area	= 3.430 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.30 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



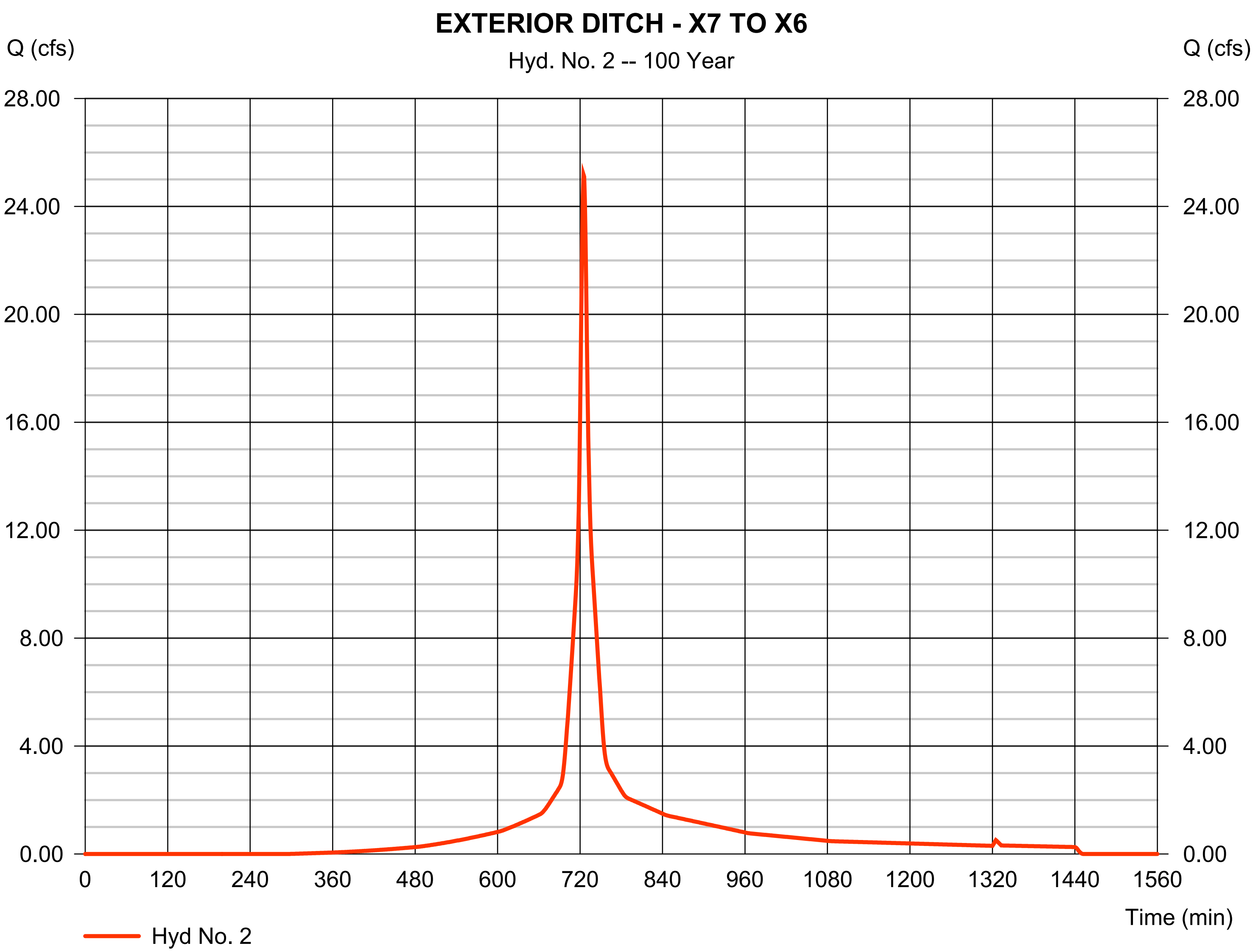
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 2

EXTERIOR DITCH - X7 TO X6

Hydrograph type	= SCS Runoff	Peak discharge	= 25.18 cfs
Storm frequency	= 100 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 82,997 cuft
Drainage area	= 3.470 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.70 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



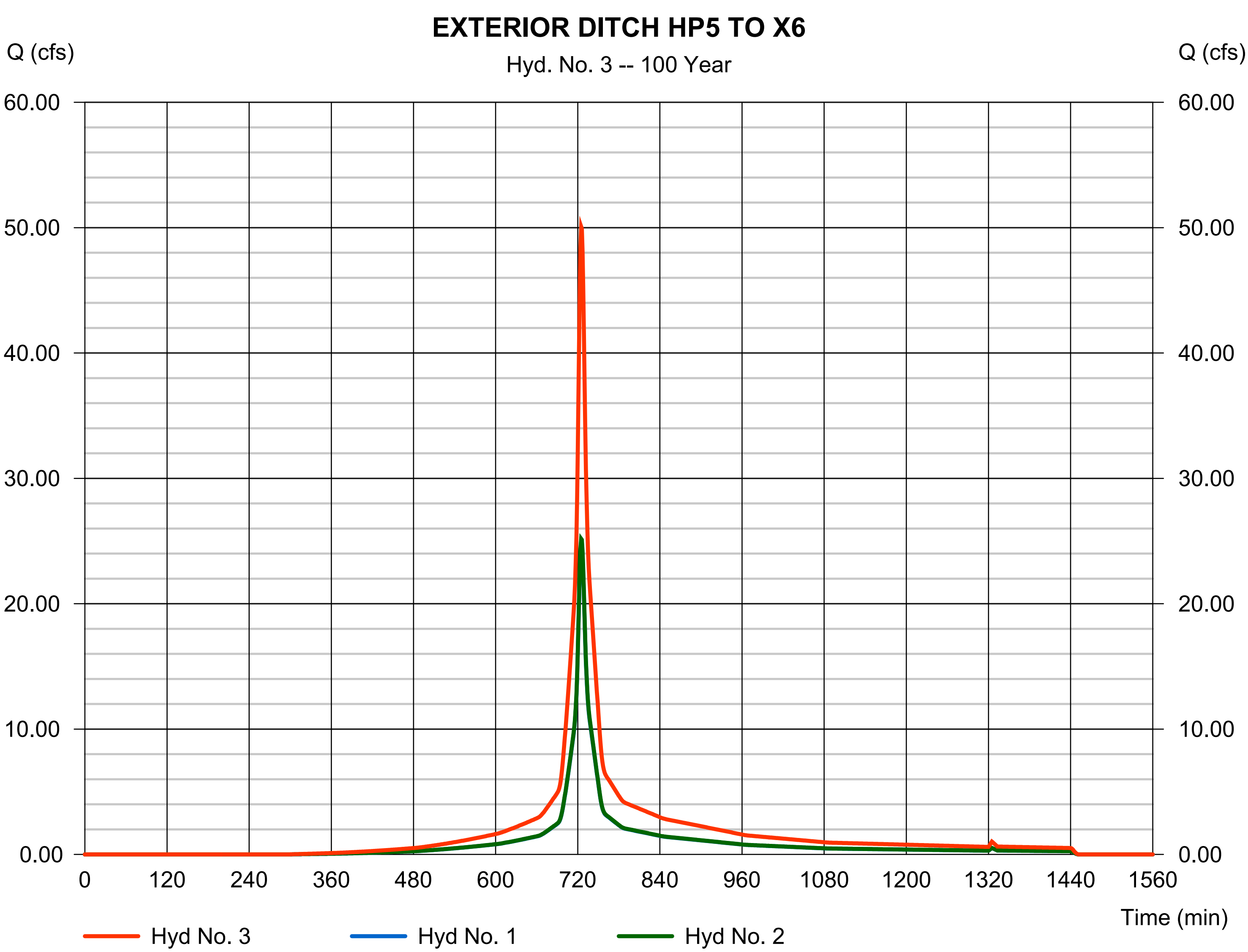
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 3

EXTERIOR DITCH HP5 TO X6

Hydrograph type	= Combine	Peak discharge	= 50.07 cfs
Storm frequency	= 100 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 165,037 cuft
Inflow hyds.	= 1, 2	Contrib. drain. area	= 6.900 ac



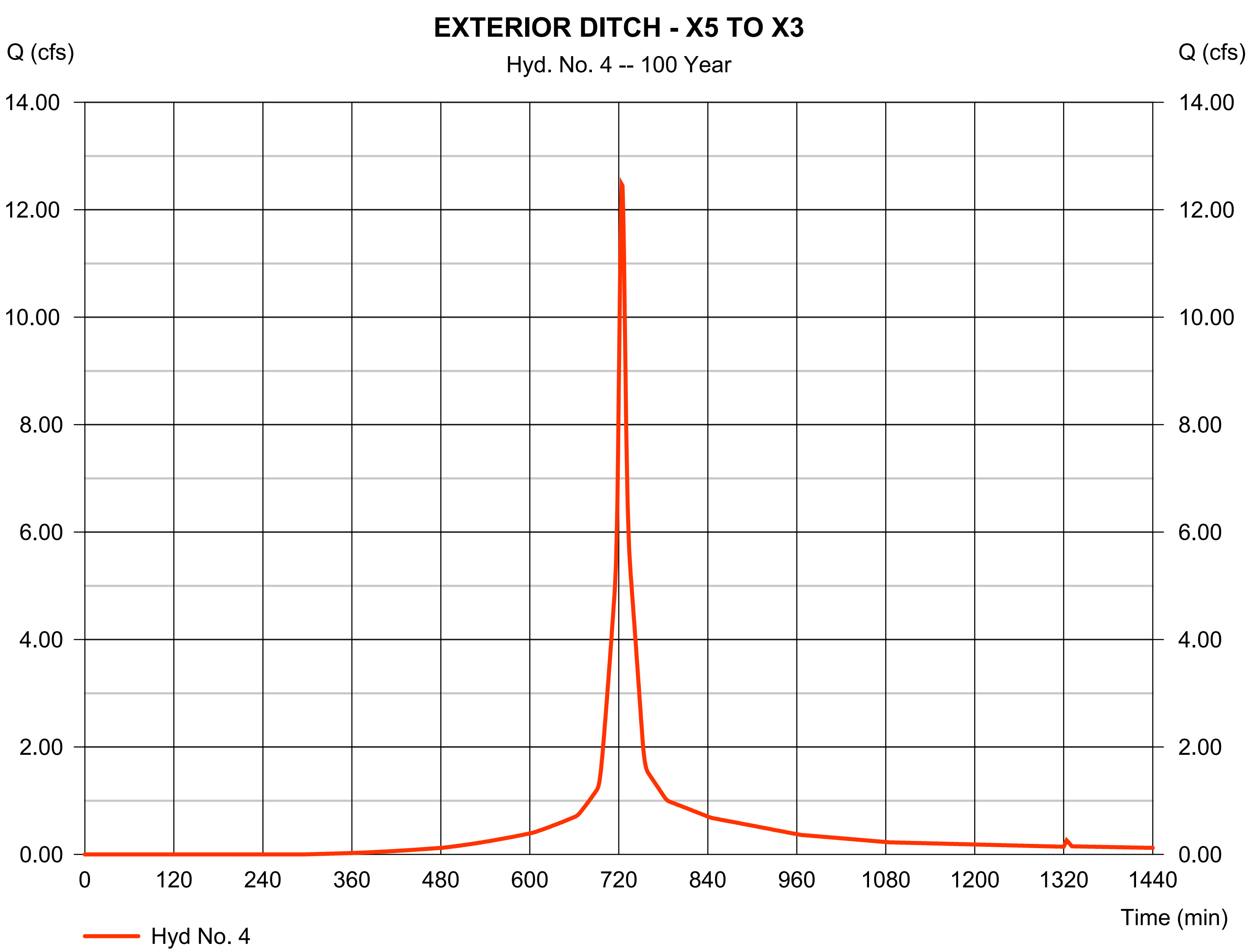
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 4

EXTERIOR DITCH - X5 TO X3

Hydrograph type	= SCS Runoff	Peak discharge	= 12.47 cfs
Storm frequency	= 100 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 39,465 cuft
Drainage area	= 1.560 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.90 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



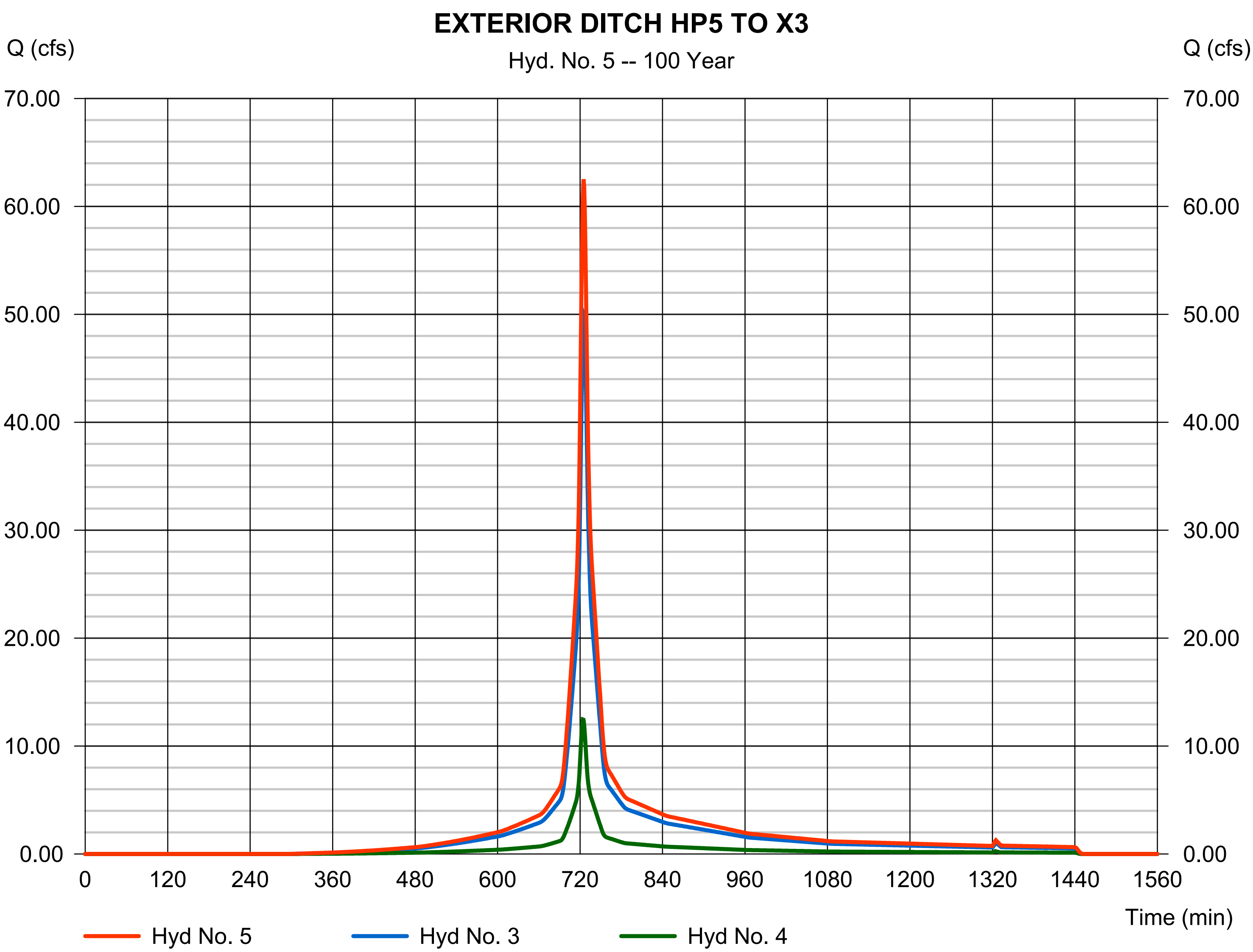
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 5

EXTERIOR DITCH HP5 TO X3

Hydrograph type	= Combine	Peak discharge	= 62.51 cfs
Storm frequency	= 100 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 204,502 cuft
Inflow hyds.	= 3, 4	Contrib. drain. area	= 1.560 ac



Hydrograph Report

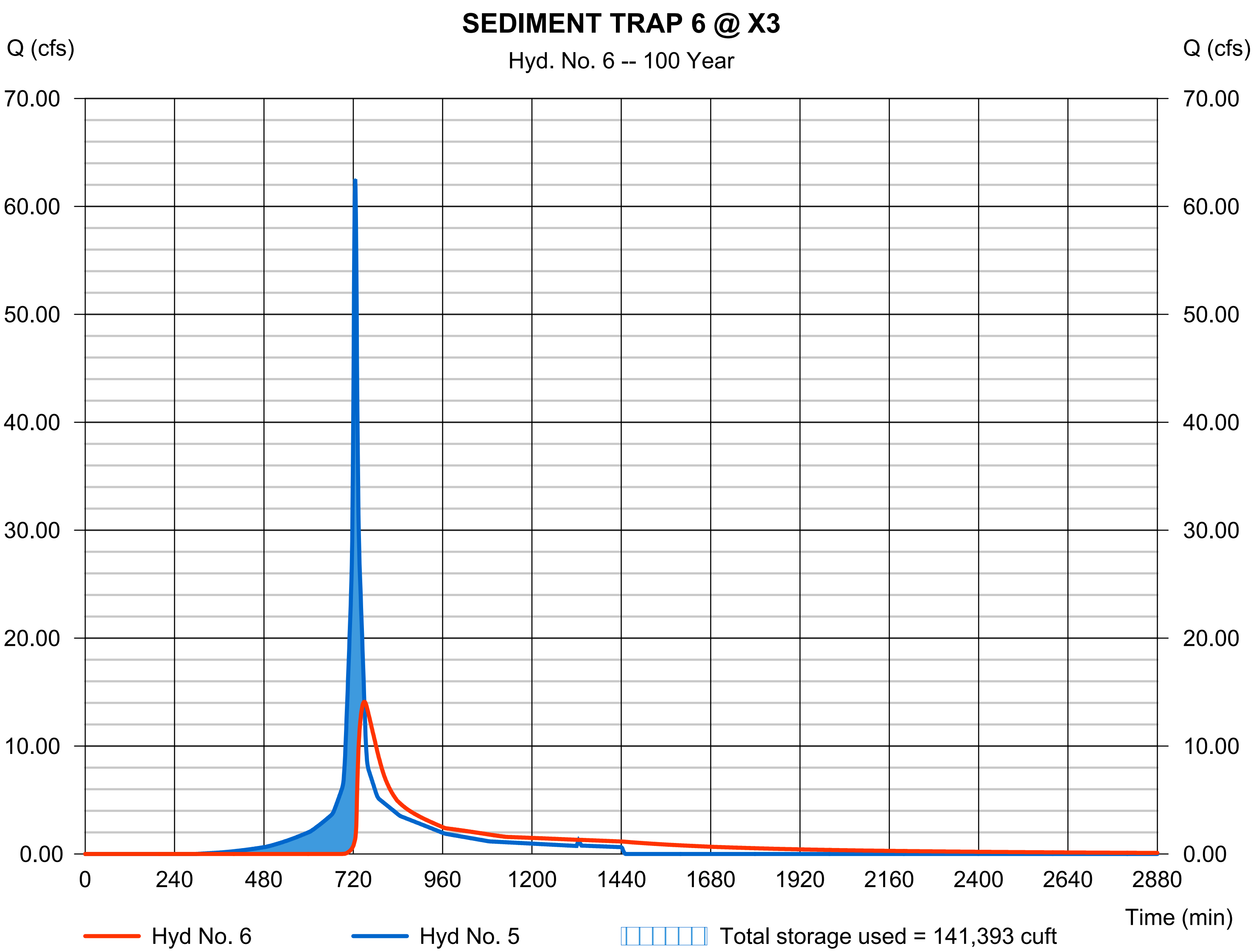
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 | Friday, 01 / 30 / 2015

Hyd. No. 6

SEDIMENT TRAP 6 @ X3

Hydrograph type	=	Reservoir	Peak discharge	=	14.10 cfs
Storm frequency	=	100 yrs	Time to peak	=	750 min
Time interval	=	1 min	Hyd. volume	=	167,433 cuft
Inflow hyd. No.	=	5 - EXTERIOR DITCH HP5 TO X3	Max. Elevation	=	258.31 ft
Reservoir name	=	SEDIMENT TRAP 6 @ X3	Max. Storage	=	141,393 cuft

Storage Indication method used. Wet pond routing start elevation = 254.00 ft.



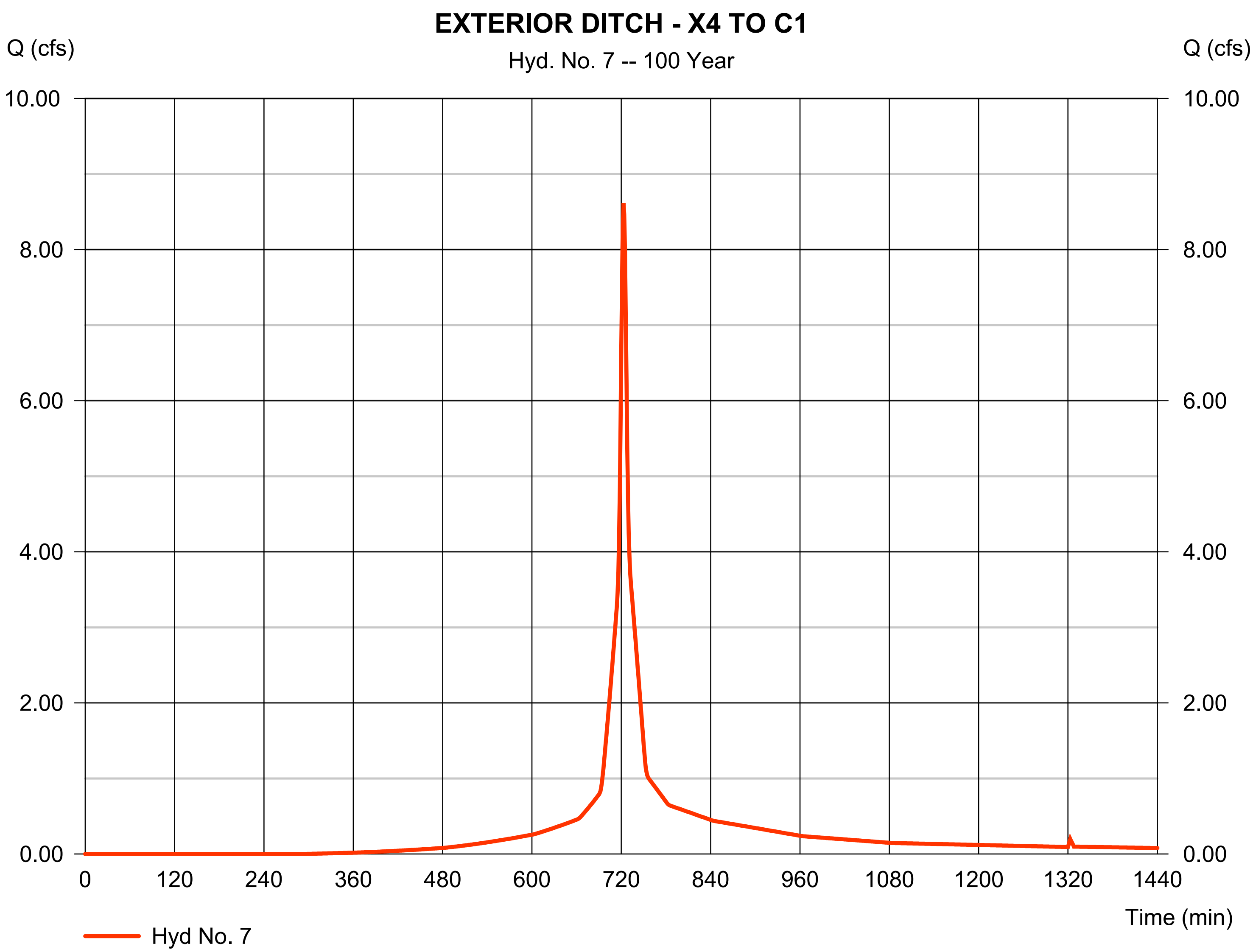
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 7

EXTERIOR DITCH - X4 TO C1

Hydrograph type	= SCS Runoff	Peak discharge	= 8.615 cfs
Storm frequency	= 100 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 25,513 cuft
Drainage area	= 1.040 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.70 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



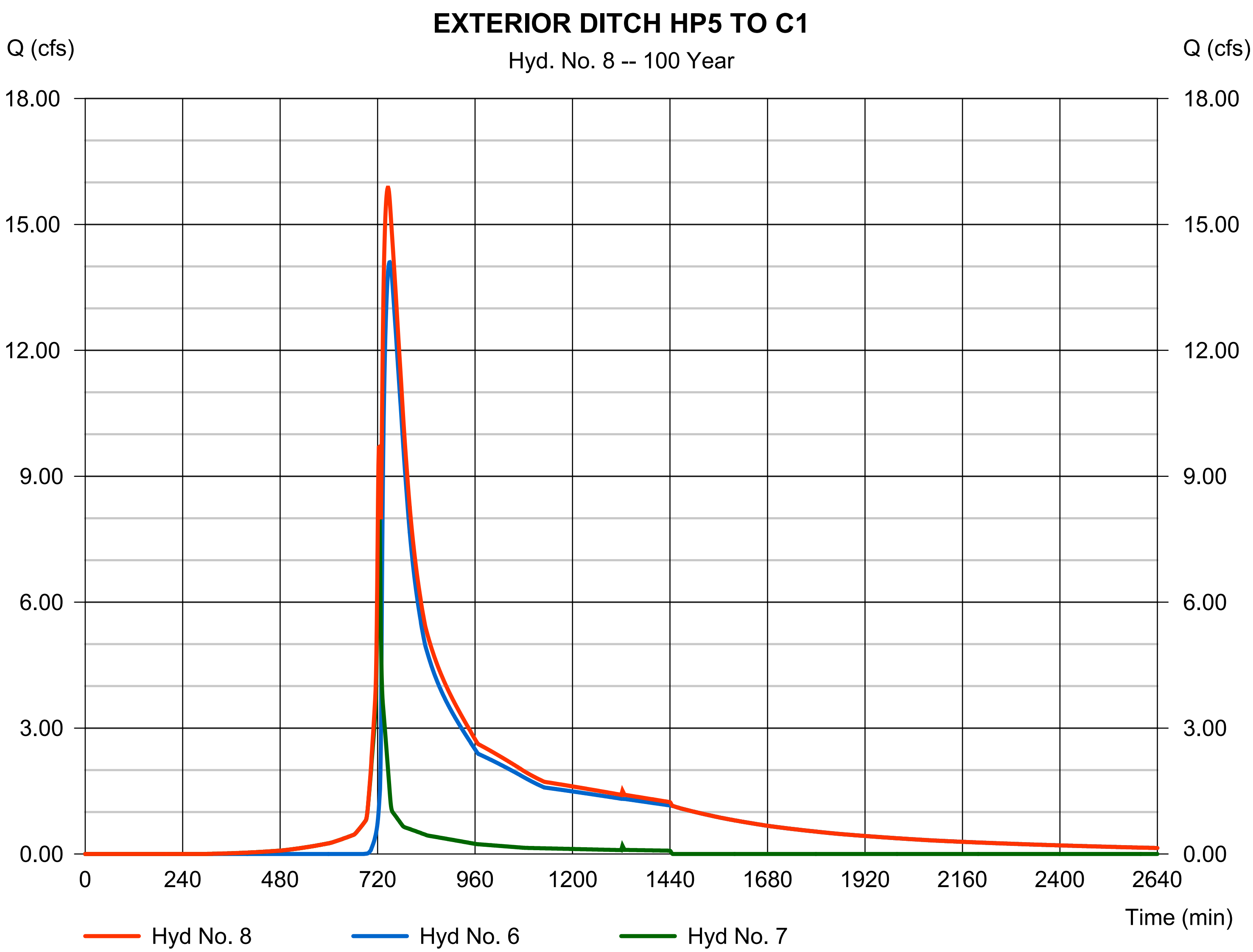
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 8

EXTERIOR DITCH HP5 TO C1

Hydrograph type	= Combine	Peak discharge	= 15.88 cfs
Storm frequency	= 100 yrs	Time to peak	= 745 min
Time interval	= 1 min	Hyd. volume	= 192,946 cuft
Inflow hyds.	= 6, 7	Contrib. drain. area	= 1.040 ac



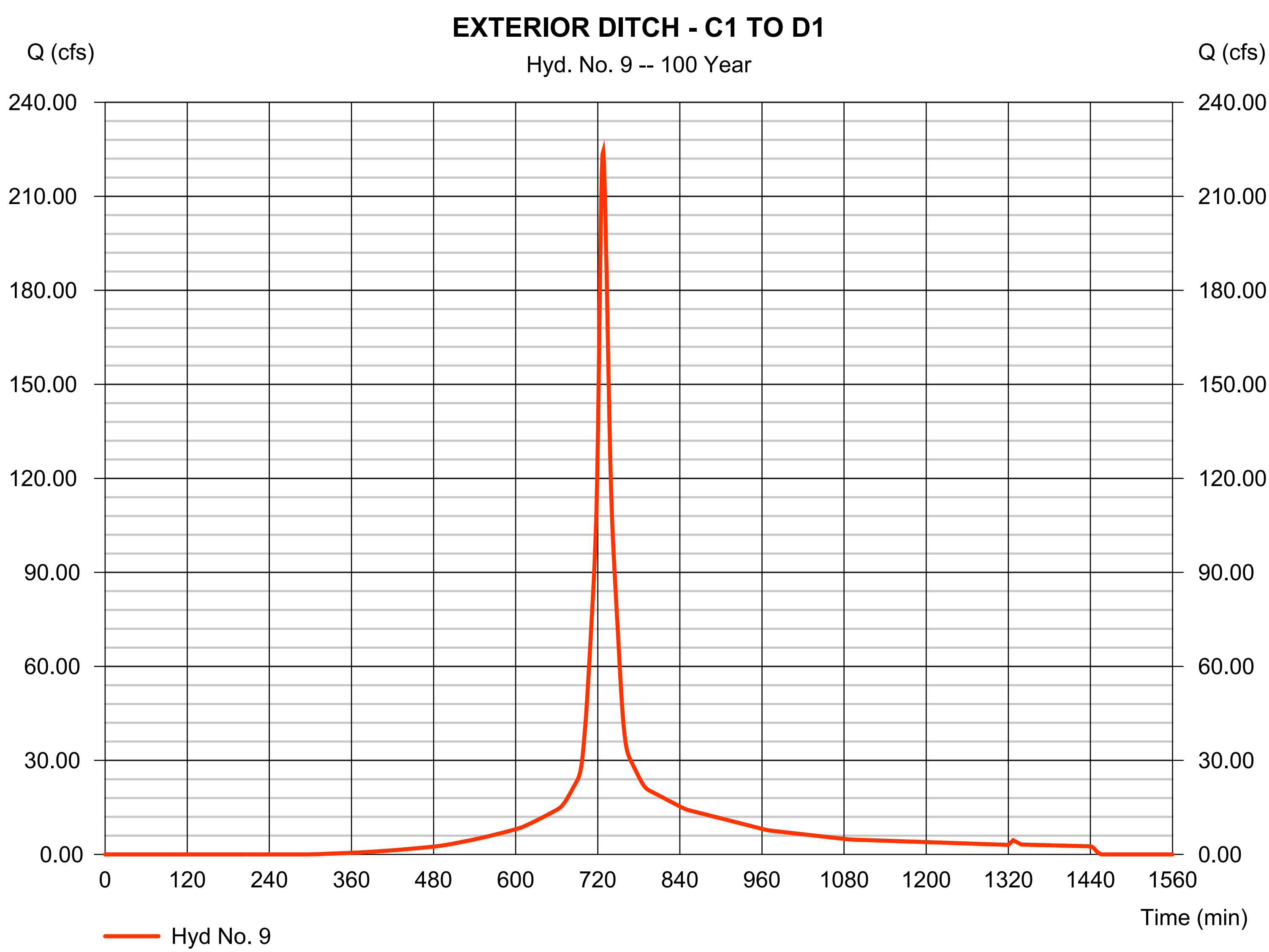
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 9

EXTERIOR DITCH - C1 TO D1

Hydrograph type	= SCS Runoff	Peak discharge	= 224.24 cfs
Storm frequency	= 100 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 833,490 cuft
Drainage area	= 33.380 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.00 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



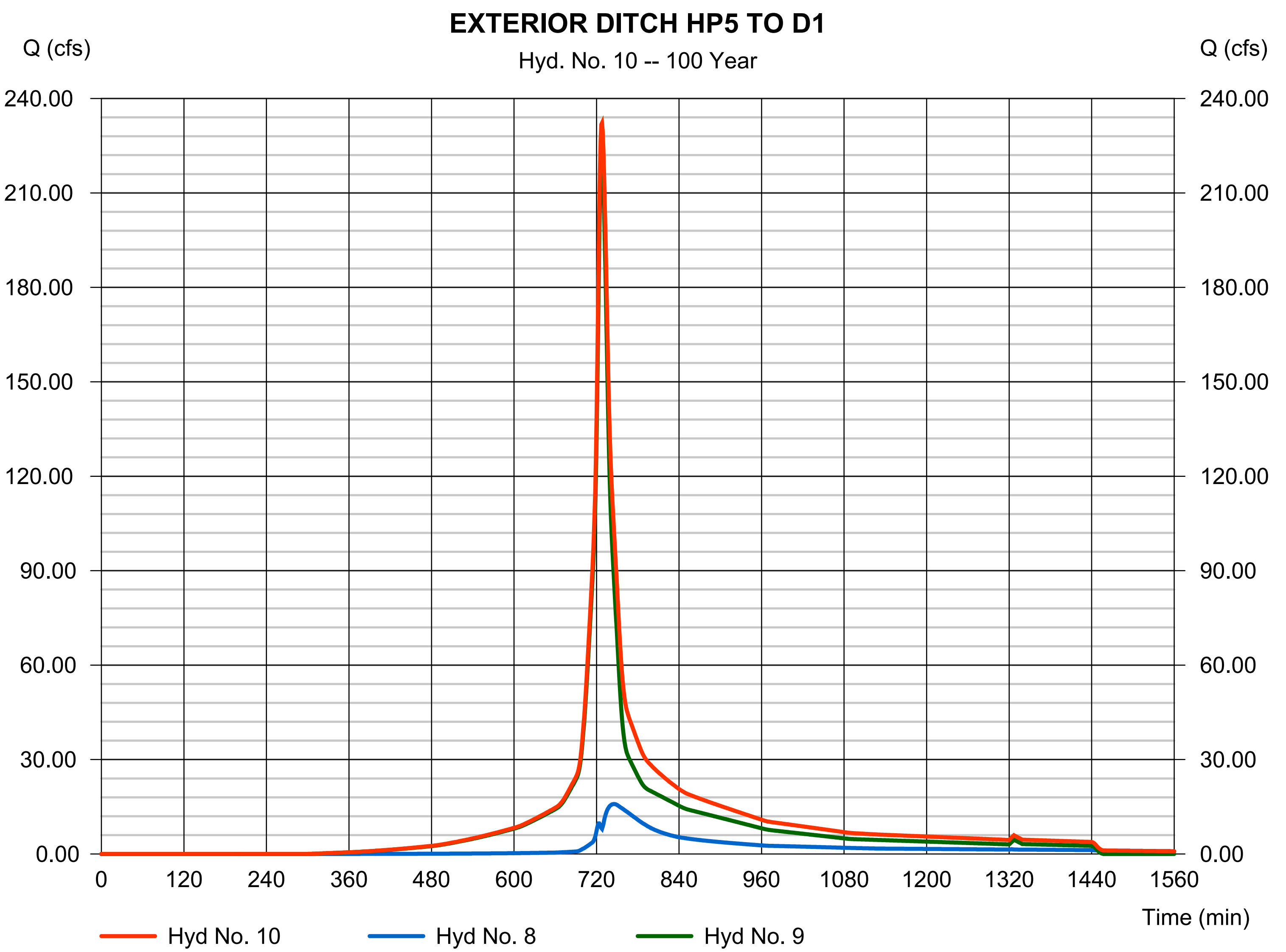
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 10

EXTERIOR DITCH HP5 TO D1

Hydrograph type	= Combine	Peak discharge	= 232.22 cfs
Storm frequency	= 100 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 1,026,435 cuft
Inflow hyds.	= 8, 9	Contrib. drain. area	= 33.380 ac



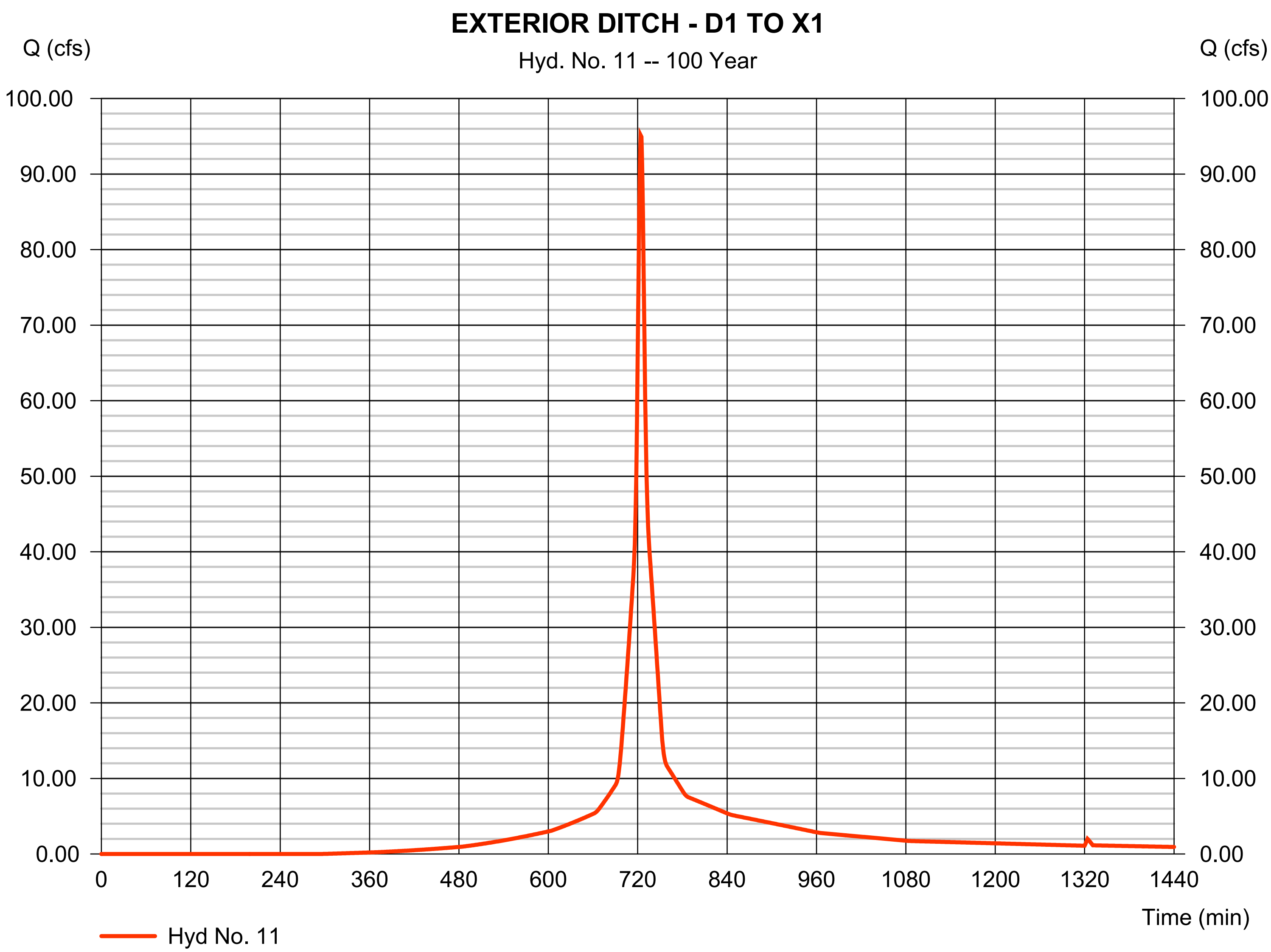
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 11

EXTERIOR DITCH - D1 TO X1

Hydrograph type	= SCS Runoff	Peak discharge	= 95.13 cfs
Storm frequency	= 100 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 301,050 cuft
Drainage area	= 11.900 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.20 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



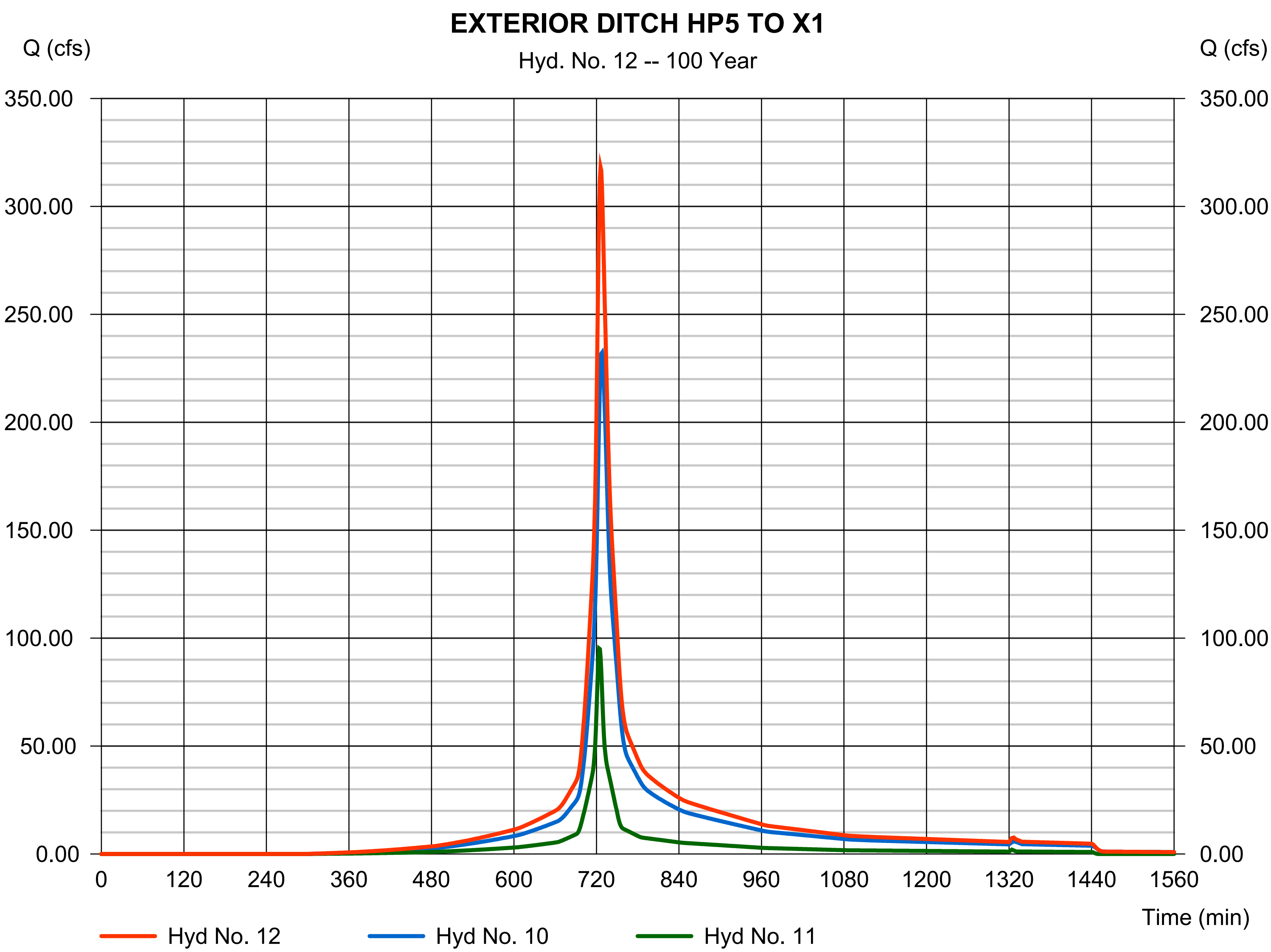
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 12

EXTERIOR DITCH HP5 TO X1

Hydrograph type	= Combine	Peak discharge	= 318.07 cfs
Storm frequency	= 100 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,327,486 cuft
Inflow hyds.	= 10, 11	Contrib. drain. area	= 11.900 ac



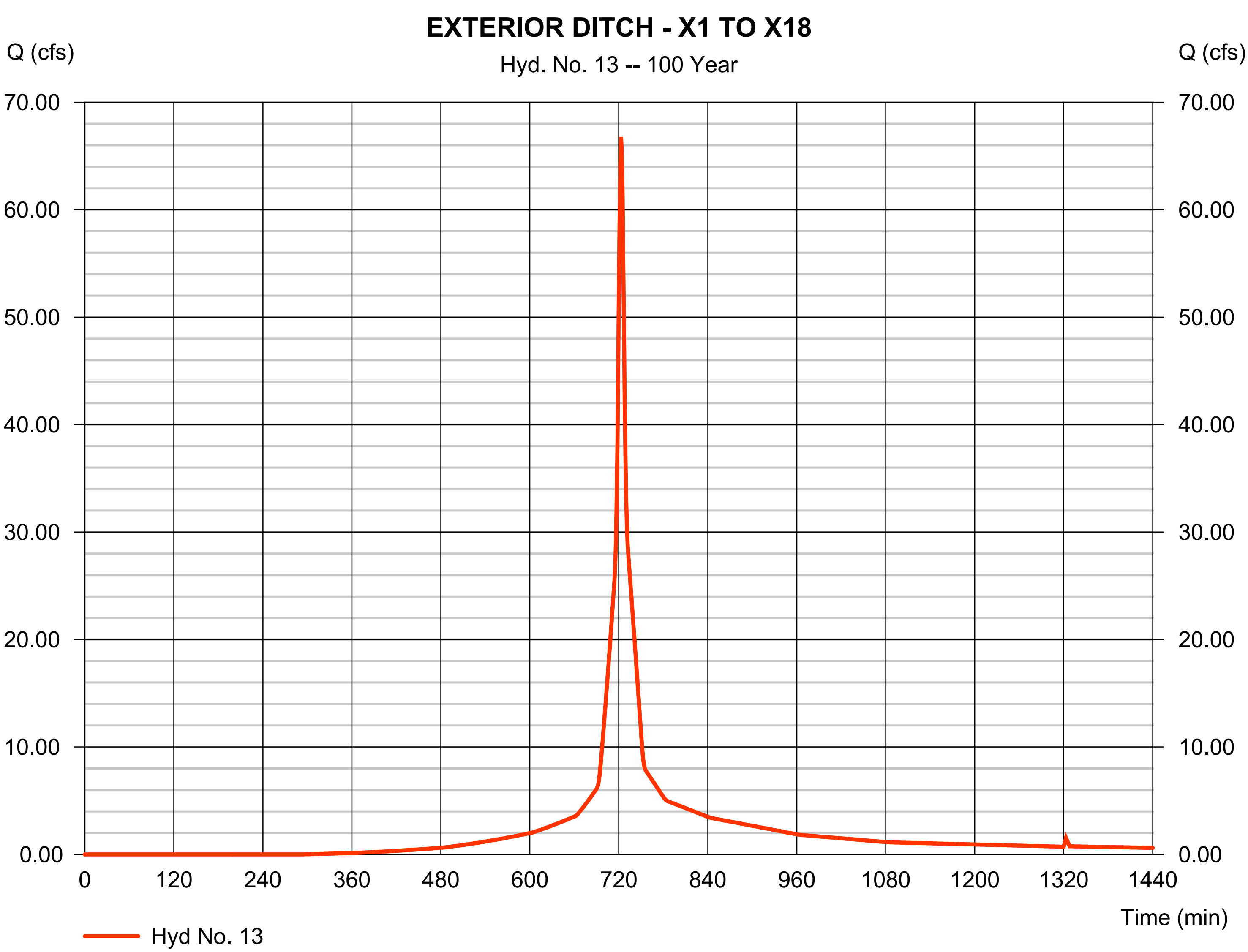
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 13

EXTERIOR DITCH - X1 TO X18

Hydrograph type	=	SCS Runoff	Peak discharge	=	66.77 cfs
Storm frequency	=	100 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	197,725 cuft
Drainage area	=	8.060 ac	Curve number	=	80
Basin Slope	=	25.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	3.80 min
Total precip.	=	9.20 in	Distribution	=	Type III
Storm duration	=	24 hrs	Shape factor	=	484



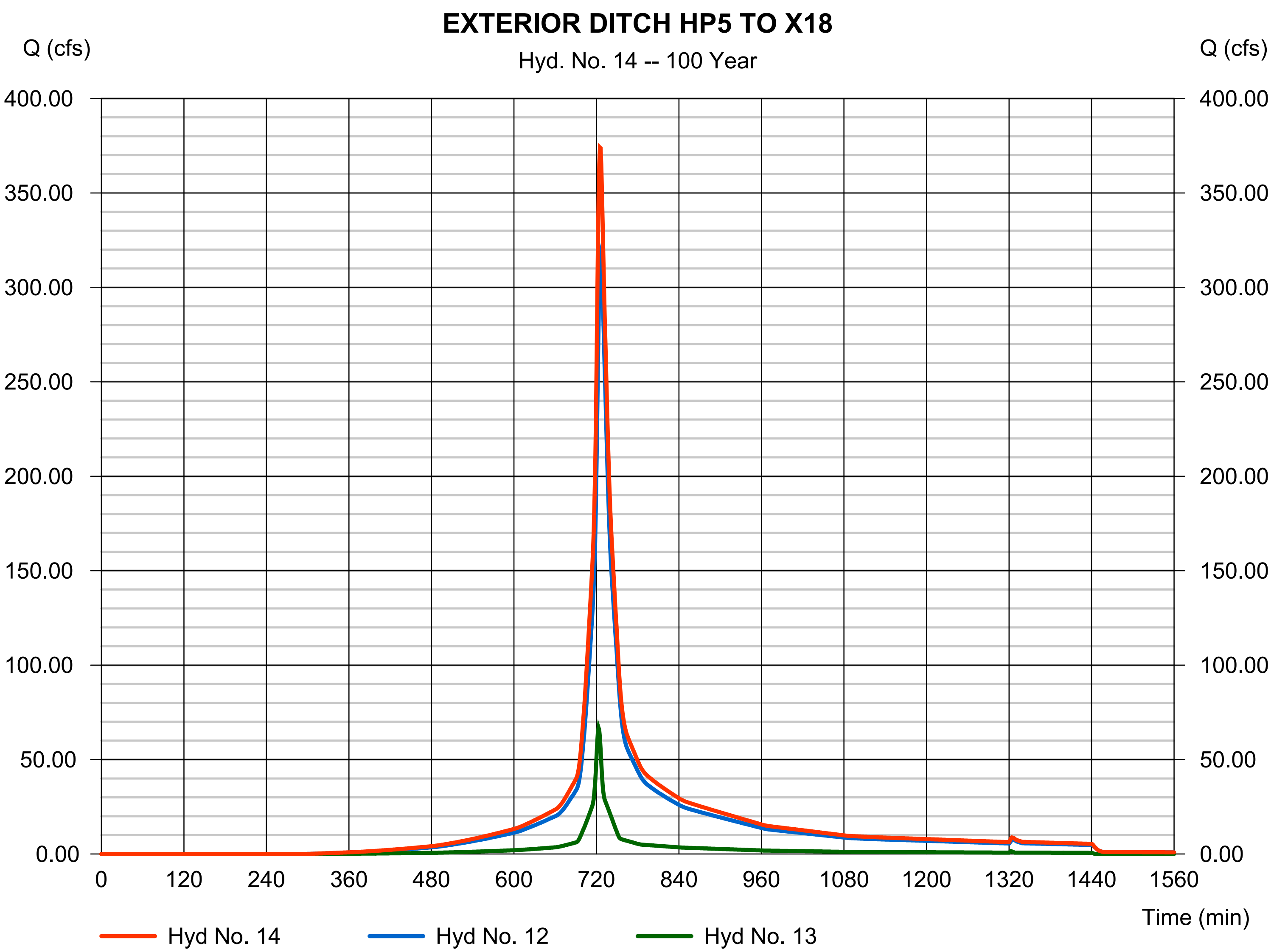
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 14

EXTERIOR DITCH HP5 TO X18

Hydrograph type	= Combine	Peak discharge	= 374.09 cfs
Storm frequency	= 100 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,525,212 cuft
Inflow hyds.	= 12, 13	Contrib. drain. area	= 8.060 ac



Hydrograph Report

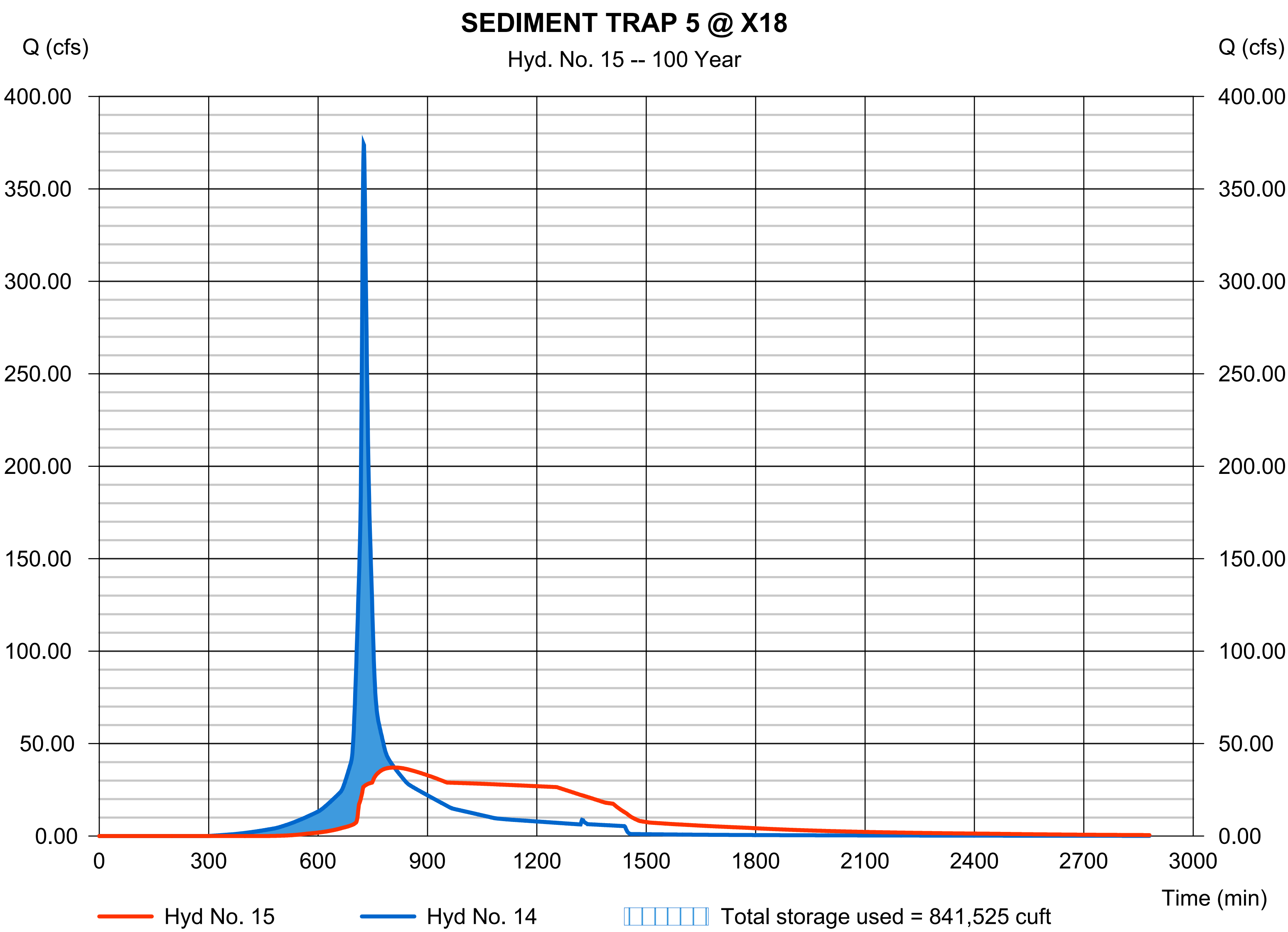
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 15

SEDIMENT TRAP 5 @ X18

Hydrograph type	= Reservoir	Peak discharge	= 37.06 cfs
Storm frequency	= 100 yrs	Time to peak	= 809 min
Time interval	= 1 min	Hyd. volume	= 1,490,566 cuft
Inflow hyd. No.	= 14 - EXTERIOR DITCH HP5 TO X18	Max. Elevation	= 250.75 ft
Reservoir name	= SEDIMENT TRAP 5 @ X18	Max. Storage	= 841,525 cuft

Storage Indication method used. Wet pond routing start elevation = 242.00 ft.



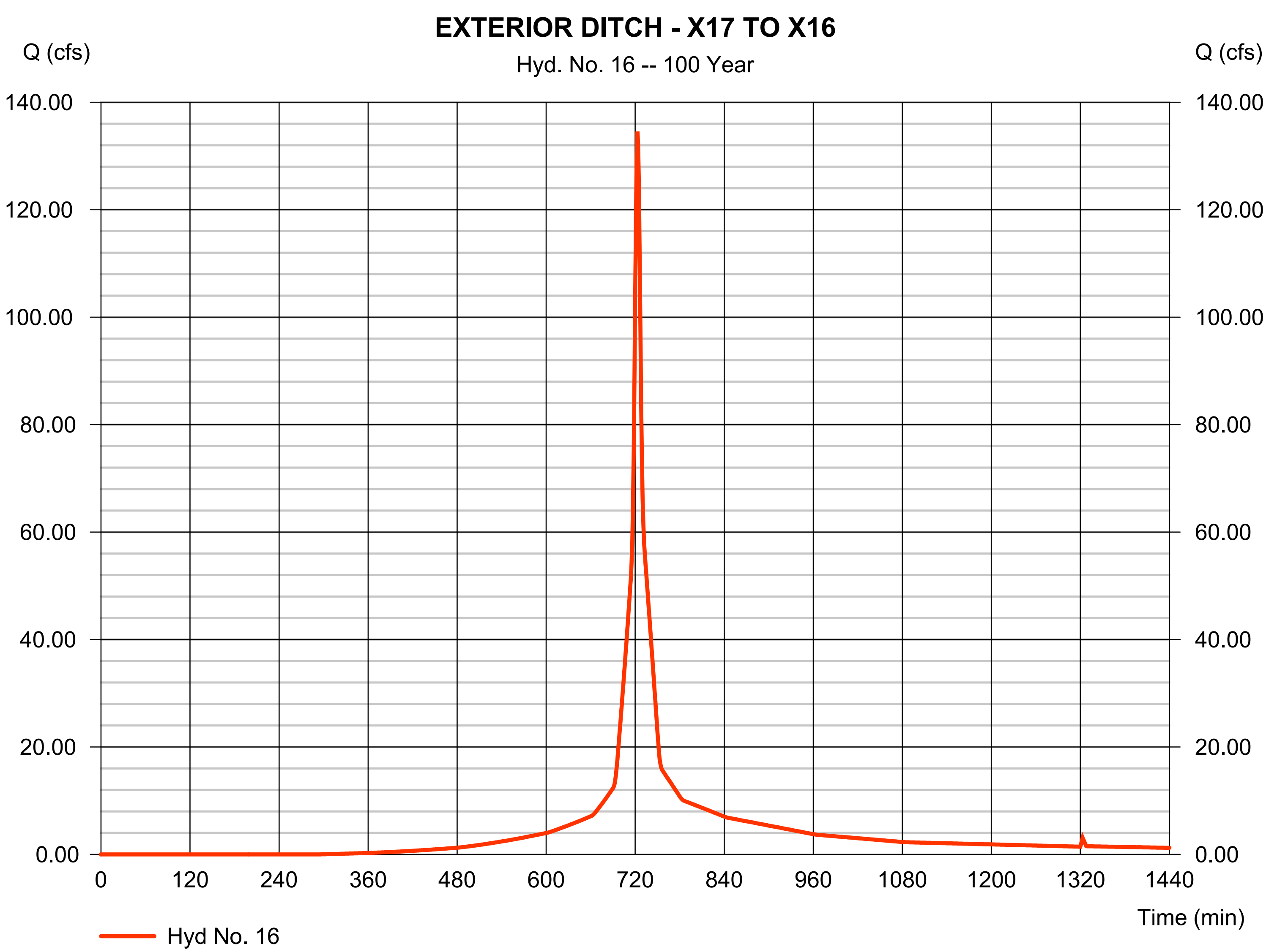
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 16

EXTERIOR DITCH - X17 TO X16

Hydrograph type	= SCS Runoff	Peak discharge	= 134.53 cfs
Storm frequency	= 100 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 398,394 cuft
Drainage area	= 16.240 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



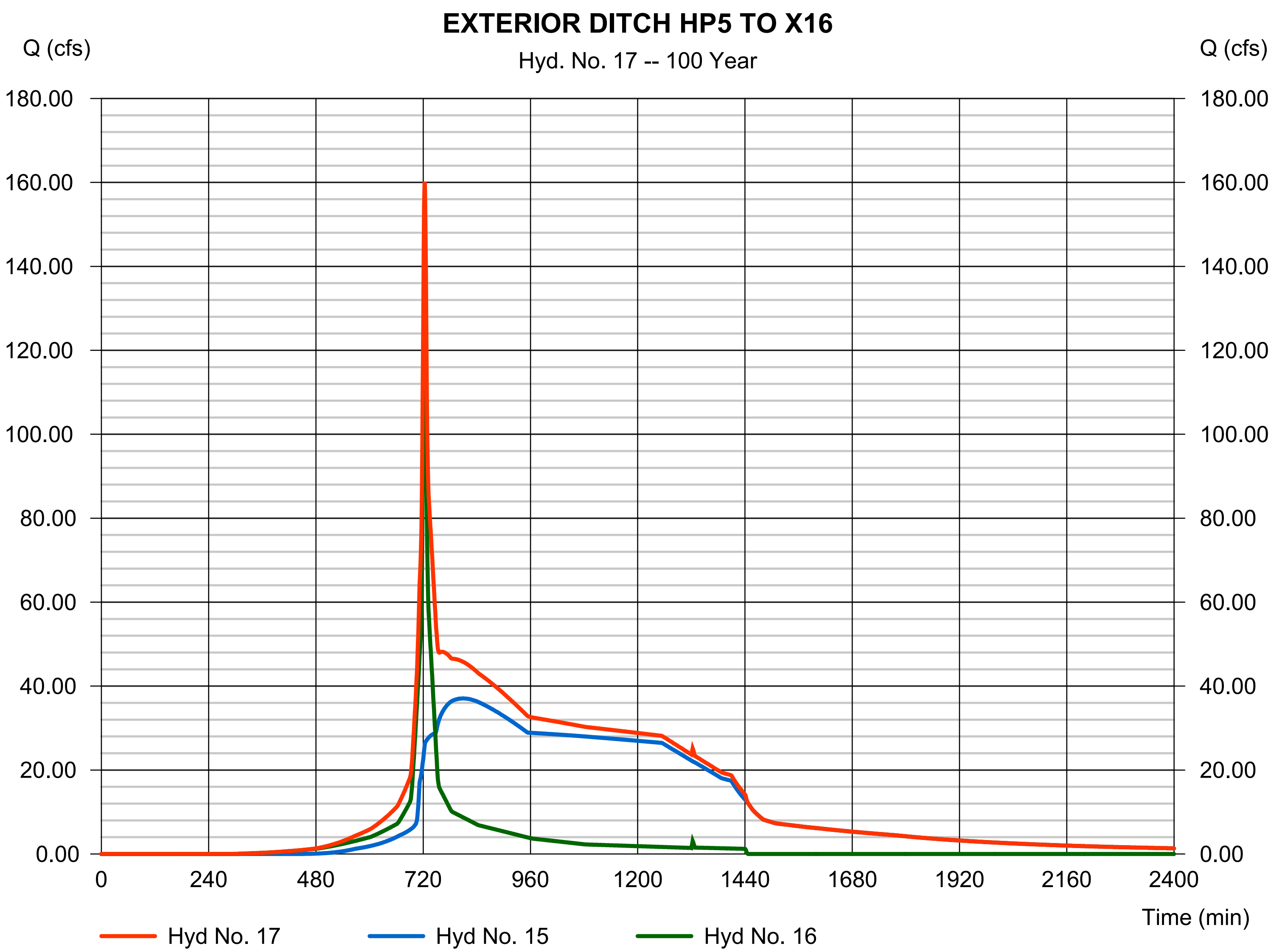
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 17

EXTERIOR DITCH HP5 TO X16

Hydrograph type	= Combine	Peak discharge	= 160.17 cfs
Storm frequency	= 100 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 1,888,960 cuft
Inflow hyds.	= 15, 16	Contrib. drain. area	= 16.240 ac



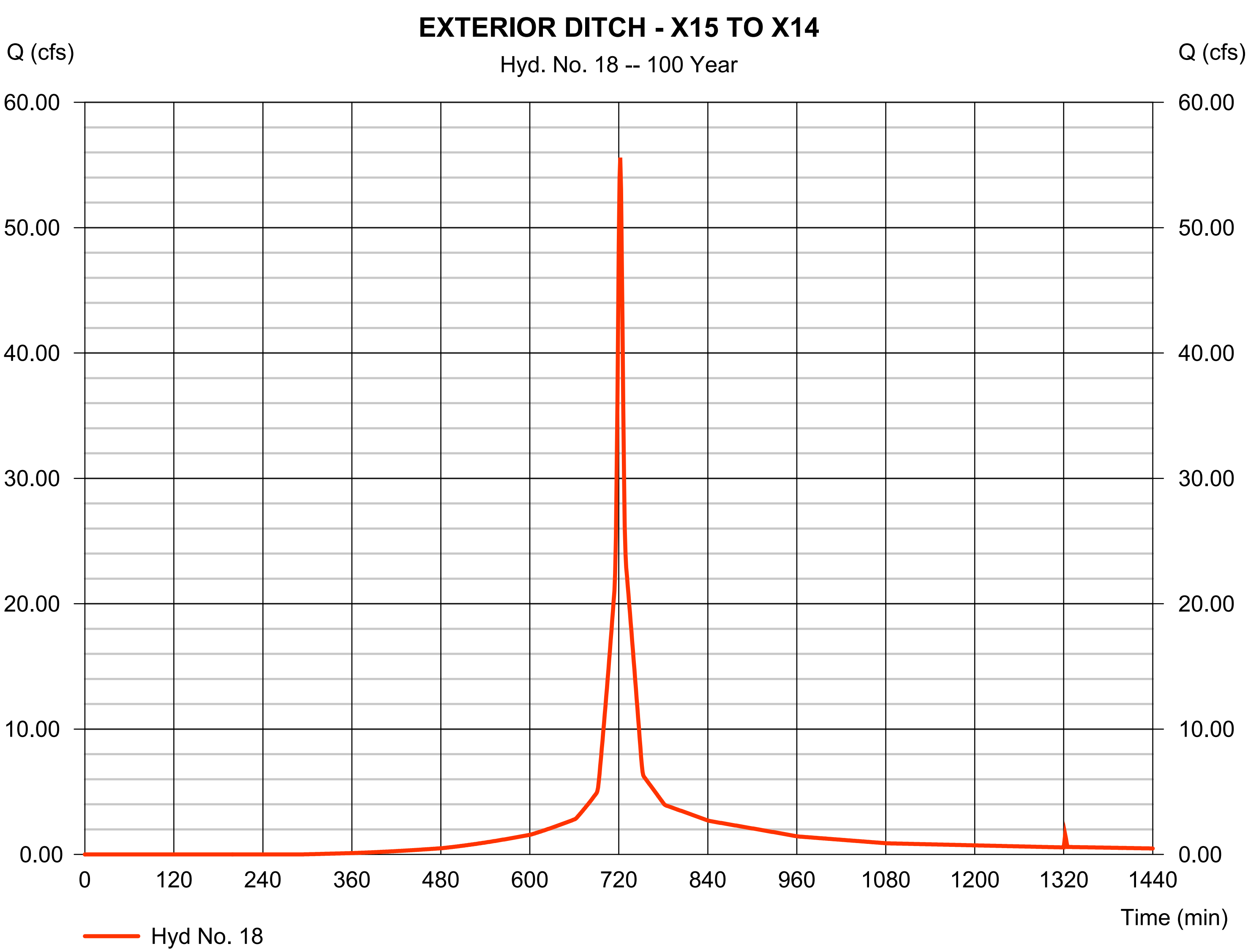
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 18

EXTERIOR DITCH - X15 TO X14

Hydrograph type	= SCS Runoff	Peak discharge	= 55.58 cfs
Storm frequency	= 100 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 155,009 cuft
Drainage area	= 6.740 ac	Curve number	= 80
Basin Slope	= 25.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 2.00 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



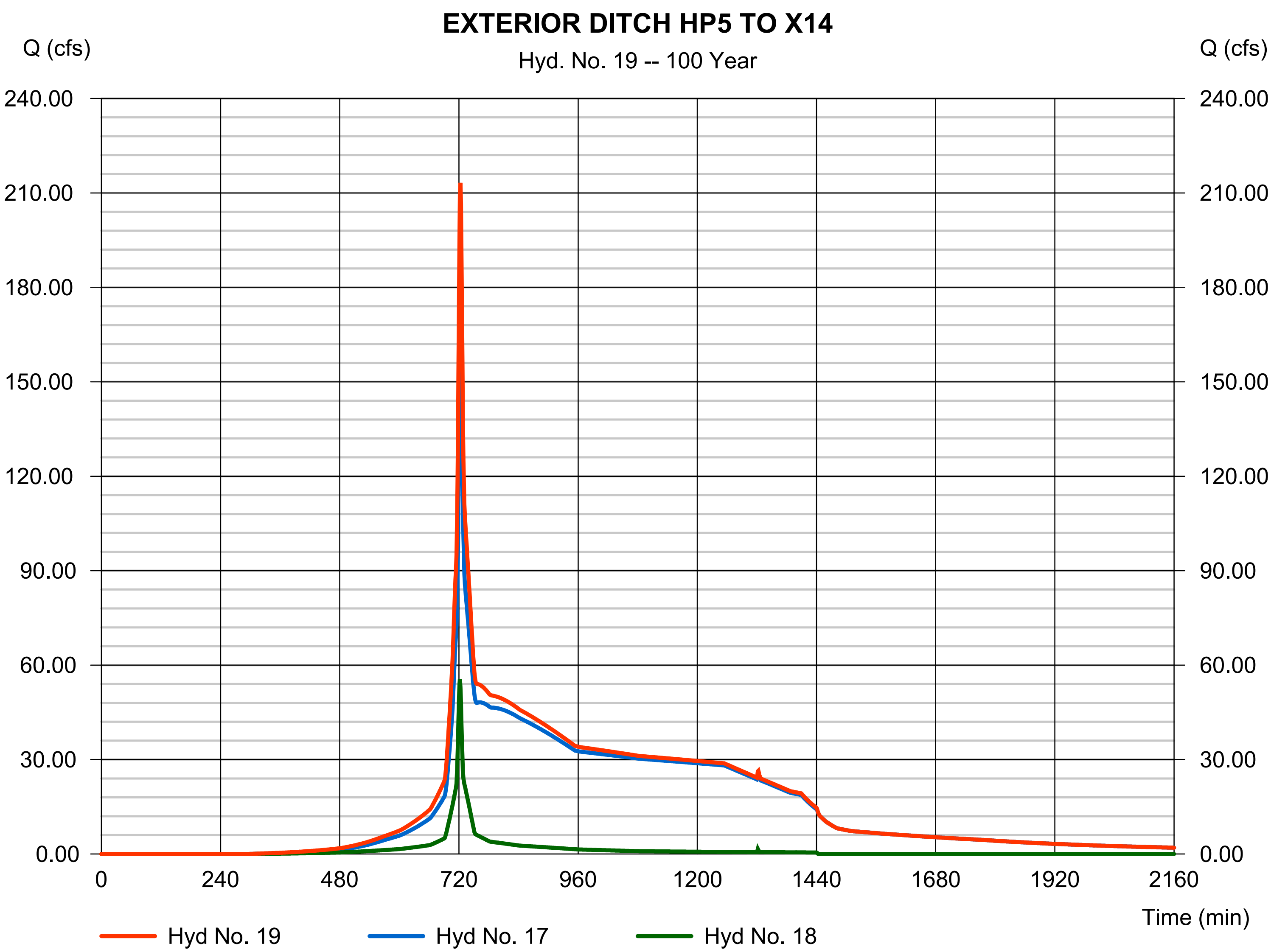
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 19

EXTERIOR DITCH HP5 TO X14

Hydrograph type	= Combine	Peak discharge	= 213.22 cfs
Storm frequency	= 100 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 2,043,970 cuft
Inflow hyds.	= 17, 18	Contrib. drain. area	= 6.740 ac



Hydrograph Report

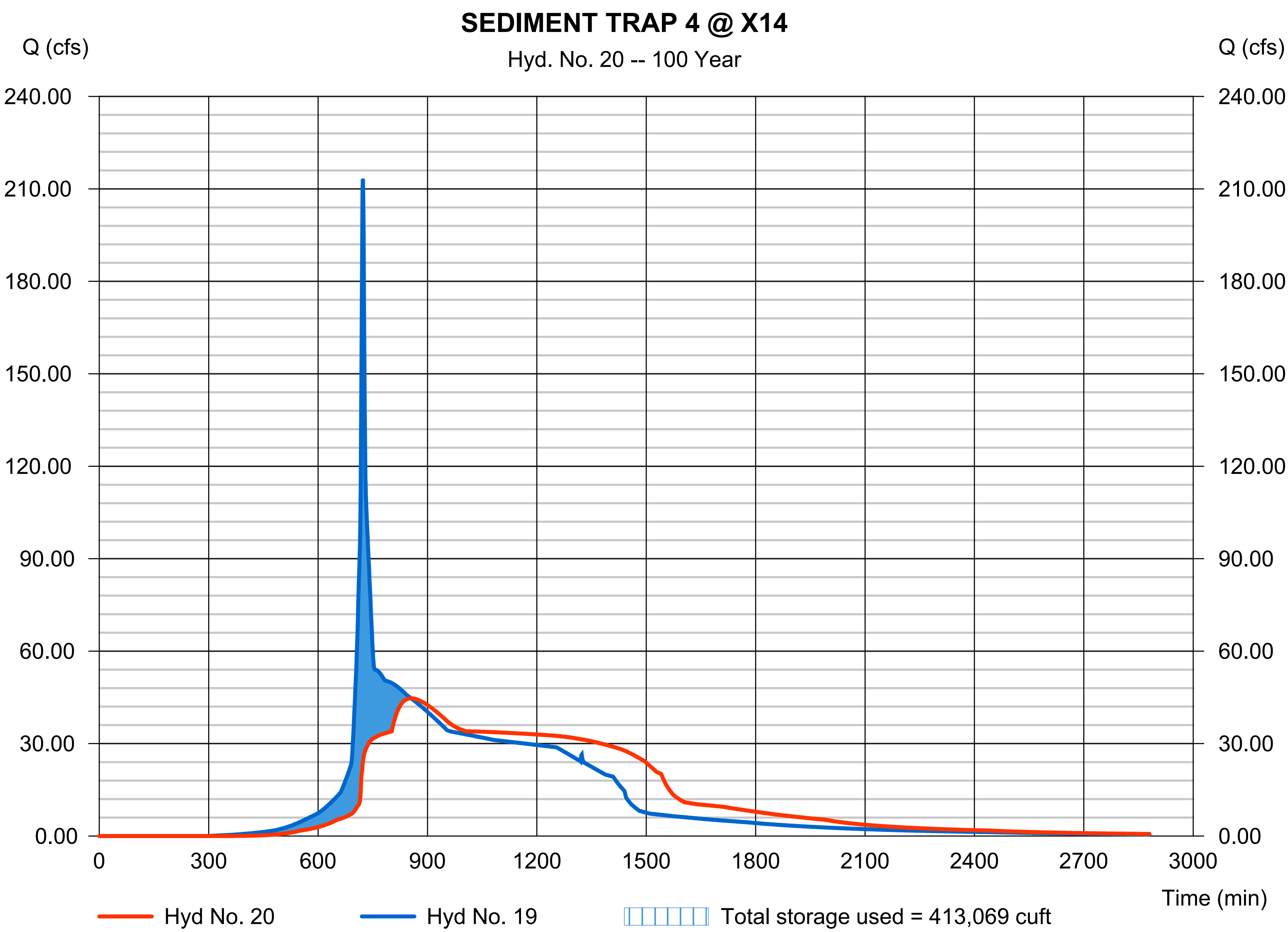
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 20

SEDIMENT TRAP 4 @ X14

Hydrograph type	= Reservoir	Peak discharge	= 44.67 cfs
Storm frequency	= 100 yrs	Time to peak	= 855 min
Time interval	= 1 min	Hyd. volume	= 2,035,627 cuft
Inflow hyd. No.	= 19 - EXTERIOR DITCH HP5 TO X14	Max. Elevation	= 248.58 ft
Reservoir name	= SEDIMENT TRAP 4 @ X14	Max. Storage	= 413,069 cuft

Storage Indication method used. Wet pond routing start elevation = 238.00 ft.



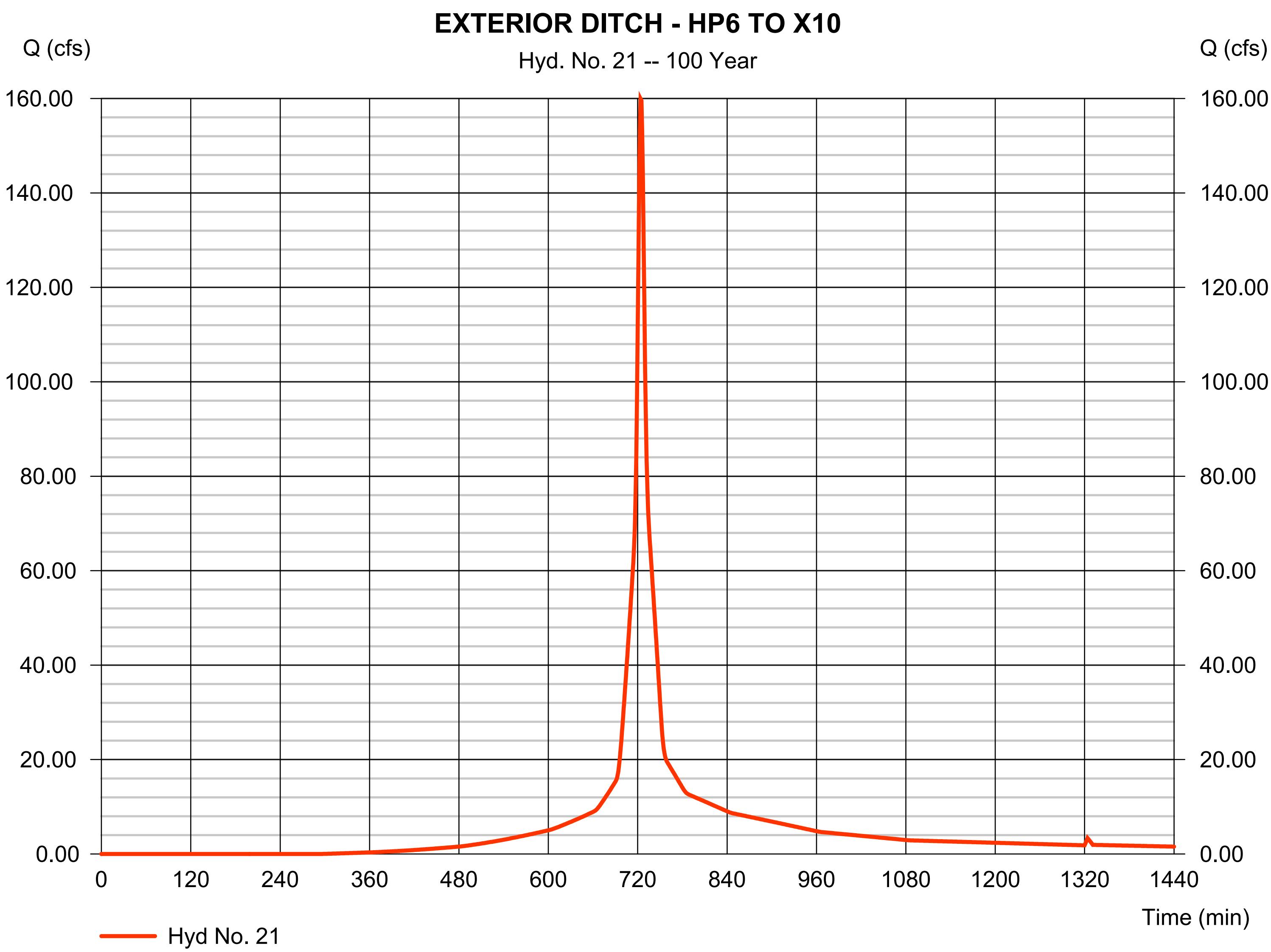
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 21

EXTERIOR DITCH - HP6 TO X10

Hydrograph type	= SCS Runoff	Peak discharge	= 159.89 cfs
Storm frequency	= 100 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 505,966 cuft
Drainage area	= 20.000 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

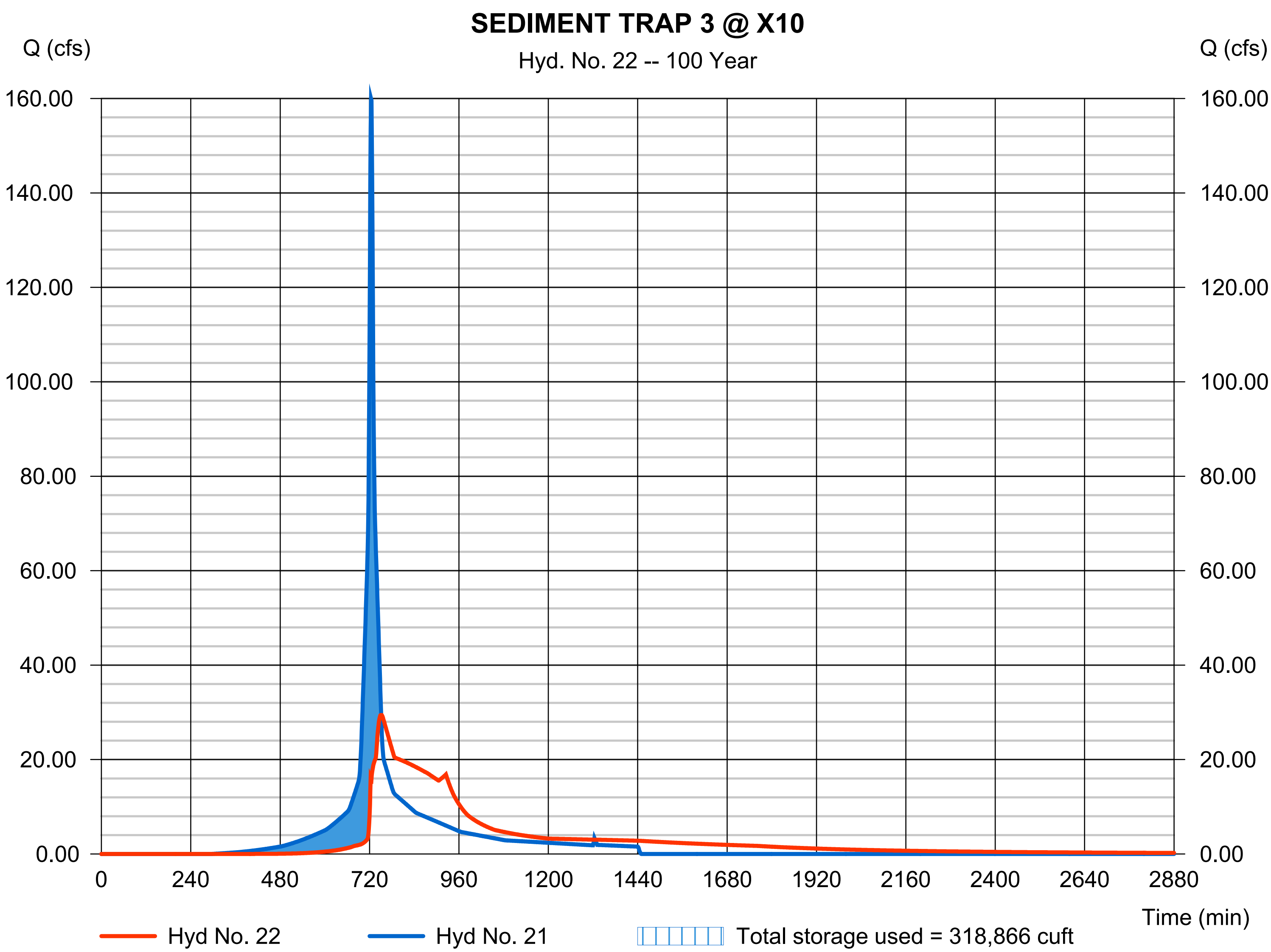
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 | Friday, 01 / 30 / 2015

Hyd. No. 22

SEDIMENT TRAP 3 @ X10

Hydrograph type	= Reservoir	Peak discharge	= 29.41 cfs
Storm frequency	= 100 yrs	Time to peak	= 751 min
Time interval	= 1 min	Hyd. volume	= 489,037 cuft
Inflow hyd. No.	= 21 - EXTERIOR DITCH - HP6 TO X10	Max. Elevation	= 253.00 ft
Reservoir name	= SEDIMENT TRAP 3 @ X10	Max. Storage	= 318,866 cuft

Storage Indication method used. Wet pond routing start elevation = 248.00 ft.



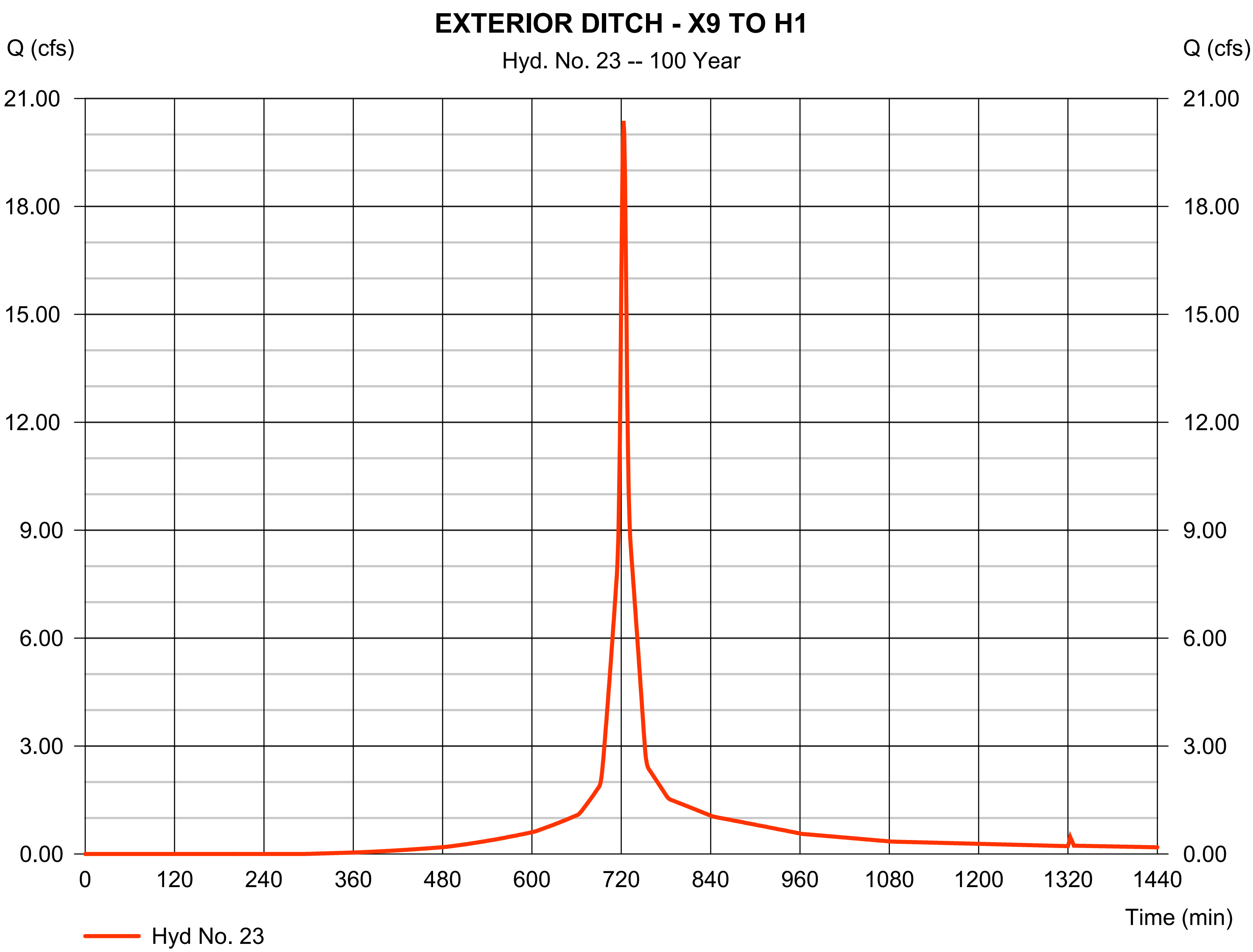
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 23

EXTERIOR DITCH - X9 TO H1

Hydrograph type	= SCS Runoff	Peak discharge	= 20.38 cfs
Storm frequency	= 100 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 60,348 cuft
Drainage area	= 2.460 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.50 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



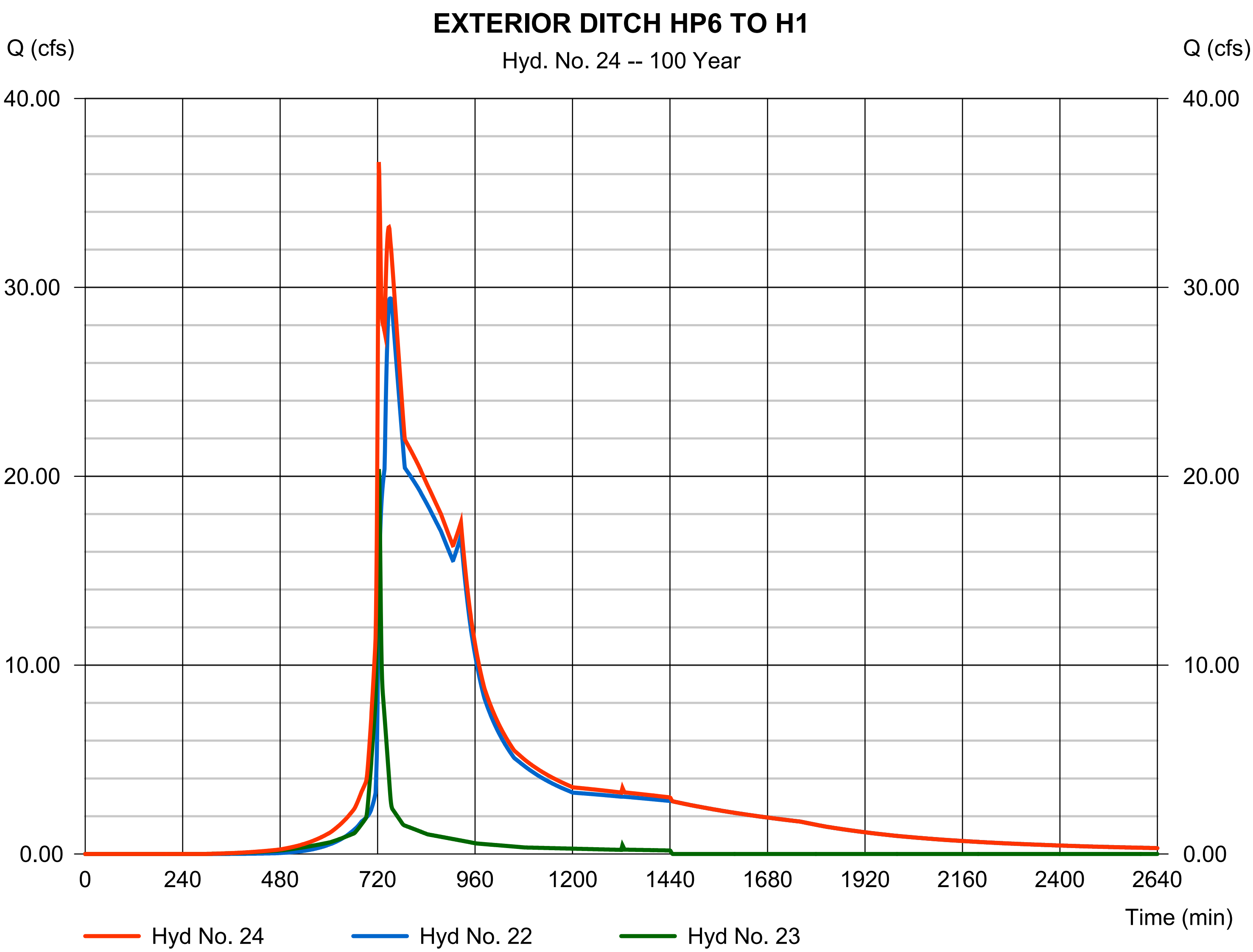
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 24

EXTERIOR DITCH HP6 TO H1

Hydrograph type	= Combine	Peak discharge	= 36.63 cfs
Storm frequency	= 100 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 549,385 cuft
Inflow hyds.	= 22, 23	Contrib. drain. area	= 2.460 ac



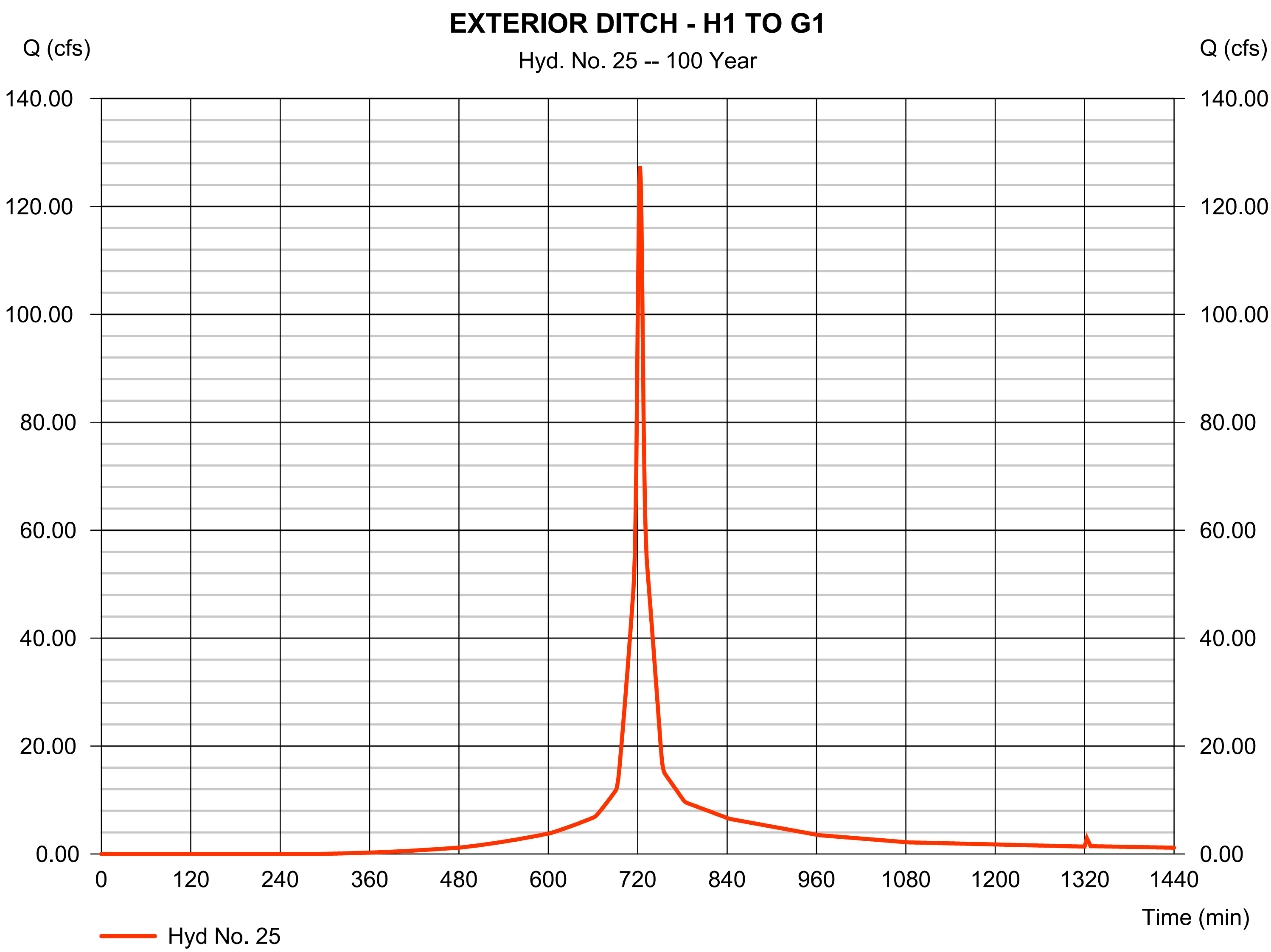
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 25

EXTERIOR DITCH - H1 TO G1

Hydrograph type	= SCS Runoff	Peak discharge	= 127.49 cfs
Storm frequency	= 100 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 377,542 cuft
Drainage area	= 15.390 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.30 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



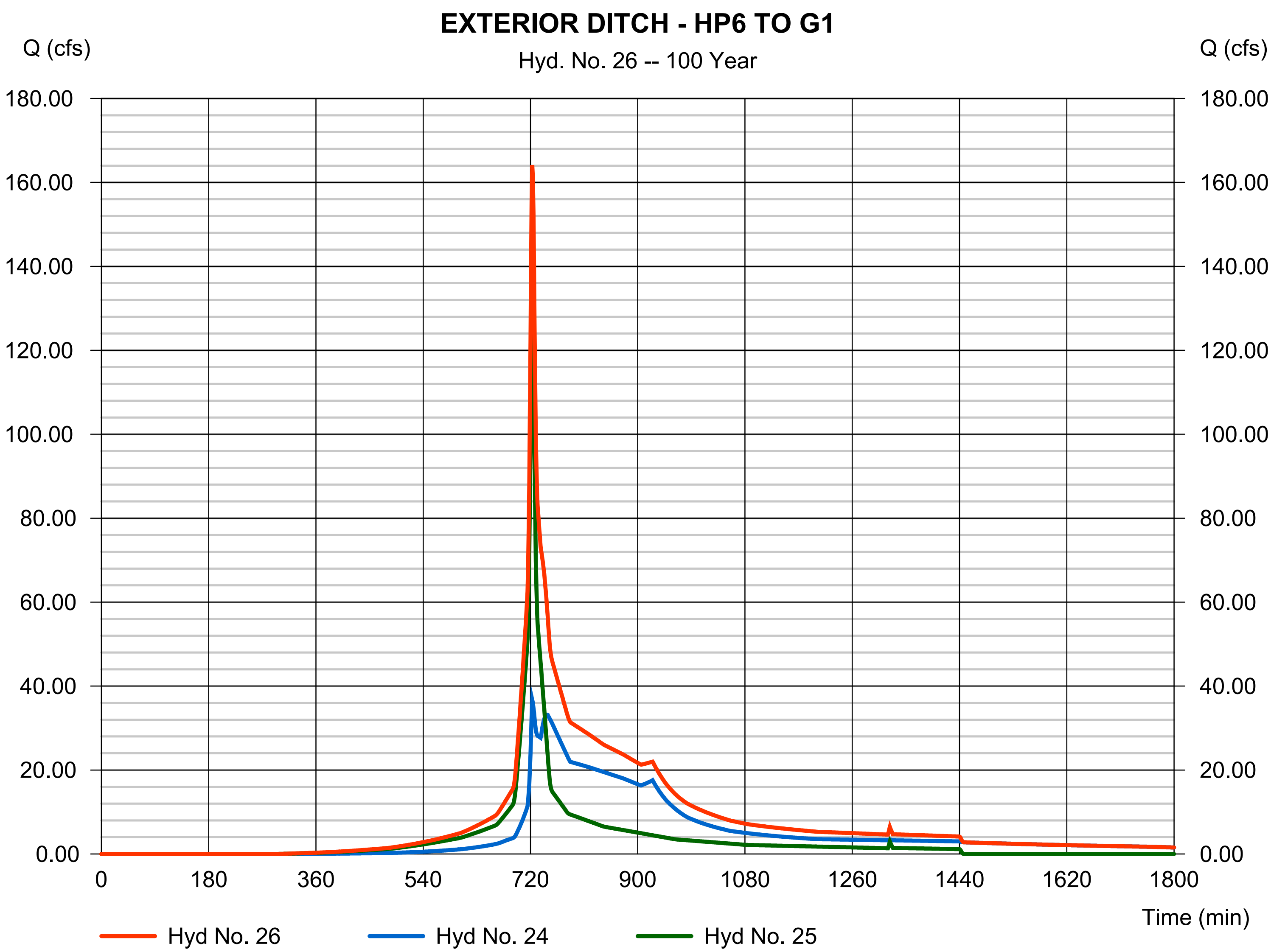
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 26

EXTERIOR DITCH - HP6 TO G1

Hydrograph type	= Combine	Peak discharge	= 164.12 cfs
Storm frequency	= 100 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 926,927 cuft
Inflow hyds.	= 24, 25	Contrib. drain. area	= 15.390 ac



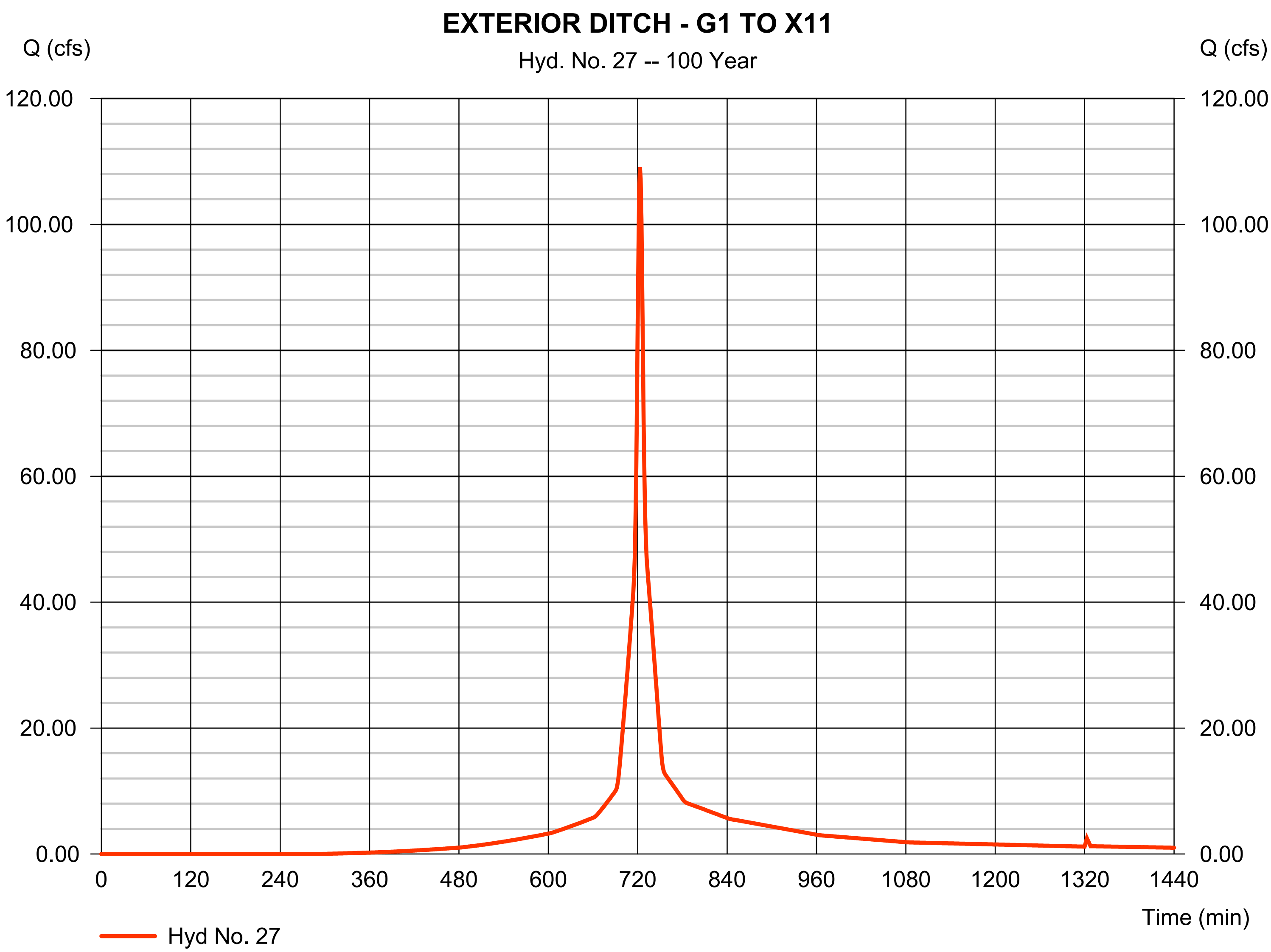
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 27

EXTERIOR DITCH - G1 TO X11

Hydrograph type	= SCS Runoff	Peak discharge	= 109.10 cfs
Storm frequency	= 100 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 323,082 cuft
Drainage area	= 13.170 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 4.00 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



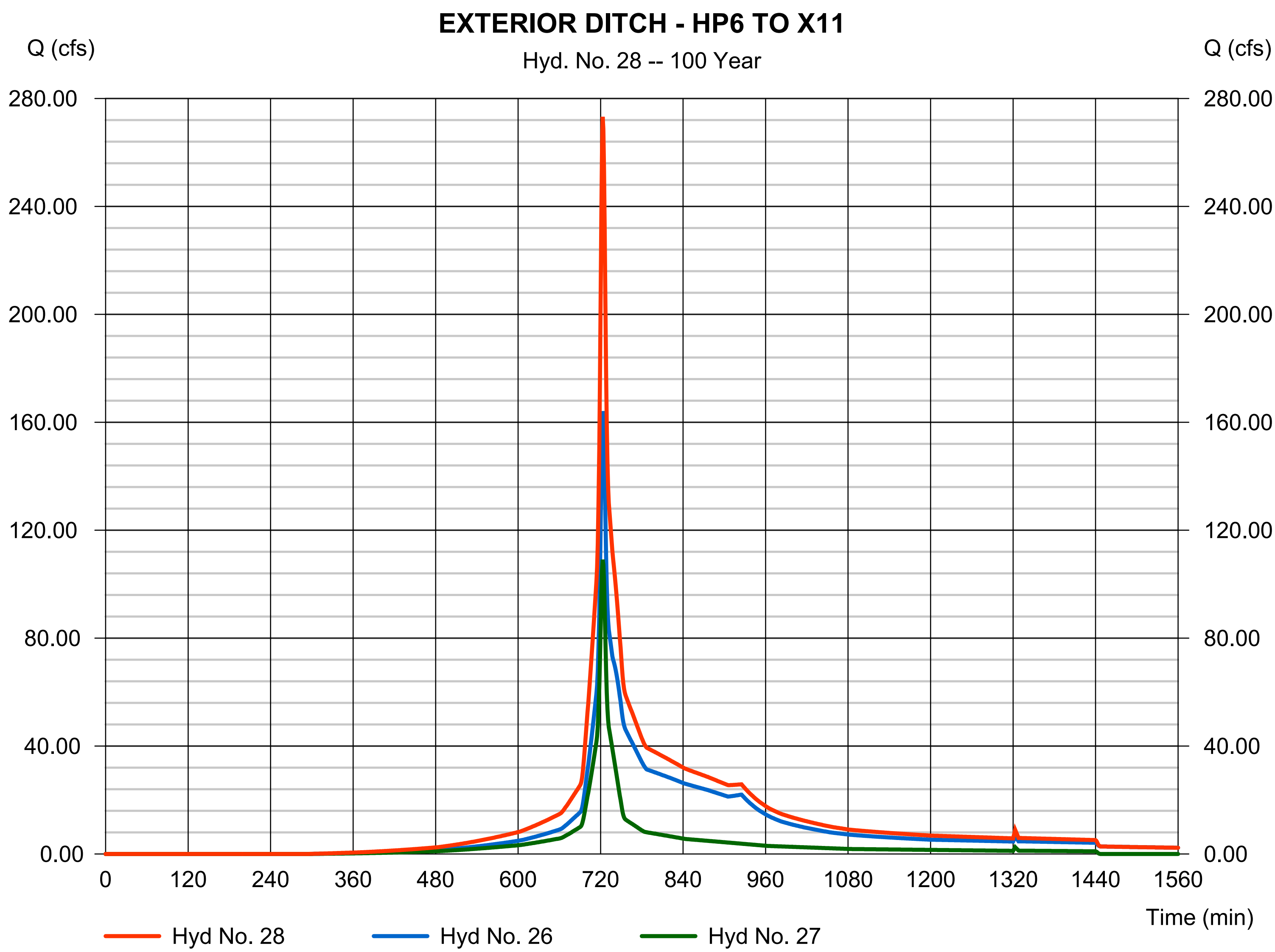
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 28

EXTERIOR DITCH - HP6 TO X11

Hydrograph type	= Combine	Peak discharge	= 273.22 cfs
Storm frequency	= 100 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 1,250,010 cuft
Inflow hyds.	= 26, 27	Contrib. drain. area	= 13.170 ac



Hydrograph Report

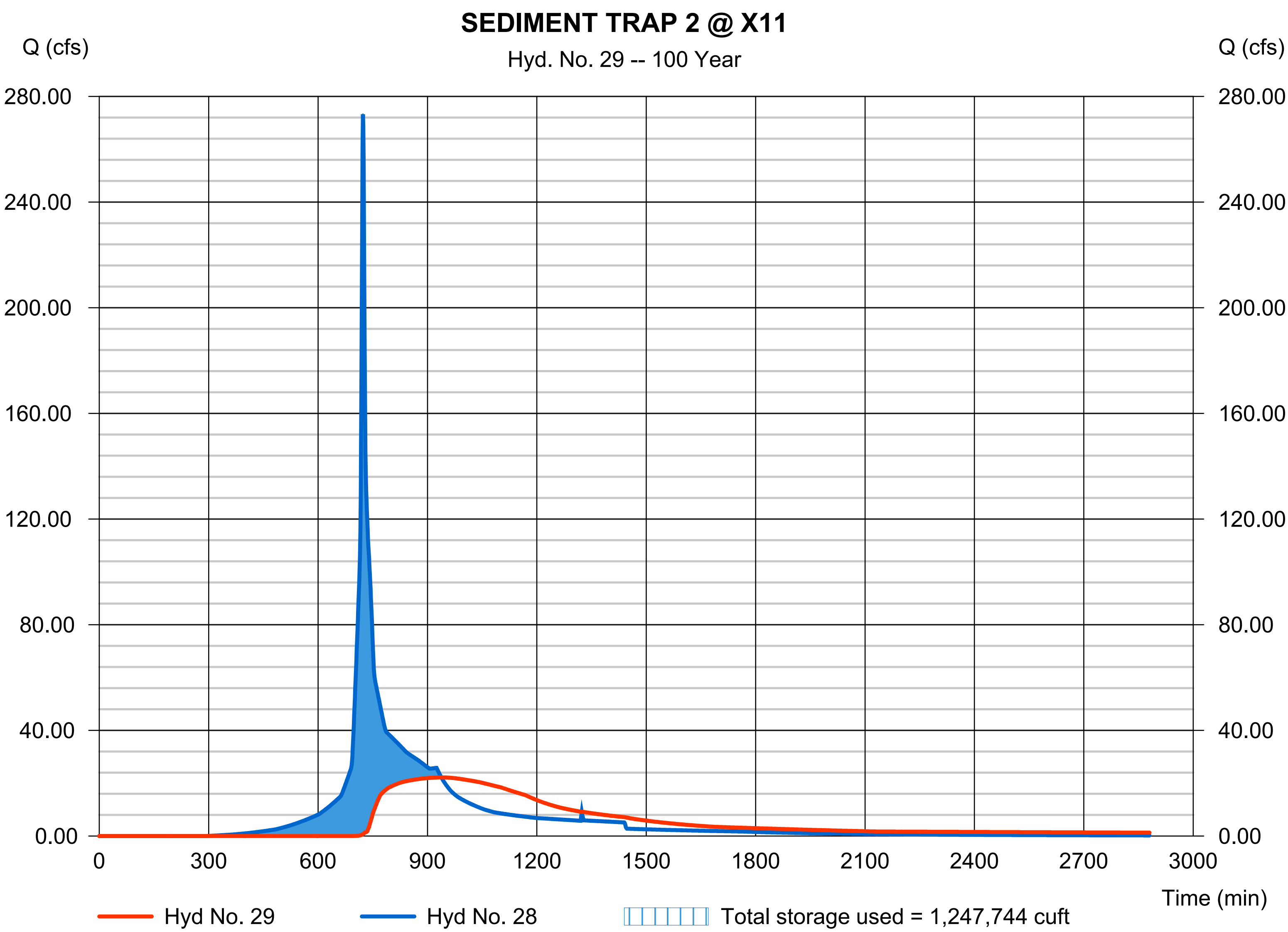
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 29

SEDIMENT TRAP 2 @ X11

Hydrograph type	= Reservoir	Peak discharge	= 22.21 cfs
Storm frequency	= 100 yrs	Time to peak	= 938 min
Time interval	= 1 min	Hyd. volume	= 873,487 cuft
Inflow hyd. No.	= 28 - EXTERIOR DITCH - HP6 TO X11	Max. Elevation	= 247.44 ft
Reservoir name	= SEDIMENT TRAP 2 @ X11	Max. Storage	= 1,247,744 cuft

Storage Indication method used. Wet pond routing start elevation = 243.00 ft.



