Prepared for

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CCR SURFACE IMPOUNDMENT FINAL CLOSURE PLAN

HENNEPIN POWER PLANT
EAST ASH POND
(IEPA ID W1550100002-05)
Hennepin, Illinois

Prepared by

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1. INTRODUCTION

Dynegy Midwest Generation, LLC (Dynegy) is the owner of the coal-fired Hennepin Power Plant (HPP), also referred to as Hennepin Power Station (HEN), in Hennepin, Illinois. Five Coal Combustion Residuals (CCR) surface impoundments are present at the Hennepin Power Station; all were closed prior to promulgation 35 Ill. Admin. Code 845, Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments (Part 845) except for the East Ash Pond (EAP). This Closure Plan is for the EAP only. The EAP has an Illinois Environmental Protection Agency (IEPA) identification number of W1550100002-05.

1.1. Proposed Selected Closure Method

<u>Section 845.720(b)(3):</u> *The final closure plan must identify the proposed selected closure method and must include the information required in subsection (a)(1) and the closure alternatives analysis specified in Section 845.710.*

Based on the Closure Alternatives Analysis, closure with a final cover system has been identified as the most appropriate closure method, also known as Closure-in-Place (CIP, per Section 845.740). An alternatives analysis, provided in **Attachment A**, was prepared to evaluate CIP versus Closure by Removal (CBR, per Section 845.750) and CIP was the most appropriate closure method for the EAP. Information developed to support the Closure Alternatives Analysis is provided in **Attachment B**.

1.2. Organization of Final Closure Plan

This Final Closure Plan is organized in the following manner:

- **Section 2** includes the Final Closure Plan, as required by Section 875.720(a)(1);
- **Section 3** includes a summary of amendments of the Closure Plan;
- **Section 4** includes a discussion of how the closure using a final cover system will comply with the performance and design requirements of Section 845.720;
- **Section 5** includes a Certification from a Qualified Professional Engineer; and
- **Section 6** includes reference documents used in the development of this Final Closure Plan.

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2. FINAL CLOSURE PLAN

<u>Section 845.720(a)(1):</u> *Content of the Preliminary Closure Plan. The owner or operator of a new CCR surface impoundment or an existing CCR surface impoundment not required to close under Section 845.700 must prepare a preliminary written closure plan that describes the steps necessary to close the CCR surface impoundment at any point during the active life of the CCR surface impoundment consistent with recognized and generally accepted engineering practices.*

This section includes the final closure plan for the EAP, as required by Section 845.720(a)(1). Specific requirements of the closure plan and the relevant regulatory citations are included in the following sections.

2.1. Narrative Closure Description

Section 845.720(a)(1)(A): A narrative description of how the CCR surface impoundment will be closed in accordance with this Part.

The EAP will be closed in place and covered with a final cover compliant with 40 C.F.R. § 257.102(d)(3) and Section 845.720(a)(1)(C). The EAP is a lined CCR surface impoundment. The bottom liner includes a 4-ft thick compacted clay liner with a design permeability of 1×10^{-7} cm/sec overlying a 1-ft thick layer of sand. The side slope liner consists of two layers of 45-mil reinforced polypropylene geomembrane overlying 1-ft of compacted clay [1]. Therefore, closing the EAP with a final cover system will result in the CCR retained within the EAP being encapsulated within a continuous liner system on the sides, bottom, and top of the CCR.

Closure of the EAP with a final cover system will include the following tasks:

- Preparing the site for closure by establishing perimeter stormwater Best Management Practices (BMPs), as and if needed, at the construction limits of disturbance.
- Unwatering the EAP by removing free surface liquids and pumping them to the adjacent Leachate Pond or Polishing Pond (non-CCR surface impoundments) for ultimate discharge at National Pollutant Discharge Elimination System (NPDES) Outfall 003.
- Abandoning existing outflow structures and culverts connecting the EAP to the adjacent Leachate Pond or Polishing Pond, in order to prevent CCR from migrating through these conduits during post-closure conditions, by:
    - For the primary spillway structure, demolishing the above-grade portions of the concrete intake structure and catwalk. Below-grade portions will be left in place and placed beneath by the final cover system. The interior of the riser and culvert

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will then be cleaned via pressure washing and sealed by filling with cement-bentonite grout.

  - For the 18-inch diameter spillway connecting the EAP to the Leachate Pond, cleaning the interior of the pipe via pressure washing and sealing by filling the interior of the pipe with cement bentonite grout.

  - For the two, 12-inch plastic pipes, cutting off the pipes behind the existing EAP side-slope geomembrane liner, capping the pipes, backfilling the area with soil, and patching the EAP geomembrane liner.

- Abandoning existing geotechnical piezometers HEN-P006 and HEN-P007 that will not be utilized as post-closure instrumentation. Abandonment will be performed in accordance with Illinois monitoring well regulations.

- Establishing a temporary dewatering and water management system within the EAP consisting of ditches and sumps to support passive (i.e., gravity) dewatering of CCR for stabilization and to collect contact stormwater during closure and maintain the EAP in an unwatered state. Contact stormwater, during construction, will be pumped to the Leachate Pond or Polishing Pond for discharge at NDPES Outfall 003.

- Stabilizing the EAP by excavating unsaturated CCR from the west side of the EAP and using it as subgrade fill within the lower east side of the EAP. CCR will be placed in lifts and compacted to provide a subgrade suitable for construction of a final cover system. Dewatering will be performed, as needed to support construction activity and fill placement, using the water management system.

  - Approximately 7,000 CY (9,500 tons) of bottom ash ballast will be excavated from the adjacent Hennepin CCR Landfill and beneficially used as compacted subgrade fill, to supplement CCR excavated from within the EAP. The bottom ash ballast material is the only CCR that has been placed in the Hennepin Landfill, and was utilized to provide freeze protection for the underlying liner system. Production CCR was never placed in the Hennepin Landfill.

- Modifying the dike between the EAP and adjacent Polishing Pond by lowering the grades to be consistent with the final cover subgrades, thereby allowing stormwater to flow by gravity into the Polishing Pond. The Polishing Pond will remain in-place as a post-closure, non-CCR, stormwater management pond.

- Constructing a final cover system extending over the entire footprint of the EAP that contains CCR, and includes, from bottom to top:

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  - A 40-mil linear low-density polyethylene (LLDPE) geomembrane, placed on a prepared subgrade with rocks no larger than one inch in diameter and other sharp objects removed prior to placement;
  - A nonwoven geotextile cushioning layer, to protect the geomembrane from rocks and/or sharp objects in the cover soil;
  - Based on a demonstration to be submitted to IEPA for approval pursuant to Section 845.750(c)(2), 1.5 ft of cover soil to protect the geomembrane from freeze thaw action, burrowing animals, and erosion and 0.5 ft of topsoil capable of supporting vegetation.
  - The final cover system grades will be approximately 2.5% over the majority of the EAP, although 20% (5 horizontal to 1 vertical [5H:1V]) grades will be used in limited areas, where needed to tie the final cover system into existing grades.
  - The final cover system will include an anchor trench for the geosynthetic materials along the entire perimeter of the EAP to secure the final cover system into existing grades. The anchor trench will be placed beyond the current limits of the bottom liner to provide a continuous containment system for the retained CCR.
  - Existing groundwater monitoring wells MW-52, MW-53, MW-54, MW-55, XPW-01, XPW-02, and XPW-03 will be retained and modified by extending the wells through the final cover system, sealing the penetration with a pipe boot, and constructing a new surface completion on top of the final cover.
- Constructing a post-closure non-contact stormwater management system consisting of:
  - Stormwater channels leading from west to east to convey stormwater into the Polishing Pond; and
  - Riprap-lined downchutes where channels flow from the EAP final cover and lead into the Polishing Pond, to reduce erosion.
- Establishing vegetation on the final cover system by:
  - Fertilizing the topsoil, as needed to support vegetation, based on agronomical soil tests;
  - Seeding the topsoil with a suitable grass seed for local climatic and soil conditions;

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- Providing temporary BMPs measures such as mulch, erosion control blankets, silt fences, and/or straw wattles, as necessary to reduce the potential for soil erosion until vegetation is established; and

- Restoring the site, after vegetation is established and the site is stabilized, by removing stormwater BMPs and temporary stabilization measures that are no longer needed.

Permit-level engineering drawings and material specifications for the closure are provided in **Attachment C**.

2.2. Decontamination of CCR Surface Impoundment

Section 845.720(a)(1)(B): If closure of the CCR surface impoundment will be accomplished through removal of CCR from the CCR surface impoundment, a description of the procedures to remove the CCR and decontaminate the CCR surface impoundment in accordance with Section 845.740.

The EAP will be closed-in-place and will not be closed by removal of CCR. Therefore, 845.720(a)(1)(B) is not applicable.

2.3. Final Cover System

Section 845.720(a)(1)(C): If closure of the CCR surface impoundment will be accomplished by leaving CCR in place, a description of the final cover system, designed in accordance with Section 845.750, and the methods and procedures to be used to install the final cover. The closure plan must also discuss how the final cover system will achieve the performance standards specified in Section 845.750.

A description of the final cover system design, methods and procedures used for installation, and how the final cover system will achieve the Section 845.750 performance standards is provided in **Section 4** of this Closure Plan.

2.4. Maximum CCR Inventory

Section 845.720(a)(1)(D): An estimate of the maximum inventory of CCR ever on-site over the active life of the CCR surface impoundment.

The maximum inventory of CCR ever on-site within the EAP is approximately 680,000 cubic yards. This inventory will increase by approximately 7,000 CY to approximately 687,000 CY through the excavation of currently present, onsite-generated, bottom ash ballast from the Hennepin Landfill and utilizing it in the EAP as compacted subgrade fill.

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2.5. Largest Surface Area Estimate

Section 845.720(a)(1)(E): An estimate of the largest area of the CCR surface impoundment ever requiring a final cover (see Section 845.750), at any time during the CCR surface impoundment's active life.

The largest surface area of the EAP, in plan view, is approximately 21.1 acres [2]. Final cover will be placed over an area of approximately 22.5 acres to extend completely across the surface area of the EAP and beyond the limits of CCR and the existing liner system in plan view. This will provide a continuous encapsulation system consisting of the final cover on the top of the EAP and the existing liner system on the sides and bottom of the EAP.

2.6. Closure Completion Schedule

Section 845.720(a)(1)(F): A schedule for completing all activities necessary to satisfy the closure criteria in this Section, including an estimate of the year in which all closure activities for the CCR surface impoundment will be completed. The schedule should provide sufficient information to describe the sequential steps that will be taken to close the CCR surface impoundment, including identification of major milestones such as coordinating with and obtaining necessary approvals and permits from other agencies, the dewatering and stabilization phases of CCR surface impoundment closure, or installation of the final cover system, and the estimated timeframes to complete each step or phase of CCR surface impoundment closure.

A milestone closure completion schedule has been prepared and is provided in **Table 1**. Key sequential phases and sub-tasks that will be completed as part of the closure will include:

- Agency Coordinating, Approvals, and Permitting
    - Approval of the closure Construction Permit Application by IEPA.
    - Obtaining an NDPES permit modification to allow dewatering flows from the EAP to be discharged via NPDES Outfall 003 during closure.
    - Obtaining a construction permit from the Illinois Department of Natural Resources (IDNR), Office of Water Resources (OWR), Dam Safety Program (DSP) to allow the eastern and western EAP embankments to be modified and outlet structures to be abandoned.
    - Obtaining a NPDES permit for construction activities (i.e., a Land Disturbance Permit) from IEPA.
- Final Design and Bidding

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- Completion of final design documents, including drawings and specifications.
- Bidding and selection of a closure construction contractor.
- Dewater and Stabilize CCR, Install Final Cover System
- Closure contractor mobilization and material procurement.
- Installing stormwater BMPs around the construction area, per the Land Disturbance Permit.
- Unwatering the EAP by pumping impounded water to the Polishing Pond.
- Abandoning existing outfall structures and culverts.
- Stabilizing the subgrade through dewatering and the placement of compacted CCR fill.
- Constructing design final cover subgrades, including stormwater channel subgrades and modifications to the EAP east dike.
- Installing the final cover system geosynthetics and anchor trench.
- Placing cover soil and topsoil over the geosynthetics.

- Site Restoration
  - Constructing riprap-lined letdown structures.
  - Seeding and stabilizing the surface of the final cover system and other disturbed areas and allowing the vegetation to become established.
  - Removing temporary stormwater BMPs and other temporary stabilization measures, after vegetation is established.
  - Closure contractor demobilization from the site.

The project is expected to be completed by April of 2026. Additional project schedule may be required if delays in permitting or significant weather delays occur.

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Table 1 – Closure Completion Milestone Schedule

Milestone	Timeframe (Preliminary Estimates)
Final Closure Plan Submittal	February 2022
Agency Coordination, Approvals, and Permitting • Obtain state permits, as needed, for dewatering, water discharge, land disturbance, and dam modifications.	6 to 12 months after Final Closure Plan Approval
Final Design and Bid Process • Complete final design of the closure and select a construction contractor.	2 to 18 months after Agency Coordination, Approvals, and Permitting
Dewater and Stabilize CCR, Install Final Cover System • Complete contractor mobilization, installation of stormwater BMPs, and unwatering of the EAP • Abandon outfall structures, stabilize the EAP, and complete grading. • Install the final cover system and stormwater downchutes.	3 to 8 months after necessary permits are issued
Site Restoration • Seed and stabilize the EAP. • Complete contractor demobilization.	1 to 5 months after the final cover system is complete
Timeframe to Complete Closure	Prior to April 2026

Section 845.720(a)(1)(F) (Continued): When preparing the preliminary written closure plan, if the owner or operator of a CCR surface impoundment estimates that the time required to complete closure will exceed the timeframes specified in Section 845.760(a), the preliminary written closure plan must include the site-specific information, factors and considerations that would support any time extension sought under Section 845.760(b).

The time required to complete closure construction is not currently expected to exceed the timeframe specified in Section 845.760(a). Therefore, closure extensions for the EAP are not being sought at this time.

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3. AMENDMENTS OF FINAL CLOSURE PLAN

<u>Section 845.720(b)(4):</u> *If a final written closure plan revision is necessary after closure activities have started for a CCR surface impoundment, the owner or operator must submit a request to modify the construction permit within 60 days following the triggering event.*

If revisions are required for this Final Closure Plan, the owner will submit a request to modify the construction permit within 60 days following the triggering event.

Table 2. CCR Final Closure Plan Revisions

Revision Number and Date	Pages or Section	Description of Revision	Professional Engineer Certifying Plan

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4. CLOSURE WITH FINAL COVER SYSTEM

This section includes a description of the final closure with a final cover that will be completed for the EAP surface impoundment, including principal design and construction features, material specifications, and a discussion of how each feature is in accordance with the requirements of Section 845.750. Drawings showing each design feature and material specifications are provided in **Attachment C**.

4.1. Minimization of Post-Closure Infiltration and Releases

<u>Section 845.750(a)(1):</u> *The owner or operator of a CCR surface impoundment must ensure that, at a minimum, the CCR surface impoundment is closed in a manner that will: Control, minimize or eliminate, to the maximum extent feasible, post-closure infiltration of liquids into the waste and releases of CCR, leachate, or contaminated run-off to the ground or surface waters or to the atmosphere.*

Closure will minimize the post-closure infiltration of liquids into the retained CCR through the installation of a final cover system with the following design features and specifications:

- A 40-mil LLDPE geomembrane low-permeability layer will placed on the prepared subgrade to control, minimize vertical infiltration into the surface impoundment. The geomembrane will be constructed on a subgrade that is free of sharp rocks or other debris and will be protected from damage by installing a geotextile cushion layer and a total of two feet of cover soil and topsoil over the top of the geomembrane.

- Surface stormwater will be routed off of the top of the final cover by the construction of a free-draining post-closure stormwater management system including channels and letdown structures. The stormwater management system will drain by gravity and preclude water impoundment on top of the final cover system, thereby minimizing post-closure infiltration into the CCR.

Releases of CCR leachate and run-off into the groundwater, surface waters, and/or atmosphere will be minimized by:

- The EAP includes an existing liner system, consisting of both compacted clay on lower portion and the bottom of the liner system and a geomembrane on the side slopes of the impoundment. This liner system will be retained and will continue to minimize any releases of CCR leachate into ground or surface waters.
    - The final cover system will tie into the existing liner system, by constructing a final cover anchor trench at or beyond the horizontal limits of the liner system. The final cover will therefore provide continuous encapsulation between the CCR and

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surrounding environment on the top, bottom, and sides of the CCR, utilizing the final cover and existing liner system.

  - This continuous barrier will result in the CCR being physically isolated from the surrounding environment on all sides, including the groundwater, surface water, and atmosphere.

- CCR leachate (e.g., pore water within the CCR) volumes will be minimized via the installation of the final cover system including a low-permeability geomembrane layer. The final cover system will minimize infiltration and therefore the amount of leachate within the CCR.

- Releases of CCR leachate via the existing outlet culverts will be prevented by sealing all culverts connecting the EAP to adjacent areas. Sealing will include the capping of plastic culverts and the cleaning of concrete pipe culverts and filling with cement-bentonite grout, thereby removing potential flow paths that could otherwise allow leachate to be released.

4.2. Preclusion of Future Impoundment

<u>Section 845.750(a)(2):</u> *Preclude the probability of future impoundment of water, sediment, or slurry.*

A final cover system will be installed on top of the EAP. All areas of the final cover system will be sloped to positively drain to the exterior of the EAP and preclude future impoundment of water, sediment, or slurry. This will include installing cross-slopes at approximately 2.5% grades, slopes at up to 20% (e.g., 5 horizontal to 1 vertical [5H:1V]) grades at the tie-in between the final cover system and existing grades, and stormwater channel grades at 1% slopes. Stormwater channels will flow by gravity into the adjacent non-CCR Polishing Pond via riprap-lined downchutes. Hydrologic and hydraulic calculations used to design the stormwater channels and other control features to preclude impoundment are provided in **Attachment D**.

4.3. Provisions for Preventing Instability, Sloughing and Movement

<u>Section 845.750(a)(3):</u> *Include measures that provide for major slope stability to prevent the sloughing or movement of the final cover system during the closure and post-closure care period.*

The perimeter berms of the EAP are constructed out of compacted fill materials and are founded on a layer of dense to very dense sand and gravel. The east berm between the EAP and Polishing Pond will be modified during closure to allow for stormwater to gravity-flow into the Polishing Pond. The west berm between the EAP and East Ash Pond No. 4 will generally be maintained as-is, although the final cover system will extend over the top of the berm. The effects of these modifications have been evaluated by performing global slope stability analyses considering post-

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closure conditions. The resulting factors of safety exceed typical regulatory minimum values for static and seismic loading conditions. Slope stability analyses are provided in **Attachment E**.

Sloughing and movement of the final cover system will be minimized by constructing the final cover system at relatively flat slopes, including 2.5% over most of the final cover and 20% (5H:1V) at the edges of the final cover, as necessary to tie into existing grades. The limited areas of 5H:1V slope are relatively flat and are limited to 10 ft in total slope height. The potential for sloughing and movement of the final cover system has been evaluated by performing veneer stability analyses for the various interfaces within the final cover system. The resulting factors of safety exceed typical minimum values for static and seismic loading conditions. Veneer stability analyses are provided in **Attachment E**.

4.4. Minimize the Need for Further Maintenance

<u>Section 845.750(a)(4):</u> *Minimize the need for further maintenance of the CCR surface impoundment.*

Future maintenance needs will be minimized using the following design features:

- The final cover system will be installed at gentle 2.5% slopes over most of the final closure with 20% slopes in limited areas at the extents of the final cover, with maximum heights of 10 ft, as needed to tie into existing grades.
  - These relatively flat slopes will minimize erosion of the final cover soils and thereby minimize maintenance needs by reducing stormwater flow velocities relative to steeper slopes.
  - The relatively flat slopes will also promote routine mowing of vegetation of the final cover system by allowing tractor-based mowing equipment to operate on the slopes with a reduced risk of equipment flip-over.
- The final cover, outside of stormwater channels, will be stabilized by placing topsoil, fertilizing the topsoil, establishing vegetation using suitable grass species.
  - The vegetation will minimize erosion of the final cover system by stabilizing the topsoil. The use of fertilizer and selection of a suitable grass species will minimize maintenance required to repair areas of poor vegetation establishment.
- Stormwater channels will be stabilized with erosion control blankets and straw wattles. Where the stormwater channels pass through the EAP east perimeter dike and flow into the Polishing Pond they will be armored with riprap erosion protection. Erosion control

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blankets and riprap will minimize post-closure erosion and associated maintenance for stormwater channels.

- Calculations used to design the stormwater channel stabilization and riprap armoring were based on the 100-year, 24-hour, and 25-year, 24-hour storms. These calculations are provided in **Attachment D**.

4.5. Be Completed in Shortest Amount of Time

<u>Section 845.750(a)(5):</u> *Be completed in the shortest amount of time consistent with recognized and generally accepted engineering practices.*

Closure construction is expected to be completed within an amount of time that is consistent with recognized and generally accepted timeframes required to permit, design, bid, and construct a CCR impoundment final closure system, with a consideration of other permits form multiple agencies that are also required for the project. An estimated closure construction schedule is provided in **Section 2.6**. It should be noted that this schedule may change based on contractor, equipment, and material availability and actual weather conditions at the time at which closure occurs.

4.6. Drainage and Stabilization

<u>Section 845.750(b)(1):</u> *Free liquids must be eliminated by removing liquid wastes or solidifying the remaining wastes and waste residues.*

<u>Section 845.750(b)(2):</u> *Remaining wastes must be stabilized sufficiently to support the final cover system.*

Impounded water will be removed from the EAP and pumped into the Polishing Pond during the initial portions of closure construction. Remaining CCR will be stabilized by one of the following methods:

- Unsaturated subgrade fill, consisting of CCR excavated from within the EAP, beneficially placed bottom ash removed from the on-site landfill, or non-CCR imported contouring fill soil, will be placed over the top the existing CCR subgrade, in a thickness of approximately five feet, to provide a bridge lift that stabilizes the subgrade and allows equipment to work on top of the CCR.

- In areas where a bridge lift is not feasible due to the existing grade of the CCR being relatively close to final cover system subgrades, the phreatic water level in the CCR will be lowered by constructing a system of shallow trenches and/or sumps. Phreatic water will be allowed to gravity-drain to the sumps and will be removed and pumped to the Polishing Pond, until the phreatic water level is approximately five feet below design subgrades.

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Subgrade fill will be placed and compacted on top of stabilized subgrades utilizing compacted lifts, until design subgrades for the final cover system have been achieved.

4.7. Final Cover System

<u>Section 845.750(c):</u> *If a CCR surface impoundment is closed by leaving CCR in place, the owner or operator must install a final cover system that is designed to minimize infiltration and erosion, and, at a minimum, meets the requirements of this subsection (c) unless the owner or operator demonstrates that another construction technique or material provides equivalent or superior performance to the requirements of this subsection (c) and is approved by the Agency. The final cover system must consist of a low permeability layer and a final protective layer. The design of the final cover system must be included in the preliminary and final written closure plans required by Section 845.720 and the construction permit application for closure submitted to the Agency.*

A final cover system has been designed consistent with the requirements of Section 845.720(c). The final cover will use a geomembrane as a low-permeability layer. The design of the final cover system is discussed within this section.

4.7.1. Low Permeability Layer - Geomembrane

<u>Section 845.750(c)(1)(B):</u> *A geomembrane constructed in accordance with the following standards: i) The geosynthetic membrane must have a minimum thickness of 40 mil (0.04 inches) and, in terms of hydraulic flux, must be equivalent or superior to a three-foot layer of soil with a hydraulic conductivity of 1 x 10-7 cm/sec; ii) The geomembrane must have strength to withstand the normal stresses imposed by the waste stabilization process; and (iii) The geomembrane must be placed over a prepared base free from sharp objects and other materials that may cause damage.*

The geomembrane will consist of a 40-mil linear low-density polyethylene (LLDPE) layer. Ramboll completed a Hydrologic Evaluation of Landfill Performance (HELP) [3] model to compare flux through the geomembrane cover to an equivalent cover system with 3 ft of 1×10^{-7} cm/sec clay, in order to demonstrate that the geomembrane final cover is superior to a soil-only cover. The HELP modeling estimated a total infiltration of 0.32 in of water per year (in/yr) for the geomembrane cover system, relative to 1.4 in/year for the cover system using 3 ft of 1×10^{-7} cm/sec clay [4]. Therefore, the proposed geomembrane final cover system is superior to a cover system using 3 ft of 1×10^{-7} cm/sec clay, as infiltration is reduced by a factor of approximately 4.

The geomembrane will be installed on a prepared subgrade, after the underlying CCR has been stabilized. Therefore, additional normal stresses will not be imparted on the geomembrane due to the waste stabilization process.

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The subgrade (e.g., base) for the geomembrane will be visually inspected and sharp objects such as rocks or debris that may damage the geomembrane will be removed, prior to deployment of the geomembrane.

4.7.2. Final Protective Layer

Section 845.750(c)(2)(A): *The final protective layer must meet the following requirements…A) Cover the entire low permeability layer; B) Be at least three feet thick, be sufficient to protect the low permeability layer from freezing, and minimize root penetration of the low permeability layer; C) Consist of soil material capable of supporting vegetation; D) Be placed as soon as possible after placement of the low permeability layer; and E) Be covered with vegetation to minimize wind and water erosion.*

A final protective layer will be placed over and extend slightly beyond the entire geomembrane low-permeability layer in plan. Based on a demonstration to be submitted to IEPA for approval pursuant to Section 845.750(c)(2), the protective layer will include, from bottom to top, a nonwoven geotextile, a 1.5-ft thick cover soil layer, and a 0.5-ft thick topsoil layer, for a total thickness of 2 ft.

The nonwoven geotextile and 1.5-ft thick cover soil layer will protect the geomembrane from freezing and root penetration. The geotextile and cover soil will be placed as soon as practical after the geomembrane has been deployed and both quality assurance and quality control testing has been performed on the geomembrane seams.

The 0.5-ft thick topsoil layer will be fertilized, as necessary to support appropriate grass species, in order to vegetate the final protective layer.

4.8. Uses of CCR in Closure

Section 845.750(d): *This subsection specifies the allowable uses of CCR in the closure of CCR surface impoundments closing under Section 845.700. Notwithstanding the prohibition on further placement in Section 845.700, CCR may be placed in these surface impoundments, but only for purposes of grading and contouring in the design and construction of the final cover system, if: 1) The CCR placed was generated at the facility and is located at the facility at the time closure was initiated; 2) CCR is placed entirely above the elevation of CCR in the surface impoundment, following dewatering and stabilization (see subsection (b)); 3) The CCR is placed entirely within the perimeter berms of the CCR surface impoundment.*

Approximately 7,000 cubic yards (9,500 tons) of bottom ash were beneficially placed over the primary geomembrane liner system in the adjacent Hennepin Landfill [5]. Production CCR was never placed in the Hennepin Landfill and this bottom ash is the only material that has been placed in the Hennepin Landfill to date. This bottom ash was generated onsite.

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This bottom ash will be excavated from the Hennepin Landfill and transported to the adjacent EAP to be beneficially used as compacted structural subgrade fill below the final cover system. The bottom ash will be placed on top of the existing subgrade (i.e., existing elevation of CCR in the surface impoundment) after dewatering of the EAP and used as a free-draining subgrade stabilization layer. CCR placement will only occur completely beneath the limits of the EAP final cover system. This is in accordance with the Section 845.750(d) criteria.

4.9. Final Cover System Slopes

Section 845.750(d)(4): The final cover system is constructed with either: A) A slope not steeper than 5% grade after allowance for settlement; or B) At a steeper grade, if the Agency determines that the steeper slope is necessary, based on conditions at the site, to facilitate run-off and minimize erosion, and that side slopes are evaluated for erosion potential based on a stability analysis to evaluate possible erosion potential. The stability analysis, at a minimum, must evaluate the site geology; characterize soil shear strength; construct a slope stability model; establish groundwater and seepage conditions, if any; select loading conditions; locate critical failure surface; and iterate until minimum factor of safety is achieved.

Final cover slopes will typically consist of 2.5% cross-slopes and 1% stormwater flowline slopes within the limits of final cover, which are less than 5%.

However, short lengths of 20% final cover slopes, up to 10 ft in height, will be used in limited areas near the perimeter of the final cover, as needed to tie the final cover into the existing grades, as shown in the drawing package provided in **Attachment C**. Twenty percent slopes will be utilized to route the majority of stormwater in the EAP to the east, into the Polishing Pond, and reduce the volume of post-closure stormwater runoff that is routed to the west (towards the closed East Ash Pond No. 4) and the north (towards the closed East Ash Pond No. 2 and the inactive Hennepin Landfill). This approach will minimize maintenance at these other CCR units that could be induced if significant stormwater flows from the EAP were routed onto the CCR units.

The stability of 20% final cover slopes has been evaluated both for the final cover system itself (e.g., veneer stability) and the global stability of the slope. These calculations included characterizing soil shear strength based on site geology, constructing slope stability models, establishing groundwater seepage conditions, selecting loading conditions, locating the critical failure surface, and iterating until minimum factors of safety were calculated. These calculations are provided in **Attachment E**. Resulting factors of safety exceed typical minimum factors of safety for both global and veneer stability.

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5. CERTIFICATION FROM A QUALIFIED PROFESSIONAL ENGINEER

Section 845.720(b)(5): *The owner or operator of the CCR surface impoundment must obtain and submit with its construction permit application for closure a written certification from a qualified professional engineer that the final written closure plan meets the requirements of this Part.*

I, Lucas P. Carr, being a Registered Professional Engineer in good standing in the State of Illinois, do hereby certify, to the best of my knowledge, information, and belief, that the information contained in this construction permit application has been prepared in accordance with the accepted practice of engineering and the requirements of Title 35, Subtitle G, Chapter I, Subchapter j, Section 845.720 of the Illinois Administrative Code.

____

Printed Name

____

Signature Date

____

Registration Number State Expiration Date

Affix Seal

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6. REFERENCES

[1] AECOM, "CCR Certification Report: Liner Design Criteria Evaluation for East Ash Pond at Hennepin Power Station," St. Louis, MO, October 2016.

[2] IngenAE, LLC, "Luminant, Dynegy Midwest Generation, LLC, Hennepin Power Plant, CCR Facility Boundary Exhibit," Earth City, MO, September 21, 2021.

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[4] Ramboll, "Groundwtaer Model Report, East Ash Pond, Hennepin Power Plant, Henenpin, Illinois," November 2021.

[5] D. Jones and S. F. Putrich, "Construction Documentation, Hennepin Station - Phase 1 Landfill Frost Protection Layer Installation, CEC Project No. 082-255.6006," March 3, 2021.

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ATTACHMENT A

Closure Alternatives Analysis

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Closure Alternatives Analysis
East Ash Pond
Hennepin Power Plant
Hennepin, Illinois

November 8, 2021

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Abbreviations

AACE	Association for the Advancement of Cost Engineering
BMP	Best Management Practice
CAA	Closure Alternatives Analysis
CBR-Offsite	Closure-by-Removal with Off-Site CCR Disposal
CCR	Coal Combustion Residual
CIP	Closure-in-Place
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CQA	Construction Quality Assurance
CY	Cubic Yard
DMG	Dynegy Midwest Generation, LLC
EAP	East Ash Pond
EJ	Environmental Justice
GHG	Greenhouse Gas
GWPS	Groundwater Protection Standards
IAC	Illinois Administrative Code
ID	Identification
IDNR	Illinois Department of Natural Resources
IEPA	Illinois Environmental Protection Agency
LLDPE	Linear Low-Density Polyethylene
N_2O	Nitrous Oxide
NID	National Inventory of Dams
NO_x	Nitrogen Oxides
NPDES	National Pollutant Discharge Elimination System
PM	Particulate Matter
US DOT	United States Department of Transportation
USGS	United States Geological Survey
VOC	Volatile Organic Compound

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Summary of Findings

Title 35, Part 845 of the Illinois Administrative Code (IAC; IEPA, 2021a) requires the development of a Closure Alternatives Analysis (CAA) prior to undertaking closure activities at certain surface impoundments containing coal combustion residuals (CCRs) in the State of Illinois. Pursuant to requirements under IAC Section 845.710, this report presents a CAA for the East Ash Pond (EAP) located on Dynegy Midwest Generation, LLC's (DMG) Hennepin Power Plant property near the Village of Hennepin, Illinois. The goal of a CAA is to holistically evaluate potential closure scenarios with respect to a wide range of factors, including the efficiency, reliability, and ease of implementation of the closure scenario; its potential positive and negative short- and long-term impacts on human health and the environment; and its ability to address concerns raised by residents (IAC Part 845; IEPA, 2021a). Gradient evaluated two specific closure scenarios for the EAP: Closure-in-Place (CIP) and Closure-by-Removal with Off-Site CCR Disposal (CBR-Offsite). The CIP scenario entails capping the EAP with a new cover system consisting of, from bottom to top, a geomembrane layer, a geotextile cushion if needed, and 24 inches of vegetated soil. The CBR-Offsite scenario entails excavating all of the CCR from the EAP and transporting it to an off-Site landfill for disposal.

IAC Section 845.710(c)(2) requires CAAs to "[i]dentify whether the facility has an onsite landfill with remaining capacity that can legally accept CCR, and, if not, whether constructing an onsite landfill is possible" (IEPA, 2021a). There is an existing CCR landfill at the Hennepin site: the Hennepin Landfill. However, the single cell at the Hennepin Landfill is only 4.5 acres in size (Geosyntec, 2021a). This landfill does not currently have the capacity to contain all of the CCR that would be excavated from the EAP under the CBR-Offsite scenario (Geosyntec, 2021a). Due to the presence of other closed impoundments in the immediate vicinity of the landfill, the landfill also cannot be expanded in order to increase its capacity. No other areas on the property were identified that are suitable for construction of a new on-Site landfill (Geosyntec, 2021a). Construction of a new on-Site landfill would also interfere with existing plans to re-develop the property for use in utility-scale solar generation and battery storage; construction of the new on-Site landfill (and other closure activities) would need to occur concurrently with solar re-development activities, resulting in increased traffic on Site access roads and greater risks to workers due to on-Site accidents (Geosyntec, 2021a). In summary, neither expansion of the existing on-Site landfill nor construction of a new on-Site landfill is a viable alternative at this Site.

Table S.1 summarizes the expected impacts of the CIP and CBR-Offsite closure scenarios with regard to each of the factors specified under IAC Section 845.710 (IEPA, 2021a). Based on this evaluation and the additional details provided in Section 2 of this report, CIP has been identified as the most appropriate closure scenario for the EAP. Key benefits of the CIP scenario relative to the CBR-Offsite scenario include the more rapid re-development of the Site for use in utility-scale solar generation and greatly reduced impacts to workers, community members, and the environment during construction (*e.g.*, fewer constructed-related accidents, lower energy demands, less air pollution and greenhouse gas [GHG] emissions, less traffic, and potentially lower impacts to environmental justice [EJ] communities). This conclusion is subject to change as additional data are collected and following the completion of an upcoming public meeting, which will be held in December 2021 pursuant to requirements under IAC Section 845.710(e). Following the public meeting, a final closure decision will be made based on the considerations identified in this report, the results of additional data that are collected, and any additional considerations that arise during the public meeting. The final closure recommendation will be provided in a Final Closure Plan, which will be submitted to the Illinois Environmental Protection Agency (IEPA) as described under IAC Section 845.720(b) (IEPA, 2021a).

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Table S.1 Comparison of Proposed Closure Scenarios

Evaluation Factor (Report Section; IAC Part 845 Section)	Closure Scenario	
	CIP	CBR-Offsite
Closure Alternative Descriptions (Section 2.1, IAC Section 845.710(c))	The EAP will be capped in place with a new cover system consisting of, from bottom to top, a geomembrane layer, a geotextile cushion if needed, and 24 inches of vegetated soil.	All CCR and existing liner materials will be excavated from the EAP and transported to an off-Site landfill for disposal.
Type and Degree of Long-Term Management, Including Monitoring, Operation, and Maintenance (Section 2.2.3, IAC Section 845.710(b)(1)(C))	Monitoring will be performed for 30 years post-closure or until groundwater protection standards (GWPSs) are achieved, whichever is longer. The final cover system for the EAP will undergo 30 years of annual inspections, mowing, and maintenance.	Monitoring will be performed for 3 years post-closure or until GWPSs are achieved, whichever is longer.
Magnitude of Reduction of Existing Risks (Section 2.2.1, IAC Sections 845.710(b)(1)(A) and 845.710(b)(1)(F))	There are no current risks to any human or ecological receptors associated with the EAP. Because there are no current risks, and dissolved constituent concentrations are expected to decline post-closure, no risks to human or ecological receptors are expected post-closure.	There are no current risks to any human or ecological receptors associated with the EAP. Because there are no current risks, and dissolved constituent concentrations are expected to decline post-closure, no risks to human or ecological receptors are expected post-closure.
Likelihood of Future Releases of CCR (Section 2.2.2, IAC Sections 845.710(b)(1)(B) and 845.710(b)(1)(F))	During closure, there is minimal risk of dike failure occurring (due to, *e.g.*, flooding or seismic activity) and minimal risk of dike overtopping during flood conditions. Post-closure, the risks of overtopping and dike failure will be even smaller than they are currently, due to the installation of a protective soil cover and new stormwater control structures. Dikes, final cover, and stormwater control features have been designed to withstand earthquakes and storm events.	During closure, there is minimal risk of dike failure occurring (due to, *e.g.*, flooding or seismic activity) and minimal risk of dike overtopping during flood conditions. Following excavation, there is no risk of CCR releases due to dike failure.

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Evaluation Factor (Report Section; IAC Part 845 Section)	Closure Scenario	
	CIP	**CBR-Offsite**
Worker Risks (Section 2.2.4.1, IAC Sections 845.710(b)(1)(D) and 845.710(b)(1)(F))	An estimated 0.0024 worker fatalities and 0.36 worker injuries are expected to occur on-Site under this closure scenario. An additional 0.0030 worker fatalities and 0.21 worker injuries are expected to occur off-Site due to vehicle accidents during hauling, labor and equipment mobilization and demobilization, and material deliveries. In total, 0.0054 worker fatalities and 0.58 worker injuries are expected under this closure scenario (a smaller number than under the CBR-Offsite scenario). Simultaneous with closure activities, the Hennepin Site will be re-developed for use in utility-scale solar generation. The simultaneous pursuit of two large construction projects may lead to significant traffic congestion on Site access roads, resulting in greater overall risks to workers than would result from either project alone. The CIP scenario is expected to result in less traffic congestion – and, hence, a smaller increase in risks to workers – than the CBR-Offsite scenario.	An estimated 0.0017 worker fatalities and 0.27 worker injuries are expected to occur on-Site under this closure scenario. An additional 0.023 worker fatalities and 1.3 worker injuries are expected to occur off-Site due to vehicle accidents during hauling, labor and equipment mobilization and demobilization, and material deliveries. In total, 0.024 worker fatalities and 1.6 worker injuries are expected under this closure scenario (a greater number than under the CIP scenario). Simultaneous with closure activities, the Hennepin Site will be re-developed for use in utility-scale solar generation. The simultaneous pursuit of two large construction projects may lead to significant traffic congestion on Site access roads, resulting in greater overall risks to workers than would result from either project alone. The CBR-Offsite scenario is expected to result in more traffic congestion – and, hence, a greater increase in risks to workers – than the CIP scenario.
Community Risks (Section 2.2.4.2, IAC Sections 845.710(b)(1)(D) and 845.710(b)(1)(F))		

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Evaluation Factor (Report Section; IAC Part 845 Section)	Closure Scenario	
	CIP	**CBR-Offsite**
Off-Site Impacts on Nearby Residents and EJ Communities	Off-Site impacts on nearby residents and EJ communities (including accidents, traffic, noise, and air pollution) will be much smaller under this closure scenario because it requires significantly less off-Site vehicle and equipment travel miles than the CBR-Offsite scenario: 537,000 total off-Site travel miles are required for the CIP scenario, whereas 5,850,000 total off-Site travel miles are required for the CBR-Offsite scenario. In total, an estimated 0.0041 fatalities and 0.16 injuries are expected to occur among community members due to off-Site activities. A haul truck is likely to pass a location near the Site every 4 minutes on average during working hours for approximately five months under this closure scenario due to the hauling of borrow soil to the Site, resulting in considerable traffic demands for a short period of time.	Off-Site impacts on nearby residents and EJ communities will be much greater under this closure scenario because it requires significantly more off-Site vehicle and equipment travel miles. In total, an estimated 0.066 fatalities and 2 injuries are expected to occur among community members due to off-Site activities. A haul truck is likely to pass a location near the Site every 2.5 minutes on average during working hours for approximately 30 months under this closure scenario due to the hauling of CCR from the Site and the hauling of borrow soil to the Site, resulting in severe traffic demands for an extended period of time.
Impacts on Scenic, Historical, and Recreational Value	Due to (*e.g.*) noise and visual disturbances, construction activities may have short-term negative impacts on the recreational use of the Donnelley/DePue State Fish and Wildlife Areas complex and the Illinois River. Because the duration of construction activities is expected to be shorter under this closure scenario (approximately 10 months) compared to the CBR-Offsite scenario (approximately 33 months), short-term impacts on the scenic and recreational value of natural areas near the Site will be smaller under this closure scenario compared to CBR-Offsite scenario.	Due to (*e.g.*) noise and visual disturbances, construction activities may have short-term negative impacts on the recreational use of the Donnelley/DePue State Fish and Wildlife Areas complex and the Illinois River. Because the duration of construction activities is expected to be longer under this closure scenario compared to the CIP scenario, short-term impacts on the scenic and recreational value of natural areas near the Site will be greater under this closure scenario compared to CIP scenario.
Environmental Risks (Section 2.2.4.3, IAC Sections 845.710(b)(1)(D) and 845.710(b)(1)(F))		

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Evaluation Factor (Report Section; IAC Part 845 Section)	**Closure Scenario**	
	CIP	**CBR-Offsite**
Impacts on Greenhouse Gas Emissions and Energy Consumption	Total energy demands and GHG emissions are expected to be much smaller under this closure scenario than under the CBR-Offsite scenario, because the total equipment and vehicle mileages required under this closure scenario are an order of magnitude smaller than those required under the CBR-Offsite scenario: 591,000 total on-Site and off-Site travel miles are required for the CIP scenario, whereas 6,080,000 total on-Site and off-Site travel miles are required for the CBR-Offsite scenario. At the grid scale, construction of a solar facility at the Site will put energy back on the grid and reduce reliance on non-renewable energy sources. Re-development of the Site for solar will occur more rapidly under the CIP scenario than under the CBR-Offsite scenario.	Total energy demands and GHG emissions are expected to be much greater under this closure scenario than under the CIP scenario, because the total equipment and vehicle mileages required under this closure scenario are an order of magnitude greater than those required under the CIP scenario. At the grid scale, construction of a solar facility at the Site will put energy back on the grid and reduce reliance on non-renewable energy sources. Re-development of the Site for solar will occur more slowly under the CBR-Offsite scenario than under the CIP scenario.
Impacts on Natural Resources and Habitat	Construction may have short-term negative impacts on terrestrial species located near the EAP and the off-Site borrow soil location. Impacts on natural resources and habitat are expected to be smaller under the CIP scenario than under the CBR-Offsite scenario, because the overall duration of construction is shorter under the former scenario. Post-closure, we expect habitat on top of the EAP to improve since the cover system will be vegetated with grasses.	Construction may have short-term negative impacts on terrestrial species located near the EAP and the off-Site borrow soil location. Impacts on natural resources and habitat are expected to be greater under the CBR-Offsite scenario than under the CIP scenario, because the overall duration of construction is longer under the former scenario. Post-closure, we expect habitat on top of the EAP to improve.

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Evaluation Factor (Report Section; IAC Part 845 Section)	Closure Scenario	
	CIP	**CBR-Offsite**
Time Until Groundwater Protection Standards Are Achieved (Section 2.2.5, IAC Sections 845.710(b)(1)(E) and 845.710(d)(2 and 3))	Groundwater modeling was performed to evaluate future groundwater quality in the vicinity of the EAP under each of the proposed closure alternatives (Ramboll, 2021a). Because there are no known potential GWPS exceedances in groundwater associated with the EAP (Ramboll, 2021b), modeling of closure alternatives evaluated whether groundwater quality would be maintained in compliance with the relevant GWPSs post-closure. Boron was selected for groundwater transport modeling as a primary indicator of CCR impacts in groundwater. Boron is commonly used as a parameter for CCR contaminant transport modeling due to its presence in CCR and because it is relatively mobile and not very reactive in groundwater. The modeling concluded that groundwater quality near the EAP, based on simulations of boron in groundwater, will maintain compliance with the GWPSs for a period of at least 30 years post-closure for both CIP and CBR-Offsite (Ramboll, 2021a).	Groundwater modeling was performed to evaluate future groundwater quality in the vicinity of the EAP under each of the proposed closure alternatives (Ramboll, 2021a). Because there are no known potential GWPS exceedances in groundwater associated with the EAP (Ramboll, 2021b), modeling of closure alternatives evaluated whether groundwater quality would be maintained in compliance with the relevant GWPSs post-closure. Boron was selected for groundwater transport modeling as a primary indicator of CCR impacts in groundwater. Boron is commonly used as a parameter for CCR contaminant transport modeling due to its presence in CCR and because it is relatively mobile and not very reactive in groundwater. The modeling concluded that groundwater quality near the EAP, based on simulations of boron in groundwater, will maintain compliance with the GWPSs for a period of at least 30 years post-closure for both CIP and CBR-Offsite (Ramboll, 2021a).
Long-Term Reliability of the Engineering and Institutional Controls (Section 2.2.7; IAC Section 845.710(b)(1)(G))	CIP is expected to be a reliable closure alternative over the long term.	CBR-Offsite is expected to be a reliable closure alternative over the long term.
Potential Need for Future Corrective Action (Section 2.2.8; IAC Section 845.710(b)(1)(H))	Corrective action is not expected to be required at this Site under either closure scenario.	Corrective action is not expected to be required at this Site under either closure scenario.
Effectiveness of the Alternative in Controlling Future Releases (Section 2.3; IAC Section 845.710(b)(2)(A and B))	There are no current or future risks to any human or ecological receptors associated with the EAP under either closure scenario. During closure, there is minimal risk of dike failure occurring and minimal risk of dike overtopping during flood conditions. Post-closure, the risks of overtopping and dike failure will be even smaller than they are currently, due to the installation of a protective soil cover and new stormwater control structures. Dikes, final cover, and stormwater control features have been designed to withstand earthquakes and storm events.	There are no current or future risks to any human or ecological receptors associated with the EAP under either closure scenario. During closure, there is minimal risk of dike failure occurring and minimal risk of dike overtopping during flood conditions. Following excavation, there is no risk of CCR releases due to dike failure.

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Evaluation Factor (Report Section; IAC Part 845 Section)	Closure Scenario	
	CIP	**CBR-Offsite**
Ease or Difficulty of Implementing the Alternative (Section 2.4, IAC Section 845.710(b)(3))		
Degree of Difficulty Associated with Construction	CIP is a reliable and standard method for managing and closing waste impoundments. Dewatering and excavating saturated CCR to construct a stabilized final cover system subgrade may present challenges during closure; however, these challenges are common to most CCR surface impoundment closures and are commonly addressed *via* surface water management and dewatering techniques.	Relative to CIP, CBR-Offsite will cause additional implementation difficulties due to significantly higher earthwork volumes and dewatering volumes, a longer construction schedule, and the need to remove and dispose of the existing bottom liner geomembrane. Hauling will also be more difficult to implement under the CBR-Offsite scenario, due to significantly greater earthwork volumes and increased haul traffic on public roadways. Because CCR will require hauling on public roads (*i.e.*, intrastate travel), it will need to be dewatered to a greater extent than will be necessary for the CIP scenario. Off-Site landfilling under the CBR-Offsite scenario will require the development of a disposal plan and may raise issues related to the co-disposal of CCR and other non-hazardous wastes. The off-Site landfill may also need to be expanded to receive all of the CCR generated during excavation.
Expected Operational Reliability	Operational reliability is expected under both closure scenarios.	Operational reliability is expected under both closure scenarios.
Need for Permits and Approvals	Permits and approvals will be needed under both closure scenarios.	Permits and approvals will be needed under both closure scenarios. Relative to the CIP scenario, additional permits and approvals may be required under the CBR-Offsite scenario if the landfill must be expanded to receive all of the CCR from the EAP.

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Evaluation Factor (Report Section; IAC Part 845 Section)	**Closure Scenario**	
	CIP	**CBR-Offsite**
Availability of Equipment and Specialists	CIP and CBR-Offsite rely on common construction equipment and materials and typically do not require the use of specialists. However, global supply chains have been disrupted due to the COVID-19 pandemic, resulting in shortages in the availability of construction equipment and parts. There may be delays in construction under both scenarios if supply chain resilience does not improve by the time of construction. Due to smaller earthwork volumes and a lesser need for construction equipment under the CIP scenario than under the CBR-Offsite scenario, shortages may cause fewer challenges under the CIP scenario than under the CBR-Offsite scenario.	CIP and CBR-Offsite rely on common construction equipment and materials and typically do not require the use of specialists. However, global supply chains have been disrupted due to the COVID-19 pandemic, resulting in shortages in the availability of construction equipment and parts. There may be delays in construction under both scenarios if supply chain resilience does not improve by the time of construction. Due to significantly higher earthwork volumes and a greater need for construction equipment under the CBR-Offsite scenario than under the CIP scenario, shortages may cause greater challenges under the CBR-Offsite scenario than under the CIP scenario. The current shortage of truck drivers may be particularly impactful under the CBR-Offsite scenario, due to the large volumes of borrow soil and CCR to be hauled to and from the Site.

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Evaluation Factor (Report Section; IAC Part 845 Section)	Closure Scenario	
	CIP	**CBR-Offsite**
Available Capacity and Location of Treatment, Storage, and Disposal Services	Under the CIP scenario, all of the CCR currently within the EAP will be stored within the footprint of the EAP. Treatment will consist of unwatering the EAP at the start of construction, performing limited dewatering to stabilize the CCR subgrade, and managing stormwater inflow. Water from unwatering and dewatering of the EAP will be discharged *via* the existing NPDES permit, utilizing the existing Leachate Pond and Polishing Pond as settling basins.	The capacity remaining at the chosen off-Site landfill in Ottawa, Illinois, is sufficient to receive all of the CCR in the EAP. However, closure of the EAP would increase the annual waste receipt rate at the off-Site landfill by approximately 50%. Due to the short time frame over which CCR would be received at the landfill, vertical and/or lateral expansions may become necessary. Additionally, the landfill operators may need to develop a disposal plan to account for the increased volume of material that will be received and the unique CCR waste characteristics. Elements of this disposal plan might include increasing daily operational capacity and procedures, expediting planned airspace construction, and potentially expediting landfill expansion. If expansion of the LandComp landfill were found to be impractical or infeasible, then an alternative landfill located farther from the Site would need to be identified. Water treatment will consist of unwatering/dewatering the EAP at the start of construction. Water from unwatering and dewatering of the EAP will be discharged *via* the existing NPDES permit, utilizing the existing Leachate Pond and Polishing Pond as settling basins. Under the CBR-Offsite scenario, a higher volume of water will be sent to the Leachate Pond/Polishing Pond compared to the CIP scenario, due to the longer construction schedule and the greater amount of dewatering that will need to occur for CCR to be transported on public roads to an off-Site disposal location.

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Evaluation Factor (Report Section; IAC Part 845 Section)	Closure Scenario	
	CIP	CBR-Offsite
Impact of Alternative on Waters of the State (Section 2.5, IAC Section 845.710(d)(4))	No current or future exceedances of any screening benchmarks for surface water are anticipated.	No current or future exceedances of any screening benchmarks for surface water are anticipated.
Potential Modes of Transportation Associated with CBR (Section 2.1; IAC Section 845.710(c)(1)	This factor is not relevant for CIP.	IAC Section 845.710(c)(1) requires CBR alternatives to consider multiple methods for transporting CCR off-Site, including rail, barge, and trucks. Geosyntec (2021a) evaluated the feasibility of transporting CCR to the off-Site landfill *via* rail or barge and found that neither option is viable at this Site. Truck transport has been identified as the preferred option for transport of CCR to the off-Site landfill.
Concerns of Residents Associated with Alternatives (Section 2.6, IAC Section 845.710(b)(4))	Despite the preference for CBR that has been expressed by nonprofits representing community interests near the Site, CIP will effectively address residents' concerns regarding potential impacts to groundwater and surface water quality at the Site. Relative to CBR-Offsite, CIP also presents far less risks to nearby residents and potentially EJ communities in the form of accidents, traffic, noise, and air pollution. Moreover, under the CIP scenario, the Site could be more rapidly re-developed for use in utility-scale solar generation.	Nonprofits representing community interests near the Site have expressed a preference for CBR over CIP. However, the CBR-Offsite scenario has several disadvantages with regard to potential community concerns. Relative to CIP, the CBR-Offsite scenario presents far greater risks to nearby residents and potentially EJ communities in the form of accidents, traffic, noise, and air pollution. Moreover, under the CBR-Offsite scenario, the Site could take longer to re-develop for use in utility-scale solar generation.
Class 4 Cost Estimate (Section 2.7, IAC Section 845.710(d)(1))	A Class 4 cost estimate will be prepared in the final closure plan consistent with AACE classification standards.	A Class 4 cost estimate will be prepared in the final closure plan consistent with AACE classification standards.

Notes:
AACE = Association for the Advancement of Cost Engineering; CBR-Offsite = Closure-by-Removal with Offsite CCR Disposal; CCR = Coal Combustion Residual; CIP = Closure-in-Place; EAP = East Ash Pond; EJ = Environmental Justice; GHG = Greenhouse Gas; IAC = Illinois Administrative Code; NPDES = National Pollutant Discharge Elimination System.

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1 Introduction

1.1 Site Description and History

1.1.1 Site Location and History

Dynegy Midwest Generation, LLC's (DMG) Hennepin Power Plant is an electric power generating facility with coal-fired units located approximately 4 miles northeast of the Village of Hennepin, Illinois, along the Illinois River. The facility began operating in the early 1950s and was retired in 2019 (Ramboll, 2021b). The plant had two coal-fired units constructed in 1953 and 1959 with a capacity of 70 MW and 210 MW, respectively (Ramboll, 2021b).

1.1.2 CCR Impoundment

The Hennepin Power Plant produced and stored coal combustion residuals (CCRs) as a part of its historical operations. The East Ash Pond (EAP; Vistra ID No. CCR Unit 803, Illinois Environmental Protection Agency [IEPA] ID No. W1550100002-05, and National Inventory of Dams [NID] ID No. IL50363) is the subject of this report.

The EAP (Figure 1.1) is a lined surface impoundment that underwent the first phase of construction in the mid-1990s, when the pond bottom and sidewalls were constructed (Ramboll, 2021b). The sidewall liners were raised during the second phase of construction in 2003 (Ramboll, 2021b). The pond was used to store and dispose of bottom ash, fly ash, and other non-CCR waste until the plant was retired in 2019 (Ramboll, 2021b). Today, only stormwater flows to the EAP. Flows from the EAP are routed to the Leachate Pond and the Secondary (Polishing) Pond (Figure 1.1). The Secondary Pond flows to the Illinois River *via* a National Pollutant Discharge Elimination System (NPDES)-permitted outfall (Geosyntec, 2021a).

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Figure 1.1 Site Location Map. Adapted from Ramboll (2021b).

1.1.3 Surface Water Hydrology

The Illinois River is located approximately 0.1 miles north of the outer perimeter of the EAP. In the vicinity of the EAP, the river flows from east to west. As described below (Section 1.1.4, Hydrogeology), the Illinois River acts as a regional sink for surface water and groundwater in the vicinity of the Site.

The EAP is located within the DePue Lake-Illinois River Watershed (Ramboll, 2021b). The IEPA classifies the River as a General Use Water: it is designated for aquatic life and use in primary contact recreation; however, it is not designated for use in food processing or as a public water supply. The segment of the Illinois River adjacent to the Site (Section D-16) is listed on the 2018 Illinois Section 303(d) List as being impaired for fish consumption, due to mercury and polychlorinated biphenyls. DePue Lake, which is located north of the Site along the north bank of the Illinois River, is listed as impaired for aquatic life due to cadmium, endrin, silver and zinc; it is also listed as impaired for fish consumption due to mercury and polychlorinated biphenyls (IEPA, 2016, 2019a).

Surface water samples were collected from 15 locations along the Illinois River adjacent to the Hennepin Power Plant in September 2020. The samples were taken along five transects, with three samples collected per transect (Geosyntec, 2021b). The results from the September 2020 surface water sampling

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campaign are summarized in Gradient's Human Health and Ecological Risk Assessment for the Site, which is provided as Appendix A of this report.

1.1.4 Hydrogeology

Two distinct hydrostratigraphic units have been identified in the area: the uppermost water-bearing unit, which consists of the clayey sands to sandy clays of the Cahokia Alluvium and the sand and gravels of the Henry Formation, and a confining shale bedrock unit. The Cahokia Alluvium consists of fine-grained sandy-silts and clay deposits of the Illinois River. The Henry Formation fills the valley under the Cahokia Alluvium and is composed of highly permeable glacial outwash deposits of sands and gravels. The total thickness of the uppermost water-bearing unit is approximately 80 feet (ft) beneath the EAP (Ramboll, 2021b). The low-permeability bedrock aquitard underlying the Henry Formation acts as a barrier to the downward migration of groundwater (Ramboll, 2021b). This aquitard consists of low-permeability shales and thin layers of limestone, sandstone, and coal beds of the Pennsylvanian Carbondale Formation (Ramboll, 2021b). In the vicinity of the EAP, the estimated thickness of this layer is approximately 300-400 ft (Ramboll, 2021b).

The highly permeable glacial outwash and re-worked glacial deposits of the Henry Formation are the primary conduit for groundwater flows beneath the EAP (Ramboll, 2021b). Groundwater flows from south to north/northwest beneath the EAP towards the Illinois River, which serves as a large regional hydraulic boundary. Groundwater surrounding the EAP flows northwards and upwards into the River (Ramboll, 2021b). During groundwater interaction with surface water, CCR-related constituents may partition between sediments and the surface water column. It should be noted that many CCR-related constituents occur naturally in sediments and surface water (and can also arise from other industrial sources). As a result, their presence in the sediments and/or surface water of the Illinois River does not signify contributions from the EAP.

Groundwater samples have been collected from monitoring wells at the Site since approximately 1983. The Hydrogeologic Site Characterization Report prepared by Ramboll as part of the Operating Permit for the EAP includes a summary of groundwater data collected from EAP monitoring wells between 1995 and 2021 at the Site (Ramboll, 2021b).

1.1.5 Site Vicinity

The EAP is surrounded by the Illinois River to the north, industrial properties to the east (Tri-Con Materials) and south (Tri-Con Materials and Washington Mills), agricultural land to the southwest, and the Hennepin Power Station to the west (Figure 1.1). Tri-Con Materials produces various fill and washed sand, gravel, rock and boulder products (Ramboll, 2018-2020). Washington Mills produces abrasive grains and specialty electro-fused minerals (Ramboll, 2018-2020).

Notable natural areas and recreational areas in the vicinity of the EAP include the Illinois River and the Donnelley/DePue State Fish and Wildlife Areas complex, which is located opposite the EAP along the northern bank of the Illinois River. The Illinois River is popular for canoeing and other forms of water recreation (Illinois Dept. of Natural Resources, 2021). The nearby DePue Lake and Lyons Lake are popular spots for recreational boating and fishing (Illinois River Road National Scenic Byway, 2021; HookandBullet.com, 2021).

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1.2 IAC Part 845 Regulatory Review and Requirements

Title 35, Part 845 of the Illinois Administrative Code (IAC; IEPA, 2021a) requires the development of a Closure Alternatives Analysis (CAA) prior to undertaking closure activities at certain CCR-containing surface impoundments in the State of Illinois. Section 2 of this report presents a CAA for the EAP pursuant to requirements under IAC Section 845.710. The goal of a CAA is to holistically evaluate each potential closure scenario with respect to a wide range of factors, including the efficiency, reliability, and ease of implementation of the closure scenario; its potential positive and negative short- and long-term impacts on human health and the environment; and its ability to address concerns raised by residents (IEPA, 2021a). A CAA is a decision-making tool that is designed to aid in the selection of an optimal closure alternative for the impoundments at a site.

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2 Closure Alternatives Analysis

2.1 Closure Alternative Descriptions (IAC Section 845.710(c))

This section of the report presents a CAA for the EAP pursuant to requirements under IAC Section 845.710 (IEPA, 2021a). The two closure scenarios evaluated in this CAA are Closure-in-Place (CIP) and Closure-by-Removal with Off-Site CCR Disposal (CBR-Offsite). Under the CIP scenario, the CCR will remain in place and the EAP will be capped with a new cover system. Under the CBR-Offsite scenario, all of the CCR will be excavated from the impoundment and hauled to an off-Site landfill.

IAC Section 845.710(c)(2) requires CAAs to, "[i]dentify whether the facility has an onsite landfill with remaining capacity that can legally accept CCR, and, if not, whether constructing an onsite landfill is possible" (IEPA, 2021a). There is an existing CCR landfill located adjacent to the EAP at the Hennepin site, the Hennepin Landfill (Figure 1.1). However, the single cell at the Hennepin Landfill is only 4.5 acres in size (Geosyntec, 2021a). This landfill does not currently have the capacity to contain all of the CCR that would be excavated from the EAP under the CBR-Offsite scenario (Geosyntec, 2021a). Due to the presence of other closed impoundments in the immediate vicinity of the landfill, the landfill also cannot be expanded in order to increase its capacity. Geosyntec has attempted to identify another area on the property that would be suitable for construction of a new on-Site landfill; however, none of the six areas that Geosyntec evaluated were found to be suitable for new landfill construction, due to either their location with respect to the floodplain or various engineering limitations (Geosyntec, 2021a). Construction of a new on-Site landfill would also interfere with existing plans to re-develop the property for use in utility-scale solar generation and battery storage; construction of the new on-Site landfill (and other closure activities) would need to occur concurrently with solar re-development activities, resulting in increased traffic on Site access roads and greater risks to workers due to on-Site accidents (Geosyntec, 2021a). In summary, neither expansion of the existing on-Site landfill nor construction of a new on-Site landfill is a viable alternative at this site.

While not addressed in this report, closure of the Hennepin Landfill may be performed concurrently with the planned closure of the EAP. The Hennepin Landfill was constructed with approximately 7,500 cubic yards (CY) of bottom ash used as a protection layer, which protects the landfill's secondary clay liner from damage during freezing and thawing cycles (Geosyntec, 2021a). Other than the bottom ash protective layer, the Hennepin Landfill never received CCR waste material prior to or post-retirement in 2019. As is described below (Section 2.1.1), the CIP scenario includes excavation of this bottom ash protection layer for use as contouring fill during closure of the EAP (Geosyntec, 2021a), consistent with the requirements in IAC Section 845.750(d) (IEPA, 2021a; Geosyntec, 2021a).

Sections 2.1.1 and 2.1.2 provide detailed descriptions of the CIP and CBR-Offsite closure scenarios. These scenarios are based on closure documents and analyses provided to Gradient by Geosyntec (Geosyntec, 2021a,c).

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2.1.1 Closure-in-Place

Under the CIP scenario, the EAP will be capped in place with a final cover system. This scenario includes the following work elements (Geosyntec, 2021a):

- Removal of the existing free water from the EAP *via* pumping to the adjacent Secondary Pond or Leachate Pond, which drain to the Illinois River.
- Contouring and grading to manage stormwater.
- Construction of a cover system consisting of a 40-mil linear low-density polyethylene (LLDPE) geomembrane layer, a geotextile cushion if needed, and 24 inches of soil sourced from an off-Site location. The soil layer would include a 6-inch-thick topsoil layer and be revegetated with native grasses.
- Long-term (post-closure) monitoring and maintenance, including at least 30 years of groundwater monitoring at the impoundment, or until such time as groundwater protection standards (GWPSs) are achieved. Additionally, 30 years of post-closure care will be undertaken for the final cover system, including annual cap inspections, mowing, and maintenance.

In total, 84,200 CY of material are required for contouring and grading of the EAP. Geosyntec estimates that 37,200 CY of this material will be sourced from the CCR within the EAP. An additional 8,000 CY will be sourced from the bottom ash protection layer of the Hennepin Landfill. Contouring of this bottom ash material will be performed consistent with the requirements in IAC Section 845.750(d) (IEPA, 2021a; Geosyntec, 2021c). The remaining material (39,000 CY of compacted material, or 41,000 CY of hauled material before compaction) will be sourced from a borrow area near the Site (Geosyntec, 2021a). Geosyntec estimates that construction of the final cover system will require an additional 70,000 CY of borrow soil to be hauled to the Site, resulting in a total hauled volume of borrow soil of approximately 111,000 CY (Geosyntec, 2021a). Borrow soil will be hauled to the Site using haul trucks with an assumed capacity of 12 CY (Geosyntec, 2021a).

DMG owns property near the Site that could potentially be used as a borrow site; however, this property is being reserved for use in utility-scale solar generation and battery storage. A borrow site will therefore need to be established off-Site. Because the area surrounding the property is rural, we assume that it will be possible to identify a suitable borrow location within 10 miles of the Site. Under the CIP scenario, the overall duration of closure activities is expected to be approximately 10 months (Geosyntec, 2021c). Key parameters for the CIP scenario are shown in Table 2.1.

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Table 2.1 Key Parameters for the Closure-in-Place Scenario

Parameter	
Surface Area of EAP	21 acres
Duration of Construction Activities	10 months
Distance to the Borrow Site	10 miles
Hauled Volume of Borrow Soil	111,000 CY
Labor Hours	
Total On-Site Labor	31,500 hours
Total Off-Site Labor	7,210 hours
Engineering Support and CQA During Construction	2,640 hours
30% Contingency	12,400 hours
Total Labor Hours:	53,700 hours
Vehicle and Equipment Travel Miles	
Vehicles On-Site	7,810 miles
Equipment On-Site	44,400 miles
On-Site Haul Trucks (Unloaded + Loaded)	850 miles
Labor Mobilization	298,000 miles
Equipment Mobilization (Unloaded + Loaded)	24,300 miles
Off-Site Haul Trucks (Unloaded + Loaded)	187,000 miles
Material Deliveries (Unloaded + Loaded)	28,100 miles
Total On-Site Vehicle and Equipment Travel Miles:	53,100 miles
Total Off-Site Vehicle and Equipment Travel Miles:	537,000 miles
Total Vehicle and Equipment Travel Miles:	591,000 miles

Notes:
CQA = Construction Quality Assurance; CY = Cubic Yards; EAP = East Ash Pond.
Sources: Geosyntec (2021a,c).

2.1.2 Closure-by-Removal with Off-Site CCR Disposal

Under the CBR-Offsite scenario, CCR will be excavated from the EAP and transported to an off-Site landfill for disposal. CCR will be sent to the LandComp Landfill in Ottawa, Illinois (2840 E. 13th Road), which is located approximately 32 miles from the Site (Geosyntec, 2021a). As is described below in Section 2.4.5, it is possible that the LandComp Landfill will have to be expanded in order to accept all of the CCR from the EAP.

IAC Section 845.710(c)(1) requires CBR alternatives to consider multiple methods for transporting CCR off-Site, including rail, barge, and trucks. Geosyntec (2021a) evaluated the feasibility of transporting CCR to the off-Site landfill *via* rail or barge and found that neither option is viable at this Site. Transporting CCR by rail would require the construction of a new rail loading terminal on-Site and the construction of a new railing unloading terminal near the off-Site landfill. The construction of new rail terminals would require coordination with the railroad and additional permitting, which could negatively impact the project schedule. Trucks would still be needed to haul CCR to and from the terminals, and additional CCR exposures could occur during the loading and unloading of CCR into trucks and rail cars. Moreover, because there is no direct rail route from the Site to the off-Site landfill, the transport of CCR to the off-Site landfill would require 51 miles of rail transport on tracks owned by three separate rail lines.

Barge transport would similarly require the construction of a new loading terminal along the Illinois River, which would necessitate additional permitting and could negatively impact the project schedule. There are other loading terminals located within 5 miles of the Site; however, these terminals belong to other parties. Use of these terminals would therefore require negotiating agreements with the terminal

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owner and/or operator. Additionally, upgrades would likely be required at these terminals. Negotiations and terminal upgrades would also likely be required to secure the use of a terminal near the off-Site landfill. The terminal closest to the off-Site landfill is a loading terminal and would require upgrades to allow CCR to be unloaded. As with rail terminals, trucks would still be needed to haul CCR to and from the loading and unloading terminals, and additional CCR exposures could occur during the loading and unloading of CCR into trucks and onto barges. For all of these reasons, truck transport has been identified as the preferred option for transport of CCR to the off-Site landfill. Transportation *via* truck would not require the construction of additional loading or unloading infrastructure, and would not result in project delays due to permitting and coordination with other parties. The existing travel routes from the Site to the off-Site landfill are suitable for CCR transport *via* truck (Geosyntec, 2021a).

This scenario includes the following work elements (Geosyntec, 2021a):

- Removal of the existing free water from the EAP *via* pumping to the adjacent Secondary Pond or Leachate Pond, which drain to the Illinois River.
- Construction of stormwater control structures to convey runoff away from the impoundment and towards the Secondary Pond or Leachate Pond.
- Excavation of CCR, the existing geomembrane slide-slope liner, and an additional one foot of perimeter soils from the impoundment, and transport of these materials to the off-Site landfill.
- To allow stormwater to undergo gravity-driven flow into the Secondary Pond post-closure and prevent the impoundment of water, the excavated area will be backfilled with soil to an elevation of 480.4 ft near the riser structure.
- Site restoration, including the placement of six inches of topsoil along the side slopes and bottom of the EAP and revegetation with native grasses.
- Monitoring for 3 years post-closure or until such time as GWPSs are achieved, whichever is longer.

Material for backfilling the EAP post-closure will be hauled in from an offsite borrow area. In total, a hauled borrow soil volume of 410,000 CY will potentially be required under this closure scenario (Geosyntec, 2021a). As with the CIP scenario, we assume that it will be possible to identify a suitable borrow location within 10 miles of the Site. A haul truck capacity of 12 CY is assumed for both the transport of borrow soil and CCR (Geosyntec, 2021a).

The overall duration of closure activities under this closure scenario is approximately 33 months (Geosyntec, 2021a). Key parameters for the CBR-Offsite scenario are shown in Table 2.2.

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Table 2.2 Key Parameters for the Closure-by-Removal with Off-Site CCR Disposal Scenario

Parameter	Value
Surface Area of EAP	21 acres
Duration of Construction Activities	33 months
Distance to the Off-Site Landfill	32 miles
Hauled Volume of CCR and Liner	710,000 CY
Distance to the Borrow Site	10 miles
Hauled Volume of Borrow Soil	410,000 CY
Labor Hours	
Total On-Site Labor	23,200 hours
Total Off-Site Labor	121,000 hours
Engineering Support and CQA During Construction	45,800 hours
30% Contingency	8,340 hours
Total Labor Hours:	198,000 hours
Vehicle and Equipment Travel Miles	
Vehicles On-Site	38,500 miles
Equipment On-Site	199,000 miles
On-Site Haul Trucks (Unloaded + Loaded)	0 miles
Labor Mobilization	1,160,000 miles
Equipment Mobilization (Unloaded + Loaded)	158,000 miles
Off-Site Haul Trucks (Unloaded + Loaded)	4,470,000 miles
Material Deliveries (Unloaded + Loaded)	60,000 miles
Total On-Site Vehicle and Equipment Travel:	238,000 miles
Total Off-Site Vehicle and Equipment Travel:	5,850,000 miles
Total Vehicle and Equipment Travel:	6,080,000 miles

Notes:
CCR = Coal Combustion Residual; CQA = Construction Quality Assurance; CY = Cubic Yard; EAP = East Ash Pond.
Sources: Geosyntec (2021a).

2.2 Long- and Short-Term Effectiveness of the Closure Alternative (IAC Section 845.710(b)(1))

2.2.1 Magnitude of Reduction of Existing Risks (IAC Section 845.710(b)(1)(A))

This section of the report addresses the potential risks to human and ecological receptors due to exposure to CCR-associated constituents in groundwater or surface water. Gradient has performed a Human Health and Ecological Risk Assessment (Appendix A), which provides a detailed evaluation of the magnitude of existing risks to human and ecological receptors associated with the EAP. This report concluded that there are no current unacceptable risks to any human or ecological receptors. Because there are no current risks to any human or ecological receptors, and dissolved constituent concentrations are expected to decline post-closure, no post-closure risks are expected under either closure scenario. Thus, there is no current risk or future risk under either closure scenario, and the magnitude of reduction of existing risks is the same under both closure scenarios.

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2.2.2 Likelihood of Future Releases of CCR (IAC Section 845.710(b)(1)(B))

This section of the report quantifies the risk of future releases of CCR that may occur during dike failure and storm-related events.

Storm-Related Releases and Dike Failure During Flood Conditions

Engineering analyses show that the EAP dikes are expected to remain stable under static, seismic, and flood conditions (Geosyntec, 2021d; AECOM, 2016). Prior to closure (*i.e.*, under current conditions), the risk of dike failure occurring during floods or other storm-related events is therefore minimal. Engineering analyses similarly show that the risk of overtopping occurring during flood conditions is minimal under current conditions. Specifically, Geosyntec evaluated the risk of flood overtopping occurring at the EAP and found that the impoundment can adequately manage flow during peak discharge from even a 1,000-year storm event, thus preventing overtopping (Geosyntec, 2021d). Post-closure, the risks of overtopping and dike failure occurring due to floods or other storm-related events will be even smaller than they are currently. Under the CIP scenario, a new cover system will be installed, which will include 24 inches of soil and a geomembrane liner, as well as new stormwater control structures. Relative to current conditions, this cover system will provide increased protection against berm and surface erosion, groundwater infiltration, and other adverse effects that could potentially trigger a dike slope failure event. Geosyntec evaluated slope stability under post-closure conditions and determined that the factor of safety required to prevent dike failure will be well above minimum required values (Geosyntec, 2021c). Under the CBR-Offsite scenario, all of the CCR in the EAP will be excavated and relocated, eliminating the risk of a CCR release occurring post-closure. In summary, there is minimal current or future risk of sudden CCR releases occurring under either closure scenario either during or following closure.

Dike Failure Due to Seismicity

Four unnamed faults associated with the Troy Grove Dome are located approximately 11 miles northeast of the property (Ramboll, 2021b). Additionally, the Sandwich Fault Zone and the Plum River Fault Zone are located approximately 35 miles northeast and 60 miles northwest of the property, respectively (Ramboll, 2021b). While detailed information about the Sandwich Fault Zone is not readily available, United States Geological Survey (USGS) seismic hazard maps show no enhanced ground acceleration in the vicinity of the Plum River Fault Zone (Ramboll, 2021b). Despite the presence of these faults, seismic analyses have revealed that the Site does not lie within a seismic impact area. Moreover, the EAP does not lie within 200 feet of an active fault or fault damage zone at which displacement has occurred within the current geological epoch (*i.e.*, within the last ~11,650 years; Ramboll, 2021b). For the CIP scenario, dikes, final cover, and stormwater control features have been designed to withstand earthquakes and storm events. The factor of safety in these design calculations are well above minimum regulatory requirements (Geosyntec, 2021c). Thus, the risk of dike failure occurring during or following closure activities due to seismic activity is low.

2.2.3 Type and Degree of Long-Term Management, Including Monitoring, Operation, and Maintenance (IAC Section 845.710(b)(1)(C))

The long-term operation and management plans for the EAP under each closure scenario are described in Section 2.1 (Closure Alternatives Descriptions). In summary, under the CIP scenario, the EAP will undergo monitoring for 30 years post-closure, or until such time as GWPSs are achieved. Under the CBR-Offsite scenario, the EAP will undergo monitoring for 3 years post-closure, or until such time as

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GWPSs are achieved. The post-closure care plan for the CIP scenario additionally includes annual inspections, mowing, and maintenance of the final cover system.

2.2.4 Short-Term Risks to the Community or the Environment During Implementation of Closure (IAC Section 845.710(b)(1)(D))

2.2.4.1 Worker Risks

Best practices will be employed during construction in order to ensure worker safety and comply with all relevant regulations, permit requirements, and safety plans. However, it is impossible to completely eliminate the risk of accidents occurring during construction activities, both on- and off-Site. On-Site accidents include injuries and deaths arising from the use of heavy equipment and/or earthmoving operations during construction activities. Off-Site accidents include injuries and deaths due to vehicle accidents during labor and equipment mobilization/demobilization, material deliveries, and the hauling of borrow soil and CCR.

As shown in Tables 2.1 and 2.2, Geosyntec (2021a) estimates that the CIP scenario will require 31,500 on-Site labor hours (excluding labor hours related to engineering support and construction quality assurance [CQA] during construction and a 30% contingency). The CBR-Offsite scenario requires approximately 23,200 on-Site labor hours. The US Bureau of Labor Statistics (US DOL, 2020a,b) provides an estimate of the hourly fatality and injury rates for construction workers. Based on the accident rates reported by US Bureau of Labor Statistics and the on-Site labor hours reported by Geosyntec, we estimate that approximately 0.36 worker injuries and 0.0024 worker fatalities will occur on-Site under the CIP scenario (Table 2.3). Under the CBR-Offsite scenario, approximately 0.27 worker injuries and 0.0017 worker fatalities are expected to occur on-Site (Table 2.3). The rate of on-Site worker accidents is therefore expected to be slightly higher under the CIP scenario than under the CBR-Offsite scenario.

Table 2.3 Expected Number of On-Site Worker Accidents Under Each Closure Scenario

Closure Scenario	Injuries	Fatalities
CIP	0.36	0.0024
CBR-Offsite	0.27	0.0017

Notes:
CIP = Closure-in-Place; CBR-Offsite = Closure-by-Removal with Off-Site CCR Disposal.

A much greater number of off-Site haul truck miles, labor and equipment mobilization/demobilization miles, and material delivery miles are required under the CBR-Offsite scenario than are required under the CIP scenario (Tables 2.1 and 2.2). For example, under the CBR-Offsite scenario, 4,470,000 haul truck miles are required to haul CCR to the off-Site landfill and haul borrow soil to the Site; in contrast, under the CIP scenario, only 187,000 haul truck miles are required to haul borrow soil to the Site (Geosyntec, 2021a). Thus, in contrast to the trends observed for on-Site worker accidents, the expected number of off-Site worker accidents will be higher under the CBR-Offsite scenario than under the CIP scenario.

The United States Department of Transportation (US DOT, 2020) provides estimates of the expected number of fatalities and injuries "per vehicle mile driven" for drivers and passengers of large trucks and passenger vehicles. Table 2.4 shows the expected number of off-Site accidents under each closure scenario due to all categories of off-Site vehicle usage. For these calculations, it was assumed that labor mobilization/demobilization relied upon passenger vehicles (cars or light trucks, including pickups, vans, and sport utility vehicles) and that hauling, equipment mobilization/demobilization, and material

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deliveries relied upon large trucks. Based on US DOT's accident statistics and Geosyntec's mileage estimates, an estimated 0.21 injuries and 0.0030 fatalities are expected to occur among workers due to off-Site activities under the CIP scenario. Under the CBR-Offsite scenario, an estimated 1.3 injuries and 0.023 fatalities are expected to occur among workers due to off-Site activities.

Table 2.4 Expected Number of Off-Site Worker Accidents Under Each Closure Scenario

Off-Site Vehicle Use Category	CIP		CBR-Offsite	
	Injuries	Fatalities	Injuries	Fatalities
Hauling	0.024	0.00054	0.57	0.013
Labor Mobilization/Demobilization	0.18	0.0023	0.71	0.0091
Equipment Mobilization/Demobilization	0.0031	7.1×10^{-5}	0.020	0.00046
Material Deliveries	0.0036	8.2×10^{-5}	0.0077	0.00017
Total:	0.21	0.0030	1.3	0.023

Notes:
CIP = Closure-in-Place; CBR-Offsite = Closure-by-Removal with Off-Site CCR Disposal.

Overall, taking into account accidents occurring both on- and off-Site, 0.58 worker injuries and 0.0054 worker fatalities are expected under the CIP scenario, whereas 1.6 worker injuries and 0.024 worker fatalities are expected under the CBR-Offsite scenario. Thus, overall risks to workers are higher under the CBR-Offsite scenario than under the CIP scenario.

Concurrently with closure activities, a utility-scale solar facility will be constructed on the Hennepin Site. The simultaneous pursuit of closure-related construction and solar facility construction may lead to significant traffic congestion on Site access roads, resulting in greater overall risks to workers than would result from closure or solar re-development alone. Because the CIP scenario requires less hauling activity (and other forms of ingress and egress to and from the Site) than the CBR-Offsite scenario and will also be completed over a shorter time period, the CIP scenario is expected to result in less congestion on Site access roads during Site re-development – and, hence, a smaller increase in the risks to workers – than under the CBR-Offsite scenario.

In summary, risks to workers due to accidents are expected to be greater under the CBR-Offsite scenario than under the CIP scenario. Differences in worker risks between the two scenarios are largely driven by off-Site activities.

2.2.4.2 Community Risks

Accidents

Vehicle accidents that occur off-Site can result in injuries or fatalities among community members, as well as workers. Based on the accident statistics reported by US DOT (2020) and the off-Site travel mileages required under the CBR-Offsite scenario (Geosyntec, 2021a), off-Site vehicle accidents could result in an estimated 2 injuries and 0.066 fatalities among community members (*i.e.*, people involved in haul truck accidents that are neither haul truck drivers nor passengers, including pedestrians, drivers of other vehicles, *etc.*) under this closure scenario (Table 2.5). Off-Site activities are expected to result in a smaller number of expected community injuries (0.16 injuries) and fatalities (0.0041 fatalities) under the CIP scenario (Table 2.5).

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Table 2.5 Expected Number of Community Accidents Under Each Closure Scenario

Closure Scenario	Injuries	Fatalities
CIP	0.16	0.0041
CBR-Offsite	2	0.066

Notes:
CIP = Closure-in-Place; CBR-Offsite = Closure-by-Removal with Off-Site CCR Disposal.

Traffic

Haul routes are expected to use major arterial roads and highways wherever possible, which will reduce the incidence of traffic. However, the heavy use of local roads for construction operations may result in traffic near the Site, the off-Site landfill, and the borrow site.

Traffic may increase temporarily around the Site under both closure scenarios due to the daily arrival and departure of the workforce, equipment mobilization/demobilization, and material deliveries. However, these impacts are expected to largely occur at the beginning or end of each work day (for the arrival/departure of the work force), at the beginning or end of the construction period (for equipment mobilization/demobilization), and at specific times throughout the construction period (for material deliveries). These impacts will therefore likely be less disruptive to community members than the constant and steady movement of haul trucks to and from the Site due to CCR hauling (CBR-Offsite scenario only) and borrow soil hauling (CIP and CBR-Offsite scenarios). Under the CBR-Offsite scenario, hauling-related construction activities (*i.e.*, CCR excavation and backfilling of the EAP) are expected to take approximately 30 months and require approximately 93,000 truckloads (59,000 truckloads of CCR and 34,000 truckloads of borrow soil; Geosyntec, 2021a). Assuming 26 working days per month and 10-hour working days, a haul truck would need to pass a given location near the Site once every 2.5 minutes on average for 30 months under this closure scenario. The traffic demands of the CBR-Offsite scenario are therefore considerable. This level of traffic could potentially cause traffic delays on local roads and cause damage to local roadways. It could also cause delays in the re-development of the Site for use in utility-scale solar generation.

Traffic demands due to hauling are expected to be smaller, though still substantial, under the CIP scenario. The CIP scenario requires approximately 9,300 truckloads to transport borrow soil to the Site, which corresponds with a haul truck passing a given location near the Site once every 4 minutes on average for the approximately 5-month duration of hauling-related construction activities (dewatering/subgrade stabilization, final cover subgrade construction, and installation of the final cover system; Geosyntec, 2021a,c).

Noise

Construction generates a great deal of noise, both in the vicinity of the Site and along haul routes. In a closure impact analysis performed by the Tennessee Valley Authority (TVA, 2015), the authors found that "[T]ypical noise levels from construction equipment used for closure are expected to be 85 dBA or less when measured at 50 ft. These types of noise levels would diminish with distance…at a rate of approximately 6 dBA per each doubling of distance and therefore would be expected to attenuate to the recommended EPA noise guideline of 55 dBA at 1,500 ft." There are no residences within 1,500 feet of the Site; however, there are two industrial operations (Tri-Con Materials and Washington Mills). Employees at Tri-Con Materials and Washington Mills may be adversely impacted by noise pollution under both closure alternatives. Additionally, recreators and wildlife along the Illinois River, which lies within 1,500 feet of the EAP, could be temporarily impacted by construction noise under both scenarios. The duration of noise impacts in the vicinity of the EAP will be greater under the CBR-Offsite scenario

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than under the CIP scenario, because the expected duration of construction is longer under the former scenario (33 months *vs.* 10 months).

In addition to impacts in the immediate vicinity of the EAP, local roads near the Site, the off-Site landfill (CBR-Offsite scenario only), and the borrow site (CIP and CBR-Offsite scenarios) may also experience noise pollution due to high volumes of truck traffic. As described above (Traffic), the construction schedule for the CBR-Offsite scenario requires haul trucks to pass by a given location every 2.5 minutes on average for 10 hours each day for approximately 30 months. The construction schedule for the CIP scenario requires haul trucks to pass a given location every 4 minutes on average for 10 hours each day for approximately 5 months. Dump trucks generate significant noise pollution, with noise levels of approximately 88 decibels or higher expected within a 50-foot radius of the truck (Exponent, 2018). This noise level is similar to the noise level of a gas-powered lawnmower or leaf blower (CDC, 2019). Decibel levels above 80 can damage hearing after 2 hours of exposure (CDC, 2019). In addition to haul truck impacts, noise pollution may also arise from the daily arrival and departure of the workforce, equipment mobilization/demobilization, and material deliveries. These impacts are expected to largely occur at the beginning or end of each work day (for the arrival/departure of the work force), at the beginning or end of the construction period (for equipment mobilization/demobilization), and at specific times throughout the construction period (for material deliveries). These impacts will therefore likely be less disruptive to community members than the constant and steady movement of haul trucks to and from the Site. In summary, noise impacts are expected to be greater under the CBR-Offsite scenario than under the CIP scenario.

Air Quality

Construction can adversely impact air quality. Air pollution can occur both on-Site and off-Site (*e.g.*, along haul routes), potentially impacting workers as well as community members. With regard to construction activities, two categories of air pollution are of particular concern: equipment emissions and fugitive dust. The equipment emissions of greatest concern are those found in diesel exhaust. Most construction equipment is diesel-powered, including the dump trucks used to haul material to and from the Site. Diesel exhaust contains hundreds of air pollutants, including nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide (CO), and volatile organic compounds (VOCs; Hesterberg *et al*., 2009; Mauderly and Garshick, 2009). Fugitive dust, another major air pollutant at construction sites, is generated by earthmoving operations and other soil- and CCR-handling activities. Along haul routes, an additional source of fugitive dust is road dust along unpaved dirt roads. Careful planning and the use of Best Management Practices (BMPs) such as wet suppression are used to minimize and control fugitive dust during construction activities; however, it is not possible to prevent dust generation entirely.

On-Site, emissions will be much higher under the CBR-Offsite scenario than under the CIP scenario, due to the greater amount of on-Site vehicle and equipment travel miles required under the former scenario relative to the latter (238,000 on-Site travel miles under the CBR-Offsite scenario *versus* 53,100 on-Site travel miles under the CIP scenario; Tables 2.1 and 2.2). Off-Site, emissions will similarly be much higher under the CBR-Offsite scenario than under the CIP scenario due to the greater amount of off-Site vehicle and equipment travel miles required under the former scenario relative to the latter (5,850,000 off-Site travel miles under the CBR-Offsite scenario *versus* 537,000 off-Site travel miles under the CIP scenario; *i.e.*, over an order of magnitude difference).

Environmental Justice

The State of Illinois defines environmental justice (EJ) communities to be those communities with a minority population above twice the state average and/or a total population below twice the state poverty rate (IEPA, 2019b). Relative to other communities, EJ communities experience an increased risk of

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adverse health impacts due to environmental pollution and other factors associated with remediation activities (US EPA, 2016).

As shown in a map of EJ communities throughout the state (IEPA, 2019b), the nearest EJ community lies approximately 5.5 miles northeast of the Site near the City of Spring Valley (Figure 2.1). This community is unlikely to be directly impacted by on-Site air emissions, noise pollution, traffic, accidents, or other negative impacts arising at the Site. However, they may be impacted by off-Site impacts, including CCR hauling (CBR-Offsite scenario only), soil hauling (CIP and CBR-Offsite scenarios), labor and equipment mobilization/demobilization, and material deliveries. Off-Site impacts due to labor and equipment mobilization/demobilization and material deliveries are expected to be diffuse (*i.e.,* to span a wide range of transport routes originating over a wide area). Additionally, these impacts are expected to largely occur at the beginning or end of each work day (for the arrival/departure of the work force), at the beginning or end of the construction period (for equipment mobilization/demobilization), and at specific times throughout the construction period (for material deliveries). Haul truck impacts, in contrast, will rely on a single transport route and will result in significant traffic impacts on local roads throughout the entire excavation period. Off-Site hauling is therefore more likely to have a significant impact on EJ communities than other types of off-Site vehicle use.

Two types of off-Site hauling are evaluated in this report: CCR hauling (CBR-Offsite scenario only) and borrow soil hauling (CIP and CBR-Offsite scenarios). Haul truck impacts on EJ communities due to soil hauling under the CIP and CBR-Offsite scenarios are expected to be small, because borrow soil will be sourced from within 10 miles of the Site. There are two EJ communities (one near Spring Valley, and one near La Salle/Peru) within approximately 10 miles of the Site; however, it was assumed that a suitable borrow soil location can be found outside of these communities. In contrast, under the CBR-Offsite scenario, EJ communities located along the haul route to the off-Site landfill or near the off-Site landfill itself may be negatively impacted throughout the excavation period by the air pollution, noise, traffic, and accidents generated by CCR-hauling activities. A review of the Illinois map of EJ communities reveals that the off-Site landfill is not located within the buffer zone of an EJ community. However, based on the three major haul routes suggested by Google Maps (Google, 2021), transport of CCR to the landfill may require hauling CCR through the buffer zone of the EJ community near Peru/La Salle (Figure 2.1).

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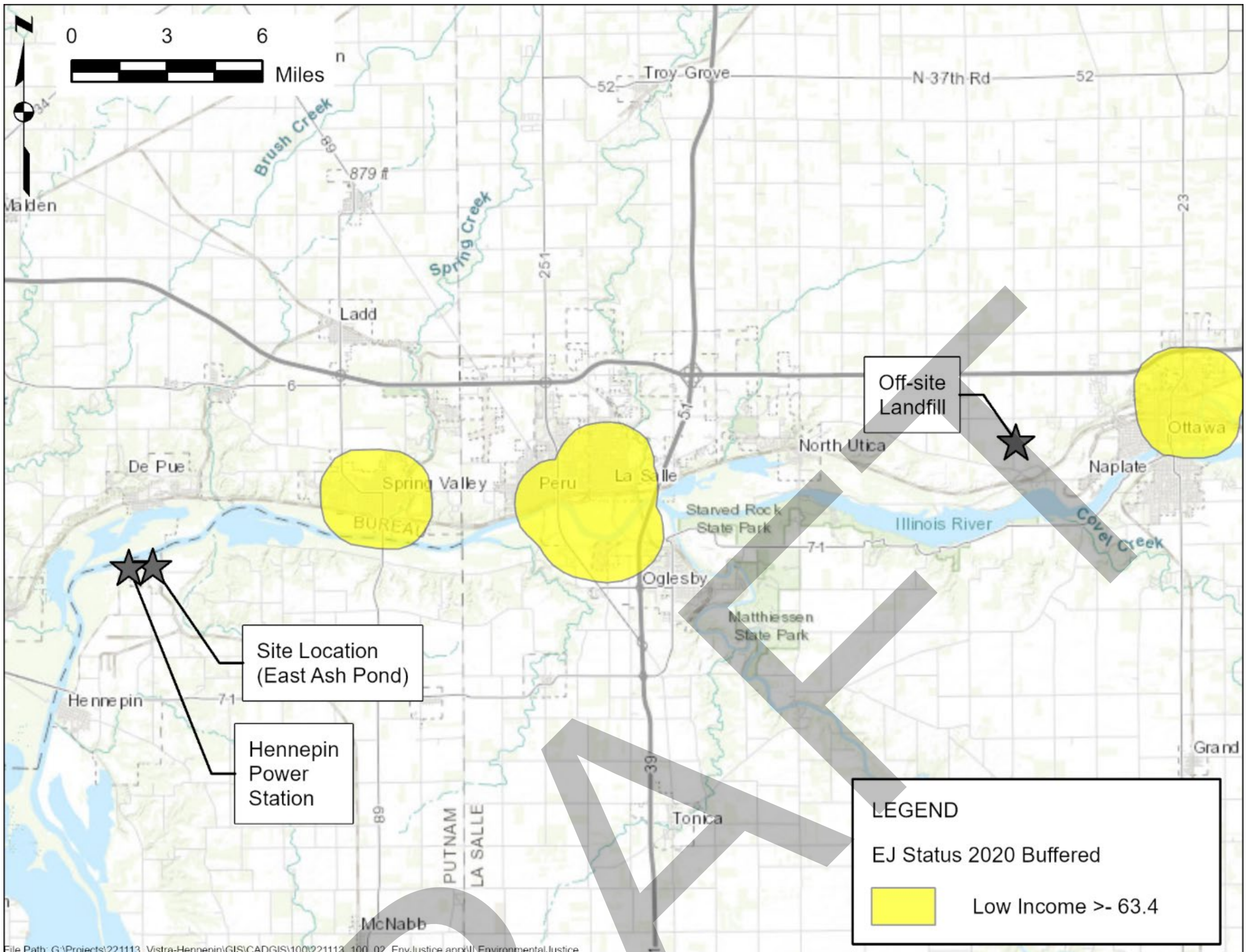

Figure 2.1 Environmental Justice Communities in the Vicinity of the Off-Site Landfill. Adapted from IEPA (2019b).

Scenic, Historical, and Recreational Value

During construction activities, negative impacts on scenic and recreational value may occur along the Illinois River and within the Donnelley/DePue State Fish and Wildlife Areas complex. The Donnelley/DePue State Fish and Wildlife Areas border the Hennepin Site to the north and west and include DePue Lake, Spring Lake, and Coleman Lake. Noise impacts were described above. In addition, construction activities at the EAP may be visible to recreators using the Illinois River, potentially interfering with enjoyment of the view. The duration of construction activities is expected to be longer under the CBR-Offsite scenario than under the CIP scenario (33 months *vs.* 10 months). It is therefore anticipated that short-term impacts on the scenic and recreational value of natural areas near the Site will be greater under the CBR-Offsite scenario than under the CIP scenario.

Based on a review of the Illinois Department of Natural Resources (IDNR) Historic Preservation Division database and the Illinois State Archaeological Survey database, there are no historic sites located within 1,000 meters of the EAP (Ramboll, 2021b).

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2.2.4.3 Environmental Risks

Greenhouse Gas Emissions

In addition to the air pollutants listed above in Section 2.2.4.2, construction equipment emits greenhouse gases (GHGs), including carbon dioxide (CO_2) and possibly nitrous oxide (N_2O). The potential impact of each closure scenario on GHG emissions is proportional to the potential impact of each closure scenario on other emissions from construction vehicles and equipment, as described above in Section 2.2.4.2. In summary, GHG emissions from construction equipment and vehicles will be greater under the CBR-Offsite scenario than under the CIP scenario, because the total on-Site and off-Site vehicle and equipment travel miles required under the CBR-Offsite scenario (6,080,000 vehicles and equipment travel miles) are an order of magnitude greater than those required under the CIP scenario (591,000 vehicle and equipment travel miles; Tables 2.1 and 2.2).

We did not quantify the carbon footprint of the approximately 21 acres of 40-mil LLDPE geomembrane liner required for the final EAP cover system under the CIP scenario. The carbon footprint of this geomembrane (*i.e.*, the fossil fuel emissions required to manufacture it) is an additional source of GHG emissions at the Site under the CIP scenario. If expansion of the off-Site landfill becomes necessary in order to accept all of the CCR from the EAP, then the CBR-Offsite scenario may also have an additional, unquantified carbon footprint due to the manufacture of geomembranes used in the expanded landfill's liner.

Energy Consumption

Energy consumption at a construction site is synonymous with fossil fuel consumption, because the energy to power construction vehicles and equipment comes from the burning of fossil fuels. Fossil fuel demands considered in this analysis include the burning of diesel fuel during construction activities and the carbon footprint of manufacturing geomembrane textiles. Because GHG emission impacts and energy consumption impacts both arise from the same sources at construction sites, the trends discussed above with respect to GHG emissions also apply to the evaluation of energy demands. Specifically, the energy demands of construction equipment and vehicles will be much greater under the CBR-Offsite scenario than under the CIP scenario. We did not quantify the energy demands of the geomembrane required for the construction of the final cover system under the CIP scenario or, potentially, the expansion of the off-Site landfill under the CBR-Offsite scenario.

The Hennepin Site is slated for re-development as a utility-scale solar power generating facility. At the grid scale, solar generation will add energy back onto the grid and reduce reliance on non-renewable energy sources. In the short-term, closure activities at the Site may delay and obstruct these re-development efforts. The magnitude of expected delays will scale with the expected duration and intensity of construction activities during closure. Because the CIP scenario requires less construction activity than the CBR-Offsite scenario and will be completed over a shorter time period, the CIP scenario is expected to result in fewer delays to re-development – and, hence, the more rapid realization of grid-scale energy benefits – than the CBR-Offsite scenario.

Natural Resources and Habitat

Construction is likely to have a negative short-term impact on the natural resources and habitat in the vicinity of the EAP and the off-Site borrow soil location. For example, excavation of the impoundment and the borrow soil location will result in the destruction of some habitat that may currently overlie these areas. Closure will also result in long-term shifts in the habitat overlying the EAP and the borrow soil

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location (*e.g.*, areas of the EAP that are not currently grassland will be converted to grassland). Use of the off-Site landfill under the CBR-Offsite scenario, in contrast, is not expected to result in significant habitat loss, because this landfill is already in use.

In addition to direct impacts to the existing habitat atop the EAP and the off-Site borrow soil location, construction activities may have indirect impacts by causing alarm and escape behavior in wildlife near these locations. The duration of time over which both direct and indirect habitat impacts occur during construction will be longer under the CBR-Offsite scenario than under the CIP scenario, due to the longer expected duration of construction activities under the former scenario (33 months *vs.* 10 months). Thus, negative short-term impacts to natural resources and habitat are expected to be greater under the CBR-Offsite scenario than under the CIP scenario.

The EAP is separated spatially from the Illinois River by a closed impoundment (AP2), the Hennepin Landfill, and the Leachate Pond (Figure 1.1). The EAP is also not located immediately adjacent to any wetlands (USFWS, 2021a). Construction activities in the vicinity of the impoundment are therefore not expected to have a significant negative impact on any wetland or aquatic species (due to, *e.g.*, erosion and sediment runoff). Impacts are expected to be limited to terrestrial species. According to the IDNR Natural Heritage Database, there are 9 state threatened species and 14 state endangered species within Putnam County (Ramboll, 2021b). There is also a large area of critical habitat for the federally endangered Indiana Bat located immediately north of the Illinois River opposite the EAP. If protective action is found to be necessary at the Site, then efforts will be undertaken to minimize disturbances to critical bat habitat during construction activities (USFWS, 2021b).

2.2.5 Time Until Groundwater Protection Standards Are Achieved (IAC Sections 845.710(b)(1)(E) and 845.710(d)(2 and 3))

The highly permeable Henry Formation of the uppermost aquifer, consisting of sands and gravels, is the primary conduit for groundwater to discharge into the Illinois River (Ramboll, 2021b). The downward groundwater migration from the uppermost aquifer to underlying units is significantly limited due to the presence of thick, low-permeability shale bedrock, which acts as a confining layer (Ramboll, 2021b). No other potential groundwater transport pathways, other than discharges to the Illinois River, have been identified for the uppermost aquifer (Ramboll, 2021b). Because the Illinois River is a large regional hydraulic boundary (*i.e.*, serves as a sink for groundwater discharges in the area), all shallow groundwater underlying the EAP is expected to discharge into the river. Similarly, based on measured groundwater elevations, lateral (*i.e.*, side-gradient or parallel to the Illinois River) groundwater flow is not expected. Under each closure scenario, constituents that are in groundwater near the EAP will continue to migrate toward the river.

Groundwater modeling was performed to evaluate future groundwater quality in the vicinity of the EAP under each of the proposed closure alternatives (Ramboll, 2021a). Because there are no known potential GWPS exceedances in groundwater associated with the EAP (Ramboll, 2021b), modeling of closure alternatives evaluated whether groundwater quality would be maintained in compliance with the relevant GWPSs post-closure. Boron was selected for groundwater transport modeling as a primary indicator of CCR impacts in groundwater. Boron is commonly used as a parameter for CCR contaminant transport modeling due to its presence in CCR and because it is relatively mobile and not very reactive in groundwater. The applicable GWPS for boron is 2 mg/L (IEPA, 2021a).

The modeling concluded that groundwater quality near the EAP, based on simulations of boron in groundwater, will maintain compliance with the GWPSs for a period of at least 30 years post-closure for both CIP and CBR-Offsite (Ramboll, 2021a).

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Since the objective of model simulations for unit closure is to estimate long-term concentrations, steady-state, average river stage elevations were used to represent the river (Ramboll, 2021a). However, periodic flooding of the river can create short-term reversals in the groundwater flow direction near the river, which has been documented in Site reports (Ramboll, 2021b). The potential effects of river floods on groundwater flow and boron concentrations in Site groundwater have been previously evaluated at the Site using a transient model developed specifically to represent these conditions (Ramboll, 2021a). As documented in the modeling report, saturation of ash at the EAP due to high river stages is unlikely to occur even during extreme flood events (Ramboll, 2021a). Thus, while high river stages may cause short-term groundwater flow reversals, the use of a long-term steady-state model is appropriate for evaluating the fate and transport of constituents over a multi-year period subsequent to the implementation of each potential closure scenario.

2.2.6 Potential for Exposure of Humans and Environmental Receptors to Remaining Wastes, Considering the Potential Threat to Human Health and the Environment Associated with Excavation, Transportation, Re-disposal, Containment, or Changes in Groundwater Flow (IAC Section 845.710(b)(1)(F))

Section 2.2.1 evaluates potential risks to human and ecological receptors arising from the leaching of CCR-associated constituents into groundwater during closure activities and following closure of the EAP. Section 2.2.2 evaluates the potential for CCR releases to occur due to dike failure or overtopping during floods or other storm-related events. In summary, there is no current or future risk to any human or ecological receptors associated with the EAP. Additionally, there is minimal current or future risk of overtopping occurring at the embankments due to flood conditions at the Site. Dike failure due to, *e.g.*, seismic activity and storm-related events is also exceedingly unlikely.

Section 2.2.4 evaluates several potential risks to human health and the environment during closure activities, including risks of accidents occurring among workers; risks to nearby residents and EJ communities related to accidents, traffic, noise, and air pollution; and risks to natural resources and wildlife. The findings from this section of the text are summarized in Table S.1 (Summary of Findings).

2.2.7 Long-Term Reliability of the Engineering and Institutional Controls (IAC Section 845.710(b)(1)(G))

Post-closure, there is minimal risk of engineering or institutional failures leading to sudden releases of CCR from the impoundment under the CIP scenario. There is no post-closure risk of engineering or institutional failures under the CBR scenario (see Section 2.2.2 above). Additionally, there are no current or future unacceptable risks to any human or ecological receptors under either closure scenario (see Section 2.2.1 above). Reliable engineering and institutional controls (*e.g.*, a bottom liner, a leachate management system, and groundwater monitoring) will be implemented at the off-Site landfill under the CBR-Offsite scenario. The CIP and CBR-Offsite scenarios are therefore both reliable with respect to long-term engineering and institutional controls.

2.2.8 Potential Need for Future Corrective Action Associated with the Closure (IAC Section 845.710(b)(1)(H))

At this time, we do not anticipate a need for corrective action at this Site under either closure scenario.

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2.3 Effectiveness of the Closure Alternative in Controlling Future Releases (IAC Section 845.710(b)(2))

2.3.1 Extent to Which Containment Practices Will Reduce Further Releases (IAC Section 845.710(b)(2)(A))

The CCR in the EAP currently poses no unacceptable risks to human health or the environment (Section 2.2.1). Because current conditions do not present a risk to human health or the environment, and dissolved constituent concentrations are expected to decline post-closure, there will also be no unacceptable risks to human health or the environment following closure, regardless of the closure scenario.

Section 2.2.2 discussed the potential for dike failure or overtopping to occur during or following closure activities, resulting in a sudden release of CCR. That analysis showed that there is minimal risk of sudden CCR releases occurring during or following closure under either closure scenario.

2.3.2 Extent to which Treatment Technologies May Be Used (IAC Section 845.710(b)(2)(B))

At this time, we do not anticipate a need for the use of treatment technologies other than source control (*i.e.*, CIP and CBR-Offsite) at this Site under either closure scenario.

2.4 Ease or Difficulty of Implementing Closure Alternative (IAC Section 845.710(b)(3))

2.4.1 Degree of Difficulty Associated with Constructing the Closure Alternative

Closure-in-Place using a final cover system is a reliable and standard method for managing and closing impoundments that relies on common construction activities. Dewatering and excavating saturated CCR to construct a stabilized final cover system subgrade can present challenges during closure; however, these challenges are common to most CCR surface impoundment closures and are commonly addressed *via* surface water management and dewatering techniques.

Excavation of CCR *via* CBR-Offsite is also a reliable and well-standardized method for closing impoundments. However, relative to CIP, CBR-Offsite will have additional implementation difficulties due to:

- Significantly higher earthwork volumes;
- A longer construction schedule, resulting in the potential for additional weather delays over a multi-year period. A longer construction schedule for CBR-Offsite may also result in a commensurate increase in the amount of precipitation that comes in contact with CCR within the closure area, which could increase the volume of water discharged to the Illinois River *via* the facility's NPDES permit and could potentially require additional water quality controls (*e.g.*, treatment) to meet NPDES discharge requirements;
- Significantly higher dewatering volumes, due to the need to dewater all of the CCR within the EAP under the CBR-Offsite scenario to allow the material to be hauled offsite-in a non-saturated

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condition. This will result in increased water discharge volumes to the Illinois River, relative to CIP, for which only the top 5 to 10 ft of the CCR will be dewatered; and

- Removal and disposal of the existing bottom liner geomembrane under the CBR-Offsite scenario, which may cause unique difficulties. Specifically, it may be difficult to remove and handle the geomembrane; additionally, the geomembrane may not be accepted for disposal at the landfill and it may need to be decontaminated prior to disposal.

Hauling will be easier to implement under the CIP scenario than under the CBR-Offsite scenario, due to significantly smaller earthwork volumes and less haul traffic on public roadways. Hauling under the CIP scenario would only require the importation of approximately 111,000 CY of soils and would not require the transportation of any CCR over public roadways. Additionally, because the CBR-Offsite scenario involves hauling ash off-Site (*i.e.*, intrastate travel), a higher level of dewatering will be required compared to the CBR-Onsite scenario. As described in Section 2.2.4.2 ("Community Impacts"), off-Site hauling may also have detrimental impacts due to an increased incidence of vehicle accidents, truck traffic, noise, and air pollution.

In addition to off-Site hauling, off-Site landfilling under the CBR-Offsite scenario may pose particular challenges. A disposal plan will need to be developed between DMG and the owner/operator of the third-party landfill in order to outline acceptable waste conditions upon delivery, daily waste production rates, and the expected duration of the project. Off-Site landfilling may additionally raise issues related to the co-disposal of CCR and other non-hazardous wastes. Finally, the construction schedule for excavation may be negatively impacted if, during the course of closure, it is determined that the off-Site landfill must be expanded in order to receive all of the CCR excavated from the impoundment.

2.4.2 Expected Operational Reliability of the Closure Alternative

The operational reliability of the CIP scenario and the CBR-Offsite scenario is expected to be similar. CIP will utilize a final cover system that includes a geomembrane, and the EAP currently includes a bottom liner system. Therefore, under the CIP scenario, the CCR will be surrounded by an engineered containment system on the top, sides, and bottom. The CBR-Offsite scenario similarly involves placing the CCR in an engineered landfill system that has a bottom liner, leachate collection system, and final cover system, resulting in the CCR being surrounded by an engineered containment system on the top, sides, and bottom. The operational reliability of both closure scenarios is therefore expected to be similar. Moreover, high reliability is expected under both scenarios due to the full containment of CCR. Operational reliability under the CIP scenario is further assured by the fact that the CCR within the EAP is located above normal groundwater levels (Ramboll, 2021b), and groundwater impacts requiring corrective action have not been encountered at the EAP.

2.4.3 Need to Coordinate with and Obtain Necessary Approvals and Permits from Other Agencies

Permits and approvals will be needed under both closure scenarios. Components of both the CIP and CBR-Offsite closure scenarios that are expected to require a permit include:

- A modification to the existing NPDES permit through IEPA to allow the disposal of water generated from unwatering and dewatering operations to the Illinois River *via* the existing NPDES-permitted outfall for the Site;

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- A construction permit from the Illinois Department of Natural Resources, Office of Water Resources, Dam Safety Program to allow the embankment and spillways of the EAP to be modified as part of closure; and
- A construction stormwater permit through IEPA, including construction stormwater controls and other BMPs such as silt fences and other measures.

Under the CBR-Offsite scenario, it may be necessary to construct additional, pre-approved cells at the off-Site landfill in order to accommodate the mass of waste to be received. It may also be necessary to modify the operating plan for the off-Site landfill in order to accommodate the increased rate of filling of the landfill and the likely need for additional equipment and personnel to manage the receipt and disposal of the CCR.

2.4.4 Availability of Necessary Equipment and Specialists

CIP and CBR-Offsite are both reliable and standardized methods for managing waste that rely on common construction equipment and materials and typically do not require the use of specialists, outside of typical construction labor and equipment operators. However, global supply chains have been disrupted due to the COVID-19 pandemic, resulting in shortages in the availability of construction equipment and parts. There may be some shortages in construction equipment under both scenarios if supply chain resilience does not improve by the time of construction. Alternatively, extended downtime may be required for equipment repairs and maintenance. A national shortage of truck drivers has also developed during the COVID-19 pandemic. Due to significantly higher earthwork volumes and a greater need for construction equipment under the CBR-Offsite scenario than under the CIP scenario, shortages in construction equipment may cause greater challenges under the CBR-Offsite scenario than under the CIP scenario. The current shortage of truck drivers may be particularly impactful under the CBR-Offsite scenario, due primarily to the large volume of CCR to be hauled from the Site. If sufficient trucks and truck drivers are not available, the construction schedule may lengthen based on hauling-related delays.

The availability of critical materials such as metal, wood, and electronic chips has also been impacted by the COVID-19 pandemic. However, soil materials, which are utilized for both scenarios, and geomembrane liner materials, which are required for the CIP scenario, have generally been available during 2021 for landfill development and closure projects.

2.4.5 Available Capacity and Location of Needed Treatment, Storage, and Disposal Services

Under the CIP scenario, all of the CCR currently within the EAP and approximately 8,000 CY of bottom ash excavated from the Hennepin Landfill will be stored within the footprint of the EAP. Treatment will consist of unwatering the EAP at the start of construction, performing limited dewatering to stabilize the CCR subgrade, and managing stormwater inflow. Water from unwatering and dewatering of the EAP will be discharged *via* the existing NPDES permit, utilizing the existing Leachate Pond and Polishing Pond as settling basins. Under the CBR-Offsite scenario, water treatment will similarly consist of unwatering/dewatering the EAP at the start of construction and discharging water from unwatering/dewatering *via* the existing NPDES permit, utilizing the existing Leachate Pond and Polishing Pond as settling basins. Under the CBR-Offsite scenario, a higher volume of water will be sent to the Leachate Pond/Polishing Pond compared to the CIP scenario due to the longer construction schedule and the greater amount of dewatering that will need to occur for CCR to be transported on public roads to the off-Site disposal location.