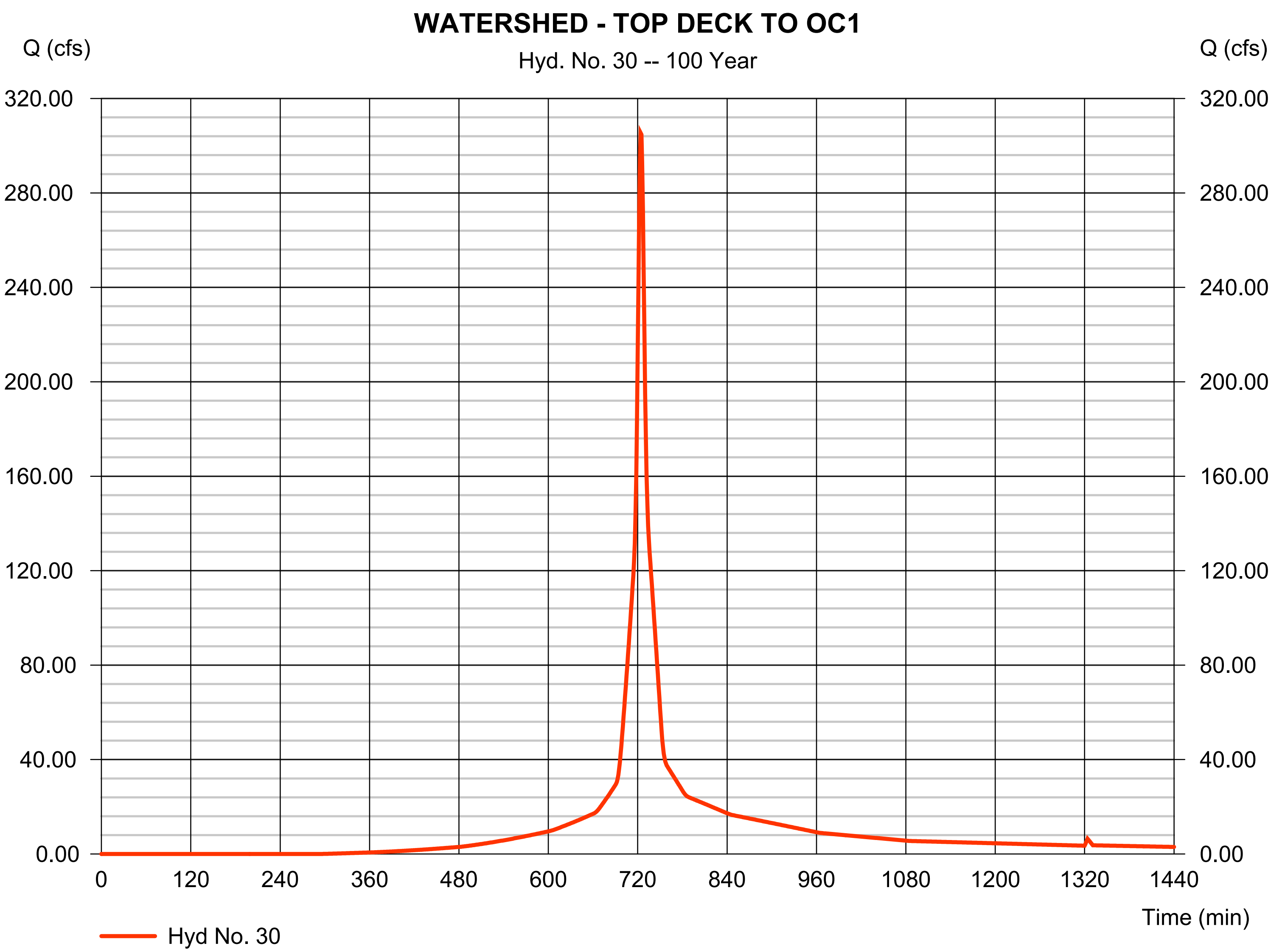
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Friday, 01 / 30 / 2015

Hyd. No. 30

WATERSHED - TOP DECK TO OC1

Hydrograph type	= SCS Runoff	Peak discharge	= 305.38 cfs
Storm frequency	= 100 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 966,395 cuft
Drainage area	= 38.200 ac	Curve number	= 80
Basin Slope	= 10.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 9.20 in	Distribution	= Type III
Storm duration	= 24 hrs	Shape factor	= 484



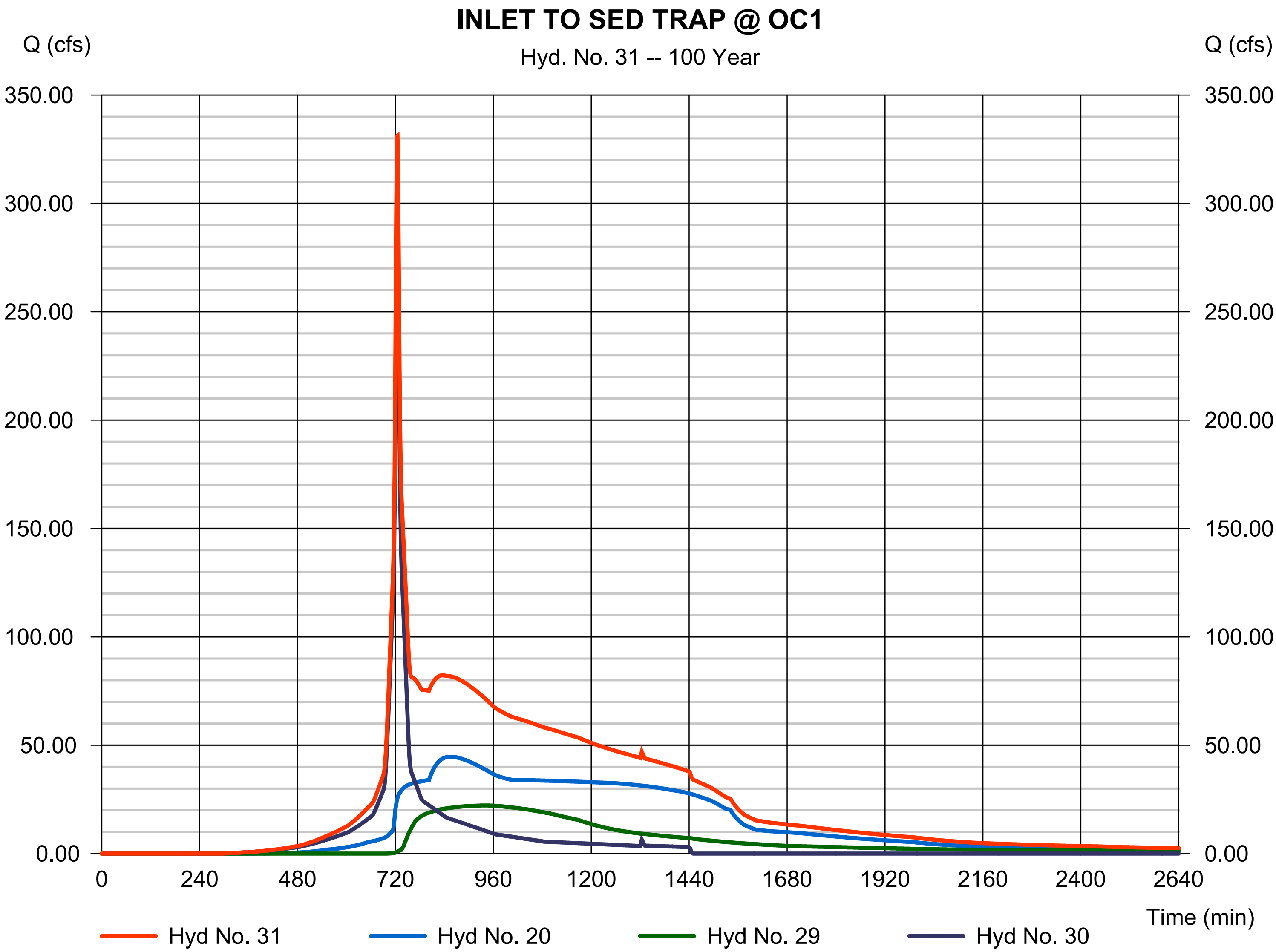
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 31

INLET TO SED TRAP @ OC1

Hydrograph type	= Combine	Peak discharge	= 331.29 cfs
Storm frequency	= 100 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 3,875,507 cuft
Inflow hyds.	= 20, 29, 30	Contrib. drain. area	= 38.200 ac



Hydrograph Report

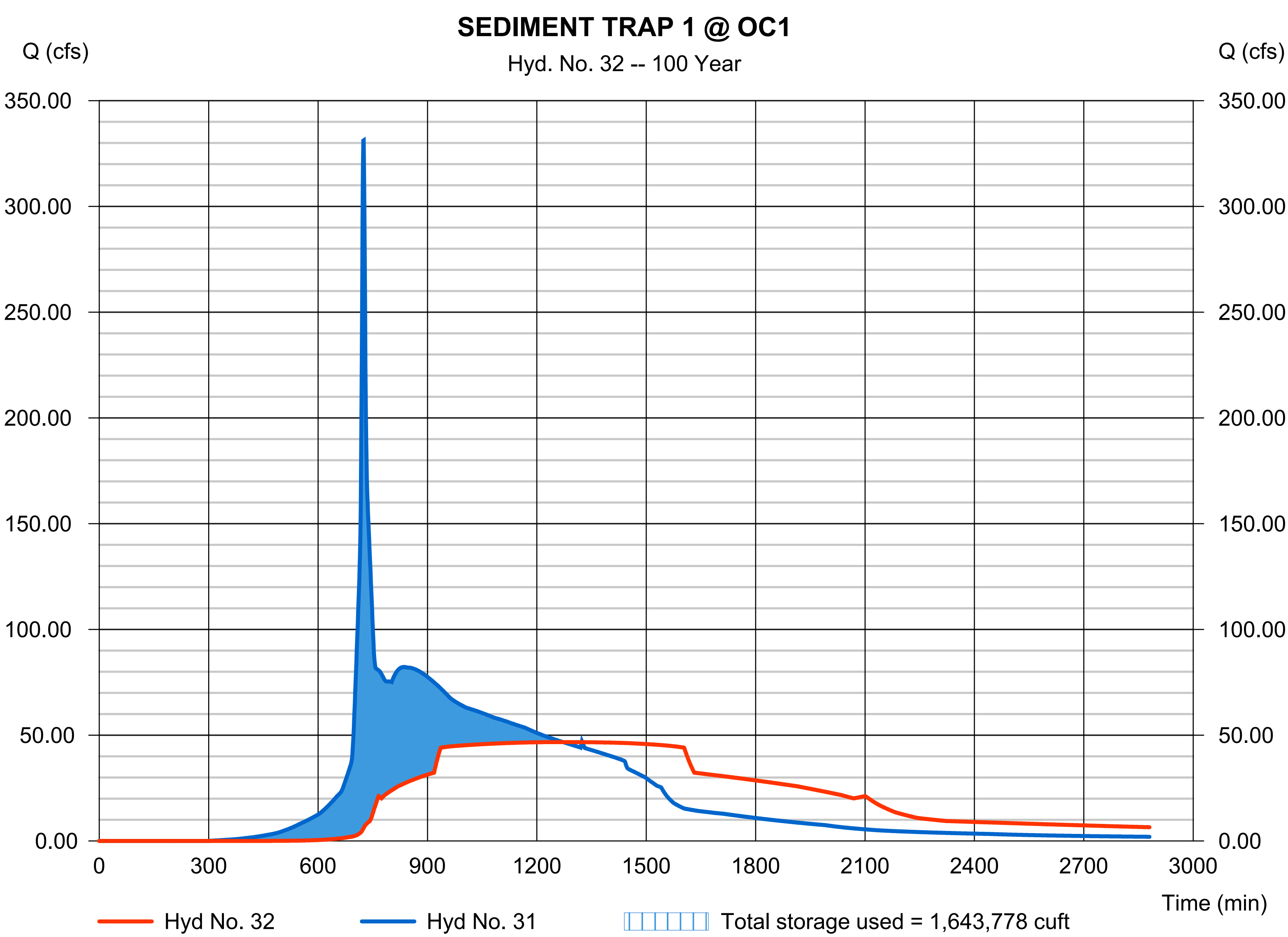
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 01 / 30 / 2015

Hyd. No. 32

SEDIMENT TRAP 1 @ OC1

Hydrograph type	= Reservoir	Peak discharge	= 46.75 cfs
Storm frequency	= 100 yrs	Time to peak	= 1271 min
Time interval	= 1 min	Hyd. volume	= 3,428,631 cuft
Inflow hyd. No.	= 31 - INLET TO SED TRAP @ OC1	Max. Elevation	= 238.77 ft
Reservoir name	= SEDIMENT TRAP 1 @ OC1	Max. Storage	= 1,643,778 cuft

Storage Indication method used. Wet pond routing start elevation = 228.00 ft.



Hydraflow Rainfall Report

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	0.0000	0.0000	0.0000	--------
3	0.0000	0.0000	0.0000	--------
5	0.0000	0.0000	0.0000	--------
10	0.0000	0.0000	0.0000	--------
25	0.0000	0.0000	0.0000	--------
50	0.0000	0.0000	0.0000	--------
100	0.0000	0.0000	0.0000	--------

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Tc = time in minutes. Values may exceed 60.

ojects\2014\EJ147461\Working Files\Calculations-Analyses\SCS METHOD\Peachtree City (24 hr GA Green Book).pcp

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.75	4.50	0.00	5.65	6.50	7.50	8.40	9.20
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

EXHIBIT H-6

References

U.S. DEPARTMENT OF COMMERCE
LUTHER H. HODGES, Secretary

WEATHER BUREAU
F. W. REICHELDERFER, Chief

TECHNICAL PAPER NO. 40

RAINFALL FREQUENCY ATLAS OF THE UNITED STATES

for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years

Prepared by
DAVID M. HERSHFIELD
Cooperative Studies Section, Hydrologic Services Division
for
Engineering Division, Soil Conservation Service
U.S. Department of Agriculture

WASHINGTON, D.C.
May 1961
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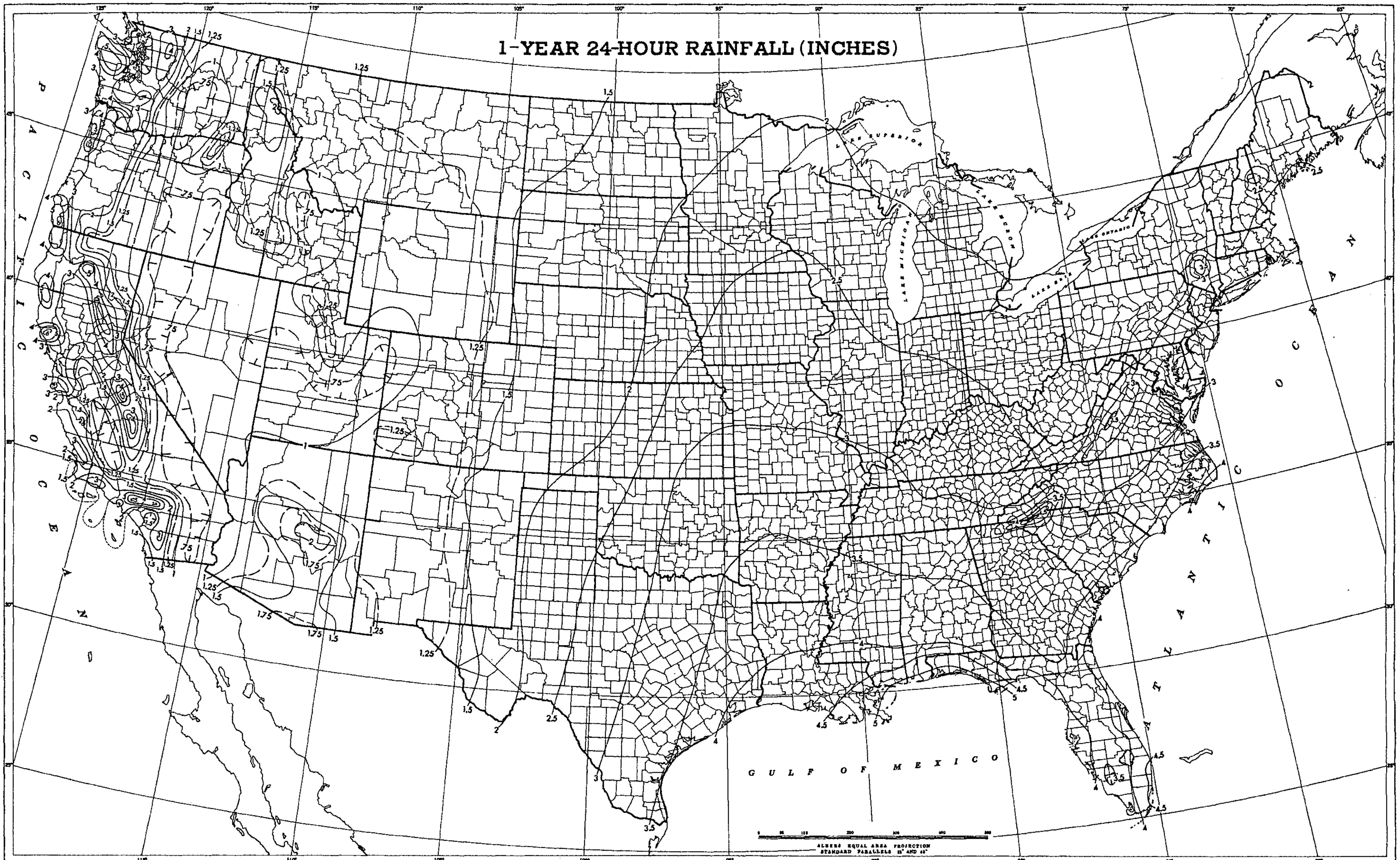
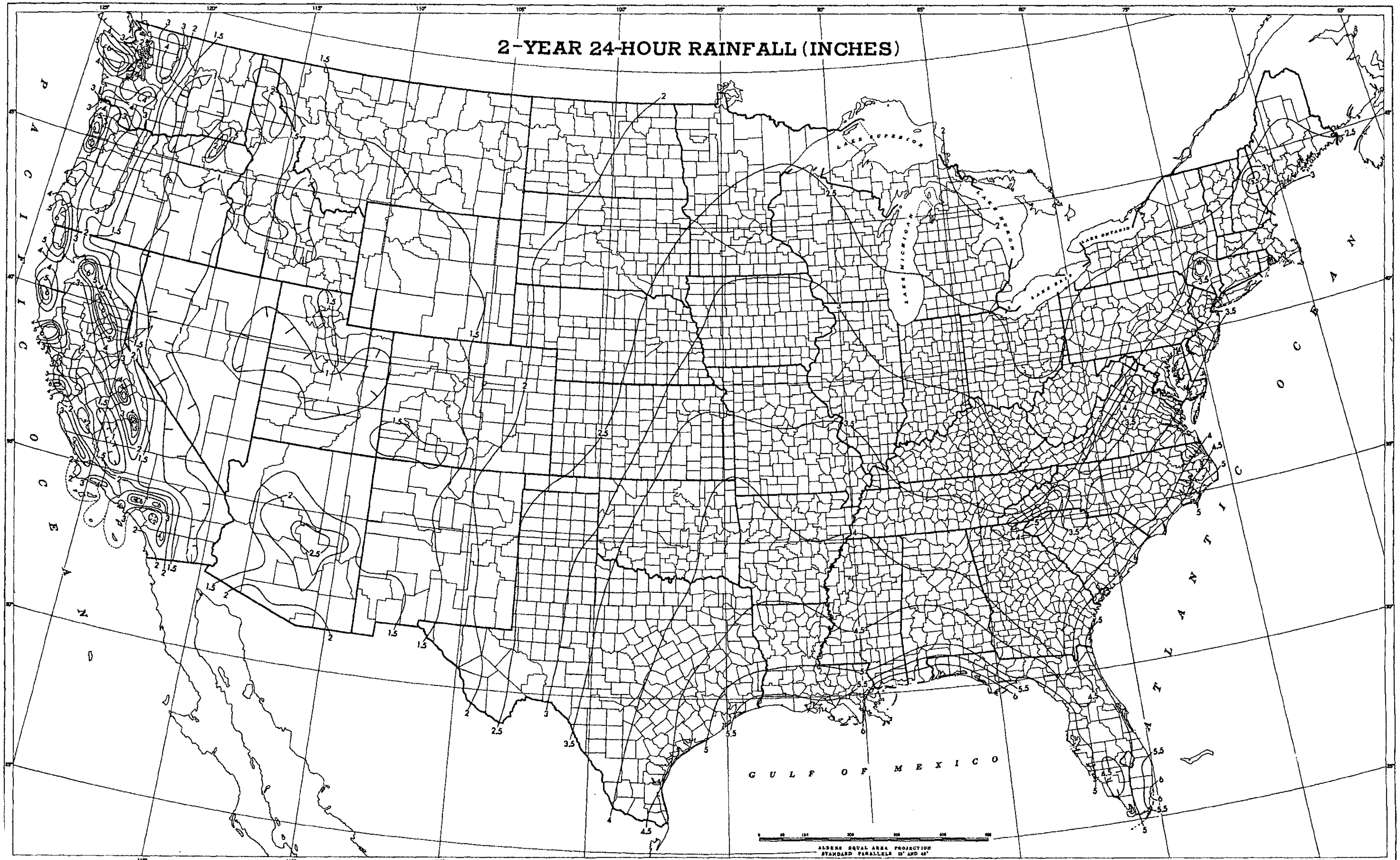
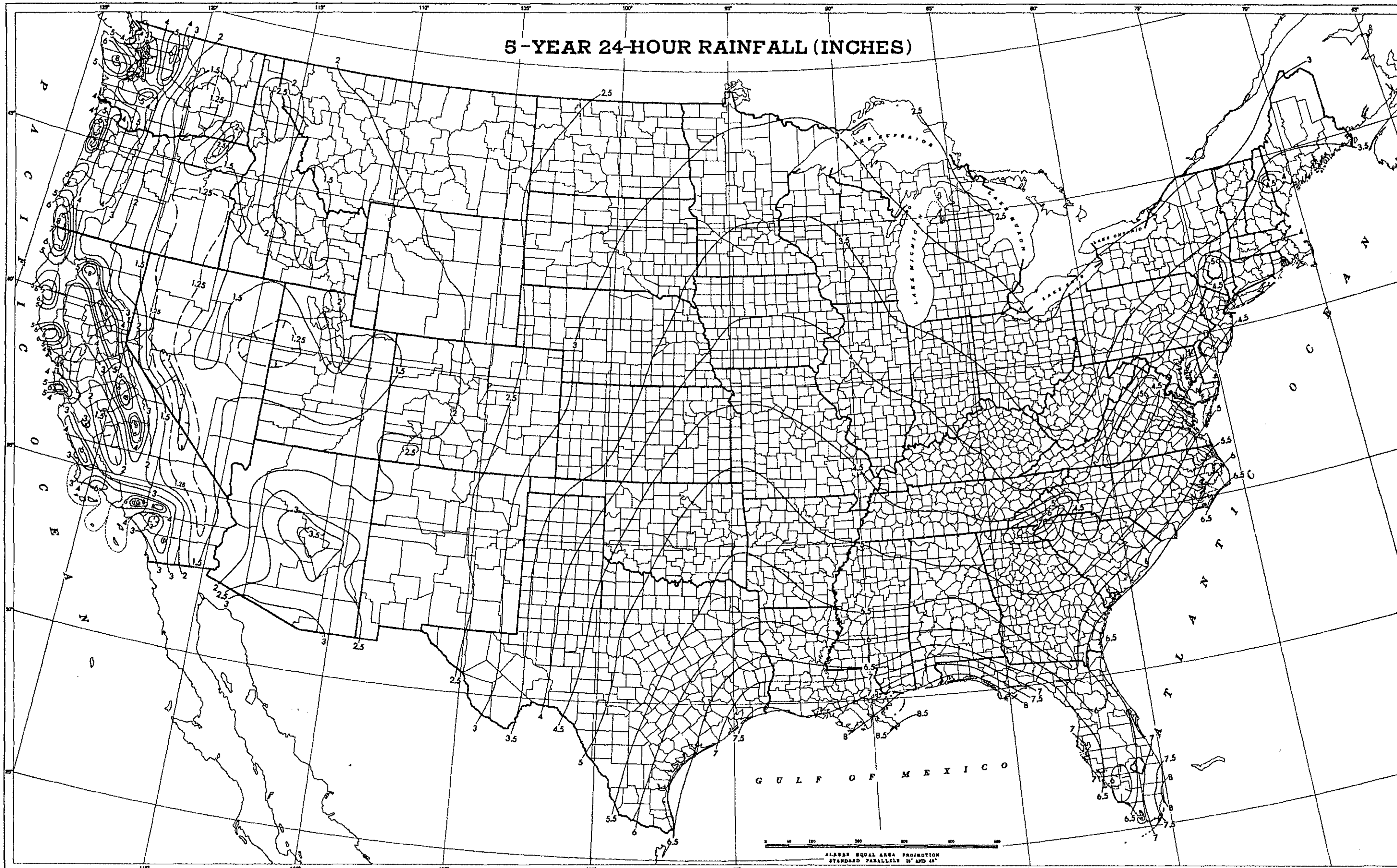
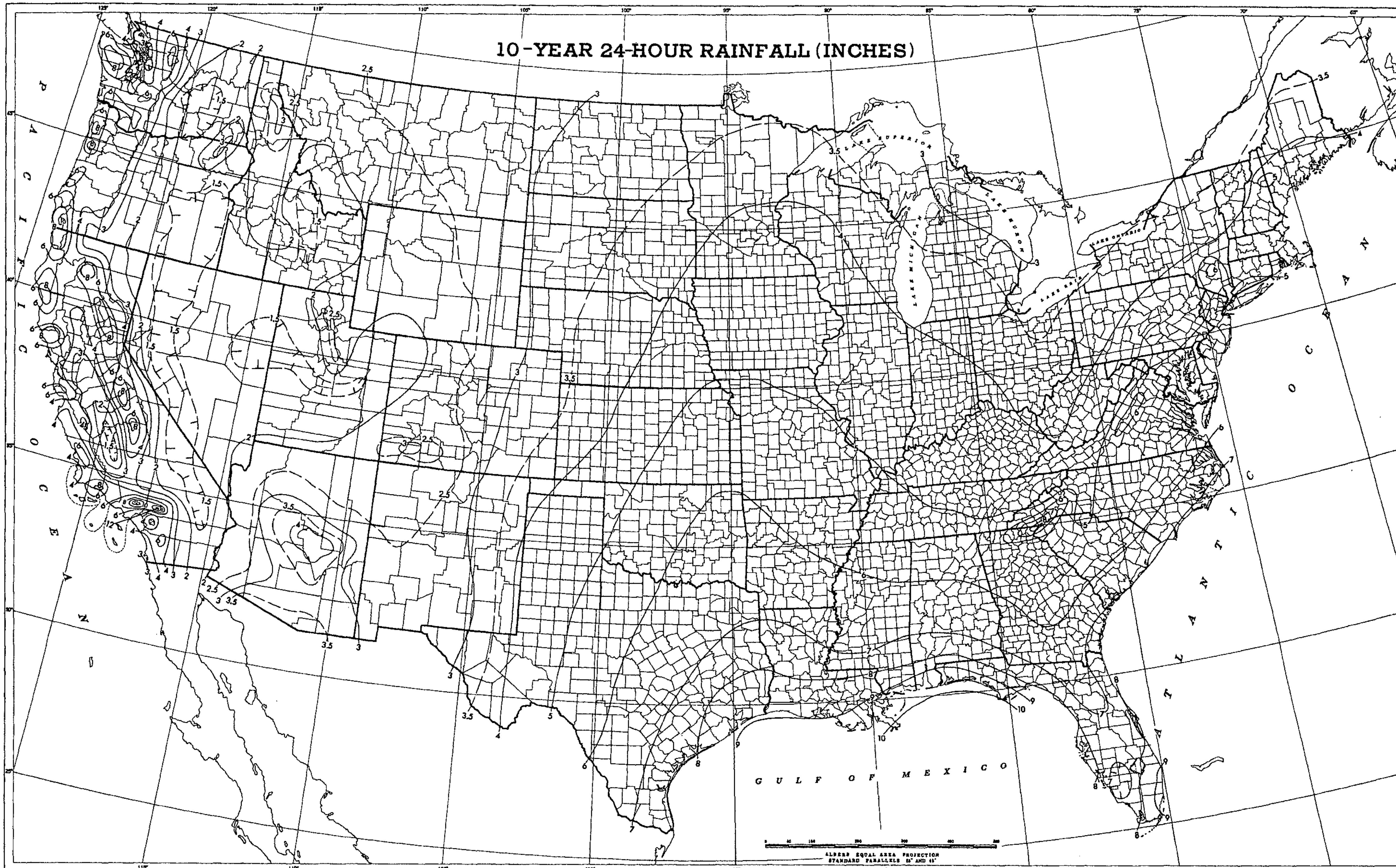
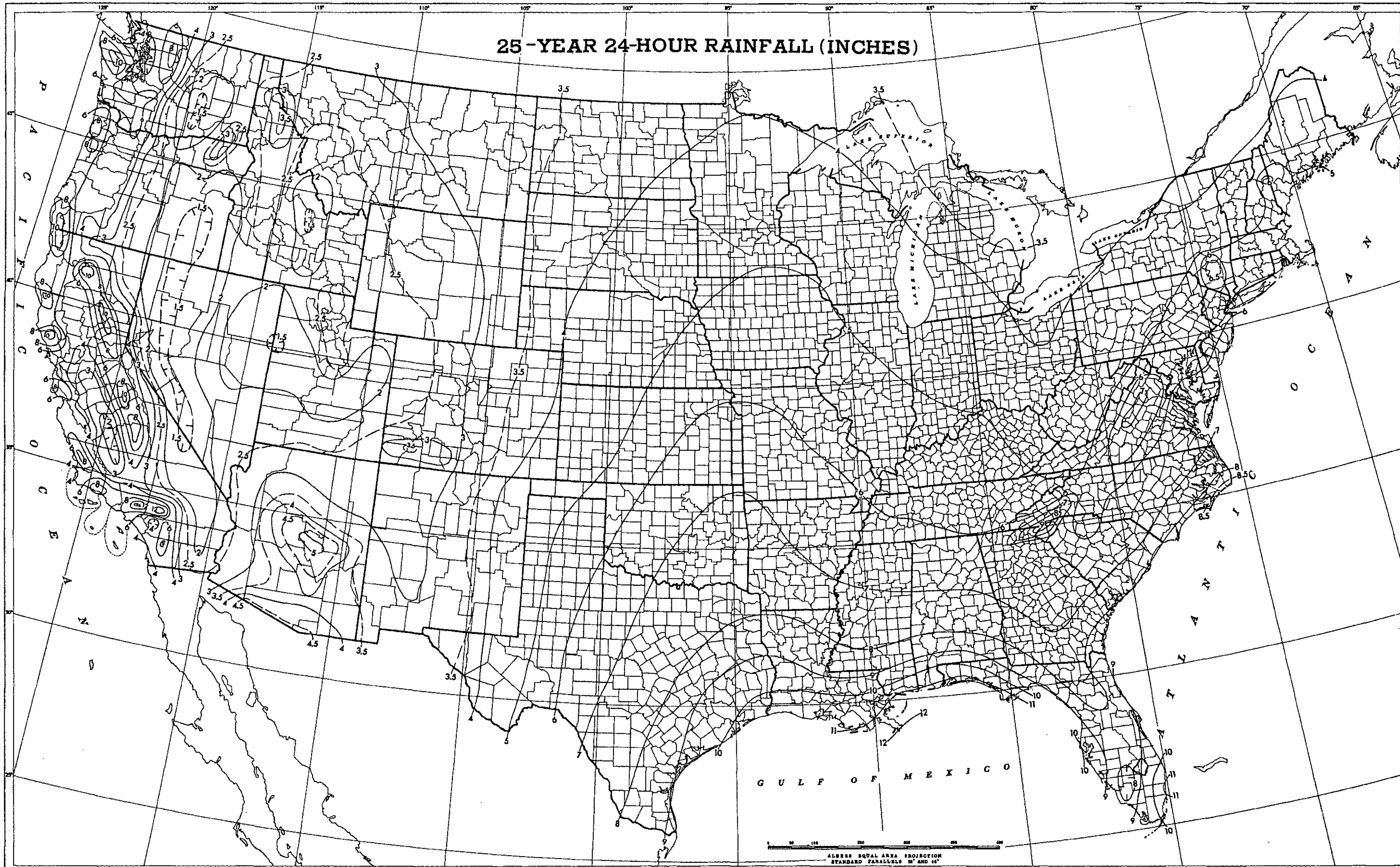

1-YEAR 24-HOUR RAINFALL (INCHES)
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS 29° AND 45°


2-YEAR 24-HOUR RAINFALL (INCHES)
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS 29° AND 45°


5-YEAR 24-HOUR RAINFALL (INCHES)
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS 29° AND 45°


10-YEAR 24-HOUR RAINFALL (INCHES)
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS 29° AND 45°


25-YEAR 24-HOUR RAINFALL (INCHES)
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS 29° AND 45°

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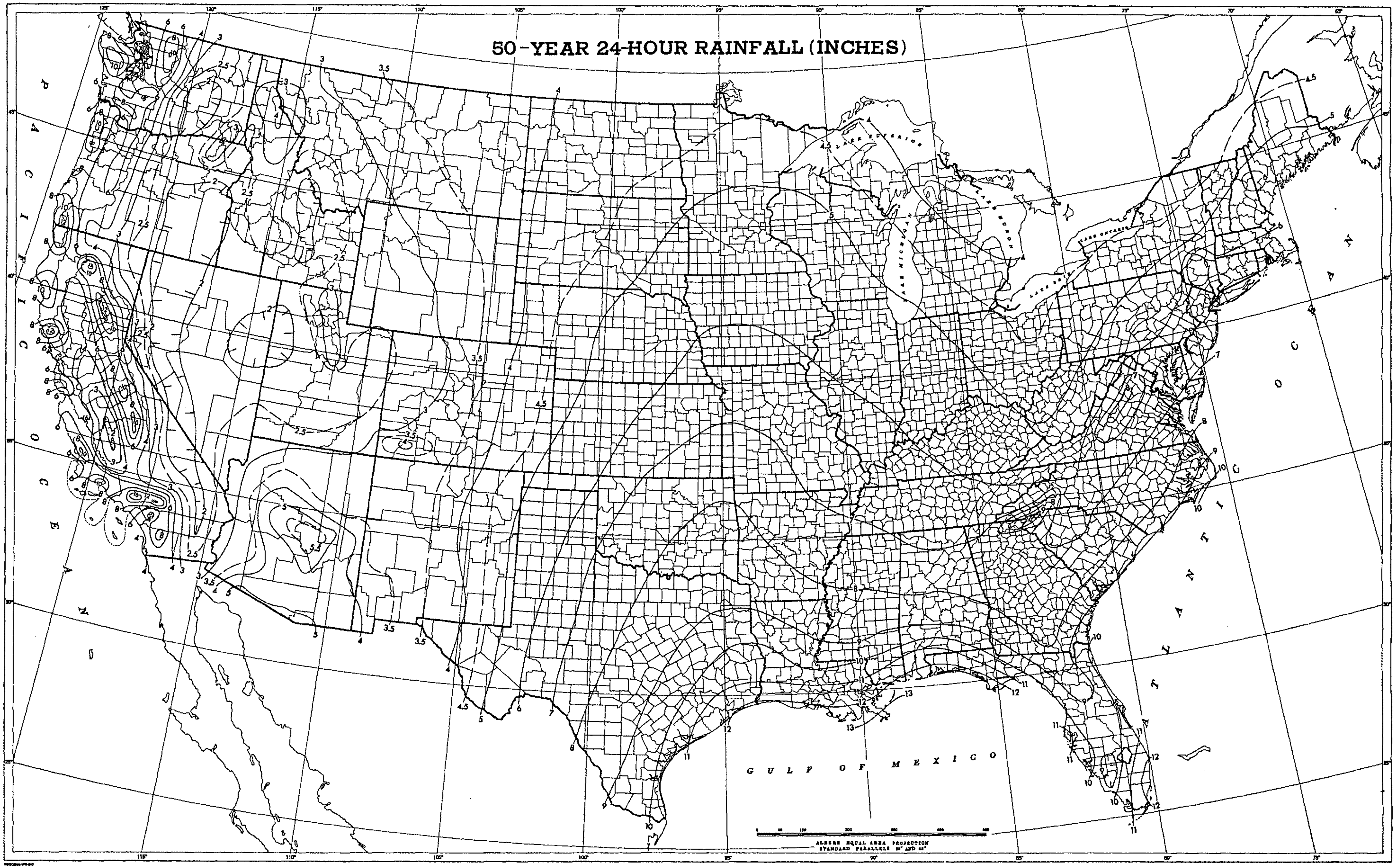
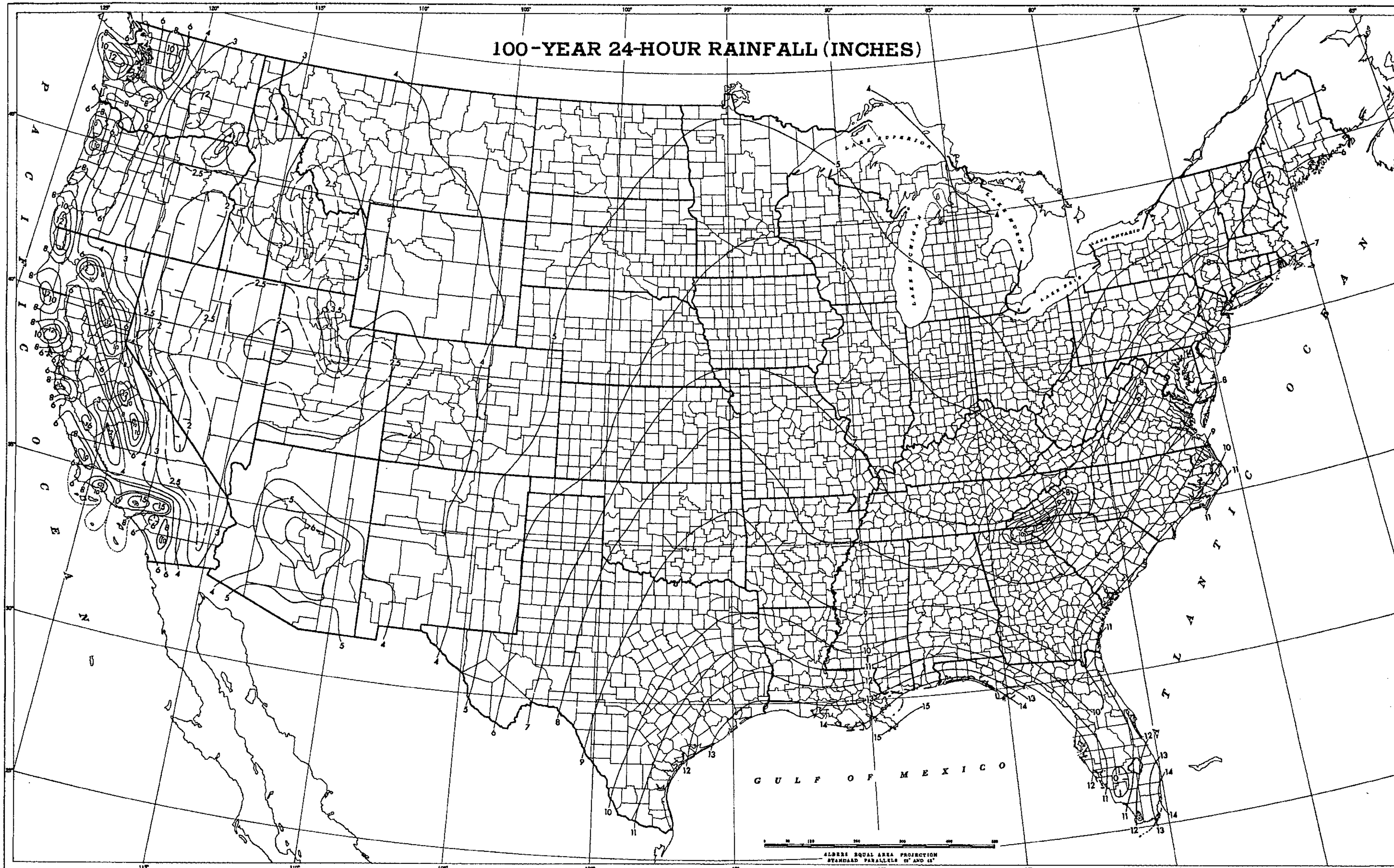

50-YEAR 24-HOUR RAINFALL (INCHES)
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS 29° AND 45°


100-YEAR 24-HOUR RAINFALL (INCHES)
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS 29° AND 45°

56

APPENDIX D-6-2

SECTION D-6

LANDFILL DESIGN DRAWINGS

Revision No.
5.0

APPENDIX D-6-2

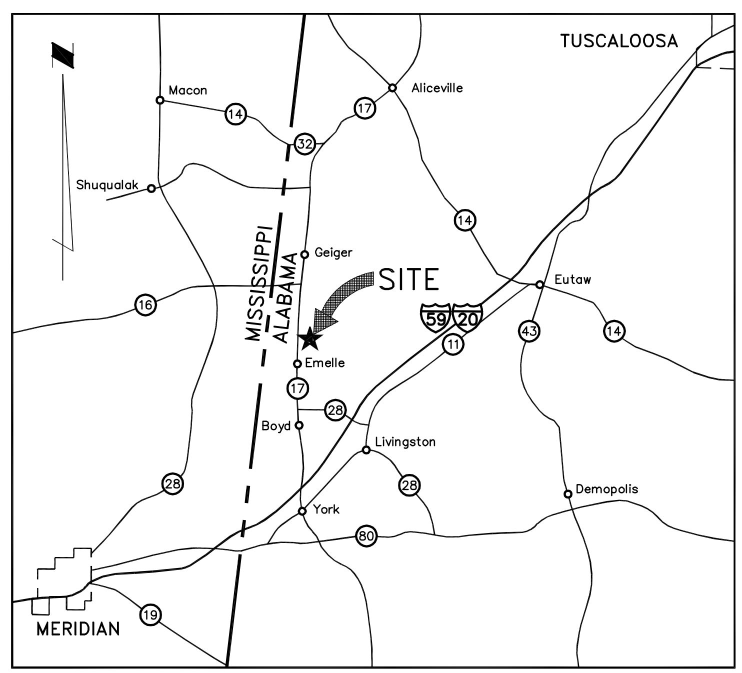
LANDFILL DESIGN DRAWINGS FOR TRENCH 22

Chemical Waste Management, Inc.

Emelle Facility
Emelle, Alabama

APPENDIX D-6-2 LANDFILL DESIGN DRAWINGS FOR TRENCH 22

INDEX TO DRAWINGS



LOCATION MAP

REVISION 3.3: NOVEMBER 12, 2010
REVISION 3.0: MAY 1, 2009
REVISION 2.1: JULY 31, 2002
SUBMITTAL 2.0: MARCH 25, 2002
REVISION 12.6: JANUARY, 1998
REVISION 12.4: JULY, 1997
REVISION 12: NOVEMBER, 1994
REVISION 11A: FEBRUARY, 1994
REVISION 11: OCTOBER, 1993
REVISION 9: NOVEMBER, 1988
REVISION 4: JUNE, 1986
REVISION 3: MAY, 1986
REVISION 2: MAY, 1986
REVISION 1: FEBRUARY, 1986

Plans Prepared By:

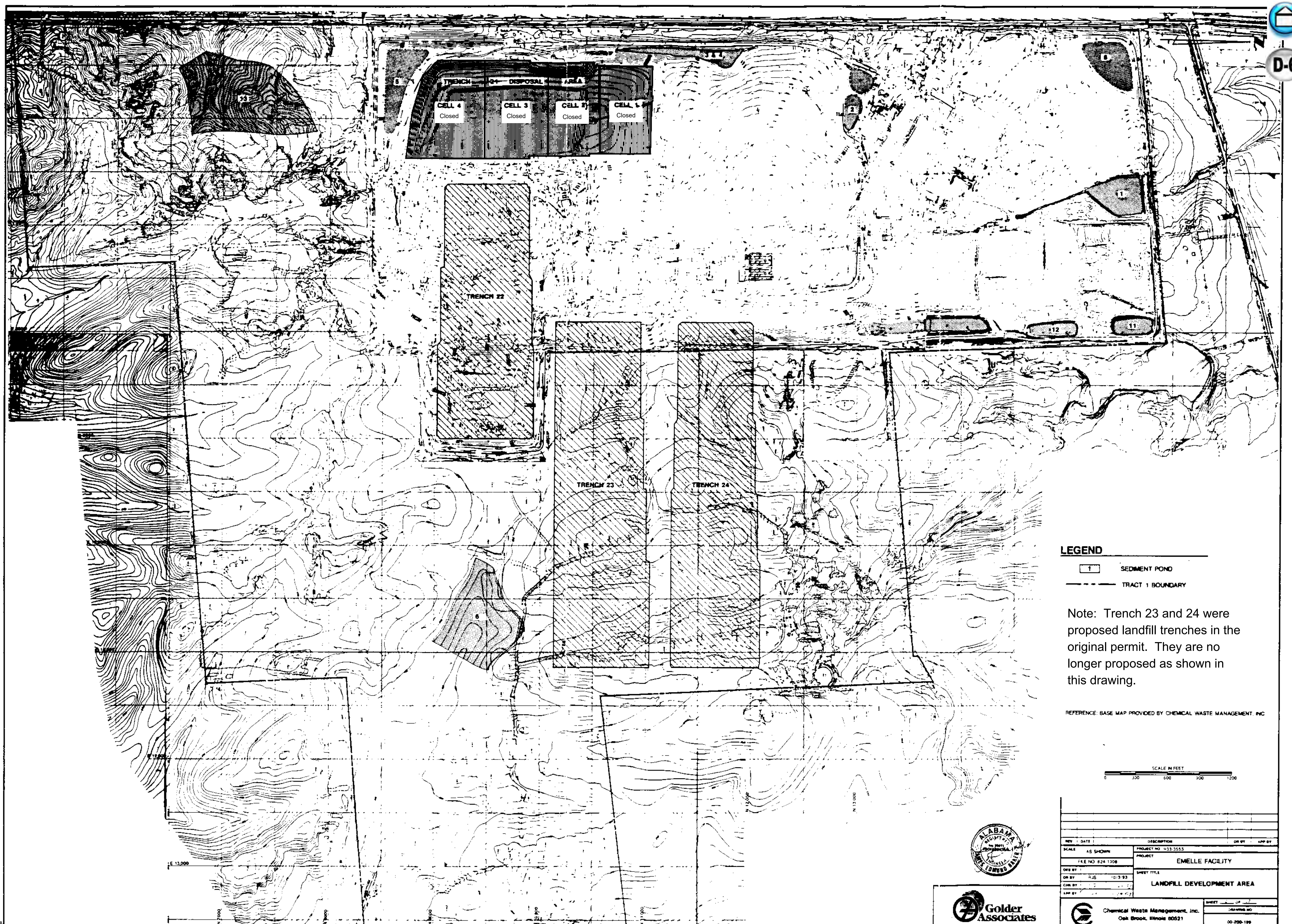
Golder Associates
Atlanta, Ga.

PART B PERMIT APPLICATION
LANDFILL DESIGN

NO.	DATE	DESCRIPTION OF REVISION
4.0	03-15-15	2015 PART B PERMIT RENEWAL
3.3	11-12-10	FINAL-RCRA PART B APPN RENEWAL
3.0	05-01-09	PART B APPLICATION RENEWAL-2009
2.1	07-31-02	REMOVAL OF PROPOSED UNITS
2.0	03-25-02	PART B APPLICATION RENEWAL-2002

JACOBS

SHEET NO. 1 OF 27
DRAWING NO. 00-200-198



LEGEND

1	SEDIMENT POND
— — — —	TRACT 1 BOUNDARY

Note: Trench 23 and 24 were proposed landfill trenches in the original permit. They are no longer proposed as shown in this drawing.

REFERENCE: BASE MAP PROVIDED BY CHEMICAL WASTE MANAGEMENT, INC

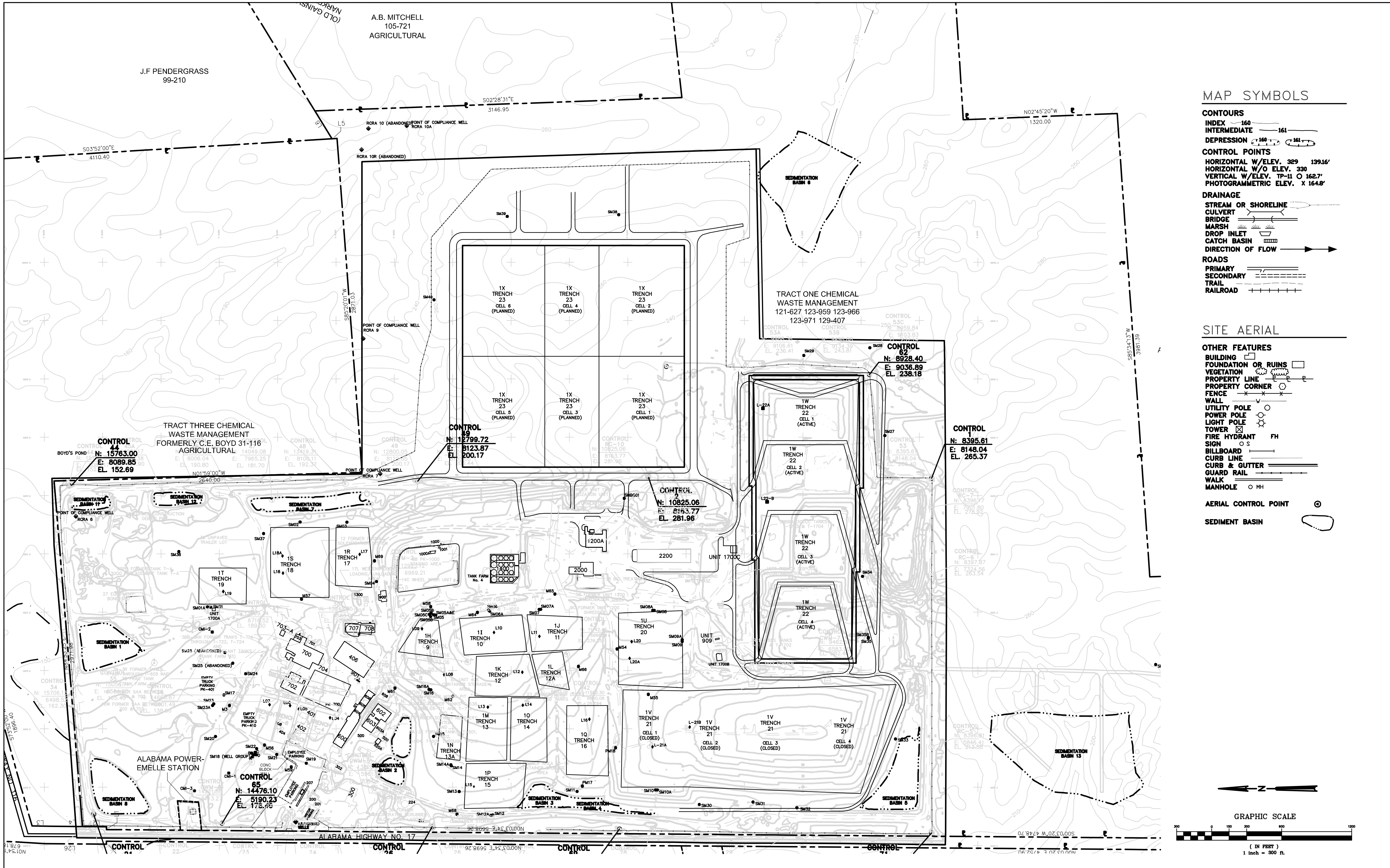
SCALE IN FEET
0 300 600 900 1200

SCALE AS SHOWN	PROJECT NO 933-3553
FILE NO 824 1308	PROJECT EMELLE FACILITY
DR BY RJS 10/3/93	SHEET TITLE LANDFILL DEVELOPMENT AREA

Golder Associates

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

DRAWING NO 00-200-199



NO.	DATE	DESCRIPTION OF REVISION
4.0	03-15-15	2015 PART B PERMIT RENEWAL
3.3	11-12-10	FINAL-RCRA PART B APPN RENEWAL
3.0	05-01-09	PART B APPLICATION RENEWAL-2009
2.1	07-31-02	REMOVAL OF PROPOSED UNITS
2.0	03-25-02	PART B APPLICATION RENEWAL-2002

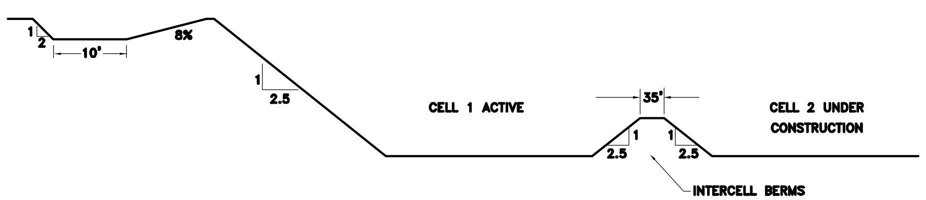
JACOBS

REV.	DATE	DESCRIPTION	DR BY	APP BY

SCALE: AS SHOWN
PROJECT NO. 933-3553
PROJECT: EMELLE FACILITY
DES BY CMW 9/93
DR BY RMS 10/94
CHK BY
APP BY
SHEET TITLE: SURVEY CONTROL OF TRENCH LOCATIONS
SHEET 3 of 27
DRAWING NO. 00-200-200

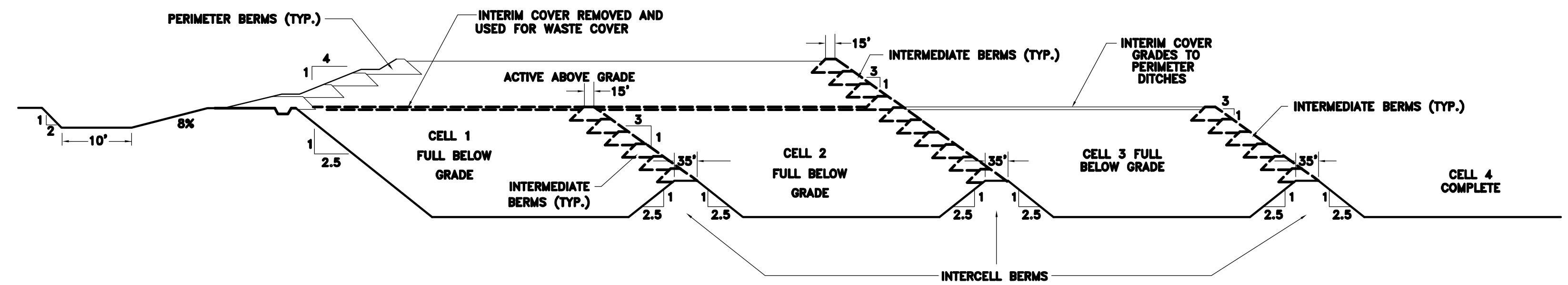
Golder Associates
Atlanta, Georgia

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521



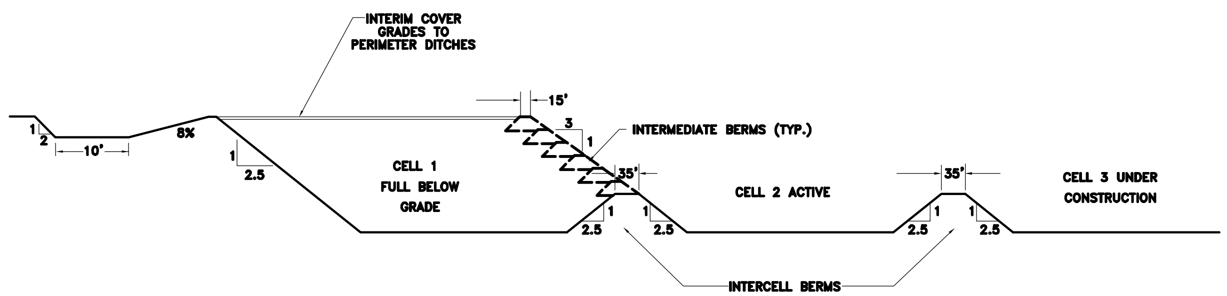
LANDFILL CONSTRUCTION SEQUENCE – PHASE 1

NTS



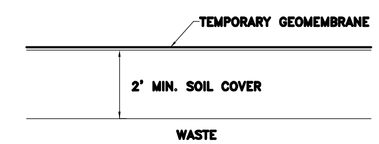
LANDFILL CONSTRUCTION SEQUENCE – PHASE 4

NTS



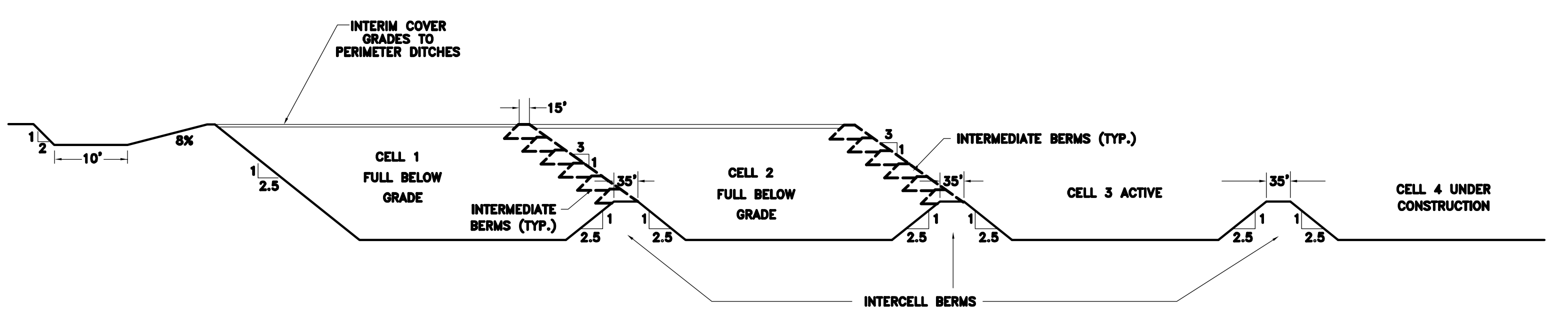
LANDFILL CONSTRUCTION SEQUENCE – PHASE 2

NTS



INTERIM COVER DETAIL

NTS



LANDFILL CONSTRUCTION SEQUENCE – PHASE 3

NTS

NOTES:

1. OPERATING SEQUENCE IS TYPICAL AND IS NOT MEANT TO REPRESENT ACTUAL OPERATING CONFIGURATIONS.
2. INTERCELL BERM WIDTH IN TRENCH 22 IS 30' AT THE TOP.
3. THE INTERIM COVER IS COMPOSED OF A MINIMUM OF 2 FEET OF CHALK TO PREVENT INFILTRATION. BEFORE WASTE PLACEMENT RESUMES, 1 FOOT OF THE CHALK LAYER WILL BE REMOVED.

NO.	DATE	DESCRIPTION OF REVISION
4.0	03-15-15	2015 PART B PERMIT RENEWAL
3.3	11-12-10	FINAL-RCRA PART B APPN RENEWAL
3.0	05-01-09	PART B APPLICATION RENEWAL-2009
2.1	07-31-02	REMOVAL OF PROPOSED UNITS
2.0	03-25-02	PART B APPLICATION RENEWAL-2002

JACOBS

Golder Associates — Atlanta, Georgia

REV.	DATE	DESCRIPTION	DR BY	APP BY
1	10/94	REVISE NOTES	RMS	

SCALE: AS SHOWN

FILE NO. 824-1308

DES BY	T.s.R.	10/93
DR BY	T.s.R.	10/93
CHK BY		
APP BY		

PROJECT NO. 933-3553

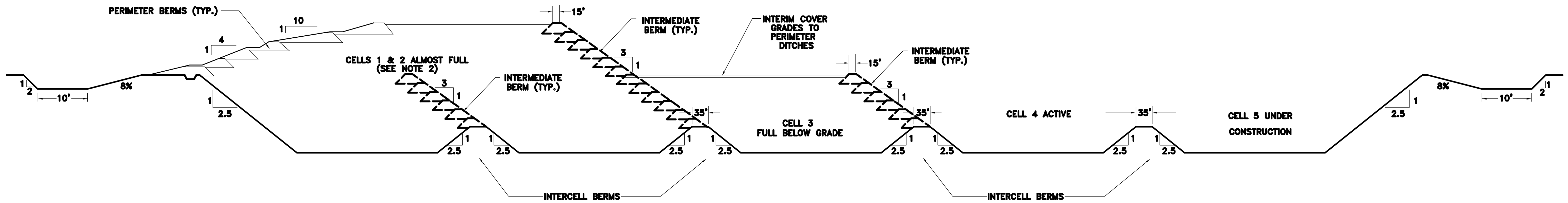
PROJECT: EMELLE FACILITY

SHEET TITLE: TYPICAL CONSTRUCTION SEQUENCE (TRENCH 22) (SHEET 1 OF 3)

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

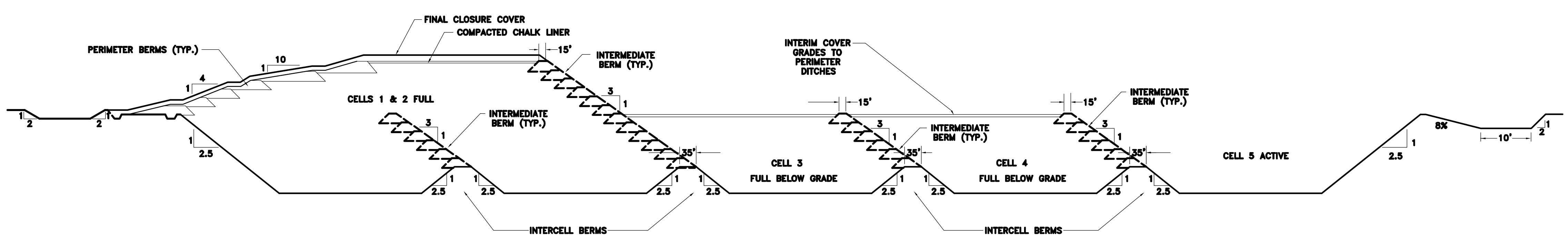
SHEET 4 OF 27

DRAWING NO. 00-200-203



LANDFILL CONSTRUCTION SEQUENCE – PHASE 5

NTS



LANDFILL CONSTRUCTION SEQUENCE – PHASE 6

NTS

NOTES:

1. OPERATING SEQUENCE IS TYPICAL AND IS NOT MEANT TO REPRESENT ACTUAL OPERATING CONFIGURATIONS.
2. THE INTERIM COVER IS COMPOSED OF A MINIMUM OF 2 FEET OF CHALK TO PREVENT INFILTRATION. BEFORE WASTE PLACEMENT RESUMES, 1 FOOT OF THE CHALK LAYER WILL BE REMOVED.
3. INTERCELL BERM WIDTH IN TRENCH 22 IS 30' AT THE TOP.

NO.	DATE	DESCRIPTION OF REVISION
4.0	03-15-15	2015 PART B PERMIT RENEWAL
3.3	11-12-10	FINAL-RCRA PART B APPN RENEWAL
3.0	05-01-09	PART B APPLICATION RENEWAL-2009
2.1	07-31-02	REMOVAL OF PROPOSED UNITS
2.0	03-25-02	PART B APPLICATION RENEWAL-2002

JACOBS

Golder Associates

Atlanta, Georgia

REV.	DATE	DESCRIPTION	DR BY	APP BY
1	10/94	REVISED NOTES	RMS	

SCALE: AS SHOWN

FILE NO. 824-1308

DES BY	T.s.R.	10/93
DR BY	T.s.R.	10/93
CHK BY		
APP BY		

PROJECT NO. 933-3553

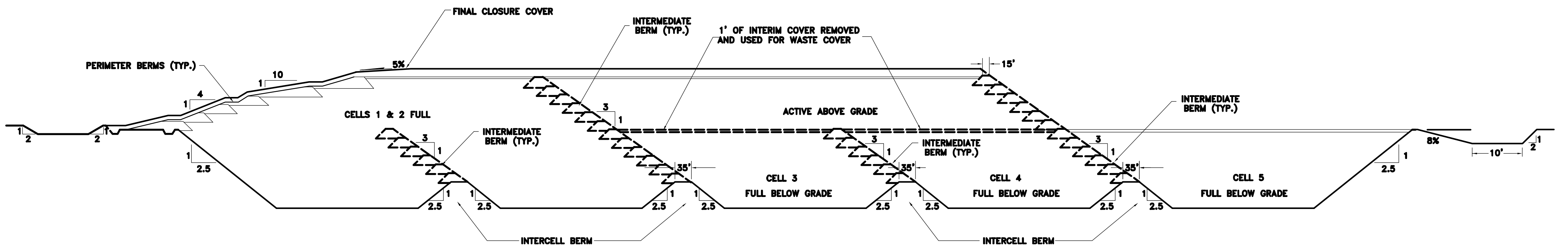
PROJECT: EMELLE FACILITY

SHEET TITLE: TYPICAL CONSTRUCTION SEQUENCE (TRENCH 22) (SHEET 2 OF 3)

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

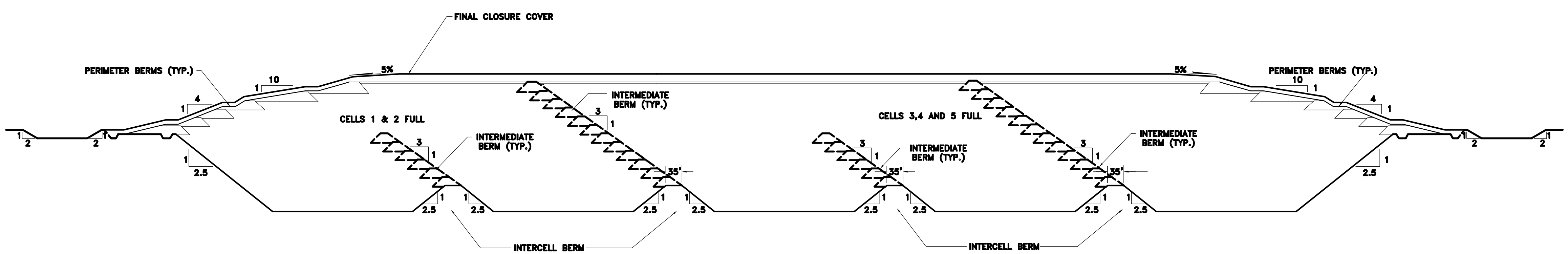
SHEET 5 OF 27

DRAWING NO. 00-200-204



LANDFILL CONSTRUCTION SEQUENCE – PHASE 7

NTS



LANDFILL CONSTRUCTION SEQUENCE – PHASE 8

NTS

NOTES:

1. OPERATING SEQUENCE IS TYPICAL AND IS NOT MEANT TO REPRESENT ACTUAL OPERATING CONFIGURATIONS.
2. CELL 4 WILL BECOME ACTIVE WHEN CELLS 1 AND 2 ARE STILL ACTIVE ABOVE GRADE, BUT NEARLY FULL. THIS IS NECESSARY TO ACCOMODATE WASTE WHICH DOES NOT FIT INTO THE CELLS 1 & 2 SUCH AS TRANSFORMERS.
3. THE INTERIM COVER IS COMPOSED OF A MINIMUM OF 2 FEET OF CHALK TO PREVENT INFILTRATION. BEFORE WASTE PLACEMENT RESUMES, 1 FOOT OF THE CHALK LAYER WILL BE REMOVED.
4. INTERCELL BERM WIDTH IN TRENCH 22 IS 30' AT THE TOP.
5. THE ABOVE GRADE MODULES MAY CONTAIN ONE OR TWO CELLS.

REV.	DATE	DESCRIPTION	DR BY	APP BY
1	10/94	REVISE NOTES	RMS	

NO.	DATE	DESCRIPTION OF REVISION
4.0	03-15-15	2015 PART B PERMIT RENEWAL
3.3	11-12-10	FINAL-RCRA PART B APPN RENEWAL
3.0	05-01-09	PART B APPLICATION RENEWAL-2009
2.1	07-31-02	REMOVAL OF PROPOSED UNITS
2.0	03-25-02	PART B APPLICATION RENEWAL-2002

JACOBS

Golder Associates
Atlanta, Georgia

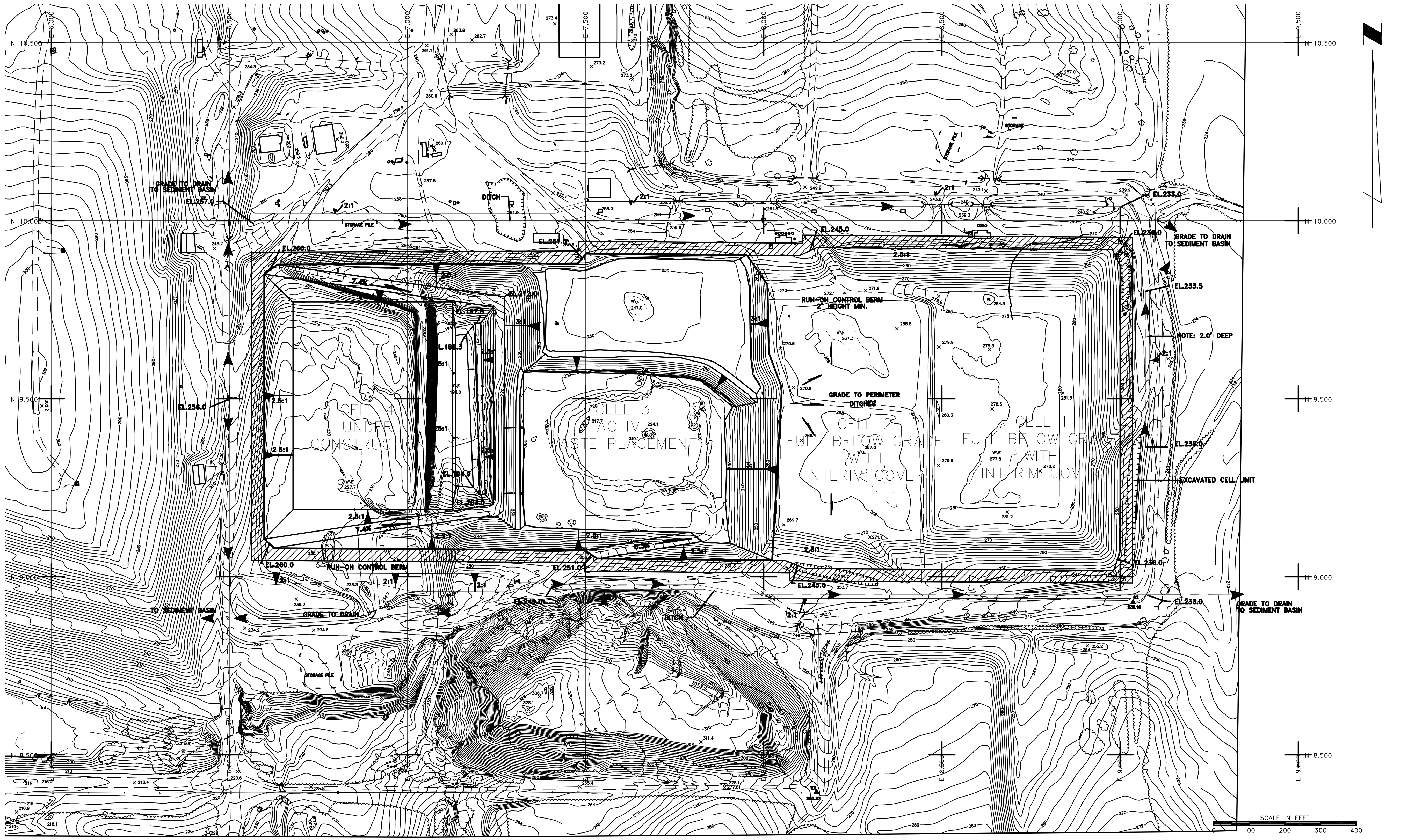
SCALE: AS SHOWN
FILE NO. 824-1308

DES BY	T.s.R.	10/93
DR BY	T.s.R.	10/93
CHK BY		
APP BY		

PROJECT NO. 933-3553
PROJECT: EMELLE FACILITY
SHEET TITLE: TYPICAL CONSTRUCTION SEQUENCE (TRENCH 22) (SHEET 3 OF 3)

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 6 OF 27
DRAWING NO. 00-200-205



NOTES:

1. Base map provided by Chemical Waste Management, Inc. Date of aerial photography 2009.
2. The typical trench development shows trench 22.

NO.	DATE	DESCRIPTION OF REVISION
4.0	03-15-15	2015 PART B PERMIT RENEWAL
3.3	11-12-10	FINAL-RCRA PART B APPN RENEWAL
3.0	05-01-09	PART B APPLICATION RENEWAL-2009
2.1	07-31-02	REMOVAL OF PROPOSED UNITS
2.0	03-25-02	PART B APPLICATION RENEWAL-2002

JACOBS

Golder Associates

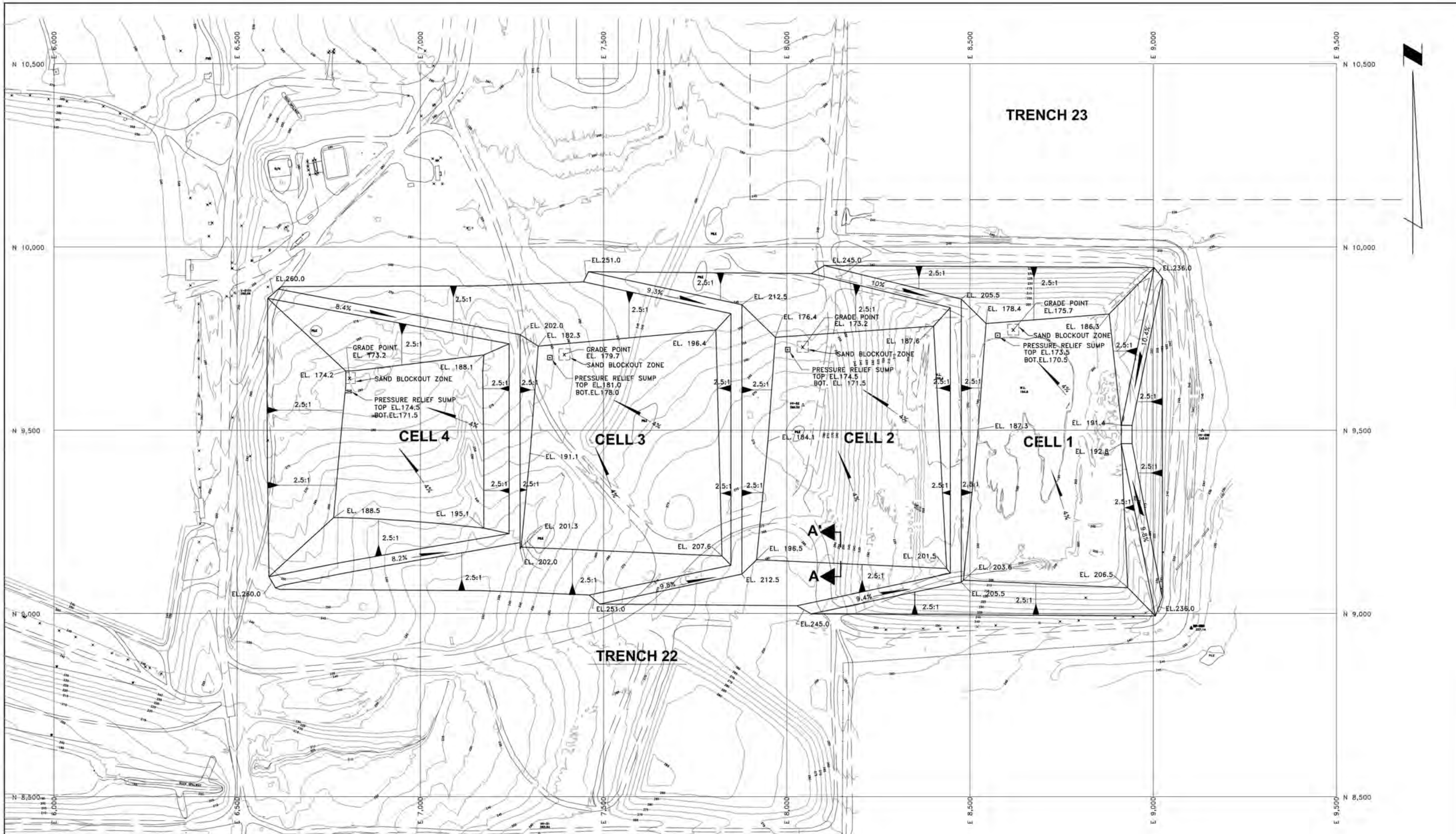
REV.	DATE	DESCRIPTION	DR BY	APP BY

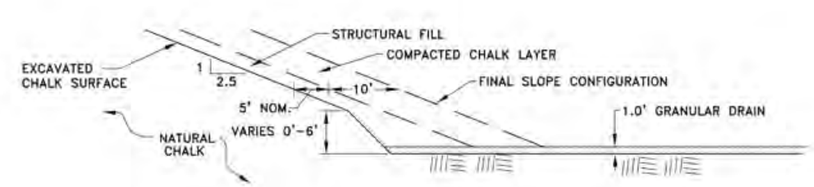
SCALE: AS SHOWN
FILE NO. 824-1308
DES BY T.s.R. 10/93
DR BY T.s.R. 10/93
CHK BY
RVW BY

PROJECT NO. 933-3553
PROJECT: EMELLE FACILITY
SHEET TITLE: TYPICAL TRENCH DEVELOPMENT

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 7 OF 27
DRAWING NO. 00-200-206





TYPICAL SECTION A-A'

SCALE IN FEET 0 10 20

NOTES:

1. Base map provided by Chemical Waste Management, Inc. Date of aerial photography 1993.
2. The bottom elevations shown represent the chalk surface prior to installation of the pressure relief blanket drain.
3. The blanket drain extends to the excavation limits of the cell floor on the trench perimeter.
4. The grading point for the pressure relief system of each cell floor is directly below the grading point for secondary liner system.

SCALE IN FEET 0 100 200 300 400

7/22/10

REV	DATE	DESCRIPTION	DR BY	APP BY
3	12/08	REVISED STRUCTURAL FILL AND EXCAVATED CHALK SURFACE	RJC	AS
2	11/94	REVISED NOTES, REVISE CELL FLOOR GRADES	T.s.R.	
1	10/94	REGRADED TRENCH 22 AS PER NEW GRADING POINT ELEVATION	T.s.R.	

SCALE: AS SHOWN		
FILE NO. 824-1308		
DES BY	T.s.R.	10/93
DR BY	T.s.R.	10/93
CHK BY		
APP BY		

PROJECT NO: 933-3553

PROJECT: EMELLE FACILITY

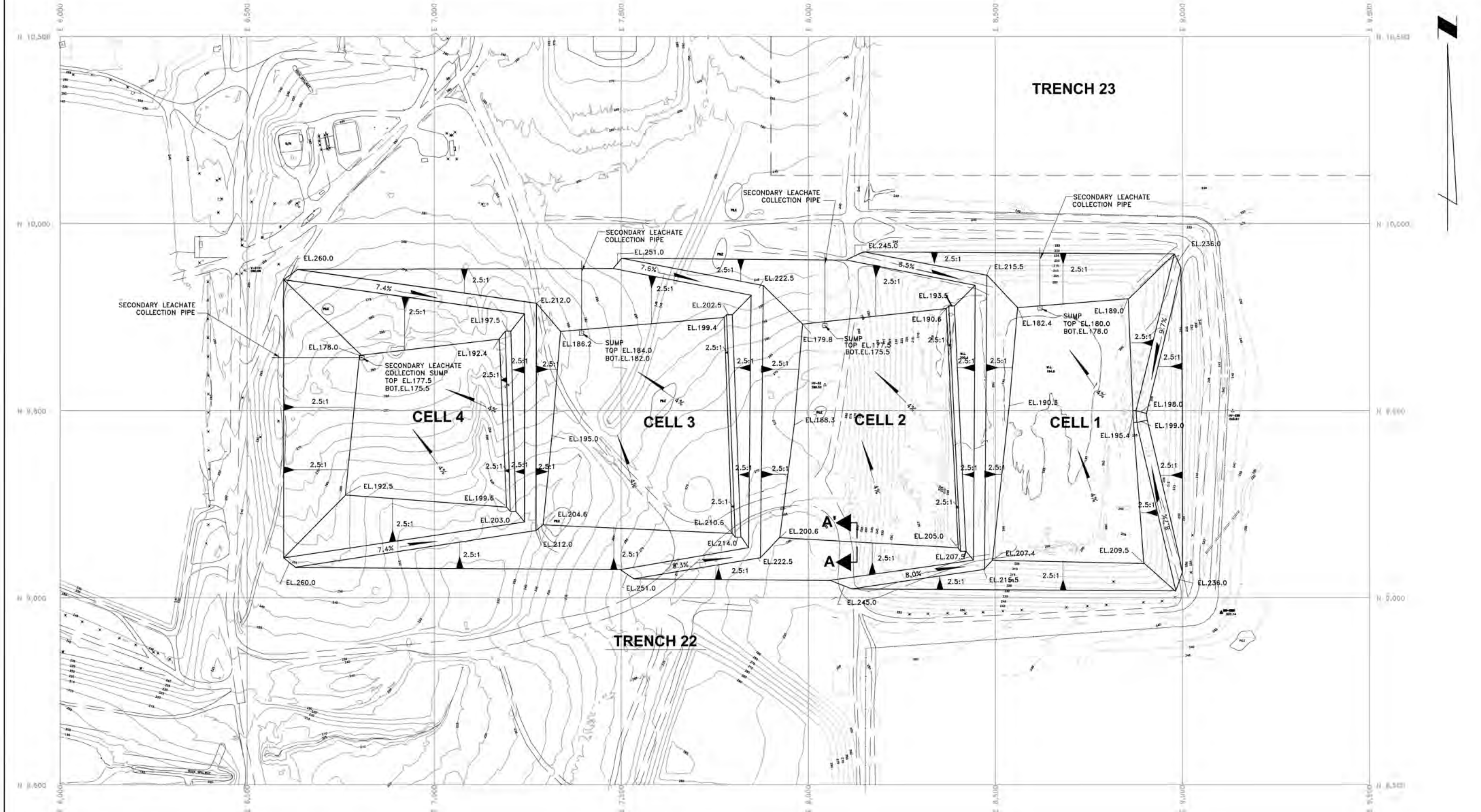
SHEET TITLE: TRENCH 22 EXCAVATED CELL CONFIGURATION

Golder Associates, Atlanta, Georgia

Chemical Waste Management, Inc. Oak Brook, Illinois 60521

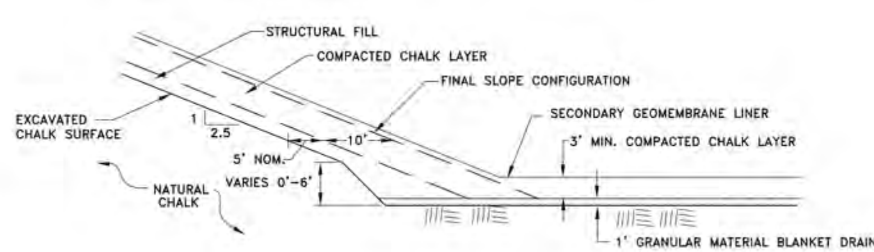
SHEET 8 OF 27

DRAWING NO. 00-200-208



SCALE IN FEET

0 100 200 300 400



TYPICAL SECTION A-A'

SCALE IN FEET

0 10 20

NOTES:

1. Base map provided by Chemical Waste Management, Inc. Date of aerial photography 1993.
2. The bottom elevations shown represent the top of the secondary geomembrane liner.
3. Each cell floor is graded radially about the top center of the secondary sump.
4. Elevation at east end of Trench 22 must be a minimum of 236 ft. MSL to allow drainage to sediment basin 6.
5. See Drawing No. 00-200-224 and 00-200-225 for liner and collection system details.
6. See Drawing No. 00-200-225 for anchor trench details.

ALABAMA REGISTERED No. 20266 PROFESSIONAL ENGINEER WILLIAM R. SULLIVAN

7/22/10

REV.	DATE	DESCRIPTION	DR BY	APP BY
2	12/09	REVISED STRUCTURAL FILL AND EXCAVATED CHALK SURFACE	RJC	AS
1	12/94	REVISE NOTES	RMS	

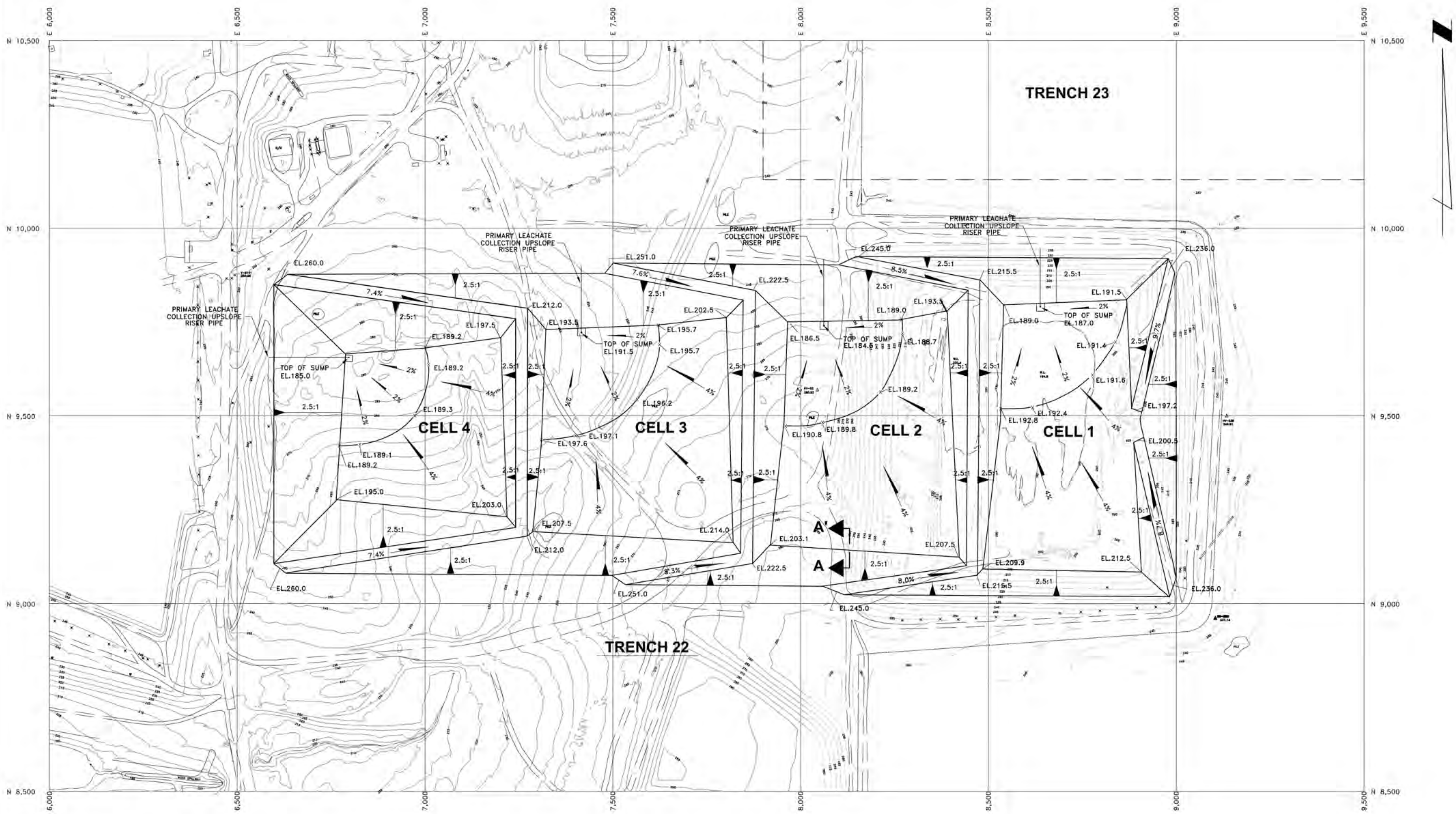
SCALE: AS SHOWN		PROJECT NO. 933-3553
FILE NO. 824-1308		PROJECT: EMELLE FACILITY
DES BY T.s.R.	10/93	SHEET TITLE: TRENCH 22 SECONDARY LINER SYSTEM DESIGN
DR BY T.s.R.	10/93	
CHK BY		
APP BY		

Golder Associates
Atlanta, Georgia

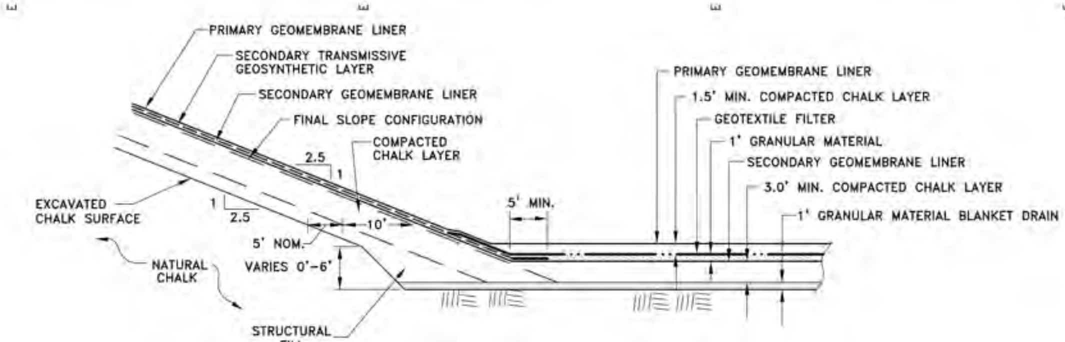
Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 10 OF 27

DRAWING NO. 00-200-210



SCALE IN FEET 0 100 200 300 400



TYPICAL SECTION A-A'

SCALE IN FEET 0 10 20

NOTES:

1. Base map provided by Chemical Waste Management, Inc. Date of aerial photography 1993.
2. The bottom elevations shown represent the top of the primary geomembrane liner.
3. Each cell floor is graded radially about the centerline of the primary sump.
4. Elevation at east end of Trench 22 must be a minimum of 236 ft. MSL to allow drainage to sediment basin 6.
5. See Drawing No. 00-200-223 and 00-200-225 for liner and collection system details.
6. See Drawing No. 00-200-225 for anchor trench details.

7/22/10

REV.	DATE	DESCRIPTION	DR BY	APP BY
3	12/09	REVISED STRUCTURAL FILL AND EXCAVATED CHALK SURFACE	RJC	AS
2	10/94	REVISE NOTES	SMS	
1	1/94	ADDED GEOTEXTILE FILTER ABOVE GRANULAR MATERIAL IN SECONDARY LEACHATE COLLECTION SYSTEM	WME	

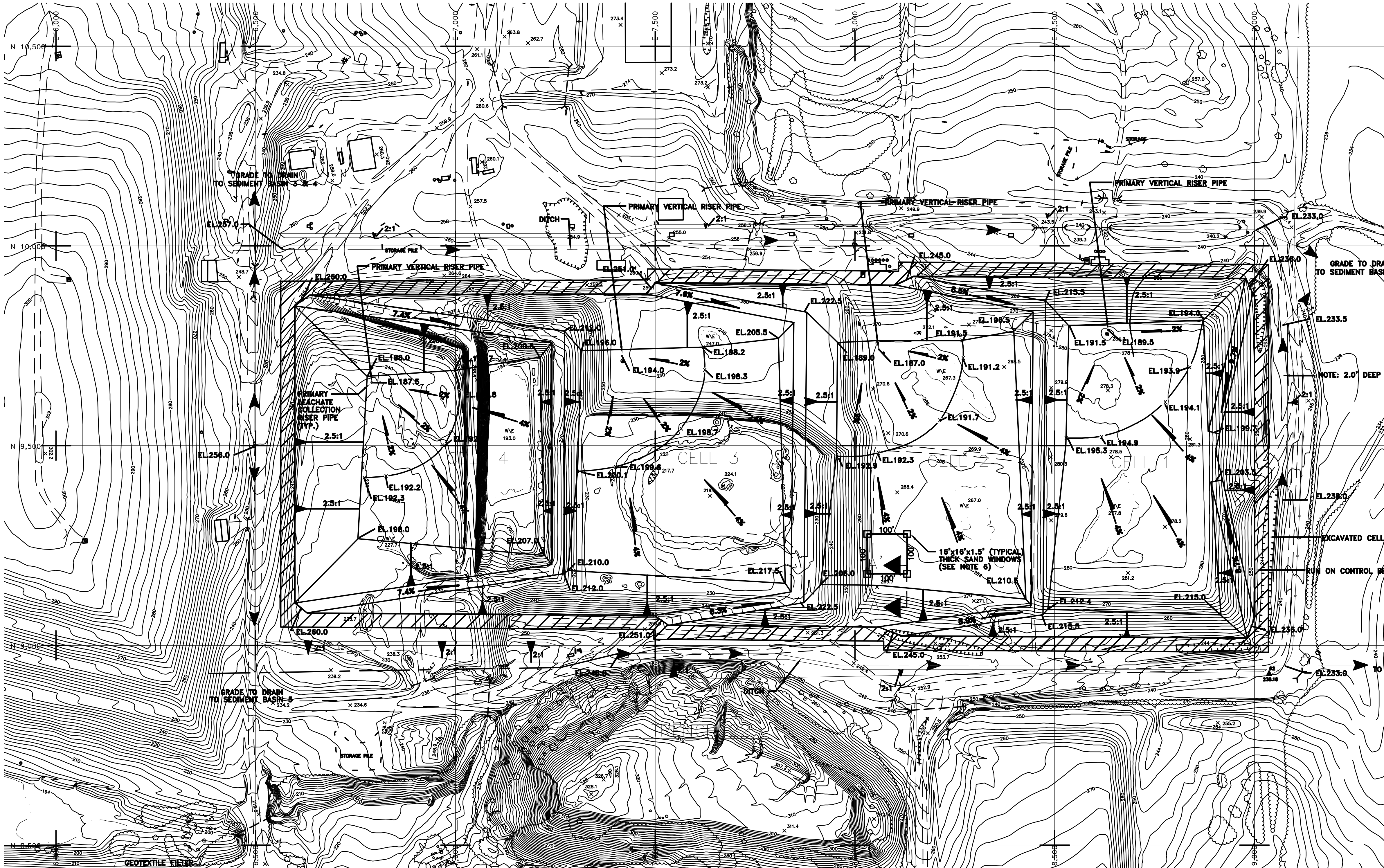
SCALE: AS SHOWN
FILE NO. 824-1308
DES BY T.s.R. 10/93
DR BY T.s.R. 10/93
CHK BY JEF 10/29/93
APP BY WRS 10/29/93

PROJECT NO. 933-3553
PROJECT: EMELLE FACILITY
SHEET TITLE: TRENCH 22 PRIMARY LINER SYSTEM DESIGN

Golder Associates, Atlanta, Georgia

Chemical Waste Management, Inc. Oak Brook, Illinois 60521

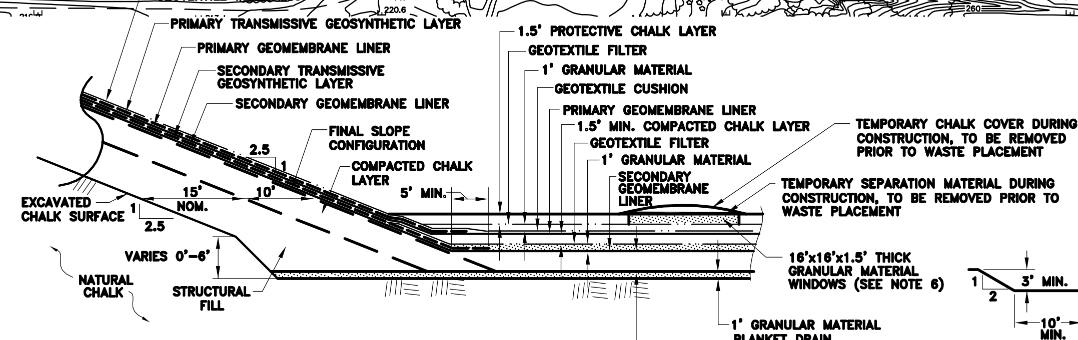
SHEET 12 OF 27
DRAWING NO. 00-200-212



NOTES:

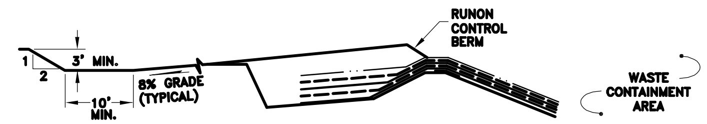
1. Base map provided by Chemical Waste Management, Inc. Date of aerial photography 2009.
2. The bottom elevations shown represent the top of the chalk backfill layer.
3. See Drawing No. 00-200-225 for anchor trench details.
4. The grading point for each cell lies is located located at the centerline of the primary sump.
5. See Drawing No. 00-200-215 for typical section A-A' and ditch cross-sections.
6. Granular material windows will be placed on an approximate 100' grid throughout the entire floor of all cells within the trench to within 25' of sideslopes and and outside a 100' radius of vertical riser.