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For the CBR-Offsite scenario, 710,000 CY of CCR and liner materials will be excavated from the EAP and require disposal. According to the IEPA "Landfill Disposal Capacity Report" for 2020 (IEPA, 2021b), the closest nearby third-party landfill with the ability to receive and dispose of CCR from the Site is the Republic Services LandComp Landfill in Ottawa, Illinois. This facility has 8,500,000 CY of remaining capacity in its current permitted footprint. It receives 450,000 CY of waste annually, and is located 32 miles from the Site by road. The LandComp Landfill therefore has sufficient capacity to receive CCR from the EAP. However, closure of the EAP would increase the annual waste receipt rate at the off-Site landfill by approximately 50%. Due to the short time frame over which CCR would be received at the landfill, vertical and/or lateral expansions may become necessary. Additionally, the landfill operators may need to develop a disposal plan to account for the increased volume of material that will be received and the unique CCR waste characteristics. Elements of this disposal plan might include increasing daily operational capacity and procedures, expediting planned airspace construction, and potentially expediting landfill expansion.

If expansion of the LandComp Landfill is impractical or infeasible, then an alternative landfill located farther from the Site would need to be identified. A likely alternative to the LandComp Landfill is the Eco Hill Landfill (aka Atkinson Landfill) in Atkinson, Illinois. It has 11,700,000 CY of remaining capacity in its current permitted footprint, receives 270,000 CY of waste annually, and is located 54 miles from the Site (IEPA, 2021b).

2.5 Impact of Closure Alternative on Waters of the State (IAC Section 845.710(d)(4))

As demonstrated in Gradient's Human Health and Ecological Risk Assessment (Appendix A of this report), both modeled and measured surface water concentrations in the Illinois River are all below relevant human health and ecological screening benchmarks. Surface water concentrations of CCR-associated constituents are expected to decline over time under both closure scenarios. Thus, no future exceedances of any human health or ecological screening benchmarks are anticipated under either closure scenario. Additionally, the lined landfill that will receive the CCR excavated from the impoundment under the CBR-Offsite scenario will be managed to ensure that no surface water impacts occur in the vicinity of the landfill.

2.6 Concerns of Residents Associated with Closure Alternatives (IAC Section 845.710(b)(4))

Several nonprofits representing community interests near the Site have raised concerns regarding the potential impacts of coal ash impoundments at this Site on groundwater and surface water quality, including Earthjustice, the Prairie Rivers Network, and the Sierra Club (Earthjustice *et al*., 2018; Sierra Club, 2014; Sierra Club and CIHCA, 2014). These parties generally prefer CBR to CIP, citing fears that allowing CCR to remain in place "allows the widespread groundwater contamination to continue indefinitely" (Earthjustice *et al*., 2018, p. 24). However, it is not the case that closing the EAP *via* CIP rather than CBR would result in undue risks to groundwater and surface water post-closure. As described in Sections 2.2.1 and 2.2.2, no current or future unacceptable risks to human or ecological receptors are associated with the EAP under either scenario. There is also minimal risk of future CCR releases occurring under either scenario. Furthermore, modeling concluded that groundwater quality near the EAP, based on simulations of boron in groundwater, will maintain compliance with the GWPSs for a period of at least 30 years post-closure for both CIP and CBR-Offsite (Ramboll, 2021a). Both closure

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scenarios are therefore responsive to residents' concerns regarding impacts to groundwater and surface water quality.

The CIP scenario has several advantages over the CBR-Offsite scenario with regards to likely community concerns. Notably, the CIP scenario presents far fewer risks to workers, nearby residents, and potentially EJ communities during construction in the form of accidents, traffic, noise, and air pollution (Section 2.2.4 above). Closure will also be achieved more rapidly under the CIP scenario than under the CBR-Offsite scenario, due to the shorter duration of construction activities. Finally, the Site can be more rapidly re-developed for use in utility-scale solar generation under the CIP scenario than under the CBR-Offsite scenario. Re-development of the Site for use in solar generation and storage will bring new jobs to the community and contribute positively to Illinois's growing renewable energy portfolio.

2.7 Class 4 Cost Estimate (IAC Section 845.710(d)(1))

A Class 4 cost estimate will be prepared in the final closure plan consistent with the Advancement of Cost Engineering (AACE) Classification Standard (or a comparable classification practice as provided in the AACE Classification Standard), as required by IAC Section 845.710 (IEPA, 2021a).

2.8 Summary

Table S.1 (Summary of Findings) summarizes the expected impacts of the CIP and CBR-Offsite closure scenarios with regard to each of the factors specified under IAC Section 845.710 (IEPA, 2021a). Based on this evaluation and the details provided in Section 2 above, CIP has been identified as the most appropriate closure scenario for the EAP. Key benefits of the CIP scenario relative to the CBR-Offsite scenario include more rapid re-development of the Site for use in utility-scale solar generation and greatly reduced impacts to workers, community members, and the environment due to construction activities (*e.g.*, fewer constructed-related accidents, lower energy demands, less air pollution and GHG emissions, less traffic, and potentially lower impacts to EJ communities). Furthermore we do not anticipate a need for any groundwater corrective measures other than source control (*i.e.*, CIP and CBR-Offsite) at this Site under either closure scenario. These conclusions are subject to change as additional data are collected and following the completion of an upcoming public meeting, which will be held in December 2021 pursuant to requirements under IAC Section 845.710(e). Following the public meeting, a final closure decision will be made based on the considerations identified in this report, the results of additional data that are collected, and any additional considerations that arise during the public meeting. The final closure recommendation will be provided in a Final Closure Plan, which will be submitted to IEPA as described under IAC Section 845.720(b) (IEPA, 2021a).

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Appendix A

Human Health and Ecological Risk Assessment

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Human Health and Ecological Risk Assessment
East Ash Pond
Hennepin Power Plant
Hennepin, Illinois

November 8, 2021

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Abbreviations

ADI	Acceptable Daily Intake
BCF	Bioconcentration Factor
CAA	Closure Alternatives Assessment
CCR	Coal Combustion Residual
CEM	Conceptual Exposure Model
COI	Constituent of Interest
COPC	Constituent of Potential Concern
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
CWS	Community Water Supply Well
DMG	Dynegy Midwest Generation, LLC
DWW	Drinking Water Watch
EAP	East Ash Pond
ESV	Ecological Screening Value
GWPS	Groundwater Protection Standards
GWQS	Groundwater Quality Standards
HPP	Hennepin Power Plant
HTC	Human Threshold Criteria
IAC	Illinois Administrative Code
ID	Identification
IEPA	Illinois Environmental Protection Agency
ISGS	Illinois State Geological Survey
MCL	Maximum Contaminant Level
NID	National Inventory of Dams
NRWQC	National Recommended Water Quality Criteria
ORNL RAIS	Oak Ridge National Laboratory's Risk Assessment Information System
PWS	Public Water System
RfD	Reference Dose
RME	Reasonable Maximum Exposure
RSL	Regional Screening Level
SDWIS	Safe Drinking Water Information System
SWQS	Surface Water Quality Standards
TDS	Total Dissolved Solids
TEC	Threshold Effect Concentration
US DOE	United States Department of Energy's
US EPA	United States Environmental Protection Agency
USGS	US Geological Survey

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1 Introduction

Dynegy Midwest Generation Company's Hennepin Power Plant (HPP, or "the Site") is an electric power-generating facility with coal-fired units located in Hennepin, Illinois. The facility began operations in the early 1950s and was retired in 2019 (Ramboll, 2021). The HPP produced and stored coal combustion residuals (CCRs) as a part of its historical operations in several CCR ash ponds located both east and west of the power plant (East Ash Pond No. 2, East Ash Pond No. 4, East Ash Pond [EAP], Leachate Pond, Polishing Pond; Old West Ash Pond [Pond No. 1 and Pond No. 3], and Old West Polishing Pond). The EAP (Vistra identification [ID] number [No.] 803, Illinois Environmental Protection Agency [IEPA] ID No. W1550100002-05, and National Inventory of Dams [NID] No. IL50363) is planned for closure and is the subject of this report.

This report presents the results of an evaluation that characterizes potential risk to human and ecological receptors that may be exposed to CCR constituents in environmental media potentially impacted by the EAP. This risk evaluation was performed to support the Closure Alternatives Assessment (CAA) for the EAP in accordance with requirements in Title 35 Part 845 of the Illinois Administrative Code (IAC) (IEPA, 2021a). Human and ecological risks were evaluated for Site-specific constituents of interest (COIs). The conceptual site model (CSM) assumed that Site-related COIs in groundwater may migrate to the Illinois River and affect surface water and sediment in the vicinity of the Site.

Consistent with United States Environmental Protection Agency (US EPA) guidance (US EPA, 1989), this report used a tiered approach to evaluate potential risks, which included the following steps:

1. Identify complete exposure pathways and develop a conceptual exposure model (CEM).
2. Identify Site-related COIs: Constituents detected in groundwater were considered COIs if their maximum detected concentration over the period from 2015 to 2021 exceeded a groundwater protection standard (GWPS), identified in Part 845.600 (IEPA, 2021a), or a relevant surface water quality standard (IEPA, 2019a; US EPA Region IV, 2018).
3. Perform screening-level risk analysis: Compare maximum measured or modeled COI concentrations in surface water and sediment to conservative, health-protective benchmarks to determine constituents of potential concern (COPCs).
4. Perform refined risk analysis: If COPCs are identified, perform a refined analysis to evaluate potential risks associated with the COPCs.
5. Formulate risk conclusions and discuss any associated uncertainties.

This assessment relies on a conservative (*i.e.*, health-protective) approach and is consistent with the risk approaches outlined in US EPA guidance. Specifically, we considered evaluation criteria detailed in IEPA guidance documents (*e.g.*, IEPA, 2013, 2019a), incorporating principles and assumptions consistent with the Federal CCR Rule (US EPA, 2015a) and US EPA's "Human and Ecological Risk Assessment of Coal Combustion Residuals" (US EPA, 2014).

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Based on the evaluation presented in this report, no unacceptable risks to human and ecological receptors resulting from CCR exposures associated with the EAP were identified. Specific risk assessment results include the following:

- No unacceptable risks were identified for recreators swimming or boating in the Illinois River adjacent to the Site.
- No unacceptable risks were identified for recreators exposed to sediment in the Illinois River adjacent to the Site.
- No unacceptable risks were identified for anglers consuming locally caught fish.
- No unacceptable risks were identified for ecological receptors exposed to surface water or sediment.
- No bioaccumulative ecological risks were identified.

It should be noted that this evaluation incorporates a number of conservative assumptions that tend to overestimate exposure and risk. Moreover, it should be noted that because current conditions do not present a risk to human health or the environment, there will also be no unacceptable risk to human health or the environment for future conditions when the EAP is closed. For all future closure scenarios, potential releases of CCR-related constituents will decline over time and consequently potential exposures to CCR-related constituents in the environment will also decline.

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2 Site Overview

2.1 Site Description

The HPP is located four miles northeast of the Village of Hennepin in north central Illinois in Putnam County. The HPP property is bordered on the north by the Illinois River, on the south and east by industrial property, and on the west by agricultural land. The Illinois River flows past the facility from east to west. The CCR ash ponds located to the east of the power plant include East Ash Pond No. 2, East Ash Pond No. 4, and the EAP (Figure 2.1). East Ash Pond No. 2 and East Ash Pond No. 4 have been closed with IEPA approval. The EAP is a lined unit constructed from 1995 to 1996 to replace the East Ash Pond No. 2, which was removed from service (Ramboll, 2021). The EAP is planned for closure and is the subject of this report.

2.2 Geology/Hydrogeology

The geology underlying the Site in the vicinity of the EAP primarily consists of unlithified deposits of the Cahokia Alluvium and Henry Formation, underlain by a thick shale bedrock (Ramboll, 2021). Two distinct hydrostratigraphic units have been identified in the area: the uppermost water-bearing unit composed of the Cahokia Alluvium and Henry Formation, and a confining shale bedrock unit. The Illinois River, located less than 0.1 mile downgradient of the EAP, is the major surface water body in the area. The uppermost aquifer beneath the EAP is hydraulically connected to the Illinois River, while the low permeability bedrock aquitard acts as a barrier to downward migration of groundwater from the uppermost aquifer. These two major hydrostratigraphic units are discussed below.

The uppermost aquifer includes the Cahokia Alluvium and Henry Formation. The Cahokia Alluvium consists of fine-grained silt and clay deposits with an estimated thickness of about 20-40 feet (ft) at the EAP. The Henry Formation fills the valley under the Cahokia Alluvium and is composed of highly permeable sands and gravels (Ramboll, 2021). The thickness of the Henry Formation ranges from 21 to 45 ft within the EAP (Ramboll, 2021). The total thickness of the uppermost aquifer (*i.e.*, combined thickness of the Cahokia Alluvium and Henry Formation) directly beneath the EAP is approximately 80 ft; however, only the bottom 45 ft has been reported to be saturated (Ramboll, 2021).

Field measurements of horizontal hydraulic conductivities (K_x) of the Henry Formation ranged between 0.0016 and 3.2 cm/s, with a geometric mean of approximately 0.1 cm/s (Ramboll, 2021). The laboratory-measured vertical hydraulic conductivity values (K_z) for the uppermost aquifer ranged from 1.5×10^{-7} cm/s to 7.1×10^{-8} cm/s, with a geometric mean of about 6.4×10^{-8} cm/s (Ramboll, 2021).

Groundwater in the uppermost aquifer flows from south to north/northwest and discharges into the Illinois River under normal conditions (Ramboll, 2021). A flow reversal (*i.e.*, groundwater flows in a south to southwest direction) may occur during high river stages or flooding events when the Illinois River stage elevation is significantly higher than surrounding groundwater elevations. Under normal conditions (*i.e.*, no flow reversals), the average groundwater flow velocity from north to south across the Site is about 2.38 ft/day (Ramboll, 2021). The average horizontal hydraulic gradient near the EAP ranges from 0.0003 to 0.0035 ft/ft under normal conditions (Ramboll, 2021).

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The bedrock aquitard consists of low-permeability shales and thin layers of limestone, sandstone, and coal beds of the Pennsylvanian Carbondale Formation (Ramboll, 2018-2020, 2021). The estimated thickness of the shale bedrock in the vicinity of the EAP is approximately 300-400 ft (Ramboll, 2018-2020, 2021). The horizontal hydraulic conductivities of the shale bedrock range between 5×10^{-6} and 5×10^{-10} cm/s. The vertical hydraulic conductivities range between 5×10^{-8} and 5×10^{-12} cm/s (Ramboll, 2021), indicating an anisotropy ratio (K_x/K_z) of 100 in the bedrock aquifer. The very low hydraulic conductivities of the aquitard significantly restrict horizontal and vertical migration of groundwater and do not yield usable quantities of water required for domestic water supply.

Figure 2.1 Site Location Map. Source: Ramboll (2021).

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2.3 Conceptual Site Model

A CSM describes sources of contamination, the hydrogeological units, and the physical processes that control the transport of water and solutes. In this case, the CSM describes how groundwater underlying the EAP migrates and interacts with surface water and sediment in the adjacent Illinois River. The CSM was developed using available hydrogeological data (Ramboll, 2021), including information on groundwater flow and surface water characteristics.

The highly permeable Henry Formation of the uppermost aquifer, consisting of sands and gravels, is the primary conduit for groundwater to discharge into the Illinois River (Ramboll, 2021). The downward groundwater migration from the uppermost aquifer to underlying units is significantly limited due to the presence of thick, low-permeability shale bedrock, which acts as a confining layer (Ramboll, 2021). No other potential groundwater transport pathways, other than discharges to the Illinois River, have been identified for the uppermost aquifer (Ramboll, 2021). Because the Illinois River is a large regional hydraulic boundary (*i.e.*, serves as a sink for groundwater discharges in the area), all shallow groundwater underlying the EAP is expected to discharge into the river. Similarly, based on measured groundwater elevations, lateral (*i.e.*, side-gradient or parallel to the Illinois River), groundwater flow is not expected.

At its discharge location, groundwater near the EAP mixes with surface water in the Illinois River. During groundwater discharge into the river, dissolved constituents in groundwater may partition between sediments and surface water.

2.4 Groundwater Monitoring

Thirteen wells have been used to monitor the groundwater quality near and downgradient of the EAP. Of these, 12 wells are screened in the uppermost aquifer, and 1 is screened in the bedrock unit (Table 2.1). The analyses presented in this report relied on all available data from the 13 wells collected between 2015 and 2021, which is the period subsequent to the promulgation of the Federal CCR Rule. Groundwater samples were analyzed for a suite of metals, both total and dissolved, specified in Illinois CCR Rule Part 845.600 (IEPA, 2021a).[1] A summary of the groundwater data used in this risk evaluation is presented in Table 2.2. The EAP well locations are shown in Figure 2.1. Note that there are additional wells in the vicinity of the EAP (shown on Figure 2.1) that were not used in this risk analysis, because these wells are downgradient of, and potentially affected by the presence of, other CCR disposal units including East Ash Pond No. 2, East Ash Pond No. 4, a landfill, and a leachate pond. The use of groundwater data in this risk evaluation does not imply that detected constituents are associated with the EAP or that they have been identified as potential groundwater exceedances.

[1] Samples were analyzed for a longer list of inorganic constituents and general water quality parameters (chloride, fluoride, sulfate, and total dissolved solids), but these constituents were not evaluated in the risk evaluation.

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Table 2.1 Groundwater Monitoring Wells Related to Hennepin East Ash Pond

Well	Date Constructed	Screen Top Depth (ft BGS)	Screen Bottom Depth (ft BGS)	Well Depth from Ground Surface (ft BGS)	Hydrogeologic Unit
7	11/15/1984	67.5	77.5	78	UA
8	11/17/1984	51.5	61.5	62	UA
08D	4/17/2009	83	88	90	UA
12	3/28/1995	49.5	59.5	60	UA
13	3/1/1995	67	69	75	UA
16	3/30/1995	56	66	68	UA
17	3/30/1995	58.1	68.1	68	UA
46	8/11/2015	50	60	60	UA
47	8/11/2015	50	60	60	UA
52	2/11/2021	51	61	60.9	UA
53	1/13/2021	53.8	63.8	64.1	UA
54	2/9/2021	65	75	74.1	UA
55	2/10/2021	90	95	94.7	BR

Notes:
BGS = Below Ground Surface; BR: Bedrock Unit; UA = Uppermost Aquifer.

Table 2.2 Groundwater Data Summary

Constituent	Samples with Constituent Detected	Samples Analyzed	Minimum Detected Value	Maximum Detected Value	Maximum Laboratory Detection Limit
Total Metals (mg/L)					
Antimony	0	146	-	-	0.002
Arsenic	8	165	0.001	0.0025	0.001
Barium	176	176	0.0351	0.23	0.004
Beryllium	0	146	-	-	0.001
Boron	186	186	0.0544	1.41	0.1
Cadmium	7	172	0.0011	0.0024	0.002
Chromium	11	165	0.001	0.019	0.005
Cobalt	64	160	0.001	0.147	0.001
Lead	9	165	0.0011	0.0036	0.001
Lithium	163	164	0.0051	0.0414	0.005
Mercury	0	161	-	-	0.0002
Molybdenum	129	176	0.001	0.0681	0.01
Selenium	53	175	0.001	0.0093	0.001
Thallium	0	146	-	-	0.002
Dissolved Metals (mg/L)					
Antimony	4	182	0.0011	0.0022	0.001
Arsenic	0	182	-	-	0.001
Barium	182	182	0.03	0.175	0.0025
Beryllium	0	182	-	-	0.001
Boron	182	182	0.05	1.32	0.025
Cadmium	1	182	0.0023	0.0023	0.002
Chromium	0	182	-	-	0.005
Cobalt	38	182	0.0039	0.124	0.005
Lead	4	182	0.0011	0.0013	0.001
Mercury	0	182	-	-	0.0002
Molybdenum	55	110	0.0055	0.04	0.01

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Constituent	Samples with Constituent Detected	Samples Analyzed	Minimum Detected Value	Maximum Detected Value	Maximum Laboratory Detection Limit
Selenium	58	182	0.001	0.009	0.001
Thallium	0	182	-	-	0.002
Radionuclides (pCi/L)					
Radium-226+228	86	159	0	3.21	2.0

Note:
- = Not applicable.

2.5 Surface Water Monitoring

Surface water samples were collected in September 2020 from 15 locations in the Illinois River adjacent to the HPP. The samples were collected along five transects, with three samples per transect collected from the two edges and the center of the river (Figure 2.2). Sample set IR-01 was collected approximately one mile upstream of the HPP. Sample sets IR-02 and IR-03 were located immediately upstream and downstream, respectively, of the EAP area. Sample sets IR-04 and IR-05 were located downstream of the EAP. It should be noted that many constituents occur naturally in the environment and/or could be associated with industrial activities unrelated to the EAP. The use of surface water data in this risk assessment does not imply that any constituents are associated with the EAP. A summary of the surface water data used in this risk evaluation is presented in Table 2.3.

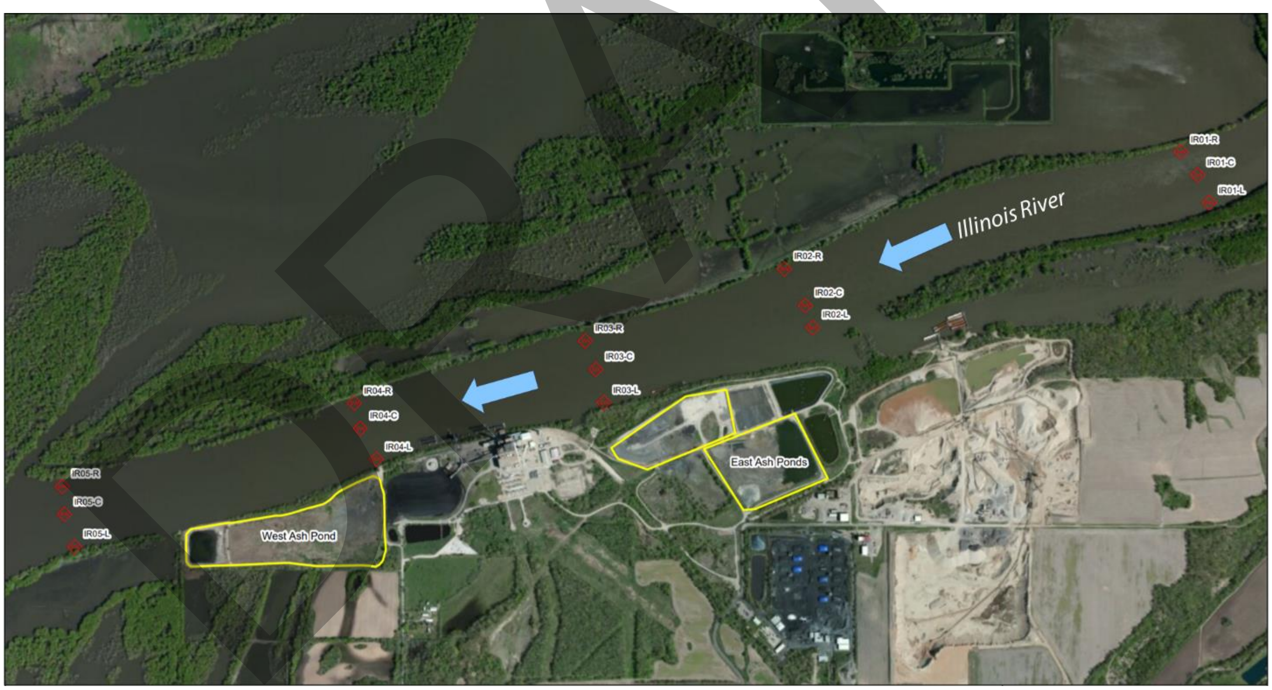

Figure 2.2 Surface Water Sampling Locations. Source: Geosyntec (2021a).

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Table 2.3 Surface Water Data Summary

Constituent	Samples with Constituent Detected	Samples Analyzed	Minimum Detected Value	Maximum Detected Value	Maximum Detection Limit
Dissolved Metals (mg/L)					
Aluminum	1	15	0.641	0.641	0.025
Antimony	0	15	-	-	0.001
Arsenic	15	15	0.0026	0.0034	-
Barium	15	15	0.0351	0.0462	-
Beryllium	0	15	-	-	0.001
Boron	15	15	0.125	0.147	-
Cadmium	0	15	-	-	0.001
Chromium	1	15	0.015	0.015	0.015
Cobalt	0	15	-	-	0.001
Lead	1	15	0.002	0.002	0.001
Lithium	15	15	0.0071	0.0083	-
Molybdenum	15	15	0.0048	0.0063	-
Selenium	0	15	-	-	0.001
Thallium	0	15	-	-	0.002
Other (mg/L, unless otherwise noted)					
Chloride	15	15	97	103	-
pH (SU)	15	15	8.6	8.6	-
Sulfate	15	15	73	79	-
Total Dissolved Solids	10	10	368	416	-

Note:
- = Not applicable; SU = Standard Unit.

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3 Risk Evaluation

3.1 Risk Evaluation Process

A risk evaluation was conducted to determine whether constituents present in groundwater underlying and downgradient of the EAP have the potential to pose adverse health effects to human and ecological receptors. The risk evaluation is consistent with the principles of risk assessment established by US EPA and has considered evaluation criteria detailed in Illinois guidance documents (*e.g.*, IEPA, 2013, 2019a).

The general risk evaluation approach is summarized in Figure 3.1 and discussed below.

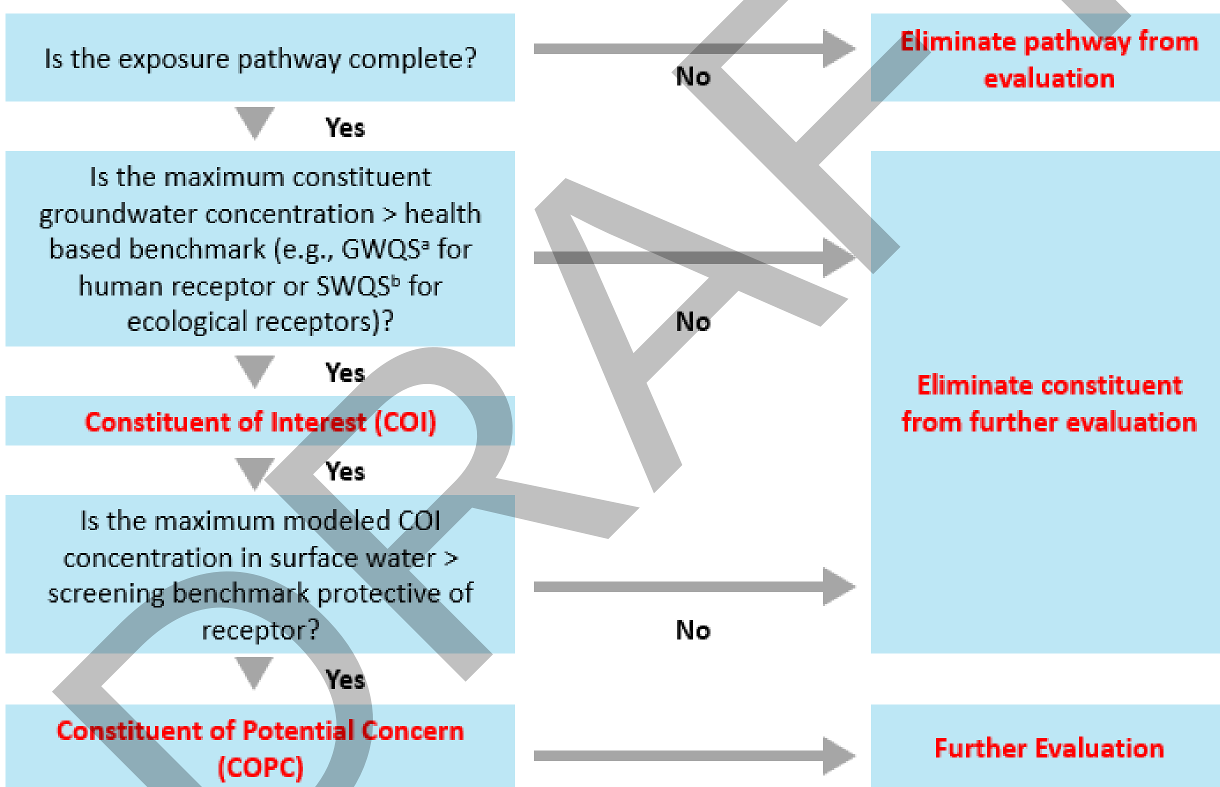

Figure 3.1 Overview of Risk Evaluation Methodology
IEPA = Illinois Environmental Protection Agency; GWQS = IEPA Groundwater Quality Standards; SWQS = IEPA Surface Water Quality Standards.
(a) The IEPA Part 845 groundwater protection standards were used to identify COIs.
(b) IEPA SWQS protective of chronic exposures to aquatic organisms were used to identify ecological COIs. In the absence of an SWQS, US EPA Region IV ecological screening values were used.

The first step in the risk evaluation was to develop the CEMs and identify complete exposure pathways. All potential receptors and exposure pathways based on groundwater use and surface water use in the vicinity of the Site were considered. Exposure pathways that are incomplete were excluded from the evaluation.

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Groundwater data were used to identify COIs. COIs were identified as constituents with maximum concentrations in groundwater in excess of groundwater quality standards (GWQS)[2] for human receptors and surface water quality standards (SWQS) for ecological receptors. Based on the CSM (Section 2.2), groundwater underlying the EAP flows from south to north toward the Illinois River. Therefore, any potential EAP-related constituents in groundwater would flow toward and discharge into surface water.

Surface water samples have been collected from the Illinois River adjacent to the Site; however, sediment samples have not been collected from the river. Gradient modeled the potential migration of COIs from groundwater to surface water and sediment to evaluate potential risks to receptors (see Section 3.3.3). Gradient modeled the COI concentrations in surface water and sediment based on the groundwater data from the EAP-related wells. The measured and modeled COI concentrations in surface water, and the modeled sediment concentrations, were compared to conservative, generic risk-based screening benchmarks for human health and ecological receptors. These generic screening benchmarks rely on default assumptions with limited consideration of site-specific characteristics. Human health benchmarks are receptor-specific values calculated for each pathway and environmental medium that are designed to be protective of human health. Ecological benchmarks are medium-specific values designed to be protective of all potential ecological receptors exposed to surface water. Ecological and human health screening benchmarks are inherently conservative because they are intended to screen out chemicals that are of no concern with a high level of confidence. Therefore, a measured or modeled COI concentration exceeding a screening benchmark does not indicate an unacceptable risk, but only that further risk evaluation is warranted. COIs with maximum concentrations exceeding a conservative screening benchmark are identified as COPCs requiring further evaluation.

As described in more detail below, this evaluation relied on the screening assessment to demonstrate that constituents present in groundwater underlying the EAP do not pose an unacceptable human health or ecological risk. That is, after the screening step, no COPCs were identified and further assessment was not warranted.

3.2 Human and Ecological Conceptual Exposure Models

A CEM provides an overview of the receptors and exposure pathways requiring risk evaluation. The CEM describes the source of the contamination, the mechanism that may lead to a release of contamination, the environmental media to which a receptor may be exposed, the route of exposure (exposure pathway), and the types of receptors that may be exposed to these environmental media.

3.2.1 Human Conceptual Exposure Model

The human CEM for the Site depicts the relationships between the off-Site environmental media potentially impacted by constituents in groundwater and human receptors that could be exposed to these media. Figure 3.2 presents a human CEM for the Site. It considers a human receptor who could be exposed to COIs hypothetically released from the EAP into groundwater, surface water, sediment, and fish. The following human receptors and exposure pathways were evaluated for inclusion in the Site-specific CEM.

- Residents – exposure to groundwater/surface water as drinking water;

[2] As discussed further in Section 3.3.2, GWQS are protective of human health and not necessarily of ecological receptors. While ecological receptors are not exposed to groundwater, groundwater can potentially enter into the adjacent surface water and impact ecological receptors. Therefore, two sets of COIs were identified: one for humans and another for ecological receptors.

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- Residents – exposure to groundwater/surface water used for irrigation;
- Recreators in the river near the Site:
  - Boaters – exposure to surface water and sediment while boating;
  - Swimmers – exposure to surface water and sediment while swimming;
  - Anglers – exposure to surface water and sediment and consumption of locally caught fish.

All of these exposure pathways were considered complete except for residential exposure to groundwater or surface water used for drinking water or irrigation. Section 3.2.1.1 explains why the residential drinking water and irrigation pathways are incomplete, and Section 3.2.1.2 provides additional description of the recreational exposures.

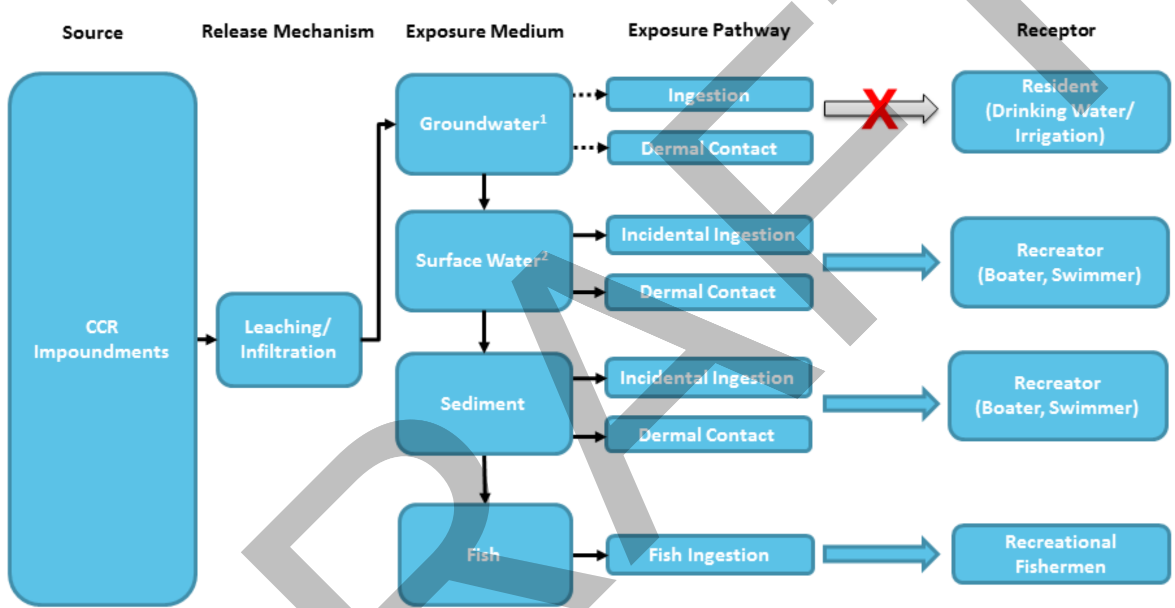

Figure 3.2 Human Conceptual Exposure Model. CCR = Coal Combustion Residual. Dashed line/Red X = Incomplete or insignificant exposure pathway. (1) Groundwater in the vicinity of the Site is not used as a drinking water or irrigation source. (2) Surface water is not used as a drinking water source.

3.2.1.1 Groundwater or Surface Water as a Drinking Water/Irrigation Source

Groundwater as a source of drinking water and/or irrigation water is not a complete exposure pathway for CCR-related constituents originating from the EAP. Specifically, shallow groundwater from the uppermost aquifer in the vicinity of the EAP is not used as a source of drinking water, and no public groundwater systems are downgradient of Hennepin. Further, the downward migration of groundwater from the uppermost aquifer is restricted due to the presence of a thick, shale bedrock (Ramboll, 2021). A summary of the evidence supporting the conclusion that there are no residential uses of the shallow groundwater and Illinois River surface water as a source of drinking water is presented below:

- **No potential groundwater receptors are in the vicinity of the EAP**. The public water systems (PWS) in the Putnam and Bureau Counties in the vicinity of the Hennepin EAP rely on groundwater as a source of potable water. A review of existing drinking water intakes within the US EPA Safe

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Drinking Water Information System (SDWIS)[3] and IEPA Illinois Drinking Water Watch (DWW)[4] databases yielded no PWS wells within 1,000 meters of the Site (Ramboll, 2021).

- A total of 10 wells were identified within a 1,000-meter radius of the EAP during a comprehensive search of the Illinois State Geological Survey's (ISGS) Illinois Water and Related Wells (ILWATER) Map[5] (Ramboll, 2021) (see Figure 3.3). Under normal groundwater flow conditions, 3 out of those 10 wells are located downgradient from the EAP (Well IDs 121552059800, 121552043500, and 121550012800), 2 wells are located side-gradient (Well IDs 121552045800, 121552059900), and the remaining 5 wells are located upgradient (Well IDs 121552029200, 121552049700, 121552025800, 121552051800, 121552068500) (Ramboll, 2021).
  - ♦ Because groundwater flow under the EAP is predominantly to the north/northwest towards the Illinois River, the CCR-impacted groundwater will not impact the seven wells that are located either upgradient or side-gradient of the EAP.
- Further, the three downgradient wells and one of the side-gradient wells (Well ID 121552059900) are owned by the Dynegy Midwest Generation, LLC (DMG) and are non-potable and non-contact industrial wells (Ramboll, 2021). A 2009 water well survey conducted in the area by Kelron/Natural Resource Technology concluded that CCR-impacted groundwater at Hennepin is not likely to impact any existing potable or non-potable off-Site water wells that are located within 2,500 ft of the Hennepin Power Plant property boundary (Ramboll, 2018-2020).
- In a letter to IEPA (Morris, 2021), DMG noted that 16 private wells were identified near the Site, with 1 well located potentially downgradient of the Site. However, DMG noted that this well is unlikely to be in use, based on the installation date (1884) and its remote floodplain location. DMG noted that three non-community water supply wells (CWS) were identified but that they are unlikely to be at risk because they are either inactive and/or not-located hydraulically downgradient of the EAP.

▪ **There is no off-Site migration of EAP-related constituents to nearby wells because all shallow groundwater flows into the Illinois River**. The Illinois River is the regional discharge point for groundwater in the uppermost aquifer. Groundwater hydraulic head measurements in wells screened within the uppermost aquifer near the EAP indicate that groundwater flows toward the river (Ramboll, 2021). Based on groundwater elevation data and because the Illinois River is a large regional hydraulic boundary (*i.e.*, serves as a sink for groundwater discharges in the area), any potential constituents present in groundwater underlying the EAP are not likely to migrate under or beyond the river.

▪ **The Illinois River adjacent to the Site is not used as a public water supply.** IEPA classified the Illinois River as a "General Use Water." IEPA fully supports the use of the Illinois River for aquatic life and primary contact recreation, but it is not designated for public and food processing water supplies. The segment of the Illinois River adjacent to the Site (Section D-16) is listed on the 2018 Illinois Section 303(d) List as being impaired for fish consumption, due to mercury and polychlorinated biphenyls (IEPA, 2016, 2018, 2019b). Therefore, surface water adjacent to the Site is not used as a source of drinking water, and this exposure pathway was not evaluated further.

▪ **The EAP has a limited hydraulic connection to underlying bedrock groundwater resources**. The bedrock aquitard is composed of a 300-400 ft thick shale unit of the Carbondale Formation

[3] US EPA SDWIS (US EPA, 2021a): https://www.epa.gov/enviro/sdwis-search.
[4] IEPA Illinois DWW (IEPA, 2021b): http://water.epa.state.il.us/dww/index.jsp.
[5] ISGS ILWATER Map (ISGS, 2020): https://prairieresearch.maps.arcgis.com/apps/webappviewer/index.html?id=e06b64ae0c814ef3a4e43a191cb57f87.

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(Ramboll, 2021). This thick, continuous shale bedrock forms a hydraulic barrier between the EAP and deeper groundwater resources. Very low hydraulic conductivities of the shale bedrock and the lack of a downward gradient restrict any downward migration of shallow groundwater originating from the EAP to the underlying aquifers (Ramboll, 2021). Vertical hydraulic gradients measured in well nests downgradient and adjacent to the north edge of the EAP (wells 12, 13, and 55) were reported to be either flat or upward (Ramboll, 2021). This further reduces the likelihood of EAP-related impacts to the deep groundwater resources in the area.

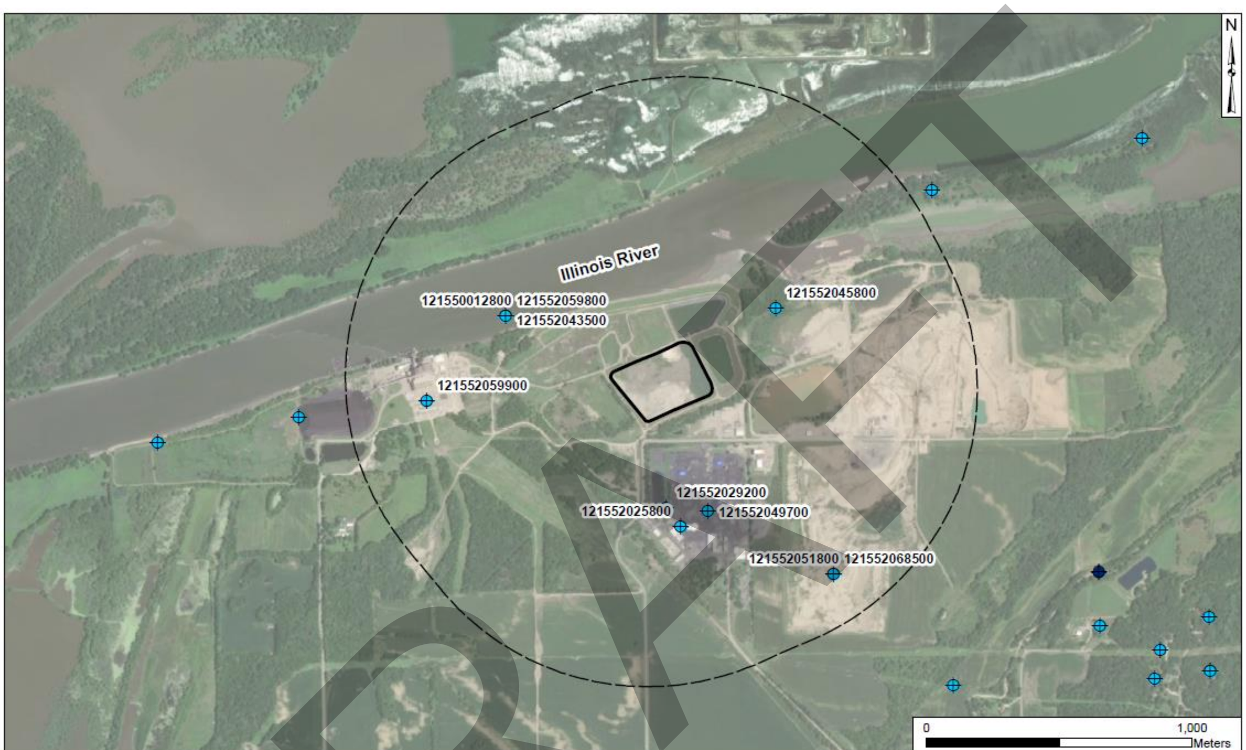

Figure 3.3 Water Wells Within 1,000 Meters of the East Ash Pond. Source: Geosyntec (2021b, Figure A-4).

3.2.1.2 Recreational Exposures

The Illinois River flows east to west past the Site. Recreational exposure to surface water and sediment may occur during activities such as swimming or boating in the river. Exposure estimates for swimmers provide a health-protective means to evaluate exposure during other recreational activities. Recreational anglers may also consume locally caught fish from the Illinois River.

3.2.2 Ecological Conceptual Exposure Model

The ecological CEM for the Site depicts the relationships between off-Site environmental media (surface water and sediment) potentially impacted by COIs in groundwater and ecological receptors that may be exposed to these media. The ecological risk evaluation considered both direct toxicity as well as secondary toxicity *via* bioaccumulation. Figure 3.4 presents the ecological CEM for the Site. The following ecological receptor groups and exposure pathways were considered:

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- **Ecological Receptors Exposed to Surface Water:**
    - Aquatic plants, amphibians, reptiles, and fish.
- **Ecological Receptors Exposed to Sediment:**
    - Benthic invertebrates (*e.g.*, insects, crayfish, mussels).
- **Ecological Receptors Exposed to Bioaccumulative COIs:**
    - Higher trophic-level wildlife (avian and mammalian) *via* direct exposures (surface water and sediment exposure) and secondary exposures through the consumption of prey (*e.g.*, plants, invertebrates, small mammals, fish).

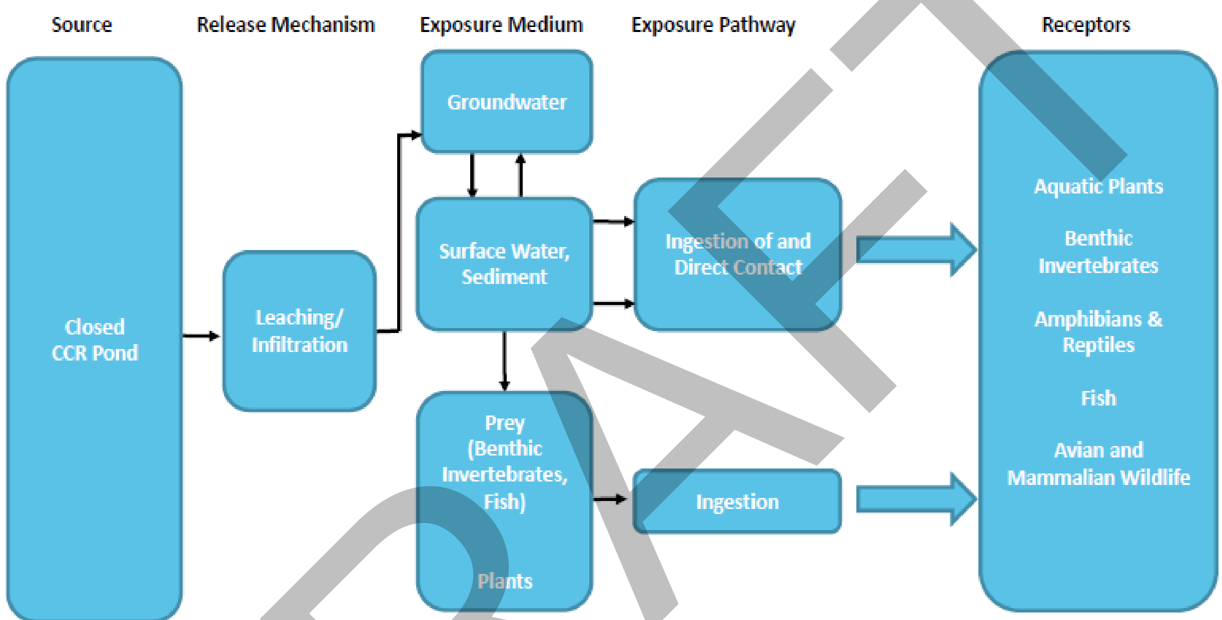

Figure 3.4 Ecological Conceptual Exposure Model. CCR = Coal Combustion Residual.

3.3 Identification of Constituents of Interest

Risks were evaluated for COIs. A constituent was considered a COI if the maximum detected constituent concentration in groundwater exceeded a health-based benchmark. According to US EPA risk assessment guidance (US EPA, 1989), this screening step is designed to reduce the number of constituents carried through the risk evaluation that are anticipated to have a minimal contribution to the overall risk. Identified COIs are the constituents that are most likely to pose a risk concern in the surface water adjacent to the Site.

3.3.1 Human Health Constituents of Interest

For the human health risk evaluation, COIs were conservatively identified as constituents with maximum concentrations in groundwater above the GWPSs listed in the Illinois CCR Rule Part 845.600 (IEPA, 2021a). The use of groundwater data in this risk evaluation does not imply that detected constituents are associated with the EAP or that they have been identified as potential groundwater exceedances. Using this approach, two COIs (cobalt and lithium) were identified for the human health risk evaluation *via* a surface water pathway (Table 3.1). The water quality parameters that exceeded the GWPS included chloride, sulfate, and total dissolved solids (TDS); however, these constituents were not included in the risk

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evaluation because the GWPS are likely based on aesthetic quality. US EPA set secondary maximum contaminant levels (MCLs) for chloride, sulfate, and TDS based on aesthetic quality. Chloride (200 mg/L) and sulfate (250 mg/L) MCLs are based on salty taste. The secondary MCL for TDS (500 mg/L) is based on hardness, colored water, staining, and salty taste (US EPA, 2021b). Given that these parameters are not likely to pose a human health risk concern in the event of exposure, they were not identified as COIs.

Table 3.1 Human Health Constituents of Interest

Analytes[a]	Maximum Groundwater Concentration	GWPS[b]	Human Health COI[c]
Dissolved Metals (mg/L)			
Antimony	0.0022	0.006	No
Barium	0.175	2	No
Boron	1.32	2	No
Cadmium	0.0023	0.005	No
Cobalt	0.124	0.006	Yes
Lead	0.0013	0.008	No
Molybdenum	0.04	0.1	No
Selenium	0.009	0.05	No
Total Metals (mg/L)			
Arsenic	0.0025	0.01	No
Barium	0.23	2	No
Boron	1.41	2	No
Cadmium	0.0024	0.005	No
Chromium	0.019	0.1	No
Cobalt	0.147	0.006	Yes
Lead	0.0036	0.0075	No
Lithium	0.041	0.04	Yes
Molybdenum	0.0681	0.1	No
Selenium	0.0093	0.05	No
Radionuclides (pCi/L)			
Radium-226 +228	3.21	5	No
Other Dissolved (mg/L)			
Chloride	325	200	No
Fluoride	0.34	4	No
Sulfate	479	400	No
Total Dissolved Solids	1,690	1,200	No
Other (mg/L, unless otherwise noted)			
Chloride	366	200	No
Fluoride	0.41	4	No
pH (SU)	7.9	9	No
Sulfate	278	400	No
Total Dissolved Solids	1,520	1,200	No

Notes:
COI = Constituent of Interest; GWPS = Groundwater Protection Standards; SU = Standard Unit.
Shaded = Compound identified as a COI.
(a) The constituents are those listed in the IL Part 845.600 GWPS (IEPA, 2021a).
(b) The IL Part 845.600 GWPS (IEPA, 2021a) were used to identify COIs.
(c) COIs are constituents for which the maximum concentration exceeds the groundwater standard.

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3.3.2 Ecological Constituents of Interest

The Illinois GWPS, as defined in IEPA's guidance, were developed to protect human health but not necessarily ecological receptors. While ecological receptors are not exposed to groundwater, groundwater can potentially migrate into the adjacent surface water and impact ecological receptors. Therefore, to identify ecological COIs, the maximum concentrations of analytes detected in groundwater were compared to ecological surface water benchmarks protective of aquatic life.

The surface water screening benchmarks for freshwater organisms were obtained from the following hierarchy of sources:

- IEPA (2019a) SWQS. IEPA SWQS are health-protective benchmarks for aquatic life exposed to surface water on a long-term basis (*i.e.*, chronic exposure). The SWQS for several metals are hardness dependent (cadmium, chromium, copper, fluoride, lead, manganese, nickel, and zinc). Screening benchmarks for these constituents were calculated assuming US EPA's (2019a) default hardness of 100 mg/L.[6]
- US EPA Region IV (2018) surface water Ecological Screening Values (ESVs) for hazardous waste sites.

For radium, benchmarks from the United States Department of Energy's (US DOE) guidance document, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (US DOE, 2019), were used. US DOE presents benchmarks for radium-226 and radium-228 separately (4 and 3 pCi/L, respectively). Given that radium concentrations are expressed as total radium (radium-226+228, *i.e.*, the sum of radium-226 and radium-228), Gradient used the lower of the two benchmarks (3 pCi/L for radium-228) to evaluate total radium concentrations.

Consistent with the human health risk evaluation, Gradient used the maximum detected concentrations from groundwater samples collected from the EAP-associated wells, without considering spatial or temporal representativeness for ecological receptor exposures. The use of the maximum constituent concentrations in this evaluation is designed to conservatively identify COIs that warrant further investigation. Cadmium and cobalt were identified as COIs for ecological receptors (Table 3.2).

It should be noted that although cadmium and cobalt were screened in as ecological COIs based on the maximum groundwater concentration, neither constituent was detected in surface water (out of 15 samples) (Table 2.3), and the maximum detection limit (0.001 mg/L) was below the ecological benchmark for both constituents. In addition, no constituent was detected in surface water at a concentration exceeding its ecological benchmark (Table 3.3).

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[6] While hardness data are not available for the Illinois River adjacent to the Site, a US Geological Survey (USGS) station (05556200) located at Hennepin, Illinois, approximately five miles downstream from the Site, measured hardness concentrations ranging from 200 to 370 mg/L, with a mean hardness of 288 mg/L, from 106 samples collected between 1980 and 1997 (USGS, 2021a). These are older data and may not reflect current conditions; therefore, US EPA's default hardness of 100 mg/L was used. However, use of a higher hardness value (288 mg/L) would result in less stringent screening values, and thus, use of the US EPA default hardness is conservative.

Table 3.2 Ecological Constituents of Interest

Analyte[a]	Maximum Groundwater Concentration	Ecological Benchmark[b]	Basis	Ecological COI[c]
Dissolved Metals (mg/L)				
Antimony	0.0022	0.19	EPA R4 ESV	No
Barium	0.175	5	IEPA SWQC	No
Boron	1.32	7.6	IEPA SWQC	No
Cadmium	0.0023	0.00093	IEPA SWQC	Yes
Cobalt	0.12	0.019	EPA R4 ESV	Yes
Lead	0.0013	0.016	IEPA SWQC	No
Molybdenum	0.04	0.8	EPA R4 ESV	No
Selenium	0.009	1	IEPA SWQC	No
Total Metals (mg/L)				
Arsenic	0.0025	0.19	IEPA SWQC	No
Barium	0.23	5	IEPA SWQC	No
Boron	1.41	7.6	IEPA SWQC	No
Cadmium	0.0024	0.0011	IEPA SWQC	Yes
Chromium	0.019	0.21	IEPA SWQC	No
Cobalt	0.147	0.019	EPA R4 ESV	Yes
Lead	0.0036	0.020	IEPA SWQC	No
Lithium	0.041	0.44	EPA R4 ESV	No
Molybdenum	0.068	7.2	EPA R4 ESV	No
Selenium	0.0093	1	IEPA SWQC	No
Radionuclides (pCi/L)				
Radium-226 +228	3.21	3.0	US DOE	No[d]
Other Dissolved (mg/L)				
Chloride	325	500	IEPA SWQC	No
Fluoride	0.34	4	IEPA SWQC	No
Sulfate	479	NA	NA	No
Total Dissolved Solids	1690	NA	NA	No
Other (mg/L, unless otherwise noted)				
Chloride	366	500	IEPA SWQC	No
Fluoride	0.41	4	IEPA SWQC	No
pH (SU)	7.9	NA	NA	No
Sulfate	278	NA	NA	No
Total Dissolved Solids	1,520	NA	NA	No

Notes:
COI = Constituent of Interest; DOE = Department of Energy; EPA R4 ESV = US Environmental Protection Agency Region IV Ecological Screening Value; GWPS = Groundwater Protection Standards; IEPA SWQS = Illinois Environmental Protection Agency Surface Water Quality Standard; NA = Not Available; SU = Standard Unit.
Shaded = Compound identified as a COI.
(a) The constituents are those listed in the IL Part 845.600 GWPS (IEPA, 2021a) that were detected in at least one groundwater sample from the 13 wells related to the Hennepin EAP.
(b) Ecological benchmarks are from the hierarchy of sources discussed in Section 3.3.2: IEPA SWQS (IEPA, 2019a); US EPA R4 "Ecological Risk Assessment Supplemental Guidance" (US EPA Region IV, 2018); US DOE's guidance document "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (US DOE, 2019).
(c) Analytes with maximum detected concentrations exceeding a benchmark protective of surface water exposure are considered ecological COIs.
(d) Of the 159 groundwater samples analyzed for radium-226+228, only 1 sample was detected slightly above the ecological benchmark. Given that the maximum result is considered an outlier at the 1% and 5% significance levels, radium-226+228 was not considered an ecological COI.

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Table 3.3 Measured Surface Water Data

Constituent	Maximum Detect (mg/L)	Maximum Detection Limit (mg/L)	Ecological Benchmark (mg/L)
Dissolved Metals			
Aluminum	0.641	0.025	
Antimony		0.001	0.19
Arsenic	0.0034		0.19
Barium	0.0462		5.0
Beryllium		0.001	0.064
Boron	0.147		7.6
Cadmium		0.001	0.0011
Chromium	0.015	0.015	0.21
Cobalt		0.001	0.019
Lead	0.002	0.001	0.020
Lithium	0.0083		0.44
Molybdenum	0.0063		7.2
Selenium		0.001	1.0
Thallium		0.002	0.0060

3.3.3 Surface Water and Sediment Modeling

Surface water sampling has been conducted in the Illinois River adjacent to the Site. To estimate the potential contribution to surface water (and sediment) from groundwater specifically associated with the EAP, Gradient modeled concentrations in the Illinois River surface water and sediment from groundwater discharge to the Illinois River for the detected COIs (cadmium, cobalt, and lithium). This is because the constituents detected in groundwater above a health-based benchmark are most likely to pose a risk concern in the adjacent surface water. Gradient modeled human health and ecological COI concentrations in the surface water and sediment using a mass balance calculation based on the surface water and groundwater mixing. The model assumes a well-mixed groundwater-surface water location.

The maximum detected concentrations in groundwater (regardless of well location) from 2015 to 2021 were conservatively used to model COI concentrations in surface water and sediment. For COIs that were measured as both total and dissolved fractions, we used the maximum of the total and dissolved COI concentrations for the modeling. In this case, the maximum concentration was from the total fraction for all three COIs. Use of the total metal concentration for these COIs may overestimate surface water concentrations because dissolved concentrations, which are lower than total concentrations, represent the mobile fractions of constituents that could likely flow into and mix with surface water.

The modeling approach does not account for geochemical transformations that may occur during groundwater mixing with surface water. Gradient assumed that predicted surface water concentrations were influenced only by the physical mixing of groundwater as it enters the surface water and were not further influenced by the geochemical reactions in the water and sediment, such as precipitation. In addition, the model only predicts surface water and sediment concentrations as a result of the potential migration of COI concentrations in EAP-related groundwater and does not account for background concentrations in surface water or sediment.

For this evaluation we adapted a simplified and conservative form of US EPA's indirect exposure assessment methodology (US EPA, 1998) that was used in US EPA's coal combustion waste risk

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assessment (US EPA, 2014). The original model is a mass balance calculation based on surface water and groundwater mixing and the concept that the dissolved and sorbed concentrations can be related through an equilibrium partitioning coefficient (K_d). The model assumes a well-mixed groundwater-surface water location, with partitioning among total suspended solids, dissolved water column, sediment porewater, and solid sediments.

Sorption to soil and sediment is highly dependent on the surrounding geochemical conditions. To be conservative, we ignored the natural attenuation capacity of soil and sediment and estimated the surface water concentration based only on the physical mixing of groundwater and surface water (*i.e.*, dilution) at the point of discharge of groundwater to the surface water.

The aquifer and surface water properties used to estimate the volume of groundwater flowing into the Illinois River and surface water concentrations are presented in Table 3.4. The COI concentrations in sediment were modeled using the COI-specific sediment-to-water partition coefficients and the sediment properties presented in Table 3.5. In the absence of Site-specific information for the Illinois River, we used default assumptions (*e.g.*, depth of the upper benthic layer and bed sediment porosity) to model sediment concentrations. The modeled surface water and sediment concentrations are presented in Table 3.6. These modeled concentrations reflect conservative contributions from groundwater discharge. A description of the modeling and the detailed results are presented in Appendix A.

Table 3.4 Groundwater and Surface Water Properties Used in Modeling

Parameter	Unit	Values	Notes/Source
Groundwater			
COI Concentration	mg/L	Constituent specific	Maximum detected dissolved concentration in groundwater
Cross Section Area for the Uppermost aquifer	m^2	800	Estimated assuming that the entire thickness of the uppermost aquifer (2.4 m) that intersects the Illinois River (Ramboll 2018-2020) is saturated. The discharge length was assumed to be equal to the length of the EAP (333 m)
Hydraulic Gradient	m/m	0.0038	Maximum hydraulic gradient measured between well 17 and well 19S in the vicinity of the EAP (Ramboll, 2021)
Hydraulic Conductivity of the Uppermost aquifer	cm/s	0.1	As reported in Ramboll (2021)
Surface Water			
Surface Water Flow Rate	L/yr	4.56×10^{12}	Representative low flow (10^{th} percentile) discharge rate for the Illinois River (5,100 cfs), as derived from USGS station at Henry (USGS 05558300) (USGS, 2021b)
Total Suspended Solids (TSS)	mg/L	6	6 mg/L is the representative average river concentration (Hanson Professional Services Inc., 2019)
Depth of the Water Column	m	3.96	As indicated in cross-section (Ramboll 2018-2020)
Suspended Sediment to Water Partition Coefficient	mg/L	Constituent specific	Values based on US EPA (2014)

Notes:
cfs = Cubic Feet per Second; COI = Constituent of Interest; US EPA = United States Environmental Protection Agency.

Table 3.5 Sediment Properties Used in Modeling

Parameter	Unit	Value	Notes/Source
Sediment			
Depth of Upper Benthic Layer	m	0.03	Default (US EPA, 2014)
Depth of Water Body	m	3.99	Depth of water column (3.96 m, as indicated in Table 4.3 of Ramboll [2018-2020]) plus depth of upper benthic layer (0.03 m) (US EPA, 2014)
Bed Sediment Particle Concentration	g/cm^3	1	Default (US EPA, 2014)
Bed Sediment Porosity	-	0.6	Default (US EPA, 2014)
TSS Mass per Unit Area	kg/m^2	0.024	Depth of water column × TSS × conversion factors (10^{-6} kg/mg and 1,000 L/m^3)
Sediment Mass per Unit Area	kg/m^2	30	Depth of upper benthic layer × bed sediment particulate concentration × conversion factors (0.001 kg/g, 10^6 cm^3/m^3)
Sediment to Water Partition Coefficients	mg/L	Constituent specific	Values based on US EPA (2014)

Notes:
TSS = Total Suspended Solids; US EPA = United States Environmental Protection Agency.

Table 3.6 Surface Water and Sediment Modeling Results

Contaminant	Max Groundwater Concentration (mg/L)	Mass Discharge Rate (mg/year)	Modeled Surface Water Concentration (mg/L)	Modeled Sediment Concentration (mg/kg)
Cadmium	0.0024	2.30E+05	5.09E-08	6.88E-05
Cobalt	0.147	1.41E+07	3.12E-06	2.85E-03
Lithium	0.041	3.97E+06	8.78E-07	NA

Note:
NA: Lithium sediment concentration was not calculated because Lithium lacks a K_d value.

3.4 Human Health Risk Evaluation

The section below presents the results of the human health risk evaluation for recreators (swimmers and anglers) along the Illinois River adjacent to the Site. Risks were assessed using the maximum measured and modeled COIs in surface water.

3.4.1 Recreators Exposed to Surface Water

Screening Exposures: Recreators could be exposed to surface water *via* incidental ingestion and dermal contact while swimming. In addition, anglers could consume fish caught in the Illinois River. The maximum measured or modeled COI concentrations in surface water were used as conservative upper-end estimates of the COI concentrations to which a recreator might be exposed directly (incidental ingestion of COIs in surface water while swimming) and indirectly (consumption of locally caught fish exposed to COIs in surface water).

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Screening Benchmarks: Illinois surface water criteria (IEPA, 2019a), known as human threshold criteria (HTC), are based on incidental exposure through contact or ingestion of small volumes of water while swimming or during other recreational activities, as well as the consumption of fish. The HTC values were calculated from the following equation (IEPA, 2019a):

$$\mathrm{HTC} = \frac{\mathrm{ADI}}{\mathrm{W} + (\mathrm{F} \times \mathrm{BCF})}$$

where:

HTC = Human health protection criterion in milligrams per liter (mg/L)
ADI = Acceptable daily intake (mg/day)
W = Water consumption rate (L/day)
F = Fish consumption rate (kg/day)
BCF = Bioconcentration factor (L/kg)

Illinois defines the acceptable daily intake (ADI) as the "maximum amount of a substance which, if ingested daily for a lifetime, results in no adverse effects to humans" (IEPA, 2019a). US EPA defines its chronic reference dose (RfD) as an "estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure for a chronic duration (up to a lifetime) to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime" (US EPA, 2011a). Illinois lists methods to derive an ADI from the primary literature (IEPA, 2019a). In accordance with Illinois guidance, we derived an ADI by multiplying the MCL by the default water ingestion rate of 2 L/day (IEPA, 2019a). In the absence of an MCL, we used the RfD used by US EPA to derive its Regional Screening Levels (RSLs) (US EPA, 2020) as a conservative estimate of the ADI. The RfDs are given in mg/kg-day, while the ADIs are given in mg/day; thus, we multiplied the RfD by a standard body weight of 70 kg to obtain the ADI in mg/day. The calculation of the HTC values is shown in Appendix Table B.1.

We used bioconcentration factors (BCFs) from a hierarchy of sources. The primary BCFs were those that US EPA used to calculate the national recommended water quality criteria (NRWQC) for human health (US EPA, 2002, 2016). Other sources included BCFs used in the US EPA coal combustion ash risk assessment (US EPA, 2014) and BCFs reported by Oak Ridge National Laboratory's Risk Assessment Information System (ORNL RAIS).[7] Lithium did not have a BCF value available from any authoritative source. Therefore, the water quality criterion for lithium was calculated assuming a BCF of 1. This is a conservative assumption as lithium does not readily bioaccumulate in the aquatic environment (ECHA, 2020a,b; ATSDR, 2010).

Illinois recommends a fish consumption rate of 0.020 kg/day (20 g/day) for an adult weighing 70 kg (IEPA, 2019a). Illinois recommends a water consumption rate of 0.01 L/day for "incidental exposure through contact or ingestion of small volumes of water while swimming or during other recreational activities" (IEPA, 2019a). Appendix Table B.1 presents the calculated HTC for fish and water, and for fish consumption only.

Screening Risk Evaluation: The maximum modeled and measured COI concentrations in surface water were compared to the calculated Illinois HTC values (Table 3.7). All surface water concentrations were below their respective benchmarks. The HTC values are protective of recreational exposure *via* water and/or fish ingestion and do not account for dermal exposures to COIs in surface water while swimming. However, given that the modeled COI surface water concentrations are orders of magnitude below HTC

[7] Although recommended by US EPA (2015c), US EPA EpiSuite 4.1 (US EPA, 2019b) was not used as a source of BCFs because inorganic compounds are outside the estimation domain of the program.

protective of water and/or fish ingestion, dermal exposures to COIs are not expected to be a risk concern. Moreover, the dermal uptake of metals is considered to be minimal and only a small proportion of ingestion exposures. Thus, none of the COIs evaluated would be expected to pose an unacceptable risk to recreators exposed to surface water while swimming and anglers consuming fish caught in the Illinois River.

Table 3.7 Risk Evaluation for Recreators (Swimmers and Anglers)

COI	Max Modeled SW Conc. (mg/L)	Max Measured SW Conc. (mg/L)	HTC for Water and Fish (mg/L)	HTC for Water Only (mg/L)	HTC for Fish Only (mg/L)	COPC Based on Modeled Conc.	COPC Based on Measured Conc.
Cobalt	3.1E-06	ND	0.0035	2.1	0.0035	No	No
Lithium	8.8E-07	0.0083[a]	4.7	14	7.0	No	No

Notes:
COI = Constituent of Interest; COPC = Constituent of Potential Concern; EAP = East Ash Pond; HTC = Human Threshold Criteria; ND = Not Detected; SW = Surface Water.
(a) Measured surface water concentrations may be different from modeled concentrations because measured data include the effects of background and other industrial sources. Modeled concentrations only represent the potential effect on surface water quality resulting from the measured groundwater concentrations.

3.4.2 Recreators Exposed to Sediment

Recreational exposure to sediment may occur during boating and swimming activity along the Illinois River; exposure to sediment may occur through incidental ingestion and dermal contact.

Screening Exposures: COIs in impacted groundwater flowing into the river can sorb to sediments. In the absence of sediment data, sediment concentrations were modeled using maximum detected groundwater concentrations.

Screening Benchmarks: There are no established recreator RSLs that are protective of recreational exposures to sediment (US EPA, 2019c). Therefore, benchmarks that are protective of recreational exposures to sediment *via* incidental ingestion and dermal contact were calculated using US EPA's RSL guidance (US EPA, 2019c). These benchmarks were calculated using the recommended assumptions (*i.e.*, oral bioavailability, body weights, averaging time) and toxicity reference values (*i.e.*, RfD and cancer slope factor [CSF]), with the following changes: Recreators were assumed to be exposed to sediment while recreating 60 days a year (or two weekend days per week for 30 weeks a year, from April to October). The exposure duration was assumed for a child 6 years of age and an adult 20 years of age, per US EPA guidance (Stalcup, 2014). The daily recommended residential soil ingestion rates of 200 mg/day for a child and 100 mg/day for an adult are based on an all-day exposure to residential soils (Stalcup, 2014; US EPA, 2011b). Since recreational exposures to sediment are assumed to occur for less than four hours per day, one-third of the daily residential soil ingestion (67 mg/day for a child and 33 mg/day for an adult) was used as a conservative assumption. For dermal exposures, recreators were assumed to be exposed to sediment on their lower legs and feet (1,026 cm^2 for the child and 3,026 cm^2 for the adult, based on the age-weighted surface areas reported in US EPA, 2011b). While other body parts may be exposed to sediment, the contact time will likely be very short, as the sediment would wash off in the surface water. We used US EPA's recommended adherence factor of 0.2 mg/cm^2 based on child exposure to wet soil (US EPA, 2004; Stalcup, 2014), which was used in the US EPA RSL User's Guide for a child recreator exposed to soil or sediment (US EPA, 2019c). The sediment screening benchmarks for cadmium and cobalt were calculated based on a target hazard quotient of 1. Appendix Table B.2 presents the calculation of RSLs protective of recreational exposures to sediment.

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Screening Risk Evaluation: The modeled sediment concentrations were well below the recreational sediment RSLs (Table 3.8). Therefore, exposure to sediment is not expected to pose an unacceptable risk to recreators while swimming or boating.

Table 3.8 Risk Evaluation for Recreators Exposed to Sediment

COI	Modeled Sediment Concentration (mg/kg)	Recreator RSL (mg/kg)	COPC
Cobalt	2.8E-03	411	No

Notes:
Lithium could not be modeled in sediment because it lacks a K_d value.
COI = Constituent of Interest; COPC = Constituent of Potential Concern.

3.5 Ecological Risk Evaluation

Based on the ecological CEM (Figure 3.4), ecological receptors could be exposed to surface water and dietary items (*i.e.*, prey and plants) potentially impacted by identified COIs (cadmium and cobalt).

3.5.1 Ecological Receptors Exposed to Surface Water

Screening Exposures: The ecological evaluation considered aquatic communities in the Illinois River potentially impacted by identified ecological COIs. Measured and modeled surface water concentrations were compared to risk-based ecological screening benchmarks.

Screening Benchmarks: Surface water screening benchmarks protective of aquatic life were obtained from the following hierarchy of sources:

- IEPA SWQS (IEPA, 2019a), regulatory standards that are intended to protect aquatic life exposed to surface water on a long-term basis (*i.e.*, chronic exposure). For cadmium, the surface water benchmark is hardness dependent and calculated using a default hardness of 100 mg/L[8];
- NRWQC – Aquatic Life Criteria Table (US EPA, 2019a); and
- US EPA Region IV (2018) surface water ESVs for hazardous waste sites.

Risk Evaluation: The maximum modeled COI concentrations in surface water were compared to the benchmarks protective of aquatic life (Table 3.9). The measured and modeled surface water concentrations were below their respective benchmarks. Thus, none of the COIs evaluated are expected to pose an unacceptable risk to aquatic life in the Illinois River.

[8] While USGS hardness data are available, US EPA's (2019a) default hardness of 100 mg/L was conservatively used. Conservatisms associated with using a default hardness value are discussed in Section 3.4.

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Table 3.9 Risk Evaluation of Ecological Receptors Exposed to Surface Water

COI	Maximum SW Conc., Modeled (mg/L)	Maximum Detected SW Conc. (mg/L)	Ecological Freshwater Benchmark (mg/L)	Basis	COPC Based on Modeled Conc.	COPC Based on Measured Conc.
Cadmium	5.1E-08	ND	0.00093	IEPA (2019a)	No	No
Cobalt	3.1E-06	ND	0.019	US EPA R4 (2018)	No	No

Notes:
COI = Constituent of Interest; COPC = Constituent of Potential Concern; IEPA = Illinois Environmental Protection Agency; ND = Not Detected; SW = Surface Water; US EPA R4 = United States Environmental Protection Agency Region IV.
(a) Modeled COI concentrations reflect the potential maximum COI surface water concentrations from groundwater mixing with surface water.
(b) A default hardness value of 100 mg/L was used to calculate this hardness-dependent benchmark.

3.5.2 Ecological Receptors Exposed to Sediment

Screening Exposures: COIs in impacted groundwater discharging into the Illinois River can sorb to sediments *via* chemical partitioning. In the absence of sediment data, sediment concentrations were modeled using maximum detected groundwater concentrations. Therefore, the modeled COI sediment concentrations reflect the potential maximum Site-related sediment concentration from groundwater discharge.

Screening Benchmarks: Sediment screening benchmarks were obtained from US EPA Region IV (2018). The majority of the sediment ESVs are based on threshold effect concentrations (TECs) from MacDonald *et al.* (2000), which provide consensus values that identify concentrations below which harmful effects on sediment-dwelling organisms are unlikely to be observed. The benchmarks used in this evaluation are listed in Table 3.10.

Screening Risk Results: The maximum modeled COI sediment concentrations were below their respective sediment screening benchmarks (Table 3.10). The modeled sediment concentrations attributed to potential contributions from Site groundwater for all COIs were less than 1% of the sediment screening benchmark. Therefore, the modeled sediment concentrations attributed to potential contributions from Site groundwater are not expected to significantly contribute to ecological exposures in the Illinois River adjacent to the Site.

Table 3.10 Risk Evaluation of Ecological Receptors Exposed to Sediment

COI	Modeled Sediment Concentration (mg/kg)	ESV[a] (mg/kg)	COPC	% of Benchmark
Cadmium	6.9E-05	0.99	No	0.007%
Cobalt	2.8E-03	50	No	0.006%

Notes:
COI = Constituent of Interest; COPC = Constituent of Potential Concern; ESV = Ecological Screening Value.
(a) ESV from US EPA Region IV (2018).

3.5.3 Ecological Receptors Exposed to Bioaccumulative Constituents of Interest

Screening Exposures: COIs with bioaccumulative properties can impact higher-trophic-level wildlife exposed to these COIs *via* direct exposures (surface water and sediment exposure) and secondary exposures through the consumption of dietary items (*e.g.*, plants, invertebrates, small mammals, and fish).

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Screening Benchmark: US EPA Region IV (2018) guidance and IEPA's SWQS (IEPA, 2019a) guidance were used to identify analytes with potential bioaccumulative effects.

Risk Evaluation: The ecological COIs, cadmium and cobalt,[9] were not identified as having potential bioaccumulative effects. Therefore, these COIs are not considered to pose an ecological risk *via* bioaccumulation.

3.6 Uncertainties and Conservatisms

A number of uncertainties and their potential impact on the risk evaluation are discussed below. Wherever possible, conservative assumptions were used in an effort to minimize uncertainties and overestimate rather than underestimate risks.

Exposure Estimates:

- The risk evaluation included the IL Part 845.600 constituents detected in groundwater samples collected from wells downgradient of the EAP. However, it is possible that not all of the detected constituents are related specifically to the EAP, since there are several sources in this area.
- The human health and ecological risk characterizations were based on the maximum modeled COI concentrations, rather than on averages. Thus, the variability in exposure concentrations was not considered. Assuming continuous exposure to the maximum concentration overestimates human and ecological exposures, given that receptors are mobile and concentrations change over time. For example, US EPA guidance states that risks should be estimated using average exposure concentrations as represented by the 95% upper confidence limit on the mean (US EPA, 1992). Given that exposure estimates based on the maximum concentrations did not exceed risk benchmarks, we have greater confidence that there is no risk concern.
- Only analytes detected in groundwater were used to identify COIs and model COI concentrations in surface water and sediment. For the constituents that were not detected in EAP groundwater, the detection limits were below the IL Part 845 GWPS and thus do not require further evaluation.
- COI concentrations in surface water were modeled using the maximum detected total or dissolved COI concentrations. In this case, maximum detected concentrations for cadmium, cobalt, and lithium are based on total concentrations. Modeling surface water concentrations using total metal concentrations for these COIs may overestimate surface water concentrations because dissolved concentrations, which are lower than total concentrations, represent the mobile fractions of constituents that could likely flow into and mix with surface water.
- The COIs identified in this evaluation also occur naturally in the environment. Contributions to exposure from natural or other non-EAP-related sources were not considered in the evaluation of modeled concentrations; only exposure contributions potentially attributable to Site groundwater mixing with surface water were evaluated. While not quantified, exposures from potential EAP-related groundwater contributions are likely to represent only a small fraction of the overall human and ecological exposure to COIs that also have natural or non-EAP-related sources.
- Screening benchmarks for human health were developed using exposure inputs based on US EPA's recommended values for reasonable maximum exposure (RME) assessments (Stalcup, 2014). RME is defined as "the highest exposure that is reasonably expected to occur at a site but that is

[9] US EPA Region IV (2018) identifies only mercury (including methyl mercury) and selenium as having potential bioaccumulative effects. IEPA (2019a) identifies mercury as the only metal with bioaccumulative properties. Mercury was not detected in groundwater. Selenium was detected in groundwater but was not considered an ecological COI.

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still within the range of possible exposures" (US EPA, 2004). US EPA states the "intent of the RME is to estimate a conservative exposure case (*i.e.*, well above the average case) that is still within the range of possible exposures" (US EPA, 1989). US EPA also notes that this high-end exposure "is the highest dose estimated to be experienced by some individuals, commonly stated as approximately equal to the 90^{th} percentile exposure category for individuals" (US EPA, 2015b). Thus, most individuals will have lower exposures than those presented in this risk assessment.

- Although the maximum radium-226+228 concentration in groundwater exceeded the ecological screening benchmark, radium-226+228 was not considered an ecological COI because the maximum result, detected slightly above the benchmark, is considered an outlier at the 1% and 5% significance levels. While risks to ecological receptors exposed to radium-226+228 in surface water, sediment, and diet were not evaluated, the risks are expected to be *de minimis*.[10]

Toxicity Benchmarks:

- Screening-level ecological benchmarks were compiled from IEPA and US EPA guidance and designed to be protective of the majority of Site conditions, leaving the option for Site-specific refinement. In some cases, these benchmarks may not be representative of the Site-specific conditions or receptors found at the Site, or may not accurately reflect concentration-response relationships encountered at the Site. For example, the ecological benchmark for cadmium is hardness dependent. While a USGS station had available hardness data, we relied on US EPA's default hardness of 100 mg/L due to the limitations of the USGS data. USGS data from Hennepin, Illinois (five miles downstream of the Site), reported hardness ranging from 200 to 370 mg/L, with a mean hardness of 288 mg/L, based on samples collected in 1980-1997 (USGS, 2021a). Increasing the hardness from 100 to 288 mg/L would increase the cadmium SWQS because benchmarks become less stringent with higher levels of hardness. Regardless of the hardness, the maximum modeled cadmium concentration is orders of magnitude below the SWQS.
- In addition, for the ecological evaluation, we conservatively assumed all constituents to be 100% bioavailable. Modeled COI concentrations in surface water are considered total COI concentrations. US EPA recommends using dissolved metals as a measure of exposure to ecological receptors because it represents the bioavailable fraction of metal in water (US EPA, 1993). Therefore, the modeled surface water COI concentrations may be an overestimation of exposure concentrations to ecological receptors.
- In general, it is important to appreciate that the human health toxicity factors used in this risk evaluation are developed to account for uncertainties, such that safe exposure levels used as benchmarks are often many times lower (even orders of magnitude lower) than the levels that cause effects that have been observed in human or animal studies. For example, toxicity factors incorporate a 10-fold safety factor to protect sensitive subpopulations. This means that a risk exceedance does not necessarily equate to actual harm.

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[10] Radium was not analyzed in surface water. However, the surface water and sediment modeling for other ecological COIs demonstrate that the modeled concentrations are orders of magnitude lower than the measured COI concentration in surface water and sediment. Given that the maximum groundwater concentration slightly exceeds the surface water benchmark, the modeled surface water and sediment concentrations will be below their respective benchmarks. Furthermore, radium is not described in US EPA Region IV guidance, but it is identified as bioaccumulative by other entities (*e.g.*, ATSDR, 1990). However, the benchmark used to identify ecological COIs already considers bioaccumulative exposures. Given that the modeled concentrations are anticipated to be below benchmarks, which account for bioaccumulative exposures, radium-226+228 is not expected to pose a risk concern to ecological receptors based on its bioaccumulative properties.

4 Summary and Conclusions

A screening-level risk evaluation was performed for Site-related constituents in groundwater at the Hennepin Power Plant in Hennepin, Illinois. The CSM developed for the Site indicates that groundwater beneath the EAP flows into the Illinois River adjacent to the Site and may potentially impact surface water and sediment.

CEMs were developed for human and ecological receptors. The complete exposure pathways for humans include recreators in the Illinois River who are exposed to surface water and sediment (boaters and swimmers) and anglers who consume locally caught fish. Based on the local hydrogeology, residential exposure to groundwater used for drinking water or irrigation is not a complete pathway and was not evaluated. The complete exposure pathways for ecological receptors include aquatic life (including aquatic and marsh plants, amphibians, reptiles, and fish) exposed to surface water; benthic invertebrates exposed to sediment; and avian and mammalian wildlife exposed to bioaccumulative COIs in surface water, sediment, and dietary items.

Surface water data collected in 2020, and groundwater data collected from 2015 to 2021, were used to estimate exposures. The maximum detected concentrations in surface water were used for human and ecological receptors exposed to surface water. For analytes detected in groundwater, surface water concentrations were also modeled using the maximum detected groundwater concentration. In the absence of sediment data, modeled sediment concentrations based on the maximum detected groundwater concentrations were used as the exposure estimate for human and ecological receptors. Surface water and sediment exposure estimates were screened against benchmarks protective of human health and ecological receptors for this risk evaluation.

For recreators (boaters and swimmers) exposed to surface water, all COIs were below the conservative risk-based screening benchmarks. Therefore, none of the COIs evaluated in surface water are expected to pose an unacceptable risk to recreators swimming or boating in the Illinois River adjacent to the Site.

For recreators exposed to sediment *via* incidental ingestion and dermal contact, the modeled sediment concentration for cobalt was below the health protective sediment benchmark. Therefore, the modeled cobalt concentration in sediment is not expected to pose an unacceptable risk to recreators exposed to sediment in the Illinois River adjacent to the Site.

For anglers consuming locally caught fish, the maximum measured and modeled concentrations of all COIs in surface water were below conservative benchmarks protective of fish consumption. Therefore, none of the COIs evaluated are expected to pose an unacceptable risk to recreators consuming fish caught in the Illinois River.

Ecological receptors exposed to surface water include aquatic and marsh plants, amphibians, reptiles, and fish. The risk evaluation showed that none of the modeled or measured COIs in surface water exceeded protective screening benchmarks. Ecological receptors exposed to sediment include benthic invertebrates. The modeled sediment COIs did not exceed the conservative screening benchmarks; therefore, none of the COIs evaluated in sediment are expected to pose an unacceptable risk to ecological receptors. Ecological receptors were also evaluated for exposure to bioaccumulative COIs. This evaluation considered higher-trophic-level wildlife with direct exposure to surface water and sediment and secondary exposure through the consumption of dietary items (*e.g.*, plants, invertebrates, small mammals, fish). The ecological COIs

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(cadmium and cobalt) were not identified as having potential bioaccumulative effects. Therefore, these COIs are not considered to pose an ecological risk *via* bioaccumulation. Overall, this evaluation demonstrated that none of the COIs evaluated are expected to pose an unacceptable risk to ecological receptors.

It should be noted that this evaluation incorporates a number of conservative assumptions that tend to overestimate exposure and risk. The risk evaluation was based on the maximum detected COI concentration; however, US EPA guidance states that risks should be based on a representative average concentration such as the 95% upper confidence limit on the mean; thus, using the maximum concentration tends to overestimate exposure. Although the COIs identified in this evaluation also occur naturally in the environment, the contributions to exposure from natural background sources and nearby industry were not considered; thus, CCR-related exposures were likely overestimated. Exposure estimates assumed 100% metal bioavailability, which likely results in overestimates of exposure and risks. Exposure estimates were based on inputs to evaluate the "reasonable maximum exposure"; thus, most individuals will have lower exposures than those estimated in this risk assessment.

Finally, it should be noted that because current conditions do not present a risk to human health or the environment, there will also be no unacceptable risk to human health or the environment for future conditions when the EAP is closed. For all future closure scenarios, potential releases of CCR-related constituents will decline over time and, consequently, potential exposures to CCR-related constituents in the environment will also decline.

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Appendix A

Surface Water and Sediment Modeling

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Gradient modeled concentrations in river surface water and sediment based on available groundwater data. First, we estimated the flow rate of constituents of interest (COIs) discharged to the Illinois River *via* groundwater. Then, we adapted United States Environmental Protection Agency's (US EPA's) indirect exposure assessment methodology (US EPA, 1998) in order to model surface water and sediment water concentrations in the Illinois River.

Model Overview

The groundwater flow into the river is represented by a one-dimensional steady-state model. In this model, the groundwater plume migrates horizontally in the uppermost aquifer, from south to north, in the direction of the Illinois River. The groundwater flow entering the river is the flow going through a cross-sectional area that has a length equal to the length of the river adjacent to the East Ash Pond (EAP) with potential coal combustion residual (CCR)-related impacts and a height equal to the saturated thickness of the uppermost aquifer (Table 3.4). It was assumed that all the groundwater flowing through the uppermost aquifer discharges to the Illinois River. The length of the river adjacent to the EAP was estimated using Google Earth Pro.

The groundwater flow into the river mixes with the surface water in the Illinois River. The COIs entering the river *via* groundwater can dissolve into the water column, sorb to suspended sediments, or sorb to benthic sediments. Using US EPA's indirect exposure assessment methodology (US EPA, 1998), the model evaluates the surface water and sediment concentrations at a location downstream of the groundwater discharge, assuming a well-mixed water column.

Groundwater Discharge Rate

We used conservative assumptions to evaluate the groundwater discharge rate of the COIs. We conservatively assumed that the groundwater concentrations were uniformly equal to the maximum detected concentration for each individual COI. We ignored adsorption by subsurface soil and assumed that all the groundwater flowing through the uppermost aquifer was discharged into the river.

For each groundwater unit, the groundwater flow rate into the river was derived using Darcy's Law:

$$Q = KiA$$

where:

Q = Groundwater flow rate (m^3/s)
K = Hydraulic conductivity (m/s)
i = Hydraulic gradient (m/m)
A = Cross-sectional area (m^2)

For each COI, the mass discharge rate into the river was then calculated by:

$$m_c = C_c \times Q \times CF$$

where:

m_c = Mass discharge rate of the COI (mg/year)
C_c = Maximum groundwater concentration of the COI (mg/L)
CF = Conversion factors needed for unit conversion: 1,000 L/m^3; 31,557,600 s/year

The values of the aquifer parameters used for these calculations are provided in Table A.1. The calculated mass discharge rates were then used as inputs for the surface water and sediment partitioning model.

Surface Water and Sediment Concentration

Groundwater discharged into the river gets diluted in the surface water flow. Constituents transported by groundwater into the surface water migrate into the water column and the bed sediments. The surface water model we used to estimate the surface water and sediment concentrations is a steady-state model described in US EPA's indirect exposure assessment methodology (US EPA, 1998) and also used in US EPA's "Human and Ecological Risk Assessment of Coal Combustion Residuals" (US EPA, 2014). This model describes the partitioning of constituents between surface water, suspended sediments, and benthic sediments based on equilibrium partition coefficients. It estimates the concentrations of constituents in surface water, suspended sediments, and benthic sediments at steady-state equilibrium at a theoretical location downstream of the discharge point after complete mixing of the water column. In our analysis, we used the partitioning coefficients given in Table J-1 of the US EPA CCR Risk Assessment for all COIs (US EPA, 2014). These coefficients are presented in Table A.2.

To be conservative, we assumed that the constituents were not affected by dissipation or degradation once they entered the water body. The total water body concentration of the COI was calculated as (US EPA, 1998):

$$C_{wtot} = \frac{m_c}{V_f \times f_{water}}$$

where:

C_{wtot}	=	Total water body concentration of the constituent (mg/L)
V_f	=	Water body annual flow (L/year)
f_{water}	=	Fraction of COI in the water column (unitless)
m_c	=	Mass discharge rate of the COI (mg/year)

For the Illinois River annual flow rate, we conservatively used the low flow (10^{th} percentile) discharge rate of about 5,100 cubic feet per second (cfs) based on the daily mean discharge rates measured at Henry (USGS station #558300) between 1981 and 2021 (USGS, 2021b).

The fraction of COIs in the water column was calculated for each COI using the sediment/water and suspended solids/water partition coefficients (US EPA 2014, Table J-1). The fraction of COIs in the water column is defined as (US EPA 2014):

$$f_{water} = \frac{(1 + [K_{dsw} \times TSS \times 0.000001]) \times \frac{d_w}{d_z}}{\left([1 + (K_{dsw} \times TSS \times 0.000001)] \times \frac{d_w}{d_z}\right) + ([bsp + K_{dbs} \times bsc] \times \frac{d_b}{d_z})}$$

where:

K_{dsw}	=	Suspended sediment-water partition coefficient (mL/g)
K_{dbs}	=	Sediment-water partition coefficient (mL/g)

TSS	=	Total suspended solids in the surface water body (mg/L), set equal to the representative average river concentration of 6 mg/L (Hanson Professional Services Inc., 2019)
0.000001	=	Units conversion factor
d_w	=	Depth of the water column (m)
d_b	=	Depth of the upper benthic layer (m), set equal to 0.03 m (US EPA, 2014)
$d_z = d_w + d_b$	=	Depth of the water body (m)
bsp	=	Bed sediment porosity (unitless), set equal to 0.6 (US EPA, 2014)
bsc	=	Bed sediment particle concentration (g/cm^3), set equal to 1.0 g/cm^3 (US EPA, 2014)

The fraction of COIs dissolved in the water column (f_d) is calculated as (US EPA 2014):

$$f_d = \frac{1}{1 + K_{dsw} \times TSS \times 0.000001}$$

The values of the fraction of COIs in the water column and other calculated parameters are presented in Table A.3. Other water body parameters are presented in Table A.4.

The total water column concentration (C_{wcTot}) of the COIs, comprising both the dissolved and suspended sediment phases, is then calculated as (US EPA 2014):

$$C_{wcTot} = C_{wtot} \times f_{water} \times \frac{d_z}{d_w}$$

Finally, the dissolved water column concentration (C_{dw}) for the COIs is calculated as (US EPA 2014):

$$C_{dw} = f_d \times C_{wcTot}$$

The dissolved water column concentration was then used to calculate the concentration of COIs sorbed to suspended solids in the water column (US EPA, 1998):

$$C_{sw} = C_{dw} \times K_{dsw}$$

where:

C_{sw}	=	Concentration sorbed to suspended solids (mg/kg)
C_{dw}	=	Concentration dissolved in the water column (mg/L)
K_{dsw}	=	Suspended solids/water partition coefficient (mL/g)

In the same way, using the total water body concentration and the fraction of COIs in the benthic sediments, the model derives the total concentration in benthic sediments (US EPA 2014, Table J-1-12):

$$C_{bstot} = f_{benth} \times C_{wtot} \times \frac{d_z}{d_b}$$

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where:

C_{bstot}	=	Total concentration in bed sediment (mg/L or g/m^3)
C_{wtot}	=	Total water body concentration of the constituent (mg/L)
f_{benth}	=	Fraction of contaminant in benthic sediments (unitless)
d_b	=	Depth of the upper benthic layer (m)
$d_z = d_w + d_b$	=	Depth of the water body (m)

This value can be used to calculate dry weight sediment concentration as follows:

$$C_{sed-dw} = \frac{C_{bstot}}{bsc}$$

where:

C_{sed-dw}	=	Dry weight sediment concentration (mg/kg)
C_{bstot}	=	Total sediment concentration (mg/L)
bsc	=	Bed sediment bulk density (used the default value of 1 g/cm^3 from US EPA, 2014)

The total sediment concentration is composed of the concentration dissolved in the bed sediment pore water (equal to the concentration dissolved in the water column) and the concentration sorbed to benthic sediments (US EPA, 1998).

The concentration sorbed to benthic sediments was calculated from (US EPA, 1998):

$$C_{sb} = C_{dbs} \times K_{dbs}$$

where:

C_{sb}	=	Concentration sorbed to bottom sediments (mg/kg)
C_{dbs}	=	Concentration dissolved in the sediment pore water (mg/L)
K_{dbs}	=	Sediments/water partition coefficient (mL/kg)

For each COI, the modeled total water column concentration, the modeled dry weight sediment concentration, and the modeled concentration sorbed to sediment are presented in Table A.5.

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Table A.1 Parameters Used to Estimate Groundwater Discharge to Surface Water

GW Unit	Parameter	Full Name	Value	Unit
Uppermost Aquifer	A	Cross-Sectional Area	800	m^2
Uppermost Aquifer	i	Hydraulic Gradient	0.0038	m/m
Uppermost Aquifer	K	Hydraulic Conductivity	0.10	cm/s

Notes:
GW = Groundwater.
Source: Hydraulic gradient and hydraulic conductivity values from Ramboll (2021).

Table A.2 Partition Coefficients

Constituent	Sediment-Water, Mean, Kdbs		Suspended Sediment-Water, Mean, Kdsw	
	Value (log_{10}) (mL/g)	Value (mL/g)	Value (log_{10}) (mL/g)	Value (mL/g)
Cadmium	3.3	2.00E+03	4.9	7.94E+04
Cobalt	3.1	1.26E+03	4.8	6.31E+04

Notes:
Lithium was not modeled because it lacks a Kd value in US EPA (2014a).
Source: US EPA (2014a).

Table A.3 Calculated Parameters

Constituent	Fraction of Constituent in the Water Column f_{water}	Fraction of Constituent in the Benthic Sediments $f_{benthic}$	Fraction of Constituent Dissolved in the Water Column $f_{dissolved}$
Cadmium	0.0890	0.9110	0.6772
Cobalt	0.1263	0.8737	0.7254

Table A.4 Surface Water Parameters

Parameter	Full Name	Value	Unit
TSS	Total Suspended Solids	6	mg/L
V_{fx}	Surface Water Flow Rate	4.56E+12	L/yr
db	Depth of Upper Benthic Layer (default: 0.03)	0.03	m
dw	Depth of Water Column	3.96	m
dz	Depth of Water Body	3.99	m
bsc	Bed Sediment Bulk Density (default: 1.0)	1	g/cm^3
bsp	Bed Sediment Porosity (default: 0.6)	0.6	-
M_{TSS}	TSS Mass per Unit Area	0.024	kg/m^2
M_S	Sediment Mass per Unit Area	30	kg/m^2

Notes:
Source of default values: US EPA (2014a).

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Table A.5 Input Groundwater Concentrations and Output Surface Water and Sediment Concentrations

Constituent	Groundwater Concentration (mg/L)	Mass Discharge Rate to Surface Water (mg/year)	Total Water Column Concentration (mg/L)	Concentration Sorbed to Bottom Sediments (mg/kg)
Cadmium	2.40E-03	2.30E+05	5.09E-08	6.88E-05
Cobalt	1.47E-01	1.41E+07	3.12E-06	2.85E-03
Lithium	4.14E-02	3.97E+06	8.78E-07	Not Applicable

Note:
Lithium was not modeled due to lack of Kd value in US EPA (2014a).

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Appendix B

Screening Benchmarks

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Table B.1 Calculated Water Quality Standards Protective of Incidental Ingestion and Fish Consumption

Analytes	Bioconcentration Factor (BCF)		Average Daily Intake (ADI)			Human Threshold Criteria (HTC)		
	BCF[a] (L/kg-tissue)	Basis	MCL (mg/L)	RfD (mg/kg-d)	ADI[b] (mg/day)	Water & Fish (mg/L)	Water Only (mg/L)	Fish Only (mg/L)
Cobalt	300	ORNL RAIS	NC	0.00030	0.021	0.0035	2.1	0.0035
Lithium	1	(d)	NC	0.002	0.14	4.7	14	7.0

Notes:

(a) BCFs from the following hierarchy of sources:

NRWQC (US EPA, 2016). National Recommended Water Quality Criteria.

NRWQC (US EPA, 2002). National Recommended Water Quality Criteria: 2002. Human Health Criteria Calculation Matrix.

US EPA (2014). Human and Ecological Risk Assessment of Coal Combustion Residuals.

ORNL RAIS (ORNL, 2018). Risk Assessment Information System (RAIS) Toxicity Values and Chemical Parameters.

(b) ADI based on the MCL is calculated as the MCL (mg/L) multiplied by a water ingestion rate of 2 L/day. In the absence of an MCL, the ADI was calculated as the RfD (mg/kg-d) multiplied by the body weight (70 kg).

(c) SWQC based on US EPA's action level.

(d) BCF of 1 was used as a conservative assumption, due to lack of published BCF.

Equations from IEPA (2019a):

Consumption of Water and Fish

$$HTC = \frac{ADI}{W + (F \times BCF)}$$

Incidental Consumption of Water only

$$HTC = \frac{ADI}{W}$$

Consumption of Fish only

$$HTC = \frac{ADI}{F \times BCF}$$

Where

Average Daily Intake (ADI)	=	Chem. Specific	mg/day
Fish Consumption Rate (F)	=	0.02	kg/day
Bioconcentration Factor (BCF)	=	Chem. Specific	L/kg-tissue
Water Consumption Rate (W)	=	0.01	L/day

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Table B.2 Recreator Exposure to Sediment

Chemical COIs	Relative Bioavailability B (unitless)	Dermal Absorption Fraction ABS (unitless)	Cancer				Cancer SL (mg/kg)	Non-Cancer								Recreator RSL Sediment (mg/kg)	Basis
			TRV		Child + Adult			TRV		Child		Adult		Child	Adult		
			CSF $(mg/kg\text{-}d)^{-1}$	Derm. CSF $(mg/kg\text{-}d)^{-1}$	Incidental Ingestion SL_{ing} (mg/kg)	Dermal Contact SL_{derm} (mg/kg)		RfD (mg/kg-d)	Derm. RfD (mg/kg-d)	Incidental Ingestion SL_{ing} (mg/kg)	Dermal Contact SL_{derm} (mg/kg)	Incidental Ingestion SL_{ing} (mg/kg)	Dermal Contact SL_{derm} (mg/kg)	Non-Cancer SL (mg/kg)			
Cobalt	1	NA	NC	NC	NC	NC	NC	3.0E-04	3.0E-04	4.1E+02	NA	4.4E+03	NA	4.1E+02	4.4E+03	411	nc

Notes:

AL = EPA Action Level; COI = Constituent of Interest; CSF = Cancer Slope Factor; derm = Dermal Contact; ing = Ingestion; NC = No criterion available; RfD = Reference Dose; SL = Screening Level; TRV = Toxicity Reference Value.

Health Benchmark defined as the lower of the Screening Levels for cancer and non-cancer. The basis of the Health Benchmark presented as c = based on cancer endpoint or nc = based on non-cancer endpoint.

$$\text{Screening Benchmark} = \frac{1}{\frac{1}{SL_{ing}} + \frac{1}{SL_{derm}}}$$

$$\text{Non-cancer } SL_{ing} = \frac{THQ * RfD}{Intake} \qquad \text{Cancer } SL_{ing} = \frac{TR}{Intake * CSF}$$

$$\text{Non-cancer } SL_{derm} = \frac{THQ * RfD}{Intake * ABS} \qquad \text{Cancer } SL_{derm} = \frac{TR}{Intake * ABS * CSF}$$

Target Cancer Risk (TR) = 1E-05

Target Hazard Quotient (THQ) = 1

Sediment – Ingestion (Chemical)

			Non-Cancer		Cancer		
Intake Factor (IF) =		$\frac{IR \times EF \times ED \times CF}{BW \times AT}$ =	7.3E-07 Child	6.8E-08 Adult	6.3E-08 Child	2.0E-08 Adult	Basis
	IR	Ingestion Rate (mg/day)	67	33	67	33	One-third of US EPA residential soil ingestion rate (Prof. Judgment)
	EF	Sediment Exposure Frequency (days/year)	60	60	60	60	2 days/week between April and Oct when air temp. > 70°F (Prof. Judgment)
	ED	Exposure Duration (years)	6	20	6	20	Default value for Resident (US EPA, 2019c)
	CF	Conversion Factor (kg/mg)	0.000001	0.000001	0.000001	0.000001	
	BW	Body Weight (kg)	15	80	15	80	Default value for Resident (US EPA, 2019c)
	AT	Averaging Time (d)	2,190	7,300	25,550	25,550	Default value for Resident (US EPA, 2019c)

Sediment – Dermal Contact (Chemical)

			Non-Cancer		Cancer		
Intake Factor (IF) =		$\frac{SA \times AF \times EF \times ED \times CF}{BW \times AT}$ =	2.2E-06 Child	1.2E-06 Adult	1.9E-07 Child	3.6E-07 Adult	Basis
	SA	Surface Area Exposed to Sediment (cm^2/day)	1,026	3,026	1,026	3,026	Age weighted SA for lower legs and feet (US EPA, 2011b)
	AF	Sediment Skin Adherence Factor (mg/cm^2)	0.2	0.2	0.2	0.2	Age weighted AF for children exposed to sediment (US EPA, 2011b)
	EF	Sediment Exposure Frequency (days/year)	60	60	60	60	2 days/week between April and Oct when air temp. > 70°F (Prof. Judgment)
	ED	Exposure Duration (years)	6	20	6	20	Default value for Resident (US EPA, 2019c)
	CF	Conversion Factor (kg/mg)	0.000001	0.000001	0.000001	0.000001	
	BW	Body Weight (kg)	15	80	15	80	Default value for Resident (US EPA, 2019c)
	AT	Averaging Time (d)	2,190	7,300	25,550	25,550	Default value for Resident (US EPA, 2019c)

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ATTACHMENT B

Supporting Information for Closure Alternatives Analysis

Prepared for

Dynegy Midwest Generation, LLC
1500 Eastport Plaza Drive
Collinsville, Illinois 62234

CLOSURE ALTERNATIVES ANALYSIS SUPPORTING INFORMATION REPORT

HENNEPIN POWER PLANT
EAST ASH POND
(IEPA ID W1550100002-05)
Hennepin, Illinois

Prepared by

Geosyntec consultants
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Project Number GLP8026

Revision 0

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Geosyntec consultants

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1. INTRODUCTION AND BACKGROUND

Dynegy Midwest Generation, LLC (Dynegy) is the owner of the coal-fired Hennepin Power Plant (HPP), also referred to as Hennepin Power Station, in Hennepin, Illinois. The HPP is currently inactive. Dynegy intends to complete closure of the East Ash Pond (EAP) at the HPP (IEPA ID No. W1550100005-05, Dynegy CCR Unit ID 803, and National Inventory of Dams Number IL50363). Closure of the EAP will be performed under the relevant Illinois Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments (Part 845) [1] and the United States Environmental Protection Agency (USEPA) CCR Rule [2].

Part 845 requires a Closure Alternatives Analysis (CAA) to be completed, pursuant to the requirements of Section 854.710, to support the Closure Plan prepared pursuant to Section 845.720. The CAA for the HPP EAP will be performed by Gradient Corporation (Gradient). Geosyntec has prepared this Closure Alternatives Analysis Supporting Information Report (Report) to provide information requested by Gradient to support their preparation of the CAA.

1.1. Report Contents

The following information is contained within this report:

- **Section 1** includes the Introduction and Background;
- **Section 2** includes information related to closure-by-removal (CBR) including:
  - A feasibility evaluation of CBR using an onsite landfill (CBR-Onsite);
  - An evaluation of potential offsite landfills to receive the CCR for CBR-Offsite; and
  - A feasibility evaluation of CCR transportation for CBR-Offsite using over-the-road trucks, rail, and barging.
- **Section 3** includes an overview of the planned construction for both CIP and CBR-Offsite;
- **Section 4** includes a project schedule for both CIP and CBR-Offsite; and
- **Section 5** includes estimates for construction material quantities, labor, vehicle miles, and equipment miles, for both CIP and CBR-Offsite.

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2. CLOSURE-BY-REMOVAL INFORMATION

Section 845.710(c)(1) requires the evaluation of complete removal of CCR (e.g., CBR), and Section 845.710(d)(2) requires the CAA to identify if the Power Plant has a landfill that can accept the CCR, or if constructing an onsite landfill is feasible. Additionally, Section 845.710(c)(1) requires the evaluation of multiple modes of transportation of CCR, including rail, barge, and truck. This section includes evaluation of onsite landfill options, potential offsite landfills, and potential methods for transporting CCR to offsite landfills.

2.1. Evaluation of Onsite Landfill Options

2.1.1. Existing Hennepin CCR Landfill

An existing CCR landfill, the Hennepin Landfill, was constructed at the HPP in 2011 and was never used to store waste actively generated at the HPP, although approximately 7,000 cubic yards (CY) of bottom ash ballast were placed over the top of the leachate collection layer in 2011 to provide freeze protection for the underlying liner system. The existing landfill cell is approximately 4.5 acres in size [3].

The EAP contains approximately 680,000 CY of CCR [4]. Placing all CCR from the EAP within the landfill would require the landfill to be constructed to a height of approximately 330 feet with 1.2 horizontal (H) to one vertical (V) side-slopes. A landfill of this geometry is unlikely to be stable from a geotechnical perspective.

The landfill is adjacent on the west to East Ash Pond No. 2 (EAP#2), which has been closed-in-place [5], on the south by the EAP, and on the east by the non-CCR Leachate Pond. Any lateral expansions to the landfill would adversely impact the adjacent CCR and non-CCR surface impoundments.

Therefore, using the existing onsite landfill at the HPP is not feasible due to the limited capacity and inability of the landfill to be expanded.

2.1.2. Feasibility of New Onsite Landfill Construction

The HPP site boundary was evaluated for suitable areas for the construction of an onsite landfill. The site was divided into multiple areas, Area 1 through Area 6, as shown in **Figure 1**. The feasibility of constructing a new landfill in each area is described below:

- Area 1 is approximately 54 acres in size and is located immediately south of the closed Old West Ash Pond and Old West Polishing Pond.
    - Most of this area is located within the 100-year floodplain of the Illinois River and may contain wetlands.

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  - This area is also adjacent to the Illinois Department of Natural Resources (IDNR) Donnelly Wildlife Management Area.

  - Therefore, there are no feasible locations for constructing a landfill within Area 1, due to impacts to the 100-year floodplain and potential impacts to adjacent protected areas.

- Area 2 is approximately 224 acres in size and is located south of the HPP.

  - Area 2 contains multiple utility service corridors, including five high-voltage electric lines leading to the switchyard at the HPP and one 10-inch natural gas line. These utilities are still active. Construction of a landfill in this area would likely require the utilities to be disturbed and potentially re-routed.

  - This area also includes County Road 875 East, which is an active roadway and provides access to adjacent industrial facilities. Construction of a landfill in this area may require the roadway to be relocated.

  - Most of Area 2 is planned for the development of a solar farm for generating electricity. Use of Area 2 for a landfill would impede solar development and potentially reduce the amount of low-carbon solar energy that could be developed at the site.

  - Some of Area 2 is within the 100-year floodplain of the Illinois River.

  - Therefore, there are no feasible locations for constructing a landfill within Area 2, due to existing utility corridors, existing public roadways, conflicts with proposed solar developments, and potential 100-year floodplain impacts.

- Area 3 is approximately 66 acres in size and is located immediately adjacent to and includes the HPP.

  - Approximately 10 acres of this area is the former HPP Coal Pile. Constructing a pyramid-shaped landfill to contain the approximately 680,000 CY of CCR from the EAP would require a total waste height of approximately 160 ft and 2.5H:1V side slopes, which may be geotechnically-challenging, considering the Coal Pile area is located at the top of a steep slope that leads to the Illinois River.

  - Outside of the Coal Pile, Area 3 has multiple conflicts related to existing site access roads and utilities and an electrical switchyard. The utilities and roads will need to be utilized as supporting infrastructure for future solar development at the stie.

  - Some of Area 3 is within the 100-year floodplain of the Illinois River.

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  - Therefore, there are no feasible locations for constructing a landfill within Area 3, due to space limitations relative to the required capacity, existing utilities and roadways, and potential 100-year floodplain impacts.

- Area 4 is approximately 40 acres and Area 5 is approximately 39 acres in size. These areas consist of CCR surface impoundments that have been previously closed-in-placed and adjacent areas to the closed CCR surface impoundments.

  - Portions of Areas 4 and 5 that overlie closed CCR surface impoundments are unlikely to be suitable for constructing a landfill due to settlement induced by the overlying waste potentially damaging the final cover system of the closed CCR surface impoundment.

  - Portions of Areas 4 and 5 that do not overlie closed CCR surface impoundments are generally located on steep slopes leading to the Illinois River or the Illinois River floodplain.

  - Therefore, there are no feasible locations for constructing a landfill within Areas 4 or 5, due to the presence of existing CCR surface impoundments, steep slopes leading to the Illinois River, and potential 100-year floodplain impacts.

- Area 6 is approximately 21 acres in size and consists of existing non-CCR surface impoundments, including the Leachate Pond and Polishing Pond.

  - Both the Leachate Pond and Polishing Pond are currently used as settlement basins to manage discharge from the HPP to the Illinois River via National Pollutant Discharge Elimination System (NPDES) Outfall 003.

  - Both ponds will need to remain in-service during closure constructing to allow unwatering and dewatering flow from the EAP to be managed prior to discharge via NPDES Outfall 003. Without the use of these ponds, there would be not onsite facilities suitable for managing construction-generated water and stormwater prior to discharge.

  - Therefore, there are no feasible locations for constructing a landfill within Area 6, as the existing non-CCR surface impoundments in Area 6 will be used as settling basins during closure construction.

In summary, there are no feasible locations for constructing a landfill within the existing HPP site boundary. Each evaluated location has multiple conflicts related to future solar development, potential 100-year floodplain impacts, existing closed CCR surface impoundments, existing utility corridors and site roadways, and steep slopes precluding landfill development.

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2.2. Potential CBR-Offsite Receiving Landfills

Potential offsite landfills suitable for disposing of the approximately 680,000 CY of CCR within the EAP were evaluated using IEPA's online Illinois Disposal Capacity Report [6]. The closest landfills to the site, by road miles, were determined to be the Republic Services LandComp Landfill in Ottawa, Illinois and the Ecology Solutions Eco Hill Landfill (a.k.a. Atkinson Landfill) in Atkinson, Illinois.

The LandComp landfill is the preferred landfill due to its location being closer to the HPP (32 vs. 53 one-way miles, respectively), thereby resulting in reduced hauling mileage. Both landfills have sufficient remining permitted capacity to receive the approximately 680,000 CY of CCR, although the landfills have not yet been contacted, as of the date of this report, to confirm that they would be willing to accept the CCR. Information on both landfills is provided in **Table 1** and the location of each landfill relative to the HPP is provided in **Figure 2**.

2.3. Potential CBR-Offsite Transportation Methods

Section 845.710(c)(1) requires CBR to consider multiple methods for transporting removed CCR, including using rail, barge, and trucks. An evaluation of each method is included within this section.

2.3.1. <u>Transportation by Rail</u>

The HPP does not currently have an established rail terminal, although the HPP property does border a Norfolk Southern rail spur leading to the adjacent Washington Mills industrial facility. In order for CCR to be transported by rail, a new rail loading terminal would need to be constructed onsite, which would increase the project schedule due to the need to coordinate with the railroad, complete design and permitting, and construct the terminal. CCR would still need to be hauled by truck to the new onsite loading terminal and loaded into rail cars, resulting in additional CCR handing and exposure to the surrounding environment.

While both the Land Comp and Atkinson landfills are located within approximately one mile of existing rail lines, an existing terminal suitable for the unloading of CCR is not present near either landfill. A rail unloading terminal would need to be constructed which would increase the project schedule due to the need to coordinate with the railroad, complete design and permitting, and construct the terminal. CCR would still need to be hauled by truck from the new offsite unloading terminal to the landfill, resulting in additional CCR handling and exposure to the surrounding environment.