SCALE IN FEET
0 100 200 300 400



TYPICAL SECTION A–A'

SCALE IN FEET
0 10 20



TYPICAL RUNON CONTROL BERM AND DITCH

SCALE IN FEET
0 10 20

NO.	DATE	DESCRIPTION OF REVISION
4.0	03–15–15	2015 PART B PERMIT RENEWAL
3.3	11–12–10	FINAL–RCRA PART B APPN RENEWAL
3.0	05–01–09	PART B APPLICATION RENEWAL–2009
2.1	07–31–02	REMOVAL OF PROPOSED UNITS
2.0	03–25–02	PART B APPLICATION RENEWAL–2002

JACOBS

REV.	DATE	DESCRIPTION	DR BY	APP BY
3	10/94	REVISE NOTES, REVISE SECTION A–A	RMS	
2	1/94	ADDED SAND WINDOWS AND NOTE 7	WME	
1	1/94	ADDED GEOTEXTILE FILTER ABOVE GRANULAR MATERIAL IN SECONDARY LEACHATE COLLECTION SYSTEM	WME	

SCALE: AS SHOWN
FILE NO. 824–1308

DES BY	T.s.R.	10/93
DR BY	T.s.R.	10/93
CHK BY	JEF	10/29/93
APP BY	WRS	10/29/93

PROJECT NO. 933–3553

PROJECT: EMELLE FACILITY

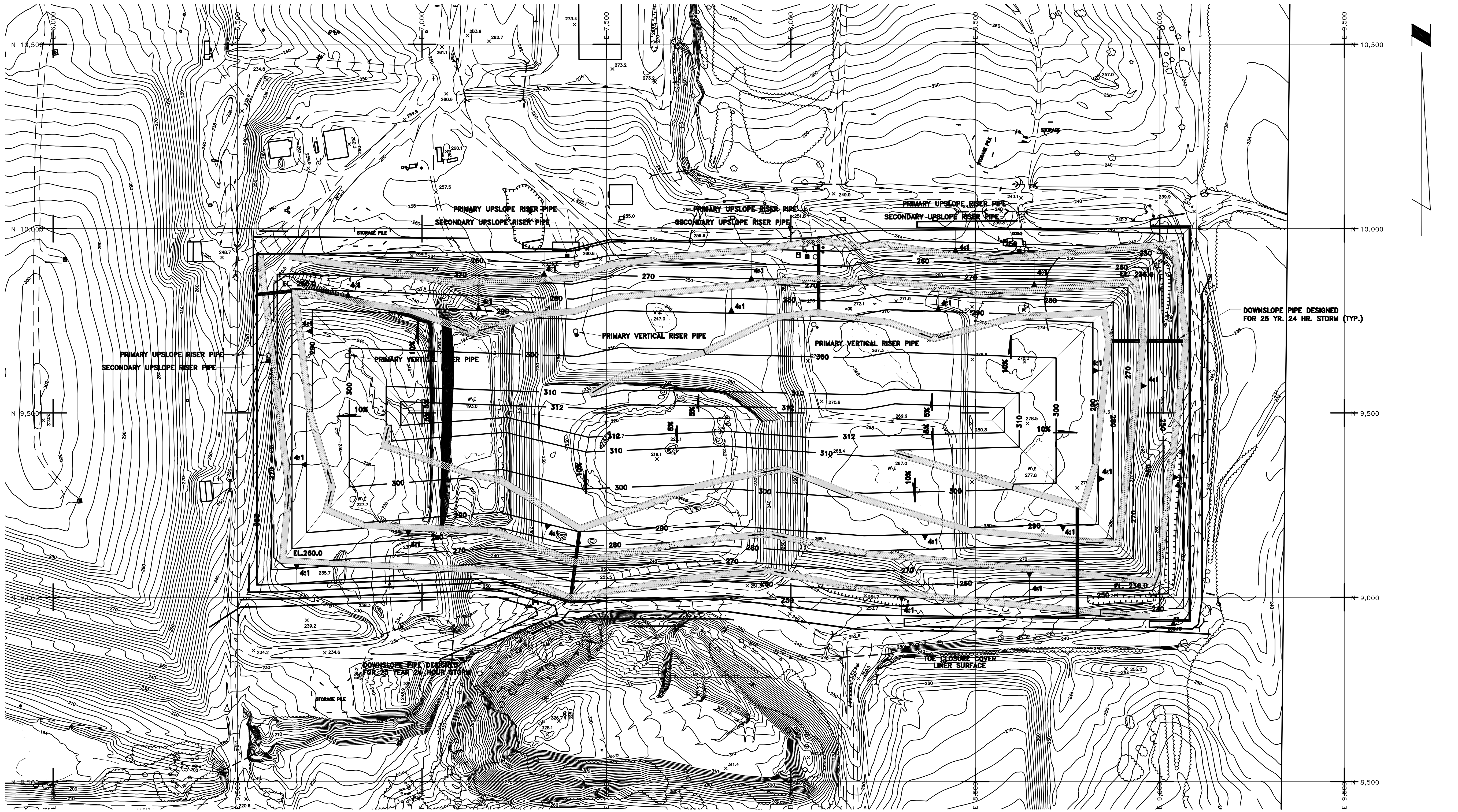
SHEET TITLE: TRENCH 22 COMPLETED CELL CONFIGURATION

Golder Associates
Atlanta, Georgia

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 14 OF 27

DRAWING NO. 00–200–215



NOTES:

1. Base map provided by Chemical Waste Management, Inc. Date of aerial photography 2009.
2. Elevations shown represent the top of the closure cover geomembrane liner.
3. Benches will be grassed temporarily during operation.
4. Interceptor subsurface cover drains to be constructed along benches. Refer to Drawing No. 00-200-227 for cover drain details.
5. Anchor trench toe drains to be constructed in anchor trench. Refer to Drawing No. 00-200-225 for anchor trench details.

LEGEND

- ● PRIMARY UPSLOPE RISER PIPE
- ○ PRIMARY VERTICAL RISER PIPE
- ■ SECONDARY UPSLOPE RISER PIPE
- EL. 260.0 — PERIMETER ELEVATION AT CORNER OF COMPLETED TRENCH

SCALE IN FEET: 0 100 200 300 400

NO.	DATE	DESCRIPTION OF REVISION
4.0	03-15-15	2015 PART B PERMIT RENEWAL
3.3	11-12-10	FINAL-RCRA PART B APPN RENEWAL
3.0	05-01-09	PART B APPLICATION RENEWAL-2009
2.1	07-31-02	REMOVAL OF PROPOSED UNITS
2.0	03-25-02	PART B APPLICATION RENEWAL-2002

JACOBS

Golder Associates

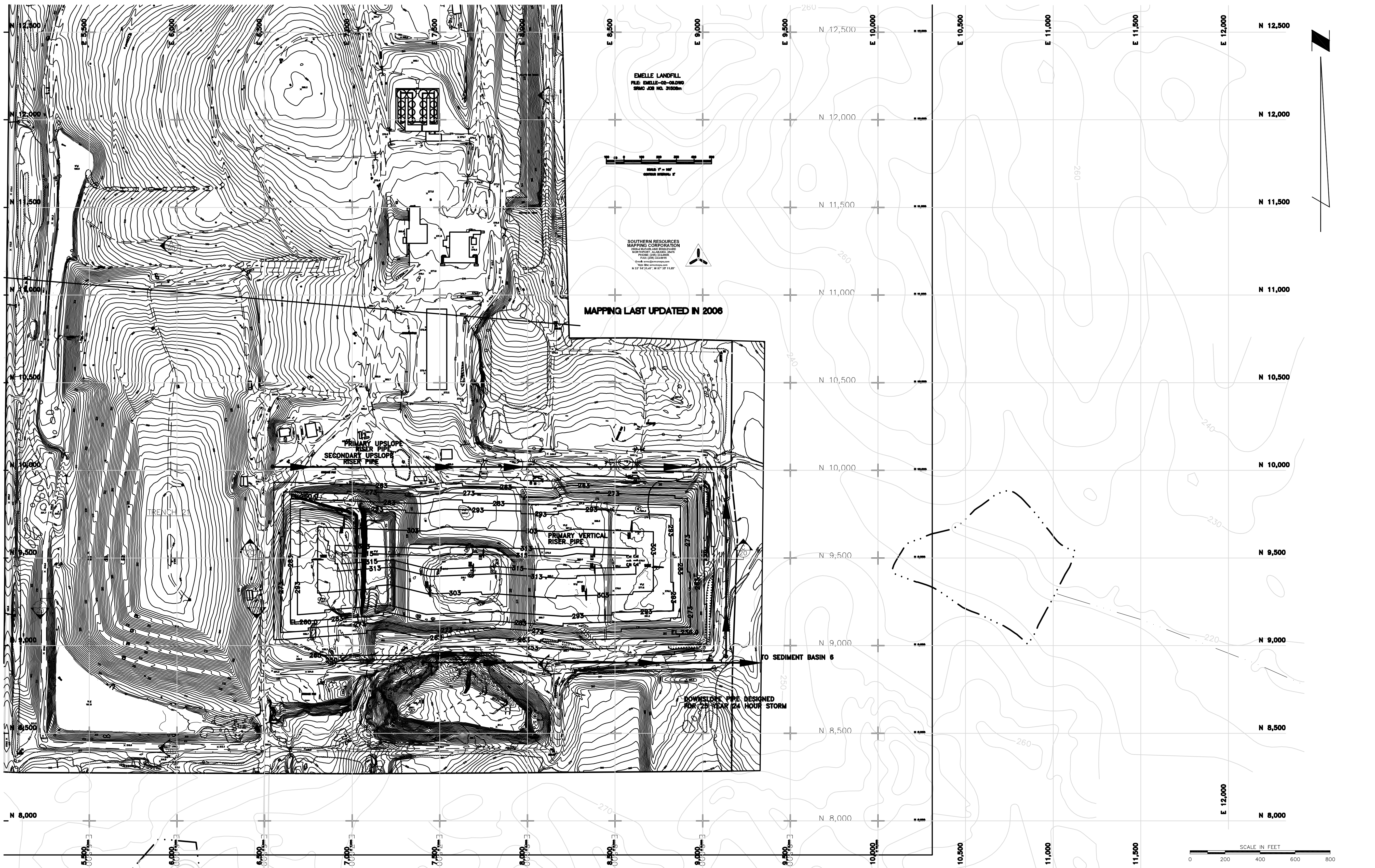
REV.	DATE	DESCRIPTION	DR BY	APP BY
2	11/94	ADDED FLOW ARROWS TO BENCHES, REVISED NOTES	RMS	
1	10/94	REVISE NOTES	RMS	

SCALE: AS SHOWN
FILE NO. 824-1308
DES BY T.s.R. 10/93
DR BY T.s.R. 10/93
CHK BY
RVW BY

PROJECT NO. 933-3553
PROJECT: EMELLE FACILITY
SHEET TITLE: TRENCH 22 CLOSURE COVER LINER SURFACE

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 17 OF 27
DRAWING NO. 00-200-218



NOTES:

LEGEND

1. Base map provided by Chemical Waste Management, Inc. Date of aerial photography 2009.

3. Refer to Drawing No. 00–200–226, 00–200–227 and 00–200–228 for closure cover details.

- ● PRIMARY UPSLOPE RISER PIPE
- ○ PRIMARY VERTICAL RISER PIPE
- SECONDARY UPSLOPE RISER PIPE
- BENCH
- DRAINAGE DIRECTION ON BENCHES
- 260 PERIMETER ELEVATION AT CORNER

NO.	DATE	DESCRIPTION OF REVISION
4.0	03–15–15	2015 PART B PERMIT RENEWAL
3.3	11–12–10	FINAL–RCRA PART B APPN RENEWAL
3.0	05–01–09	PART B APPLICATION RENEWAL–2009
2.1	07–31–02	REMOVAL OF PROPOSED UNITS
2.0	03–25–02	PART B APPLICATION RENEWAL–2002

JACOBS

Golder Associates
Atlanta, Georgia

REV.	DATE	DESCRIPTION	DR BY	APP BY
2	11/94	ADDED FLOW ARROW TO BENCHES	RMS	
1	10/94	REVISE NOTES, AND TRENCH 21 COVER	RMS	

SCALE: AS SHOWN

FILE NO. 824–1308

DES BY	T.s.R.	10/93
DR BY	T.s.R.	10/93
CHK BY		
APP BY		

PROJECT NO.:

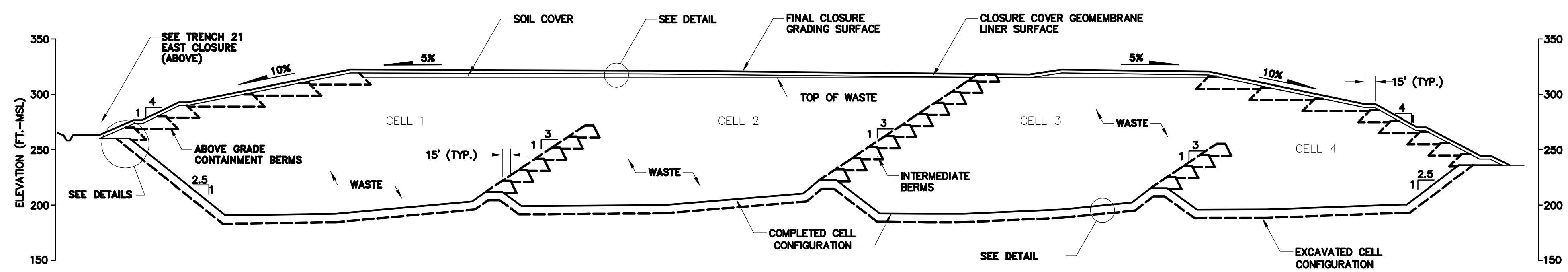
PROJECT: EMELLE FACILITY

SHEET TITLE: FINAL CLOSURE COVER GRADING PLAN

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 19 OF 27

DRAWING NO. 00–200–220



C/20 SECTION THROUGH TRENCH 22

SCALE IN FEET 0 100 200

VERTICAL SCALE EXAGGERATION 2X

NOTES

1. SECTION LOCATIONS SHOWN ON DRAWING NO. 00-200-220 (SHEET 19).
2. TOP ELEVATIONS SHOWN REPRESENT THE TOP OF CLOSURE COVER GROWTH MEDIA.
3. DETAILS SHOWN ON DRAWING Nos. 00-200-225 AND 00-200-226 (SHEETS 25 AND 26).

NO.	DATE	DESCRIPTION OF REVISION
4.0	03-15-15	2015 PART B PERMIT RENEWAL
3.3	11-12-10	FINAL-RCRA PART B APPN RENEWAL
3.0	05-01-09	PART B APPLICATION RENEWAL-2009
2.1	07-31-02	REMOVAL OF PROPOSED UNITS
2.0	03-25-02	PART B APPLICATION RENEWAL-2002

JACOBS

Golder Associates, Atlanta, Georgia

REV.	DATE	DESCRIPTION	DR BY	APP BY
2	11/94	REVISE SECTIONS A AND B	RMS	
1	1/94	ADDED NOTE 4 AND TO NOTE 1	WME	

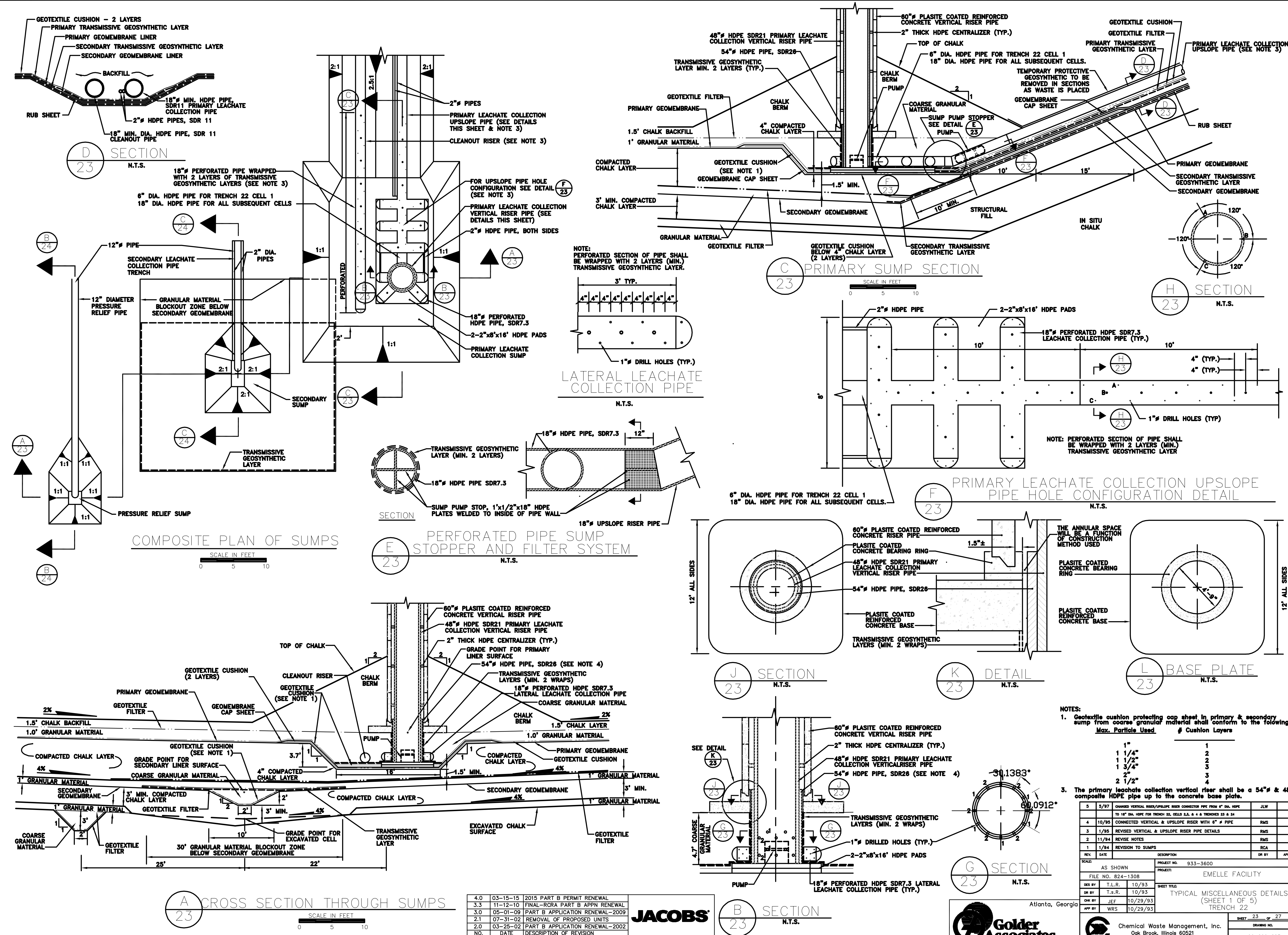
SCALE: AS SHOWN
FILE NO. 824-1308

DES BY	T.s.R.	10/93
DR BY	T.s.R.	10/93
CHK BY	JEF	10/29/93
APP BY	WRS	10/29/93

PROJECT NO. 933-3553
PROJECT: EMELLE FACILITY
SHEET TITLE: CLOSED TRENCH CROSS SECTIONS

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 20 OF 27
DRAWING NO. 00-200-221



NOTES:

1. Geotextile cushion protecting cap sheet in primary & secondary sump from coarse granular material shall conform to the following

Max. Particle Used	# Cushion Layers
1"	1
1 1/4"	2
1 1/2"	2
1 3/4"	3
2"	3
2 1/2"	4

3. The primary leachate collection vertical riser shall be a 54"Ø & 48"Ø composite HDPE pipe up to the concrete base plate.

REV.	DATE	DESCRIPTION	DR BY	APP BY
5	3/97	CHANGED VERTICAL RISER/UPSLOPE RISER CONNECTOR PIPE FROM 6" DIA. HDPE TO 18" DIA. HDPE FOR TRENCH 22, CELLS 2,3, & 4 & TRENCHES 23 & 24	JLW	
4	10/95	CONNECTED VERTICAL & UPSLOPE RISER WITH 6" Ø PIPE	RMS	
3	1/95	REVISED VERTICAL & UPSLOPE RISER PIPE DETAILS	RMS	
2	11/94	REVISE NOTES	RMS	
1	1/94	REVISION TO SUMPS	RCA	

NO.	DATE	DESCRIPTION OF REVISION
4.0	03-15-15	2015 PART B PERMIT RENEWAL
3.3	11-12-10	FINAL-RCRA PART B APPN RENEWAL
3.0	05-01-09	PART B APPLICATION RENEWAL-2009
2.1	07-31-02	REMOVAL OF PROPOSED UNITS
2.0	03-25-02	PART B APPLICATION RENEWAL-2002

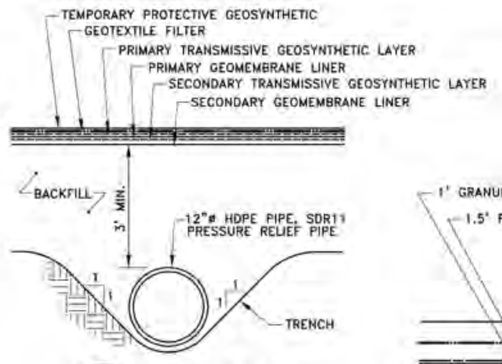
JACOBS

Golder Associates, Atlanta, Georgia

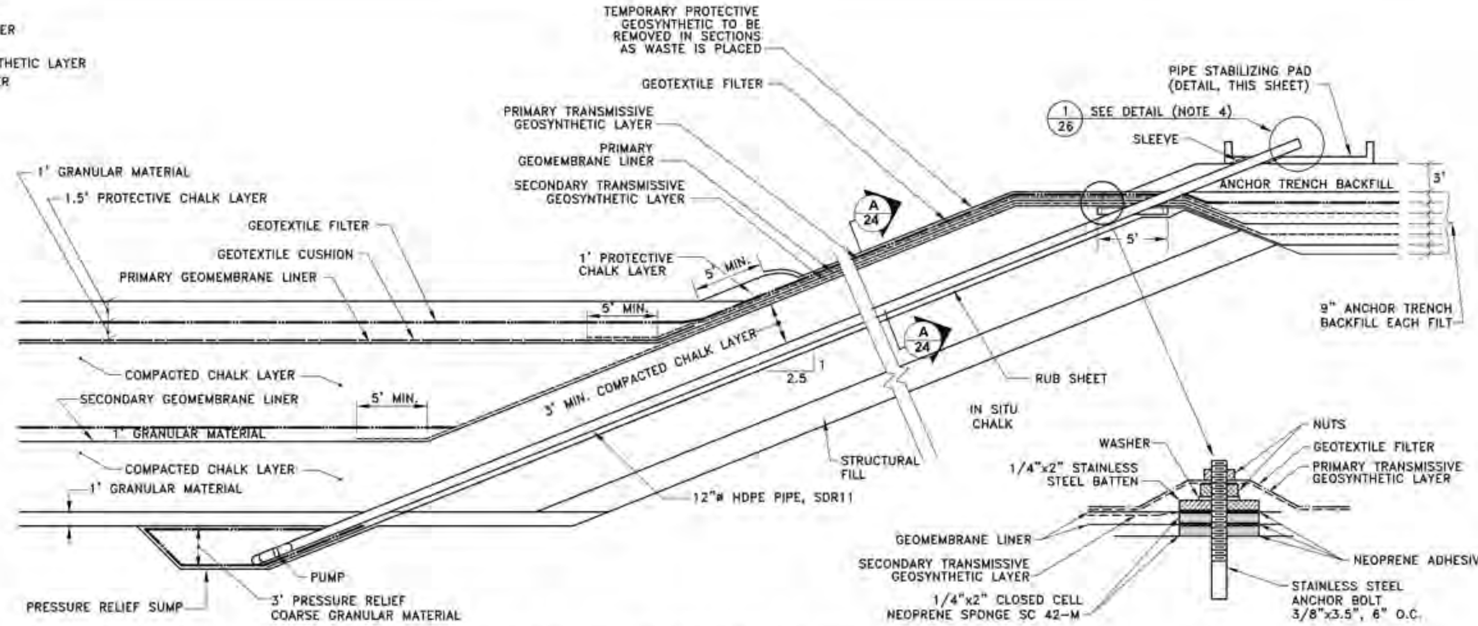
SCALE: AS SHOWN
FILE NO. 824-1308
DES BY T.L.R. 10/93
DR BY T.s.R. 10/93
CHK BY JEF 10/29/93
APP BY WRS 10/29/93

PROJECT NO. 933-3600
PROJECT: EMELLE FACILITY
SHEET TITLE: TYPICAL MISCELLANEOUS DETAILS (SHEET 1 OF 5) TRENCH 22
SHEET 23 OF 27
DRAWING NO. 00-200-223

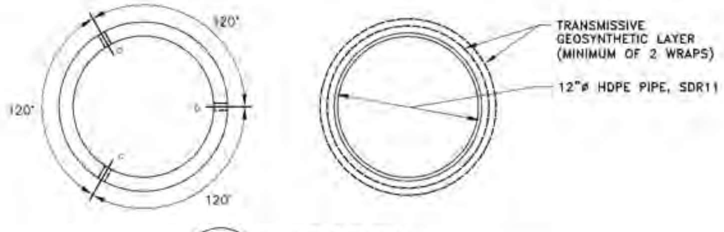
Chemical Waste Management, Inc.
Oak Brook, Illinois 60521



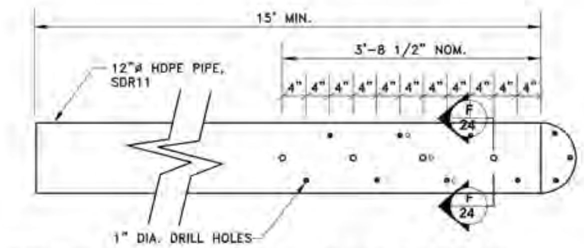
A 24 SECTION
N.T.S.



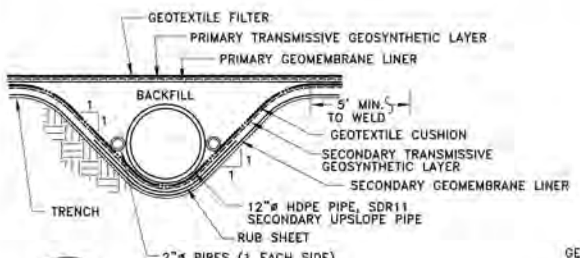
B 24 PRESSURE RELIEF PIPE CROSS SECTION
SCALE IN FEET 0 5 10



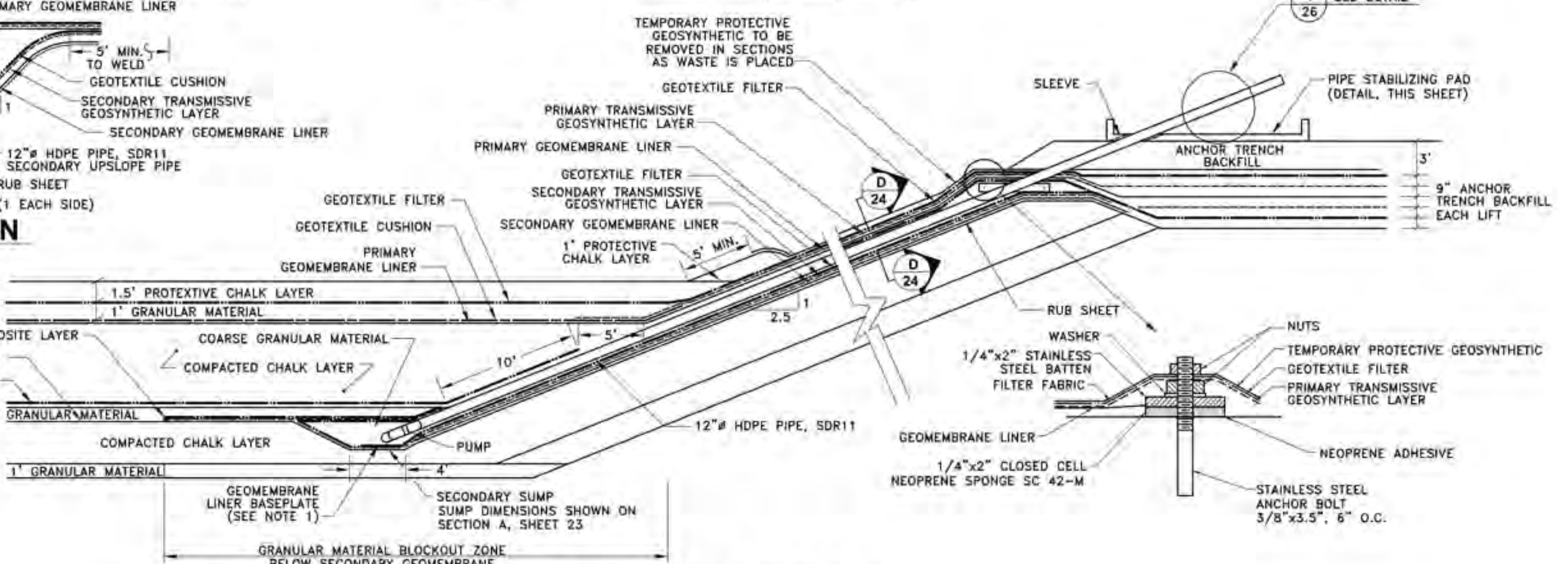
F 24 SECTION
PERFORATED PIPE AND FILTER SYSTEM
NTS



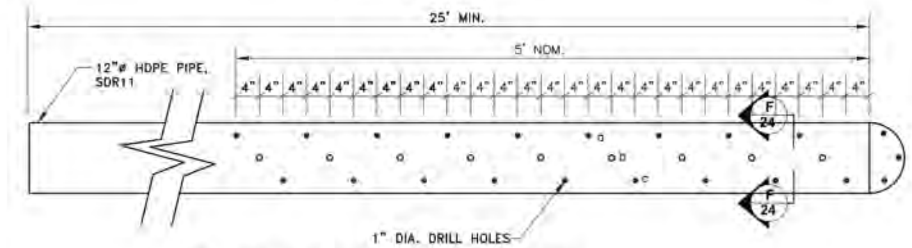
SECONDARY LEACHATE COLLECTION SYSTEM RISER PIPE
SCALE IN FEET 0 1 2



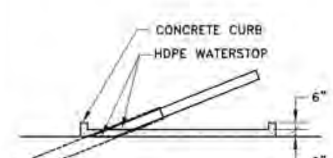
D 24 SECTION
N.T.S.



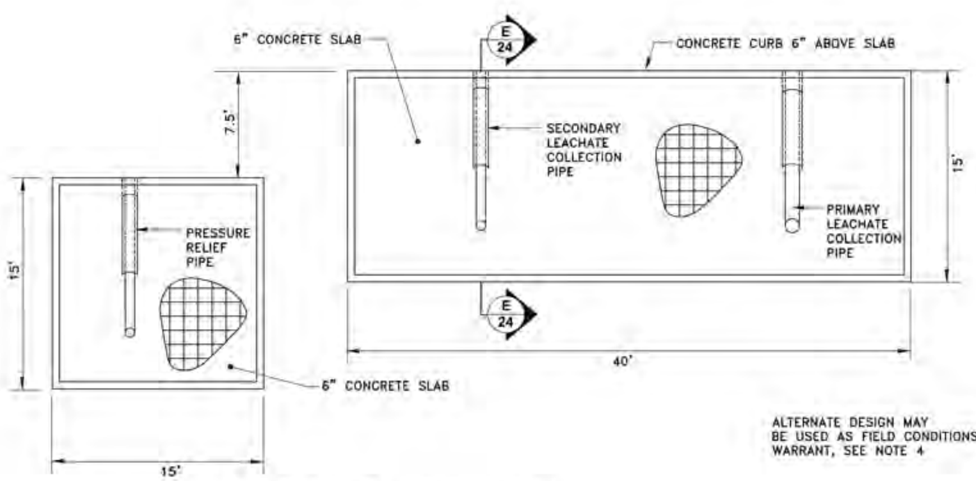
C 24 SECONDARY LEACHATE PIPE CROSS SECTION
SCALE IN FEET 0 5 10



PRESSURE RELIEF SYSTEM RISER PIPE
SCALE IN FEET 0 1 2

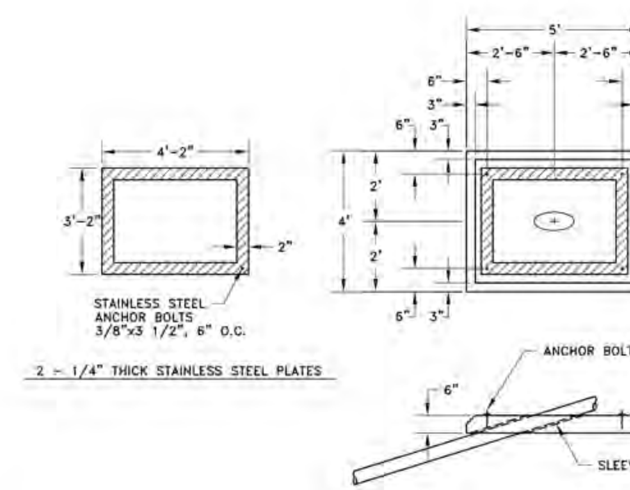


E 24 SECTION
SCALE IN FEET 0 5 10



ALTERNATE DESIGN MAY BE USED AS FIELD CONDITIONS WARRANT, SEE NOTE 4

PIPE STABLIZING PADS
SCALE IN FEET 0 5 10



BATTEN PAD DETAIL
SCALE IN FEET 0 2 4

NOTES:

1. GEOMEMBRANE LINER BASE PLATE IN THE SECONDARY IS REQUIRED TO PROTECT THE SECONDARY LINER. THE BASE PLATE SHALL HAVE A MINIMUM THICKNESS OF 0.5 INCHES. THE BASE PLATE MAY BE CONSTRUCTED OF SEVERAL LAYERS OF HDPE LINER WELDED TOGETHER.
2. SECTION LOCATIONS SHOWN ON DRAWING NO. 00-200-223.
3. UPSLOPE RISER PIPES WILL BE SUPPORTED DURING OPERATION BY COUNTER WEIGHT SYSTEM ON DRAWING NO. 00-200-226.
4. SEE DETAIL D/27 ON SHEET 27 FOR ALTERNATE PIPE STABILIZING PAD DETAILS.

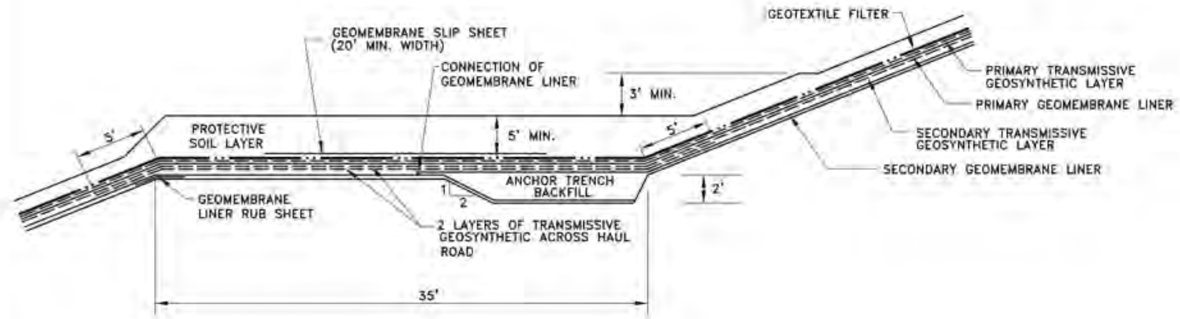
ALABAMA REGISTERED PROFESSIONAL ENGINEER
7/22/10

REV	DATE	DESCRIPTION	DR BY	APP BY
4	12/09	REVISED STRUCTURAL FILL AND EXCAVATED CHALK SURFACE	KJC	AS
3	2/95	REVISE PIPE PAD DETAILS	RMS	
2	10/94	REVISE NOTES, EMBED PRESSURE INLET PIPE 3', & PIPE PADS	RMS	
1	1/94	GENERAL REVISION TO SECTIONS A, B, C & D	RCA	

SCALE: AS SHOWN
FILE NO. 824-1308
PROJECT NO. 933-3600
PROJECT: EMELLE FACILITY
DES BY T.L.R. 10/93
DR BY T.L.R. 10/93
CHK BY JEF 10/29/93
REV BY WRS 10/29/93
SHEET TITLE: TYPICAL MISCELLANEOUS DETAILS (SHEET 2 OF 5)
SHEET 24 OF 27
DRAWING NO. 00-200-224

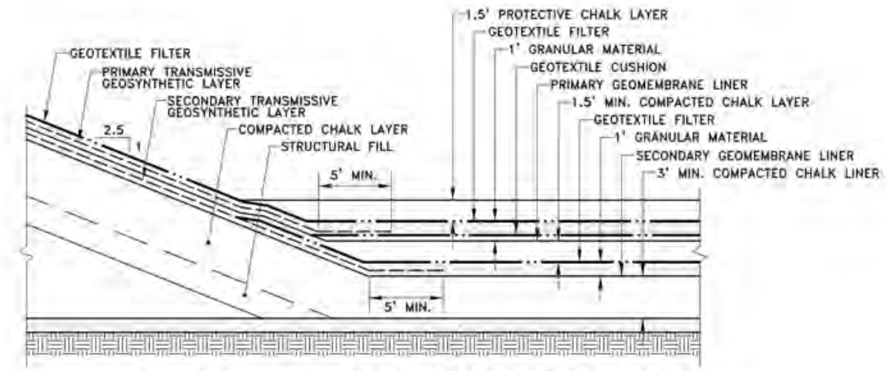
Atlanta, Georgia
Golder Associates

Chemical Waste Management, Inc.



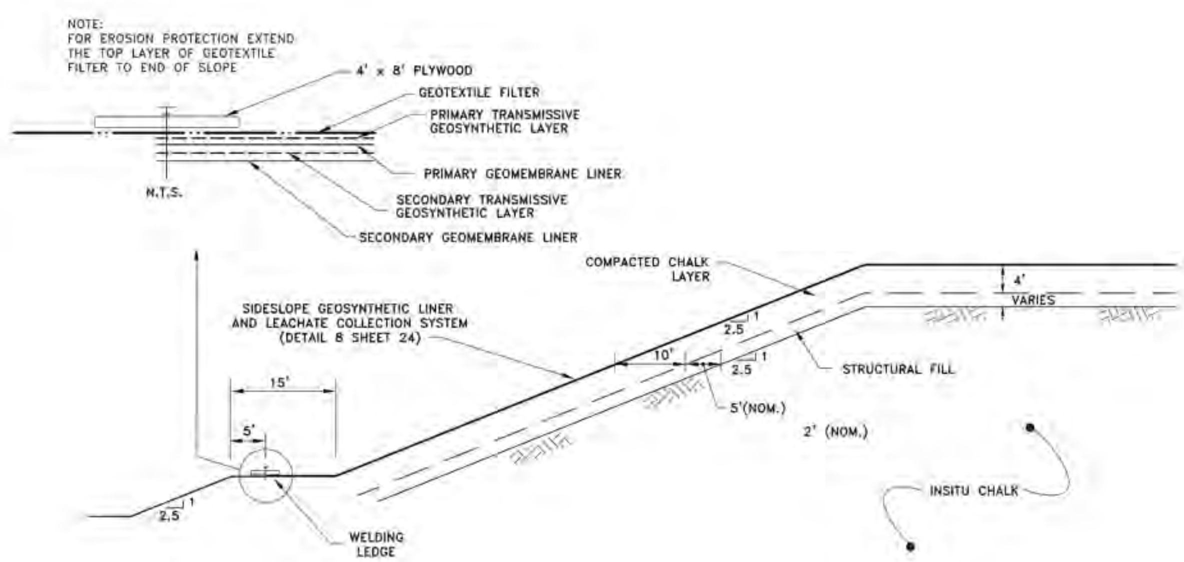
TYPICAL HAUL ROAD ANCHOR TRENCH

SCALE IN FEET
0 5 10



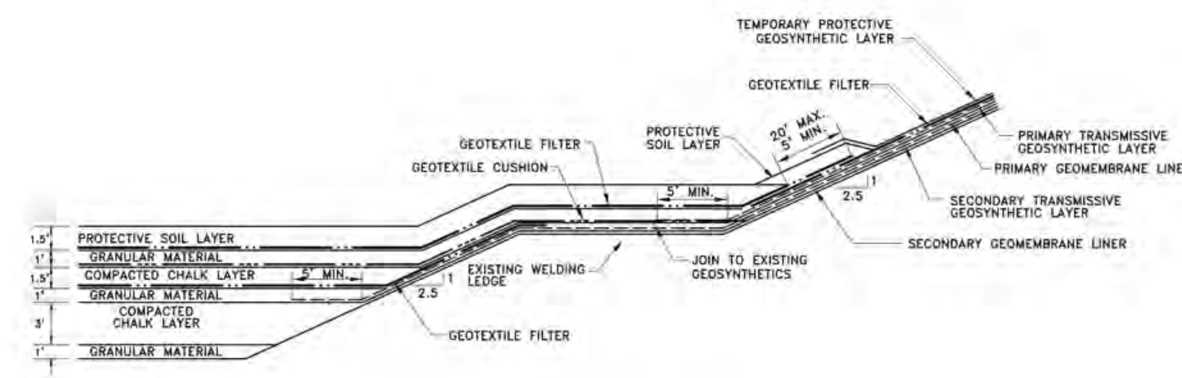
FLOOR AND SLOPE INTERSECTION DETAIL

SCALE IN FEET
0 5 10



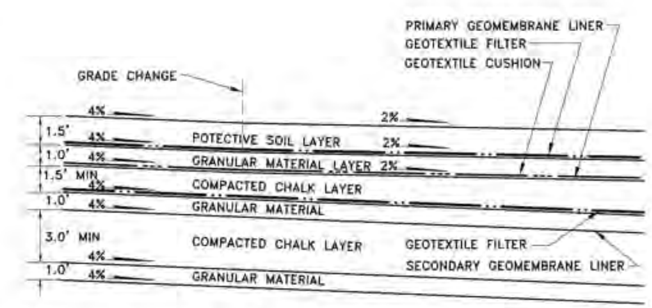
INTERCELL BERM ANCHOR

SCALE IN FEET
0 10 20



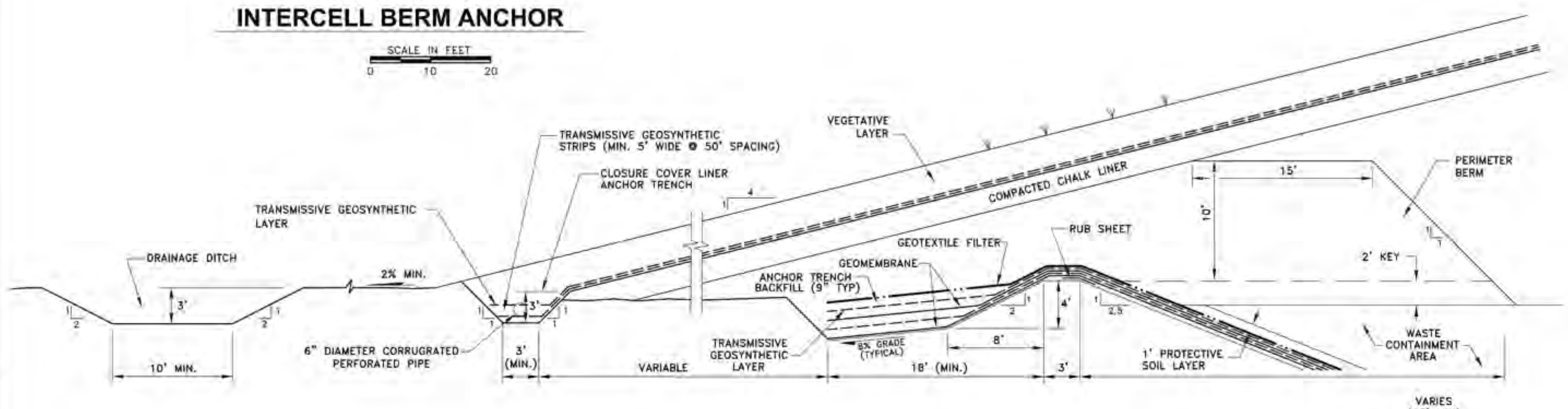
INTERCELL BERM SYNTHETIC CONNECTION

SCALE IN FEET
0 5 10



TYPICAL LINER AND LEACHATE COLLECTION SYSTEM

SCALE IN FEET
0 4 8



TYPICAL PERIMETER ANCHOR TRENCHES DETAIL (TRENCHES 22, 23 AND 24)

SCALE IN FEET
0 5 10

ALABAMA REGISTERED PROFESSIONAL ENGINEER WILLIAM R. SOLLIS
7/22/10

REV.	DATE	DESCRIPTION	DR. BY	APP. BY
3	12/09	REVISED STRUCTURAL FILL AND EXCAVATED CHALK SURFACE	RJC	AS
2	10/94	REVISE NOTES, ADD DETAIL	RWS	
1	1/94	ADDED GEOTEXTILE FILTER ABOVE GRANULAR MATERIAL IN SECONDARY LEACHATE COLLECTION SYSTEM	WMC	

SCALE: AS SHOWN
FILE NO. 824-1308
PROJECT NO. 933-3553
PROJECT: EMELLE FACILITY

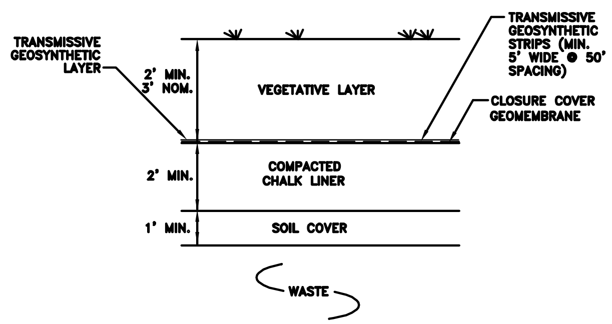
DES. BY	T.L.R.	10/93
DR. BY	T.a.R.	10/93
CHK. BY	JEF	10/29/93
RVW. BY	WRS	10/29/93

SHEET TITLE: TYPICAL MISCELLANEOUS DETAILS (SHEET 3 OF 5)

Golder Associates
Atlanta, Georgia

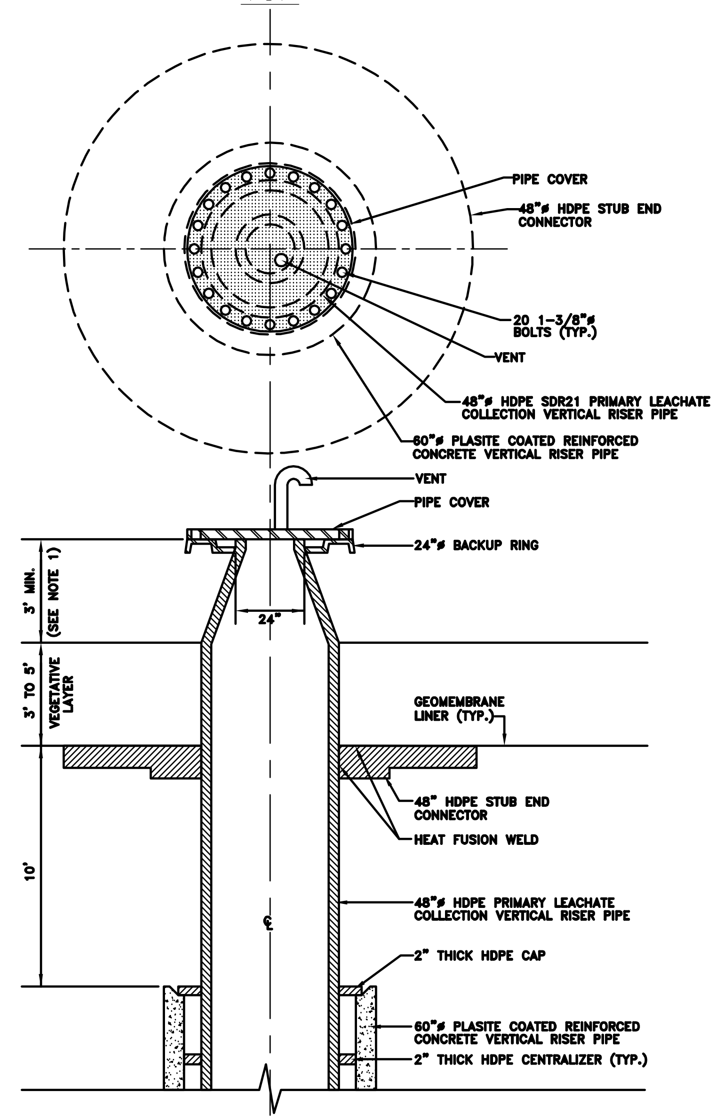
Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 25 OF 27
DRAWING NO. 00-200-225



TYPICAL CLOSURE COVER

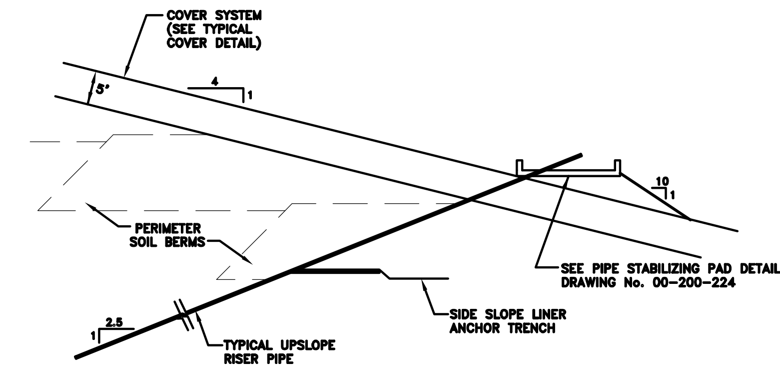
SCALE IN FEET 0 2 4



SECTION

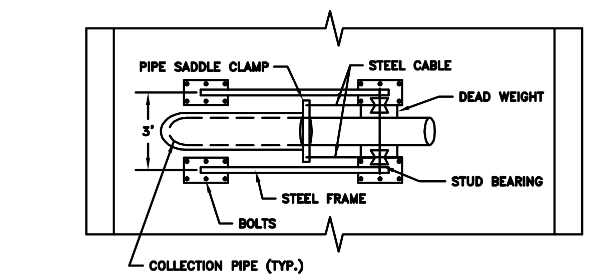
TYPICAL PRIMARY LEACHATE RISER PIPE CLOSURE

SCALE IN FEET 0 2 4

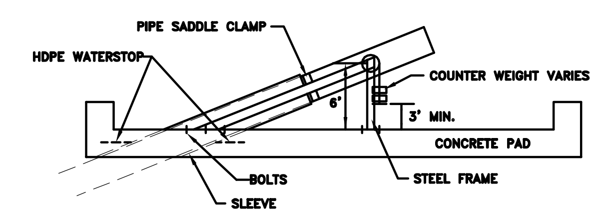


UPSLOPE PIPE CLOSURE COVER

SCALE IN FEET 0 10 20



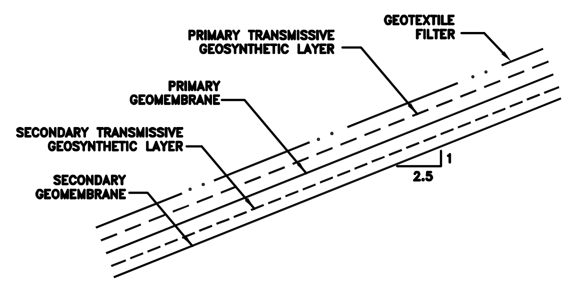
PLAN VIEW



ELEVATION VIEW

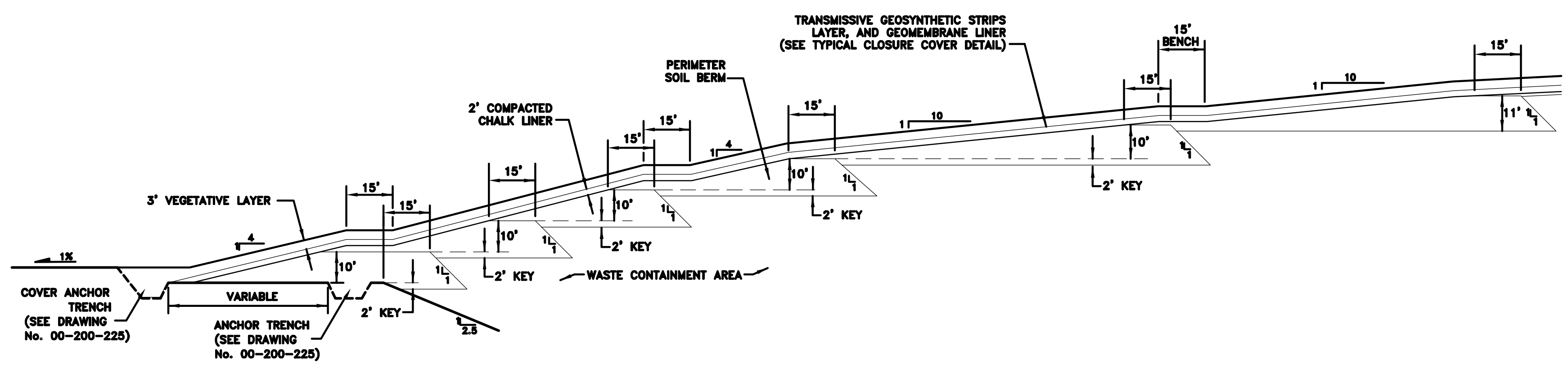
A 26 COLLECTION PIPE COUNTER WEIGHT SYSTEM DETAILS

N.T.S.



TYPICAL SIDESLOPE GEOSYNTHETIC LAYERING

N.T.S.



TYPICAL PERIMETER BERM DETAIL

SCALE IN FEET 0 20 40

NOTE:

1. HDPE REDUCER SECTION AND PIPE COVER WILL NOT BE PLACED UNTIL AFTER POST-CLOSURE CERTIFICATION.
2. SEE DETAIL A/27 ON SHEET 27 FOR ALTERNATE COLLECTION PIPE COUNTER WEIGHT SYSTEM DETAILS.

Permit Drawing Rev. 12.0

REV.	DATE	DESCRIPTION	DR BY	APP BY
3	2/95	REVISED VERTICAL AND UPSLOPE RISER PIPE DETAILS	RMS	
2	10/94	REVISED NOTES	RMS	JEF
1	1/94	REVISED RISER PIPE CLOSURE; ADDED COUNTER WEIGHT DETAIL	WME	WRS

SCALE: AS SHOWN
FILE NO. 824-1308
DES BY JEF 10/93
DR BY WME 10/93
CHK BY JEF 10/29/93
APP BY WRS 10/29/93
PROJECT NO. 933-3553
PROJECT: EMELLE FACILITY
SHEET TITLE: TYPICAL MISCELLANEOUS DETAILS (SHEET 4 OF 5)

NO.	DATE	DESCRIPTION OF REVISION
4.0	03-15-15	2015 PART B PERMIT RENEWAL
3.3	11-12-10	FINAL-RCRA PART B APPN RENEWAL
3.0	05-01-09	PART B APPLICATION RENEWAL-2009
2.0	03-25-02	PART B APPLICATION RENEWAL-2002

JACOBS

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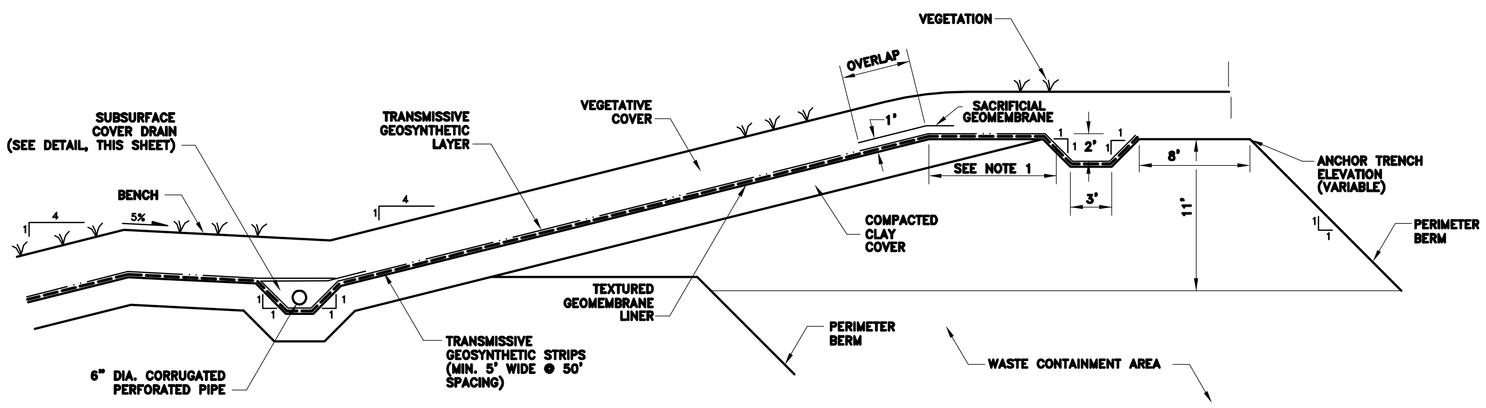
Atlanta, Georgia

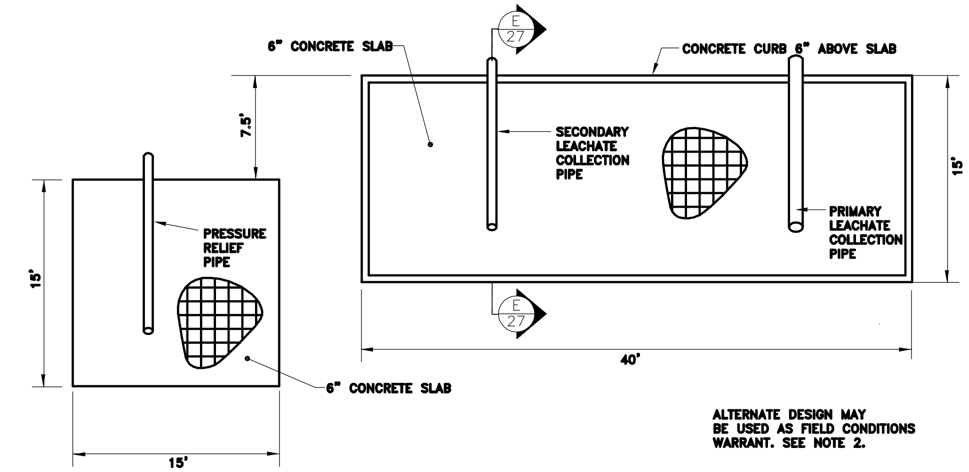
Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 26 OF 27
DRAWING NO. 00-200-226



DETAIL OF OPTIONAL TEMPORARY ANCHOR TRENCH IN COVER

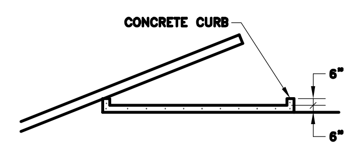
SCALE IN FEET 0 5 10



ALTERNATE DESIGN MAY BE USED AS FIELD CONDITIONS WARRANT. SEE NOTE 2.

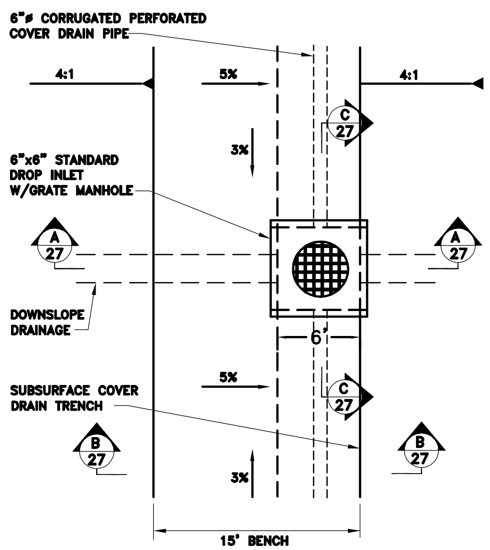
D / 27 ALTERNATE PIPE STABILIZING PAD DETAILS

SCALE IN FEET 0 5 10



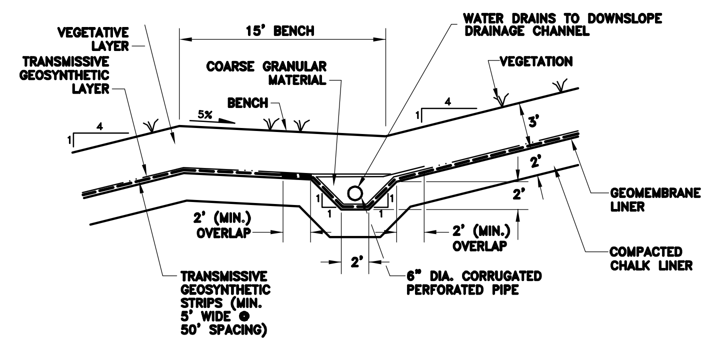
E / 27 SECTION

SCALE IN FEET 0 5 10



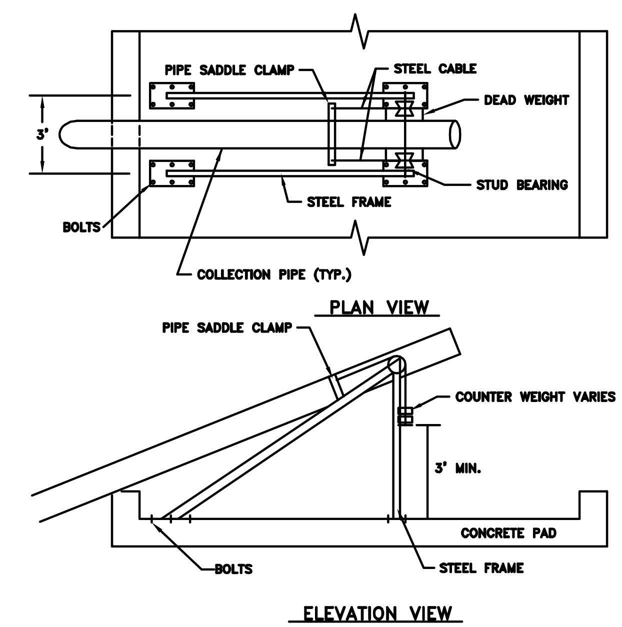
TERRACE – DOWNSLOPE PIPE INTERSECTION PLAN VIEW

SCALE IN FEET 0 5 10



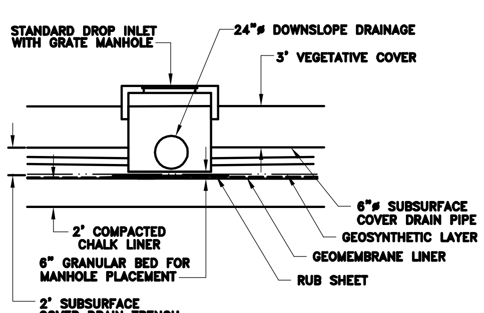
B / 27 TYPICAL SUBSURFACE COVER DRAIN

SCALE IN FEET 0 5 10



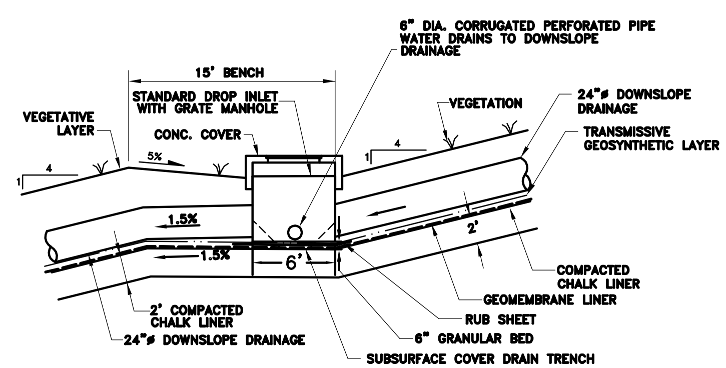
F / 27 ALTERNATE COLLECTION PIPE COUNTER WEIGHT SYSTEM DETAILS

N.T.S.



C / 27 TYPICAL CROSS SECTION THROUGH SUBSURFACE COVER DRAIN TRENCH CELLS 3 AND 4

SCALE IN FEET 0 5 10



A / 27 TYPICAL CROSS SECTION THROUGH DOWNSLOPE PIPE CELLS 3 AND 4

SCALE IN FEET 0 5 10

MATERIAL SPECIFICATIONS

1. For specifications related to soil layers, vegetative cover, geomembranes, and geosynthetic materials, see Appendix D-6-1-4, Landfill Design Report.

NOTES:

1. Prior to continuation of cover system above the temporary anchor trench, the vegetative cover will be removed to expose the sacrificial geomembrane. Next, hand excavation will be used to locally expose the geosynthetic components in the cover. The geosynthetic components will be removed where they cross the compacted chalk liner and placement of the final cover will resume. Geosynthetic components will be connected by welding of the geomembrane and overlapping drainage layers per specifications.
2. See sheet 24 for pipe stabilizing pad details.

Permit Drawing Rev. 12.0

REV.	DATE	DESCRIPTION	DR BY	APP BY
3	3/95	ADDED ALTERNATE PIPE PAD DETAILS	TsR	
2	11/94	REVISE ANCHOR TRENCH DETAIL	RMS	
1	10/94	REVISE NOTES, ADD COVER DRAIN DETAILS, REVISE ANCHOR TRENCH DETAIL	RMS	

SCALE: AS SHOWN
FILE NO. 824-1308
DES BY JEF 10/93
DR BY WME 10/93
CHK BY
APP BY
PROJECT NO. 933-3553
PROJECT: EMELLE FACILITY
SHEET TITLE: TYPICAL MISCELLANEOUS DETAILS (SHEET 5 OF 5)

NO.	DATE	DESCRIPTION OF REVISION
4.0	03-15-15	2015 PART B PERMIT RENEWAL
3.3	11-12-10	FINAL-RCRA PART B APPN RENEWAL
3.0	05-01-09	PART B APPLICATION RENEWAL-2009
2.0	03-25-02	PART B APPLICATION RENEWAL-2002

JACOBS

Golder Associates
Atlanta, Georgia

Chemical Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 27 OF 27
DRAWING NO. 00-200-227

APPENDIX D-6-2

LANDFILL DESIGN DRAWINGS

FOR TRENCH 23

RCRA PART B PERMIT APPLICATION
APPENDIX D-6-2 LANDFILL DESIGN DRAWINGS
FOR TRENCH 23

EMELLE TREATMENT FACILITY

36964 AL HWY. 17
SUMTER COUNTY
EMELLE, ALABAMA 35459

Terracon Project # EJ147410

SITE LOCATION
Latitude 32° 47' 16.05" N
Longitude 88° 18' 46.64" W

PREPARED FOR

CHEMICAL WASTE MANAGEMENT

P.O. BOX 55
36964 AL. HIGHWAY 17
EMELLE, ALABAMA 35459

PREPARED BY

Terracon
Consulting Engineers and Scientists

4040 ROYAL DRIVE; SUITE 100
KENNESAW, GA 30144
PH: 770.924.9799 FAX: 770.924.7866

VICINITY MAP

LOCATION MAP
N.T.S.

SUBMITTAL			
SUBMITTAL #	DATE	SHEET #	DESCRIPTION
A	3/17/2015	ALL	SUBMITTAL TO ADEM

REVISIONS			
REVISION #	DATE	SHEET #	DESCRIPTION

Sheet List Table

Sheet Number	Sheet Title
00-300-001	COVER SHEET
00-300-002	OVERALL SITE PLAN
00-300-003	EXCAVATED CELL PLAN
00-300-004	PRIMARY LINER SYSTEM PLAN
00-300-005	COMPLETED CELL PLAN
00-300-006	FINAL COVER & STORMWATER MANAGEMENT PLAN
00-300-007	LINER SYSTEM DETAILS
00-300-008	LEACHATE SYSTEM DETAILS - I
00-300-009	LEACHATE SYSTEM DETAILS - II
00-300-010	FINAL COVER & STORMWATER MANAGEMENT DETAILS
00-300-011	MISCELLANEOUS DETAILS
00-300-012	TRENCH 23 PROFILES

COVER SHEET
EMELLE FACILITY
36964 AL. HIGHWAY 17
EMELLE, SUMTER COUNTY, ALABAMA

DESIGNED BY:	JEA / RSG
DRAWN BY:	JEA
APPVD. BY:	RSG / MAK
JOB NO.	EJ147410

DRAWING
00-300-001

SCALE IN FEET: 300 0 300 600

NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.
2. BOUNDARY SURVEY BY ETI FOR CHEMICAL WASTE MANAGEMENT, REVISION DATE SEPTEMBER 1994.
3. WELL SMBG01 SHALL BE ABANDONED BEFORE CONSTRUCTION OF TRENCH 23, CELL 1.
4. STORMWATER FOR TRENCH 23 DIRECTED TO SEDIMENT BASIN 6 AS INDICATED ON SHEET 011.

LEGEND:

- EXISTING SEDIMENT BASIN
- PROPERTY LINE
- ROAD CENTERLINE
- PRIMARY LINER LIMIT
- TRENCH CELL DIVISION
- SMBG01 — EXISTING SHALLOW WELL (SEE NOTE 3)
- P-26 — LEACHATE FORCEMAIN JUNCTION VAULT

REV (R) SUB (S)	DATE	BY	DESCRIPTION
(S) A	3/17/2015	JEA	SUBMITTAL TO ADEM

Terracon
Consulting Engineers and Scientists
4040 ROYAL DRIVE STE 100 KENNESAW, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

WASTE MANAGEMENT
36964 AL. HIGHWAY 17 EMELLE, ALABAMA 35459

2/19/2015

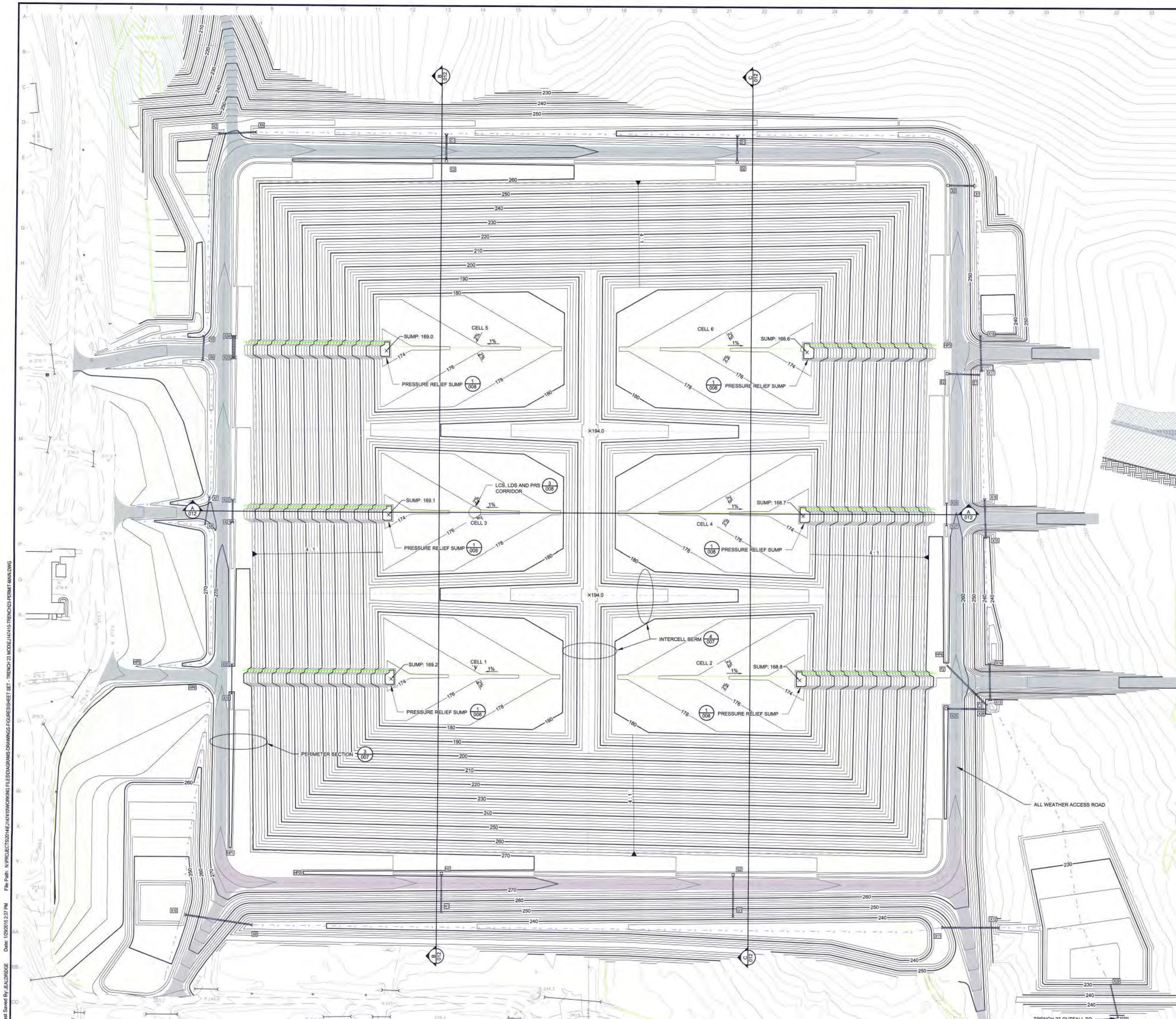
OVERALL SITE PLAN

EMELLE FACILITY
36964 AL. HIGHWAY 17
EMELLE, SUMTER COUNTY, ALABAMA

DESIGNED BY:	JEA / RSG
DRAWN BY:	JEA
APPVD. BY:	RSG / MAK
JOB NO.	EJ147410

DRAWING

00-300-002



SCALE IN FEET

NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.
2. SEE SHEET 006 FOR STORMWATER MANAGEMENT PLAN. SEE SHEET 011 FOR STORMWATER MANAGEMENT PIPE CHART.
3. GRADES SHOWN OUTSIDE THE SYNTHETIC LINER ANCHOR REPRESENT TOP OF FINAL GRADES (INCLUDING FINAL PAVING OR CHANNEL LINING MATERIALS).

LEGEND:

- PROPERTY LINE
- ROAD CENTERLINE
- PRIMARY LINER LIMIT
- TRENCH CELL DIVISION
- ALL-WEATHER ACCESS ROAD
- STORMWATER FLOW & DIRECTION
- PRESSURE RELIEF SYSTEM

GRADING KEY

REV (R) SUB (S)	DATE	BY	DESCRIPTION
(S) A	3/17/2015	JEA	SUBMITTAL TO ADEM

Terracon
Consulting Engineers and Scientists
4040 ROYAL DRIVE STE 100 KENNESAW, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

WASTE MANAGEMENT
36964 AL. HIGHWAY 17 EMELLE, ALABAMA 35459

2/19/2015

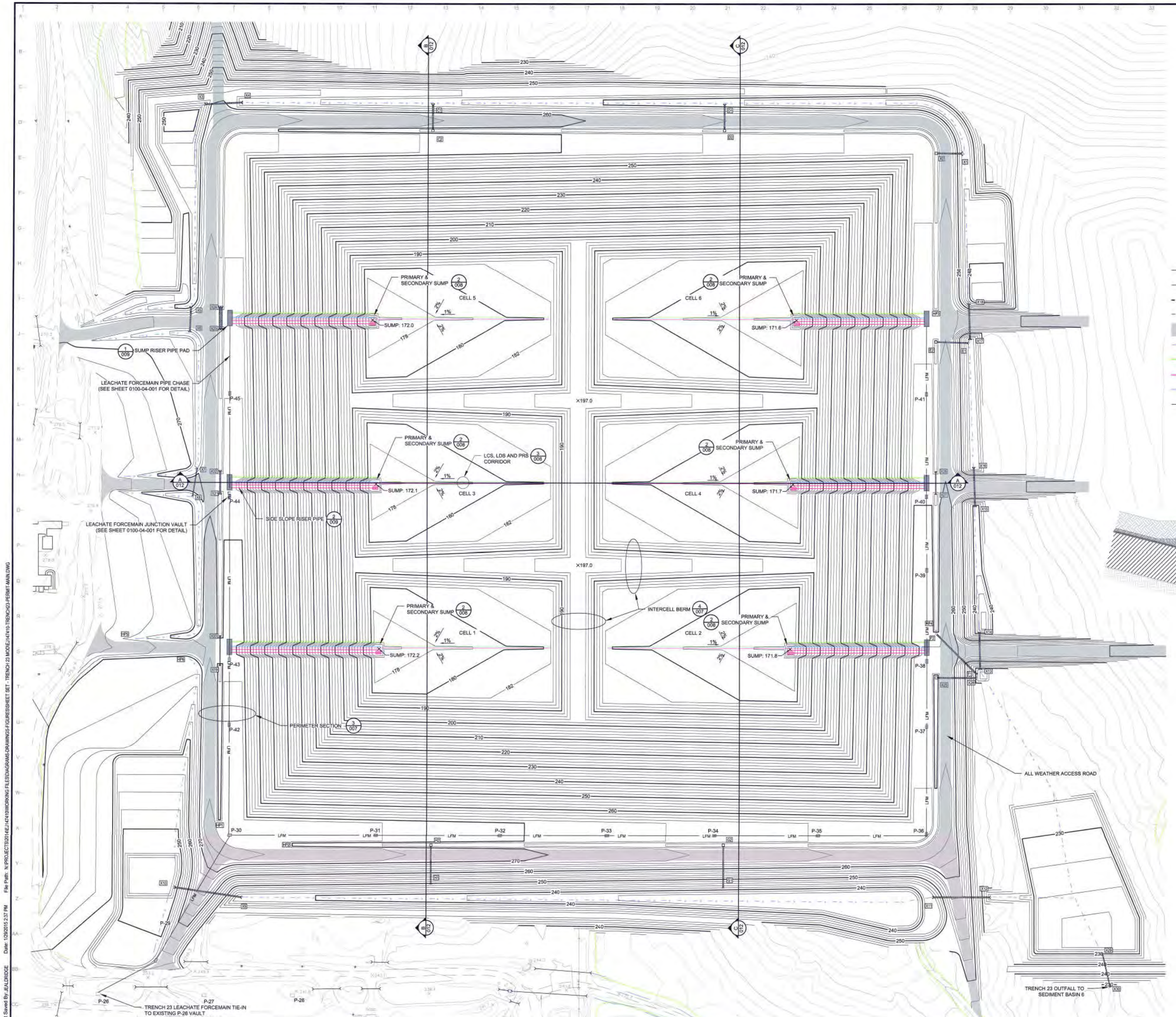
EXCAVATED CELL PLAN

EMELLE FACILITY
36964 AL. HIGHWAY 17
EMELLE, SUMTER COUNTY, ALABAMA

DESIGNED BY:	JEA / RSG
DRAWN BY:	JEA
APPVD. BY:	RSG / MAK
JOB NO.	EJ147410

DRAWING

00-300-003



100 0 100 200

SCALE IN FEET

NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.
2. SEE SHEET 006 FOR STORMWATER MANAGEMENT PLAN. SEE SHEET 011 FOR STORMWATER MANAGEMENT PIPE CHART.
3. GRADES SHOWN OUTSIDE THE SYNTHETIC LINER ANCHOR REPRESENT TOP OF FINAL GRADES (INCLUDING FINAL PAVING OR CHANNEL LINING MATERIALS).
4. OPTIONAL STORMWATER SEPARATION BERM MAY BE CONSTRUCTED WITHIN EACH CELL BASED ON OPERATIONAL NEEDS. SEE DETAIL 6/007 ON SHEET 007 FOR ADDITIONAL INFORMATION.

LEGEND:

- PROPERTY LINE
- ROAD CENTERLINE
- PRIMARY LINER LIMIT
- TRENCH CELL DIVISION
- ALL-WEATHER ACCESS ROAD
- STORMWATER FLOW & DIRECTION
- PRESSURE RELIEF SYSTEM
- PRIMARY LEACHATE SYSTEM
- SECONDARY LEACHATE SYSTEM
- LFM — LEACHATE FORCEMAIN
- SUMP RISER PIPE PAD
- P-40 LEACHATE FORCEMAIN JUNCTION VAULT

GRADING KEY

REV (R) SUB (S)	DATE	BY	DESCRIPTION
(S) A	3/17/2015	JEA	SUBMITTAL TO ADEM

Terracon
Consulting Engineers and Scientists
4040 ROYAL DRIVE STE 100 KENNESAW, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

WM WASTE MANAGEMENT
36964 AL. HIGHWAY 17 EMELLE, ALABAMA 35459

2/19/2015

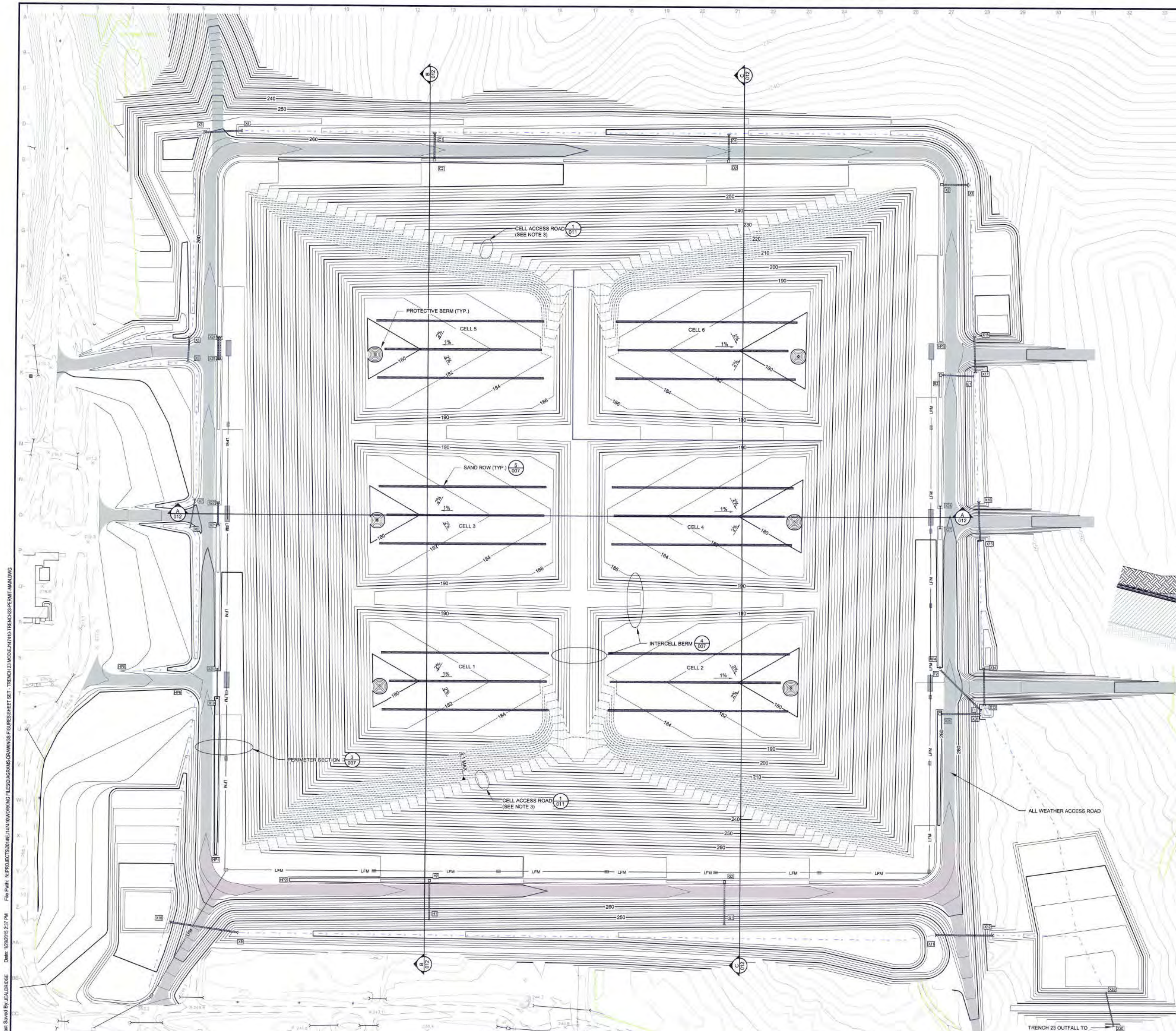
PRIMARY LINER SYSTEM PLAN

EMELLE FACILITY
36964 AL. HIGHWAY 17
EMELLE, SUMTER COUNTY, ALABAMA

DESIGNED BY:	JEA / RSG
DRAWN BY:	JEA
APPVD. BY:	RSG / MAK
JOB NO.	EJ147410

DRAWING

00-300-004



SCALE IN FEET

NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.
2. SEE SHEET 006 FOR STORMWATER MANAGEMENT PLAN. SEE SHEET 011 FOR STORMWATER MANAGEMENT PIPE CHART.
3. CELL ACCESS ROADS ARE SHOWN FOR GRAPHICAL REPRESENTATION. OPERATION OF EACH CELL MAY REQUIRE ADDITIONAL ROADS FOR MULTIPLE ACCESS POINTS AND ROADS MAYBE RELOCATED FROM THE LOCATIONS SHOWN ON THIS PLAN BASED ON OPERATIONAL NEEDS.
4. GRADES SHOWN OUTSIDE THE SYNTHETIC LINER ANCHOR REPRESENT TOP OF FINAL GRADES (INCLUDING FINAL PAVING OR CHANNEL LINING MATERIALS).
5. OPTIONAL STORMWATER SEPARATION BERM MAY BE CONSTRUCTED WITHIN EACH CELL BASED ON OPERATIONAL NEEDS. SEE DETAIL 6/007 ON SHEET 007 FOR ADDITIONAL INFORMATION.

LEGEND:

- PROPERTY LINE
- ROAD CENTERLINE
- PRIMARY LINER LIMIT
- TRENCH CELL DIVISION
- ALL-WEATHER ACCESS ROAD
- STORMWATER FLOW WITH DIRECTION
- LEACHATE FORCEMAIN
- SUMP RISER PIPE PAD
- P-40 LEACHATE FORCEMAIN JUNCTION VAULT
- SAND ROW
- CELL ACCESS GRADES (SEE NOTE 3)

GRADING KEY

REV (R) SUB (S)	DATE	BY	DESCRIPTION
(S) A	3/17/2015	JEA	SUBMITTAL TO ADEM

Terracon
Consulting Engineers and Scientists
4040 ROYAL DRIVE STE 100 KENNESAW, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

WM WASTE MANAGEMENT
36964 AL. HIGHWAY 17 EMELLE, ALABAMA 35459

2/19/2015

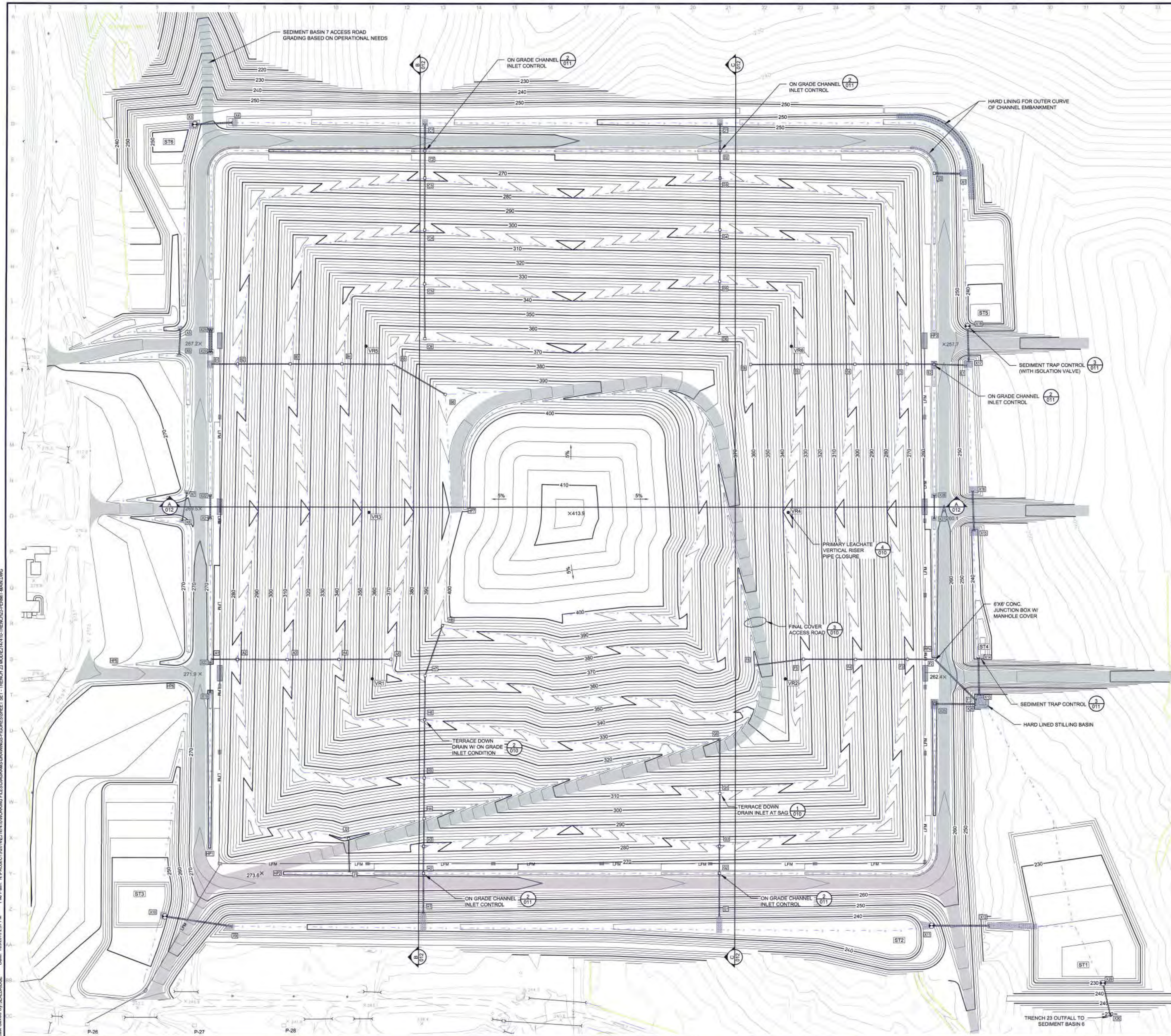
COMPLETED CELL PLAN

EMELLE FACILITY
36964 AL. HIGHWAY 17
EMELLE, SUMTER COUNTY, ALABAMA

DESIGNED BY:	JEA / RSG
DRAWN BY:	JEA
APPVD. BY:	RSG / MAK
JOB NO.	EJ147410

DRAWING

00-300-005



SCALE IN FEET

NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.
2. SEE SHEET 011 FOR STORMWATER MANAGEMENT PIPE CHART AND CHANNEL LINING CHART.
3. STORMWATER FOR TRENCH 23 IS DIRECTED TO SEDIMENT BASIN 6 NPDES PERMIT AL0050580.
4. ALL SEDIMENT TRAPS SHALL HAVE VEGETATIVE LINING FOR REMOVING SEDIMENT WITH HEAVY EQUIPMENT.
5. ALL INLETS FOR CULVERTS OUTSIDE OF SEDIMENT TRAPS SHALL HAVE INLET PROTECTION.
6. ALL PIPE OUTLETS SHALL HAVE HARD LINING OUTLET PROTECTION.

LEGEND:

Symbol	Description
	ALL-WEATHER ACCESS ROAD
	STORMWATER FLOW & DIRECTION
LFM	LEACHATE FORCEMAIN
	SUMP RISER PIPE PAD
P-40	LEACHATE FORCEMAIN JUNCTION VAULT
	ISOLATION VALVE
X1 TO X30	PERIMETER DRAINAGE SYSTEM
A1 TO J2	FINAL COVER DRAINAGE SYSTEM
HP1 TO HP4	CHANNEL REACH HIGH POINT
ST1 TO ST6	UPSTREAM SEDIMENT TRAP
VR1 TO VR6	PRIMARY LEACHATE VERTICAL RISER
	HARD LINING FOR CHANNEL PROTECTION, INLET& OUTLET PROECTION, SLOPE STABILITY. SEE SHEET 011 FOR PERMISSIBLE HARD LINING MATERIALS

REV (R) SUB (S)	DATE	BY	DESCRIPTION
(S) A	3/17/2015	JEA	SUBMITTAL TO ADEM

Terracon
Consulting Engineers and Scientists
4040 ROYAL DRIVE STE 100 KENNESAW, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

WM WASTE MANAGEMENT
36964 AL. HIGHWAY 17 EMELLE, ALABAMA 35459

2/19/2015

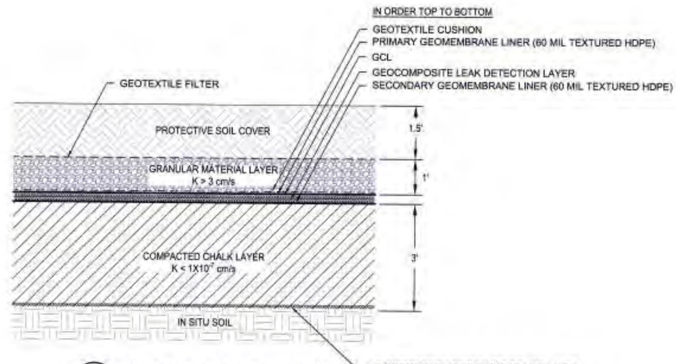
FINAL COVER & STORMWATER MANAGEMENT PLAN

EMELLE FACILITY
36964 AL. HIGHWAY 17
EMELLE, SUMTER COUNTY, ALABAMA

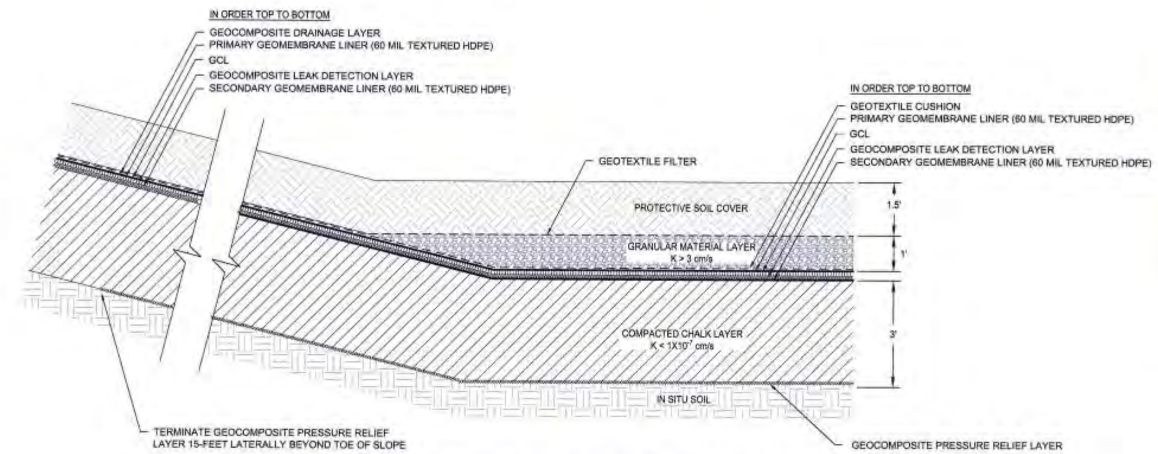
DESIGNED BY:	JEA / RSG
DRAWN BY:	JEA
APPVD. BY:	RSG / MAK
JOB NO.	EJ147410

DRAWING

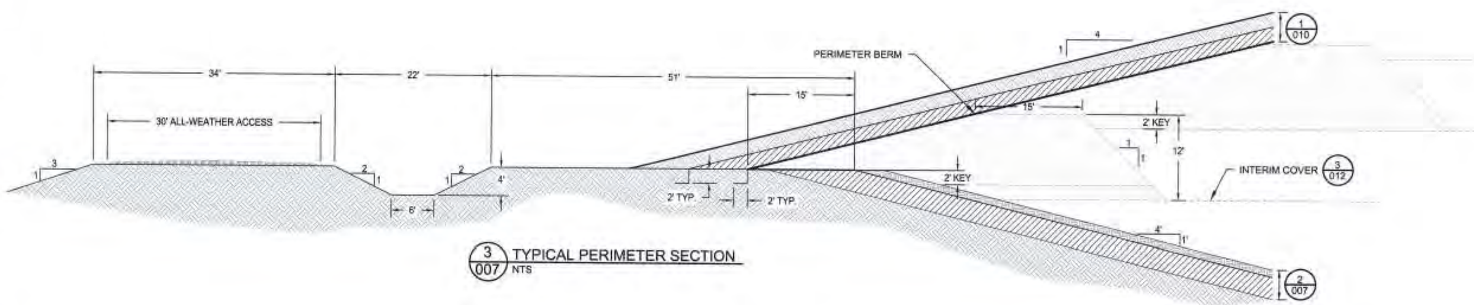
00-300-006



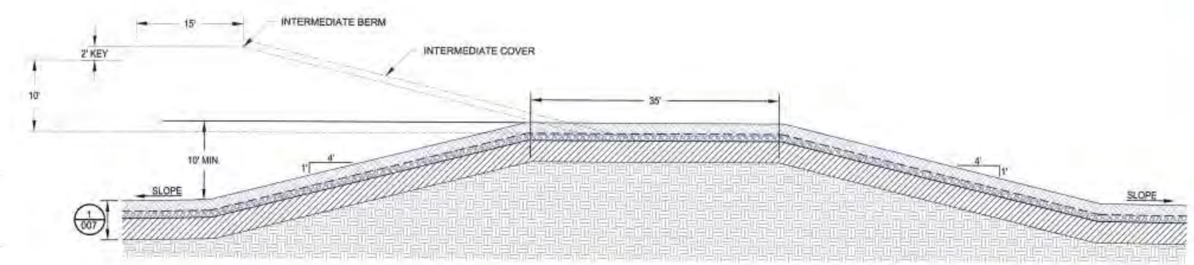
1 / 007 TYPICAL FLOOR LINER DETAIL
NTS



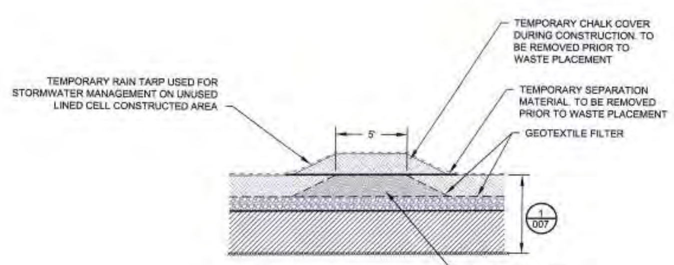
2 / 007 LINER SYSTEM AT FLOOR AND SIDE SLOPE INTERSECTION
NTS



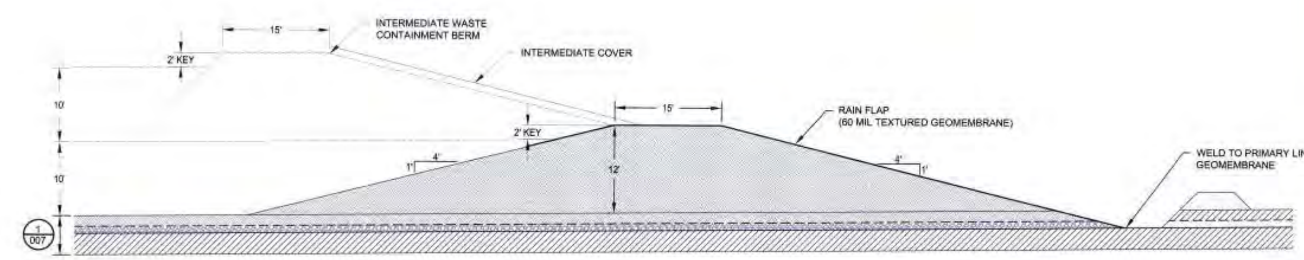
3 / 007 TYPICAL PERIMETER SECTION
NTS



4 / 007 INTERCELL BERM
NTS



5 / 007 SAND ROW
NTS



6 / 007 OPTIONAL STORMWATER SEPARATION BERM
NTS

REV.	DATE	BY	DESCRIPTION
A	3/17/2015	JEA	SUBMITTAL TO ADEM

Terracon
Consulting Engineers and Scientists
4540 ROYAL DRIVE STE 100, KENNESAW, GA 30144
PH. (770) 924-9799 FAX (770) 924-7866

WM WASTE MANAGEMENT
36964 AL. HIGHWAY 17, EMELLE, ALABAMA 35459

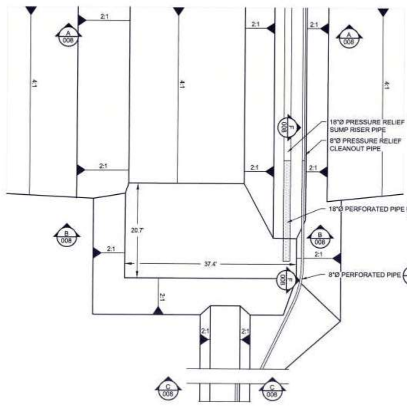
2/19/2015

LINER SYSTEM DETAILS

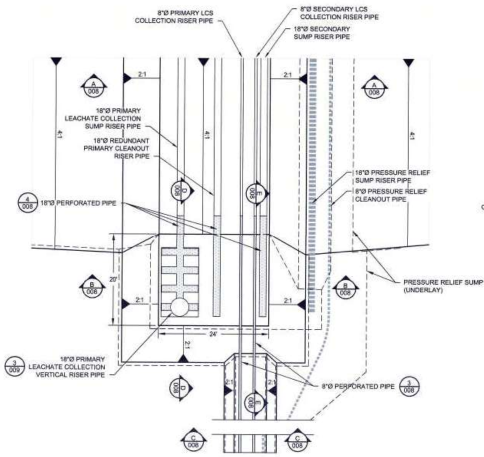
EMELLE FACILITY
36964 AL. HIGHWAY 17
EMELLE, SUMTER COUNTY, ALABAMA

DESIGNED BY:	JEA / RSG
DRAWN BY:	JEA
APPVD. BY:	RSG / MAK
JOB NO.	EJ147410

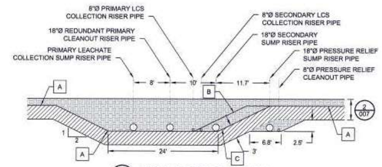
DRAWING
00-300-007



1 PRESSURE RELIEF SUMP PLAN
008 NTS



2 PRIMARY SUMP PLAN
008 NTS



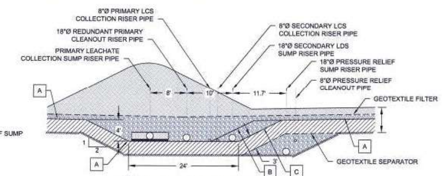
A SIDE SLOPE RISER TRENCH
008 NTS

A
GEOTEXTILE CUSHION
PRIMARY GEOMEMBRANE LINER (60 MIL TEXTURED HDPE)
GCL
GEOCOMPOSITE LEAK DETECTION LAYER
SECONDARY GEOMEMBRANE LINER (60 MIL TEXTURED HDPE)

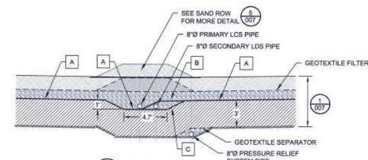
B
GEOTEXTILE CUSHION
PRIMARY GEOMEMBRANE LINER (60 MIL TEXTURED HDPE)
GCL
GEOTEXTILE CUSHION (USE WHEN PRESSURE RELIEF PIPE IS SURROUNDED BY GRANULAR DRAINAGE MATERIAL)

C
GEOCOMPOSITE LEAK DETECTION LAYER
SECONDARY GEOMEMBRANE LINER (60 MIL TEXTURED HDPE)

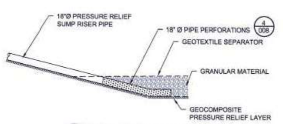
NOTE: 60 MIL TEXTURED RUB SHEET SHALL BE PLACED UNDER ALL SIDE SLOPE RISERS AND SUMP PIPES



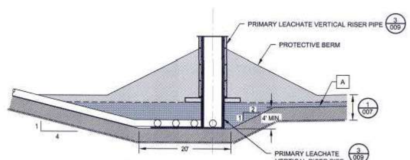
B PRIMARY SUMP SECTION
008 NTS



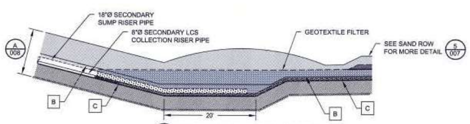
C LCS TRENCH
008 NTS



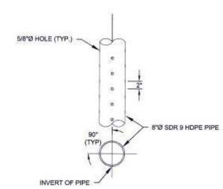
E SECONDARY SUMP SECTION
008 NTS



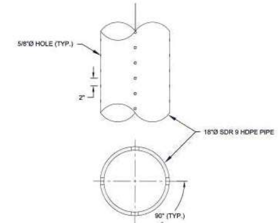
D PRIMARY SUMP SECTION
008 NTS



E SECONDARY SUMP SECTION
008 NTS



3 8"Ø PIPE PERFORATION
008 NTS



4 18"Ø PIPE PERFORATIONS
008 NTS

REV (R) SUB (S)	DATE	BY	DESCRIPTION
(S) A	3/17/2015	JEA	SUBMITTAL TO ADEM

Terracon
Consulting Engineers and Scientists
4040 ROYAL DRIVE STE 100 KENNESAW, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

WM WASTE MANAGEMENT
36964 AL. HIGHWAY 17 EMELLE, ALABAMA 35459

2/19/2015

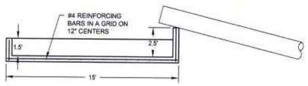
LEACHATE SYSTEM DETAILS - I

EMELLE FACILITY
36964 AL. HIGHWAY 17
EMELLE, SUMTER COUNTY, ALABAMA

DESIGNED BY:	JEA / RSG
DRAWN BY:	JEA
APPVD. BY:	RSG / MAK
JOB NO.	EJ147410

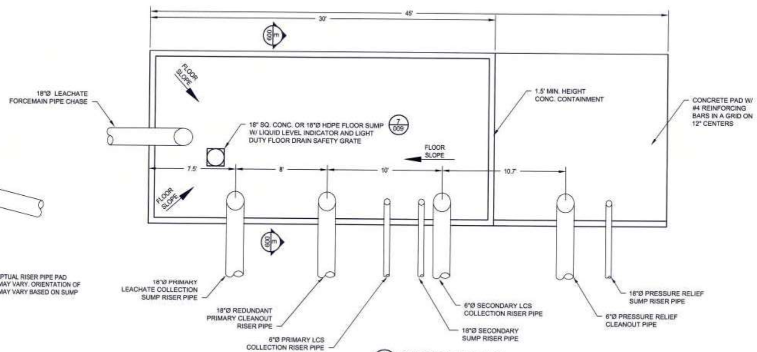
DRAWING
00-300-008

NOTE: RISER PAD MAY BE ENCLOSED WITH AN OPTIONAL CONTAINMENT STRUCTURE AND ROOF BASED ON OPERATIONAL NEEDS.

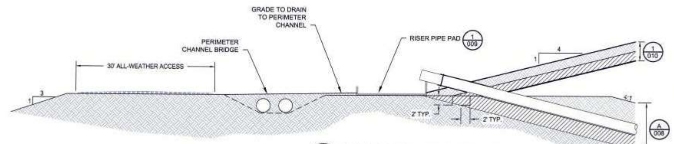


E/009 RISER PIPE PAD SECTION
NTS

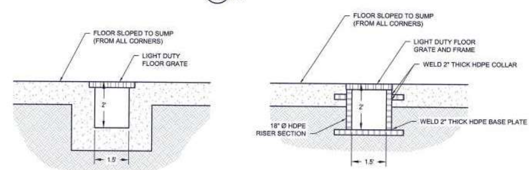
NOTE: CONCEPTUAL RISER PIPE PAD DIMENSIONS MAY VARY. ORIENTATION OF PAD LAYOUT MAY VARY BASED ON SUMP LOCATION.



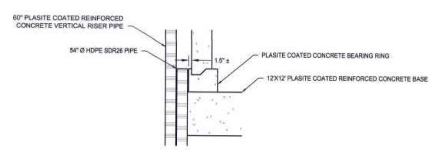
1/009 RISER PIPE PAD PLAN
NTS



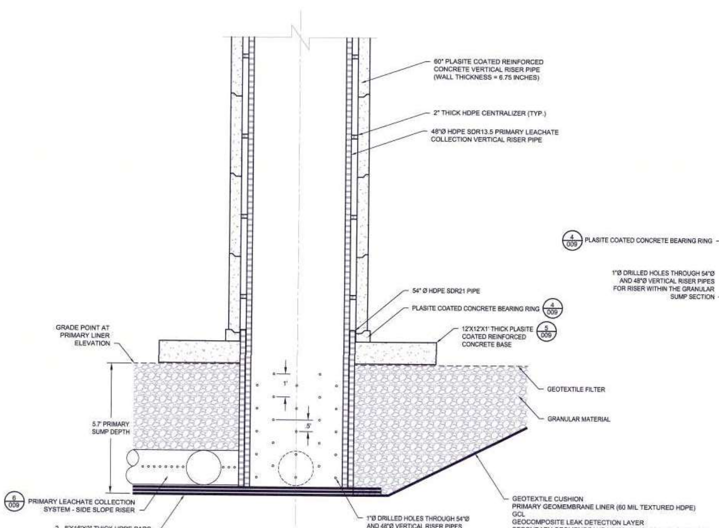
2/009 PRIMARY SIDE SLOPE RISER PIPE
NTS



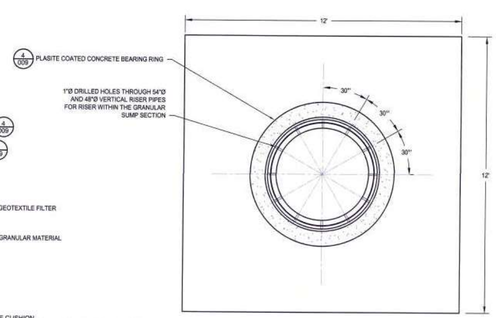
7/009 CONCRETE OR HDPE FLOOR SUMP
NTS



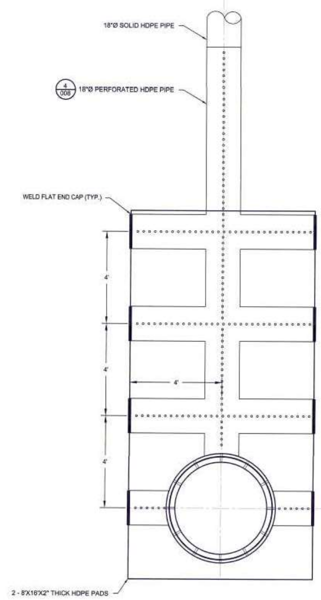
4/009 CONCRETE BEARING RING
NTS



3/009 PRIMARY LEACHATE VERTICAL RISER PIPE
NTS



5/009 CONCRETE BASE
NTS



6/009 PRIMARY LEACHATE COLLECTION SYSTEM - SIDE SLOPE RISER
NTS

REV (R) SUB (S)	DATE	BY	DESCRIPTION
(S) A	3/17/2015	JEA	SUBMITTAL TO ADEM

Terracon
Consulting Engineers and Scientists
4040 ROYAL DRIVE STE 100 KENNESAW, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

WM WASTE MANAGEMENT
36964 AL. HIGHWAY 17 EMELLE, ALABAMA 35459

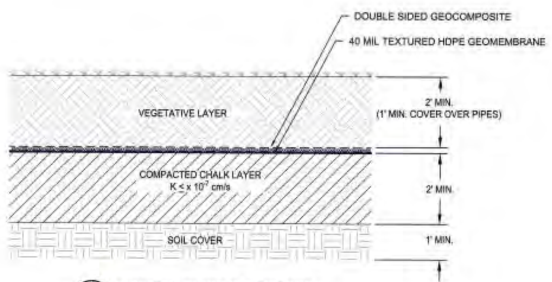
12/9/2015

LEACHATE SYSTEM DETAILS - II

EMELLE FACILITY
36964 AL. HIGHWAY 17
EMELLE, SUMTER COUNTY, ALABAMA

DESIGNED BY:	JEA / RSG
DRAWN BY:	JEA
APPVD. BY:	RSG / MAK
JOB NO.	EJ147410

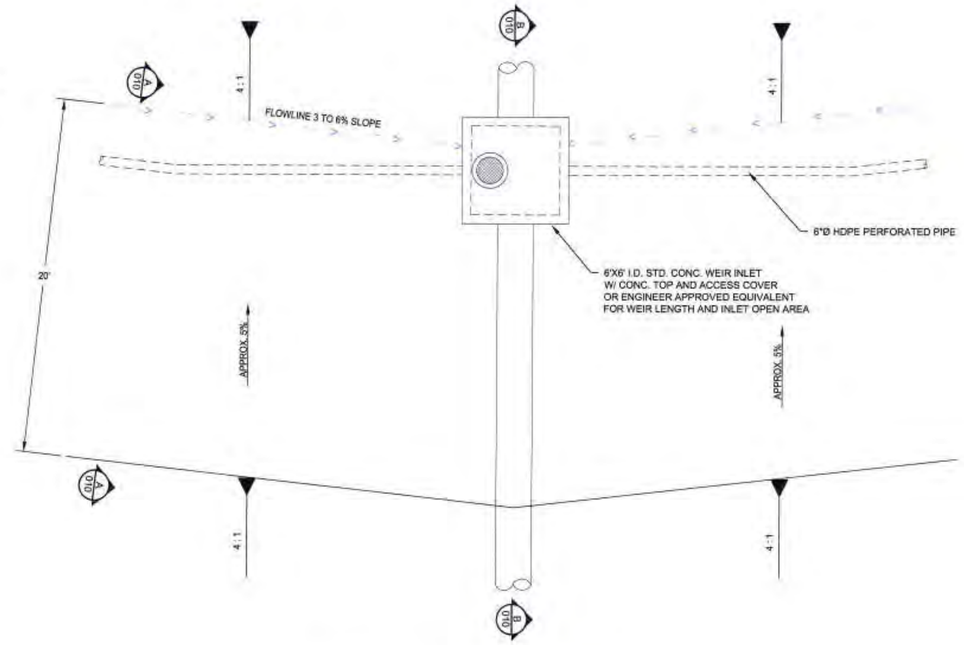
DRAWING
00-300-009



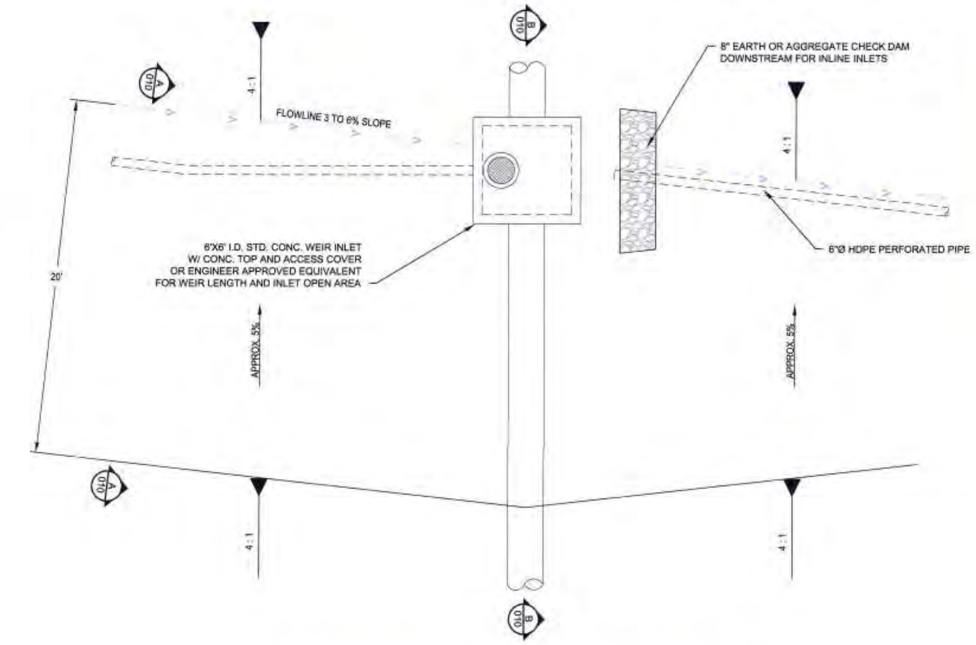
1/010 TYPICAL CLOSURE COVER
NTS

NOTE:

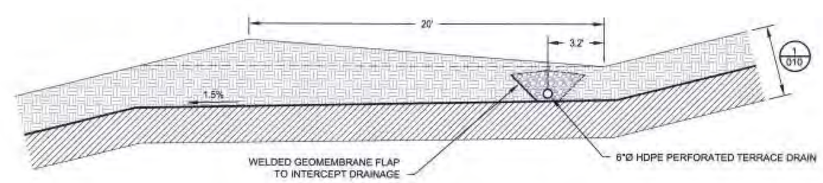
1. THE FINAL COVER GEOCOMPOSITE DRAINAGE LAYER AND TEXTURED GEOMEMBRANE LINER MAY BE SUBSTITUTED WITH A 50 MIL STRUCTURED GEOMEMBRANE WITH AN INTEGRATED DRAINAGE LAYER AND OVERLAIN BY A GEOTEXTILE FILTER.



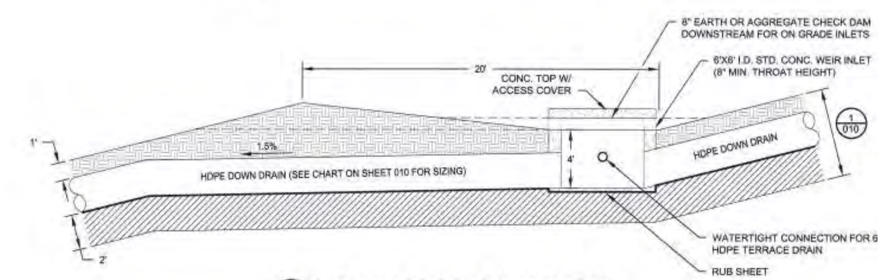
1/010 TERRACE DOWN DRAIN AT SAG
NTS



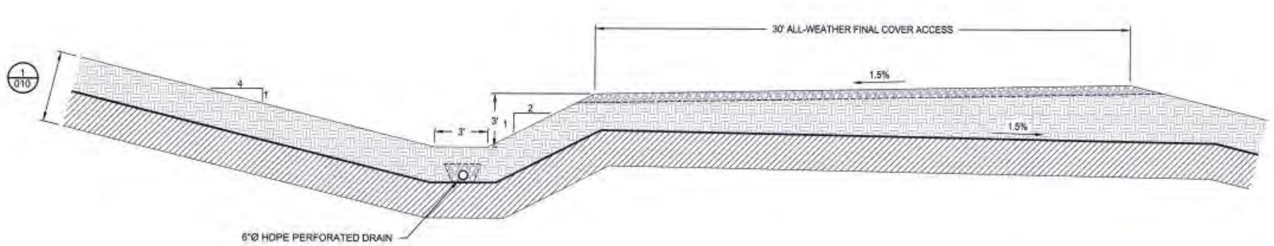
2/010 TERRACE DOWN DRAIN W/ ON GRADE INLET CONDITION
NTS



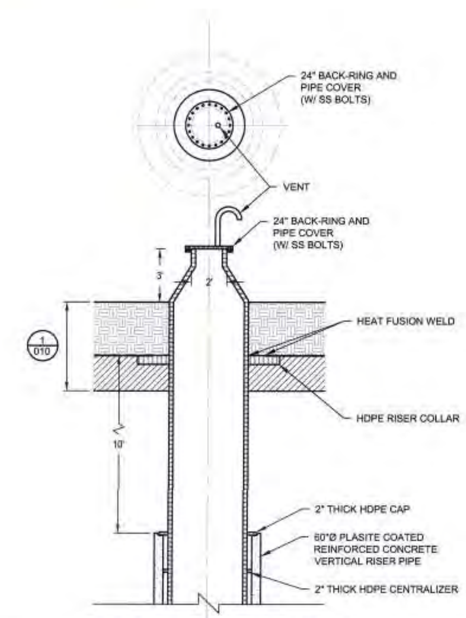
A/010 FINAL COVER TERRACE
NTS



B/010 FINAL COVER TERRACE AT DOWNDRAIN
NTS



3/010 FINAL COVER ACCESS ROAD
NTS



4/010 PRIMARY LEACHATE VERTICAL RISER PIPE CLOSURE
NTS

REV (R) SUB (S)	DATE	BY	DESCRIPTION
(S) A	3/17/2015	JEA	SUBMITTAL TO ADEM

Terracon
Consulting Engineers and Scientists
4040 ROYAL DRIVE STE 100 KENNESAW, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

WM WASTE MANAGEMENT
36964 AL. HIGHWAY 17 EMELLE, ALABAMA 35459

2/19/2015

FINAL COVER & STORMWATER MANAGEMENT DETAILS

EMELLE FACILITY
36964 AL. HIGHWAY 17
EMELLE, SUMTER COUNTY, ALABAMA

DESIGNED BY:	JEA / RSG
DRAWN BY:	JEA
APPVD. BY:	RSG / MAK
JOB NO.	EJ147410

DRAWING
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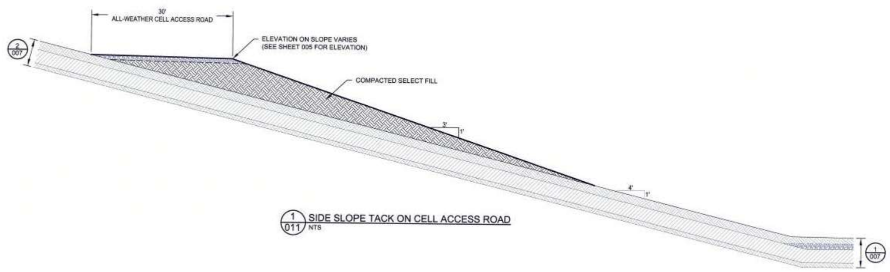
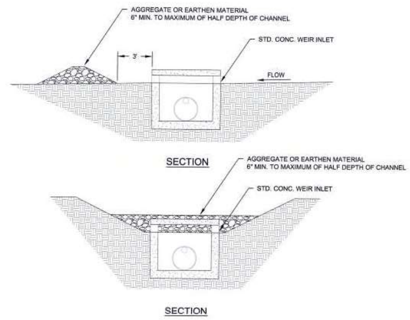


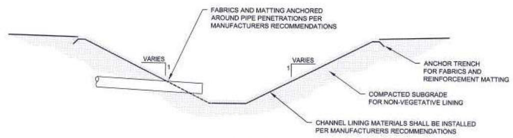
1/011 SIDE SLOPE TACK ON CELL ACCESS ROAD
NTS



2/011 ON GRADE INLET CONTROL MEASURE
NTS

PERIMETER DRAINAGE SYSTEM						
Pipe ID Up	Pipe Invert Up	Pipe ID Down	Pipe Invert Down	Barrel Count	Pipe Length (LF)	Pipe Size
X2	247.0	X1	246.0	1.0	72	36"
X3	255.5	X4	255.0	1.0	103	36"
X6	263.2	X5	258.9	1.0	67	36"
X8	266.5	X7	266.0	1.0	74	24"
X10	248.0	X9	240.9	1.0	188	36"
X11	244.0	X12	233.0	1.0	159	36"
X14	238.0	X13	237.5	1.0	101	36"
X16	241.8	X15	240.1	1.0	107	36"
X18	242.4	X17	241.9	1.0	97	36"
X19	267.7	X20	267.4	1.0	83	24"
X21	259.0	X22	258.7	1.0	62	36"
X23	261.5	X24	261.2	2.0	62	36"
X25	247.0	X26	239.0	1.0	112	36"
X27	249.5	X28	249.2	1.0	62	24"
X29	228.0	X30	227.5	1.0	95	36"

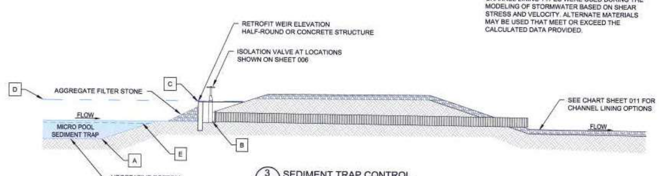
FINAL COVER DRAINAGE SYSTEM						
Down Drain System	Structure Type	Weir Inlet Elevation	Invert In	Invert Out	Pipe Connection Size	Pipe Length
A1	HW or Channel Lining	-	-	267.3	36"	70
A2	6' x 6' Conc. Box	277.6	274.6	273.6	36"	135
A3	6' x 6' Conc. Box	306.0	303.0	302.0	36"	140
A4	6' x 6' Conc. Box	336.0	333.0	332.0	36"	140
A5	6' x 6' Conc. Box	366.0	363.0	362.0	36"	
B1	HW or Channel Lining	-	-	263.2	36"	70
B2	6' x 6' Conc. Box	273.4	270.4	269.4	36"	145
B3	6' x 6' Conc. Box	304.0	301.0	300.0	36"	140
B4	6' x 6' Conc. Box	334.0	331.0	330.0	36"	140
B5	6' x 6' Conc. Box	364.0	361.0	360.0	36"	160
B6	6' x 6' Conc. Box	394.0	391.0	390.0	36"	
C1	HW or Channel Lining	-	-	252.4	42"	73
C2	6' x 6' Conc. Box	257.8	254.8	252.8	36"	70
C3	6' x 6' Conc. Box	268.1	265.1	264.1	36"	140
C4	6' x 6' Conc. Box	298.2	295.2	294.2	36"	150
C5	6' x 6' Conc. Box	330.0	327.0	326.0	36"	150
C6	6' x 6' Conc. Box	362.0	359.0	358.0	36"	
D1	HW or Channel Lining	-	-	248.3	36"	73
D2	6' x 6' Conc. Box	253.7	250.7	249.3	36"	75
D3	6' x 6' Conc. Box	263.9	260.9	259.9	36"	140
D4	6' x 6' Conc. Box	294.0	291.0	290.0	36"	140
D5	6' x 6' Conc. Box	324.0	321.0	320.0	36"	140
D6	6' x 6' Conc. Box	354.0	351.0	350.0	36"	
E1	HW or Channel Lining	-	-	242.4	36"	91
E2	6' x 6' Conc. Box	253.7	250.7	245.9	36"	75
E3	6' x 6' Conc. Box	263.9	260.9	259.9	36"	140
E4	6' x 6' Conc. Box	294.0	291.0	290.0	36"	140
E5	6' x 6' Conc. Box	324.0	321.0	320.0	36"	140
E6	6' x 6' Conc. Box	354.0	351.0	350.0	36"	
F1	HW or Channel Lining	-	-	238.0	36"	160
F2	6' x 6' Conc. Box	257.8	254.8	253.8	36"	76
F3	6' x 6' Conc. Box	268.1	265.1	264.1	36"	140
F4	6' x 6' Conc. Box	298.0	295.0	294.0	36"	145
F5	6' x 6' Conc. Box	328.0	325.0	324.0	36"	130
F6	4' x 4' Conc. Box	348.5	345.5	344.5	36"	
G1	HW or Channel Lining	-	-	242.4	36"	120
G2	6' x 6' Conc. Box	263.2	260.2	249.6	36"	75
G3	6' x 6' Conc. Box	273.4	270.4	269.4	36"	145
G4	6' x 6' Conc. Box	304.0	301.0	300.0	36"	150
G5	4' x 4' Conc. Box	330.2	327.2	326.2	36"	
H1	HW or Channel Lining	-	-	250.0	36"	110
H2	6' x 6' Conc. Box	267.3	264.3	256.3	36"	75
H3	6' x 6' Conc. Box	277.6	274.6	273.6	36"	75
H4	4' x 4' Conc. Box	284.9	281.9	280.9	36"	110
H5	6' x 6' Conc. Box	306.9	303.9	302.9	36"	160
H6	6' x 6' Conc. Box	341.4	338.4	337.4	36"	120
H7	6' x 6' Conc. Box	366.8	363.8	362.8	36"	145
H8	6' x 6' Conc. Box	393.7	390.7	389.7	36"	
J1	HW or Channel Lining	-	-	268.5	36"	90
J2	6' x 6' Conc. Box	278.0	275.0	274.0	36"	



CHANNEL LINING

CHANNEL REACH SYSTEM							
UPSTREAM NODE	DOWNSTREAM NODE	BOTTOM WIDTH (ft)	SIDE SLOPE	CALCULATED VELOCITY (ft/s)	CALCULATED SHEAR STRESS (lbs/ft²)	CHANNEL LINING TYPE	DESIGN MODEL CHANNEL LINING TYPE
HP7	F6	3	4:1 / 2:1	11.5	6.0	HARD LINING	RIPRAP D50=12" OR VMAX W3000
F6	G5	3	4:1 / 2:1	7.7	2.9	HARD LINING	RIPRAP D50=12" OR VMAX W3000
G5	H4	3	4:1 / 2:1	8.6	3.4	HARD LINING	RIPRAP D50=12" OR VMAX W3000
H4	J2	3	4:1 / 2:1	5.7	1.8	TRM	VMAX P550
HP1	X19	6	2:1 / 2:1	2.1	0.2	TRM	SC250
X20	X21	6	2:1 / 2:1	3.9	0.5	TRM	SC250
X22	X23	6	2:1 / 2:1	4.6	0.7	TRM	SC250
X24	C2	6	2:1 / 2:1	4.7	0.8	TRM	SC250
C2	D2	6	2:1 / 2:1	2.5	0.2	TRM	SC250
D2	X2	6	2:1 / 2:1	2.3	0.2	TRM	SC250
HP3	X2	6	2:1 / 2:1	2.1	0.2	TRM	SC250
HP4	X27	6	2:1 / 2:1	2.1	0.2	TRM	SC250
X28	E2	6	2:1 / 2:1	2.6	0.2	TRM	SC250
HP2	J1	6	2:1 / 2:1	1.8	0.1	TRM	SC250
J1	H2	6	2:1 / 2:1	2.7	0.3	TRM	SC250
H2	G2	6	2:1 / 2:1	2.4	0.2	TRM	SC250
G2	X25	6	2:1 / 2:1	2.5	0.3	TRM	SC250
HP5	X8	10	3:1 / 3:1	4.3	1.3	TRM	SC250
X7	X6	10	3:1 / 3:1	5.9	2.4	TRM	P550
X5	ST6	10	3:1 / 3:1	5.0	1.7	TRM	C350
X4	C1	14	3:1 / 3:1	1.5	0.1	TRM	SC250
C1	D1	14	3:1 / 3:1	4.6	0.6	TRM	SC250
D1	X1	14	3:1 / 3:1	5.0	0.7	TRM	SC250
X19	ST5	14	3:1 / 3:1	5.2	0.8	TRM	SC250
X17	X16	14	3:1 / 3:1	4.1	0.5	TRM	SC250
X15	ST4	14	3:1 / 3:1	4.4	0.6	TRM	SC250
HP6	ST3	10	3:1 / 3:1	8.8	2.7	TRM	P550
X9	H1	14	3:1 / 3:1	2.4	0.2	TRM	SC250
H1	G1	14	3:1 / 3:1	4.0	0.5	TRM	SC250
G1	ST2	14	3:1 / 3:1	6.0	1.1	TRM	SC250

CHANNEL LINING TYPES WERE USED DURING THE MODELING OF STORMWATER BASED ON SHEAR STRESS AND VELOCITY. ALTERNATE MATERIALS MAY BE USED THAT MEET OR EXCEED THE CALCULATED DATA PROVIDED.



3/11 SEDIMENT TRAP CONTROL
NTS

SEDIMENT TRAP GUIDE							
	A	B	C	D	E	RETROFIT	
ST ID	BOTTOM ELEVATION	PIPE INVERT OUT	WIER ELEVATION	MAX. POOL ELEVATION	SEDIMENT CLEANOUT	PERF. DIA.	PERF. COUNT
ST1	224.0	228.0	234.0	242.0	227.0	1"	345
ST2	235.0	244.0	246.0	248.0	243.0	1"	165
ST3	244.0	248.0	251.0	254.0	247.0	1"	165
ST4	234.0	238.0	244.5	256.0	237.0	1"	375
ST5	238.0	242.4	247.5	252.0	241.4	1"	315
ST6	250.0	255.5	257.5	259.0	254.5	1"	195

NOTES:

1. STORMWATER SYSTEM INLETS AND PIPE INFORMATION MAY BE ADJUSTED BASED ON PRODUCT AVAILABILITY AT TIME OF FINAL CLOSURE. INVERT AND PIPE LENGTHS AND LOCATIONS MAY BE ADJUSTED BASED ON BENCH LOCATIONS AT THE TIME OF CLOSURE.
2. FOR ALTERNATIVE PIPE MATERIALS CONSIDER THE STORMWATER SYSTEM WAS MODELED USING ADS N-12 WT (WATERTIGHT JOINTS) SMOOTH INNER WALL HDPE PIPE WITH MANNING'S "n" VALUE 0.012, MEETING FITTING AND JOINT REQUIREMENTS OF AASHTO M294, AASHTO M252, ASTM D3212,ASTM, F2306, ASTM F477. INSTALLATION IN ACCORDANCE TO ASTM D2321 FOR HDPE PIPE EXCEPT IN TRAFFIC AREAS MUST BE INSTALLED WITH A MINIMUM OF 1-FOOT OF COVER. INSTALLATION ON FINAL COVER BASED ON FINAL COVER DETAILS WITHIN THIS PLAN.
3. WEIR INET BOXES WERE SIZED FOR USING 24 FEET OPEN WEIR LENGTH AND A MINIMUM THROAT OPENING OF 6-INCHES UNLESS NOTED OTHERWISE.
4. GEOTEXTILE FABRIC USED AS AN UNDERLAY FOR ALL AGGREGATES USED AS EROSION AND SEDIMENT CONTROL. (RIPRAP, CHECKDAMS, RETROFITS, INLET CONTROL)
5. TURF REINFORCEMENT AND EROSION CONTROL MATTING SHALL BE ANCHORED AND PINNED PER MANUFACTURERS RECOMMENDATIONS.
6. HARD CHANNEL LININGS, SUCH AS, CONCRETE OR FABRIC FILLED CONCRETE SHALL USE WEEP HOLES AS RECOMMENDED BY MANUFACTURER OR INSTALLER.

REV (R) SUB (S)	DATE	BY	DESCRIPTION
(S) A	3/17/2015	JEA	SUBMITTAL TO ADEM

Terracon
Consulting Engineers and Scientists
4040 ROYAL DRIVE STE 100 KENNESAW, GA 30144
PH. (770) 924-9799 FAX. (770) 924-7866

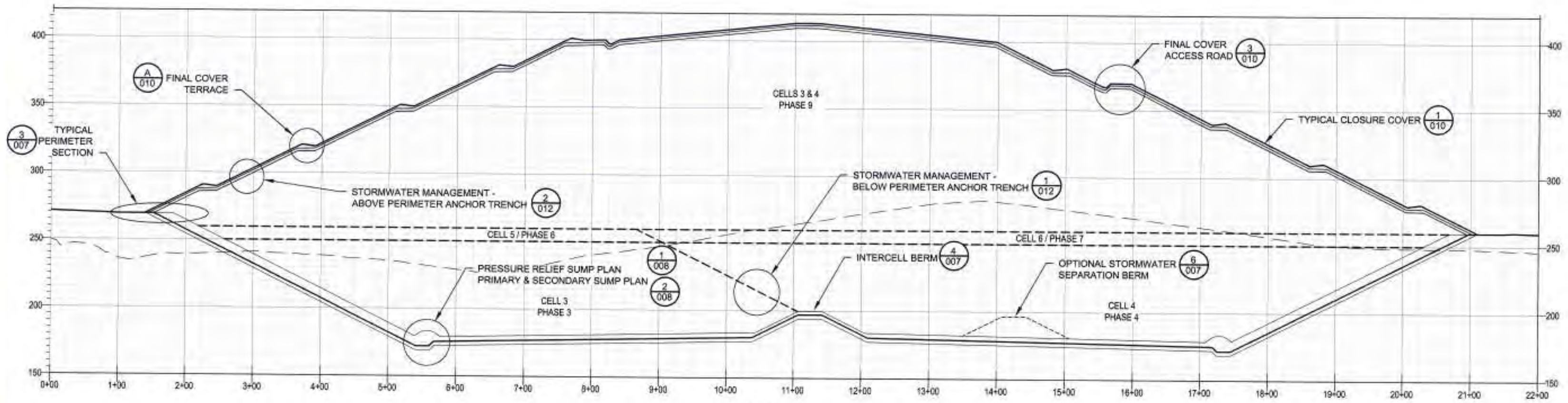
WM WASTE MANAGEMENT
36964 AL. HIGHWAY 17 EMELLE, ALABAMA 35459

2/19/2015

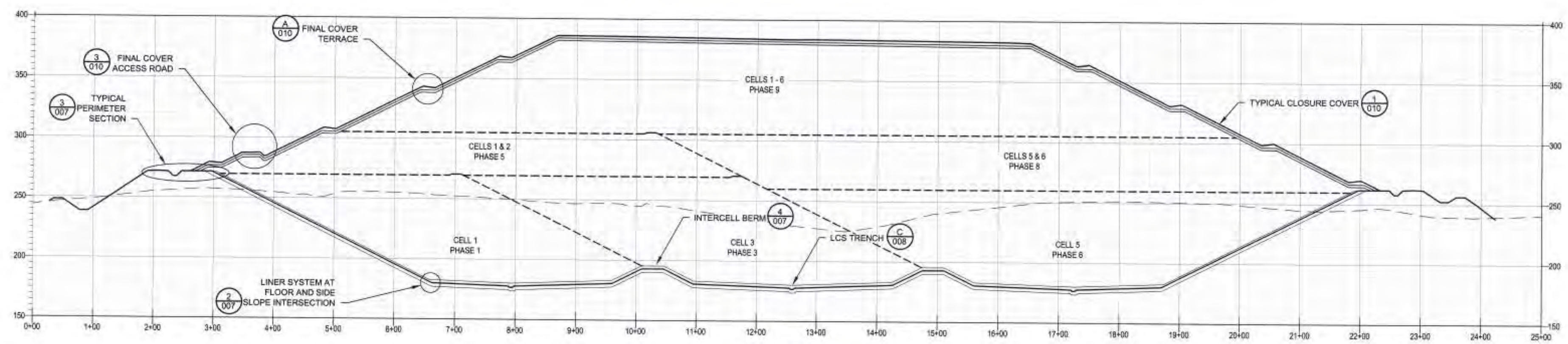
MISCELLANEOUS DETAILS
EMELLE FACILITY
36964 AL. HIGHWAY 17
EMELLE, SUMTER COUNTY, ALABAMA

DESIGNED BY:	JEA / RSG
DRAWN BY:	JEA
APPVD. BY:	RSG / MAK
JOB NO.	EJ147410

DRAWING
00-300-011



PROFILE A
1" = 100' HORZ.
1" = 50' VERT.



PROFILE B
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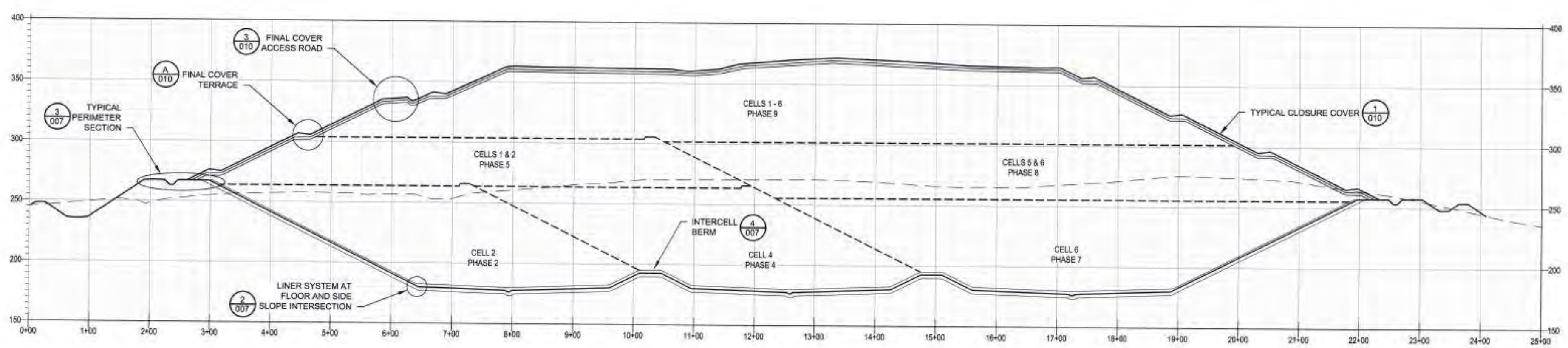
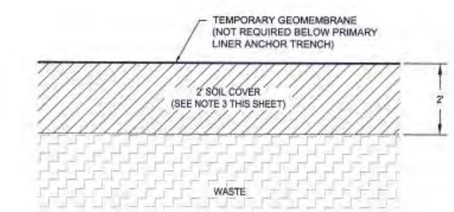
1" = 50' VERT.



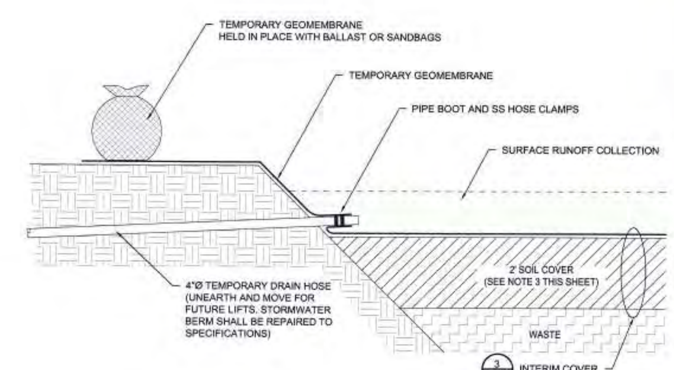
PROFILE C
1" = 100' HORZ.
1" = 50' VERT.

NOTES:

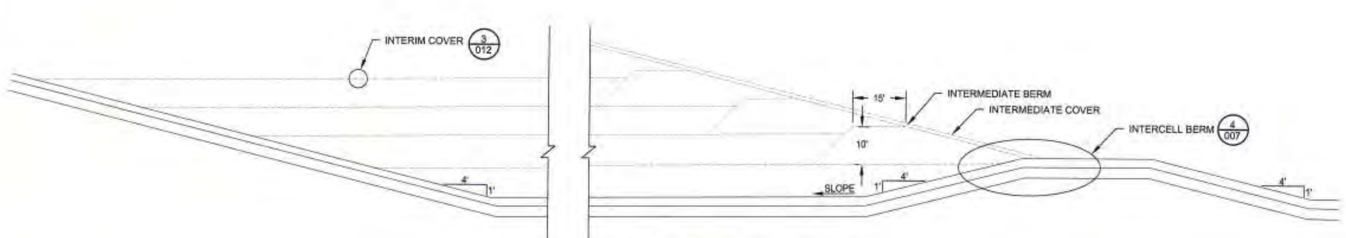
1. SEE OPERATION PLAN SECTION D-6-1-1-1-7 FOR STORMWATER MANAGEMENT CONTROL WITHIN OPERATING AREA FOR RUN-ON AND RUN-OFF CONTROL.
2. INTERMEDIATE BERM EXCAVATED DURING WASTE PLACEMENT IN ADJACENT CELL.
3. THE INTERIM COVER IS COMPOSED OF A MINIMUM 2 FEET OF CHALK TO PREVENT INFILTRATION. BEFORE WASTE PLACEMENT RESUMES, 1 FOOT OF THE CHALK LINER WILL BE REMOVED.
4. THE STORMWATER CONSIDERED NON-CONTAMINATED RUNOFF WILL BE DIRECTED TO THE DESIGNATED SEDIMENT BASIN. A TEMPORARY FLEXIBLE HOSE OR DRAIN PIPE MAY BE USED TO DIRECT NON-CONTAMINATED WATER TO THE PERIMETER CHANNEL OR TO FINAL COVER TERRACES.



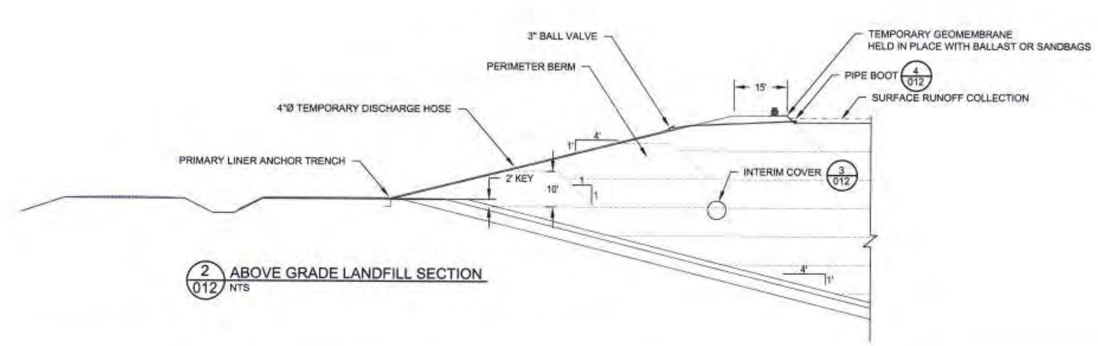
3/012 INTERIM COVER DETAIL
NTS



4/012 PIPE BOOT
NTS



1/012 BELOW GRADE LANDFILL SECTION
NTS



2/012 ABOVE GRADE LANDFILL SECTION
NTS

REV (R) SUB (S)	DATE	BY	DESCRIPTION
(S) A	3/17/2015	JEA	SUBMITTAL TO ADEM

Terracon
Consulting Engineers and Scientists
4040 ROYAL DRIVE STE 100 KENNESAW, GA 30144
PH. (770) 924-9799 FAX (770) 924-7866

WM WASTE MANAGEMENT
36964 AL. HIGHWAY 17 EMELLE, ALABAMA 35459

2/19/2015

TRENCH 23 PROFILES

EMELLE FACILITY
36964 AL. HIGHWAY 17
EMELLE, SUMTER COUNTY, ALABAMA

DESIGNED BY:	JEA / RSG
DRAWN BY:	JEA
APPVD. BY:	RSG / MAK
JOB NO.	EJ147410

DRAWING
00-300-012

APPENDIX D-6-3

SECTION D-6

LEACHATE – LINER COMPATIBILITY STUDY

Revision No.
5.0

A Final Report:

Laboratory Testing of Geosynthetics for Waste Containment EPA Method 9090

October 1994

A Final Report:

Laboratory Testing of Geosynthetics
for Waste Containment
EPA Method 9090

October 1994

Submitted to:

Mr. Steve Pekera
Chemical Waste Management: Emelle Facility
Highway 17, Milemarker 163
Emelle, Alabama 35449

Attn: Mr. Ken Mullins

Submitted by:

TRI/Environmental, Inc.
9063 Bee Caves Rd.
Austin, Texas 78733

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

February 17, 1995

Mr. Steve Pekera
Chemical Waste Management: Emelle Facility
Highway 17, Milemarker 163
Emelle, Alabama 35449

Dear Mr. Pekera:

TRI/Environmental, Inc. (TRI) is pleased to present this Final Report for EPA Methods 9090A chemical compatibility testing of geosynthetics and natural materials to be used in a waste facility.

TRI is very pleased to have worked on this project in support of Chemical Waste Management and looks forward to serving you again in the future. Please call me if you have any questions or require any additional information.

Respectfully submitted,

Sam R. Allen

Sam R. Allen
Program Manager: Geosynthetics Technologies

9063 Bee Caves Road • Austin, TX 78733-6201 • (512) 263-2101 • FAX (512) 263-2558

TABLE OF CONTENTS

FOREWORD

The testing reported herein is based upon accepted industry practice as well as the test method listed. TRI/Environmental Inc. (TRI) neither accepts responsibility for nor makes claim as to the final use and purpose of the materials tested.

Tests were performed under laboratory conditions and not under actual usage conditions. TRI can give no conclusions as to the serviceability, life expectancy or general durability of the products tested when used in a lining and/or leachate collection system.

1.0 INTRODUCTION

This report describes the work performed by TRI/Environmental, Inc. (TRI) to determine the chemical compatibility of various geosynthetic and natural materials with one waste leachate. The study included one high density polyethylene (HDPE) geomembrane, one polyester drainage geotextile, one polyester cushion geotextile, two polypropylene drainage geotextiles, two polypropylene cushion geotextiles, one HDPE geonet, one sand, one gravel, one reinforced concrete material and one synthetic laminated reinforced concrete material. The objective was to determine the resistance of each material to changes caused by exposure to leachate. Changes in physical, mechanical and hydraulic properties were measured after exposure to a Emelle facility leachate at 23°C and 50°C for 30, 60, 90 and 120 days following the exposure regimen specified in United States Environmental Protection Agency (EPA) Method 9090.

Methods, results and discussion are provided in the sections which follow. Test results are provided in the Tables and Graphs of Results which accompany this report.

2.0 METHODS

2.1 Materials

Table 1 lists products selected for evaluation in this chemical compatibility study.

Table 1. List of materials evaluated in chemical compatibility study
60 mil National Seal HDPE Smooth Geomembrane
National Seal HDPE Geonet
PolyFelt TS 800 Filter Geotextile
PolyFelt TS1000 Cushion Geotextile
Synthetic Industries 12 oz Filter geotextile
Synthetic Industries 16 oz Cushion Geotextile
Trevira 1145 Filter Geotextile
Trevira 1155 Cushion Geotextile
Chem Waste Management provided sand and gravel
Chem Waste Management provided reinforced concrete cores
Chem Waste Management provided laminated reinforced concrete beams

2.2 Leachate

The waste leachate used during the testing was secured from the Emelle facility in Emelle, Alabama. The leachate was provided to TRI and used as the immersion media during EPA Method 9090 material exposure.

2.3 Exposure Conditions

All material specimens were exposed to the waste leachate following the specifications of EPA Method 9090A as they relate to exposure to waste fluids. The tanks used for these exposures were maintained at 23 $\pm$ 2°C and 50 $\pm$ 2°C throughout the 120-day exposure period. Tanks were constructed from chemically resistant stainless steel, fitted with stirrers and heated with a circulating hot water heat exchanger system. The 50°C tanks were sealed with a lid, and a reflux condenser was installed to minimize loss of volatile leachate components.

2.4 Testing Procedures

The following sections list tests performed on the various geosynthetic products.

2.4.1 *HDPE Geomembrane*

Table 2 lists tests performed on HDPE geomembrane. The number of test replicates was doubled for baseline determinations on unexposed material.

Table 2. Tests performed on HDPE geomembrane

Test or Physical Property	Method
Dimensions and weight	EPA 9090A
Hardness	ASTM D 2240 D scale
Volatiles and Extractables	EPA SW 870 Appendix III
Specific Gravity	ASTM D 792
Tensile Properties	ASTM D 638
Modulus of Elasticity	ASTM D 882, 2% secant method
Hydrostatic Resistance	ASTM D 751 Method A
Puncture Resistance	FTMS 101C Method 2065
Seam Tests: Peel and Shear	ASTM D 413/D 3083 / NSF 54

Where required, testing was performed in both the machine and transverse directions. Baseline testing was performed using twice the number of required test replicates.

Geomembrane modulus of elasticity data was generated in accordance with ASTM D 638 using secant values at 2% strain. This procedure served to eliminate the inherent variability in modulus testing of plastics.

In order to reduce variability of seam test results, specimens for individual, replicate seam tests were cut from different locations on the length of the seamed sample as received. Specimens were cut in the following order progressing down the length of the seam. First, one baseline replicate was cut, followed by the next testing period's test replicate. This order was repeated until all the specimens were cut for baseline testing and laboratory exposures.

2.4.2 Geotextiles

Table 3 lists tests performed on each of the drainage geotextiles. The number of test replicates was doubled for baseline determinations on unexposed material.

Table 3. Tests performed on geotextiles

Test or Physical Property	Method
Dimensions and weight	EPA 9090A
Grab Tensile Properties (MD only)	ASTM D 4632
Trap Tear Resistance (MD only)	ASTM D 4533
Puncture Resistance	ASTM D 4833
Mullen Burst Strength	ASTM D 3786
Permittivity (flow rate: gal/min/ft^2)	ASTM D 4491

Where applicable, machine direction test specimens only were tested. Baseline testing was performed using twice the number of required test replicates.

To reduce the effects of dimensional variability on test results, screening of coupons entered into the project test pool was performed. Upon receipt of all geotextile materials, TRI determined the mass per unit area average roll values for each product by taking 20 specimens randomly from various parts of the roll and measuring mass. Test specimens were cut from the rolls using standard dies (about 1.5X the actual number required will be cut). Each specimen was weighed for mass. Only those specimens falling within +/- 25% of the average roll value for mass were entered into the test pool.

Unexposed geotextile specimens dedicated to tracking of mass, thickness and dimensions were rinsed in deionized water, patted with absorbent towels, dried in an air oven at 45°C for eight hours and measured for physical properties. Selected exposed samples were prepared and testing using this same procedure at each testing period. At each testing period, exposed geotextile specimens dedicated to mechanical property testing were rinsed, blotted dry with absorbent towels and stored in polyethylene bags until tested. Samples were tested in a moist condition.

2.4.3 *Geonets*

Table 4 lists tests performed on the drainage geonet. The number of test replicates was doubled for baseline determinations on unexposed material.

Table 4. Tests performed on geonets

Test or Physical Property	Method
Dimensions and weight	EPA 9090A
Tensile Properties	NETLON QC/ASTM D 1682
Specific Gravity	ASTM D 792
Geonet Compression Resistance	GRI-GN1
Permittivity (flow rate: gal/min/ft^2)	ASTM D 4491
Transmissivity Grad. 1.00 Normal Load:1000 psf	ASTM D 4716

Strip tensile testing was performed using machine direction specimens only. Peak strength was determined. Compressive strength was determined in accordance with GRI GN1. Deformation vs. applied stress and strain vs. applied stress will be monitored.

Transmissivity testing was performed in accordance with ASTM D4716 using a normal compressive load of 1000 psf. At this compressive load, transmissivity at an hydraulic gradient of 1 was determined. Three measurements were recorded for each condition.

2.4.4 Geopipe

Table 4 lists tests performed on the HDPE geopipe. The number of test replicates was doubled for baseline determinations on unexposed material.

Table 5. Tests performed on geopipe	
Test or Physical Property	**Method**
Dimensions and weight	EPA 9090A
Wall Thickness	Vernier Calipers
Length	Vernier Calipers
Hardness	ASTM D 2240
Stiffness @ 5% & 10%	ASTM D 2412: (modified using arc bend configuration)

Pipe stiffness testing was performed in accordance with ASTM D 2412, modified using a bend test configuration. During testing, the "legs" of each semi-circle arc test specimen were constrained while normal loading occurred.

2.4.5 Sand and Gravel

One pea gravel material and one sand material were tested against the project leachate by exposing these materials wrapped in geotextile holding bags. Retention of mass as a function of leachate exposure was monitored for samples removed from the leachate at each testing period.

2.4.6 Reinforced Concrete Cores

Project reinforced concrete cylinders, approximately 2" (diameter) by 4" in length, were cut from concrete pads at the Emelle facility by CWM personnel and shipped to TRI laboratories for subsequent exposure and testing. Upon receipt, the cores were observed to "slant" from bottom to top, a result from "angular" rather than normal coring into the pad. Exposed samples were removed from the leachate at each testing interval and visually inspected for changes as a function of chemical exposure. The concrete cylinders were tested for compressive strength in accordance with ASTM C 42. When feasible, slanted cores were cut down to enable testing.One pea gravel material and one sand material were tested against the project leachate by exposing these materials wrapped in geotextile holding bags. Retention of mass as a function of leachate exposure was monitored for samples removed from the leachate at each testing period.

2.4.7 *Reinforced Laminated Concrete Beams*

Synthetic laminate material was tested via the lamination of reinforced concrete beams measuring approximately 2" x 2" x 4". The lamination was performed by an independent contractor to CWM. Laminated cores were then shipped to TRI laboratories for subsequent leachate exposure and testing. The unexposed and exposed beams were axially loaded to failure following the general guidelines established in ASTM D 116.

3.0 DISCUSSION/RESULTS

Test results are presented in the Tables of Test Results (raw data) and graphical presentations are presented in Appendix A.

In considering these results, it must be determined through engineering judgment whether observed differences in the value of test results measured before and after immersion are due to product variability, unidentified factors relating to the test procedure, or leachate interaction with the products. Any significant chemical interaction with leachate would be expected to result in degradation trends which are consistent across the various properties being evaluated, and not isolated to one set of test results only. However, with each type of material there may be specific properties which are highly sensitive to leachate-induced effects. These factors must be considered in evaluating the various test results for a given product. These issues are addressed in the following sections for each class of geosynthetic

Also of critical importance is the issue of product variability. With geotextiles, a range of physical and mechanical index test values covering 25% or more of the average is not uncommon. This can be traced to variability inherent in the product, and the randomness associated with the onset of failure under the specified testing conditions. However, in chemical compatibility testing the statistical sampling of a broad range of manufactured product is not possible. Therefore, the small size of the sample population tested at each time point must be taken into consideration. The criteria to be applied in evaluating data measured before and after leachate immersion should be that property changes, if observed, are consistent and so great that product variability and experimental factors can be ruled out.

In this report, standard deviations (STD) are reported for most measurements involving three or more replicate specimens. In statistics, the standard deviation is defined as root of the mean squared deviations of individual test results about the mean value. The standard deviation is a quantitative measure of variability within a group of measurements.

One related measure of variability observed within a sample set, relative to the magnitude of the mean value itself, is the *coefficient of variation or variance* (COV). The coefficient of variance is defined as the standard deviation divided by the mean associated with a group of specimens, and may be expressed as a percentage. The COV provides an indication of what proportion of the mean value may be attributable to random experimental factors or product variability. It is useful to consider apparent changes in property values against the criterion of COV since observed changes which fall below the COV may not be significant. This approach was used in preparing the tables in the next sections.

The term *range* refers to the difference between the extreme highest and lowest points within a group of measured values. Considering range as a percentage of the mean values provides another measure of variability within a dataset.

In the tables, the high and low extremes for percentage change in mean values are listed for comparison against COV and range as a percentage of mean from the baseline sample group. The high and low percentage changes are the extremes from data measured at 30, 60, 90 and 120 days.

3.1 National Seal Company 60 mil HDPE Geomembrane

Table 6 illustrates the range of variability in baseline data compared with some of the observed changes in average test values measured after immersion for Gundle HDPE geomembrane.

Table 6. Baseline coefficients of variation and range of percentage change results for National Seal Company HDPE Geomembrane

Test	Baseline COV (%)	Baseline Range as % of Mean	High Observed % Change	Low Observed % Change
Stress at yield (MD)	4	11	1	-9
Stress at break (MD)	8	20	6	-8
Elongation at yield (MD)	8	25	14	8
Elongation at break (MD)	6	18	10	0
Modulus (MD)	2	7	6	-18
Puncture Resistance	1	1	0.3	-1.1
Hydrostatic Resistance	3	7	-1	-5
Seam Peel Strength	2	5	-1	-9
Seam Shear Strength	1	4	1	-7

3.2 Polyester Trevira Geotextile

Tables 7 and 8 illustrate the range of variability in baseline data compared with some of the observed changes in average test values measured after immersion for polyester Trevira 1145 and 1155 geotextiles.

Table 7. Baseline coefficients of variation and range of percentage change results for Polyester Trevira 1145 Geotextile

Test	Baseline COV (%)	Baseline Range as % of Mean	High Observed % Change	Low Observed % Change
Grab Strength (MD)	8	32	-2	-22
Grab Elongation (MD)	4	17	7	-21
Tear Strength (MD)	7	27	17	-17
Puncture Resistance	9	28	1	-25
Burst Strength	8	31	3	-10
Permittivity	6	21	14	0.2

Table 8. Baseline coefficients of variation and range of percentage change results for Polyester Trevira 1155 Geotextile

Test	Baseline COV (%)	Baseline Range as % of Mean	High Observed % Change	Low Observed % Change
Grab Strength (MD)	8	32	22	-3
Grab Elongation (MD)	4	17	12	-10
Tear Strength (MD)	7	27	22	-6
Puncture Resistance	8	26	-3	-30
Burst Strength	12	38	21	2
Permittivity	10	33	21	-15

3.3 Polypropylene Synthetic Industries Geotextile

Tables 9 and 10 illustrate the range of variability in baseline data compared with some of the observed changes in average test values measured after immersion for polypropylene Synthetic Industries 12 oz. and 16 oz. geotextiles.

Table 9. Baseline coefficients of variation and range of percentage change results for Polypropylene Synthetic Industries 12 oz. Geotextile

Test	Baseline COV (%)	Baseline Range as % of Mean	High Observed % Change	Low Observed % Change
Grab Strength (MD)	5	15	12	-12
Grab Elongation (MD)	5	18	18	-11
Tear Strength (MD)	12	43	23	-21
Puncture Resistance	7	19	14	-5
Burst Strength	6	20	15	1
Permittivity	5	17	18	-7

Table 10. Baseline coefficients of variation and range of percentage change results for Polypropylene Synthetic Industries 16 oz. Geotextile

Test	Baseline COV (%)	Baseline Range as % of Mean	High Observed % Change	Low Observed % Change
Grab Strength (MD)	4	15	3	-16
Grab Elongation (MD)	4	13	18	-10
Tear Strength (MD)	12	42	28	-5
Puncture Resistance	7	23	12	-17
Burst Strength	4	14	14	-3
Permittivity	5	32	19	-10

3.4 Polypropylene PolyFelt Geotextile

Tables 11 and 12 illustrate the range of variability in baseline data compared with some of the observed changes in average test values measured after immersion for polypropylene PolyFelt TS800 and TS1000 geotextiles.

Table 11. Baseline coefficients of variation and range of percentage change results for Polypropylene PolyFelt TS800 Geotextile

Test	Baseline COV (%)	Baseline Range as % of Mean	High Observed % Change	Low Observed % Change
Grab Strength (MD)	8	31	19	-5
Grab Elongation (MD)	6	17	21	-12
Tear Strength (MD)	20	58	3	-21
Puncture Resistance	13	37	5	-28
Burst Strength	14	46	21	-17
Permittivity	7	23	31	8

Table 12. Baseline coefficients of variation and range of percentage change results for Polypropylene PolyFelt TS1000 Geotextile

Test	Baseline COV (%)	Baseline Range as % of Mean	High Observed % Change	Low Observed % Change
Grab Strength (MD)	12	40	1	-22
Grab Elongation (MD)	11	32	4	-21
Tear Strength (MD)	14	48	-24	-45
Puncture Resistance	13	413	8	-2
Burst Strength	16	60	26	11
Permittivity	11	40	23	1

3.5 National Seal Company HDPE Geonet

Table 13 illustrates the range of variability in baseline data compared with some of the observed changes in average test values measured after immersion for National Seal Company provided HDPE geonet.

Table 13. Baseline coefficients of variation and range of percentage change results for HDPE National Seal Company Geonet

Test	Baseline COV (%)	Baseline Range as % of Mean	High Observed % Change	Low Observed % Change
Tensile Strength (MD)	9	29	31	-7
Net Compression	9	29	3	-35
Transmissivity (MD): 1K, grad.: 1	2	4	9	-4

3.6 HDPE Geopipe

Table 14 illustrates the range of variability in baseline data compared with some of the observed changes in average test values measured after immersion for HDPE geopipe.

Table 14. Baseline coefficients of variation and range of percentage change results for HDPE Geopipe

Test	Baseline COV (%)	Baseline Range as % of Mean	High Observed % Change	Low Observed % Change
Load @ 5% Deflection	0.1	39	30	-1
Load @ 10% Deflection	0.03	12	30	-8

3.7 Concrete and Laminated Concrete

Table 15 illustrates the range of variability in baseline data compared with some of the observed changes in average test values measured after immersion for concrete and laminated concrete.

Table 15. Baseline coefficients of variation and range of percentage change results for Concrete and Laminated concrete

Test	Baseline COV (%)	Baseline Range as % of Mean	High Observed % Change	Low Observed % Change
Laminated Concrete: compressive strength	10	25	-36	-3
Concrete: compressive strength	25	63	0	-30

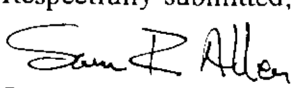
The "as-received" concrete core and laminated concrete beam materials were observed to exhibit a high degree of variability during testing. This variability was believed to be related to the randomness of steel reinforcement as it was located in the test specimens. In addition, the concrete cores were noted to have been cored at various angles to the test pad during test specimen generation. These specimens were trimmed as appropriate during specimen preparation to reduce bias, however, the angled specimens and randomness of reinforcement contributed to observed variability in the results.

4.0 CONCLUSION

While changes in certain measured physical and mechanical properties were noted for some products, the effects of product variability and experimental factors could not be ruled out as causes. In the opinion of the authors, the data, considered together, do not support the conclusion that observed changes were consistently and uniformly caused by the test exposures.

TRI/Environmental, Inc. is pleased to have been selected to participate in this project. We trust that the information provided in this report meets your requirements for technical documentation of this chemical compatibility study. Please do not hesitate to call if we can provide any further information.

Respectfully submitted,



Sam R. Allen
Program Manager: Geosynthetics Testing Technologies

APPENDIX A:

TEST RESULTS

(Tabular and Graphical Presentation)

Note: Graphical presentations reflect average, high and low values generated for both testing temperatures (23°C - left "I" beam and 50°C - right "I" beam) at each testing period.

DIMENSION/MASS TEST RESULTS

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Dimensional Stability Data

Exposure Time and Temperature

Test Parameters	Temp.	30 Day Baseline	30 Day Exposed	30 Day % Change	60 Day Baseline	60 Day Exposed	60 Day % Change	90 Day Baseline	90 Day Exposed	90 Day % Change	120 Day Baseline	120 Day Exposed	120 Day % Change
GEOMEMBRANE: NATIONAL SEAL HDPE													
Thickness (mils)	23C	63	62	-2	63	64	2	63	64	2	61	61	0
	50C	62	62	0	62	62	0	62	61	-2	60	60	0
Length (inches)	23C	10.09	10.08	-0.1	10.09	10.13	0.4	10.09	10.07	-0.2	10.69	10.69	0.0
	50C	10.08	10.08	0.0	10.08	10.09	0.1	10.08	10.06	-0.2	10.79	10.65	-1.3
Width (inches)	23C	10.14	10.11	-0.3	10.14	10.08	-0.6	10.14	10.13	-0.1	8.02	8.02	0.0
	50C	10.11	10.14	0.3	10.11	10.06	-0.5	10.11	10.09	-0.2	8.04	8.05	0.1
Mass (g)	23C	98.61	98.70	0.1	98.61	98.65	0.0	98.61	98.64	0.0	79.69	79.69	0.0
	50C	97.15	97.15	0.0	97.15	97.00	-0.2	97.15	97.00	-0.2	75.05	75.02	-0.0
GEONET:													
Thickness (mils)	23C	230	230	0	230	230	0	230	230	0	226	226	0
	50C	229	228	-0	229	229	0	229	228	-0	227	229	1
Length (inches)	23C	5.98	5.96	-0.3	5.98	5.96	-0.3	5.98	5.98	0.0	6.00	6.02	0.3
	50C	5.93	5.94	0.2	5.93	5.91	-0.3	5.93	6.00	1.2	6.04	6.03	-0.2
Width (inches)	23C	1.91	1.95	2.1	1.91	1.97	3.1	1.91	1.91	0.0	1.88	1.87	-0.5
	50C	2.10	2.09	-0.5	2.10	2.09	-0.5	2.10	2.06	-1.9	1.89	1.91	1.1
Mass (g)	23C	8.26	8.27	0.04	8.26	8.26	-0.04	8.26	8.26	-0.04	8.80	8.82	0.23
	50C	8.47	8.47	0.06	8.47	8.48	0.12	8.47	8.47	0.06	9.13	9.12	-0.11
GEOPIPE:													
Thickness (mils)	23C	0.8263	0.8268	0.06	0.8263	0.8220	-0.52	0.8263	0.8197	-0.80	0.8247	0.8279	0.39
	50C	0.8063	0.8112	0.61	0.8183	0.8127	-0.68	0.8183	0.8225	0.51	0.8219	0.8264	0.55
Width (inches)	23C	0.9332	0.9313	-0.2	0.9332	0.93	-0.1	0.9332	0.9312	-0.2	1.0241	1.0231	-0.1
	50C	1.0587	1.0693	1.0	1.0543	1.07	1.1	1.0543	1.0657	1.1	0.9743	0.9757	0.1
Mass (g)	23C	286.4	286.4	0.0	286.4	286.4	0.0	286.4	286.4	0.0	292.2	292.0	-0.1
	50C	327.3	327.4	0.0	326.8	326.9	0.0	326.8	326.8	0.0	317.3	317.8	0.2

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SPA
Quality Review

The testing listed herein is based upon accepted industry practice as well as by the test method listed.
TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material.

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Dimensional Stability Data

Exposure Time and Temperature

Test Parameters	Temp.	30 Day Baseline	30 Day Exposed	30 Day % Change	60 Day Baseline	60 Day Exposed	60 Day % Change	90 Day Baseline	90 Day Exposed	90 Day % Change	120 Day Baseline	120 Day Exposed	120 Day % Change
GEOTEXTILE: POLYFELT TS 800 12 OZ.													
Thickness (mils)	23C	139	150	8	139	141	1	139	143	3	182	180	-1
	50C	172	186	8	172	192	12	172	178	3	176	172	-2
Length (inches)	23C	7.93	7.92	-0.1	7.93	7.91	-0.3	7.93	7.89	-0.5	7.93	7.91	-0.3
	50C	8.00	7.89	-1.4	8.00	7.83	-2.1	8.00	7.83	-2.1	8.00	7.83	-2.1
Width (inches)	23C	4.03	4.04	0.2	4.03	4.04	0.2	4.03	4.04	0.2	4.03	4.04	0.2
	50C	4.06	4.08	0.5	4.06	4.05	-0.2	4.06	4.12	1.5	4.06	4.05	-0.2
Mass (g)	23C	7.50	8.12	8.34	7.50	7.51	0.20	7.50	7.53	0.47	7.50	7.51	0.20
	50C	10.09	10.04	-0.51	10.09	10.18	0.88	10.09	10.13	0.39	9.09	9.18	0.98
GEOTEXTILE: POLYFELT 1000 16 OZ.													
Thickness (mils)	23C	206	220	7	206	208	1	206	210	2	205	208	1
	50C	205	219	7	205	224	9	205	219	7	204	210	3
Length (inches)	23C	8.00	7.99	-0.1	8.00	7.96	-0.5	8.00	7.96	-0.5	7.99	7.99	0.0
	50C	8.00	7.95	-0.6	8.00	7.93	-0.9	8.00	7.90	-1.2	7.99	7.96	-0.4
Width (inches)	23C	4.02	4.08	1.5	4.02	4.06	1.0	4.02	4.05	0.7	4.04	4.05	0.2
	50C	4.03	4.01	-0.5	4.03	4.02	-0.2	4.03	4.03	0.0	4.04	3.97	-1.7
Mass (g)	23C	14.58	15.11	3.61	14.58	14.59	0.05	14.58	14.64	0.39	14.31	14.31	0.00
	50C	13.26	13.30	0.32	13.26	13.35	0.69	13.26	13.32	0.47	1.30	14.33	1002.31

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SRA
Quality Review

The testing listed herein is based upon accepted industry practice as well as by the test method listed.
TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material.

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Dimensional Stability Data

Exposure Time and Temperature

GEOTEXTILE: SYNTHETIC INDUSTRIES 12 OZ.

Test Parameters	Temp.	Baseline	30 Day Exposed	% Change	Baseline	60 Day Exposed	% Change	Baseline	90 Day Exposed	% Change	Baseline	120 Day Exposed	% Change
Thickness (mils)	23C	145	154	6	145	155	7	145	152	5	153	157	3
	50C	138	143	4	138	148	7	138	141	2	138	130	-6
Length (inches)	23C	7.99	7.93	-0.8	7.99	7.93	-0.8	7.99	7.90	-1.1	7.93	7.89	-0.5
	50C	7.99	7.92	-0.9	7.99	7.89	-1.3	7.99	7.88	-1.4	8.00	7.83	-2.1
Width (inches)	23C	4.02	4.03	0.2	4.02	4.02	0.0	4.02	4.05	0.7	4.03	4.04	0.2
	50C	4.01	4.03	0.5	4.01	4.01	0.0	4.01	4.02	0.2	4.06	4.12	1.5
Mass (g)	23C	9.32	9.40	0.89	9.32	9.31	-0.08	9.32	9.39	0.78	8.64	8.65	0.12
	50C	8.59	8.60	0.12	8.59	8.69	1.16	8.59	8.68	1.05	9.81	9.76	-0.51

GEOTEXTILE: SYNTHETIC INDUSTRIES 16 OZ.

Test Parameters	Temp.	Baseline	30 Day Exposed	% Change	Baseline	60 Day Exposed	% Change	Baseline	90 Day Exposed	% Change	Baseline	120 Day Exposed	% Change
Thickness (mils)	23C	202	205	1	202	206	2	202	201	0	196	202	3
	50C	201	203	1	201	200	0	201	196	-2	195	209	7
Length (inches)	23C	7.99	7.98	-0.1	7.99	7.96	-0.4	7.99	7.96	-0.4	8.00	7.99	-0.1
	50C	8.04	7.93	-1.4	8.04	7.92	-1.5	8.04	7.90	-1.7	8.00	7.95	-0.6
Width (inches)	23C	4.01	4.02	0.2	4.01	4.00	-0.2	4.01	4.01	0.0	4.02	4.08	1.5
	50C	4.03	4.02	-0.2	4.03	4.00	-0.7	4.03	4.00	-0.7	4.03	4.01	-0.5
Mass (g)	23C	13.80	13.85	0.38	13.80	13.77	-0.20	13.80	13.94	1.03	13.58	13.41	-1.27
	50C	13.38	13.34	-0.31	13.38	13.55	1.26	13.38	13.56	1.34	13.26	13.30	0.32

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SRA
Quality Review

The testing listed herein is based upon accepted industry practice as well as by the test method listed.
TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material.

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Dimensional Stability Data

Exposure Time and Temperature

Test Parameters	Temp.	30 Day Baseline	30 Day Exposed	% Change	60 Day Baseline	60 Day Exposed	% Change	90 Day Baseline	90 Day Exposed	% Change	120 Day Baseline	120 Day Exposed	% Change
GEOTEXTILE: TREVIRA 1145 12 OZ.													
Thickness (mils)	23C	186	181	-3	186	188	1	186	177	-5	180	183	2
	50C	180	189	5	180	203	13	180	185	3	178	188	6
Length (inches)	23C	8.03	8.02	-0.1	8.03	8.04	0.1	8.03	8.04	0.1	8.01	8.00	-0.1
	50C	8.02	7.96	-0.7	8.02	7.96	-0.7	8.02	7.97	-0.6	8.02	7.98	-0.5
Width (inches)	23C	4.02	4.03	0.2	4.02	4.02	0.0	4.02	4.05	0.7	4.03	4.03	0.0
	50C	4.03	4.01	-0.5	4.03	3.98	-1.2	4.03	3.99	-1.0	4.03	3.99	-1.0
Mass (g)	23C	9.39	10.31	9.80	9.39	9.46	0.75	9.39	9.63	2.56	9.92	9.92	0.00
	50C	9.80	10.02	2.29	9.80	10.04	2.49	9.80	9.92	1.27	9.24	9.25	0.11
GEOTEXTILE: TREVIRA 1155 16 OZ.													
Thickness (mils)	23C	204	204	0	204	206	1	204	195	-4	189	190	1
	50C	204	204	0	204	213	4	204	199	-2	195	200	3
Length (inches)	23C	8.01	8.04	0.4	8.01	8.03	0.2	8.01	8.03	0.2	7.99	7.93	-0.8
	50C	7.99	7.91	-1.0	7.99	7.92	-0.9	7.99	7.92	-0.9	7.99	7.89	-1.3
Width (inches)	23C	4.02	4.06	1.0	4.02	4.05	0.7	4.02	4.06	1.0	4.02	4.02	0.0
	50C	4.01	4.00	-0.2	4.01	4.00	-0.2	4.01	4.01	0.0	4.01	4.01	0.0
Mass (g)	23C	11.22	11.81	5.31	11.22	11.27	0.49	11.22	11.61	3.52	11.17	11.31	1.25
	50C	11.14	11.23	0.80	11.14	11.44	2.68	11.14	11.42	2.50	11.59	11.69	0.86

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SRA
Quality Review

The testing listed herein is based upon accepted industry practice as well as by the test method listed.
TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material.

GEOMEMBRANE TEST RESULTS

NATIONAL SEAL COMPANY 60 MIL HDPE GEOMEMBRANE

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day		60 Day		90 Day		120 Day	
		23C	50C	23C	50C	23C	50C	23C	50C
GEOMEMBRANE: NATIONAL SEAL 60 mil SMOOTH HDPE									
Tensile Properties:									
Tensile Stress @ Yield (psi)	2710	2710	2580	2650	2650	2620	2710	2580	2620
ASTM D638	2580	2540	2710	2690	2790	2560	2670	2480	2560
Machine Direction	2770	2600	2650	2710	2860	2520	2670	2400	2560
	2890								
	2820								
	2620								
Average	2732	2617	2647	2683	2767	2567	2683	2487	2580
STD	108	70	53	25	87	41	19	74	28
Coefficient of Variation	4	3	2	1	3	2	1	3	1
% Change		-4	-3	-2	1	-6	-2	-9	-6
Tensile Strength @ Break (psi)	4200	4710	4710	3940	5030	4850	4970	4390	4200
ASTM D638	4970	4640	4390	4850	4830	4920	4950	4570	4850
Machine Direction	4260	4640	4650	4710	4950	4840	4730	4440	3930
	4530								
	4980								
	5120								
Average	4677	4663	4583	4500	4937	4870	4883	4467	4327
STD	364	33	139	400	82	36	109	76	386
Coefficient of Variation	8	1	3	9	2	1	2	2	9
% Change		-0	-2	-4	6	4	4	-4	-7
Tensile Properties:									
Elongation @ Yield (%)	17	18	18	20	19	18	20	18	19
ASTM D638	18	18	18	18	20	18	18	18	19
Machine Direction	17	17	18	18	18	18	18	20	18
	14								
	17								
	15								
Average	16	18	18	19	19	18	19	19	19
STD	1	0	0	1	1	0	1	1	0
Coefficient of Variation	8	3	0	5	4	0	5	5	3
% Change		8	10	14	16	10	14	14	14

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Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

	Baseline	30 Day		60 Day		90 Day		120 Day	
Test Parameters		23C	50C	23C	50C	23C	50C	23C	50C
Elongation @ Break (%)	793	910	941	776	957	893	938	858	841
ASTM D638	943	884	856	936	928	910	1010	879	949
Machine Direction	808	893	891	894	946	912	885	868	788
	824								
	874								
	913								
Average	859	896	896	869	944	905	944	868	859
STD	55	11	35	68	12	9	51	9	67
Coefficient of Variation	6	1	4	8	1	1	5	1	8
% Change		4	4	1	10	5	10	1	0
Set after Break (%)	777	884	891	811	897	841	950	698	832
ASTM D638	870	847	833	882	824	909	983	852	890
Machine Direction	795	871	863	835	849	874	910	890	830
	813								
	840								
	840								
Average	823	867	862	843	857	875	948	813	851
STD	31	15	24	29	30	28	30	83	28
Coefficient of Variation	4	2	3	3	4	3	3	10	3
% Change		5	5	2	4	6	15	-1	3
Stress @ 100% Elongation (psi)	1940	1870	1870	1940	1940	1970	1870	1870	1840
ASTM D638	1870	1841	1870	1900	2030	1840	1780	1900	1840
Machine Direction	1940	1910	1870	1940	2030	1940	1870	1840	1840
	1970								
	1970								
	1900								
Average	1932	1874	1870	1927	2000	1917	1840	1870	1840
STD	36	28	0	19	42	56	42	24	0
Coefficient of Variation	2	2	0	1	2	3	2	1	0
% Change		-3	-3	-0	4	-1	-5	-3	-5

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Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Stress @ 200% Elongation (psi)	1940	1940	1940	2000	2000	1970	1940	1940	1840
ASTM D638	1940	1910	1940	1970	2030	1970	1840	1900	1970
Machine Direction	1940	1970	1940	2000	2030	1940	2000	1900	1900
	1970								
	1970								
	1970								
Average	1955	1940	1940	1990	2020	1960	1927	1913	1903
STD	15	24	0	14	14	14	66	19	53
Coefficient of Variation	1	1	0	1	1	1	3	1	3
% Change		-1	-1	2	3	0	-1	-2	-3
Tensile Properties:									
Tensile Stress @ Yield (psi)	2840	2650	2770	2900	2790	2650	2650	2650	2540
ASTM D638	2770	2620	2770	2770	2790	2710	2580	2480	2580
Transverse Direction	2840	2580	2650	2710	2790	2650	2750	2580	2450
	2890								
	2840								
	2900								
Average	2847	2617	2730	2793	2790	2670	2660	2570	2523
STD	42	29	57	79	0	28	70	70	54
Coefficient of Variation	1	1	2	3	0	1	3	3	2
% Change		-8	-4	-2	-2	-6	-7	-10	-11
Tensile Strength @ Break (psi)	5030	4580	4900	4320	4700	4650	4790	4190	4630
ASTM D638	5100	4980	4770	5160	4700	4970	4770	3810	4900
Transverse Direction	4840	4710	4770	4320	5020	4710	4330	4130	4650
	4200								
	4260								
	4200								
Average	4605	4757	4813	4600	4807	4777	4630	4043	4727
STD	393	167	61	396	151	139	212	167	123
Coefficient of Variation	9	4	1	9	3	3	5	4	3
% Change		3	5	-0	4	4	1	-12	3

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Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Tensile Properties:									
Elongation @ Yield (%)	15	17	18	20	20	18	18	20	18
ASTM D638	17	14	18	18	20	18	18	18	20
Transverse Direction	14	18	18	18	18	18	18	18	20
	17								
	14								
	17								
Average	16	16	18	19	19	18	18	19	19
STD	1	2	0	1	1	0	0	1	1
Coefficient of Variation	9	10	0	5	5	0	0	5	5
% Change		4	15	19	23	15	15	19	23
Elongation @ Break (%)	930	938	985	911	1002	963	908	912	995
ASTM D638	959	1002	978	1054	1000	1020	978	842	1110
Transverse Direction	909	959	984	1007	1050	975	880	900	1053
	805								
	800								
	789								
Average	865	966	982	991	1017	986	922	885	1053
STD	69	27	3	60	23	25	41	31	47
Coefficient of Variation	8	3	0	6	2	2	4	3	4
% Change		12	14	14	18	14	7	2	22
Set after Break (%)	830	900	948	873	852	959	903	945	950
ASTM D638	903	934	887	939	924	980	950	870	994
Transverse Direction	852	900	880	909	938	970	920	873	965
	815								
	835								
	790								
Average	838	911	905	907	905	970	924	896	970
STD	35	16	31	27	38	9	19	35	18
Coefficient of Variation	4	2	3	3	4	1	2	4	2
% Change		9	8	8	8	16	10	7	16

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Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Stress @ 100% Elongation (psi)	1940	1810	1810	1940	1900	1810	1840	1810	1710
ASTM D638	1870	1840	1810	1870	1840	1810	1810	1710	1740
Transverse Direction	1940	1810	1870	1870	1840	1810	1900	1740	1740
	1970								
	1940								
	1940								
Average	1933	1820	1830	1893	1860	1810	1850	1753	1730
STD	30	14	28	33	28	0	37	42	14
Coefficient of Variation	2	1	2	2	2	0	2	2	1
% Change		-6	-5	-2	-4	-6	-4	-9	-11
Stress @ 200% Elongation (psi)	1940	1870	1810	1940	1900	1810	1900	1810	1780
ASTM D638	1940	1900	1810	1870	1900	1940	1870	1780	1810
Transverse Direction	1940	1870	1870	1940	1840	1810	1900	1810	1810
	1970								
	1940								
	1940								
Average	1945	1880	1830	1917	1880	1853	1890	1800	1800
STD	11	14	28	33	28	61	14	14	14
Coefficient of Variation	1	1	2	2	2	3	1	1	1
% Change		-3	-6	-1	-3	-5	-3	-7	-7
Modulus of Elasticity:									
ASTM D882 (psi)	47600	42700	48400	42200	43300	49200	50000	55400	37500
Machine Direction	45200	50800	48400	42200	41800	50000	50000	40000	37500
2% Secant	47600	48400	46700	42200	41800	50800	50000	41900	41000
	46800								
	48400								
	47600								
Average	47200	47300	47833	42200	42300	50000	50000	45767	38667
STD	1103	4161	981	0	866	800	0	8397	2021
Coefficient of Variation	2	9	2	0	2	2	0	18	5
% Change		0	1	-11	-10	6	6	-3	-18

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Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

eport Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Modulus of Elasticity:									
ASTM D882 (psi)	50800	50000	50000	41500	43300	50800	54000	43500	45100
Transverse Direction	49200	45200	50000	46000	41800	51500	52400	42700	39500
2% Secant	46800	49200	48400	44600	41800	51600	52400	40000	43400
	48400								
	47600								
	48400								
Average	48533	48133	49467	44033	42300	51300	52933	42067	42667
STD	1378	2572	924	2303	866	436	924	1834	2871
Coefficient of Variation	3	5	2	5	2	1	2	4	7
% Change		-1	2	-9	-13	6	9	-13	-12
Indentation Hardness:									
Reading	57	58	58	59	58	60	59	62	61
ASTM D2240	57	58	58	58	58	59	58	62	56
(with TYPE D DUROMETER)	57	57	59	57	59	58	59	62	61
	54	57	59	58	58	58	57	62	61
	57	58	59	58	59	59	58	62	61
	58								
Average	57	58	59	58	58	59	58	62	60
STD	1	1	1	1	1	1	1	0	2
Coefficient of Variation	2	1	1	1	1	1	1	0	4
% Change		2	3	2	3	4	3	9	6
Specific Gravity:									
ASTM D792, Method A	0.945	0.945	0.950	0.947	0.946	0.936	0.936	0.953	0.952
	0.948	0.949	0.949	0.946	0.946	0.938	0.944	0.942	0.950
	0.945	0.954	0.951	0.948	0.948	0.935	0.952	0.940	0.953
	0.949								
	0.950								
	0.952								
Average	0.948	0.949	0.950	0.947	0.947	0.936	0.944	0.945	0.952
STD	0.003	0.005	0.001	0.001	0.001	0.002	0.008	0.007	0.002
Coefficient of Variation	0	0	0	0	0	0	1	1	0
% Change		0.12	0.19	-0.12	-0.16	-1.25	-0.44	-0.33	0.37
Environmental Stress Crack Resistance:									
ASTM D1693, Condition B									
Machine Direction (% Failed)	N/A	0	0	0	0	0	0	0	0
Transverse Direction (% Failed)	N/A	0	0	0	0	0	0	0	0

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Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
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Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Puncture Resistance:									
Load @ Rupture (lbs)	91	84	88	94	95	84	85	87	91
FTMS 101C Method 2065	92	84	88	92	95	83	86	87	91
	92	86	89	92	95	82	86	85	92
	92								
	91								
	91								
Average	92	85	88	93	95	83	86	86	91
STD	1	1	0	1	0	1	0	1	0
Coefficient of Variation	1	1	1	1	0	1	1	1	1
% Change		-7	-3	1	4	-9	-6	-6	-0
Volatiles and Extractables:									
Machine Diameter Change (%)	0.10	-0.63	-0.55	-0.10	-0.28	0.25	-0.18	-0.55	-1.05
SW 870 - Appendix III-D	-0.85	-0.70	-0.93	-0.73	-0.33	-0.25	-0.25	-0.25	-0.30
	-0.35								
	-0.40								
Average	-0.38	-0.66	-0.74	-0.41	-0.30	0.00	-0.22	-0.40	-0.68
STD	0.34	0.04	0.19	0.31	0.02	0.25	0.04	0.15	0.38
Volatiles and Extractables:									
Transverse Diameter Change (%)	0.28	-0.15	-0.08	-0.23	0.00	0.20	-0.10	-0.03	-0.13
SW 870 - Appendix III-D	0.13	2.00	0.23	0.175	-0.25	-0.10	-0.20	-0.20	0.00
	0.10								
	-0.03								
Average	0.12	0.92	0.08	-0.03	-0.13	0.05	-0.15	-0.11	-0.06
STD	0.11	1.07	0.15	0.20	0.13	0.15	0.05	0.09	0.06
% Volatiles	0.06	0.11	0.11	0.10	0.11	0.06	0.07	0.11	0.11
SW 870 - Appendix III-D	0.05	0.10	0.11	0.12	0.11	0.07	0.08	0.10	0.16
	0.05								
	0.05								
Average	0.05	0.11	0.11	0.11	0.11	0.07	0.08	0.11	0.14
STD	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.03
% Extractables	0.49	0.53	0.64	0.64	0.57	0.70	0.78	0.36	0.48
SW 870 - Appendix III-D	0.59	0.56	0.52	0.39	0.58	0.76	0.79	0.29	0.39
	0.69								
	0.47								
Average	0.56	0.55	0.58	0.52	0.58	0.73	0.79	0.33	0.44
STD	0.09	0.02	0.06	0.13	0.01	0.03	0.01	0.04	0.04

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Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

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Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Hydrostatic Resistance:									
ASTM D751	500	460	480	470	475	450	455	450	450
(psi)	465	470	480	470	475	455	460	460	460
	470	475	420	465	465	450	465	445	460
	470								
	470								
	470								
Average	474	468	460	468	472	452	460	452	457
STD	13	8	35	3	6	3	5	8	6
Coefficient of Variation	3	2	8	1	1	1	1	2	1
% Change		-1	-3	-1	-1	-5	-3	-5	-4
Seam Peel Adhesion:									
ASTM D4437 (lbs)	123	111	123	125	121	129	128	123	125
	126	114	109	115	136	121	125	121	118
	127	117	113	123	108	123	120	127	118
	129								
	124								
	125								
Average	126	114	115	121	122	124	124	124	120
STD	2	2	6	4	11	3	3	2	3
Coefficient of Variation	2	2	5	4	9	3	3	2	3
% Change		-9	-8	-4	-3	-1	-1	-2	-4
Failure Mode (FTB = All Film Tear Bond)	FTB	FTB	FTB	FTB	FTB	FTB	FTB	FTB	FTB
Shear Seam Strength:									
Shear Seam Strength (lbs)	157	153	148	149	163	154	158	153	163
ASTM D4437	159	153	150	160	161	152	159	157	162
	159	152	151	157	162	157	158	157	158
	159								
	163								
	163								
Average	160	153	150	155	162	154	158	156	161
STD	2	0	1	5	1	2	0	2	2
Coefficient of Variation	1	0	1	3	1	1	0	1	1
% Change		-5	-6	-3	1	-4	-1	-3	1

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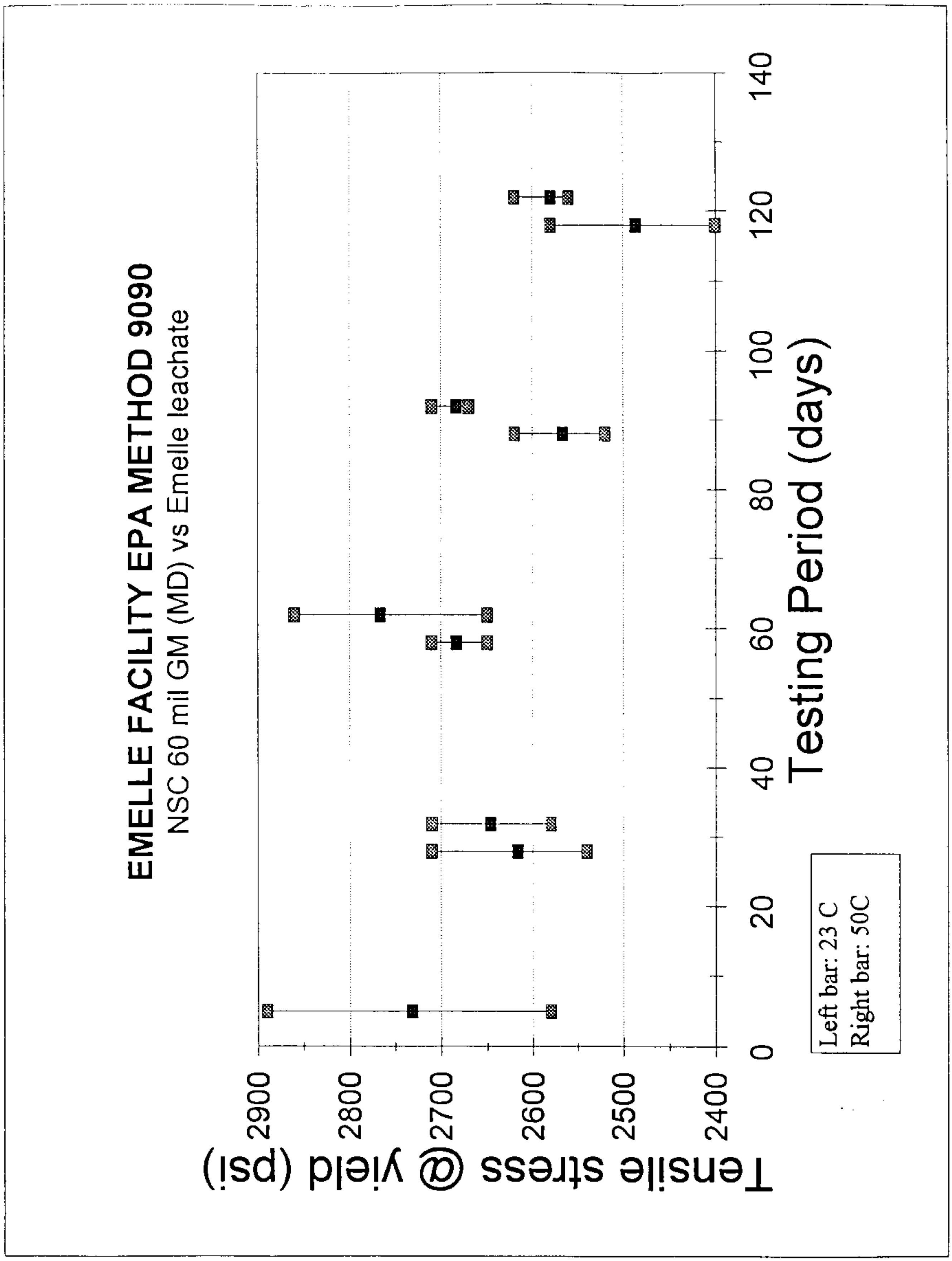
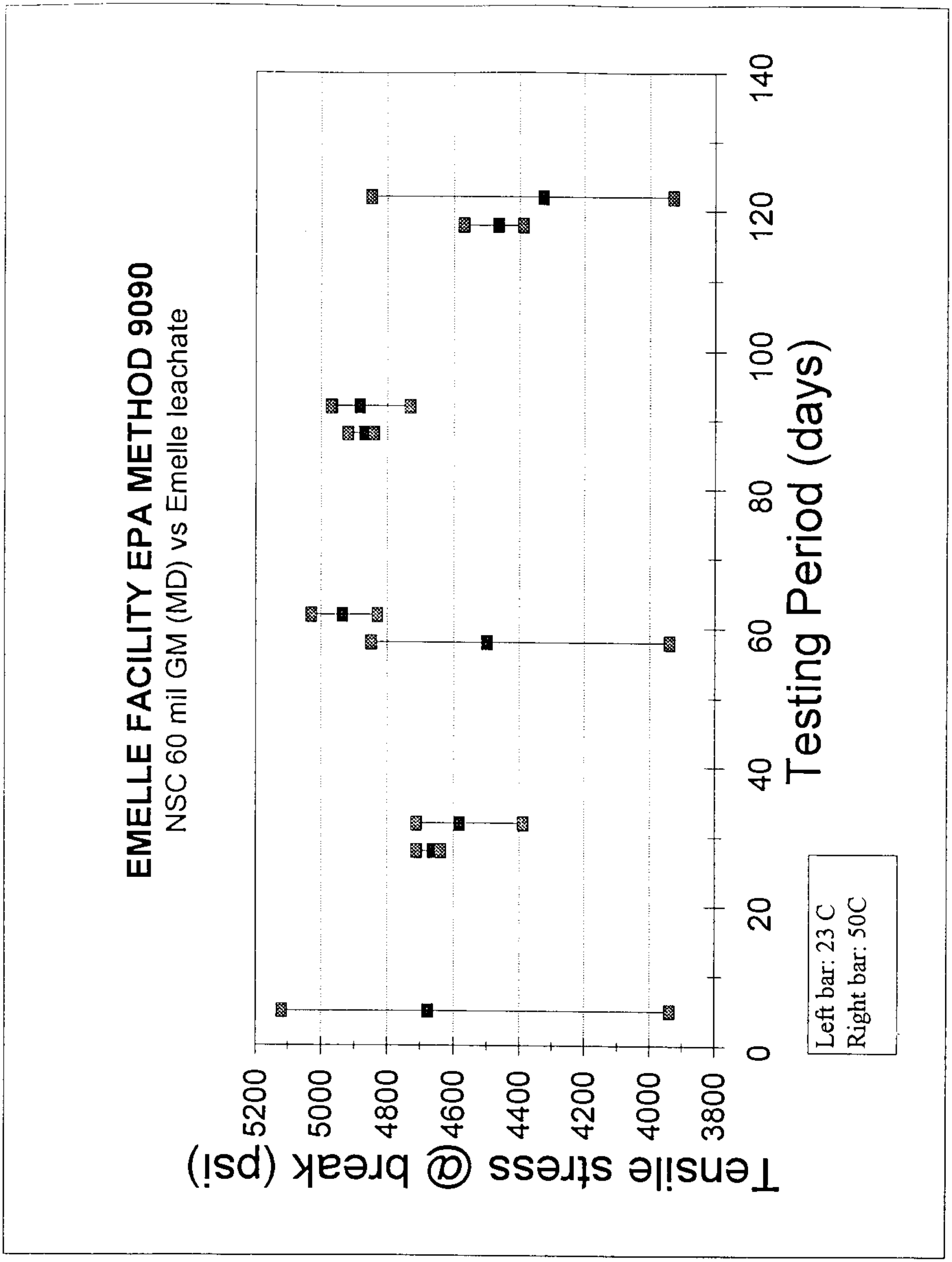
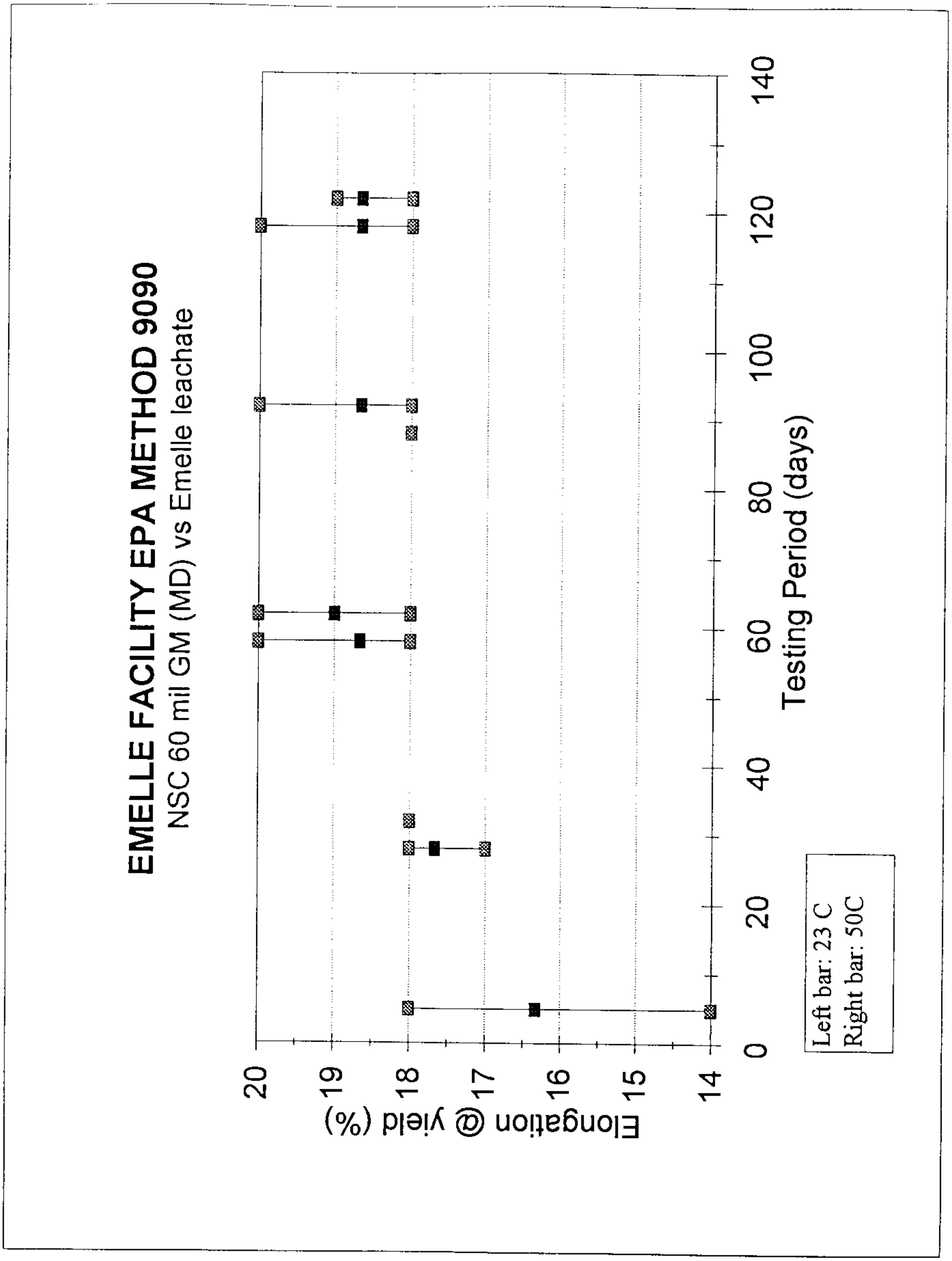
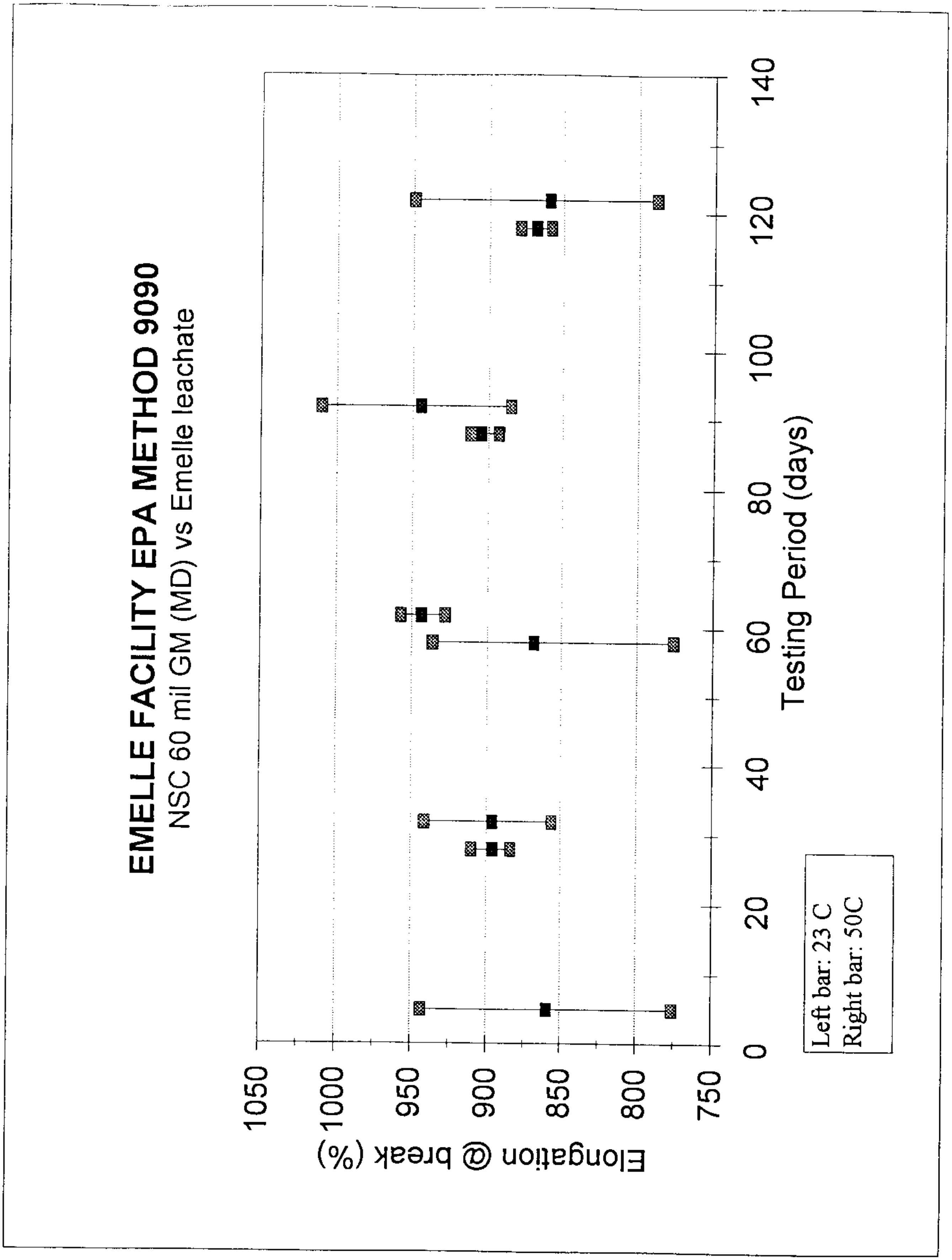


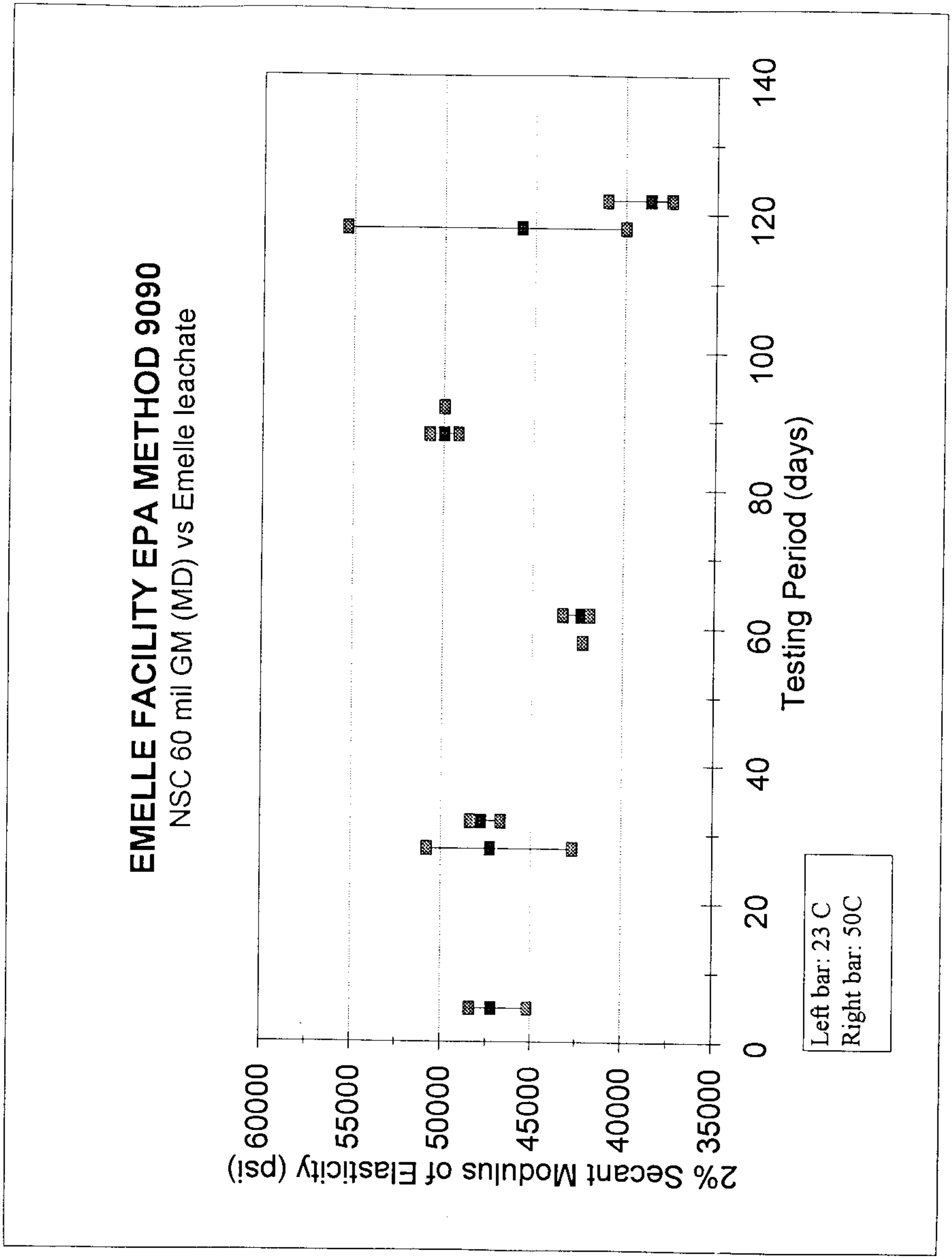
EMELLE FACILITY EPA METHOD 9090
NSC 60 mil GM (MD) vs Emelle leachate
Tensile stress @ yield (psi)
2900
2800
2700
2600
2500
2400
0
20
40
60
80
100
120
140
Testing Period (days)
Left bar: 23 C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
NSC 60 mil GM (MD) vs Emelle leachate
Tensile stress @ break (psi)
5200
5000
4800
4600
4400
4200
4000
3800
Testing Period (days)
0
20
40
60
80
100
120
140
Left bar: 23 C
Right bar: 50C

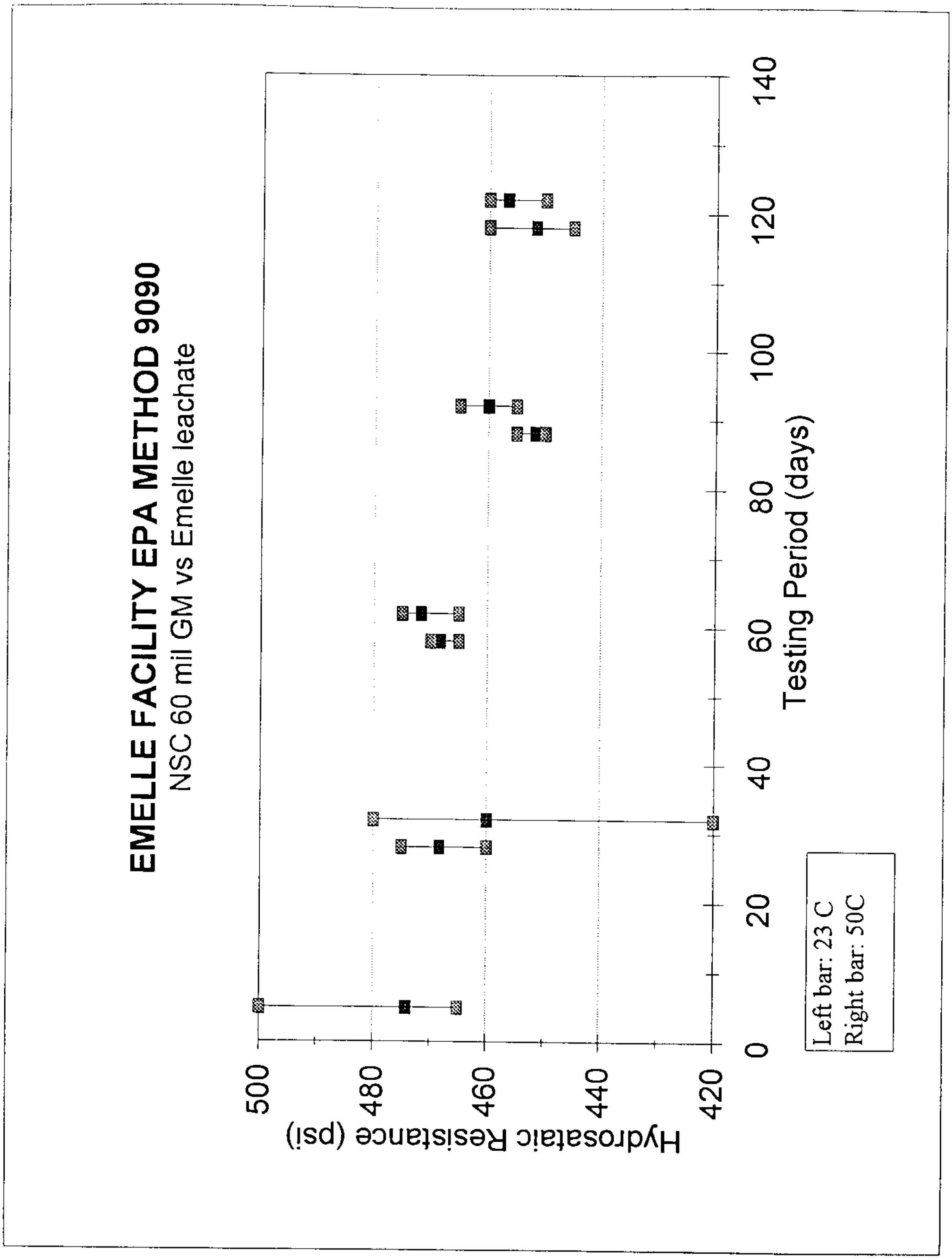

EMELLE FACILITY EPA METHOD 9090
NSC 60 mil GM (MD) vs Emelle leachate
Elongation @ yield (%)
20
19
18
17
16
15
14
0
20
40
60
80
100
120
140
Testing Period (days)
Left bar: 23 C
Right bar: 50C