Furthermore, a direct rail route from the Hennepin Power Plant to either landfill does not exist. Hauling CCR to the Land Comp or Atkinson landfill would involve approximately 51 and 115 miles, respectively, of hauling by rail on tracks owned by three separate rail lines (Norfolk Southern, Illinois Railway, LLC, and Iowa Interstate Railroad, Ltd), as shown on **Figure 2**. The

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ability of CCR to be hauled over multiple lines and transferred from line to line is currently unknown.

Therefore, transporting CCR by rail is unlikely to be a viable option for the HPP EAP, due to the need to design, permit, and construct additional loading and unloading infrastructure, resulting in corresponding project schedule delays, and the distance and number of rail lines which the CCR would need to be transported over.

2.3.2. Transportation by Barge

The HPP is located along the Illinois River and formerly received coal shipments by barge, which were unloaded via an unloading terminal. The coal unloading terminal includes a clamshell unloading bucket that was utilized for removing coal from barges and placing the coal into a conveyor system that transported to the former coal pile at the HPP. This terminal is not currently suitable for the loading of CCR into barges as it was designed and constructed for unloading, rather than loading. The clamshell is unlikely to be sufficient to load CCR without potentially releases of minor amounts of CCR dust from the clamshell into the surrounding environment. Additionally, the terminal was partially decommissioned by removing associated transformers and disconnecting the electrical supply after HPP was closed in 2019. In order for CCR to be hauled by barge from the HPP a new loading terminal would need to be constructed, thereby increasing the project schedule due to the need to complete design, permitting, and construction.

Other barge terminals are located within five miles of the Hennepin Power Plant, but offsite, including a terminal at the adjacent Tri-Con Materials site, a terminal adjacent to the Marquis Energy facility, and the CBG grain terminal on the west bank of the Illinois River, as shown in **Figure 2**. However, use of these other terminals would require negotiating agreements with the terminal owner and/or operator. Additionally, it is unknown if these other terminals are suitable for the loading of CCR. If the terminals are not suitable, use of the terminals may require the design, permitting, and construction of improvements at each terminal, to allow CCR to be unloaded, thereby increasing the project schedule.

The Land Comp landfill is located approximately 3 miles from an existing barge loading terminal on the Illinois River, as shown in **Figure 2**. However, an agreement would need to be negotiated with the terminal owner. It is unknown if this terminal is suitable for the unloading of CCR. If the terminal is not suitable, us of the terminal may require the design, permitting, and construction of improvements to allow CCR to be unloaded. CCR would still need to be hauled by truck to the landfill and unloaded, resulting in additional CCR handling and exposure to the surrounding environment.

The Atkinson Landfill is not located near the Illinois River and, therefore, transportation of CCR to the Atkinson landfill by barge is not feasible.

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Therefore, transporting CCR by barge is unlikely to be a viable option for the HPP East Ash Pond, due to the need to design, permit, and construct additional loading and potentially unloading infrastructure, resulting in corresponding schedule delays.

2.3.3. Transportation by Truck

The HPP is located approximately four miles from Interstate 180 (I-180) and Illinois Route 71 (IL-71), both of which are suitable for receiving truck hauling traffic. County Road 700E and 800E link the HPP to IL-71 and I-180 and routinely receive truck traffic associated with adjacent industrial facilities and the HPP. Potential travel routes between the HPP and LandComp and Atkinson Landfills are shown on **Figure 2**, although actual travel routes may vary.

Transporting CCR by truck will not require the construction of additional loading or unloading infrastructure at either the receiving landfill or the HPP. CCR would be loaded into truck using heavy equipment at the EAP. CCR will then be unloaded at the receiving landfill by the truck directly. Since no construction is required, project delays related to coordination with other entities, design, and permitting are unlikely to occur. Therefore, transporting CCR by truck is a viable option for the HPP EAP.

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3. CLOSURE DESCRIPTION NARRATIVES

Section 845.720(a)(1)(A) requires narrative description of CCR impoundment closures to be prepared. Narrative descriptions have been prepared for both CIP and CBR-Offsite and are included within this section.

3.1. CIP

A narrative description of how the EAP will be closed in place is provided in Section 2.1 of the HPP Closure Plan [7].

3.2. CBR-Offsite

A narrative description of how CBR-Offsite of the EAP will be includes:

- The EAP will be unwatered by pumping free surface water to the adjacent non-CCR Leachate Pond or Polishing Pond (non-CCR surface impoundments) for ultimate discharge at NPDES Outfall 003.

- A temporary water management system will be constructed within the EAP, including ditches and sumps. The system will maintain the EAP in an unwatered state by collecting contact stormwater during closure construction. Unwatering flows will be pumped to the Leachate Pond or Polishing Pond for ultimate discharge at NDPES Outfall 003.

- CCR will be removed from the EAP using mass mechanical excavation techniques. Much of the CCR will be saturated or nearly saturated, so mass excavation will include the use of dewatering trenches or other forms of passive dewatering (i.e., rim ditching or windrowing) to moisture-condition the CCR prior to handling. Dewatering flows will be pumped to the Polishing Pond or Leachate Pond for ultimate discharge at NPDES Outfall 003.

- CCR will be loaded into over-the-road dump trucks and hauled to the offsite receiving landfill.

- Any accumulated CCR within the riser structure and culvert leading to the Polishing Pond will be removed and the riser structure and culvert will be decontaminated by pressure washing. Decontamination water will be routed to the Leachate Pond or Polishing Pond. The removed CCR will also be disposed of in the offsite receiving landfill.

- The existing EAP liner system, including the geomembrane side-slope liner and bottom soil liner, will be removed and disposed of in the offsite landfill. The EAP bottom and side-slopes will be decontaminated by removing approximately one foot of foundation soil beneath the side-slope and bottom liners. The liner system and foundation soils will be disposed of in the offsite receiving landfill.

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- The decontaminated EAP will be backfilled to a minimum elevation of 480.4 ft and sloped to drain towards the existing riser structure, in order to allow post-closure, non-contact stormwater to gravity flow into the adjacent Polishing Pond through the existing spillway structure and preclude the impoundment of water within the EAP. Backfill materials would include clean soil material excavated from an offsite borrow source.

- The EAP will be restored by placing six inches of topsoil on the bottom and side slopes of the EAP and establishing vegetation. Stormwater best management practices (BMPs) such as erosion control blankets and straw wattles will be used, as needed to reduce erosion during vegetation establishment.

- After vegetation is established, BMPs will be removed, and closure construction will be considered completed.

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4. CONSTRUCTION SCHEDULES

Section 845.720(a)(1)(F) requires a schedule including all activities necessary to complete closure to be prepared. Schedules have been prepared for both CIP and CBR-Offsite and are included within this section. Schedules were prepared using estimates of task durations based on Geosyntec's experience, typical weather conditions at the site, and expected construction rates relative to estimated construction quantities.

4.1. CIP

The proposed closure completion schedule for CIP is provided in Section 2.6 of the HPP Closure Plan [7].

4.2. CBR-Offsite

The proposed closure construction schedule for CBR-Offsite is provided in **Table 2**.

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5. MATERIAL, QUANTITY, LABOR, AND MILEAGE ESTIMATES

Estimates of material quantities, total labor hours, and mileage estimates were requested for each alternative by Gradient to support the CAA. Estimates for both CIP and CBR-Offsite were prepared utilizing the following approach:

- Major construction components and line-items were identified, in accordance with the narrative closure description (**Section 3**).
- Construction quantities were estimated based on volume estimates, area estimates, and proposed construction schedules (**Section 4**).
- Soil fill was assumed to come from offsite borrow sources located within 10 miles of the site, as limited borrow soil is expected to be available at the HPP, due to the need to avoid disturbing large portions of the site and potentially precluding eventual solar development.
- RSMeans Heavy Construction Cost Data [8] (RS Means) was used to estimate the crew size, equipment description, and daily output associated with each line-item.
- For line items where RSMeans data was unavailable, the crew size, equipment description, and daily output were estimated based on Geosyntec's experience.
- Daily labor mobilization miles were estimating assuming an average one-way commute of 35 miles for each individual working onsite. The number of working days were estimated from the construction schedules (**Section 4**).
- Estimates of material delivery miles were prepared based on Geosyntec's experience.
- Total project material quantities, labor hours, and mileage estimates were then prepared both closure alternatives, considering individual quantity, labor, and mileage estimates associated with each line-item.

The detailed quantity, labor and mileage estimates for CIP are provided in **Tables 3** and **4**, respectively, and the detailed quantity, labor, and mileage estimates for CBR-Offsite are provided in **Tables 5** and **6**, respectively.

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6. REFERENCES

[1] Illinois Environmental Protection Agency, "35 Ill. Adm. Code Part 845, Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments," Springfield, IL, 2021.

[2] United Stated Environmental Protection Agency, "40 CFR Parts 257 and 261, Hazardous and Solid Waste Management System, Disposal of Coal Combustion Residuals from Electric Utilities, Final Rule, 2015," 2015.

[3] Geosyntec Consultants, "2021 USPEA CCR Rule Periodic Operating Record Run-on and Run-off Control Plan Review Report, §257.81, CCR Landfill, Hennepin Power Plant," Chesterfield, Missouri, October 11, 2021.

[4] Geosyntec Consultants, "Construction Permit Application, Hennepin Power Plant, East Ash Pond," Chesterfield, Missouri, November 2021.

[5] D. Tickner, "Hennepin Power Station; Old West Ash Pond, Ash Pond No. 2, Notification of Completion of Closure," Luminant, Collinsville, Illinois, December 17, 2020.

[6] Illinois Environmental Protection Agency, "Illinois Landfill Disposal Capacity Report," August 2021.

[7] Geosyntec Consultants, "CCR Final Closure Plan, Hennepin Power Plant, East Ash Pond," Chesterfield, Missouri, November 2021.

[8] RSMeans, "Heavy Construction Costs with RSMeans Data," Gordian, 2021.

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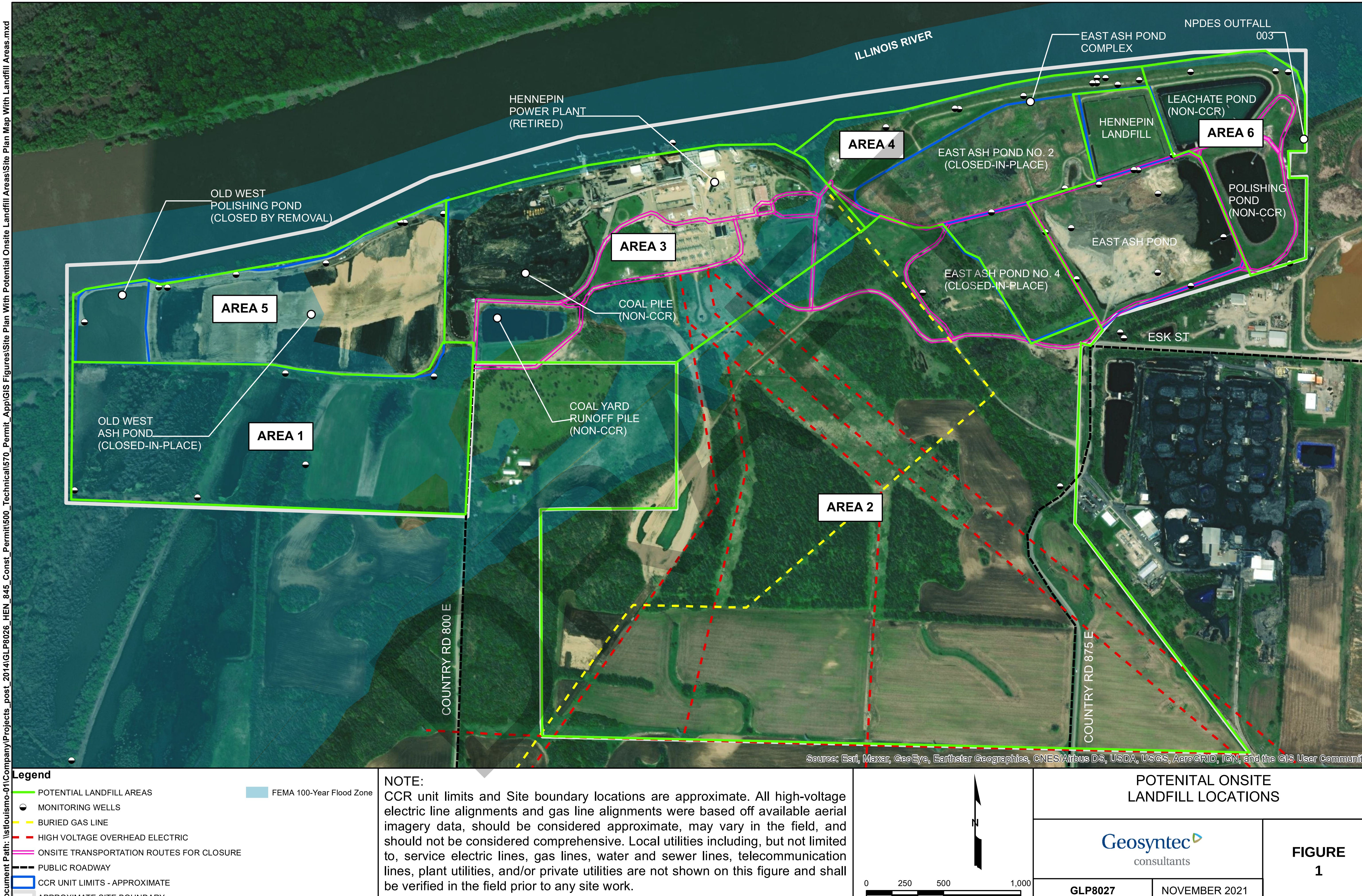
FIGURES

Document Path: \\stlouismo-01\Company\Projects_post_2014\GLP8026_HEN_845_Const_Permit\500_Technical\570_Permit_App\GIS Figures\Site Plan With Potential Onsite Landfill Areas\Site Plan Map With Landfill Areas.mxd



NOTE:
CCR unit limits and Site boundary locations are approximate. All high-voltage electric line alignments and gas line alignments were based off available aerial imagery data, should be considered approximate, may vary in the field, and should not be considered comprehensive. Local utilities including, but not limited to, service electric lines, gas lines, water and sewer lines, telecommunication lines, plant utilities, and/or private utilities are not shown on this figure and shall be verified in the field prior to any site work.

POTENITAL ONSITE LANDFILL LOCATIONS

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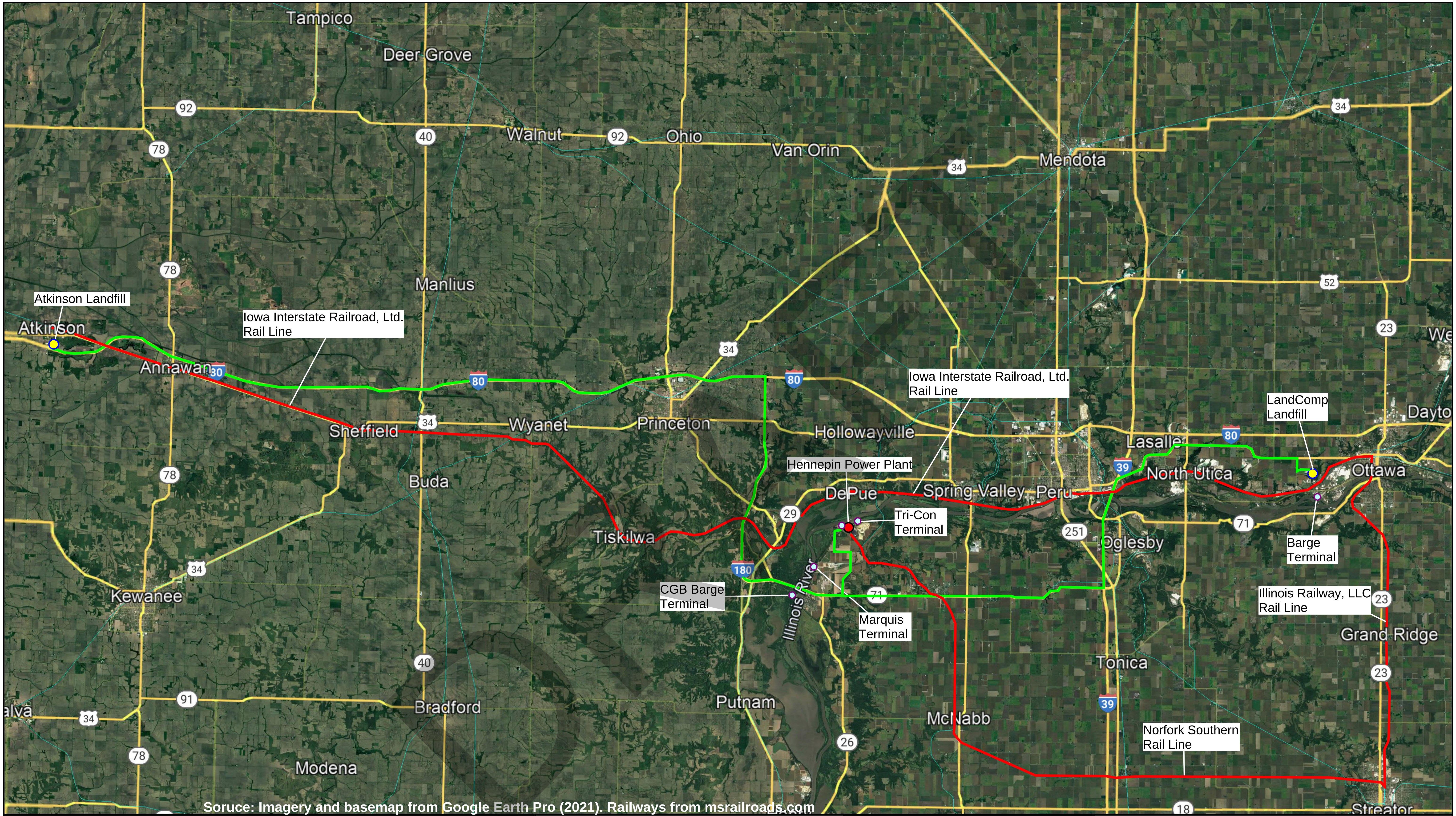
GLP8027 | NOVEMBER 2021

FIGURE 1



Legend

Symbol	Description	Symbol	Description
Red dot	Hennepin Power Plant	Green line	Potential Truck Haul Route
Yellow dot	Potential Offsite Landfill	Red line	Potential Rail Haul Route
Purple circle	Existing Barge Terminal	Blue dotted line	Potential Barge Haul Route
Cyan line	Railroad Right-of-Way		
Yellow line	Highway		

Note: Some railroad right-of-ways no longer contain tracks. The potential rail haul route was selected to include right-of-ways with existing tracks, based on an evaluation of Google Earth imagery.

N

0 5 10

Miles

OFFISTE LANDFILL LOCATIONS AND TRANSPORTATION ROUTES

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FIGURE 2

GLP8027 NOVEMBER 2021

TABLES

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Table 1: Offsite Landfill Information

Landfill Name	Owner	Location	One-Way Distance from Site by Road (Miles)	2020 Five-Year Average Disposal Volume (in-place CY) [6]	2020 Remaining Capacity Reported (in-place CY) [6]
LandComp	Republic Services	Ottawa, IL	32	450,497	8,478,610
Eco Hill (a.k.a. Atkinson)	Ecology Solutions	Atkinson, IL	53	271,715	11,745,000

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Table 2 – Construction Schedule – CBR-Offsite

Milestone	Timeframe (Preliminary Estimates)
Agency Coordination, Approvals, and Permitting • Obtain state permits, as needed, for dewatering, water discharge, land disturbance, and dam modifications	6 to 12 months after Final Closure Plan Approval
Final Design and Bid Process • Complete final design of the closure and select a construction contractor.	6 to 24 months after Agency Coordination, Approvals, and Permitting
Dewater and Excavate CCR, Decontaminate CCR Unit • Complete contractor mobilization, installation of stormwater BMPs, and unwatering of the EAP. • Complete mass excavation of CCR and decontamination of the EAP. • Winter weather delays are assumed between November and March of each construction year.	16 to 24 months after necessary permits are issues
Backfill with Clean Soil • Backfill the EAP to clean soil to El. 480.4 ft and slope to drain.	8 to 12 months after decontamination is complete
Site Restoration • Seed and stabilize the EAP. • Complete contractor demobilization.	2 to 5 months after backfill is complete
Timeframe to Complete Closure	38 to 77 months

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Table 3 - Material Quantity Estimate - CIP

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ITEM NO.	SITE PREPARATION	Units	Quantity	Crew	Daily Output	Labor Hours	Equipment Hours	Notes
1	Mow Vegetation in East Ash Pond and Landfill	MSF	30	B84	22	11	11	320190191660: Mowing, mowing brush, light density, tractory with rotary mower
2	Construction Soil Erosion & Sediment Controls (Silt Fence)	LF	5,000	B62	650	185	62	312514161000: Synthetic erosion control, silt fence, install and remove, 3' high
3	Construction Facilities	MO - in use	10	-	-			
	Sub-Units							
	Office Trailer	MO - in use	10	-	-	-	-	015213200350: Office trailer, furnished, no hookups, 32' x 8', rent per month
	Storage Trailers (x2)	MO - in use	10	-	-	-	-	015213201350: Storage boxes, 40' x 8', rent per month
	Portable Toilet (x2)	MO - in use	10	-	-	-	-	015433406410: Rent toilet, portable chemical
4	Dust Control	DAY	163	B59	0.5	2,607	2,607	312323202510: Dust control, heavy; utlizing truck tractor and water tank trailer per RSMeans Crew B59. Quantity is assumed to be 3/4 of working days will need dust control = 1.25 days/week.
5	Haul Road Maintenance	DAY	43	B86A	1	348	348	312323202600: Haul road maintenance Quantity is assumed to be 1 day/week.
	SITE PREPARATION ESTIMATED SUBTOTAL					**3,150**	**3,030**	
ITEM NO.	**DEWATERING, UNWATERING, AND STORMWATER MANAGEMENT**	**Units**	**Quantity**	**Crew**	**Daily Output**	**Labor Hours**	**Equipment Hours**	**Notes**
6	Unwatering, Dewatering, and Stormwater Management for the East Ash Pond	DAY	87	Dewater	4	174	43	312319200650: Dewatering, pumping 8 hours, attended 2 hours per day, 4" discharge pump used for 8 hours, includes 20 LF of suction hose and 100 LF of discharge hose. Crew and Daily Output multiplied by 4 based on experience. Quantity is 5 days/week for 4 months.
7	Temporary Unwatering of the Polishing Pond	DAY	15	B10I	4	45	30	312319200650: Dewatering, pumping 8 hours, attended 2 hours per day, 4" discharge pump used for 8 hours, includes 20 LF of suction hose and 100 LF of discharge hose. Crew and daily Output multiplied by 4 based on experience.
8	Dewatering Sumps Installation	EA - in place	4	Sump Install	4	16	8	Crew and Daily Output based on experience. Materials include 24" corrugated HDPE pipe with geotextile wrapping, and 1 C.Y. of gravel backfill.
	DEWATERING, UNWATERING, AND STORMWATER MANAGEMENT ESTIMATED SUBTOTAL					**230**	**80**	
ITEM NO.	**EAST ASH POND CLOSURE**	**Units**	**Quantity**	**Crew**	**Daily Output**	**Labor Hours**	**Equipment Hours**	**Notes**
9	Removal and Abandonment of Outlet Structure	LS	-	-	-	155	23	
	Sub-Units							
	Demolition of Steel Walkway	SF	800	B21C	500	90	13	024116330200: Bridge demolition, pedestrian, steel, 50' to 160' long, 8' to 10' wide
	Demolition of Outlet Structure	LF	20	B69	300	3	1	024113430100:Selective demolition, box culvert, precast, 8' x 6' x 3' to 8' x 8' x 8', excludes excavation
	Plugging of Outlet Pipe	CY	2	C14A	18	22	2	033053401040: Cast-in-place Concrete, including forms (4 uses), Grade 60 rebar, concrete (portland cement Type I), placement and finishing included; Columns, square (4000 psi), 36" x 36", up to 3% reinforcing by area
	Cleaning of Pipe Interior	LS	1	2 Clab	1	16	0	Crew and Daily Output based on experience.
	Grouting of Pipe	CY	79	Grout/Concrete	80	24	8	Crew and Daily Output based on experience.
10	Excavation and Placement of Ballast Material Contouring Fill from Hennepin Landfill	CY - in place	8,000	-	-	2,099	734	
	Sub-Units							
	Excavation of Ballast Material (Upper 8 inches)	CY - as excavated	5,628	B11C	150	600	300	312316130050: Excavating, Trench or continuous footing, common earth with no sheeting or dewatering included, 1' to 4' deep, 3/8 C.Y. excavator
	Fine/detailed Cleaning of Surface	MSF	220	1 Clab	7.5	235	0	320130104500: Site maintenance, lawn maintenance, rake leaves or lawn, by hand
	Excavate of Materials by Hand and Skidsteer (Lower 4 inches)	SY	24,200	B63	1000.0	968	194	311413231540: Topsoil stripping and stockpiling, loam or topsoil, remove and stockpile onsite, by skid steer, 901-1100 S.Y., 6" deep, 200' haul
	Loading of Material	CY - as excavated	8,400	B14A	3230	31	21	312316435400: Excavating, large volume projects; excavation with truck loading; excavator, 4.5 C.Y. bucket, 95% fill factor (assume 5% shrinkage factor from ground to in-place)
	Hauling of Ballast Material	CY - as excavated	8,400	B34F	528	127	127	312323205000: Hauling; no loading equipment, including hauling, waiting, loading/dumping; 22 C.Y. off-road, 15 min wait/ld/uld., 5 MPH, cycle 2000 feet
	Spreading of Material	CY - as excavated	8,400	B10B	1000	101	67	312323170020: Spread dumped material, no compaction, by dozer
	Compaction of Material	CY - in place	8,000	B10F	2600	37	25	312323235100: Compaction; Riding, vibrating roller, 12" lifts, 4 passes (RSMeans Crew is B10Y; altered to B10F based on experience)
11	Excavation and Placement of Contouring Fill within Construction Limits	CY - in place	37,200	-	-	1,435	1,163	
	Sub-Units							
	Excavation and Loading of Material	CY - as excavated	40,920	B14A	3230	152	101	312316435400: Excavating, large volume projects; excavation with truck loading; excavator, 4.5 C.Y. bucket, 95% fill factor (assume 5% shrinkage factor from ground to in-place)
	Hauling of Material	CY - as excavated	40,920	B34F	528	620	620	312323205000: Hauling; no loading equipment, including hauling, waiting, loading/dumping; 22 C.Y. off-road, 15 min wait/ld/uld., 5 MPH, cycle 2000 feet
	Spreading of Material	CY - as excavated	40,920	B10B	1000	491	327	312323170020: Spread dumped material, no compaction, by dozer
	Compaction of Material	CY - in place	37,200	B10F	2600	172	114	312323235100: Compaction; Riding, vibrating roller, 12" lifts, 4 passes (RSMeans Crew is B10Y; altered to B10F based on experience)
12	Placement of Imported Offsite Contouring Fill	CY - in place	39,220	-	-	4,300	3,536	
	Sub-Units							
	Excavation and Loading of Material	CY - as excavated	41,181	B14A	3230	153	102	312316435400: Excavating, large volume projects; excavation with truck loading; excavator, 4.5 C.Y. bucket, 95% fill factor (assume 5% shrinkage factor from ground to in-place)
	Hauling of Material	CY - as excavated	41,181	B34B	132	2,496	2,496	312323201098: Hauling; no loading equipment, including hauling, waiting, loading/dumping; 12 C.Y. truck, 15 min wait/ld/uld., 45 MPH, cycle 20 miles
	Spreading of Material	CY - as excavated	41,181	B10B	1000	494	329	312323170020: Spread dumped material, no compaction, by dozer
	Finish Grading of Material	SY	101,640	B32C	5000	976	488	312216101020: Fine grading, loam or topsoil fine grade for large area, 15,000 S.Y. or more
	Compaction of Material	CY - in place	39,220	B10F	2600	181	121	312323235100: Compaction; Riding, vibrating roller, 12" lifts, 4 passes (RSMeans Crew is B10Y; altered to B10F based on experience)
13	Piezometer and Monitoring Well Extensions	EA	8	Grout/Concrete	4	48	16	Crew and Daily Output based on experience. Includings extension and replacing surface completions (cover, cast-in-place reinforced concrete pad, and bollards)
14	Geomembrane	SF - in place	914,760	B63B	1600	18,295	4,574	310519531200: Pond and reservoir liners, membrane lining systems HDPE, 100,000 S.F. or more, 60 mil thick, per S.F. (muliplied unit rate by 0.5 based on experience)
15	Geotextile	SF - in place	914,760	2 Clab	22500	650	0	313219161550: Geotextile soil stabilization; non-woven 120 lb. tensile strength (multiplied unit rate by 4 to account for heavier geotextile based on experience)
16	Anchor Trench Installation	LF	2,700	-	-	181	121	
	Sub-Units							
	Excavation of Material	CY - as excavated	945	B11C	150	101	50	312316130050: Excavating, Trench or continuous footing, common earth with no sheeting or dewatering included, 1' to 4' deep, 3/8 C.Y. excavator
	Backfilling Material	CY - as excavated	945	B10R	400	28	19	312316133020: Backfill trench, F.E. Loader, wheel mtd., 1 C.Y. bucket, minimal haul
	Compacting Material	CY - in place	900	A1D	140	51	51	312323237040: Compaction, walk behind, vibrating plate 18" wide, 6" lifts, 4 passes
17	Placement of Imported Offsite Protective Cover Soil	CY - in place	49,830	-	-	5,199	4,360	
	Sub-Units							
	Excavation and Loading of Material	CY - as excavated	52,322	B14A	3230	194	130	312316435400: Excavating, large volume projects; excavation with truck loading; excavator, 4.5 C.Y. bucket, 95% fill factor (assume 5% shrinkage factor from ground to in-place)
	Hauling of Material	CY - as excavated	52,322	B34B	132	3,171	3,171	312323201098: Hauling; no loading equipment, including hauling, waiting, loading/dumping; 12 C.Y. truck, 15 min wait/ld/uld., 45 MPH, cycle 20 miles
	Spreading of Material	CY - as excavated	52,322	B10B	1000	628	419	312323170020: Spread dumped material, no compaction, by dozer
	Finish Grading of Material	SY	101,640	B32C	5000	976	488	312216101020: Fine grading, loam or topsoil fine grade for large area, 15,000 S.Y. or more
	Compaction of Material	CY - in place	49,830	B10F	2600	230	153	312323235100: Compaction; Riding, vibrating roller, 12" lifts, 4 passes (RSMeans Crew is B10Y; altered to B10F based on experience)
18	Placement of Imported Offsite Vegetative Soil	CY - in place	16,950	-	-	2,324	1,746	
	Sub-Units							
	Excavation and Loading of Material	CY - as excavated	17,798	B14A	3230	66	44	312316435400: Excavating, large volume projects; excavation with truck loading; excavator, 4.5 C.Y. bucket, 95% fill factor (assume 5% shrinkage factor from ground to in-place)
	Hauling of Material	CY - as excavated	17,798	B34B	132	1,079	1,079	312323201098: Hauling; no loading equipment, including hauling, waiting, loading/dumping; 12 C.Y. truck, 15 min wait/ld/uld., 45 MPH, cycle 20 miles
	Spreading of Material	CY - in place	16,950	B10B	1000	203	136	312323170020: Spread dumped material, no compaction, by dozer
	Finish Grading of Material	SY	101,640	B32C	5000	976	488	312216101020: Fine grading, loam or topsoil fine grade for large area, 15,000 S.Y. or more
	EAST ASH POND ESTIMATED SUBTOTAL					**34,690**	**16,270**	
ITEM NO.	**SITE RESTORATION**	**Units**	**Quantity**	**Crew**	**Daily Output**	**Labor Hours**	**Equipment Hours**	**Notes**
19	Establish Access Roads	LF	2,700	-	-	67	62	
	Sub-Units							
	Hauling of Material	CY	800	B34B	132	48	48	312323201098: Hauling; no loading equipment, including hauling, waiting, loading/dumping; 12 C.Y. truck, 15 min wait/ld/uld., 45 MPH, cycle 20 miles
	Spreading and Compacting Material	SY	2,400	B32	4200	18	14	321123230400: Base course drainage layers, aggregate base course for roadways and large paved areas, bank run gravel, spread and compacted, 12" deep
20	Riprap Stormwater Chutes	SF - in place	2,400	-	-	283	40	
	Sub-Units							
	Geotextile	SF - in place	2,400	2 Clab	22500	2	0	313219161550: Geotextile soil stabilization; non-woven 120 lb. tensile strength (multiplied unit rate by 4 to account for heavier geotextile based on experience)
	RipRap	SF - in place	2,400	B13	477	282	40	313713100200: Riprap and rock lining, random, broken stone, machine placed for slope protection, 18" minimum thickness, not grouted
21	Erosion Control Blanket	SF - in place	26,880	ECB	22500	29	10	Crew based on experience. Daily Output based on 312314160100: Rolled erosion control mats and blankets, plastic netting, stapled, 2" x 1" mesh, 20 mil.
22	Straw Wattle Ditch Checks	LF - in place	2,500	A2	1000	60	20	312514160705: Sediment Log, Filter Sock, 9"
23	Seed, Mulch, and Maintain Vegetated Surfaces	AC	21	-	-	189	189	
	Sub-Units							
	Lime	MSF	915	B66	700	10	10	329113234250: Soil preparation, structural soil mixing, spread soil conditioners, ground limestone, 1#/S.Y., tractor spreader
	Fertilizer	MSF	915	B66	700	10	10	329113234150: Soil preparation, tructural soil mixing, spread soil conditioners, fertilizer, 0.2#/S.Y., tractor spreader
	Seed	MSF	915	B66	52	141	141	329219142300: Seeding athletic fields, seeding fescue, tall, 5.5 lb. per M.S.F., tractor spreader
	Mulch	MSF	915	B65	530	28	28	329113160350: Mulching, Hay, 1" deep, power mulcher, large
	SITE RESTORATION ESTIMATED SUBTOTAL					**630**	**320**	
ITEM NO.	**ENGINEERING AND PERMITTING TASKS**	**Units**	**Quantity**	**Crew**	**Output**	**Labor Hours**	**Equipment Hours**	**Notes**
24	Engineering Support and CQA During Construction	LS	1	Eng	60 hrs/week	2,640	880	Crew and Output based on experience.
	ENGINEERING AND PERMITTING ESTIMATED SUBTOTAL					**2,640**	**880**	

NOTES:
1. LS = Lump Sum, AC = Acre, LF = Linear Foot, EA = Each, SY = Square Yard, MO = Month, YR = Year, CY = Cubic Yard, MSF = Thousand Sqaure Feet
2. "Subtotal" and "Total" costs are for comparative purposes only. Actual costs will be paid based on actual quantities, as listed in the Specifications, and subtotal and total costs may vary from those calculated using this Bid Form.
3. RS Means refers to the 2021 online edition of RS Means Commercial New Construction. All unit rates refer to standard union labor in La Salle, IL.

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Table 4 - Labor, Equipment, and Mileage Estimate - CIP

Geosyntec consultants

Item	Quantity	Assumptions
Labor Total Hours	42,400	Per projected total in cost estimate
Duration of Onsite Construction in Days	284	Per Construction Schedule Revision A, dated 9/22/21
Average Daily Crew Size	15	10 hour days
Daily Labor Mobilization Miles	298,200	Average of 70 miles round trip per day
Vehicles Miles Onsite	7,810	1 mile round trip from gate to parking 5 miles per day for CQA tech and Construction Supervisor 10% Contingency for site visitors (client and engineering support)
Equipment Mobilization Miles - Unloaded	12,171	Average of 300 miles one way for equipment hauling Average 1 load of equipment per working week
Equipment Mobilization Miles - Loaded	12,171	Average of 300 miles one way for equipment hauling Average 1 load of equipment per working week
Daily Equipment Miles Onsite	44,447	Average of 10 of 15 crew members running equipment Assume 15 miles per piece of equipment (based on 15 minute round trip path across EAP) 10 miles per day used for water truck 5 miles per day used for grader
Onsite Haul Truck Miles - Unloaded	425	22 CY Haul Truck 2000 ft cycle
Onsite Haul Truck Miles - Loaded	425	22 CY Haul Truck 2000 ft cycle
Offsite Haul Truck Miles - Unloaded	93,417	12 CY Dump Truck 20 mi cycle
Offsite Haul Truck Miles - Loaded	93,417	12 CY Dump Truck 20 mi cycle
Material Delivery Miles - Unloaded	14,050	Same geosynthetic material source, trailer quantities, and roll sizes as HEN WAPS project assumed 30 extra trips for seed, fertilizer, lime, mulch, ECBs, straw wattles, and concrete - source 1000 miles away average
Material Delivery Miles - Loaded	14,050	Same geosynthetic material source, trailer quantities, and roll sizes as HEN WAPS project assumed 30 extra trips for seed, fertilizer, lime, mulch, ECBs, straw wattles, and concrete - source 1000 miles away average

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Table 5 - Material Quantity Estimate - CBR-Offsite

Geosyntec consultants

ITEM NO.	SITE PREPARATION	Units	Quantity	Crew	Daily Output	Labor Hours	Equipment Hours	Notes
1	Mow Vegetation in East Ash Pond	MSF	30	B84	22	11	11	320190191660: Mowing, mowing brush, light density, tractory with rotary mower
2	Construction Soil Erosion & Sediment Controls (Silt Fence)	LF	10,000	B62	650	369	123	312514161000: Synthetic erosion control, silt fence, install and remove, 3' high
3	Construction Facilities	MO - in use	32	-	-			
	Sub-Units							
	Office Trailer	MO - in use	32	-	-	-	-	015213200350: Office trailer, furnished, no hookups, 32' x 8', rent per month
	Storage Trailers (x2)	MO - in use	32	-	-	-	-	015213201350: Storage boxes, 40' x 8', rent per month
	Portable Toilet (x2)	MO - in use	32	-	-	-	-	015433406410: Rent toilet, portable chemical
4	Dust Control	DAY	521	B59	0.5	8,342	8,342	312323202510: Dust control, heavy; utlizing truck tractor and water tank trailer per RSMeans Crew B59. Quantity is assumed to be 3/4 of working days will need dust control = 1.25 days/week.
5	Haul Road Maintenance	DAY	139	B86A	1	1,112	1,112	312323202600: Haul road maintenance Quantity is assumed to be 1 day/week.
	SITE PREPARATION ESTIMATED SUBTOTAL					**9,830**	**9,590**	
ITEM NO.	DEWATERING, UNWATERING, AND STORMWATER MANAGEMENT	Units	Quantity	Crew	Daily Output	Labor Hours	Equipment Hours	Notes
6	Unwatering, Dewatering, and Stormwater Management for the East Ash Pond	DAY	347	Dewater	4	694	174	312319200650: Dewatering, pumping 8 hours, attended 2 hours per day, 4" discharge pump used for 8 hours, includes 20 LF of suction hose and 100 LF of discharge hose. Crew, and Daily Output, and Unit Rate multiplied by 4 based on experience. Quantity is 5 days/week for 64 weeks (unwatering/dewatering and excavation duration) and 1 day/week for 27 weeks (backfill duration)
7	Dewatering Sumps Installation	EA - in place	40	Sump Install	4	160	80	Unit Rate, Crew, and Daily Output based on experience. Materials include 24" corrugated HDPE pipe with geotextile wrapping, and 1 C.Y. of gravel backfill.
	DEWATERING, UNWATERING, AND STORMWATER MANAGEMENT ESTIMATED SUBTOTAL					**850**	**250**	
ITEM NO.	EAST ASH POND CLOSURE	Units	Quantity	Crew	Daily Output	Labor Hours	Equipment Hours	Notes
8	Excavation of CCR and Liner	CY - in place	709,800	-	-	98,131	96,825	
	Sub-Units							
	Excavation and Loading of Material	CY - as excavated	709,800	B14A	3230	2,637	1,758	312316435400: Excavating, large volume projects; excavation with truck loading; excavator, 4.5 C.Y. bucket, 95% fill factor (assume 5% shrinkage factor from ground to in-place)
	Hauling of Material	CY - as excavated	709,800	B34B	60	94,640	94,640	312323201304: Hauling; no loading equipment, including hauling, waiting, loading/dumping; 12 C.Y.truck, 20 min wait/ld/uld., 45 MPH, cycle 50 miles
	Finish Grading of Excavation Surface	SY	89,000	B32C	5000	854	427	312216101020: Fine grading, loam or topsoil fine grade for large area, 15,000 S.Y. or more
9	Abandonment of Piezometers and Monitoring Wells	EA	8	Grout/Concrete	4	48	16	Crew and Daily Output based on experience.
10	Placement of Imported Offsite Backfill Soil	CY - in place	373,360	-	-	32,619	29,503	
	Sub-Units							
	Excavation and Loading of Material	CY - as excavated	392,028	B14A	3230	1,456	971	312316435400: Excavating, large volume projects; excavation with truck loading; excavator, 4.5 C.Y. bucket, 95% fill factor (assume 5% shrinkage factor from ground to in-place)
	Hauling of Material	CY - as excavated	392,028	B34B	132	23,759	23,759	312323201098: Hauling; no loading equipment, including hauling, waiting, loading/dumping; 12 C.Y. truck, 15 min wait/ld/uld., 45 MPH, cycle 20 miles
	Spreading of Material	CY - as excavated	392,028	B10B	1000	4,704	3,136	312323170020: Spread dumped material, no compaction, by dozer
	Finish Grading of Material	SY	101,640	B32C	5000	976	488	312216101020: Fine grading, loam or topsoil fine grade for large area, 15,000 S.Y. or more
	Compaction of Material	CY - in place	373,360	B10F	2600	1,723	1,149	312323235100: Compaction; Riding, vibrating roller, 12" lifts, 4 passes (RSMeans Crew is B10Y; altered to B10F based on experience)
11	Placement of Imported Offsite Vegetative Soil	CY - in place	16,950	-	-	2,324	1,746	
	Sub-Units							
	Excavation and Loading of Material	CY - as excavated	17,798	B14A	3230	66	44	312316435400: Excavating, large volume projects; excavation with truck loading; excavator, 4.5 C.Y. bucket, 95% fill factor (assume 5% shrinkage factor from ground to in-place)
	Hauling of Material	CY - as excavated	17,798	B34B	132	1,079	1,079	312323201098: Hauling; no loading equipment, including hauling, waiting, loading/dumping; 12 C.Y. truck, 15 min wait/ld/uld., 45 MPH, cycle 20 miles
	Spreading of Material	CY - in place	16,950	B10B	1000	203	136	312323170020: Spread dumped material, no compaction, by dozer
	Finish Grading of Material	SY	101,640	B32C	5000	976	488	312216101020: Fine grading, loam or topsoil fine grade for large area, 15,000 S.Y. or more
	EAST ASH POND ESTIMATED SUBTOTAL					**133,120**	**128,090**	
ITEM NO.	SITE RESTORATION	Units	Quantity	Crew	Daily Output	Labor Hours	Equipment Hours	Notes
12	Erosion Control Blanket	SF - in place	101,720	ECB	22500	109	36	Crew based on experience. Daily Output based on 312514160100: Rolled erosion control mats and blankets, plastic netting, stapled, 2" x 1" mesh, 20 mil.
13	Straw Wattle Ditch Checks	LF - in place	2,500	A2	1000	60	20	312514160705: Sediment Log, Filter Sock, 9"
14	Seed, Mulch, and Maintain Vegetated Surfaces	AC	21	-	-	189	189	
	Sub-Units							
	Lime	MSF	915	B66	700	10	10	329113234250: Soil preparation, structural soil mixing, spread soil conditioners, ground limestone, 1#/S.Y., tractor spreader
	Fertilizer	MSF	915	B66	700	10	10	329113234150: Soil preparation, tructural soil mixing, spread soil conditioners, fertilizer, 0.2#/S.Y., tractor spreader
	Seed	MSF	915	B66	52	141	141	329219142300: Seeding athletic fields, seeding fescue, tall, 5.5 lb. per M.S.F., tractor spreader
	Mulch	MSF	915	B65	530	28	28	329113160350: Mulching, Hay, 1" deep, power mulcher, large
	SITE RESTORATION ESTIMATED SUBTOTAL					**360**	**250**	
ITEM NO.	ENGINEERING AND PERMITTING TASKS	Units	Quantity	Crew	Output	Labor Hours	Equipment Hours	Notes
15	Engineering Support and CQA During Construction	LS	1	Eng	60 hrs/week	8,340	2,780	Crew and Output based on experience.
	ENGINEERING AND PERMITTING ESTIMATED SUBTOTAL					**8,340**	**2,780**	

NOTES:
1. LS = Lump Sum, AC = Acre, LF = Linear Foot, EA = Each, SY = Square Yard, MO = Month, YR = Year, CY = Cubic Yard, MSF = Thousand Sqaure Feet
3. RS Means refers to the 2021 online edition of RS Means Commercial New Construction.

DRAFT

Table 6 - Labor, Equipment, and Mileage Estimate - CBR-Offsite

Geosyntec consultants

Item	Quantity	Assumptions
Labor Total Hours	151,700	Per projected total in cost estimate
Duration of Onsite Construction in Days	1,841	Per Construction Schedule Revision A, dated 9/22/21
Average Daily Crew Size	9	10 hour days
Daily Labor Mobilization Miles	1,159,830	Average of 70 miles round trip per day
Vehicles Miles Onsite	38,477	1 mile round trip from gate to parking 5 miles per day for CQA tech and Construction Supervisor 10% Contingency for site visitors (client and engineering support)
Equipment Mobilization Miles - Unloaded	78,900	Average of 300 miles one way for equipment hauling Average 1 load of equipment per working week
Equipment Mobilization Miles - Loaded	78,900	Average of 300 miles one way for equipment hauling Average 1 load of equipment per working week
Daily Equipment Miles Onsite	199,214	Average of 7 of 9 crew members running equipment Assume 15 miles per piece of equipment (based on 15 minute round trip path across EAP) 10 miles per day used for water truck 5 miles per day used for grader
Onsite Haul Truck Miles - Unloaded	0	No onsite hauling included as CCR material is assumed to be disposed of at an offsite landfill and backfill will be imported from offsite.
Onsite Haul Truck Miles - Loaded	0	No onsite hauling included as CCR material is assumed to be disposed of at an offsite landfill and backfill will be imported from offsite.
Offsite Haul Truck Miles - Unloaded	2,234,321	12 CY Dump Truck 20 mi cycle for imported soil; 64 mi cycle for exported CCR
Offsite Haul Truck Miles - Loaded	2,234,321	12 CY Dump Truck 20 mi cycle for imported soil; 64 mi cycle for exported CCR
Material Delivery Miles - Unloaded	30,000	30 extra trips for seed, fertilizer, lime, mulch, ECBs, straw wattles, and concrete - source 1000 miles away average
Material Delivery Miles - Loaded	30,000	30 extra trips for seed, fertilizer, lime, mulch, ECBs, straw wattles, and concrete - source 1000 miles away average

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Geosyntec consultants

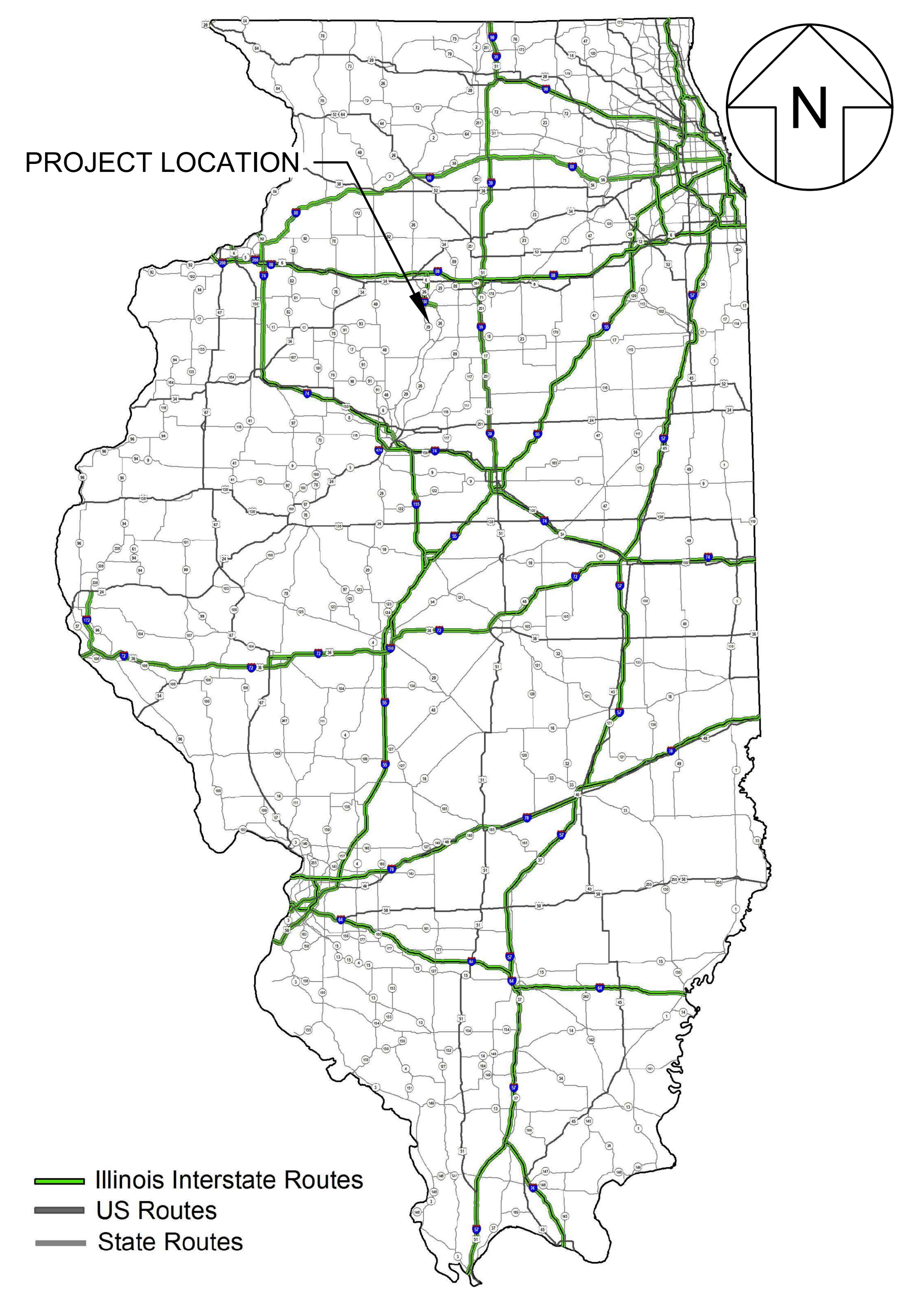
ATTACHMENT C

Final Closure Plans and Material Specifications

DRAFT

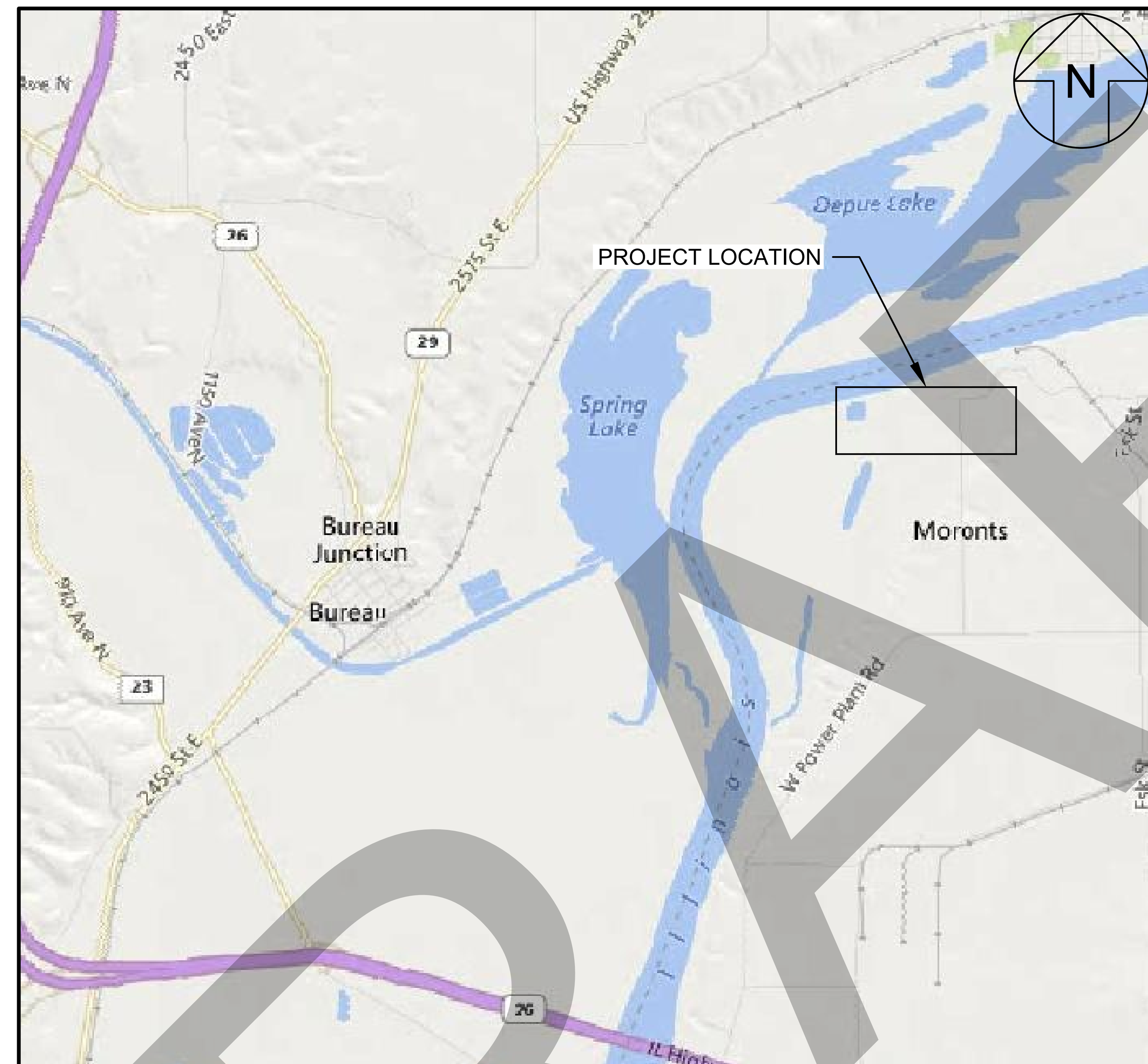
DYNEGY MIDWEST GENERATION, LLC
HENNEPIN POWER PLANT
HENNEPIN, ILLINOIS
EAST ASH POND CONSTRUCTION PERMIT APPLICATION CLOSURE DRAWINGS

DRAFT



SOURCE: IDOT

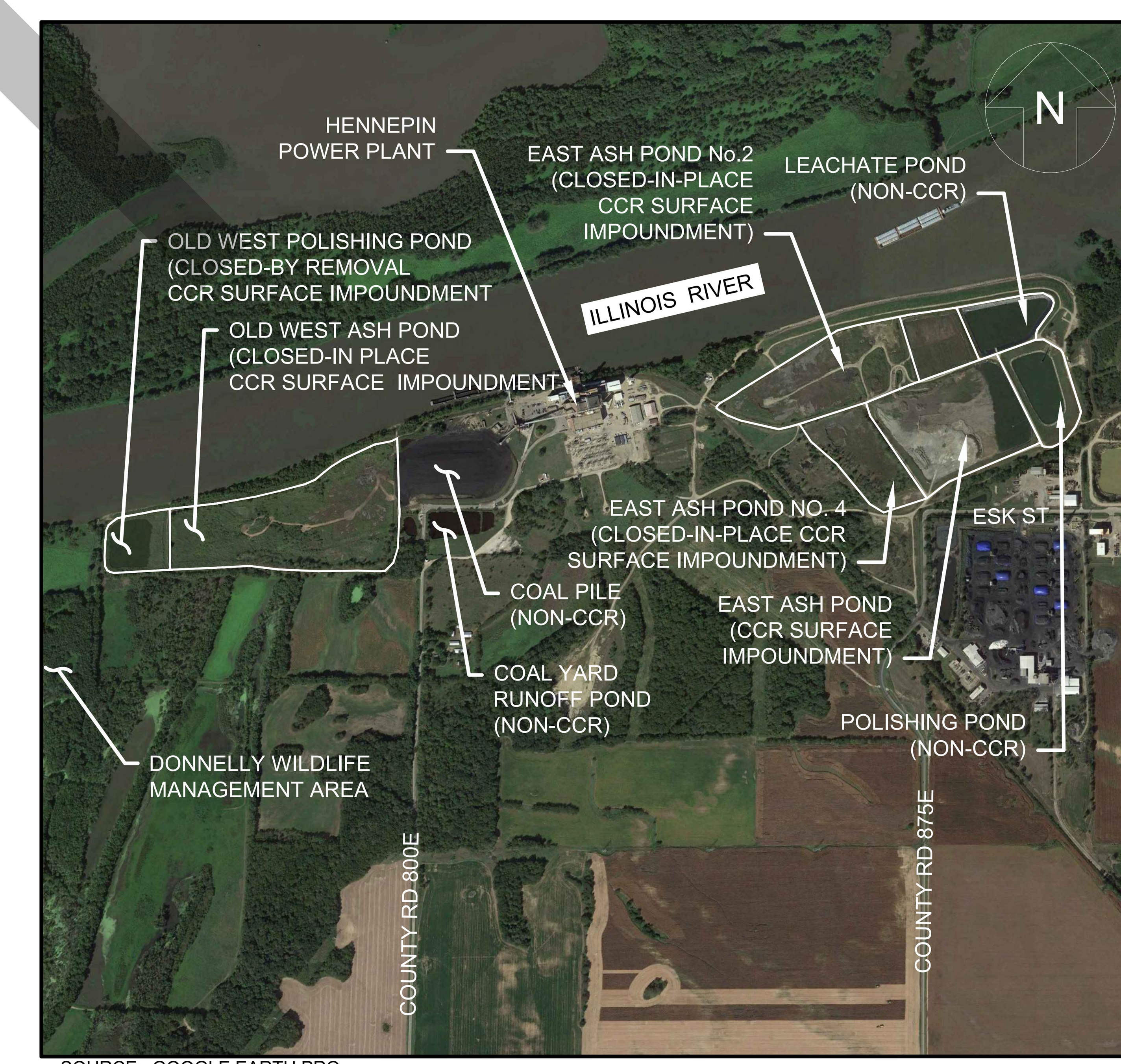
STATE MAP
NOT TO SCALE



SOURCE: BING MAPS

LOCATION MAP

0 3000 6000
SCALE IN FEET



SOURCE: GOOGLE EARTH PRO

SITE MAP

0 1500 3000
SCALE IN FEET

DETAIL NUMBER
4 / 6
DRAWING ON WHICH ABOVE DETAIL IS PRESENTED

DETAIL NUMBER
DRAWING ON WHICH ABOVE DETAIL WAS FIRST REFERENCED
4 / 3 XXXXXXXXXX
TITLE2
SCALE:
XREF:

EXAMPLE: DETAIL NUMBER 4 PRESENTED ON DRAWING NO. 6 WAS REFERENCED FOR THE FIRST TIME ON DRAWING NO. 3.

ABOVE SYSTEM ALSO APPLIES TO SECTION IDENTIFICATIONS.

DETAIL IDENTIFICATION LEGEND

DRAWINGS LIST

SHEET NO.	SHEET TITLE
G-100	COVER SHEET AND LOCATION MAP
G-101	EXISTING CONDITIONS
C-100	OUTFALL AND PIEZOMETER ABANDONMENT PLAN
C-101	OVERALL GRADING PLAN
C-102	SECTIONS
C-103	DETAILS AND MATERIAL SPECIFICATIONS

ISSUED FOR REVIEW
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REV	DATE	DESCRIPTION	DRN	APP
0	11/5/2021	DRAFT CLOSURE PLAN ISSUE	MGK	LPC

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CHESTERFIELD, MO 63005 USA
TELEPHONE: 636.812.0800

DYNEGY MIDWEST GENERATION, LLC
1500 EASTPORT PLAZE DRIVE
COLLINSVILLE, IL 62234 USA

TITLE: COVER SHEET AND LOCATION MAP

PROJECT: EAST ASH POND CONSTRUCTION PERMIT APPLICATION CLOSURE DRAWINGS

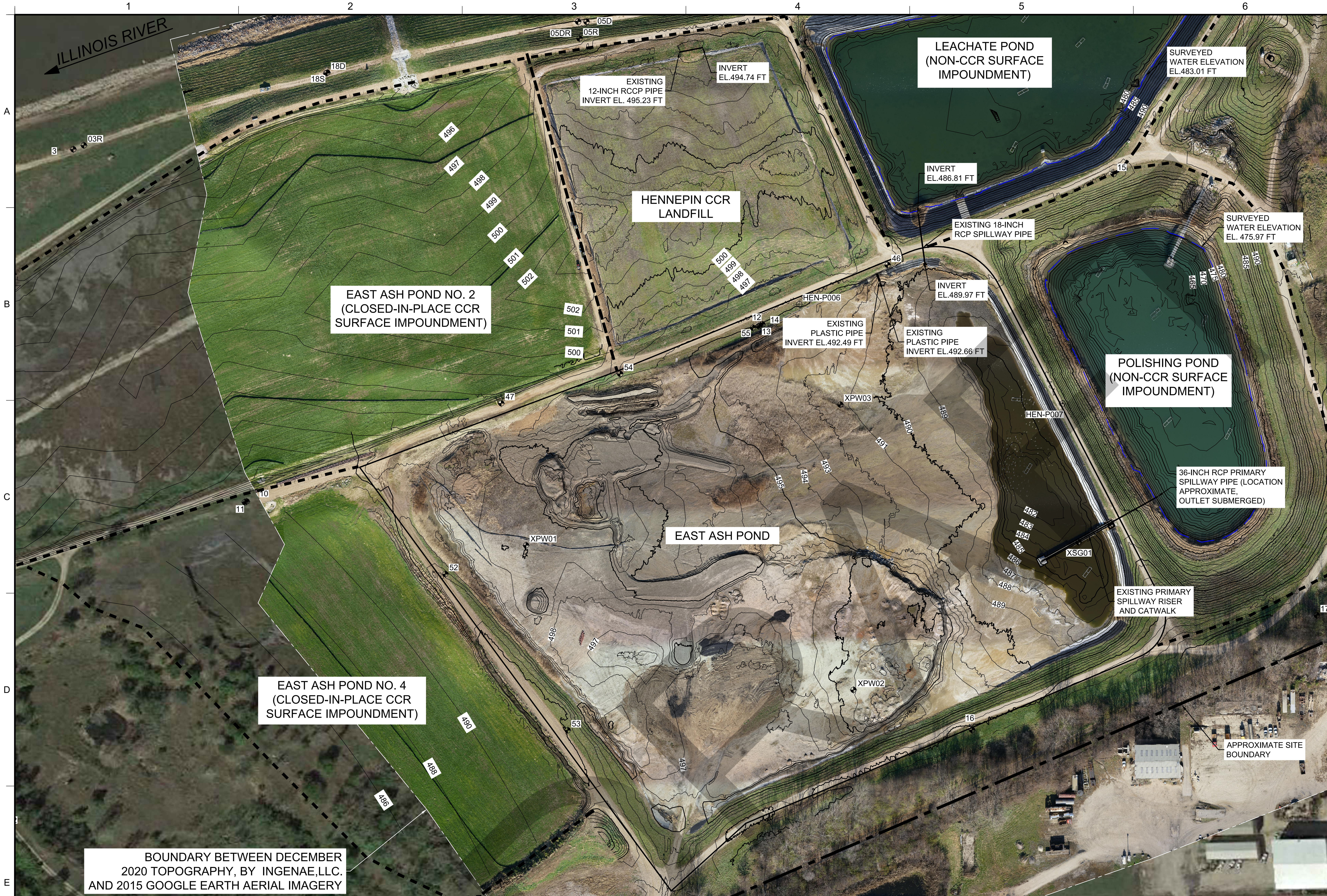
SITE: HENNEPIN POWER PLANT
HENNEPIN, ILLINOIS

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	LPC	DATE:	NOVEMBER 2021
DRAWN BY:	IJV/MGK	PROJECT NO.:	GLP8026
CHECKED BY:	TWW	FILE:	
REVIEWED BY:	JPS	DRAWING NO.:	G-100
APPROVED BY:	LPC		



LEGEND

- EXISTING GROUND SURFACE ELEVATION (MAJOR) (5-FT INTERVAL)
- EXISTING GROUND SURFACE ELEVATION (MAJOR) (1-FT INTERVAL)
- 2020 SURVEYED IMPOUNDMENT WATER LEVEL
- APPROXIMATE LIMITS OF CCR UNITS AND NON-CCR SURFACE IMPOUNDMENT
- APPROXIMATE SITE BOUNDARY
- BOUNDARY BETWEEN DECEMBER 2020 TOPOGRAPHY, BY INGENAE,LLC. AND 2015 GOOGLE EARTH AERIAL IMAGERY
- EXISTING MONITORING WELL
- EXISTING PIEZOMETERS

N

0 100 200

SCALE IN FEET

NOTES:

1. COORDINATES AND DIRECTIONS SHOWN IN THESE DRAWINGS WERE BASED ON THE ILLINOIS STATE PLANE COORDINATE SYSTEM (NAD83, IN US FEET). ELEVATIONS WERE BASED ON THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88, IN US FEET).
2. EXISTING CONTOURS, AERIAL IMAGERY AND WATER SURFACE ELEVATIONS FOR THE EAP, POLISHING POND, LEACHATE POND, AND HENNEPIN LANDFILL WERE TAKEN FROM "DYNEGY MIDWEST GENERATION, LLC - HENNEPIN POWER STATION - DECEMBER 2020 TOPOGRAPHY, 3/10/2021", BY INGENAE, LLC.
3. EXISTING CONTOURS AND AERIAL IMAGERY FOR EAST ASH POND NO. 2 AND EAST ASH POND NO. 4 WERE TAKEN FROM "HENNEPIN POWER STATION, EAST ASH PONDS #2 & #4, DYNEGY MIDWEST GENERATION, LLC", 11/17/2020, BY INGENAE, LLC
4. AERIAL IMAGERY FOR AREAS OUTSIDE OF THE LIMITS OF THE INGENAE IMAGERY IS DATED SEPTEMBER 20, 2015 AND WAS OBTAINED FROM GOOGLE EARTH PRO ON SEPTEMBER 12, 2017.

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DYNERGY MIDWEST GENERATION, LLC
1500 EASTPORT PLAZE DRIVE
COLLINSVILLE, IL 62234 USA

TITLE: EXISTING CONDITIONS

PROJECT: EAST ASH POND CONSTRUCTION PERMIT APPLICATION CLOSURE DRAWINGS

SITE: HENNEPIN POWER PLANT, HENNEPIN, ILLINOIS

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

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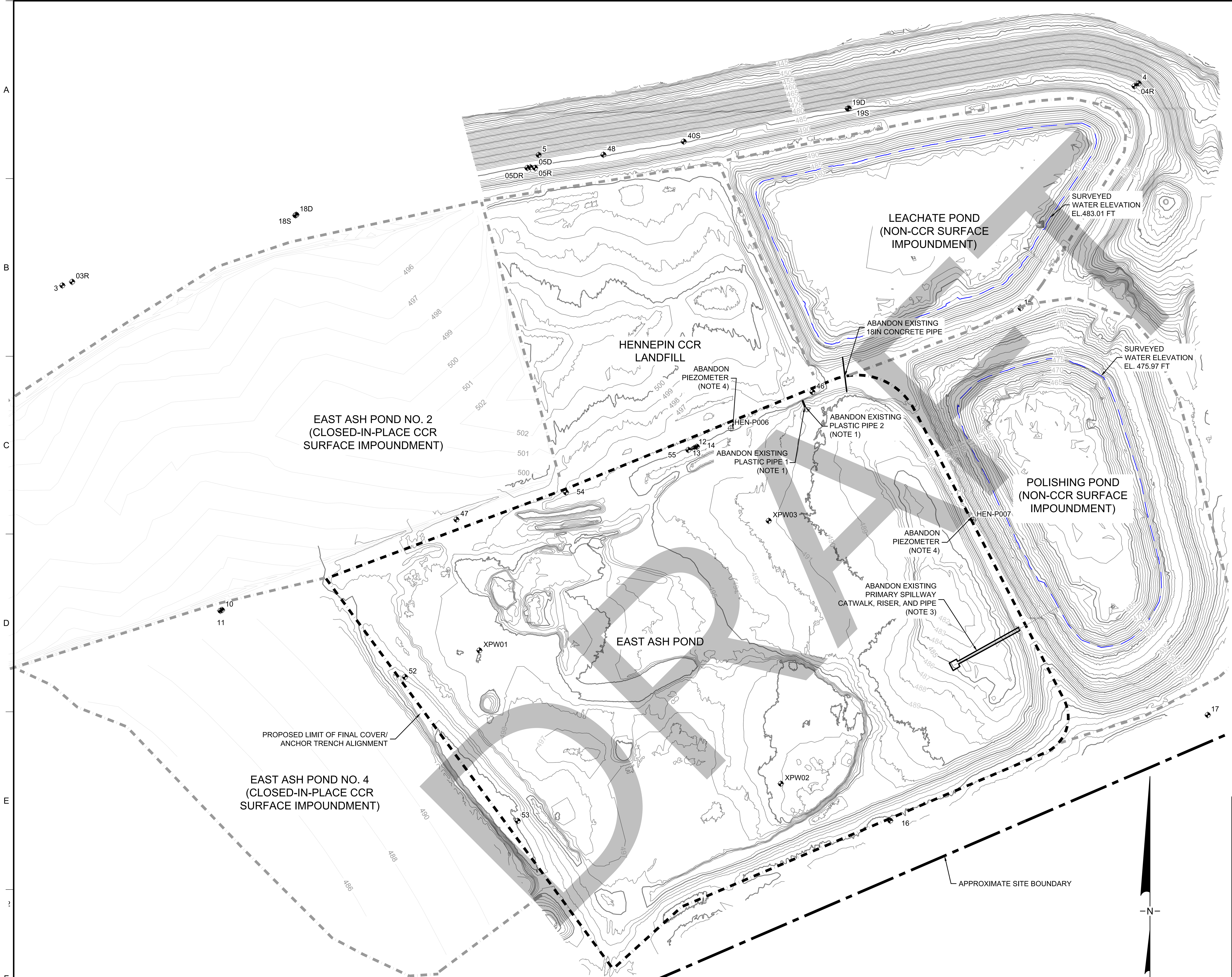
DESIGN BY:	LPC	DATE:	NOVEMBER 2021
DRAWN BY:	IJV/MGK	PROJECT NO.:	GLP8026
CHECKED BY:	TWW	FILE:	
REVIEWED BY:	JPS	DRAWING NO.:	G-101
APPROVED BY:	LPC		



LEGEND

- EXISTING GROUND SURFACE ELEVATION (MAJOR) (5-FT INTERVAL)
- EXISTING GROUND SURFACE ELEVATION (MAJOR) (1-FT INTERVAL)
- 2020 SURVEYED IMPOUNDMENT WATER LEVEL
- APPROXIMATE LIMITS OF CCR UNITS AND NON-CCR SURFACE IMPOUNDMENT
- PROPOSED LIMIT OF FINAL COVER/ ANCHOR TRENCH ALIGNMENT
- APPROXIMATE SITE BOUNDARY
- EXISTING MONITORING WELL
- EXISTING PIEZOMETERS

NOTES:

1. EXISTING PLASTIC PIPES 1 AND 2 TO BE ABANDONED BY CUTTING THE LINER SYSTEM AND PIPE BOOT AROUND THE PIPE PENETRATION, CUTTING THE PIPE OFF FLUSH AT LEAST 1 FT BEHIND THE LINER, AND INSTALLING A GLUED PIPE CAP OF THE SAME MATERIAL AS THE PIPE. THE PIPE AREA IS TO BE BACKFILLED WITH CLEAN SOIL AND THE LINER IS TO BE PATCHED USING THE SAME LINER MATERIAL AND EXTRUSION WELDING TECHNIQUES.
2. THE EXISTING 18" RCP SPILLWAY PIPE IS TO BE ABANDONED BY THOROUGHLY CLEANING THE INSIDE OF THE PIPE WITH PRESSURIZED WATER, CONSTRUCTING A BULKHEAD SEAL AT THE DOWNSTREAM END OF THE PIPE, INSIDE OF THE LEACHATE POND, AND THEN FILLING THE ANNULUS OF THE PIPE COMPLETELY WITH CEMENT-BENTONITE GROUT.
3. THE EXISTING PRIMARY SPILLWAY PIPE IS TO BE ABANDONED BY DEMOLISHING THE CATWALK AND RISER ABOVE THE LEVEL OF CCR IMPOUNDED ADJACENT TO THE STRUCTURE. DEMOLITION DEBRIS ARE TO BE DISPOSED OF WITHIN CCR RETAINED IN THE EAP. THE INSIDE OF THE REMAINING RISER STRUCTURE AND PIPE ARE TO BE THOROUGHLY CLEANED USING PRESSURIZED WATER. A BULKHEAD OR INFLATABLE PIPE BLADDER IS TO BE CONSTRUCTED AT THE DOWNSTREAM END OF THE PIPE, INSIDE THE POLISHING POND, AND THE REMAINING ANNULUS OF THE PIPE AND RISER STRUCTURE AT TO BE FILLED COMPLETELY WITH CEMENT-BENTONITE GROUT.
4. PIEZOMETERS HEN-P006 AND HEN-P007 ARE TO BE ABANDONED BY REMOVING THE SURFACE CASING AND CASTING TO 1 FT BELOW GRADE AND FILLING THE ANNULUS OF THE WELLS WITH GRANULATED BENTONITE. WELL ABANDONMENT FORMS ARE TO BE SUBMITTED TO THE PUTNAM COUNTY HEALTH DEPARTMENT.
5. ALL OTHER PIEZOMETERS AND MONITORING WELLS ARE TO BE MAINTAINED AND ARE NOT BE DAMAGED DURING CLOSURE CONSTRUCTION.
6. COORDINATES AND DIRECTIONS SHOWN IN THESE DRAWINGS WERE BASED ON THE ILLINOIS STATE PLANE COORDINATE SYSTEM (NAD83, IN US FEET). ELEVATIONS WERE BASED ON THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88, IN US FEET).
7. EXISTING CONTOURS AND WATER SURFACE ELEVATIONS FOR THE EAP, POLISHING POND, LEACHATE POND, AND HENNEPIN LANDFILL WERE TAKEN FROM "DYNEGY MIDWEST GENERATION, LLC - HENNEPIN POWER STATION - DECEMBER 2020 TOPOGRAPHY, 3/10/2021", BY INGENAE, LLC.
8. EXISTING CONTOURS FOR EAST ASH POND NO. 2 AND EAST ASH POND NO. 4 WERE TAKEN FROM "HENNEPIN POWER STATION, EAST ASH PONDS #2 & #4, DYNEGY MIDWEST GENERATION, LLC", 11/17/2020, BY INGENAE, LLC

REV	DATE	DESCRIPTION	DRN	APP
0	11/5/2021	DRAFT CLOSURE PLAN ISSUE	MGK	LPC

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DYNERGY MIDWEST GENERATION, LLC
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COLLINSVILLE, IL 62234 USA

TITLE: OUTFALL AND PIEZOMETER ABANDONMENT PLAN

PROJECT: EAST ASH POND CONSTRUCTION PERMIT APPLICATION CLOSURE DRAWINGS

SITE: HENNEPIN POWER PLANT
HENNEPIN, ILLINOIS

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	LPC	DATE:	NOVEMBER 2021
DRAWN BY:	IJV/MGK	PROJECT NO.:	GLP8026
CHECKED BY:	TWW	FILE:	
REVIEWED BY:	JPS	DRAWING NO.:	
APPROVED BY:	LPC		C-100

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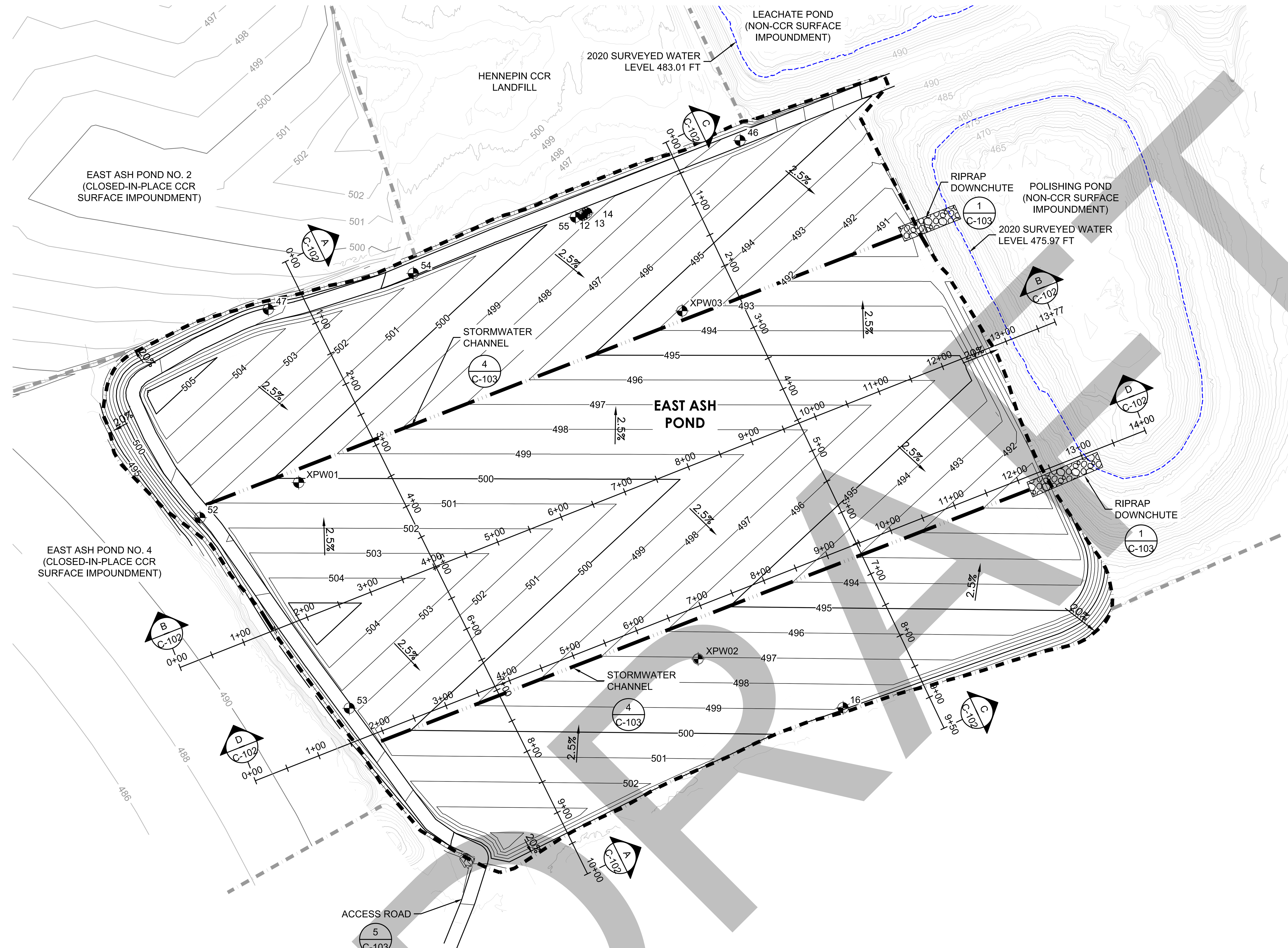
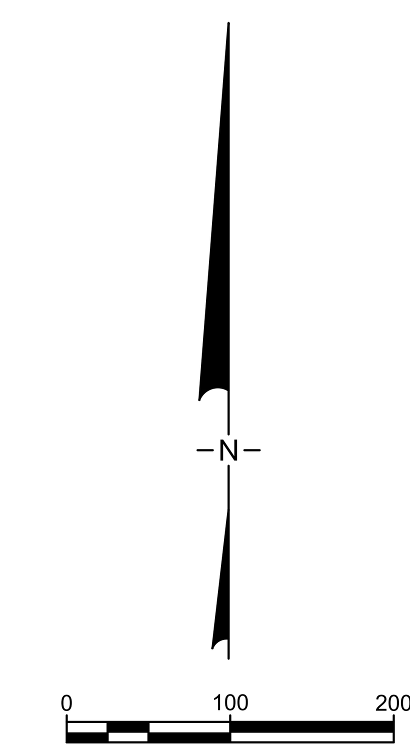
LEGEND

480	EXISTING GROUND SURFACE ELEVATION (2-FT INTERVAL)
505	PROPOSED TOP OF FINAL COVER GRADE ELEVATION
	2020 SURVEYED IMPOUNDMENT WATER LEVEL
	PROPOSED STORMWATER CHANNEL (4 / 103)
	APPROXIMATE LIMITS OF CCR UNITS AND NON-CCR SURFACE IMPOUNDMENT
	PROPOSED LIMIT OF FINAL COVER/ ANCHOR TRENCH ALIGNMENT (3 / 103)
	EAP MONITORING WELL-TO BE RETAINED (2 / 103)





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TELEPHONE: 636.812.0800

DYNEGY MIDWEST GENERATION, LLC
1500 EASTPORT PLAZE DRIVE
COLLINSVILLE, IL 62234 USA

TITLE: OVERALL GRADING PLAN

PROJECT: EAST ASH POND CONSTRUCTION PERMIT APPLICATION CLOSURE DRAWINGS

SITE: HENNEPIN POWER PLANT HENNEPIN, ILLINOIS

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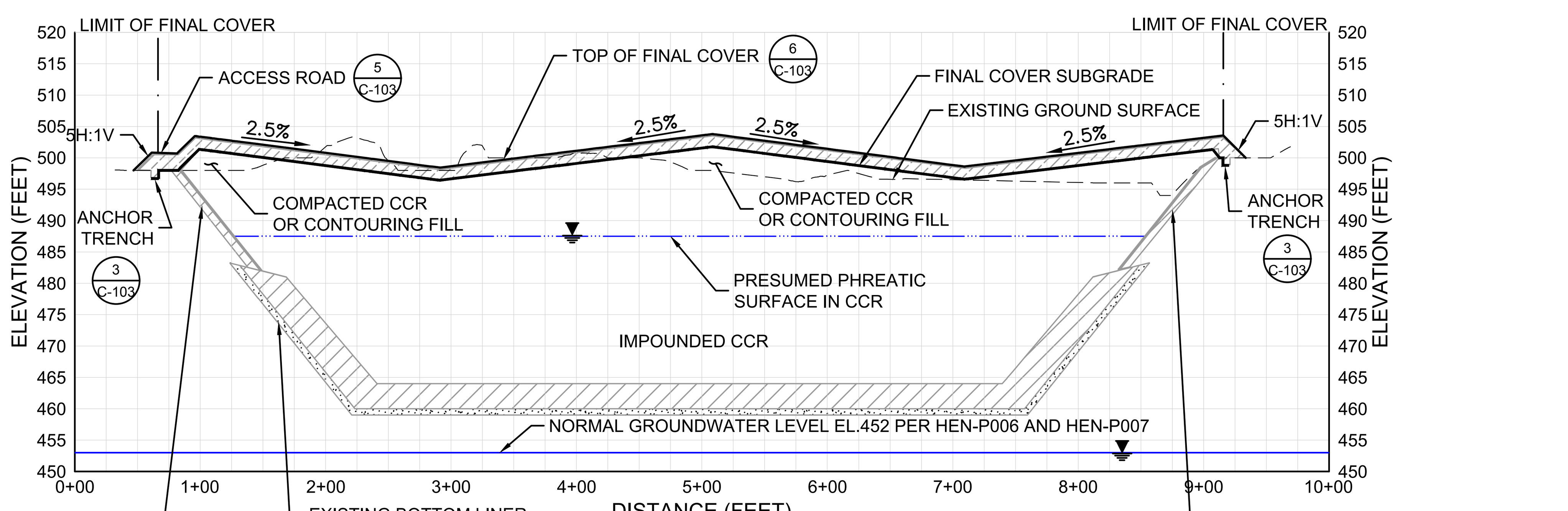
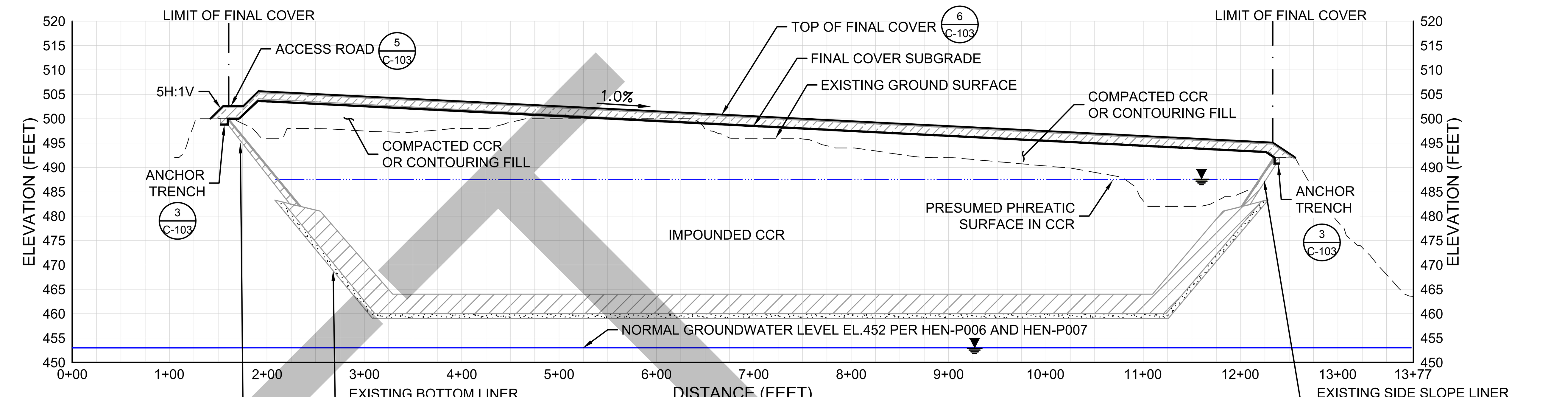
SIGNATURE

DATE

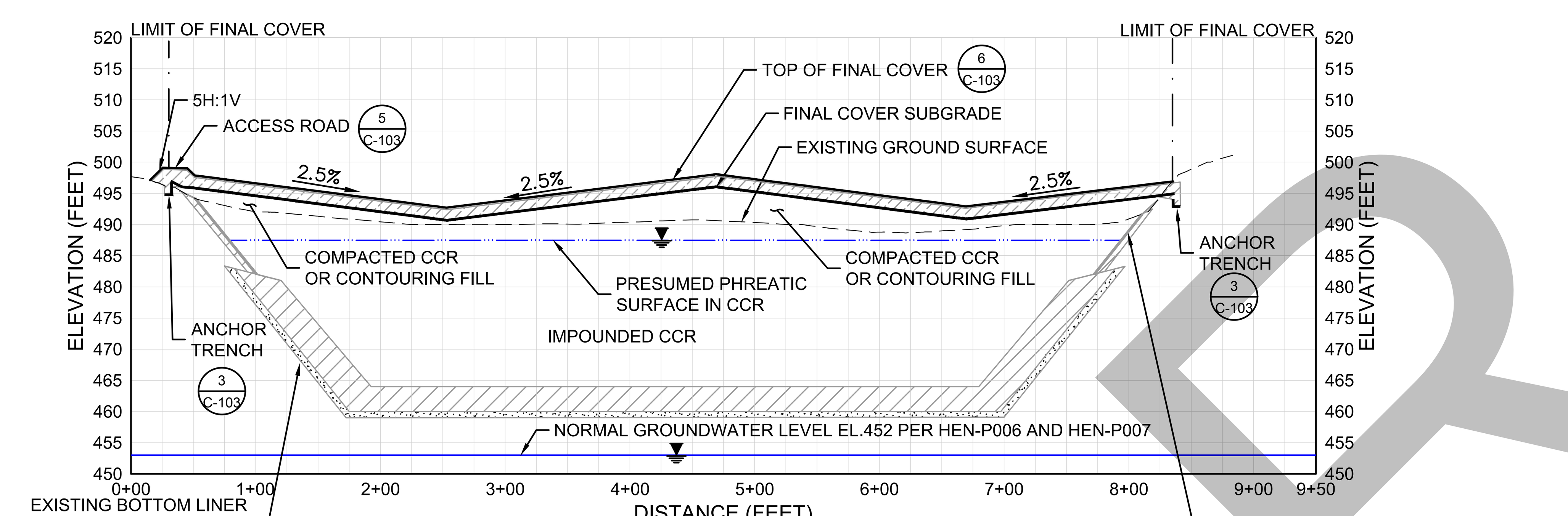
DESIGN BY:	LPC	DATE:	NOVEMBER 2021
DRAWN BY:	IJV/MGK	PROJECT NO.:	GLP8026
CHECKED BY:	TWW	FILE:	
REVIEWED BY:	JPS	DRAWING NO.:	C-101
APPROVED BY:	LPC		



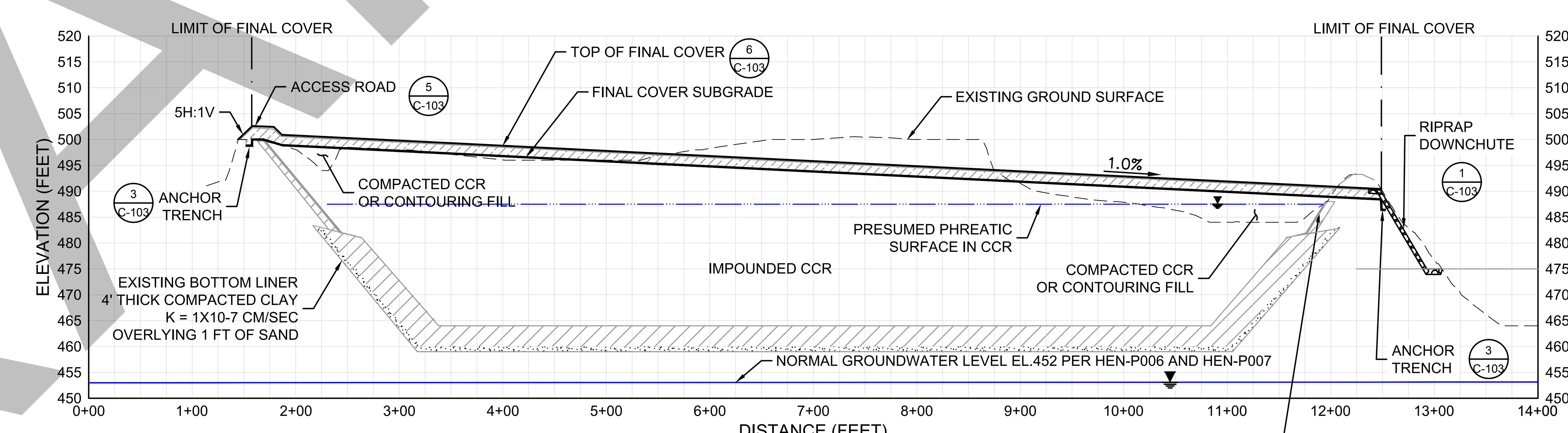
A PROFILE
HORIZONTAL: 1" =100'
VERTICAL: 1" =20'



B PROFILE
HORIZONTAL: 1" =100'
VERTICAL: 1" =20'



C PROFILE
HORIZONTAL: 1" =100'
VERTICAL: 1" =20'



D PROFILE
HORIZONTAL: 1" =100'
VERTICAL: 1" =20'

NOTES:

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2. EXISTING CONTOURS AND WATER SURFACE ELEVATIONS TAKEN FROM "DYNEGY MIDWEST GENERATION, LLC - HENNEPIN POWER STATION - DECEMBER 2020 TOPOGRAPHY", 3/10/2021, BY INGENAE, LLC.
3. EXISTING CONTOURS FOR EAST ASH POND NO. 2 AND EAST ASH POND NO. 4 WERE TAKEN FROM "HENNEPIN POWER STATION, EAST ASH PONDS #2 & #4, DYNEGY MIDWEST GENERATION, LLC", 11/17/2020, BY INGENAE, LLC
4. INFORMATION ON THE EXISTING SIDE SLOPE AND BOTTOM LINERS WAS TAKEN FROM "HISTORY OF CONSTRUCTION, USEPA FINAL CCR RULE, 40 CFR §257.73(C), HENNEPIN POWER STATION, HENNEPIN, ILLINOIS", OCTOBER 2016, BY AECOM.

LEGEND

- TOP OF FINAL COVER
- EXISTING GROUND SURFACE
- PRESUMED PHREATIC SURFACE IN CCR
- NORMAL GROUNDWATER LEVEL
- GEOMEMBRANE
- PROTECTIVE COVER SOIL
- COMPACTED CLAY LAYER
- SAND LAYER
- RIPRAP

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REV	DATE	DESCRIPTION	DRN	APP
0	11/5/2021	DRAFT CLOSURE PLAN ISSUE	MGK	LPC

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TELEPHONE: 636.812.0800

DYNERGY MIDWEST GENERATION, LLC
1500 EASTPORT PLAZE DRIVE
COLLINSVILLE, IL 62234 USA

TITLE: SECTIONS

PROJECT: EAST ASH POND CONSTRUCTION PERMIT APPLICATION CLOSURE DRAWINGS

SITE: HENNEPIN POWER PLANT HENNEPIN, ILLINOIS

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SIGNATURE

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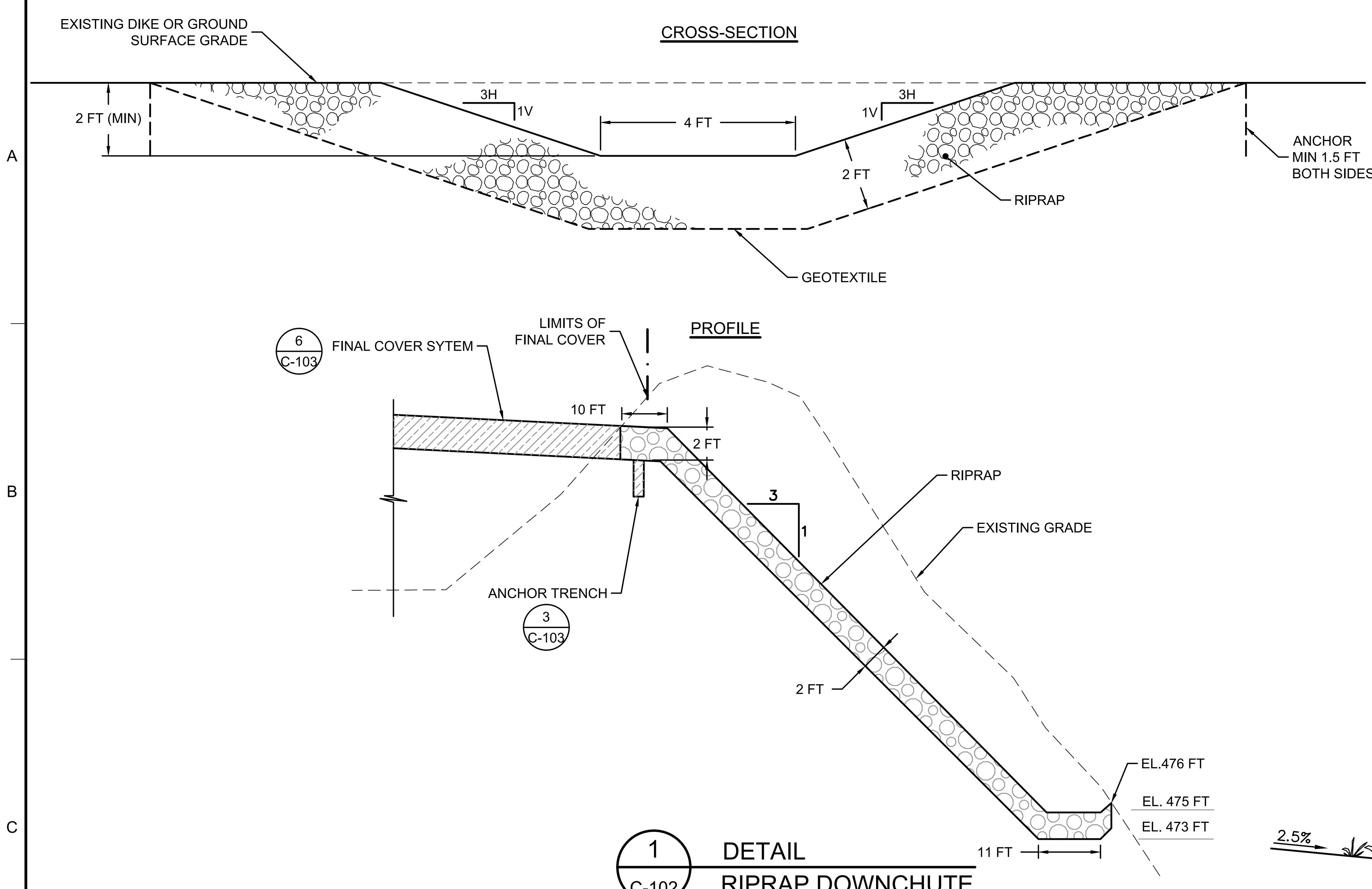
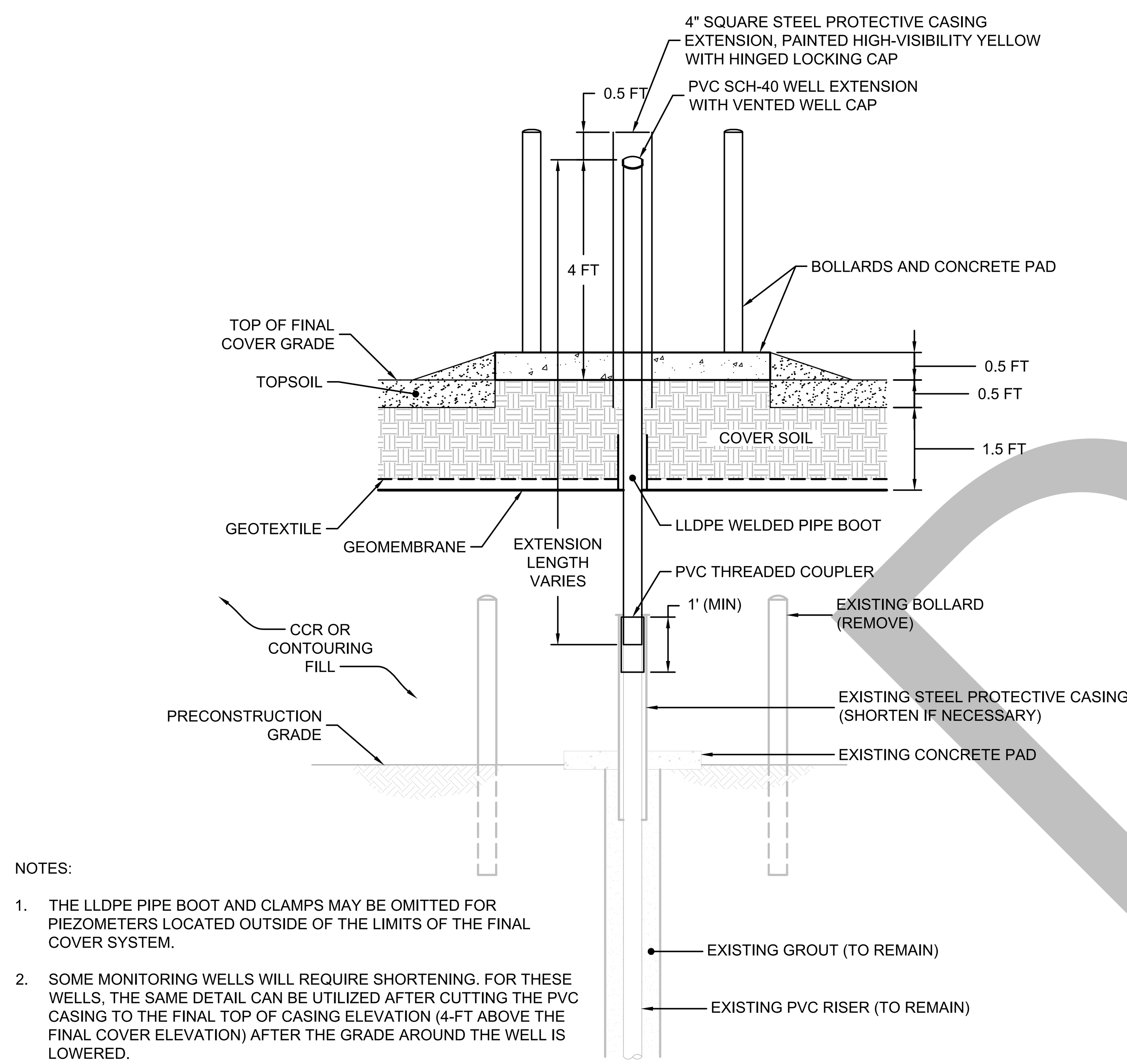
DESIGN BY:	LPC	DATE:	NOVEMBER 2021
DRAWN BY:	IJV/MGK	PROJECT NO.:	GLP8026
CHECKED BY:	TWW	FILE:	
REVIEWED BY:	JPS	DRAWING NO.:	
APPROVED BY:	LPC		C-102

O:\DWG\DYNEGY\HENNEPIN\GLP8026-30% DESIGN\CHE8356-004



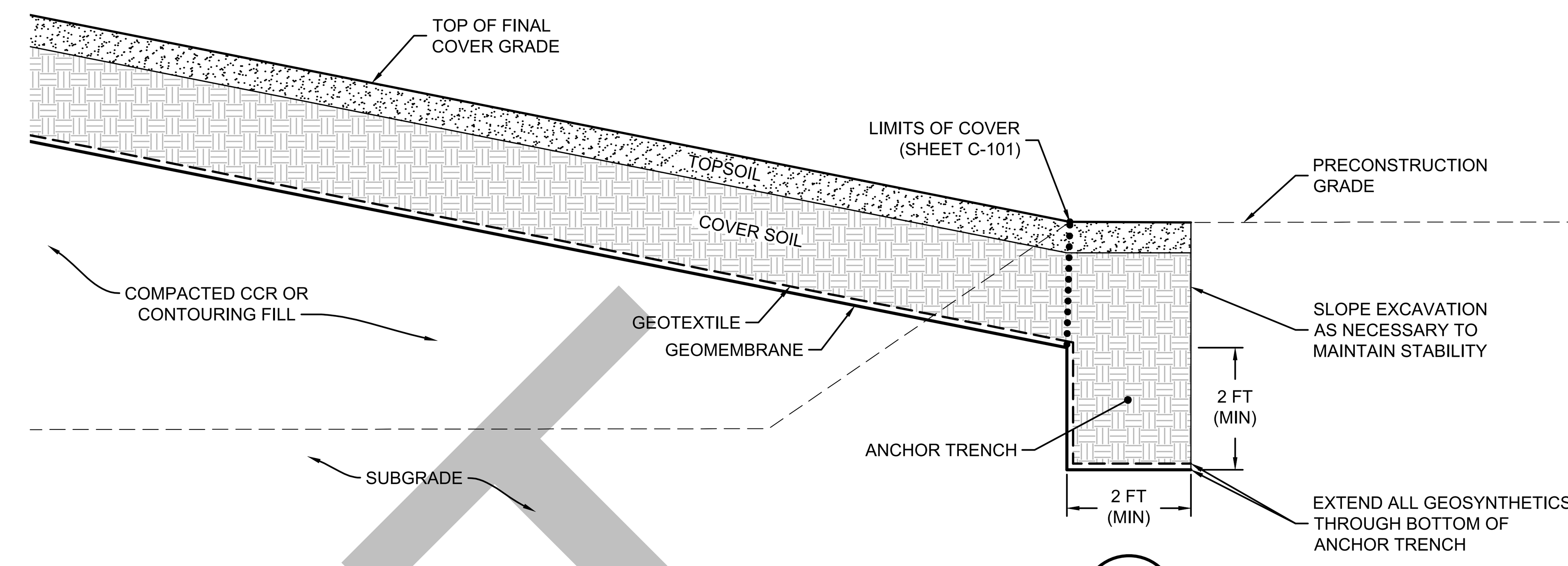
1 C-102 DETAIL RIPRAP DOWNCHUTE
N.T.S



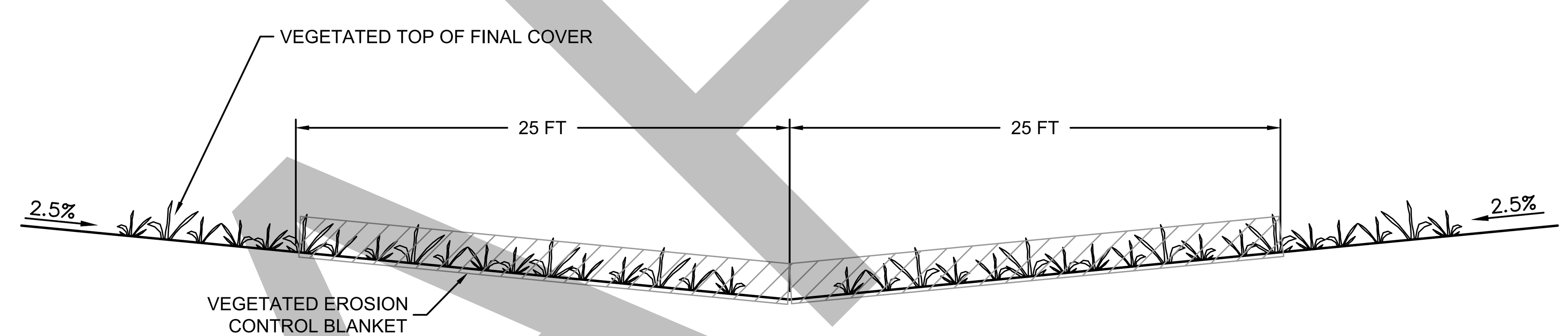
NOTES:

1. THE LLDPE PIPE BOOT AND CLAMPS MAY BE OMITTED FOR PIEZOMETERS LOCATED OUTSIDE OF THE LIMITS OF THE FINAL COVER SYSTEM.
2. SOME MONITORING WELLS WILL REQUIRE SHORTENING. FOR THESE WELLS, THE SAME DETAIL CAN BE UTILIZED AFTER CUTTING THE PVC CASING TO THE FINAL TOP OF CASING ELEVATION (4-FT ABOVE THE FINAL COVER ELEVATION) AFTER THE GRADE AROUND THE WELL IS LOWERED.
3. FOR MONITORING WELLS LOCATED IN AN ACTIVE SITE ROADWAY,THE ABOVE-GRADE PROTECTIVE CASING, BOLLARDS, AND CONCRETE PAD MAY BE SUBSTITUTED WITH A FLUSH MOUNT CASING AND A CONCRETE PAD AT LEAST 3 FT IN DIAMETER AND 4 INCHES IN THICKNESS. ALL OTHER DETAILS ARE TO REMAIN THE SAME.

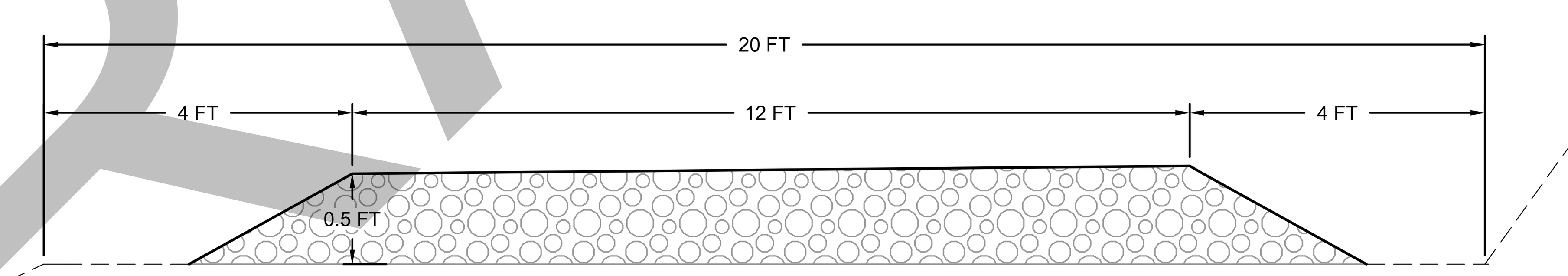
2 C-102 DETAIL MONITORING WELL EXTENSION
N.T.S



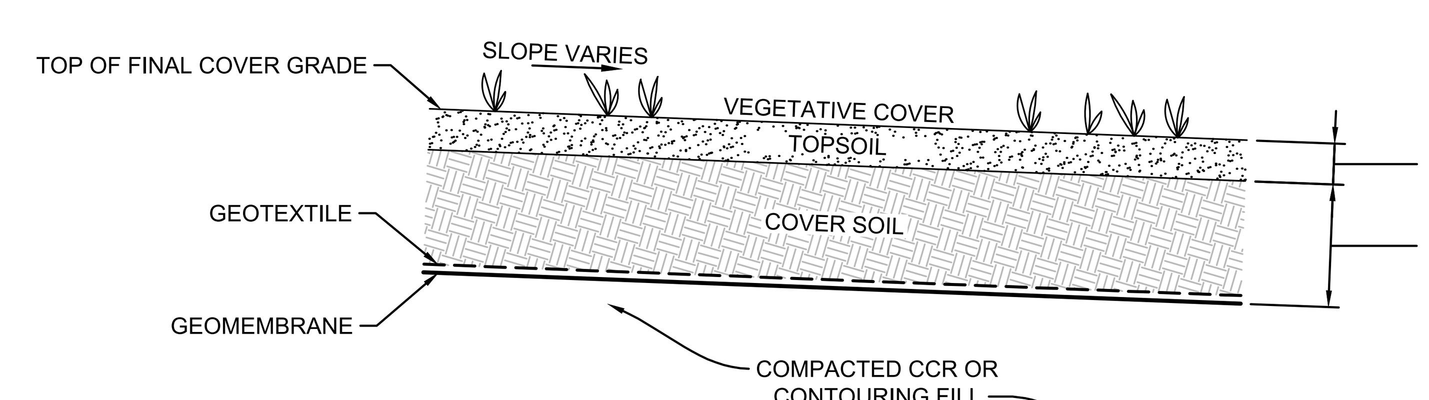
3 C-102 DETAIL ANCHOR TRENCH
N.T.S



4 C-102 DETAIL STORMWATER CHANNEL
N.T.S



5 C-102 DETAIL ACCESS ROAD
N.T.S



6 C-102 DETAIL FINAL COVER
N.T.S

MATERIAL SPECIFICATIONS

1. RIPRAP
RIPRAP IS TO CONSIST OF A CRUSHED NATURAL LIMESTONE OR DOLOMITE MATERIAL WITH A D50 OF AT LEAST 11 INCHES, AND CONFORMING TO THE ILLINOIS DEPARTMENT OF TRANSPORTATION (IDOT) STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION SECTION 281 REQUIREMENTS, CLASS A OR CLASS B QUALITY.
2. EROSION CONTROL BLANKET
EROSION CONTROL BLANKETS ARE TO BE A ROLLED EROSION CONTROL PRODUCT WITH NETTING CAPABLE OF STORMWATER FLOW VELOCITIES OF UP TO 2.1 FEET PER SECOND.
3. CRUSHED STONE
CRUSHED STONE IS TO CONSIST OF A SCREENED GRAVEL MATERIAL CONFORMING TO THE IDOT STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION SECTION 1004 REQUIREMENTS, GRADATION CA 6.
4. TOPSOIL
TOPSOIL IS TO CONSIST OF A NATURAL SOIL MATERIAL THAT IS RELATIVELY HOMOGENOUS, FREE OF DEBRIS, FOREIGN OBJECTS, AND LARGE ROCK FRAGMENTS. THE TOPSOIL IS TO:
   - BE CLASSIFIED AS SC, CL, ML, OR OL (PER ASTM D2487), AND
   - BE FERTILIZED, AS NECESSARY BASED ON AGRONOMIC TESTING, TO SUPPORT VEGETATION GROWTH AT THE SITE.
5. COVER SOIL
COVER SOIL IS TO CONSIST OF A NATURAL SOIL MATERIAL THAT IS RELATIVELY HOMOGENOUS, FREE OF DEBRIS, FOREIGN OBJECTS, AND LARGE ROCK FRAGMENTS. THE COVER SOIL IS TO:
   - BE CLASSIFIED AS A CL, CH, CL-CH, CL-ML, SC, OR SM (PER ASTH D2487), AND
   - HAVE A MAXIMUM PARTICLE SIZE OF 1.5 INCHES (PER ASTM D422 OR D6943).
6. GEOTEXTILE
THE GEOTEXTILE IS TO CONSIST OF A NONWOVEN POLYPROPYLENE MATERIAL MANUFACTURED IN ACCORDANCE WITH THE LATEST VERSION OF GEOSYNTHETIC INSTITUTE GRI-GT12(A) STANDARD SPECIFICATION, AND WITH THE FOLLOWING REQUIREMENTS:
   - MINIMUM MASS PER UNIT ARE OF 16 OZ/YD2 (PER ASTM D5261),
   - MINIMUM GRAB STRENGTH OF 270 LB (PER ASTM D4632),
   - MINIMUM TEAR STRENGTH OF 105 LB (PER ASTM D4533), AND
   - MINIMUM PUNCTURE STRENGTH OF 725 LB (PER ASTM D6241).
GEOTEXTILE SEAMS ARE TO OVERLAPPED BY 1 FT DURING PLACEMENT AND EITHER MACHINE-SEWN OR THERMALLY BONDED TO ONE ANOTHER.
7. GEOMEMBRANE
THE GEOMEMBRANE IS TO CONSIST OF A LINEAR, LOW-DENSITY POLYETHYLENE (LLDPE) MATERIAL, TEXTURED ON BOTH SIDES, MANUFACTURED IN ACCORDANCE WITH THE LATEST VERSION OF GEOSYNTHETIC INSTITUTE GM17 STANDARD SPECIFICATION, AND WITH THE FOLLOWING REQUIREMENTS:
   - MINIMUM NOMINAL HEIGHT OF 40 MIL (PER ASTM D5994),
   - MINIMUM ASPERITY HEIGHT OF 16 MIL (PER ASTM D7466),
   - MAXIMUM DENSITY OF 0.939 G/ML (PER ASTM D792, OR ASTM D1505),
   - MINIMUM TENSILE STRENGTH AT BREAK OF 60 LB/IN (PER ASTM D6693),
   - MINIMUM ELONGATION AT BREAK OF 250% (PER ASTM D6693),
   - MINIMUM TEAR RESISTANCE OF 22 LB (PER ASTM D1004), AND
   - MINIMUM PUNCTURE RESISTANCE OF 44 LB (PER ASTM D3895).
GEOMEMBRANE SEAMS ARE TO BE FUSION-WELDED; REPAIRS AND PENETRATIONS FOR PIPE BOOTS ARE TO BE EXTRUSION WELDED.