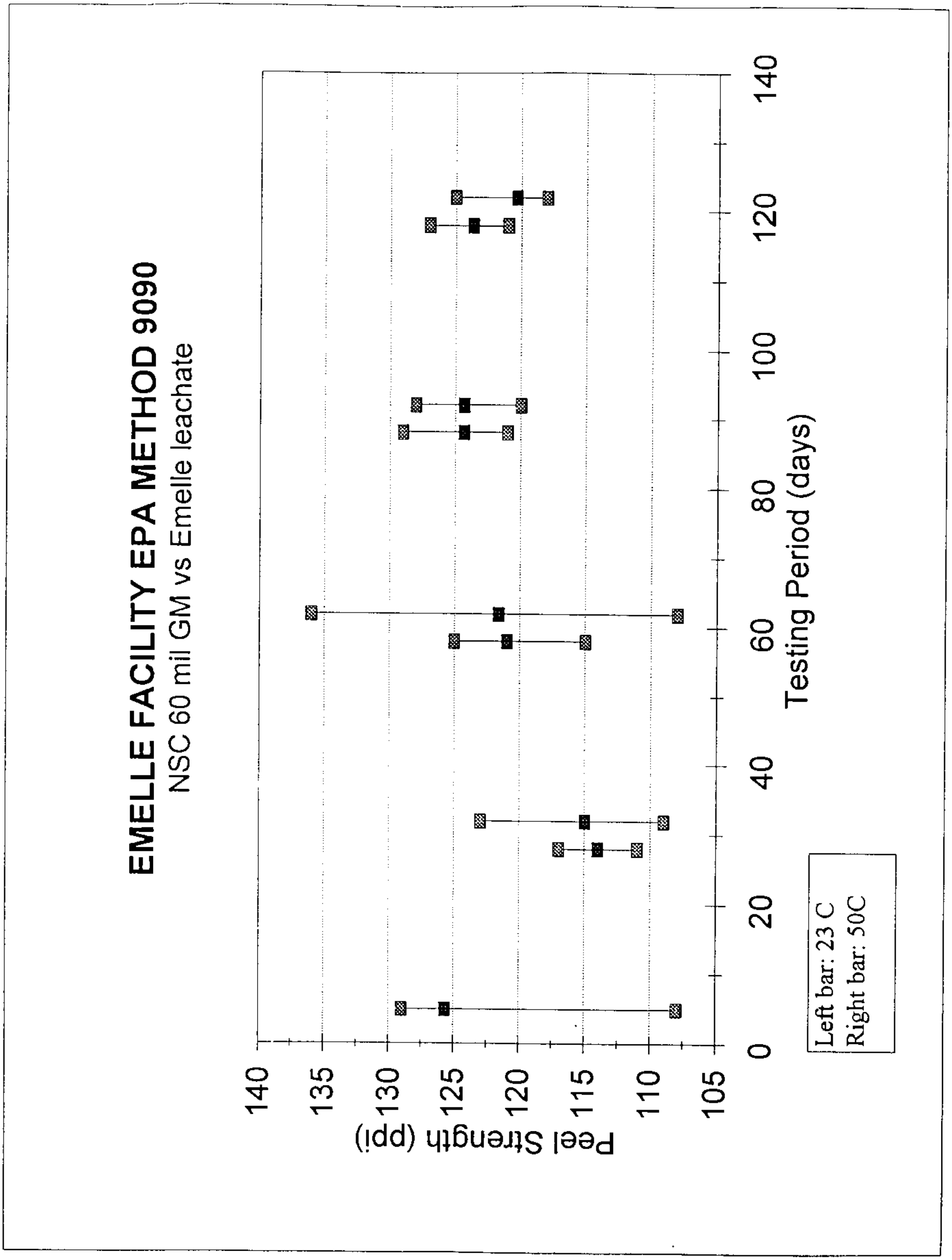
EMELLE FACILITY EPA METHOD 9090
NSC 60 mil GM (MD) vs Emelle leachate
Elongation @ break (%)
1050
1000
950
900
850
800
750
Testing Period (days)
0
20
40
60
80
100
120
140
Left bar: 23 C
Right bar: 50C



EMELLE FACILITY EPA METHOD 9090
NSC 60 mil GM (MD) vs Emelle leachate
2% Secant Modulus of Elasticity (psi)
60000
55000
50000
45000
40000
35000
0
20
40
60
80
100
120
140
Testing Period (days)
Left bar: 23 C
Right bar: 50C



EMELLE FACILITY EPA METHOD 9090
NSC 60 mil GM vs Emelle leachate
Hydrostatic Resistance (psi)
500
480
460
440
420
0
20
40
60
80
100
120
140
Testing Period (days)
Left bar: 23 C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
NSC 60 mil GM vs Emelle leachate
Peel Strength (ppi)
140
135
130
125
120
115
110
105
Testing Period (days)
0
20
40
60
80
100
120
140
Left bar: 23 C
Right bar: 50C

GEOTEXTILE TEST RESULTS

POLYESTER TREVIRA 1145 AND 1155 GEOTEXTILE

POLYPROPYLENE SYNTHETIC INDUSTRIES 12 OZ AND 16 OZ GEOTEXTILE

POLYPROPYLENE POLYFELT TS 800 AND TS 1000 GEOTEXTILE

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
GEOTEXTILE: TREVIRA 1145 12 OZ.									
Grab:									
Grab Strength (lb)	535	553	590	500	552	560	395	575	465
ASTM D4632	534	500	489	563	581	541	465	510	570
Machine Direction	475	577	447	543	530	557	407	525	520
	527	520	404	598	541	514	477	550	570
	653	579	470	471	532	560	421	580	530
	564								
	539								
	574								
	559								
	615								
Average	558	546	480	535	547	546	433	548	531
STD	47	31	62	45	19	18	32	27	39
Coefficient of Variation	8	6	13	8	3	3	7	5	7
% Change		-2	-14	-4	-2	-2	-22	-2	-5
Grab Elongation (%)	108	98	107	80	87	101	104	65	98
ASTM D4632	100	94	108	89	88	94	108	67	100
Machine Direction	91	101	102	86	84	98	100	71	86
	101	107	103	86	104	90	106	97	91
	103	96	111	85	84	96	106	93	98
	99								
	97								
	98								
	98								
	96								
Average	99	99	106	85	89	96	105	79	95
STD	4	5	3	3	7	4	3	14	5
Coefficient of Variation	4	5	3	3	8	4	3	17	6
% Change		0	7	-14	-10	-3	6	-21	-5

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Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Tear Resistance:									
Trapezoidal Tear Strength (lb)	231	224	197	230	227	218	218	226	190
ASTM D4533	212	227	181	199	180	206	253	300	225
Machine Direction	221	245	204	191	166	234	163	250	250
	196	235	215	249	185	244	185	260	215
	215	230	220	206	163	187	209	250	260
	235								
	213								
	210								
	217								
	255								
Average	221	232	203	215	184	218	206	257	228
STD	15	7	14	21	23	20	30	24	25
Coefficient of Variation	7	3	7	10	12	9	15	9	11
% Change		5	-8	-2	-16	-1	-7	17	3
Puncture:									
Load @ Rupture (lb)	251	230	232	240	238	207	218	188	172
ASTM D4833	201	226	252	202	222	202	203	200	156
	221	223	241	212	192	189	186	179	175
	247	250	217	189	197	206	203	156	160
	238	227	207	193	198	193	187	192	192
	197								
	261								
	212								
	226								
	232								
Average	229	231	230	207	209	199	199	183	171
STD	20	10	16	18	18	7	12	15	13
Coefficient of Variation	9	4	7	9	8	4	6	8	7
% Change		1	1	-9	-8	-13	-13	-20	-25

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SEA
Quality Review

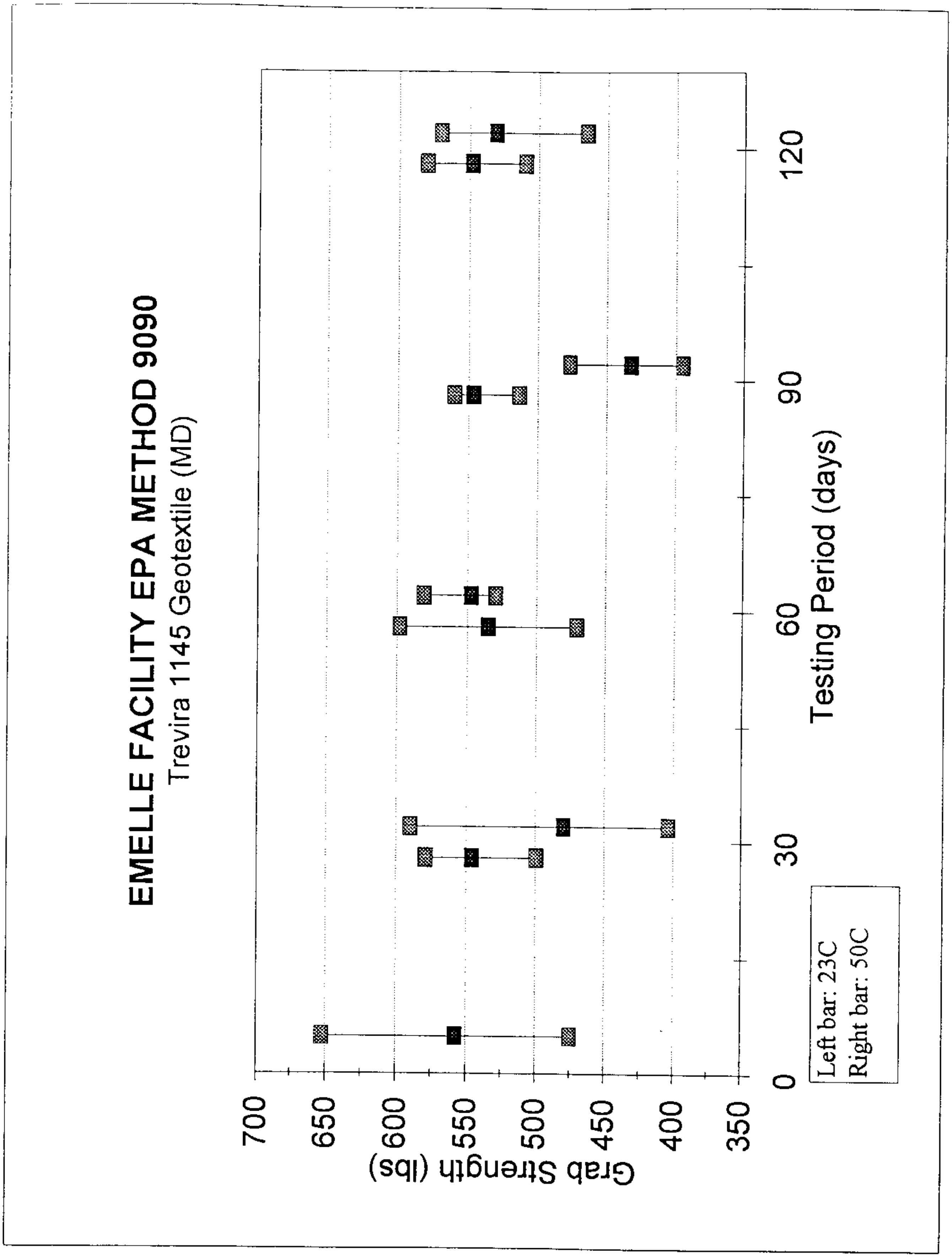
TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

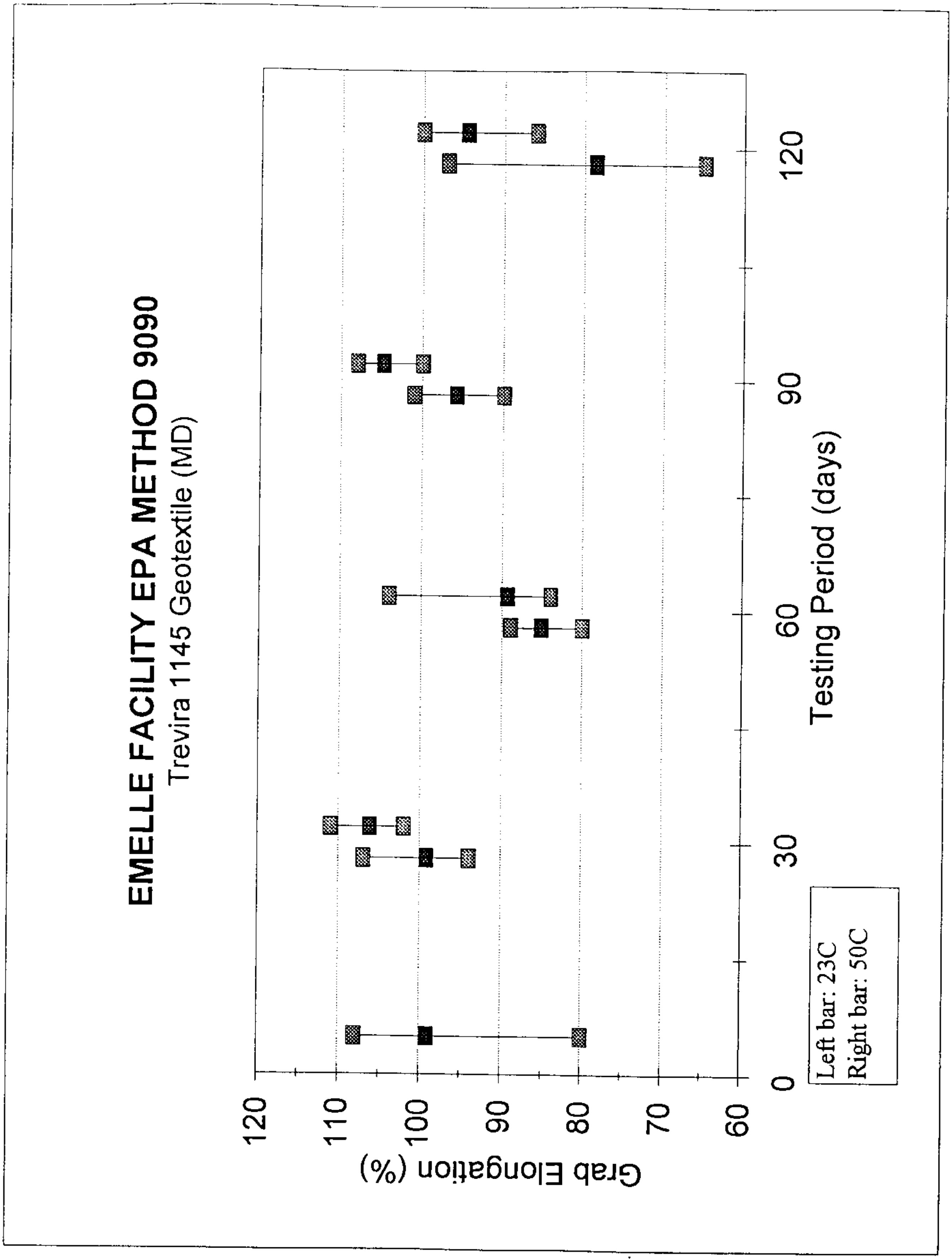
Exposure Time and Temperature

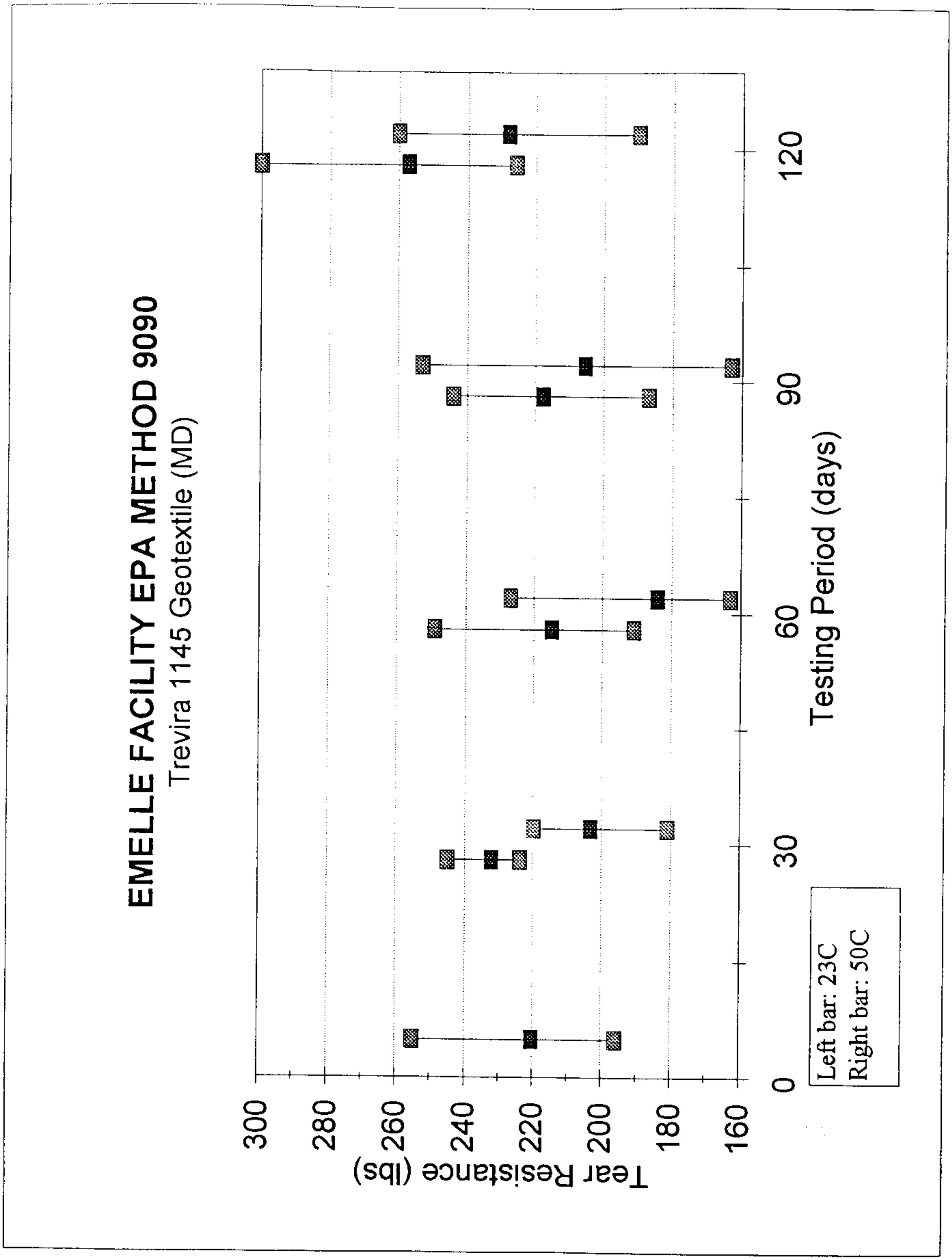
Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Permittivity: flow rate									
(gal/min/ft2)	68.97	75.72	71.22	71.22	72.72	78.72	76.47	79.39	66.08
ASTM D4491	71.97	78.72	69.72	72.72	71.97	83.97	68.97	75.46	73.40
	61.48	74.22	68.97	74.22	69.72	71.22	62.23	70.74	69.14
	71.22	76.47	72.72	72.72	68.22	79.47	76.47	74.05	69.14
	66.72	71.97	69.72	71.97	72.72	77.22	68.22	76.36	64.90
	68.97								
	70.47								
	62.23								
	75.72								
	65.97								
Average	68.37	75.42	70.47	72.57	71.07	78.12	70.47	75.20	68.53
STD	4.17	2.25	1.34	0.99	1.80	4.12	5.43	2.84	2.96
Coefficient of Variation	6	3	2	1	3	5	8	4	4
% Change		10	3	6	4	14	3	10	0
Mullen Burst:									
Burst Strength (psi)	680	835	830	785	810	670	790	680	760
ASTM D3786	805	795	730	770	765	790	830	745	695
	790	850	770	740	740	775	765	715	625
	790	770	915	765	770	755	770	840	705
	785	730	780	735	755	780	775	725	760
	920								
	730								
	730								
	780								
	835								
Average	785	796	805	759	768	754	786	741	709
STD	62	44	64	19	23	44	24	54	50
Coefficient of Variation	8	5	8	2	3	6	3	7	7
% Change		1	3	-3	-2	-4	0	-6	-10

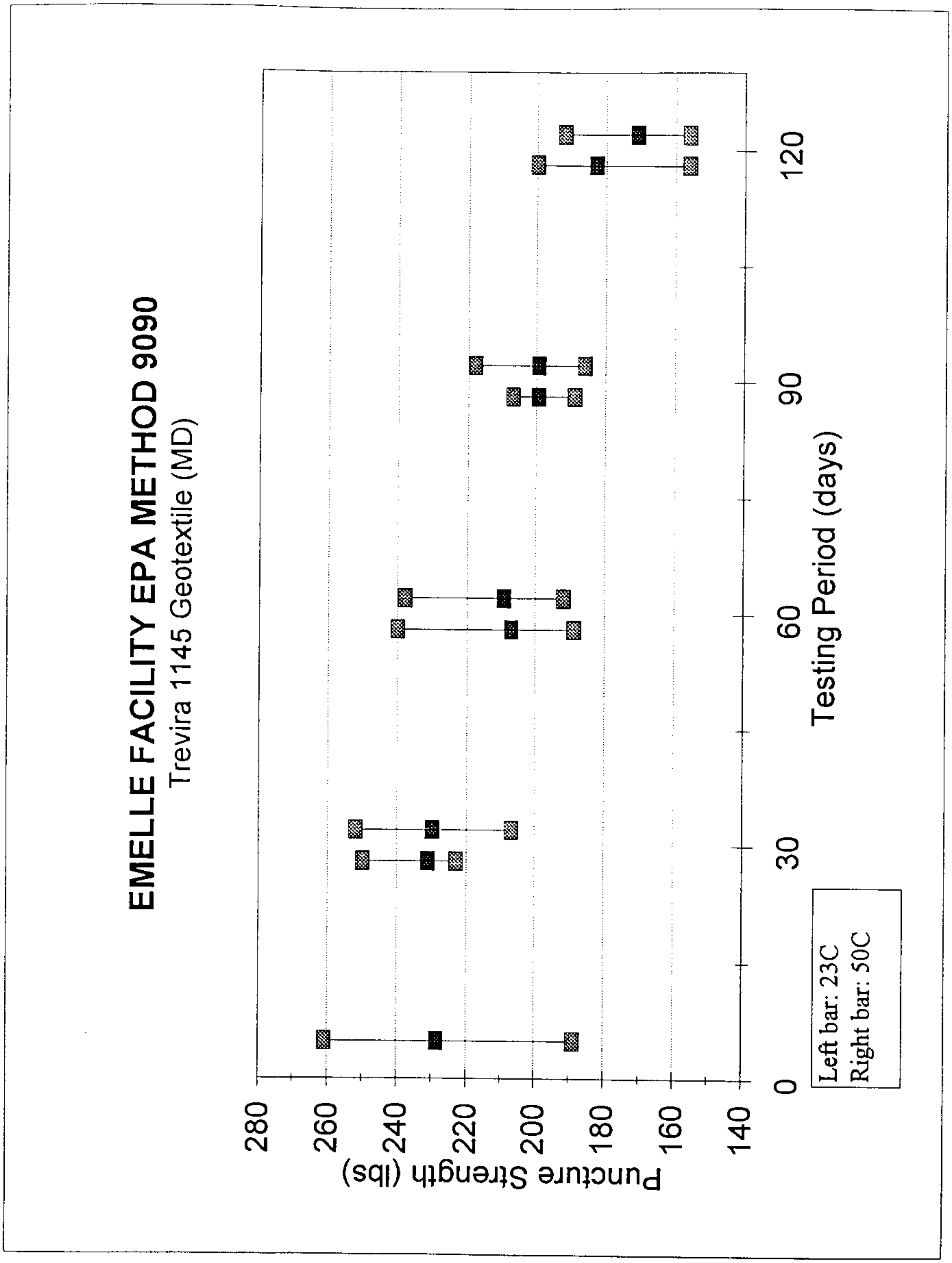
SEA
Quality Review

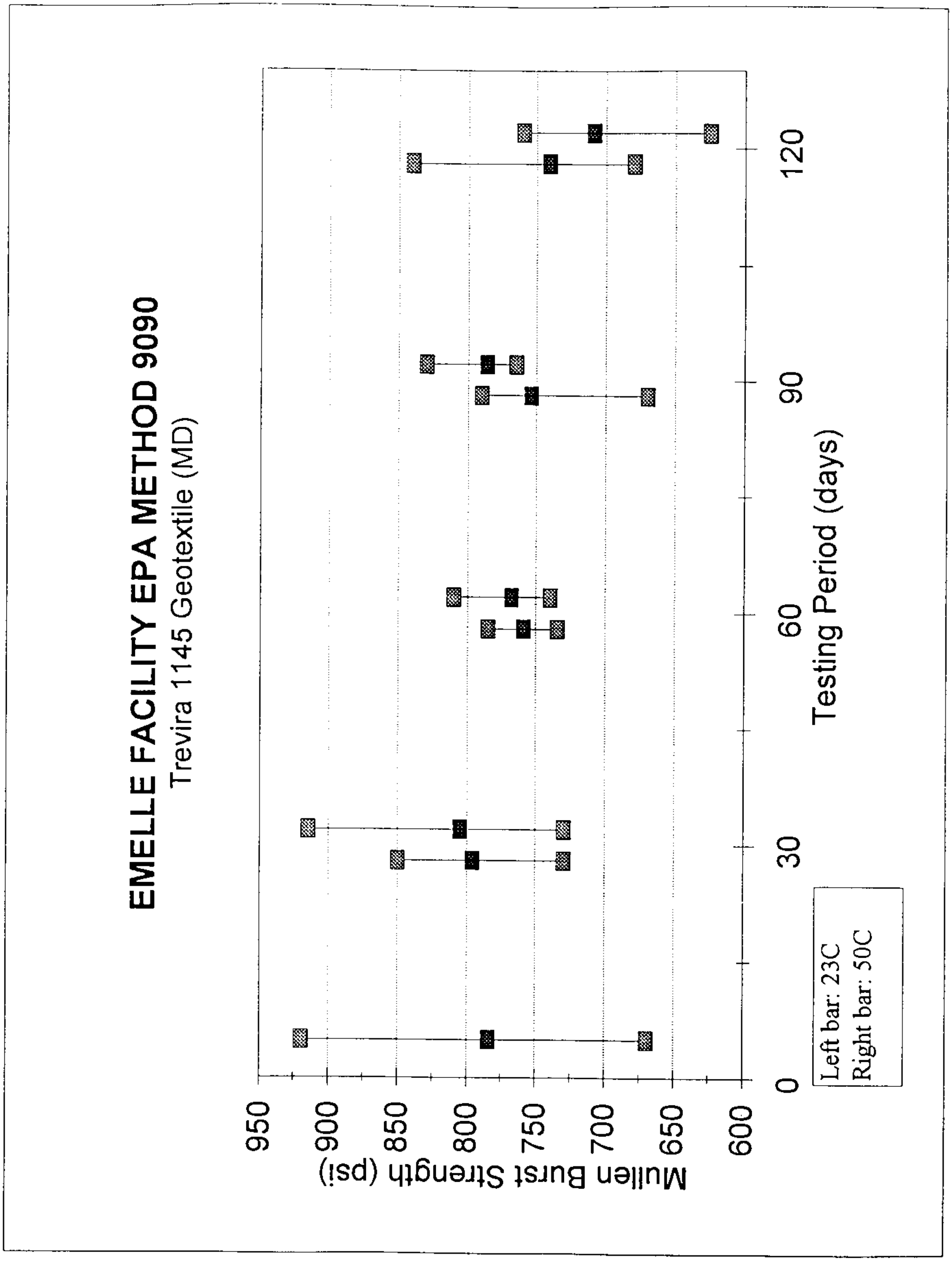


EMELLE FACILITY EPA METHOD 9090
Trevira 1145 Geotextile (MD)
Grab Strength (lbs)
700
650
600
550
500
450
400
350
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
Trevira 1145 Geotextile (MD)
Grab Elongation (%)
120
110
100
90
80
70
60
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
Trevira 1145 Geotextile (MD)
Tear Resistance (lbs)
300
280
260
240
220
200
180
160
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
Trevira 1145 Geotextile (MD)
Puncture Strength (lbs)
280
260
240
220
200
180
160
140
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
Trevira 1145 Geotextile (MD)
Mullen Burst Strength (psi)
950
900
850
800
750
700
650
600
Testing Period (days)
0
30
60
90
120
Left bar: 23C
Right bar: 50C

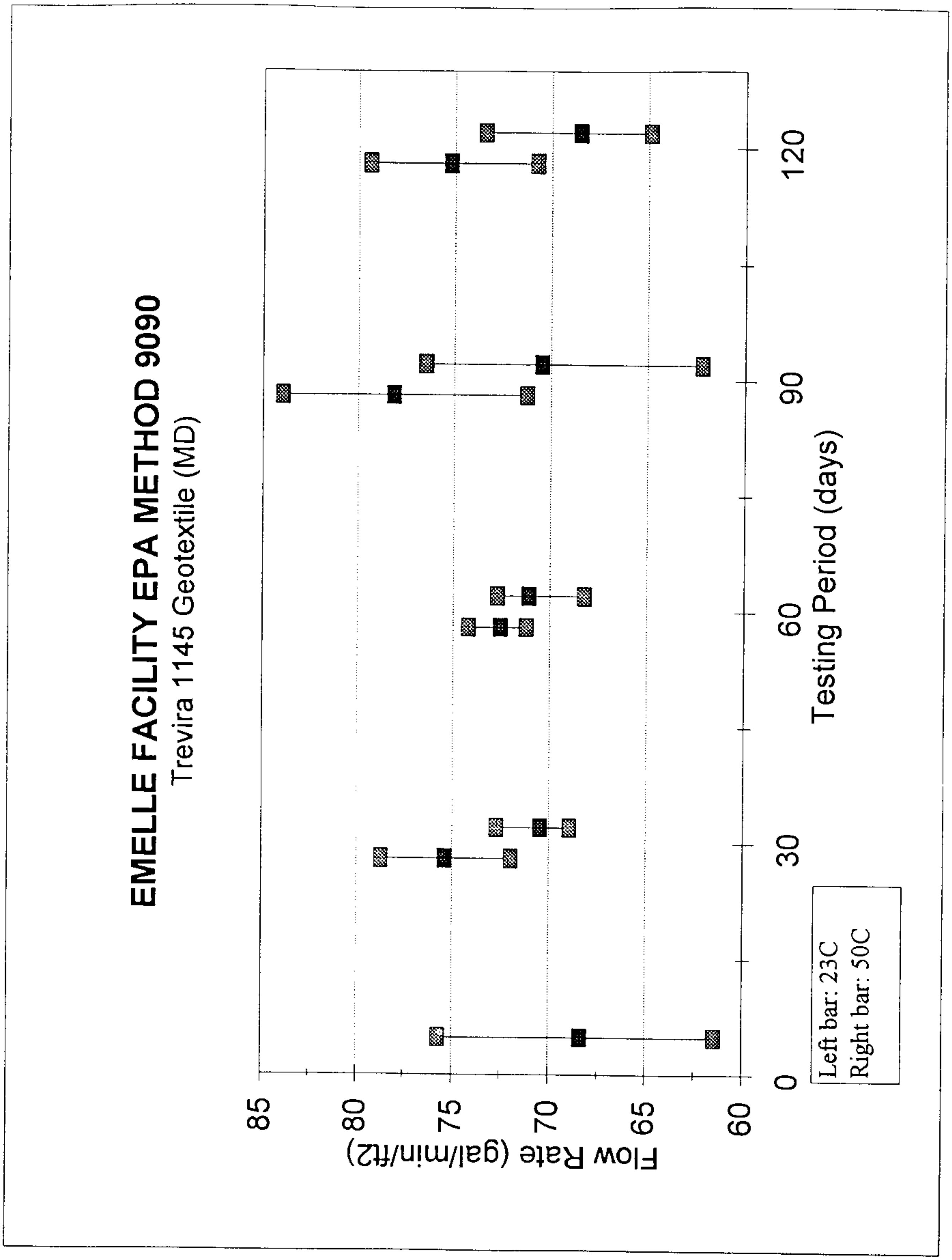

EMELLE FACILITY EPA METHOD 9090
Trevira 1145 Geotextile (MD)
Flow Rate (gal/min/ft2)
85
80
75
70
65
60
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
GEOTEXTILE: TREVIRA 1155 16 OZ.									
Grab:									
Grab Strength (lb)	535	653	558	706	568	690	567	640	680
ASTM D4632	534	628	675	638	550	665	610	630	580
Machine Direction	475	682	647	618	548	692	670	665	690
	527	598	645	672	528	678	610	595	600
	653	638	622	663	506	670	565	690	670
	564								
	539								
	574								
	559								
	615								
Average	558	640	629	659	540	679	604	644	644
STD	47	28	39	30	21	11	38	32	45
Coefficient of Variation	8	4	6	5	4	2	6	5	7
% Change		15	13	18	-3	22	8	16	16
Grab Elongation (%)	108	112	101	94	93	107	102	97	100
ASTM D4632	100	104	122	86	93	112	105	99	86
Machine Direction	91	104	115	96	90	91	120	91	101
	101	108	108	92	82	109	106	96	105
	103	92	110	88	88	109	101	94	97
	99								
	97								
	98								
	98								
	96								
Average	99	104	111	91	89	106	107	95	98
STD	4	7	7	4	4	7	7	3	6
Coefficient of Variation	4	6	6	4	5	7	6	3	7
% Change		5	12	-8	-10	7	8	-4	-1

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Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Tear Resistance:									
Trapezoidal Tear Strength (lb)	231	264	198	219	213	229	258	247	212
ASTM D4533	212	212	175	253	224	240	235	260	190
Machine Direction	221	190	230	242	207	238	215	265	205
	196	167	207	229	242	318	218	310	240
	215	215	230	214	215	234	223	263	295
	235								
	213								
	210								
	217								
	255								
Average	221	210	208	231	220	252	230	269	228
STD	15	32	21	14	12	33	16	21	37
Coefficient of Variation	7	15	10	6	6	13	7	8	16
% Change		-5	-6	5	-0	14	4	22	4
Puncture:									
Load @ Rupture (lb)	249	275	227	268	223	226	221	248	204
ASTM D4833	276	288	229	256	232	212	232	232	128
	233	258	243	261	198	244	232	224	206
	257	243	241	224	209	225	227	288	218
	252	252	231	262	222	230	238	198	188
	293								
	287								
	304								
	295								
	257								
Average	270	263	234	254	217	227	230	238	189
STD	23	16	7	16	12	10	6	30	32
Coefficient of Variation	8	6	3	6	5	5	2	13	17
% Change		-3	-13	-6	-20	-16	-15	-12	-30

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TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Permittivity: flow rate									
(gal/min/ft2)	52.48	56.98	52.48	54.73	57.73	56.23	53.98	82.10	81.95
ASTM D4491	57.73	56.98	54.73	56.98	54.73	65.97	56.98	74.30	82.05
	61.48	56.23	56.98	56.98	53.23	58.48	56.98	70.85	79.48
	44.23	55.48	52.48	54.73	53.98	59.98	53.98	79.34	86.32
	53.23	53.23	56.23	56.23	53.98	50.23	60.73	83.53	84.79
	53.23								
	56.98								
	53.98								
	60.73								
	41.23								
Average	53.53	55.78	54.58	55.93	54.73	58.18	56.53	78.02	82.92
STD	6.19	1.39	1.86	1.02	1.57	5.12	2.49	4.78	2.39
Coefficient of Variation	12	2	3	2	3	9	4	6	3
% Change		4	2	4	2	9	6	14	21
Mullen Burst:									
Burst Strength (psi)	810	880	1055	960	740	855	850	920	950
ASTM D3786	850	1000	840	980	850	865	820	980	910
	950	930	880	870	760	920	920	765	920
	950	1040	790	1025	770	1040	915	1010	1100
	1115	875	970	890	835	850	800	820	860
	855								
	960								
	895								
	1060								
	820								
Average	927	945	907	945	791	906	861	899	948
STD	96	65	95	57	43	72	49	93	81
Coefficient of Variation	10	7	10	6	5	8	6	10	9
% Change		2	-2	2	-15	-2	-7	15	21

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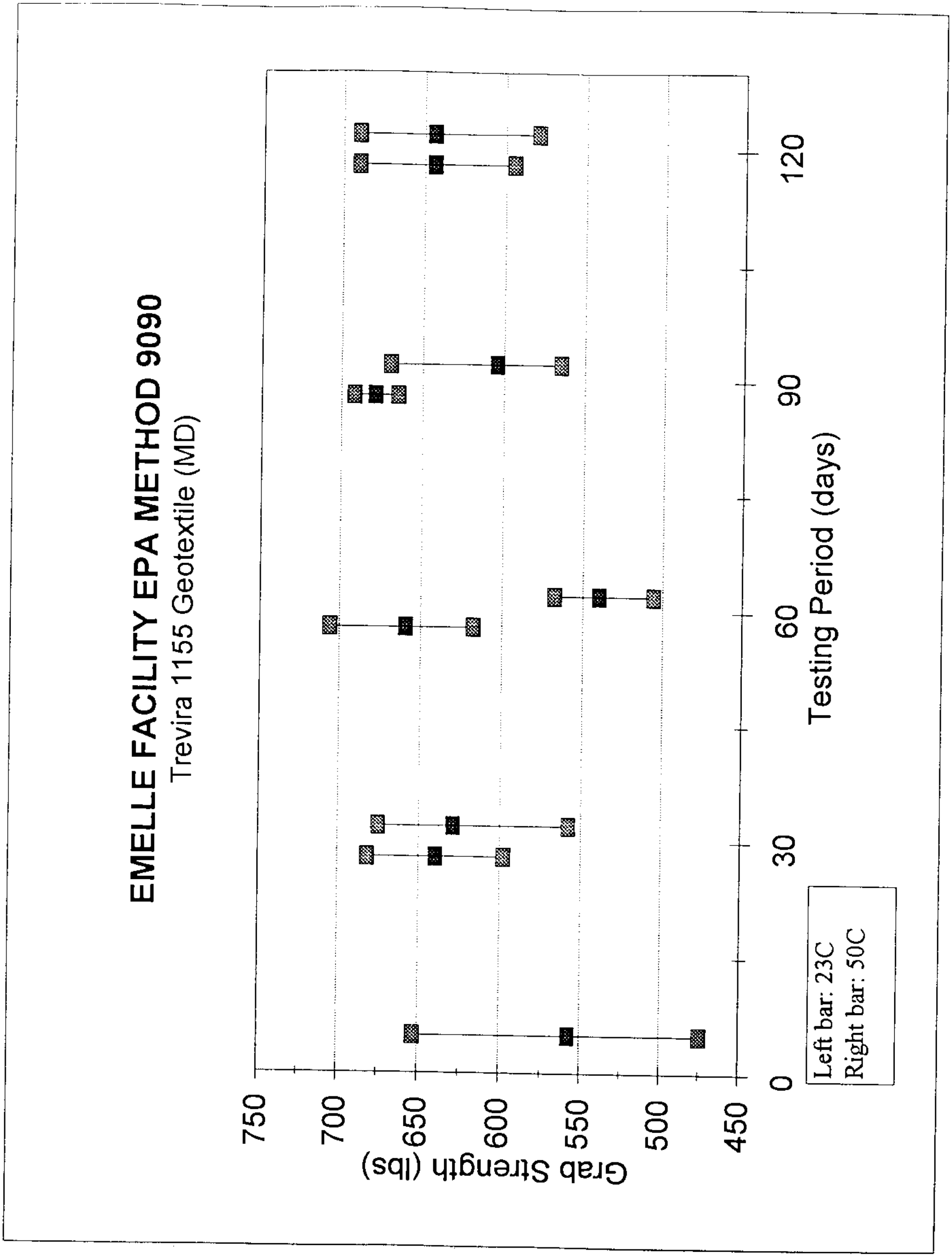
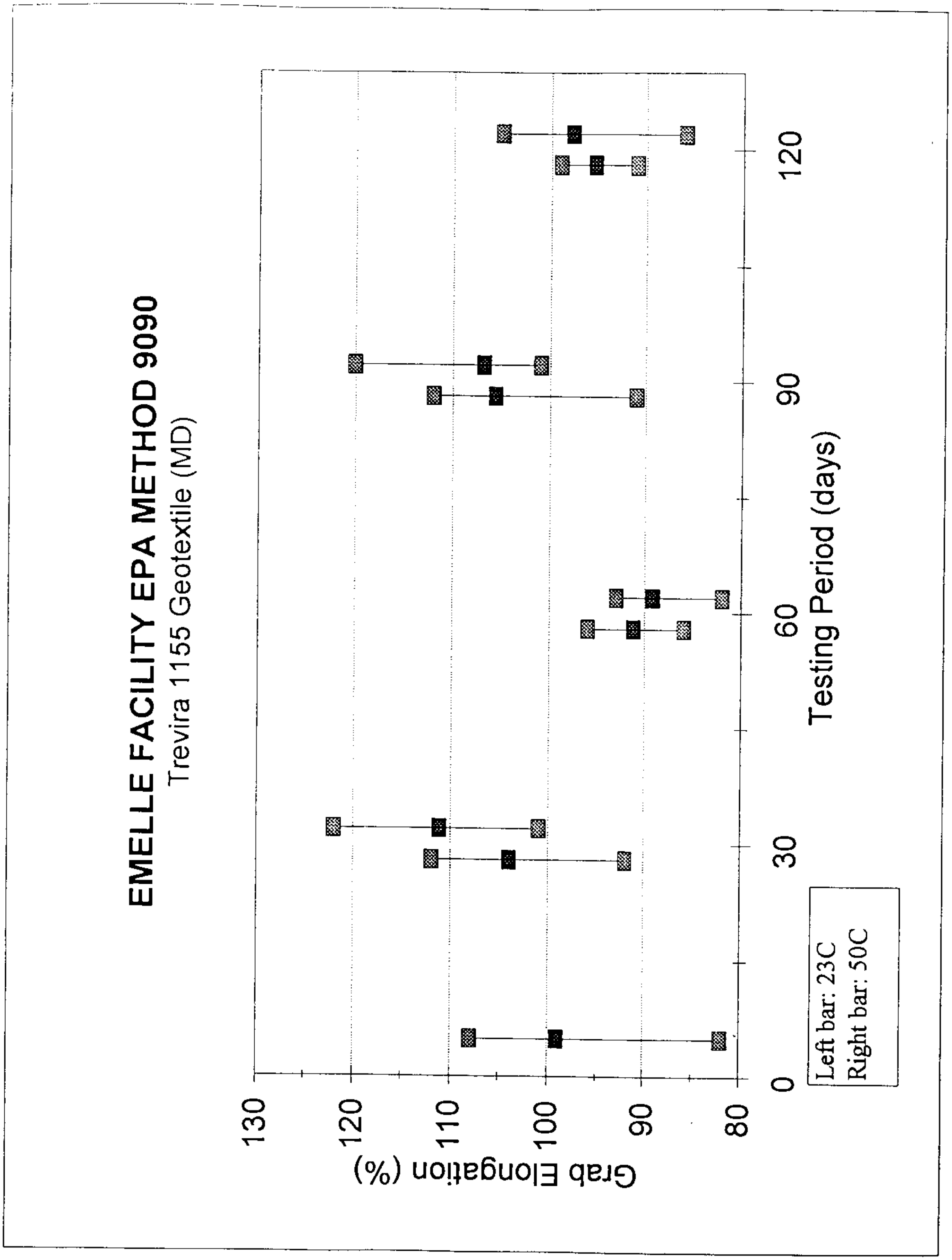
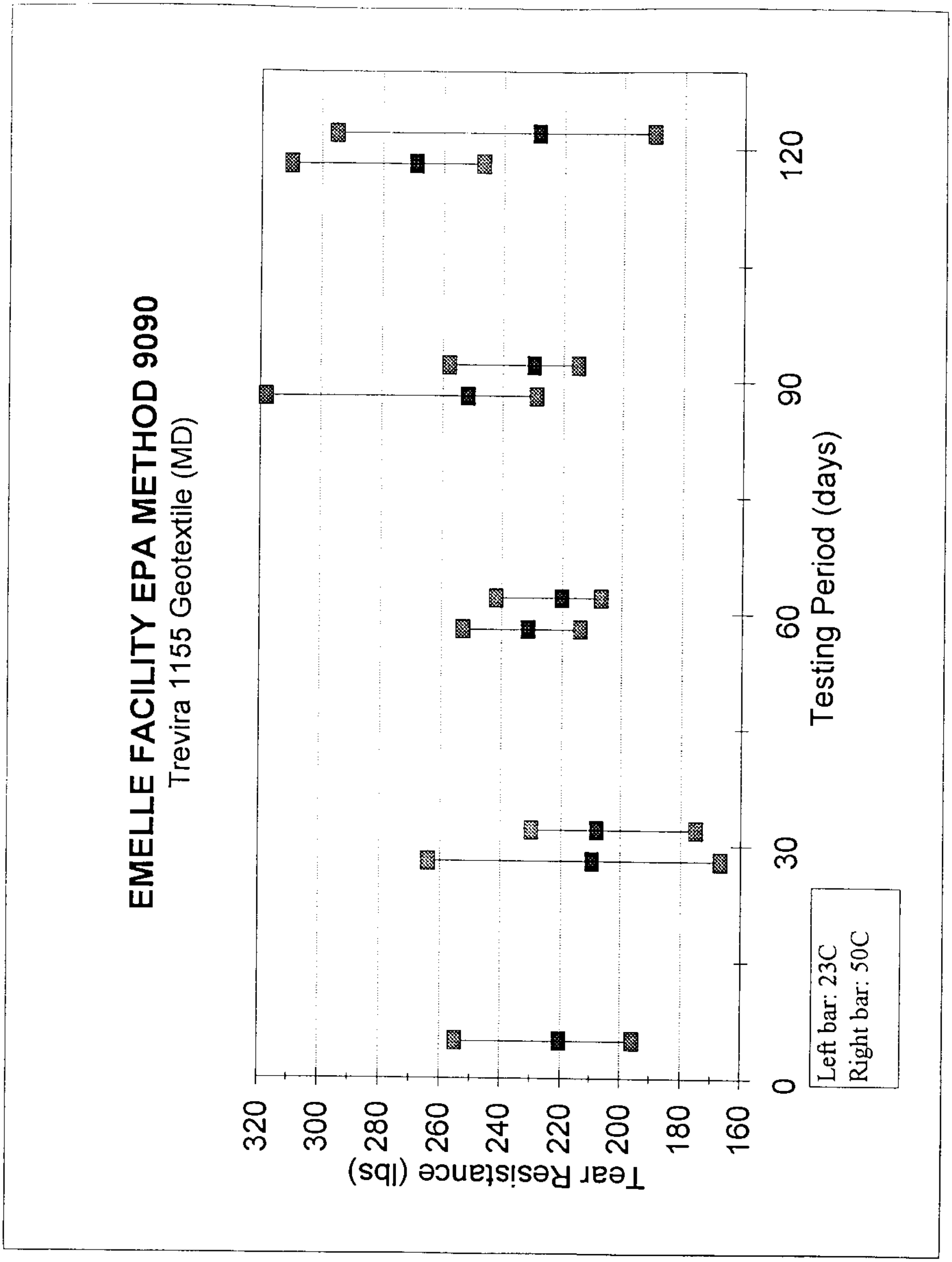
Quality Review

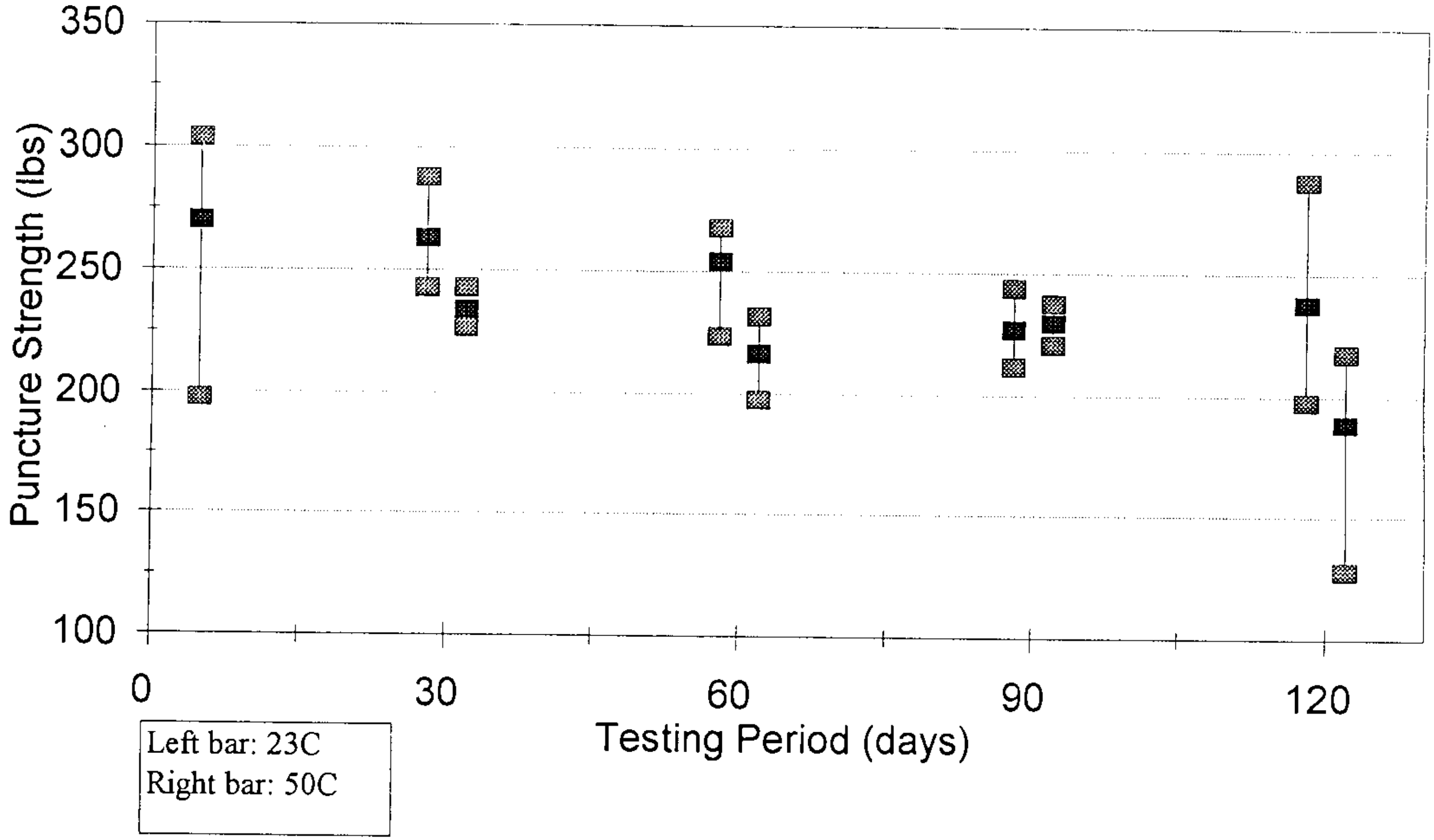


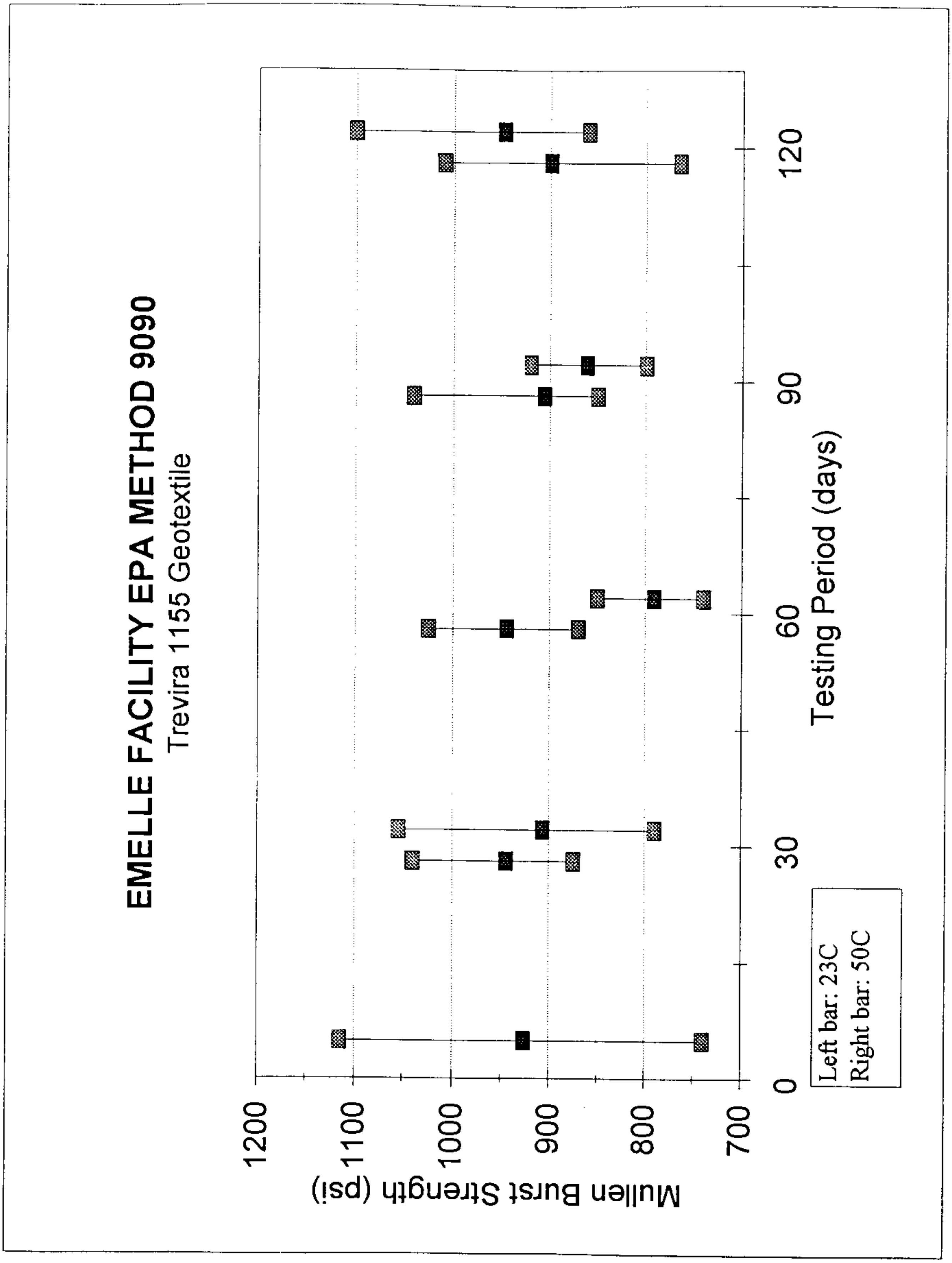
EMELLE FACILITY EPA METHOD 9090
Trevira 1155 Geotextile (MD)
Grab Strength (lbs)
750
700
650
600
550
500
450
Testing Period (days)
0
30
60
90
120
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
Trevira 1155 Geotextile (MD)
Grab Elongation (%)
130
120
110
100
90
80
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C

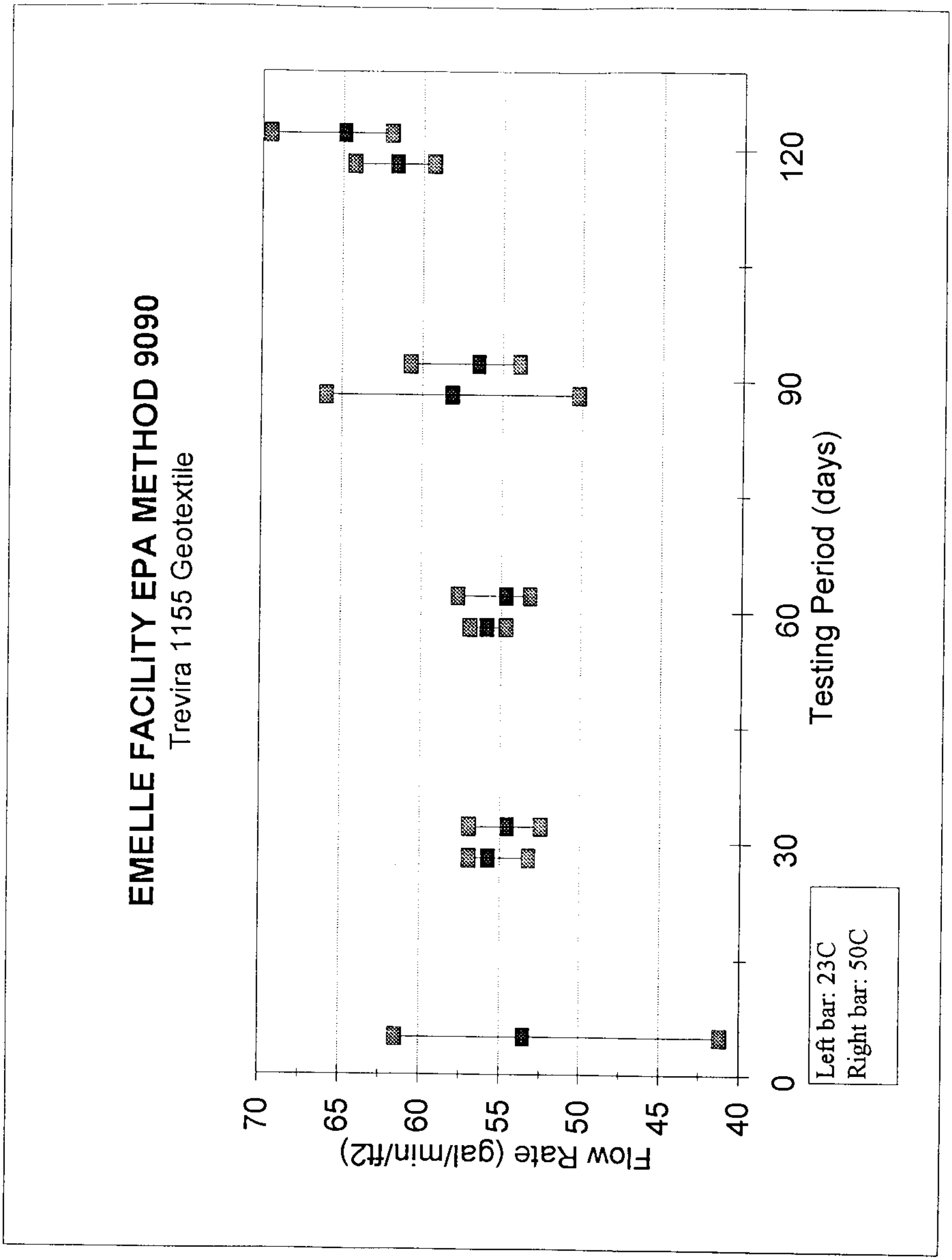

EMELLE FACILITY EPA METHOD 9090
Trevira 1155 Geotextile (MD)
Tear Resistance (lbs)
320
300
280
260
240
220
200
180
160
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C

EMELLE FACILITY EPA METHOD 9090
Trevira 1155 Geotextile





EMELLE FACILITY EPA METHOD 9090
Trevira 1155 Geotextile
Mullen Burst Strength (psi)
1200
1100
1000
900
800
700
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C



EMELLE FACILITY EPA METHOD 9090
Trevira 1155 Geotextile
Flow Rate (gal/min/ft2)
70
65
60
55
50
45
40
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
GEOTEXTILE: SYNTHETIC INDUSTRIES 12 OZ.									
Grab:									
Grab Strength (lb)	422	463	460	483	398	400	468	400	415
ASTM D4632	448	470	537	463	375	455	446	390	415
Machine Direction	422	503	493	419	402	455	400	390	440
	442	491	500	410	391	405	460	370	420
	458	500	507	410	403	400	341	400	410
	475								
	458								
	483								
	418								
	422								
Average	445	485	499	437	394	423	423	390	420
STD	22	16	25	30	10	26	47	11	10
Coefficient of Variation	5	3	5	7	3	6	11	3	2
% Change		9	12	-2	-11	-5	-5	-12	-6
Grab Elongation (%)	85	92	111	74	89	86	94	86	84
ASTM D4632	91	78	94	78	82	90	91	102	83
Machine Direction	85	85	93	75	87	93	90	83	88
	87	84	98	74	83	84	97	81	87
	79	86	98	74	93	85	100	76	105
	81								
	82								
	88								
	76								
	87								
Average	84	85	99	75	87	88	94	86	89
STD	4	4	6	2	4	3	4	9	8
Coefficient of Variation	5	5	7	2	5	4	4	10	9
% Change		1	17	-11	3	4	12	2	6

SRA
Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Tear Resistance:									
Trapezoidal Tear Strength (lb)	193	194	251	176	137	185	183	125	205
ASTM D4533	145	180	195	178	143	180	152	185	225
Machine Direction	180	171	243	184	150	166	152	210	220
	223	144	222	167	143	218	153	195	205
	185	185	200	154	142	163	166	207	185
	165								
	180								
	208								
	173								
	156								
Average	181	175	222	172	143	182	161	184	208
STD	22	17	22	10	4	20	12	31	14
Coefficient of Variation	12	10	10	6	3	11	8	17	7
% Change		-3	23	-5	-21	1	-11	2	15
Puncture:									
Load @ Rupture (lb)	242	274	268	242	265	237	241	284	246
ASTM D4833	246	212	218	244	253	228	255	220	267
	248	228	260	207	241	217	248	222	237
	238	213	249	242	275	223	267	196	225
	217	288	273	222	298	212	249	214	264
	245								
	254								
	240								
	210								
	209								
	225								
Average	234	243	254	231	266	223	252	227	248
STD	15	32	20	15	19	9	9	30	16
Coefficient of Variation	7	13	8	6	7	4	3	13	6
% Change		4	8	-1	14	-5	8	-3	6

SRA
Quality Review

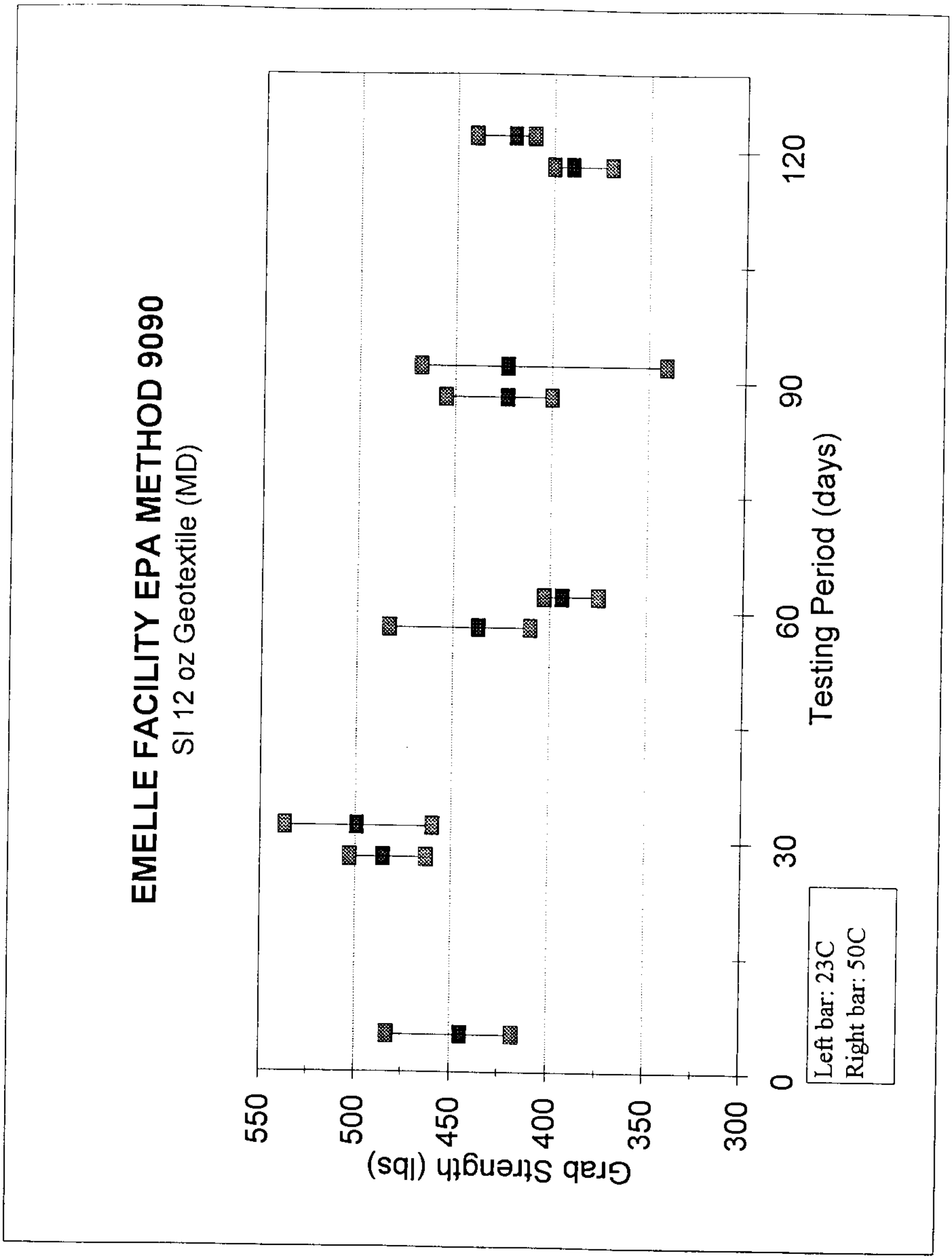
TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

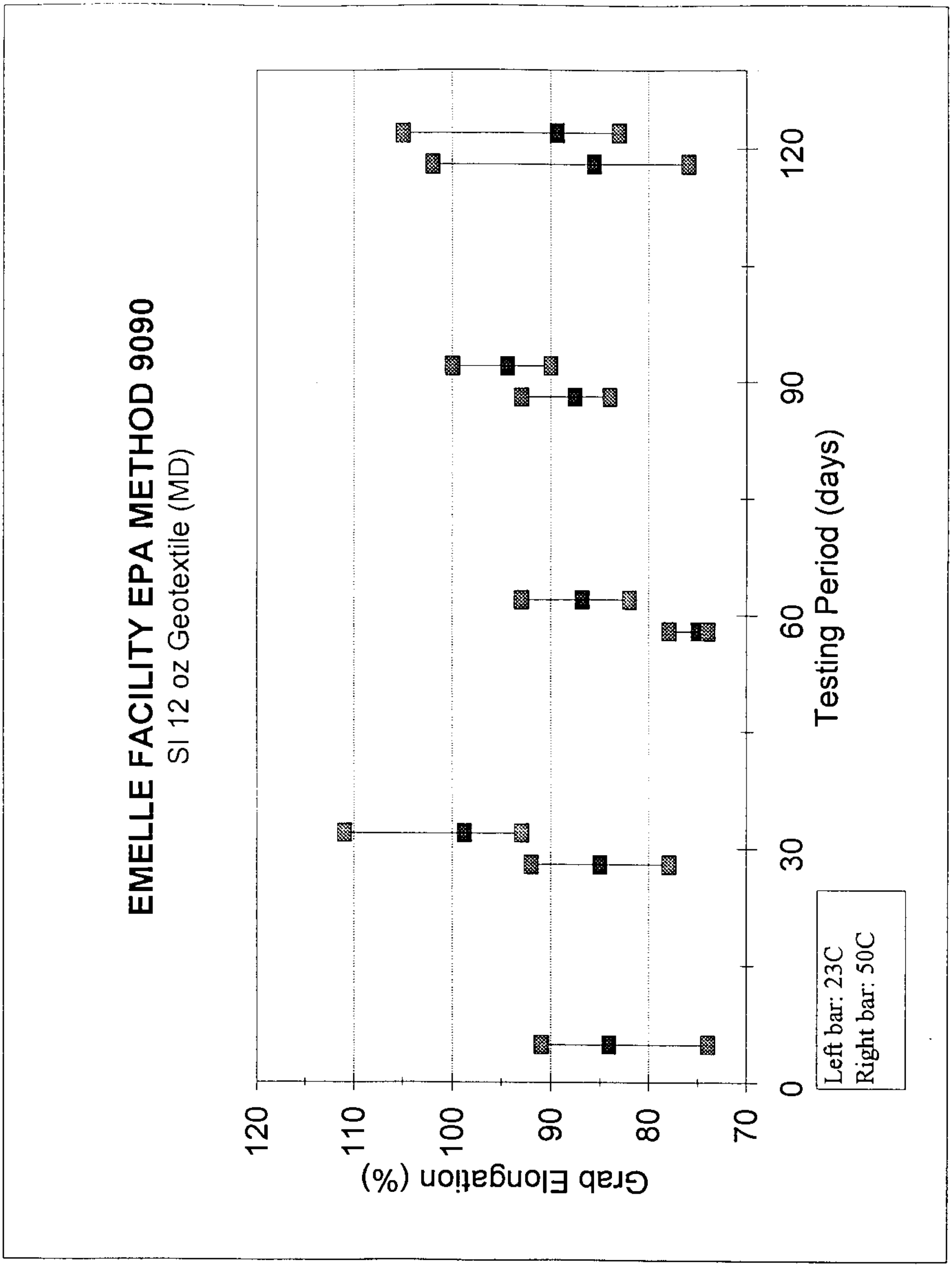
Report Date: June 30, 1994

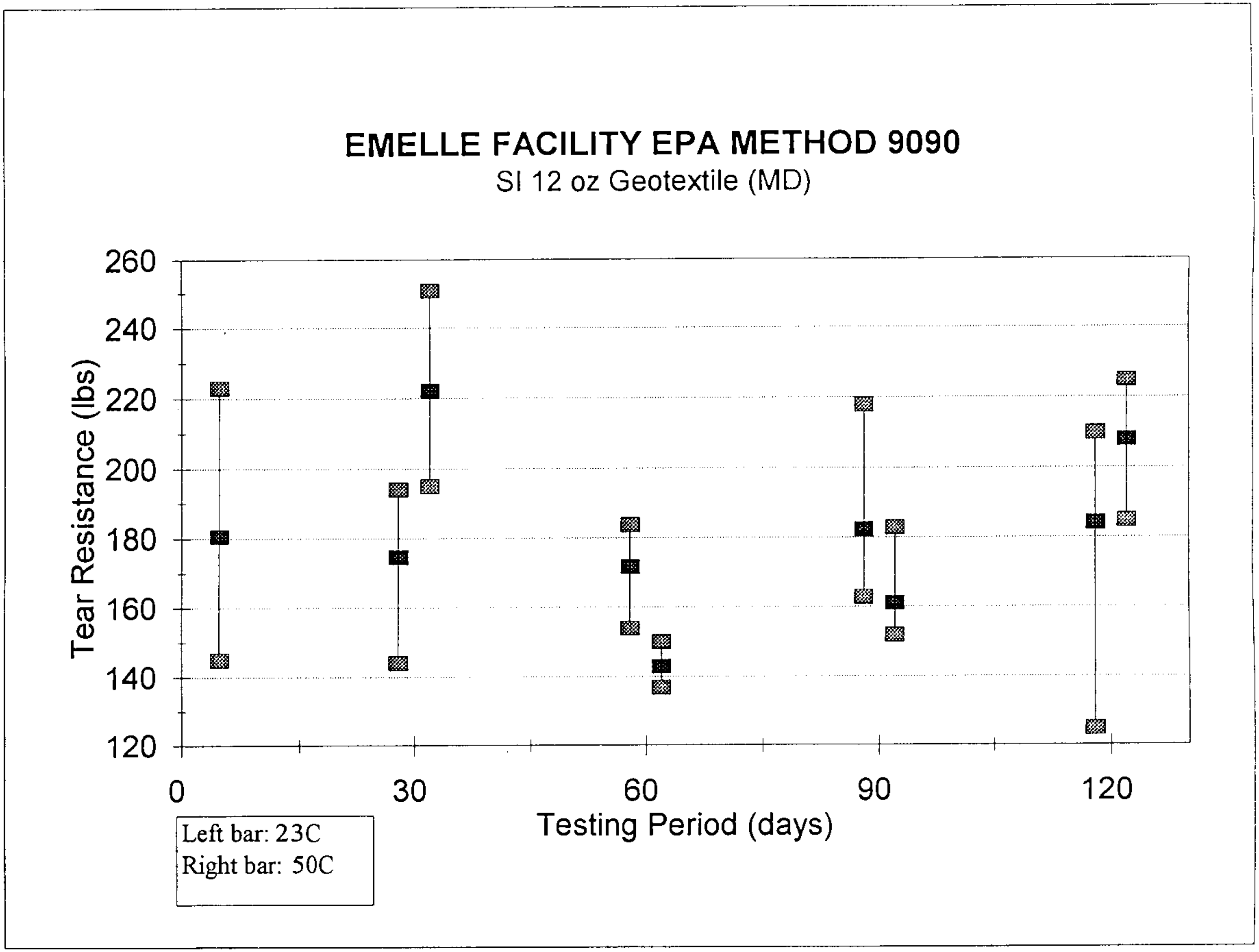
Exposure Time and Temperature

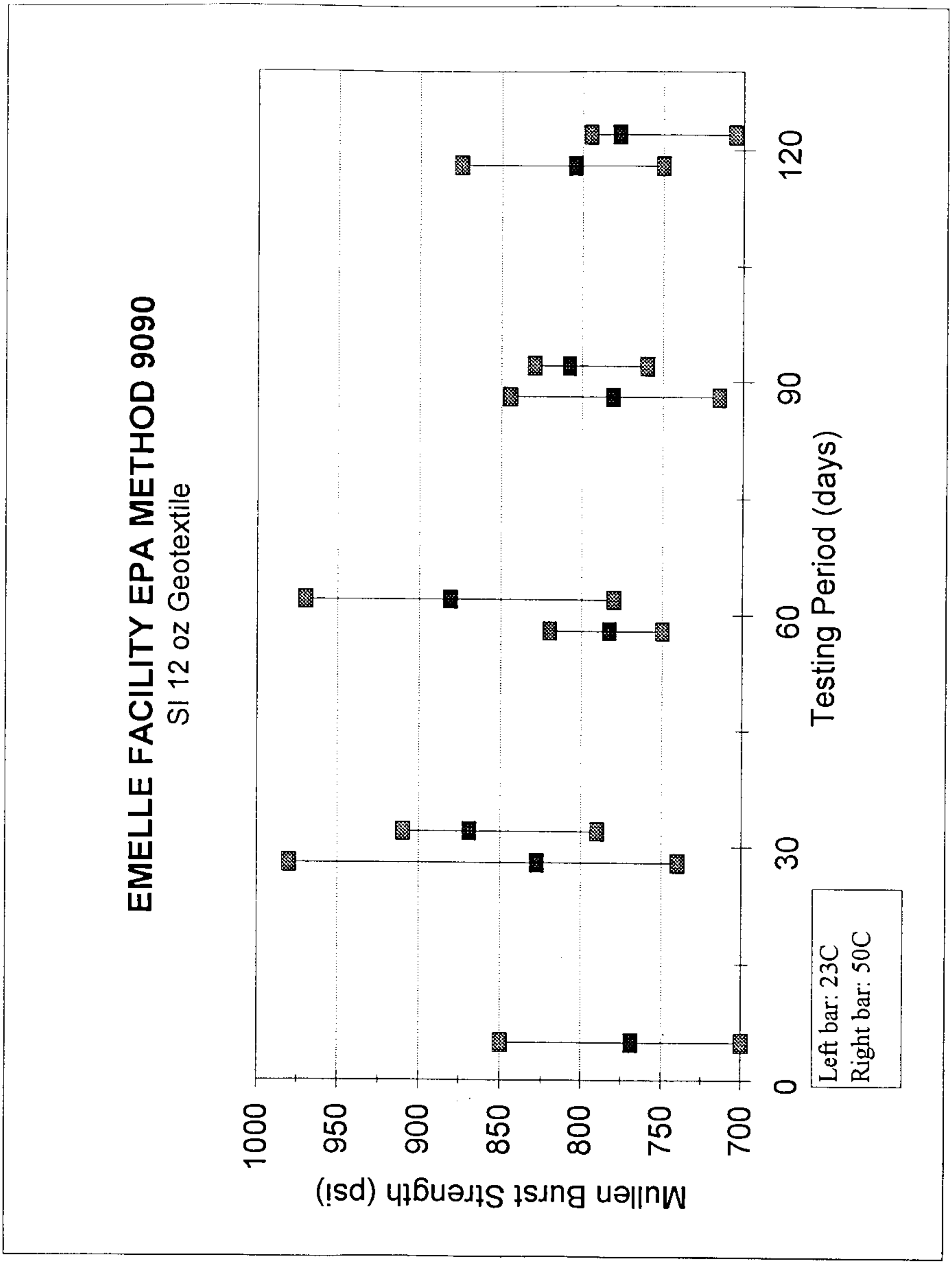
Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Permittivity: flow rate	68.22	72.72	85.47	80.22	74.97	83.97	86.22	65.31	62.69
(gal/min/ft2)	71.22	82.47	83.97	74.97	72.72	91.46	71.97	70.74	72.30
ASTM D4491	80.97	83.97	75.72	79.47	76.47	89.96	65.97	74.54	62.69
	74.22	80.97	83.22	76.47	74.22	87.71	67.47	71.79	80.10
	78.72	85.47	87.71	73.47	76.47	86.22	74.97	81.60	78.64
	72.72								
	80.22								
	69.72								
	74.22								
	76.47								
Average	75.39	83.22	82.65	76.09	74.97	88.84	70.10	74.67	73.43
STD	3.74	1.68	4.35	2.22	1.59	2.02	3.58	4.24	6.86
Coefficient of Variation	5	2	5	3	2	2	5	6	9
% Change		10	10	1	-1	18	-7	-1	-3
Mullen Burst:									
Burst Strength (psi)	750	980	820	750	855	765	830	845	780
ASTM D3786	800	790	910	760	970	845	805	875	760
	780	840	790	820	780	740	790	800	705
	750	740	910	805	915	715	760	750	795
	720	790	915	780	885	840	855	755	845
	830								
	780								
	850								
	700								
	730								
Average	769	828	869	783	881	781	808	805	777
STD	46	82	53	26	63	53	33	49	46
Coefficient of Variation	6	10	6	3	7	7	4	6	6
% Change		8	13	2	15	2	5	5	1

SRA
Quality Review


EMELLE FACILITY EPA METHOD 9090
SI 12 oz Geotextile (MD)
Grab Strength (lbs)
550
500
450
400
350
300
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
SI 12 oz Geotextile (MD)
Grab Elongation (%)
120
110
100
90
80
70
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
SI 12 oz Geotextile (MD)
Tear Resistance (lbs)
260
240
220
200
180
160
140
120
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
SI 12 oz Geotextile
Mullen Burst Strength (psi)
1000
950
900
850
800
750
700
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C

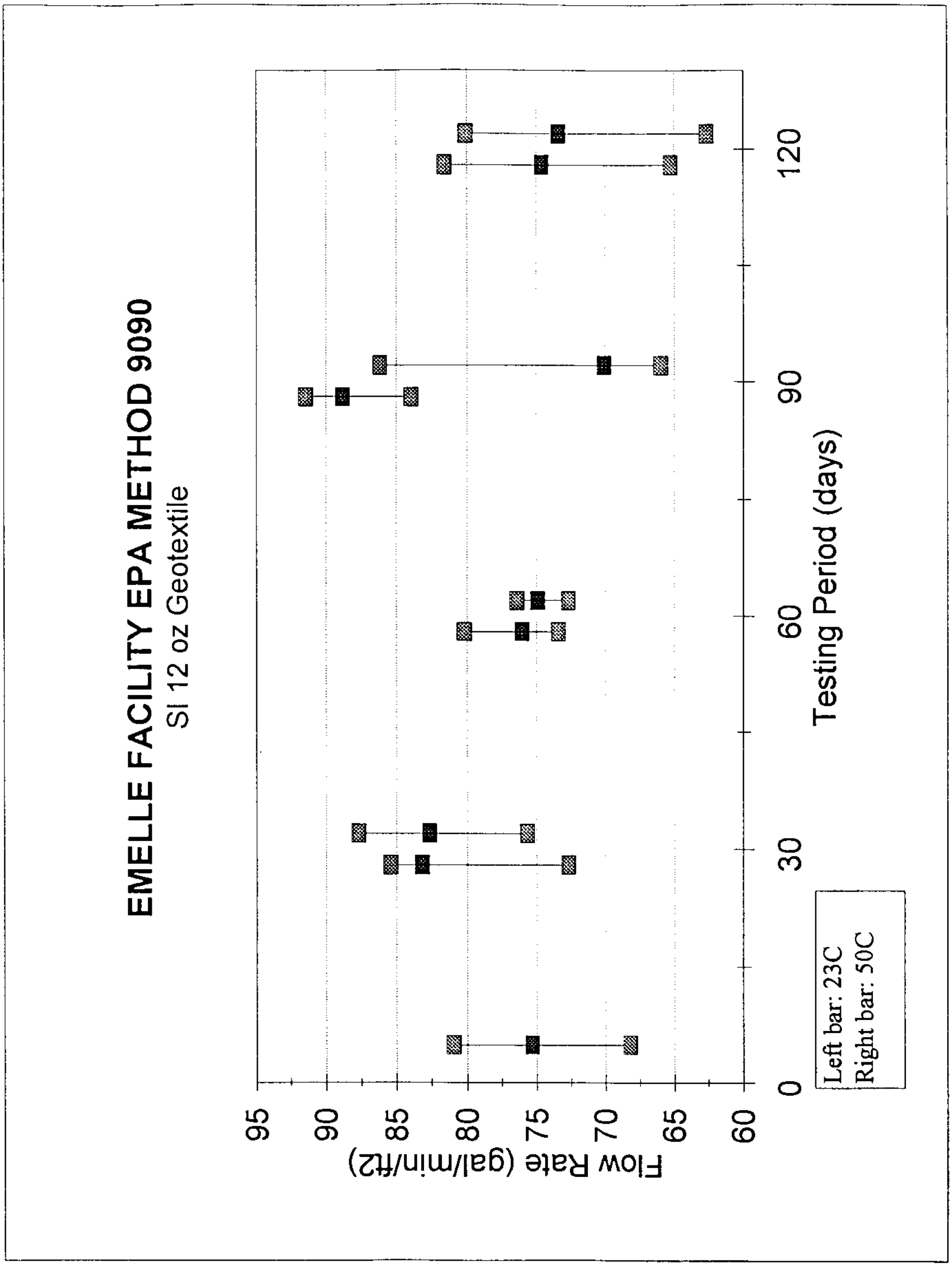

EMELLE FACILITY EPA METHOD 9090
SI 12 oz Geotextile
Flow Rate (gal/min/ft2)
95
90
85
80
75
70
65
60
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
GEOTEXTILE: SYNTHETIC INDUSTRIES 16 OZ.									
Grab:									
Grab Strength (lb)	706	640	573	628	607	688	592	660	545
ASTM D4632	662	665	560	614	526	540	580	620	640
Machine Direction	633	660	579	586	562	547	575	630	620
	626	660	610	728	512	670	620	585	600
	637	713	614	603	508	547	547	610	610
	606								
	676								
	646								
	650								
	647								
Average	649	668	587	632	543	598	583	621	603
STD	26	24	21	50	37	66	24	25	32
Coefficient of Variation	4	4	4	8	7	11	4	4	5
% Change		3	-10	-3	-16	-8	-10	-4	-7
Grab Elongation (%)	95	104	94	79	86	99	102	82	83
ASTM D4632	91	122	104	85	87	90	100	93	95
Machine Direction	89	102	104	82	80	95	97	92	100
	96	104	113	80	86	96	111	95	97
	94	104	105	82	90	99	94	92	99
	88								
	93								
	92								
	84								
	89								
Average	91	107	104	82	86	96	101	91	95
STD	3	7	6	2	3	3	6	5	6
Coefficient of Variation	4	7	6	3	4	3	6	5	6
% Change		18	14	-10	-6	5	11	-0	4

SRA
Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

		Exposure Time and Temperature							
	Baseline	30 Day		60 Day		90 Day		120 Day	
Test Parameters		23C	50C	23C	50C	23C	50C	23C	50C
Tear Resistance:									
Trapezoidal Tear Strength (lb)	226	186	255	224	203	243	257	207	312
ASTM D4533	235	193	290	175	201	197	229	220	260
Machine Direction	198	197	202	228	207	230	226	225	210
	150	185	298	220	206	239	239	210	267
	220	210	263	237	243	224	284	225	222
	211								
	227								
	202								
	191								
	181								
Average	204	194	262	217	212	227	247	217	254
STD	24	9	34	22	16	16	21	8	36
Coefficient of Variation	12	5	13	10	7	7	9	3	14
% Change		-5	28	6	4	11	21	7	25
Puncture:									
Load @ Rupture (lb)	399	305	318	329	355	289	343	284	348
ASTM D4833	339	368	407	363	362	305	325	332	292
	318	353	393	317	390	322	336	240	252
	352	347	405	361	467	250	344	268	296
	348	363	310	387	364	299	342	348	252
	339								
	328								
	358								
	372								
	323								
Average	348	347	367	351	388	293	338	294	288
STD	23	22	43	25	41	24	7	40	35
Coefficient of Variation	7	6	12	7	11	8	2	14	12
% Change		-0	5	1	12	-16	-3	-15	-17

SRA
Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Permittivity: flow rate	44.23	53.23	55.48	55.48	56.98	52.48	41.98	46.86	40.54
(gal/min/ft2)	55.48	55.48	55.48	53.98	53.23	54.73	41.23	54.79	38.43
ASTM D4491	48.73	56.23	54.73	53.98	51.73	50.23	45.73	59.47	40.49
	51.73	56.23	56.23	55.48	53.23	50.98	43.48	55.79	40.12
	44.23	56.98	56.98	54.73	54.73	52.48	47.98	53.35	50.53
	52.48								
	40.48								
	44.23								
	40.48								
	46.48								
	0.62								
Average	42.50	56.23	55.85	54.54	53.23	52.10	44.61	55.85	42.39
STD	14.75	0.53	0.84	0.62	1.06	1.72	2.51	2.26	4.76
Coefficient of Variation	35	1	2	1	2	3	6	4	11
% Change		32	31	28	25	23	5	31	-0
Mullen Burst:									
Burst Strength (psi)	960	1110	1050	1070	1090	1175	1290	1070	1195
ASTM D3786	1000	1200	1080	1105	1115	1030	1140	1070	1040
	1050	1090	1070	955	1095	1090	1255	1230	1095
	1060	1190	800	1185	1085	1230	1100	1070	1080
	1000	950	1030	1110	1135	1150	1130	1225	925
	1045								
	1085								
	1095								
	1100								
	1000								
Average	1040	1108	1006	1085	1104	1135	1183	1133	1067
STD	45	90	104	75	19	69	75	77	87
Coefficient of Variation	4	8	10	7	2	6	6	7	8
% Change		7	-3	4	6	9	14	9	3

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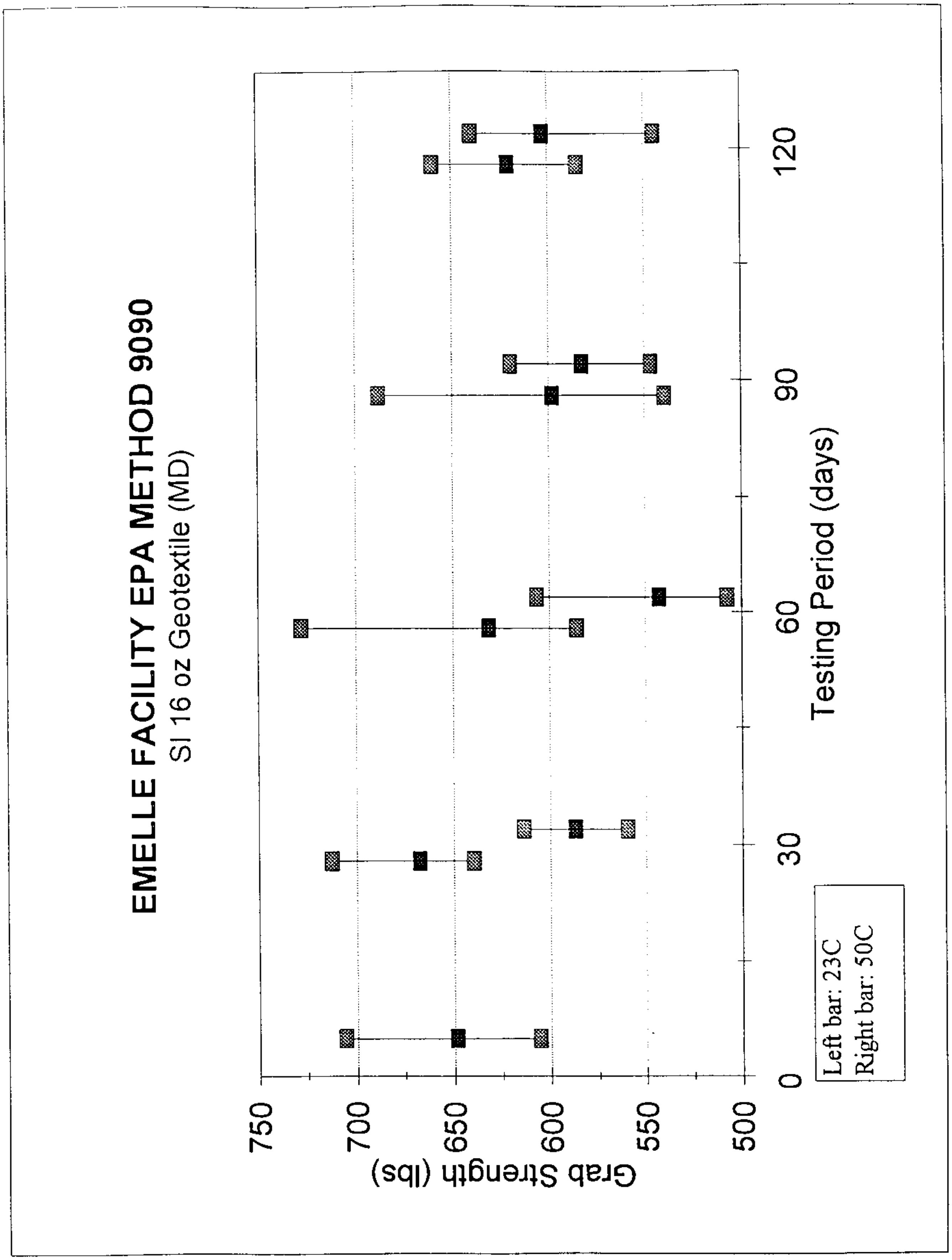
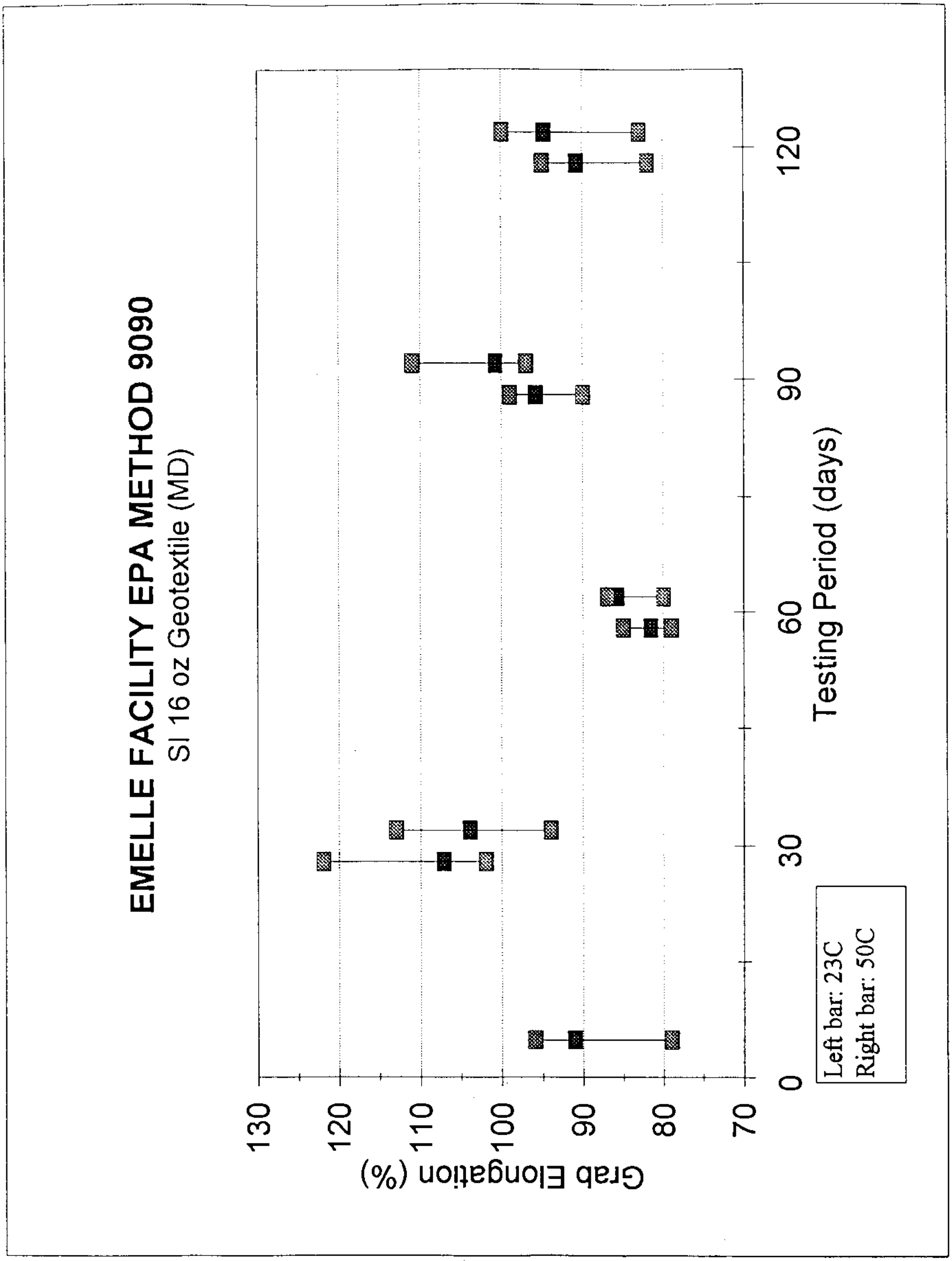
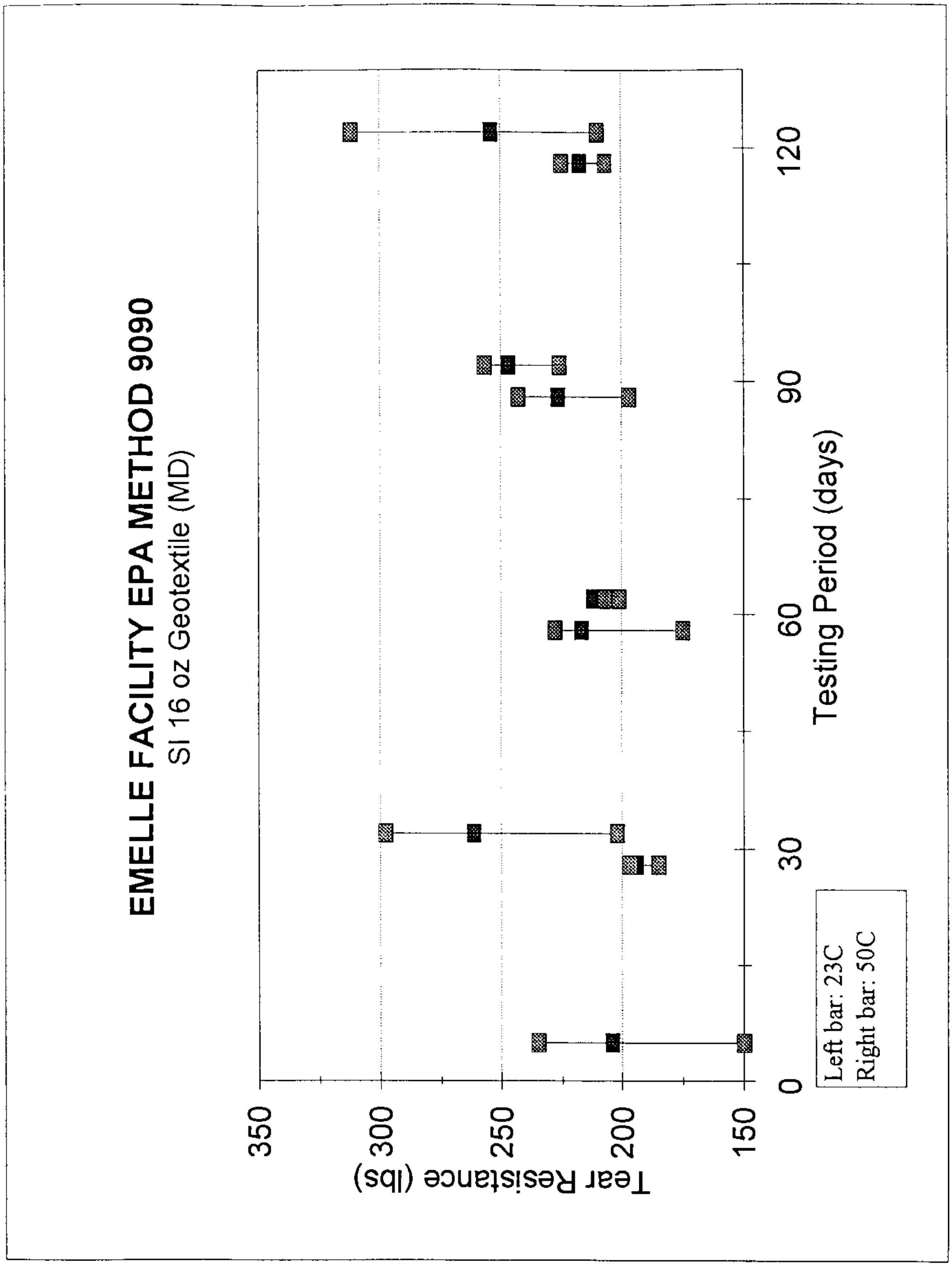
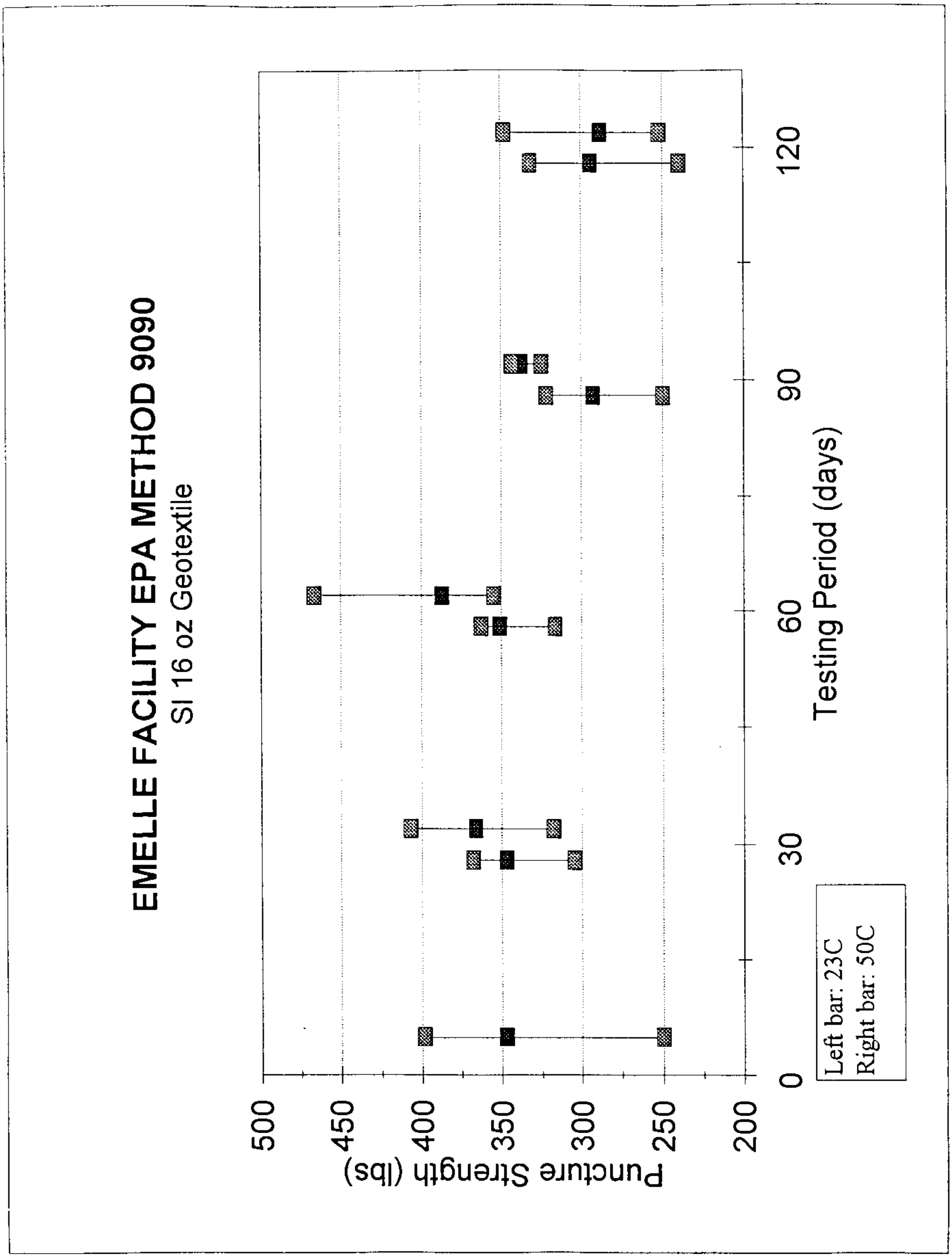
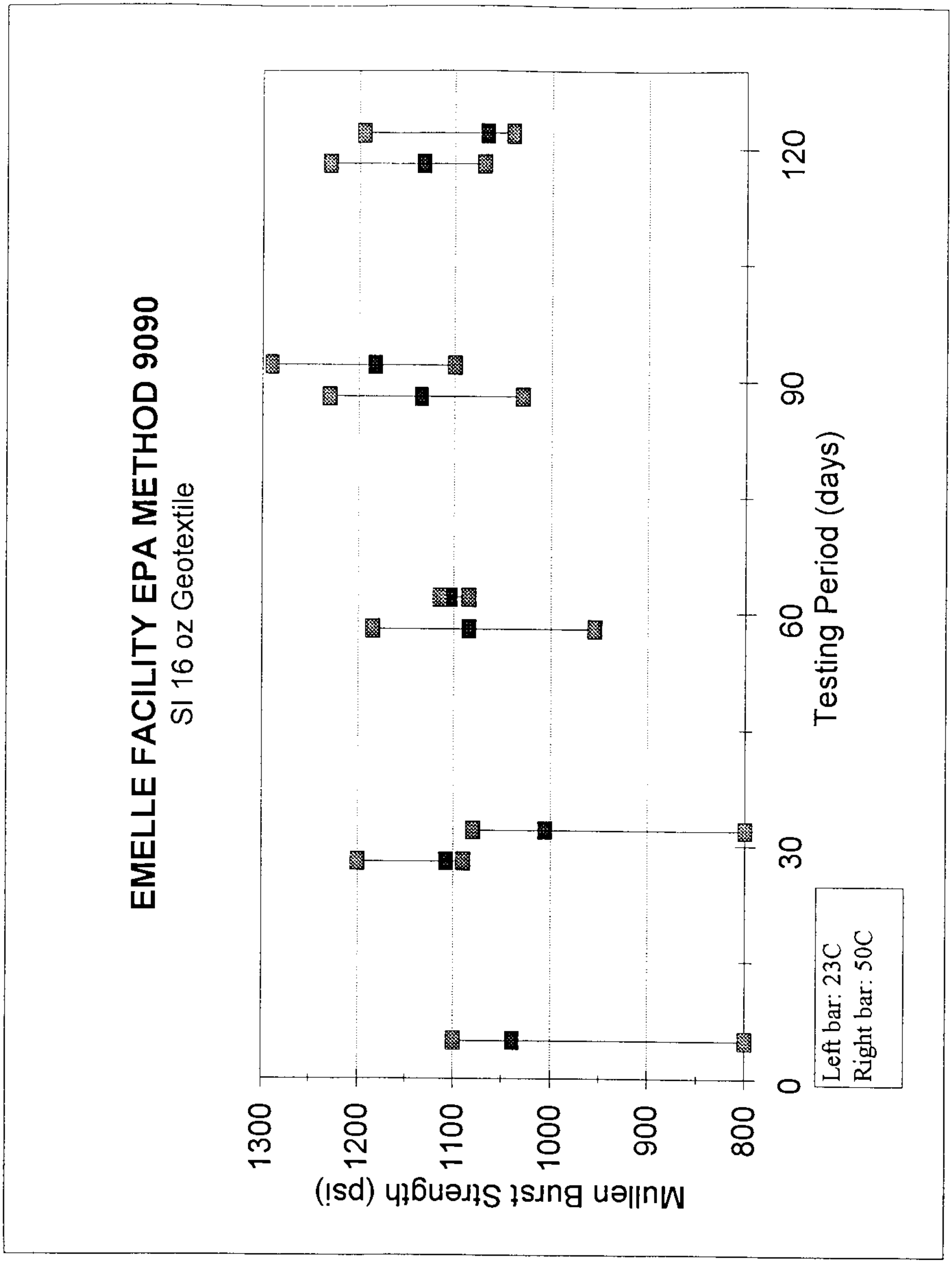
Quality Review


EMELLE FACILITY EPA METHOD 9090
SI 16 oz Geotextile (MD)
Grab Strength (lbs)
750
700
650
600
550
500
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
SI 16 oz Geotextile (MD)
Grab Elongation (%)
130
120
110
100
90
80
70
Testing Period (days)
0
30
60
90
120
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
SI 16 oz Geotextile (MD)
Tear Resistance (lbs)
350
300
250
200
150
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
SI 16 oz Geotextile
Puncture Strength (lbs)
500
450
400
350
300
250
200
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
SI 16 oz Geotextile
Mullen Burst Strength (psi)
1300
1200
1100
1000
900
800
Testing Period (days)
0
30
60
90
120
Left bar: 23C
Right bar: 50C