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0	11/5/2021	DRAFT CLOSURE PLAN ISSUE	MGK	LPC

Geosyntec consultants
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DYNERGY MIDWEST GENERATION, LLC
1500 EASTPORT PLAZE DRIVE
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TITLE: DETAILS AND MATERIAL SPECIFICATIONS

PROJECT: EAST ASH POND CONSTRUCTION PERMIT APPLICATION CLOSURE DRAWINGS

SITE: HENNEPIN POWER PLANT HENNEPIN, ILLINOIS

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	LPC	DATE:	NOVEMBER 2021
DRAWN BY:	IJV/MGK	PROJECT NO.:	GLP8026
CHECKED BY:	TWW	FILE:	
REVIEWED BY:	JPS	DRAWING NO.:	C-103
APPROVED BY:	LPC		

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ATTACHMENT D

Hydrologic and Hydraulic Design of Stormwater Management System

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Geosyntec consultants

COMPUTATION COVER SHEET

Client: **Dynegy**	Project: **Hennepin Closure Plan**	Project/ Proposal No.:	**CHE8356**
		Task No.	**A/03**

Title of Computations **Hennepin West Cover Stormwater Calculation Package**

Computations by:	Signature	[signature]	9-22-2021 (Date)
	Printed Name	Lee Hauser	
	Title	Professional	
Assumptions and Procedures Checked by: (peer reviewer)	Signature	[signature]	10-05-2021 (Date)
	Printed Name	Patrick VanDeWiele	
	Title	Project Engineer	
Computations Checked by:	Signature	[signature]	10-05-2021 (Date)
	Printed Name	Patrick VanDeWiele	
	Title	Project Engineer	
Computations backchecked by: (originator)	Signature	[signature]	10-06-2021 (Date)
	Printed Name	Lee Hauser	
	Title	Professional	
Approved by: (pm or designate)	Signature	[signature]	10-06-2021 (Date)
	Printed Name	Lucas Carr, P.E.	
	Title	Senior Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

DRAFT

Written by:	LH	Date:	09/22/21 (DD MM YY)	Reviewed by:	PVW	Date:	9/23/21 (DD MM YY)
Client:	Dynegy	Project:	Hennepin Closure Plan	Project No.:	GLP8026	Task No.:	A/03

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Written by:	LH	Date:	09/22/21 (DD MM YY)	Reviewed by:	PVW	Date:	9/23/21 (DD MM YY)
Client:	Dynegy	Project:	Hennepin Closure Plan	Project No.:	GLP8026	Task No.:	A/03

LIST OF APPENDICES

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Written by:	LH	Date:	09/22/21 (DD MM YY)	Reviewed by:	PVW	Date:	9/23/21 (DD MM YY)
Client:	Dynegy	Project:	Hennepin Closure Plan	Project No.:	GLP8026	Task No.:	A/03

1. Purpose

The purpose of this calculation package is to provide documentation of the hydrologic and hydraulic calculations of the cover design for the final closure of the 21-acre Hennepin Power Plant East Ash Pond. In particular, the analysis evaluates the performance of the cover's proposed drainage features and outlet chutes for the 25-year and 100-year, 24-hour Soil Conservation Service (SCS) Type II storm event in accordance with the CCR Rule (USEPA, 2015). HEC-HMS 4.2.1 (USACE, 2016) was used for the Hydrologic analysis to estimate the peak runoff rate from each subcatchment for the identified storm events. A Manning's spreadsheet calculation was performed for the hydraulic analysis of the cover swales and down chutes.

2. Design Basis

The proposed drainage swales and rock chutes were designed to meet the following:

1. Designed for the 25-year storm event to satisfy IL Part 845.510; and
2. Safely convey the 100-year storm event to satisfy IL Part 845.510.

For design purposes, the SCS Type-II rainfall distribution was applied to both storm events listed above. The SCS Type-II distribution is a conservative temporal distribution for a 24-hour duration storm event in context of this closure design due to its peak rainfall intensity, which is greater than the other acceptable standardized distributions that were considered; such as Huff 3rd Quartile (for areas less than 10 square miles) as published in the Illinois State Water Survey (ISWS) Circular 173 (ISWS, 1990).

3. Assumptions and Data Input

The following section presents a summary of the assumptions and inputs associated with the hydrologic and hydraulic analysis and design.

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Client:	Dynegy	Project:	Hennepin Closure Plan	Project No.:	GLP8026	Task No.:	A/03

Summary of Survey Data and Site Improvement Data

Site topographic surveys of existing conditions (e.g., pre-closure conditions) were performed by IngenAE, LLC in December 2020, which were prepared and provided to Dynegy as a drawing set (IngenAE, March 2021). Site improvements are based on the preliminary closure design for the EAP prepared by Geosyntec Consultants.

Hydrology Inputs

The following design assumptions and hydrologic parameters were used to perform the hydrologic analysis.

Rainfall Depth and Distribution

Rainfall depths were based on NOAA Atlas 14 (NOAA, 2006) Point Precipitation Frequency Estimates, as shown in Appendix 1. The Type II SCS storm distribution was used to evaluate the imbedded high rainfall intensity portion of the storm as a critical flood risk analysis. The SCS was preferred over the huff distribution as it is more conservative and will reduce the long-term structural maintenance of channels/letdown structures. This storm temporal distribution is considered conservative for a 24-hour duration event and therefore adequate for design purposes (see Section 2 for detailed explanation). The following storm events were used to size the proposed stormwater features:

- Type II SCS 25-year, 24-hour event is 5.08 inches (Design)
- Type II SCS 100-year, 24-hour event is 6.58 inches (Safely Convey)

Curve Number (CN)

Curve numbers (CN) were estimated using Table 2-2 in the TR-55 manual (USDA, 1986) and assumed soil conditions based on soil maps and knowledge of the site. A single curve number was used to represent the final cover. The final cover will include, from bottom to top, a geomembrane, geotextile, 2.5 ft of cover soil, 0.5 ft of topsoil, and established vegetation. The following assumed conditions were used in determining the curve numbers based on those conditions:

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Client:	Dynegy	Project:	Hennepin Closure Plan	Project No.:	GLP8026	Task No.:	A/03

- Post-development Areas (CN=78)
- Cover Type – Meadow
- Hydrologic Condition – Fair
- Hydrologic Soil Group – D

Subcatchments

The total 21-acre cover was subdivided into north and south drainage areas and are approximately 10.99 and 9.83 acres respectively. The areas were subdivided based on the grading plan and drainage feature tributaries. The drainage map and associated subcatchment parameters are shown in the Appendix 2, Figure 1.

Hydraulic Inputs

The following section summarizes the design assumptions and hydraulic parameters used to perform the hydraulic analysis.

Cover Swales

The location and longitudinal slope of the cover swales were based the 30% grading plans. The swales were designed as V-ditches with side slopes of 40:1 to match the grading plan (2.5% side-slopes), a maximum flow depth of 2 feet, and longitudinal slope of one percent. The channels were oversized to accommodate mowing equipment and allow for any additional maintenance needs. According to Manning's n for Channels (Chow, 1959), a manning's roughness coefficient of 0.03 was used for excavated earthen channels with short grass and few weeds.

Rock Chutes

The hydraulic performance of the rock chutes were designed to have a maximum longitudinal slope of 3H:1V with a 4-ft bottom width and 3H:1V side slopes. Manning's n was derived from the Design of Rock Chutes Spreadsheet calculator (Robinson et al., 1998) based on the size of the rock used to line the channel.

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Written by: LH Date: 09/22/21 (DD MM YY) Reviewed by: PVW Date: 9/23/21 (DD MM YY)
Client: Dynegy Project: Hennepin Closure Plan Project No.: GLP8026 Task No.: A/03

4. Results

Cover Swale Design

Cover swales were designed to convey the 25-year, 24-hour event. The cover has two (2) swales, however, there was only one (1) swale design that was based on the critical drainage area – i.e., highest peak discharge from a drainage area. Peak discharge outputs were taken from the HEC-HMS model to determine the critical drainage area. Table 1 displays critical swale results for the north drainage area while all of the HEC-HMS peak flow outputs are shown in Appendix 3. The peak flows are 18.0 cfs and 26.5 cfs for the 25-year, and 100-year events respectively. Additionally, swale velocities and depths were calculated from a Manning's spreadsheet calculation based on the peak discharges and the typical swale cross-section. Swales were designed to have side slopes of 40:1 to, a maximum flow depth of 2 feet, and a graded longitudinal slope of 1 percent. This resulted in velocities of 1.9 ft/s and 2.1 ft/s and depths of 0.49 feet and 0.56 feet for the 25-year and 100-year events, respectively (shown in Table 1). The spreadsheet calculation sheets for both storm events are shown in Appendix 4.

Table 1 - Peak Swale Parameters

Storm Event	Peak Flow (CFS)	Max Velocity (ft/s)	Max Flow Depth (ft)
25-year	18.0	1.9	0.49
100-year	26.5	2.1	0.56

Using guidance from Chapter 8 of the Natural Resources Conservation Services (NRCS) Engineering Handbook (NRCS, 2007), temporary erosion control blanket and grass cover provide enough protection to prevent erosion. Using the max velocities of 2.1 ft/s for the 100-year storm event and Table 8-11 from Chapter 8, table shown below in Figure 1, the swales can use "Jute net" or "Straw with net" as a temporary erosion control product. To be conservative, it is recommended the swales be lined with "straw with net" as an erosion control product as it has an allowable velocity of 3 ft/s compared to an allowable velocity of 2.5 ft/s that is indicated for "jute net". Grass vegetation is expected to establish through the temporary erosion control product within the swales and has a recommended

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allowable velocity of 5 to 8 ft/s dependent on grass type – e.g., bermudagrass versus Kentucky bluegrass per Table 8-11 for Chapter 8.

Table 8–11 Allowable velocity and shear stress for selected lining materials[1/]

Boundary category	Boundary type	Allowable velocity (ft/s)	Allowable shear stress (lb/ft^2)	Citation(s)
Temporary degradable reinforced erosion control products (RECP)	Jute net	1–2.5	0.45	B, E, F
	Straw with net	1–3	1.5–1.65	B, E, F
	Coconut fiber with net	3–4	2.25	B, F
	Fiberglass roving	2.5–7	2	B, E, F
Nondegradable RECP	Unvegetated	5–7	3	B, D, F
	Partially established	7.5–15	4–6	B, D, F
	Fully vegetated	8–21	8	C, F
Hard surface	Gabions	1–19	10	A
	Concrete	>18	12.5	E

1/ Ranges of values generally reflect multiple sources of data or different testing conditions

(Goff 1999)
(Gray and Sotir 1996)
(Julien 1995)
(Kouwen, Li, and Simons 1980)
(Norman 1975)
(TXDOT 1999)

Figure 1: Excerpt Table 8-11 from Chapter 8 of the NRCS Engineering Handbook

Rock Chute Design

The rock chutes were designed using the Design of Rock Chutes spreadsheet developed by the NRCS (Robinson et al., 1998). The peak flows presented in Table 1 were used to design the channel geometry and rock-armor sizing applied to both rock chutes. Based on the calculations presented in Appendix 5, the rock chutes shall consist of an outlet apron no less than 13-feet long, an inlet apron no less than 9-feet long, have a D50 rock size of 10.8 inches or larger, and a bed thickness of 21.6 inches. Appendix 5 presents a plan sheet of the rock chute design.

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5. Conclusions

The three design features are summarized as follows:

1. A V-ditch swale with a longitudinal slope of 1% and side slopes of 40H to 1V to match the proposed grading plan is expected to safely convey the 25-year, and 100-year events at flow depths of 0.49 feet and 0.56 feet for respectively.
2. According to Table 8-11 in Chapter 8 of the Natural Resources Conservation Services Engineering Handbook, the max velocities of 2.1 ft/s for the 100-year storm event in the swales are low enough to be supported by temporary erosion control blanket and grass cover.
3. The rock chute should be constructed with rock of minimum D50 of 10.8 inches and minimum bed thickness of 21.6 inches. The rock chutes will include inlet and outlet aprons with minimum lengths of 9 feet and 13 feet, respectively. Plan detail is shown in Attachment 3.

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Client:	Dynegy	Project:	Hennepin Closure Plan	Project No.:	GLP8026	Task No.:	A/03

6. References

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United States Department of Agriculture, Natural Resources Conservation Service, 2007 (NRCS, 2007), Threshold Channel Design, Part 654 Stream Restoration Design National Engineering Handbook.

United States Department of Agriculture, Natural Resources Conservation Service, Technical Release 55, June 1986.

United States Geological Survey Central Midwest Water Science Center (USGS, 2008). Discharge time-series data for Station Number 0558300 (Illinois River at Henry, IL). Provided via email from John Latour (USGS) to Lee Hauser (Geosyntec).

United States Environmental Protection Agency (USEPA, 2015). Final Rule: Disposal of Coal Combustion Residuals from Electric Utilities.

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Weaver Consultants (2015). Hennepin 2015 Aerial Topography Existing Site Conditions, Hennepin Power Station, 01 December 2015.

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APPENDIX 1

NOAA Atlas 14, Volume 2, Version 3

NOAA Atlas 14, Volume 2, Version 3
Location name: Hennepin, Illinois, USA*
Latitude: 41.302°, Longitude: -89.3152°
Elevation: 463.74 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.394** (0.357-0.435)	**0.463** (0.420-0.510)	**0.546** (0.495-0.601)	**0.625** (0.564-0.687)	**0.716** (0.644-0.786)	**0.794** (0.710-0.873)	**0.866** (0.769-0.955)	**0.942** (0.829-1.04)	**1.04** (0.906-1.16)	**1.13** (0.968-1.26)
10-min	**0.613** (0.554-0.676)	**0.723** (0.656-0.797)	**0.848** (0.769-0.933)	**0.964** (0.871-1.06)	**1.10** (0.984-1.20)	**1.20** (1.08-1.32)	**1.30** (1.16-1.44)	**1.41** (1.24-1.56)	**1.53** (1.33-1.70)	**1.64** (1.41-1.84)
15-min	**0.751** (0.680-0.829)	**0.884** (0.803-0.974)	**1.04** (0.944-1.15)	**1.19** (1.07-1.31)	**1.35** (1.22-1.49)	**1.49** (1.33-1.64)	**1.62** (1.44-1.79)	**1.75** (1.54-1.94)	**1.91** (1.66-2.13)	**2.05** (1.76-2.30)
30-min	**0.993** (0.899-1.10)	**1.18** (1.07-1.30)	**1.43** (1.29-1.57)	**1.65** (1.49-1.81)	**1.91** (1.72-2.10)	**2.13** (1.90-2.34)	**2.34** (2.08-2.58)	**2.55** (2.25-2.83)	**2.83** (2.46-3.15)	**3.08** (2.64-3.45)
60-min	**1.21** (1.10-1.34)	**1.45** (1.32-1.60)	**1.79** (1.62-1.97)	**2.10** (1.89-2.31)	**2.48** (2.23-2.72)	**2.81** (2.51-3.09)	**3.13** (2.78-3.45)	**3.47** (3.05-3.83)	**3.92** (3.41-4.36)	**4.32** (3.71-4.84)
2-hr	**1.46** (1.31-1.61)	**1.75** (1.58-1.92)	**2.16** (1.95-2.37)	**2.55** (2.29-2.80)	**3.04** (2.72-3.33)	**3.47** (3.09-3.81)	**3.92** (3.46-4.31)	**4.40** (3.85-4.86)	**5.07** (4.37-5.63)	**5.68** (4.84-6.36)
3-hr	**1.55** (1.41-1.71)	**1.86** (1.69-2.05)	**2.31** (2.10-2.54)	**2.73** (2.47-3.00)	**3.27** (2.94-3.59)	**3.75** (3.35-4.12)	**4.24** (3.75-4.66)	**4.77** (4.18-5.26)	**5.51** (4.76-6.11)	**6.19** (5.28-6.92)
6-hr	**1.85** (1.68-2.04)	**2.21** (2.01-2.43)	**2.74** (2.49-3.02)	**3.25** (2.94-3.58)	**3.92** (3.52-4.31)	**4.54** (4.04-4.99)	**5.19** (4.57-5.72)	**5.90** (5.13-6.53)	**6.92** (5.91-7.70)	**7.89** (6.62-8.85)
12-hr	**2.13** (1.94-2.34)	**2.53** (2.31-2.79)	**3.12** (2.84-3.43)	**3.68** (3.34-4.03)	**4.41** (3.98-4.83)	**5.08** (4.54-5.56)	**5.77** (5.11-6.34)	**6.53** (5.72-7.21)	**7.60** (6.55-8.44)	**8.63** (7.31-9.66)
24-hr	**2.41** (2.23-2.62)	**2.90** (2.68-3.15)	**3.62** (3.34-3.93)	**4.22** (3.88-4.58)	**5.08** (4.64-5.53)	**5.80** (5.26-6.34)	**6.58** (5.91-7.22)	**7.43** (6.59-8.19)	**8.66** (7.56-9.63)	**9.68** (8.32-10.9)
2-day	**2.81** (2.61-3.03)	**3.37** (3.14-3.65)	**4.17** (3.88-4.50)	**4.82** (4.47-5.20)	**5.73** (5.28-6.19)	**6.48** (5.94-7.02)	**7.26** (6.60-7.91)	**8.10** (7.30-8.86)	**9.28** (8.24-10.3)	**10.2** (8.97-11.4)
3-day	**2.98** (2.77-3.21)	**3.57** (3.33-3.85)	**4.39** (4.09-4.74)	**5.06** (4.70-5.46)	**5.99** (5.54-6.48)	**6.76** (6.21-7.33)	**7.56** (6.89-8.23)	**8.40** (7.60-9.20)	**9.60** (8.55-10.6)	**10.6** (9.29-11.8)
4-day	**3.14** (2.93-3.39)	**3.76** (3.51-4.06)	**4.61** (4.30-4.97)	**5.30** (4.93-5.72)	**6.26** (5.79-6.76)	**7.04** (6.48-7.64)	**7.86** (7.17-8.55)	**8.71** (7.90-9.53)	**9.91** (8.87-11.0)	**10.9** (9.61-12.1)
7-day	**3.65** (3.41-3.93)	**4.35** (4.07-4.69)	**5.25** (4.91-5.66)	**5.96** (5.56-6.43)	**6.93** (6.43-7.49)	**7.69** (7.10-8.35)	**8.47** (7.76-9.24)	**9.27** (8.43-10.2)	**10.4** (9.31-11.5)	**11.2** (9.96-12.5)
10-day	**4.15** (3.89-4.45)	**4.94** (4.62-5.30)	**5.89** (5.51-6.32)	**6.62** (6.19-7.12)	**7.59** (7.07-8.17)	**8.35** (7.73-9.01)	**9.10** (8.38-9.86)	**9.85** (9.02-10.7)	**10.9** (9.84-11.9)	**11.6** (10.4-12.8)
20-day	**5.57** (5.22-5.94)	**6.61** (6.21-7.07)	**7.87** (7.39-8.41)	**8.80** (8.25-9.42)	**10.0** (9.37-10.7)	**11.0** (10.2-11.8)	**11.9** (11.0-12.8)	**12.8** (11.8-13.8)	**14.0** (12.8-15.2)	**14.9** (13.5-16.3)
30-day	**6.87** (6.48-7.28)	**8.14** (7.68-8.65)	**9.54** (8.98-10.1)	**10.6** (9.94-11.2)	**11.8** (11.1-12.6)	**12.8** (11.9-13.6)	**13.7** (12.7-14.6)	**14.5** (13.5-15.5)	**15.6** (14.4-16.8)	**16.4** (15.0-17.7)
45-day	**8.62** (8.15-9.11)	**10.2** (9.64-10.8)	**11.9** (11.2-12.6)	**13.1** (12.4-13.8)	**14.6** (13.8-15.5)	**15.8** (14.8-16.7)	**16.8** (15.8-17.9)	**17.9** (16.7-19.1)	**19.2** (17.8-20.6)	**20.1** (18.6-21.8)
60-day	**10.3** (9.72-10.9)	**12.1** (11.5-12.8)	**14.0** (13.3-14.8)	**15.4** (14.5-16.3)	**17.1** (16.1-18.1)	**18.3** (17.2-19.4)	**19.4** (18.2-20.6)	**20.5** (19.2-21.8)	**21.8** (20.3-23.3)	**22.7** (21.1-24.5)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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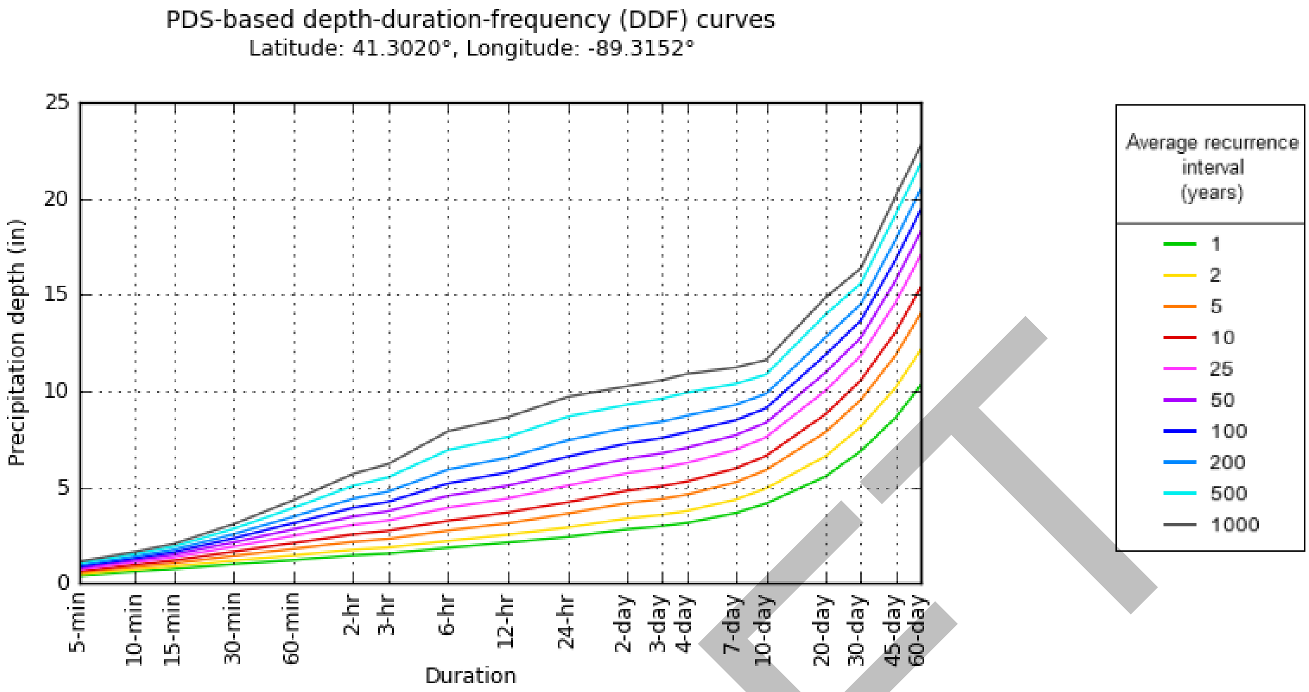
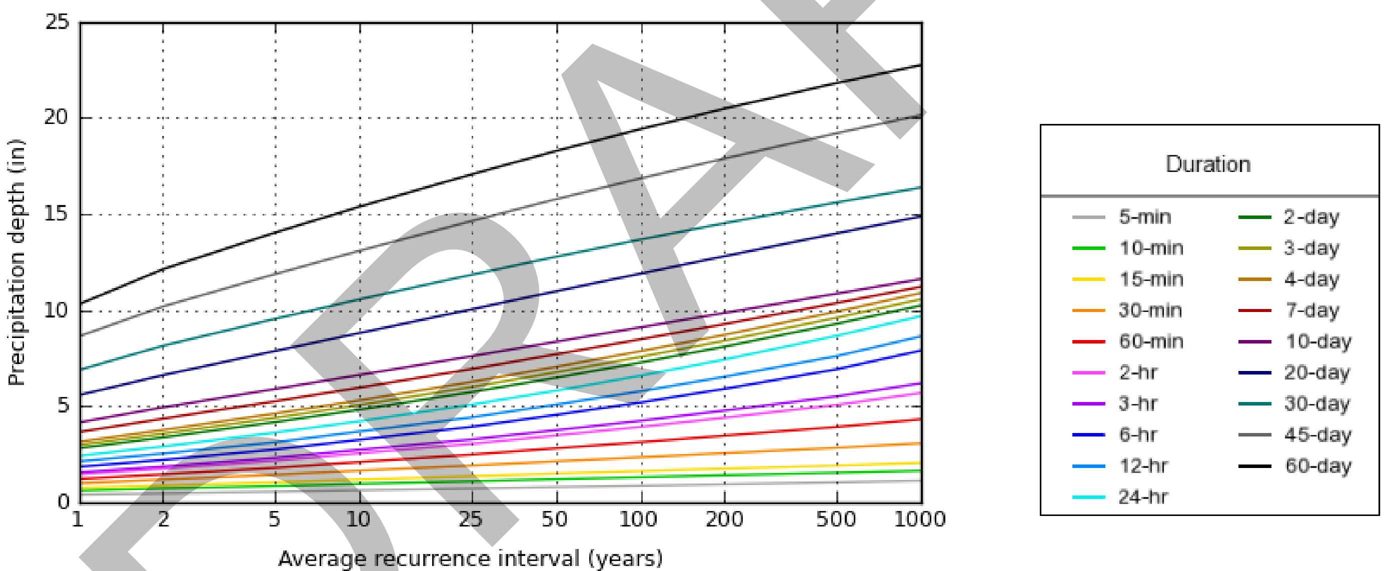
PF graphical





NOAA Atlas 14, Volume 2, Version 3

Created (GMT): Tue Aug 29 22:02:03 2017

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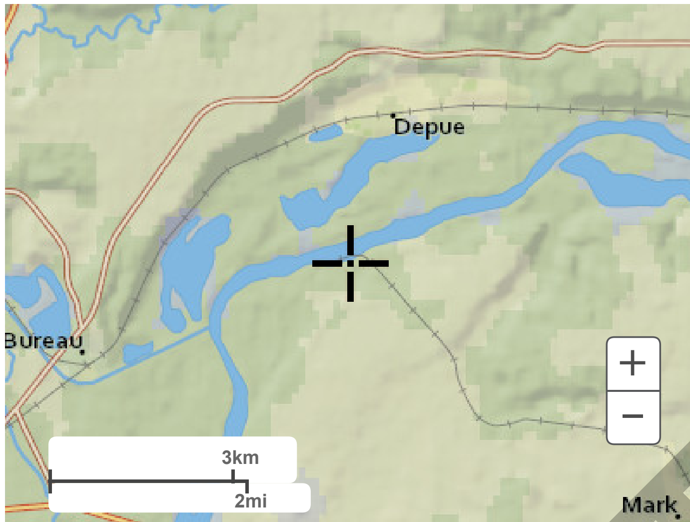
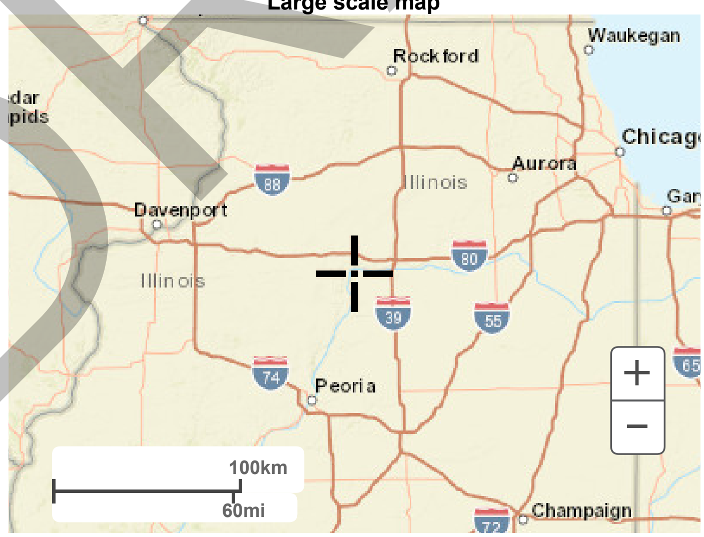
Maps & aerials

Small scale terrain



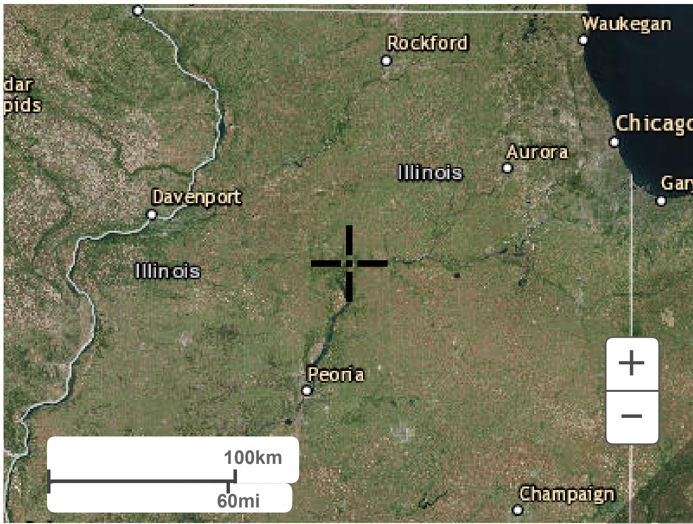
Large scale terrain

Large scale map



Large scale aerial

DRAFT



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US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

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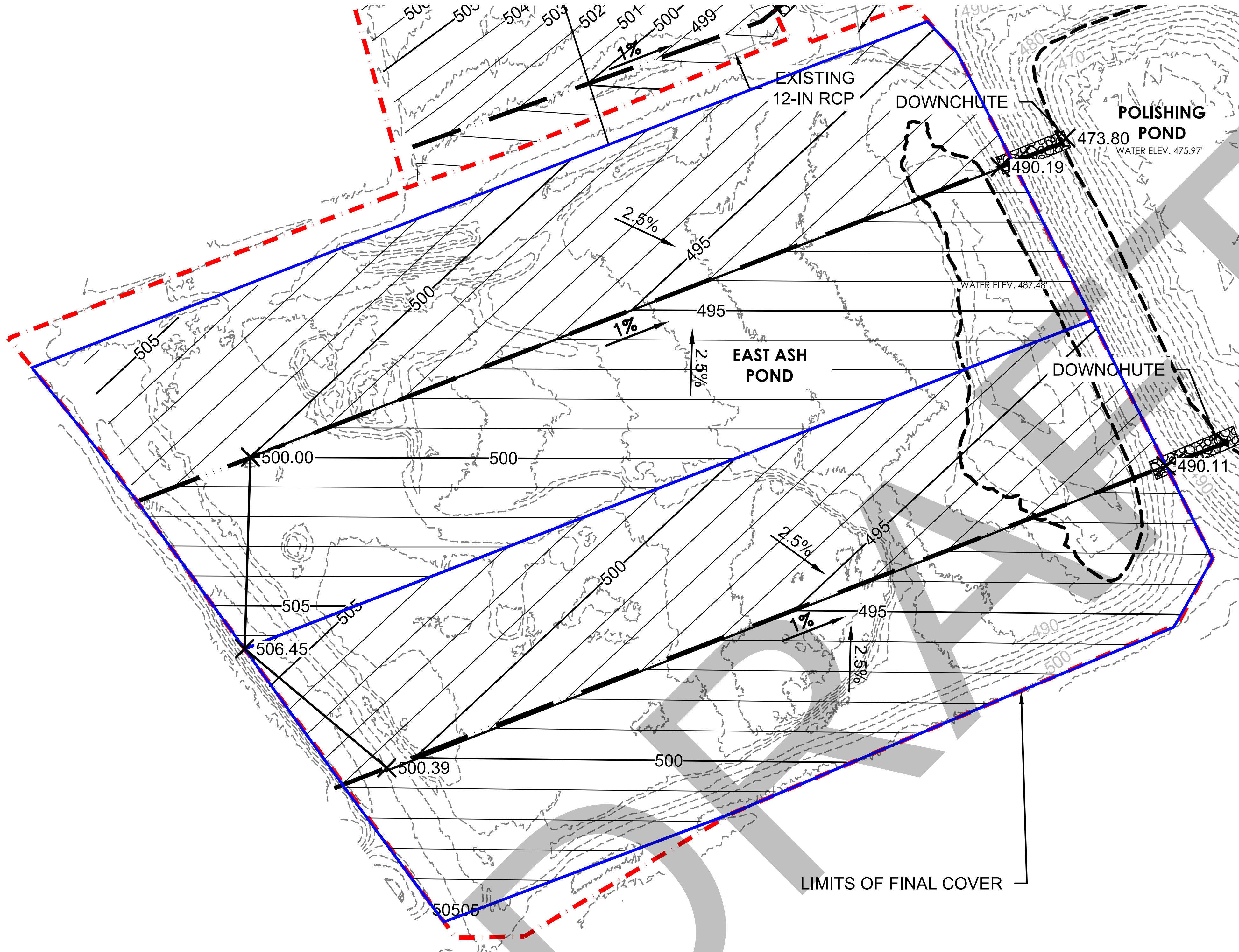
APPENDIX 2

Cover Grading Plan and Drainage Map



LEGEND

480	EXISTING GROUND SURFACE ELEVATION (2 FT INTERVAL)
505	TOP OF FINAL COVER GRADE ELEVATION
	EXISTING RCP PIPE
	STORMWATER CHANNEL
	LIMIT OF FINAL COVER
	DRAINAGE AREA BOUNDARY

N

0 150

SCALE IN FEET

NOTES:

1. COORDINATES AND DIRECTIONS SHOWN IN THESE DRAWINGS WERE BASED ON THE ILLINOIS STATE PLANE COORDINATE SYSTEM (NAD83, IN US FEET). ELEVATIONS WERE BASED ON THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88, IN US FEET).

2. EXISTING CONTOURS AND WATER SURFACE ELEVATIONS TAKEN FROM DYNEGY MIDWEST GENERATION, LLC - HENNEPIN POWER STATION - DECEMBER 2020 TOPOGRAPHY, 3/10/2021, BY INGENAE, LLC.

CONCEPTUAL - NOT FOR CONSTRUCTION

DRAFT

COVER GRADING PLAN AND DRAINAGE MAP
EAST ASH POND
DYNEGY MIDWEST GENERATION, LLC
HENNEPIN POWER STATION

Geosyntec consultants

PROJECT NO: GLP8026	SEPTEMBER 2021	DRAWING 1

S:\COMPANY\PROJECTS_POST_2014\GLP8026\HEN_845_CONST_PERMIT\500_TECHNICAL\530_CAD\GLP8026-001-EAST POND_COVER_DRAINAGE MAP - Last Saved by: ... on 9/20/21

DRAFT

APPENDIX 3

Hydrologic Summary

Geosyntec consultants
engineers | scientists | innovators

1420 Kensington Road, Suite 103
Oak Brook, IL
TELEPHONE (630)
FAX (630) 203 3341

JOB	GLP8026 Hennepin East Ash Pond Closure		
SHEET NO.		OF	
CALCULATED BY	LH	DATE	9/22/2021
CHECKED BY	PV	DATE	9/23/2021
SCALE			
DESCRIPTION	Subcatchment Peak Flow Summary		

Subcatchment Summary

Catchment	Area (acres)	25-yr Peak Flows (CFS)	100-yr Peak Flows (CFS)
North Drainage Area	11.0	18.0	26.5
South Drainage Area	9.8	16.0	23.5

(yellow highlight) Indicates Flows used for swale and chute design

DRAFT

Written by:	LH	Date:	09/22/21 (DD MM YY)	Reviewed by:	PVW	Date:	9/23/21 (DD MM YY)
Client:	Dynegy	Project:	Hennepin Closure Plan	Project No.:	GLP8026	Task No.:	A/03

DRAFT

APPENDIX 4

Cover Swale Hydraulic Analysis

Geosyntec consultants
engineers | scientists | innovators
1420 Kensington Road, Suite 103
Oak Brook, IL
TELEPHONE (630)
FAX (630) 203 3341

JOB	GLP8026 Hennepin East Ash Pond Closure		
SHEET NO.		OF	
CALCULATED BY	LH	DATE	9/20/2021
CHECKED BY	PV	DATE	9/23/2021
SCALE			
DESCRIPTION	2021 Cover Updates		
	25-year, 24 hr SCS Type II		

Peak Discharge, Q_{max}=	18.00	cfs
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	40.00	horizontal :1 vertical
Right Side Slope, Z_2 =	40.00	horizontal :1 vertical
Manning's Roughness Coeff., n =	0.030	
Longitudinal Channel Slope, S_o =	0.0100	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Channel Slope ft/ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.80	0.00	0.010	0.14	0.00	0.00	
0.18	1.24	14.07	0.09	0.010	0.98	1.21	0.05	
0.34	4.67	27.34	0.17	0.010	1.53	7.13	0.11	
0.51	10.30	40.61	0.25	0.010	1.99	20.49	0.16	
0.67	18.14	53.88	0.34	0.010	2.40	43.56	0.21	
0.84	28.17	67.15	0.42	0.010	2.78	78.37	0.26	
1.01	40.40	80.43	0.50	0.010	3.14	126.77	0.31	
1.17	54.83	93.70	0.59	0.010	3.47	190.51	0.37	
1.34	71.47	106.97	0.67	0.010	3.80	271.24	0.42	
1.50	90.30	120.24	0.75	0.010	4.10	370.52	0.47	
1.67	111.33	133.51	0.83	0.010	4.40	489.86	0.52	
1.83	134.57	146.78	0.92	0.010	4.69	630.72	0.57	
2.00	160.00	160.05	1.00	0.010	4.97	794.50	0.62	
0.49	9.60	39.21	0.24	0.01	1.94	18.66	0.15	DESIGN Q

DRAFT

Geosyntec consultants
engineers | scientists | innovators

1420 Kensington Road, Suite 103
Oak Brook, IL
TELEPHONE (630)
FAX (630) 203 3341

JOB	GLP8026 Hennepin East Ash Pond Closure
SHEET NO.	OF
CALCULATED BY	LH DATE 9/20/2021
CHECKED BY	PV DATE 9/23/2021
SCALE	
DESCRIPTION	2021 Cover Updates
	100-year, 24 hr SCS Type II

Peak Discharge, Q_{max}=	26.50	cfs
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	40.00	horizontal :1 vertical
Right Side Slope, Z_2 =	40.00	horizontal :1 vertical
Manning's Roughness Coeff., n =	0.030	
Longitudinal Channel Slope, S_o =	0.0100	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Channel Slope ft/ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.80	0.00	0.010	0.14	0.00	0.00	
0.18	1.24	14.07	0.09	0.010	0.98	1.21	0.05	
0.34	4.67	27.34	0.17	0.010	1.53	7.13	0.11	
0.51	10.30	40.61	0.25	0.010	1.99	20.49	0.16	
0.67	18.14	53.88	0.34	0.010	2.40	43.56	0.21	
0.84	28.17	67.15	0.42	0.010	2.78	78.37	0.26	
1.01	40.40	80.43	0.50	0.010	3.14	126.77	0.31	
1.17	54.83	93.70	0.59	0.010	3.47	190.51	0.37	
1.34	71.47	106.97	0.67	0.010	3.80	271.24	0.42	
1.50	90.30	120.24	0.75	0.010	4.10	370.52	0.47	
1.67	111.33	133.51	0.83	0.010	4.40	489.86	0.52	
1.83	134.57	146.78	0.92	0.010	4.69	630.72	0.57	
2.00	160.00	160.05	1.00	0.010	4.97	794.50	0.62	
0.56	12.54	44.81	0.28	0.01	2.12	26.65	0.17	DESIGN Q

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APPENDIX 5

Rock Chute Analysis

Rock_Chute.xls
for construction plan

Rock Chute Design - Cut/Paste Plan

(Version WI-July-2010, Based on Design of Rock Chutes by Robinson, Rice, Kadavy, ASAE, 1998)

Project: Hennepin East Pond Closure **County:** Putnam
Designer: LWH
Date: 10/6/2021

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Design Values

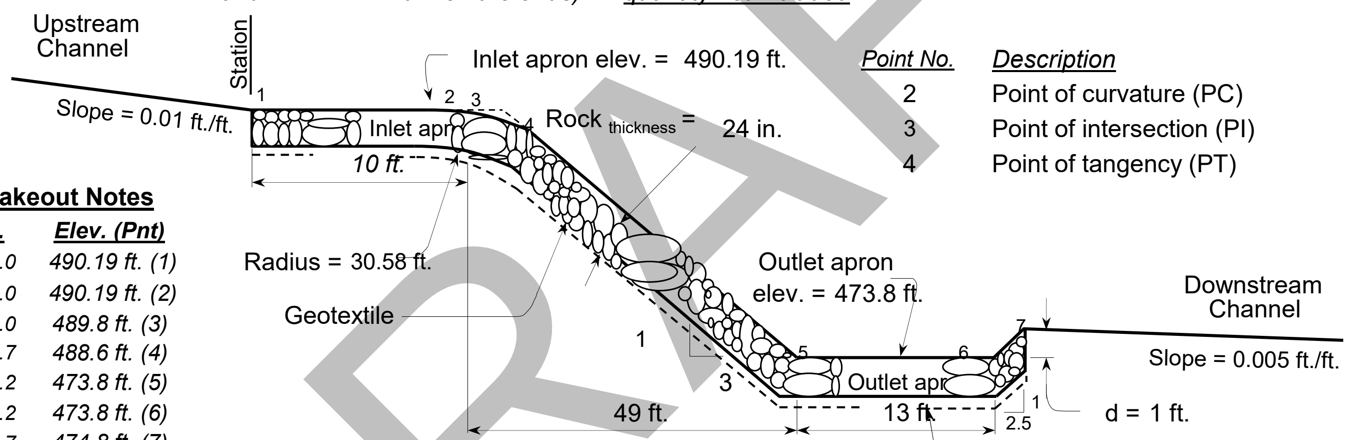
D_{50} dia. = 11.0in.
$Rock_{chute}$ thickness = 24.0in
Inlet apron length = 10 ft.
Outlet apron length = 13 ft.
Radius = 31 ft
Will bedding be used? No

Rock Gradation Envelope

% Passing	*Diameter, in. (weight, lbs.)*
D_{100}--------	17 - 22 (318 - 754)
D_{85}---------	14 - 20 (207 - 549)
D_{50}---------	11 - 17 (94 - 318)
D_{10}---------	9 - 14 (48 - 207)

Coefficient of Uniformity, $(D_{60})/(D_{10})$ < 1.7

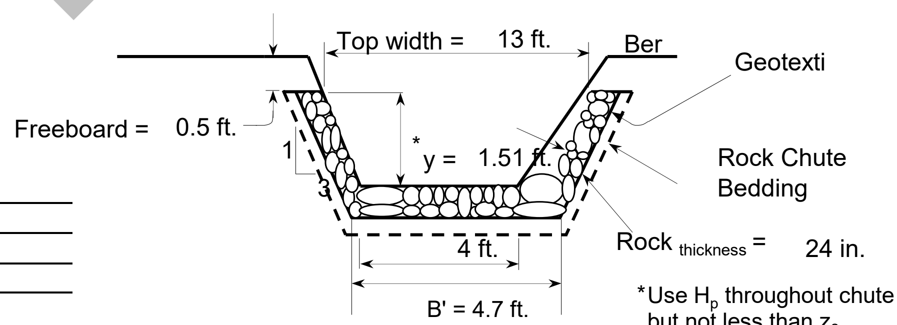
Notes: [a] *Rock, bedding, and geotextile quantities are determined from x-section below (neglect radius).*
[b] *Geotextile Class I (Non-woven) shall be overlapped and anchored (18-in. minimum along sides and 24-in. minimum on the ends) --- quantity not included.*



Stakeout Notes

Sta.	*Elev. (Pnt)*
0+00.0	*490.19 ft. (1)*
0+05.0	*490.19 ft. (2)*
0+10.0	*489.8 ft. (3)*
0+14.7	*488.6 ft. (4)*
0+59.2	*473.8 ft. (5)*
0+72.2	*473.8 ft. (6)*
0+74.7	*474.8 ft. (7)*

Profile Along Centerline of Rock Chute



Rock Chute Cross Section

Notes:
Rock gradation envelope can be met with
DOT Extra Heavy riprap Gradation

Profile, Cross Sections, and Quantities

NRCS Natural Resources Conservation Service United States Department of Agriculture	Hennepin East Pond Closure Putnam County	Designe LWH Drawn Checked Approved	Date	File Name Drawing Name Sheet __ of __

ATTACHMENT E

Geotechnical Design of Slopes and Final Cover System

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Geosyntec consultants

COMPUTATION COVER SHEET

Client: **Dynegy** Project: **Hennepin EAP Closure Plan** Project No.: **GLP8026**
Task No.: **B/02**

Title of Computations **Geotechnical Calculations for Closure Design**

Computations by:	Signature		10-27-2021 Date
	Printed Name	Isaiah Vaught, EIT & Lucas P. Carr, P.E.	
	Title	Staff Professional & Senior Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		11-01-2021 Date
	Printed Name	John P. Seymour. P.E.	
	Title	Senior Principal	
Computations Checked by:	Signature		11-01-2021 Date
	Printed Name	Zachary J. Fallert, P.E.	
	Title	Engineer	
Computations backchecked by: (originator)	Signature		11-01-2021 Date
	Printed Name	Isaiah Vaught, EIT & Lucas P. Carr, P.E.	
	Title	Staff Professional & Senior Engineer	
Approved by: (pm or designate)	Signature		11-01-2021 Date
	Printed Name	Lucas P. Carr, P.E.	
	Title	Senior Professional	

Approval notes: Closure Plan Submittal

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

DRAFT

Geosyntec consultants

TABLE OF CONTENTS

LIST OF ATTACHMENTS

DRAFT

1. PURPOSE

This calculation package presents geotechnical calculations performed to support the development of the closure design for the East Ash Pond (EAP) at the Hennepin Power Plant (HPP) in Hennepin, Illinois. The analyses provided in this calculation package include:

(i) A summary of past geotechnical investigations completed at and around the EAP;

(ii) A summary of subsurface conditions, selected geotechnical design parameters, and seismic inputs developed by others;

(iii) The results of liquefaction screening analyses performed by others;

(iv) Global slope stability analyses considering post-closure conditions for static and seismic conditions;

(v) Cover system veneer stability analyses, and

(vi) A discussion of the potential for closure-induced settlements.

2. SUMMARY OF SUBSURFACE INVESTIGATIONS

2015 AECOM Investigation

A subsurface investigation program was performed by AECOM at the EAP and adjacent CCR surface impoundments in September and October of 2015 [1]. The investigation program provided information to complete the initial geotechnical analyses for the EAP. Boring locations are shown on **Figure 1**.

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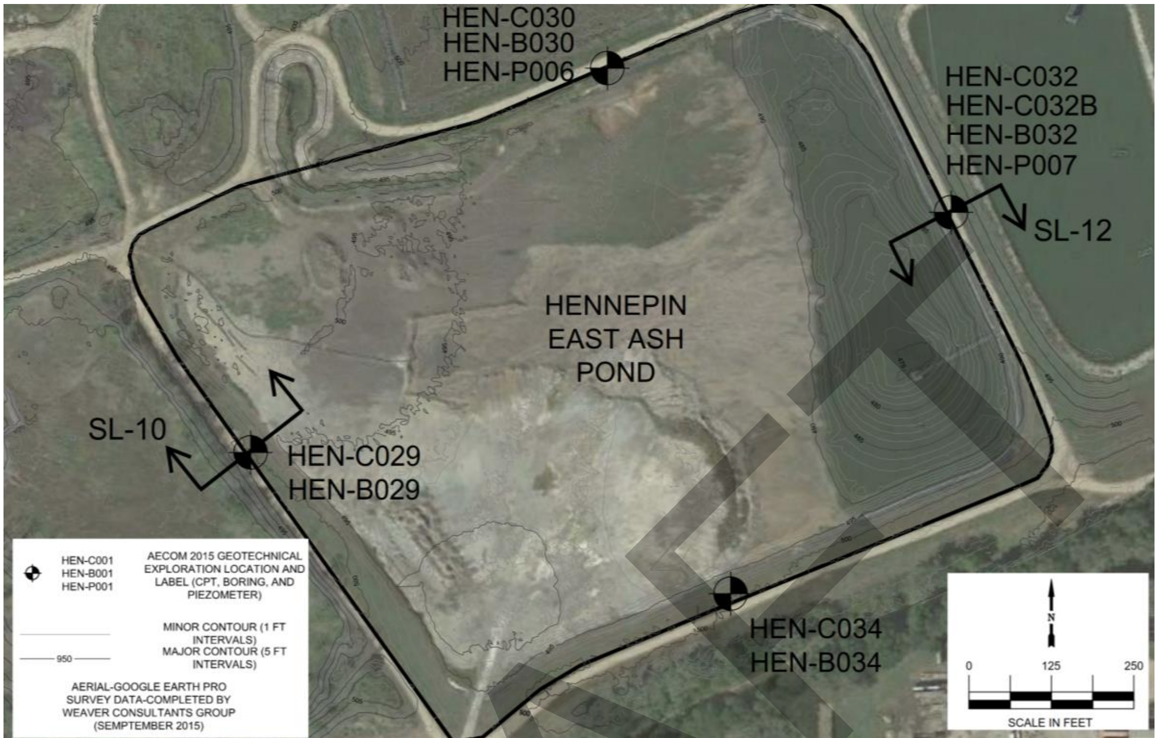

Figure 1 – 2015 AECOM Subsurface Investigation Locations

AECOM's geotechnical report is provided in **Attachment A**.

2021 Geosyntec Investigation

A supplemental investigation of the CCR contained within the East Ash Pond was completed by Geosyntec in 2021 [2]. The investigation program included advancing three hollow-stem auger borings within the interior of the EAP and four monitoring well borings using sonic drilling techniques, as shown in **Figure 2**. Borings in the EAP were terminated above the liner system.

The hollow-stem auger borings were advanced to between 17 and 20 ft below grade and the sonic borings were advanced to between 64 and 98 ft below grade. Laboratory testing was only performed on samples of CCR collected from the hollow-stem auger borings, and the following laboratory tests were performed:

<u>Index Tests</u>:

- Moisture content (ASTM D2216): 7 tests
- Atterberg limits (ASTM D4318): 4 tests
- Grain size analyses (ASTM D422): 7 tests
- Dry unit weight (ASTM D7263): 5 tests
- Specific Gravity (ASTM D854): 7 tests

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Hydraulic Tests:

- Flexible Wall Hydraulic Conductivity (ASTM D5084): 3 tests

Each of the borings were converted into monitoring wells after completion. Excerpts from Geosyntec's report, including boring location information, boring logs, and laboratory testing data, is provided in **Attachment B**.

Figure 2 – 2021 Geosyntec Subsurface Investigation Locations[1]

3. SUMMARY OF SUBSURFACE CONDITIONS

AECOM [1] and Geosyntec [2] identified the following subsurface materials within, beneath, and around the EAP:

(i) Roadway fill;
(ii) Embankment fill;
(iii) Alluvial foundation materials;
(iv) CCR;
(v) Liner System;

[1] The 2021 Geosyntec investigation also included monitoring wells installed around the perimeter of the EAP. These monitoring wells were advanced using sonic drilling techniques and did not include conducting in-situ geotechnical tests or laboratory tests and are therefore not discussed further in this report.

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(vi) Bedrock.

Each material is discussed below:

Roadway Fill

Roadway fill consisting of silty sand comprised an access road located around the perimeter of the EAP. The fill was considered very dense, based on SPT blow counts [1].

Embankment Fill

Embankment fill consists of the materials used to construct the north, south, east, and west embankments. Reportedly, the original dikes were constructed to El. 483 ft and then raised to El. 494 to 500 ft in the early 2000s. The dike soils were considered to be stiff to hard clayey silt and clay, with some zones of sand and gravel, based on CPT logs and SPT N-values [1].

Alluvial Foundations

Native alluvial foundations materials were encountered below the embankments. The material included medium dense to dense sand and gravel with isolated zones and lenses of silt and clay ([1], [2]).

CCR

CCR consists of ash materials that were sluiced into the EAP for disposal. The CCR materials included well-graded sand to silt with trace slag and coal fragments, generally consisting of fly ash, bottom ash, and fly ash/bottom ash mixtures. The CCR was typically saturated and loose to very loose (for bottom ash) and soft to very soft (for fly ash) [2].

Liner System

The EAP contains a 4-ft thick compacted clay liner on the bottom and side-slopes, with a sand filter layer on the side and bottom slopes of the pond (6 and 12 inches thick, respectively). When the dikes were raised in the early 2000s, the liner was extended using an 8-ounce geotextile, 1 ft of compacted clay, and a 45-mil geomembrane. Laboratory or other test data were not collected on the liner system to avoid damage [1].

Bedrock

Shale bedrock was encountered beneath the alluvial foundation material in MW-55. The rock was grey-green in color and noted to be silty [2]. Bedrock was not considered in geotechnical analyses for the site due to its depth (approximately 86 ft below grade) and

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the thickness of relatively high-strength alluvial foundation material above the bedrock (approximately 67 ft).

4. DESIGN GEOTECHNICAL STRENGTH AND UNIT WEIGHT PARAMETERS

Design geotechnical strength and unit weight parameters for each subsurface soil material were selected by AECOM using available laboratory data, CPT sounding information, published correlations, and engineering judgment [1]. Geosyntec reviewed AECOM's design parameters for soil materials and generally agreed with selected values. Design geotechnical parameters for CCR were selected by Geosyntec based on available laboratory test data [2] and Geosyntec's experience. Design geotechnical materials for the final covers were also selected based on Geosyntec's experience. Design geotechnical parameters are summarized in **Table 1**.

Table 1. Design Geotechnical Parameters

Material	Total Unit Weight (γ_t, pcf)	Drained Shear Strength		Undrained Shear Strength (Su, psf)
		Friction Angle (ϕ', deg)	Cohesion (c', psf)	
Road Fill	130	38	0	Assumed drained under each evaluated loading condition
Embankment Fill	105	32	30	2,500
Alluvial Foundation	135	38	0	Assumed drained under each evaluated loading condition
CCR	80	30	0	
Liner System	120	30	60	2,500
Final Cover System	110	27	0	Assumed drained under each evaluated loading condition

5. GROUNDWATER CONDITIONS

Available groundwater data for the two piezometers at the EAP (HEN-P005 and HEN-P006) was provided by the HPP, with the data collected between October 27, 2015 and April 23, 2021. Both piezometers are screened in alluvial soils beneath the embankments. This data was plotted, as shown in **Figure 3**.

The data indicates that groundwater levels in the foundation soil typically vary between El. 446 ft and El. 452 ft. This is similar to the water level in the adjacent Illinois River, and observed spikes to El. 456 ft in June of 2019 and El. 457 ft in June of 2020 are coincident with observed flooding events. The data also indicates that groundwater levels are well below the normal pool level in the EAP (approximately El. 490 ft), which is to be expected as the EAP has a liner system. For geotechnical analyses, a groundwater level of EL. 452 ft was selected for the foundation soils, as this is consistent with conditions observed from HEN-P006 and normal water levels in the Illinois River.

For the CCR retained within the EAP, a water level of El. 490 ft was conservatively selected to represent the pre-closure normal pool level. Actual water levels within the EAP are expected decrease during closure due to dewatering and due to a reduction in infiltration caused by installation of the final cover system.

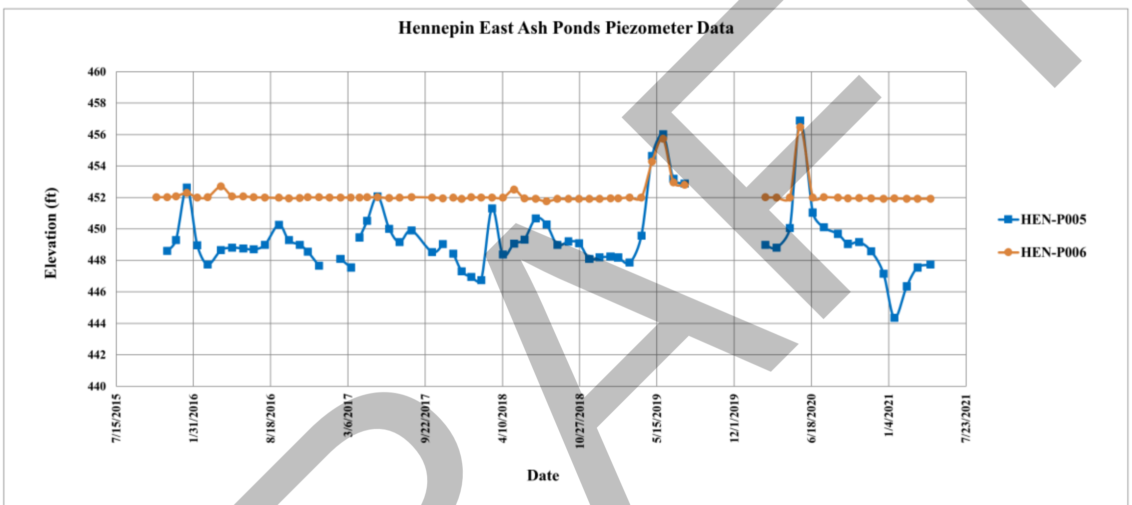

Figure 3 – EAP Piezometer Data

6. SEISMIC ASSESSMENTS

Site Seismic Hazard Assessment

AECOM evaluated seismic hazards at the site using published United States Geological Survey (USGS) data for the 2% probability of exceedance in 50-years (2,500-yr return period) seismic event. The bedrock acceleration, 0.073g, was then used in conjunction with the seismic site classification of D to estimate a site-class amplified ground surface acceleration of 0.119 g. AECOM then estimated a peak transverse acceleration at the crest of the dike of 0.35 g and a pseudostatic seismic coefficient of 0.119g. Geosyntec reviewed AECOM's seismic hazard assessment and generally agreed with the approach. Additional details regarding AECOM's seismic hazard assessment [1] is provided in **Attachment A**.

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Liquefaction Triggering Analysis – Dike and Foundation Soils

AECOM noted that saturated, cohesionless soils were not encountered within the dikes of the EAP, and therefore the dikes were not susceptible to liquefaction. AECOM also evaluated the potential for liquefaction in the foundation soils by comparing ranges in SPT blow counts (17 to 85 blows per foot and 53 as a mean), comparing them to liquefaction case histories published by Idriss and Boulanger [3], and finding that SPT blow counts were well above any case history where liquefaction was identified. AECOM then concluded that liquefaction of the foundation soils was unlikely to occur at the EAP [1]. Geosyntec reviewed AECOM's liquefaction triggering analysis and generally agreed with the approach. Additional data on the liquefaction triggering analysis is provided in **Attachment A**.

Liquefaction Triggering Analysis – Retained CCR

The potential for the liquefaction of retained CCR within the EAP was not evaluated by AECOM, as the material was not present within the dikes or foundation soils of the EAP and evaluation was therefore not required by the CCR Rule [4]. However, the potential for liquefaction of the retained CCR should be considered for closure, as the CCR will be supporting the final cover system and the dikes will be retaining CCR.

Geosyntec conservatively assumed that saturated CCR will be susceptible to liquefaction under post-closure conditions. A lower-bound post-liquefaction residual strength ratio (S_r/σ'_{vo}) of 0.05 was assigned for the CCR, based on Geosyntec's experience.

7. GLOBAL SLOPE STABILITY

Global slope stability analyses for the post-closure EAP were performed using limit-equilibrium SLOPE/W software [5], to calculate the factor of safety (FoS) of the perimeter dikes of the EAP against global instability. Slope stability analyses utilized the Spencer's method [6] and evaluated circular slip surface defined using the entry-exist method, with each critical slip surface being optimized into a non-circular slip surface. Factors of safety were calculated for the following loading conditions:

> <u>End-of-Construction Static Conditions</u>: This loading condition corresponds to the stability of the post-closure EAP dikes immediately after construction of the closure is completed. Peak undrained material properties are used for all cohesive materials, as pore pressures induced by construction may not yet have dissipated. Peak drained material properties are used for all free-draining materials, as these materials are assumed to dissipate pore pressures concurrently with loading. The minimum acceptable FoS for this loading condition is 1.30, per the USEPA CCR Rule [4] and the Illinois Part 845 Rule [7].

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<u>Long-Term Static Conditions</u>: This loading condition corresponds to the stability of the post-closure EAP dikes under long-term, normal operating conditions with estimated static groundwater levels. Drained material properties, representing effective stress conditions, are used for all materials, as this condition corresponds to static conditions without the application of pore-pressure inducing loads. The minimum acceptable FoS for this loading condition is 1.50, per the USEPA CCR Rule [4] and the Illinois Part 845 Rule [7].

<u>Pseudostatic Seismic Conditions</u>: This loading condition corresponds to the stability of the EAP dikes under short-term seismic shaking conditions. This loading condition assumed peak drained strengths in all free-draining materials (CCR, road fill, and alluvial foundation) and was checked with both peak drained and peak undrained strengths in the embankment fill and liner materials, in order to evaluate the sensitivity of the analysis to two separate material parameter assumptions. The seismic loads are modeled as an outward-acting horizontal force of 0.119 g, as discussed in **Section 6**. The minimum acceptable FoS for this loading condition is 1.00, per the USEPA CCR Rule [4] and the Illinois Part 845 Rule [7].

<u>Post-Earthquake Conditions</u>: This loading condition corresponds to the stability of the EAP dikes and final cover surface immediately following a seismic event. This loading condition assumed peak drained strengths in all non-liquified free-draining materials (unsaturated CCR, road fill, and alluvial foundation), residual liquefied shear strengths in saturated CCR (below El. 490 ft) and was checked with both peak drained and peak undrained strengths in the embankment fill and liner materials, in order to evaluate the sensitivity of the analysis to two separate material parameter assumptions. It should be noted that this loading condition is not expressly required by the USEPA CCR Rule [4] and the Illinois Part 845 Rule [7], as liquefaction-susceptible materials are not present within the dikes or foundations of the EAP. However, this condition was checked to evaluate the mass stability of the EAP dikes and final cover system, as saturated CCR may remain beneath the final cover system and retained by the dikes of the EAP under post-closure conditions, and liquefaction could potentially occur in this material. A minimum acceptable FoS of 1.20 was assumed. This is equal to the USEPA CCR Rule [4] and the Illinois Part 845 Rule [7] loading condition where liquefaction-susceptible materials are present within the dike of a CCR surface impoundment.

It should be noted that flood loading conditions (e.g., maximum storage pool [4], [7]) were not evaluated as closure of the EAP will remove the ability of the EAP to retain water. Therefore, this loading condition will not be appliable.

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All slope stability analyses include proposed post-closure grades within the EAP and the estimated long-term groundwater levels of El. 490 ft in the CCR and El. 452 ft in foundation soils (see **Section 5**). The static water level in the Polishing Pond was conservatively assumed as empty, thereby resulting in no stabilizing water force on the downstream embankment of the EAP. This assumption as made because the water level in the pond may vary during and after construction, based on site precipitation and other factors.

Subsurface material interfaces at each cross-section were developed using available boring data (**Section 3**), including interpolations between borings using available historic data [1] and engineering judgment.

Selected Cross-sections

Geosyntec reviewed the cross-sections previously selected for the Initial SFA and generally agreed with AECOM's findings [8]. AECOM selected two cross-sections for analysis of the EAP (SL-10 and SL-12), with cross-section SL-10 located along the west dike of the EAP and cross-section SL-12 located along the east dike, as shown in **Figure 1**. The cross-sections were selected based on critical subsurface geometry and subsurface conditions and were considered the critical cross-sections for the EAP. Cross-sections were not evaluated along the north and south dikes and grades were essentially flat or sloped inward into the EAP. Geosyntec utilized the AECOM cross-sections, including subsurface stratigraphy and material layering developed by AECOM based on AECOM's borings completed at the site [1]. Cross-sections were modified by Geosyntec to include critical post-closure grades (consisting of highest cover system slopes along each side of the EAP), the final cover materials, and assumed post-closure groundwater conditions.

Results

The results of each of the design scenarios is presented in **Table 2**. Each calculated factor of safety exceeds minimum acceptable values. The output from SLOPE/W is provided in **Attachment C** for each of the design scenarios and Sections.

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Table 2. Results of Stability Analyses

Loading Condition	Minimum Factor of Safety	Results		Pass/ Fail
		SL-10	SL-12	
End-of-Construction	1.30	8.94	3.65	PASS
Long-Term Static	1.50	2.35	2.74	PASS
Pseudostatic Seismic – Drained Embankment and Liner	1.00	1.76	1.90	PASS
Pseudostatic Seismic – Undrained Embankment and Liner	1.00	5.04	2.35	PASS
Post-Earthquake – Drained Embankment and Liner	1.20	2.35	2.74	PASS
Post-Earthquake – Undrained Embankment and Liner	1.20	8.93	3.65	PASS

8. VENEER COVER STABILITY

Veneer stability refers to the shallow, translational stability of the cover system and each material interface within the cover system. The cover system will include, from bottom to top, a CCR subgrade, a geomembrane low permeability layer, 1.5 ft of cover soil, and 0.5 ft of topsoil capable of sustaining vegetation. Veneer stability calculations were performed to evaluate the factor of safety against sliding between each of the material interfaces within the final cover system. Material interfaces within the cover system include, from top to bottom:

- Geotextile against the cover soil;
- Geotextile against the 40-mil geomembrane low-permeability layer; and
- CCR subgrade against the geomembrane low-permeability layer.

Veneer stability for static loading conditions was evaluated following published methodology [9]. Two final cover system slopes were evaluated at the site and represent critical veneer stability sections, based on the maximum height of 2.5% slope (Slope A) and maximum height of 20% slope (Slope B). The evaluated slopes are listed in **Table 3** and shown in plan in **Figure 4**.

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Table 3 – Slopes Evaluated for Veneer Stability

Slope	Grade	Height (ft)	Length (ft)	Crest Elevation (ft)
Slope 1	2.5% (40H:1V)	6	233	505.5
Slope 2	20% (5H:1V)	10	48	503.0

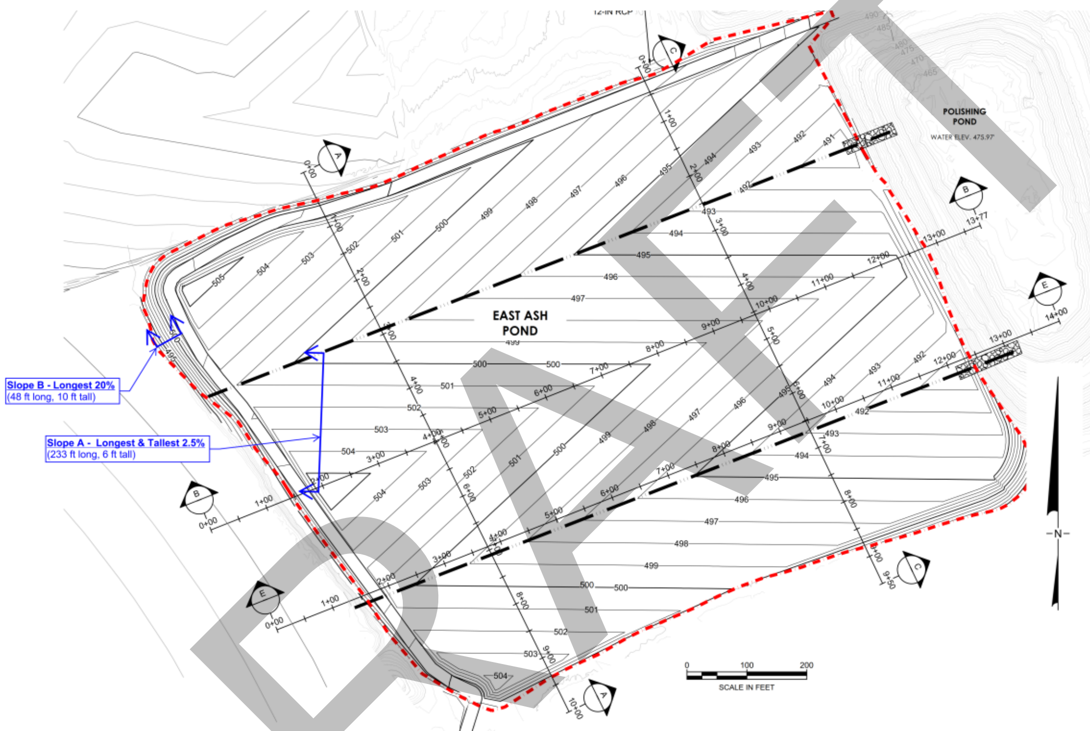

Figure 4 – Veneer Stability Slope Locations

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Interface friction angles and adhesion values were taken from results of site-specific laboratory interface friction testing data (ASTM D5321) performed by Geosyntec for the closure of the Old West Ash Pond (OWAP) at the Hennepin Power Plant. Materials tested by Geosyntec included granular cover soil to a 16-ounce nonwoven geotextile, the 16-ounce nonwoven geotextile to a 40-mil textured liner low density polyethylene (LLDPE) geomembrane, and the 40-mil textured LLDPE geomembrane to the CCR subgrade soils and granular soil [10]. Similar materials will be utilized for the final cover system at the EAP; therefore, it is appropriate to use this data for the veneer stability assessment. The resulting interface friction data is provided in **Table 4** and interface testing data is provided in **Attachment D**.

Table 4 – Interface Friction Data

Material (Top to Bottom)	Peak		Large Displacement	
	Friction Angle (degrees)	Interface Adhesion (psf)	Friction Angle (degrees)	Interface Adhesion (psf)
Clay Cover Soil Skaps Nonwoven Geotextile GE116 Skaps 40 mil LLDPE Textured Geomembrane CCR	27.8	81	17.1	0
Sand and Gravel Cover Soil Skaps Nonwoven Geotextile GE116	26.9	102	27.5	77
Sand and Gravel Cover Soil Skaps 40 mil LLDPE Textured Geomembrane	25.3	51	18.9	0
Design Parameters for EAP	**25.3**	**51**	**17.1**	**0**

Analyses were performed for the lower interfaces (one single analysis considering sliding along the subgrade against geomembrane liner, geomembrane liner against geotextile, and geotextile against cover soil), as the effective stresses would be the same for all three interfaces. Each analyzed loading condition is described below:

> Normal Static Conditions: This analysis considers the stability of the cover system under normal, static, steady-state operating conditions. The cover system soil is assumed to be unsaturated, and 0.25 inches of water is present within the geotextile, which corresponds to a full thickness of water within a geotextile. The minimum acceptable FoS for this condition is 1.5, as recommended by Koerner and Soong [11]. Peak interface shear strength data was used for this condition.

> Saturated Conditions: This analysis considers the stability of the cover system under static, saturated operating conditions that could potentially occur after a rainfall event that results in the entire cover system becoming fully saturated with two feet of water present (full cover soil thickness). Because this is a temporary condition and is expected to only occur after a significant rainfall event, a minimum acceptable FoS for this condition of 1.2 was selected for design. No regulatory guidance in Part 845 or the CCR Rule is available for this loading condition. Peak interface shear strength data was used for this condition.

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Seismic Conditions: Veneer stability for seismic conditions was calculated following Matasovic (1991), for the same slope orientations as the static veneer analyses. Saturated conditions were not considered for the seismic analyses as the likelihood of a significant rainfall event occurring at the same time as a seismic event is low. A pseudostatic seismic coefficient of 0.078 g was selected for analysis, which is 65% of the site-class amplified peak ground acceleration of 0.119 g, as recommended by Matasovic [12]. The minimum acceptable factor of safety for this condition is 1.0, also as recommended by Matasovic. Peak interface shear strength data was used for this condition.

Post-Earthquake Conditions: This analysis considers the stability of the final cover condition under conditions immediately after a seismic event, when seismic shaking has stopped. Saturated conditions were not considered for the seismic analyses as the likelihood of a significant rainfall event occurring at the same time as a seismic event is low. The minimum factor of safety for this condition was assumed to be 1.2, which corresponds to the USEPA CCR Rule [4] and Illinois Part 845 [7] regulatory guidance for global dike stability. The residual, large-displacement friction angle was used for this condition, to account for reduced post-peak shear strengths that may be induced by seismic shaking.

Resulting veneer stability factors of safety are provided in **Table 5.** Each calculated factor of safety exceeds minimum acceptable values. Calculation output data is provided in **Attachment E**.

Table 5 – Veneer Stability Analysis Results

Loading Condition	Minimum Factor of Safety	Results		Pass/ Fail
		Slope A	Slope B	
Normal	1.5	32	3.8	PASS
Saturated	1.2	19	2.4	PASS
Seismic	1.0	6.8	2.5	PASS
Post-Earthquake	1.2	16	1.8	PASS

9. SETTLEMENT ANALYSES

The EAP is underlain by highly permeability sand and gravel materials (see **Section 3**). Settlement in these materials is expected to occur elastically and essentially immediately after stresses increased induced by fill placement or dewatering occur. CCR within the EAP may also be susceptible to settlement. However, based on Geosyntec's experience, CCR also rapidly settles, and settlement is expected to occur concurrently with fill placement and dewatering. Therefore, there is expected to be a negligible amount of post-closure settlement at the EAP. While settlements will occur in the CCR and alluvial foundation soils, they are expected to occur concurrently with construction and will be

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mitigated by placing additional fill, as needed to reach design grades. Consequently, a formal settlement analysis for closure of the EAP was not performed as post-construction settlements are expected to be negligible.

10. CONCLUSIONS

The calculations presented in this report demonstrate that the proposed closure plan for the East Ash Pond at the Hennepin Power Plant provides sufficient geotechnical dike stability, exceeding minimum acceptable factors of safety, for end-of-construction, long-term static, seismic, and post-earthquake loading conditions. Additionally, the cover system veneer stability exceeds minimum acceptable factors of safety for static, saturated, seismic, and post-earthquake conditions. Lastly, closure-induced settlements are expected to occur during construction and negligible post-closure settlements are expected.

11. REFERENCES

[1] AECOM, "Geotechnical Report, Hennepin Power Station, East Ash Pond," St. Louis, Missouri, October 7, 2016.

[2] Geosyntec Consultants, "Illinois Administrative Code, Part 845 Data Gap Analysis, Hennepin Power Plant, East Ash Pond - CCR Unit 8-3," Chesterfield, Missouri, July 29, 2021.

[3] I. Idriss and R. Boulanger, "Soil Liquefaction During Earthquakes," Earthquake Engineering Reserach Institute, Oakland, California, 2008.

[4] United Stated Environmental Protection Agency, "40 CFR Parts 257 and 261, Hazardous and Solid Waste Management System, Disposal of Coal Combustion Residuals from Electric Utilities, Final Rule, 2015," 2015.

[5] GeoSlope International, "GeoSudio 2012, August 2015 Release, Version 8.15.6.13446," Calgary, Alberta, Canada, 2015.

[6] E. Spencer, "A Method fo Analysis of The Stability of Embankments Assuming Parallel Interslice Forces," *Geotechnique,* vol. 17, pp. 11-26, 1967.

[7] Illinois Environmental Protection Agency, "35 Ill. Adm. Code Part 845, Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments," Springfield, IL, 2021.

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[8] Geosyntec Consultants, "2021 USEPA CCR Rule Periodic Certification Report, §257.73(a)(2), (c), (d), (e), and §257.82, East Ash Pond, Hennepin Power Plant, Hennepin, Illinois," Chesterfield, Missouri, October 11, 2021.

[9] Giroud and B. R. B. R. J.P., "Influence of Water Flow on the Stability of Geosynthetic-Soil Layered Systems on Slopes," *Geosynthetics International*, vol. 2, no. 6, pp. 1149-1180, 1995.

[10] Geosyntec Consultants, "Draft Construction Certification Report, Closure of the Old West Ash Pond and Old West Polishing Pond, Hennepin Power Station, Hennepin, Illinois," Chesterfield, MIssouri, March 25, 2021.

[11] R. S. T. Koerner, "Analysis and Design of Veneer Cover Soils," in *Proceedings: Sixth International Conference on Geosynthetics, Industrial Fabrics Association International*, St. Paul, Minnesota, 1998.

[12] N. Matasovic, "Selection of Method for Seismic Slope Stability Analysis," in *Proceedings: Second International Conference on Recent Advances in Geotechnical Engineering and Soil Dynamics*, St. Louis, Missouri, 1991.

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APPENDIX A

2016 AECOM Geotechnical Report

AECOM
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314.429.0100 tel
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October 7, 2016

Mr. Matt Ballance, PE
Senior Project Engineer
Dynegy Inc.
1500 Eastport Plaza Drive
Collinsville, Illinois 62234

RE: Geotechnical Report
Hennepin Power Station
East Ash Pond

Dear Mr. Ballance:

AECOM is pleased to provide this Geotechnical Report for the Dynegy Midwest Generation, LLC (DMG) East Ash Pond Coal Combustion Residuals (CCR) unit at the Hennepin Power Station located in Hennepin, Illinois. This Geotechnical Report has been prepared to document the analysis performed to check that the facility meets the geotechnical slope stability requirements including Factors of Safety required by 40 CFR § 257.73.

AECOM looks forward to providing continued support to DMG and working together on this important program. Please do not hesitate to call Ron Hager at 314-429-0100 (office) / 440-591-7868 (mobile), if you have any questions or comments on this Geotechnical Report.

Sincerely,

AECOM

Jeremy Thomas, PE
Site Manager
jeremy.thomas@aecom.com

Ronald Hager
Program Manager
ronald.hager@aecom.com

cc: Mark Rokoff, PE – AECOM

Attachments:

A. Figures
B. Boring Logs
C. Piezometer Logs
D. CPT Data Report
E. Laboratory Test Data
F. Material Characterization Calculations
G. Slope Stability Analysis

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1. INTRODUCTION

1.1. Purpose of This Report

This report presents the results of the geotechnical analyses prepared by AECOM for the Dynegy Midwest Generation, LLC (DMG[1]) East Ash Pond Coal Combustion Residuals (CCR) unit at the Hennepin Power Station in Hennepin, Illinois (see **Figure 1, Attachment A** for Location Map). The purpose of the geotechnical investigation and analyses performed is to evaluate the design, performance, and condition of the impoundment and associated structures using the data collected from surface and subsurface investigations, available design drawings, construction records, inspection reports, previous engineering investigations, and other pertinent historical documents provided to AECOM by DMG. This information was then used to evaluate the design and operation of the surface impoundment against the regulatory standards set in 40 CFR § 257.73.

The geotechnical field exploration was conducted between September 1 and October 21, 2015. The field program consisted of conventional hollow-stem auger and mud rotary borings, Standard Penetration Testing (SPT), Cone Penetration testing (CPT), and piezometer installation. Laboratory testing was conducted on the materials obtained through various sampling techniques to assist in characterization of the subsurface conditions, especially with respect to defining material parameters for use in stability analyses. Stability analyses were performed by AECOM to evaluate the potential for slope instabilities, in accordance with the Environmental Protection Agency (EPA) regulation 40 CFR § 257.73(d) and (e).

A summary or the geotechnical field program, laboratory testing program, and stability evaluations are presented herein. Detailed interpretations, calculations, and presentation of analysis results are provided in the Attachments to this report.

1.2. Description of Impoundment

The Hennepin Station has one active CCR surface impoundment, the East Ash Pond, which receives sluiced bottom ash, fly ash, boiler slag, and plant process water. The East Ash Pond is approximately 21 acres in size and is contained by an earthen perimeter embankment that forms the exterior of the CCR unit on all but the south side, where the East Ash Pond is bordered by high natural ground.

A site specific aerial and bathymetric survey of the East Ash Pond was completed by Weaver Consultants Group in September of 2015. The survey is spatially referenced to the Illinois NAD 1983 State Plane West, Zone 12020. Elevations are in feet and referenced to the North American Vertical Datum 1988 (NAVD88). Coordinates and elevations in this report are referenced to NAD83 and NAVD88, respectively, unless otherwise stated.

The north side of the East Ash Pond is bordered by the inactive Ash Pond No. 2 and the Hennepin Landfill. The crest of the Hennepin Landfill is at an elevation slightly higher than the East Ash Pond embankment. To the northeast and east of the East Ash Pond are the East Leachate Pond and the East Polishing Pond, respectively, both of which are non-CCR impoundments and are located at lower elevations than the East Ash Pond. The plant operations sluice bottom ash into the East Ash Pond for particle settling before being discharged downstream to the East Leachate Pond.

[1] Although the Hennepin Power Station and the East Ash Pond are owned and operated by DMG, Dynegy Administrative Services Company (*Dynegy*) contracted AECOM to develop this geotechnical report on behalf of DMG. Therefore, "Dynegy" is referenced in materials attached to this geotechnical report.

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The East Ash Pond also utilizes a secondary outflow to the East Polishing Pond. The south side of the East Ash Pond is bordered by natural high ground. The west side is bordered by the former East Ash Pond No. 4.

According to the “Modification to Primary Ash Pond” design drawings, the perimeter embankment was raised from an elevation of 483 feet to the current elevations from 494 to 500 feet in the early 2000’s. The original East Ash Pond included an interior liner system consisting of a 4-foot thick compacted clay layer (design permeability of $1.0x10^{-7}$ centimeters per second) overlying a 1-foot thick sand drainage layer under the pond footprint. During the perimeter embankment raise, the liner system was extended from El. 480 feet (top of the original liner) to El. 494.0 feet using, from bottom to top, an 8-ounce polypropylene geotextile, 1-foot of compacted clay, and a double-layer of 45-mil polypropylene geomembrane. The raised East Ash Pond embankment is composed primarily of compacted clay fill materials with a gravel crest access road (described further in **Section 3.1**).

Embankment height on the west and east sides range from approximately 16 to 36 feet, as referenced to the downstream toe. The downstream embankment slope between the East Ash Pond and East Ash Pond No. 4 is approximately 3.5H:1V. The slope between the East Ash Pond and the East Polishing Pond is approximately 4H:1V. Embankment crest widths range from approximately 18 feet to 19 feet along the west and east sides of the East Ash Pond..

The site location and vicinity map are included in **Attachment A**.

2. SUMMARY OF FIELD INVESTIGATIONS

A subsurface exploration was performed at the Hennepin East Ash Pond, including 4 soil borings, installation of 2 piezometers, and 6 cone penetration test (CPT) soundings with shear wave velocity measurements and pore pressure dissipation (PPD) testing. Two of the CPT soundings were performed within the adjacent inactive East Ash Pond No. 2 to characterize behavior of the impounded CCR materials. The borings were drilled by AECOM's subcontractor Strata Earth Services, LLC of Palatine, IL, under the full-time supervision of AECOM geotechnical personnel. Strata Earth Services used a truck-mounted Mobile B-57 drill rig in conjunction with 3¼-inch inner diameter hollow stem augers with mud rotary methods as needed to drill the borings. CPT soundings were performed by AECOM's subcontractor ConeTec, Inc. of Charles City, Virginia, again with full-time oversight by AECOM personnel.

Borings extended to a predetermined depth of 41.5 feet, within alluvial sand and gravel present beneath the East Ash Pond and CPT depths varied based on refusal from approximately 11 to 29.5 feet below existing grades. Piezometers were installed in un-sampled boreholes, with drilling bottom-of-boring depths of 50 and 55 feet, in order to gather phreatic data in the alluvial sand and gravel layer. Approximate boring, piezometer, and CPT sounding locations are depicted on **Figure 2** in **Attachment A**. Logs of the borings are presented in **Attachment B**. Logs of the CPT soundings are presented in **Attachment D**, and piezometer logs are presented in **Attachment C**. Locations of borings and CPTs, as surveyed by Weaver Consultants in 2015, are summarized in **Table 1**.

Representative soil samples were collected from each of the borings for classification and/or testing. The soil samples were obtained by SPT with a split-spoon sampler, in accordance with ASTM D 1586. Undisturbed samples of fine-grained soils were obtained using 3-inch outside diameter steel (Shelby) tubes conventionally pushed in accordance with ASTM D 1587. Results of the laboratory testing are presented in **Attachment E**.

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Table 1
Boring and CPT Exploration Location Data

Exploration ID	Easting (ft NAD83)	Northing (ft NAD83)	Elevation (ft NAVD88)
Auger Borings			
HEN-B029	2533022	1689436	499.7
HEN-B030	2533585	1690015	495.4
HEN-B032	2534055	1689837	494.3
HEN-B034	2533831	1689246	499.3
CPT Soundings			
HEN-C029	2533022	1689436	499.6
HEN-C030	2533582	1690014	495.3
HEN-C032	2534055	1689837	494.3
HEN-C032B[1]	2534056	1689838	494.0
HEN-C034	2533831	1689245	499.4

1. Location of HEN-CO32B was not surveyed as the CPT could not be located in the field. Locations are approximated based on handheld GPS measurements taken during investigation. The elevation for this boring is based on site topographic survey data from Weaver Consultants Group in September of 2015. The accuracy of this measurement is assumed to be approximately ±5 feet horizontal and ±1 foot vertical.

3. SUMMARY OF SITE-SPECIFIC SUBSURFACE CONDITIONS

3.1. *Site Stratigraphy*

Road Fill Materials: An access road surrounds the perimeter of the East Ash Pond. The material is primarily comprised of silty sand. The relative density of the road fill measured by the standard penetration test was very dense.

Embankment Fill: The perimeter embankment of the East Ash Pond was constructed in two stages, with an original embankment and a later raise constructed on top of the original. According to the "Modification to Primary Ash Pond" design drawings, this raise was completed in the early 2000s, raising the dike crest from an original elevation around 483 feet to the current elevations ranging from 494 to 500 feet. As indicated by the CPT logs, the new dike section was constructed primarily with clayey silt and clay, although some zones of sand and gravel were also noted, as well as limited amounts of CCRs. The consistency of the fill, as measured by uncorrected SPT N-values and pocket penetrometer tests, ranged from stiff to hard. Per construction drawings, the fill material was to be compacted to 95 percent (minimum) ASTM D698. Historical compaction records for the fill material were not available, but current field data were generally indicative of well-compacted materials.

Alluvial Foundation: Alluvial foundation materials, consisting primarily of sand and gravel with varying amounts of silt and clay were encountered in the borings drilled around the perimeter of the Hennepin East Ash Pond. The relative density of the alluvial foundation as measured by the standard penetration test ranged from medium dense to very dense.

Fly Ash (Impounded CCR Materials): Borings and CPTs were not performed within the footprint of the East Ash Pond to minimize any risk of compromising the existing liner system. Material properties for the CCRs in the East Ash Pond (assumed to be fly ash and bottom ash) were estimated based on data obtained from CPT soundings in CCR materials encountered in East Ash Pond No. 2. CPT correlations indicated soil behavior types corresponding to silt and sand with some gravel and clay.

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Liner System: Per the “Modification to Primary Ash Pond” record drawings, the East Ash Pond has a 4-foot thick compacted clay liner on the bottom and side slopes of the pond. Under the clay liner is a 6-inch thick sand filter layer on the bottom of the pond and 12-inch thick sand layer on the side slopes of the pond. The liner was extended during the dike raise using, from top to bottom, a 8-ounce polypropylene geotextile, 1 foot of compacted clay, and a 45-mil polypropylene geomembrane. CPTs and borings were not performed within the lined area, to avoid puncturing the liner and construction documentation data was not available, therefore material properties for the liner system were estimated based on typical published values and AECOM’s experience.

Bedrock: Bedrock was not encountered in the soil borings. It was estimated that bedrock is greater than 100 feet below the ground surface based on AECOM borings completed within the vicinity in 2015.

Specific information used to assess and develop the design site stratigraphy can be found in **Attachment B** – Boring Logs, **Attachment D** – CPT Data Report, and **Attachment E** – Laboratory Test Data.

3.2. Phreatic Water Conditions

AECOM evaluated piezometer data from five measurement events (10/27/15, 11/24/15, 12/17/15, 1/14/16, and 2/10/16) and borehole phreatic water depths measured immediately after drilling. Piezometer readings were judged to be the most representative of in-situ, steady state phreatic conditions. Saturated conditions did not appear to be encountered during CPT soundings surrounding the Hennepin East Ash Pond or in any of the other soil borings, other than a saturated pocket in boring HEN-B030 at 33 feet.

A total of two standpipe piezometers were installed for the Hennepin East Ash Pond. The two piezometers were installed through the perimeter embankment with the screened elevations located within the alluvial foundation soils.

Refer to **Table 2** for the piezometer locations and phreatic data.

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Table 2
Piezometer Location and Water Level Data

PZ No.	Embankment	Northing[1] (NAD83 feet)	Easting[1] (NAD83 feet)	Ground Surface Elevation[1] (NAVD88 feet)	Location	PZ Type[2]	Total Depth[3] (ft)	Phreatic Surface Elevation (NAVD88 feet)				
								10/27/2015	11/24/2015	12/17/2015	1/14/2016	2/10/2016
HEN-P006	North	1690015	2533585	495.4	Crest	OSP_{stick}	43.7	452.1	452.1	452.2	452.4	452.1
HEN-P007	East	1689837	2534055	494.3	Crest	OSP_{flush}	47.4	450.7	449.4	449.7	452.8	449.3

Notes:

1. Piezometer locations based on adjacent surveyed SPT boring locations. Actual piezometer locations were not surveyed. Accuracy is assumed to be +/- 5 feet horizontal and +/- 1 foot vertical.
2. OSP = open standpipe piezometer.
3. Total Depth = Approx. bottom of screen for standpipe piezometers.

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4. SUMMARY OF LABORATORY TESTING

4.1. Summary of Laboratory Testing Scope

Soil samples collected from the subsurface exploration were sealed at the site and transported to AECOM's laboratory testing subcontractor, Terracon of Vernon Hills, Illinois, where an AECOM geotechnical engineer reviewed and selected samples for laboratory testing. The laboratory testing program performed for the East Ash Pond was intended to obtain information on index properties and shear strength parameters of the subsurface materials at the site. The laboratory testing program for characterization of the materials at the East Ash Pond is summarized in **Table 3**.

Table 3
Summary of Laboratory Testing Program for Hennepin East Ash Pond

ASTM Designation	Test Type	Number of Tests				
		Total	Road Fill	Embankment Fill	Alluvial Foundation	Other Materials
D2216	Moisture Content	45	5	16	22	2
D4318	Atterberg Limits	3	-	3	-	-
T311[1], D1140, D422	Gradation / Hydrometer	6	1	-	5	-
D854	Specific Gravity	3	-	2	1	-
D5084	Hydraulic Conductivity	0	-	-	-	-
D2435	Consolidation	1	-	1	-	-
D 2166	Unconfined Compression	1	-	1	-	-
D4767	Consolidated Undrained Triaxial (CIU)	1	-	1	-	-
D6528	Direct Shear (DS)	1	-	1	-	-

[1] American Association of State Highway and Transportation Officials (AASHTO) test designation

4.2. Summary of Laboratory Testing Results

A summary of laboratory test results for the identified material horizons with the exception of the impounded CCR materials at the Hennepin East Ash Pond are presented in **Tables 4, 5** and **6**, respectively. Laboratory test data is included in **Attachment E**. Graphical displays of the shear strength characterization for the stratigraphic materials are included in the Material Characterization Calculation Package in **Attachment F**.

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Table 4
Summary of Laboratory Test Results – Road Fill

Boring Number	Sample Number	Depth (feet)	USCS[1]	WC%[2]	% Gravel	% Sand	% Silt	% Clay
HEN-B029	S-1	0.0-1.5		4.7				
HEN-B030	S-1A	0.0-1.5		7				
HEN-B030	S-2	2.5-4.0	SM	6.4	34	45.7	11	9.3
HEN-B032	S-1A	0.0-1.0		2.7				
HEN-B034	S-1A	0.0-0.5		4.2				

Table 5
Summary of Laboratory Test Results –Embankment Fill

Boring Number	Sample Number	Depth (feet)	USCS[1]	WC%[2]	LL[3]	PL[4]	PI[5]	Specific Gravity	Direct Shear	
									c' (psf)[6]	phi' (deg)[7]
HEN-B029	S-2	2.5-4.0		14.7						
HEN-B029	S-3	5.0-7.0	CL	10.8	22	15	7			
HEN-B029	S-4	7.0-8.5		14.8						
HEN-B029	S-5	10.0-12.0	CL	16.7	31	17	14		62.2	31.8
HEN-B029	S-6	15.0-16.5		21.7						
HEN-B030	S-3	5.0-6.5		11.5				2.746		
HEN-B030	S-4	7.5-9.0		17.1						
HEN-B030	S-5	10.0-11.0		18.1						
HEN-B030	S-7	21.5		23.9						
HEN-B032	S-1B	1.0-1.5		7.9						
HEN-B032	S-2	2.5-4.0		9.7						
HEN-B032	S-3	5.0-7.0	CL	14	35	18	17			
HEN-B032	S-4	7.5-9.0		16.7						
HEN-B032	S-5	10.0-11.5		16.2						
HEN-B032	S-9	30.0-31.5		10.6						
HEN-B034	S-1B	0.5-1.5		9.1						
HEN-B034	S-2	2.5-4.0		14.2				2.704		
HEN-B034	S-3A	5.0-5.5		15.9						

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Table 6
Summary of Laboratory Test Results – Alluvial Foundation

Boring Number	Sample Number	Depth (feet)	USCS[1]	WC%[2]	% Gravel	% Sand	% Silt	% Clay	Specific Gravity
HEN-B029	S-7	20.0-21.5		11.5					
HEN-B029	S-8	25.0-26.5		8.8					
HEN-B029	S-9	30.0-30.9		12.7					
HEN-B029	S-10	35.0-36.5	GP-GC	13.8	61	26			
HEN-B029	S-11	40.0-41.5		4.6					
HEN-B030	S-6	15.0-16.5	GW	17.6	81.4	14.8			
HEN-B030	S-8	25.0-26.5		11.2					
HEN-B030	S-10	35.0-36.5		8.9					
HEN-B030	S-11	40.0-41.5		9					
HEN-B032	S-6	15.0-16.5		8.2					
HEN-B032	S-7	20.0-21.5	SM	11.1	30.5	43.6	13.4	12.5	
HEN-B032	S-8	25.0-26.5		9.1					
HEN-B032	S-10	35.0-36.5		5.5					
HEN-B032	S-11	40.0-41.3		10.9					
HEN-B034	S-3B	5.5-6.5		1.4					
HEN-B034	S-4	7.5-9.0		2.5					
HEN-B034	S-5	10.0-11.5	GP-GM	11.2	60.1	27	7.7	5.2	
HEN-B034	S-6	15.0-16.5		9.1					2.808
HEN-B034	S-7	20.0-21.5		12.5					
HEN-B034	S-9	30.0-31.5		13.6					
HEN-B034	S-10	35.0-36.5	GP-GM	10.9	82.8	11.3			
HEN-B034	S-11	40.0-41.5		1.5					

Notes:
[1]USCS = Unified Soil Classification System
[2] WC% = Water Content (percent)
[3]LL = Liquid Limit
[4]PL = Plastic Limit
[5]PI = Plasticity Index
[6]C’ = Cohesion
[7]Phi’ = Friction Angle

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5. SLOPE STABILITY ANALYSES

Slope stability analyses were performed for varying loading conditions at selected cross-sections, as described in the following sub-sections. Analysis section development, soil material properties, and seismic analyses related to the slope stability analysis are also discussed in the following sub-sections.

5.1. Cross-Sections for Analysis

Two cross sections were identified as representative cross sections for the stability evaluation of the East Ash Pond perimeter embankments. As the geometry and the foundation conditions underneath the East Ash Pond embankments were fairly uniform, sections were selected based primarily on the critical subsurface conditions and slope geometry (embankment height and slopes) along east and west sides of the East Ash Pond. Cross-sections were not analyzed along the north side of the East Ash Pond, as the grade is essentially flat beyond the East Ash Pond Dike, and therefore a slope is not present. Along the south side of the East Ash Pond, a dike is not present as the adjacent ground is sloping into the East Ash Pond, and an analysis was not performed. The location of each analysis section is listed in **Table 7** and shown on **Figure 2 (Attachment A)**.

Table 7
Cross-section Locations for Slope Stability Analyses

Cross-Section	Boring/CPT Numbers
SL-10	HEN-B029, HEN-C029
SL-12	HEN-B032, HEN-C032, HEN-C032B

The section geometry for each analysis cross-section was determined based on the site topographic survey data from Weaver Consultants Group in September of 2015, shown on **Figure 2 (Attachment A)**, and subsurface information from the borings and CPT soundings. Additionally, design drawings from the "1995 Ash Facility Hennepin Power Station" by Illinois Power Company (1993) and "Modification to Primary Ash Pond Hennepin Power Station" by Sargent & Lundy (2003) were used to supplement the subsurface investigation in developing the subsurface embankment geometry. The piezometric surfaces for each analysis section were determined based on the normal pool elevation of approximately 490.4 feet within the East Ash Pond and phreatic water level readings from the piezometers. The development of the analysis sections is discussed further in **Attachment G**.

5.2. Stability Analysis Conditions Considered

Consistent with the criteria provided in the USEPA CRR Rule § 257.73(e), the stability of the ash pond embankments was evaluated for four load cases:

Static, Steady-State, Normal Pool Condition*:* This case models the embankment under static, long-term conditions, at normal water level within the impoundment of El. 490.4 feet based on AECOM's *Hydrologic and Hydraulic Summary Report* for the Hennepin East Ash Pond (AECOM, 2016). Drained (effective stress) shear strength parameters were used for all materials, and phreatic conditions were estimated based on available piezometer data. ***Target Factor of Safety of 1.50.***

Static, Maximum Surcharge Pool Condition: This case models the conditions under short-term surcharge pool conditions, at a surcharge pool level within the impoundment of EL. 492.2 feet, based on AECOM's *Hydrologic and Hydraulic Summary Report* for the Hennepin East Ash Pond

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(AECOM, 2016). Drained (effective stress) shear strength parameters were used for all materials, as the change in pool elevation is temporary and fairly small, and is unlikely to initiate total stress mechanisms of failure. It was assumed that the temporary surcharge load did not alter the phreatic surface in the embankment or foundation, due to the presence of a liner system. Therefore, the phreatic surface was modeled equivalent to the steady state case. ***Target Factor of Safety of 1.40.***

Seismic Slope Stability Analysis: These analyses incorporate a horizontal seismic coefficient k_h selected to be representative of expected loading during the design earthquake event (i.e., a "pseudostatic" analysis). The analyses utilized peak undrained strengths for all materials. The pool elevation and phreatic conditions corresponding to the steady state pool from the static analyses were utilized for this analysis. ***Target Factor of Safety of 1.00***.

Post-Liquefaction Slope Stability Analyses: Soils susceptible to liquefaction were not identified in the embankment or foundation soils at the East Ash Pond. Therefore, post-liquefaction conditions were not evaluated.

5.3. Material Properties

Material properties for slope stability analyses were developed using laboratory testing data (index and strength testing) and strength correlations from CPT and SPT data. The material characterization and development of strength parameters is described further in **Attachment F**.

Unit weight for the embankment fill was evaluated using laboratory test results from relatively undisturbed samples. All other materials were conservatively assigned unit weights based on typical published values and previous experience with similar materials.

Effective (drained) shear strengths for the embankment fill layers were evaluated using results from the consolidated undrained triaxial (CIU) and direct shear (DS) tests, as well as correlations with SPT data. In general, when assigning lab tests, direct shear tests were assigned for deeper samples and CIU tests were assigned to shallower samples to match the assumed orientation of the slope stability slip surface.

Total (undrained) shear strengths were developed using CIU and unconfined compression (UC) tests for the embankment fill and fly ash, as well and published correlations for SPT data.

The material properties developed for use in the slope stability analyses are listed in **Table 8**.

Table 8
Material Properties for Slope Stability Analyses

Material	Unit Weight Above and Below WT (pcf)	Effective (drained) Shear Strength Parameters		Total (undrained) Shear Strength Parameters	
		c' (psf)	Φ' (°)	c (psf)	Φ (°)
Road Fill	130	0	38	0	38
Embankment Fill	105	30	32	2500	0
Alluvial Foundation	135	0	38	0	38
Fly Ash	105	100	27	600	0
Liner System	120	60	30	2500	0

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5.4. Methodology of Analyses

Limit equilibrium stability analysis was completed using the two-dimensional SLOPE/W 2012 (v. 8.15.4.11512 by GeoStudio) computer program. Factors of safety were calculated using Spencer's method utilizing circular search routines with optimization to develop non-circular sliding planes through lower-strength layers which may represent a lower factor of safety. Pore pressures were assigned as hydrostatic pressure under the piezometric line.

A brief summary of the analyses is presented in the following sections. A more detailed discussion is provided in **Attachment G**.

5.4.1. Static Analysis Conditions

Static stability was evaluated for steady-state phreatic conditions using both the normal pool elevation and the maximum flood surcharge pool elevation. Phreatic surfaces for impounded CCR materials in the stability models were developed utilizing a normal pool elevation of 490.4 feet and a maximum flood surcharge pool elevation of 492.2 feet. Phreatic surfaces for all non-impounded fill and native materials were modeled at elevations of 450 feet in cross section SL-12 and 452 feet in cross section SL-10, based on data form piezometers installed by AECOM.

5.4.2. Earthquake Analysis Conditions

Earthquake ground motions at the site were developed using simplified procedures, as described in the following sub-sections.

5.4.3. Determination of Ground Motion Parameters

Seismic ground motions were estimated using the United States Geological Survey (USGS) 2008 Interactive Deaggregation tool (http:earthquake.usgs.gov/hazards/apps/). This application generates acceleration values, including peak ground acceleration (PGA) for top of rock, and mean and modal moment magnitudes based on user entered values of location, exceedance probability, and spectral period. Results are computed based on the 2008 National Seismic Hazard Mapping Project (NSHMP) Probabilistic Seismic Hazard Analysis (PSHA) Seismic Hazard Maps.

For the Hennepin Power Station, the calculated PGA for an event with a probability of exceedance of 2% in 50 years (approximately a 2,500 year event) was 0.073g for top of hard rock. To estimate the free-field, ground surface horizontal acceleration, the site was classified according to the site classes defined in the International Building Code (2003) and amplified using the site amplification factors found in NEHRP (2009). The site class was determined based on the weighted average of the shear wave velocities of the upper 100 feet of the stratigraphic profile and found to be Site Class D (600 ≤ Vs ≤ 1,200 ft/sec). This corresponds to a NEHRP amplification factor of 1.6, resulting in a ground surface acceleration of 0.119g. The Peak Transverse Acceleration at the dike crest was estimated using the ground surface acceleration and the procedure proposed by Idriss (2015), resulting in a peak crest acceleration of 0.35g. Details of the estimation of ground motion parameters are included in **Attachment G**.

5.4.4. Seismic Coefficient

The seismic coefficient was calculated for use in the pseudo-static slope stability analysis based on the simplified procedure developed by Makdisi and Seed (1978). For the estimated peak crest acceleration value of 0.34g and full-height slip surfaces that were identified in the stability analyses

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(presented in **Attachment G**), a seismic coefficient of 0.119g was estimated for the pseudo-static analyses.

5.4.5. Liquefaction Triggering Analysis

Liquefaction is used to describe the contraction of coarse-grained (i.e. cohesionless) sand and gravel soils under cyclic loading imposed by earthquake shaking. The result is a reduction in the effective confining stress within the soil and an associated loss of strength (Idriss and Boulanger 2008). Liquefaction only occurs in saturated soils. Liquefaction susceptibility also largely depends on compositional characteristics such as particle size, shape, and gradation; however, laboratory and field observations also indicate that plasticity characteristics influence liquefaction susceptibility (Kramer 1996). Idriss and Boulanger (2008) suggested that soils with a plasticity index (PI) greater than about 7 are not susceptible to liquefaction.

AECOM's field exploration did not encounter saturated cohesionless soils in the embankment or foundation of the East Ash Pond. All cohesive soils encountered by AECOM were also unsaturated, and had PI's equal to or greater than 7, which means that neither the cohesive or cohesionless soils encountered in AECOM's field exploration are susceptible to liquefaction. However, AECOM's piezometers did indicate that the alluvial sand and gravel is typically saturated below El. 450 to 452 feet beneath the embankments, while the deepest SPT data collected by AECOM was at El. 452.8 feet. SPT blowcounts collected by AECOM in the alluvial sand and gravel between El. 470 and 452.8 feet ranges from 17 to 85 blows per foot, with a mean value of 53 blows per foot. Based on correlations provided in Idriss and Boulanger (2008), these blow counts are generally well above any case history where liquefaction was identified, meaning that the risk of liquefaction is low given the relatively low seismicity at the Hennepin Power Station and high observed blowcounts. Two SPT blowcounts, of 17 and 21, represent the lower-bound data for the alluvial sand, while most of the data is above 30 blows per foot. Consequently, a formal liquefaction analysis was determined unnecessary as the embankment and foundation soils at the site are not susceptible to liquefaction based on their composition, consistency, index properties, and observed saturation.

Due to the typically stiff nature of the compacted clay embankment fill, and relatively low seismicity at the site, the materials are also not susceptible to cyclic softening.

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6. RESULTS

6.1. Results of Static Stability Analyses

The results of the limit equilibrium slope stability analyses for the static load cases are summarized in **Table 9**. The SLOPE/W output figures showing the critical slip surfaces and details of the analyses are included in **Attachment G.1**.

Table 9
Summary of Minimum Slope Stability Factors of Safety for Static Load Cases

Load Case	Program Criteria	Cross-Section	
		SL-10	SL-12
Steady State (Normal Pool)	FS≥1.50	2.14	2.81
Surcharge Pool (Flood Pool)	FS≥1.40	2.14	2.81

6.2. ***Results of Earthquake Stability Analyses***

6.2.1. Slope Stability Analysis

The results of the slope stability analyses for the seismic load cases are summarized in **Table 10**. The SLOPE/W output figures showing the critical slip surfaces and details of the analyses are included in **Attachment G.1**.

Table 10
Summary of Minimum Slope Stability Factors of Safety for Earthquake Load Cases

Load Case	Program Criteria	Cross Section	
		SL-10	SL-12
Seismic (Pseudostatic)	FS ≥ 1.00	4.23	2.53

7. CONCLUSIONS

The calculated factors of safety from the limit equilibrium slope stability analysis satisfy the USEPA CCR Rule § 257.73(e) requirements for each loading condition at all of the analysis sections that represent the embankments of East Ash Pond at the Hennepin Power Station. Load cases analyzed for this study included static (steady-state) normal pool, maximum flood surcharge pool and seismic (pseudo-static).

8. LIMITATIONS

Background information, design basis, and other data have been furnished to AECOM by DMG. AECOM has used this data in preparing this report. AECOM has relied on this information as furnished, and is not responsible for the accuracy of this information.

Borings have been spaced as closely as economically feasible, but variations in soil properties between borings, that may become evident at a later date, are possible. The conclusions developed in this report are based on the assumption that the subsurface soil, rock, and phreatic water conditions do not deviate appreciably from those encountered in the site-specific exploratory borings. If any variations or undesirable conditions are encountered in any future exploration, we should be notified so that additional analyses can be made, if necessary.

The conclusions presented in this report are intended only for the purpose, site location, and project indicated. The recommendations presented in this report should not be used for other projects or purposes. Conclusions or recommendations made from these data by others are their responsibility. The conclusions and recommendations are based on AECOM's understanding of current plant operations, maintenance, stormwater handling, and ash handling procedures at the station, as provided by DMG. Changes in any of these operations or procedures may invalidate the findings in this report until AECOM has had the opportunity to review the changes, and revise the report if necessary.

This geotechnical investigation was performed in accordance with the standard of care commonly used as state-of-practice in our profession. Specifically, our services have been performed in accordance with accepted principles and practices of the geological and geotechnical engineering profession. The conclusions presented in this report are professional opinions based on the indicated project criteria and data available at the time this report was prepared. Our services were

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provided in a manner consistent with the level of care and skill ordinarily exercised by other professional consultants under similar circumstances. No other representation is intended.