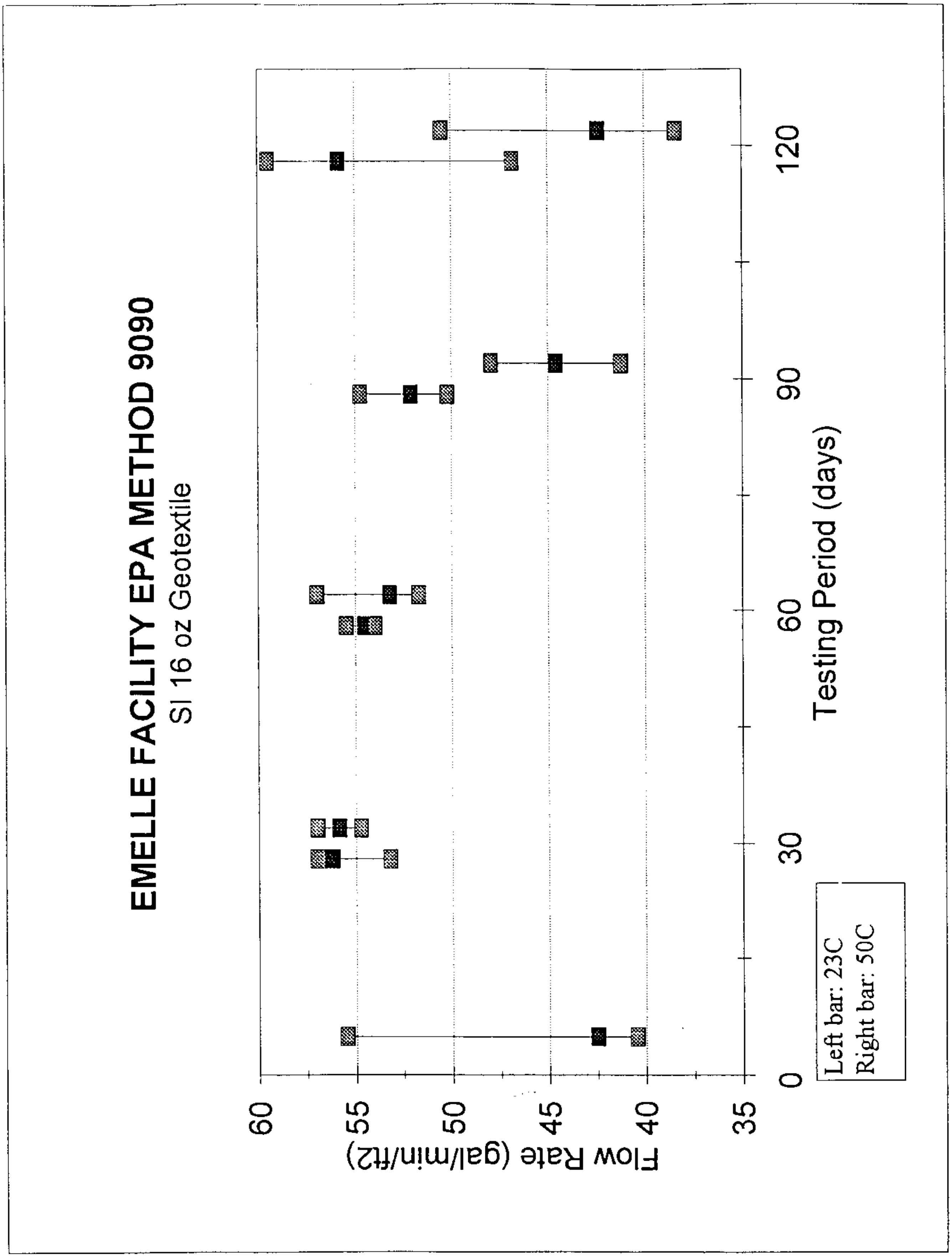

EMELLE FACILITY EPA METHOD 9090
SI 16 oz Geotextile
Flow Rate (gal/min/ft2)
60
55
50
45
40
35
Testing Period (days)
0
30
60
90
120
Left bar: 23C
Right bar: 50C

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
		Exposure Time and Temperature							
GEOTEXTILE: POLYFELT TS 800 12 OZ.									
Grab:									
Grab Strength (lb)	373	425	318	481	256	455	271	470	265
ASTM D4632	382	347	357	510	298	265	320	370	390
Machine Direction	341	345	385	365	459	340	395	380	380
	400	517	292	298	441	515	349	430	385
	356	465	318	427	490	430	335	440	335
	341								
	362								
	328								
	291								
	349								
Average	352	420	334	416	389	401	334	418	351
STD	29	67	33	77	94	88	40	38	47
Coefficient of Variation	8	16	10	19	24	22	12	9	13
% Change		19	-5	18	10	14	-5	19	-0
Grab Elongation (%)	113	130	138	111	110	133	123	108	112
ASTM D4632	111	136	125	112	122	117	136	116	116
Machine Direction	107	151	153	106	116	152	133	92	101
	124	132	112	124	102	143	114	92	107
	111	137	141	103	120	125	145	93	116
	109								
	118								
	108								
	112								
	126								
Average	114	137	134	111	114	134	130	100	110
STD	6	7	14	7	7	12	11	10	6
Coefficient of Variation	6	5	11	6	6	9	8	10	5
% Change		20	17	-2	0	18	14	-12	-3

SRH
Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Tear Resistance:									
Trapezoidal Tear Strength (lb)	135	150	125	158	158	115	121	137	160
ASTM D4533	114	156	128	141	156	115	189	130	190
Machine Direction	210	193	107	114	114	142	121	157	155
	145	204	136	129	110	177	133	147	155
	200	148	153	146	158	139	147	185	150
	154								
	183								
	193								
	191								
	121								
Average	165	170	130	138	139	138	142	151	162
STD	33	24	15	15	22	23	25	19	14
Coefficient of Variation	20	14	12	11	16	17	18	13	9
% Change		3	-21	-16	-15	-16	-14	-8	-2
Puncture:									
Load @ Rupture (lb)	202	198	188	190	218	195	125	156	138
ASTM D4833	154	143	123	240	150	187	157	128	114
	176	177	207	201	178	158	116	128	142
	168	207	128	164	145	200	164	156	152
	160	189	170	200	150	134	170	170	136
	218								
	180								
	212								
	200								
	223								
Average	189	183	163	199	168	175	146	148	136
STD	24	22	33	24	27	25	22	17	12
Coefficient of Variation	12	12	20	12	16	14	15	11	9
% Change		-3	-14	5	-11	-8	-23	-22	-28

DRA
Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Permittivity: flow rate									
(gal/min/ft2)	71.97	82.47	88.46	85.47	89.96	95.96	87.71	121.52	85.50
ASTM D4491	86.22	84.72	84.72	88.46	90.71	99.71	84.72	88.83	97.53
	79.47	82.47	83.22	89.96	90.71	77.22	96.71	88.89	94.51
	68.22	83.22	85.47	89.96	87.71	83.22	92.96	105.41	106.25
	73.47	85.47	85.47	86.97	87.71	93.71	101.21	103.86	85.66
	85.47								
	76.47								
	82.47								
	72.72								
	77.97								
Average	77.44	83.67	85.47	88.16	89.36	89.96	92.66	101.70	93.89
STD	5.70	1.22	1.71	1.75	1.37	8.40	5.95	12.17	7.80
Coefficient of Variation	7	1	2	2	2	9	6	12	8
% Change		8	10	14	15	16	20	31	21
Mullen Burst:									
Burst Strength (psi)	580	660	435	495	540	680	390	535	685
ASTM D3786	450	590	590	520	550	610	475	615	580
	625	470	595	620	660	685	360	520	480
	395	660	390	550	550	655	600	580	595
	645	540	480	520	600	620	415	515	595
	590								
	450								
	560								
	540								
	555								
Average	539	584	498	541	580	650	448	553	587
STD	78	73	82	43	45	30	85	39	65
Coefficient of Variation	14	12	17	8	8	5	19	7	11
% Change		8	-8	0	8	21	-17	3	9

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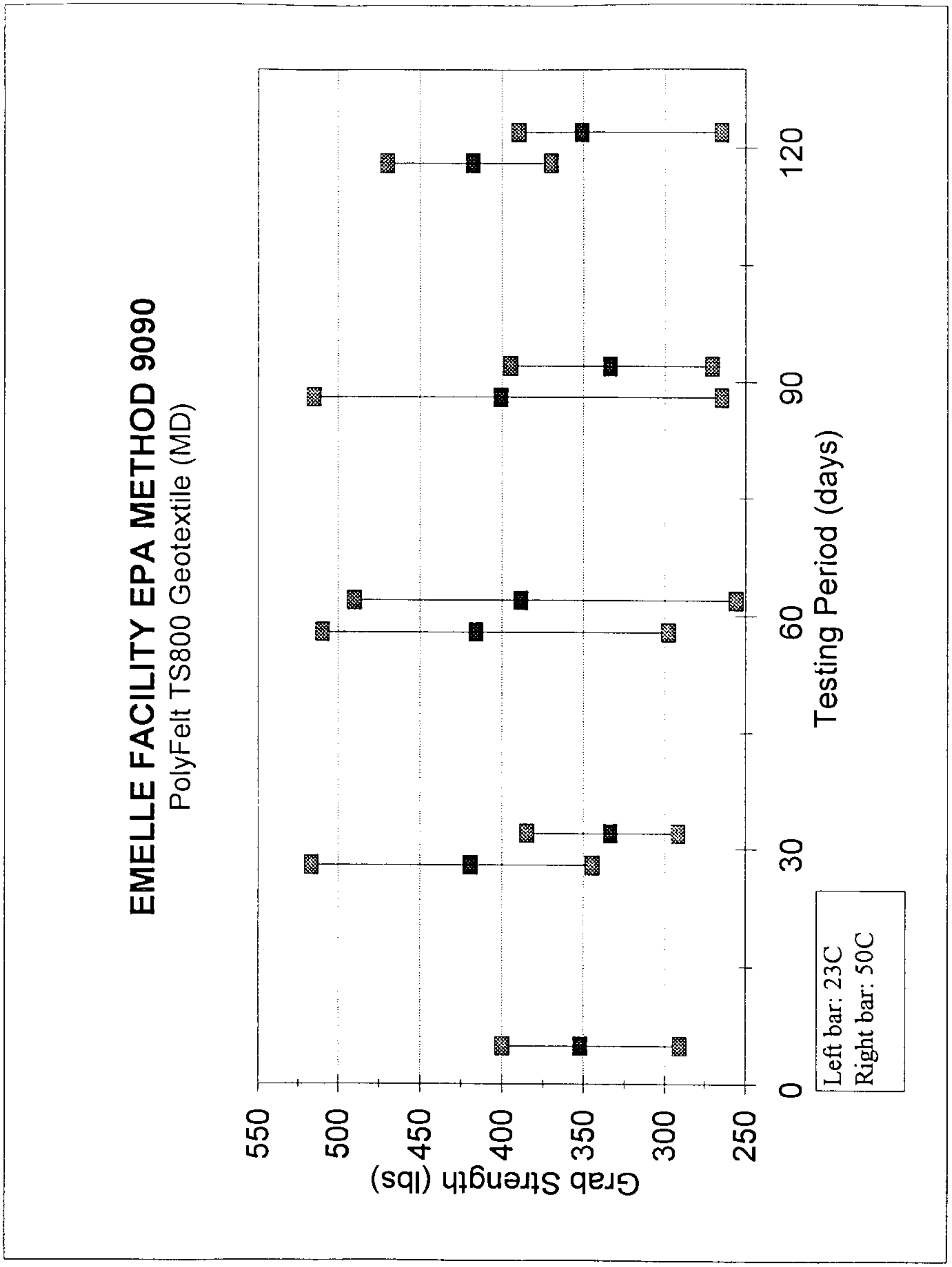
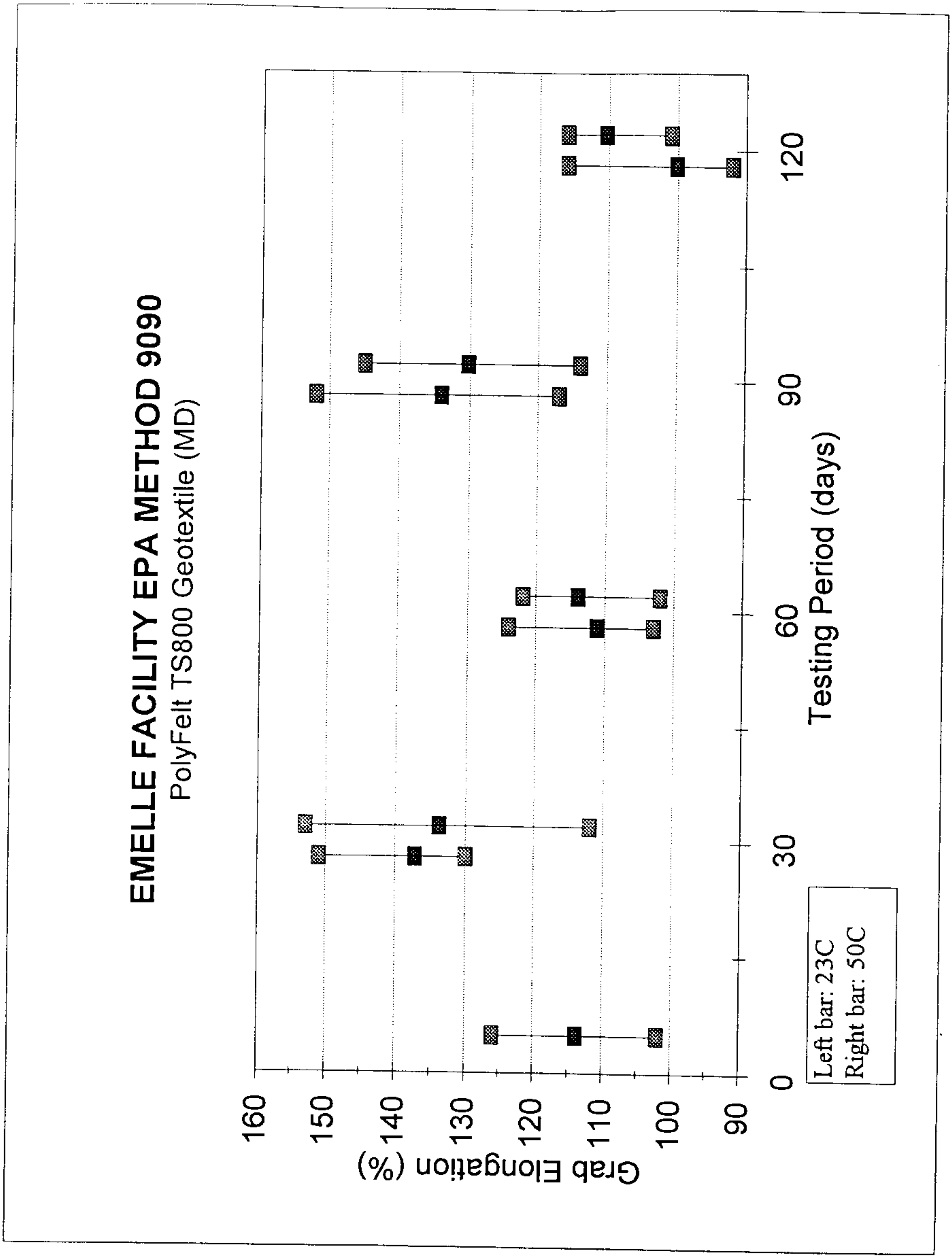
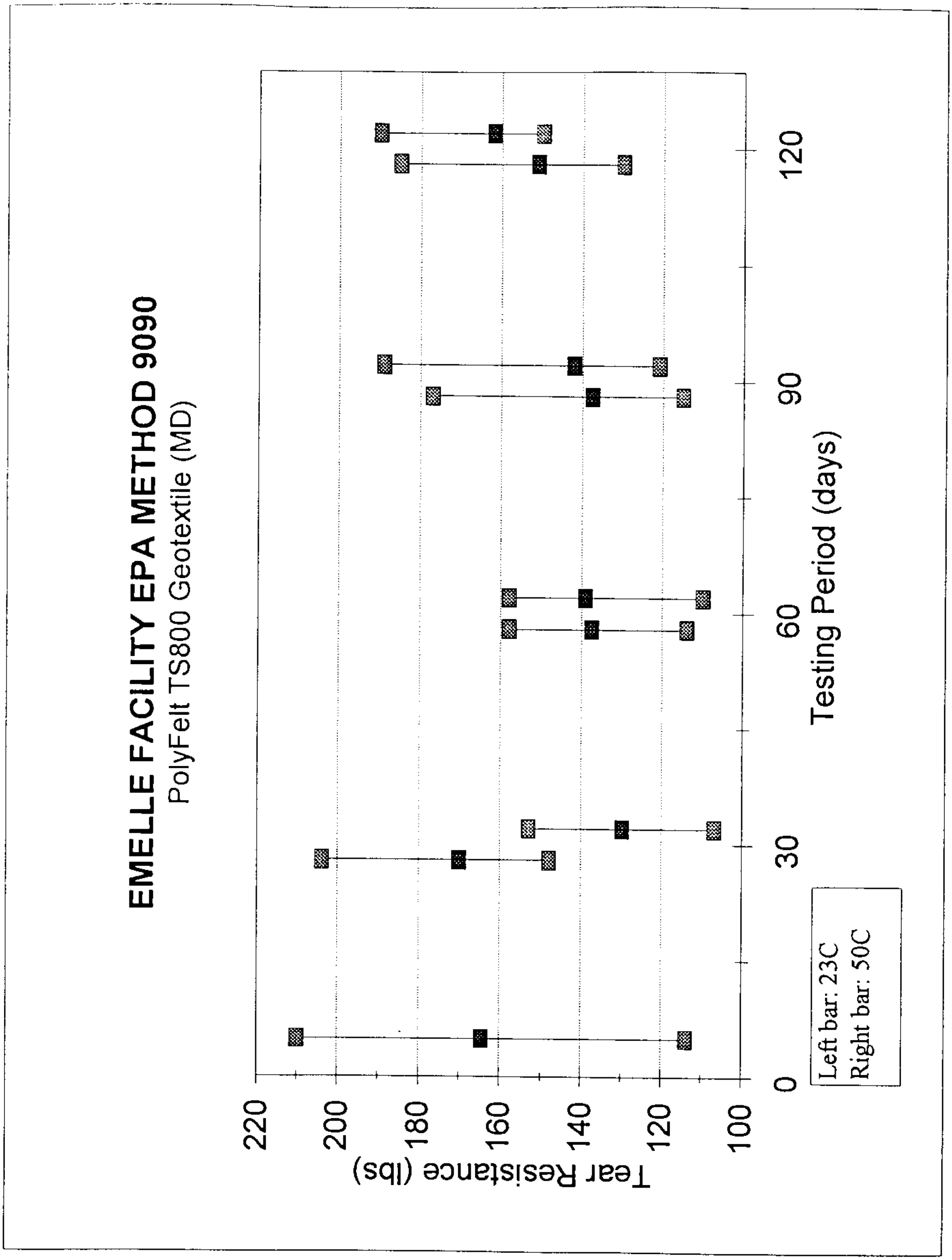
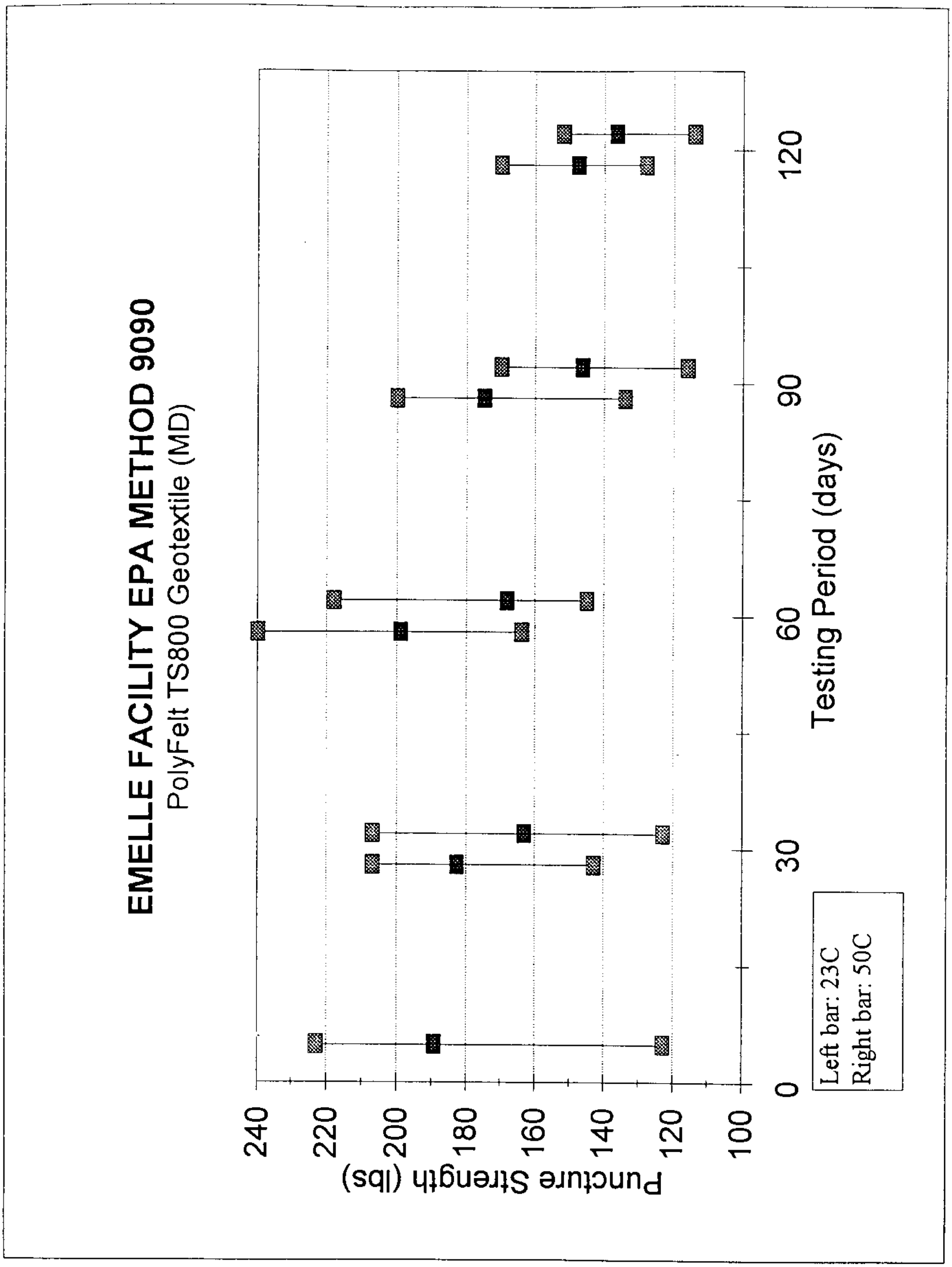
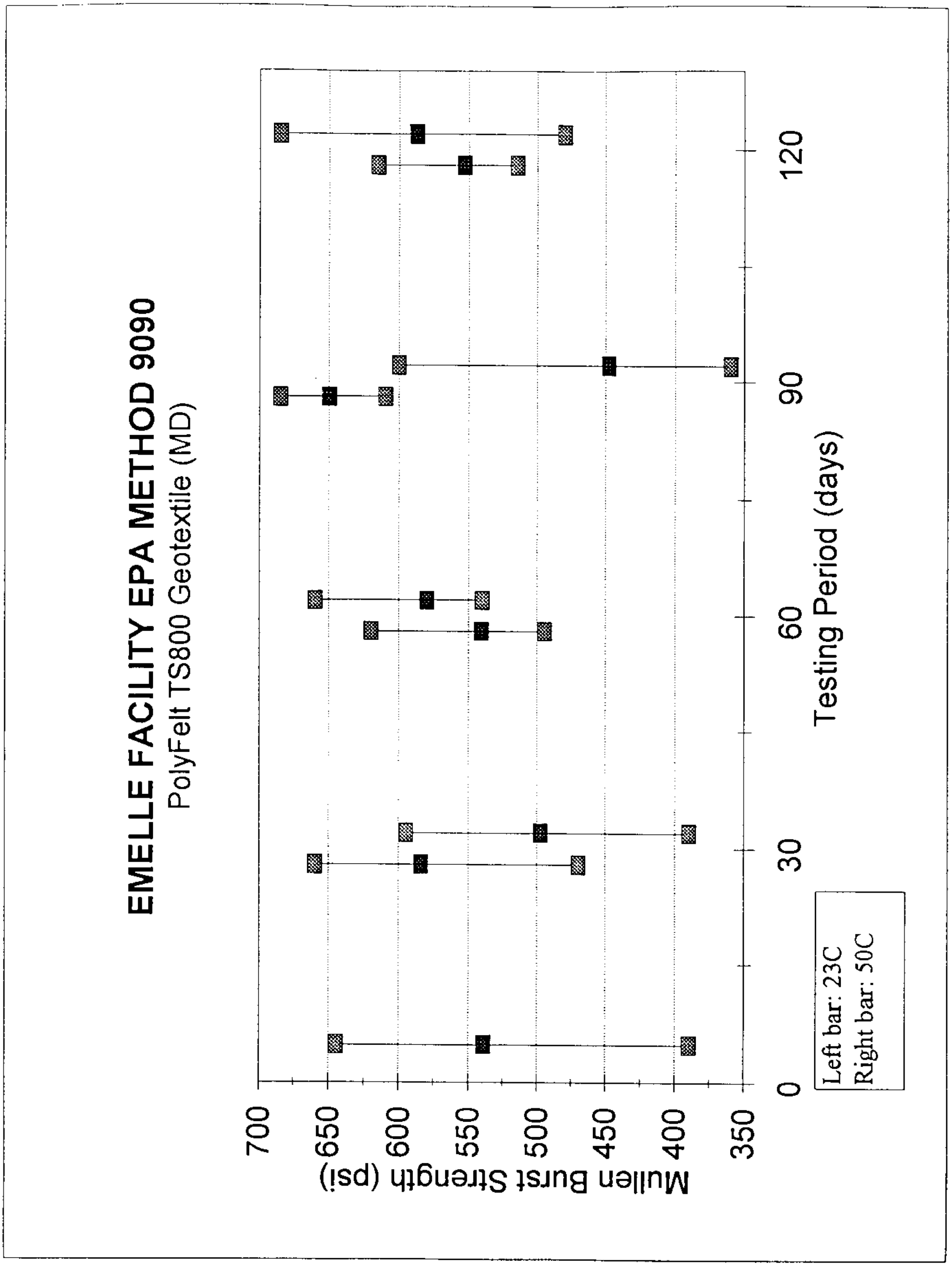
Quality Review

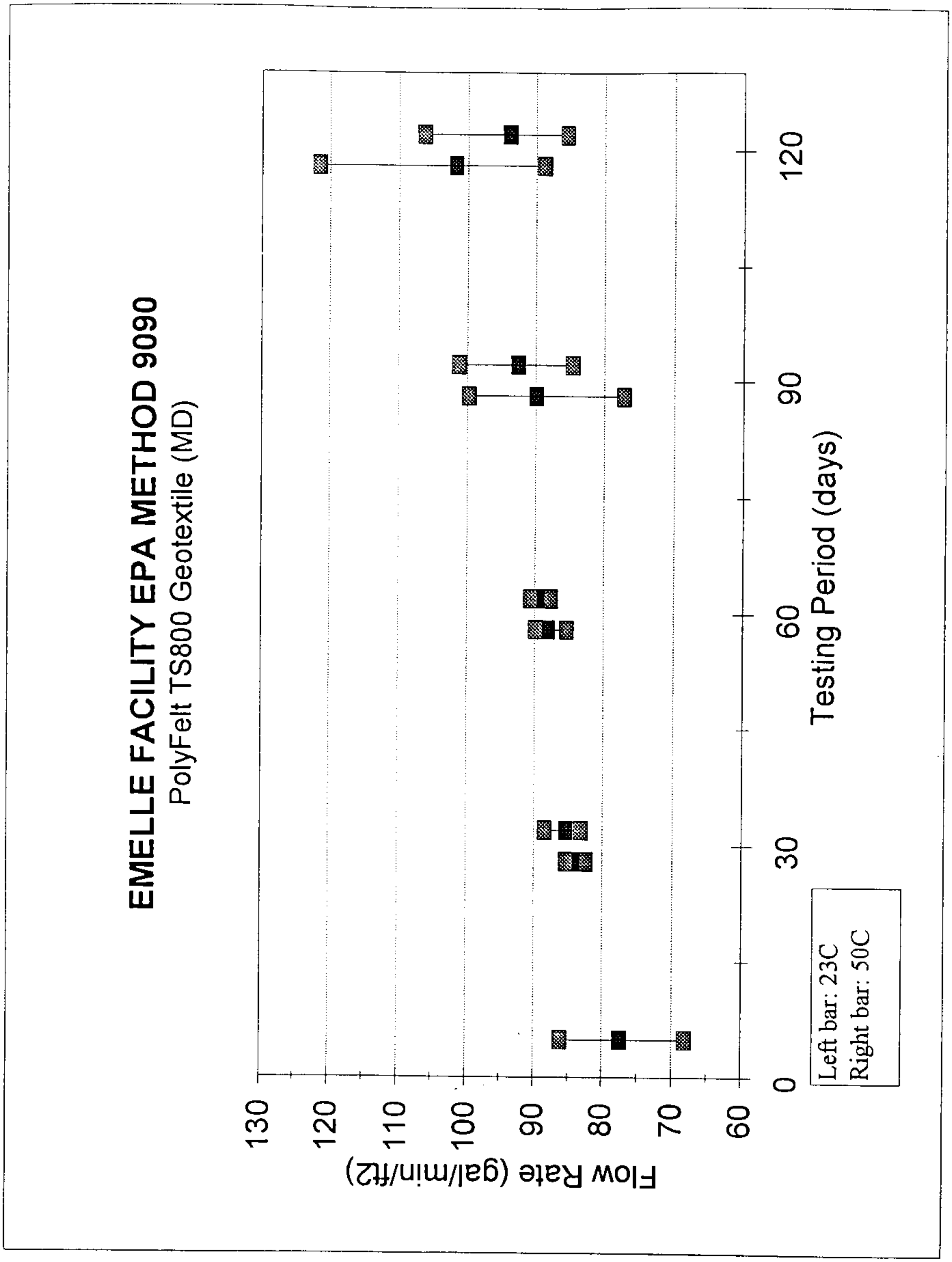

EMELLE FACILITY EPA METHOD 9090
PolyFelt TS800 Geotextile (MD)
Grab Strength (lbs)
550
500
450
400
350
300
250
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
PolyFelt TS800 Geotextile (MD)
Grab Elongation (%)
160
150
140
130
120
110
100
90
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
PolyFelt TS800 Geotextile (MD)
Tear Resistance (lbs)
220
200
180
160
140
120
100
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
PolyFelt TS800 Geotextile (MD)
Puncture Strength (lbs)
240
220
200
180
160
140
120
100
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
PolyFelt TS800 Geotextile (MD)
Mullen Burst Strength (psi)
700
650
600
550
500
450
400
350
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C



EMELLE FACILITY EPA METHOD 9090
PolyFelt TS800 Geotextile (MD)
Flow Rate (gal/min/ft2)
130
120
110
100
90
80
70
60
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
GEOTEXTILE: POLYFELT TS 1000 16 OZ.									
Grab:									
Grab Strength (lb)	502	543	670	482	543	520	523	470	500
ASTM D4632	720	473	585	513	569	625	605	430	555
Machine Direction	551	546	615	601	709	455	700	465	600
	689	548	673	520	671	494	705	560	610
	652	550	529	406	765	660	615	620	610
	757								
	628								
	661								
	583								
	712								
Average	646	532	614	504	651	551	630	509	575
STD	76	30	54	63	84	78	68	70	43
Coefficient of Variation	12	6	9	12	13	14	11	14	7
% Change		-18	-5	-22	1	-15	-2	-21	-11
Grab Elongation (%)	100	110	123	104	93	120	129	92	93
ASTM D4632	131	110	114	89	90	123	111	80	105
Machine Direction	110	109	109	109	111	102	122	86	111
	126	121	127	102	103	122	131	104	117
	106	117	103	119	118	141	118	101	113
	138								
	109								
	113								
	109								
	133								
Average	118	113	115	105	103	122	122	93	108
STD	13	5	9	10	11	12	7	9	8
Coefficient of Variation	11	4	8	9	10	10	6	10	8
% Change		-3	-2	-11	-12	3	4	-21	-8

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Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Tear Resistance:									
Trapezoidal Tear Strength (lb)	388	237	344	273	184	239	277	282	250
ASTM D4533	440	387	243	188	237	247	259	240	220
Machine Direction	325	290	219	180	188	242	292	260	270
	427	234	272	247	223	282	267	247	315
	419	255	316	280	191	254	322	228	222
	263								
	382								
	353								
	345								
	362								
Average	370	281	279	234	205	253	283	251	255
STD	50	57	46	42	21	15	22	18	35
Coefficient of Variation	14	20	16	18	10	6	8	7	14
% Change		-24	-25	-37	-45	-32	-23	-32	-31
Puncture:									
Load @ Rupture (lb)	230	206	218	199	244	240	214	231	205
ASTM D4833	188	216	168	205	182	231	274	222	235
	238	227	236	257	237	194	212	184	260
	241	149	205	217	205	174	235	240	220
	247	247	250	229	199	258	217	180	184
	159								
	213								
	195								
	193								
	229								
Average	213	209	215	221	213	219	230	211	221
STD	27	33	28	21	23	31	23	25	26
Coefficient of Variation	13	16	13	9	11	14	10	12	12
% Change		-2	1	4	0	3	8	-1	4

SEA
Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Permittivity: flow rate									
(gal/min/ft2)	76.47	80.22	77.22	78.72	83.97	77.97	84.72	82.10	81.95
ASTM D4491	62.23	78.72	76.47	82.47	83.22	78.72	78.72	74.30	82.05
	68.22	80.22	76.47	83.97	84.72	87.71	83.97	70.85	79.48
	77.97	78.72	76.47	81.72	86.22	89.96	87.71	79.34	86.32
	70.47	78.72	76.47	78.72	86.22	86.97	77.22	83.53	84.79
	81.72								
	66.72								
	66.72								
	65.97								
	53.98								
Average	69.05	79.32	76.62	81.12	84.87	84.27	82.47	78.02	82.92
STD	7.69	0.73	0.30	2.09	1.20	4.94	3.91	4.78	2.39
Coefficient of Variation	11	1	0	3	1	6	5	6	3
% Change		15	11	17	23	22	19	1	7
Mullen Burst:									
Burst Strength (psi)	350	700	480	730	630	545	700	570	775
ASTM D3786	585	680	680	675	650	620	620	625	600
	665	720	650	580	680	525	630	610	635
	620	570	730	720	700	670	680	630	635
	530	620	665	590	500	580	705	655	710
	500								
	470								
	580								
	500								
	480								
Average	528	658	641	659	632	588	667	618	671
STD	85	55	85	63	70	52	35	28	63
Coefficient of Variation	16	8	13	10	11	9	5	5	9
% Change		25	21	25	20	11	26	15	24

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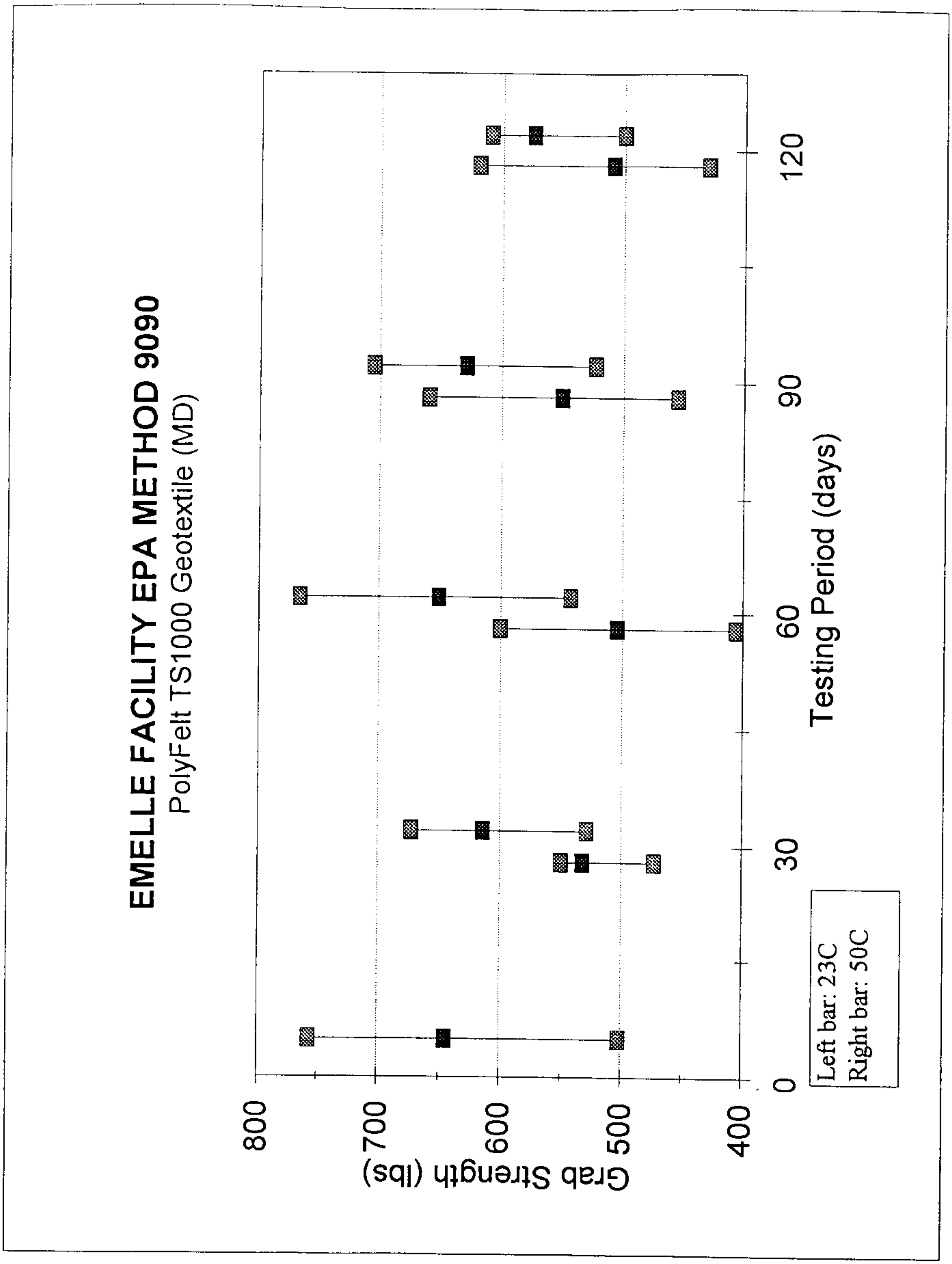
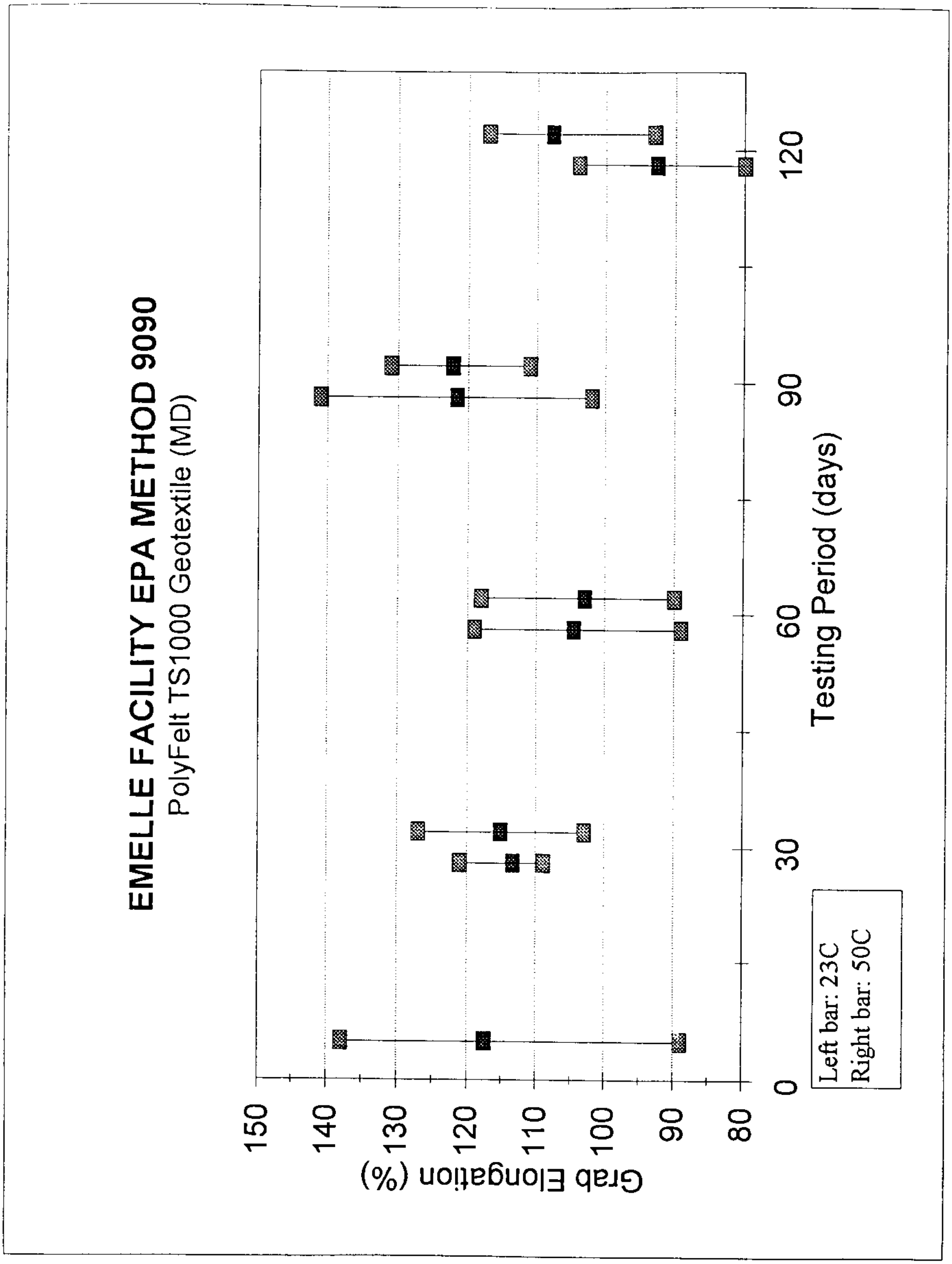
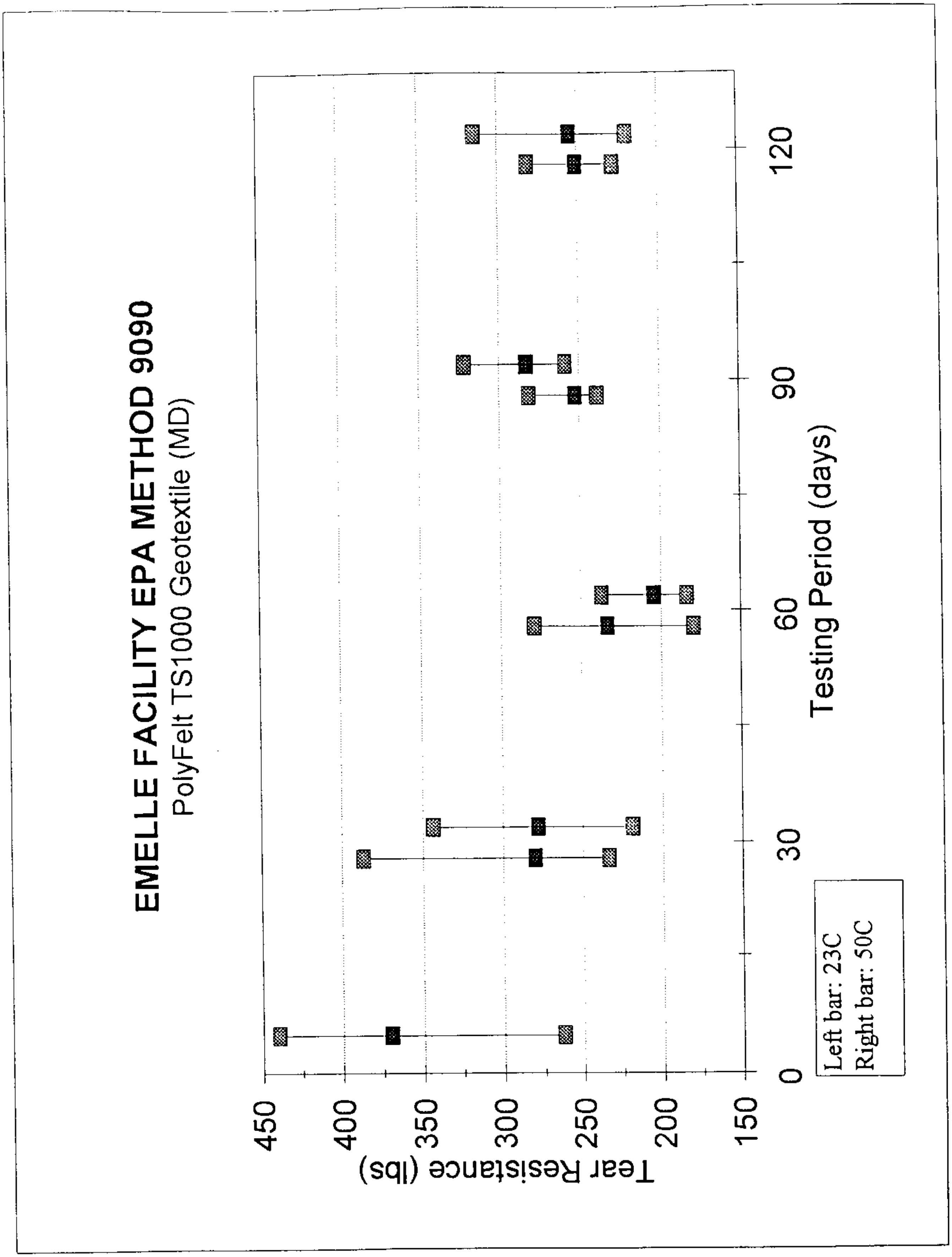
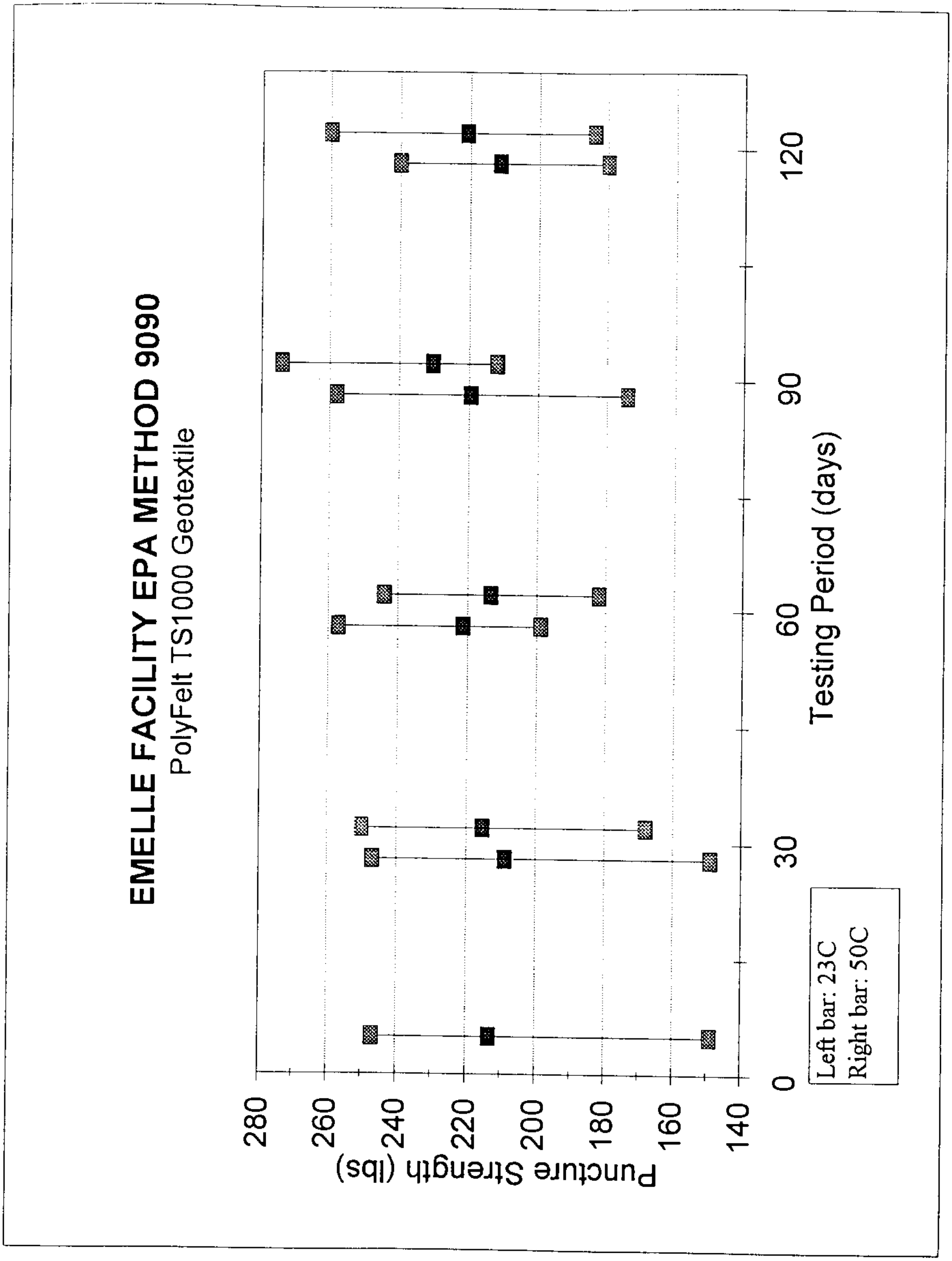
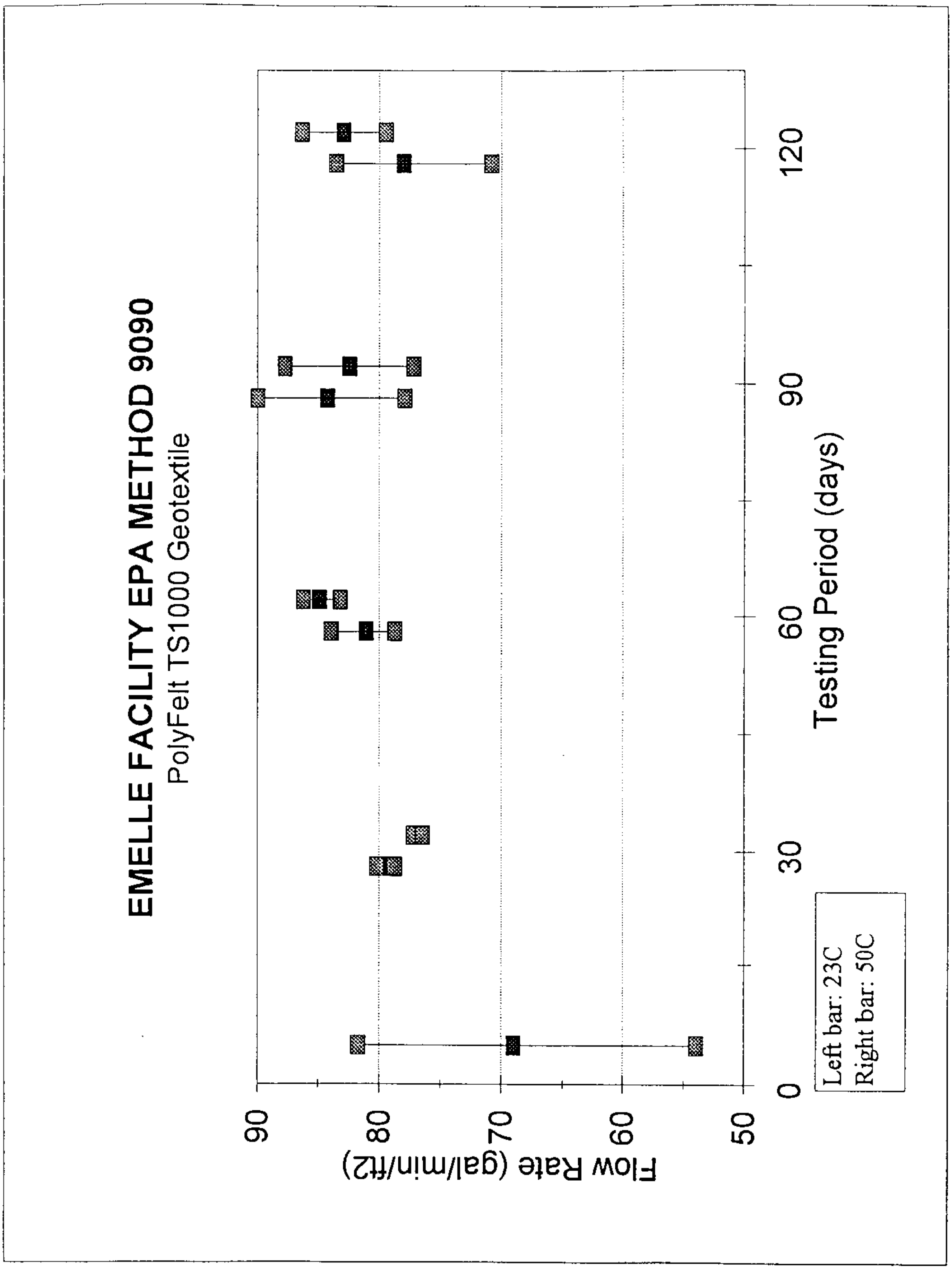

EMELLE FACILITY EPA METHOD 9090
PolyFelt TS1000 Geotextile (MD)
Grab Strength (lbs)
800
700
600
500
400
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C

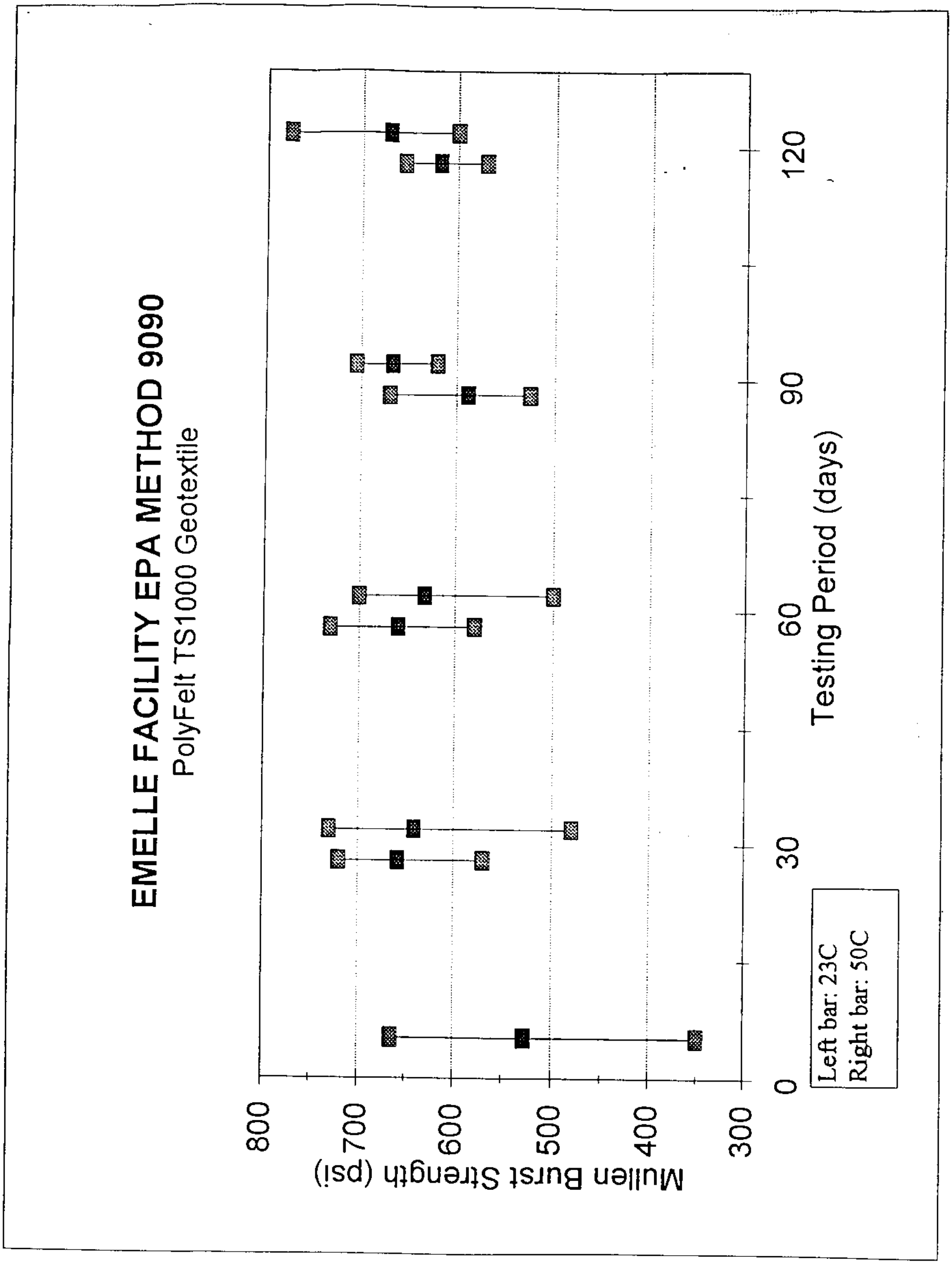

EMELLE FACILITY EPA METHOD 9090
PolyFelt TS1000 Geotextile (MD)
Grab Elongation (%)
150
140
130
120
110
100
90
80
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
PolyFelt TS1000 Geotextile (MD)
Tear Resistance (lbs)
450
400
350
300
250
200
150
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
PolyFelt TS1000 Geotextile
Puncture Strength (lbs)
280
260
240
220
200
180
160
140
Testing Period (days)
0
30
60
90
120
Left bar: 23C
Right bar: 50C



EMELLE FACILITY EPA METHOD 9090
PolyFelt TS1000 Geotextile
Flow Rate (gal/min/ft2)
90
80
70
60
50
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
PolyFelt TS1000 Geotextile
Mullen Burst Strength (psi)
800
700
600
500
400
300
0
30
60
90
120
Testing Period (days)
Left bar: 23C
Right bar: 50C

<u>GEONET TEST RESULTS</u>

NATIONAL SEAL COMPANY

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
GEONET									
Tensile Properties:									
Maximum Load (lb/ft)	564	690	492	672	690	576	594	600	618
Machine Direction	570	708	558	660	762	678	576	636	624
Netlon QC2.1	582	690	516	618	744	588	654	702	654
	636								
	474								
	528								
Average	559	696	522	650	732	614	608	646	632
STD	50	8	27	23	31	46	33	42	16
Coefficient of Variation	9	1	5	4	4	7	5	7	2
% Change		25	-7	16	31	10	9	16	13
Net Compression:									
Rib Lay Down Strength (psf)	20000	18900	21600	17200	18000	17000	15800	22400	20000
GRI GN1	21000	20000	21400	17100	16400	16600	14000	23600	25700
	18600	16600	22000	15600	17000	22800	12400	20800	20000
	24800								
	22400								
	23000								
Average	21633	18500	21667	16633	17133	18800	14067	22267	21900
STD	2031	1417	249	732	660	2833	1389	1147	2687
Coefficient of Variation	9	8	1	4	4	15	10	5	12
% Change		-14	0	-23	-21	-13	-35	3	1

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CONCRETE AND LAMINATED CONCRETE TEST RESULTS

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
LAMINATED CONCRETE BEAMS									
Compressive Strength:									
Ultimate Strength (psi)	6150	4880	5460	3820	3970	4030	4200	2860	5120
ASTM C42	5250	4250	5640	3500	3710	3260	4100	3890	4800
	6460								
	5040								
Average	5725	4565	5550	3660	3840	3645	4150	3375	4960
STD	595	315	90	160	130	385	50	515	160
Coefficient of Variation	10	7	2	4	3	11	1	15	3
% Change		-20	-3	-36	-33	-36	-28	-41	-13
CONCRETE CORES									
Compressive Strength:	6410	3260	5610	3100	7460	4830	5070	4450	5210
Ultimate Strength (psi)	3180	4240	4670	6390	3200	3220	3880	4300	3330
ASTM C116 (modified)	6550								
	5160								
Average	5325	3750	5140	4745	5330	4025	4475	4375	4270
STD	1351	490	470	1645	2130	805	595	75	940
Coefficient of Variation	25	13	9	35	40	20	13	2	22
% Change		-30	-3	-11	0	-24	-16	-18	-20

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Quality Review

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Report Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Transmissivity:									
ASTM D4716 (m2/sec)	2.28E-03	2.20E-03	2.55E-03	2.40E-03	2.32E-03	2.44E-03	2.42E-03	2.42E-03	2.35E-03
Machine Direction	2.25E-03	2.87E-03	2.34E-03	2.32E-03	2.00E-03	2.44E-03	2.30E-03	2.30E-03	2.35E-03
Hydraulic Grad.: 1.0	2.25E-03	2.41E-03	2.39E-03	2.42E-03	2.26E-03	2.45E-03	2.45E-03	2.35E-03	2.37E-03
Compressive Load: 1000 psf	2.34E-03								
	2.32E-03								
	2.32E-03								
Average	2.29E-03	2.49E-03	2.43E-03	2.38E-03	2.19E-03	2.44E-03	2.39E-03	2.36E-03	2.36E-03
STD	3.54E-05	2.80E-04	8.96E-05	4.32E-05	1.39E-04	4.71E-06	6.48E-05	4.92E-05	9.43E-06
Coefficient of Variation	1.55E+00	1E+01	4E+00	1.82E+00	6.33E+00	1.93E-01	2.71E+00	2.09E+00	4.00E-01
% Change		9	6	4	-4	7	4	3	3
Transmissivity:									
ASTM D4716 (m2/sec)	7.46E-04	6.91E-04	6.25E-04	6.88E-04	7.91E-04	7.38E-04	7.02E-04	7.13E-04	7.31E-04
Transverse Direction	7.36E-04	7.03E-04	6.25E-04	6.58E-04	7.12E-04	7.38E-04	6.98E-04	7.21E-04	7.25E-04
Hydraulic Grad.: 1.0	7.36E-04	6.62E-04	6.24E-04	6.73E-04	7.08E-04	7.45E-04	7.12E-04	7.20E-04	7.36E-04
Compressive Load: 1000 psf	8.26E-04								
	9.31E-04								
	9.31E-04								
Average	8.18E-04	6.85E-04	6.25E-04	6.73E-04	7.37E-04	7.40E-04	7.04E-04	7.18E-04	7.31E-04
STD	8.59E-05	1.72E-05	4.71E-07	1.22E-05	3.82E-05	3.30E-06	5.89E-06	3.56E-06	4.50E-06
Coefficient of Variation	1.05E+01	2.51E+00	7.55E-02	1.82E+00	5.19E+00	4.46E-01	8.36E-01	4.96E-01	6.15E-01
% Change		-16	-24	-18	-10	-9	-14	-12	-11
Specific Gravity:									
ASTM D792, Method A	0.962	0.938	0.923	0.944	0.946	0.951	0.948	0.947	0.952
	0.951	0.942	0.939	0.943	0.946	0.951	0.948	0.948	0.951
	0.950	0.938	0.947	0.943	0.945	0.951	0.947	0.945	0.948
	0.949								
	0.944								
	0.945								
Average	0.950	0.939	0.936	0.943	0.946	0.951	0.948	0.947	0.950
STD	0.006	0.002	0.010	0.000	0.000	0.000	0.000	0.001	0.002
Coefficient of Variation	0.618	0.201	1.066	0.050	0.050	0.000	0.050	0.132	0.179
% Change		-1	-1	-1	0	0	0	-0	0

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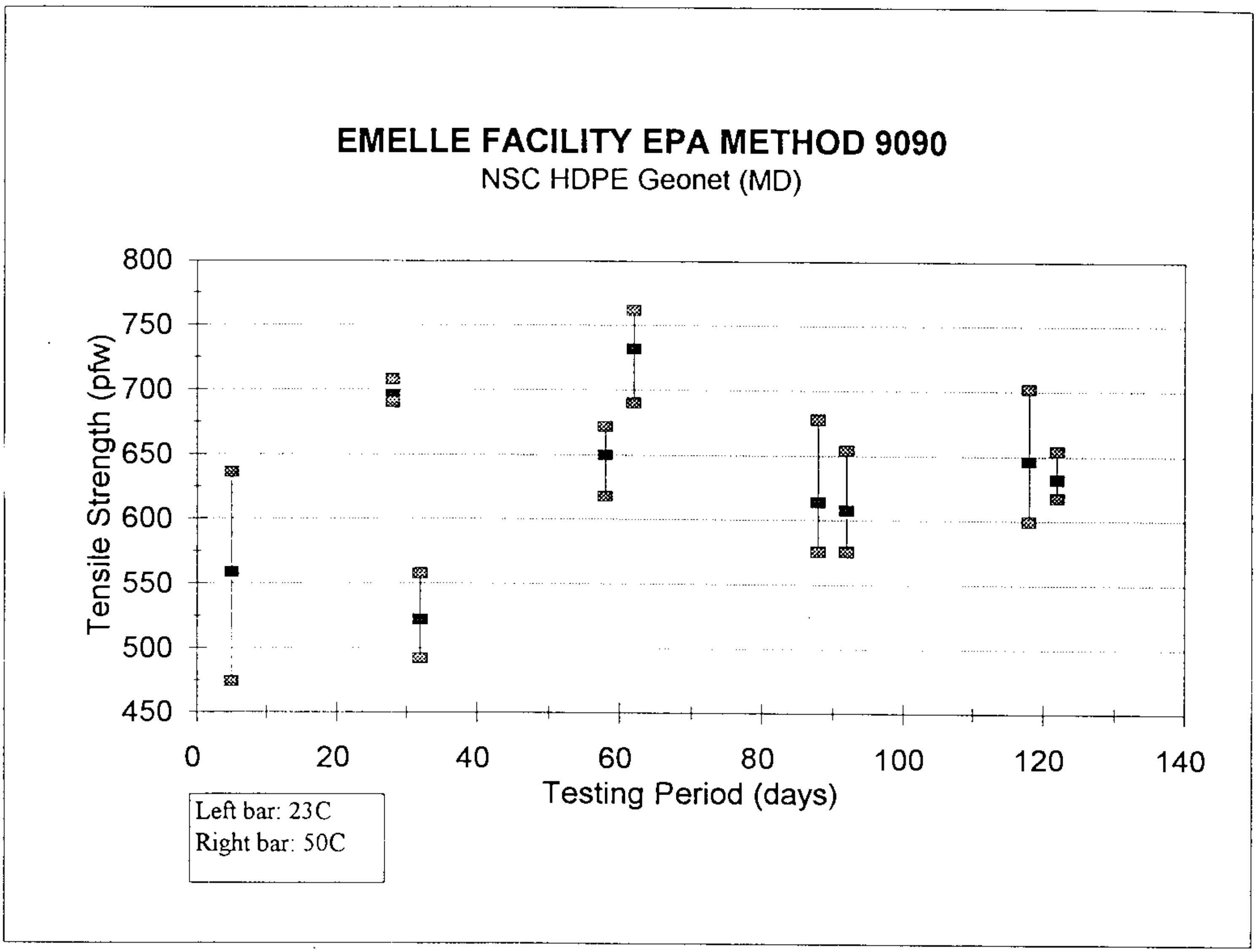
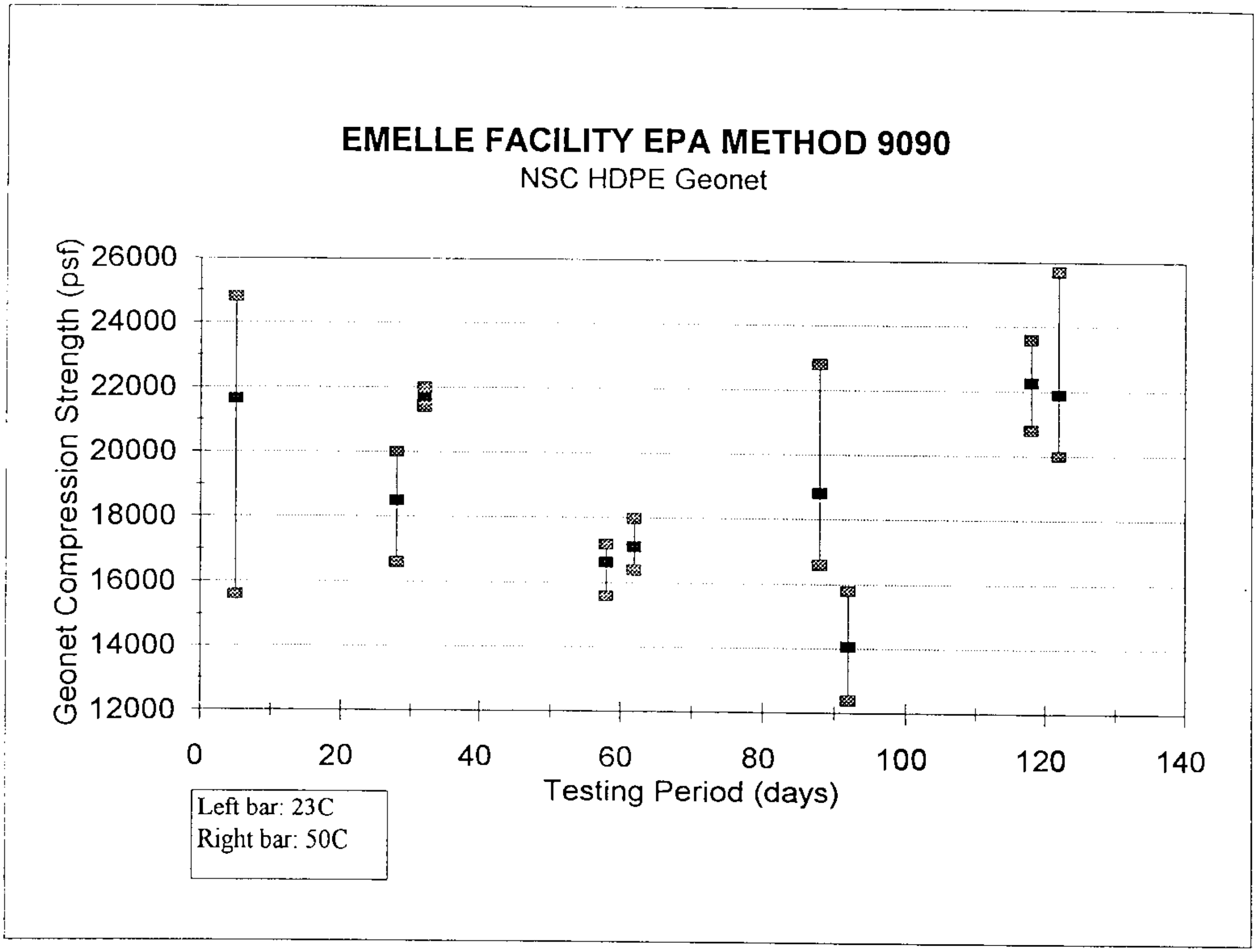
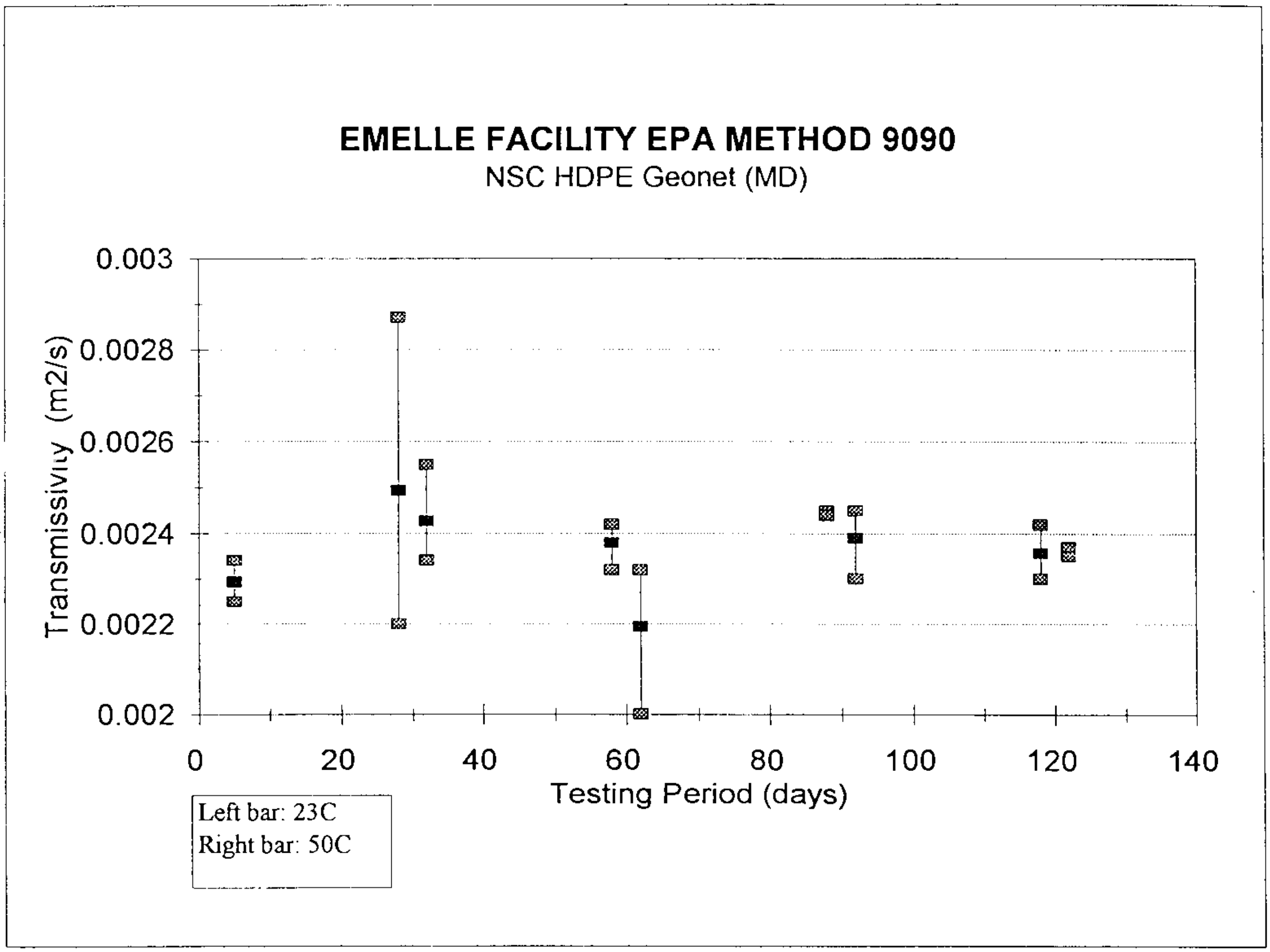


EMELLE FACILITY EPA METHOD 9090
NSC HDPE Geonet (MD)
800
750
700
650
600
550
500
450
Tensile Strength (pfw)
0
20
40
60
80
100
120
140
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
NSC HDPE Geonet
Geonet Compression Strength (psf)
26000
24000
22000
20000
18000
16000
14000
12000
0
20
40
60
80
100
120
140
Testing Period (days)
Left bar: 23C
Right bar: 50C


EMELLE FACILITY EPA METHOD 9090
NSC HDPE Geonet (MD)
Transmissivity (m2/s)
0.003
0.0028
0.0026
0.0024
0.0022
0.002
0
20
40
60
80
100
120
140
Testing Period (days)
Left bar: 23C
Right bar: 50C

HDPE GEOPIPE TEST RESULTS

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

eport Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
GEOPIPE									
Compression Test:									
Load @ 5% Deflection (lb)	113	156	152	115	139	127	141	143	105
ASTM D2412	127	163	141	148	139	137	133	127	127
	90	127	143	107	103	131	182	114	114
	136								
	107								
	127								
Average	117	149	145	123	127	132	152	128	115
STD	15	16	5	18	17	4	21	12	9
Coefficient of Variation	0.13	0.10	0.03	0.14	0.13	0.03	0.14	0.09	0.08
% Change		27	25	6	9	13	30	10	-1
Compression Test:									
Load @ 10% Deflection (lb)	206	293	280	207	193	298	220	193	186
ASTM D2412	193	170	224	227	243	211	211	187	172
	190	245	247	217	197	225	228	183	177
	193								
	183								
	194								
verage	193	236	250	217	211	245	220	188	178
D	7	51	23	8	23	38	7	4	6
oefficient of Variation	0.04	0.21	0.09	0.04	0.11	0.16	0.03	0.02	0.03
% Change		22	30	12	9	27	14	-3	-8
Compression Test:									
Pipe Stiffness @ 5% Deflection (lb/in-in)	467	660	643	475	574	529	588	591	439
ASTM D2412	525	689	596	612	574	571	554	525	525
	409	537	605	442	426	546	763	471	471
	618								
	486								
	577								
Average	514	629	615	510	525	549	635	529	478
STD	69	66	20	74	70	17	92	49	35
Coefficient of Variation	0.14	0.10	0.03	0.14	0.13	0.03	0.14	0.09	0.07
% Change		22	20	-1	2	7	24	3	-7
Compression Test:									
Pipe Stiffness @ 10% Deflection (lb/in-in)	426	619	592	438	408	621	458	399	384
ASTM D2412	399	359	474	480	514	440	440	413	385
	431	518	522	459	416	469	475	400	416
	439								
	416								
	441								
Average	425	499	529	459	446	510	458	404	395
D	14	107	48	17	48	79	14	6	15
efficient of Variation	0.03	0.21	0.09	0.04	0.11	0.16	0.03	0.02	0.04
% Change		17	24	8	5	20	8	-5	-7

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TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

port Date: June 30, 1994

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Indentation Hardness:									
Reading	60	64	58	62	64	60	60	62	61
ASTM D2240	61	63	62	61	64	62	58	60	60
(with TYPE D DUROMETER)	57	62	61	63	62	62	60	62	62
	55								
	52								
	53								
Average	56	63	60	62	63	61	59	61	61
STD	3	1	2	1	1	1	1	1	1
Coefficient of Variation	0.06	0.02	0.03	0.02	0.02	0.02	0.02	0.019	0.016
% Change		12	7	10	12	9	5	9	8

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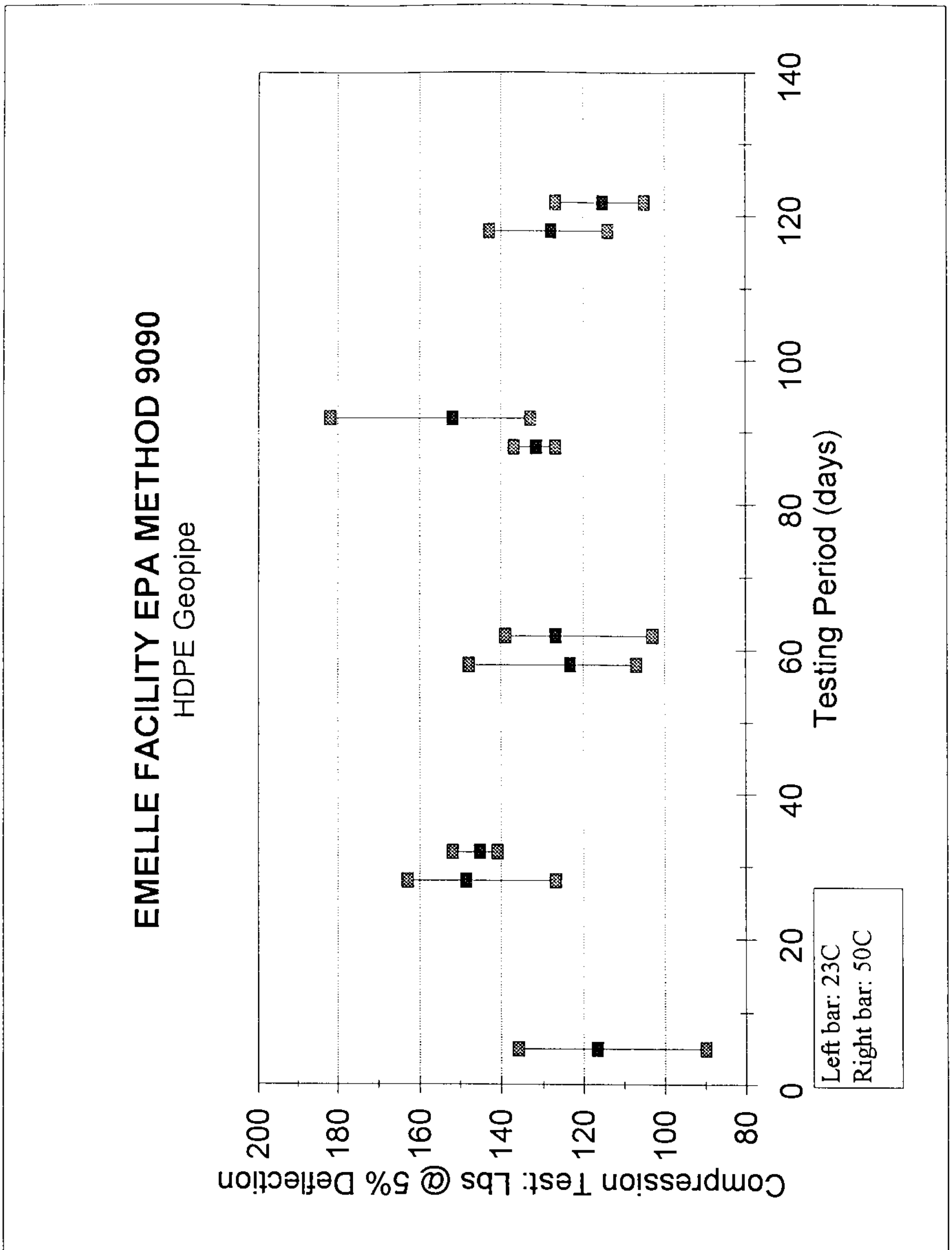
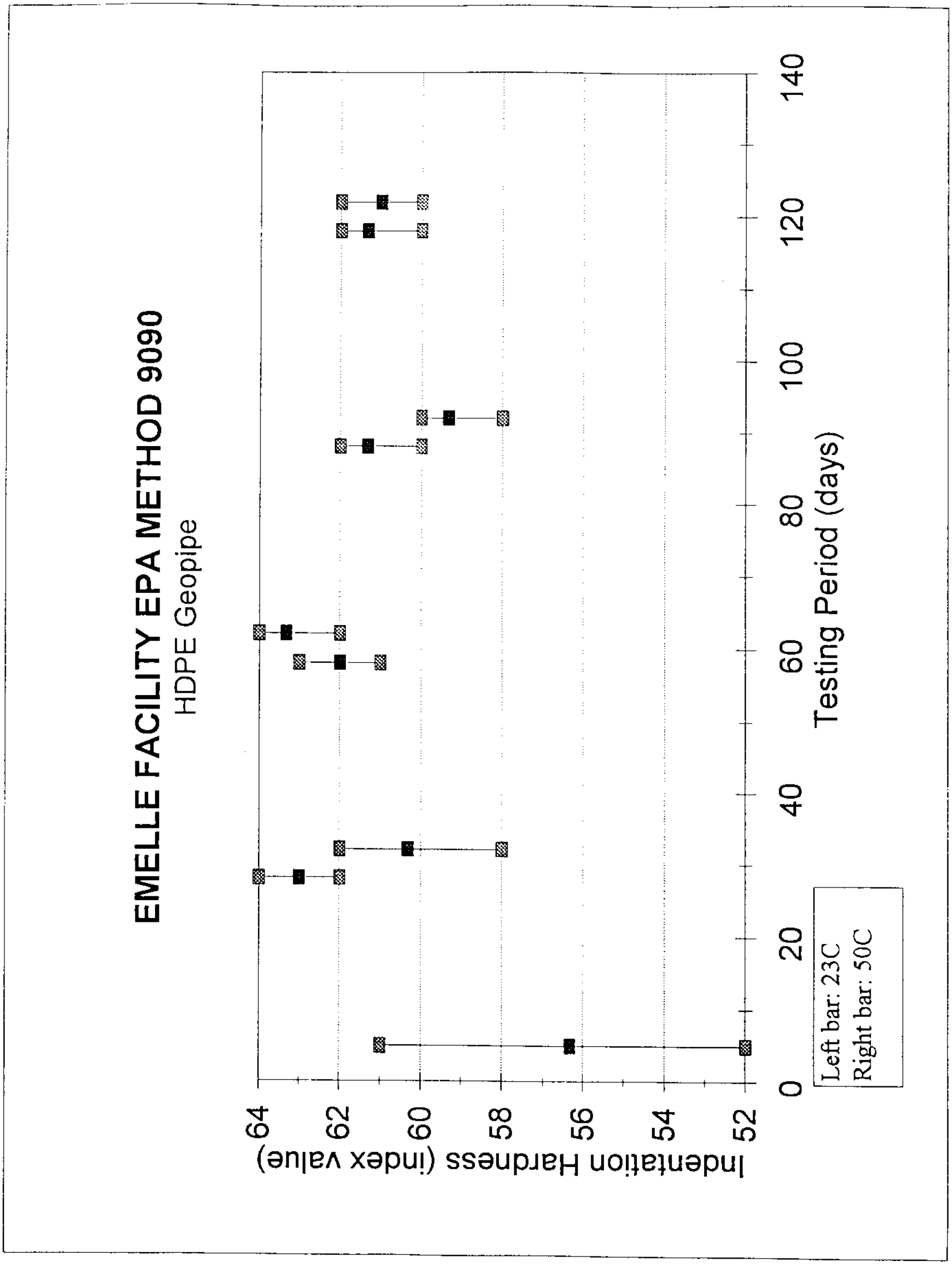

EMELLE FACILITY EPA METHOD 9090
HDPE Geopipe
Compression Test: Lbs @ 5% Deflection
Testing Period (days)
Left bar: 23C
Right bar: 50C
200
180
160
140
120
100
80
0
20
40
60
80
100
120
140


EMELLE FACILITY EPA METHOD 9090
HDPE Geopipe
Indentation Hardness (index value)
64
62
60
58
56
54
52
Testing Period (days)
0
20
40
60
80
100
120
140
Left bar: 23C
Right bar: 50C

DRAINAGE MATERIAL TEST RESULTS

SAND AND GRAVEL

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to Emelle Landfill Facility leachate

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
DRAINAGE PRODUCT:									
Gravel Percent Retained Weight: (%)	N/A	97	96	96	94	96	94	96	95
Sand Percent Retained Weight: (%)	N/A	96	96	92	91	88	88	93	92

Exposure Time and Temperature

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APPENDIX D-6-4

SECTION D-6

LABORATORY TESTING SERVICES REPORT

Revision No.
5.0

GEOSYNTEC CONSULTANTS

Geomechanics and Environmental Laboratory
5775 Peachtree Dunwoody Road • Suite 10D
Atlanta, Georgia 30342 • USA
Tel. (404) 705-9500 • Fax (404) 705-9300

9 November 1993

Mr. Rafael I. Ospina
Project Engineer
Golder Associates Inc.
3730 Chamblee Tucker Road
Atlanta, Georgia 30341

Subject: Final Report
Laboratory Testing Services
Emelle Site
Golder Project No. 933-3553

Dear Mr. Ospina:

GeoSyntec Consultants (GeoSyntec) is pleased to present the final report of the laboratory testing services recently performed for Golder Associates Inc. (Golder) for the Emelle site, Golder Project No. 933-3553. The work was performed in general accordance with the procedures defined in Table 1 of the 19 October 1993 letter prepared by Mr. Rafael I. Ospina of Golder. All of the laboratory testing was conducted at the GeoSyntec's Geomechanics and Environmental Laboratory in Atlanta, Georgia.

GeoSyntec appreciates the opportunity to provide laboratory testing services to Golder. Should you have any questions regarding the enclosed report, please do not hesitate to contact any of the undersigned.

Sincerely,

Zehong Yuan, Ph.D., E.I.T.
Assistant Division Manager
Soil-Geosynthetic Interaction Testing

Robert H. Swan, Jr., E.I.T.
Division Manager
Soil-Geosynthetic Interaction Testing

Gary R. Schmertmann, Ph.D., P.E.
Project Engineer

Enclosure

GL3478/GEL93264

...rate Office:
... N.W. 53rd Street • Suite 650
Boca Raton, Florida 33487 • USA
Tel. (407) 995-0900 • Fax (407) 995-0925

Regional Offices:
Atlanta, GA • Boca Raton, FL
Columbia, MD • Huntington Beach, CA
Walnut Creek, CA • Brussels, Belgium

Laboratories:
Atlanta, GA
Boca Raton, FL
Huntington Beach, CA

Prepared for

Golder Associates Inc.
3730 Chamblee Tucker Road
Atlanta, Georgia 30341

FINAL REPORT

LABORATORY TESTING SERVICES
EMELLE SITE
GOLDER PROJECT NO. 933-3553

Prepared by

GeoSyntec Consultants
Geomechanics and Environmental Laboratory
5775 Peachtree Dunwoody Road, Suite 10D
Atlanta, Georgia 30342

Project Number: GL3478

9 November 1993

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1. INTRODUCTION

1.1 Terms of Reference

This report was prepared by Mr. Robert H. Swan, Jr. and Dr. Zehong Yuan, both of GeoSyntec Consultants (GeoSyntec), Atlanta, Georgia. The report was reviewed by Dr. Gary R. Schmertmann, P.E., also of GeoSyntec, in accordance with the internal peer review policy of the firm. The laboratory testing program described in this report was performed at the request of Mr. Rafael I. Ospina of Golder Associates Inc. (Golder), Atlanta, Georgia.

Golder authorized GeoSyntec to undertake a laboratory testing program to evaluate the compaction characteristics of a clay soil, the shearing resistance of selected soil-geosynthetic and geosynthetic-geosynthetic interfaces, and hydraulic transmissivity of selected geosynthetics for the Emelle site, Golder Project No. 933-3553. The materials used in the testing program included a 60-mil (1.5-mm) thick National Seal Company (NSC) smooth high density polyethylene (HDPE) geomembrane, a 60-mil (1.5-mm) thick NSC textured HDPE geomembrane, a NSC PN-3000 geonet, a Trevira 1155 geotextile, and a site-specific clay soil. All samples of materials used in the testing program were provided to GeoSyntec by Golder.

The tests were conducted in general accordance with the procedures defined in Table 1 of the 19 October 1993 letter prepared by Mr. Ospina of Golder. GeoSyntec understands that the sample preparation procedures and testing conditions used for the program were selected by Golder to simulate anticipated field conditions. All of the tests were conducted at GeoSyntec's Geomechanics and Environmental Laboratory located in Atlanta, Georgia.

1.2 Organization

The remainder of the report is organized as follows:

- background information regarding the laboratory testing program is presented in Section 2;
- details of the laboratory testing program are described in Section 3; and
- results of the laboratory testing program are presented in Section 4.

2. BACKGROUND

2.1 Overview

The laboratory testing program consisted of a soil compaction test, nine interface direct shear test series, and two hydraulic transmissivity test series. Each interface direct shear test series included testing of a specific soil-geosynthetic or geosynthetic-geosynthetic interface at one to four normal stress levels ranging from 2 to 130 psi (14 to 910 kPa). Each hydraulic transmissivity test series included testing of a specific geotextile or geonet specimen at four different normal stresses ranging from 300 to 20,000 psf (14 to 960 kPa). A general description of each test method used in this testing program is given in the following sections.

2.2 Soil Compaction Tests

A standard Proctor compaction test was conducted on the clay soil in general accordance with the American Society for Testing and Materials (ASTM) Standard Test Method D 698, *"Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lb/ft^3 (600 kN-m/m^3))"* in order to evaluate its compaction characteristics.

2.3 Interface Direct Shear Tests

The interface direct shear tests were performed in general accordance with the ASTM Standard Test Method D 5321, "*Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method*". The tests were conducted in a large direct shear device containing an upper and lower shear box. The upper shear box measures 12 in. by 12 in. (300 mm by 300 mm) in plan and 3 in. (75 mm) in depth. The lower shear box measures 12 in. by 14 in. (300 mm by 360 mm) in plan and 3 in. (75 mm) in depth.

2.4 Hydraulic Transmissivity Tests

The hydraulic transmissivity tests were performed in general accordance with ASTM Standard Test Method D 4716, "*Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products*". The testing was conducted in a hydraulic transmissivity device measuring 13 in. by 12 in. (330 mm by 300 mm) in plan and 6 in. (150 mm) in depth.

3. TESTING PROGRAM

3.1 Overview

The testing program consisted of a soil compaction test, nine interface direct shear test series, and two hydraulic transmissivity test series. The materials used in the testing program are summarized in Section 3.2. Details of the tests and specific testing procedures are presented in Section 3.3 (Soil Compaction Tests), Section 3.4 (Interface Direct Shear Tests) , and Section 3.5 (Hydraulic Transmissivity Tests).

3.2 Geosynthetic and Soil Materials

3.2.1 Geosynthetic Materials

Four geosynthetic materials were used in the testing program. These materials are referenced by name in this report, and include:

- 60-mil (1.5-mm) thick NSC smooth HDPE geomembrane, referred to as 60-mil NSC smooth geomembrane;
- 60-mil (1.5-mm) thick NSC textured HDPE geomembrane, referred to 60-mil NSC textured HDPE geomembrane;
- NSC PN-3000 geonet; and
- Trevira 1155 geotextile.

The four geosynthetic materials used in the testing program were provided to GeoSyntec by Golder.

3.2.2 Soil Materials

A clay soil obtained from the project site was used in the testing program. Bulk samples of the clay were provided to GeoSyntec by Golder. A concrete sand was supplied by GeoSyntec to serve as a bedding layer above and/or below each test interface in each interface direct shear test series.

3.3 Soil Compaction Tests

A soil compaction test was conducted on the clay soil. The compaction test was conducted in general accordance with ASTM Standard Test Method D 698.

3.4 Interface Direct Shear Tests

3.4.1 Configuration of the Test Specimens

The configurations of the specimens used in the nine interface direct shear test series are described below. Table 1 summarizes the general testing conditions that were used for each of the interface direct shear test series.

- *Test Series Numbers 1, 4, 6, and 9*: interface between soaked clay and 60-mil NSC smooth HDPE geomembrane. From top to bottom, each test specimen consisted of:
  - clay;
  - 60-mil NSC smooth HDPE geomembrane; and
  - concrete sand.

- *Test Series Numbers 2 and 5:* interface between saturated Trevira 1155 geotextile and 60-mil NSC smooth HDPE geomembrane. From top to bottom, each test specimen consisted of:
  - concrete sand;
  - Trevira 1155 geotextile;
  - 60-mil NSC smooth HDPE geomembrane; and
  - concrete sand.

- *Test Series Number 3:* interface between saturated Trevira 1155 geotextile and 60-mil NSC textured HDPE geomembrane. From top to bottom, each test specimen consisted of:
  - concrete sand;
  - Trevira 1155 geotextile;
  - 60-mil NSC textured HDPE geomembrane; and
  - concrete sand.

- *Test Series Number 7:* interface between saturated NSC PN-3000 geonet and 60-mil NSC smooth HDPE geomembrane. From top to bottom, each test specimen consisted of:
    - concrete sand;
    - Trevira 1155 geotextile;
    - NSC PN-3000 geonet;
    - 60-mil NSC smooth HDPE geomembrane; and
    - concrete sand.

- *Test Series Number 8*: interface between soaked clay and 60-mil NSC textured HDPE geomembrane. From top to bottom, each test specimen consisted of:
    - clay;
    - 60-mil NSC textured HDPE geomembrane; and
    - concrete sand.

3.4.2 Test Procedure

A summary of the test equipment and conditions used to conduct the interface direct shear tests is presented in Table 2. This table includes the size of the shear box, the initial compaction conditions for the soil components (i.e., dry unit weight and moisture content), soaking stress, time for soaking, consolidation stress, time for consolidation, the moisture content of the soil components at the completion of testing, the normal stress applied to the soil in the upper shear box during testing, and the horizontal displacement rate for each test.

In all of the interface direct shear tests, fresh geosynthetic specimens were used for each normal stress condition. For each test series, the test specimens were set up and tested as described below to achieve the desired moisture condition and to cause shearing to occur at the desired test interface.

- *Test Series Number 1:* the geomembrane specimen was attached to the lower shear box with mechanical compression clamps. A fresh specimen of the clay was moisture-conditioned and compacted away from the geomembrane specimen by hand tamping to the reported dry unit weight for each normal stress condition and then placed on the geomembrane for testing. This set-up caused shearing to occur at the clay-geomembrane interface. As specified by Golder, the target dry unit weight and moisture content for the clay corresponded to 95 percent of the maximum dry unit weight and 3 percentage points wet of the optimum moisture content, based on the standard Proctor compaction test results determined by GeoSyntec.

  For each test, the entire test specimen was soaked in tap water for 24 hours under a normal stress of 0.35 psi (2.5 kPa) prior to shearing. The normal stress for soaking was applied to the test specimen prior to submerging the test specimen in the water. After the 24-hour soaking period, the specimen was placed in the shear box. The normal stress for shearing (i.e., 30, 60, or 130 psi (210, 420, or 910 kPa)) was applied to the test specimen within approximately five minutes after the removal of soaking normal stress, and shearing of the specimen followed immediately.

- *Test Series Number 2 and 3:* the geotextile and geomembrane specimens were attached to the upper and lower shear boxes, respectively, with mechanical compression clamps. This set-up caused shearing to occur at the geotextile-geomembrane interface. For each test in these two test series, the entire test specimen was submerged in tap water for 1 hour under a normal stress of 2 psi (14 kPa), and then immediately sheared without changing the normal stress.

- *Test Series Number 4 and 8:* the geomembrane specimen was attached to the lower shear box with mechanical compression clamps. A fresh specimen of the clay was moisture-conditioned and compacted away from the geomembrane specimen by hand tamping to the reported dry unit weight and then placed on the geomembrane for testing. This set-up caused shearing to occur at the clay-geomembrane interface. As specified by Golder, the target dry unit weight and moisture content for the clay corresponded to 95 percent of the maximum dry unit weight and 3 percentage points wet of the optimum moisture content, based on the standard Proctor compaction test results determined by GeoSyntec.

  For the test, the entire test specimen was soaked in tap water for 24 hours under a normal stress of 0.35 psi (2.5 kPa). The normal stress for soaking was applied to the test specimen prior to submerging the test specimen in the water. Following the soaking period, the test specimen remained submerged in tap water and was consolidated for 17 hours (Test Series 4) or 19.5 hours (Test Series 8) under a normal stress of 2 psi (14 kPa) prior to shearing. After the 24-hour soaking period and 17-hour or 19.5-hour consolidation period, the test specimen was then sheared without changing the normal stress at a constant displacement rate such that the time to failure was approximately equal to 50 times t_{50}, where t_{50} is the time required to achieve 50 percent consolidation as determined from the consolidation phase of the test, (see Appendix B).

- *Test Series Number 5:* the geotextile and geomembrane specimens were attached to the upper and lower shear boxes, respectively, with mechanical compression clamps. This set-up caused shearing to occur at the geotextile-geomembrane interface. For each test in this series, the entire test specimen was soaked in tap water for 1 hour under a normal stress of 2 psi (14 kPa) prior to shearing. The normal stress for soaking was applied to the test specimen prior to submerging the test specimen in the water. After the 1-hour soaking period, the normal stress for shearing (i.e., 10, 30, 60, or 130 psi (70, 210, 420, or 910 kPa)) was applied to the test specimen, and shearing of the specimen followed immediately.

- *Test Series Number 6:* the geomembrane specimen was attached to the lower shear box with mechanical compression clamps. A fresh specimen of the clay was moisture-conditioned and compacted away from the geomembrane specimen by hand tamping to the reported dry unit weight and then placed on the geomembrane for testing. This set-up caused shearing to occur at the clay-geomembrane interface. As specified by Golder, the target dry unit weight and moisture content for the clay corresponded to 95 percent of the maximum dry unit weight and 3 percentage points wet of the optimum moisture content, based on the standard Proctor compaction test results determined by GeoSyntec.

  For the test, the entire test specimen was soaked in tap water for 24 hours under a normal stress of 30 psi (210 kPa). The normal stress for soaking was applied to the test specimen prior to submerging the test specimen in the water. After the 24-hour soaking period, the specimen was placed in the shear box. The normal stress for shearing (i.e., 30 psi (210 kPa)) was applied to the test specimen within approximately five minutes after the removal of consolidation normal stress, and shearing of the specimen followed immediately.

- *Test Series Number 7:* the geonet and geomembrane specimens were attached to the upper and lower shear boxes, respectively, with mechanical compression clamps. A geotextile specimen was placed on top of the geonet specimen prior to placement of the concrete sand. This set-up caused shearing to occur at the geonet-geomembrane interface. For each test in this series, the entire test specimen was soaked in tap water for 1 hour under a normal stress of 2 psi (14 kPa) prior to shearing. The normal stress for soaking was applied to the test specimen prior to submerging the test specimen in the water. After the 1-hour soaking period, the normal stress for shearing (i.e., 10, 30, 60, or 130 psi (70, 210, 420, or 910 kPa)) was applied to the test specimen, and shearing of the specimen followed immediately.

- *Test Series Number 9:* the geomembrane specimen was attached to the lower shear box with mechanical compression clamps. A fresh specimen of the clay was moisture-conditioned and compacted away from the geomembrane specimen by hand tamping to the reported dry unit weight and then placed on the geomembrane for testing. This set-up caused shearing to occur at the clay-geomembrane interface. As specified by Golder, the target dry unit weight and moisture content for the clay corresponded to 95 percent of the maximum dry unit weight and 3 percentage points wet of the optimum moisture content, based on the standard Proctor compaction test results determined by GeoSyntec.

  For the test, the entire test specimen was soaked in tap water for 24 hours under a normal stress of 60 psi (420 kPa) prior to shearing. The normal stress for soaking was applied to the test specimen prior to submerging the test specimen in the water. After the 24-hour soaking period, the specimen was then sheared at a constant displacement rate such that the time to failure was approximately equal to 50 times t_{50}, where t_{50} is the time required to achieve 50 percent consolidation as determined from the consolidation phase of the test, (see Appendix B).

For Test Series 1, 4, 6, 8, and 9, the target dry unit weight and moisture conditions for the clay were selected by Golder based on the results of standard Proctor compaction tests conducted by GeoSyntec. The reported values of dry unit weight for each clay specimen were determined by measuring the as-placed volume of soil and dividing this volume into the calculated total dry weight of the moisture-conditioned soil specimen.

Other features of the testing procedure included the following:

- a freshly remolded 3-in. (75-mm) thick layer of concrete sand was used as a bedding layer below each test interface in all of the test series and above each interface in Test Series 2, 3, 5, and 7; the concrete sand was compacted by hand tamping to a relatively dense state under dry conditions;

- the direction of shearing for each test was in the direction of manufacture (machine direction) of the geosynthetic samples;

- all of the tests were performed using a constant effective sample area (i.e., the plan area of the geosynthetics were larger than that of the upper shear box); therefore, no area correction was required when computing normal and shear stresses; and

- all of the tests were sheared until a constant, residual shear load was recorded.

3.5 Hydraulic Transmissivity Tests

3.5.1 Configuration of the Test Specimens

The test configurations for the two hydraulic transmissivity test series are described below:

- *Test Series Number 1*: Hydraulic transmissivity of Trevira 1155 geotextile. From top to bottom, the test specimen consisted of:

- rigid platen;
- compacted clay;
- Trevira 1155 geotextile;
- 60-mil NSC smooth HDPE geomembrane; and
- rigid platen.

- *Test Series Number 2*: Hydraulic transmissivity of NSC PN-3000 geonet. From top to bottom, the test specimen consisted of:

  - rigid platen;
  - 60-mil NSC smooth HDPE geomembrane;
  - NSC PN-3000 geonet;
  - 60-mil NSC smooth HDPE geomembrane; and
  - rigid platen.

3.5.2 Test Procedure

The actual test equipment and test procedures which were used to conduct the hydraulic transmissivity tests are as follows:

- the size of the hydraulic transmissivity box was 13 in. by 12 in. (330 mm by 300 mm) in plan dimension and 6-in. (150-mm) in depth;

- the clay was moisture-conditioned to 3 percentage points wet of its optimum moisture content as determined from the standard Proctor compaction test. The clay was then compacted by hand tamping to a dry unit weight corresponding to 85 percent of the maximum standard Proctor dry unit weight as specified by Golder;

- for each test series, normal stresses of 300, 1,000, 10,000 and 20,000 psf (14, 48, 480, and 960 kPa) were applied to each test specimen in the transmissivity box and each normal stress was maintained for 15 minutes prior to test commencement;

- constant head hydraulic gradients of 0.04, 0.10, 0.25, and 0.40, were used to evaluate each test specimen under each applied normal stress;

- the direction of flow for each test was in the direction of manufacture (machine direction) of the geotextile and geonet specimens; and

- the flow was isolated to occur only within the geotextile or geonet component of the test specimen in each test series.

4. TEST RESULTS

4.1 Overview

The data reduction procedures and test results are summarized in the following sections. The results of standard Proctor compaction tests on the clay are presented in Appendix A. The results of interface direct shear tests and comprehensive summary plots are presented in Appendix B. The results of hydraulic transmissivity tests are presented in Appendix C.

4.2 Soil Compaction Tests

The results of the standard Proctor compaction test on the clay are summarized in Table 3. The compaction curve of the clay is presented in Appendix A.

4.3 Interface Direct Shear Tests

For Test Series 4, 6, 8, and 9, the top plate displacement data recorded during the consolidation or soaking/consolidation phases for these tests were plotted on a graph of top plate displacement versus square root of time and are presented in Appendix B. For each test, the time corresponding to 50 and 90 percent of consolidation (T_{50} and T_{90}, respectively), and the coefficient of consolidation (C_v) were evaluated.

The total-stress interface shearing resistance was evaluated for each applied normal stress. The test data were plotted on a graph of shear force versus horizontal displacement. The resulting plots are also presented in Appendix B. The peak value of shear force was used to calculate the peak shear strength. For this report, the residual shear strength was assumed to be equal to the stabilized post-peak shear force measured at the end of each test.