9. REFERENCES

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Attachment A. Figures

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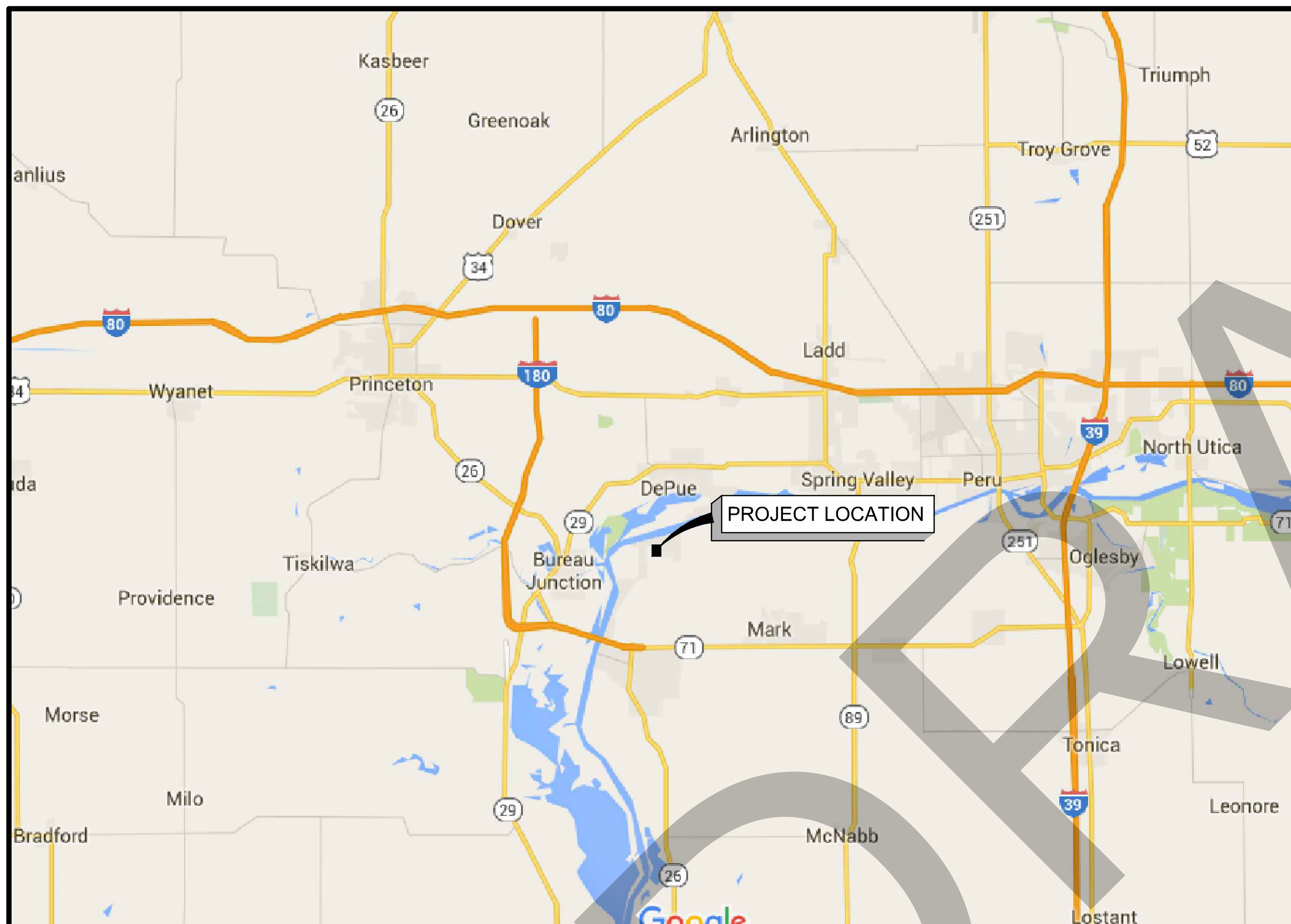
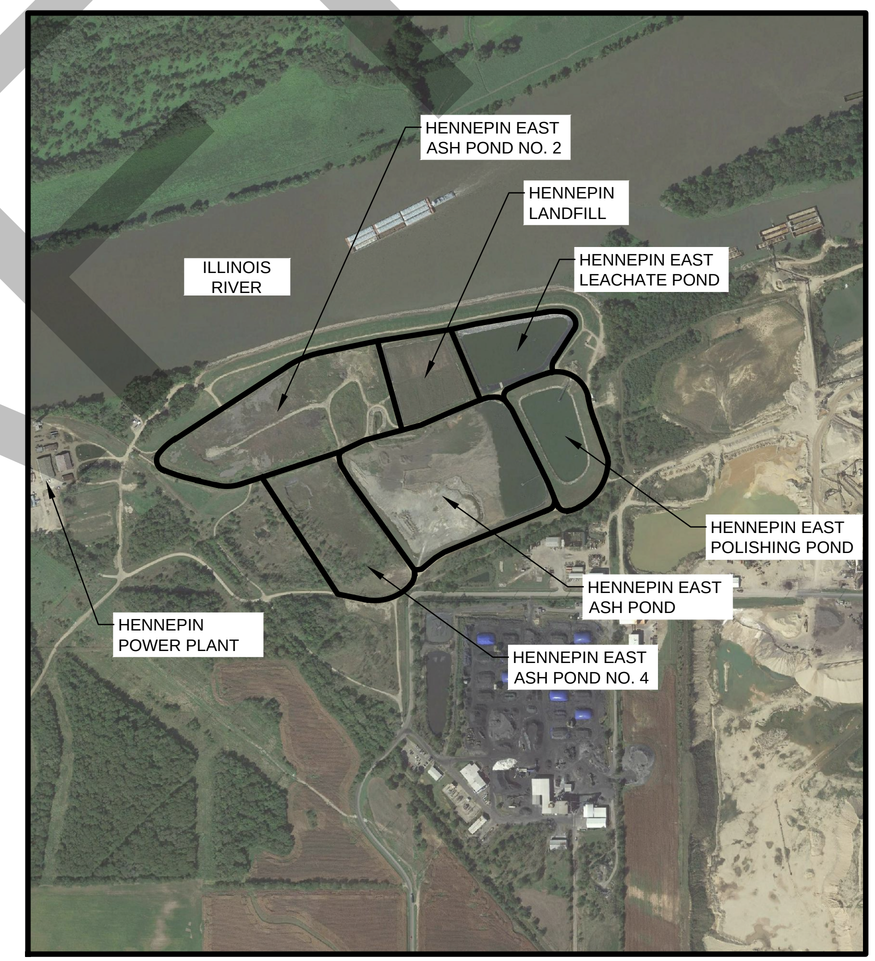


LOCATION MAP

NOT TO SCALE



VICINITY MAP

NOT TO SCALE

AERIAL FROM GOOGLE EARTH PRO
MAP FROM GOOGLE

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558 N Main Street
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DYNEGY
Dynegy Inc.
1500 East Port Plaza Drive
Collinsville, IL 62234

CCR RULE ASSESSMENT OF PLANTS

HENNEPIN POWER PLANT
HENNEPIN, ILLINOIS

GEOTECHNICAL REPORT
EAST ASH POND

ISSUED FOR BIDDING — DATE BY

ISSUED FOR CONSTRUCTION — DATE BY

REVISIONS

NO.	DESCRIPTION	DATE
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AECOM PROJECT NO:	60439752
DRAWN BY:	TPB
DESIGNED BY:	TPB
CHECKED BY:	SRA
DATE CREATED:	2/25/2016
PLOT DATE:	2/26/2016
SCALE:	AS SHOWN
ACAD VER:	2014

SHEET TITLE

LOCATION MAP AND SITE VICINITY MAP

FIGURE 1

AECOM DRAWING PATH: K:\Projects\60427894-Dynegy\900-WORKING DOCS-CAD\902-SHEETS\30% Design Sheets_East\Draft Geotechnical Report for Dynegy Hennepin Ash Pond CCR Unit\HEN 1-1 LOCATION PLAN.dwg
ALLEN, SHANNON (OSHKOSH), 3/2/2016 9:21 AM

LEGEND:

HEN-C001 HEN-B001 HEN-P001	AECOM 2015 GEOTECHNICAL EXPLORATION LOCATION AND LABEL (CPT, BORING, AND PIEZOMETER)
	MINOR CONTOUR (1 FT INTERVALS)
950	MAJOR CONTOUR (5 FT INTERVALS)

AERIAL-GOOGLE EARTH PRO
SURVEY DATA-COMPLETED BY
WEAVER CONSULTANTS GROUP
(SEMPTEMBER 2015)

AECOM
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Oshkosh, Wisconsin
920 235-0270 (phone)
920 235-0321 (fax)

DYNEGY
Dynegy Inc.
1500 East Port Plaza Drive
Collinsville, IL 62234

HENNEPIN POWER PLANT
HENNEPIN, ILLINOIS

N

250.52 ft

0 125 250

SCALE IN FEET

ISSUED FOR BIDDING ______ DATE BY

ISSUED FOR CONSTRUCTION ______ DATE BY

REVISIONS

NO.	DESCRIPTION	DATE
△		
△		
△		
△		
△		

AECOM PROJECT NO:	60439752
DRAWN BY:	TPB
DESIGNED BY:	TPB
CHECKED BY:	SRA
DATE CREATED:	2/25/2016
PLOT DATE:	2/26/2016
SCALE:	AS SHOWN
ACAD VER:	2014

SHEET TITLE

OVERALL
GEOTECHNICAL
SITE PLAN

FIGURE 2

AECOM DRAWING PATH: K:\Projects\60427894-Dynegy\900-WORKING DOCS-CAD\902-SHEETS\30% Design Sheets_East\Draft Geotechnical Report for Dynegy Hennepin Ash Pond CCR Unit\HEN 2-1 OVERALL GEOTECHNICAL SITE PLAN.dwg BRAND, TRAVIS, 2/26/2016 8:40 AM

Attachment B. Boring Logs

DRAFT

Project:	HENNEPIN POWER STATION
Project Location:	HENNEPIN, ILLINOIS
Project Number:	60439752

Key to Soil Boring Logs

Group	Graphic Symbol	Description	USCS Classification
SAND AND GRAVEL		SAND poorly graded	SP
		SAND well graded	SW
		Silty SAND	SM
		Clayey SAND	SC
		GRAVEL poorly graded	GP
LOW PLASTIC SILTS AND CLAYS		Inorganic low plastic SILT	ML
		Inorganic low plastic CLAY	CL
		Inorganic low plastic SILTY-CLAY	CL-ML
HIGH PLASTIC SILT AND CLAYS		Inorganic high plastic CLAY	CH
		Sandy Inorganic high plastic CLAY	CH
		Inorganic elastic SILT	MH
SURFACE MATERIALS		Asphalt, Pavement	
		Topsoil	
		Gravel Limestone	
		Fly Ash	
		Bottom Ash	
		Fill	

TERMS DESCRIBING DENSITY OR CONSISTENCY

Coarse grained soils (major portion retained on No. 200 sieve) include gravels and sands. Density is based on the Standard Penetration Test (SPT).

Density	SPT blows per foot
Very loose	0 - 5
Loose	5 - 10
Medium dense	10 - 30
Dense	30 - 50
Very dense	Greater than 50

Fine grained soils (major portion passing No. 200 sieve) include clays and silts. Consistency is rated according to shearing strength, as indicated by uncorrected SPT blows per foot.

Descriptive Term	SPT blows per foot	Estimated undrained shear strength (ksf)	Hand Test
Very soft	0-2	< 0.25	Extrudes between fingers
Soft	2-4	0.25-0.5	Molded by slight pressure
Medium stiff	4-8	0.5-1.0	Molded by strong pressure
Stiff	8-15	1.0-2.0	Indented by thumb
Very stiff	15-30	2.0-4.0	Indented by thumbnail
Hard	> 30	> 4.0	Difficult to indent

LEGEND AND NOMENCLATURE

	Standard penetration split spoon test sample
	Undisturbed shelby tube sample
PP qu	Pocket penetrometer unconfined compressive strength
NMC	Natural Moisture Content, %
LL	Liquid Limit
PL	Plastic Limit
PI	Plasticity Index
NP	Non-plastic
▽	Depth Groundwater enters at time of drilling.
▼	Groundwater Level at some specified time after drilling
Su	Undrained Shear Strength
TXUU	Triaxial Unconsolidated Undrained
DTW	Depth to water
N/A	Not Applicable

SAMPLING RESISTANCE

P	Sample pushed by hydraulic rig action.
3 6 9	Numbers indicate blows per 6 in. of sampler penetration. Standard penetration test sampler, (2-in O.D.) and oversize penetration sample (3-in O.D.) are driven by a 140 lb hammer falling freely 30-in
50/2	Number of blows (50) used to drive a penetration sampler a certain number of inches (2)
WOH	Weight of hammer
WOR	Weight of rods

ABBREVIATIONS USED UNDER "REMARKS"

HSA	Hollow Stem Auger	No.	Number
ATD	At Time of Drilling	CIU	Isotropically Consolidated Undrained
AD	After Drilling	ST	Shelby Tube
ID	Inside Diameter	SS	Split Spoon
OD	Outside Diameter		
RQD	Rock Quality Designation		
-#200	(% Pass #200 Sieve)		
Sa (%)	Sieve Analysis (% Passing #200)		

DRAFT

File: P:\RESOURCES\GINTDATA\GINT\GEOTECHNICAL\BORING KEY LOGS\DYNEGY GEO KEY.DWG Last edited: DEC. 16, 15 @ 09:38 a.m. by: david_deguire

Report: GEO_SOIL; File P:\PROJECTS\GEOTECH\60428794_DYNEGYCCR\21_REVISED_CERT_REPORTS\08_HENREV 1\GEOTECH\ATTACHMENT REVISIONS\ATT. A&B_FIGURES-GINT\60439752_HENNEPINDYNEGYBORINGLOGS_EAST ASH POND.GPJ; 9/22

Project: Hennepin Power Station

Project Location: Hennepin, Illinois
Project Number: 60439752

Log of Boring HEN-B029

Date(s) Drilled	**12:00AM 10/01/2015 to 12:00AM 10/01/2015**	Logged By	**Robert Weseljak**	Checked By	**AJW**
Drilling Method	**Mud Rotary**	Drilled By	**S. Komen**	Borehole Depth	**41.5 '**
Drill Rig Type	**Mobile 57 Truck Mounted**	Drilling Contractor	**Strata Earth Services**	Surface Elevation	**499.7 ' (NAVD88)**
Borehole Backfill	**Portland Cement and Grout**	Drill Bit Size/Type	**3 7/8" Tricone Roller Bit**	Hammer Data	**Automatic, 140 lbs, 30" drop**
Boring Location	**N 1689435.679 E 2533022.216 (NAD83)**	Sampling Method(s)	**Split Spoon/3" Thin Walled Tube**	Groundwater Level(s)	**Not Encountered**

Elevation (feet)	Depth (feet)	SAMPLES: Type / Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	MATERIAL DESCRIPTION	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU, Su (ksf)	REMARKS
499.7	0.0	SS-1	24 28 34	556	Very dense, dry, brown, silty GRAVEL (GM) [Road Fill].	4.7							
497.2	2.5	SS-2	10 6 11	556	Stiff to very stiff, dry, brown to very dark brown and gray, lean CLAY (CL) with sand and gravel [Embankment Fill].	14.7				4.5			
		ST-3		417		10.8		22	7	4.5			*Pushed shelby tube from 5.0 to 7.0 feet*
		SS-4	12 14 17	556		14.8				4.0			
		ST-5		417		16.7		31	14	2.5			*Pushed shelby tube from 10.0 to 12.0 feet*
484.7	15.0	SS-6	4 6 8	461	Stiff, dark brown with trace rust, lean CLAY (CL), trace fine to coarse gravel [Embankment Fill].	21.7				1.5			
479.5	20.2	SS-7	6 12 20	433	Dense, dry, brown, clayey GRAVEL with sand (GP-GC).	11.5				1.5			
		SS-8	17 17 43	311		8.8							

DRAFT

Project: Hennepin Power Station

Project Location: Hennepin, Illinois
Project Number: 60439752

Log of Boring HEN-B029

Depth (feet)	Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	MATERIAL DESCRIPTION	Elevation (feet)	Depth (feet)	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU, Su (ksf)	REMARKS
30	SS	SS-9	29, 50/5"	122				12.7							*Less fines in Sample 9*
35	SS	SS-10	20, 25, 28	339				13.8							
40	SS	SS-11	16, 14, 15	33		458.2	41.5	4.6							
41.5					End of Boring at 41.5 '										*Boring backfilled with 94 pounds of Portland Cement and 25 pounds of bentonite*

Depth scale: 30–64 feet; Elevation scale: 465, 460, 455, 450, 445, 440, 435.

DRAFT

Project: Hennepin Power Station

Project Location: Hennepin, Illinois
Project Number: 60439752

Log of Boring HEN-B030

Date(s) Drilled	12:00AM 09/29/2015 to 12:00AM 09/30/2015	Logged By	Norm Seiler	Checked By	AJW
Drilling Method	Hollow-Stem Auger	Drilled By	S. Komen	Borehole Depth	41.5 '
Drill Rig Type	Mobile 57 Truck Mounted	Drilling Contractor	Strata Earth Services	Surface Elevation	495.4 ' (NAVD88)
Borehole Backfill	Portland Cement and Grout	Drill Bit Size/Type	3 7/8" Tricone Roller Bit	Hammer Data	Automatic, 140 lbs, 30" drop
Boring Location	N 1690014.94 E 2533585.318 (NAD83)	Sampling Method(s)	Split Spoon/3" Thin Walled Tube	Groundwater Level(s)	33.0 ' at 12:00AM on 09/30/2016

Elevation (feet)	Depth (feet)	Samples: Type / Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Material Description (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU, Su (ksf)	Remarks
495.4	0.0	SS-1	22 17 37	461	Very Dense, Brownish gray sand, gravel, and clay [Fill].	7.0							
492.9	2.5	SS-2	15 17 15	372	Dense, Brown and light brown, silty sand with gravel (SM) [Fill].	6.4							
491.4	4.0	SS-3	18 20 30	461	Very Dense, Dark gray silty SAND (SM) with trace gravel, sand, and clay, with ASH [Fill].	11.5							
		SS-4	4 5 6	556	Becomes medium dense	17.1							9.0 feet: Wet
485.4	10.0	ST-5		275	Black ASH with gravel [Fill].	18.1							Pushed shelby tube from 10.0 to 11.0 feet 10.0 feet: Switch to mud rotary
480.4	15.0	SS-6	11 11 16	311	Medium dense, light brown and tan, well graded GRAVEL with sand (GW) [Embankment Fill].	17.6							
475.4	20.0	SS-7	3 4 7	122	Soft, dark gray and rust CLAY (CL) with organics and wood.	23.9							
470.4	25.0	SS-8	30 36 40	494	Dense to very dense, brown and some black, clayey fine to coarse GRAVEL (GC) with sand.	11.2							25.0 feet - Drillers note - rock pieces in Sample 8

DRAFT

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Project: Hennepin Power Station

Project Location: Hennepin, Illinois
Project Number: 60439752

Log of Boring HEN-B030

Elevation (feet)	Depth (feet)	Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU, Su (ksf)	REMARKS
465	30	SS	SS-9	56	42										
	33														33.0 feet - Drillers note - water level at 33.0 feet and dropping
460	35	SS	SS-10	7 8 25	211			8.9							
455	40	SS	SS-11	20 46 27				9.0							
453.9	41.5						End of Boring at 41.5 '								Boring backfilled with 2 batches Portland Cement and bentonite grout

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Project: Hennepin Power Station

Project Location: Hennepin, Illinois
Project Number: 60439752

Log of Boring HEN-B032

Date(s) Drilled	12:00AM 09/30/2015 to 12:00AM 09/30/2015	Logged By	Robert Weseljak	Checked By	AJW
Drilling Method	Mud Rotary	Drilled By	S. Komen	Borehole Depth	41.5 '
Drill Rig Type	Mobile 57 Truck Mounted	Drilling Contractor	Strata Earth Services	Surface Elevation	494.3 ' (NAVD88)
Borehole Backfill	Portland Cement and Grout	Drill Bit Size/Type	3 7/8" Tricone Roller Bit	Hammer Data	Automatic, 140 lbs, 30" drop
Boring Location	N 1689837.064 E 2534055.482 (NAD83)	Sampling Method(s)	Split Spoon/3" Thin Walled Tube	Groundwater Level(s)	Not Encountered

Elevation (feet)	Depth (feet)	Samples: Type / Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION (Elevation (feet) / Depth (feet))	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU, Su (ksf)	REMARKS
494.3	0.0													
	0–1.0	SS-1	32 29 20	372		Very dense, dry, brown, fine to coarse well graded GRAVEL with silt and sand [Fill].	2.7				4.5			
493.3	1.0					Hard, dry, dark brownish gray, Lean CLAY (CL)with sand and gravel [Embankment Fill]								
	2.5–4	SS-2	6 18 17	556			9.7				3.5			
490														
	5–7	ST-3		329			14.0		35	17	4.5			*Pushed shelby tube from 5.0 to 7.0 feet*
	7.5–9	SS-4	8 12 16	556			16.7				3.5			
485														
	10–11.5	SS-5	8 16 20	244			16.2				0.5			*10.0 feet: Coarse gravel*
480														
479.3	15.0					Very dense, moist, brown, Silty SAND (SM) with gravel.								
	15–16.5	SS-6	19 39 43	400			8.2							
475														
	20–21.5	SS-7	18 36 50/3"	339			11.1							
470														
	25–26.5	SS-8	98 35 50/4"	433			9.1							*24.5: Drillers Note - boulder from 24.5 to 25.2 feet*
465														
464.3	30.0													

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Project: Hennepin Power Station

Project Location: Hennepin, Illinois
Project Number: 60439752

Log of Boring HEN-B032

Elevation (feet)	Depth (feet)	Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU, Su (ksf)	REMARKS
	30	SS	SS-9	18 11 30	556		Hard, moist, brown, fine to coarse gravelly lean CLAY (CL).	10.6				3.0 4.5			
459.3	35.0	SS	SS-10	41 28 40	372		Very dense, moist, brown and black, clayey fine to coarse Silty SAND (SM) with gravel.	5.5							
	40	SS	SS-11	12 18 50/4"	400			10.9							
452.8	41.5						End of Boring at 41.5 '								*Boring backfilled with 94 pounds of Portland Cement and 25 pounds of bentonite*

Elevation scale (feet): 460, 455, 450, 445, 440, 435, 430
Depth scale (feet): 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64

DRAFT

Project: Hennepin Power Station

Project Location: Hennepin, Illinois
Project Number: 60439752

Log of Boring HEN-B034

Date(s) Drilled	12:00AM 09/30/2015 to 12:00AM 10/01/2015	Logged By	Robert Weseljak	Checked By	AJW
Drilling Method	Mud Rotary	Drilled By	S. Komen	Borehole Depth	41.5 '
Drill Rig Type	Mobile 57 Truck Mounted	Drilling Contractor	Strata Earth Services	Surface Elevation	499.3 ' (NAVD88)
Borehole Backfill	Portland Cement and Grout	Drill Bit Size/Type	3 7/8" Tricone Roller Bit	Hammer Data	Automatic, 140 lbs, 30" drop
Boring Location	N 1689245.6 E 2533830.734 (NAD83)	Sampling Method(s)	Split Spoon/3" Thin Walled Tube	Groundwater Level(s)	Not Encountered

MATERIAL DESCRIPTION

Elevation (feet)	Depth (feet)	Material Description
499.3 – 498.8	0.0 – 0.5	Very dense, dry, brown, silty SAND (SM) [Fill].
498.8 – 494.3	0.5 – 5.0	Hard, dry, black, gravelly lean CLAY (CL) [Fill].
494.3 – 493.8	5.0 – 5.5	Dense, dry, brown, silty SAND (SM).
493.8 – 479.3	5.5 – 20.0	Very dense, moist, brown to gray, silty fine to coarse GRAVEL (GP-GM) with silt [Embankment Fill].
479.3 – 469.3	20.0 – 30.0	Medium dense, dry, silty fine to coarse GRAVEL (GM).

SAMPLES

Type Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU, Su (ksf)	REMARKS
SS-1	25 19 21	556	4.2				1.5 2.5			
SS-2	7 8 11	556	14.2				3.5 4.5			
SS-3	17 28 32	556	15.9							
SS-4	11 18 32	556	2.5							
SS-5	27 35 18	311	11.2							
SS-6	21 24 25	244	9.1							
SS-7	10 11 9	244	12.5							
SS-8	11 13 16	33								

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Report: GEO_SOIL; File P:\PROJECTS\GEOTECH\60428794_DYNEGYCCR\21_REVISED_CERT_REPORTS\08_HENREV 1\GEOTECH\ATTACHMENT REVISIONS\ATT. A&B_FIGURES-GINT\60439752_HENNEPINDYNEGYBORINGLOGS_EAST ASH POND.GPJ; 9/22

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Project: Hennepin Power Station

Project Location: Hennepin, Illinois
Project Number: 60439752

Log of Boring HEN-B034

Elevation (feet)	Depth (feet)	Type	Number	Sampling Resist. OR Core RQD (%)	Recovery (%)	Graphic Symbol	MATERIAL DESCRIPTION	Natural Moisture Content (%)	Total Unit Weight (pcf)	Liquid Limit	Plasticity Index	Pocket Pen. Su (ksf)	Torvane Su (ksf)	TXUU, Su (ksf)	REMARKS
	30	SS	SS-9	14 14 12	122	GP-GM	Medium dense, moist to wet, light brown and tan, poorly graded GRAVEL (GP-GM) with sand and silt.	13.6							
	32														
465	34														
	36	SS	SS-10	9 11 10	372			10.9							
	38														
460	40	SS	SS-11	10 8 9	94			1.5							
457.8	41.5						End of Boring at 41.5 '								*Boring backfilled with 94 pounds of Portland Cement and 25 pounds of bentonite*
	42														
455	44														
	46														
	48														
450	50														
	52														
445	54														
	56														
	58														
440	60														
	62														
435	64														

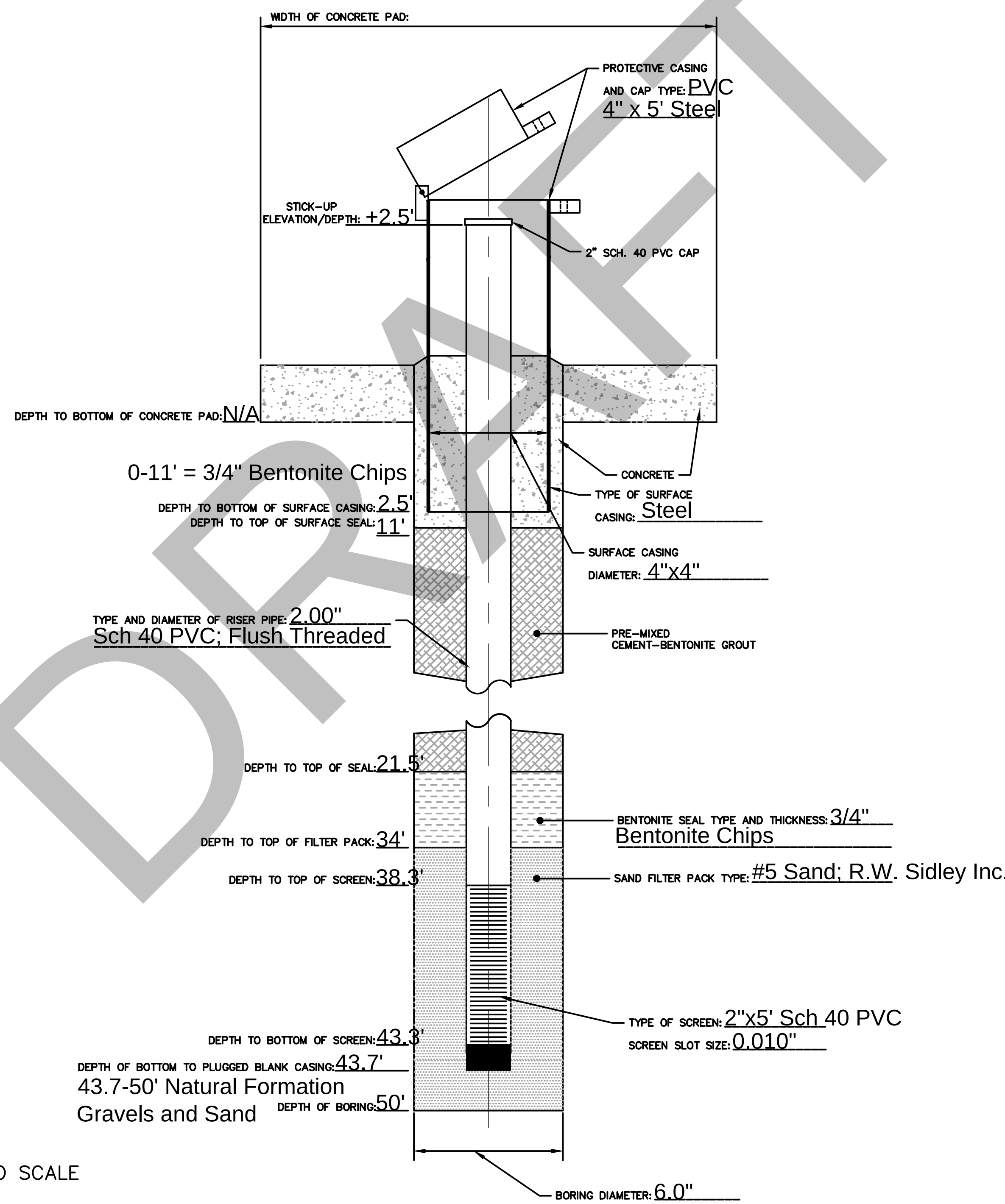
DRAFT

Attachment C. Piezometer Logs

DRAFT

Project: Dynegy Project Location: Hennepin, IL Project Number: 60439752	Log of Piezometer Sheet 1 of 1

Piezometer Location	P006	Date Installed	10/20/15	Time	11:20 A.M.
Installed By	Scott Komen	Observed By	R. Weseljak	Total Depth	50'
Method of Installation	6" Tricone Mud Rotary	Drilling Contractor	Strata	Surface Elevation	495.4'
Screened Interval	38.3-43.3'	Completion Zone	Gravel		
Remarks		Groundwater Level(s)	45.74' T.O.C.		



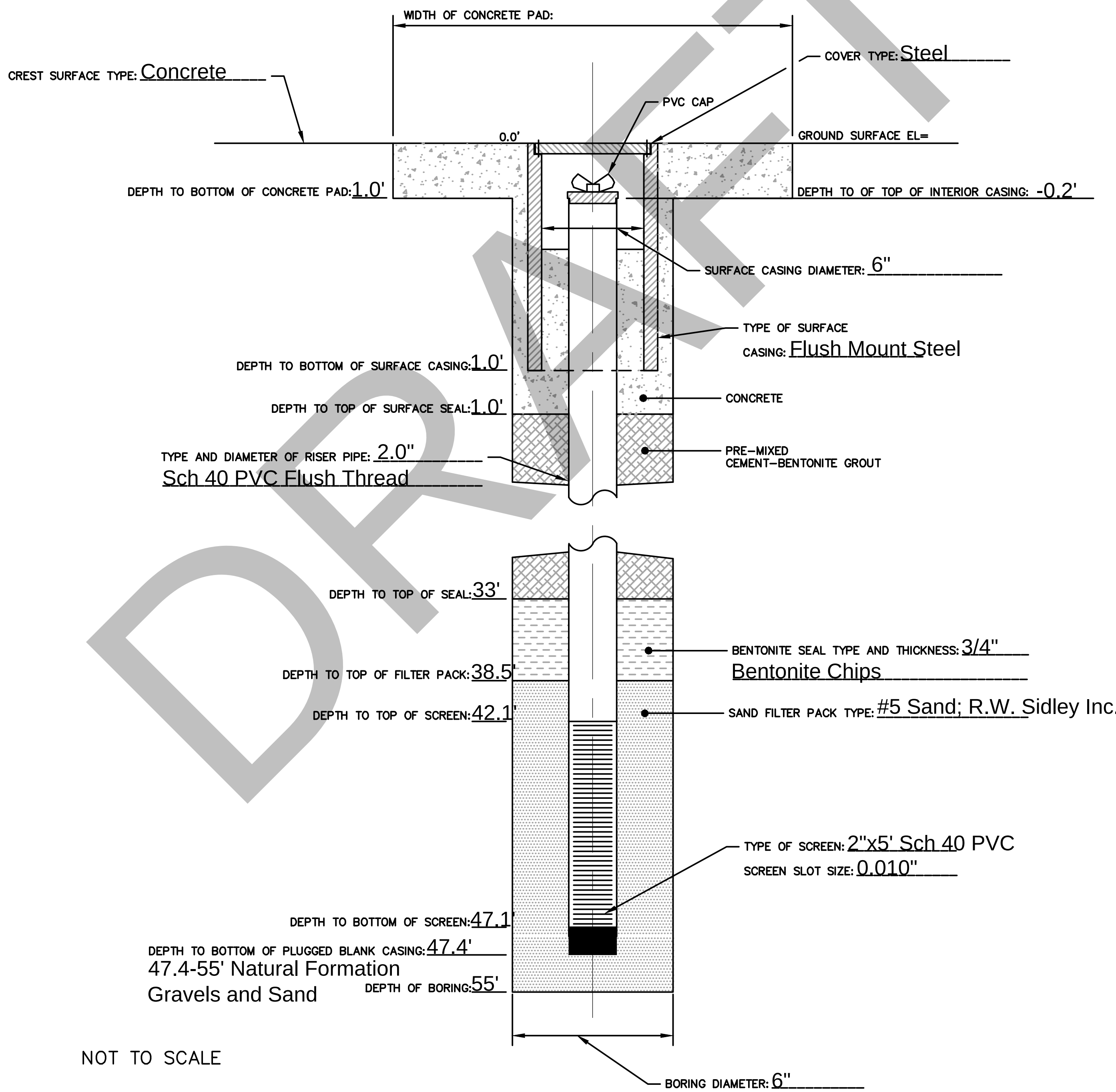
NOT TO SCALE

AECOM

DRAFT

Project: Dynegy	Log of Piezometer
Project Location: Hennepin, IL	Sheet 1 of 1
Project Number: 60439752	

Piezometer Location: P007	Date Installed: 10/21/15	Time: 5:00 P.M.
Installed By: Scott Komen	Observed By: R. Weseljak	Total Depth: 55'
Method of Installation: 6" Tricone Mud Rotary	Drilling Contractor: Strata	Surface Elevation: 494.3'
Screened Interval: 42.1-47.1'	Completion Zone: Gravels	
Remarks	Groundwater Level(s): 44.65' T.O.C.	



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AECOM

Attachment D. CPT Data Report

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Cone Penetration Test Summary and

Standard Cone Penetration Test Plots

DRAFT

Job No: 15-53081
Client: AECO
Project: Hennepin Power Station, Hennepin, IL
Start Date: 01-Sep-2015
End Date: 11-Sep-2015

CONE PENETRATION TEST SUMMARY

Sounding ID	File Name	Date	Cone	Assumed Phreatic Surface[1] (ft)	Final Depth (ft)	Shear Wave Velocity Tests	Northing[2] (m)	Easting (m)	Refer to Notation Number
HEN-C029	15-53081_CP29	01-Sep-2015	374:T1500F15U500		21.16		4574869	306935	4
HEN-C030	15-53081_SP30	02-Sep-2015	374:T1500F15U500		11.16	3	4575040	307109	4
HEN-C032	15-53081_CP32	02-Sep-2015	374:T1500F15U500		12.30		4574980	307252	4
HEN-C032B	15-53081_CP32B	02-Sep-2015	374:T1500F15U500		12.14		4574980	307253	4
HEN-C034	15-53081_SP34	02-Sep-2015	374:T1500F15U500		29.53	5	4574804	307178	4

DRAFT

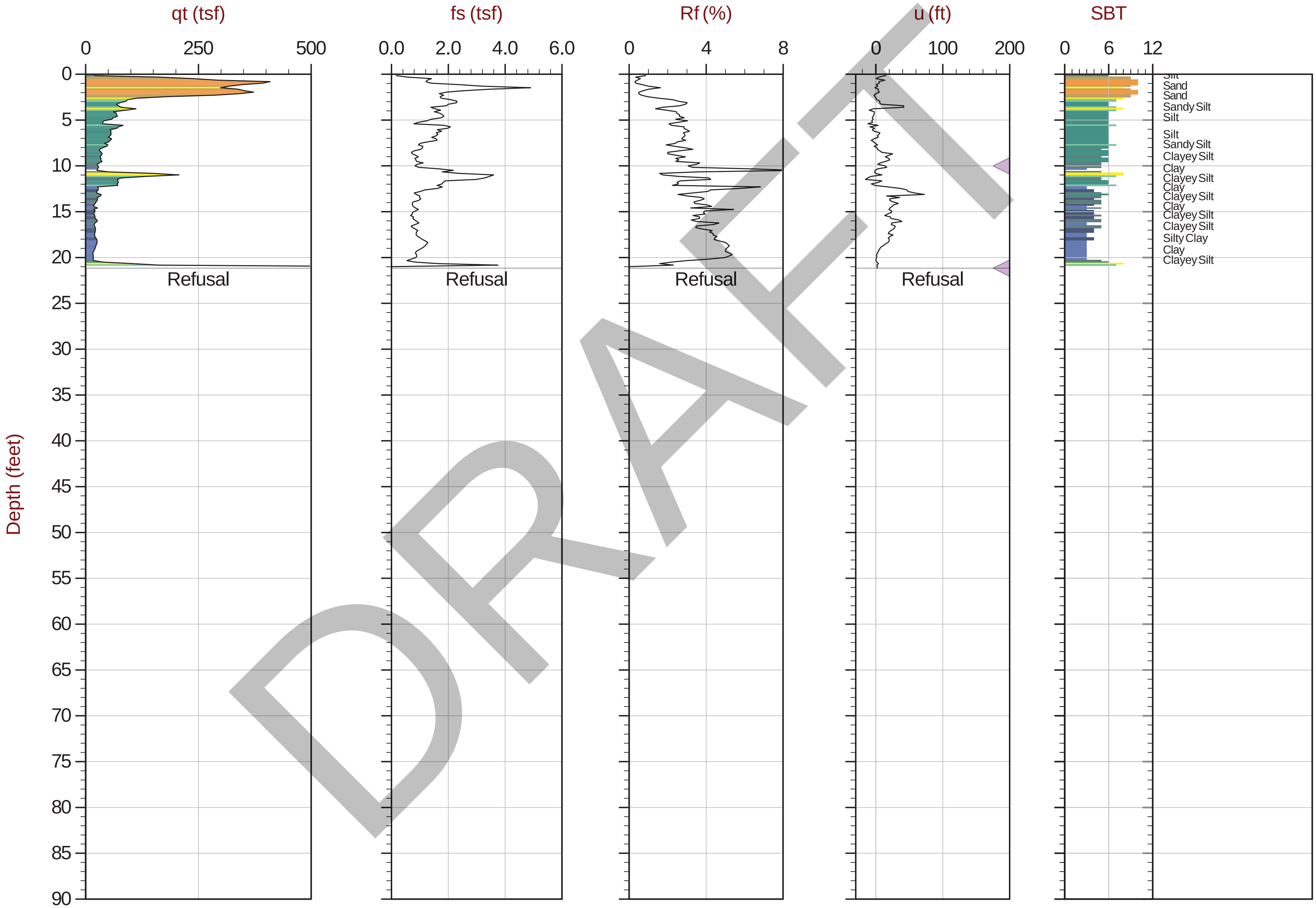
1. Assumed phreatic surface depths were determined from the pore pressure data. Hydrostatic data were used for calculated parameters.
2. Coordinates are WGS 84 / UTM Zone 16 and were collected using a GlobalSat (MR-350) and a handheld GPS Receiver.
3. Assumed phreatic surface estimated from dynamic pore pressure response.
4. No phreatic surface detected

ConeTec

AECOM

Job No: 15-53081
Date: 09:01:15 15:44
Site: Hennepin Power Station, Hennepin, IL

Sounding: HEN-C029
Cone: 374:T1500F15U500



DRAFT

Max Depth: 6.450 m / 21.16 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 15-53081_CP29.COR

SBT: Robertson and Campanella, 1986
Coords: UTM Zone 16 N: 4574869m E: 306935m

Hydrostatic Line | Ueq | Assumed Ueq | PPD, Ueq achieved | PPD, Ueq not achieved

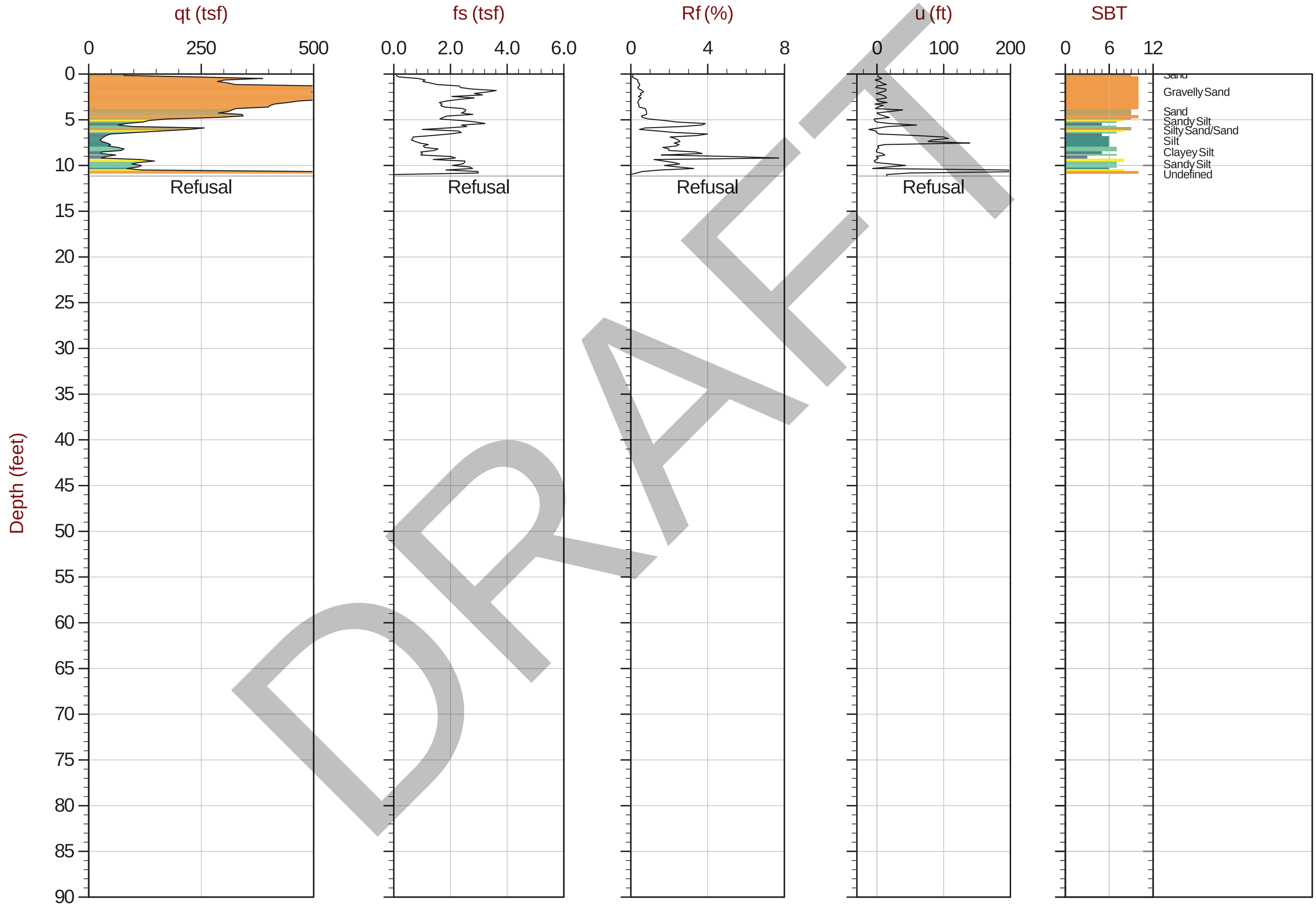
The reported coordinates were acquired from consumer-grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

AECOM

Job No: 15-53081
Date: 09:02:15 14:24
Site: Hennepin Power Station, Hennepin, IL

Sounding: HEN-C030
Cone: 374:T1500F15U500



Max Depth: 3.400 m / 11.15 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 15-53081_SP30.COR

SBT: Robertson and Campanella, 1986
Coords: UTM Zone 16 N: 4575040m E: 307109m

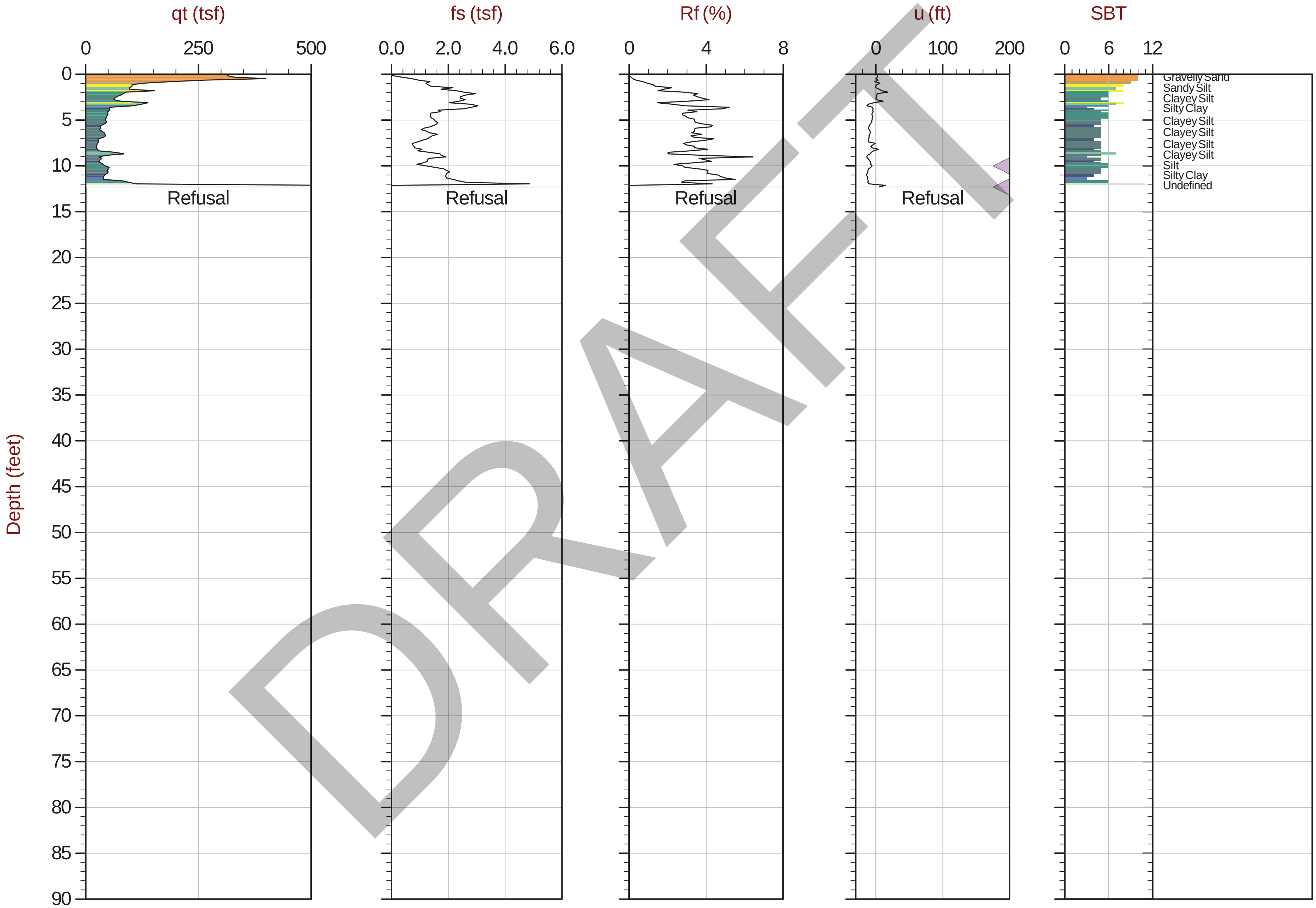
Hydrostatic Line   Ueq   Assumed Ueq   PPD, Ueq achieved   PPD, Ueq not achieved

The reported coordinates were acquired from consumer-grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

AECOM

Job No: 15-53081
Date: 09:02:15 10:27
Site: Hennepin Power Station, Hennepin, IL
Sounding: HEN-C032
Cone: 374:T1500F15U500



Max Depth: 3.750 m / 12.30 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 15-53081_CP32.COR

SBT: Robertson and Campanella, 1986
Coords: UTM Zone 16 N: 4574980m E: 307252m

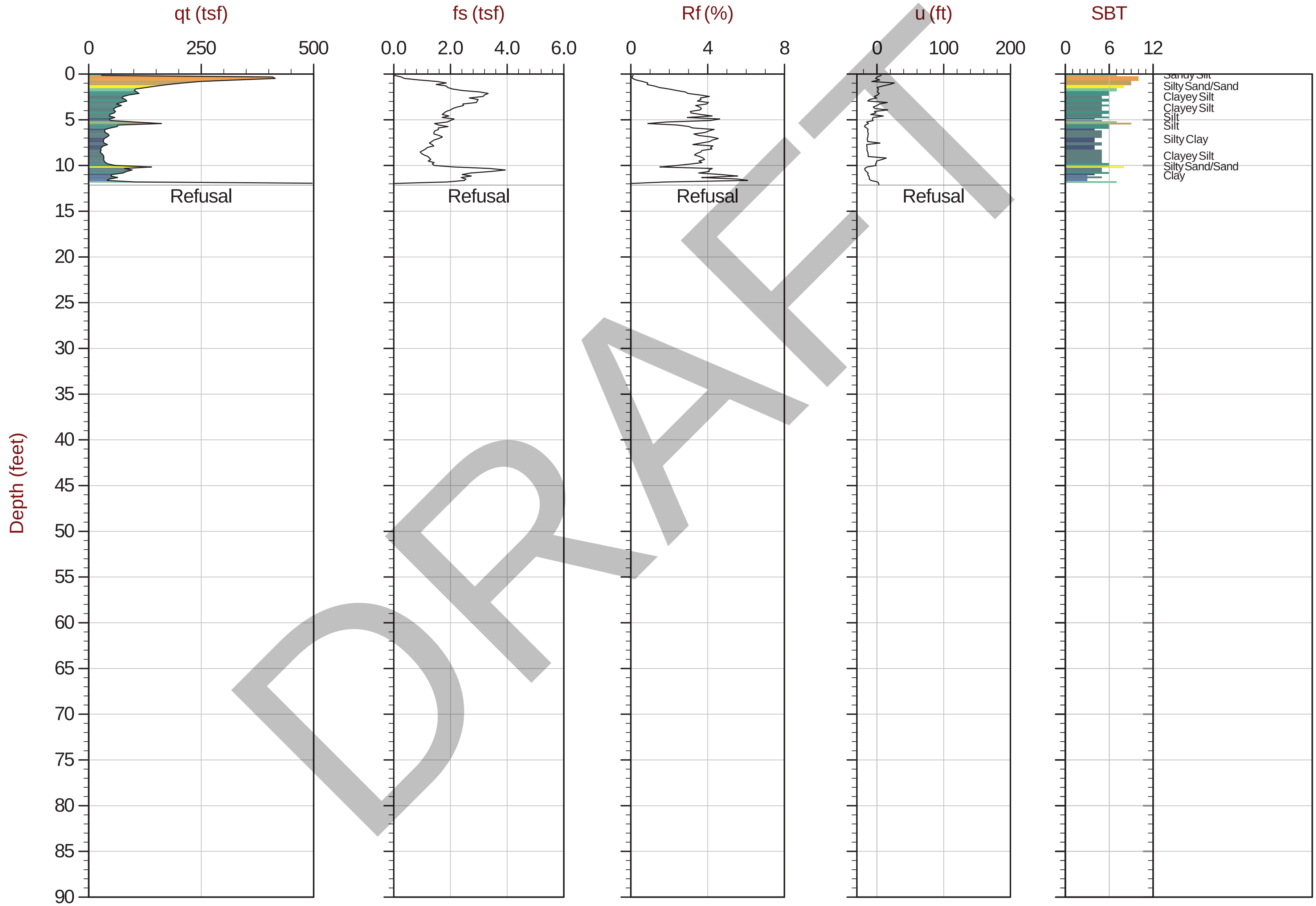
Hydrostatic Line   Ueq   Assumed Ueq   PPD, Ueq achieved   PPD, Ueq not achieved

The reported coordinates were acquired from consumer-grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

AECOM

Job No: 15-53081
Date: 09:02:15 11:26
Site: Hennepin Power Station, Hennepin, IL
Sounding: HEN-C032B
Cone: 374:T1500F15U500



Max Depth: 3.700 m / 12.14 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 15-53081_CP32B.COR

SBT: Robertson and Campanella, 1986
Coords: UTM Zone 16 N: 4574980m E: 307253m

Hydrostatic Line   Ueq   Assumed Ueq   PPD, Ueq achieved   PPD, Ueq not achieved

The reported coordinates were acquired from consumer-grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

AECOM

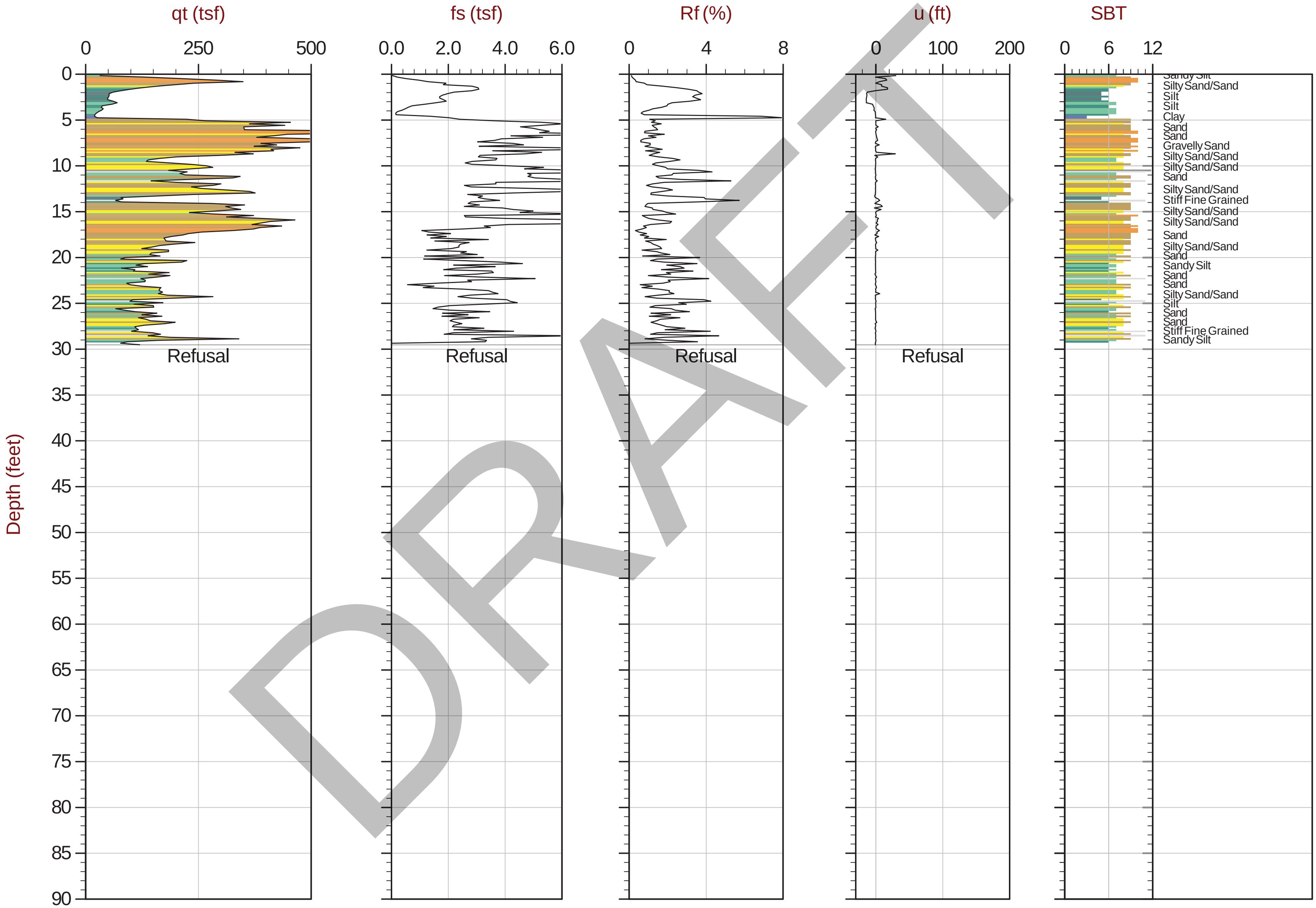
Job No: 15-53081

Date: 09:02:15 08:46

Site: Hennepin Power Station, Hennepin, IL

Sounding: HEN-C034

Cone: 374:T1500F15U500



Max Depth: 9.000 m / 29.53 ft

Depth Inc: 0.050 m / 0.164 ft

Avg Int: Every Point

File: 15-53081_SP34.COR

SBT: Robertson and Campanella, 1986

Coords: UTM Zone 16 N: 4574804m E: 307178m

Hydrostatic Line   Ueq   Assumed Ueq   PPD, Ueq achieved   PPD, Ueq not achieved

The reported coordinates were acquired from consumer-grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Seismic Cone Penetration Test Plots

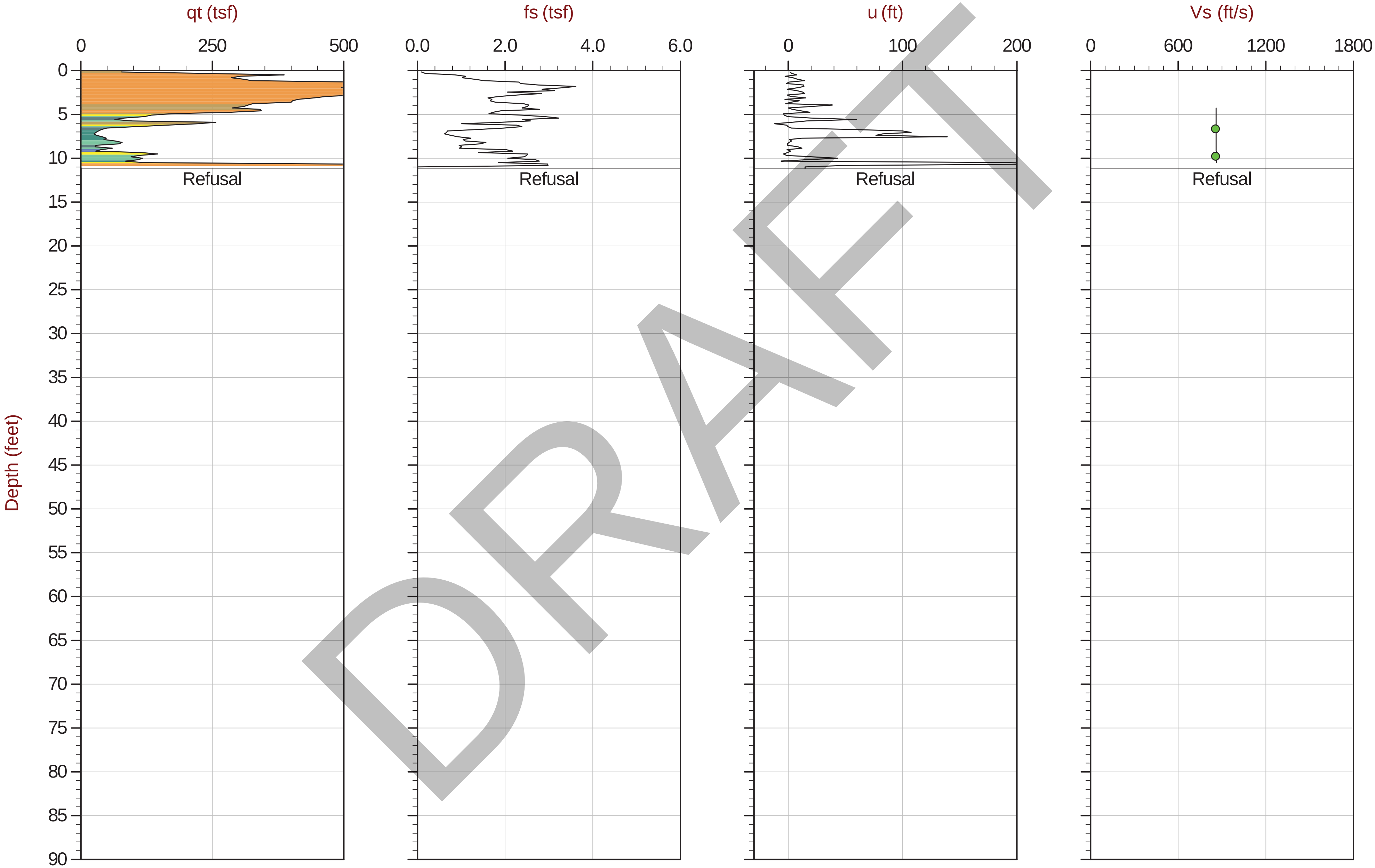
DRAFT

ConeTec

AECOM

Job No: 15-53081
Date: 09:02:15 14:24
Site: Hennepin Power Station, Hennepin, IL

Sounding: HEN-C030
Cone: 374:T1500F15U500



Max Depth: 3.400 m / 11.15 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 15-53081_SP30.COR

SBT: Robertson and Campanella, 1986
Coords: UTM Zone 16 N: 4575040m E: 307109m

Hydrostatic Line   Ueq   Assumed Ueq   PPD, Ueq achieved   PPD, Ueq not achieved

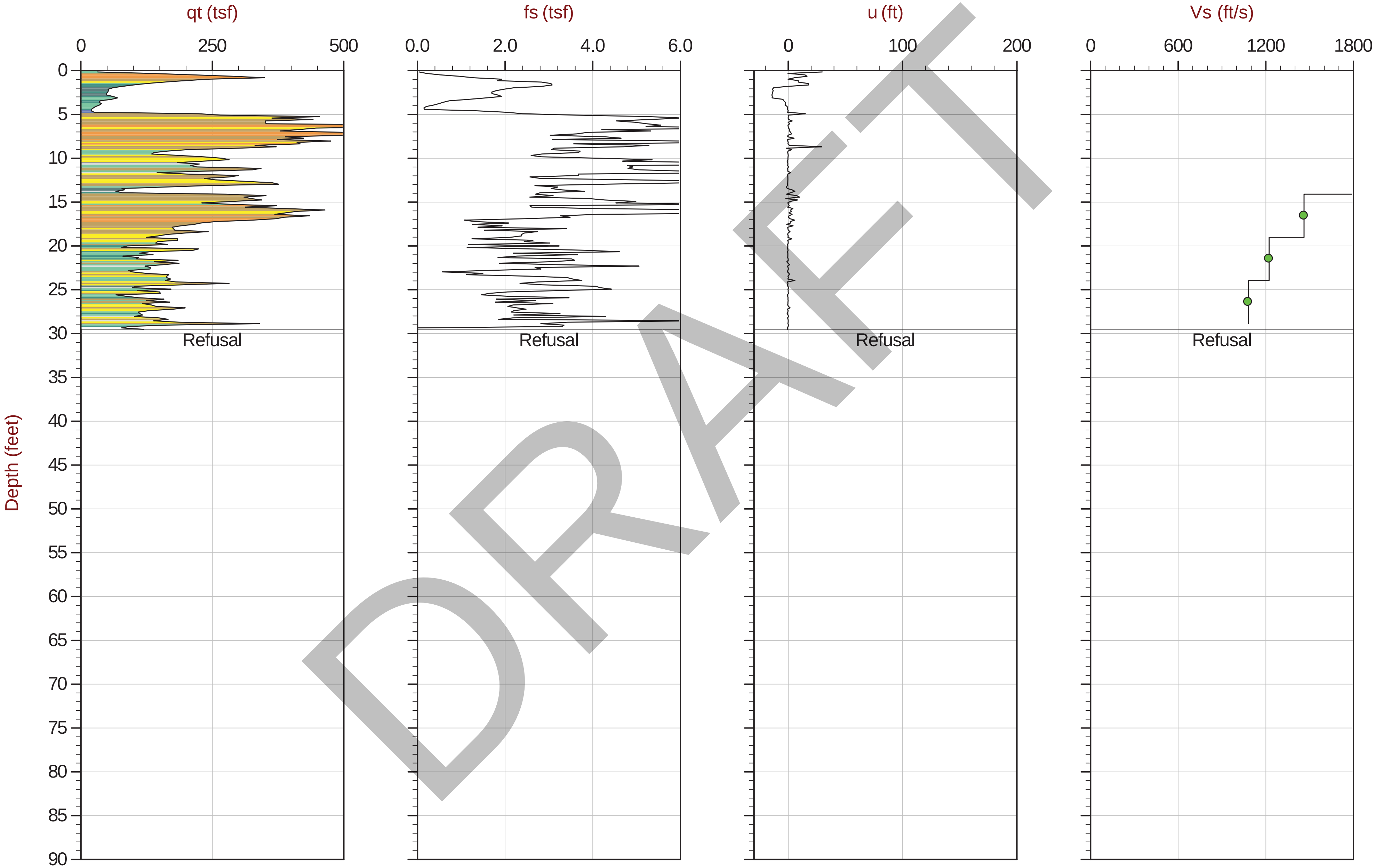
The reported coordinates were acquired from consumer-grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

AECOM

Job No: 15-53081
Date: 09:02:15 08:46
Site: Hennepin Power Station, Hennepin, IL

Sounding: HEN-C034
Cone: 374:T1500F15U500



DRAFT

Max Depth: 9.000 m / 29.53 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 15-53081_SP34.COR

SBT: Robertson and Campanella, 1986
Coords: UTM Zone 16 N: 4574804m E: 307178m

Hydrostatic Line   Ueq   Assumed Ueq   PPD, Ueq achieved   PPD, Ueq not achieved

The reported coordinates were acquired from consumer-grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Seismic Cone Penetration Test Tabular Results (Vs)

DRAFT

Job No:	15-53081
Client:	AECOM
Project:	Hennepin Power Plant
Sounding ID:	HEN-C030
Date:	02-Sep-2015

Seismic Source:	Beam
Source Offset (ft):	7.21
Source Depth (ft):	0.00
Geophone Offset (ft):	0.66

SCPTu SHEAR WAVE VELOCITY TEST RESULTS - Vs

Tip Depth (ft)	Geophone Depth (ft)	Ray Path (ft)	Ray Path Difference (ft)	Travel Time Interval (ms)	Interval Velocity (ft/s)
4.92	4.27	8.38			
9.84	9.19	11.68	3.30	3.84	860
11.15	10.50	12.74	1.06	1.23	861

DRAFT

Job No: 15-53081
Client: AECOM
Project: Hennepin Power Plant
Sounding ID: HEN-C034
Date: 02-Sep-2015

Seismic Source: Beam
Source Offset (ft): 7.21
Source Depth (ft): 0.00
Geophone Offset (ft): 0.66

SCPTu SHEAR WAVE VELOCITY TEST RESULTS - Vs

Tip Depth (ft)	Geophone Depth (ft)	Ray Path (ft)	Ray Path Difference (ft)	Travel Time Interval (ms)	Interval Velocity (ft/s)
9.84	9.19	11.68			
14.76	14.11	15.84	4.17	2.04	2038
19.69	19.03	20.35	4.51	3.08	1462
24.61	23.95	25.01	4.66	3.81	1223
29.53	28.87	29.76	4.75	4.39	1080

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Pore Pressure Dissipation Summary and

Pore Pressure Dissipation Plots

DRAFT

Job No:	15-53081
Client:	AECOM
Project:	Hennepin Power Station, Hennepin, IL
Start Date:	01-Sep-2015
End Date:	11-Sep-2015

CPTu PORE PRESSURE DISSIPATION SUMMARY

Sounding ID	File Name	Cone Area (cm^2)	Duration (s)	Test Depth (ft)	Estimated Equilibrium Pore Pressure U_{eq} (ft)	Calculated Phreatic Surface (ft)	Estimated Phreatic Surface (ft)	t_{50} [a] (s)	Assumed Rigidity Index (I_r)	c_h [b] (cm^2/min)
HEN-C029	15-53081_CP29	15	900	10.01						
HEN-C029	15-53081_CP29	15	600	21.16						
HEN-C032	15-53081_CP32	15	1200	10.01	2.40					
HEN-C032	15-53081_CP32	15	300	12.30	4.57					

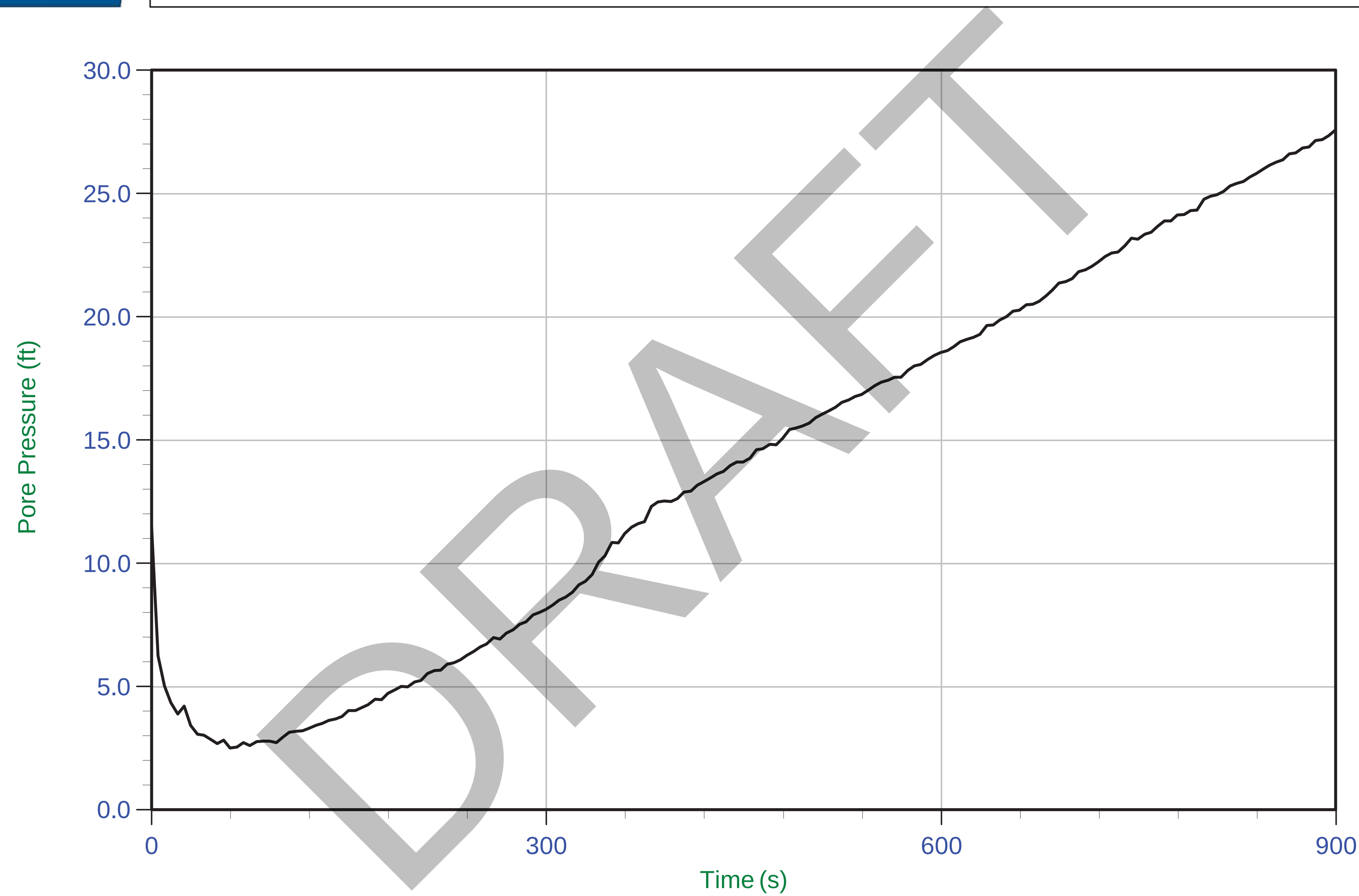
a. Time is relative to where umax occurred
b. Houlsby and Teh, 1991

DRAFT

AECOM

Job No: 15-53081
Date: 01-Sep-2015 15:44:33
Site: Hennepin Power Station, Hennepin, IL

Sounding: HEN-C029
Cone: 374
Cone Area: 15 sq cm



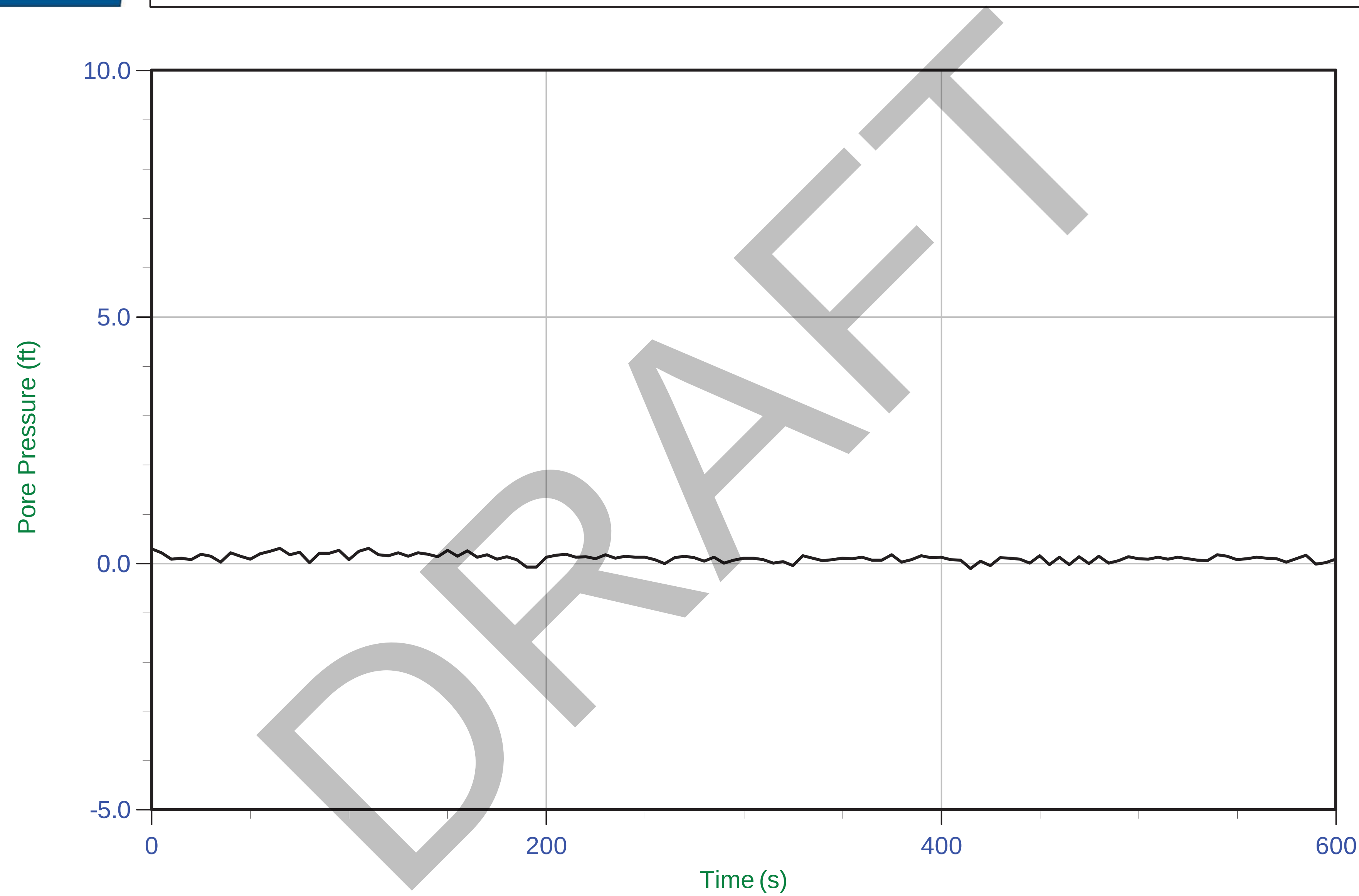
Trace Summary:

Filename: 15-53081_CP29.PPD
Depth: 3.050 m / 10.006 ft
Duration: 900.0 s

U Min: 2.5 ft
U Max: 27.6 ft

CONETEC

AECOM	Job No: 15-53081	Sounding: HEN-C029
	Date: 01-Sep-2015 15:44:33	Cone: 374
	Site: Hennepin Power Station, Hennepin, IL	Cone Area: 15 sq cm

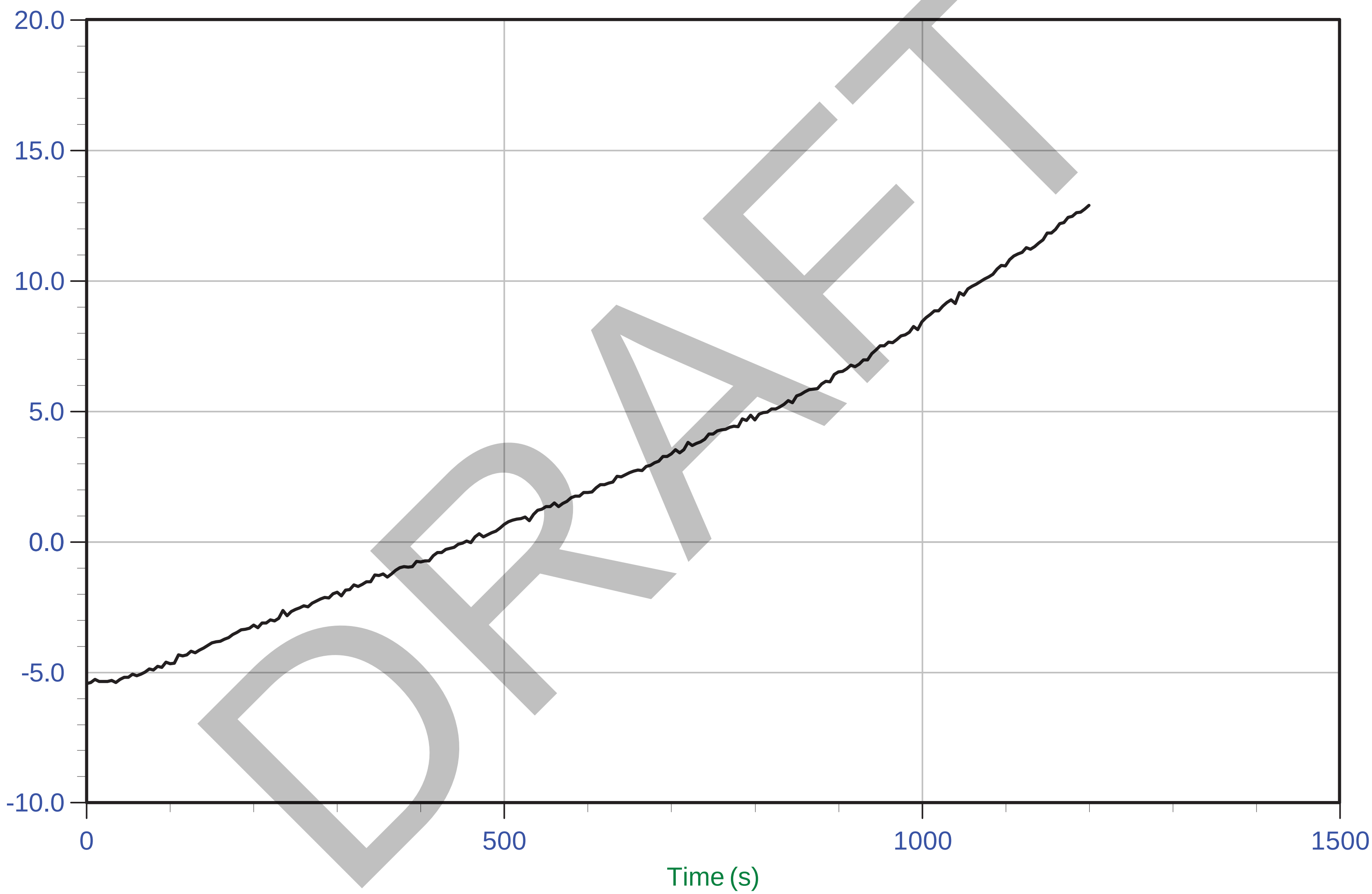


Trace Summary:

Filename: 15-53081_CP29.PPD
Depth: 6.450 m / 21.161 ft
Duration: 600.0 s

U Min: -0.1 ft
U Max: 0.3 ft

AECOM	Job No: 15-53081 Date: 02-Sep-2015 10:27:31 Site: Hennepin Power Station, Hennepin, IL	Sounding: HEN-C032 Cone: 374 Cone Area: 15 sq cm

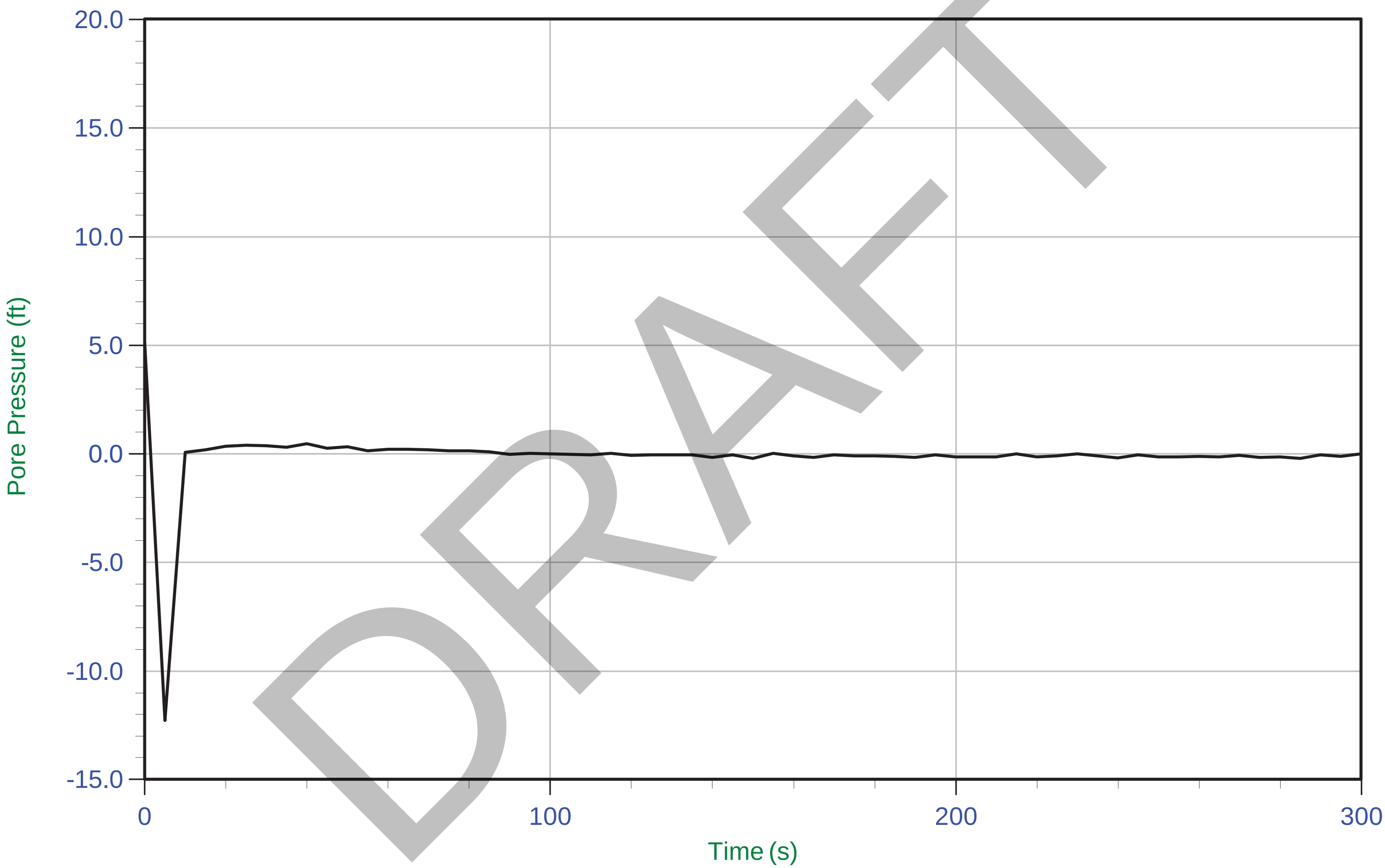


Trace Summary:

Filename: 15-53081_CP32.PPD
Depth: 3.050 m / 10.006 ft
Duration: 1200.0 s

U Min: -5.4 ft
U Max: 12.9 ft

AECOM	Job No: 15-53081 Date: 02-Sep-2015 10:27:31 Site: Hennepin Power Station, Hennepin, IL	Sounding: HEN-C032 Cone: 374 Cone Area: 15 sq cm



Trace Summary:

Filename: 15-53081_CP32.PPD
Depth: 3.750 m / 12.303 ft
Duration: 300.0 s

U Min: -12.3 ft
U Max: 5.1 ft

Attachment E. Laboratory Test Data

DRAFT

LABORATORY TESTING SUMMARY

PROJECT NAME: Dynegy - Hennepin Site **PROJECT NUMBER:** MR155233 **CLIENT:** AECOM

Boring Number	Sample Number	Depth	Description	USCS	WC %	Qp (tsf)	% Gravel	% Sand	% Silt	% Clay	% Fines	LL	PL	PI	Specific Gravity
HEN-B029	S-1	0.0'-1.5'	BROWN POORLY GRADED SAND		4.7										
HEN-B029	S-2	2.5'-4.0'	DARK BROWN SANDY LEAN CLAY		14.7										
HEN-B029	S-3	5.0'-7.0'	BROWN LEAN CLAY WITH SAND AND GRAVEL	CL	10.8							22	15	7	
HEN-B029	S-4	7.0'-8.5'	DARK BROWN LEAN CLAY		14.8										
HEN-B029	S-5	10.0'-12.0'	VERY DARK BROWN AND GRAY SLIGHTLY ORGANIC LEAN CLAY WITH SAND AND GRAVEL	CL	16.7							31	17	14	
HEN-B029	S-6	15.0'-16.5'	POSSIBLE FILL: BROWN TO DARK BROWN LEAN CLAY		21.7										
HEN-B029	S-7	20.0'-21.5'	BROWN TO GRAY SILTY LEAN CLAY		11.5										
HEN-B029	S-8	25.0'-26.5'	BROWN SILTY LEAN CLAY WITH SAND		8.8										
HEN-B029	S-9	30.0'-30.9'	BROWN SILTY LEAN CLAY WITH SAND		12.7										
HEN-B029	S-10	35.0'-36.5'	LIGHT BROWN POORLY GRADED GRAVEL WITH SAND AND CLAY	GP-GC	13.8		61.0	26.0			13.0				
HEN-B029	S-11	40.0'-41.5'	BROWN SILTY SAND WITH CLAY		4.6										

DRAFT

LABORATORY TESTING SUMMARY

Terracon

PROJECT NAME: Dynegy - Hennepin Site **PROJECT NUMBER:** MR155233 **CLIENT:** AECOM

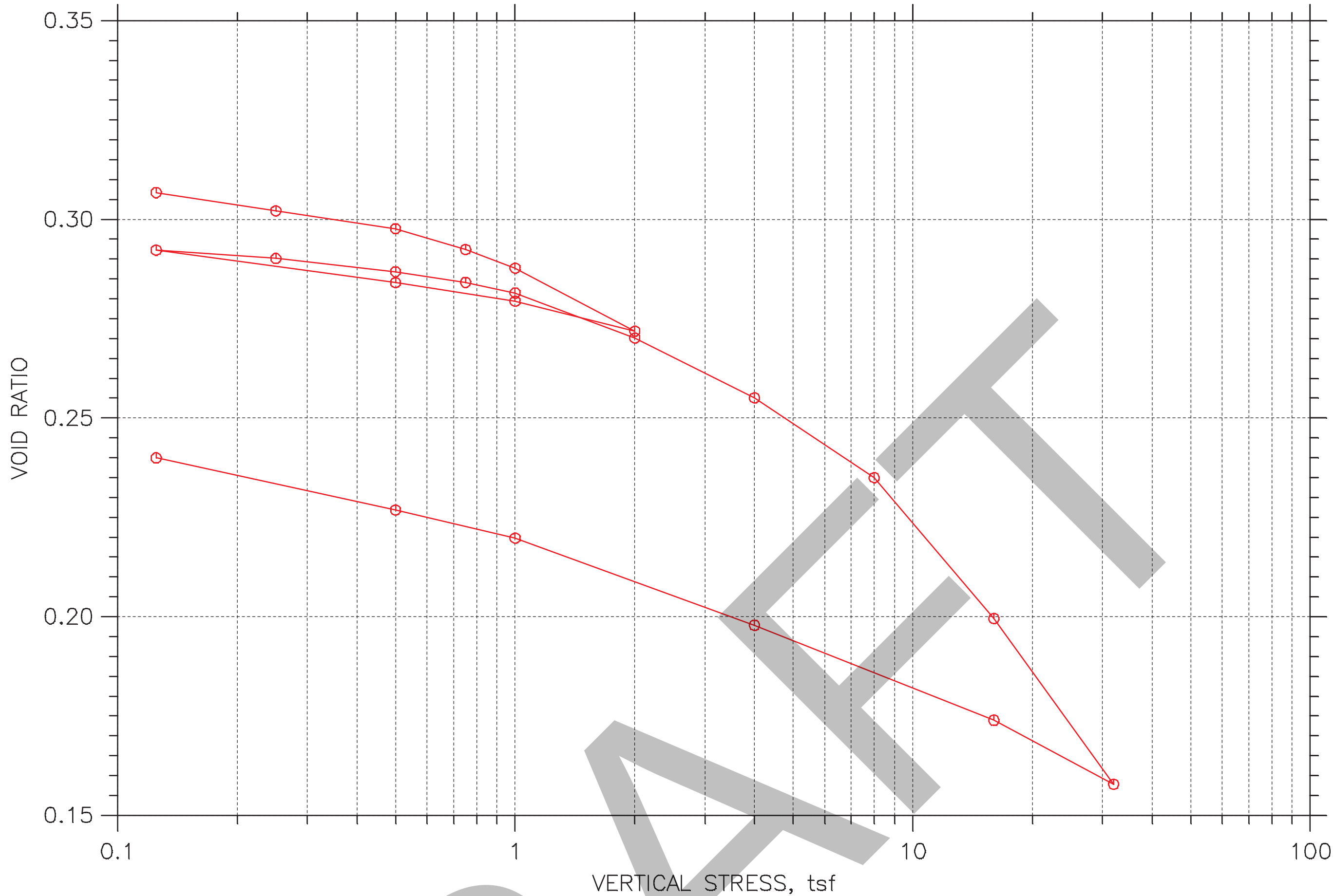
Boring Number	Sample Number	Depth	Description	USCS	WC %	Qp (tsf)	% Gravel	% Sand	% Silt	% Clay	% Fines	LL	PL	PI	Specific Gravity
HEN-B030	S-1A	0.0'-1.5'	FILL: DARK BROWN AND BROWN SANDY LEAN CLAY WITH GRAVEL		7.0										
HEN-B030	S-2	2.5'-4.0'	BROWN AND LIGHT BROWN SILTY SAND WITH GRAVEL	SM	6.4		34.0	45.7	11.0	9.3	20.3				
HEN-B030	S-3	5.0'-6.5'	FILL: BROWN AND GRAY LEAN CLAY WITH SILT, SAND AND GRAVEL		11.5										2.746
HEN-B030	S-4	7.5'-9.0'	BROWN LEAN CLAY		17.1										
HEN-B030	S-5	10.0'-11.0'	DARK BROWNISH GRAY FLY ASH AND LEAN CLAY MIXTURE WITH SAND		18.1										
HEN-B030	S-6	15.0'-16.5'	LIGHT BROWN AND TAN WELL GRADED GRAVEL WITH SAND	GW	17.6		81.4	14.8			3.8				
HEN-B030	S-7	21.5'	DARK BROWN AND BLACK ORGANIC CLAY WITH GRAVEL - WOOD NOTED		23.9										
HEN-B030	S-8	25.0'-26.5'	BROWN SILTY SAND WITH GRAVEL		11.2										
HEN-B030	S-10	35.0'-36.5'	BROWN CLAYEY SAND WITH GRAVEL		8.9										
HEN-B030	S-11	40.0'-41.5'	BROWN CLAYEY SAND		9.0										
HEN-B032	S-1A	0.0'-1.0'	BROWN AND GRAYISH BROWN CLAYEY SAND		2.7										
HEN-B032	S-1B	1.0'-1.5'	FILL: BROWN SANDY LEAN CLAY		7.9										
HEN-B032	S-2	2.5'-4.0'	FILL: DARK BROWN SANDY LEAN CLAY		9.7										
HEN-B032	S-3	5.0'-7.0'	DARK BROWNISH GRAY LEAN CLAY WITH SAND AND GRAVEL	CL	14.0							35	18	17	
HEN-B032	S-4	7.5'-9.0'	DARK BROWN LEAN CLAY		16.7										
HEN-B032	S-5	10.0'-11.5'	DARK BROWN AND DARK GRAY LEAN CLAY WITH GRAVEL		16.2										
HEN-B032	S-6	15.0'-16.5'	BROWN AND GRAYISH BROWN SILTY SAND WITH GRAVEL		8.2										
HEN-B032	S-7	20.0'-21.5'	BROWN SILTY SAND WITH GRAVEL	SM	11.1		30.5	43.6	13.4	12.5	25.9				
HEN-B032	S-8	25.0'-26.5'	BROWN SILTY SAND WITH GRAVEL AND CLAY		9.1										
HEN-B032	S-9	30.0'-31.5'	BROWN LEAN CLAY WITH SAND AND GRAVEL		10.6										
HEN-B032	S-10	35.0'-36.5'	BROWN SILTY SAND WITH GRAVEL		5.5										
HEN-B032	S-11	40.0'-41.3'	BROWN AND GRAYISH BROWN SILTY LEAN CLAY WITH SAND AND GRAVEL		10.9										
HEN-B034	S-1A	0.0'-0.5'	BROWN SILTY SAND WITH GRAVEL		4.2										
HEN-B034	S-1B	0.5'-1.5	POSSIBLE FILL: DARK BROWN LEAN CLAY		9.1										
HEN-B034	S-2	2.5'-4.0'	DARK BROWN LEAN CLAY WITH SILT AND SAND		14.2										2.704
HEN-B034	S-3A	5.0'-5.5'	BROWN SILTY SAND		15.9										
HEN-B034	S-3B	5.5'-6.5'	BROWN GRAVELLY SAND		1.4										
HEN-B034	S-4	7.5'-9.0'	BROWN AND GRAYISH BROWN SILTY SAND WITH GRAVEL		2.5										
HEN-B034	S-5	10.0'-11.5'	BROWN AND LIGHT BROWN POORLY GRADED GRAVEL WITH SILT AND	GP-GM	11.2		60.1	27.0	7.7	5.2	12.9				
HEN-B034	S-6	15.0'-16.5'	BROWN AND LIGHT BROWN POORLY GRADED GRAVEL WITH CLAY AND		9.1										2.808
HEN-B034	S-7	20.0'-21.5'	LIGHT BROWN SILTY SAND WITH GRAVEL		12.5										
HEN-B034	S-9	30.0'-31.5'	BROWN, GRAY AND PINKISH BROWN POORLY GRADED GRAVEL		13.6										
HEN-B034	S-10	35.0'-36.5'	LIGHT BROWN AND TAN POORLY GRADED GRAVEL WITH SAND AND SILT	GP-GM	10.9		82.8	11.3			5.9				
HEN-B034	S-11	40.0'-41.5'	BROWN POORLY GRADED GRAVEL WITH SILT AND SAND		1.5										

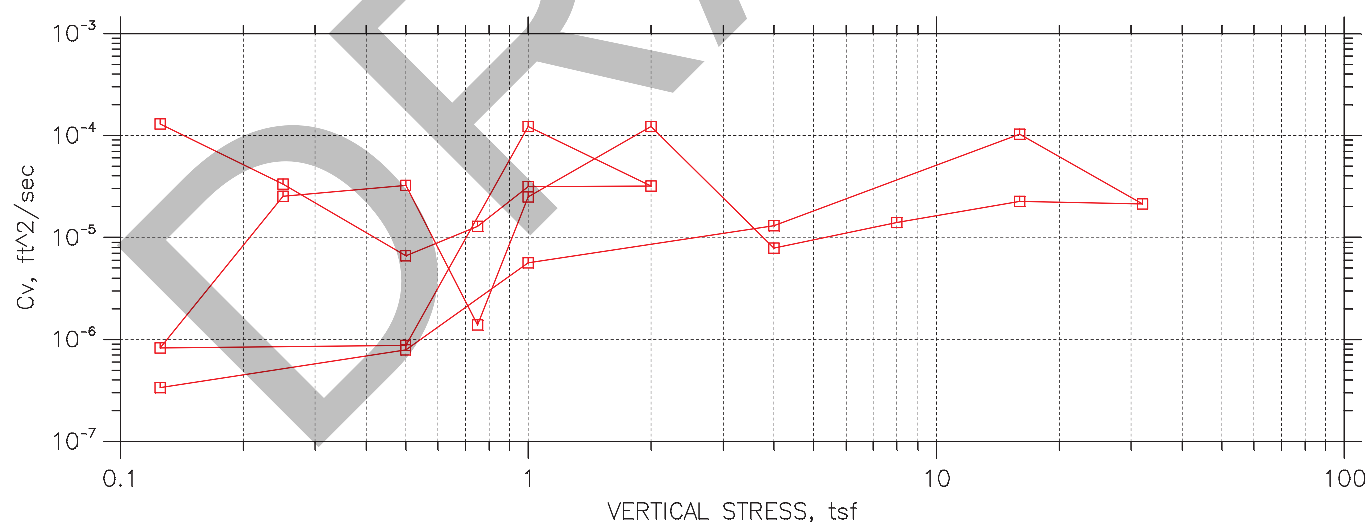
DRAFT

One-Dimensional Consolidation Tests
ASTM D 2535

DRAFT

ONE DIMENSIONAL CONSOLIDATION TEST
ASTM D2435





DRAFT

Terracon Consulting Engineers & Scientists	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

Mon, 21-DEC-2015 16:47:42

CONSOLIDATION TEST DATA

Project: DYNEGY HENNEPIN
Boring No.: HEN-029 S-3
Sample No.: S-3
Test No.: HENB029S3

Location: HENNEPIN, IL
Tested By: HP
Test Date: 12/14/15
Sample Type: 3.0" ST

Project No.: MR155233
Checked By: BCM
Depth: 5.0'-7.0'
Elevation: -----

Soil Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL
Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435

Estimated Specific Gravity: 2.72
Initial Void Ratio: 0.31
Final Void Ratio: 0.24

Liquid Limit: 22
Plastic Limit: 15
Plasticity Index: 7

Initial Height: 0.74 in
Specimen Diameter: 2.49 in

	Before Consolidation		After Consolidation	
	Trimmings	Specimen+Ring	Specimen+Ring	Trimmings
Container ID	X-7	RING	RING	118
Wt. Container + Wet Soil, gm	167.52	207.79	207.7	156.24
Wt. Container + Dry Soil, gm	155.54	196.84	196.84	145.48
Wt. Container, gm	44.63	74.87	74.87	24.64
Wt. Dry Soil, gm	110.91	121.97	121.97	120.84
Water Content, %	10.80	8.98	8.90	8.90
Void Ratio	---	0.31	0.24	---
Degree of Saturation, %	---	77.94	100.93	---
Dry Unit Weight, pcf	---	129.29	136.94	---

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CONSOLIDATION TEST DATA

Terracon Consulting Engineers & Scientists

Project: DYNEGY HENNEPIN
Boring No.: HEN-029 S-3
Sample No.: S-3
Test No.: HENB029S3

Location: HENNEPIN, IL
Tested By: HP
Test Date: 12/14/15
Sample Type: 3.0" ST

Project No.: MR155233
Checked By: BCM
Depth: 5.0'-7.0'
Elevation: -----

Soil Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL
Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435

	Applied Stress tsf	Final Displacement in	Void Ratio	Strain at End %	T50 Fitting Sq.Rt. min	T50 Fitting Log min	Coefficient of Consolidation Sq.Rt. ft^2/sec	Coefficient of Consolidation Log ft^2/sec	Coefficient of Consolidation Ave. ft^2/sec
1	0.125	0.00369	0.307	0.50	0.0	0.0	1.30e-004	0.00e+000	1.30e-004
2	0.25	0.006259	0.302	0.85	0.1	0.0	3.32e-005	0.00e+000	3.32e-005
3	0.5	0.008782	0.298	1.19	0.5	0.0	6.59e-006	0.00e+000	6.59e-006
4	0.75	0.01172	0.292	1.59	0.2	0.0	1.28e-005	0.00e+000	1.28e-005
5	1	0.01434	0.288	1.95	0.1	0.0	3.13e-005	0.00e+000	3.13e-005
6	2	0.02322	0.272	3.16	0.1	0.0	3.18e-005	0.00e+000	3.18e-005
7	1	0.01901	0.279	2.58	0.0	0.0	1.23e-004	0.00e+000	1.23e-004
8	0.5	0.0164	0.284	2.23	3.4	0.0	8.69e-007	0.00e+000	8.69e-007
9	0.125	0.01182	0.292	1.61	3.6	0.0	8.29e-007	0.00e+000	8.29e-007
10	0.25	0.01299	0.290	1.76	0.1	0.0	2.54e-005	0.00e+000	2.54e-005
11	0.5	0.01485	0.287	2.02	0.1	0.0	3.22e-005	0.00e+000	3.22e-005
12	0.75	0.01635	0.284	2.22	2.1	0.0	1.38e-006	0.00e+000	1.38e-006
13	1	0.01784	0.281	2.43	0.1	0.0	2.51e-005	0.00e+000	2.51e-005
14	2	0.0242	0.270	3.29	0.0	0.0	1.23e-004	0.00e+000	1.23e-004
15	4	0.03265	0.255	4.44	0.4	0.0	7.87e-006	0.00e+000	7.87e-006
16	8	0.04391	0.235	5.97	0.2	0.0	1.39e-005	0.00e+000	1.39e-005
17	16	0.06376	0.200	8.67	0.1	0.0	2.26e-005	0.00e+000	2.26e-005
18	32	0.08712	0.158	11.84	0.1	0.0	2.12e-005	0.00e+000	2.12e-005
19	16	0.0781	0.174	10.61	0.0	0.0	1.03e-004	0.00e+000	1.03e-004
20	4	0.0647	0.198	8.79	0.2	0.0	1.30e-005	0.00e+000	1.30e-005
21	1	0.05241	0.220	7.12	0.5	0.0	5.63e-006	0.00e+000	5.63e-006
22	0.5	0.04844	0.227	6.58	3.4	0.0	7.92e-007	0.00e+000	7.92e-007
23	0.125	0.04111	0.240	5.59	8.1	0.0	3.37e-007	0.00e+000	3.37e-007

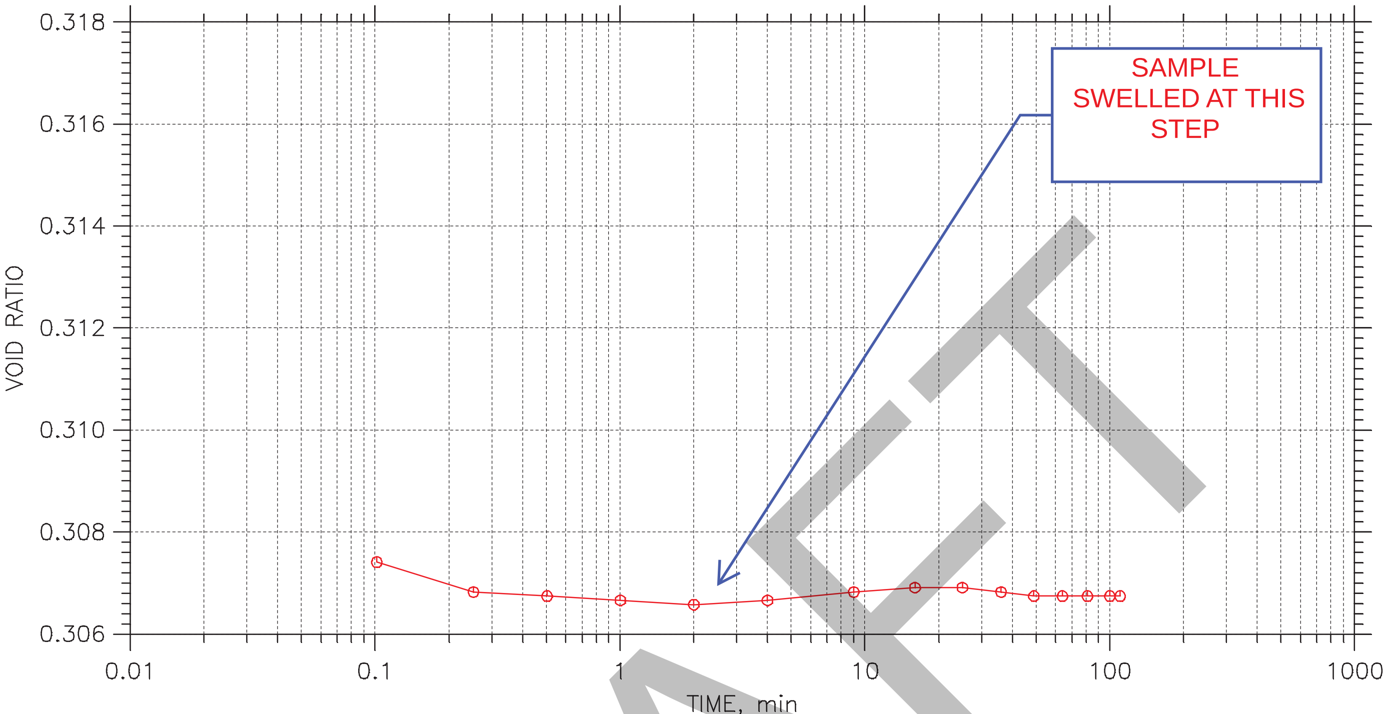
DRAFT

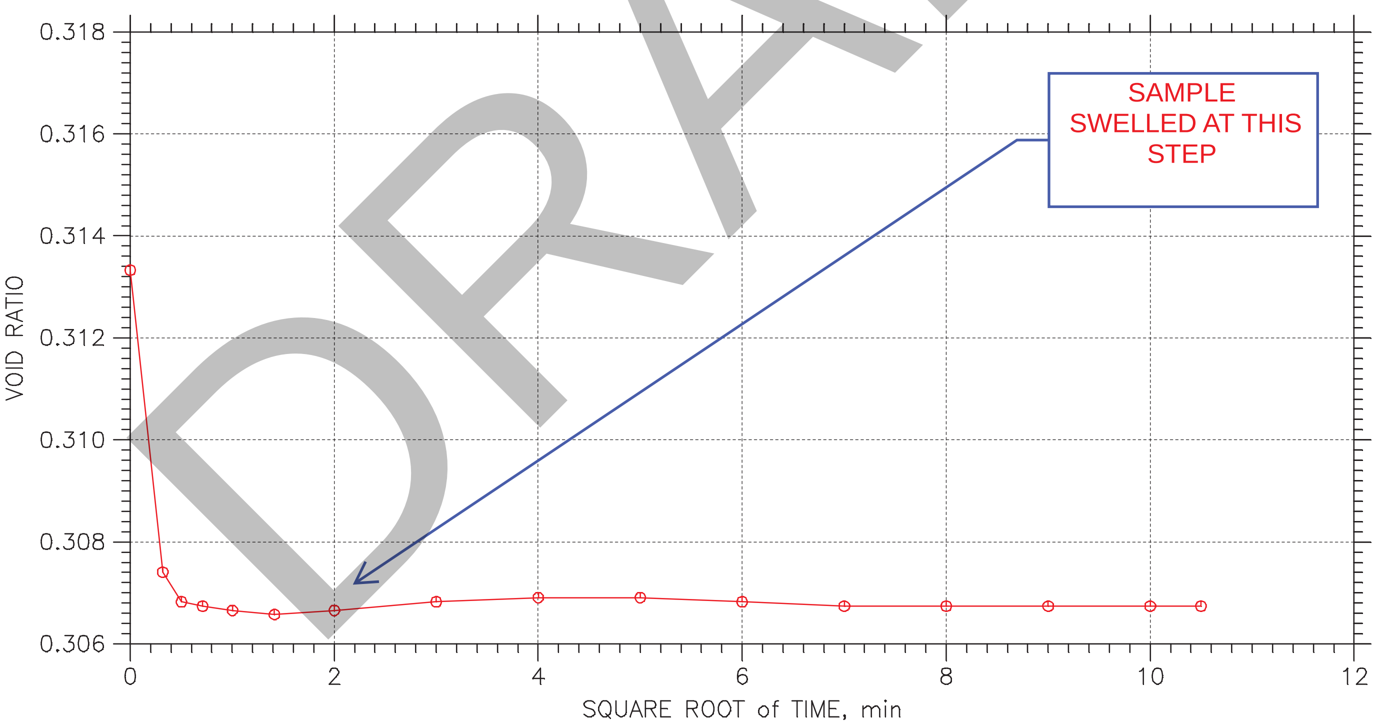
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 1 of 23

Stress: 0.125 tsf





DRAFT

Terracon Consulting Engineers & Scientists			
	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

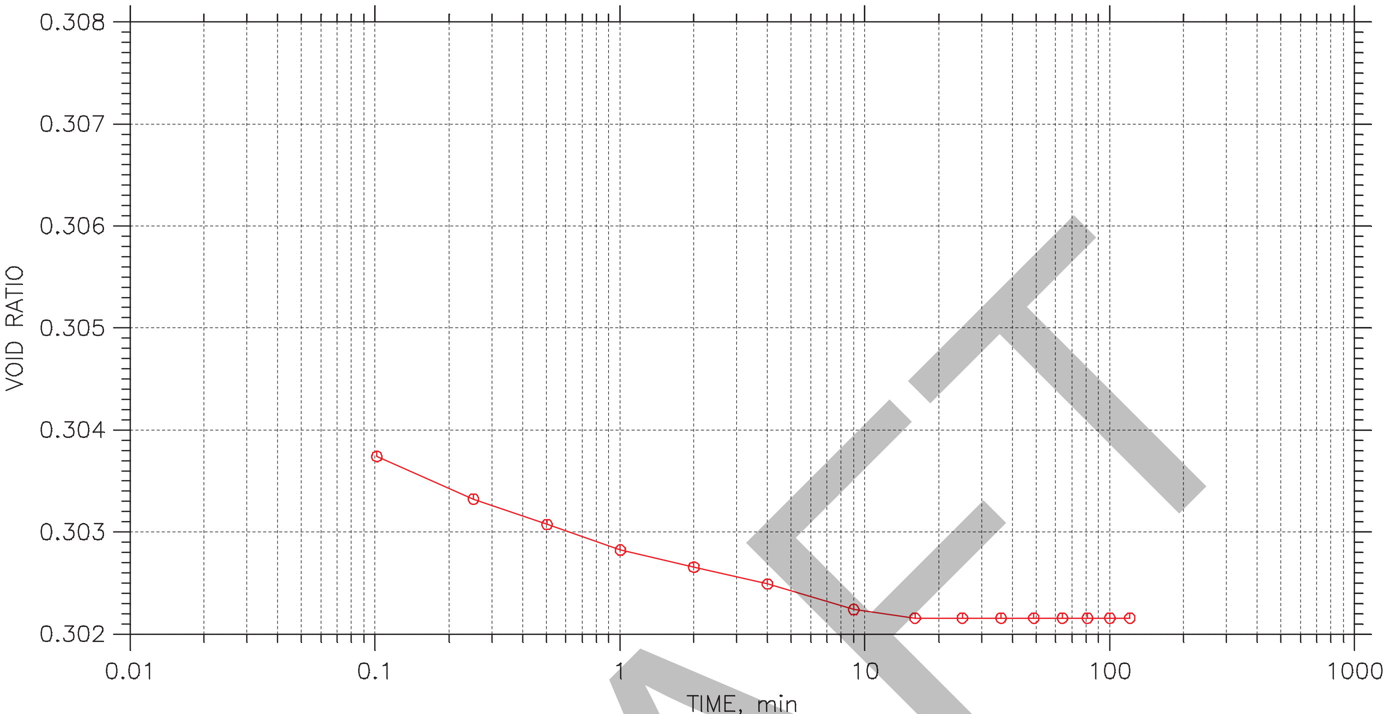
Mon, 21-DEC-2015 16:48:15

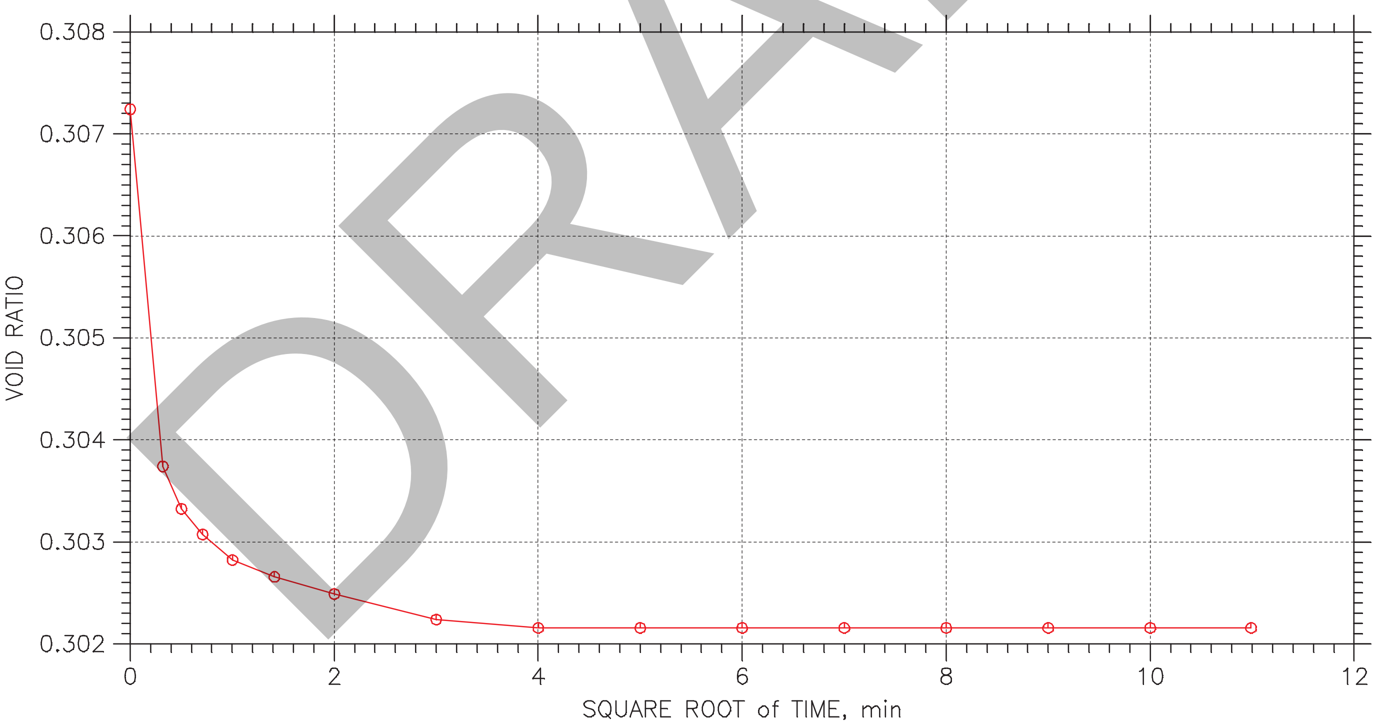
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 2 of 23

Stress: 0.25 tsf





DRAFT

Terracon Consulting Engineers & Scientists	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

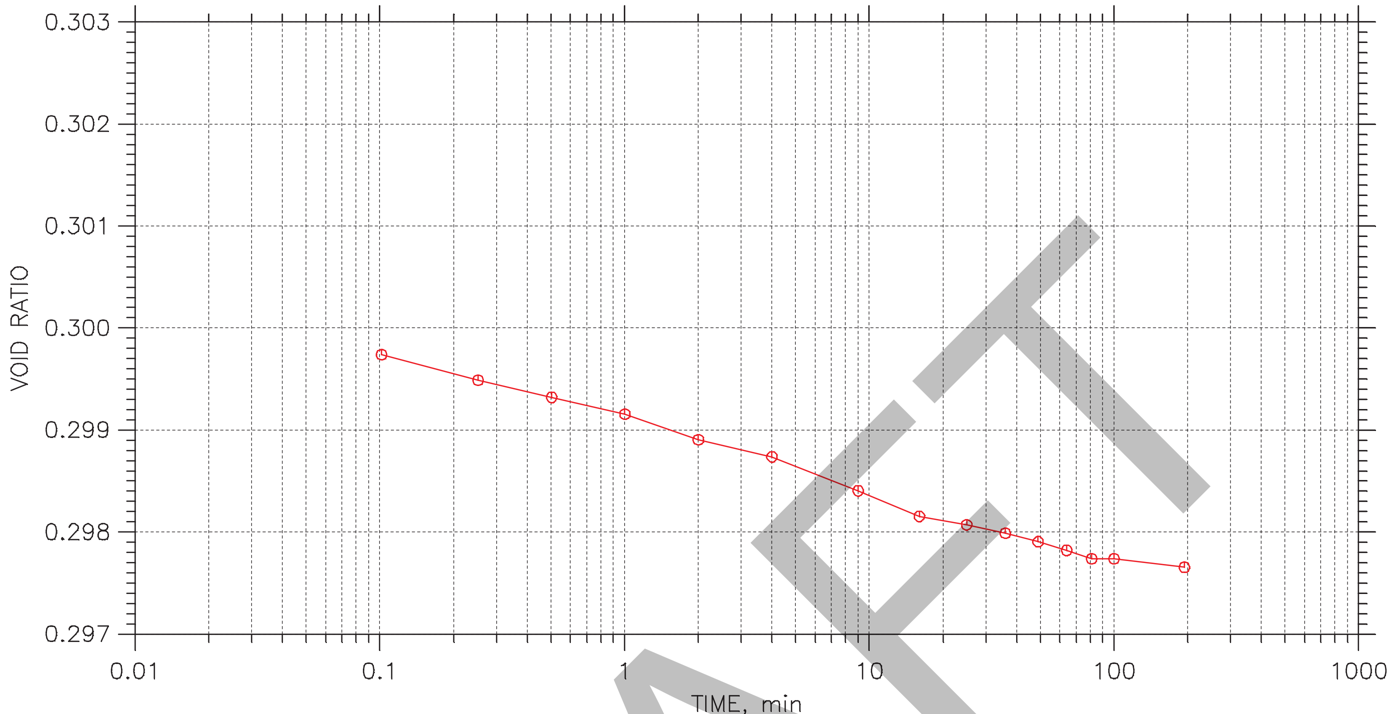
Mon, 21-DEC-2015 16:48:16

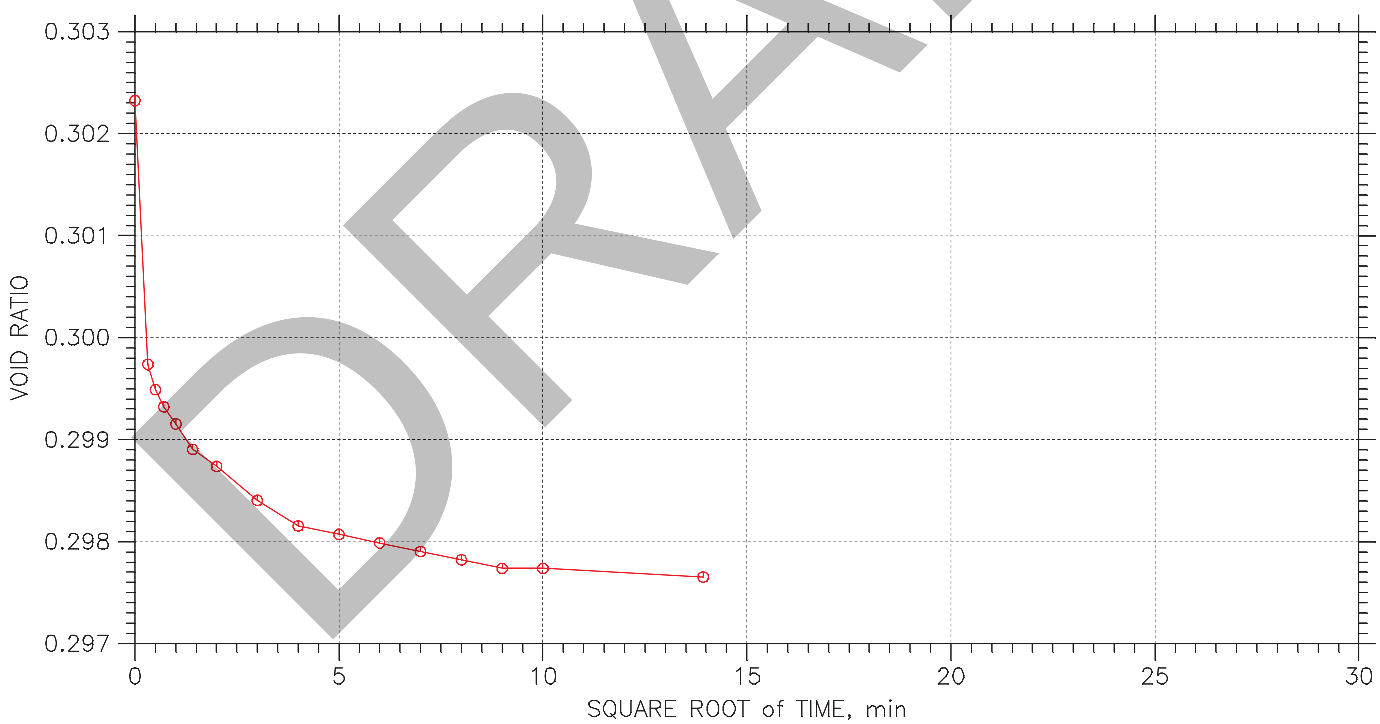
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 3 of 23

Stress: 0.5 tsf





DRAFT

Terracon Consulting Engineers & Scientists			
	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

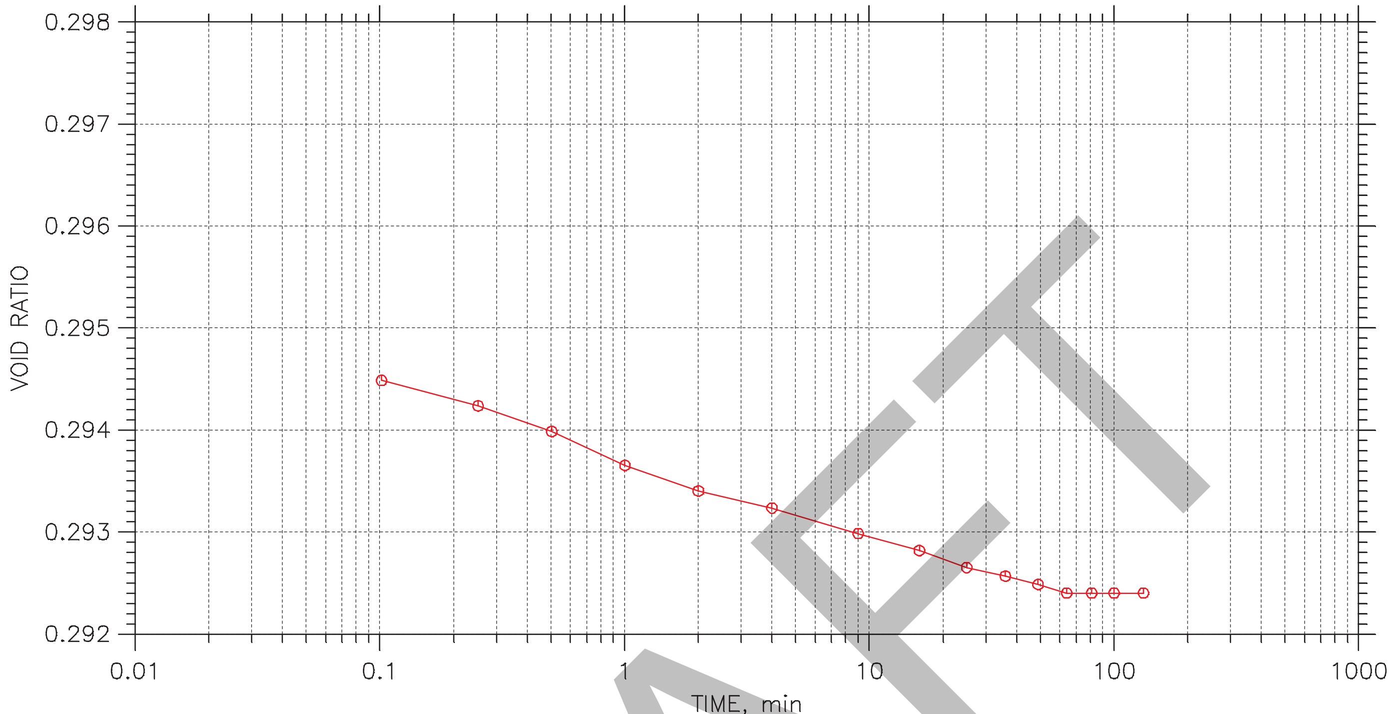
Mon, 21-DEC-2015 16:48:17

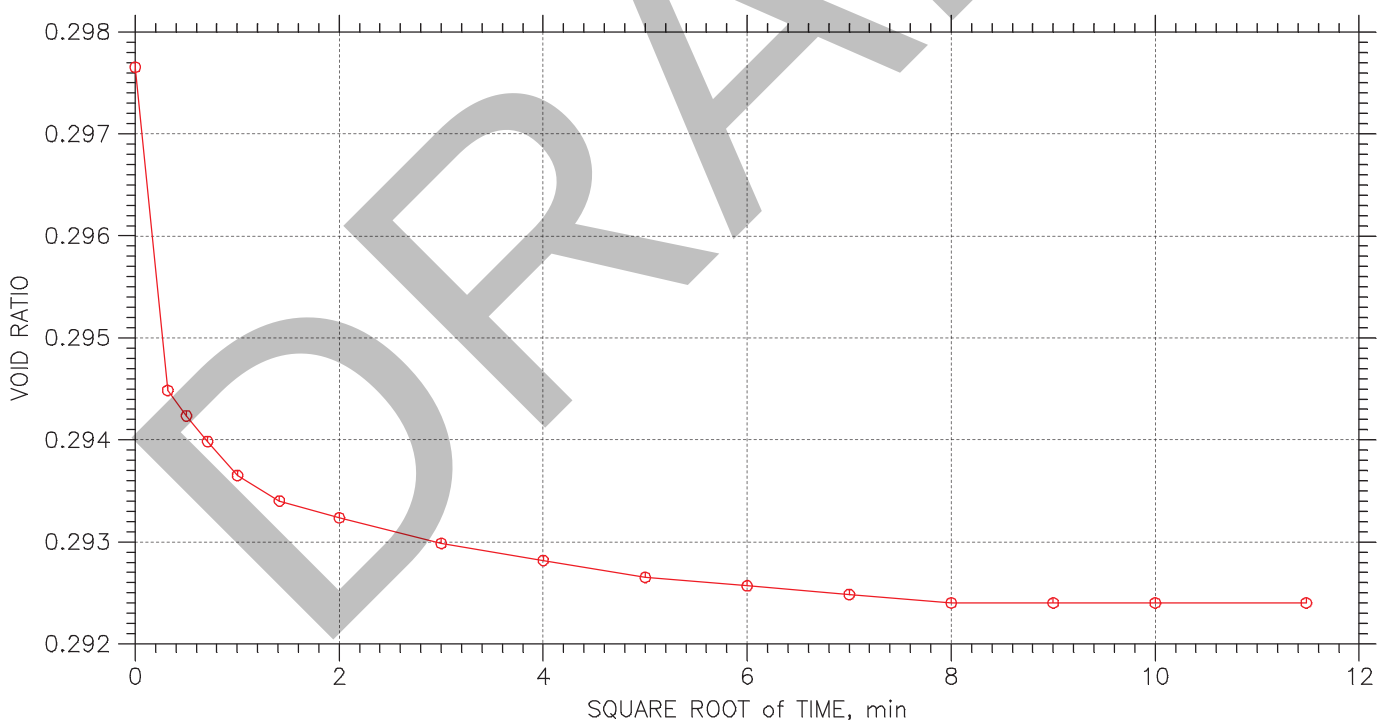
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 4 of 23

Stress: 0.75 tsf





Terracon Consulting Engineers & Scientists	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

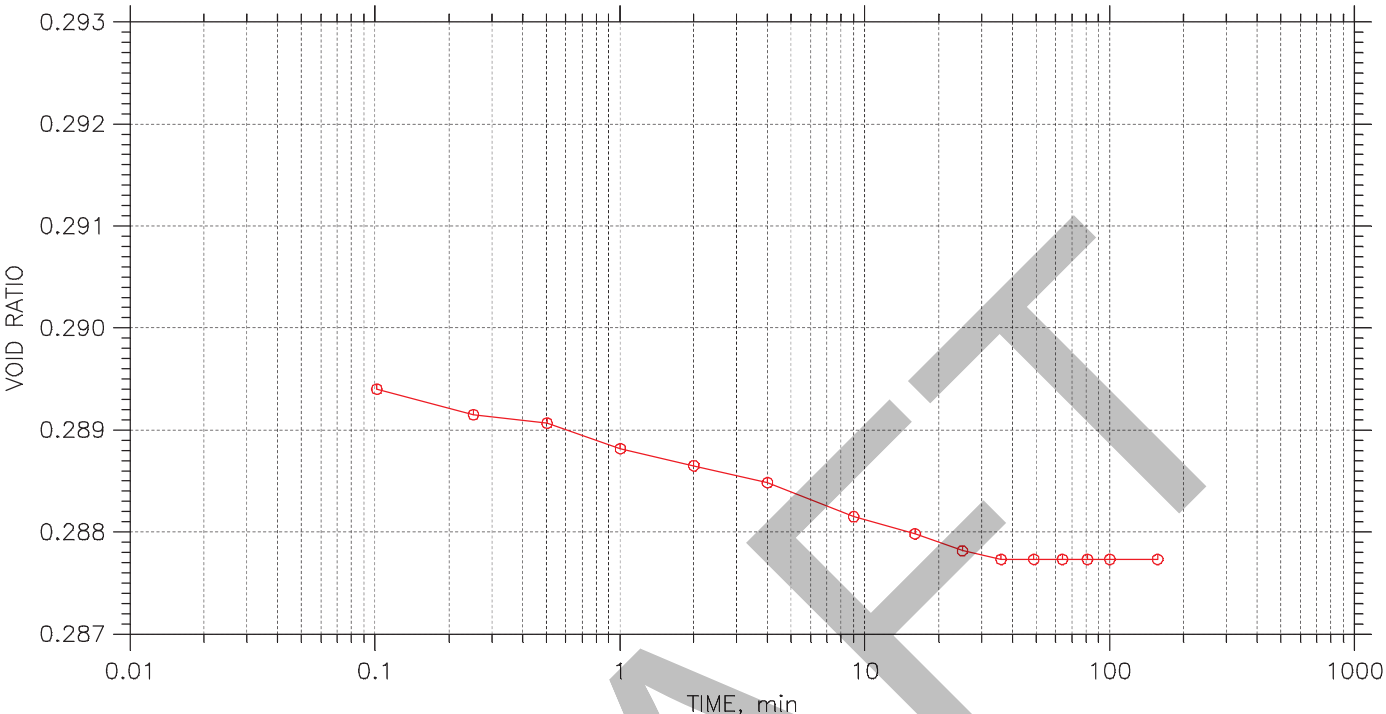
Mon, 21-DEC-2015 16:48:19

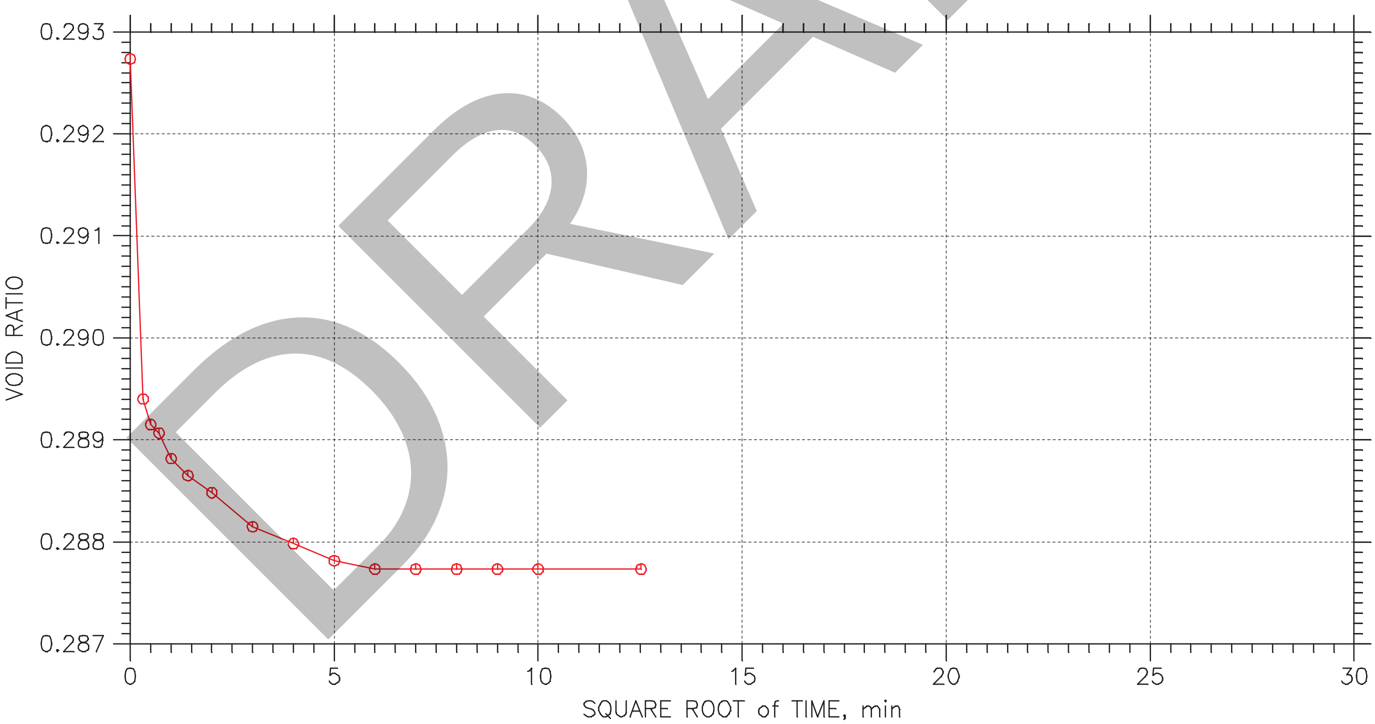
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 5 of 23

Stress: 1. tsf





DRAFT

Terracon Consulting Engineers & Scientists

Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

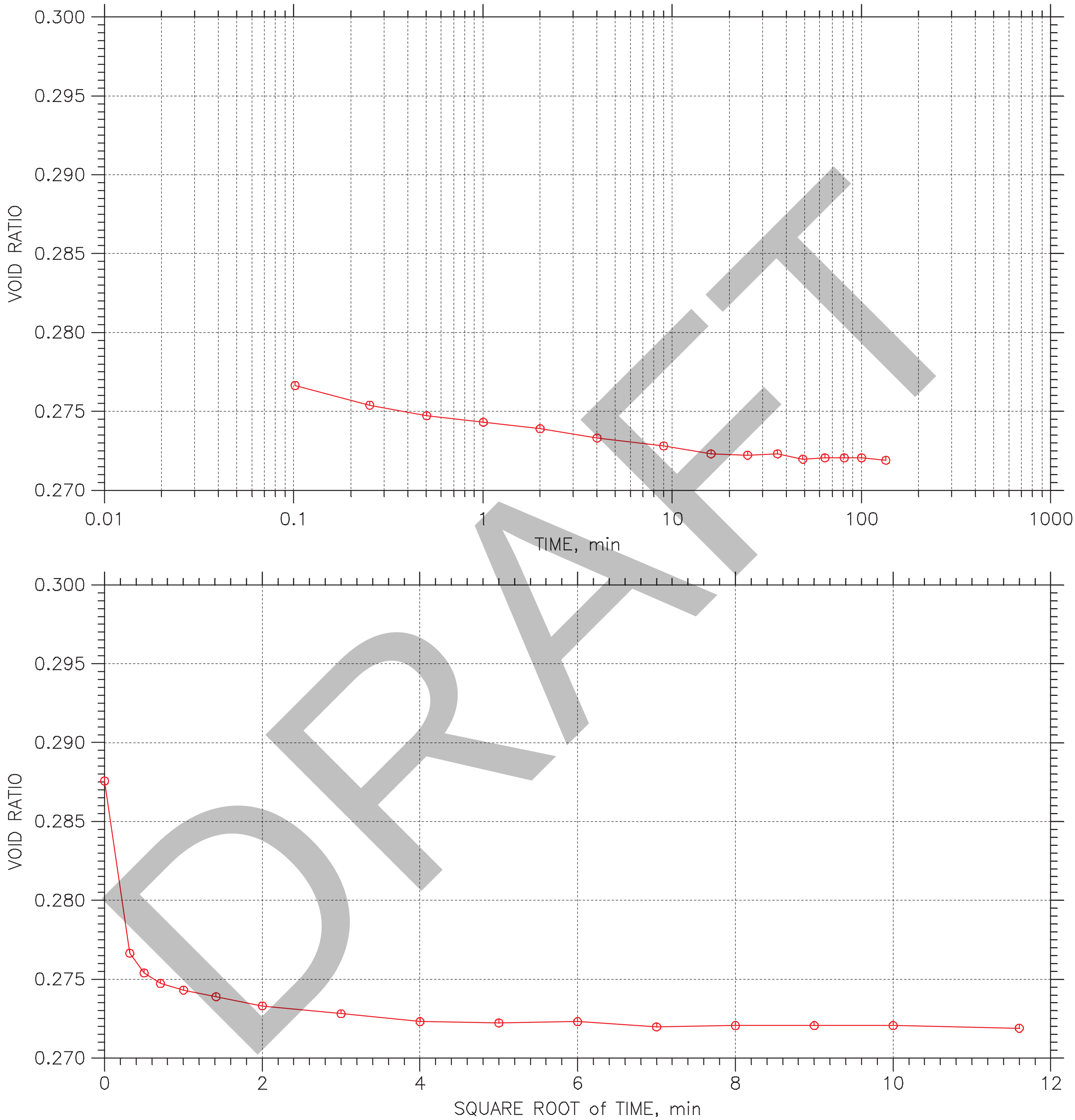
Mon, 21-DEC-2015 16:48:20

CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 6 of 23

Stress: 2. tsf



Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

Terracon Consulting Engineers & Scientists

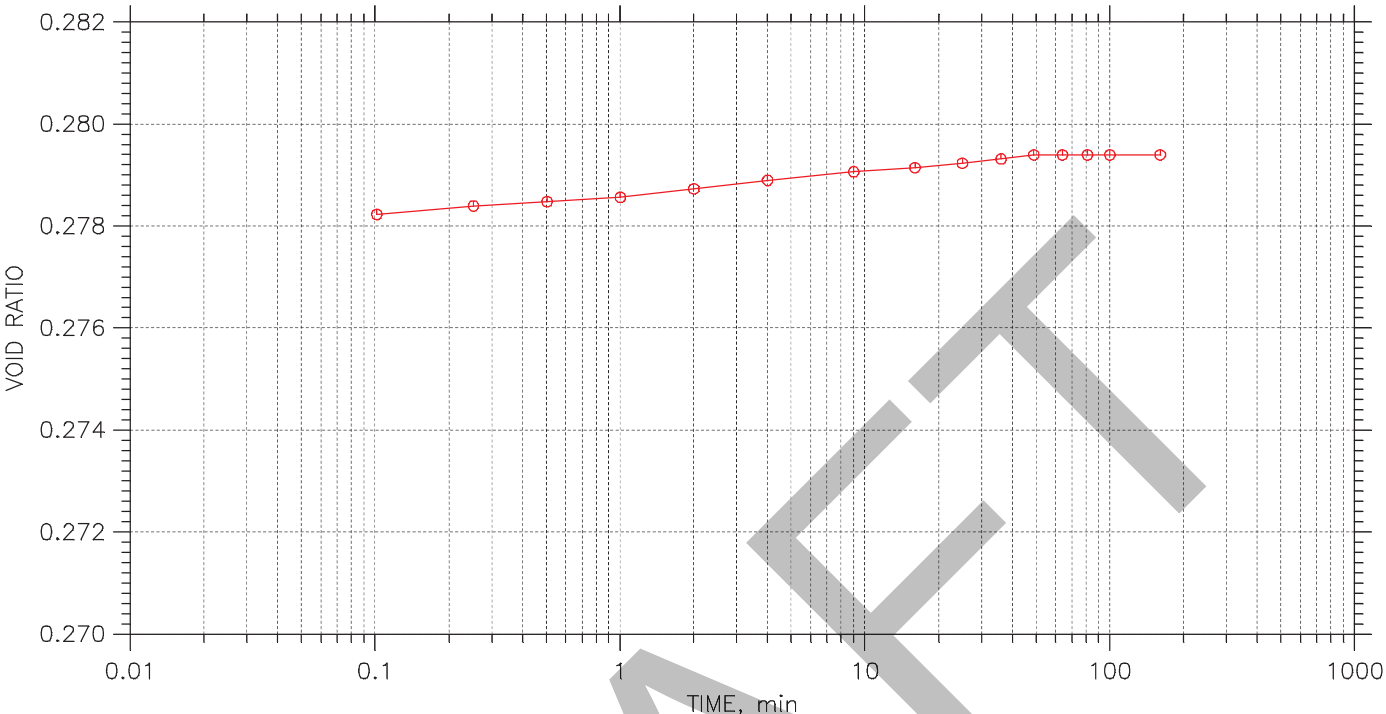
Mon, 21-DEC-2015 16:48:21

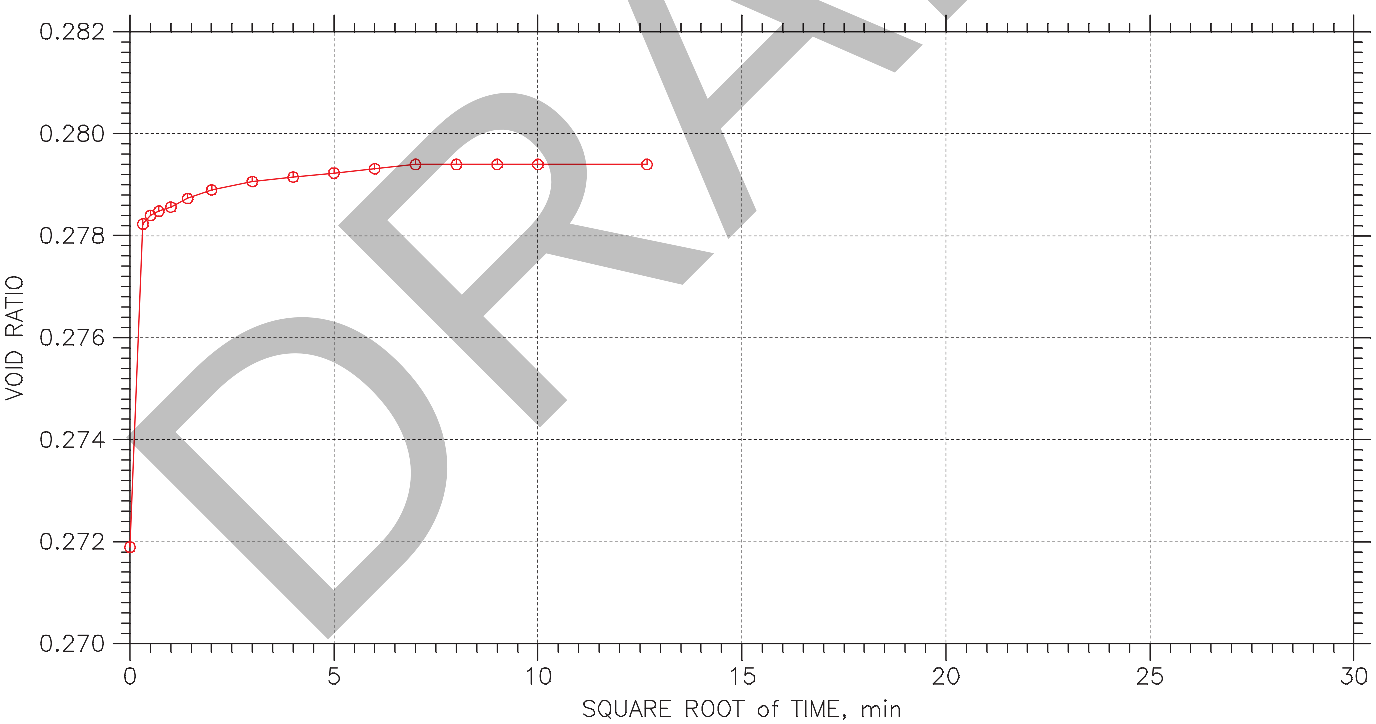
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 7 of 23

Stress: 1. tsf





DRAFT

Terracon Consulting Engineers & Scientists	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

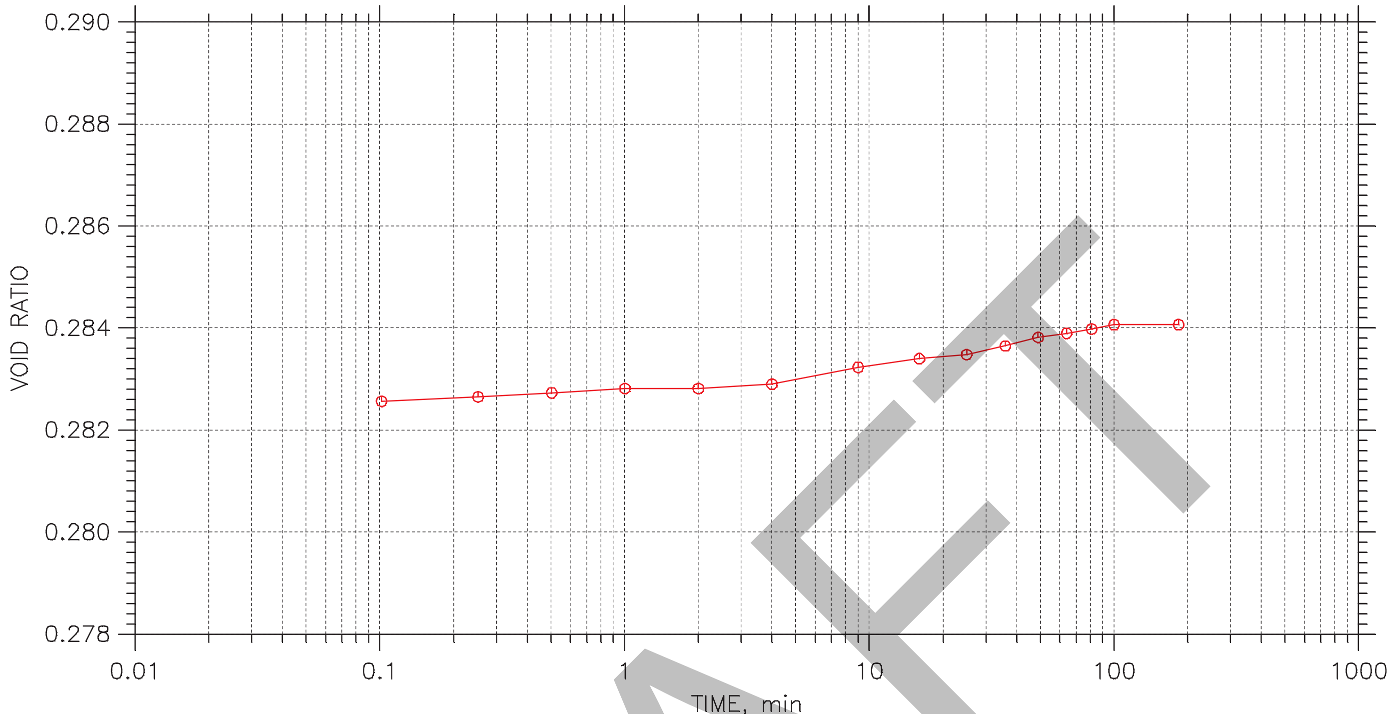
Mon, 21-DEC-2015 16:48:23

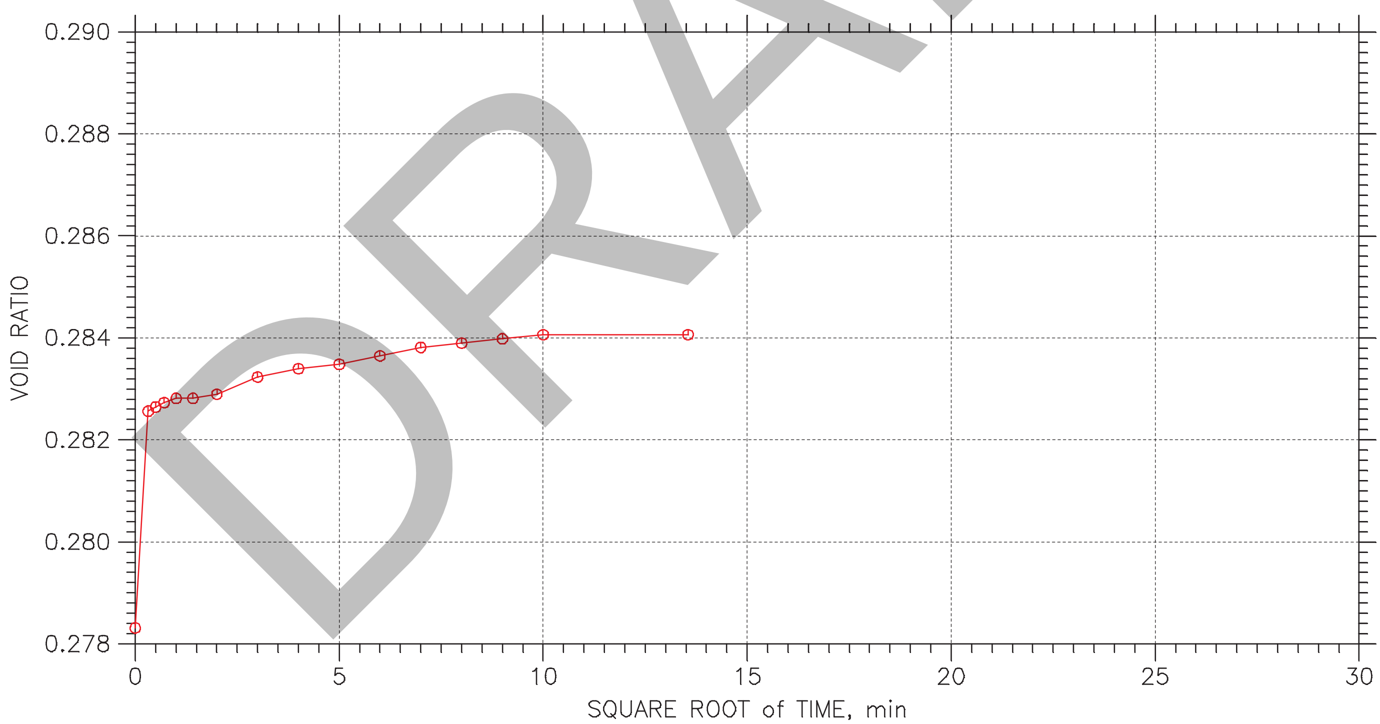
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 8 of 23

Stress: 0.5 tsf





Terracon Consulting Engineers & Scientists	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

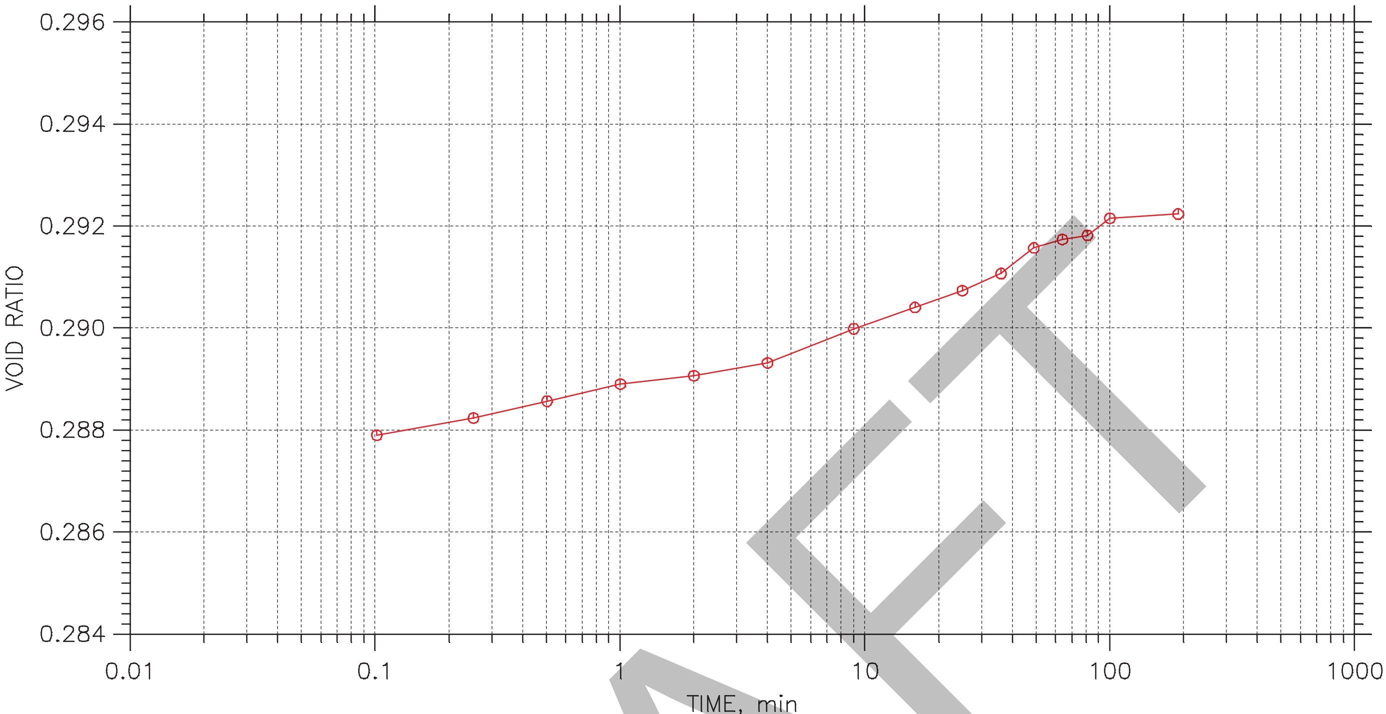
Mon, 21-DEC-2015 16:48:24

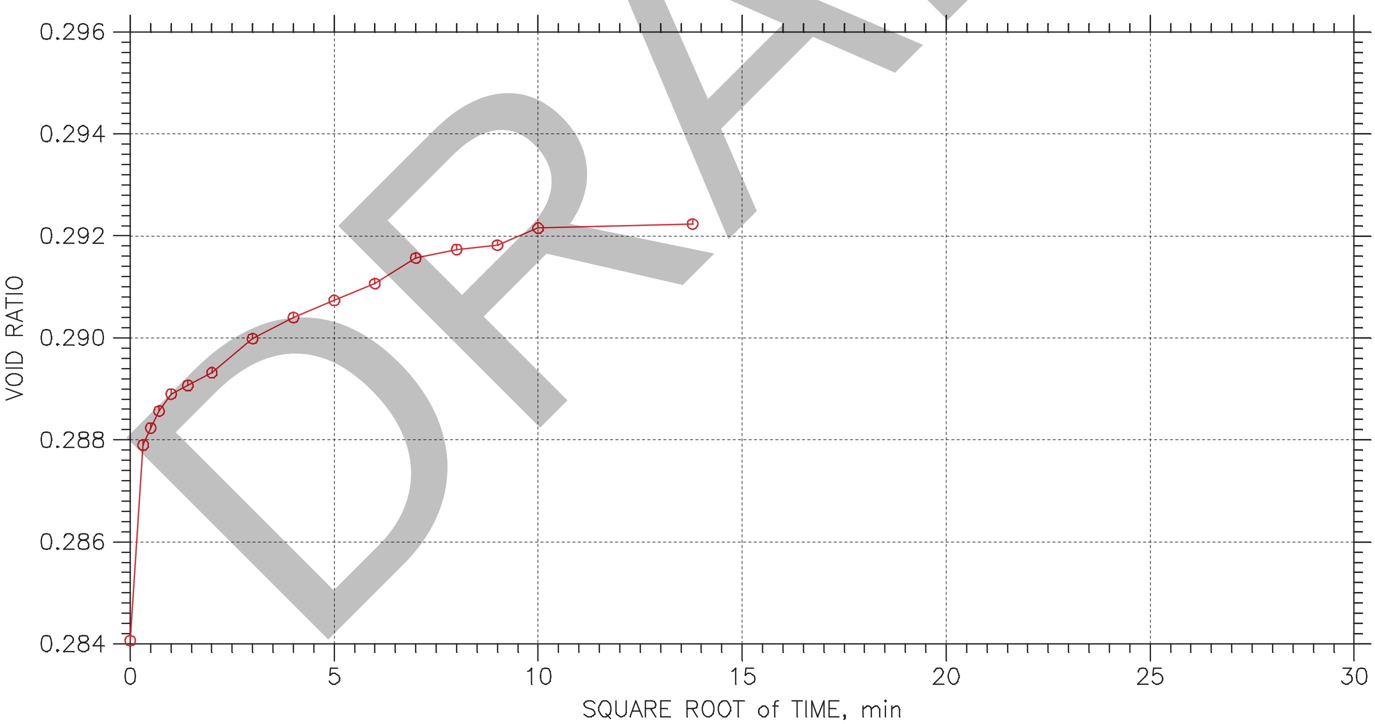
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 9 of 23

Stress: 0.125 tsf





DRAFT

Terracon Consulting Engineers & Scientists			
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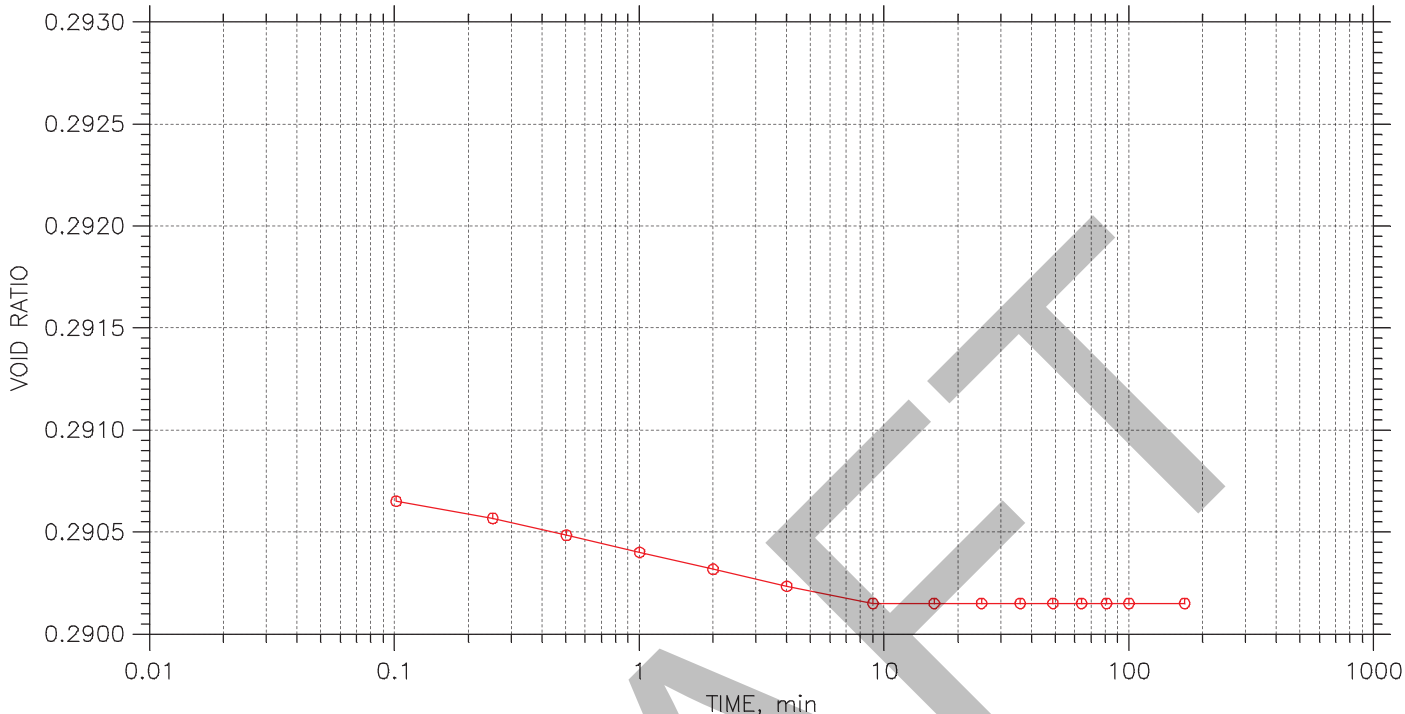
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

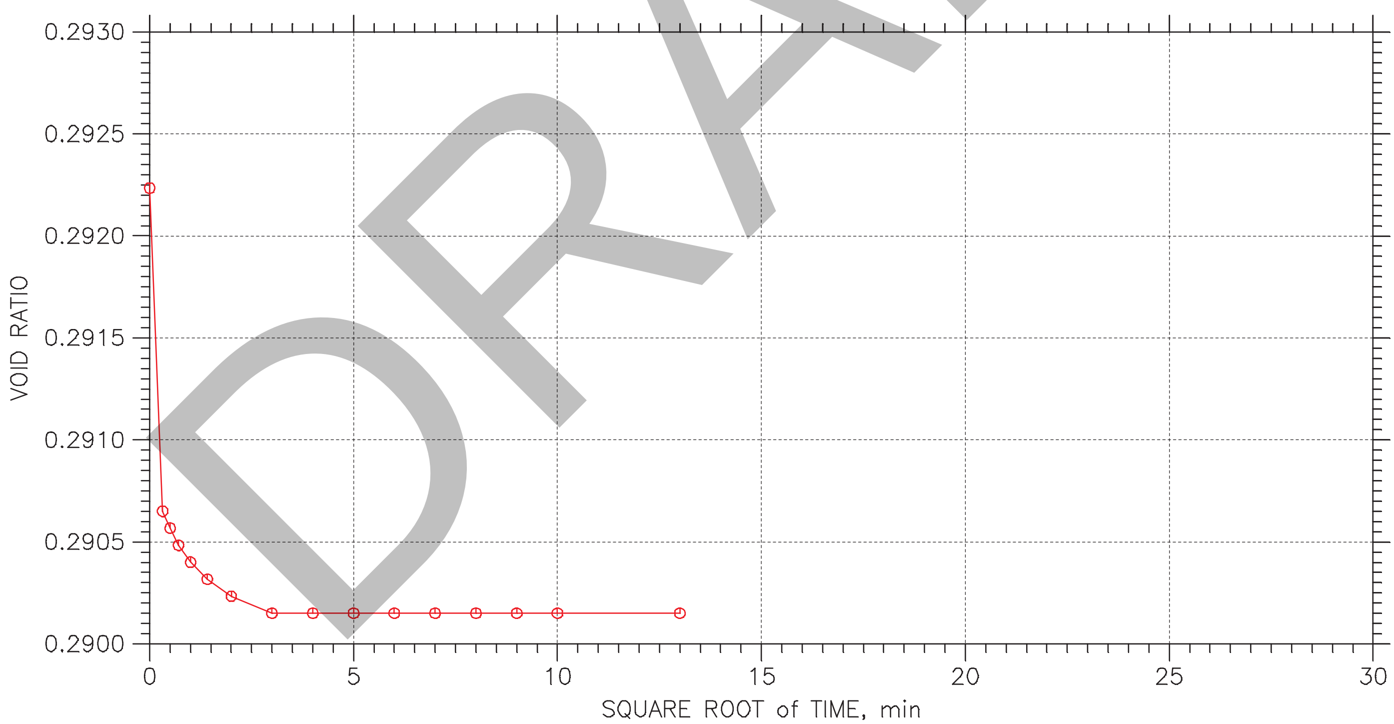
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 10 of 23

Stress: 0.25 tsf





Terracon Consulting Engineers & Scientists			
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	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

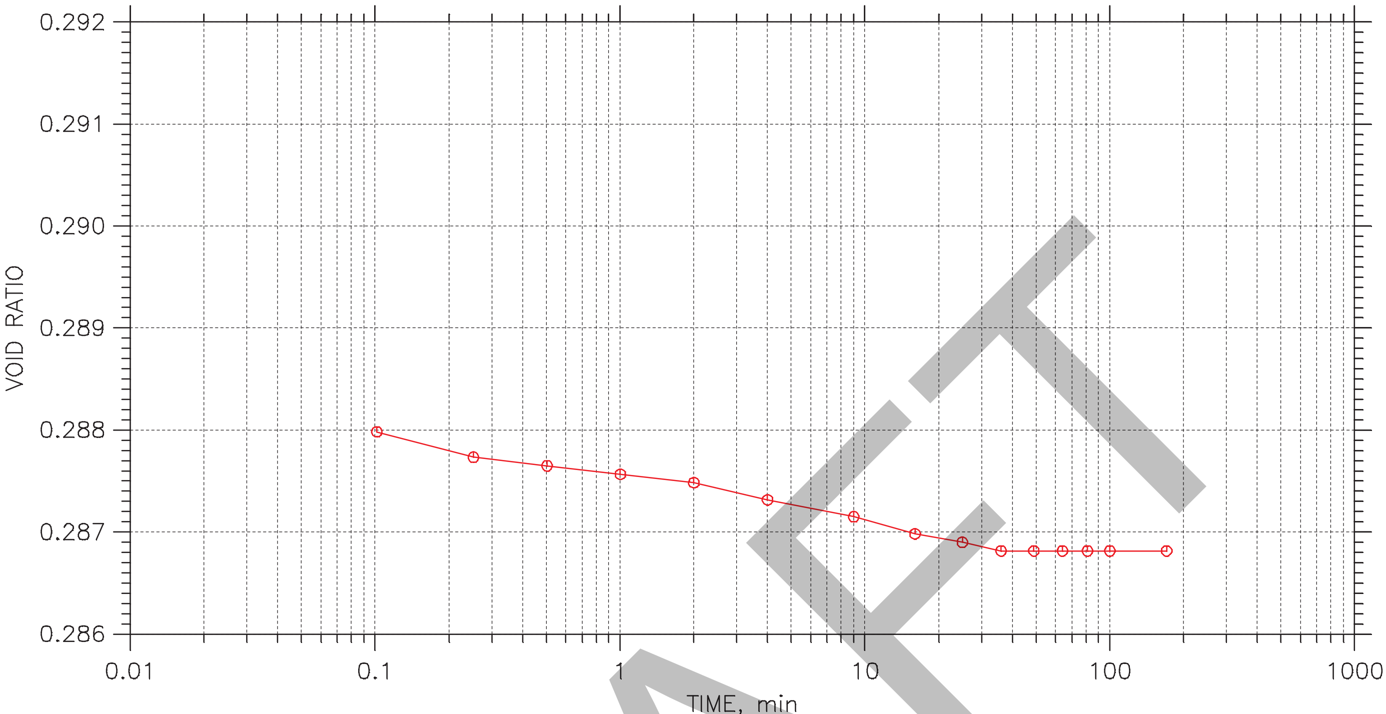
Mon, 21-DEC-2015 16:48:27

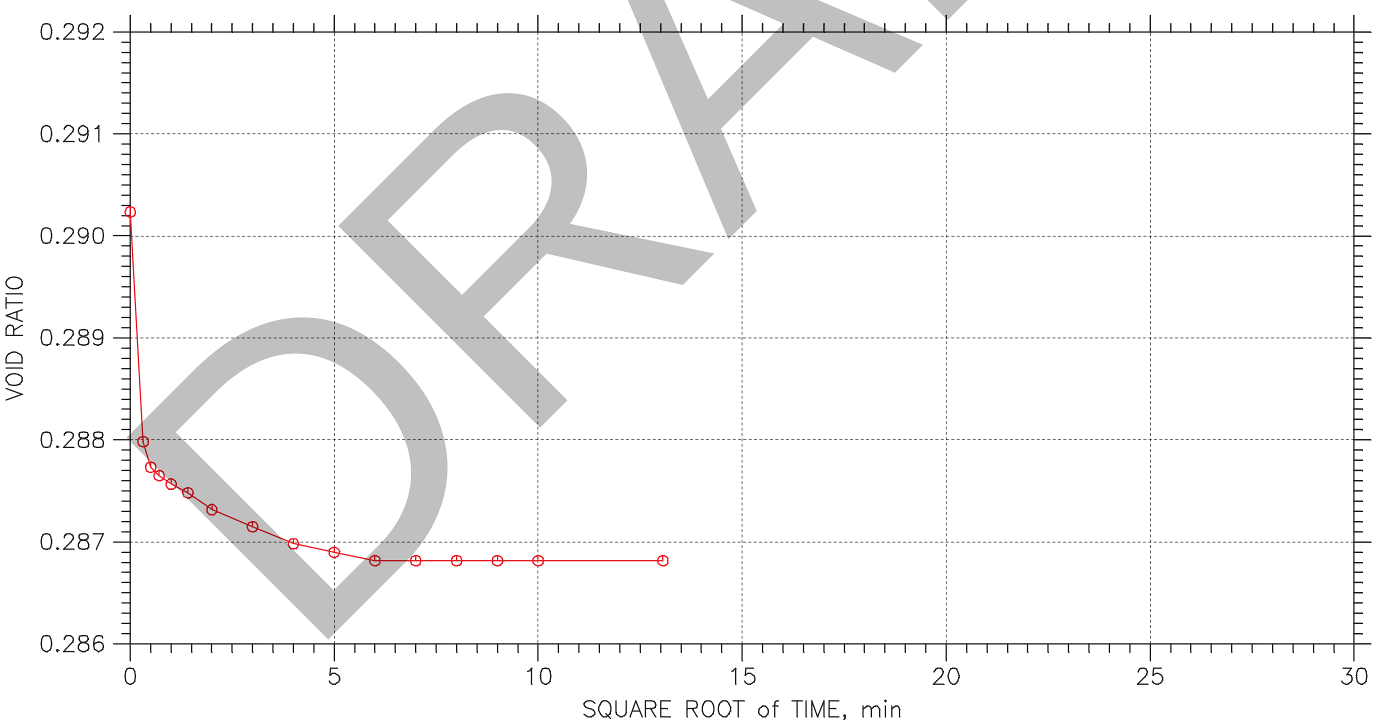
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 11 of 23

Stress: 0.5 tsf





Terracon Consulting Engineers & Scientists	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

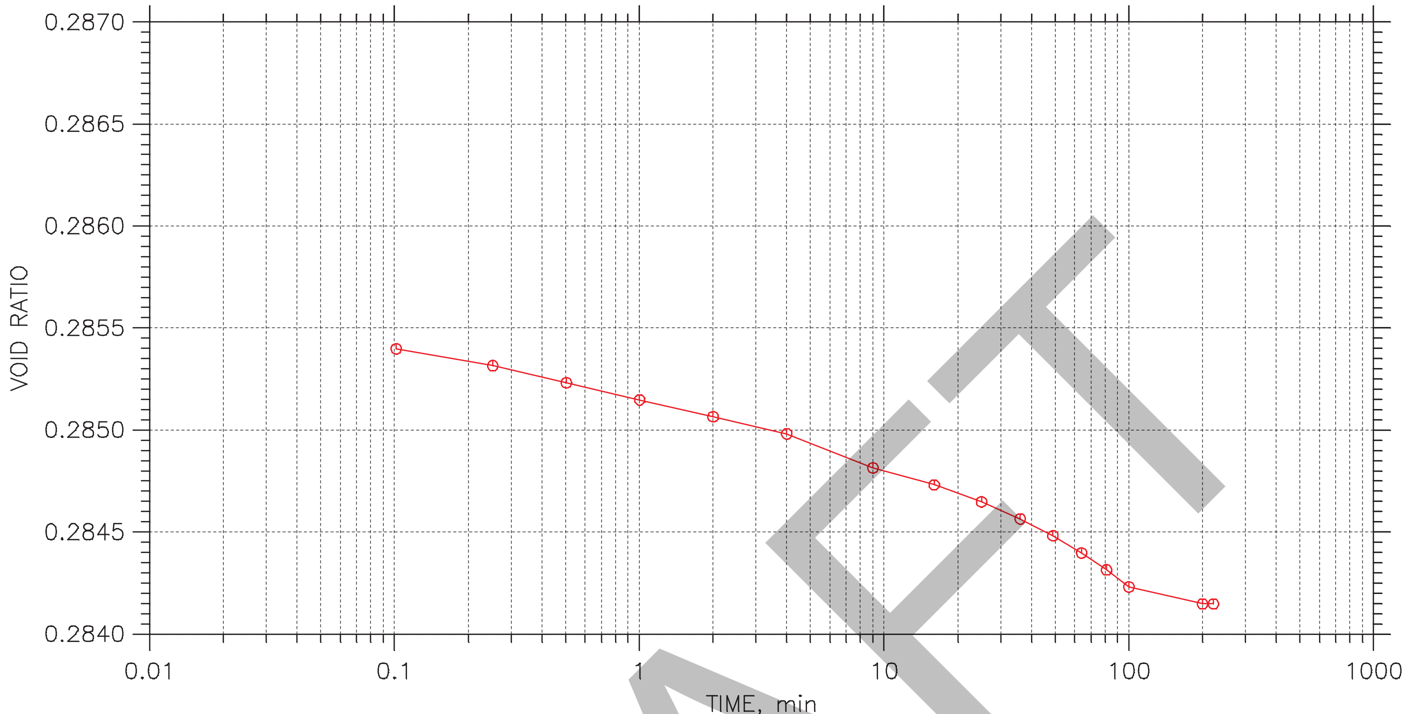
Mon, 21-DEC-2015 16:48:28

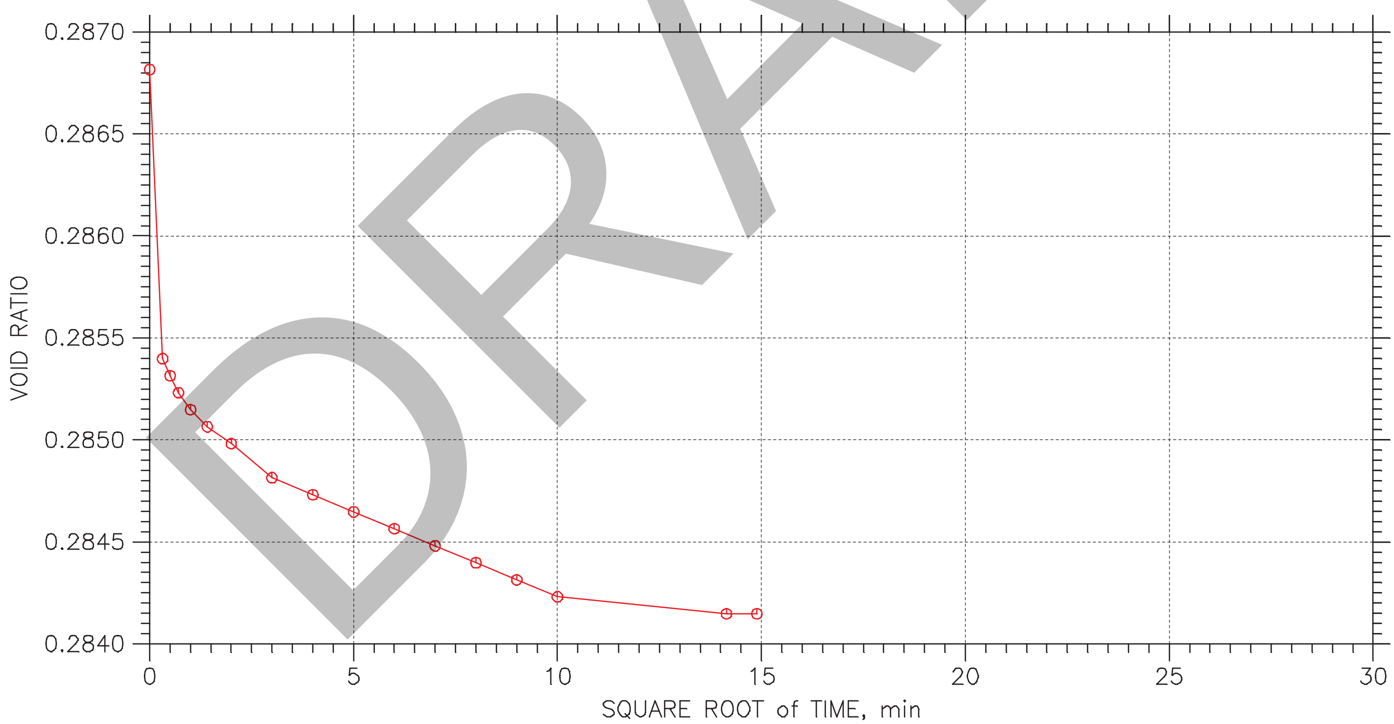
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 12 of 23

Stress: 0.75 tsf





Terracon Consulting Engineers & Scientists			
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	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

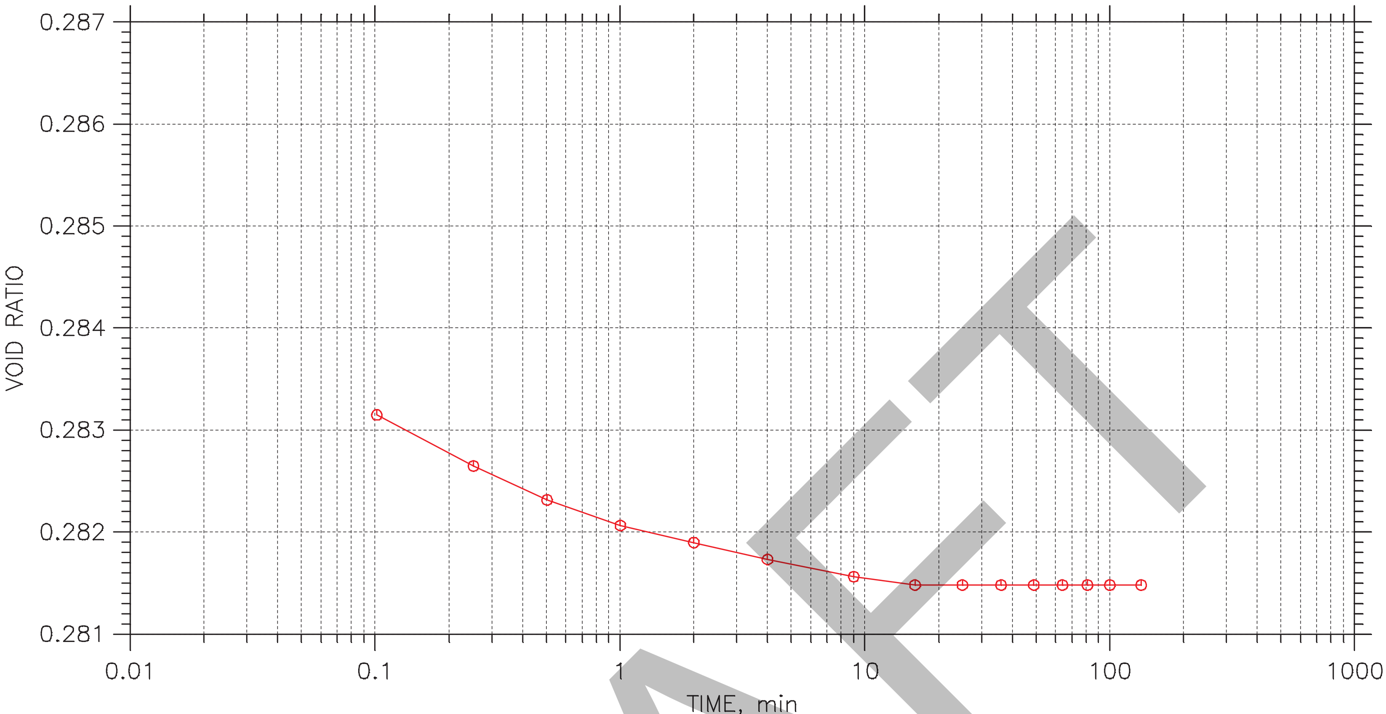
Mon, 21-DEC-2015 16:48:30

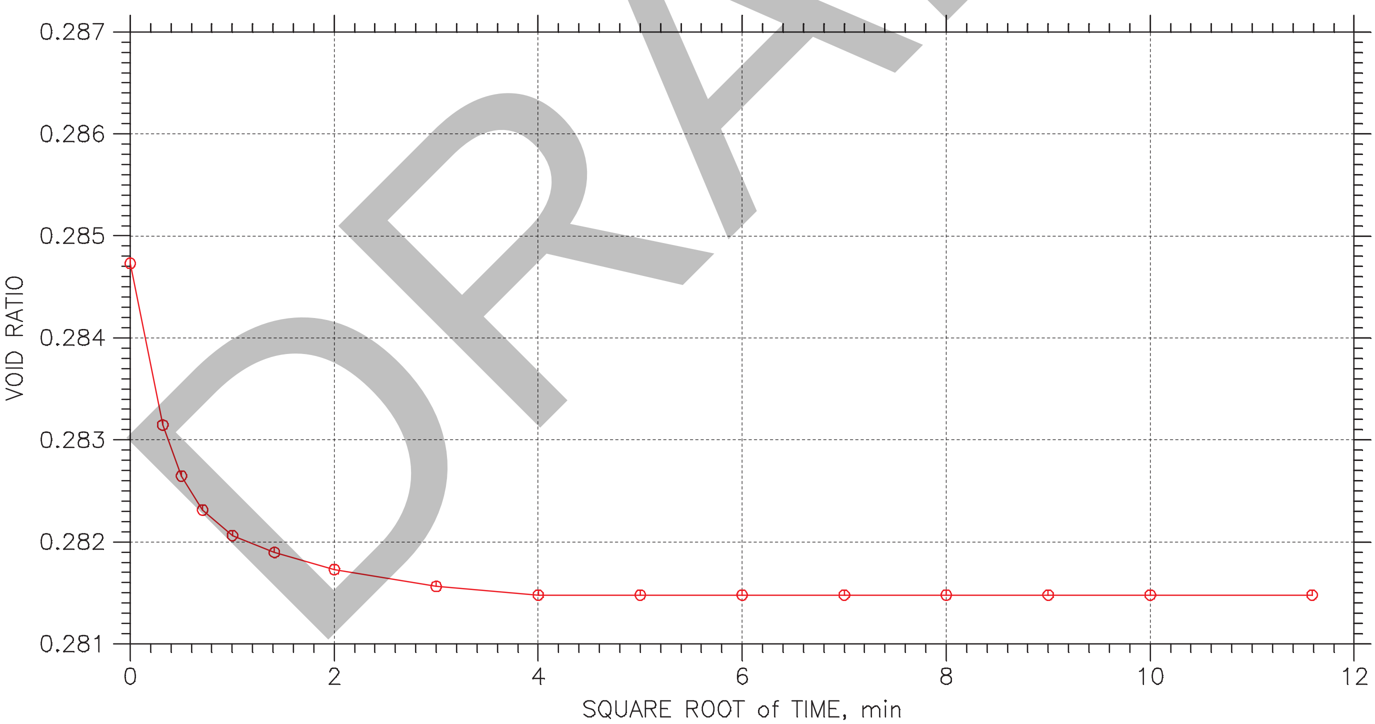
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 13 of 23

Stress: 1. tsf





DRAFT

Terracon Consulting Engineers & Scientists			
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	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

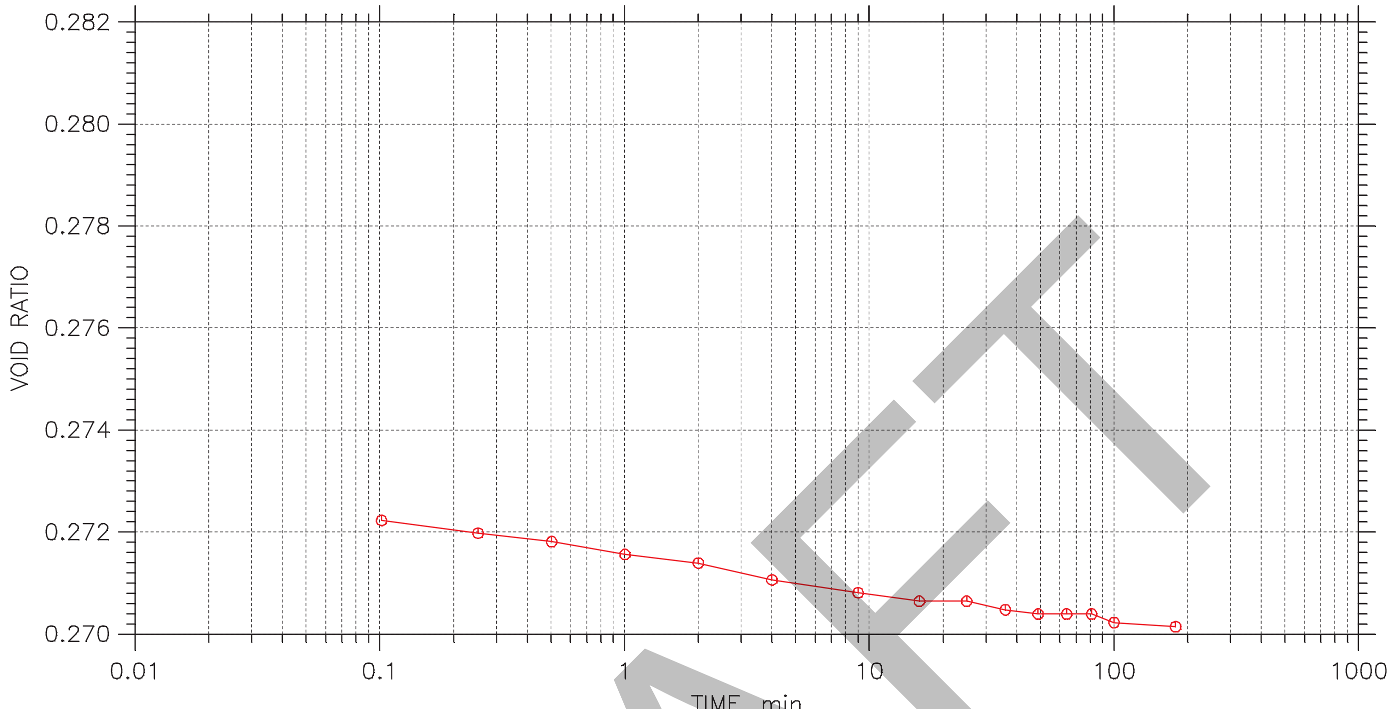
Mon, 21-DEC-2015 16:48:31

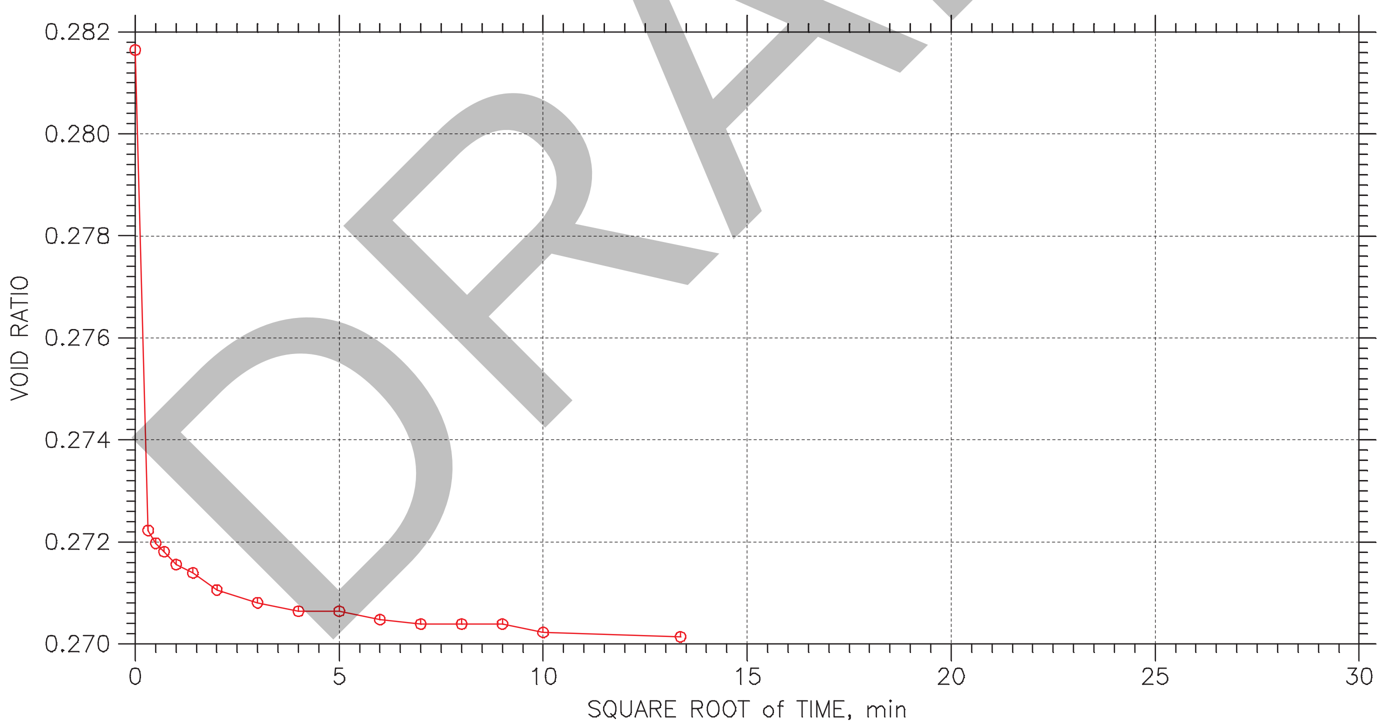
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 14 of 23

Stress: 2. tsf





Terracon Consulting Engineers & Scientists			
	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

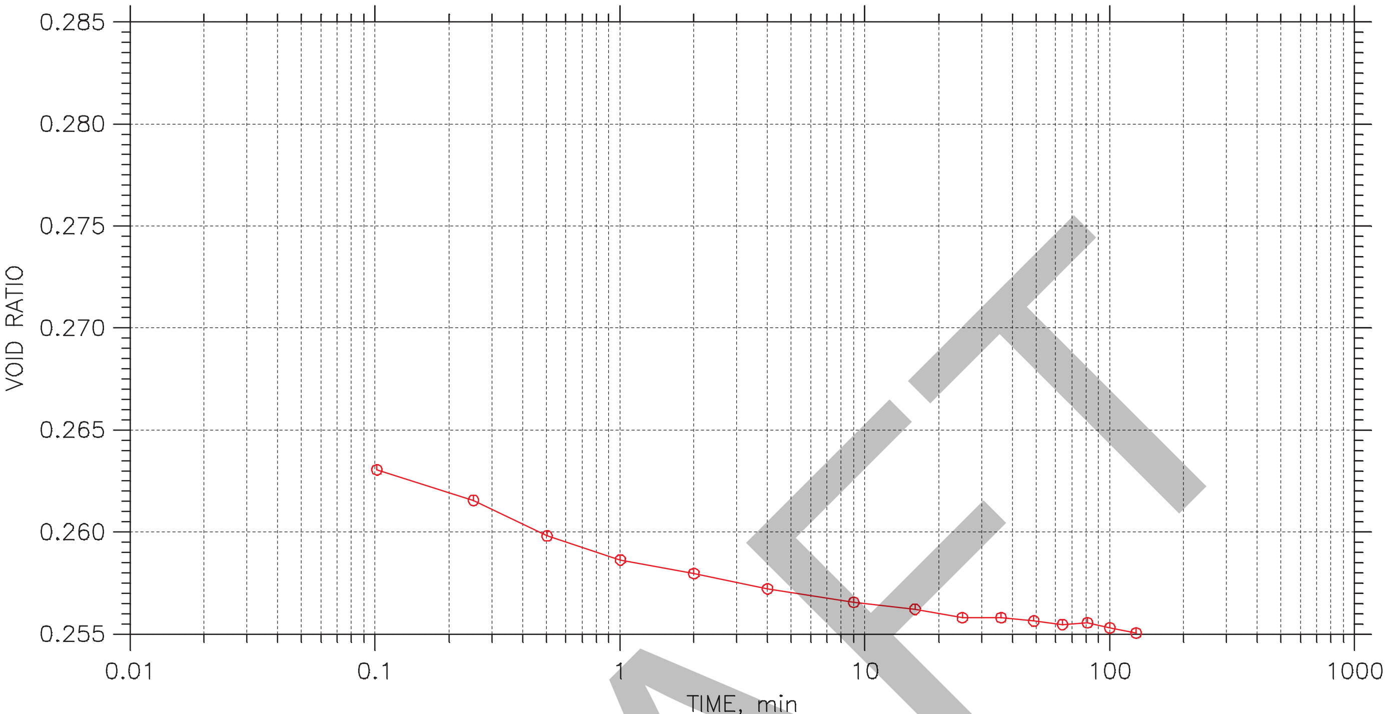
Mon, 21-DEC-2015 16:48:33

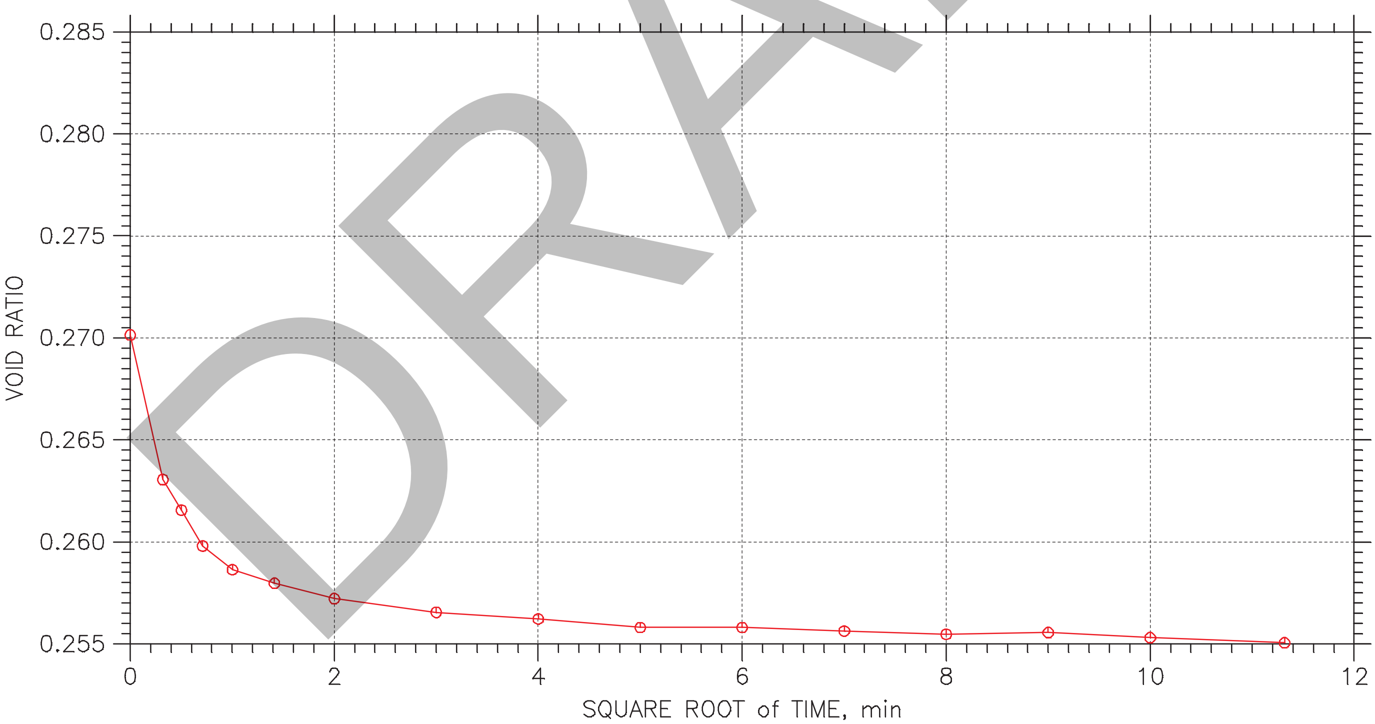
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 15 of 23

Stress: 4. tsf





DRAFT

Terracon Consulting Engineers & Scientists			
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	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

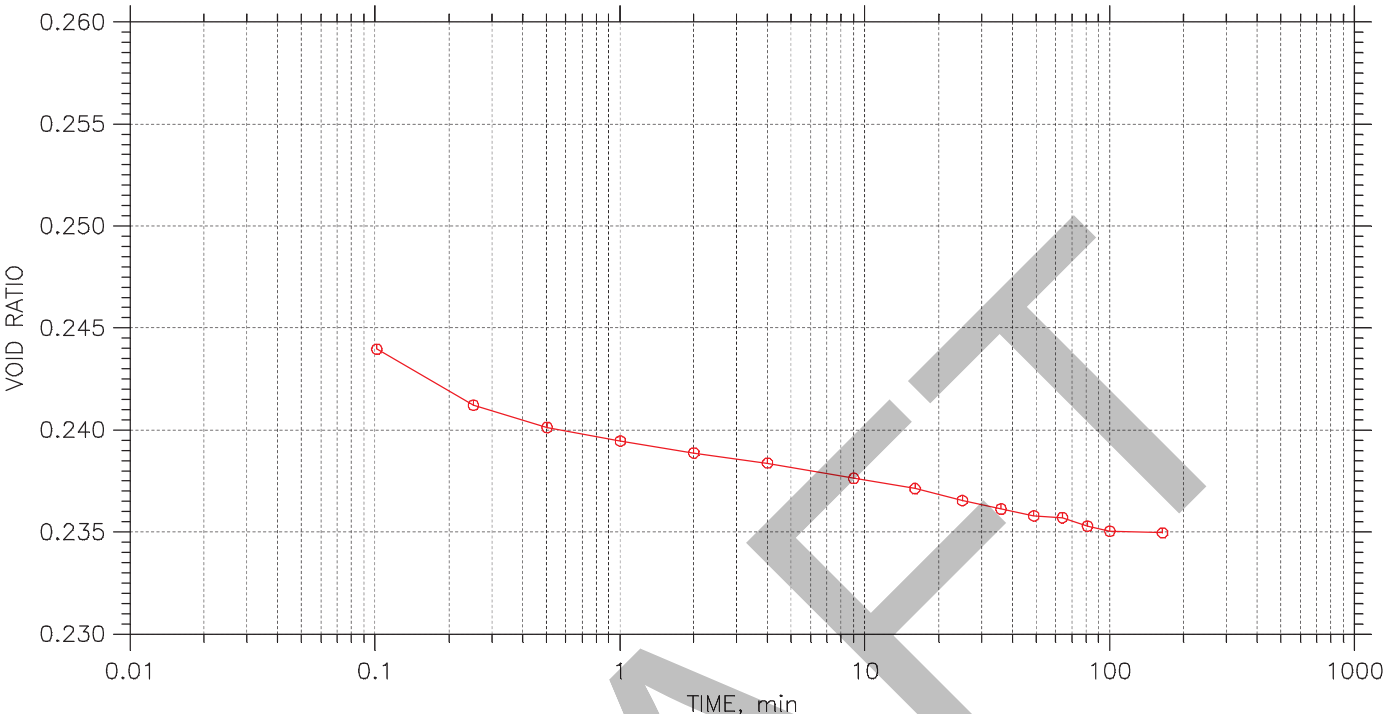
Mon, 21-DEC-2015 16:48:34

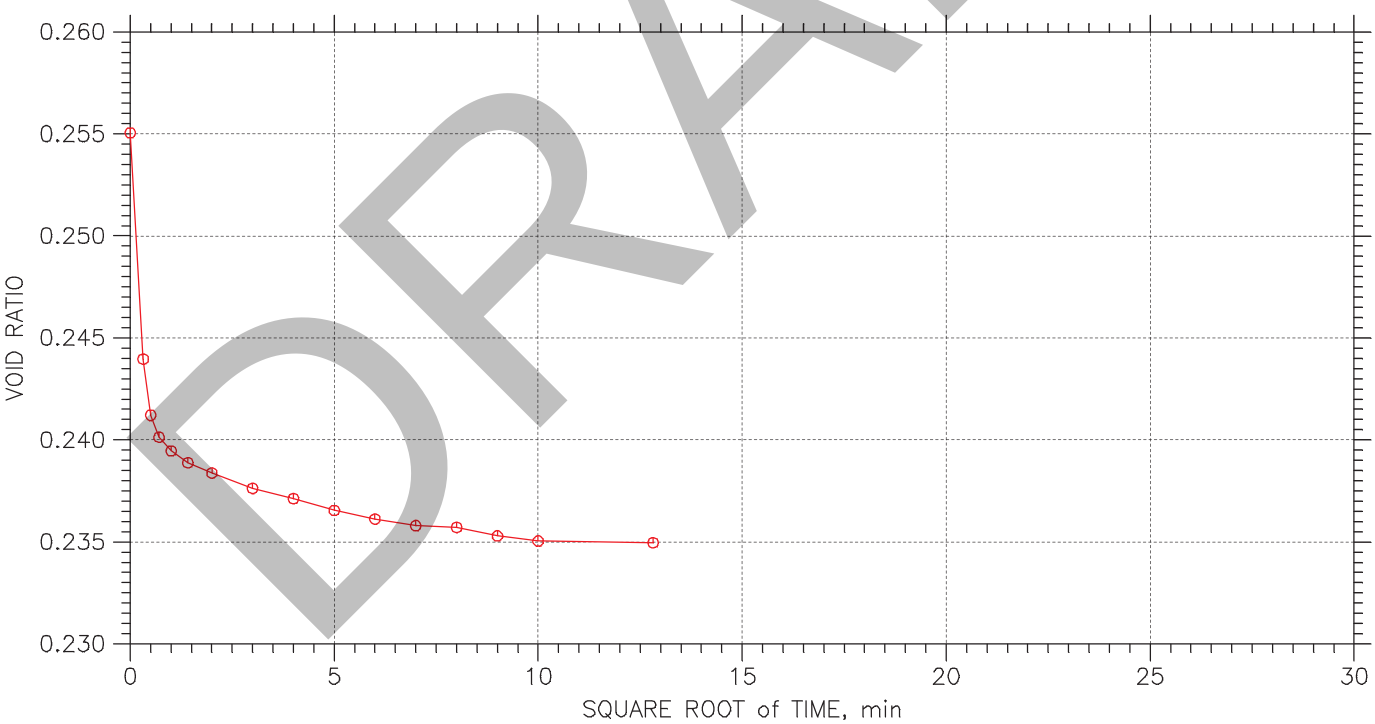
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 16 of 23

Stress: 8. tsf





DRAFT

Terracon Consulting Engineers & Scientists	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

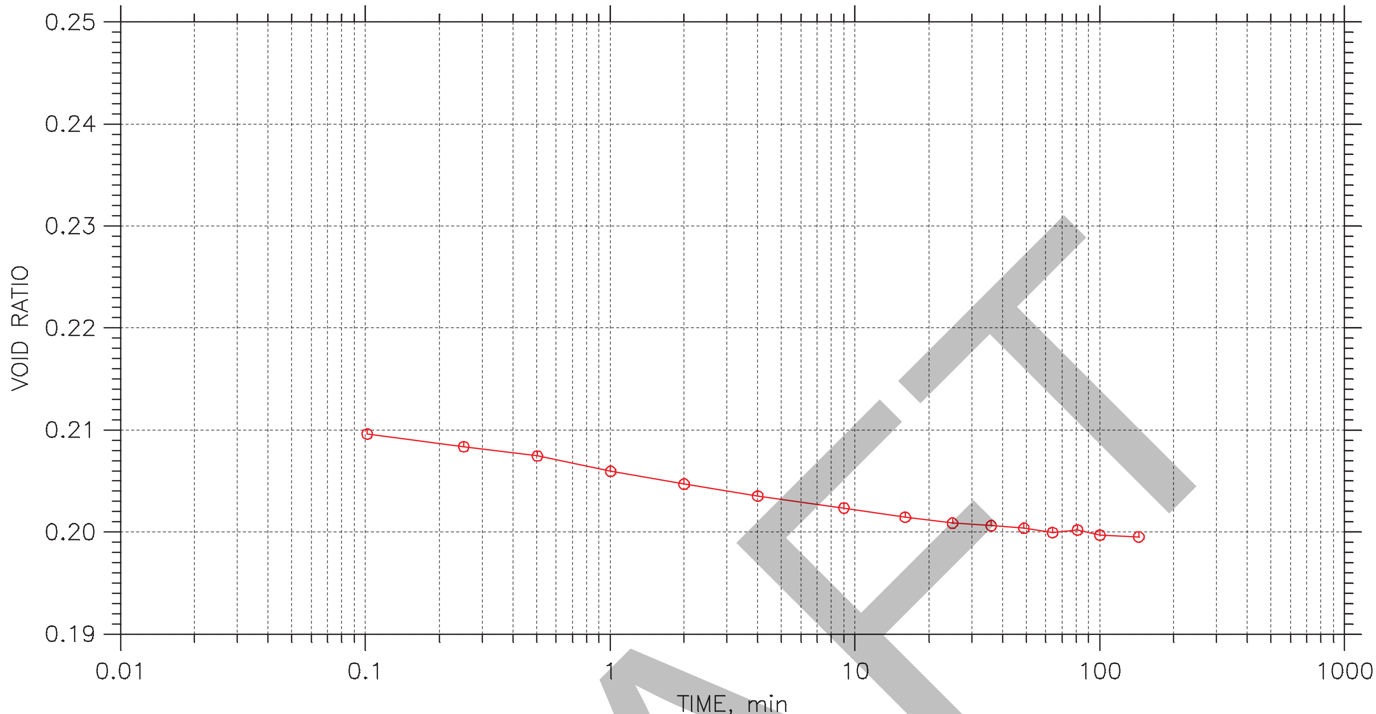
Mon, 21-DEC-2015 16:48:36

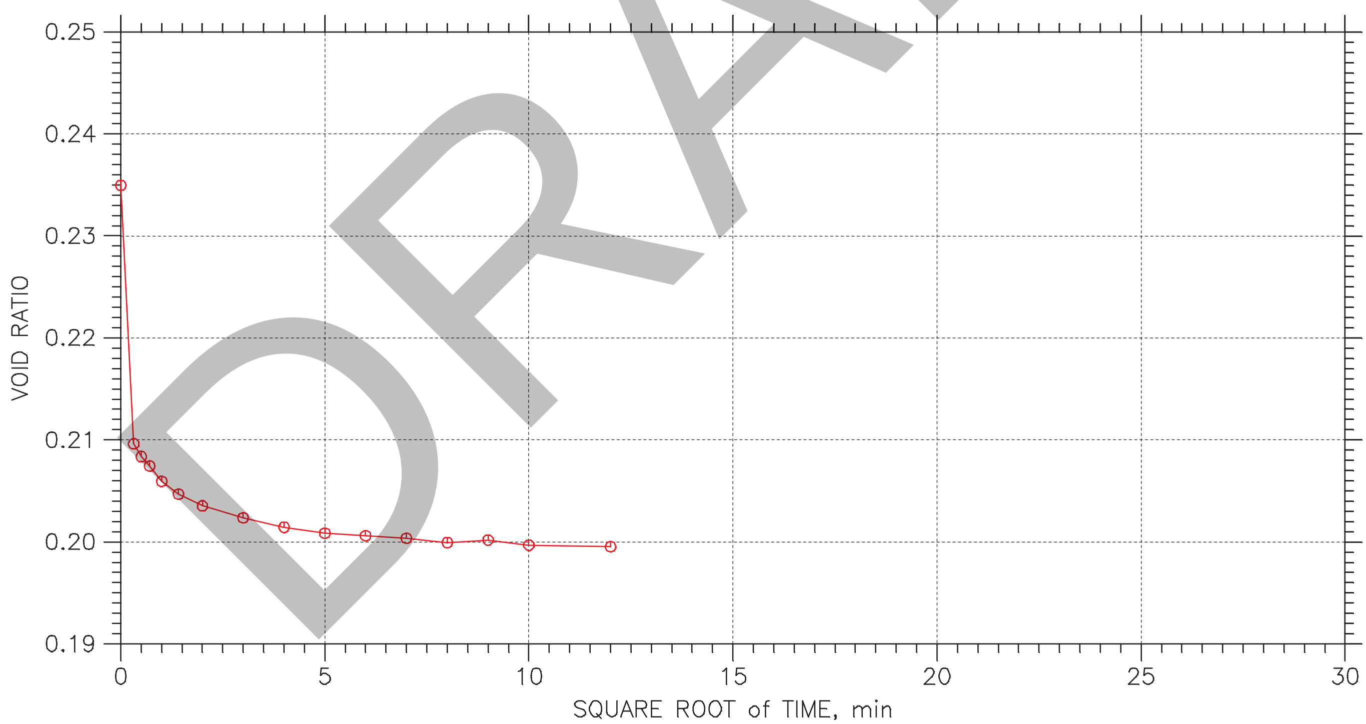
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 17 of 23

Stress: 16. tsf





DRAFT

Terracon Consulting Engineers & Scientists			
	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

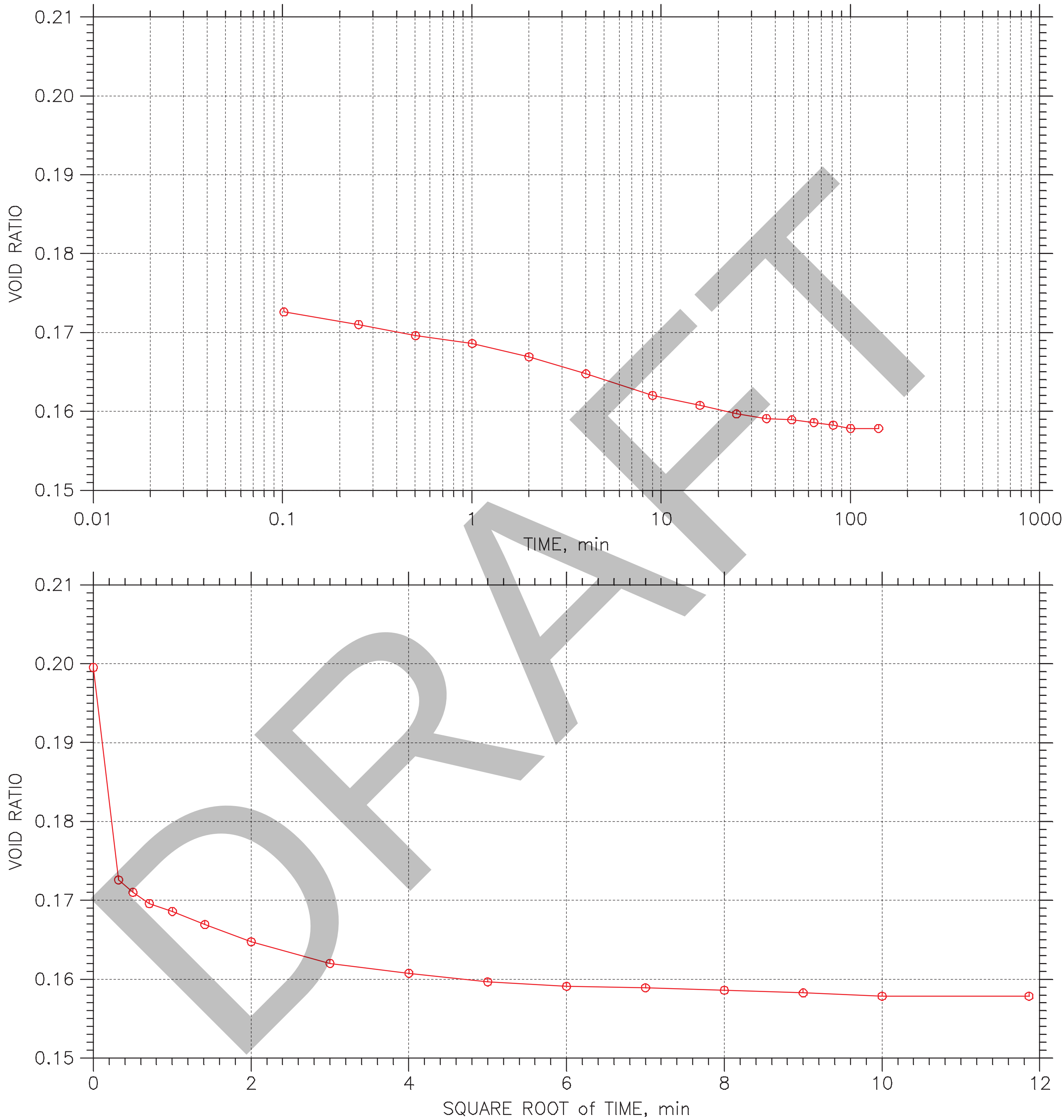
Mon, 21-DEC-2015 16:48:37

CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 18 of 23

Stress: 32. tsf



Terracon Consulting Engineers & Scientists			
	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

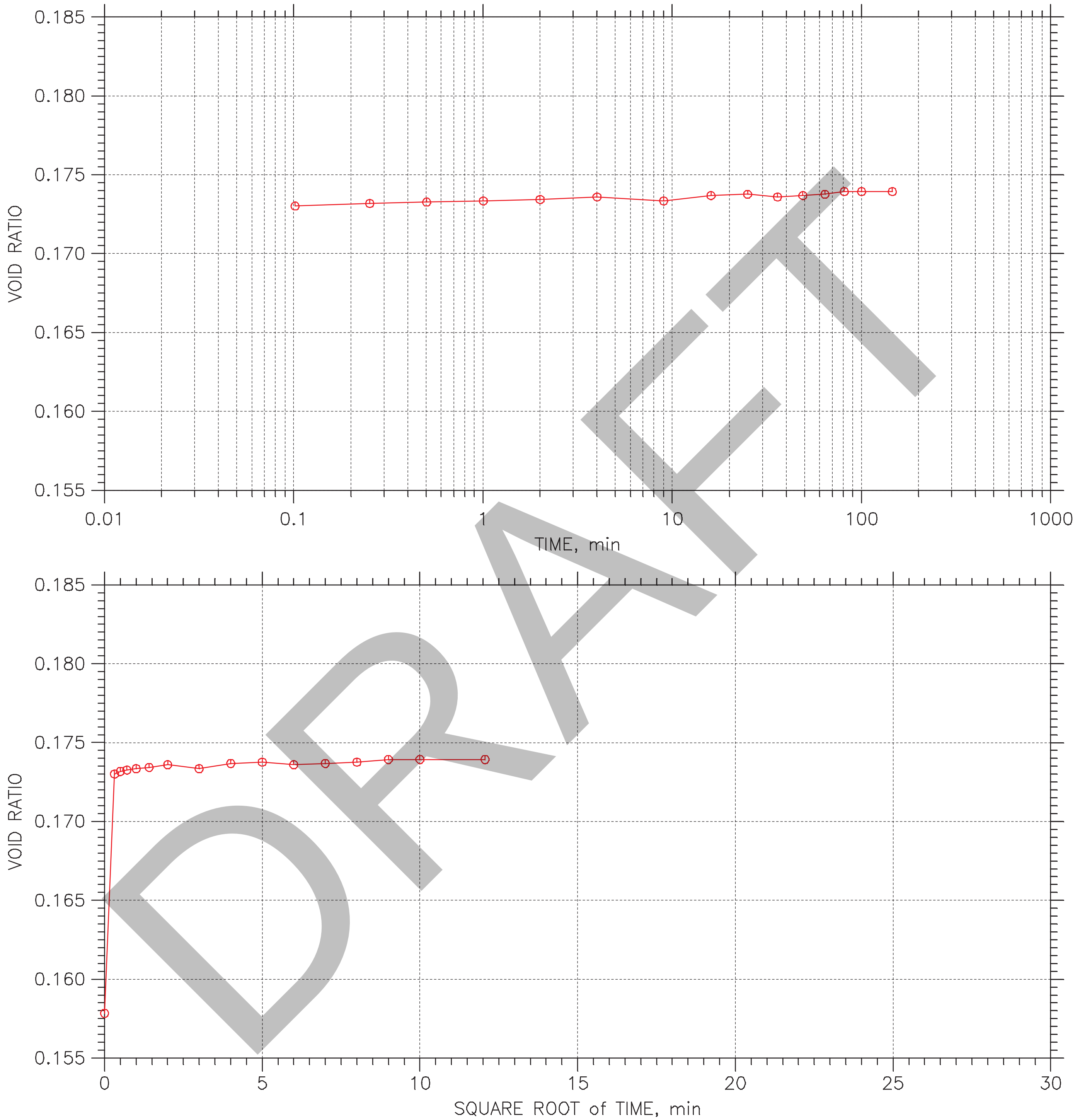
Mon, 21-DEC-2015 16:48:38

CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 19 of 23

Stress: 16. tsf



Terracon Consulting Engineers & Scientists	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0" ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

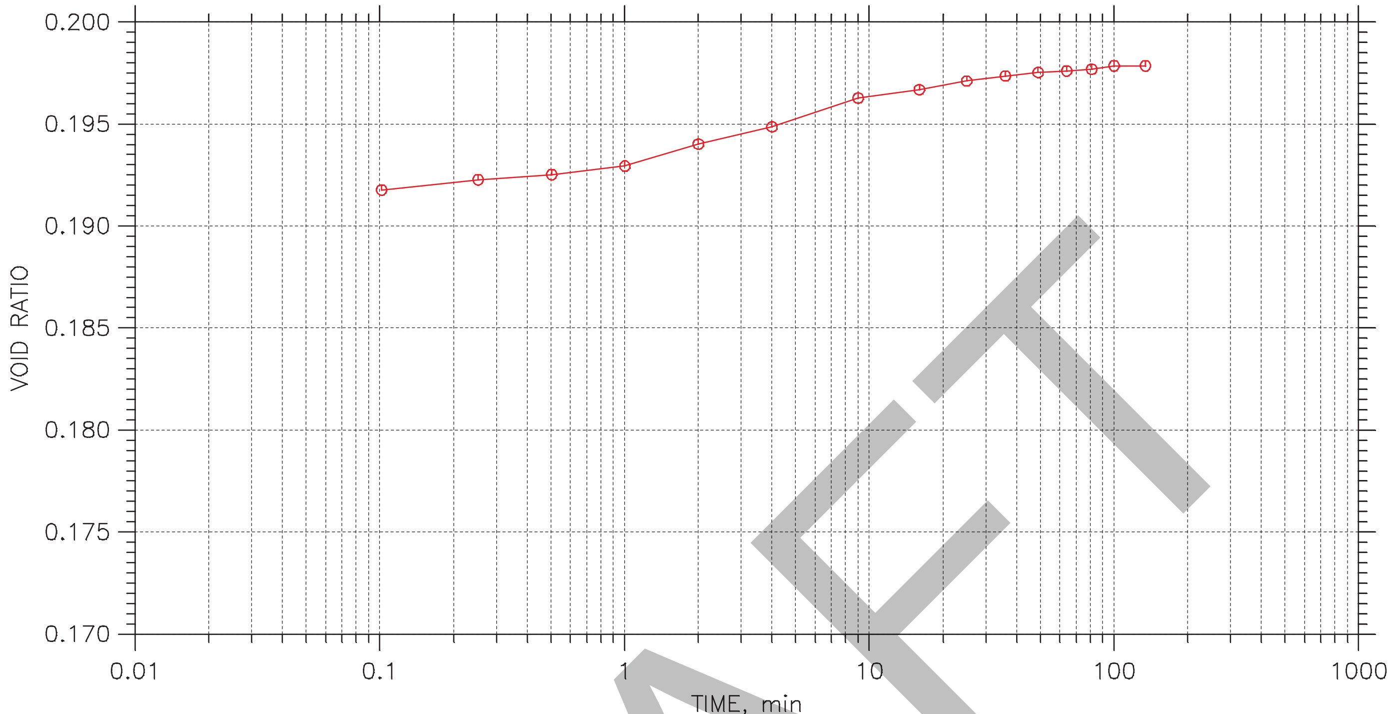
Mon, 21-DEC-2015 16:48:40

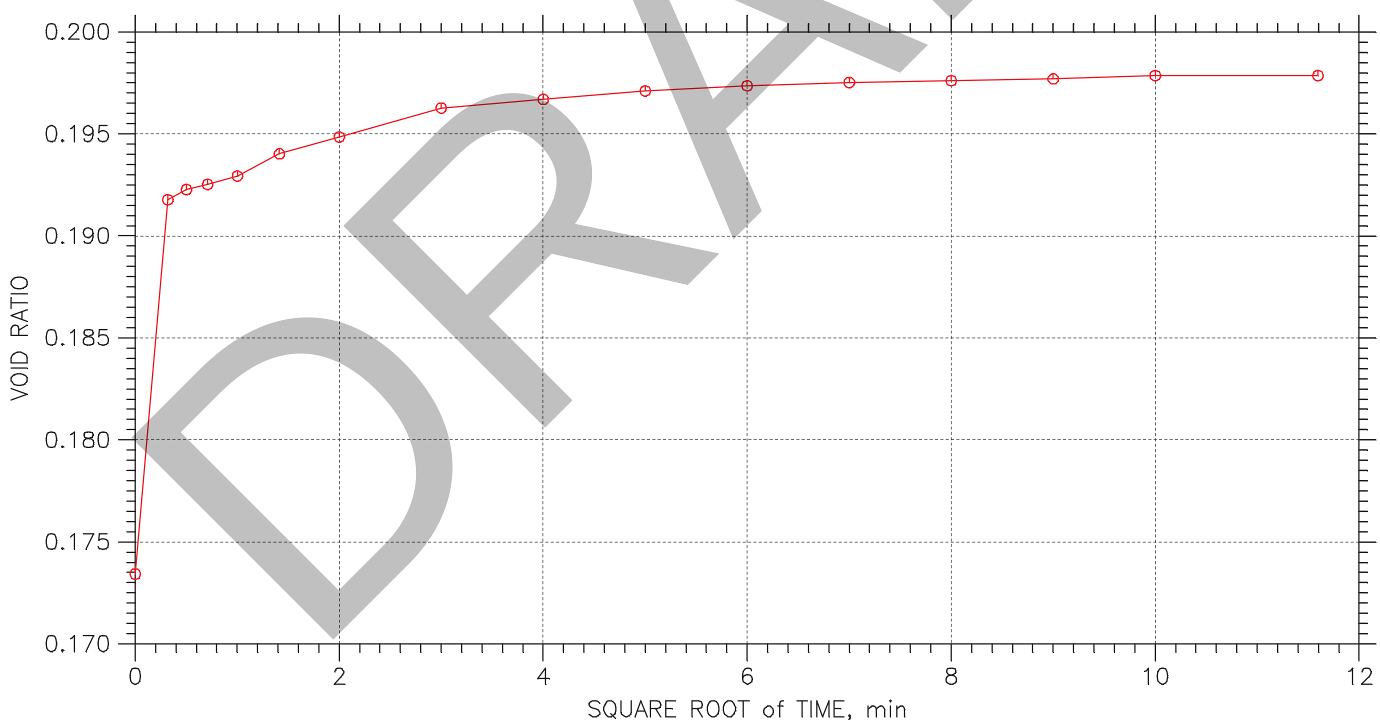
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 20 of 23

Stress: 4. tsf





Terracon Consulting Engineers & Scientists			
	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