The total-stress peak and residual shear strengths derived from the plotted test results are summarized in Table 4. These strengths were plotted on a graph of shear stress versus normal stress and the results were used to evaluate total-stress peak and residual strength envelopes. For Test Series 1, 5, and 7, a best fit straight line was drawn through the three or four data points from each test series to obtain total-stress peak and residual interface friction angles and adhesions. The coefficient of correlation (R^2), a standard statistical indicator of how well the best-fit line matches the test data, was obtained for each best-fit line. For Test Series 2, 3, 4, 6, 8, and 9, a straight line was drawn from the origin through each data point in each test series to obtain the reported total-stress peak and residual friction angles. The interface friction angles, adhesions, and R^2 values derived from the plotted test results are summarized in Table 5.

For Test Series 1, 5, and 7, it is noted that the reported adhesion is the shear stress axis intercept of the best fit straight line drawn through the test data on a plot of shear stress versus normal stress. This value may not be the "true adhesion" of the interface and caution should be exercised in using this adhesion value for applications involving normal stresses outside the range of stresses covered by each test series.

4.4 Hydraulic Transmissivity Tests

The results of the hydraulic transmissivity tests are summarized in Table 6. The values of flow rate and hydraulic transmissivity which were measured for each hydraulic gradient and normal stress condition are presented in Table 6. The summary plots of flow rate and hydraulic transmissivity versus hydraulic gradient are presented in Appendix C.

4.5 Closure

The reported results apply only to the materials and test conditions used in the laboratory testing program. The results do not necessarily apply to other materials or test conditions. The test results should not be used in engineering analyses unless the test conditions model the anticipated field conditions. The testing was performed in accordance with general engineering testing standards and requirements. This testing report is submitted for the exclusive use of Golder.

TABLE 1

SUMMARY OF GENERAL TESTING CONDITIONS
INTERFACE DIRECT SHEAR TESTING
GOLDER ASSOCIATES INC.
EMELLE SITE

Test Series Number	Interface Tested[1]	Target Dry Unit[2] Weight and Moisture Content	Soaking		Consolidation		Normal Stress During Shearing (psi)	Rate of Shear (in./min)
			Stress (psi)	Time (hours)	Stress (psi)	Time (hours)		
1	Soaked Clay//60-mil NSC Smooth HDPE Geomembrane	91.5 pcf and 26.5%	0.35	24	N/A	N/A	30, 60, and 130	0.04
2	Saturated Trevira 1155 Geotextile/60-mil NSC Smooth HDPE Geomembrane	N/A	2	1	N/A	N/A	2	0.04
3	Saturated Trevira 1155 Geotextile/60-mil NSC Textured HDPE Geomembrane	N/A	2	1	N/A	N/A	2	0.04
4	Soaked Clay/60-mil NSC Smooth HDPE Geomembrane	91.5 pcf and 26.5%	0.35	24	2	17	2	0.0017
5	Saturated Trevira 1155 Geotextile/60-mil NSC Smooth HDPE Geomembrane	N/A	2	1	N/A	N/A	10, 30, 60, and 130	0.04
6	Soaked Clay/60-mil NSC Smooth HDPE Geomembrane	91.5 pcf and 26.5%	30	24	N/A	N/A	30	0.04
7	Saturated NSC PN-3000 Geonet/60-mil NSC Smooth HDPE Geomembrane	N/A	2	1	N/A	N/A	10, 30, 60, and 130	0.04
8	Soaked Clay/60-mil NSC Textured HDPE Geomembrane	91.5 pcf and 26.5%	0.35	24	2	19.5	2	0.0017
9	Soaked Clay/60-mil NSC Smooth HDPE Geomembrane	91.5 pcf and 26.5%	60	24	N/A	N/A	60	0.0017

NOTES: (1) For Test Series, 1, 2, 3, 5, 6, 7, and 9, each test specimen was soaked in tap water for a specific period of time prior to shearing. For Test Series 4 and 8, each test specimen was soaked and then consolidated for a specific period of time prior to shearing. For Test Series 4 and 8, top plate displacements were monitored during consolidation For Test Series 6 and 9, top plate displacements were monitored during soaking.

(2) N/A refers to data which is not applicable to the test. For Test Series 1, 4, 6, 8, and 9, the clay was compacted away from the geomembrane specimen and then placed on the geomembrane specimen for testing.

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TABLE 2

SUMMARY OF ACTUAL INTERFACE DIRECT SHEAR TEST EQUIPMENT AND CONDITIONS GOLDER ASSOCIATES INC. EMELLE SITE

Test Series Number	Shear Box Size	TEST CONDITIONS[1]							Normal Stress During Shearing (psi)	Displacement Rate (in./min)
		γ_{di} (pcf)	ω_{a} (%)	Soaking		Consolidation		ω_{cf} (%)		
				Stress (psi)	Time (hours)	Stress (psi)	Time (hours)			
1	12" x 12"	91.4	26.5	0.35	24	N/A	N/A	32.9	30	0.04
		91.4	26.5	0.35	24			32.4	60	0.04
		91.9	26.5	0.35	24			32.0	130	0.04
2	12" x 12"	N/A	N/A	2	1	N/A	N/A	N/A	2	0.04
3	12" x 12"	N/A	N/A	2	1	N/A	N/A	N/A	2	0.04
4	12" x 12"	91.7	26.5	0.35	24	2	17	36.8	2	0.0017
5	12" x 12"	N/A	N/A	2	1	N/A	N/A	N/A	10	0.04
				2	1				30	0.04
				2	1				60	0.04
				2	1				130	0.04
6	12" x 12"	91.6	26.4	30	24	N/A	N/A	33.4	30	0.04
7	12" x 12"	N/A	N/A	2	1	N/A	N/A	N/A	10	0.04
				2	1				30	0.04
				2	1				60	0.04
				2	1				130	0.04
8	12" x 12"	91.7	26.3	0.35	24	2	19.5	32.9	2	0.0017
9	12" x 12"	91.5	26.5	60	24	N/A	N/A	28.6	60	0.0017

Note: (1) γ_{di} refers to initial dry unit weight of soil specimen.
ω_{a} refers to initial moisture content of soil specimen.
ω_{cf} refers to final moisture content of soil specimen.
N/A refers to data which is not applicable to test.

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TABLE 3

SOIL COMPACTION TEST RESULTS
(ASTM D 698)
GOLDER ASSOCIATES INC.
EMELLE SITE

Test Series Number	Soil Type	Optimum Moisture Content (%)	Maximum Dry Unit Weight (pcf)	Reference Appendix Figure Number
1	Clay	23.5	96.3	A-1

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TABLE 4

INTERFACE DIRECT SHEAR TEST RESULTS
MEASURED PEAK AND RESIDUAL TOTAL SHEAR STRENGTHS
GOLDER ASSOCIATES INC.
EMELLE SITE

Test Series Number	Normal Stress (psi)	Measured Peak Shear Strength (psi)	Measured Residual Shear Strength (psi)	Reference Appendix Figure Number
1	30.0 60.0 130.0	2.1 2.7 5.8	2.1 2.7 5.8	B-1 and B-2
2	2.0	0.5	0.4	B-3 and B-4
3	2.0	2.8	1.6	B-5 and B-6
4	2.0	0.8	0.7	B-7, B-8 and B-9
5	10.0 30.0 60.0 130.0	2.0 5.4 9.6 22.4	2.0 5.4 9.6 22.4	B-10 and B-11
6	30.0	4.2	3.9	B-12, B-13 and B-14
7	10.0 30.0 60.0 130.0	2.6 5.8 10.2 21.3	2.6 5.8 10.2 21.3	B-15 and B-16
8	2.0	1.2	1.0	B-17, B-18 and B-19
9	60.0	11.0	10.7	B-20, B-21 and B-22

TABLE 5

INTERFACE DIRECT SHEAR TEST RESULTS
MEASURED TOTAL STRESS SHEAR STRENGTH PARAMETERS
GOLDER ASSOCIATES INC.
EMELLE SITE

Test Series Number	Interface Tested(1)	Normal Stress Range (psi)	Peak Strength			Residual Strength		
			Friction Angle	Adhesion(2) (psf)	R^2	Friction Angle	Adhesion(2) (psf)	R^2
1	Soaked Clay/60-mil NSC Smooth HDPE Geomembrane	30 to 130	2°	105	0.980	2°	105	0.980
2	Saturated Trevira 1155 Geotextile/60-mil NSC Smooth HDPE Geomembrane	2	14°	0	N/A	12°	0	N/A
3	Saturated Trevira 1155 Geotextile/60-mil NSC Textured HDPE Geomembrane	2	54°	0	N/A	38°	0	N/A
4	Soaked Clay/60-mil NSC Smooth HDPE Geomembrane	2	21°	0	N/A	19°	0	N/A
5	Saturated Trevira 1155 Geotextile/60-mil NSC Smooth HDPE Geomembrane	10 to 130	10°	5	0.997	10°	5	0.997
6	Soaked Clay/60-mil NSC Smooth HDPE Geomembrane	30	8°	0	N/A	7°	0	N/A
7	Saturated NSC PN-3000 Geonet/60-mil NSC Smooth HDPE Geomembrane	10 to 130	9°	150	1.000	9°	150	1.000
8	Soaked Clay/60-mil NSC Textured HDPE Geomembrane	2	31°	0	N/A	27°	0	N/A
9	Soaked Clay/60-mil NSC Smooth HDPE Geomembrane	60	10°	0	N/A	10°	0	N/A

NOTES: (1) For Test Series, 1, 2, 3, 5, 6, 7, and 9 each test specimen was soaked in tap water for a specific period of time prior to shearing. For Test Series 4, and 8, each test specimen was soaked and then consolidated for a specific period of time prior to shearing. For Test Series 4 and 8, top plate displacements were monitored during consolidation. For Test Series 6 and 9, top plate displacements were monitored during soaking. For Test Series 1, 4, 6, 8, and 9, the clay was compacted away from the geomembrane specimen and then placed on the geomembrane specimen for testing.

(2) For Test Series 1, 5, and 7, the reported value of adhesion may not be the "true adhesion" of the interface and caution should be exercised in using this adhesion value for applications involving normal stresses outside the range of stresses covered by the test. For Test Series 2, 3, 4, 6, 8, and 9, the friction angles were determined by drawing a straight line from the origin through each test data point on a graph of shear stress versus normal stress. N/A refers to data which is not applicable to a single-point test series.

GL3487/GEL93264

'.E 6

HYDRAULIC TRANSMISSIVITY TEST RESULTS
GOLDER ASSOCIATES INC.
EMELLE SITE

Test Series Number	Test Configuration	Vertical Confining Pressure (psf)	Minimum Duration of Pressure (min)	Total Deflection (in.)	Hydraulic Gradient ( )	Hydraulic Transmissivity (m^2/s)	Unit Flow Rate (gpm/ft)
1	Rigid Platen/Compacted Clay/Trevira 1155 Geotextile/NSC 60-mil Smooth HDPE Geomembrane/Rigid Platen	300	15	0.028	0.04 0.10 0.25 0.40	1.0E-5 9.2E-6 8.1E-6 8.0E-6	2.0E-3 4.5E-3 9.8E-3 1.6E-2
		1,000	15	0.088	0.04 0.10 0.25 0.40	8.8E-6 7.1E-6 5.6E-6 5.3E-6	1.7E-3 3.4E-3 6.8E-3 1.0E-3
		10,000	15	0.231	0.04 0.10 0.25 0.40	2.5E-6 1.8E-6 1.2E-6 9.8E-7	4.8E-4 8.7E-4 1.4E-3 1.9E-3
		20,000	15	0.302	0.04 0.10 0.25 0.40	9.5E-7 8.7E-7 7.1E-7 5.5E-7	1.8E-4 4.2E-4 8.5E-4 1.0E-3
2	Rigid Platen/60-mil NSC Smooth HDPE Geomembrane/NSC PN-3000 Geonet/60-mil NSC Smooth HDPE Geomembrane/Rigid Platen	300	15	0.032	0.04 0.10 0.25 0.40	6.9E-3 4.7E-3 3.0E-3 2.4E-3	1.34 2.29 3.60 4.65
		1,000	15	0.082	0.04 0.10 0.25 0.40	6.8E-3 4.6E-3 2.8E-3 2.3E-3	1.32 2.22 3.36 4.47
		10,000	15	0.135	0.04 0.10 0.25 0.40	6.0E-3 3.7E-3 2.5E-3 2.1E-3	1.15 1.79 3.02 4.09
		20,000	15	0.176	0.04 0.10 0.25 0.40	3.8E-3 2.7E-3 1.9E-3 1.6E-3	0.73 1.32 2.29 3.06

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APPENDIX A

SOIL COMPACTION TEST RESULTS

GEOSYNTEC CONSULTANTS
Geomechanics and Environmental Laboratory
Atlanta, Georgia

FIGURE
PROJECT GOLDER ASSOCIATES
LOCATION
NUMBER GL 3478

GS FORM: MD1 7/93 8/90

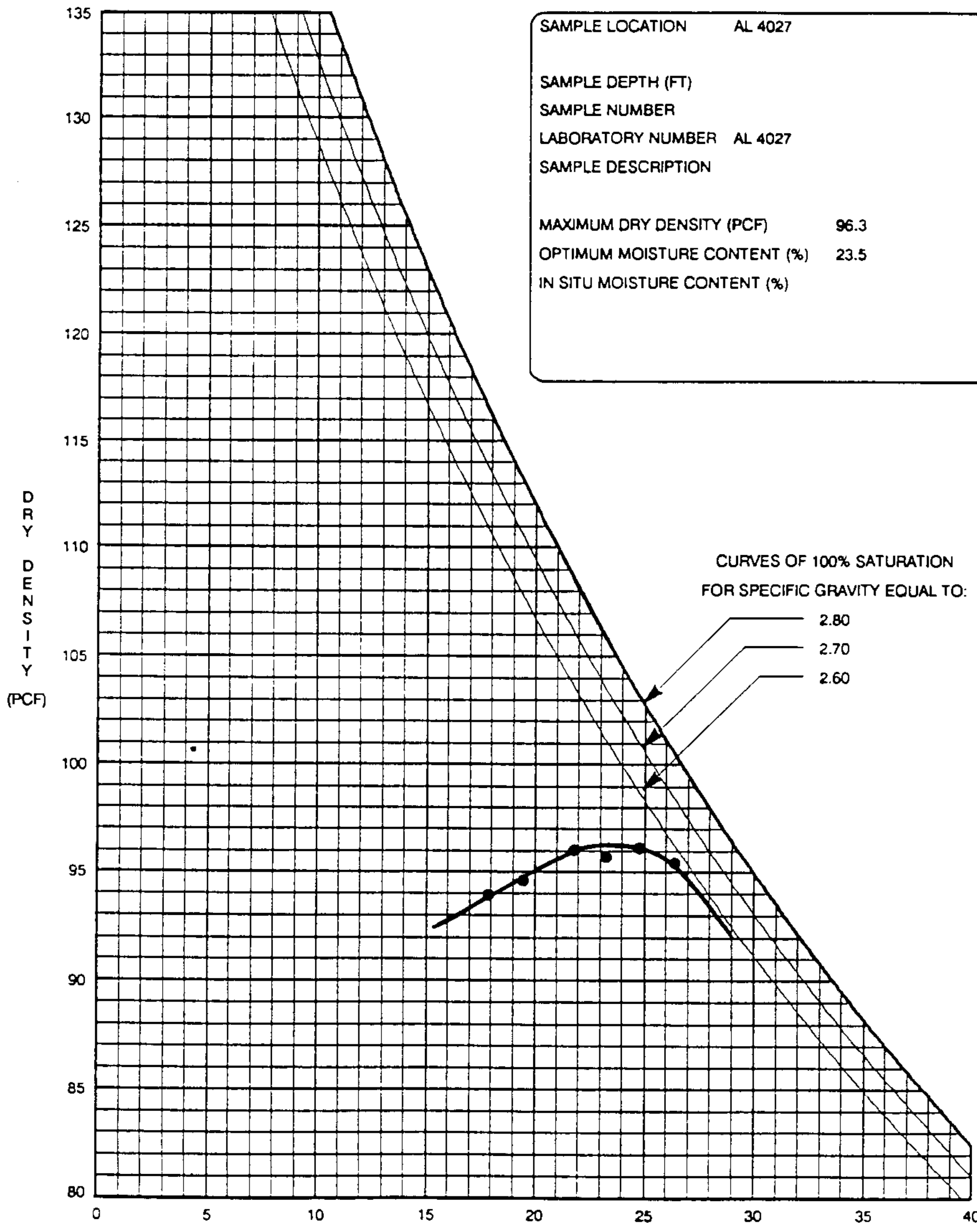
MOISTURE-DENSITY RELATIONSHIP, COMPACTION TEST

TEST PROCEDURE: ASTM D-698A

SAMPLE LOCATION AL 4027

SAMPLE DEPTH (FT)
SAMPLE NUMBER
LABORATORY NUMBER AL 4027
SAMPLE DESCRIPTION

MAXIMUM DRY DENSITY (PCF) 96.3
OPTIMUM MOISTURE CONTENT (%) 23.5
IN SITU MOISTURE CONTENT (%)

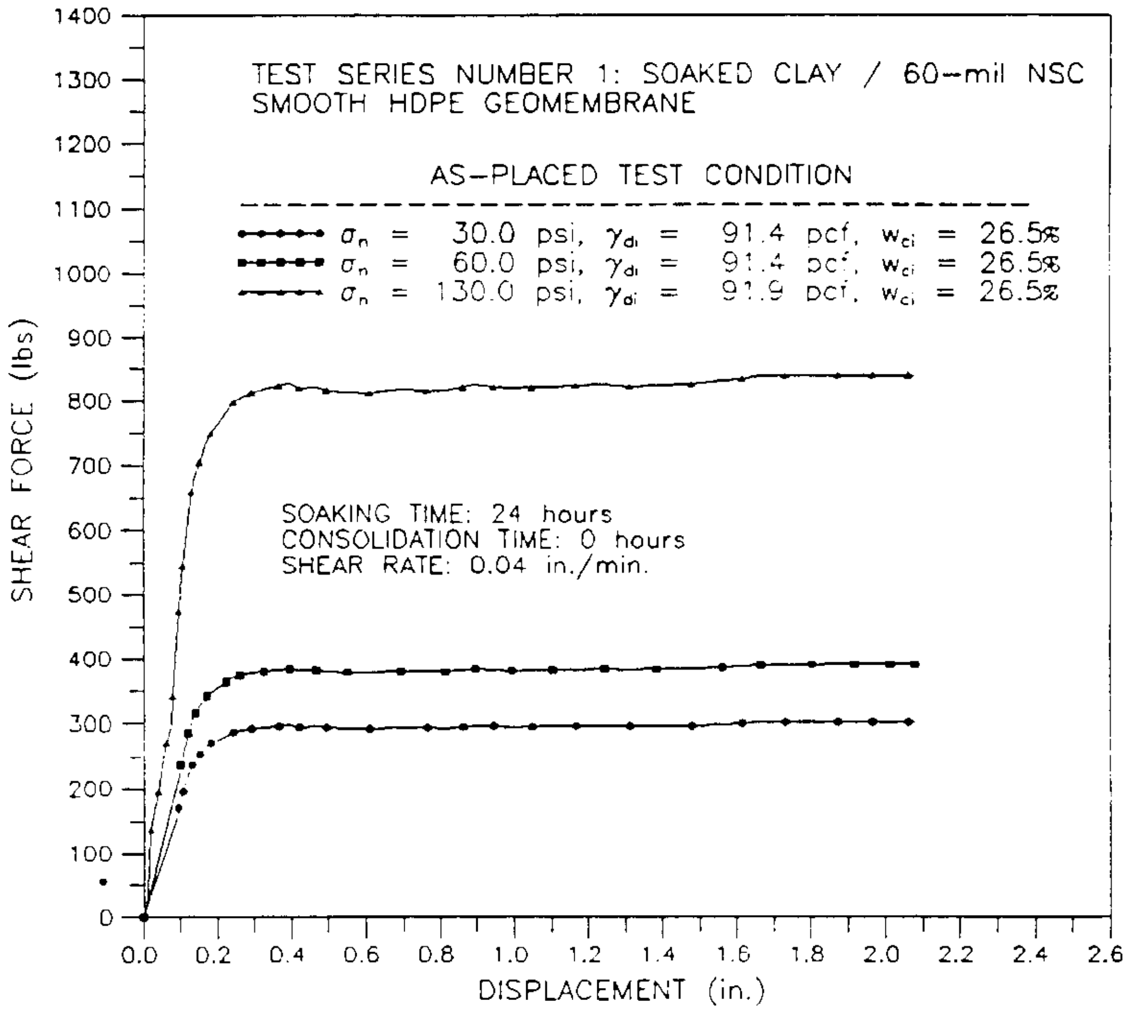


APPENDIX B

INTERFACE DIRECT SHEAR TEST RESULTS

308913

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



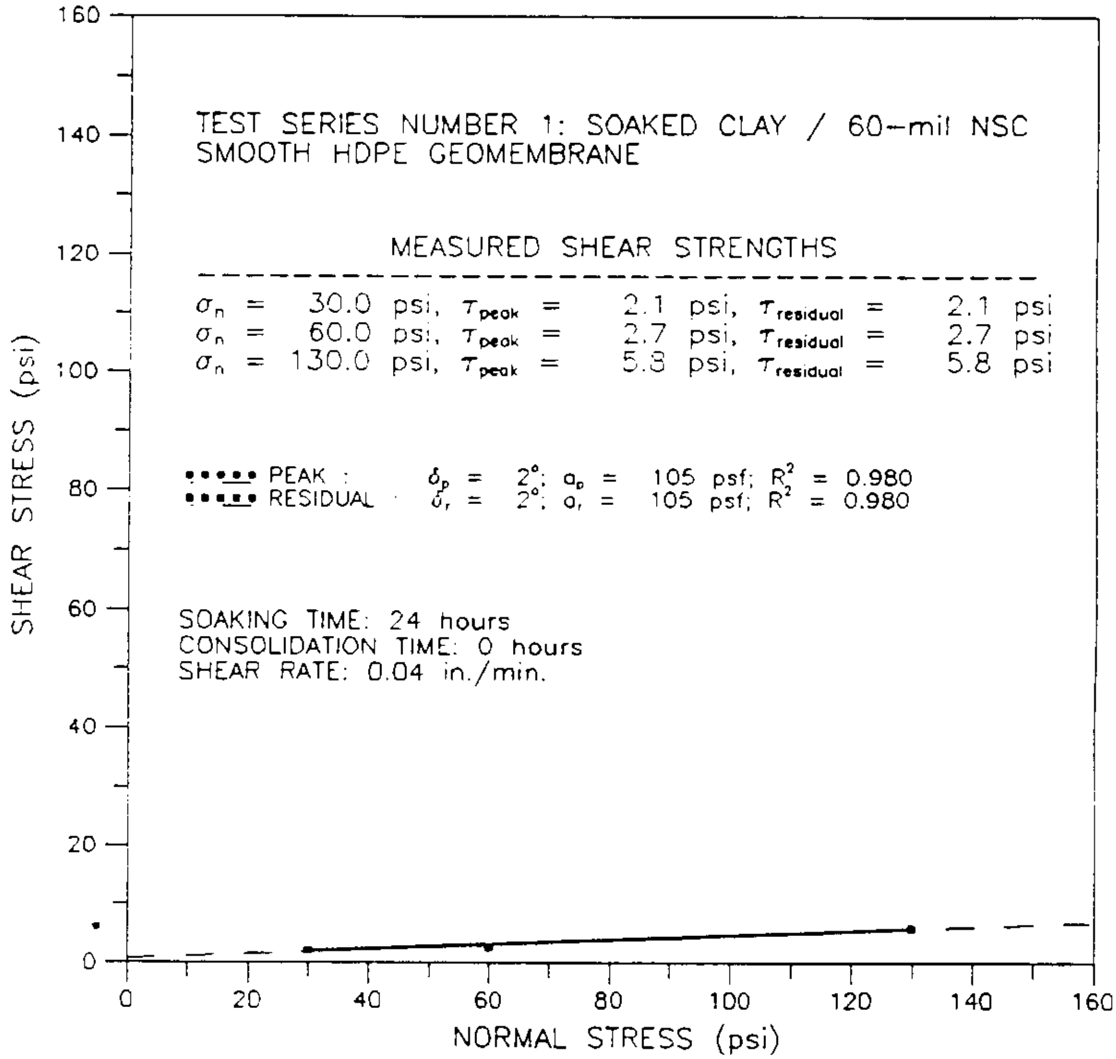
NOTE: The shear box size was 12 in. by 12 in.(300 mm by 300 mm), and the contact area remained constant throughout the entire test.

DATE TESTED: 8 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-1
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



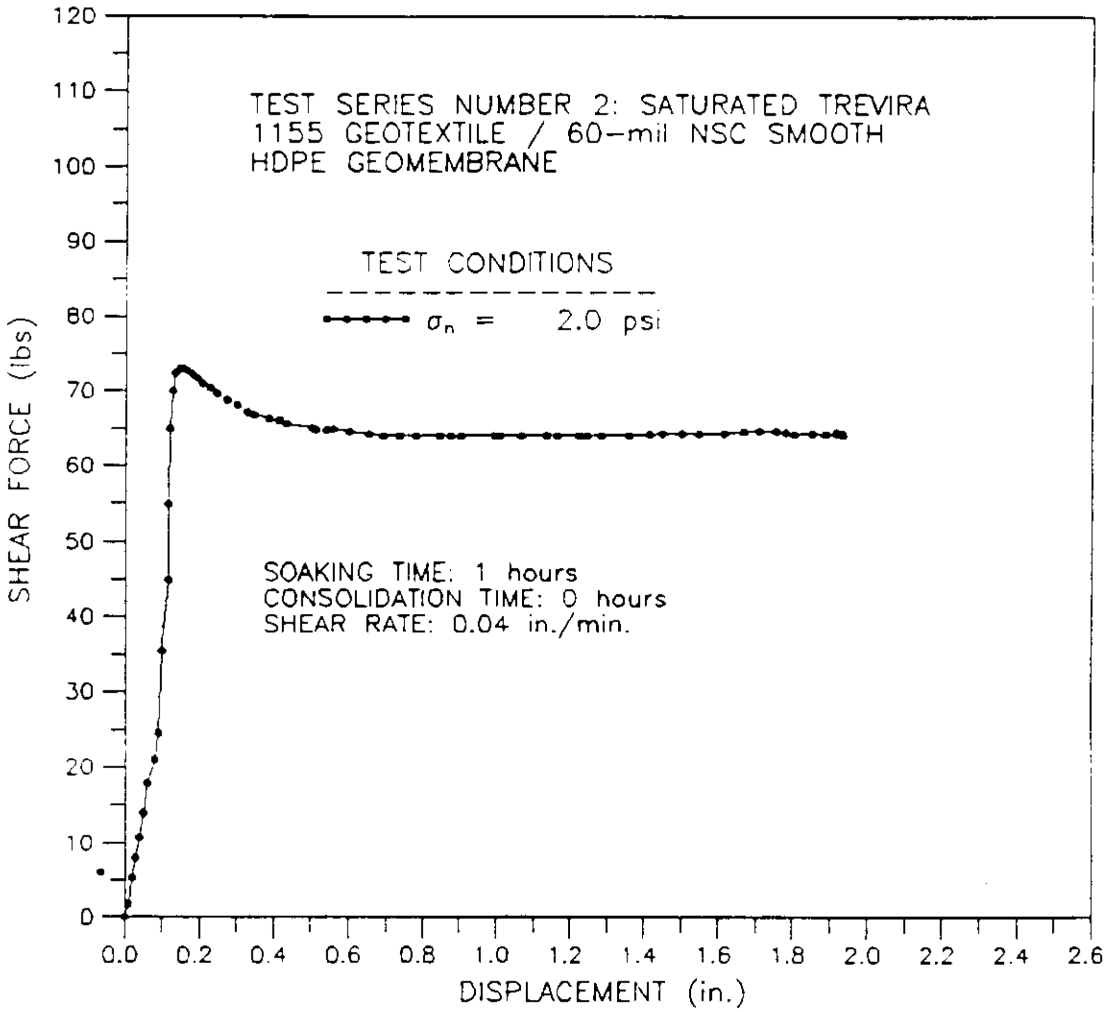
NOTE: The reported value of adhesion may not be the true adhesion of the interface, and caution should be exercised in using this adhesion value for applications involving normal stresses outside the range of stresses covered by the test.

DATE TESTED: 8 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B–2
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



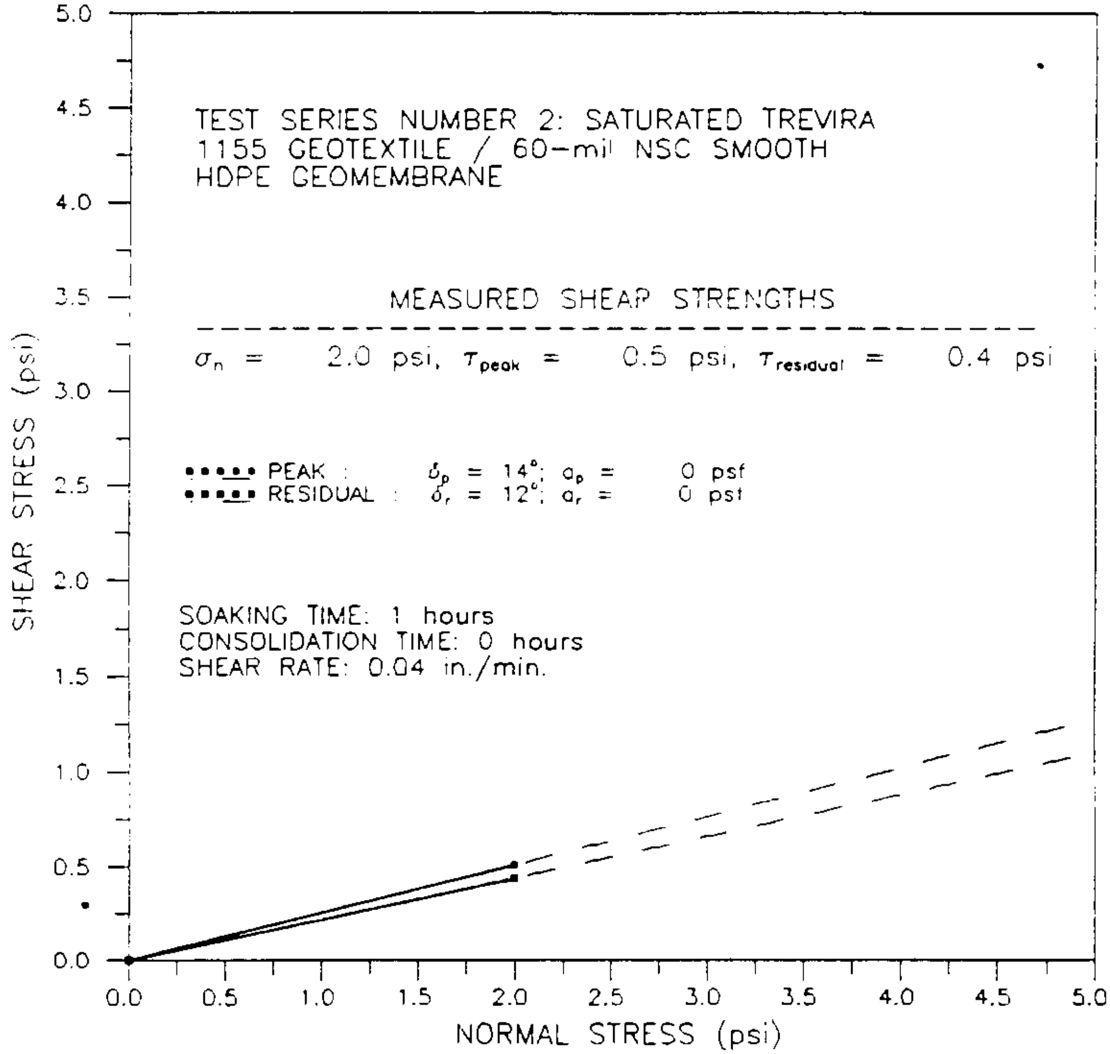
NOTE: The shear box size was 12 in. by 12 in.(300 mm by 300 mm), and the contact area remained constant throughout the entire test.

DATE TESTED: 8 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-3
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE

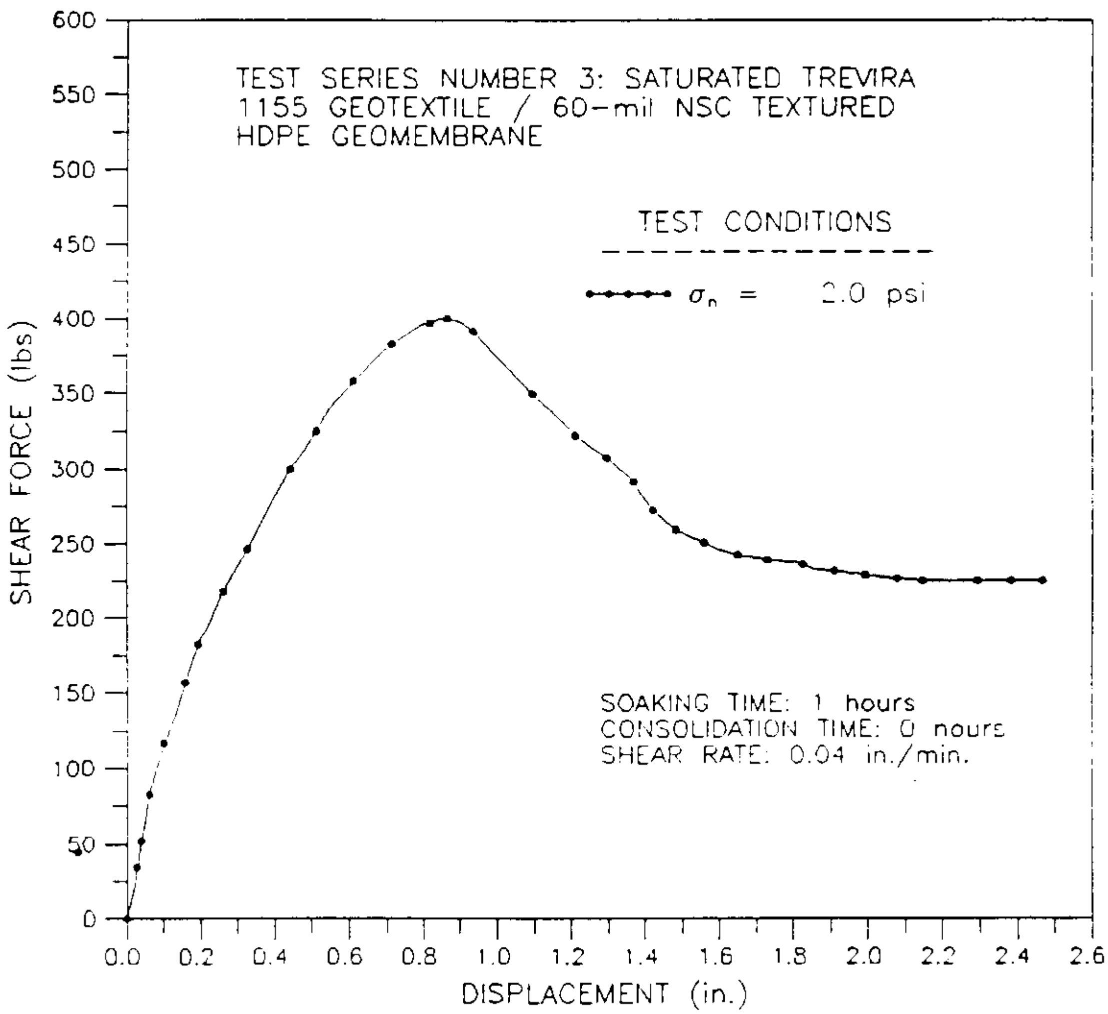


DATE TESTED: 8 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-4
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



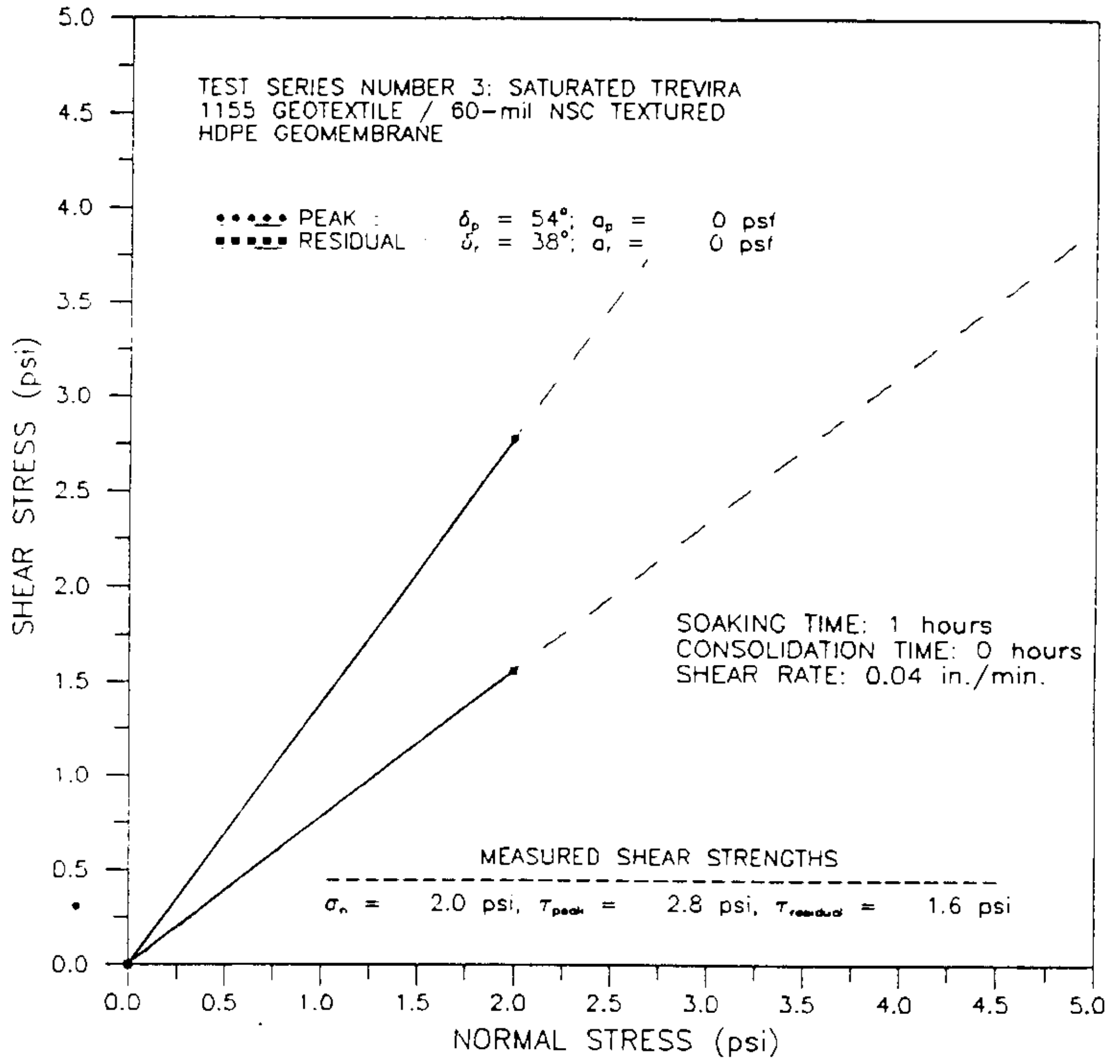
NOTE: The shear box size was 12 in. by 12 in.(300 mm by 300 mm), and the contact area remained constant throughout the entire test.

DATE TESTED: 8 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-5
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE

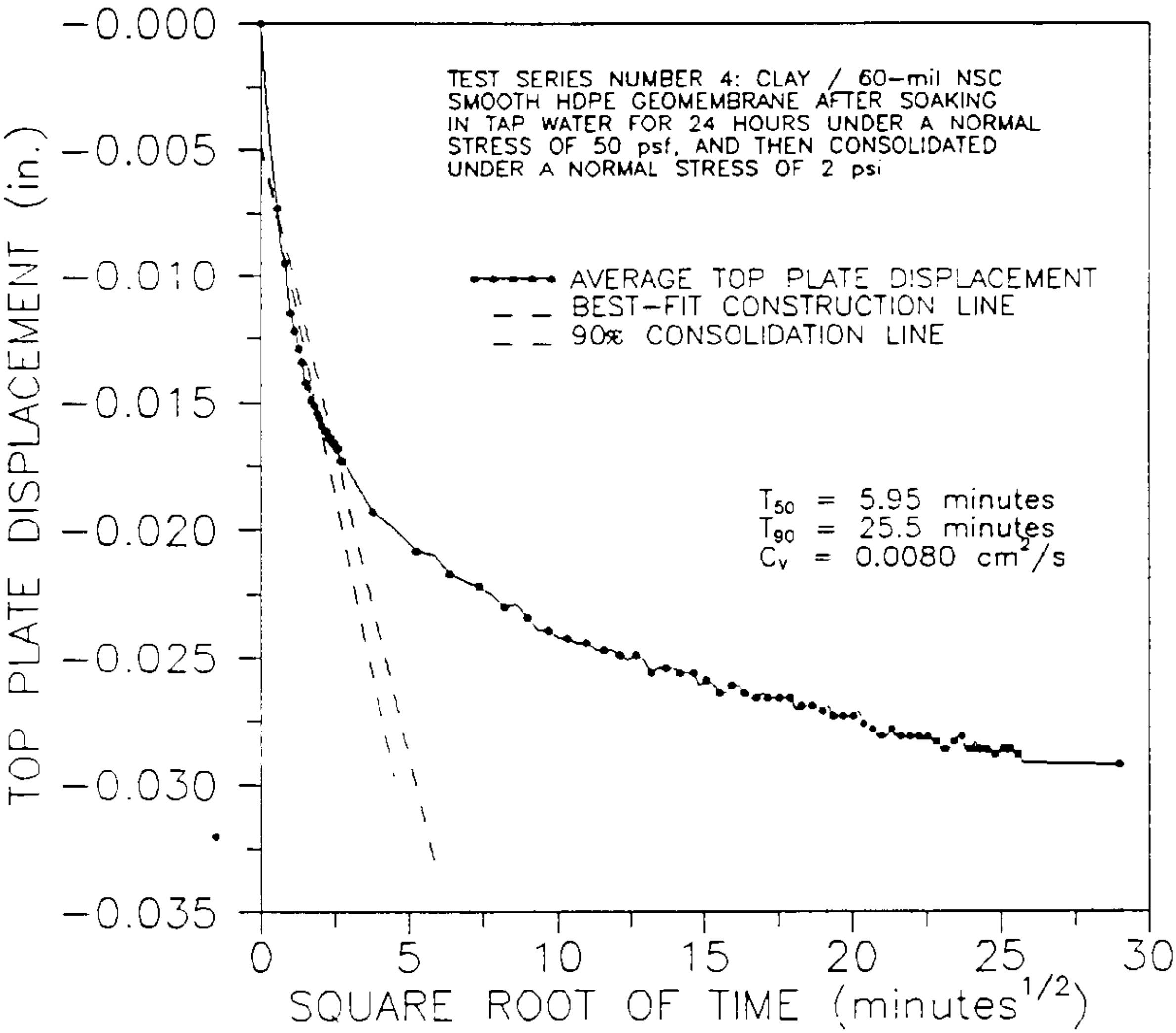


DATE TESTED: 8 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-6
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE

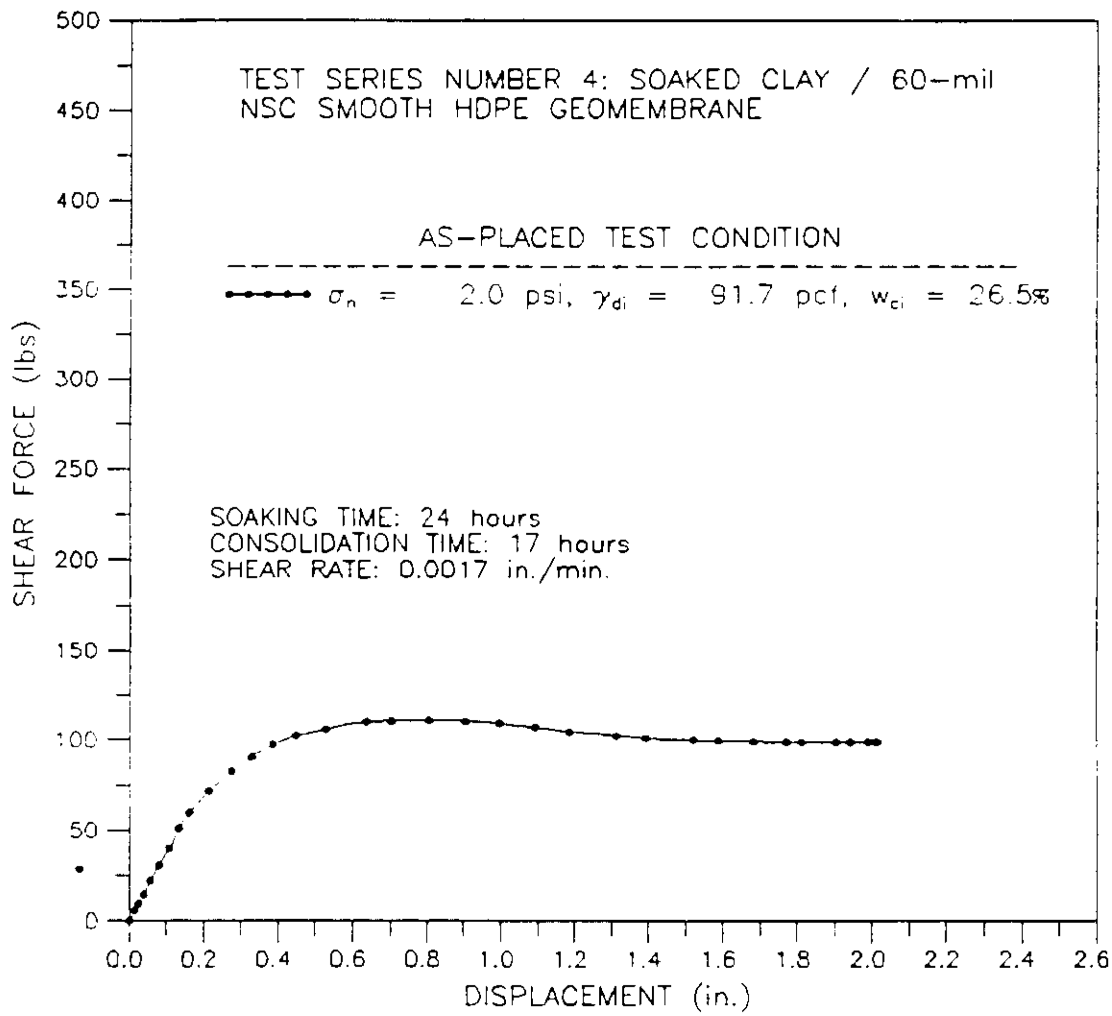


DATE TESTED: 11 TO 12 OCTOBER 1993

GeoSyntec Consultants
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-7
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



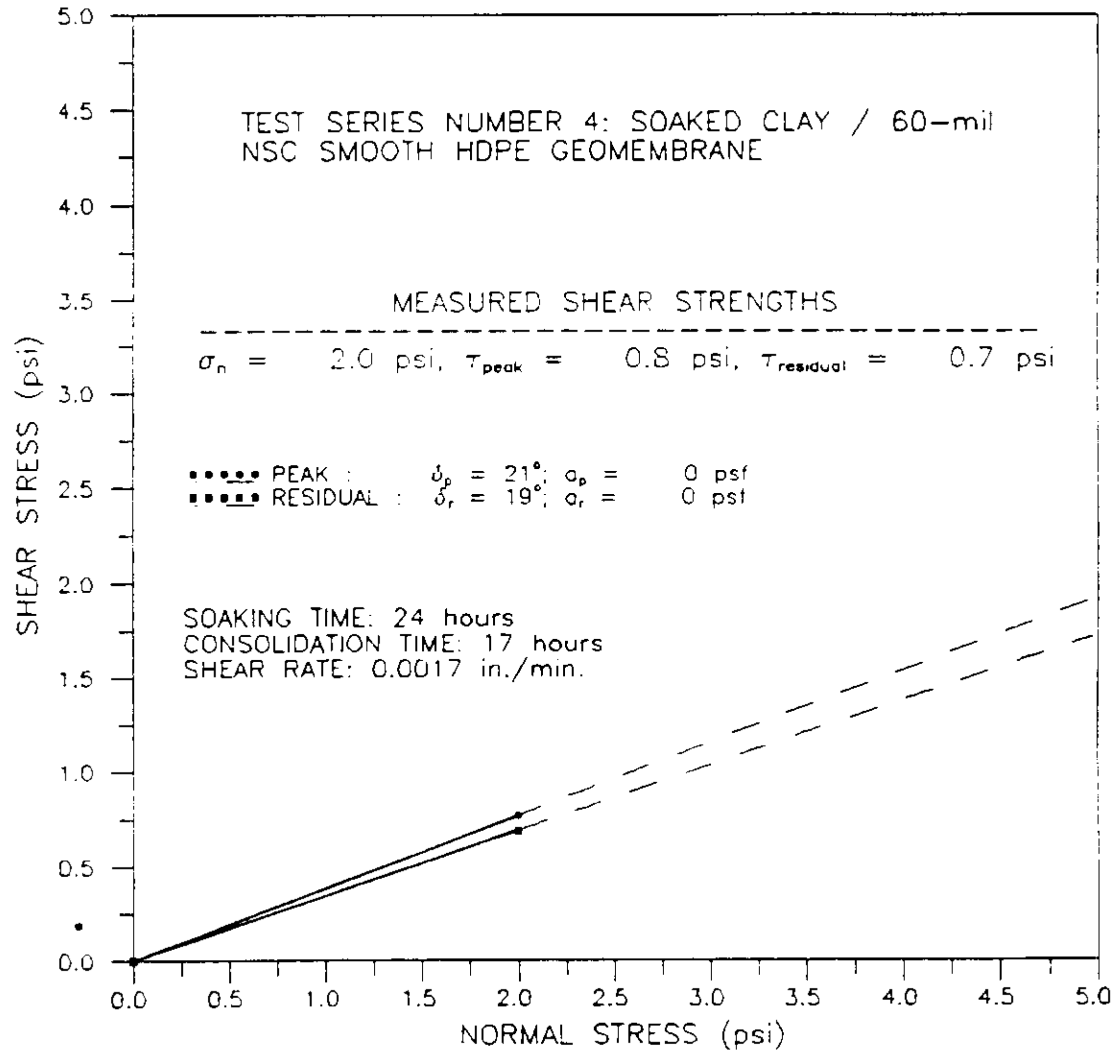
NOTE: The shear box size was 12 in. by 12 in.(300 mm by 300 mm), and the contact area remained constant throughout the entire test.

DATE TESTED: 11 TO 12 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-8
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE

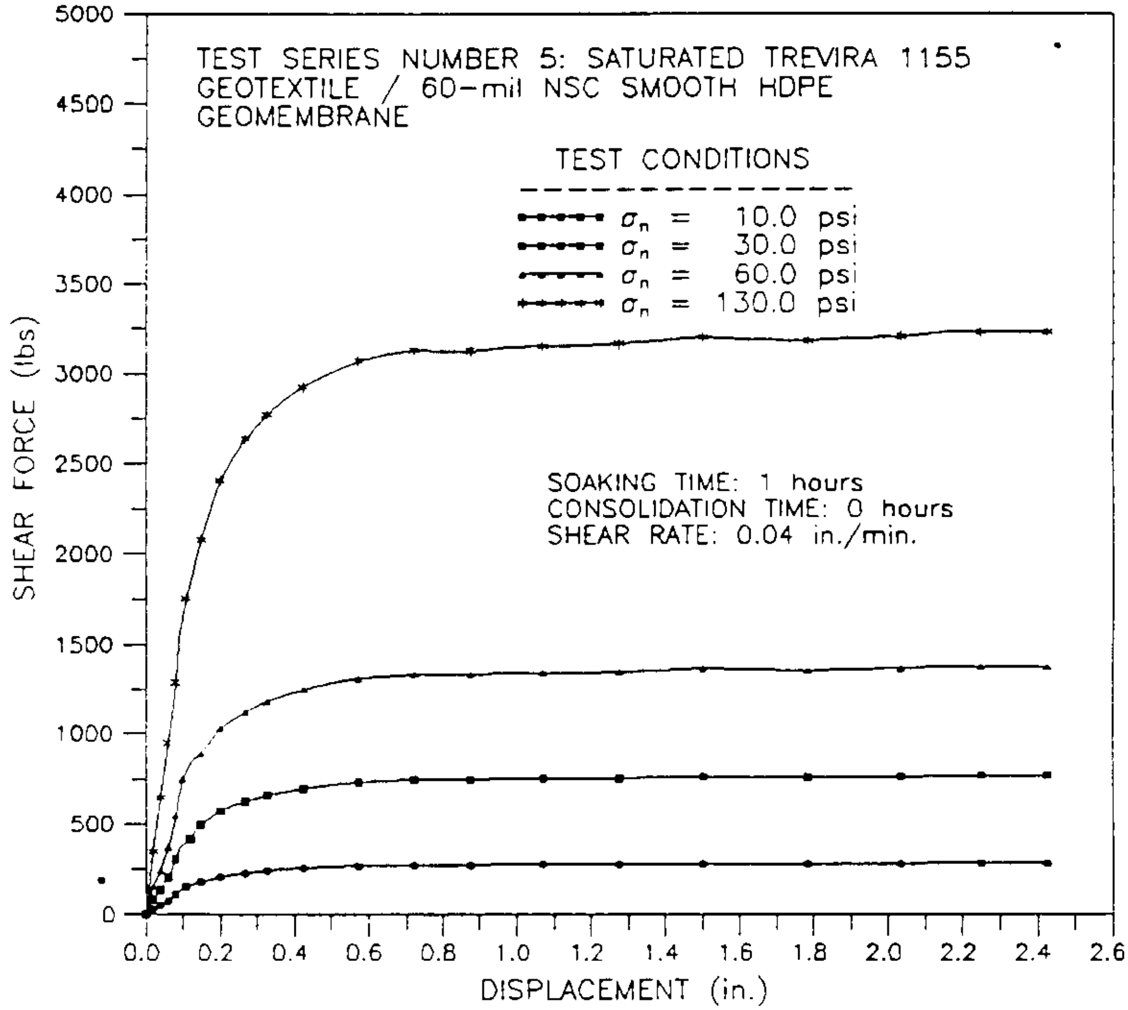


DATE TESTED: 11 TO 12 OCTOBER 1993

GeoSyntec Consultants
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-9
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



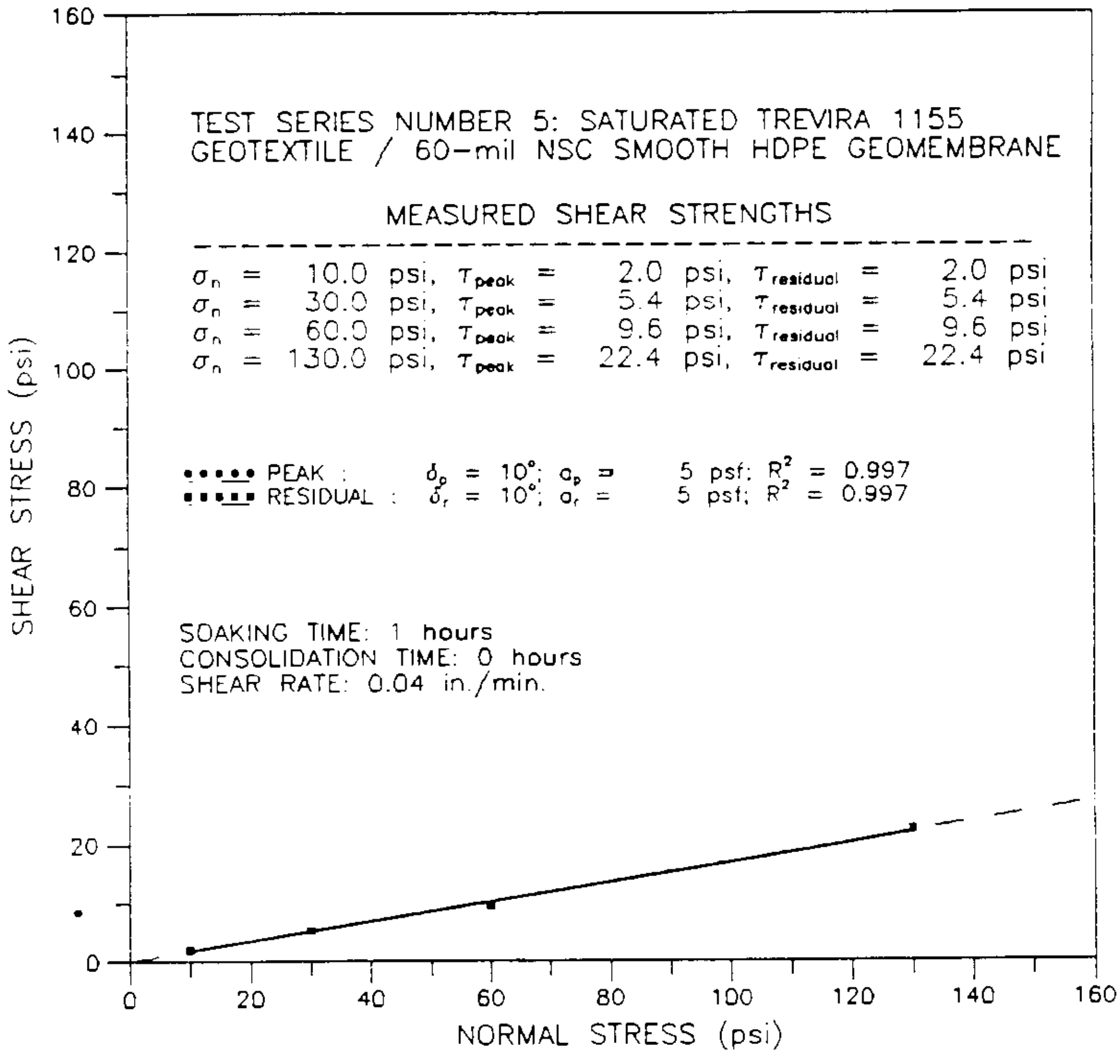
NOTE: The shear box size was 12 in. by 12 in.(300 mm by 300 mm), and the contact area remained constant throughout the entire test.

DATE TESTED: 11 TO 12 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-10
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



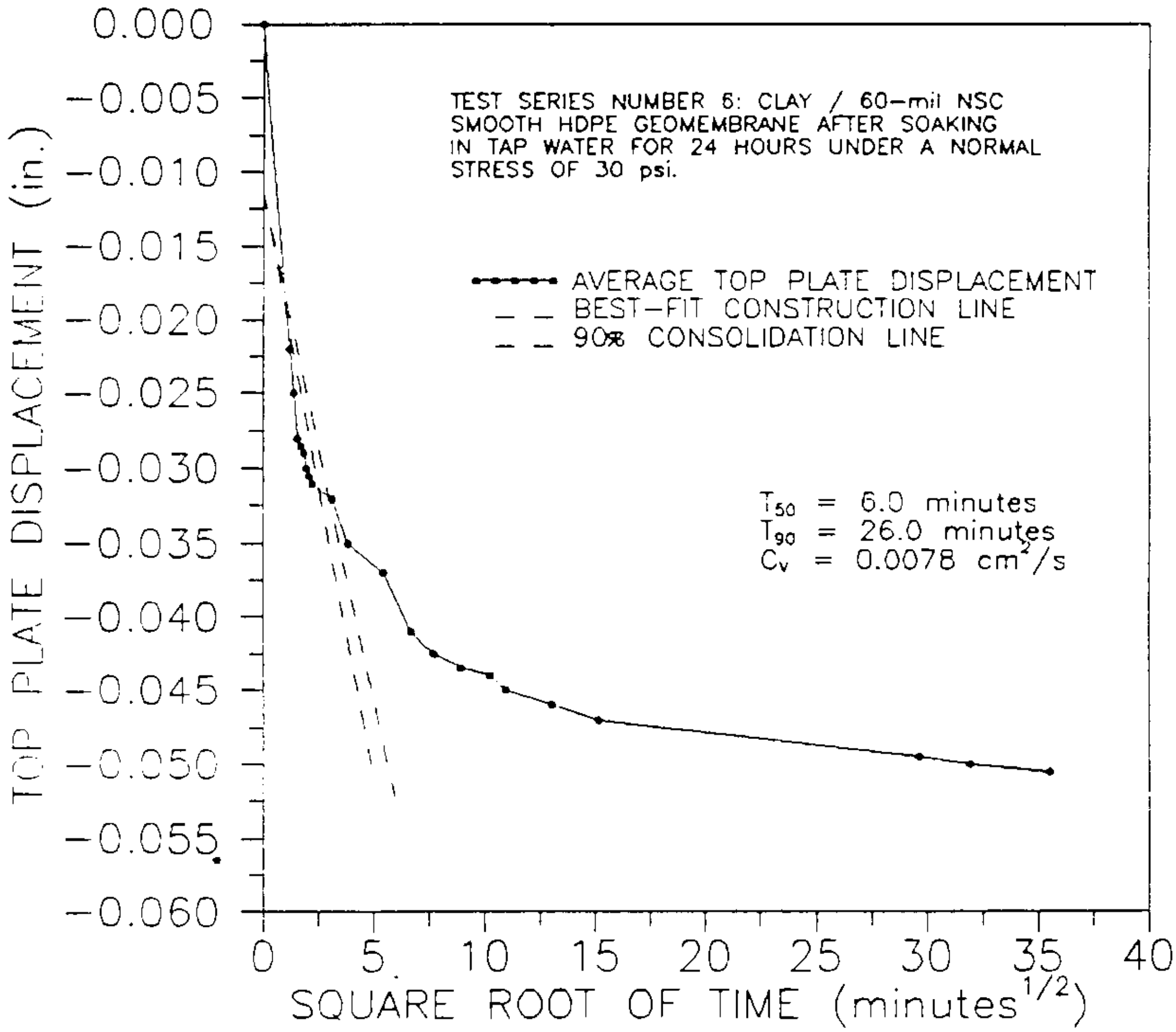
NOTE: The reported value of adhesion may not be the true adhesion of the interface, and caution should be exercised in using this adhesion value for applications involving normal stresses outside the range of stresses covered by the test.

DATE TESTED: 11 TO 12 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B–11
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE

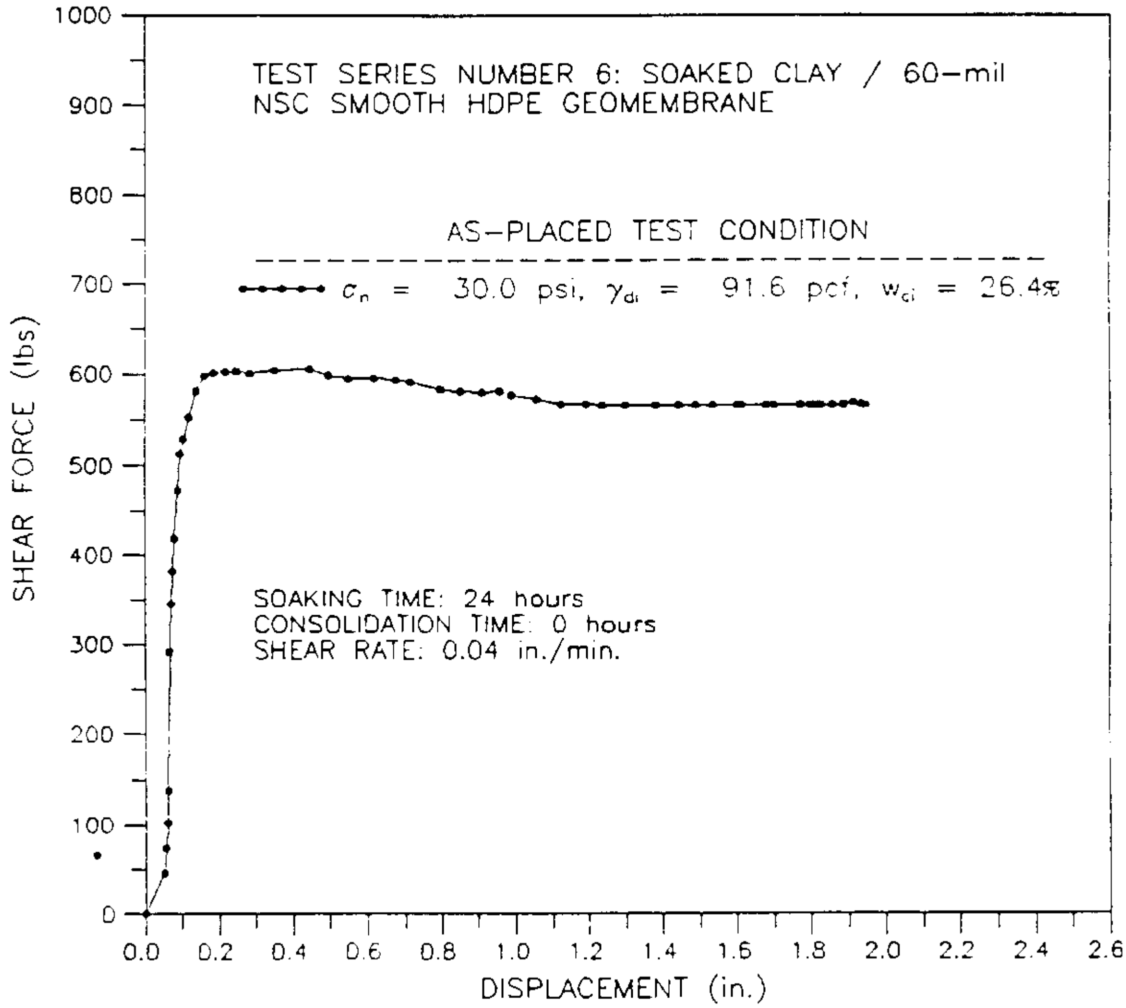


DATE TESTED: 12 TO 13 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-12
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



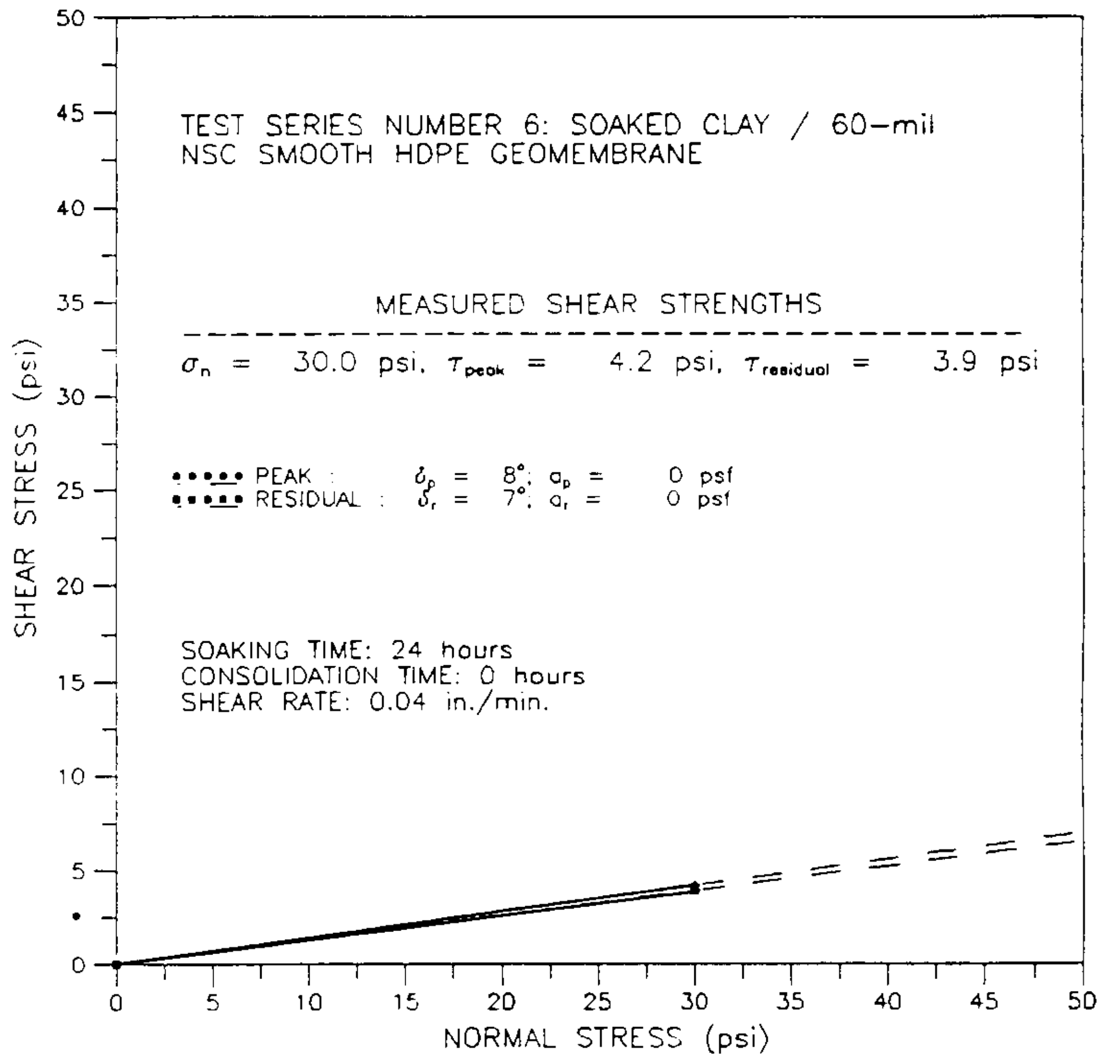
NOTE: The shear box size was 12 in. by 12 in.(300 mm by 300 mm), and the contact area remained constant throughout the entire test.

DATE TESTED: 12 TO 13 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-13
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE

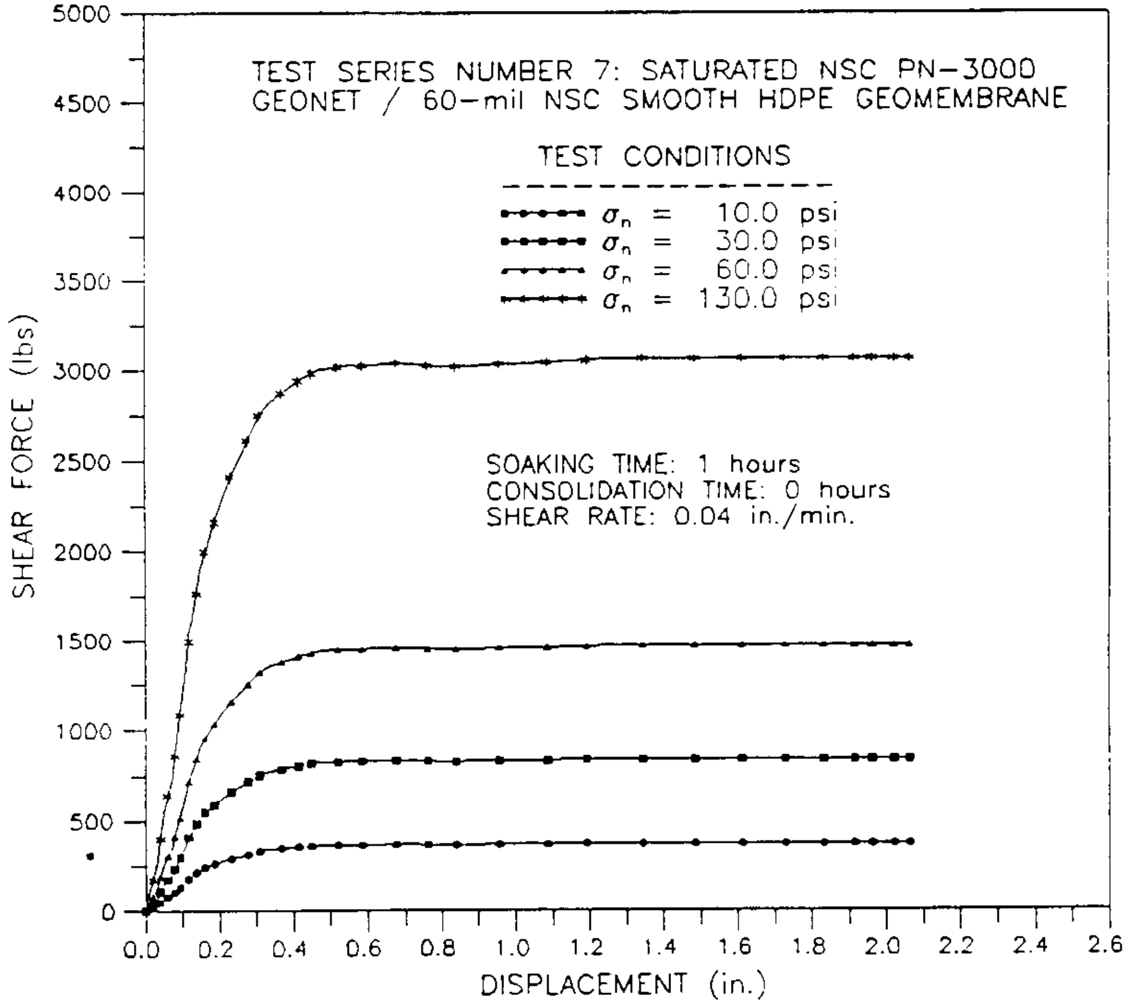


DATE TESTED: 12 TO 13 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-14
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



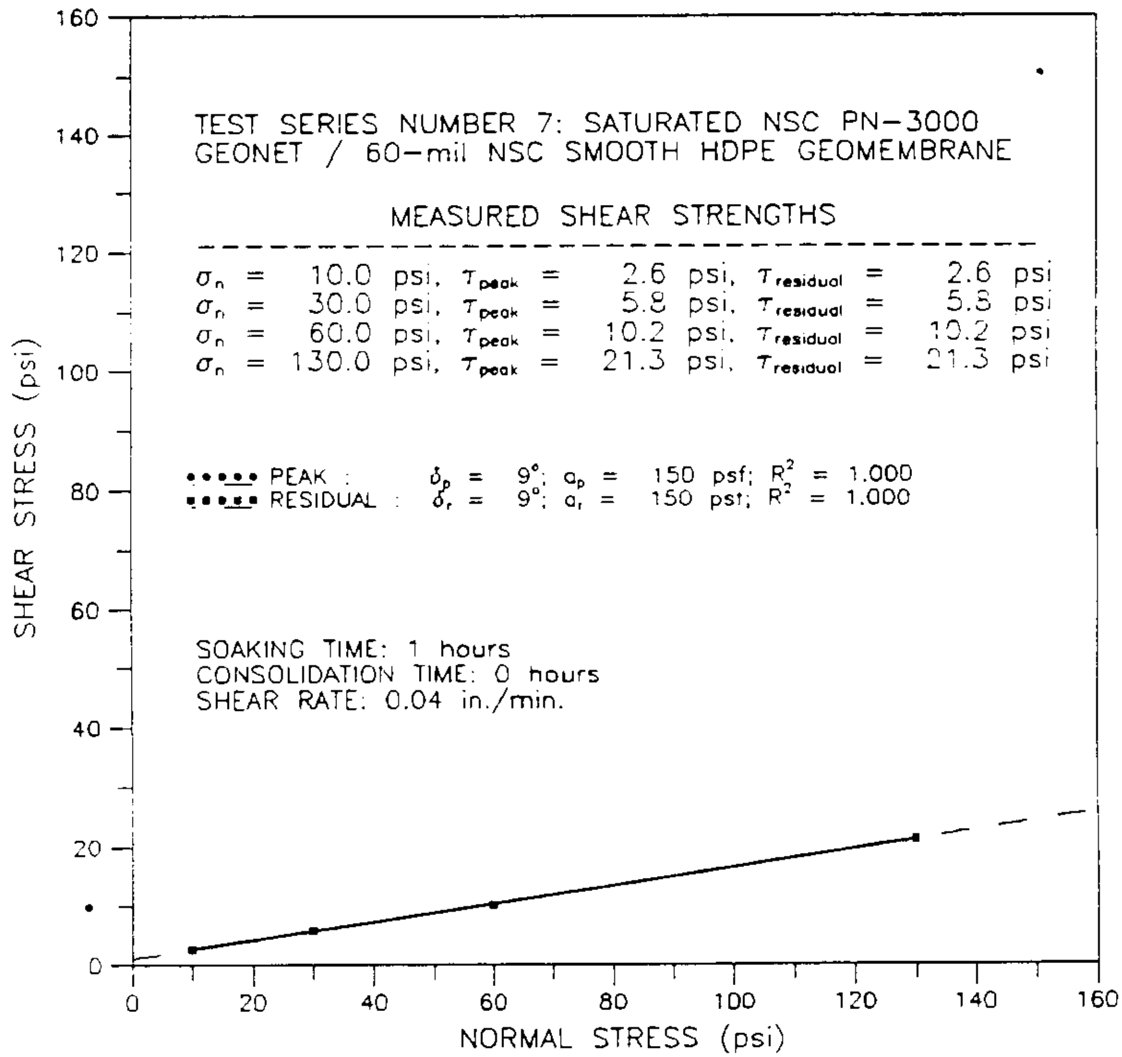
NOTE: The shear box size was 12 in. by 12 in.(300 mm by 300 mm), and the contact area remained constant throughout the entire test.

DATE TESTED: 15 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-15
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



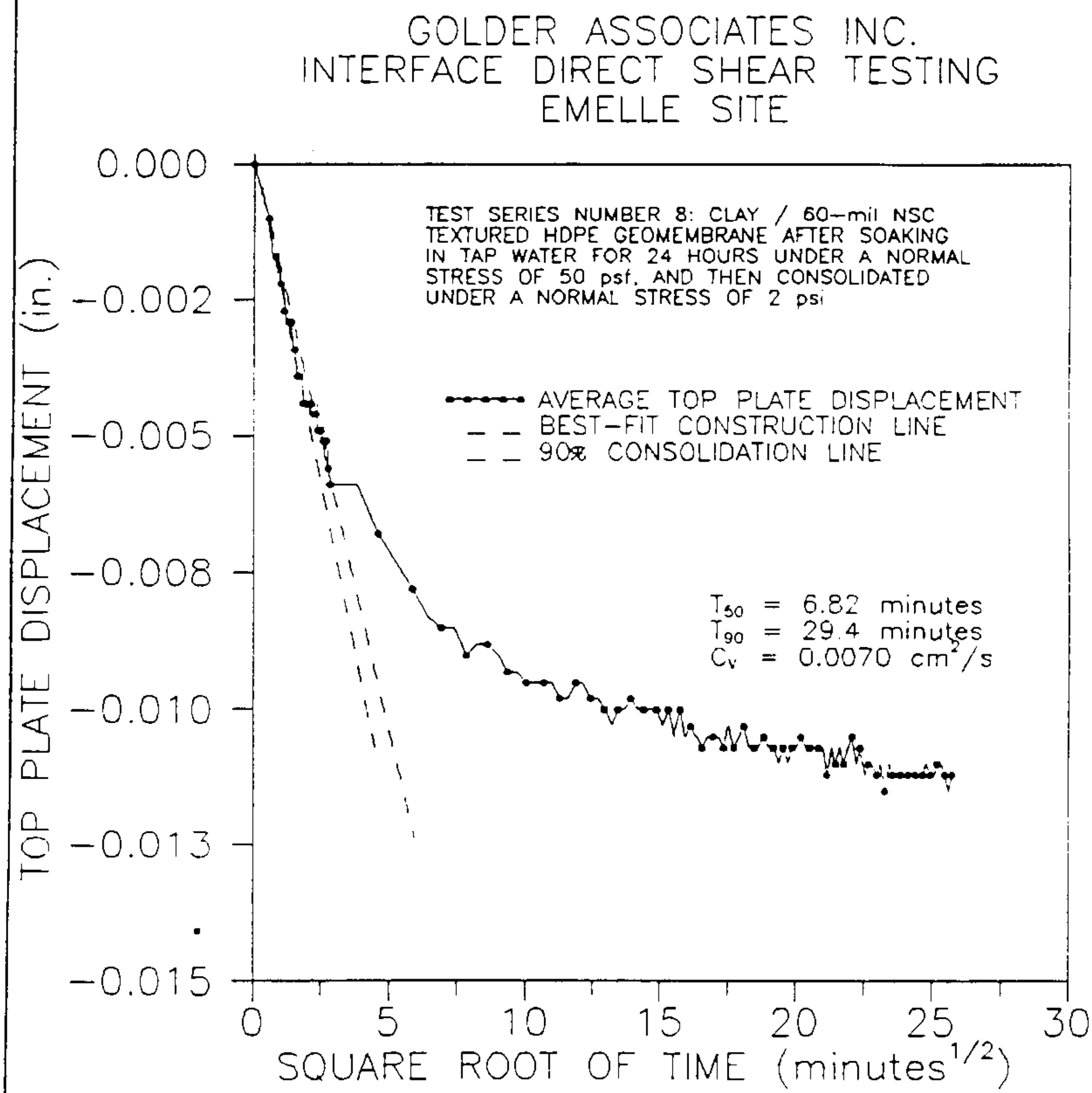
NOTE: The reported value of adhesion may not be the true adhesion of the interface, and caution should be exercised in using this adhesion value for applications involving normal stresses outside the range of stresses covered by the test.

DATE TESTED: 15 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-16
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

308913

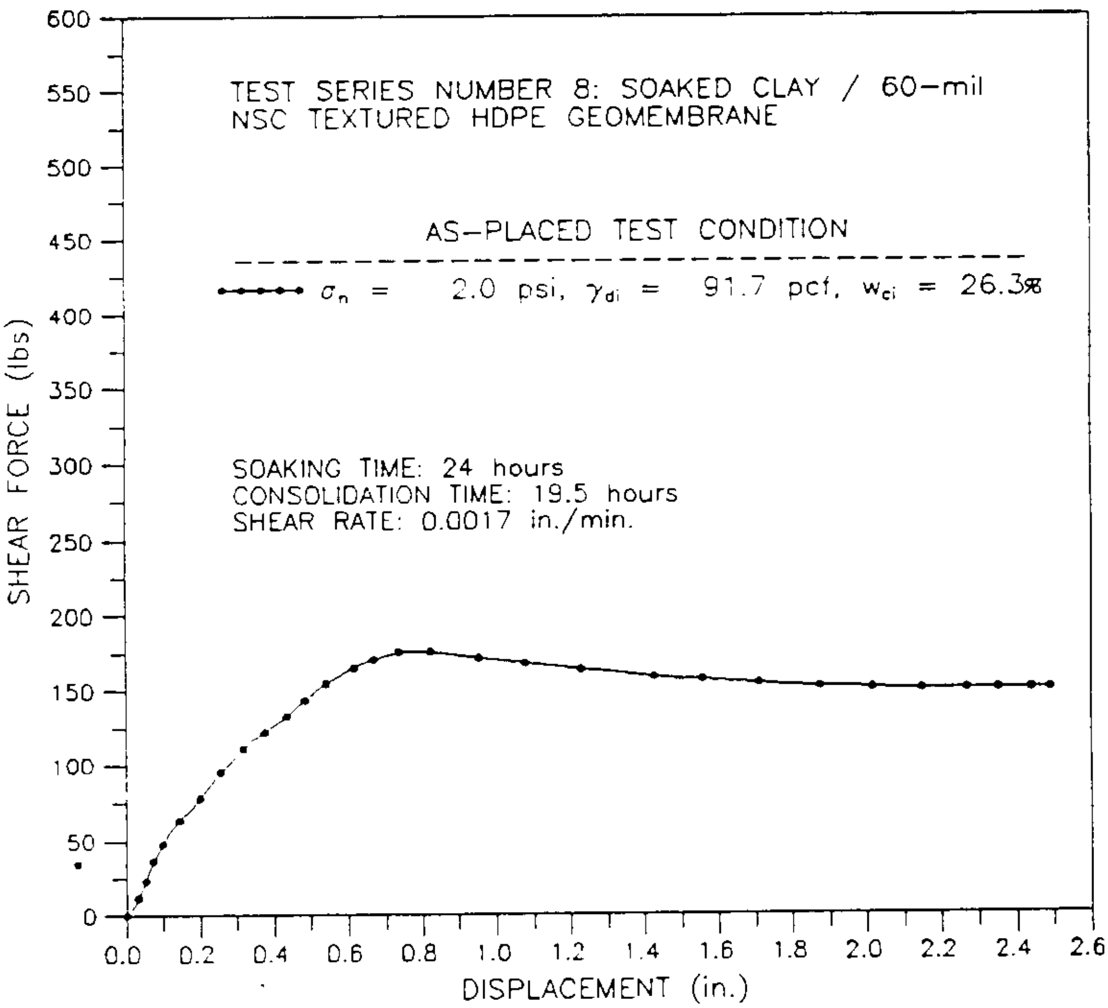


DATE TESTED: 18 TO 19 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-17
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



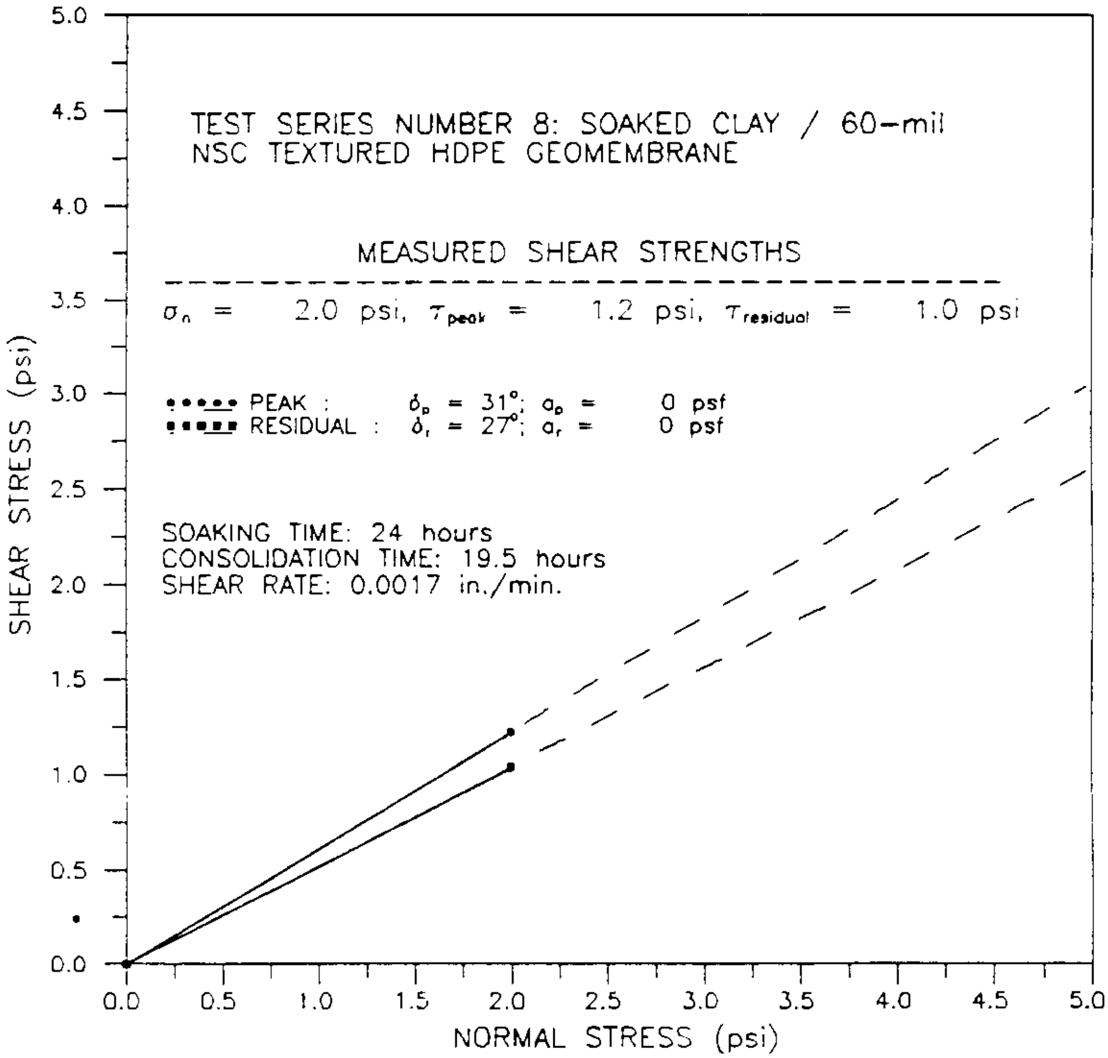
NOTE: The shear box size was 12 in. by 12 in.(300 mm by 300 mm), and the contact area remained constant throughout the entire test.

DATE TESTED: 18 TO 19 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-18
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

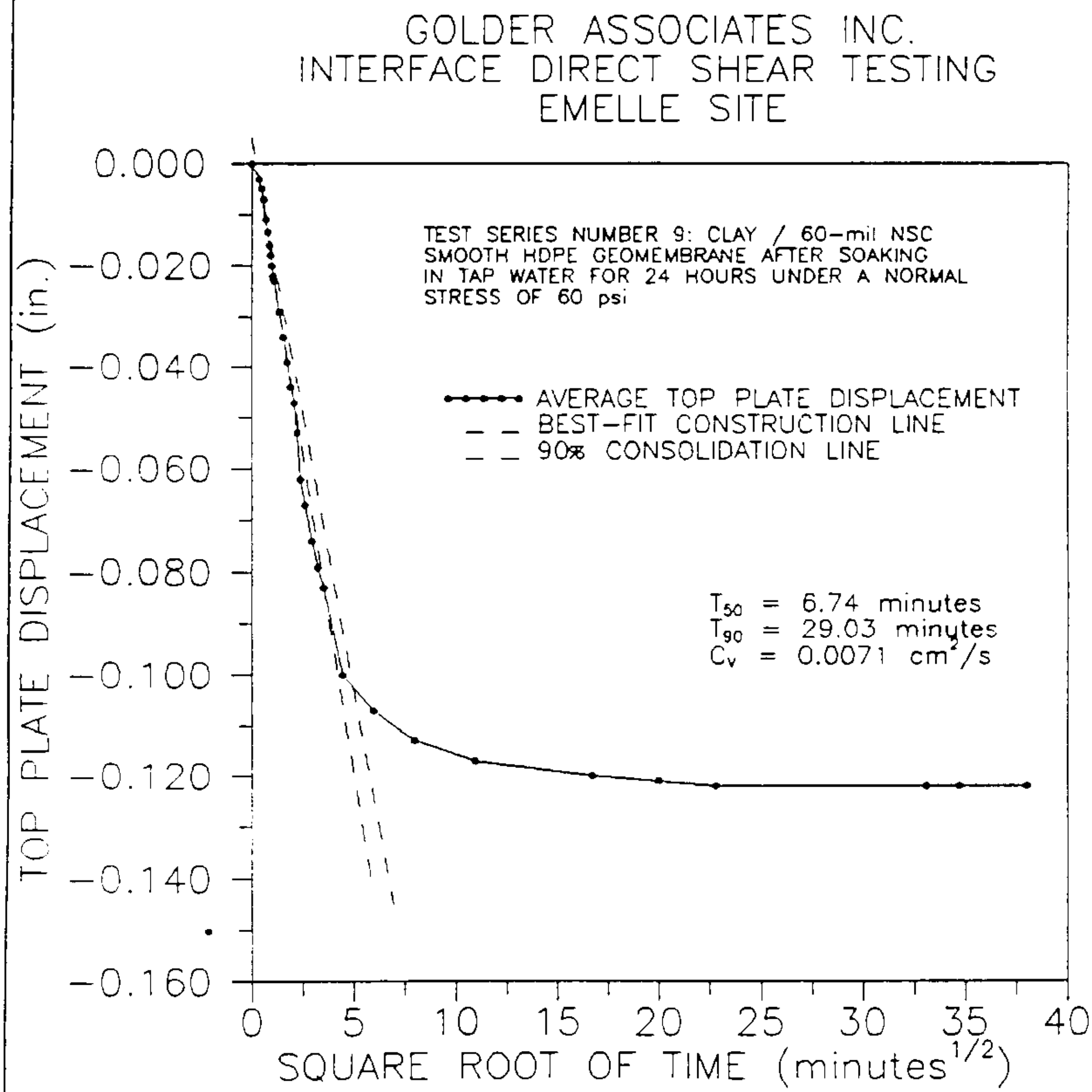
GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



DATE TESTED: 18 TO 19 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-19
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

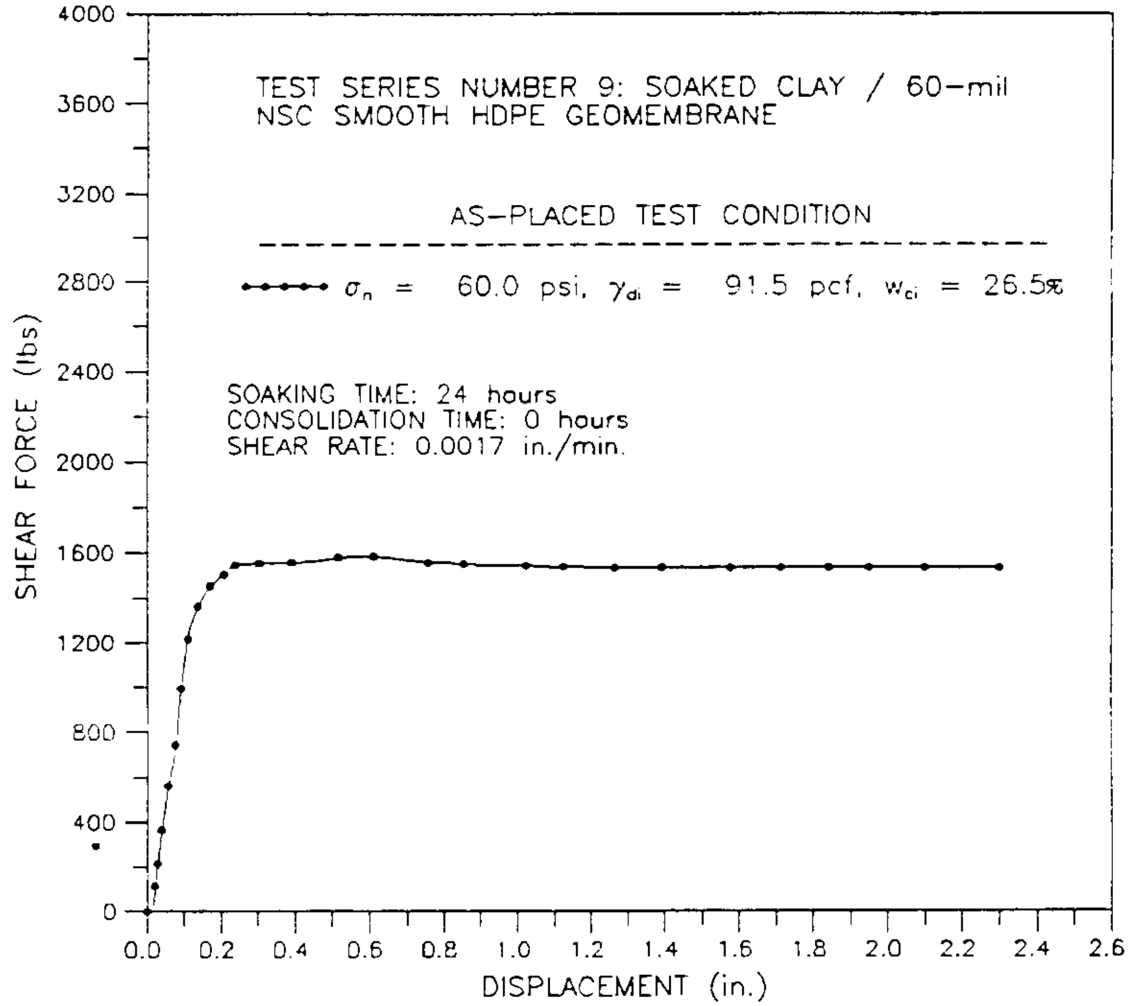


DATE TESTED: 21 TO 22 OCTOBER 1993

GeoSyntec Consultants
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-20
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



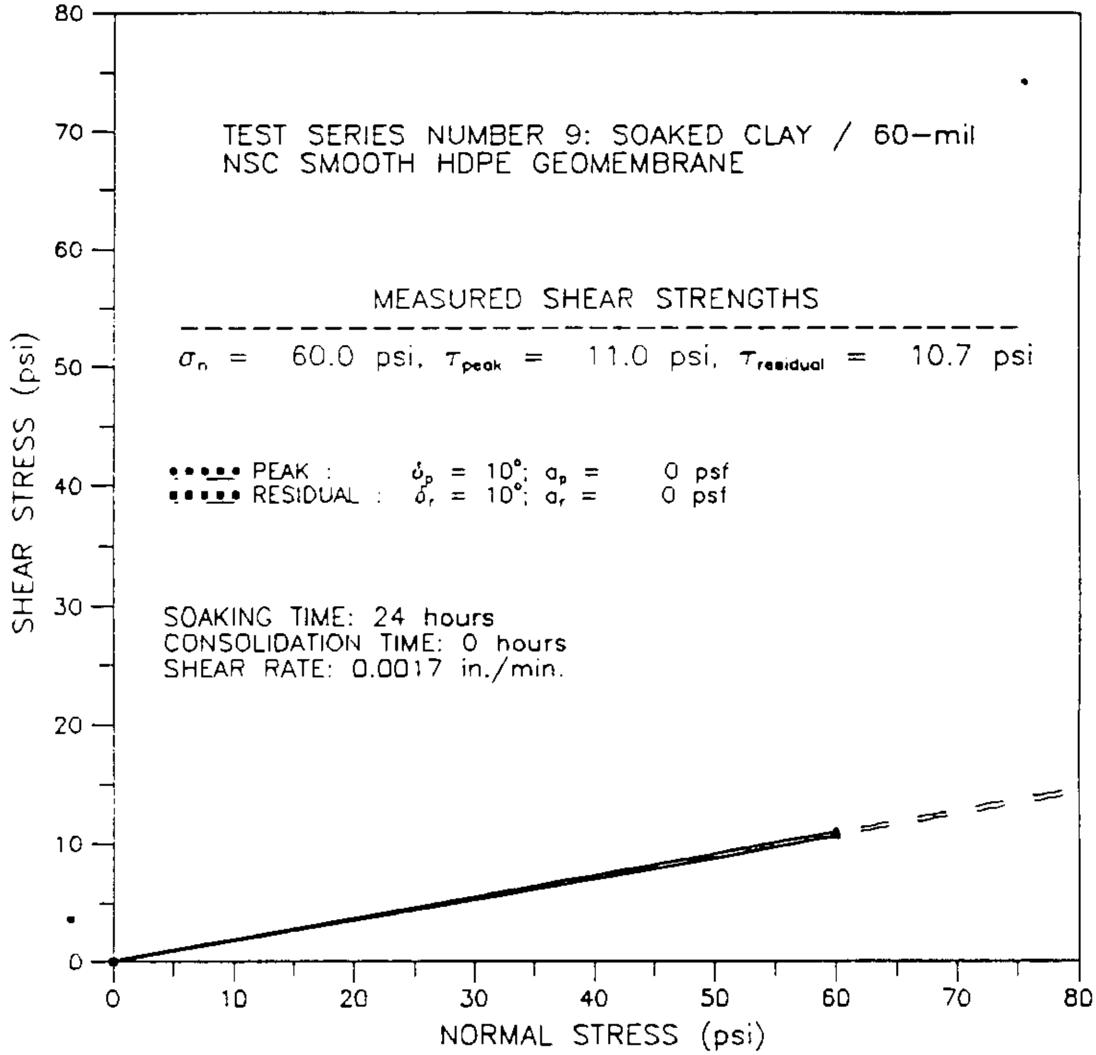
NOTE: The shear box size was 12 in. by 12 in.(300 mm by 300 mm), and the contact area remained constant throughout the entire test.