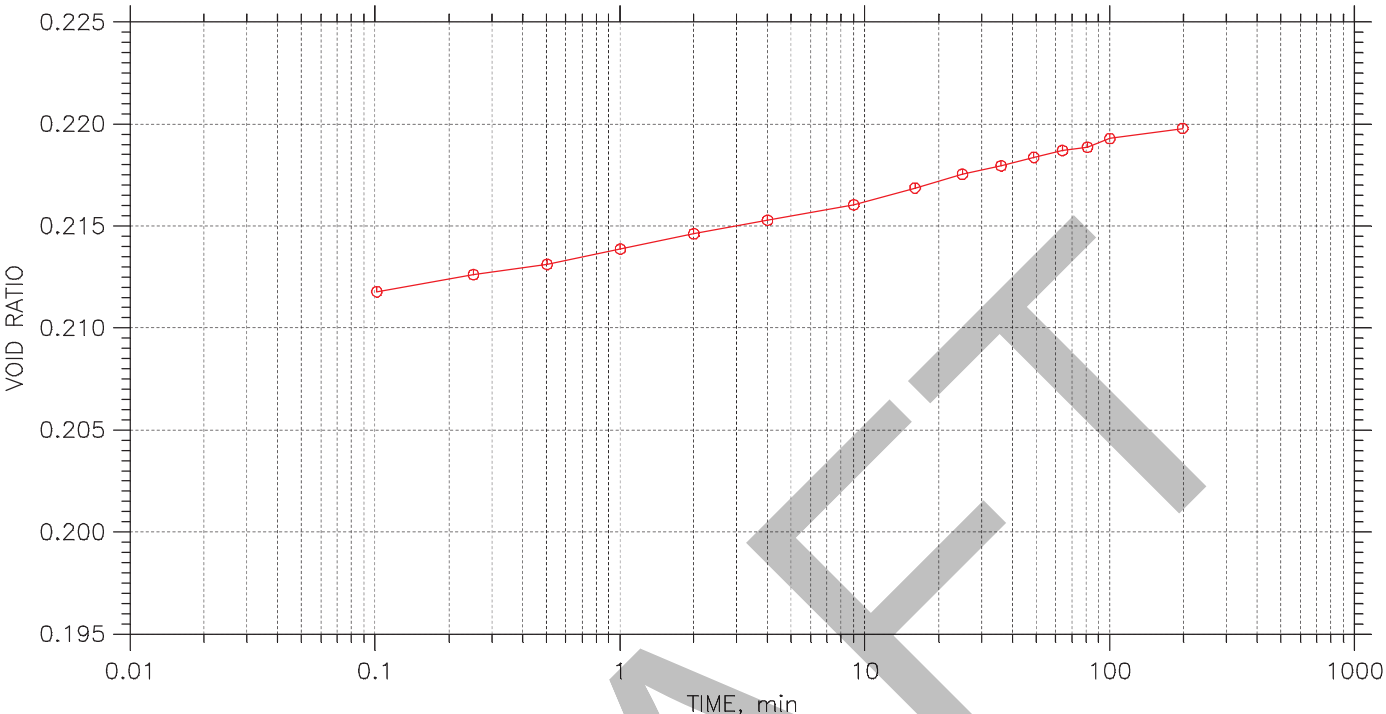
Mon, 21-DEC-2015 16:48:41

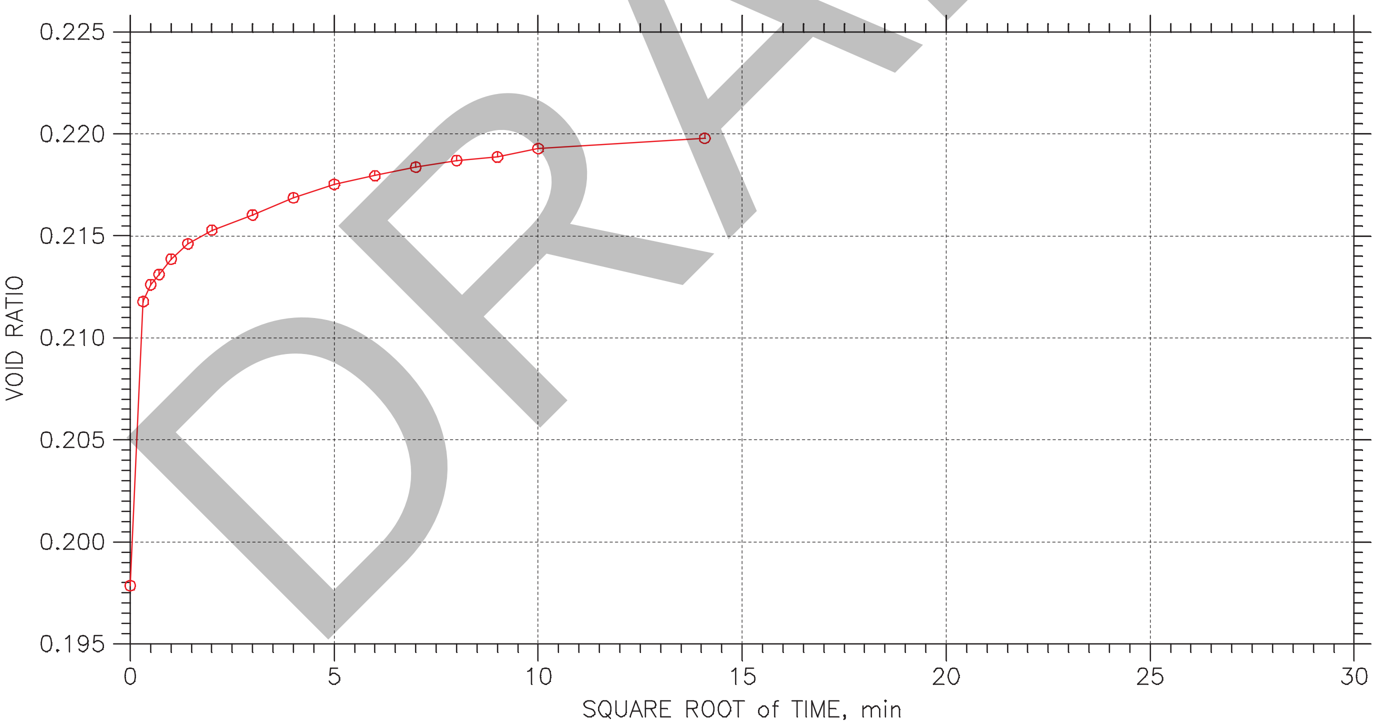
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 21 of 23

Stress: 1. tsf





DRAFT

Terracon Consulting Engineers & Scientists	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

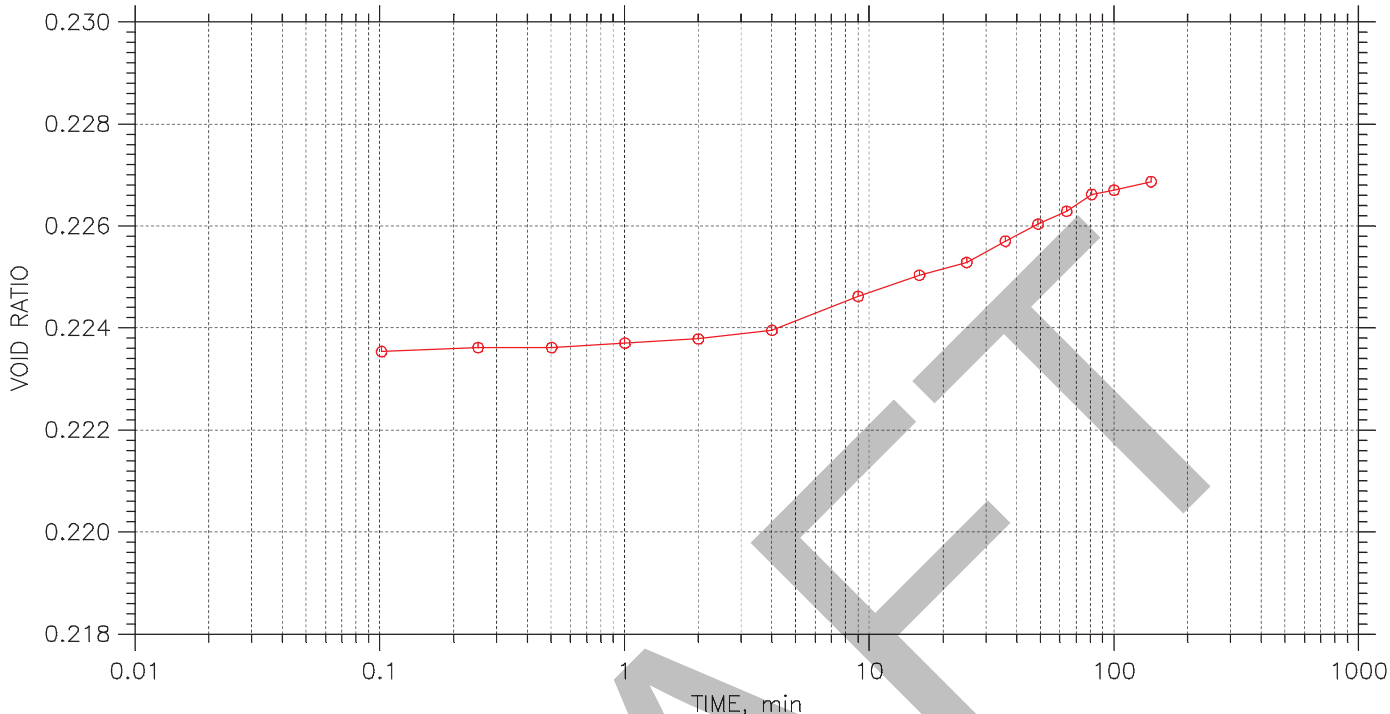
Mon, 21-DEC-2015 16:48:42

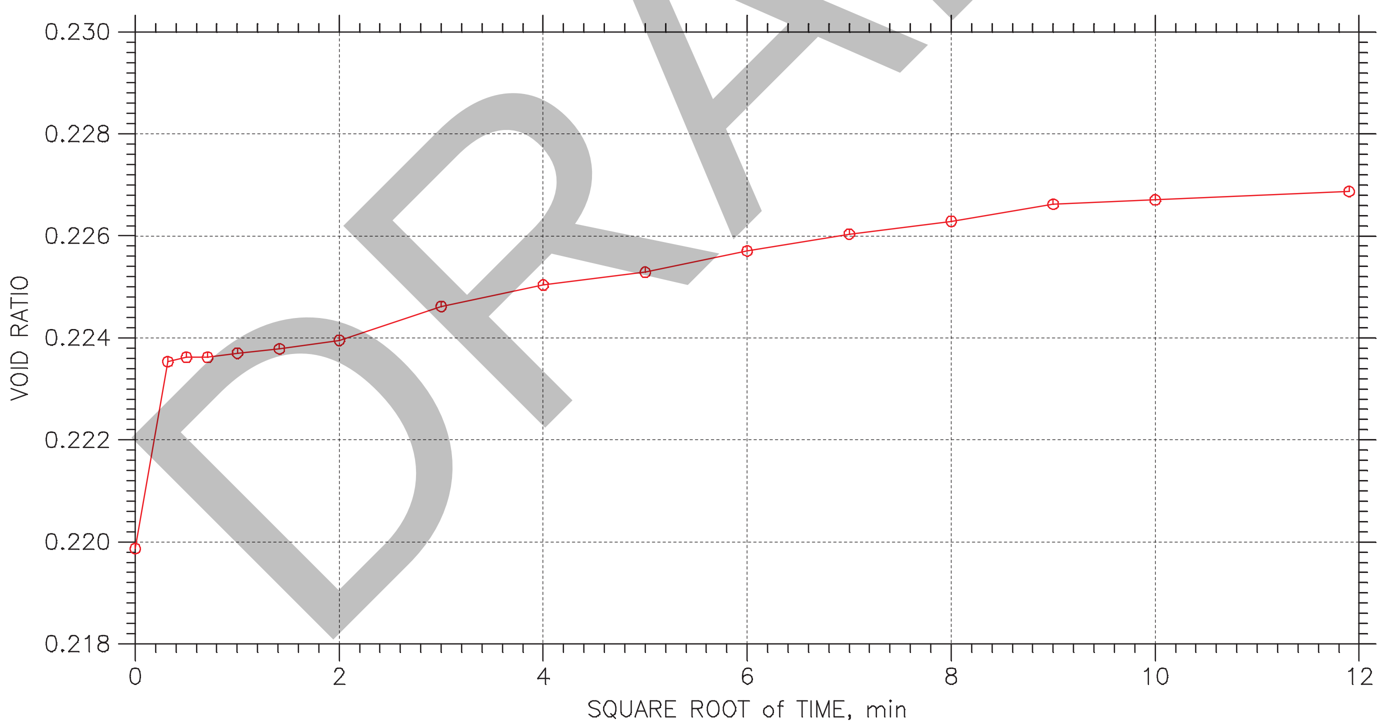
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 22 of 23

Stress: 0.5 tsf





DRAFT

Terracon Consulting Engineers & Scientists	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

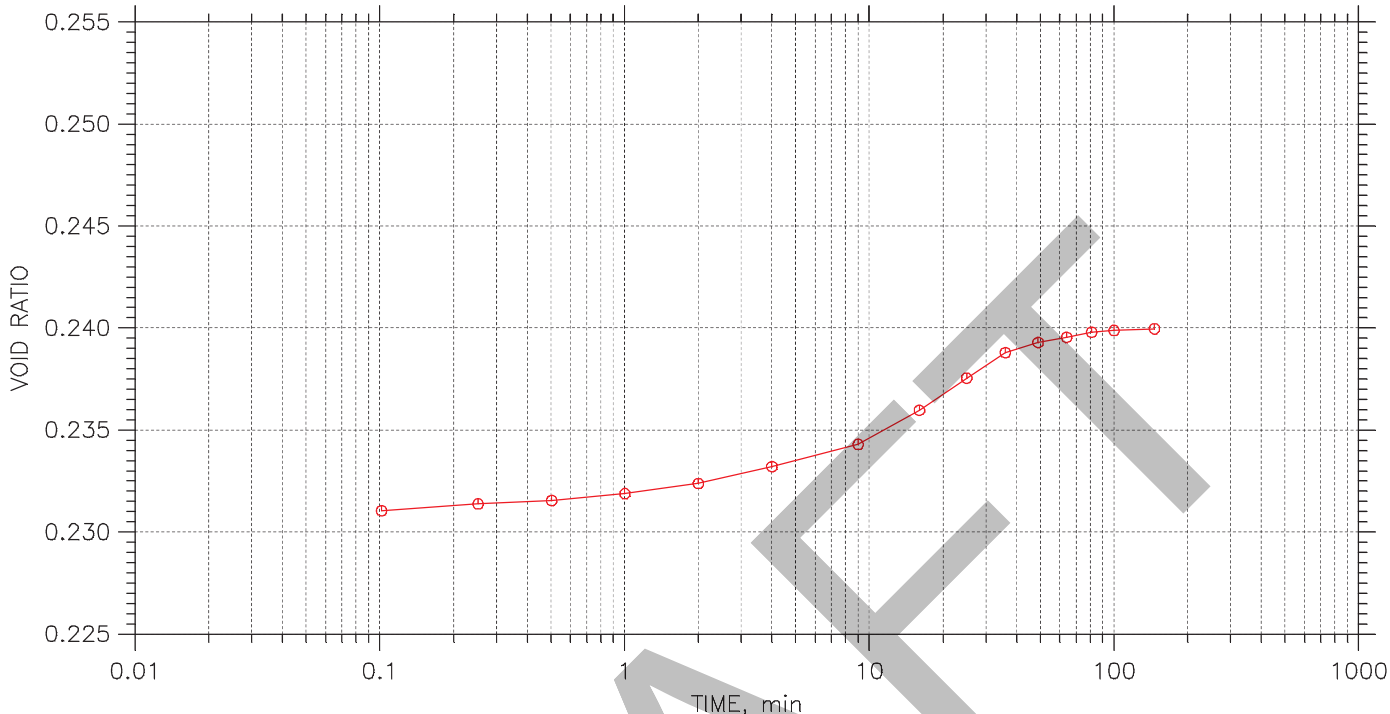
Mon, 21-DEC-2015 16:48:44

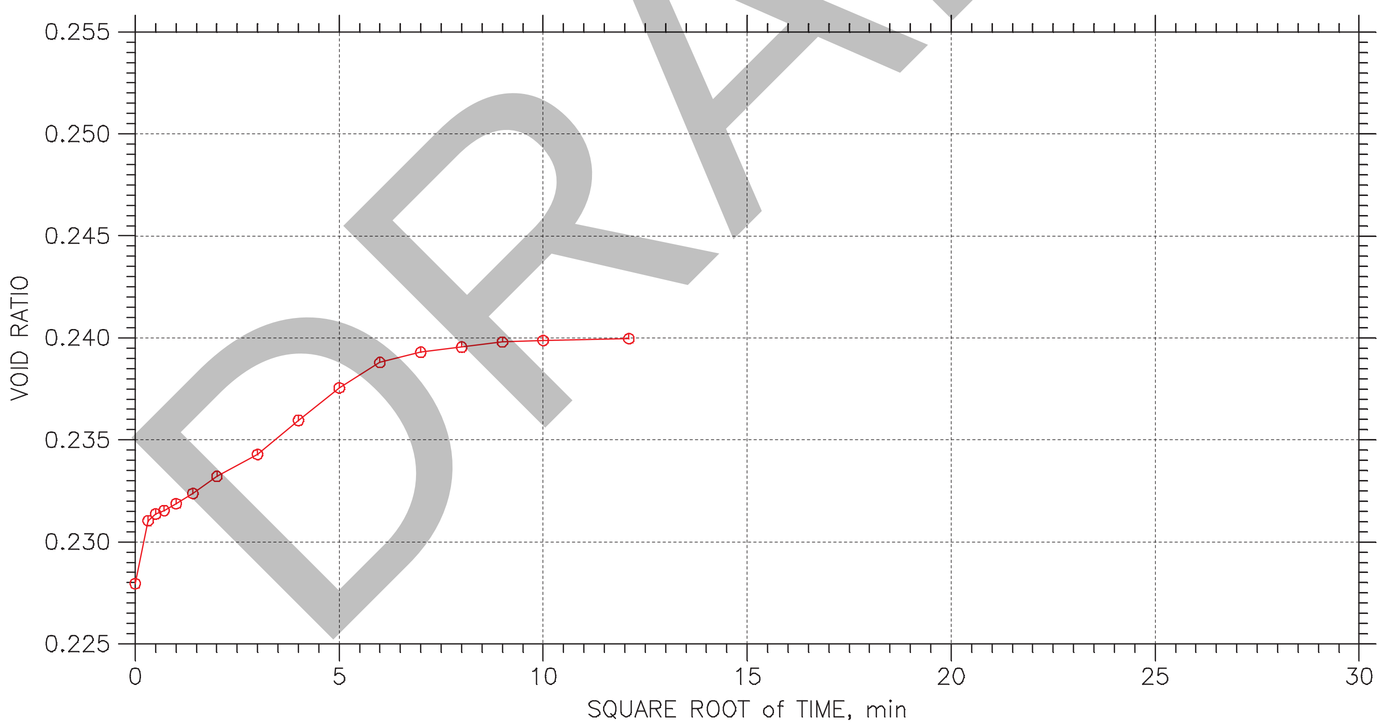
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 23 of 23

Stress: 0.125 tsf





Terracon Consulting Engineers & Scientists	Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
	Boring No.: HEN-029 S-3	Tested By: HP	Checked By: BCM
	Sample No.: S-3	Test Date: 12/14/15	Depth: 5.0'-7.0'
	Test No.: HENB029S3	Sample Type: 3.0'' ST	Elevation: -----
	Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
	Remarks: Pc = 3.1 tsf Cc = 0.128 Ccr = 0.034 TEST PERFORMED AS PER ASTM D2435		

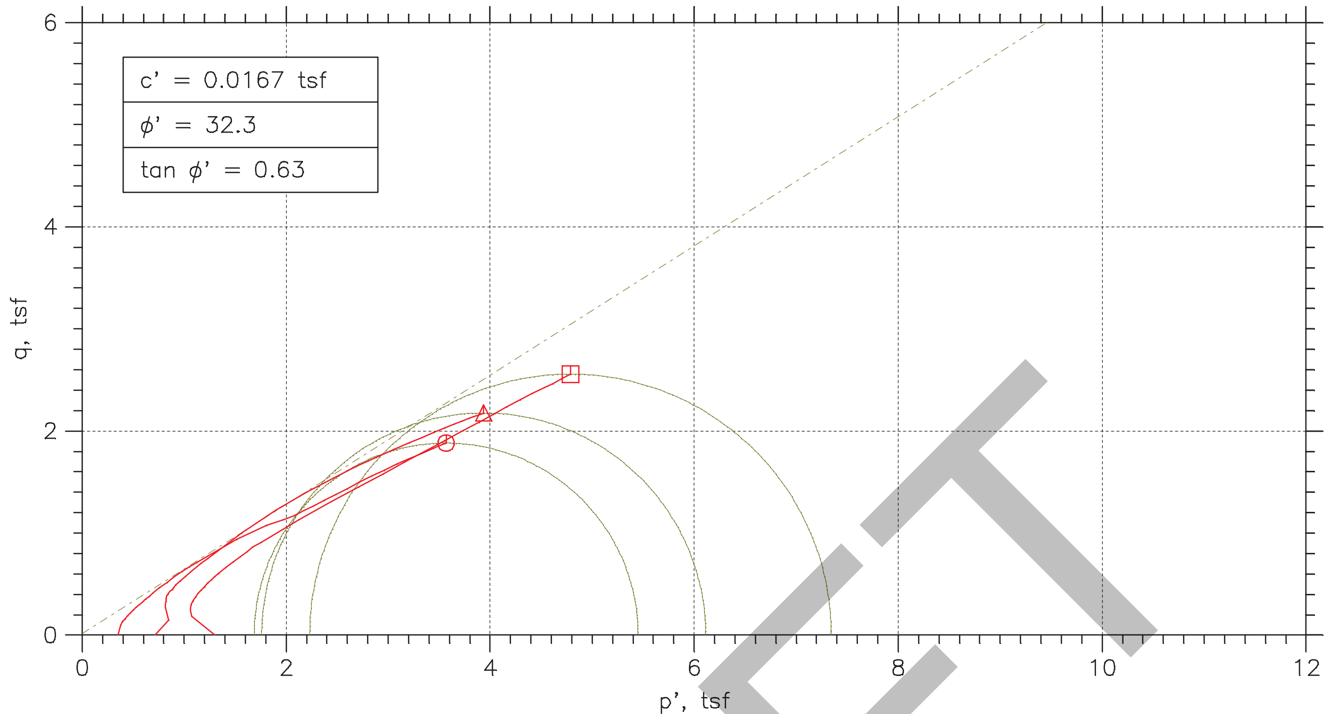
Mon, 21-DEC-2015 16:48:45

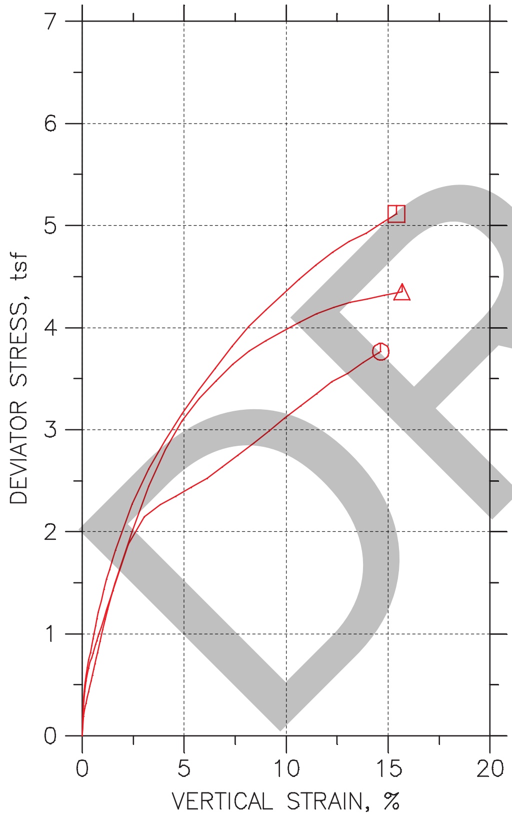
Consolidated Undrained Triaxial Compression Tests
ASTM D 4767

DRAFT

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST
ASTM D4767

Terracon
Consulting Engineers & Scientists





DRAFT

Symbol		⦶	△	⊡	
Test No.		5.0 PSI	10.0 PSI	20.0 PSI	
Initial	Diameter, in	2.813	2.7921	2.8256	
	Height, in	6.0902	5.9878	6.0303	
	Water Content, %	8.98	11.83	8.88	
	Dry Density, pcf	128.2	127.1	126.	
	Saturation, %	75.28	95.64	69.49	
	Void Ratio	0.32442	0.33638	0.34747	
Before Shear	Water Content, %	13.14	12.04	11.49	
	Dry Density, pcf	125.1	127.9	129.4	
	Saturation, %	100.00	100.00	100.00	
	Void Ratio	0.35748	0.32749	0.31248	
	Back Press., tsf	5.0458	5.0445	5.1811	
Minor Prin. Stress, tsf		0.35425	0.71546	1.2989	
Max. Dev. Stress, tsf		3.764	4.3529	5.114	
Time to Failure, min		1147.2	1143.8	1128.7	
Strain Rate, %/min		0.02	0.02	0.02	
B-Value		0.95	0.97	0.95	
Estimated Specific Gravity		2.72	2.72	2.72	
Liquid Limit		22	22	22	
Plastic Limit		15	15	15	
Plasticity Index		7	7	7	

Failure Sketch

Project: DYNEGY HENNEPIN	
Location: HENNEPIN, IL	
Project No.: MR155233	
Boring No.: HEN-029 S-3	
Sample Type: 3.0'' ST	

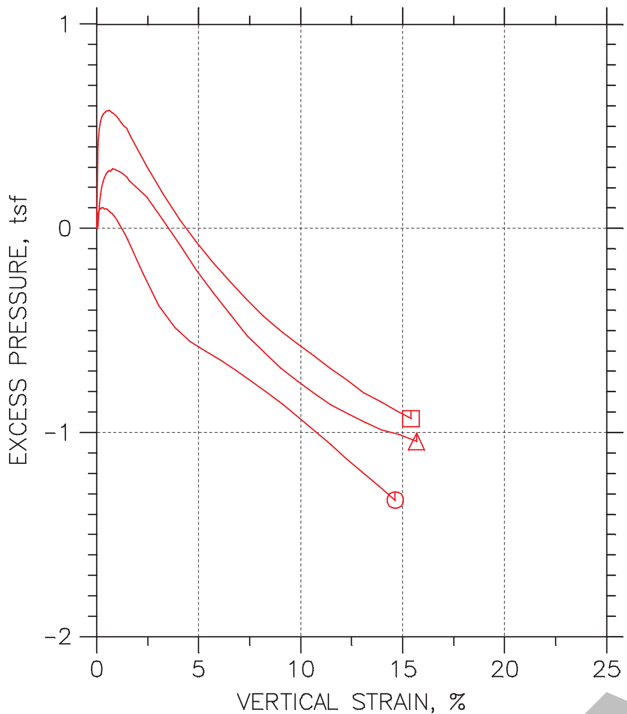
Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL

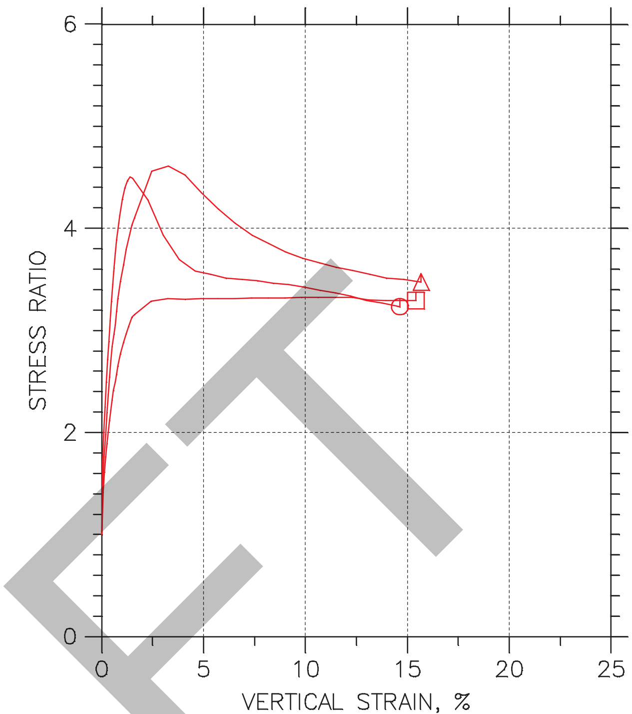
Remarks: FAILURE CRITERIA = MAXIMUM EFFECTIVE STRESS RATIO TEST PERFORMED AS PER ASTM D4767.

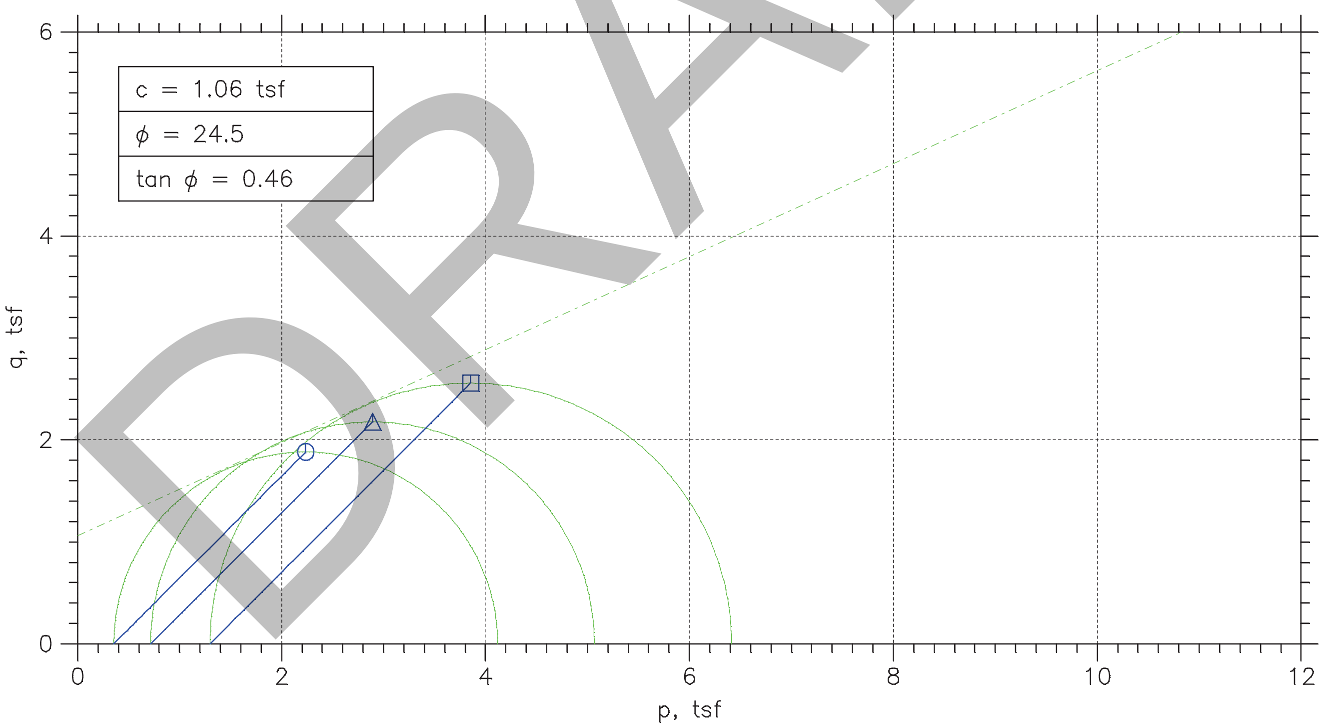
Tue, 22-DEC-2015 13:46:20

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST
ASTM D4767

Terracon
Consulting Engineers & Scientists







DRAFT

Project: DYNEGY HENNEPIN	Location: HENNEPIN, IL	Project No.: MR155233
Boring No.: HEN-029 S-3	Tested By: BCM	Checked By: WPQ
Sample No.: S-3	Test Date: 12/17/15	Depth: 5.0'-7.0'
Test No.: HEN-029 S-3	Sample Type: 3.0" ST	Elevation: ----
Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL		
Remarks: FAILURE CRITERIA = MAXIMUM EFFECTIVE STRESS RATIO TEST PERFORMED AS PER ASTM D4767.		

Tue, 22-DEC-2015 13:47:19

TRIAXIAL TEST

Project: DYNEGY HENNEPIN
Boring No.: HEN-029 S-3
Sample No.: S-3
Test No.: 5.0 PSI

Location: HENNEPIN, IL
Tested By: BCM
Test Date: 12/17/15
Sample Type: 3.0" ST

Project No.: MR155233
Checked By: WPQ
Depth: 5.0'-7.0'
Elevation: ----

Terracon
Consulting Engineers & Scientists

Soil Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL
Remarks: FAILURE CRITERIA = MAXIMUM EFFECTIVE STRESS RATIO TEST PERFORMED AS PER ASTM D4767.

Specimen Height: 6.09 in
Specimen Area: 6.21 in^2
Specimen Volume: 37.85 in^3

Piston Area: 0.00 in^2
Piston Friction: 0.00 lb
Piston Weight: 0.00 lb

Filter Strip Correction: 0.00 tsf
Membrane Correction: 0.00 lb/in
Correction Type: Uniform

Liquid Limit: 22

Plastic Limit: 15

Estimated Specific Gravity: 2.72

	Time min	Vertical Strain %	Corrected Area in^2	Deviator Load lb	Deviator Stress tsf	Pore Pressure tsf	Horizontal Stress tsf	Vertical Stress tsf
1	0	0	6.2148	0	0	5.0458	5.4	5.4
2	5.0035	0.055219	6.2182	17.005	0.1969	5.1201	5.4	5.5969
3	10.003	0.11893	6.2222	23.059	0.26683	5.1363	5.4	5.6668
4	15.003	0.17981	6.226	27.85	0.32207	5.1427	5.4	5.7221
5	20.003	0.24353	6.23	32.852	0.37967	5.1462	5.4	5.7797
6	25.003	0.30866	6.234	37.643	0.43475	5.1462	5.4	5.8348
7	30.003	0.37237	6.238	42.276	0.48795	5.1422	5.4	5.8879
8	35.003	0.43609	6.242	46.961	0.54168	5.1422	5.4	5.9417
9	40.003	0.49838	6.2459	51.752	0.59657	5.1392	5.4	5.9966
10	45.003	0.5621	6.2499	56.385	0.64956	5.1346	5.4	6.0496
11	50.003	0.6244	6.2538	61.386	0.70674	5.1294	5.4	6.1067
12	55.003	0.68811	6.2579	66.335	0.76322	5.123	5.4	6.1632
13	60.003	0.75041	6.2618	71.126	0.81783	5.1172	5.4	6.2178
14	70.003	0.87784	6.2698	80.918	0.92923	5.1027	5.4	6.3292
15	80.003	1.0067	6.278	90.553	1.0385	5.0835	5.4	6.4385
16	90.003	1.1341	6.2861	99.661	1.1415	5.0638	5.4	6.5415
17	100	1.2601	6.2941	108.72	1.2436	5.0411	5.4	6.6436
18	110	1.3904	6.3024	117.14	1.3382	5.0179	5.4	6.7382
19	120	1.5164	6.3105	124.88	1.4248	4.9917	5.4	6.8248
20	180	2.271	6.3592	165.63	1.8753	4.828	5.4	7.2753
21	240	3.037	6.4095	191.27	2.1486	4.6677	5.4	7.5486
22	300	3.8158	6.4613	203.48	2.2674	4.5591	5.4	7.6674
23	360	4.5789	6.513	212.11	2.3449	4.4923	5.4	7.7449
24	420	5.3421	6.5655	222.17	2.4364	4.4447	5.4	7.8364
25	480	6.1095	6.6192	231.96	2.5232	4.3959	5.4	7.9232
26	540	6.874	6.6735	244.18	2.6344	4.346	5.4	8.0344
27	600	7.6386	6.7288	257.13	2.7513	4.2926	5.4	8.1513
28	660	8.4116	6.7856	270.03	2.8652	4.2357	5.4	8.2652
29	720	9.1663	6.842	283.82	2.9867	4.1793	5.4	8.3867
30	780	9.9295	6.8999	298.25	3.1122	4.1172	5.4	8.5122
31	840	10.708	6.9601	312.3	3.2307	4.051	5.4	8.6307
32	900	11.471	7.0201	326.83	3.3521	3.986	5.4	8.7521
33	960	12.232	7.0809	340.94	3.4668	3.9169	5.4	8.8668
34	1020	13.009	7.1442	352.31	3.5507	3.8512	5.4	8.9507
35	1080	13.774	7.2075	366.11	3.6572	3.7891	5.4	9.0572
36	1140	14.538	7.272	379.11	3.7536	3.7217	5.4	9.1536
37	1147.2	14.632	7.28	380.59	3.764	3.7142	5.4	9.164

DRAFT

TRIAXIAL TEST

Project: DYNEGY HENNEPIN
Boring No.: HEN-029 S-3
Sample No.: S-3
Test No.: 5.0 PSI

Location: HENNEPIN, IL
Tested By: BCM
Test Date: 12/17/15
Sample Type: 3.0" ST

Project No.: MR155233
Checked By: WPQ
Depth: 5.0'-7.0'
Elevation: ----

Soil Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL
Remarks: FAILURE CRITERIA = MAXIMUM EFFECTIVE STRESS RATIO TEST PERFORMED AS PER ASTM D4767.

Specimen Height: 6.09 in
Specimen Area: 6.21 in^2
Specimen Volume: 37.85 in^3

Piston Area: 0.00 in^2
Piston Friction: 0.00 lb
Piston Weight: 0.00 lb

Filter Strip Correction: 0.00 tsf
Membrane Correction: 0.00 lb/in
Correction Type: Uniform

Liquid Limit: 22

Plastic Limit: 15

Estimated Specific Gravity: 2.72

	Vertical Strain %	Total Vertical Stress tsf	Total Horizontal Stress tsf	Excess Pore Pressure tsf	A Parameter	Effective Vertical Stress tsf	Effective Horizontal Stress tsf	Stress Ratio	Effective p tsf	q tsf
1	0.00	5.4	5.4	0	0.000	0.35425	0.35425	1.000	0.35425	0
2	0.06	5.5969	5.4	0.07433	0.378	0.47681	0.27992	1.703	0.37837	0.098449
3	0.12	5.6668	5.4	0.09059	0.340	0.53049	0.26366	2.012	0.39707	0.13342
4	0.18	5.7221	5.4	0.096978	0.301	0.57934	0.25727	2.252	0.4183	0.16104
5	0.24	5.7797	5.4	0.10046	0.265	0.63345	0.25378	2.496	0.44362	0.18983
6	0.31	5.8348	5.4	0.10046	0.231	0.68854	0.25378	2.713	0.47116	0.21738
7	0.37	5.8879	5.4	0.096397	0.198	0.7458	0.25785	2.892	0.50182	0.24397
8	0.44	5.9417	5.4	0.096397	0.178	0.79953	0.25785	3.101	0.52869	0.27084
9	0.50	5.9966	5.4	0.093494	0.157	0.85732	0.26075	3.288	0.55904	0.29829
10	0.56	6.0496	5.4	0.088848	0.137	0.91496	0.2654	3.447	0.59018	0.32478
11	0.62	6.1067	5.4	0.083622	0.118	0.97736	0.27062	3.611	0.62399	0.35337
12	0.69	6.1632	5.4	0.077234	0.101	1.0402	0.27701	3.755	0.65862	0.38161
13	0.75	6.2178	5.4	0.071427	0.087	1.1007	0.28282	3.892	0.69173	0.40892
14	0.88	6.3292	5.4	0.056909	0.061	1.2266	0.29734	4.125	0.76195	0.46462
15	1.01	6.4385	5.4	0.037746	0.036	1.355	0.3165	4.281	0.83576	0.51926
16	1.13	6.5415	5.4	0.018002	0.016	1.4777	0.33624	4.395	0.907	0.57075
17	1.26	6.6436	5.4	-0.0046456	-0.004	1.6025	0.35889	4.465	0.98071	0.62182
18	1.39	6.7382	5.4	-0.027874	-0.021	1.7203	0.38212	4.502	1.0512	0.66911
19	1.52	6.8248	5.4	-0.054006	-0.038	1.8331	0.40825	4.490	1.1207	0.71241
20	2.27	7.2753	5.4	-0.21776	-0.116	2.4473	0.57201	4.278	1.5096	0.93763
21	3.04	7.5486	5.4	-0.37804	-0.176	2.8809	0.73229	3.934	1.8066	1.0743
22	3.82	7.6674	5.4	-0.48663	-0.215	3.1083	0.84088	3.696	1.9746	1.1337
23	4.58	7.7449	5.4	-0.55341	-0.236	3.2525	0.90766	3.583	2.0801	1.1724
24	5.34	7.8364	5.4	-0.60103	-0.247	3.3917	0.95528	3.550	2.1735	1.2182
25	6.11	7.9232	5.4	-0.64981	-0.258	3.5272	1.0041	3.513	2.2656	1.2616
26	6.87	8.0344	5.4	-0.69975	-0.266	3.6884	1.054	3.499	2.3712	1.3172
27	7.64	8.1513	5.4	-0.75318	-0.274	3.8588	1.1074	3.484	2.4831	1.3757
28	8.41	8.2652	5.4	-0.81008	-0.283	4.0295	1.1643	3.461	2.5969	1.4326
29	9.17	8.3867	5.4	-0.86641	-0.290	4.2074	1.2207	3.447	2.714	1.4934
30	9.93	8.5122	5.4	-0.92855	-0.298	4.395	1.2828	3.426	2.8389	1.5561
31	10.71	8.6307	5.4	-0.99475	-0.308	4.5797	1.349	3.395	2.9643	1.6153
32	11.47	8.7521	5.4	-1.0598	-0.316	4.7661	1.414	3.371	3.0901	1.676
33	12.23	8.8668	5.4	-1.1289	-0.326	4.9499	1.4831	3.337	3.2165	1.7334
34	13.01	8.9507	5.4	-1.1945	-0.336	5.0994	1.5488	3.293	3.3241	1.7753
35	13.77	9.0572	5.4	-1.2566	-0.344	5.2681	1.6109	3.270	3.4395	1.8286
36	14.54	9.1536	5.4	-1.324	-0.353	5.4318	1.6783	3.237	3.555	1.8768
37	14.63	9.164	5.4	-1.3316	-0.354	5.4499	1.6858	3.233	3.5678	1.882

DRAFT

TRIAXIAL TEST

Project: DYNEGY HENNEPIN
Boring No.: HEN-029 S-3
Sample No.: S-3
Test No.: 10.0 PSI

Location: HENNEPIN, IL
Tested By: BCM
Test Date: 12/17/15
Sample Type: 3.0" ST

Project No.: MR155233
Checked By: WPQ
Depth: 5.0'-7.0'
Elevation: ----

Terracon
Consulting Engineers & Scientists

Soil Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL
Remarks: FAILURE CRITERIA = MAXIMUM EFFECTIVE STRESS RATIO TEST PERFORMED AS PER ASTM D4767.

Specimen Height: 5.99 in
Specimen Area: 6.12 in^2
Specimen Volume: 36.66 in^3

Piston Area: 0.00 in^2
Piston Friction: 0.00 lb
Piston Weight: 0.00 lb

Filter Strip Correction: 0.00 tsf
Membrane Correction: 0.00 lb/in
Correction Type: Uniform

Liquid Limit: 22

Plastic Limit: 15

Estimated Specific Gravity: 2.72

	Time min	Vertical Strain %	Corrected Area in^2	Deviator Load lb	Deviator Stress tsf	Pore Pressure tsf	Horizontal Stress tsf	Vertical Stress tsf
1	0	0	6.1229	0	0	5.0445	5.76	5.76
2	5.0033	0.057527	6.1265	25.039	0.29426	5.058	5.76	6.0543
3	10.003	0.12145	6.1304	37.584	0.44142	5.1518	5.76	6.2014
4	15.003	0.19176	6.1347	45.895	0.53865	5.2102	5.76	6.2986
5	20.003	0.25727	6.1387	52.089	0.61094	5.2487	5.76	6.3709
6	25.003	0.32599	6.143	57.012	0.66822	5.2731	5.76	6.4282
7	30.003	0.3931	6.1471	61.458	0.71985	5.2947	5.76	6.4799
8	35.003	0.46021	6.1512	65.375	0.76522	5.3111	5.76	6.5252
9	40.003	0.52573	6.1553	69.134	0.80868	5.321	5.76	6.5687
10	45.003	0.59444	6.1596	72.945	0.85267	5.3262	5.76	6.6127
11	50.003	0.66316	6.1638	76.651	0.89536	5.3239	5.76	6.6554
12	55.003	0.72867	6.1679	80.356	0.93803	5.3315	5.76	6.698
13	60.003	0.79898	6.1723	84.009	0.97997	5.3355	5.76	6.74
14	70.003	0.93481	6.1807	91.314	1.0637	5.3309	5.76	6.8237
15	80.003	1.0674	6.189	98.884	1.1504	5.3251	5.76	6.9104
16	90.003	1.2049	6.1976	106.24	1.2343	5.3186	5.76	6.9943
17	110	1.4781	6.2148	121.28	1.405	5.2971	5.76	7.165
18	120	1.6155	6.2235	129.06	1.4931	5.2784	5.76	7.2531
19	180	2.4465	6.2765	174.42	2.0009	5.1979	5.76	7.7609
20	240	3.2615	6.3294	215.08	2.4466	5.0819	5.76	8.2066
21	300	4.0812	6.3835	248.9	2.8074	4.9623	5.76	8.5674
22	360	4.909	6.439	275.85	3.0845	4.8381	5.76	8.8445
23	420	5.7319	6.4952	298.08	3.3042	4.7238	5.76	9.0642
24	480	6.5549	6.5524	316.61	3.479	4.6206	5.76	9.239
25	540	7.3826	6.611	334.34	3.6413	4.5173	5.76	9.4013
26	600	8.1976	6.6697	349.06	3.7681	4.4392	5.76	9.5281
27	660	9.0189	6.7299	362.08	3.8737	4.3628	5.76	9.6337
28	720	9.8547	6.7923	374.04	3.9649	4.2946	5.76	9.7249
29	780	10.668	6.8541	386.11	4.056	4.2374	5.76	9.816
30	840	11.485	6.9174	397.49	4.1373	4.1808	5.76	9.8973
31	900	12.324	6.9836	407.45	4.2007	4.1354	5.76	9.9607
32	960	13.15	7.05	415.97	4.2482	4.0945	5.76	10.008
33	1020	13.976	7.1177	423.01	4.279	4.0578	5.76	10.039
34	1080	14.808	7.1873	430.74	4.315	4.0345	5.76	10.075
35	1140	15.625	7.2568	438.47	4.3503	4.003	5.76	10.11
36	1143.8	15.678	7.2613	438.99	4.3529	4.0001	5.76	10.113

DRAFT

TRIAXIAL TEST

Project: DYNEGY HENNEPIN
Boring No.: HEN-029 S-3
Sample No.: S-3
Test No.: 10.0 PSI

Location: HENNEPIN, IL
Tested By: BCM
Test Date: 12/17/15
Sample Type: 3.0" ST

Project No.: MR155233
Checked By: WPQ
Depth: 5.0'-7.0'
Elevation: ----

Terracon
Consulting Engineers & Scientists

Soil Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL
Remarks: FAILURE CRITERIA = MAXIMUM EFFECTIVE STRESS RATIO TEST PERFORMED AS PER ASTM D4767.

Specimen Height: 5.99 in
Specimen Area: 6.12 in^2
Specimen Volume: 36.66 in^3

Piston Area: 0.00 in^2
Piston Friction: 0.00 lb
Piston Weight: 0.00 lb

Filter Strip Correction: 0.00 tsf
Membrane Correction: 0.00 lb/in
Correction Type: Uniform

Liquid Limit: 22

Plastic Limit: 15

Estimated Specific Gravity: 2.72

	Vertical Strain %	Total Vertical Stress tsf	Total Horizontal Stress tsf	Excess Pore Pressure tsf	A Parameter	Effective Vertical Stress tsf	Effective Horizontal Stress tsf	Stress Ratio	Effective p tsf	q tsf
1	0.00	5.76	5.76	0	0.000	0.71546	0.71546	1.000	0.71546	0
2	0.06	6.0543	5.76	0.013413	0.046	0.99631	0.70205	1.419	0.84918	0.14713
3	0.12	6.2014	5.76	0.10731	0.243	1.0496	0.60815	1.726	0.82886	0.22071
4	0.19	6.2986	5.76	0.16562	0.307	1.0885	0.54984	1.980	0.81916	0.26932
5	0.26	6.3709	5.76	0.20411	0.334	1.1223	0.51135	2.195	0.81681	0.30547
6	0.33	6.4282	5.76	0.22861	0.342	1.1551	0.48685	2.373	0.82096	0.33411
7	0.39	6.4799	5.76	0.25019	0.348	1.1851	0.46527	2.547	0.8252	0.35993
8	0.46	6.5252	5.76	0.26651	0.348	1.2142	0.44895	2.704	0.83155	0.38261
9	0.53	6.5687	5.76	0.27643	0.342	1.2477	0.43903	2.842	0.84337	0.40434
10	0.59	6.6127	5.76	0.28168	0.330	1.2865	0.43378	2.966	0.86012	0.42633
11	0.66	6.6554	5.76	0.27935	0.312	1.3315	0.43612	3.053	0.8838	0.44768
12	0.73	6.698	5.76	0.28693	0.306	1.3666	0.42853	3.189	0.89755	0.46901
13	0.80	6.74	5.76	0.29101	0.297	1.4044	0.42445	3.309	0.91444	0.48999
14	0.93	6.8237	5.76	0.28634	0.269	1.4928	0.42912	3.479	0.96098	0.53186
15	1.07	6.9104	5.76	0.28051	0.244	1.5853	0.43495	3.645	1.0101	0.57518
16	1.20	6.9943	5.76	0.2741	0.222	1.6756	0.44136	3.796	1.0585	0.61713
17	1.48	7.165	5.76	0.25252	0.180	1.8679	0.46294	4.035	1.1654	0.7025
18	1.62	7.2531	5.76	0.23386	0.157	1.9747	0.4816	4.100	1.2281	0.74654
19	2.45	7.7609	5.76	0.15338	0.077	2.563	0.56208	4.560	1.5625	1.0004
20	3.26	8.2066	5.76	0.037324	0.015	3.1248	0.67814	4.608	1.9014	1.2233
21	4.08	8.5674	5.76	-0.082229	-0.029	3.6051	0.79769	4.519	2.2014	1.4037
22	4.91	8.8445	5.76	-0.20645	-0.067	4.0064	0.92191	4.346	2.4641	1.5422
23	5.73	9.0642	5.76	-0.32075	-0.097	4.3404	1.0362	4.189	2.6883	1.6521
24	6.55	9.239	5.76	-0.42397	-0.122	4.6184	1.1394	4.053	2.8789	1.7395
25	7.38	9.4013	5.76	-0.5272	-0.145	4.8839	1.2427	3.930	3.0633	1.8206
26	8.20	9.5281	5.76	-0.60534	-0.161	5.0889	1.3208	3.853	3.2049	1.8841
27	9.02	9.6337	5.76	-0.68174	-0.176	5.2709	1.3972	3.772	3.3341	1.9369
28	9.85	9.7249	5.76	-0.74997	-0.189	5.4304	1.4654	3.706	3.4479	1.9825
29	10.67	9.816	5.76	-0.80713	-0.199	5.5785	1.5226	3.664	3.5506	2.028
30	11.48	9.8973	5.76	-0.8637	-0.209	5.7165	1.5792	3.620	3.6478	2.0687
31	12.32	9.9607	5.76	-0.90918	-0.216	5.8254	1.6246	3.586	3.725	2.1004
32	13.15	10.008	5.76	-0.95001	-0.224	5.9137	1.6655	3.551	3.7896	2.1241
33	13.98	10.039	5.76	-0.98675	-0.231	5.9812	1.7022	3.514	3.8417	2.1395
34	14.81	10.075	5.76	-1.0101	-0.234	6.0405	1.7255	3.501	3.883	2.1575
35	15.62	10.11	5.76	-1.0416	-0.239	6.1074	1.757	3.476	3.9322	2.1752
36	15.68	10.113	5.76	-1.0445	-0.240	6.1128	1.7599	3.473	3.9364	2.1764

DRAFT

TRIAXIAL TEST

Project: DYNEGY HENNEPIN
Boring No.: HEN-029 S-3
Sample No.: S-3
Test No.: 20.0 PSI

Location: HENNEPIN, IL
Tested By: BCM
Test Date: 12/17/15
Sample Type: 3.0" ST

Project No.: MR155233
Checked By: WPQ
Depth: 5.0'-7.0'
Elevation: ----

Terracon
Consulting Engineers & Scientists

Soil Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL
Remarks: FAILURE CRITERIA = MAXIMUM EFFECTIVE STRESS RATIO TEST PERFORMED AS PER ASTM D4767.

Specimen Height: 6.03 in
Specimen Area: 6.27 in^2
Specimen Volume: 37.81 in^3

Piston Area: 0.00 in^2
Piston Friction: 0.00 lb
Piston Weight: 0.00 lb

Filter Strip Correction: 0.00 tsf
Membrane Correction: 0.00 lb/in
Correction Type: Uniform

Liquid Limit: 22

Plastic Limit: 15

Estimated Specific Gravity: 2.72

	Time min	Vertical Strain %	Corrected Area in^2	Deviator Load lb	Deviator Stress tsf	Pore Pressure tsf	Horizontal Stress tsf	Vertical Stress tsf
1	0	0	6.2706	0	0	5.1811	6.48	6.48
2	5.0002	0.061721	6.2745	31.946	0.36658	5.5924	6.48	6.8466
3	10	0.12796	6.2786	43.274	0.49624	5.6668	6.48	6.9762
4	15	0.19419	6.2828	51.605	0.59138	5.7058	6.48	7.0714
5	20	0.26043	6.287	58.557	0.67061	5.7267	6.48	7.1506
6	25	0.32817	6.2912	65.03	0.74424	5.7413	6.48	7.2242
7	30	0.39441	6.2954	71.383	0.8164	5.7511	6.48	7.2964
8	35	0.45914	6.2995	77.257	0.88301	5.7558	6.48	7.363
9	40	0.52538	6.3037	83.31	0.95156	5.7575	6.48	7.4316
10	45	0.59312	6.308	89.244	1.0186	5.7587	6.48	7.4986
11	50	0.66086	6.3123	94.878	1.0822	5.7558	6.48	7.5622
12	55	0.72861	6.3166	100.57	1.1464	5.7511	6.48	7.6264
13	60	0.79635	6.3209	106.15	1.2091	5.7477	6.48	7.6891
14	70	0.93334	6.3297	116.22	1.3219	5.7337	6.48	7.8019
15	80.001	1.0688	6.3383	126.22	1.4338	5.718	6.48	7.9138
16	90.001	1.2043	6.347	135.51	1.5373	5.6994	6.48	8.0173
17	100	1.3428	6.3559	144.26	1.6342	5.6796	6.48	8.1142
18	110	1.4798	6.3648	152.18	1.7215	5.6726	6.48	8.2015
19	120	1.6183	6.3737	160.81	1.8165	5.6371	6.48	8.2965
20	180	2.4372	6.4272	202.52	2.2687	5.4865	6.48	8.7487
21	240	3.2501	6.4812	235.37	2.6147	5.3475	6.48	9.0947
22	300	4.0781	6.5372	263.42	2.9013	5.2224	6.48	9.3813
23	360	4.8865	6.5927	289.19	3.1583	5.1119	6.48	9.6383
24	420	5.7054	6.65	313.16	3.3906	5.0119	6.48	9.8706
25	480	6.5349	6.709	335.88	3.6046	4.92	6.48	10.085
26	540	7.3478	6.7679	358.41	3.813	4.8328	6.48	10.293
27	600	8.1637	6.828	379.99	4.0069	4.7525	6.48	10.487
28	660	8.9992	6.8907	399.41	4.1734	4.6792	6.48	10.653
29	720	9.8151	6.953	417.75	4.3259	4.6164	6.48	10.806
30	780	10.631	7.0165	435.67	4.4706	4.5565	6.48	10.951
31	840	11.459	7.0821	453.83	4.6139	4.4954	6.48	11.094
32	900	12.269	7.1475	470.55	4.7401	4.4396	6.48	11.22
33	960	13.094	7.2154	485.54	4.8451	4.3744	6.48	11.325
34	1020	13.928	7.2853	498.42	4.9259	4.3314	6.48	11.406
35	1080	14.742	7.3549	513.89	5.0307	4.2854	6.48	11.511
36	1128.7	15.412	7.4131	526.53	5.114	4.2494	6.48	11.594

DRAFT

TRIAXIAL TEST

Project: DYNEGY HENNEPIN
Boring No.: HEN-029 S-3
Sample No.: S-3
Test No.: 20.0 PSI

Location: HENNEPIN, IL
Tested By: BCM
Test Date: 12/17/15
Sample Type: 3.0" ST

Project No.: MR155233
Checked By: WPQ
Depth: 5.0'-7.0'
Elevation: ----

Terracon
Consulting Engineers & Scientists

Soil Description: BROWN LEAN CLAY WITH SAND AND GRAVEL CL
Remarks: FAILURE CRITERIA = MAXIMUM EFFECTIVE STRESS RATIO TEST PERFORMED AS PER ASTM D4767.

Specimen Height: 6.03 in
Specimen Area: 6.27 in^2
Specimen Volume: 37.81 in^3

Piston Area: 0.00 in^2
Piston Friction: 0.00 lb
Piston Weight: 0.00 lb

Filter Strip Correction: 0.00 tsf
Membrane Correction: 0.00 lb/in
Correction Type: Uniform

Liquid Limit: 22

Plastic Limit: 15

Estimated Specific Gravity: 2.72

	Vertical Strain %	Total Vertical Stress tsf	Total Horizontal Stress tsf	Excess Pore Pressure tsf	A Parameter	Effective Vertical Stress tsf	Effective Horizontal Stress tsf	Stress Ratio	Effective p tsf	q tsf
1	0.00	6.48	6.48	0	0.000	1.2989	1.2989	1.000	1.2989	0
2	0.06	6.8466	6.48	0.41121	1.122	1.2542	0.88764	1.413	1.0709	0.18329
3	0.13	6.9762	6.48	0.48566	0.979	1.3094	0.81319	1.610	1.0613	0.24812
4	0.19	7.0714	6.48	0.52463	0.887	1.3656	0.77423	1.764	1.0699	0.29569
5	0.26	7.1506	6.48	0.54557	0.814	1.4239	0.75329	1.890	1.0886	0.33531
6	0.33	7.2242	6.48	0.56011	0.753	1.483	0.73875	2.007	1.1109	0.37212
7	0.39	7.2964	6.48	0.57	0.698	1.5453	0.72886	2.120	1.1371	0.4082
8	0.46	7.363	6.48	0.57465	0.651	1.6072	0.72421	2.219	1.1657	0.4415
9	0.53	7.4316	6.48	0.57639	0.606	1.674	0.72246	2.317	1.1982	0.47578
10	0.59	7.4986	6.48	0.57756	0.567	1.7399	0.7213	2.412	1.2306	0.50932
11	0.66	7.5622	6.48	0.57465	0.531	1.8064	0.72421	2.494	1.2653	0.5411
12	0.73	7.6264	6.48	0.57	0.497	1.8752	0.72886	2.573	1.302	0.57319
13	0.80	7.6891	6.48	0.56651	0.469	1.9414	0.73235	2.651	1.3369	0.60454
14	0.93	7.8019	6.48	0.55255	0.418	2.0683	0.74631	2.771	1.4073	0.66097
15	1.07	7.9138	6.48	0.53684	0.374	2.1959	0.76201	2.882	1.4789	0.71692
16	1.20	8.0173	6.48	0.51823	0.337	2.3179	0.78062	2.969	1.5493	0.76863
17	1.34	8.1142	6.48	0.49846	0.305	2.4346	0.8004	3.042	1.6175	0.81712
18	1.48	8.2015	6.48	0.49148	0.285	2.5288	0.80738	3.132	1.6681	0.86073
19	1.62	8.2965	6.48	0.456	0.251	2.6594	0.84286	3.155	1.7511	0.90827
20	2.44	8.7487	6.48	0.30535	0.135	3.2622	0.9935	3.284	2.1279	1.1344
21	3.25	9.0947	6.48	0.16635	0.064	3.7472	1.1325	3.309	2.4399	1.3073
22	4.08	9.3813	6.48	0.041296	0.014	4.1588	1.2576	3.307	2.7082	1.4506
23	4.89	9.6383	6.48	-0.069214	-0.022	4.5263	1.3681	3.309	2.9472	1.5791
24	5.71	9.8706	6.48	-0.16925	-0.050	4.8588	1.4681	3.310	3.1634	1.6953
25	6.53	10.085	6.48	-0.26115	-0.072	5.1646	1.56	3.311	3.3623	1.8023
26	7.35	10.293	6.48	-0.3484	-0.091	5.4602	1.6472	3.315	3.5537	1.9065
27	8.16	10.487	6.48	-0.42866	-0.107	5.7345	1.7275	3.319	3.731	2.0035
28	9.00	10.653	6.48	-0.50195	-0.120	5.9742	1.8008	3.318	3.8875	2.0867
29	9.82	10.806	6.48	-0.56476	-0.131	6.1895	1.8636	3.321	4.0266	2.1629
30	10.63	10.951	6.48	-0.62467	-0.140	6.3942	1.9235	3.324	4.1588	2.2353
31	11.46	11.094	6.48	-0.68574	-0.149	6.5985	1.9846	3.325	4.2915	2.3069
32	12.27	11.22	6.48	-0.74158	-0.156	6.7805	2.0404	3.323	4.4105	2.3701
33	13.09	11.325	6.48	-0.80672	-0.167	6.9506	2.1056	3.301	4.5281	2.4225
34	13.93	11.406	6.48	-0.84976	-0.173	7.0745	2.1486	3.293	4.6116	2.463
35	14.74	11.511	6.48	-0.89571	-0.178	7.2252	2.1946	3.292	4.7099	2.5153
36	15.41	11.594	6.48	-0.93177	-0.182	7.3446	2.2306	3.293	4.7876	2.557

DRAFT

Drained Direct Shear Tests
ASTM D 3080

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DIRECT SHEAR TEST by ASTM D3080

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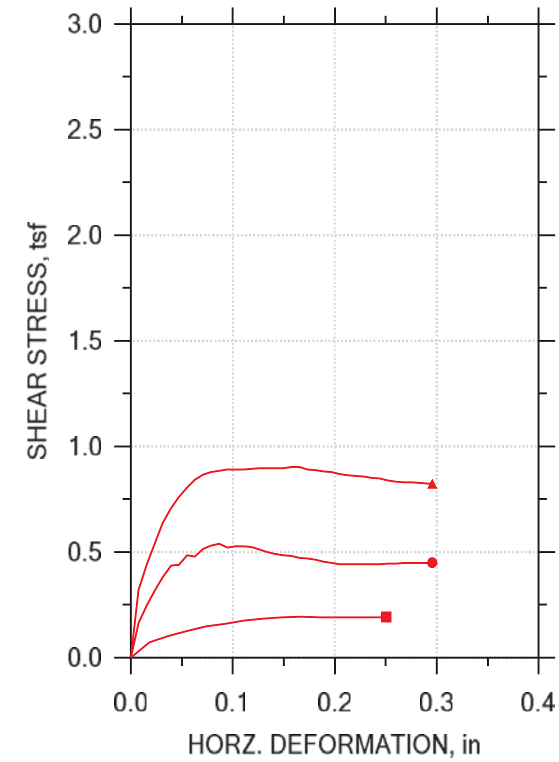
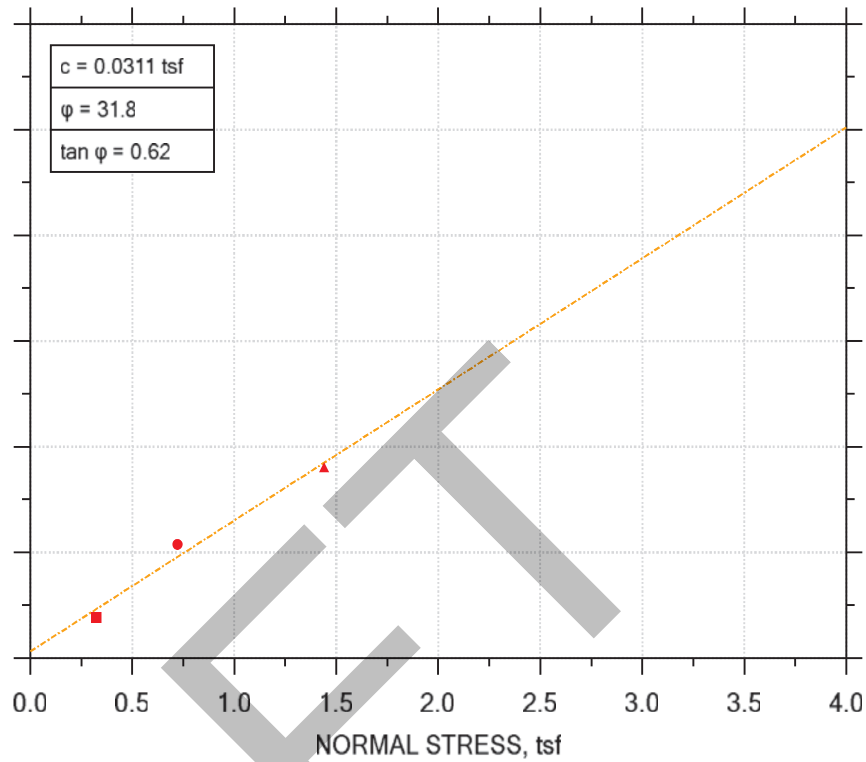
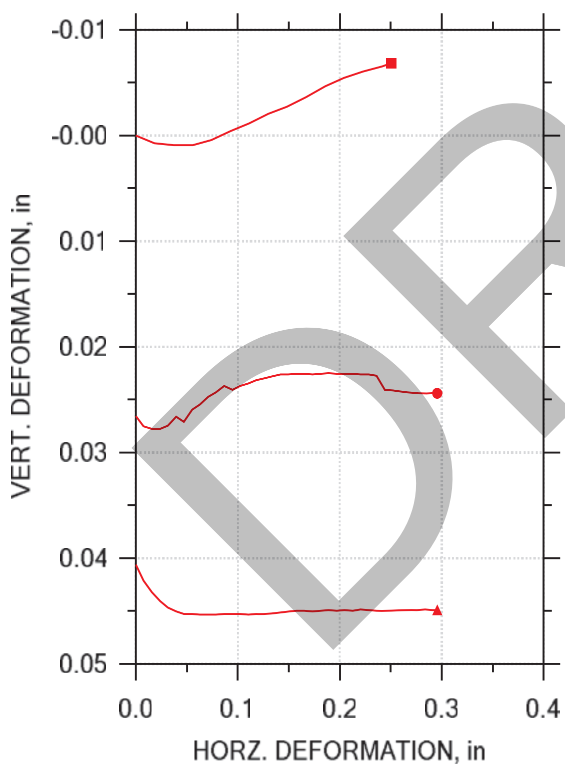






Symbol	■	●	▲	
Test No.	5.0 PSI	10.0 PSI	20.0 PSI	
Sample No.	S-5	S-5	S-5	
Shape	Circular	Circular	Circular	
Initial: Dimension, in	2.4913	2.4941	2.4976	
Initial: Area, in²	4.8748	4.8856	4.8995	
Initial: Height, in	0.9878	0.99094	0.99252	
Initial: Water Content, %	16.30	16.70	16.83	
Initial: Dry Density, pcf	112.2	111.3	110.7	
Initial: Saturation, %	86.28	86.36	85.72	
Initial: Void Ratio	0.51397	0.52594	0.53408	
Consol. Height, in	0.9878	0.9644	0.95193	
Consol. Void Ratio	0.51397	0.48506	0.47134	
Final: Water Content, %	19.67	18.05	17.75	
Final: Dry Density, pcf	111.4	114.1	115.9	
Final: Saturation, %	102.01	100.52	103.90	
Final: Void Ratio	0.52446	0.48839	0.46469	
Normal Stress, tsf	0.32343	0.72072	1.4396	
Max. Shear Stress, tsf	0.19271	0.53843	0.90226	
Ult. Shear Stress, tsf	0.19231	0.44946	0.82371	
Time to Failure, min	39.855	23.081	41.061	
Disp. Rate, in/min	0.047244	0.004	0.004	
Estimated Specific Gravity	2.72	2.72	2.72	
Liquid Limit	31	31	31	
Plastic Limit	17	17	17	
Plasticity Index	14	14	14	

Project: DYNEGY HENNEPIN

Location: HENNEPIN, IL

Project No.: MR155233

Boring No.: HEN-029 S-5

Sample Type: TRIMMED

Description: DARK BROWN AND GRAY SLIGHTLY ORGANIC CLAY CL SAND POCKETS NOTED

Remarks:

DRAFT

Project: DYNEGY HENNEPIN
Boring No.: HEN-029 S-5
Sample No.: S-5
Test No.: 5.0 PSI

Location: HENNEPIN, IL
Tested By: BCM
Test Date: 12/13/15
Sample Type: TRIMMED

Project No.: MR155233
Checked By: WPQ
Depth: 10.0'-12.0'
Elevation: ----

Soil Description: DARK BROWN AND GRAY SLIGHTLY ORGANIC CLAY CL SAND POCKETS NOTED
Remarks:

Step: 1 of 1

	Elapsed Time min	Vertical Stress tsf	Vertical Displacement in	Horizontal Stress tsf	Horizontal Displacement in	Cumulative Displacement in
1	0.00	0.323	0.0000	0.000202	0.0000	0.0000
2	5.49	0.322	0.0007383	0.0717	0.01854	0.01854
3	10.36	0.323	0.0009004	0.104	0.03709	0.03709
4	15.03	0.323	0.0009004	0.128	0.05563	0.05563
5	19.38	0.323	0.0004142	0.147	0.07418	0.07418
6	23.15	0.323	-0.0003962	0.161	0.09280	0.09280
7	27.26	0.323	-0.001135	0.175	0.1113	0.1113
8	31.47	0.323	-0.002053	0.186	0.1299	0.1299
9	35.85	0.324	-0.002755	0.191	0.1484	0.1484
10	39.85	0.323	-0.003638	0.193	0.1670	0.1670
11	44.32	0.323	-0.004646	0.192	0.1856	0.1856
12	48.69	0.323	-0.005475	0.192	0.2041	0.2041
13	53.17	0.323	-0.006051	0.192	0.2228	0.2228
14	57.05	0.323	-0.006537	0.192	0.2413	0.2413
15	60.08	0.322	-0.006843	0.192	0.2506	0.2506

DRAFT

Project: DYNEGY HENNEPIN
Boring No.: HEN-029 S-5
Sample No.: S-5
Test No.: 10.0 PSI

Location: HENNEPIN, IL
Tested By: BCM
Test Date: 12/13/15
Sample Type: TRIMMED

Project No.: MR155233
Checked By: WPQ
Depth: 10.0'-12.0'
Elevation: ----

Soil Description: DARK BROWN AND GRAY SLIGHTLY ORGANIC CLAY CL SAND POCKETS NOTED
Remarks:

Step: 1 of 1

	Elapsed Time min	Vertical Stress tsf	Vertical Displacement in	Horizontal Stress tsf	Horizontal Displacement in	Cumulative Displacement in
1	0.00	0.719	0.02654	0.000	0.0000	0.0000
2	2.71	0.719	0.02752	0.165	0.007902	0.007902
3	4.89	0.719	0.02777	0.248	0.01580	0.01580
4	7.16	0.720	0.02779	0.321	0.02364	0.02364
5	9.14	0.721	0.02746	0.382	0.03150	0.03150
6	11.21	0.721	0.02662	0.436	0.03940	0.03940
7	12.99	0.722	0.02710	0.441	0.04727	0.04727
8	14.76	0.722	0.02597	0.484	0.05517	0.05517
9	16.83	0.722	0.02543	0.479	0.06300	0.06300
10	18.94	0.722	0.02471	0.516	0.07087	0.07087
11	21.09	0.721	0.02433	0.529	0.07877	0.07877
12	23.08	0.721	0.02372	0.538	0.08664	0.08664
13	25.09	0.720	0.02404	0.521	0.09451	0.09451
14	26.95	0.721	0.02370	0.527	0.1024	0.1024
15	28.84	0.720	0.02343	0.528	0.1102	0.1102
16	30.60	0.720	0.02318	0.523	0.1182	0.1182
17	32.68	0.720	0.02294	0.512	0.1260	0.1260
18	34.69	0.720	0.02280	0.499	0.1339	0.1339
19	36.76	0.720	0.02262	0.491	0.1417	0.1417
20	38.80	0.720	0.02258	0.485	0.1496	0.1496
21	40.72	0.720	0.02256	0.482	0.1575	0.1575
22	42.71	0.720	0.02253	0.474	0.1654	0.1654
23	44.65	0.720	0.02258	0.468	0.1732	0.1732
24	46.29	0.720	0.02255	0.463	0.1811	0.1811
25	48.27	0.720	0.02249	0.455	0.1890	0.1890
26	50.29	0.720	0.02255	0.448	0.1969	0.1969
27	52.42	0.720	0.02253	0.444	0.2047	0.2047
28	54.59	0.720	0.02253	0.441	0.2126	0.2126
29	56.45	0.720	0.02260	0.441	0.2205	0.2205
30	58.41	0.720	0.02264	0.441	0.2283	0.2283
31	60.25	0.720	0.02271	0.443	0.2362	0.2362
32	62.14	0.719	0.02408	0.443	0.2441	0.2441
33	64.05	0.720	0.02410	0.444	0.2520	0.2520
34	66.14	0.720	0.02424	0.447	0.2598	0.2598
35	68.26	0.719	0.02431	0.448	0.2678	0.2678
36	70.36	0.719	0.02438	0.449	0.2756	0.2756
37	72.12	0.719	0.02442	0.449	0.2835	0.2835
38	74.01	0.719	0.02437	0.449	0.2914	0.2914
39	75.01	0.719	0.02438	0.449	0.2953	0.2953

DRAFT

Project: DYNEGY HENNEPIN
Boring No.: HEN-029 S-5
Sample No.: S-5
Test No.: 20.0 PSI

Location: HENNEPIN, IL
Tested By: BCM
Test Date: 12/13/15
Sample Type: TRIMMED

Project No.: MR155233
Checked By: WPQ
Depth: 10.0'-12.0'
Elevation: ----

Terracon Consulting Engineers & Scientists

Soil Description: DARK BROWN AND GRAY SLIGHTLY ORGANIC CLAY CL SAND POCKETS NOTED
Remarks:

Step: 1 of 1

	Elapsed Time min	Vertical Stress tsf	Vertical Displacement in	Horizontal Stress tsf	Horizontal Displacement in	Cumulative Displacement in
1	0.00	1.44	0.04059	0.000	0.0000	0.0000
2	2.82	1.44	0.04214	0.321	0.007867	0.007867
3	4.83	1.44	0.04324	0.444	0.01573	0.01573
4	7.10	1.44	0.04405	0.546	0.02360	0.02360
5	9.38	1.44	0.04470	0.641	0.03147	0.03147
6	11.33	1.44	0.04504	0.710	0.03937	0.03937
7	13.35	1.44	0.04526	0.759	0.04724	0.04724
8	15.20	1.44	0.04529	0.807	0.05510	0.05510
9	17.03	1.44	0.04533	0.841	0.06297	0.06297
10	19.00	1.44	0.04531	0.865	0.07087	0.07087
11	21.09	1.44	0.04531	0.877	0.07877	0.07877
12	23.26	1.44	0.04527	0.883	0.08660	0.08660
13	25.19	1.44	0.04529	0.890	0.09447	0.09447
14	27.24	1.44	0.04527	0.891	0.1023	0.1023
15	29.09	1.44	0.04533	0.890	0.1102	0.1102
16	30.98	1.44	0.04529	0.893	0.1181	0.1181
17	32.82	1.44	0.04526	0.896	0.1260	0.1260
18	34.93	1.44	0.04524	0.896	0.1338	0.1338
19	36.84	1.44	0.04513	0.895	0.1417	0.1417
20	39.05	1.44	0.04500	0.896	0.1496	0.1496
21	41.06	1.44	0.04499	0.902	0.1575	0.1575
22	42.87	1.44	0.04495	0.902	0.1653	0.1653
23	44.87	1.44	0.04502	0.889	0.1732	0.1732
24	46.86	1.44	0.04497	0.888	0.1811	0.1811
25	48.59	1.44	0.04493	0.883	0.1889	0.1889
26	50.54	1.44	0.04499	0.877	0.1968	0.1968
27	52.49	1.44	0.04493	0.869	0.2047	0.2047
28	54.68	1.44	0.04497	0.865	0.2126	0.2126
29	56.76	1.44	0.04488	0.862	0.2204	0.2204
30	58.63	1.44	0.04493	0.858	0.2283	0.2283
31	60.64	1.44	0.04497	0.850	0.2362	0.2362
32	62.54	1.44	0.04497	0.847	0.2441	0.2441
33	64.42	1.44	0.04499	0.840	0.2519	0.2519
34	66.26	1.44	0.04493	0.834	0.2598	0.2598
35	68.32	1.44	0.04493	0.831	0.2677	0.2677
36	70.44	1.44	0.04493	0.830	0.2756	0.2756
37	72.48	1.44	0.04488	0.828	0.2834	0.2834
38	74.27	1.44	0.04490	0.825	0.2913	0.2913
39	75.29	1.44	0.04490	0.824	0.2955	0.2955

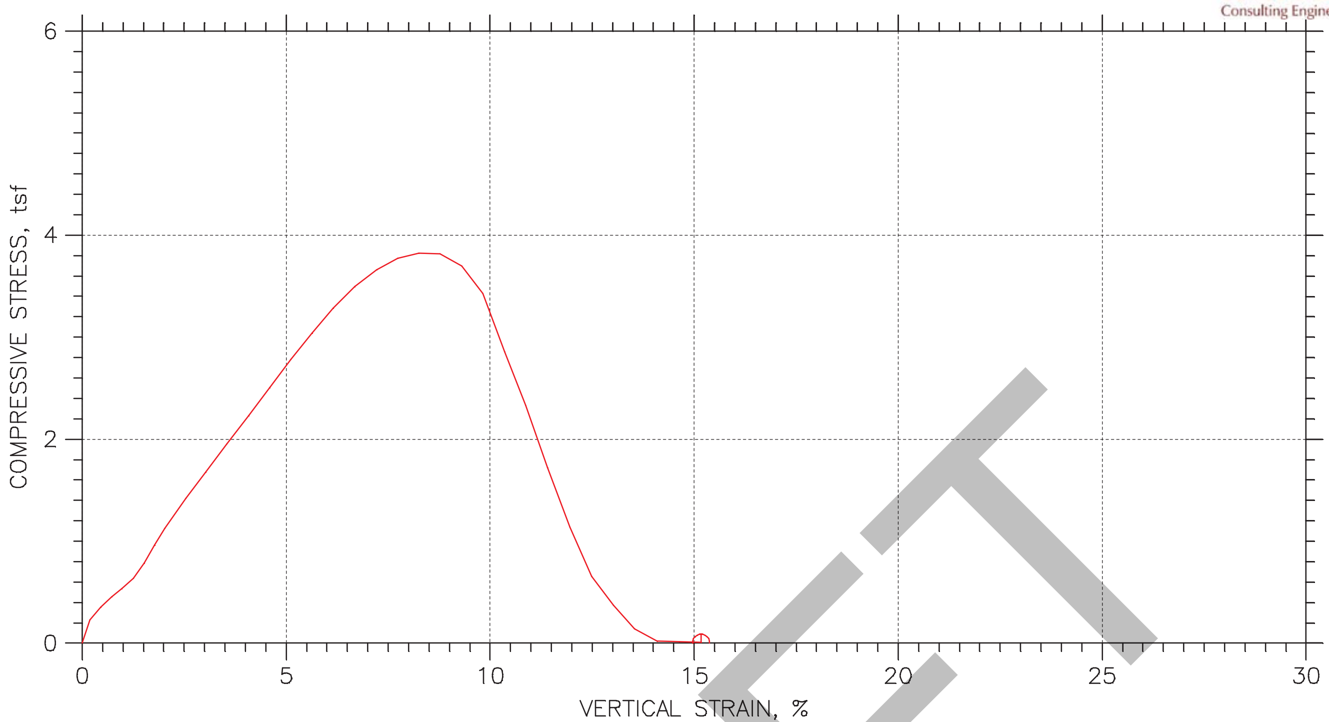
DRAFT

Unconfined Compression Tests
ASTM D 2166

DRAFT

UNCONFINED COMPRESSION TEST REPORT

Terracon
Consulting Engineers & Scientists



DRAFT

Symbol		⏀			
Test No.		HEN032S3			
Initial	Diameter, in	2.8303			
	Height, in	5.85			
	Water Content, %	14.10			
	Dry Density, pcf	115.8			
	Saturation, %	82.27			
	Void Ratio	0.46619			
Unconfined Compressive Strength, tsf		3.8231			
Undrained Shear Strength, tsf		1.9116			
Time to Failure, min		8.0041			
Strain Rate, %/min		1.14			
Estimated Specific Gravity		2.72			
Liquid Limit		35			
Plastic Limit		18			
Plasticity Index		17			
Failure Sketch					

Project: DYNEGY HENNEPIN
Location: HENNEPIN, IL
Project No.: MR155233
Boring No.: HEN032 S-3
Sample Type: 3.0'' ST
Description: DARK BROWNISH GRAY LEAN CLAY WITH SAND AND GRAVEL CL
Remarks: TEST PERFORMED AS PER ASTM D2166.

Tue, 22-DEC-2015 15:25:34

UNCONFINED COMPRESSION TEST

Project: DYNERGY HENNEPIN
Boring No.: HEN032 S-3
Sample No.: ST-3
Test No.: HEN032S3

Location: HENNEPIN, IL
Tested By: BCM
Test Date: 12/15/15
Sample Type: 3.0" ST

Project No.: MR155233
Checked By: WPQ
Depth: 5.0'-7.0'
Elevation: ----

Terracon
Consulting Engineers & Scientists

Soil Description: DARK BROWNISH GRAY LEAN CLAY WITH SAND AND GRAVEL CL
Remarks: TEST PERFORMED AS PER ASTM D2166.

Specimen Height: 5.85 in
Specimen Area: 6.29 in^2
Specimen Volume: 36.81 in^3

Liquid Limit: 35
Plastic Limit: 18
Estimated Specific Gravity: 2.72

Cap Mass: 0 gm

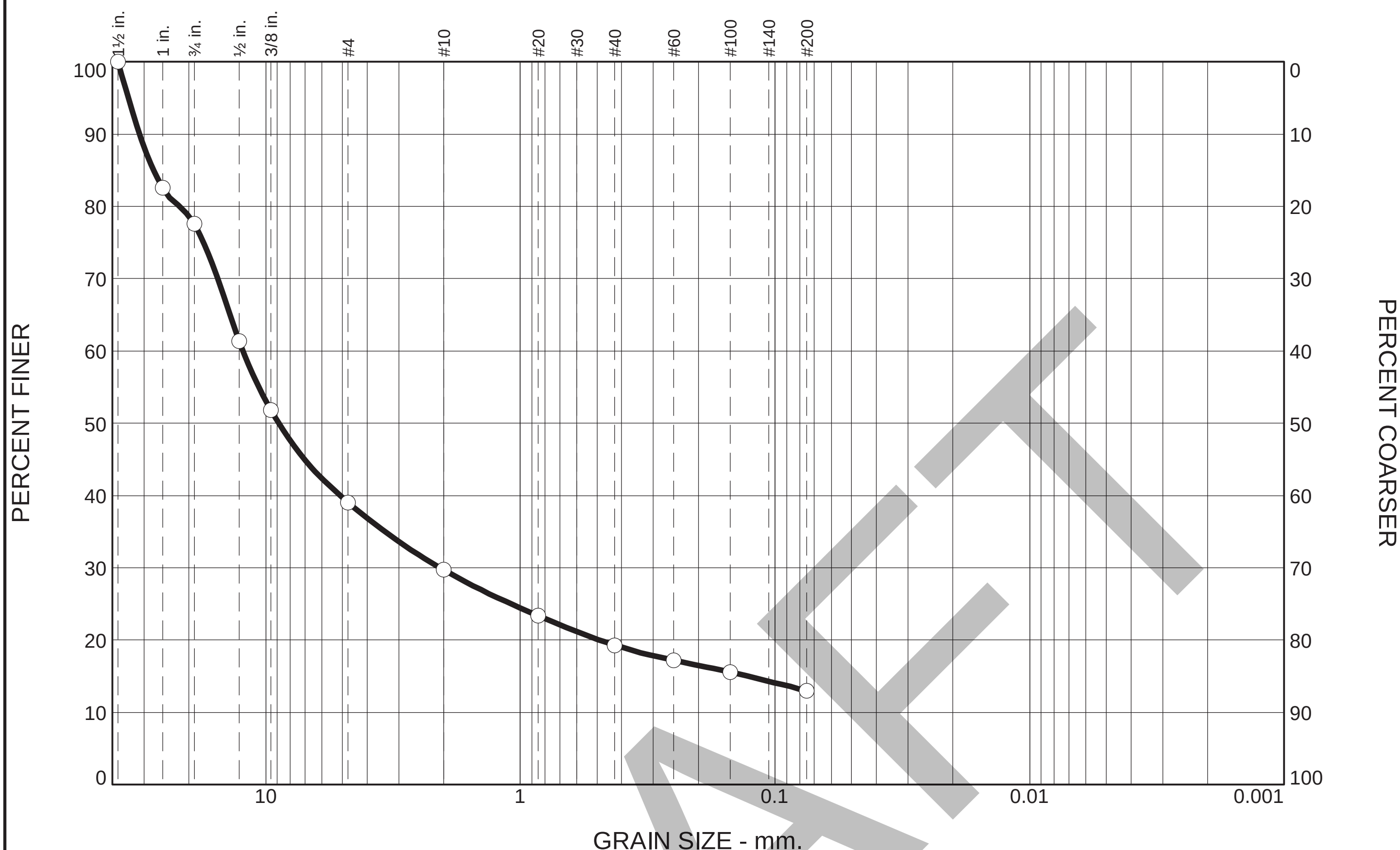
	Time min	Axial Displacement in	Axial Strain %	Load lb	Corrected Area in^2	Vertical Stress tsf	Shear Stress tsf
1	0	0	0	0	6.2916	0	0
2	0.25403	0.011115	0.18999	20.059	6.3036	0.22911	0.11456
3	0.50403	0.026602	0.45474	30.798	6.3203	0.35085	0.17543
4	0.75403	0.041999	0.71793	39.748	6.3371	0.45161	0.22581
5	1.004	0.057395	0.98111	47.382	6.3539	0.53692	0.26846
6	1.254	0.073065	1.249	56.543	6.3711	0.63899	0.31949
7	1.504	0.088735	1.5168	69.915	6.3885	0.78796	0.39398
8	1.7541	0.10358	1.7707	85.657	6.405	0.96289	0.48144
9	2.0041	0.11853	2.0261	100.35	6.4217	1.1251	0.56254
10	2.504	0.14841	2.5369	127.09	6.4553	1.4175	0.70875
11	3.004	0.17738	3.0321	151.41	6.4883	1.6802	0.8401
12	3.5041	0.20726	3.5429	176.95	6.5227	1.9532	0.97661
13	4.0041	0.23833	4.074	203.01	6.5588	2.2285	1.1143
14	4.5041	0.26903	4.5988	229.49	6.5949	2.5055	1.2527
15	5.0041	0.29937	5.1174	256.29	6.6309	2.7828	1.3914
16	5.5041	0.32943	5.6313	281.66	6.667	3.0418	1.5209
17	6.0041	0.36004	6.1545	305.56	6.7042	3.2816	1.6408
18	6.5041	0.39092	6.6825	327.41	6.7421	3.4965	1.7482
19	7.0041	0.42172	7.2089	344.52	6.7804	3.6584	1.8292
20	7.5041	0.45215	7.729	357.32	6.8186	3.773	1.8865
21	8.0041	0.48248	8.2476	364.11	6.8571	3.8231	1.9116
22	8.5041	0.51319	8.7724	365.79	6.8966	3.8189	1.9094
23	9.0041	0.54443	9.3066	356.58	6.9372	3.7009	1.8504
24	9.5041	0.57495	9.8283	332.2	6.9773	3.428	1.714
25	10.004	0.60556	10.352	278.29	7.0181	2.8551	1.4275
26	10.504	0.63636	10.878	228.38	7.0595	2.3293	1.1646
27	11.004	0.66724	11.406	169.79	7.1016	1.7214	0.8607
28	11.504	0.69895	11.948	113.14	7.1453	1.14	0.57002
29	12.004	0.73056	12.488	65.651	7.1894	0.65748	0.32874
30	12.504	0.76144	13.016	37.169	7.233	0.36999	0.185
31	13.004	0.79242	13.546	14.32	7.2773	0.14168	0.070839
32	13.504	0.82403	14.086	2.3165	7.3231	0.022775	0.011388
33	14.004	0.85619	14.636	1.5794	7.3703	0.015429	0.0077146
34	14.503	0.88735	15.168	0.7897	7.4165	0.0076665	0.0038332

DRAFT

Particle Size Analysis of Soils
ASTM D 422

DRAFT

PARTICLE SIZE ANALYSIS OF SOILS ASTM D422



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	22.4	38.6	9.3	10.4	6.3	13.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	82.5		
.75	77.6		
.5	61.4		
.375	51.8		
#4	39.0		
#10	29.7		
#20	23.4		
#40	19.3		
#60	17.2		
#100	15.6		
#200	13.0		

* (no specification provided)

LIGHT BROWN POORLY GRADED GRAVEL WITH SAND AND CLAY

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 31.2310 D_{85}= 27.6077 D_{60}= 12.2743
D_{50}= 8.8861 D_{30}= 2.0649 D_{15}= 0.1281
D_{10}= C_u= C_c=

Classification

USCS= GP-GC AASHTO=

Remarks

F.M.=5.20

Source of Sample: HEN-B029 **Depth:** 35.0'-36.5'
Sample Number: S-10

Date: 12-10-15

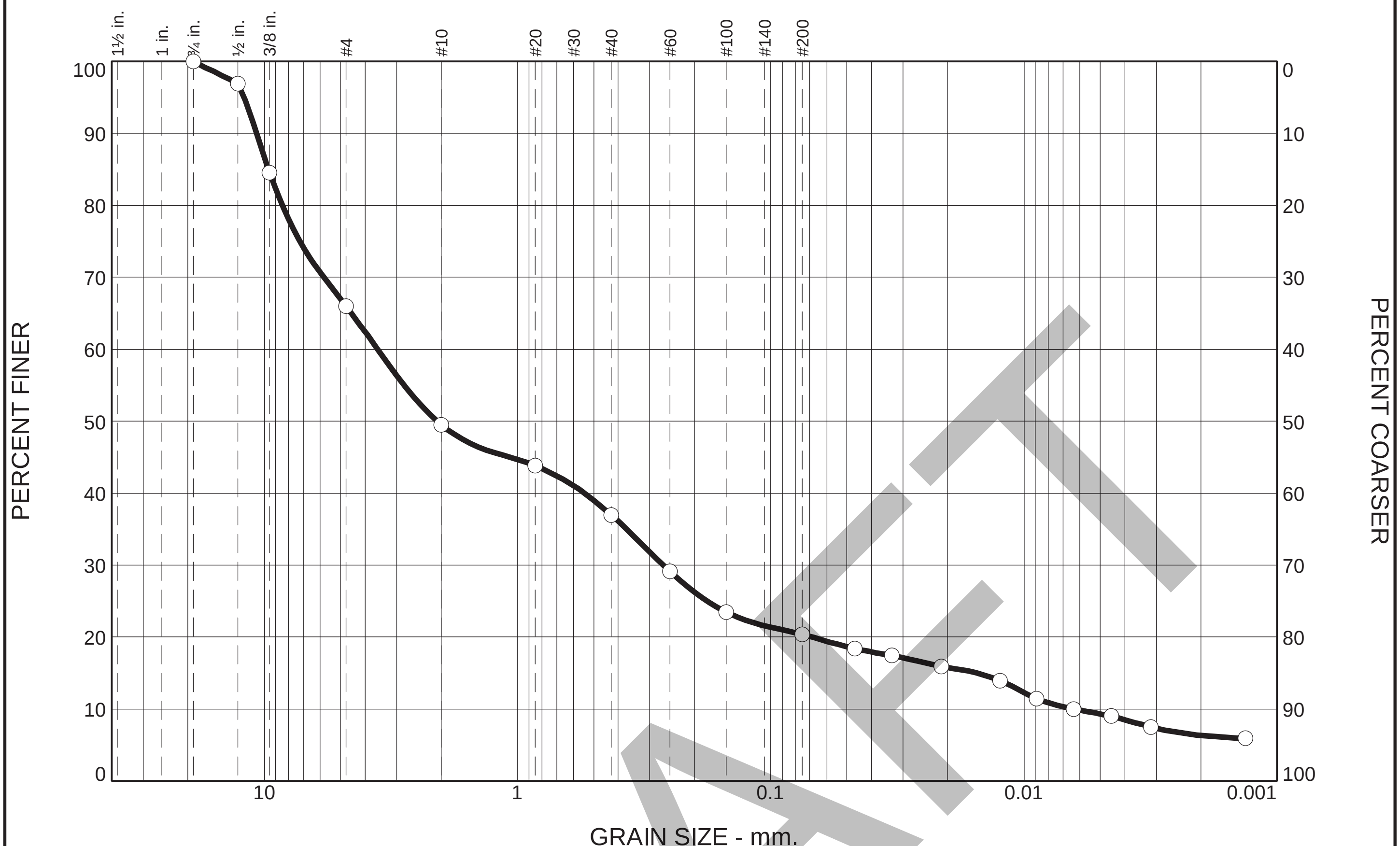
Terracon

Client: AECOM
Project: DYNERGY - HENNEPIN

Project No: MR155233 **Figure**

Tested By: SJH **Checked By:** WPQ

PARTICLE SIZE ANALYSIS OF SOILS ASTM D422



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	34.0	16.5	12.6	16.6	11.0	9.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.75	100.0		
.5	97.0		
.375	84.6		
#4	66.0		
#10	49.5		
#20	43.8		
#40	36.9		
#60	29.1		
#100	23.5		
#200	20.3		

* (no specification provided)

BROWN AND LIGHT BROWN SILTY SAND WITH GRAVEL

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 10.7082 D_{85}= 9.6174 D_{60}= 3.5682
D_{50}= 2.0785 D_{30}= 0.2659 D_{15}= 0.0154
D_{10}= 0.0064 C_u= 557.69 C_c= 3.10

Classification

USCS= SM AASHTO=

Remarks

F.M.=3.56

Source of Sample: HEN-B030 **Depth:** 2.5'-4.0'
Sample Number: S-2

Date: 12-15-15

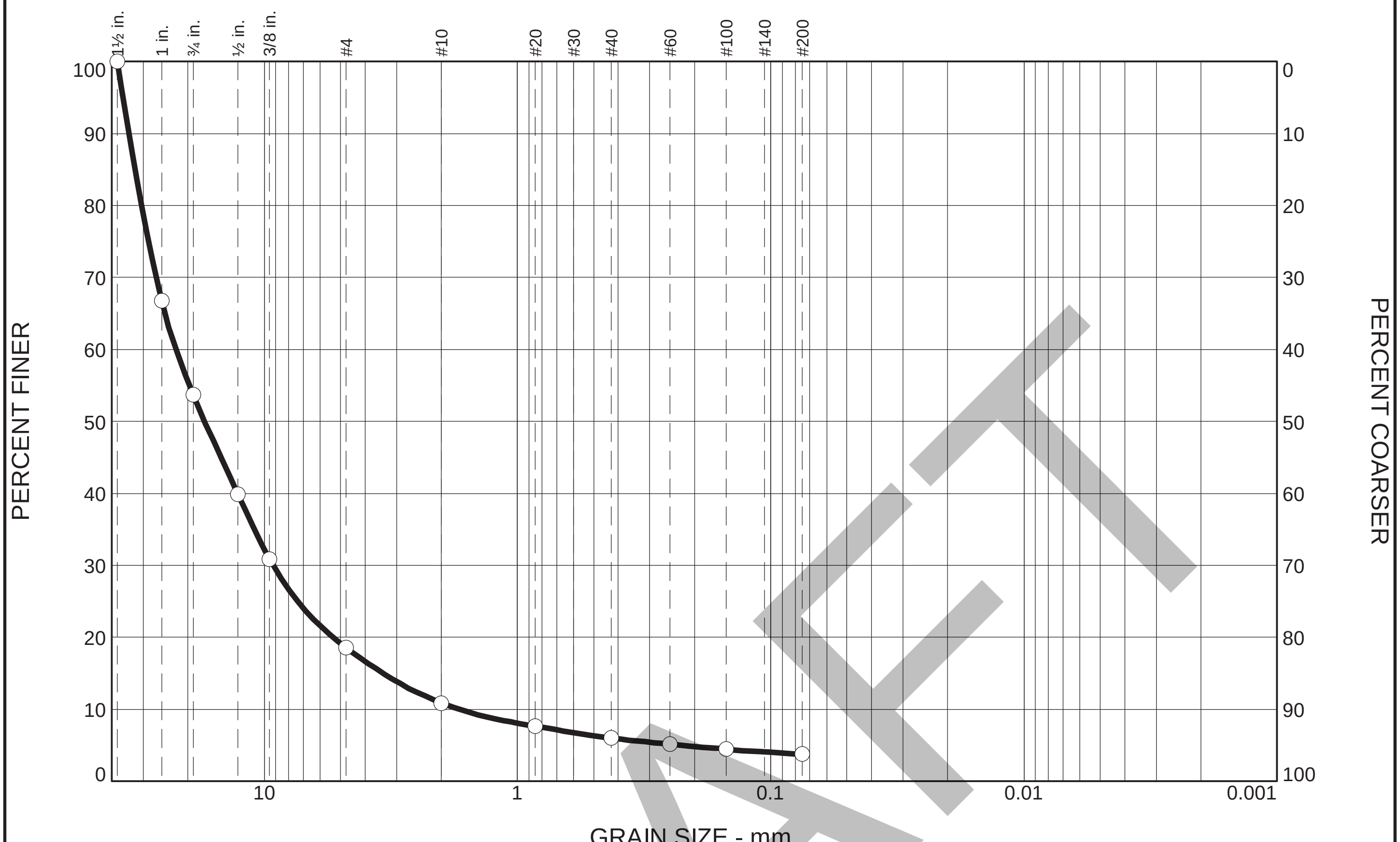
Terracon

Client: AECOM
Project: DYNEGY - HENNEPIN

Project No: MR155233 **Figure**

Tested By: SJH **Checked By:** WPQ

PARTICLE SIZE ANALYSIS OF SOILS ASTM D422



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	46.3	35.1	7.7	4.9	2.2	3.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	66.8		
.75	53.7		
.5	39.9		
.375	30.9		
#4	18.6		
#10	10.9		
#20	7.6		
#40	6.0		
#60	5.1		
#100	4.4		
#200	3.8		

* (no specification provided)

LIGHT BROWN AND TAN WELL GRADED GRAVEL WITH SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 34.1590 D_{85}= 32.2869 D_{60}= 22.3306
D_{50}= 17.1780 D_{30}= 9.2189 D_{15}= 3.3953
D_{10}= 1.7025 C_u= 13.12 C_c= 2.24

Classification

USCS= GW AASHTO=

Remarks

F.M.=6.60

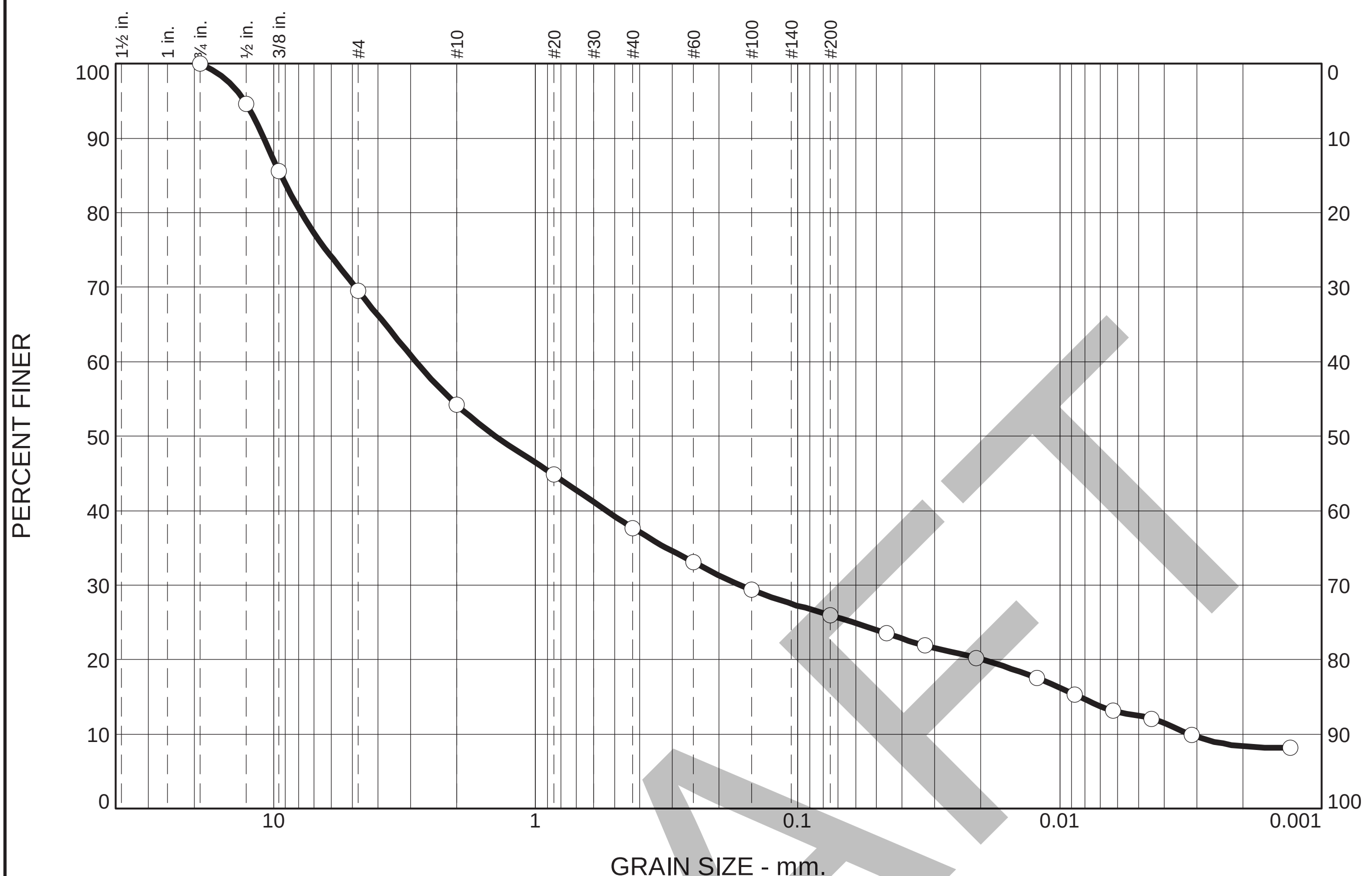
Source of Sample: HEN-B030 **Depth:** 15.0'-16.5'
Sample Number: S-6 **Date:** 12-10-15

Terracon

Client: AECOM
Project: DYNEGY - HENNEPIN
Project No: MR155233 **Figure**

Tested By: SJH **Checked By:** WPQ

PARTICLE SIZE ANALYSIS OF SOILS ASTM D422



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	30.5	15.3	16.5	11.8	13.4	12.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.75	100.0		
.5	94.6		
.375	85.6		
#4	69.5		
#10	54.2		
#20	44.8		
#40	37.7		
#60	33.1		
#100	29.4		
#200	25.9		

* (no specification provided)

BROWN SILTY SAND WITH GRAVEL

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 10.8888 D_{85}= 9.3568 D_{60}= 2.8565
D_{50}= 1.4206 D_{30}= 0.1654 D_{15}= 0.0084
D_{10}= 0.0032 C_u= 894.95 C_c= 3.00

Classification

USCS= SM AASHTO=

Remarks

F.M.=3.35

Source of Sample: HEN-B032 **Depth:** 20.0'-21.5'
Sample Number: S-7

Date: 12-15-15

Terracon

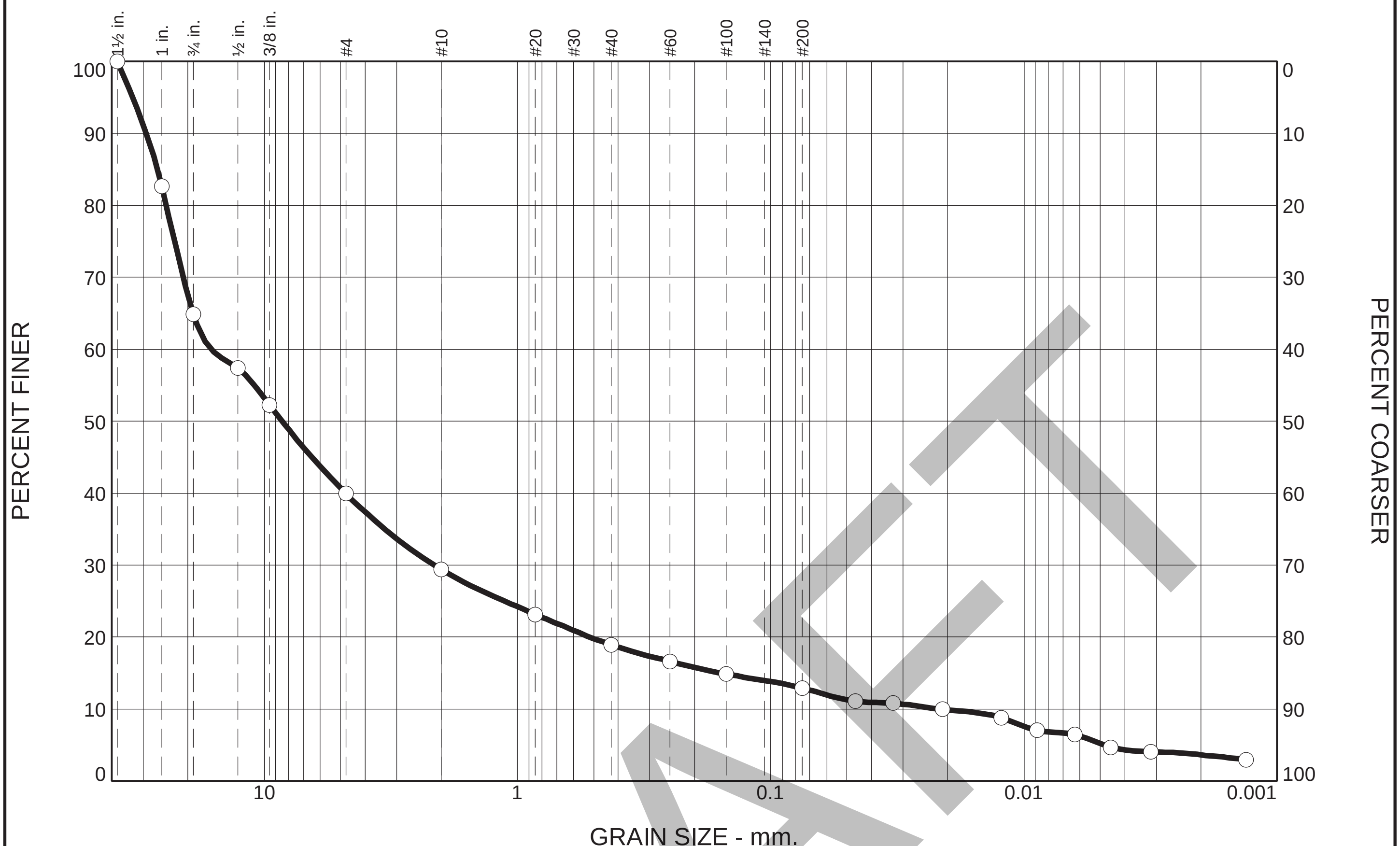
Client: AECOM
Project: DYNEGY - HENNEPIN

Project No: MR155233 **Figure**

Tested By: SJH **Checked By:** WPQ

DRAFT

PARTICLE SIZE ANALYSIS OF SOILS ASTM D422



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	35.1	25.0	10.5	10.5	6.0	7.7	5.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	82.7		
.75	64.9		
.5	57.4		
.375	52.3		
#4	39.9		
#10	29.4		
#20	23.2		
#40	18.9		
#60	16.6		
#100	14.8		
#200	12.9		

* (no specification provided)

BROWN AND LIGHT BROWN POORLY GRADED GRAVEL WITH SILT AND SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 29.2016 D_{85}= 26.4297 D_{60}= 16.1803
D_{50}= 8.4958 D_{30}= 2.1337 D_{15}= 0.1581
D_{10}= 0.0218 C_u= 742.74 C_c= 12.92

Classification

USCS= GP-GM AASHTO=

Remarks

F.M.=5.34

Source of Sample: HEN-B034 **Depth:** 10.0'-11.5'
Sample Number: S-5

Date: 12-17-15

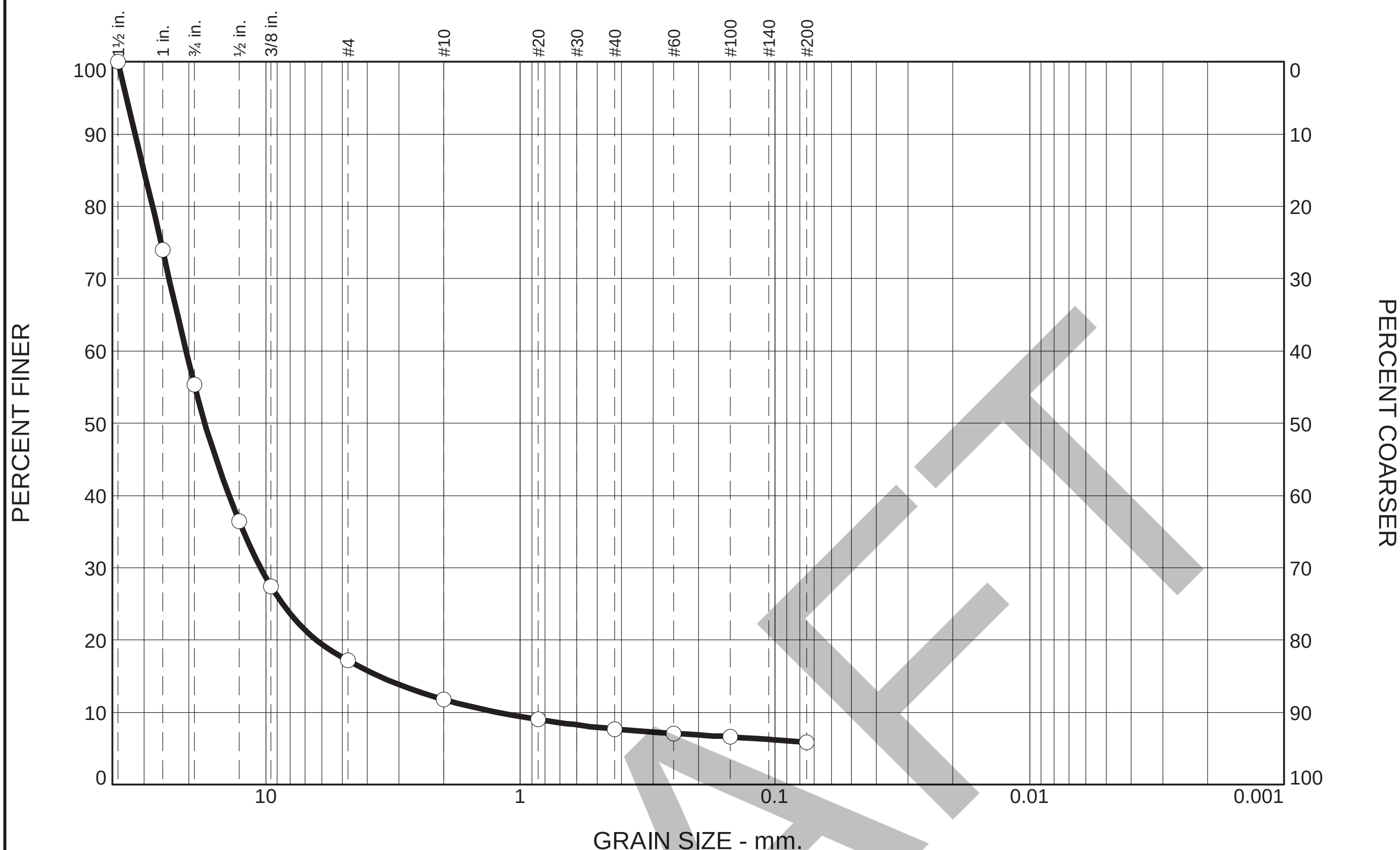
Terracon

Client: AECOM
Project: DYNEGY - HENNEPIN

Project No: MR155233 **Figure**

Tested By: SJH **Checked By:** WPQ

PARTICLE SIZE ANALYSIS OF SOILS ASTM D422



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	44.7	38.1	5.4	4.1	1.8	5.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	74.0		
.75	55.3		
.5	36.4		
.375	27.4		
#4	17.2		
#10	11.8		
#20	9.0		
#40	7.7		
#60	7.1		
#100	6.6		
#200	5.9		

* (no specification provided)

LIGHT BROWN AND TAN POORLY GRADED GRAVEL WITH SAND AND SILT

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 32.5083 D_{85}= 30.0560 D_{60}= 20.5658
D_{50}= 17.3171 D_{30}= 10.4646 D_{15}= 3.5815
D_{10}= 1.2300 C_u= 16.72 C_c= 4.33

Classification

USCS= GP-GM AASHTO=

Remarks

F.M.=6.56

Source of Sample: HEN-B034 **Depth:** 35.0'-36.5'
Sample Number: S-10 **Date:** 12-10-15