DATE TESTED: 21 TO 22 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-21
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

GOLDER ASSOCIATES INC.
INTERFACE DIRECT SHEAR TESTING
EMELLE SITE



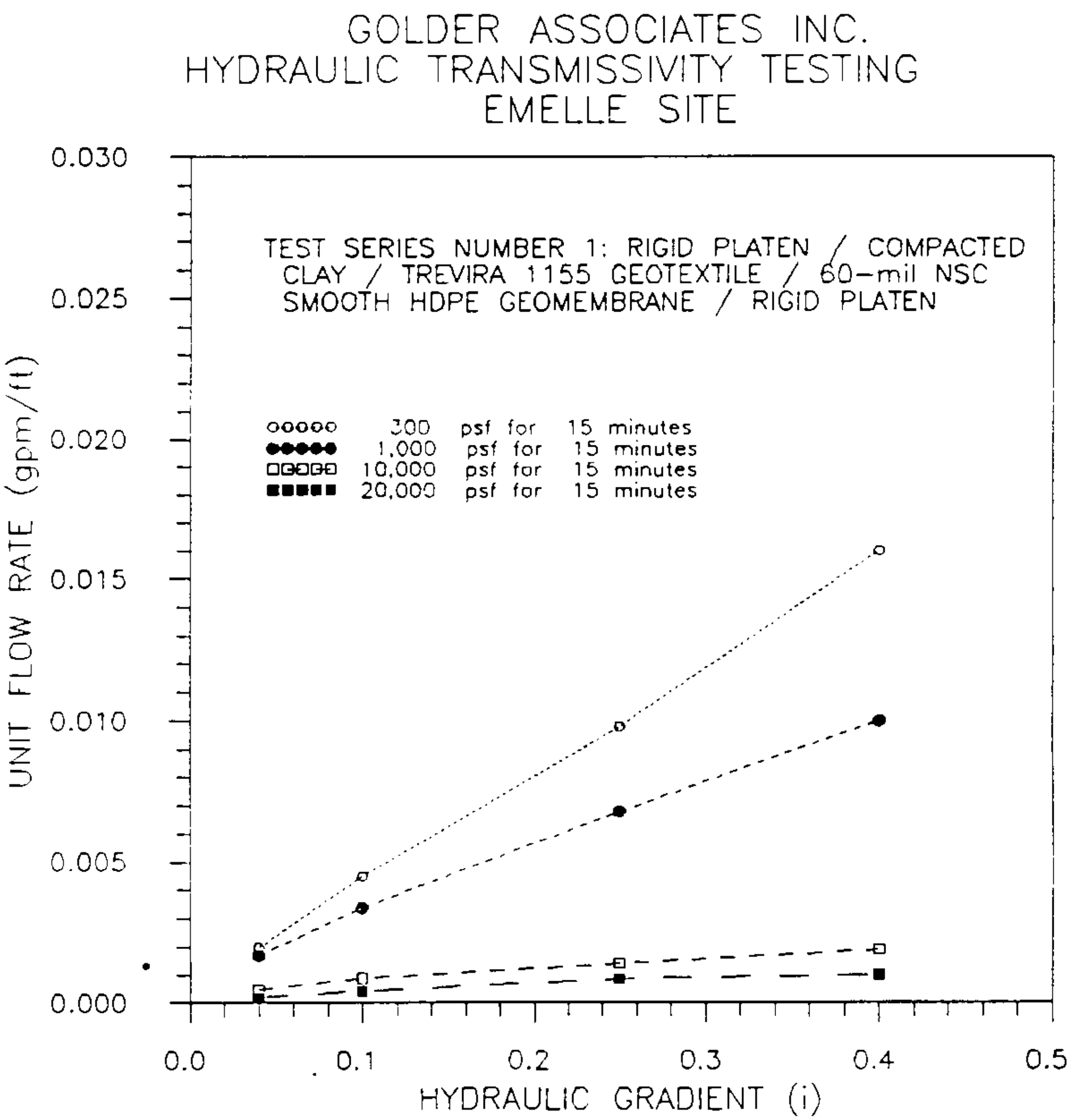
DATE TESTED: 21 TO 22 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	B-22
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

APPENDIX C

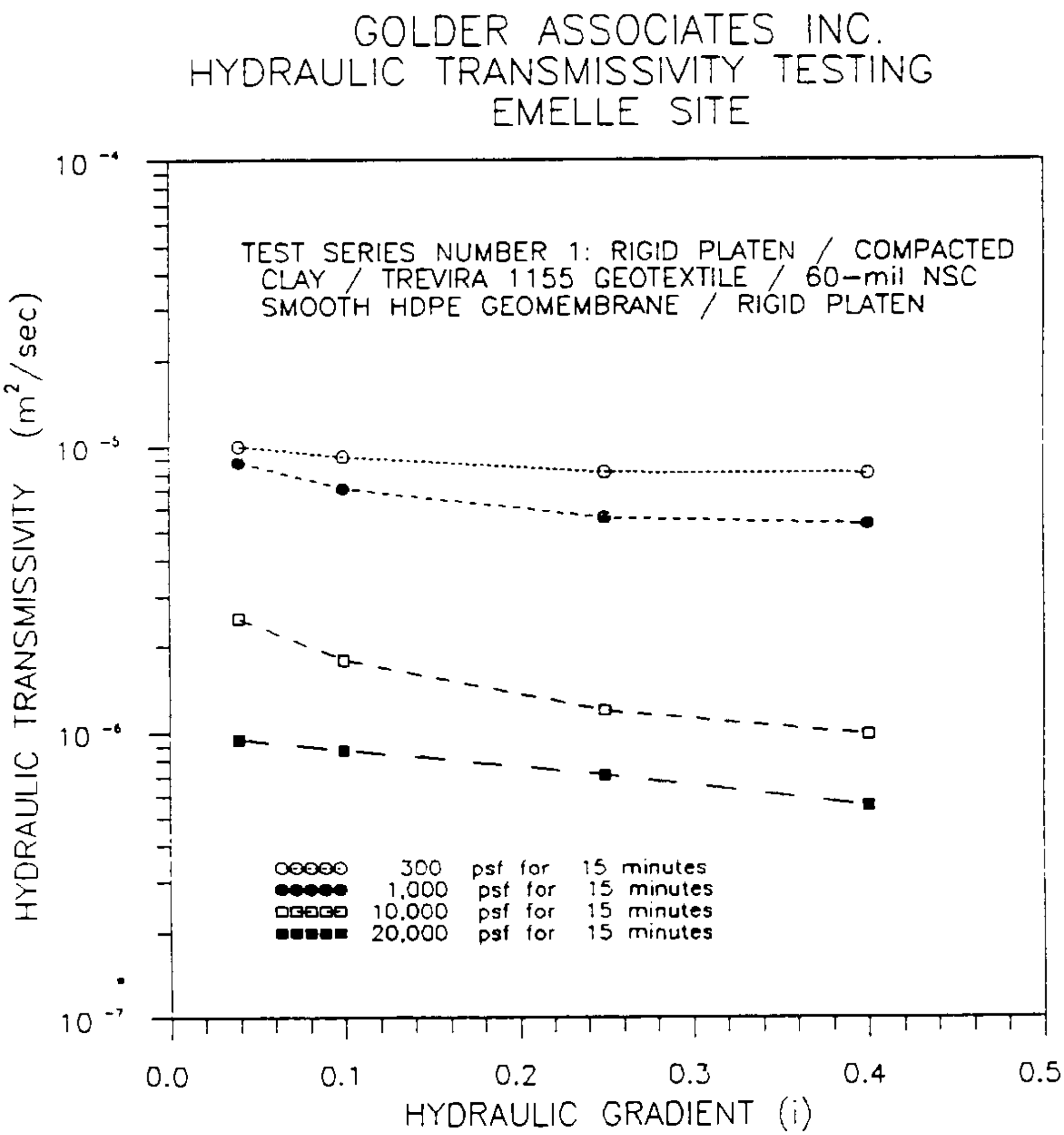
HYDRAULIC TRANSMISSIVITY TEST RESULTS



DATE TESTED: 14 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	C-1
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

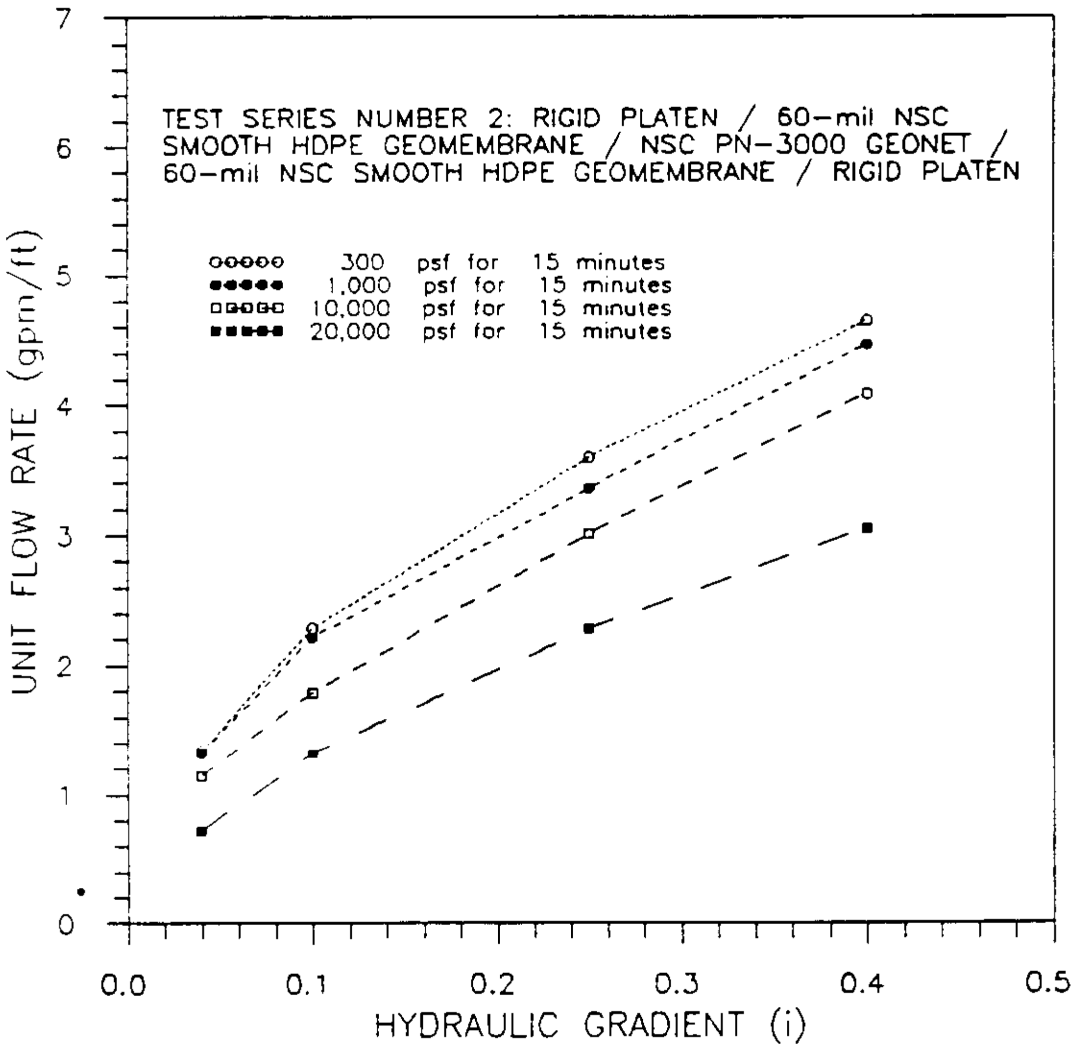


DATE TESTED: 14 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	C-2
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

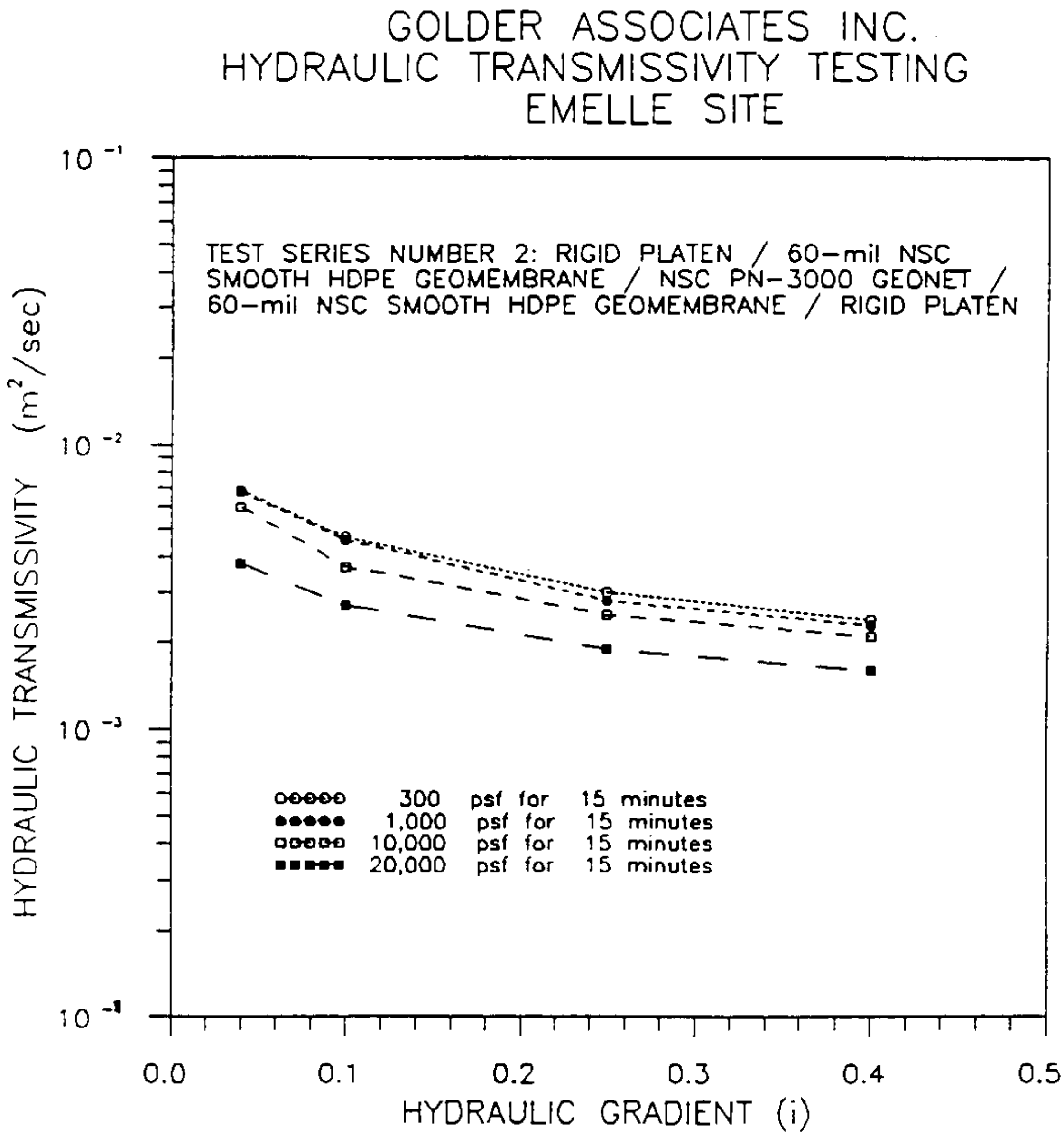
GOLDER ASSOCIATES INC.
HYDRAULIC TRANSMISSIVITY TESTING
EMELLE SITE



DATE TESTED: 13 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	C-3
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	



DATE TESTED: 13 OCTOBER 1993

GEOSYNTEC CONSULTANTS
GEOMECHANICS AND ENVIRONMENTAL LABORATORY

FIGURE NO.	C-4
PROJECT NO.	GL3478
DOCUMENT NO.	GEL93264
PAGE NO.	

APPENDIX D-6-5

SECTION D-6

HELP MODEL LEACHATE GENERATION ANALYSIS

Revision No.
5.0

APPENDIX D-6-5

HELP MODEL LEACHATE GENERATION ANALYSIS

FOR TRENCH 22

The following analysis pertaining to Trenches 22, 23, and 24 was included in the original permit. Trenches 23 and 24, as originally designed, are no longer proposed; therefore, the analysis and information related to Trenches 23 and 24 in this analysis package are not intended to be considered for this RCRA Permit Application. HELP model analyses for the current Trench 23 are included in this Appendix D-6-5 as a separate analysis package.

Golder Associates Inc.

3730 Chamblee Tucker Road
Atlanta, GA USA 30341
Telephone (404) 496-1893
Fax (404) 934-9476

Golder Associates

August 24, 1995

933-3553001

Chemical Waste Management, Inc.
Emelle Facility
P.O. Box 55
Route 17 at Milepost 163
Emelle, Alabama 35459

Attn: Mr. Steve Pekera

RE: HELP MODEL ANALYSIS
EMELLE FACILITY

Dear Mr. Pekera:

As per your request, please find attached the above referenced calculation package submitted in a format for insertion into the Part B Permit Application for the Emelle facility in Alabama.

The calculation package consists of a HELP model analysis (using Version 3.0) to demonstrate the adequacy of the primary leachate collection system for the worst condition in Trenches 22, 23, and 24, while the landfill is in operation during a 24 hour-25 year storm event. In addition, an analysis was also performed after closure to estimate the quantity of leachate that would have to be managed during the post closure care period.

Should you have any questions or require additional information, please call. We appreciate the opportunity to continue assisting CWM at the Emelle facility.

Very truly yours,

GOLDER ASSOCIATES INC.

Wilston W. Etienne, P.E.
Senior Project Manager

WWE/bt

C:\BAT\JOBLTR\3553HLP8.DOC

HELP MODELLING / LEACHATE GENERATION ANALYSIS

OBJECTIVE :

Using EPA's "Hydrologic Evaluation of Landfill Performance" (HELP) Model, estimate the leachate generation rate and the hydraulic head exerted by leachate on the bottom liner in Trenches 22, 23 and 24 at the Emelle facility. Analyze for the following conditions:

- Active Landfilling Condition with one lift (10 feet) of waste in place in the open cell.
- Final Cover Condition with closure cover in place.

APPROACH/ ASSUMPTIONS :

HELP Model (Version 3) is used to simulate various conditions of the landfill. Following are the assumptions made for this analysis:

1. For the active condition, analysis is done with a conservative assumption that only one lift (10 feet) of waste is placed in an open cell.

2. The final cover cover condition shall be analyzed for the condition when the closure cover is in place and is grassed for post-closure care.

3. HELP model does not have default climatological data for Emelle, Alabama. Therefore precipitation and additional weather patterns (solar radiation, evapotranspiration data) were modeled for Meridien, Mississippi because it is the closest city with default data in HELP.

4. In order to estimate the peak daily leachate production and the head above the liner corresponding to a 25 year- 24 hour precipitation event (7.5"), the precipitation data was edited.

5. The runoff fraction is assumed zero percent for the active condition and 100% for final cover condition.

6. The analysis is done for one acre area both cases.

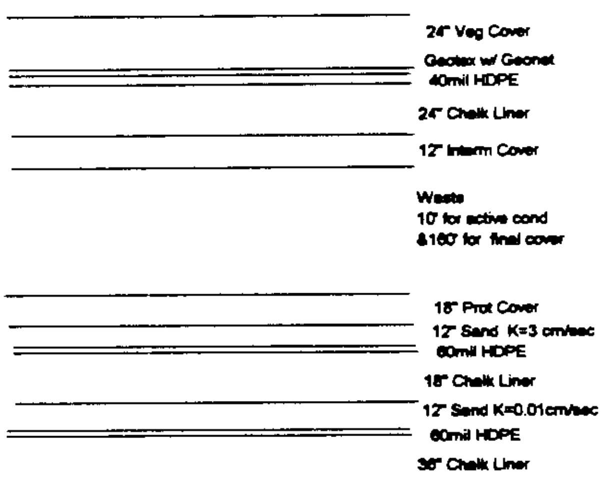
7. The curve number for estimating runoff is input as 91 for the active condition and as 79 corresponding to the final cover condition.

8. Fair grass is assumed for final cover condition while bare soil is assumed for the active condition.

9. The evaporative zone depth for active condition is assumed to be 10 inches while that for the final cover condition is input as 22 inches. These depths are default in the model. The

Maximum Leaf Area Index for the active condition is assumed zero while that for the final cover condition is asssumed as 2.0.

10. The following is the section of the landfill as modeled using HELP



11. The thickness of waste layer is assumed to be 10 feet for the active condition, and 160 feet for the final cover condition.

12. The final cover drainage layer is assumed to be a transmissive geosynthetic drainage layer with 5 feet wide geosynthetic drainage strips (geonet) placed at 50 feet spacing. The design report requires the minimum transmissivities of both the geosynthetic layer and the strips to be 3×10^{-6} m^2/sec. Therefore the minimum combined transmissivity of both the transmissive layer and the strips is 3.27×10^{-6} m^2/sec {3.27×10^{-6} +(3.27×10^{-6} *5/55)}.

13. The design report does not suggest a specific thickness of the geosynthetic transmissive layer and that of the drainage strips. In order to calculate the permeability of the layers from the transmissivity, an effective thickness is needed. It is assumed that the thickness of the geosynthetic layer shall be 125 mil and that of the strips shall be 0.2 inches (from products available in the market). Therefore the effective thickness of the combined drainage system shall be 0.143 inches {0.125+(0.2*5/55)}. Therefore using the above effective thickness (0.143 inches) and the effective transmissivity (3.27×10^{-6} m^2/sec), the effective permeability

used for HELP modelling shall be 0.09cm/sec. It is important to understand that the above thicknesses and permeabilities may not be used during actual construction. They are used only for modelling purposes and are intended to represent the minimum specified transmissivity. The actual materials used shall satisfy the requirements as outlined in the design report.

14. The liners both at the bottom of the cell (primary and secondary) and on the final cover are assumed to be recompacted chalk with a maximum permeability of 10^{-7} cm/sec.

15. The protective layer below the waste is assumed to constructed from loose chalk with a permeability of 1×10^{-5} cm/sec. In order to enhance vertical percolation of leachate for drainage and avoid the bath tub effect, sand windows are to be provided in the protective layer. The sand windows (16' x 16') are to be placed in a approximate 100' grid throughout the entire floor of the cells. The permeability of the sand windows are assumed to be that of the sand layer below it. The effective permeability of the protective layer (calculated as weighted average) is 2.66×10^{-4} cm/sec.

16. The permeability of the primary sand drainage layer is used as 3 cm/sec and that for the secondary sand drainage layer is used as 1×10^{-2} cm/sec as explained in the design report.

17. The geomembranes in the primary and secondary liner systems at the bottom of the cell are assumed to be 60 mil thick HDPE geomembranes. The geomembrane in the final cover is assumed to be 40 mil thick HDPE geomembrane.

18. The vegetative cover is assumed to be loamy soil and is selected as one of the default soils in the model. The intermediate cover soil is assumed to be loose chalk with permeability of 1×10^{-5} cm/sec.

19. The geomembrane pinhole density is assumed to be 1 hole per acre, installation defects are assumed to be 2 holes/acre and the placement quality is assumed to be good.

20. The drainage layer for the bottom liner is designed to have an average drainage length of 700 feet at 4 % slope. The drainage layer for the final cover is designed to have a maximum drainage length of 650 feet at 10% slope.

RESULTS :

The print-out for various HELP runs are attached. In each case, the hydraulic head exerted by leachate on the liner is less than 12 inches. Additionally, following is a summary of the leachate production rates per acre and head on the liner for various conditions.

CASE	AVG ANNUAL (cf/acre/year)	PEAK DAILY (cf /acre/day)	PEAK HEAD ABOVE LINER (IN)
Active Condition	109,437	8802	2.5
Final Cover Condition	18	0.12	0

5-7 24

```
******************************************************************************
******************************************************************************
*                                                                           **
*                                                                           **
*              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                **
*               HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                 **
*                  DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
*                    USAE WATERWAYS EXPERIMENT STATION                      **
*             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
*                                                                           **
*                                                                           **
******************************************************************************
******************************************************************************
```

```
'RECIPITATION DATA FILE:     C:\HELP3\DATA4.D4
EMPERATURE DATA FILE:        C:\HELP3\DATA7.D7
OLAR RADIATION DATA FILE:    C:\HELP3\DATA13.D13
:VAPOTRANSPIRATION DATA:     C:\HELP3\DATA11.D11
;OIL AND DESIGN DATA FILE:   C:\HELP3\DATA10.D10
)UTPUT DATA FILE:            C:\HELP3\emelle-b.OUT
```

```
'IME:  15:18     DATE:   5/22/1995
```

```
******************************************************************************

    TITLE:  EMELLE TRENCH 22-24  (active condition)

******************************************************************************
```

```
    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
             COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.
```

```
                                 LAYER  1
                                 --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  19
         THICKNESS                     =    120.00   INCHES
         POROSITY                      =      0.1680 VOL/VOL
         FIELD CAPACITY                =      0.0730 VOL/VOL
         WILTING POINT                 =      0.0190 VOL/VOL
         INITIAL SOIL WATER CONTENT    =      0.0715 VOL/VOL
         EFFECTIVE SAT. HYD. COND.     =  0.100000005000E-02 CM/SEC
```

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                                 LAYER  2
```

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	18.00 INCHES
POROSITY	=	0.3980 VOL/VOL
FIELD CAPACITY	=	0.2440 VOL/VOL
WILTING POINT	=	0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2630 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.265999988000E-03 CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0450 VOL/VOL
WILTING POINT	=	0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	3.00000000000 CM/SEC
SLOPE	=	4.00 PERCENT
DRAINAGE LENGTH	=	700.0 FEET

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	2.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 5

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	18.00 INCHES
POROSITY	=	0.4270 VOL/VOL
FIELD CAPACITY	=	0.4180 VOL/VOL
WILTING POINT	=	0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06 CM/SEC

LAYER 6

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 1

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4170	VOL/VOL
FIELD CAPACITY	=	0.0450	VOL/VOL
WILTING POINT	=	0.0180	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0450	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999978000E-02	CM/SEC
SLOPE	=	4.00	PERCENT
DRAINAGE LENGTH	=	700.0	FEET

LAYER 7

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	2.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 8

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	36.00	INCHES
POROSITY	=	0.4270	VOL/VOL
FIELD CAPACITY	=	0.4180	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

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SCS RUNOFF CURVE NUMBER	=	91.00	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.409	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	1.680	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.190	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	37.451	INCHES
TOTAL INITIAL WATER	=	37.451	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
MERIDIAN MISSISSIPPI

MAXIMUM LEAF AREA INDEX	= 0.00
START OF GROWING SEASON (JULIAN DATE)	= 63
END OF GROWING SEASON (JULIAN DATE)	= 325
AVERAGE ANNUAL WIND SPEED	= 6.00 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	= 71.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	= 72.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	= 76.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	= 74.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MERIDIAN MISSISSIPPI

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.99	4.58	6.65	5.41	4.20	3.49
5.32	3.36	3.57	2.59	3.48	5.66

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MERIDIAN MISSISSIPPI

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
45.50	48.80	55.90	64.60	71.70	78.40
81.30	80.60	75.70	63.90	54.10	48.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MERIDIAN MISSISSIPPI

STATION LATITUDE = 32.60 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.97	4.78	6.26	4.94	3.19	3.13
	5.57	3.39	3.43	2.41	3.19	5.01
STD. DEVIATIONS	2.36	2.61	4.37	2.71	1.85	2.51
	2.58	1.54	1.94	1.99	1.34	1.88
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.511	1.687	2.081	2.023	1.454	1.645
	2.864	1.803	1.593	0.960	1.191	1.304
STD. DEVIATIONS	0.269	0.343	0.418	1.036	0.833	1.042
	1.095	0.660	0.707	0.636	0.526	0.201
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	3.5304	3.1944	4.2999	3.0736	1.9199	1.5730
	2.3201	1.8884	1.8965	1.6941	1.7183	3.0392
STD. DEVIATIONS	2.2673	2.3338	3.5983	1.8109	1.1954	1.5728
	1.7265	0.9803	1.4585	1.4797	1.1469	1.6451
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE COLLECTED FROM LAYER 6						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 8

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 5

AVERAGES	0.1168	0.1176	0.1430	0.1056	0.0638	0.0540
	0.0771	0.0628	0.0651	0.0563	0.0590	0.1010
STD. DEVIATIONS	0.0754	0.0859	0.1196	0.0622	0.0397	0.0540
	0.0574	0.0326	0.0501	0.0492	0.0394	0.0547

DAILY AVERAGE HEAD ACROSS LAYER 8

AVERAGES	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	50.28	(7.705)	182500.1	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	20.116	(2.4788)	73020.49	40.011
LATERAL DRAINAGE COLLECTED FROM LAYER 3	30.14779	(6.41798)	109436.469	59.96516
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00006	(0.00001)	0.216	0.00012
AVERAGE HEAD ACROSS TOP OF LAYER 5	0.085	(0.018)		
LATERAL DRAINAGE COLLECTED FROM LAYER 6	0.00006	(0.00001)	0.208	0.00011
PERCOLATION/LEAKAGE THROUGH	0.00000	(0.00000)	0.009	0.00001

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LAYER 8			
ﾠAVERAGE HEAD ACROSS TOP OF LAYER 8	0.000 (0.000)		
CH GE IN WATER STORAGE	0.012 (1.5834)	42.89	0.024

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	7.50	27225.000
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	2.42484	8802.16895
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000004	0.01354
AVERAGE HEAD ACROSS LAYER 5	2.499	
DRAINAGE COLLECTED FROM LAYER 6	0.00000	0.00144
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.000000	0.00003
AVERAGE HEAD ACROSS LAYER 8	0.000	
SNOW WATER	2.05	7443.2324

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.1429

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0050

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FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	8.7099	0.0726
2	4.8380	0.2688
3	0.5412	0.0451
4	0.0000	0.0000
5	7.6860	0.4270
6	0.5400	0.0450
7	0.0000	0.0000
8	15.3720	0.4270
SNOW WATER	0.000	

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*                                                                            **
*              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                 **
*               HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                  **
*                  DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
*                    USAE WATERWAYS EXPERIMENT STATION                       **
*             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                **
*                                                                            **
*                                                                            **
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RECIPITATION DATA FILE:      C:\HELP3\DATA4.D4
EMPERATURE DATA FILE:        C:\HELP3\DATA7.D7
OLAR RADIATION DATA FILE:    C:\HELP3\DATA13.D13
VAPOTRANSPIRATION DATA:      C:\HELP3\DATA11.D11
OIL AND DESIGN DATA FILE:    C:\HELP3\DATA10.D10
UTPUT DATA FILE:             C:\HELP3\closure.OUT


IME:  14: 0     DATE:   5/23/1995


******************************************************************************

    TITLE:  EMELLE TRENCH 22-24 (final closure cover condition)

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    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
             COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                 LAYER  1
                                 --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER   8
          THICKNESS                      =     24.00   INCHES
          POROSITY                       =      0.4630 VOL/VOL
          FIELD CAPACITY                 =      0.2320 VOL/VOL
          WILTING POINT                  =      0.1160 VOL/VOL
          INITIAL SOIL WATER CONTENT     =      0.3204 VOL/VOL
          EFFECTIVE SAT. HYD. COND.      =  0.369999994000E-03 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	0.14	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.8500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.900000036000E-01	CM/SEC
SLOPE	=	10.00	PERCENT
DRAINAGE LENGTH	=	650.0	FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.04	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	2.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 4

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4270	VOL/VOL
FIELD CAPACITY	=	0.4180	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3980	VOL/VOL
FIELD CAPACITY	=	0.2440	VOL/VOL
WILTING POINT	=	0.1360	VOL/VOL

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INITIAL SOIL WATER CONTENT  =       0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-05 CM/SEC


                        LAYER  6
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  19
THICKNESS                   =     1920.00    INCHES
POROSITY                    =       0.1680 VOL/VOL
FIELD CAPACITY              =       0.0730 VOL/VOL
WILTING POINT               =       0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT  =       0.0730 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC


                        LAYER  7
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =       18.00    INCHES
POROSITY                    =       0.3980 VOL/VOL
FIELD CAPACITY              =       0.2440 VOL/VOL
WILTING POINT               =       0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =       0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.265999988000E-03 CM/SEC


                        LAYER  8
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =       12.00    INCHES
POROSITY                    =       0.4170 VOL/VOL
FIELD CAPACITY              =       0.0450 VOL/VOL
WILTING POINT               =       0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT  =       0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   3.00000000000       CM/SEC
SLOPE                       =        4.00    PERCENT
DRAINAGE LENGTH             =      700.0     FEET


                        LAYER  9
                        --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
THICKNESS                   =        0.06    INCHES
POROSITY                    =       0.0000 VOL/VOL
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FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      2.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                        LAYER 10
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                    =     18.00    INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC


                        LAYER 11
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                    =     12.00    INCHES
POROSITY                     =      0.4170 VOL/VOL
FIELD CAPACITY               =      0.0450 VOL/VOL
WILTING POINT                =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
SLOPE                        =      4.00    PERCENT
DRAINAGE LENGTH              =    700.0     FEET


                        LAYER 12
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06    INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      2.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD
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LAYER 13

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	36.00 INCHES
POROSITY	=	0.4270 VOL/VOL
FIELD CAPACITY	=	0.4180 VOL/VOL
WILTING POINT	=	0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	79.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	22.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	6.763	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	10.186	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.552	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	189.676	INCHES
TOTAL INITIAL WATER	=	189.676	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
MERIDIAN MISSISSIPPI

MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	63
END OF GROWING SEASON (JULIAN DATE)	=	325
AVERAGE ANNUAL WIND SPEED	=	6.00 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	71.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	76.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	74.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MERIDIAN MISSISSIPPI

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

4.99	4.58	6.65	5.41	4.20	3.49
5.32	3.36	3.57	2.59	3.48	5.66

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MERIDIAN MISSISSIPPI

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
45.50	48.80	55.90	64.60	71.70	78.40
81.30	80.60	75.70	63.90	54.10	48.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MERIDIAN MISSISSIPPI

STATION LATITUDE = 32.60 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.97	4.78	6.26	4.94	3.19	3.13
	5.57	3.39	3.43	2.41	3.19	5.01
STD. DEVIATIONS	2.36	2.61	4.37	2.71	1.85	2.51
	2.58	1.54	1.94	1.99	1.34	1.88
RUNOFF						
TOTALS	1.810	1.984	2.826	1.154	0.193	0.099
	0.115	0.088	0.026	0.056	0.019	0.614
STD. DEVIATIONS	1.823	2.489	3.808	1.550	0.362	0.347
	0.240	0.277	0.051	0.176	0.034	1.097
EVAPOTRANSPIRATION						
TOTALS	1.529	1.951	3.211	3.704	4.756	5.377
	4.806	3.349	2.254	2.364	1.759	1.142
TD. DEVIATIONS	0.168	0.217	0.275	1.002	0.812	1.343
	1.417	0.998	0.654	0.797	0.403	0.129

LATERAL DRAINAGE COLLECTED FROM LAYER 2

TOTALS	0.6451	0.6312	0.6949	0.6232	0.5398	0.3959
	0.3632	0.2410	0.1636	0.2296	0.2743	0.4209
STD. DEVIATIONS	0.1493	0.1003	0.0798	0.0568	0.0566	0.0350
	0.0701	0.1590	0.1731	0.1972	0.1855	0.1824

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0008	0.0008	0.0008	0.0008	0.0006	0.0003
	0.0001	0.0001	0.0001	0.0001	0.0002	0.0004
STD. DEVIATIONS	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001
	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	0.0007	0.0008	0.0009	0.0008	0.0006	0.0003
	0.0001	0.0001	0.0001	0.0001	0.0002	0.0004
STD. DEVIATIONS	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001
	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003

PERCOLATION/LEAKAGE THROUGH LAYER 10

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

ERAL DRAINAGE COLLECTED FROM LAYER 11

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 13

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 4

AVERAGES	17.7843	20.3221	20.2972	18.8841	14.8812	6.3496
	2.3943	1.7229	2.3452	3.3446	3.9348	8.6039
STD. DEVIATIONS	6.7572	4.8882	4.0146	1.9950	2.4865	3.1148
	4.0710	4.6124	4.8581	4.8177	5.0797	7.0567

DAILY AVERAGE HEAD ACROSS LAYER 10

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

DAILY AVERAGE HEAD ACROSS LAYER 13

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	50.28	(7.705)	182500.1	100.00
RUNOFF	8.983	(6.0033)	32609.77	17.868
EVAPOTRANSPIRATION	36.202	(3.3065)	131411.70	72.006
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5.22251	(0.84581)	18957.701	10.38778
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00501	(0.00124)	18.181	0.00996
AVERAGE HEAD ACROSS TOP OF LAYER 4	10.072	(2.529)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	0.00501	(0.00124)	18.172	0.00996
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.00000	(0.00000)	0.009	0.00000
AVERAGE HEAD ACROSS TOP OF LAYER 10	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 11	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 13	0.00000	(0.00000)	0.009	0.00000
AVERAGE HEAD ACROSS TOP OF LAYER 13	0.000	(0.000)		

CHANGE IN WATER STORAGE -0.137 (2.5914) -497.32 -0.273

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	7.50	27225.000
RUNOFF	4.193	15218.7754
DRAINAGE COLLECTED FROM LAYER 2	0.02580	93.65182
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000032	0.11774
AVERAGE HEAD ACROSS LAYER 4	24.143	
DRAINAGE COLLECTED FROM LAYER 8	0.00003	0.11731
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.000000	0.00003
AVERAGE HEAD ACROSS LAYER 10	0.000	
DRAINAGE COLLECTED FROM LAYER 11	0.00000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 13	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 13	0.000	
SNOW WATER	2.05	7443.2324

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4630
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1044

****

****

FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	5.0323	0.2097
2	0.0378	0.2647
3	0.0000	0.0000
4	10.2480	0.4270
5	2.9280	0.2440
6	140.1600	0.0730
7	4.3920	0.2440
8	0.5400	0.0450
9	0.0000	0.0000
10	7.6860	0.4270
11	0.5400	0.0450
12	0.0000	0.0000
13	15.3720	0.4270
SNOW WATER	0.000	

****
****

APPENDIX D-6-5

HELP MODEL LEACHATE GENERATION ANALYSIS

FOR TRENCH 23

Terracon	Made by:	JCH	Date:	12/31/14	Sheet No.:	COVER
	Checked by:	RSG	Date:	12/31/14	Job No.:	EJ147410
	Calculations for:	HELP Model: Liquid Head on Base Liner				
	Emelle Facility					

HELP MODEL ANALYSIS
LIQUID HEAD ON THE BASE LINER SYSTEM
CALCULATION COVER SHEET

Calculations by:

Signature: J. Craig Hensley — Date: 12/31/14
Name: J. Craig Hensley, E.I.T.
Title: Staff Engineer

Calculations Reviewed by:

Signature: — Date:
Name:
Title:

Calculations Approved by:

Signature: Rajendra S. Gondhalekar — Date: 12/31/14
Name: Rajendra S. Gondhalekar, P.E.
Title: Project Engineer

REVISIONS			
REVISION NO.	DATE	SHEET NO.	DESCRIPTION
0	12/31/14	ALL	Initial Submittal

1.0 OBJECTIVE

Our objective is to determine the predicted amount of liquid head on the base liner system in Trench 23 at the Emelle Facility.

2.0 METHOD

This analysis was conducted using the HELP Model to determine the predicted maximum liquid head on the base liner system over a critical leachate travel distance for a variety of stages in the landfill's life cycle. A critical travel distance for leachate was calculated for Case 1, Case 2, and Case 3 of the analysis. This path is depicted in the attached figures and discussed in Section 4.3 of this report.

3.0 DESIGN DESCRIPTION

The proposed base liner systems for the Emelle Facility include the following components, from top to bottom. Detail drawings for these liner systems are depicted on the attached figures.

Base Liner System Design:

- 18-inch thick protective soil cover;
- 12-inch thick granular material layer (k > 3 cm/sec);
- Geotextile cushion (omitted from the model);
- Primary 60-mil thick HDPE textured geomembrane layer;
- Geosynthetic Clay Liner;
- Geocomposite leak detection layer;
- Secondary 60-mil thick HDPE textured geomembrane layer; and
- 36-inch thick compacted chalk layer ($k \leq 1 \times 10^{-7}$ cm/sec);.

The proposed primary final cover system for the Emelle Facility includes the following components, from top to bottom:

Final Cover System Design:

- 24-inch thick vegetative layer;
- Double-sided geocomposite;
- 40-mil thick HDPE textured geomembrane layer;
- 24-inch thick compacted chalk layer ($k \leq 1 \times 10^{-7}$ cm/sec);
- 12-inch thick soil cover.

4.0 ANALYSIS

4.1 Weather Data

Precipitation Data was obtained using HELP 3.95 D's synthetic weather generator for nearby Meridian, MS. **In addition, a 25-year, 24-hour rainfall event was added as the peak precipitation event for the Emelle Facility.** Source data regarding the determination of this rainfall event may be found in Exhibit 1.

Temperature Data and Solar Radiation Data were obtained using HELP 3.95 D's synthetic weather generator for Meridian, MS.

Evapotranspiration Data was obtained using HELP 3.95 D's synthetic weather generator for Meridian, MS.

4.2 Soil Profiles

This study consists of two soil profiles discussed under Section 3.0. These profiles are:

- **Base Liner Profile**;
- **Base Liner Profile with Final Cover System.**

4.3 Landfill Development Stages

Initial Active Stage, which consists of (from top to bottom) 10 feet of municipal solid waste, and a base liner system with a slope of 2.0%. This stage of development is modeled over 100 years of synthetically generated weather data. This case has a critical leachate travel path of 192 feet.

Intermediate Active Stage, which consists of (from top to bottom) 13 feet of municipal solid waste (assumes waste fill to the top of the intercell berm), and a base liner system with a slope of 2.0%. This stage of development is modeled over 100 years of synthetically generated weather data. This case has a critical leachate travel path of 220 feet.

Final Closed Stage, which consists of (from top to bottom) a final cover system, 164 feet of municipal solid waste, and a base liner system. This stage of development is modeled over 100 years of synthetically generated weather data. This case has a critical leachate travel path of 520 feet.

4.4 Reduction Factor Calculations

Reduction factors have been calculated for the hydraulic conductivity or transmissivity of the proposed lateral drainage materials. Reduction factors for the 12-inch thick granular material layer account for the following clogging and deformation mechanisms:

- Particulate clogging;
- Chemical clogging; and
- Biological clogging.

Reduction factors for the geocomposite leak detection layer account for the following clogging mechanisms:

- Creep;
- Delayed intrusion;
- Particulate clogging;
- Chemical clogging; and
- Biological clogging.

The calculated reduction factors are summarized in Table 4.4. Reduction factor calculations are found in Exhibit 2.

Table 4.4: Flow Capacity Reduction Factors

Case	RF
Granular Material Layer	
Case 1: Initial, Active	0
Case 2: Intermediate, Active	1.13
Case 3: Final, Closed	2.25
Geocomposite Leak Detection Layer	
Case 1: Initial, Active	0
Case 2: Intermediate, Active	1.02
Case 3: Final, Closed	2.04

4.5 HELP Model Cases

A summary of the different HELP Model cases evaluated is presented in the tables below. Typical soil, liner, and waste characteristics values for the layering were obtained from the *"The Hydrologic Evaluation of Landfill Performance (HELP) Model: User's Guide for HELP-D (Version 3.95 D)* by Berger and Schroeder. Detailed information regarding each case may be found in the HELP Model Output Data in Exhibit 3.

Case 1: Initial Active

Layer	Description	Thickness (in)	Default Texture No.	Hydraulic Conductivity (cm/sec)
1	Waste	120	19	1×10^{-3}
2	Protective Cover Soil	18	Custom	2.65×10^{-4}
3	Granular Material Layer	12	Custom	3
5	Primary Geomembrane (HDPE)	.06	35	2×10^{-13}
6	GCL	.25	17	3×10^{-9}
7	Geocomposite Leak Detection	.2	Custom	.59
8	Secondary Geomembrane (HDPE)	.06	35	2×10^{-13}
9	Compacted Chalk Layer	36	16	1×10^{-7}

Case 2: Intermediate Active

Layer	Description	Thickness (in)	Default Texture No.	Hydraulic Conductivity (cm/sec)
1	Waste	156	19	1×10^{-3}
2	Protective Cover Soil	18	Custom	2.65×10^{-4}
3	Granular Material Layer	12	Custom	2.67
5	Primary Geomembrane (HDPE)	.06	35	2×10^{-13}
6	GCL	.25	17	3×10^{-9}
7	Geocomposite Leak Detection	.2	Custom	.579
8	Secondary Geomembrane (HDPE)	.06	35	2×10^{-13}
9	Compacted Chalk Layer	36	16	1×10^{-7}

Case 3: Final Closed

Layer	Description	Thickness (in)	Default Texture No.	Hydraulic Conductivity (cm/sec)
1	Vegetative Layer	24	8	3.7×10^{-4}
2	Geocomposite	.14	Custom	.09
3	Geomembrane (HDPE)	.04	35	2×10^{-13}
4	Compacted Chalk Layer	24	16	1×10^{-7}
5	Soil Cover	12	Custom	1×10^{-5}
6	Waste	1968	19	1×10^{-3}
7	Protective Cover Soil	18	Custom	2.65×10^{-4}
8	Granular Material Layer	12	Custom	1.33
9	Primary Geomembrane (HDPE)	.06	35	2×10^{-13}
10	GCL	.25	17	3×10^{-9}
11	Geocomposite Leak Detection	.2	Custom	.289
12	Secondary Geomembrane (HDPE)	.06	35	2×10^{-13}
13	Compacted Chalk Layer	36	16	1×10^{-7}

5.0 RESULTS AND CONCLUSIONS

5.1 Maximum Liquid Head on the Liner Results

The results for the Maximum Liquid head on the base liner system are summarized in Table 5.2 below. Cases 1, 2, and 3 were calculated using the HELP Model, and results may aso be found in the “HELP Model Output Data” in Attachment C.

Table 5.1: Maximum Head on Primary Liner

Case	Maximum Liquid Head (in)
Case 1 – Initial Active	5.1
Case 2 – Intermediate Active	7.4
Case 3 – Final Close	0.02

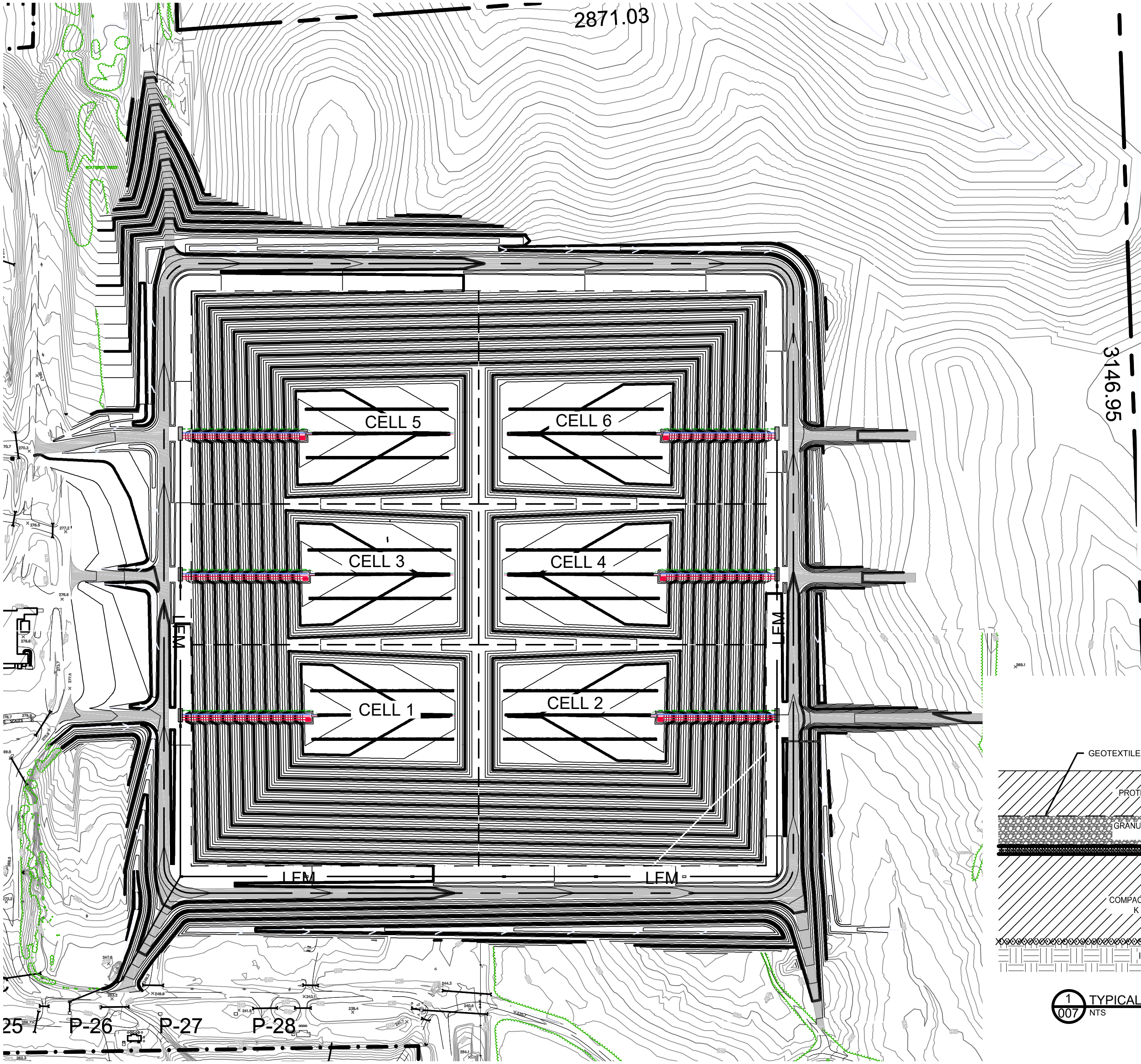
5.2 Conclusions

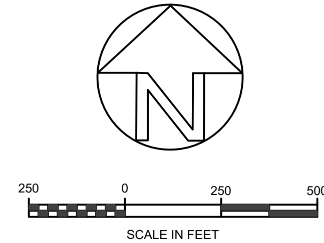
The proposed lateral drainage layers in the leachate collection and removal system satisfies the regulatory requirement for the maximum allowable liquid head on the primary base liner. For all cases, the maximum predicted head was less than the 11.8 inch (30 cm) regulatory maximum. According these results, the proposed lateral drainage layer designs will effectively transfer liquid to the piped collection system.

REFERENCES

Giroud, J.P., Zornburg, J.G., and Zhao, A., 2000, "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers", *Geosynthetics International*, Special Issue on Liquid Collection Systems, Vol. 7, Nos. 4-6, pp. 285-380.

FIGURES

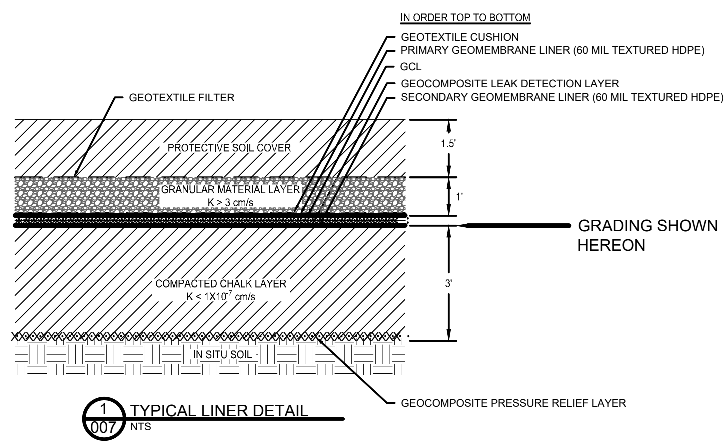




NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.

2. CELL ACCESS ROADS ARE SHOWN FOR GRAPHICAL REPRESENTATION. OPERATION OF EACH CELL MAY REQUIRE ADDITIONAL ROADS FOR MULTIPLE ACCESS POINTS AND ROADS MAYBE RELOCATED FROM THE LOCATIONS SHOWN ON THIS PLAN.



1 / 007 TYPICAL LINER DETAIL
NTS

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Drawn By: JCH	Scale: AS-SHOWN		
Checked By: RSG	File No. --		
Approved By: RSG	Date: 12-XX-2014		

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Consulting Engineers and Scientists
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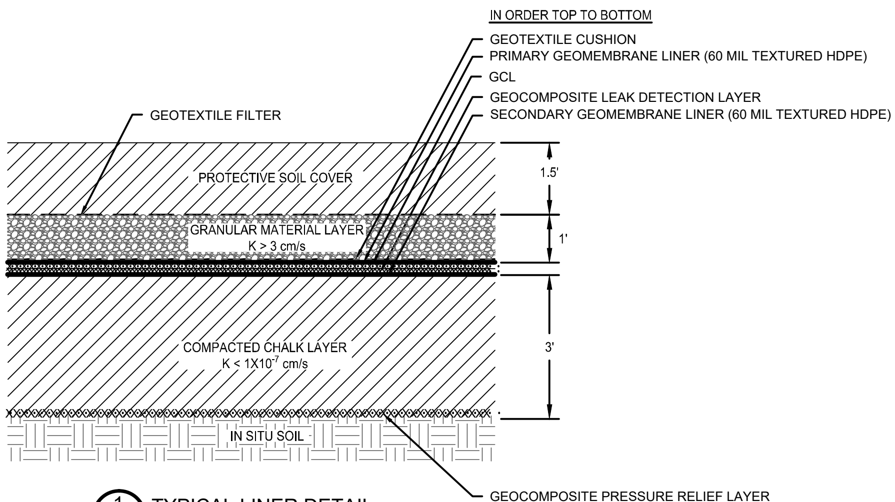
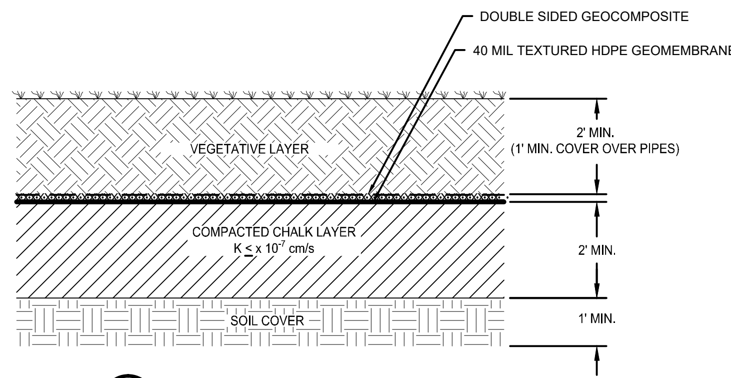
PH. (770) 924-9799 FAX. (770) 924-7866

SITE PLAN
HELP MODEL ANALYSIS
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIG. No.
1



1 / 007 TYPICAL LINER DETAIL
NTS



1 / 010 TYPICAL CLOSURE COVER
NTS

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BASE LINER AND FINAL COVER SYSTEM DETAILS
HELP MODEL ANALYSIS
EMELLE FACILITY
CHEMICAL WASTE MANAGEMENT

FIG. No. 2

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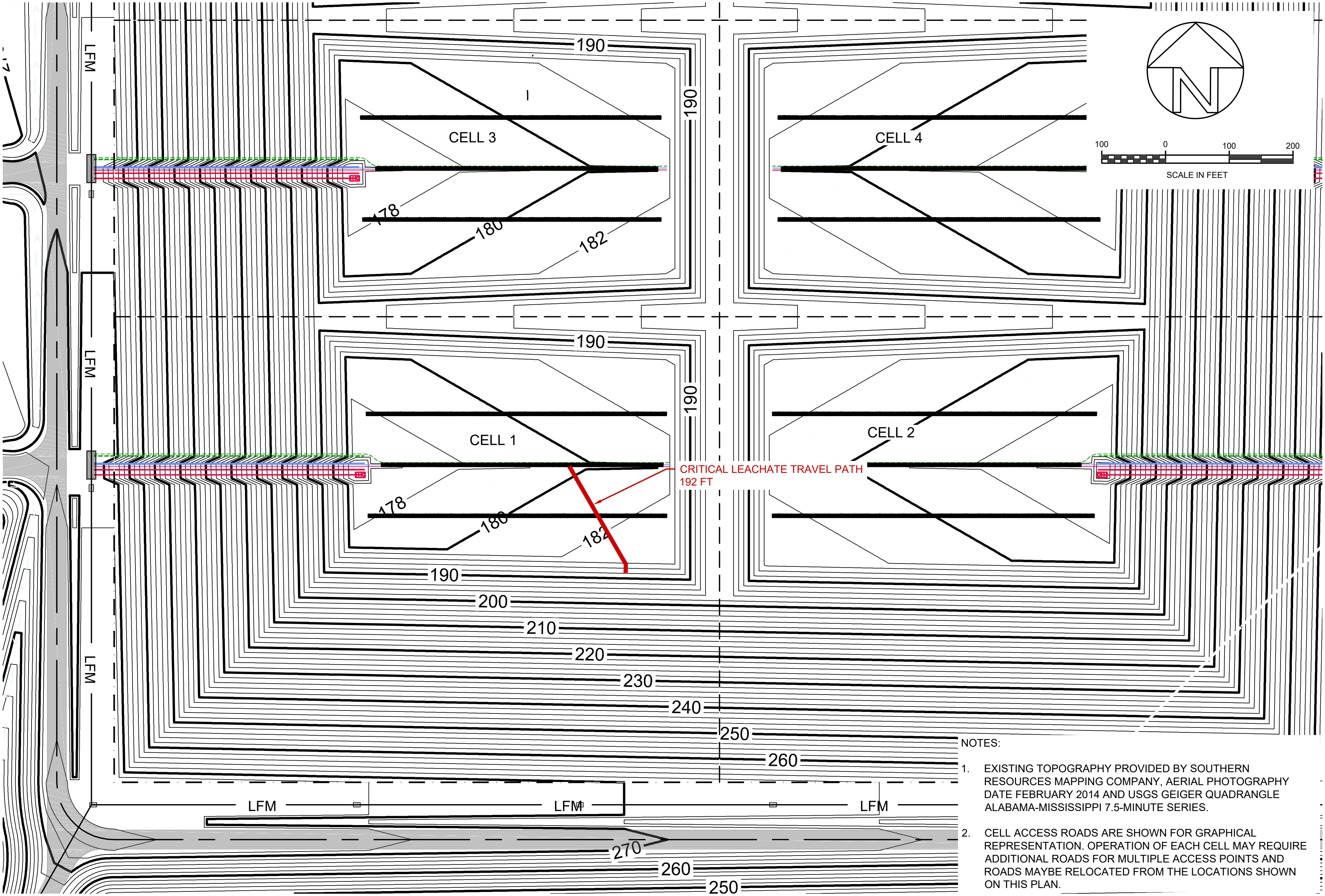

NOTES:

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CASE 1: CRITICAL TRAVEL PATH

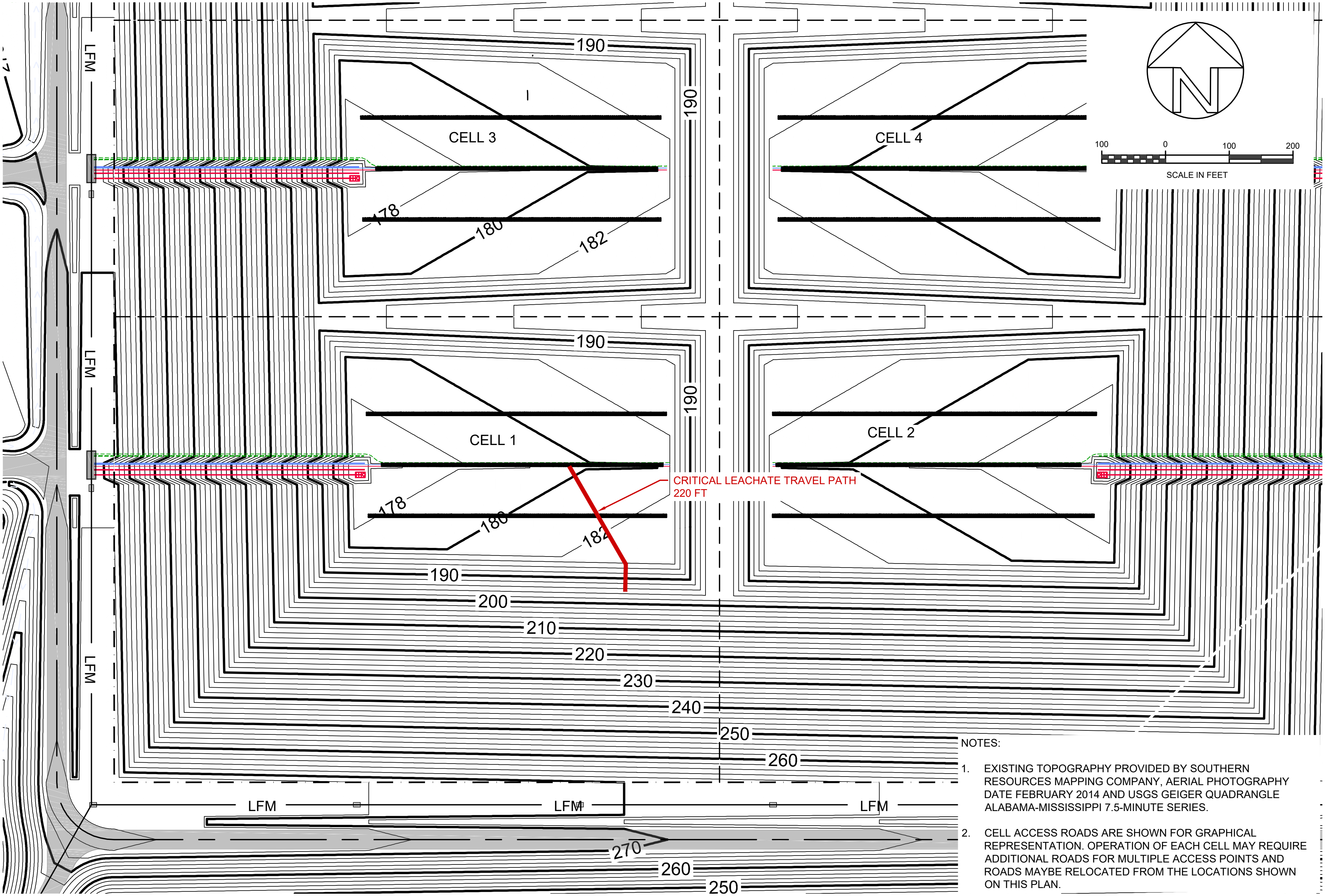
HELP MODEL ANALYSIS

EMELLE FACILITY

CHEMICAL WASTE MANAGEMENT

FIG. No.

3



NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SOUTHERN RESOURCES MAPPING COMPANY, AERIAL PHOTOGRAPHY DATE FEBRUARY 2014 AND USGS GEIGER QUADRANGLE ALABAMA-MISSISSIPPI 7.5-MINUTE SERIES.

2. CELL ACCESS ROADS ARE SHOWN FOR GRAPHICAL REPRESENTATION. OPERATION OF EACH CELL MAY REQUIRE ADDITIONAL ROADS FOR MULTIPLE ACCESS POINTS AND ROADS MAYBE RELOCATED FROM THE LOCATIONS SHOWN ON THIS PLAN.

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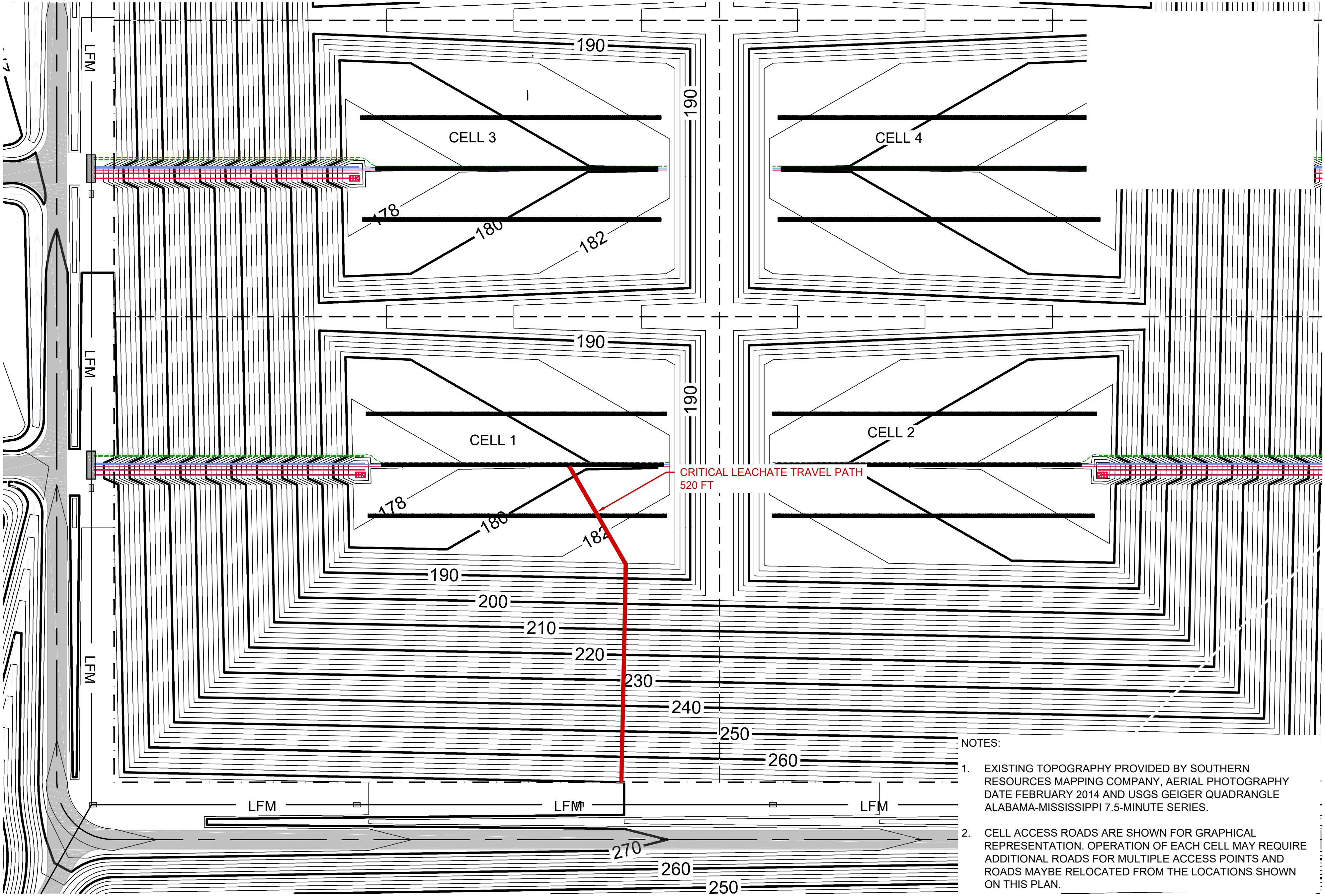
CASE 2: CRITICAL TRAVEL PATH

HELP MODEL ANALYSIS

EMELLE FACILITY

CHEMICAL WASTE MANAGEMENT

FIG. No. 4



NOTES:

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Drawn By:	JCH	Scale:	AS-SHOWN
Checked By:	RSG	File No.	--
Approved By:	RSG	Date:	12-XX-2014

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CASE 3: CRITICAL TRAVEL PATH

HELP MODEL ANALYSIS

EMELLE FACILITY

CHEMICAL WASTE MANAGEMENT

FIG. No. 5

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EXHIBIT 1

HELP Model Precipitation Data

U.S. DEPARTMENT OF COMMERCE
LUTHER H. HODGES, Secretary

WEATHER BUREAU
F. W. REICHELDERFER, Chief

TECHNICAL PAPER NO. 40

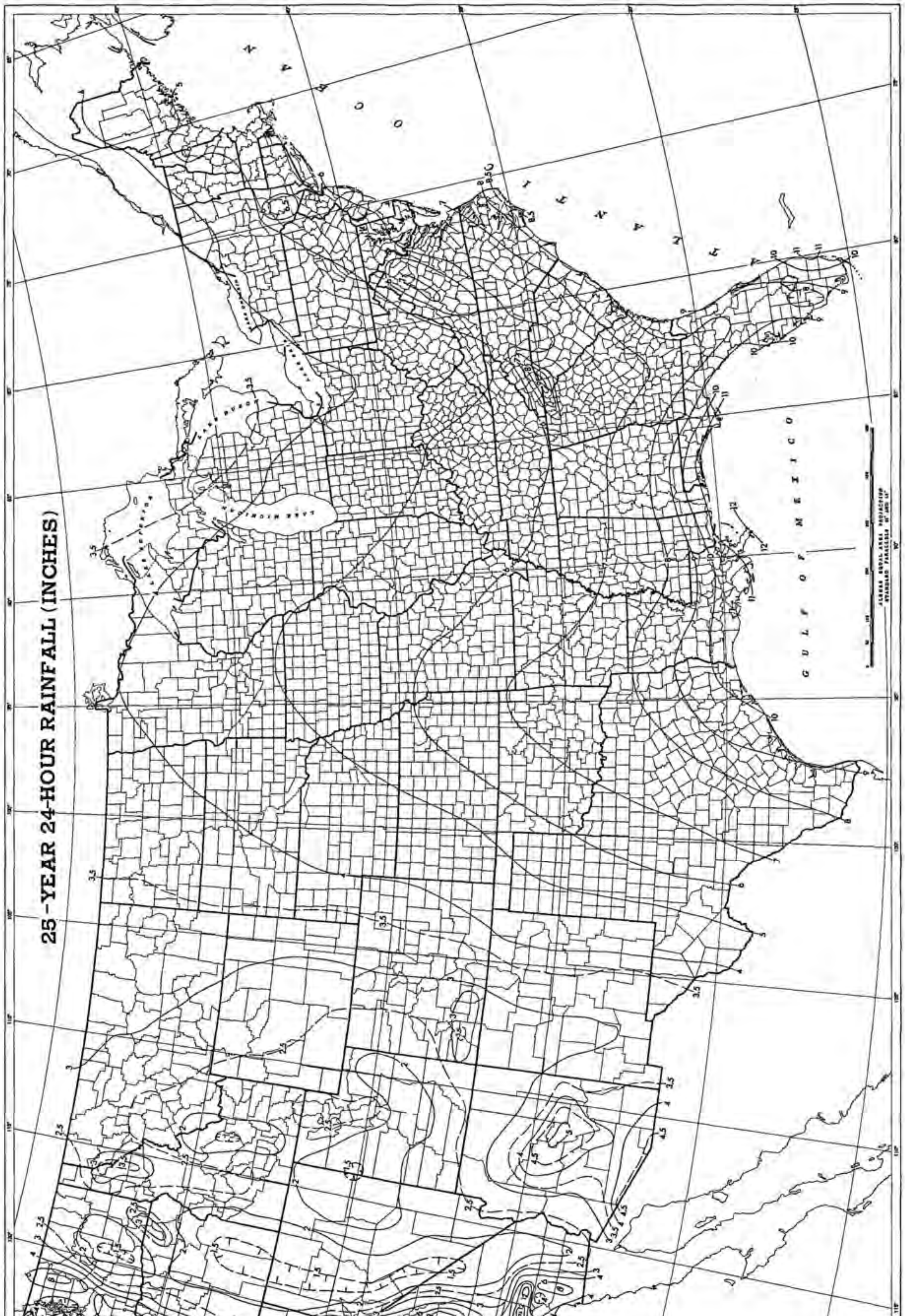
RAINFALL FREQUENCY ATLAS OF THE UNITED STATES

for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years

Prepared by
DAVID M. HERSHFIELD
Cooperative Studies Section, Hydrologic Services Division
for
Engineering Division, Soil Conservation Service
U.S. Department of Agriculture

WASHINGTON, D.C.
May 1961
Repaginated and Reprinted January 1963

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Price $1.25


25-YEAR 24-HOUR RAINFALL (INCHES)
ATLANTIC OCEAN
GULF OF MEXICO
PACIFIC OCEAN
LAKE MICHIGAN
LAKE HURON
LAKE SUPERIOR

54

EXHIBIT 2

Reduction Factor Calculations

Flow Capacity Reduction for a Granular Liquid Collection Layer

Granular Material Layer (Drainage Layer)

The following reduction factor calculations are for the long term in soil hydraulic conductivity of the proposed "Granular Material Layer". This is a drainage system consisting of a single granular drainage material. Calculations for this layer are performed below.

Equations and Input Parameters:

$$k_{LTIS} = \frac{k_{initial}}{RF_{PC} \times RF_{CC} \times RF_{BC}}$$ (Eq. 125) Long Term In Soil Hydraulic Conductivity

Initial Hydraulic Conductivity:	$k_{initial}$ =	3.00	cm/sec
RF for Particulate Clogging:	RF_{PC} =	1.5	
RF for Chemical Clogging:	RF_{CC} =	1.5	
RF for Biological Clogging:	RF_{BC} =	1	

Results for Case 3 (Final, Closed)

The reduction factors for Case 3 represent the final conditions at the landfill with a final waste thickness.

$\prod RF =$ 2.25

k_{LTIS} = 1.33 cm/sec

Results for Case 2 (Intermediate, Active)

The reduction factors for Case 2 represent intermediate conditions at the landfill with an intermediate waste

$\frac{\prod RF}{2} =$ 1.13

k_{LTIS} = 2.67 cm/sec

Flow Capacity Reduction for Geosynthetic Leak Detection Layer

Geocomposite Leak Detection Layer

The following reduction factor calculations are for the long term hydraulic conductivity of the proposed geocomposite leak detection layer. This is a leak detection system consisting of a 200 mil double sided geocomposite overlain by geosynthetic clay liner and 60 mil geomembrane and underlain by a 60 mil geomembrane. Calculations for the double sided geocomposite are performed below.

Equations and Input Parameters:

$$k_{LTIS} = \frac{k_{initial}}{RF_{CR} \times RF_{IN} \times RF_{PC} \times RF_{CC} \times RF_{BC} \times FS}$$ (Eq. 117) Long Term In Soil Hydraulic Conductivity

$$k_{initial} = \frac{\theta_{initial}}{t_{initial}}$$ (Eq. 2) Initial Hydraulic Conductivity

Initial Geonet Thickness:	$t_{initial}$ =	200	mil
Initial Geocomposite Transmissivity:	$\Theta_{initial}$ =	3.00E-05	m^2/sec
Initial Hydraulic Conductivity:	$k_{initial}$ =	0.59	cm/sec
RF for Creep:	RF_{CR} =	1.7	
RF for Delayed Intrustion:	RF_{IN} =	1.2	
RF for Particulate Clogging:	RF_{PC} =	1	
RF for Chemical Clogging:	RF_{CC} =	1	
RF for Biological Clogging:	RF_{BC} =	1	

Results for Case 3 (Final, Closed)

The reduction factors for Case 3 represents the final conditions at the landfill with a final waste thickness.

$\prod RF =$ 2.04

\

k_{LTIS} = 0.289 cm/sec

Results for Case 2 (Intermediate, Active)

The reduction factors for Case 2 represent intermediate conditions at the landfill with an intermediate waste

$\frac{\prod RF}{2} =$ 1.02

k_{LTIS} = 0.579 cm/sec

References:

Giroud, J.P., Zornburg, J.G., and Zhao, A., 2000, "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers", *Geosynthetics International*, Special Issue on Liquid Collection Systems, Vol. 7, Nos. 4-6, pp. 285-380.

Koerner, G.R., Eith, A.W., and Koerner, R.M., 2012, "Long Term Leachate Collection and Removal System (LCRS) Study", *Global Waste Management Symposium 2012*.

EXHIBIT 3

HELP Model Output Data

HELP MODEL OUTPUT DATA

Liquid Head on Base Liner

Emelle Facility, Sumter County, AL

December 8, 2014

Case 1: INITIAL

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                               developed at                               **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                 based on                                 **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


 TIME:   9.49     DATE:   8.12.2014


 PRECIPITATION  DATA  FILE:          C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\100_Years.d4
 TEMPERATURE  DATA  FILE:            C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\100_Years.d7
 SOLAR  RADIATION  DATA  FILE:       C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\100_Years.d13
 EVAPOTRANSPIRATION  DATA  F.  1:  C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\Bare_Soil.d11
 SOIL  AND  DESIGN  DATA  FILE   1:  C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\Initial.d10
 OUTPUT  DATA  FILE:                 C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\Initial.out


******************************************************************************

      TITLE:  Emelle - Trench 23

******************************************************************************


                           WEATHER DATA SOURCES
------------------------------------------------------------------------------



         NOTE:  PRECIPITATION DATA FOR     MERIDIAN            MISSISSIPPI
                  WAS ENTERED BY THE USER.



         NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    MERIDIAN            MISSISSIPPI

             NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

     JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
```

```
      -------     -------     -------     -------     -------     -------
       45.50       48.80       55.90       64.60       71.70       78.40
       81.30       80.60       75.70       63.90       54.10       48.00


          NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    MERIDIAN            MISSISSIPPI
                     AND STATION LATITUDE  =  32.60 DEGREES


******************************************************************************

                               LAYER DATA    1
------------------------------------------------------------------------------

                            VALID FOR 100 YEARS


      NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
               COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  19
           THICKNESS                     =    120.00   INCHES
           POROSITY                      =      0.1680 VOL/VOL
           FIELD CAPACITY                =      0.0730 VOL/VOL
           WILTING POINT                 =      0.0190 VOL/VOL
           INITIAL SOIL WATER CONTENT    =      0.0726 VOL/VOL
           EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-02 CM/SEC


                                  LAYER  2
                                  --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   0
           THICKNESS                     =     18.00   INCHES
           POROSITY                      =      0.3980 VOL/VOL
           FIELD CAPACITY                =      0.2440 VOL/VOL
           WILTING POINT                 =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT    =      0.2525 VOL/VOL
           EFFECTIVE SAT. HYD. CONDUCT.=      0.2650E-03 CM/SEC


                                  LAYER  3
                                  --------

                        TYPE 2 - LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER   0
           THICKNESS                     =     12.00   INCHES
           POROSITY                      =      0.4170 VOL/VOL
           FIELD CAPACITY                =      0.0450 VOL/VOL
           WILTING POINT                 =      0.0180 VOL/VOL
           INITIAL SOIL WATER CONTENT    =      0.0450 VOL/VOL
           EFFECTIVE SAT. HYD. CONDUCT.=       3.000     CM/SEC
           SLOPE                         =      2.00   PERCENT
```

```
DRAINAGE LENGTH              =    192.0     FEET


                        LAYER  4
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06    INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00    HOLES/ACRE
FML INSTALLATION DEFECTS     =      2.00    HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                        LAYER  5
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  17
THICKNESS                    =      0.25    INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.3000E-08 CM/SEC


                        LAYER  6
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20    INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.5900     CM/SEC
SLOPE                        =      2.00    PERCENT
DRAINAGE LENGTH              =    192.0     FEET


                        LAYER  7
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06    INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00    HOLES/ACRE
FML INSTALLATION DEFECTS     =      2.00    HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                        LAYER  8
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
```

```
          THICKNESS                    =     36.00   INCHES
          POROSITY                     =      0.4270 VOL/VOL
          FIELD CAPACITY               =      0.4180 VOL/VOL
          WILTING POINT                =      0.3670 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
          EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-06 CM/SEC


******************************************************************************

                GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                            VALID FOR 100 YEARS


         NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                  SOIL DATA BASE USING SOIL TEXTURE #19 WITH BARE
                  GROUND CONDITIONS, A SURFACE SLOPE OF  1.% AND
                  A SLOPE LENGTH OF  192. FEET.

        SCS RUNOFF CURVE NUMBER             =     79.95
        FRACTION OF AREA ALLOWING RUNOFF    =      0.0    PERCENT
        AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
        EVAPORATIVE ZONE DEPTH              =     10.0    INCHES
        INITIAL WATER IN EVAPORATIVE ZONE   =      0.584  INCHES
        UPPER LIMIT OF EVAPORATIVE STORAGE  =      1.680  INCHES
        FIELD CAPACITY OF EVAPORATIVE ZONE  =      0.730  INCHES
        LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.190  INCHES
        SOIL EVAPORATION ZONE DEPTH         =     10.000  INCHES
        INITIAL SNOW WATER                  =      0.000  INCHES
        INITIAL INTERCEPTION WATER          =      0.000  INCHES
        INITIAL WATER IN LAYER MATERIALS    =     29.363  INCHES
        TOTAL INITIAL WATER                 =     29.363  INCHES
        TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


******************************************************************************

                       EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                           VALID FOR 100 YEARS


         NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                  MERIDIAN            MISSISSIPPI
            STATION LATITUDE                        =  32.60 DEGREES
            MAXIMUM LEAF AREA INDEX                 =   0.00
            START OF GROWING SEASON (JULIAN DATE)   =     63
            END OF GROWING SEASON (JULIAN DATE)     =    325
            EVAPORATIVE ZONE DEPTH                  =  10.0  INCHES
            AVERAGE ANNUAL WIND SPEED               =   6.00 MPH
            AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  71.0  %
            AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  72.0  %
            AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  76.0  %
            AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  74.0  %

******************************************************************************
```

```
******************************************************************************

                  FINAL WATER STORAGE AT END OF YEAR   100
------------------------------------------------------------------------------

                    LAYER         (INCHES)        (VOL/VOL)
                    -----         --------        ---------
                      1            9.6626          0.0805

                      2            4.6364          0.2576

                      3            0.5463          0.0455

                      4            0.0000          0.0000

                      5            0.1875          0.7500

                      6            0.0020          0.0100

                      7            0.0000          0.0000

                      8           15.3720          0.4270

    TOTAL WATER IN LAYERS         30.407

    SNOW WATER                     0.000

    INTERCEPTION WATER             0.000

    TOTAL FINAL WATER             30.407

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               PEAK DAILY VALUES FOR YEARS     1 THROUGH  100
------------------------------------------------------------------------------

                                                  (INCHES)      (CU. FT.)
                                                 ----------    -------------
      PRECIPITATION                                 7.50        27225.000

      RUNOFF                                        0.000           0.0000

      DRAINAGE COLLECTED FROM LAYER  3              5.55534     20165.90039

      PERCOLATION/LEAKAGE THROUGH LAYER  5          0.000004        0.01525

      AVERAGE HEAD ON TOP OF LAYER  4               5.399

      MAXIMUM HEAD ON TOP OF LAYER  4               5.048

      LOCATION OF MAXIMUM HEAD IN LAYER  3
            (DISTANCE FROM DRAIN)                  37.5 FEET

      DRAINAGE COLLECTED FROM LAYER  6              0.00000         0.00466

      PERCOLATION/LEAKAGE THROUGH LAYER  8          0.000000        0.00002

      AVERAGE HEAD ON TOP OF LAYER  7               0.000

      MAXIMUM HEAD ON TOP OF LAYER  7               0.008
```

```
      LOCATION OF MAXIMUM HEAD IN LAYER  6
            (DISTANCE FROM DRAIN)                  0.0 FEET

      SNOW WATER                                   4.91         17825.5879

      MAXIMUM VEG. SOIL WATER (VOL/VOL)                    0.1492

      MINIMUM VEG. SOIL WATER (VOL/VOL)                    0.0190

       ***  Maximum heads are computed using McEnroe's equations.  ***

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
                        Vol. 119, No. 2, March 1993, pp. 262-270.

******************************************************************************


*******************************************************************************

         AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------

                         JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                         -------  -------  -------  -------  -------  -------
 PRECIPITATION
 -------------
   TOTALS                  4.81     4.88     6.62     5.19     4.32     3.57
                           5.69     3.52     3.24     2.59     3.76     5.78

   STD. DEVIATIONS         2.40     2.34     3.52     2.73     2.43     2.10
                           2.28     1.68     2.08     2.26     2.08     2.60

 RUNOFF
 ------
   TOTALS                  0.000    0.000    0.000    0.000    0.000    0.000
                           0.000    0.000    0.000    0.000    0.000    0.000

   STD. DEVIATIONS         0.000    0.000    0.000    0.000    0.000    0.000
                           0.000    0.000    0.000    0.000    0.000    0.000

 POTENTIAL EVAPOTRANSPIRATION
 ----------------------------
   TOTALS                  1.910    2.330    3.736    5.000    6.435    7.111
                           6.978    6.357    4.915    3.552    2.252    1.756

   STD. DEVIATIONS         0.182    0.215    0.282    0.300    0.285    0.276
                           0.320    0.288    0.283    0.218    0.160    0.151

 ACTUAL EVAPOTRANSPIRATION
 -------------------------
   TOTALS                  1.578    1.818    2.286    2.207    1.962    1.914
                           2.837    1.892    1.566    1.037    1.312    1.456

   STD. DEVIATIONS         0.328    0.404    0.607    0.838    0.960    0.925
                           0.950    0.694    0.766    0.605    0.542    0.315

 LATERAL DRAINAGE COLLECTED FROM LAYER  3
 ----------------------------------------
   TOTALS                  3.4624   3.2108   4.1970   3.3736   2.4217   1.8163
```

6

```
                            2.6332    1.8804    1.6095    1.6870    2.0989    3.6979

    STD. DEVIATIONS         2.0890    2.1498    2.8178    2.1427    1.6582    1.4676
                            1.5331    1.0828    1.2281    1.6039    1.6478    2.4283

  PERCOLATION/LEAKAGE THROUGH LAYER  5
  ------------------------------------
    TOTALS                  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                            0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

    STD. DEVIATIONS         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                            0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

  LATERAL DRAINAGE COLLECTED FROM LAYER  6
  ----------------------------------------
    TOTALS                  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                            0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

    STD. DEVIATIONS         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                            0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

  PERCOLATION/LEAKAGE THROUGH LAYER  8
  ------------------------------------
    TOTALS                  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                            0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

    STD. DEVIATIONS         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                            0.0000    0.0000    0.0000    0.0000    0.0000    0.0000


-------------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
    AVERAGES                0.0631    0.0644    0.0764    0.0635    0.0441    0.0342
                            0.0480    0.0343    0.0303    0.0315    0.0395    0.0674

    STD. DEVIATIONS         0.0381    0.0434    0.0513    0.0403    0.0302    0.0276
                            0.0279    0.0197    0.0231    0.0325    0.0310    0.0442

  DAILY AVERAGE HEAD ON TOP OF LAYER  7
  -------------------------------------
    AVERAGES                0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                            0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

    STD. DEVIATIONS         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                            0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

*******************************************************************************


*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------

                                    INCHES            CU. FEET        PERCENT
                              -------------------   -------------    ---------
 PRECIPITATION                 53.96    (   8.608)     195886.4      100.00

 RUNOFF                         0.000   (  0.0000)          0.00       0.000
```

POTENTIAL EVAPOTRANSPIRATION	52.332	(0.9310)	189964.36	
ACTUAL EVAPOTRANSPIRATION	21.864	(2.4000)	79366.49	40.517
LATERAL DRAINAGE COLLECTED FROM LAYER 3	32.08870	(7.14827)	116481.992	59.46405
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00001	(0.00000)	0.022	0.00001
AVERAGE HEAD ON TOP OF LAYER 4	0.050	(0.011)		
LATERAL DRAINAGE COLLECTED FROM LAYER 6	0.00000	(0.00000)	0.013	0.00001
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.00000	(0.00000)	0.008	0.00000
AVERAGE HEAD ON TOP OF LAYER 7	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.010	(1.5029)	37.91	0.019

****
****

CASE 2: INTERMEDIATE

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                               developed at                               **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                 based on                                 **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


 TIME:  10.10     DATE:   8.12.2014


 PRECIPITATION  DATA  FILE:         C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\100_Years.d4
 TEMPERATURE  DATA  FILE:           C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\100_Years.d7
 SOLAR  RADIATION  DATA  FILE:      C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\100_Years.d13
 EVAPOTRANSPIRATION  DATA  F.  1:  C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\Bare_Soil.d11
 SOIL  AND  DESIGN  DATA  FILE   1:  C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\Intermediate.d10
 OUTPUT  DATA  FILE:                 C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\Intermediate.out


******************************************************************************

      TITLE:  Emelle - Trench 23

******************************************************************************


                           WEATHER DATA SOURCES
 ------------------------------------------------------------------------------



          NOTE:  PRECIPITATION DATA FOR     MERIDIAN           MISSISSIPPI
                   WAS ENTERED BY THE USER.


          NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR     MERIDIAN           MISSISSIPPI

              NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

      JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
      -------     -------     -------     -------     -------     -------
```

```
      45.50         48.80         55.90         64.60         71.70         78.40
      81.30         80.60         75.70         63.90         54.10         48.00


         NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    MERIDIAN            MISSISSIPPI
                    AND STATION LATITUDE  =  32.60 DEGREES


******************************************************************************

                                LAYER DATA   1
------------------------------------------------------------------------------

                             VALID FOR 100 YEARS


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  19
           THICKNESS                 =    156.00   INCHES
           POROSITY                  =      0.1680 VOL/VOL
           FIELD CAPACITY            =      0.0730 VOL/VOL
           WILTING POINT             =      0.0190 VOL/VOL
           INITIAL SOIL WATER CONTENT  =    0.0731 VOL/VOL
           EFFECTIVE SAT. HYD. CONDUCT.=    0.1000E-02 CM/SEC


                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                 =     18.00   INCHES
           POROSITY                  =      0.3980 VOL/VOL
           FIELD CAPACITY            =      0.2440 VOL/VOL
           WILTING POINT             =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT  =    0.2491 VOL/VOL
           EFFECTIVE SAT. HYD. CONDUCT.=    0.2650E-03 CM/SEC


                                   LAYER  3
                                   --------

                       TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                 =     12.00   INCHES
           POROSITY                  =      0.4170 VOL/VOL
           FIELD CAPACITY            =      0.0450 VOL/VOL
           WILTING POINT             =      0.0180 VOL/VOL
           INITIAL SOIL WATER CONTENT  =    0.0450 VOL/VOL
           EFFECTIVE SAT. HYD. CONDUCT.=     2.670      CM/SEC
           SLOPE                     =      2.00   PERCENT
           DRAINAGE LENGTH           =    220.0    FEET
```

```
                         LAYER  4
                         --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      2.00   HOLES/ACRE
FML PLACEMENT QUALITY        =   3 - GOOD


                         LAYER  5
                         --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER  17
THICKNESS                    =      0.25   INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.3000E-08 CM/SEC


                         LAYER  6
                         --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.5790     CM/SEC
SLOPE                        =      2.00   PERCENT
DRAINAGE LENGTH              =    220.0    FEET


                         LAYER  7
                         --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      2.00   HOLES/ACRE
FML PLACEMENT QUALITY        =   3 - GOOD


                         LAYER  8
                         --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER  16
THICKNESS                    =     36.00   INCHES
```

```
            POROSITY                    =      0.4270 VOL/VOL
            FIELD CAPACITY              =      0.4180 VOL/VOL
            WILTING POINT               =      0.3670 VOL/VOL
            INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
            EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-06 CM/SEC


******************************************************************************

                GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                            VALID FOR 100 YEARS


         NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                  SOIL DATA BASE USING SOIL TEXTURE #19 WITH BARE
                  GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
                  A SLOPE LENGTH OF  220. FEET.

        SCS RUNOFF CURVE NUMBER                =     80.19
        FRACTION OF AREA ALLOWING RUNOFF       =      0.0    PERCENT
        AREA PROJECTED ON HORIZONTAL PLANE     =      1.000  ACRES
        EVAPORATIVE ZONE DEPTH                 =     10.0    INCHES
        INITIAL WATER IN EVAPORATIVE ZONE      =      0.589  INCHES
        UPPER LIMIT OF EVAPORATIVE STORAGE     =      1.680  INCHES
        FIELD CAPACITY OF EVAPORATIVE ZONE     =      0.730  INCHES
        LOWER LIMIT OF EVAPORATIVE STORAGE     =      0.190  INCHES
        SOIL EVAPORATION ZONE DEPTH            =     10.000  INCHES
        INITIAL SNOW WATER                     =      0.000  INCHES
        INITIAL INTERCEPTION WATER             =      0.000  INCHES
        INITIAL WATER IN LAYER MATERIALS       =     31.991  INCHES
        TOTAL INITIAL WATER                    =     31.991  INCHES
        TOTAL SUBSURFACE INFLOW                =      0.00   INCHES/YEAR


******************************************************************************

                       EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                           VALID FOR 100 YEARS


         NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                  MERIDIAN            MISSISSIPPI
             STATION LATITUDE                       =  32.60 DEGREES
             MAXIMUM LEAF AREA INDEX                =   0.00
             START OF GROWING SEASON (JULIAN DATE)  =     63
             END OF GROWING SEASON (JULIAN DATE)    =    325
             EVAPORATIVE ZONE DEPTH                 =  10.0  INCHES
             AVERAGE ANNUAL WIND SPEED              =   6.00 MPH
             AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  71.0  %
             AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  72.0  %
             AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  76.0  %
             AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  74.0  %

******************************************************************************



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```

```
                   FINAL WATER STORAGE AT END OF YEAR  100
------------------------------------------------------------------------------

                    LAYER        (INCHES)       (VOL/VOL)
                    -----        --------       ---------
                      1          12.2650         0.0786

                      2           4.6752         0.2597

                      3           0.5406         0.0451

                      4           0.0000         0.0000

                      5           0.1875         0.7500

                      6           0.0020         0.0100

                      7           0.0000         0.0000

                      8          15.3720         0.4270

    TOTAL WATER IN LAYERS        33.042

    SNOW WATER                    0.000

    INTERCEPTION WATER            0.000

    TOTAL FINAL WATER            33.042

******************************************************************************



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                PEAK DAILY VALUES FOR YEARS     1 THROUGH  100
------------------------------------------------------------------------------

                                                (INCHES)      (CU. FT.)
                                               ----------   -------------
      PRECIPITATION                              7.50         27225.000

      RUNOFF                                     0.000            0.0000

      DRAINAGE COLLECTED FROM LAYER  3           6.58317      23896.89258

      PERCOLATION/LEAKAGE THROUGH LAYER  5       0.000007         0.02598

      AVERAGE HEAD ON TOP OF LAYER  4            8.763

      MAXIMUM HEAD ON TOP OF LAYER  4            7.405

      LOCATION OF MAXIMUM HEAD IN LAYER  3
            (DISTANCE FROM DRAIN)               49.7 FEET

      DRAINAGE COLLECTED FROM LAYER  6           0.00000          0.00707

      PERCOLATION/LEAKAGE THROUGH LAYER  8       0.000000         0.00002

      AVERAGE HEAD ON TOP OF LAYER  7            0.000

      MAXIMUM HEAD ON TOP OF LAYER  7            0.009
```

```
     LOCATION OF MAXIMUM HEAD IN LAYER  6
           (DISTANCE FROM DRAIN)               0.0 FEET

     SNOW WATER                                4.91         17825.5879

     MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.1575

     MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.0190

      ***  Maximum heads are computed using McEnroe's equations.  ***

           Reference:  Maximum Saturated Depth over Landfill Liner
                       by Bruce M. McEnroe, University of Kansas
                       ASCE Journal of Environmental Engineering
                       Vol. 119, No. 2, March 1993, pp. 262-270.

*******************************************************************************
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*******************************************************************************

         AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------

                         JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                         -------  -------  -------  -------  -------  -------
 PRECIPITATION
 -------------
   TOTALS                  4.81     4.88     6.62     5.19     4.32     3.57
                           5.69     3.52     3.24     2.59     3.76     5.78

   STD. DEVIATIONS         2.40     2.34     3.52     2.73     2.43     2.10
                           2.28     1.68     2.08     2.26     2.08     2.60

 RUNOFF
 ------
   TOTALS                  0.000    0.000    0.000    0.000    0.000    0.000
                           0.000    0.000    0.000    0.000    0.000    0.000

   STD. DEVIATIONS         0.000    0.000    0.000    0.000    0.000    0.000
                           0.000    0.000    0.000    0.000    0.000    0.000

 POTENTIAL EVAPOTRANSPIRATION
 ----------------------------
   TOTALS                  1.910    2.330    3.736    5.000    6.435    7.111
                           6.978    6.357    4.915    3.552    2.252    1.756

   STD. DEVIATIONS         0.182    0.215    0.282    0.300    0.285    0.276
                           0.320    0.288    0.283    0.218    0.160    0.151

 ACTUAL EVAPOTRANSPIRATION
 -------------------------
   TOTALS                  1.578    1.819    2.286    2.210    1.966    1.919
                           2.841    1.895    1.570    1.040    1.311    1.456

   STD. DEVIATIONS         0.328    0.403    0.606    0.840    0.962    0.929
                           0.950    0.694    0.766    0.605    0.542    0.314

 LATERAL DRAINAGE COLLECTED FROM LAYER  3
 ----------------------------------------
   TOTALS                  3.4962   3.2174   4.1408   3.4209   2.4520   1.8215
                           2.5937   1.9120   1.5919   1.6721   2.1123   3.6320
```

```
   STD. DEVIATIONS        2.0620   2.1437   2.7488   2.1121   1.6497   1.4684
                          1.5245   1.1148   1.2078   1.5300   1.6351   2.4096

 PERCOLATION/LEAKAGE THROUGH LAYER  5
 ------------------------------------
   TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

   STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

 LATERAL DRAINAGE COLLECTED FROM LAYER  6
 ----------------------------------------
   TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

   STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

 PERCOLATION/LEAKAGE THROUGH LAYER  8
 ------------------------------------
   TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

   STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


 DAILY AVERAGE HEAD ON TOP OF LAYER  4
 -------------------------------------
   AVERAGES               0.0820   0.0830   0.0984   0.0829   0.0575   0.0441
                          0.0608   0.0448   0.0386   0.0392   0.0512   0.0852

   STD. DEVIATIONS        0.0484   0.0557   0.0676   0.0512   0.0387   0.0356
                          0.0358   0.0261   0.0293   0.0359   0.0396   0.0565

 DAILY AVERAGE HEAD ON TOP OF LAYER  7
 -------------------------------------
   AVERAGES               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

   STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

*******************************************************************************


*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------

                                INCHES            CU. FEET        PERCENT
                          -------------------  -------------    ---------
 PRECIPITATION              53.96    (   8.608)    195886.4      100.00

 RUNOFF                      0.000   (  0.0000)         0.00       0.000
```

POTENTIAL EVAPOTRANSPIRATION	52.332	(0.9310)	189964.36	
ACTUAL EVAPOTRANSPIRATION	21.890	(2.4025)	79459.80	40.564
LATERAL DRAINAGE COLLECTED FROM LAYER 3	32.06292	(7.12529)	116388.414	59.41627
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00001	(0.00000)	0.026	0.00001
AVERAGE HEAD ON TOP OF LAYER 4	0.064	(0.014)		
LATERAL DRAINAGE COLLECTED FROM LAYER 6	0.00000	(0.00000)	0.018	0.00001
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.00000	(0.00000)	0.008	0.00000
AVERAGE HEAD ON TOP OF LAYER 7	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.011	(1.6034)	38.16	0.019

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****

CASE 3: FINAL

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                               developed at                               **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                 based on                                 **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


 TIME:  10.12     DATE:   8.12.2014


 PRECIPITATION  DATA  FILE:         C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\100_Years.d4
 TEMPERATURE  DATA  FILE:           C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\100_Years.d7
 SOLAR  RADIATION  DATA  FILE:      C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\100_Years.d13
 EVAPOTRANSPIRATION  DATA  F.  1:  C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\Final_Cover.d11
 SOIL  AND  DESIGN  DATA  FILE   1:  C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\Final.d10
 OUTPUT  DATA  FILE:                C:\Temp\N_Drive_Backups\EJ147410  -  Emelle  Major  Mod\Working
Files\Calculations-Analyses\HELP\Final.out


******************************************************************************

      TITLE:  Emelle - Trench 23

******************************************************************************


                           WEATHER DATA SOURCES
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         NOTE:  PRECIPITATION DATA FOR    MERIDIAN            MISSISSIPPI
                  WAS ENTERED BY THE USER.


         NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR    MERIDIAN            MISSISSIPPI

             NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

      JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
      -------     -------     -------     -------     -------     -------
```

```
     45.50         48.80         55.90         64.60         71.70         78.40
     81.30         80.60         75.70         63.90         54.10         48.00


        NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    MERIDIAN            MISSISSIPPI
                   AND STATION LATITUDE  =  32.60 DEGREES


******************************************************************************

                              LAYER DATA   1
------------------------------------------------------------------------------

                           VALID FOR 100 YEARS


    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
             COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                 LAYER  1
                                 --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER   8
          THICKNESS                    =     24.00   INCHES
          POROSITY                     =      0.4630 VOL/VOL
          FIELD CAPACITY               =      0.2320 VOL/VOL
          WILTING POINT                =      0.1160 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3646 VOL/VOL
          EFFECTIVE SAT. HYD. CONDUCT.=      0.3700E-03 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                 LAYER  2
                                 --------

                     TYPE 2 - LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      0.14   INCHES
          POROSITY                     =      0.8500 VOL/VOL
          FIELD CAPACITY               =      0.0100 VOL/VOL
          WILTING POINT                =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.8500 VOL/VOL
          EFFECTIVE SAT. HYD. CONDUCT.=      0.9000E-01 CM/SEC
          SLOPE                        =     10.00   PERCENT
          DRAINAGE LENGTH              =    650.0    FEET


                                 LAYER  3
                                 --------

                     TYPE 4 - FLEXIBLE MEMBRANE LINER
                       MATERIAL TEXTURE NUMBER  35
          THICKNESS                    =      0.04   INCHES
          EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
          FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
          FML INSTALLATION DEFECTS     =      2.00   HOLES/ACRE
```

```
FML PLACEMENT QUALITY        =  3 - GOOD


                        LAYER  4
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                    =     24.00   INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-06 CM/SEC


                        LAYER  5
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3980 VOL/VOL
FIELD CAPACITY               =      0.2440 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-04 CM/SEC


                        LAYER  6
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  19
THICKNESS                    =   1968.00   INCHES
POROSITY                     =      0.1680 VOL/VOL
FIELD CAPACITY               =      0.0730 VOL/VOL
WILTING POINT                =      0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0730 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-02 CM/SEC


                        LAYER  7
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     18.00   INCHES
POROSITY                     =      0.3980 VOL/VOL
FIELD CAPACITY               =      0.2440 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.2650E-03 CM/SEC


                        LAYER  8
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
```

```
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4170 VOL/VOL
FIELD CAPACITY               =      0.0450 VOL/VOL
WILTING POINT                =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=        1.330     CM/SEC
SLOPE                        =      2.00   PERCENT
DRAINAGE LENGTH              =    520.0    FEET


                        LAYER  9
                        --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      2.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                        LAYER 10
                        --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER  17
THICKNESS                    =      0.25   INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.3000E-08 CM/SEC


                        LAYER 11
                        --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.2890     CM/SEC
SLOPE                        =      2.00   PERCENT
DRAINAGE LENGTH              =    520.0    FEET


                        LAYER 12
                        --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      2.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD
```

```
                              LAYER 13
                              --------

                    TYPE 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER  16
      THICKNESS                    =     36.00   INCHES
      POROSITY                     =      0.4270 VOL/VOL
      FIELD CAPACITY               =      0.4180 VOL/VOL
      WILTING POINT                =      0.3670 VOL/VOL
      INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
      EFFECTIVE SAT. HYD. CONDUCT.=       0.1000E-06 CM/SEC


******************************************************************************

                 GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
------------------------------------------------------------------------------

                        VALID FOR 100 YEARS


         NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                  SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A
                  FAIR STAND OF GRASS, A SURFACE SLOPE OF 10.%
                  AND A SLOPE LENGTH OF  650. FEET.

        SCS RUNOFF CURVE NUMBER            =     79.24
        FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
        AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
        EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
        INITIAL WATER IN EVAPORATIVE ZONE  =      7.824  INCHES
        UPPER LIMIT OF EVAPORATIVE STORAGE =     10.186  INCHES
        FIELD CAPACITY OF EVAPORATIVE ZONE =      5.104  INCHES
        LOWER LIMIT OF EVAPORATIVE STORAGE =      2.552  INCHES
        SOIL EVAPORATION ZONE DEPTH        =     18.786  INCHES
        INITIAL SNOW WATER                 =      0.000  INCHES
        INITIAL INTERCEPTION WATER         =      0.000  INCHES
        INITIAL WATER IN LAYER MATERIALS   =    186.203  INCHES
        TOTAL INITIAL WATER                =    186.203  INCHES
        TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR


******************************************************************************

                        EVAPOTRANSPIRATION DATA   1
------------------------------------------------------------------------------

                        VALID FOR 100 YEARS


         NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                  MERIDIAN            MISSISSIPPI
             STATION LATITUDE                         =  32.60 DEGREES
             MAXIMUM LEAF AREA INDEX                  =   2.00
             START OF GROWING SEASON (JULIAN DATE)    =     63
             END OF GROWING SEASON (JULIAN DATE)      =    325
             EVAPORATIVE ZONE DEPTH                   =  22.0  INCHES
             AVERAGE ANNUAL WIND SPEED                =   6.00 MPH
             AVERAGE 1ST QUARTER RELATIVE HUMIDITY    =  71.0  %
             AVERAGE 2ND QUARTER RELATIVE HUMIDITY    =  72.0  %
             AVERAGE 3RD QUARTER RELATIVE HUMIDITY    =  76.0  %
```

AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 74.0 %

****

****

FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	11.1119	0.4630
2	0.1190	0.8500
3	0.0000	0.0000
4	10.2480	0.4270
5	2.9280	0.2440
6	143.6640	0.0730
7	4.3920	0.2440
8	0.5400	0.0450
9	0.0000	0.0000
10	0.1875	0.7500
11	0.0020	0.0100
12	0.0000	0.0000
13	15.3720	0.4270
TOTAL WATER IN LAYERS	188.564	
SNOW WATER	0.000	
INTERCEPTION WATER	0.000	
TOTAL FINAL WATER	188.564	

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	7.50	27225.000
RUNOFF	6.098	22136.1191
DRAINAGE COLLECTED FROM LAYER 2	0.02557	92.80529

```
PERCOLATION/LEAKAGE THROUGH LAYER  4      0.000032         0.11772

AVERAGE HEAD ON TOP OF LAYER  3          24.140

MAXIMUM HEAD ON TOP OF LAYER  3          42.258

LOCATION OF MAXIMUM HEAD IN LAYER  2
      (DISTANCE FROM DRAIN)              75.4 FEET

DRAINAGE COLLECTED FROM LAYER  8          0.00003          0.11762

PERCOLATION/LEAKAGE THROUGH LAYER 10      0.000000         0.00003

AVERAGE HEAD ON TOP OF LAYER  9           0.000

MAXIMUM HEAD ON TOP OF LAYER  9           0.022

LOCATION OF MAXIMUM HEAD IN LAYER  8
      (DISTANCE FROM DRAIN)               0.0 FEET

DRAINAGE COLLECTED FROM LAYER 11          0.00000          0.00000

PERCOLATION/LEAKAGE THROUGH LAYER 13      0.000000         0.00002

AVERAGE HEAD ON TOP OF LAYER 12           0.000

MAXIMUM HEAD ON TOP OF LAYER 12           0.000

LOCATION OF MAXIMUM HEAD IN LAYER 11
      (DISTANCE FROM DRAIN)               0.0 FEET

SNOW WATER                                4.91         17825.5879

MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.4630

MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.1160

 ***  Maximum heads are computed using McEnroe's equations.  ***

      Reference:  Maximum Saturated Depth over Landfill Liner
                  by Bruce M. McEnroe, University of Kansas
                  ASCE Journal of Environmental Engineering
                  Vol. 119, No. 2, March 1993, pp. 262-270.

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         AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH  100
------------------------------------------------------------------------------

                        JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                        -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                4.81     4.88     6.62     5.19     4.32     3.57
                          5.69     3.52     3.24     2.59     3.76     5.78

    STD. DEVIATIONS       2.40     2.34     3.52     2.73     2.43     2.10
                          2.28     1.68     2.08     2.26     2.08     2.60
```

Terracon

```
RUNOFF
------
  TOTALS                 2.207    2.320    3.419    1.943    1.135    0.386
                         0.446    0.088    0.072    0.263    0.302    1.807

  STD. DEVIATIONS        2.186    2.008    3.075    1.979    1.454    0.775
                         0.973    0.230    0.189    0.848    0.727    2.358

POTENTIAL EVAPOTRANSPIRATION
----------------------------
  TOTALS                 1.910    2.330    3.736    5.000    6.435    7.111
                         6.978    6.357    4.915    3.552    2.252    1.756

  STD. DEVIATIONS        0.182    0.215    0.282    0.300    0.285    0.276
                         0.320    0.288    0.283    0.218    0.160    0.151

ACTUAL EVAPOTRANSPIRATION
-------------------------
  TOTALS                 1.489    1.835    2.616    2.855    3.245    4.541
                         5.562    4.534    2.584    1.423    1.278    1.301

  STD. DEVIATIONS        0.216    0.281    0.436    0.713    0.985    1.152
                         0.940    1.152    0.931    0.466    0.333    0.240

LATERAL DRAINAGE COLLECTED FROM LAYER  2
----------------------------------------
  TOTALS                 0.6873   0.6531   0.7109   0.6691   0.6454   0.5392
                         0.4778   0.4033   0.3007   0.2893   0.3460   0.5606

  STD. DEVIATIONS        0.1116   0.0636   0.0480   0.0408   0.0607   0.0971
                         0.1221   0.1279   0.1568   0.1867   0.2071   0.1764

PERCOLATION/LEAKAGE THROUGH LAYER  4
------------------------------------
  TOTALS                 0.0009   0.0008   0.0009   0.0008   0.0008   0.0006
                         0.0004   0.0003   0.0002   0.0002   0.0003   0.0006

  STD. DEVIATIONS        0.0002   0.0001   0.0001   0.0001   0.0001   0.0002
                         0.0003   0.0003   0.0002   0.0002   0.0003   0.0003

LATERAL DRAINAGE COLLECTED FROM LAYER  8
----------------------------------------
  TOTALS                 0.0008   0.0008   0.0009   0.0008   0.0008   0.0006
                         0.0005   0.0003   0.0002   0.0002   0.0003   0.0006

  STD. DEVIATIONS        0.0002   0.0001   0.0001   0.0001   0.0001   0.0002
                         0.0003   0.0003   0.0002   0.0002   0.0003   0.0003

PERCOLATION/LEAKAGE THROUGH LAYER 10
------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 11
----------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
```

```
  PERCOLATION/LEAKAGE THROUGH LAYER 13
  ------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  3
  -------------------------------------
    AVERAGES              20.3777  21.5290  21.3559  20.7300  19.1101  15.2615
                          10.4216   6.9084   4.3363   4.5826   7.5138  14.9532

    STD. DEVIATIONS        4.3097   2.5803   1.8296   1.4306   2.3053   4.8050
                           6.9519   6.4608   5.5053   5.8881   7.1931   7.2279

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES               0.0001   0.0001   0.0001   0.0001   0.0001   0.0001
                           0.0001   0.0000   0.0000   0.0000   0.0000   0.0001

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  DAILY AVERAGE HEAD ON TOP OF LAYER 12
  -------------------------------------
    AVERAGES               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

*******************************************************************************


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     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------

                                     INCHES           CU. FEET        PERCENT
                              -------------------   -------------   ---------
 PRECIPITATION                  53.96     (   8.608)    195886.4      100.00

 RUNOFF                         14.387    (  6.6203)     52224.99     26.661

 POTENTIAL EVAPOTRANSPIRATION   52.332    (  0.9310)    189964.36

 ACTUAL EVAPOTRANSPIRATION      33.263    (  2.3192)    120744.69     61.640

 LATERAL DRAINAGE COLLECTED      6.28263 (  0.90770)     22805.955   11.64244
   FROM LAYER  2

 PERCOLATION/LEAKAGE THROUGH     0.00690 (  0.00149)        25.055    0.01279
   LAYER  4

 AVERAGE HEAD ON TOP            13.923    (   3.033)
   OF LAYER  3
```

```
 LATERAL DRAINAGE COLLECTED      0.00690 (  0.00149)        25.046     0.01279
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH     0.00000 (  0.00000)         0.009     0.00000
   LAYER 10

 AVERAGE HEAD ON TOP             0.000   (    0.000)
   OF LAYER  9

 LATERAL DRAINAGE COLLECTED      0.00000 (  0.00000)         0.000     0.00000
   FROM LAYER 11

 PERCOLATION/LEAKAGE THROUGH     0.00000 (  0.00000)         0.009     0.00000
   LAYER 13

 AVERAGE HEAD ON TOP             0.000   (    0.000)
   OF LAYER 12

 CHANGE IN WATER STORAGE         0.024   (  1.8954)         85.73      0.044

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