Terracon

Client: AECOM
Project: DYNEGY - HENNEPIN
Project No: MR155233 **Figure**

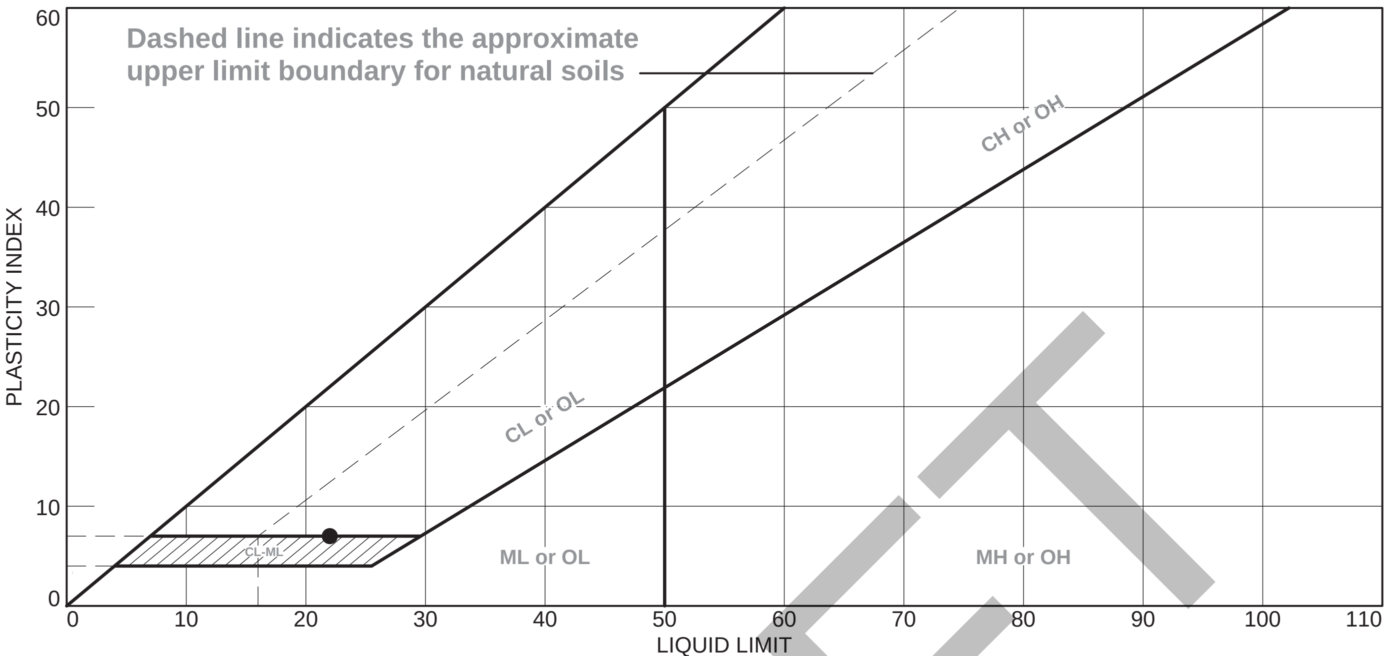
Tested By: SJH **Checked By:** WPQ

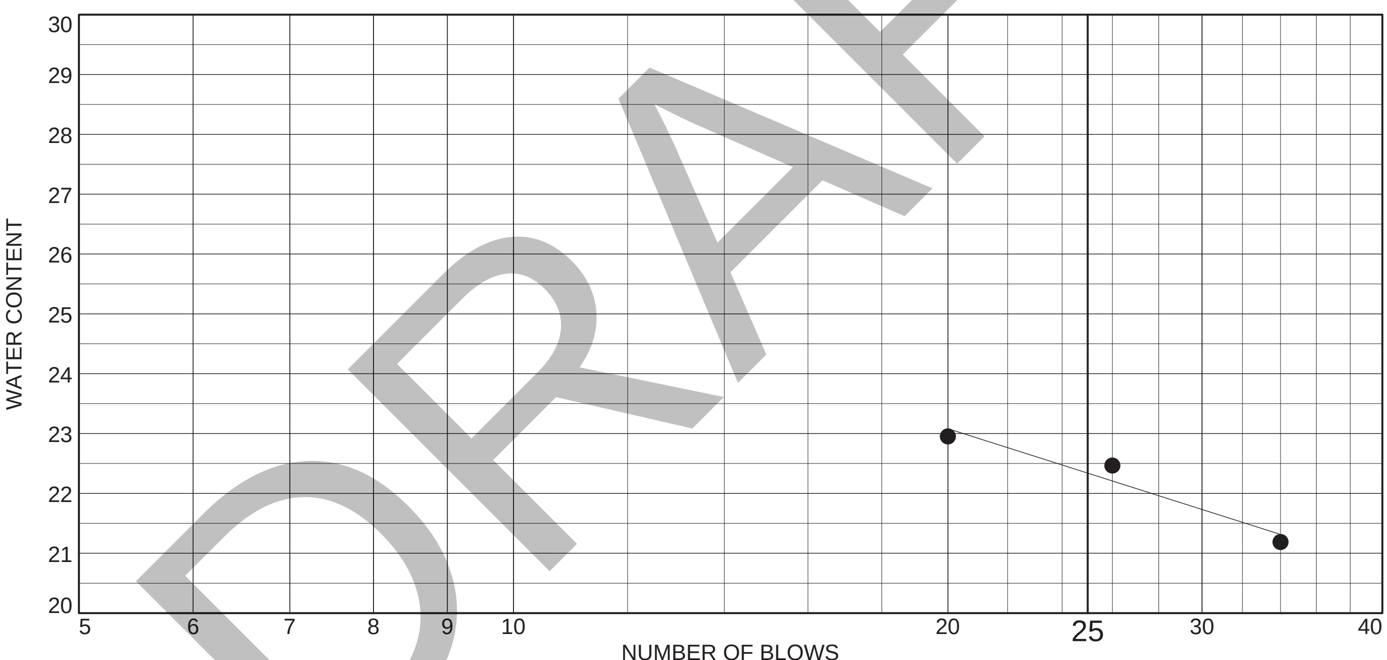
DRAFT

Liquid Limit, Plastic Limit and Plasticity Index of Soils ASTM D 4318

DRAFT

LIQUID AND PLASTIC LIMITS ASTM D4318





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	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	BROWN LEAN CLAY WITH SAND AND GRAVEL	22	15	7			CL

Project No. MR155233 **Client:** AECOM

Project: DYNEGY - HENNEPIN

Source of Sample: HEN-B029 **Depth:** 5.0'-7.0'
Sample Number: S-3

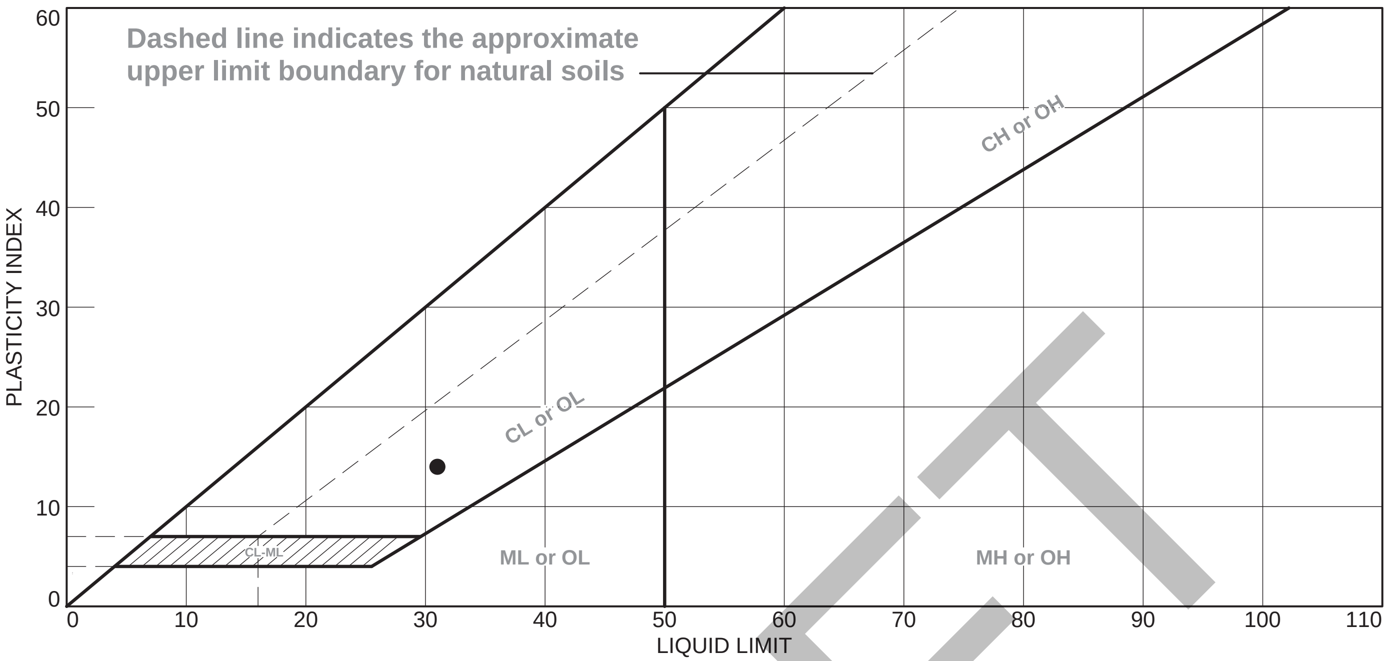
Terracon

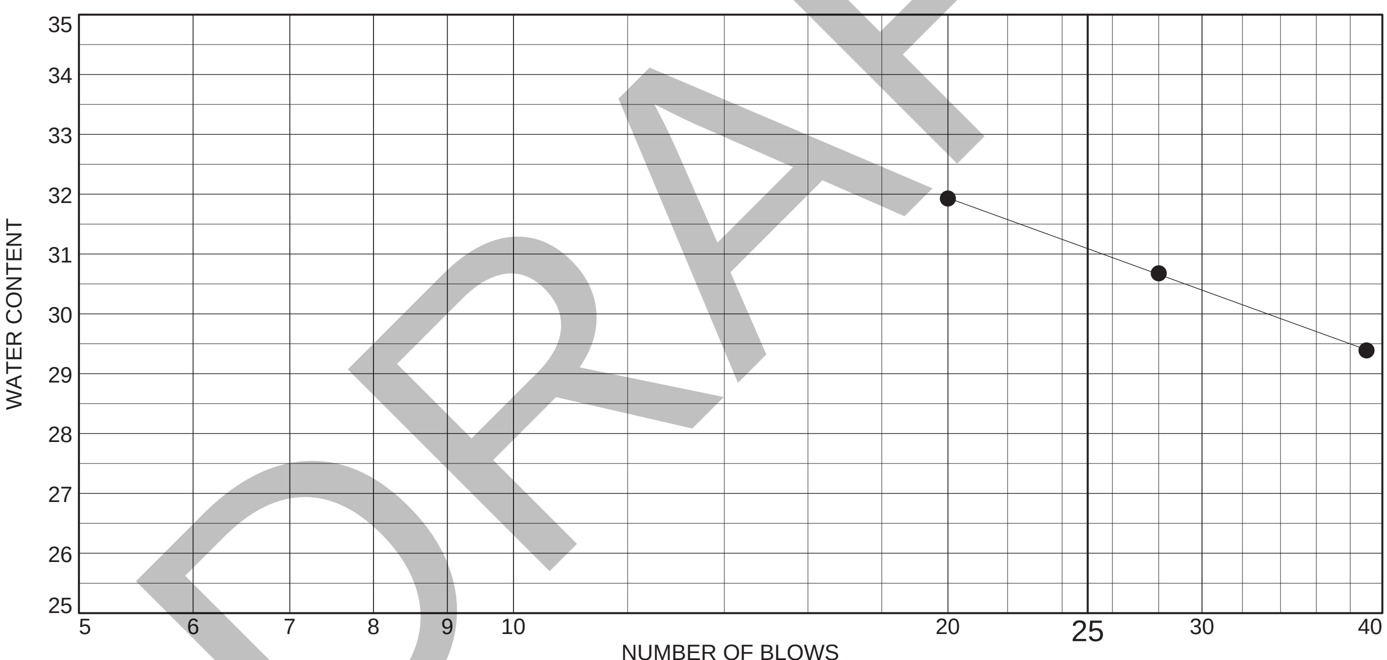
Remarks:

Figure

Tested By: BCM **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318





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	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	VERY DARK BROWN AND GRAY SLIGHTLY ORGANIC LEAN CLAY WITH SAND AND GRAVEL	31	17	14			CL

Project No. MR155233 **Client:** AECOM

Project: DYNEGY - HENNEPIN

Source of Sample: HEN-B029 **Depth:** 10.0'-12.0'
Sample Number: S-5

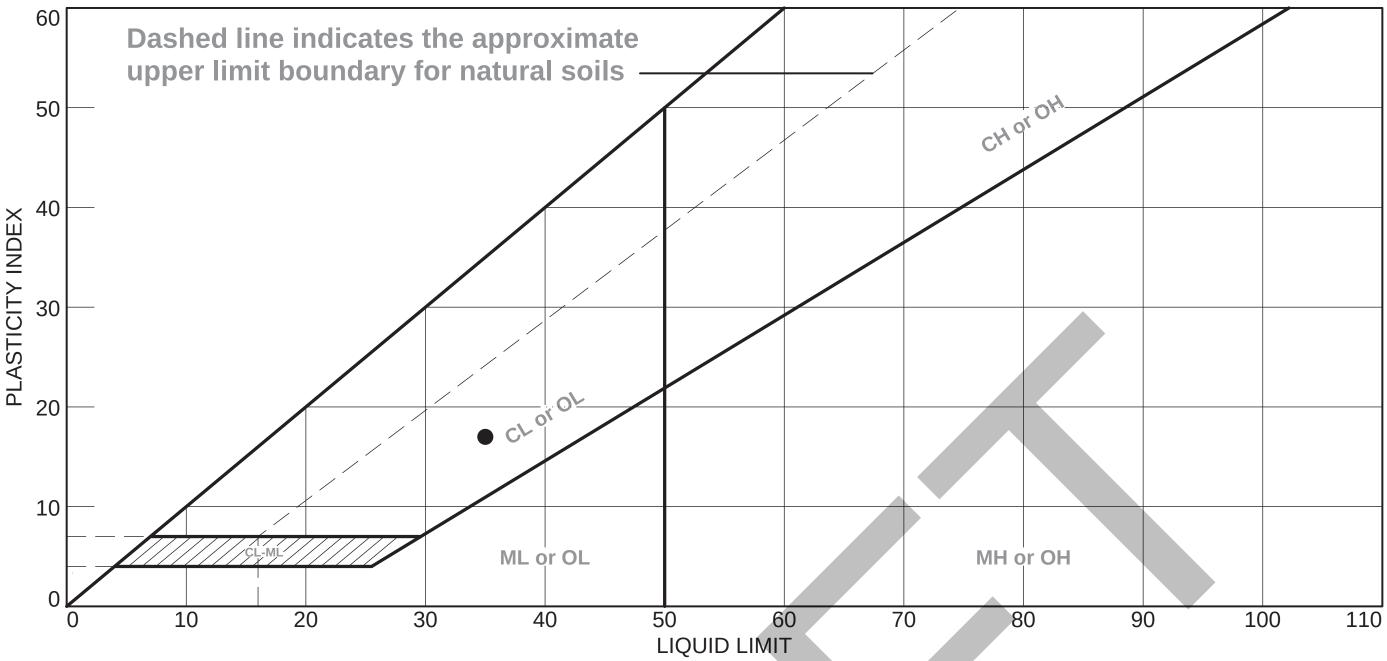
Terracon

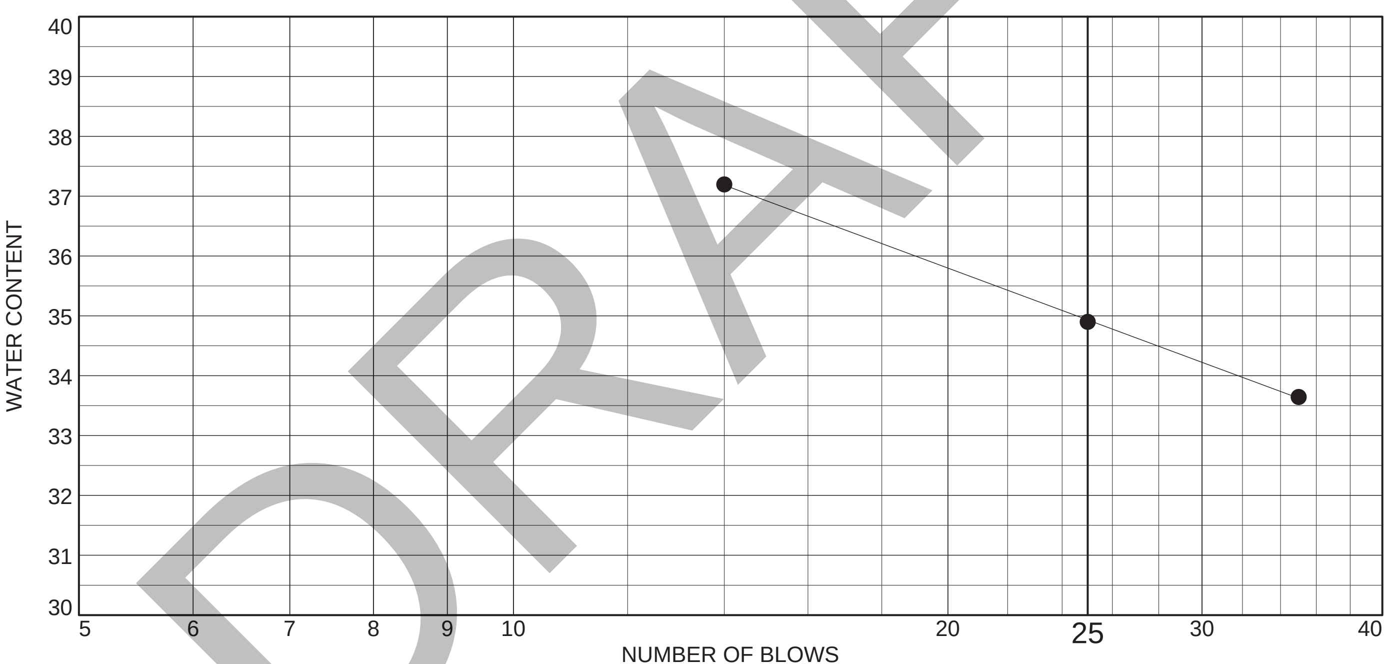
Remarks:

Figure

Tested By: BCM **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D4318





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	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	DARK BROWNISH GRAY LEAN CLAY WITH SAND AND GRAVEL	35	18	17			CL

Project No. MR155233 **Client:** AECOM

Project: DYNEGY - HENNEPIN

Source of Sample: HEN-B032 **Depth:** 5.0'-7.0'
Sample Number: S-3

Remarks:

Figure

Tested By: HP **Checked By:** WPQ

Specific Gravity of Soils
ASTM D 854

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Terracon
Consulting Engineers & Scientists

SPECIFIC GRAVITY OF SOIL SOLIDS
ASTM D-854

Project Number: MR155233
Project Name: Dynegy Hennepin
Test Date: 12/11/2015

Results Summary

Boring / Sample	Sample Description	USCS	Sample Number	Depth (ft)	Passing #4	Specific Gravity (Gs)
HEN-B030	FILL: BROWN AND GRAY LEAN CLAY WITH SILT, SAND AND GRAVEL	CL	S-3	5.0'-6.5'	100.00%	2.746
HEN-B034	DARK BROWN LEAN CLAY WITH SILT AND SAND	CL	S-2	2.5'-4.0'	100.00%	2.704
HEN-B034	BROWN AND LIGHT BROWN GRAVEL WITH CLAY AND SAND	GP-GC	S-6	15.0'-16.5'	100.00%	2.808

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Attachment F. Material Characterization Calculations

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1. Objective

This calculation package summarizes the material characteristics of the subsurface strata encountered during AECOM's geotechnical investigation of the Hennepin East Ash Pond at Dynegy's Hennepin Power Station in Hennepin, Illinois. Selection of material properties for slope stability analyses are also developed and summarized within this package.

2. Subsurface Conditions

A subsurface exploration was performed at the Hennepin East Ash Pond between September 1 and October 21, 2015. The subsurface exploration included the following; four soil borings, installation of two piezometers to monitor phreatic conditions, and a program of four cone penetrometer test (CPT) soundings. Pore pressure dissipation testing and seismic shear wave velocity measurements were conducted on a selection of the CPT soundings. A full set of AECOM's boring logs, including soil descriptions, types of sampling, and choice laboratory test results, is provided in Attachment B of the report. A complete report that includes the graphical CPT logs and the results of the SCPTu and PPD tests is included in Attachment D of the report. The geotechnical exploration locations are shown on Figure 2-1 – Hennepin East Ash Pond Geotechnical Site Plan in Attachment A of the report.

Based on the results of the investigation, five main stratigraphic materials were identified at the site. These are listed below and briefly summarized:

Road Fill: A gravel road surrounds the perimeter of the Hennepin East Ash Pond. The material is generally comprised of gravel with varying amounts of sand, silt, and clay. The relative density of the road fill measured by the standard penetration test was very dense.

Table F-1: Road Fill Material Summary

Category	Min.	Max.	Representative Average
First Encountered (ft bgs)	<0.5	<0.5	<0.5
Thickness (feet)	0.5	7.5	1.3
SPT-N	32	62	51
Pocket Penetrometer (tsf)	1.25	4.5	2.8
Cone Resistance (tsf)	20.0	654.6	334.7
Sleeve Resistance (tsf)	0.03	4.9	1.7
Cone/Sleeve Ratio (%)	0.01	1.6	0.5
SCPTu Shear Wave Velocity (ft/sec)	N/A	N/A	N/A

Embankment Fill: The perimeter embankment / dike of the Hennepin East Ash Pond was constructed in two stages, with an original embankment, and a later raise constructed on top of the existing dike. This raise was completed in the early 2000s, raising the dike crest from an original elevation around 483 ft to the current elevation ranging from 494 to 500 ft. As indicated by the CPT logs, the new dike section was backfilled primarily with clay, although some zones of silty sand and gravel were also encountered. The consistency of the fill, as measured by the standard penetration test and pocket penetrometer tests, ranged from stiff to hard. Per construction drawings, the backfill material was to be compacted to 95 percent (minimum) ASTM D698. Historical compaction data for the fill material was not available, but field data are generally indicative of well-compacted materials.

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Table F-2: Embankment Fill Material Summary

Category	Min.	Max.	Representative Average
First Encountered (ft bgs)	0.5	10	4.7
Thickness (feet)	4.5	10	6.9
SPT-N	11	50	28
Pocket Penetrometer (tsf)	0.5	4.5	3.2
Cone Resistance (tsf)	16.1	891.5	63.5
Sleeve Resistance (tsf)	0	4.9	1.5
Cone/Sleeve Ratio (%)	0	8.7	3.2
SCPTu Shear Wave Velocity (ft/sec)	860	861	861

Alluvial Foundation: Gravel materials with varying amounts of silt and clay were encountered in the borings drilled around the perimeter of the Hennepin East Ash Pond. The relative density of the alluvial foundation as measured by the standard penetration test ranged from medium dense to very dense.

Table F-3: Alluvial Foundation Material Summary

Category	Min.	Max.	Representative Average
First Encountered (ft bgs)	6	20	14
Thickness (feet)	5	36	16.8
SPT-N	17	120	55.5
Pocket Penetrometer (tsf)	1.5	1.5	1.5
Cone Resistance (tsf)	16.7	720.3	233.6
Sleeve Resistance (tsf)	0	9.7	3.4
Cone/Sleeve Ratio (%)	0	5.7	1.8
SCPTu Shear Wave Velocity (ft/sec)	1080	2038	1451

Fly Ash (Impounded CCR Materials): AECOM did not want to compromise the existing liner system within the Hennepin East Ash Pond, so borings and CPTs were not performed within the footprint of the impoundment. CPT's were obtained in the adjacent unlined impoundment, Hennepin East Ash Pond No. 2. CCR material properties for the Hennepin East Ash Pond are estimated based on materials encountered in the Hennepin East Ash Pond No. 2. The material was generally silt to sand size with some gravel and clay.

Liner System: Per record drawings, the Hennepin East Ash Pond has a 4 ft compacted clay liner on the bottom and side slopes of the pond. Underlying the clay liner is a 6 in thick sand filter layer on the bottom of the pond and 12 in thick sand layer on the side slopes of the pond. The bottom of the sand layer was constructed at an approximate elevation of 456 ft sloping up at a 4:1 on the sides of the pond to an elevation of approximate 483. In the early 2000's, the perimeter dike was raised from an elevation of 483 ft to current grades ranging from 494 to approximately 500 ft at 3:1 slopes. The liner system from top to bottom was comprised of a 45 mil thick reinforced polypropylene geomembrane, a 12-inch thick clay layer, and a 8 oz/sy polypropylene geotextile. In some areas, 2 layers of geomembrane were used. CPT's and borings were not performed within the lined area and construction documentation data was not available, therefore material properties for the liner system were estimated based on AECOM's experience.

Bedrock: Bedrock was not encountered in the soil borings. It is estimated that bedrock is greater than 100 ft below ground surface based on borings completed within the vicinity.

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Other Materials: Other materials were encountered in relatively small quantities at the site, appearing at only two exploration locations, and were not considered part of the site-wide stratigraphy. These materials include ash fill material within the road embankment at boring HEN-B030 and a 6 in dense sand layer encountered in boring HEN-B034. The ash fill material was modeled in the slope stability analyses as an embankment fill layer based on CPT readings in HEN-C030. The sand layer was modeled with the gravel layer in the slope stability analysis.

3. Laboratory Testing Program

Representative samples were collected at regular intervals from the borings and were utilized for laboratory testing. The laboratory tests were assigned to characterize the site materials including index (moisture content, unit weight, Atterberg limits, specific gravity, and particle size analysis), permeability and consolidation tests. Strength testing included isotropically consolidated-undrained triaxial tests with pore pressure measurements (CIU), Unconfined Compression (UC) tests, and direct shear tests (DS) on the native clay materials, embankment materials, and ash materials.

Table F-4: Laboratory Testing Program for East Ash Pond

ASTM Designation	Test Type	Number of Tests				
		Total	Road Fill	Embankment Fill	Alluvial Foundation	Other Material
D2216	Moisture Content	45	5	16	22	2
D4318	Atterberg Limits	3	-	3	-	-
T311[1], D1140, D422	Gradation / Hydrometer	6	1	-	5	-
D854	Specific Gravity	3	-	2	1	-
D5084	Hydraulic Conductivity	0	-	-	-	-
D2435	Consolidation	1	-	1	-	-
D 2166	Unconfined Compression	1	-	1	-	-
D4767	Consolidated Undrained Triaxial (CIU)	1	-	1	-	-
D6528	Direct Shear (DS)	1	-	1	-	-

[1] American Association of State Highway and Transportation Officials (AASHTO) test designation

Compete results of the laboratory tests are included in Attachment E of the report.

4. Material Properties

Material properties for slope stability analyses were developed using both laboratory testing data (index and strength testing) and strength correlations from SPT and CPT data.

The following specific material properties were developed for the road fill, embankment fill, alluvial foundation, fly ash, and liner system for use in the various stability analyses performed as part of this study:

- Unit Weight
- Drained and Undrained Shear Strength of Fine-Grained Soil Strata
- Drained and Undrained Shear Strength of Ash

Material properties for the liner system were conservatively estimated based on empirical correlations and experience with similar materials.

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Unit Weight

Unit weight for the road fill, embankment fill, and alluvial foundation materials were evaluated using measured results from samples collected. Values were plotted and design unit weight lines were then fit to the plotted data, and layers were divided where warranted by differences in the data. Plots of these measured values are included as Attachments F.1 through F.3 at the end of this document.

For materials that could not be directly measured for unit weight (fly ash and the liner system materials), estimates of the unit weight were based on empirical correlations and experience with similar materials.

Refer to table F-5 for total unit weights used in the stability analyses.

Drained Shear Strength Selection

Drained shear strengths were selected for all materials for use in the Long Term and Max Pool analyses. Drained strengths were primarily based on results from DS and CIU testing. Plots of both effective friction angle and effective cohesion values were created for each material type to estimate average values across each material. To supplement the effective friction angle measured in laboratory testing, correlated values of phi' were calculated using the procedure developed by Peck, Hanson, and Thornburn, 1974, based on corrected SPT blow counts. Measured laboratory values were given precedence when selecting design values. For materials that could not be directly measured for drained shear strength (fly ash and the liner systerm materials), the above correlation was used for effective friction angles. Effective cohesion values for these materials were conservatively estimated based on experience with similar materials. Design strength lines were then fit to the plotted data, and layers were divided where warranted by differences in the data. Plots of the measured and correlated drained shear strength values for the materials are included as Attachments F.1 through F.3.

Undrained Shear Strength Selection

Undrained shear strengths were selected for the cohesive materials for use in the analysis. Undrained strengths were based on results from CIU and UC testing, and correlated values of undrained shear strength from the CPT tests. Plots of undrained shear strength were created for each material type to estimate average values across each material. To supplement the undrained shear strengths measured in laboratory testing, correlated values were calculated using the procedure developed by Aas, et al (1986), based on CPT data. An NKT factor of 18 was selected for use in this correlation based on published values. Su / σ'vo lines were also calculated and plotted for comparison purposes. Design strength lines were then fit to the plotted data, and layers were divided where warranted by differences in the data. Plots of the measured and correlated undrained shear strength values for the materials are included as Attachments F.1 through F.3.

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5. Material Properties for Analysis

The table below summarizes the material parameters used in the stability analysis, based on the analysis and strength selection procedures and considerations presented in the preceding sections.

Table F-5: Summary of Material Parameters used in Stability Analysis

Material	Total Unit Weight (pcf)	Effective (drained) Shear Strength Parameters		Total (undrained) Shear Strength Parameters	
		c' (psf)	**Φ'** (°)	c (psf)	**Φ** (°)
Road Fill	130	0	38	0	38
Embankment Fill	105	30	32	2500	0
Alluvial Foundation	135	0	38	0	38
Fly Ash	105	100	27	600	0
Liner System	120	60	30	2500	0

6. References

Aas, G., Lacasse, S., Lunne, I., and Hoeg, K. (1986). "Use of In situ Tests for Foundation Design in Clay," Proceedings, In Situ 86, American Society of Civil Engineers, pp. 30.

Peck, R.B., Hanson, W.E. and Thornburn, T.H., 1974. Foundation Engineering, 2nd edition, John Wiley and Sons, Inc.

Idriss, I. M., and Boulanger, R. W. (2008). Soil Liquefaction During Earthquakes. Earthquake Engineering Research Institute, Oakland, California, USA.

7. Attachments

F.1 Material Characterization Plot – Road Fill
F.2 Material Characterization Plot – Embankment Fill
F.3 Material Characterization Plot – Alluvial Foundation

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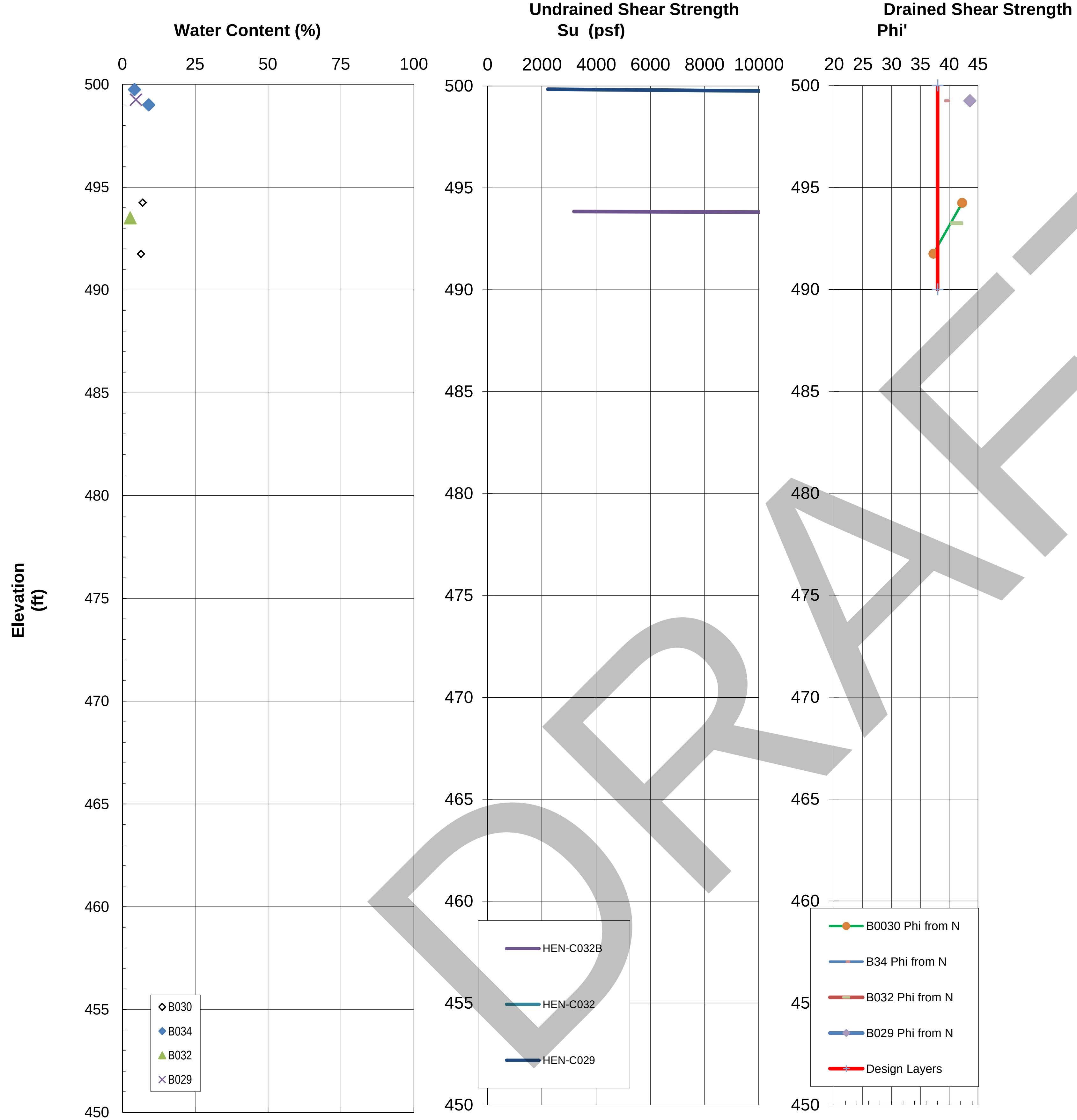

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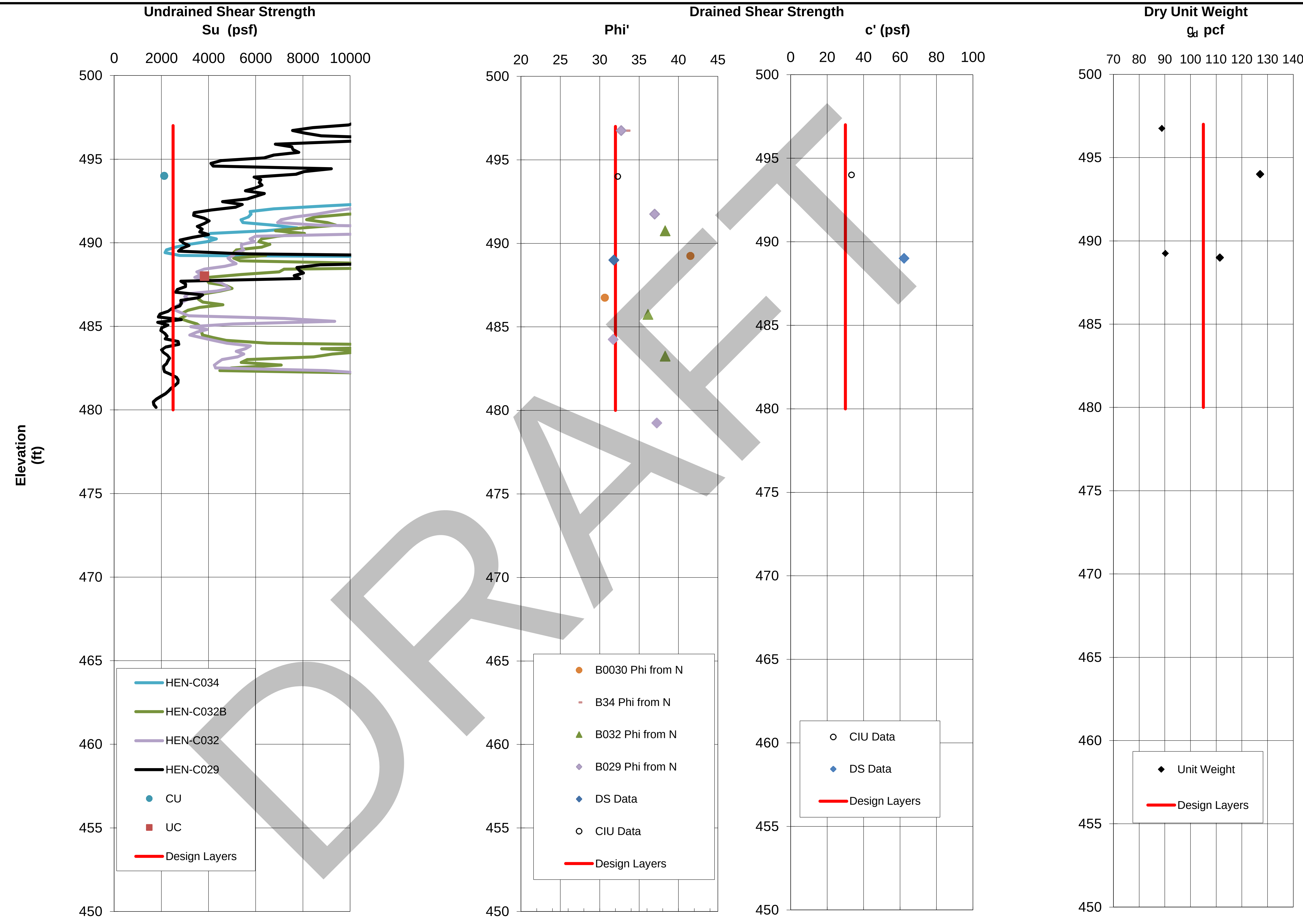
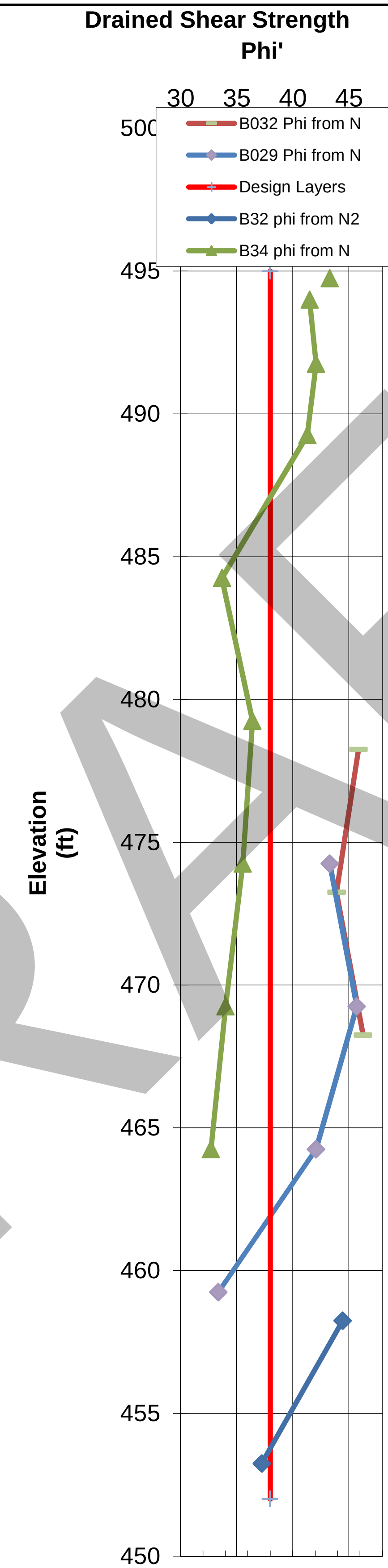
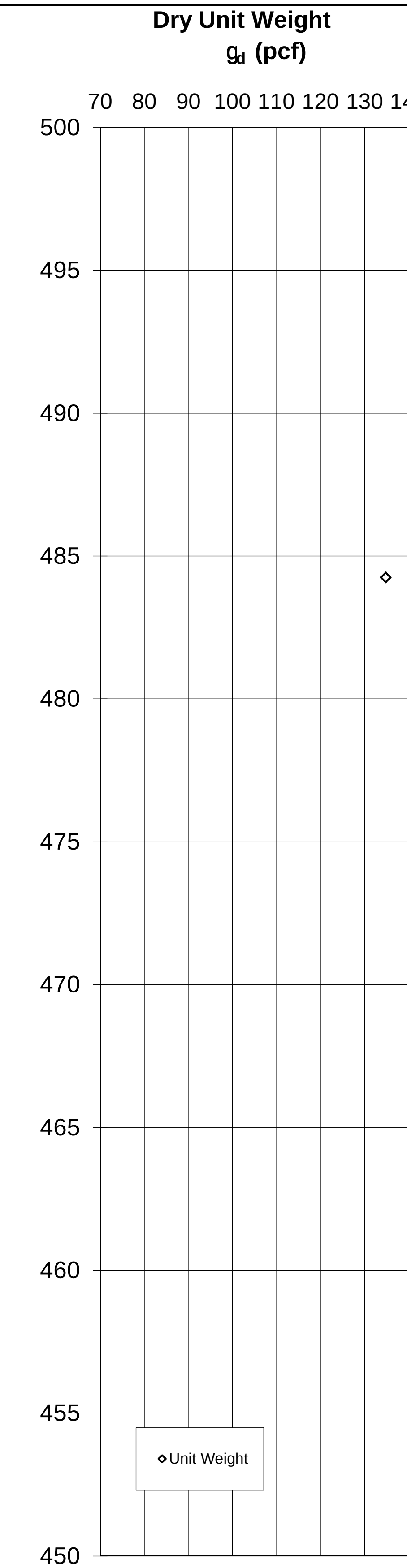
Dynegy Hennepin Hennepin, IL East Ash Pond	Project No. 60439752	Summary of Index and Engineering Properties - Road Fill	AECOM	DRN. BY: NDS DSGN. BY: AJW CHKD. BY: JMT	Attachment F.1



Dynegy Hennepin Hennepin, IL East Ash Pond	Project No. 60439752	Summary of Index and Engineering Properties - Embankment Fill	AECOM	DRN. BY: NDS DSGN. BY: AJW CHKD. BY: JMT	Attachment F.2





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Dynegy Hennepin Hennepin, IL East Ash Pond	Project No. 60439752	Summary of Index and Engineering Properties - Alluvial Foundation	AECOM	DRN. BY: NDS DSGN. BY: AJW CHKD. BY: JMT	Attachment F.3

Attachment G. Slope Stability Analysis

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1. Objective & Introduction

This calculation package summarizes the limit equilibrium slope stability analyses for both the static and seismic loading conditions performed in support of the Hennepin East Ash Pond CCR Unit Geotechnical Report for the Hennepin Power Station. Figures, calculations and computer program outputs are provided as attachments and are referenced herein. Slope stability analyses have been completed for two cross-sections within the Hennepin East Ash Pond to evaluate the stability of the embankment under the loading conditions described below.

The objective for the slope stability analysis is to determine factors of safety (FS) at critical cross section locations across the Hennepin East Ash Pond dike for the following loading cases:

- Static, Steady-State, Normal Pool Conditions;
- Static, Maximum Pool Surcharge Conditions;
- Seismic Slope Stability Analysis;

The methodology used to perform the slope stability analysis and the results of the analyses are summarized in the subsequent sections listed below.

2. Development of Cross-Sections for Analysis

Two cross-sections (SL-10 and SL-12) were utilized to evaluate the perimeter embankment stability at the Hennepin East Ash Pond. The north and south sides of the pond were not analyzed because the downstream side of the north embankment is filled with ash and the south side is not an embankment but is incised; therefore, neither the north nor south represent critical sections for slope stability analyses. A cross section on the east and west embankments, SL-12 and SL-10, respectively, were analyzed. The location of these sections can be found in **Attachment A, Figure 2**.

The section geometry for each analysis cross-section was determined based on the site specific aerial and bathymetric survey completed by Weaver Consultants Group in September 2015. The survey is spatially referenced to the Illinois NAD 1983 State Plane West, Zone 12020. Elevations are in feet and referenced with respect to the North American Vertical Datum 1988 (NAVD 88).

3. Subsurface Conditions

Subsurface materials and extents (stratigraphy) at each cross section were developed by utilizing nearby subsurface explorations (CPTs and borings) from AECOM's exploration activities and historic geotechnical explorations. The subsurface strata generally encountered across the exploration locations can be generalized into five typical layers. These layers are listed below and are further described in **Appendix F – Material Characterization**.

- Road Fill
- Embankment Fill
- Alluvial Foundation
- Fly Ash
- Liner System

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Material interfaces inferred from the subsurface explorations nearest to the cross-sections were transposed onto the profile and a reasonable interpretation of the subsurface stratigraphy between the exploration locations was developed. Table G-1 below summarizes the exploration locations utilized to construct each cross-section:

Table G-1
Cross-section Locations for Slope Stability Analyses

Cross-Section	Location (Crest/Toe)	Boring/CPT Number
SL-10	CREST	HEN-B029, HEN-C029
SL-12	CREST	HEN-B032, HEN-C032, HEN-C032B

Additionally, design drawings from "1995 Ash Facility Hennepin Power Station" by Illinois Power Company (1993) and "Modification to Primary Ash Pond Hennepin Power Station" by Sargent & Lundy (2003) were used to supplement the subsurface investigation in developing the subsurface embankment geometry.

Phreatic surfaces were modeled as a piezometric line in SLOPE/W. Elevations and configuration of the piezometric lines were established based on the phreatic water water levels recorded from the piezometers installed during the 2015 AECOM exploration ranging from approximately 449 to 452 and the normal pool elevation of 490.4 ft impounded in the Hennepin East Ash Pond, based on the 2016 AECOM Hydraulics and Hydrology report (AECOM, 2016).

4. <u>Analysis Methodology</u>

Analyses were performed using Spencer's Method which is a limit equilibrium slope stability analysis procedure. The computer program SLOPE/W 2012 by Geo-Slope International was utilized. The program analyzes a large number of potential slip surface geometries and identifies the geometry that results in a critical (i.e. lowest) factor of safety (FS). Additional information on the program is available at http://www.geo-slope.com/. Circular shaped failure surfaces, with optimization, were analyzed for the each of the loading cases considered. The optimization option within SLOPE/W allows the checking of non-circular failure surfaces by incrementally altering the location of the failure surface to find the lowest factor of safety. This procedure allows the failure surface to follow thin layers of lower strength, and interface boundaries to calculate a more critical factor of safety.

To account for the two piezometric lines in each cross section, the piezometric line within the Hennepin East Ash Pond was applied only to the fly ash and liner system. A second piezometric line was used to model phreatic water and was applied the alluvial foundation, embankment fill and road fill. This piezometric surface was modeled at elevation 450 ft and 452 ft for SL-12 and SL-10, respectively. At SL-12, the phreatic surface was assumed to rise to meet the typical pool elevation for the East Polishing Pond (482.2 ft).

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Each section was analyzed for the following cases:

• **Static, Steady-State, Normal Pool Condition:** This case models the conditions under static, long-term conditions, under the normal storage water level within the impoundment. Drained (effective stress) shear strength parameters were used for all materials, and phreatic conditions were estimated based on available data as described above. A target **Factor of Safety of 1.50** is needed for this loading condition. The operating water level of the Ash Pond is El. 490.4 ft for the Hennepin East Ash Pond..

• **Static, Maximum Surcharge Pool Condition:** This case models the conditions under short term surcharge pool conditions. Drained (effective stress) shear strength parameters were used for all materials, as the change in pool elevation is temporary and fairly small, and is unlikely to initiate total stress mechanisms of failure. Because the impoundment is lined, the phreatic surface does not extend past the embankment. Therefore, the phreatic surface in the foundation was modeled equivalent to the steady state case. A target **Factor of Safety of 1.40** is needed for this loading condition. The water level of the East Ash Pond was modeled at El. 492.2 ft for this case. This value is from the 2016 AECOM Hydraulics and Hydrology report generated for this project.

• **Seismic Stability Condition:** These analyses incorporate a horizontal seismic coefficient kh selected to be representative of expected loading during the design earthquake event (i.e., a "pseudostatic" analysis). The analyses utilized peak undrained strength parameters in soils that are not consider to be rapidly draining materials, and peak drained strengths in soils considered to freely drain. The phreatic surface and pore water pressures corresponding to the Steady State Normal Storage Pool case from the static analyses were utilized. Seismic loading was included in this analysis using a pseudostatic coefficient (kh). A **Factor of Safety of 1.00** is required for this loading condition.

Ground motion parameters for the pseudostatic analysis were estimated using the USGS Interactive Deaggregation tool (http:earthquake.usgs.gov/hazards/apps/). This application generates acceleration values, including peak ground acceleration (PGA), and mean and modal moment magnitudes, based on user entered values of location, exceedance probability, and spectral period. Results are computed based on the 2008 NSHMP PSHA Seismic Hazard Maps.

For the Hennepin Power Station, the calculated PGA for a 2,500-year event was 0.072g for top of hard rock. To determine the free-field, ground surface horizontal acceleration, the site was classified according to the site classes defined in IBC (2003) and amplified using the site amplification factors found in NEHRP (2009). The site class was determined based on the weighted average of the shear wave velocity of the foundation soils ($600 \leq vs \leq 1{,}200$ ft/s) and found to be Site Class D. This corresponds to a NEHRP amplification factor of 1.6, resulting in a ground surface acceleration of 0.119g. The Peak Transverse Acceleration at the dike crest was estimated using the ground surface acceleration and the procedure proposed by Idriss (2015), resulting in a crest acceleration of 0.35g.

The pseudostatic coefficient was calculated based on the simplified procedure developed by Makdisi and Seed (1978). Specifically, the pseudostatic coefficient was taken as the parameter kmax, which represents the peak average acceleration along the failure surface. As shown in Figure 1 below (excerpted from the above reference), the ratio kmax/umax (where umax is the peak acceleration at the crest of the embankment) for a full height failure surface (y/H = 1.0) is 0.34. From the procedure noted above, the anticipated maximum peak crest acceleration is approximately 0.35g. Therefore, the pseudostatic coefficient kh was estimated as kh= 0.34*0.35g = 0.119g for these analyses.

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The seismic hazard deaggregation output and calculations for the pseudostatic coefficient are provided at the back of this document.

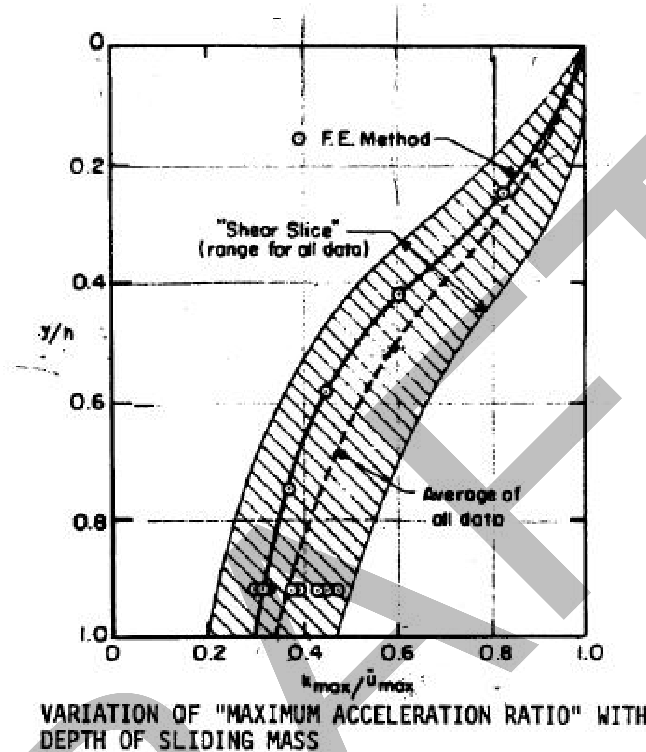

Figure 1: Determination of Maximum Average Acceleration Along Failure Surface

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5. Material Properties for Analysis

Material properties for slope stability analyses were developed using both laboratory testing data (index and strength testing) and strength correlations from CPT and SPT data. Details of the material characterization and strength parameter selection for each stratum are provided in **Attachment F** of this report. The properties used in the stability analysis are summarized in the table below:

Table G-2: Summary of Material Parameters used in Stability Analysis

Material	Unit Weight Above WT (pcf)	Effective (drained) Shear Strength Parameters		Total (undrained) Shear Strength Parameters	
		c' (psf)	Φ' (°)	c (psf)	Φ (°)
Road Fill	130	0	38	0	38
Embankment Fill	105	30	32	2500	0
Alluvial Foundation	135	0	38	0	38
Fly Ash	105	100	27	600	0
Liner System	120	60	30	2500	0

6. Results

Table G-3 summarizes the results of the stability analyses for each section, and output figures from the SLOPE/W models are provided at the back of this document.

Table G-3: Summary of Minimum Slope Stability Factors

Cross Section	Factor of Safety		
	Drained		Undrained
	Steady State (Normal Pool)	Surcharge Pool (Flood)	Seismic (Pseudostatic)
CCR Rule Criteria	*FS ≥ 1.50*	*FS ≥ 1.40*	*FS ≥ 1.00*
SL-10	2.14	2.14	4.23
SL-12	2.81	2.81	2.53

7. Conclusions

Load cases analyzed for this study included static (steady-state) normal pool, maximum flood surcharge pool and seismic (pseudostatic). The calculated factors of safety from the limit equilibrium slope stability analysis satisfy the USEPA CCR Rule § 257.73(e) requirements for all the load cases analyzed at the critical analysis sections for the perimeter of the impoundment.

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8. References

AECOM (2016). Hydrologic and Hydraulic Summary Report for Hennepin Power Station, Primary Ash Pond CCR Unit. (DRAFT)

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9. Attachments

G.1 Slope Stability Analysis Output Data
G.2 Seismic Parameter Calculations

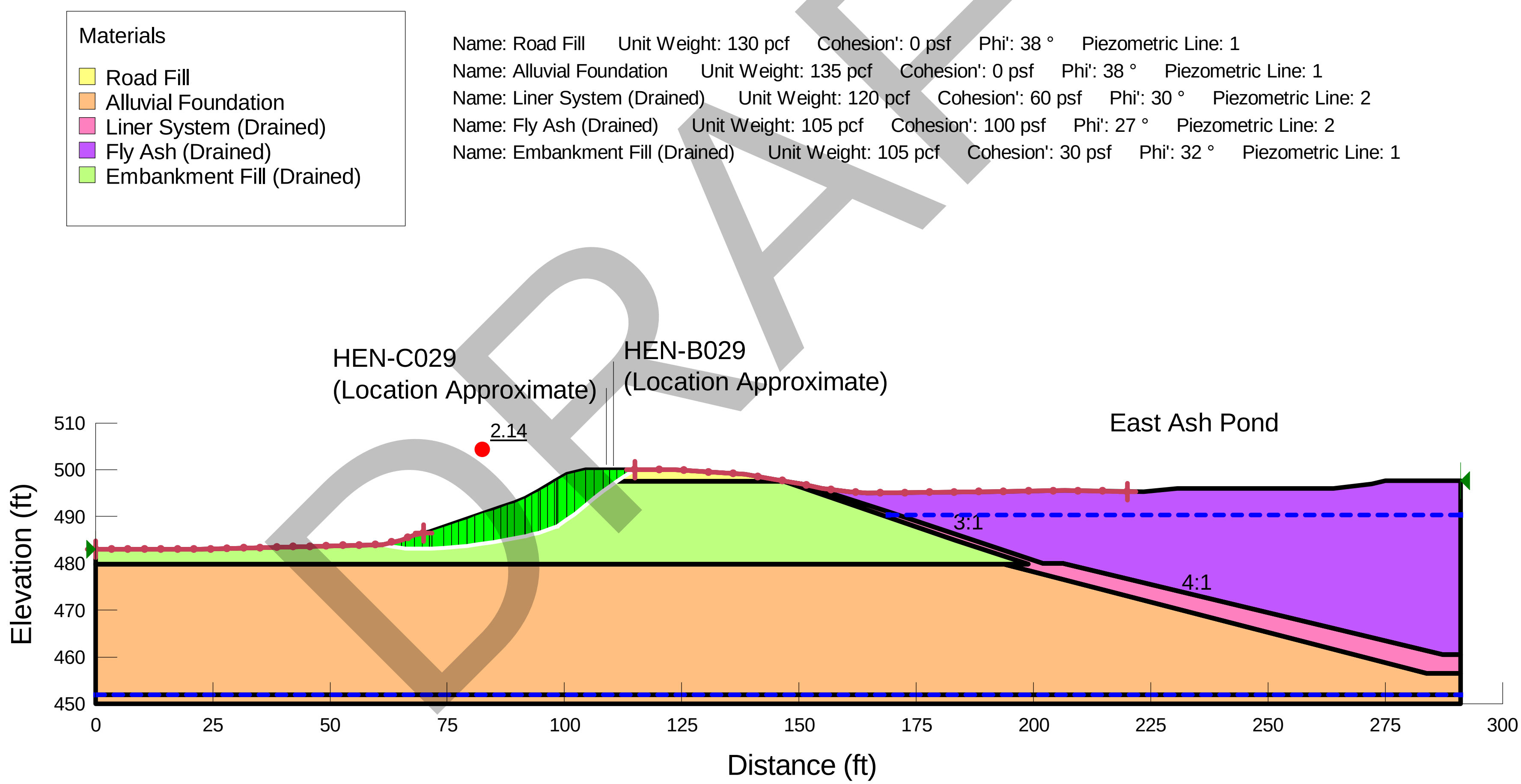
DRAFT

Attachment G.1 Slope Stability Analysis Output Data

DRAFT

Hennepin East Ash Pond
Cross Section SL-10
Effective (Drained)-Static Normal Pool

Calculated By: ZJF Date:9-21-2016
Checked By: LPC Date:9/22/16



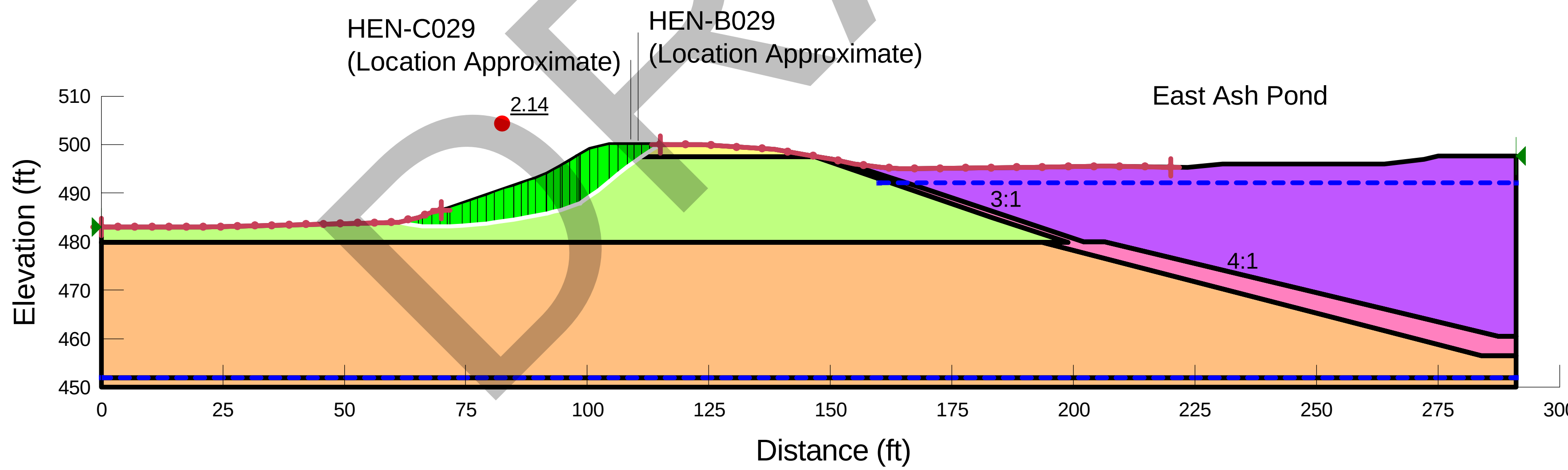
Hennepin East Ash Pond
Cross Section SL-10
Effective (Drained) - Static Max Pool

Calculated By: ZJF Date:9-21-2016
Checked By:LPC Date:9/22/16

Materials

- Road Fill
- Alluvial Foundation
- Liner System (Drained)
- Fly Ash (Drained)
- Embankment Fill (Drained)

Name	Unit Weight	Cohesion'	Phi'	Piezometric Line
Road Fill	130 pcf	0 psf	38 °	1
Alluvial Foundation	135 pcf	0 psf	38 °	1
Liner System (Drained)	120 pcf	60 psf	30 °	2
Fly Ash (Drained)	105 pcf	100 psf	27 °	2
Embankment Fill (Drained)	105 pcf	30 psf	32 °	1



DRAFT

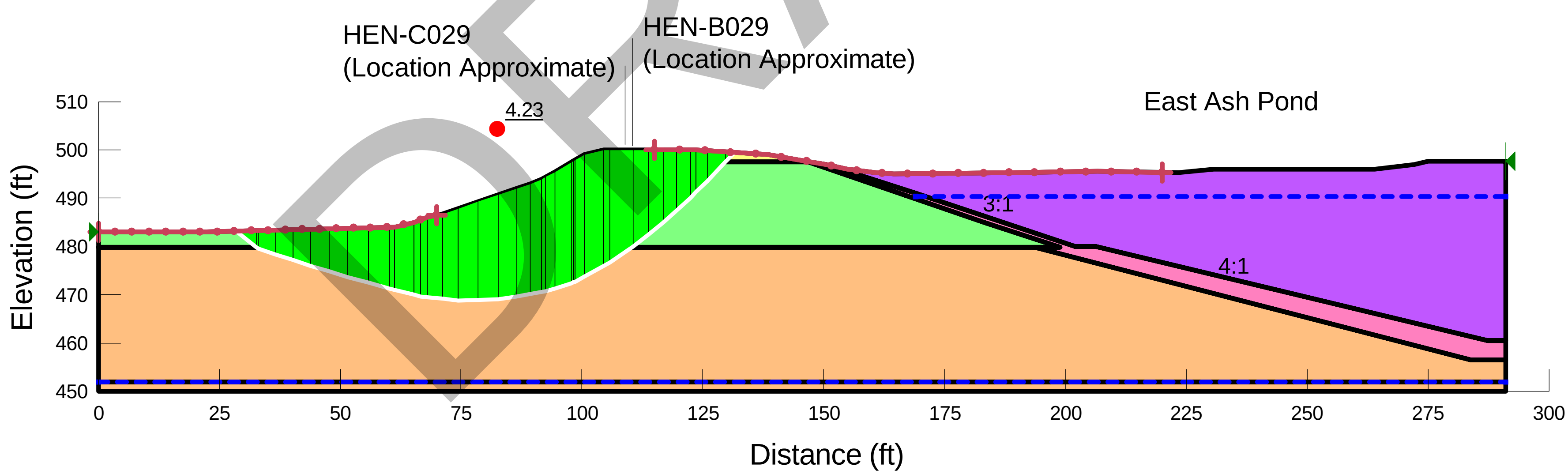
Hennepin East Ash Pond
Cross Section SL-10
Total (Undrained) - Pseudostatic

Calculated By: ZJF Date:9-21-2016
Checked By: LPC Date:9/22/16

Horz Seismic Coef.: 0.119

Materials
- Road Fill
- Alluvial Foundation
- Liner System (Undrained)
- Fly Ash (Undrained)
- Embankment Fill (Undrained)

Name: Road Fill Unit Weight: 130 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 1
Name: Alluvial Foundation Unit Weight: 135 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 1
Name: Liner System (Undrained) Unit Weight: 120 pcf Cohesion': 2,500 psf Phi': 0 ° Piezometric Line: 2
Name: Fly Ash (Undrained) Unit Weight: 105 pcf Cohesion': 600 psf Phi': 0 ° Piezometric Line: 2
Name: Embankment Fill (Undrained) Unit Weight: 105 pcf Cohesion': 2,500 psf Phi': 0 ° Piezometric Line: 1



DRAFT

East Ash Pond
Cross Section SL-12
Effective (Drained) - Static Normal Pool

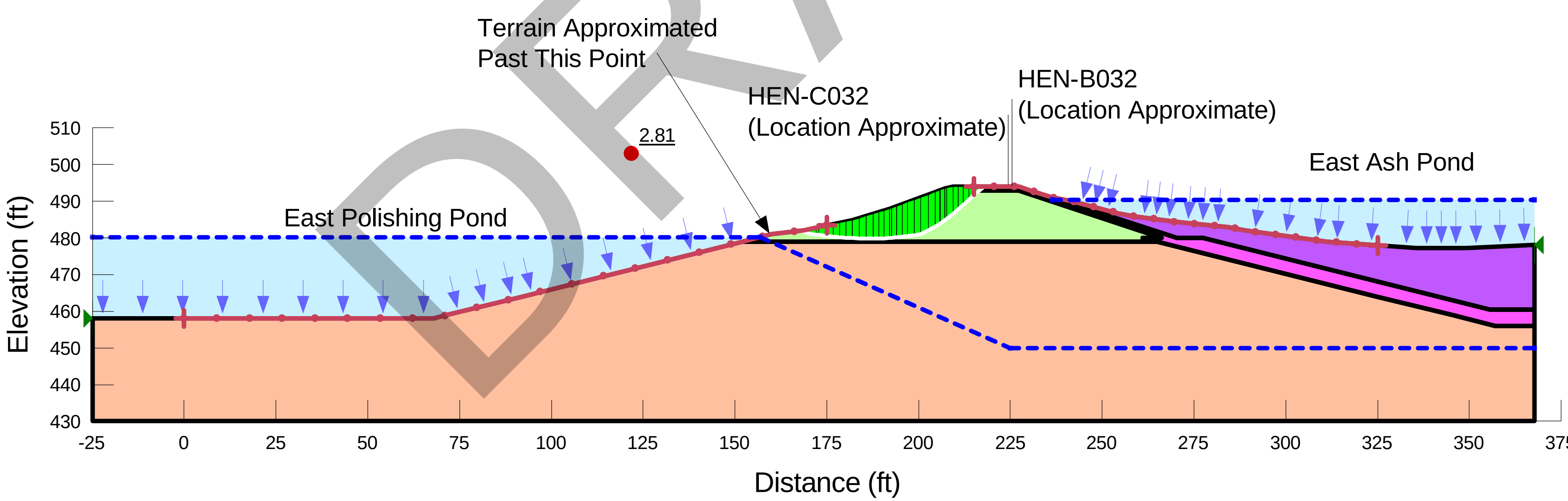
Calculated By: ZJF Date: 9/21/16
Checked By: LPC Date: 9/22/16

DRAFT

Materials

- Road Fill
- Alluvial Foundation
- Fly Ash (Drained)
- Liner System (Drained)
- Embankment Fill (Drained)

Name	Unit Weight	Cohesion'	Phi'	Piezometric Line
Road Fill	130 pcf	0 psf	38 °	2
Alluvial Foundation	135 pcf	0 psf	38 °	2
Fly Ash (Drained)	105 pcf	100 psf	27 °	1
Liner System (Drained)	120 pcf	60 psf	30 °	1
Embankment Fill (Drained)	105 pcf	30 psf	32 °	2

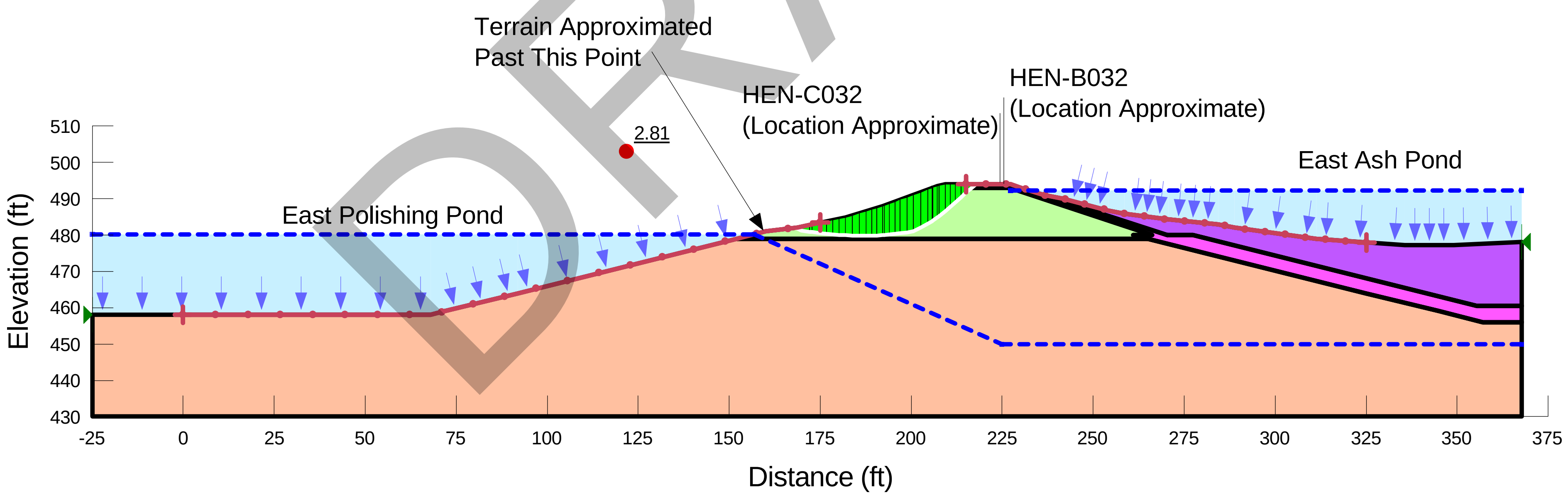


East Ash Pond
Cross Section SL-12
Effective (Drained) - Static Max Pool

Calculated By: ZJF Date: 9/21/16
Checked By: LPC Date: 9/22/16

Materials
- Road Fill
- Alluvial Foundation
- Fly Ash (Drained)
- Liner System (Drained)
- Embankment Fill (Drained)

Name: Road Fill Unit Weight: 130 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 2
Name: Alluvial Foundation Unit Weight: 135 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 2
Name: Fly Ash (Drained) Unit Weight: 105 pcf Cohesion': 100 psf Phi': 27 ° Piezometric Line: 1
Name: Liner System (Drained) Unit Weight: 120 pcf Cohesion': 60 psf Phi': 30 ° Piezometric Line: 1
Name: Embankment Fill (Drained) Unit Weight: 105 pcf Cohesion': 30 psf Phi': 32 ° Piezometric Line: 2



DRAFT

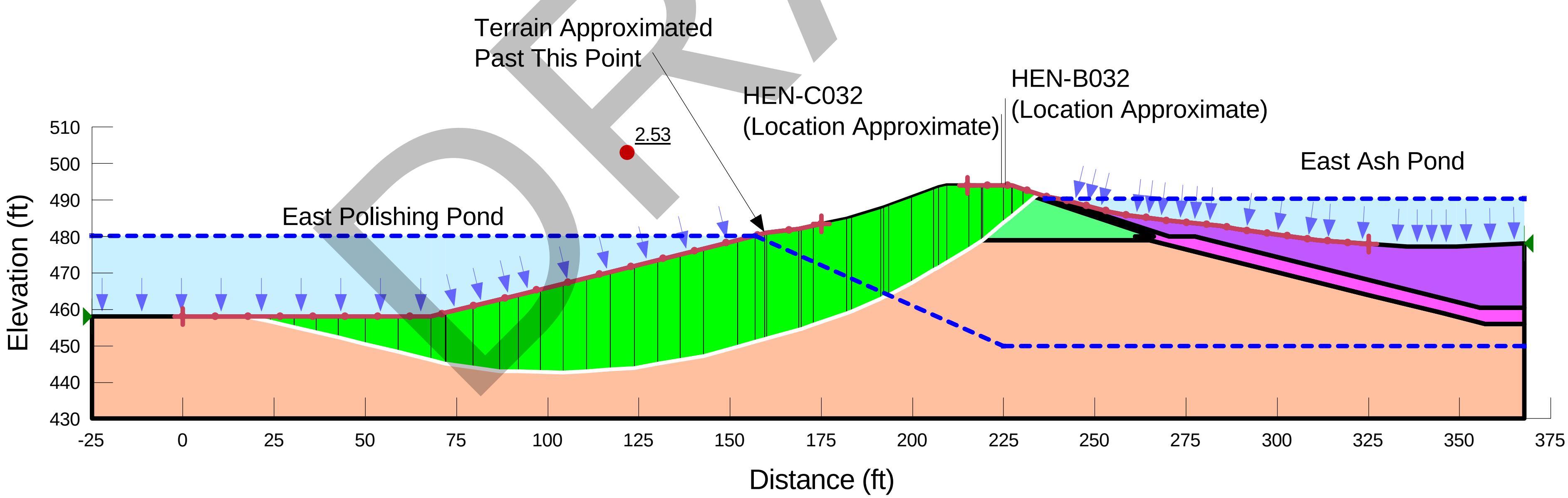
East Ash Pond
Cross Section SL-12
Total (Undrained) - Pseudostatic

Calculated By: ZJF Date: 9/21/16
Checked By: LPC Date: 9/22/16

Horz Seismic Coef.: 0.119

Materials
- Road Fill
- Alluvial Foundation
- Liner System (Undrained)
- Fly Ash (Undrained)
- Embankment Fill (Undrained)

Name: Road Fill Unit Weight: 130 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 2
Name: Alluvial Foundation Unit Weight: 135 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 2
Name: Liner System (Undrained) Unit Weight: 120 pcf Cohesion': 2,500 psf Phi': 0 ° Piezometric Line: 1
Name: Fly Ash (Undrained) Unit Weight: 105 pcf Cohesion': 600 psf Phi': 0 ° Piezometric Line: 1
Name: Embankment Fill (Undrained) Unit Weight: 105 pcf Cohesion': 2,500 psf Phi': 0 ° Piezometric Line: 2



DRAFT

Attachment G.2 Seismic Parameter Calculations

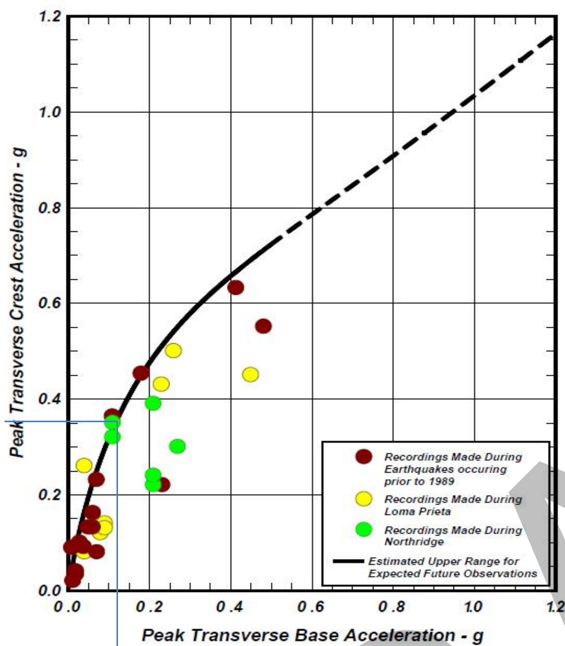
DRAFT

Calc By:	AJW
Date:	2/23/2016
Check By:	JMT
Date:	2/24/2016

Calculation of K_h for Pseudostatic Analysis

Objective: Estimate kh for pseudostatic analysis.

Given: Seismic Hazard Deaggregation with PGA_{BC} = 0.07298, M=5.9
Site Class D, based on IBC (2008)
FPGA = 1.6, based on NEHRP (2009)
Holzer (1998) Figure for estimation of crest acceleration
Makdisi Seed (1978) Figure for Max Acc of Slide Mass



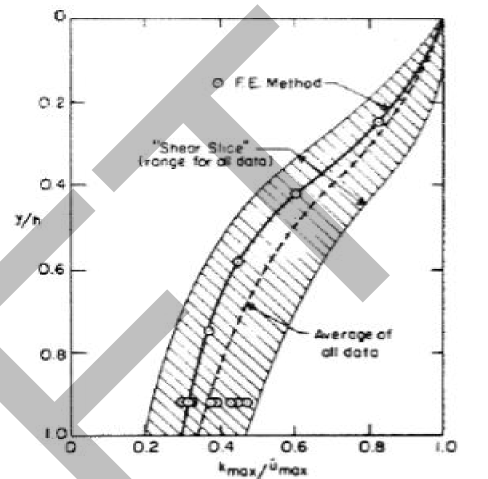


Figure 4. Variations of Maximum Acceleration Ratio with Depth of Sliding Mass (Makdisi and Seed, 1977). Maximum Acceleration Ratio is the Ratio between $(PGA)_{base\ of\ slide\ mass}$ and $(PGA)_{crest}$.

Figure 3. Variations of Recorded Peak Crest Accelerations versus those Recorded at the Base of Earth and Rock Fill Dams by Idriss (2015). Source of recorded values for Loma Prieta Earthquake and prior earthquakes: Holzer, (1998).

PGA_{BC}	Site class	F_{PGA}	PGA_{BASE}	PGA_{CREST}	Makdisi -Seed reduction for full height failure	k_h
0.07298	D	1.6	0.117	0.35	0.34	0.119

Results:

Use k_h = 0.119 for pseudostatic analyses.

DRAFT

DRAFT

APPENDIX B

Excerpts from 2021 Geosyntec Investigation

DRAFT

Legend

- Leachate Wells
- Staff Gauge
- Monitoring Wells
- CCR Unit Boundary

Notes

- Coal Combustion Residual (CCR) Unit boundary is approximate.
- Aerial imagery provided by Esri

N

0 200 Feet

Well Location and Staff Gauge Map

Hennepin Power Station
Hennepin, Illinois

Geosyntec consultants

St. Louis | March 2021

Figure 2

\\stlouismo-01\data\Company\Projects_post_2014\GLP8020_Vistra Hennepin East Part 845 Field Efforts\GIS\Hennepin East Ash Pond MW and Staff Gauge Locations.mxd 3/30/2021 2:38:18 PM

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Client: Dynegy
Project: GLP8020, Hennepin East Ash Pond
Address: 13498 E 800th, Hennepin, IL

BORING LOG

Boring No. MW52

Drilling Start Date:	**02/11/2021**	Boring Depth (ft):	**61**
Drilling End Date:	**02/11/2021**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Sampling Method(s):	**Direct Push**
Drilling Method:	**Sonic**	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	**Jason Green**	Ground Surface Elev. (ft):	**497.74**
Logged By:	**Will Blocher**	Location (Lat, Long):	**41.3024578, -89.3063692**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
0				DP	48/60			(0') GRAVELLY LEAN CLAY WITH SAND (CL); dense, somewhat cohesive, dark brown (10YR 4/3).		0
								(3.25') SANDY LEAN CLAY (CL); dark brown (10YR 4/3), medium consistency, medium plasticity, moist.		
								(3.75') Same as above: except darker (10YR 3/2).	4-8 Geotech Sample 1	
5				DP	42/60			(5') LEAN CLAY WITH SAND (CL); trace gravel, stiff, medium plasticity, very dark (10YR 2/1).		5
								(8.5') 1" Sandy interbed.		
10				DP	102/120			(10') Same as above: some gravel, lighter (10YR 3/2).		10
15								(15') SANDY SILT (ML); with some gravel, loose, dry, pale yellowish tan (10YR 6/2), color lightens downward to (10YR 7/2).		15
20										20

NOTES: Sample 1: 21.4% moisture content, 8080 mg/kg total organic carbon, 95.0 pcf dry unit weight, 2.675 specific gravity, 7.1×10^{-8} cm/s vertical hydraulic conductivity, 32 LL, 17 PL, 15 PI, 0.7% gravel, 21.0% sand, 78.3% fines.

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Client: Dynegy
Project: GLP8020, Hennepin East Ash Pond
Address: 13498 E 800th, Hennepin, IL

BORING LOG

Boring No. MW52

Drilling Start Date:	**02/11/2021**	Boring Depth (ft):	**61**
Drilling End Date:	**02/11/2021**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Sampling Method(s):	**Direct Push**
Drilling Method:	**Sonic**	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	**Jason Green**	Ground Surface Elev. (ft):	**497.74**
Logged By:	**Will Blocher**	Location (Lat, Long):	**41.3024578, -89.3063692**

DEPTH (ft)	Sample Type	Recovery (in)	SOIL/ROCK VISUAL DESCRIPTION
20	DP	66/120	
24.5			(24.5') LEAN CLAY WITH SAND (CL); moist, medium consistency, medium plasticity, dark (10YR 2/2).
25			(25') SILTY SAND WITH GRAVEL (SM); loose, dry, dull red (10YR 4/4).
27.5			(27.5') WELL-GRADED SAND WITH SILT AND GRAVEL (SM); loose, dry, grayish tan (10YR 6/3).
30	DP	96/120	
32			(32') LEAN CLAY WITH SAND AND GRAVEL (CL); stiff, medium plasticity, dark brown (10YR 5/2).
33			(33') SANDY SILT WITH GRAVEL (ML); loose, dry, light dull red (10YR 5/4).
38.5			(38.5') <1" clay interbed.
39.5			Begin drilling with water.
40			

Column headings: DEPTH (ft) | LITHOLOGY | WATER LEVEL | BORING COMPLETION | COLLECT: Sample Type, Recovery (in), Blow Counts, N Value RQD (%) | SOIL/ROCK VISUAL DESCRIPTION | MEASURE: Lab Sample | DEPTH (ft)

NOTES:

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Client: Dynegy
Project: GLP8020, Hennepin East Ash Pond
Address: 13498 E 800th, Hennepin, IL

BORING LOG
Boring No. MW52

Drilling Start Date:	**02/11/2021**	Boring Depth (ft):	**61**
Drilling End Date:	**02/11/2021**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Sampling Method(s):	**Direct Push**
Drilling Method:	**Sonic**	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	**Jason Green**	Ground Surface Elev. (ft):	**497.74**
Logged By:	**Will Blocher**	Location (Lat, Long):	**41.3024578, -89.3063692**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
40				DP	96/ 120			(40') WELL-GRADED SILTY GRAVEL WITH SAND (GM); pebble to cobble, loose, moist, light dull red (10YR 5/4).		40
45										45
								(48.5-49.5') Lighter colored interval (10YR 7/3).	49-50 Geotech (not tested)	
50				DP	24/ 132	5 5 4 5				50
55										55
								(59') WELL-GRADED GRAVEL (GW); wet, fines likely removed in drilling.		
60										60

NOTES:

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Client:	Dynegy
Project:	GLP8020, Hennepin East Ash Pond
Address:	13498 E 800th, Hennepin, IL

BORING LOG

Boring No. MW52

Drilling Start Date:	**02/11/2021**	Boring Depth (ft):	**61**
Drilling End Date:	**02/11/2021**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Sampling Method(s):	**Direct Push**
Drilling Method:	**Sonic**	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	**Jason Green**	Ground Surface Elev. (ft):	**497.74**
Logged By:	**Will Blocher**	Location (Lat, Long):	**41.3024578, -89.3063692**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
60										60
								(61') End of Boring.		
65										65

NOTES:

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Geosyntec consultants — engineers | scientists | innovators	Client: Dynegy Project: GLP8020, Hennepin East Ash Pond Address: 13498 E 800th, Hennepin, IL	**BORING LOG** **Boring No. MW54** **Page: 1 of 4**

Drilling Start Date:	**02/08/2021**	Boring Depth (ft):	**75**
Drilling End Date:	**02/09/2021**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Sampling Method(s):	**Direct Push**
Drilling Method:	**Sonic**	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	**Jason Green**	Ground Surface Elev. (ft):	**497.14**
Logged By:	**SWB**	Location (Lat, Long):	**41.3034315, -89.3052197**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
0				DP	60/60			(0') SANDY LEAN CLAY (CL); little gravel, stiff, dark brown (10YR 3/2), low plasticity, non-cohesive, moist.		0
5				DP	60/60			(5') SILTY SAND WITH GRAVEL (SM); medium dense, reddish brown (5Y 4/6), moist, non-plastic, non-cohesive.		5
								(7.9') SANDY LEAN CLAY (CL); trace gravel, stiff, mottled reddish brown (5Y 4/6), gray (2.5Y 4/1).		
10				SH	20/24	6 4 5 5		(10') FAT CLAY WITH SAND (CH); trace gravel, medium dark brown (5Y 3/1), moist, high plasticity.	10-12 Geotech (not tested) & Chem	10
				DP	60/96			(12') As above: few gravel (large).		
15										15
								(17') As above: gradational color change to darker brown (10YR 2/1).		
20										20

NOTES:

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Client:	Dynegy
Project:	GLP8020, Hennepin East Ash Pond
Address:	13498 E 800th, Hennepin, IL

BORING LOG
Boring No. **MW54**

Drilling Start Date:	**02/08/2021**	Boring Depth (ft):	**75**
Drilling End Date:	**02/09/2021**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Sampling Method(s):	**Direct Push**
Drilling Method:	**Sonic**	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	**Jason Green**	Ground Surface Elev. (ft):	**497.14**
Logged By:	**SWB**	Location (Lat, Long):	**41.3034315, -89.3052197**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
20				DP	90/ 120			(20') As above: trace gravel.		20
25								(24.5') SILTY SAND WITH GRAVEL (SM); very loose, pale yellow tan (10YR 6/3), dry, non-cohesive. (25.5') As above: color change to white (10YR 7/1). (25.8') As above: color change to yellow (10YR 6/4), color is mottled, few to some gravel.		25
30				DP	91/ 120			(30') No Recovery.		30
								(32.5') FAT CLAY WITH SAND (CH); medium stiff, very dark brown (10YR 3/1), trace gravel, cohesive, moist, medium plasticity. (possible slough)		
35								(35') WELL-GRADED SILTY SAND (SM); few gravel, non-cohesive, very loose, light tan (10YR 7/2), dry.		35
								(37.6') GRAVELLY FAT CLAY WITH SAND (CH); medium stiff, dark brown (10YR 3/2), dry to moist, medium plasticity.		
								(38.6') SILTY SAND WITH GRAVEL (SM); loose, tan (10YR 6/3), dry.		
40										40

NOTES:

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Client:	Dynegy	**BORING LOG**
Project:	GLP8020, Hennepin East Ash Pond	Boring No. MW54
Address:	13498 E 800th, Hennepin, IL	Page: 3 of 4

Drilling Start Date:	02/08/2021	Boring Depth (ft):	75
Drilling End Date:	02/09/2021	Boring Diameter (in):	6
Drilling Company:	Cascade Drilling	Sampling Method(s):	Direct Push
Drilling Method:	Sonic	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	Jason Green	Ground Surface Elev. (ft):	497.14
Logged By:	SWB	Location (Lat, Long):	41.3034315, -89.3052197

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
40				DP	108/ 120			(40') No Recovery.		40
								(41') LEAN CLAY WITH GRAVEL (CL); medium stiff, dark gray (10YR 3/1), dry to moist, medium plasticity, cohesive. (possible slough)		
45								(42.25') SILTY GRAVEL WITH SAND (GM); loose, dark yellowish tan (10YR 5/3), dry. (48') As above: wet. (49.3') As above: dry, with siltstone (compacted silt).		45
50				SH	12/24	10 8 9 9		(50') As above: wet, no silt rock.		50
				DP	78/ 120			(52') No Recovery.		
55								(53.5') CLAYEY GRAVEL WITH SAND (GC); medium dense, yellowish brown (10YR 4/3), moist, cohesive, clay matrix.	53.5-54.5 Chem 54.5-56 Geotech (not tested)	55
60								(57') WELL-GRADED GRAVEL WITH CLAY AND SAND (GW-GC); gradational contact (1ft), increased sand and decreased clay content, still moist to dry, no color change.		60

NOTES:

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Client: Dynegy		**BORING LOG**
Project: GLP8020, Hennepin East Ash Pond		**Boring No.** MW54
Address: 13498 E 800th, Hennepin, IL		

Drilling Start Date:	**02/08/2021**	Boring Depth (ft):	**75**
Drilling End Date:	**02/09/2021**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Sampling Method(s):	**Direct Push**
Drilling Method:	**Sonic**	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	**Jason Green**	Ground Surface Elev. (ft):	**497.14**
Logged By:	**SWB**	Location (Lat, Long):	**41.3034315, -89.3052197**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
60				DP	108/ 120			(61') WELL-GRADED GRAVEL WITH SAND AND CLAY (GW-GC); loose, pale yellowish brown (10Y 5/4), wet.		60
65										65
70										70
75								(75') End of Boring.		75
80										80

NOTES:

DRAFT

Client:	**Dynegy**
Project:	**GLP8020, Hennepin East Ash Pond**
Address:	**13498 E 800th, Hennepin, IL**

BORING LOG

Boring No. **MW55**

Drilling Start Date:	**02/10/2021**	Boring Depth (ft):	**100**
Drilling End Date:	**02/10/2021**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Sampling Method(s):	**Direct Push**
Drilling Method:	**Sonic**	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	**Jason Green**	Ground Surface Elev. (ft):	**495.65**
Logged By:	**Will Blocher**	Location (Lat, Long):	**41.303651, -89.3043529**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
0				DP	60/60			(0') CLAYEY SAND WITH GRAVEL (SC); yellowish brown (10YR 4/4), medium dense, clay matrix, cohesive, medium plasticity, moist.		0
5				DP	78/ 120			(5') SANDY LEAN CLAY WITH GRAVEL (CL); yellowish brown (10YR 4/4), medium consistency, medium plasticity, cohesive, moist.		5
8									8-10 Chem	
10								(10') As above: darker color (10YR 2/2).		10
15				DP	56/60	17 11 7 4			15-17.5 ST Sample 1	15
18.3								(18.3') Thin (<1") interval of grayish green silt.		
19								(19') WELL-GRADED GRAVEL WITH CLAY AND SAND (GW); yellowish tan (10YR 4/2), dry, loose, non-cohesive.		
20										20

NOTES: Sample 1: 14.4% moisture content, 9800 mg/kg total organic carbon, 109.0 pcf dry unit weight, 2.720 specific gravity, 1.5×10^{-7} cm/s vertical hydraulic conductivity, 32 LL, 19 PL, 13 PI, 12.4% gravel, 39.6% sand, 48.0% fines.

DRAFT

Geosyntec consultants (engineers | scientists | innovators)	Client: Dynegy Project: GLP8020, Hennepin East Ash Pond Address: 13498 E 800th, Hennepin, IL	**BORING LOG** **Boring No. MW55**

Drilling Start Date:	**02/10/2021**	Boring Depth (ft):	**100**
Drilling End Date:	**02/10/2021**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Sampling Method(s):	**Direct Push**
Drilling Method:	**Sonic**	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	**Jason Green**	Ground Surface Elev. (ft):	**495.65**
Logged By:	**Will Blocher**	Location (Lat, Long):	**41.303651, -89.3043529**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
20				DP	94/ 120					20
24.5								(24.5') As above: with more clay, red (2.5YR 3/6).		
25										25
25.5								(25.5') As above: less clay, yellowish tan (10YR 4/2).		
28.75								(28.75') As above: little clay, pale yellow (5YR 10/2).		
30				DP	100/ 120			(30') SANDY LEAN CLAY WITH GRAVEL (CL); moist, dark yellowish brown (10YR 2/2), medium consistency, medium plasticity.		30
32.5								(32.5') WELL-GRADED GRAVEL WITH CLAY AND SAND (GW); reddish yellowish brown (7.5YR 3/3), dry, loose, non-cohesive.		
35										35
37								(37') LEAN CLAY WITH SAND AND GRAVEL (CL); clay-rich interval, low plasticity, stiff.		
40										40

NOTES:

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Client: Dynegy
Project: GLP8020, Hennepin East Ash Pond
Address: 13498 E 800th, Hennepin, IL

BORING LOG

Boring No. MW55

Drilling Start Date:	**02/10/2021**	Boring Depth (ft):	**100**
Drilling End Date:	**02/10/2021**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Sampling Method(s):	**Direct Push**
Drilling Method:	**Sonic**	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	**Jason Green**	Ground Surface Elev. (ft):	**495.65**
Logged By:	**Will Blocher**	Location (Lat, Long):	**41.303651, -89.3043529**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
40				DP	96/120			(40') WELL-GRADED GRAVEL WITH CLAY AND SAND (GW); reddish yellowish brown (7.5YR 3/3), dry, loose, non-cohesive. Short, clay-rich interval at top of recovered core.		40
45										45
50				DP	102/120	2 8 5 8			50-52 ST Sample 2	50
51								(51') LEAN CLAY WITH SAND AND GRAVEL (CL); dark yellowish brown (10YR 3/2), dry, medium plasticity, stiff.		
52.5								(52.5') WELL-GRADED GRAVEL WITH SAND (GW); yellowish brown (10YR 4/3), dry, loose, non-cohesive.		
55										55
57								(57') Gradually wetter beginning at 57 ft.		
59								(59') Wet.		
60										60

NOTES: Sample 2: 8.2% moisture content, 50,000 mg/kg total organic carbon, 2.823 specific gravity, 21 LL, 15 PL, 6 PI, 60.0% gravel, 23.2% sand, 16.8% fines.

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BORING LOG

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Client: Dynegy
Project: GLP8020, Hennepin East Ash Pond
Address: 13498 E 800th, Hennepin, IL

Boring No. MW55

Drilling Start Date:	**02/10/2021**	Boring Depth (ft):	**100**
Drilling End Date:	**02/10/2021**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Sampling Method(s):	**Direct Push**
Drilling Method:	**Sonic**	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	**Jason Green**	Ground Surface Elev. (ft):	**495.65**
Logged By:	**Will Blocher**	Location (Lat, Long):	**41.303651, -89.3043529**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
60				DP	100/ 120					60
								(61') No clay at top of core.		
65								(65') Interval consistently wet.		65
								(68.5') Thin interval dark clay (10YR 2/2).		
								(69') Trace pebble sized gravel.		
70				DP	100/ 120					70
								(71') No clay.		
								(73') Gravel fines downward in last 1' to pebble size, poorly graded.		
								(73.5') POORLY GRADED SAND (SP); trace pebbles, dark yellowish brown (10YR 3/4), very clean, dense, wet.		
75										75
								(77.5') Quartz & feldspar black grains, sharp upper contact.		
								(78') As above: with more pebbles, darker (10Y 4/4).		
80										80

NOTES:

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Client: Dynegy		**BORING LOG**
Project: GLP8020, Hennepin East Ash Pond		Boring No. MW55
Address: 13498 E 800th, Hennepin, IL		

Drilling Start Date:	**02/10/2021**	Boring Depth (ft):	**100**
Drilling End Date:	**02/10/2021**	Boring Diameter (in):	**6**
Drilling Company:	**Cascade Drilling**	Sampling Method(s):	**Direct Push**
Drilling Method:	**Sonic**	DTW During Drilling (ft):	
Drilling Equipment:		DTW After Drilling (ft):	
Driller:	**Jason Green**	Ground Surface Elev. (ft):	**495.65**
Logged By:	**Will Blocher**	Location (Lat, Long):	**41.303651, -89.3043529**

DEPTH (ft)	LITHOLOGY	WATER LEVEL	BORING COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
80				DP	96/ 108			(80') As above.		80
								(83.25') PEBBLY CLAY (CL); trace pebbles.		
								(84') POORLY GRADED SAND WITH CLAY AND GRAVEL (SP); medium dense, non-cohesive, moist.		
85									85-89 Chem	85
								(85.5') SILTY SHALE; grayish green (GLEY1 10Y 5/2), cohesive rock chips, reacts weakly with 5% acetic acid.		
				DP	84/ 132					
90										90
95										95
100								(100') End of Boring.		100

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NOTES:

WELL LOG

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Client: Dynegy
Project: GLP8020, Hennepin East Ash Pond
Address: 13498 E 800th, Hennepin, IL

Well No. XPW01

Drilling Start Date:	**01/14/2021**	Boring Depth (ft):	**17**	Well Depth (ft):	
Drilling End Date:	**01/14/2021**	Boring Diameter (in):	**10**	Well Diameter (in):	
Drilling Company:	**Geotechnology**	DTW During Drilling (ft):		Screen Slot (in):	
Drilling Method:	**Hollow Stem Auger**	DTW After Drilling (ft):		Riser Material:	
Drilling Equipment:	**CME 55**	Top of Casing Elev. (ft)		Screen Material:	
Driller:		Ground Elev. (ft):	**498.19**	Seal Material(s):	
Logged By:	**D. Mateas**	Location (Lat/Long):	**41.30259, -89.30584**	Filter Pack:	

DEPTH (ft)	Sample Type	Recovery (in)	Blow Counts	N Value RQD (%)	Lab Sample
0	SS	15/24	4, 6, 5, 4	11	
2	SS	21/24	2, 4, 4, 5	8	
4	SS	15/24	2, 2, 2, 1	4	
6	SS	20/24	2, 2, 0, 1	2	
8	SS	24/24	0, 1, 2, 4	3	8-10 Chem
10	SH	16/24			10-12 Geotech Sample 1
12	SH	24/24			12-14 ST Sample 2
14	SS	5/12	0, 2		14-15 Chem
15	SH	24/24			15-17 ST Sample 3

SOIL/ROCK VISUAL DESCRIPTION

(0.0') WELL-GRADED SAND (SW); light brown (2.5Y 5/4), fine to medium grained, some slag and coal fragments, 2-inch piece of slag at surface, medium dense, dry, brick fragments at 0.3 to 0.4 ft. [BOT ASH]

(2.0') SILT (ML); dark gray (10YR 4/1), non-plastic, trace fine grained sand, medium stiff, moist. [FLY ASH]

(2.5') As above: light gray (7.5YR 7/1), trace slag and coal fragments.

(3.3') WELL-GRADED SAND (SW); light brown (2.5Y 5/4), fine to medium grained, some slag and coal fragments, 2-inch piece of slag at surface, medium dense, dry, brick fragments at 0.3 to 0.4 ft. [BOT ASH]

(4.0') As above.

(4.5') SILT (ML); gray (2.5Y 5/1), non-plastic, trace fine grained sand, soft, moist. [FLY ASH]

(6.0') WELL-GRADED SAND (SW); olive brown (2.5Y 4/4), fine to medium grained, little slag and coal fragments, very loose, moist. [BOTTOM ASH]

(6.75') SILT (ML); brownish gray (2.5Y 6/2), non-plastic, little medium grained sand, soft, wet. [FLY ASH]

(8.0') As above.

(10') As above. Failed Shelby Tube from 10-12' bgs.

(12') WELL-GRADED SAND (SW); light olive brown (2.5Y 3/3), fine to medium grained, some slag and coal fragments, loose, wet.

(17') End of Boring.

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NOTES: Split Fly ash and bottom ash from 0 to 17 ft bgs. Split spoon sampler advanced to 17 ft bgs. Augers advanced to 17.25 ft bgs.
Sample 1: 157.0% moisture content, 2.635 specific gravity, 4.0% gravel, 22.2% sand, 73.8% fines.
Sample 2: 42.3% moisture content, 71.0 pcf dry unit weight, 2.859 specific gravity, 14.1% gravel, 71.8% sand, 14.1% fines.
Sample 3: 31.0% moisture content, 79.0 pcf dry unit weight, 2.622 specific gravity, 10.1% gravel, 83.1% sand, 6.8% fines.

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Client: Dynegy
Project: GLP8020, Hennepin East Ash Pond
Address: 13498 E 800th, Hennepin, IL

WELL LOG

Well No. XPW02

Drilling Start Date:	**01/15/2021**	Boring Depth (ft):	**18.5**	Well Depth (ft):	
Drilling End Date:	**01/15/2021**	Boring Diameter (in):	**10**	Well Diameter (in):	
Drilling Company:	**Geotechnology**	DTW During Drilling (ft):		Screen Slot (in):	
Drilling Method:	**Hollow Stem Auger**	DTW After Drilling (ft):		Riser Material:	
Drilling Equipment:	**CME 55**	Top of Casing Elev. (ft)		Screen Material:	
Driller:		Ground Elev. (ft):	**501.60**	Seal Material(s):	
Logged By:	**D. Mateas**	Location (Lat/Long):	**41.30186, -89.30372**	Filter Pack:	

COLLECT

DEPTH (ft)	Sample Type	Recovery (in)	Blow Counts	N Value RQD (%)	MEASURE: Lab Sample
0–2	SS	24/24	3, 9, 10, 11	19	
2–4	SS	7/24	1, 2, 1, 2	3	
4–6	SS	13/24	2, 5, 34, 50/2	39	
6–8	SS	18/24	5, 5, 3, 4	3	6-8 Chem
8–10	SS	17/24	2, 3, 3, 2	6	
10–12	SS	22/24	2, 2, 1, 1	3	
12–14	SH	24/24			
14–16	SH	26/26			14-16 ST
16–18	SH	24/24			16-18 Geotech
18–18.5	SH	6/6			

SOIL/ROCK VISUAL DESCRIPTION

(0.0') SILT (ML); light yellowish brown (2.5Y 6/3), non-plastic, cohesive, few medium to coarse grained sand, few fine gravel, few clay, very stiff, wet. [FLY ASH]

(2.0') WELL-GRADED GRAVEL (GW); light yellowish brown (2.5Y 6/3), fine to coarse grained, little sand, trace silt, very loose, wet. [BOTTOM ASH]

(2.3') FAT CLAY (CH); black (2.5Y 2.5/1), medium plasticity, soft, wet. [FILL]

(4') As above.

(4.3') WELL-GRADED GRAVEL (GW); light yellowish brown (2.5Y 6/3), fine to coarse grained, little sand, trace silt, very loose, wet. [BOTTOM ASH]

(4.9') As above: gray (2.5Y 5/1)

(6.0') WELL-GRADED SAND (SW); light gray (5Y 4/1), fine to coarse grained sand, fine gravel, few silt, trace slag, loose, wet. [BOTTOM ASH]

(8') As above.

(10') As above: olive gray (5Y 5/2), very loose.

(11') SILT (ML); light gray (5Y 4/1), non-plastic, trace fine grained sand, soft, saturated. [FLY ASH]

(12') As above: no sand. Failed Shelby Tube from 12-14' bgs.

(13') Grades to partially lithified structures.

(14') As above.

(16') As above. Failed Shelby Tube from 16-18' bgs.

(18') As above.

(18.5') End of Boring.

NOTES: Fly ash, bottom ash and fill material from 0 to 18.5 ft bgs. Split spoon sampler advanced to 18.5 ft bgs. Augers advanced to 18.6 ft bgs. Sample 1: 123.3% moisture content, 36.0 pcf dry unit weight, 2.615 specific gravity, 2.9×10^{-4} cm/s vertical hydraulic conductivity, NP, 0.0% gravel, 20.8% sand, 79.2% fines. Sample 2: 113.2% moisture content, 2.622 specific gravity, NP, 0.5% gravel, 22.1% sand, 77.4% fines.

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Client: Dynegy
Project: GLP8020, Hennepin East Ash Pond
Address: 13498 E 800th, Hennepin, IL

WELL LOG

Well No. XPW03

Drilling Start Date:	**01/14/2021**	Boring Depth (ft): **20**	Well Depth (ft):
Drilling End Date:	**01/14/2021**	Boring Diameter (in): **10**	Well Diameter (in):
Drilling Company:	**Geotechnology**	DTW During Drilling (ft):	Screen Slot (in):
Drilling Method:	**Hollow Stem Auger**	DTW After Drilling (ft):	Riser Material:
Drilling Equipment:	**CME 55**	Top of Casing Elev. (ft)	Screen Material:
Driller:		Ground Elev. (ft): **492.03**	Seal Material(s):
Logged By:	**D. Mateas**	Location (Lat/Long): **41.30326, -89.30378**	Filter Pack:

DEPTH (ft)	LITHOLOGY	WATER LEVEL	WELL COMPLETION	COLLECT: Sample Type	COLLECT: Recovery (in)	COLLECT: Blow Counts	COLLECT: N Value RQD (%)	SOIL/ROCK VISUAL DESCRIPTION	MEASURE: Lab Sample	DEPTH (ft)
0				SS	13/24	2, 2, 2, 1	4	(0.0') SILT (ML); gray (10YR 5/1), non-plastic, stiff, moist. [FLY ASH] (0.4') WELL-GRADED SAND (SW); dark yellowish brown (10YR 4/4), fine to medium grained sand, little slag and coal fragments, very loose, moist. [BOTTOM ASH]		
				SS	19/24	1, 0, 3, 2	3	(0.9') As above: saturated, few silt. (2.0') As above: moist, no silt, fine to coarse grained sand. (2.6') SILT (ML); pale yellow (2.5Y 7/3), non-plastic, very soft, saturated.		
				SS	22/24	0, 0, 0, 1	0	(4.0') As above.	4-6 Chem	
5										
				SH	24/24			(6.0') As above. Failed Shelby Tube from 6-8' bgs.		
				SS	24/24	1, 0, 1, 0	1	(8.0') As above.		
10				SS	24/24	0, 0, 0, 1	0	(10.75-11.75') As above: light brownish gray (2.5Y 6/2)		
				SH	23/24			(12') As above. Failed Shelby Tube from 12-14' bgs.		
				SH	18/24			(14') As above.	14-16 ST Sample 1	
15										
				SS	24/24	0, 0, 0, 0	0	(17.25-17.75') As above: grayish brown (2.5Y 5/2)	16-18 Chem	
				SH	11/24			(17.75-18') As above: light olive brown (2.5Y 5/3)	18-20 ST Sample 2	
20								(20') End of Boring.		

NOTES: Fly ash from 0 to 20 ft bgs. Split spoon sampler advanced to 20 ft bgs. Augers advanced to 19.43 ft bgs. Sample 1: 177.0% moisture content, 28.0 pcf dry unit weight, 2.595 specific gravity, 1.7×10^{-4} cm/s vertical hydraulic conductivity, NP, 0.0% gravel, 13.7% sand, 86.3% fines. Sample 2: 138.8% moisture content, 34.0 pcf dry unit weight, 2.585 specific gravity, 2.0×10^{-4} cm/s vertical hydraulic conductivity, NP, 0.0% gravel, 18.6% sand, 81.4% fines.

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GEOTECHNOLOGY INC
FROM THE GROUND UP

Via email: akreinberg@geosyntec.com

March 29, 2021

Ms. Allison Kreinberg
Geosyntec Consultants, Inc.
941 Chatham Lane Suite 103
Columbus, Ohio 43221

Re: Laboratory Testing Services
Vistra Energy
Hennepin, Illinois
Geotechnology Project No. J037936.01

Dear Ms. Kreinberg:

Provided herein are the laboratory test results for the referenced project. Our services were performed in accordance with ASTM procedures.

This report has been prepared for the exclusive use of Geosyntec Consultants, Inc. Our scope of services was limited to performing specific tests on the provided samples and did not include engineering or interpretation of the test results.

Our services shall not be construed to constitute an expressed or implied warranty, including, but not limited to, any warranty for merchantability or fitness for a particular use. We do not accept responsibility for the manner in which the test results are used.

It has been our pleasure to provide laboratory testing services to you, and we would welcome the opportunity to provide other services during the course of the project. Please contact us if you need further information or clarification about this document.

DRAFT

* * * * *

Yours very truly,
GEOTECHNOLOGY, INC.

Erin Grimes
Laboratory Manager

EKG/CKK:ekg

Attachments: Appendix A – Summary of Laboratory Results
Appendix B – Atterberg Limits Results
Appendix C – Grain Size Distribution
Appendix D – Test Report

Copies submitted: PDF

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APPENDIX A

Summary of Laboratory Results

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Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	Maximum Size (mm)	%<#200 Sieve	Class-ification	Moisture Content (%)	Dry Unit Weight (pcf)	Qu/2 (tsf)	Specific Gravity (20°C)
MW55	15.0	32	19	13	19	48.0	SC	14.4	109.0		2.720
SB52	4.0	32	17	15	9.5	78.3	CL	21.4	95.0		2.675
SB53	2.0	29	16	13	25	51.1	CL	13.7	120.0		2.680
SB53	56.0				37.5	8.3		9.9			
SB55	50.0	21	15	6	50	16.8	GC-GM	8.2			2.823
XPW01	10.0				19	73.8		157.0			2.635
XPW01	12.0				19	14.1		42.3	71.0		2.859
XPW01	15.0				9.5	6.8		31.0	79.0		2.622
XPW02	14.0	NP	NP	NP	0.84	79.2	ML	123.3	36.0		2.615
XPW02	16.0	NP	NP	NP	9.5	77.4	ML	113.2			2.622
XPW03	14.0	NP	NP	NP	2	86.3	ML	177.0	28.0		2.595
XPW03	18.0	NP	NP	NP	2	81.4	ML	138.8	34.0		2.585

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Summary of Laboratory Results

Vistra Energy
Hennepin, Illinois
J037936.01

APPENDIX B

Atterberg Limits Results

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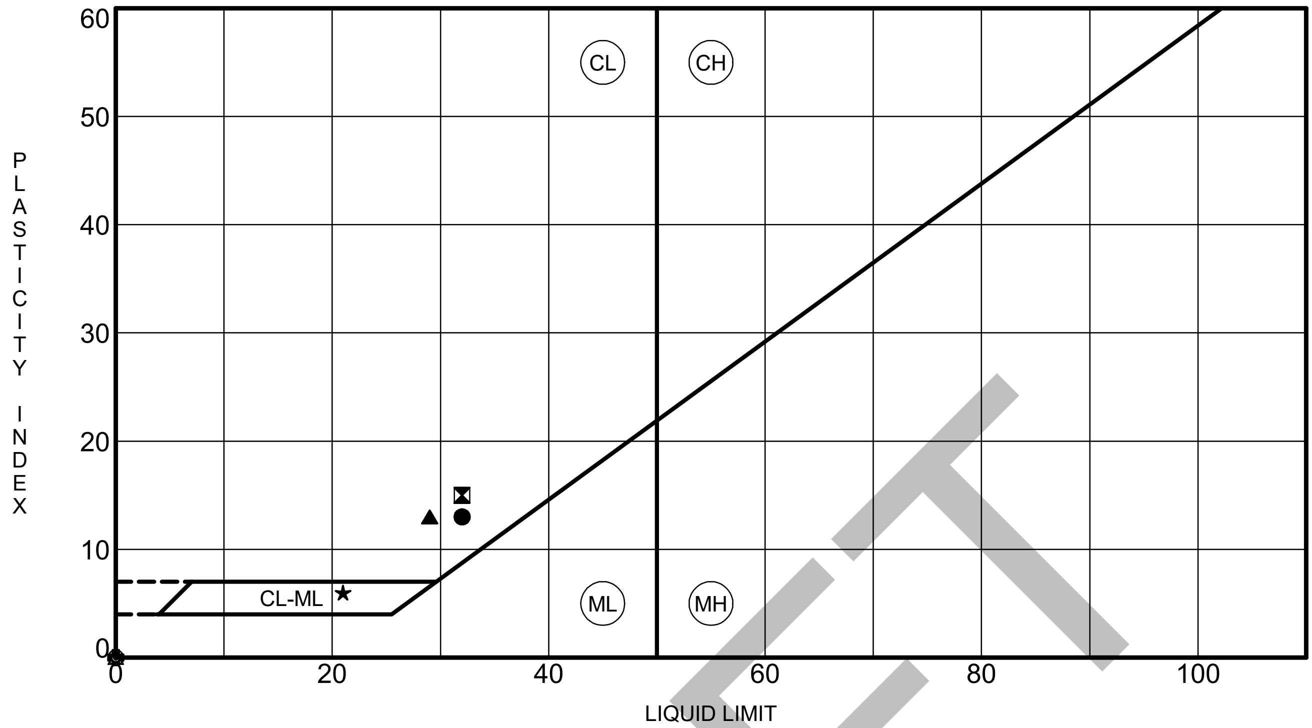

	Boring	Depth (ft.)	LL	PL	PI	Fines	Sample Description
●	**MW55**	**15.0**	**32**	**19**	**13**	**48**	**CLAYEY SAND(SC)**
⧗	**SB52**	**4.0**	**32**	**17**	**15**	**78**	**LEAN CLAY with SAND(CL)**
▲	**SB53**	**2.0**	**29**	**16**	**13**	**51**	**SANDY LEAN CLAY(CL)**
★	**SB55**	**50.0**	**21**	**15**	**6**	**17**	**SILTY, CLAYEY GRAVEL with SAND(GC-GM)**
⊙	**XPW02**	**14.0**	**NP**	**NP**	**NP**	**79**	**SILT with SAND(ML)**
✿	**XPW02**	**16.0**	**NP**	**NP**	**NP**	**77**	**SILT with SAND(ML)**
○	**XPW03**	**14.0**	**NP**	**NP**	**NP**	**86**	**SILT(ML)**
△	**XPW03**	**18.0**	**NP**	**NP**	**NP**	**81**	**SILT with SAND(ML)**

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ATTERBERG LIMITS RESULTS

Vistra Energy
Hennepin, Illinois
J037936.01

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APPENDIX C

Grain Size Distribution

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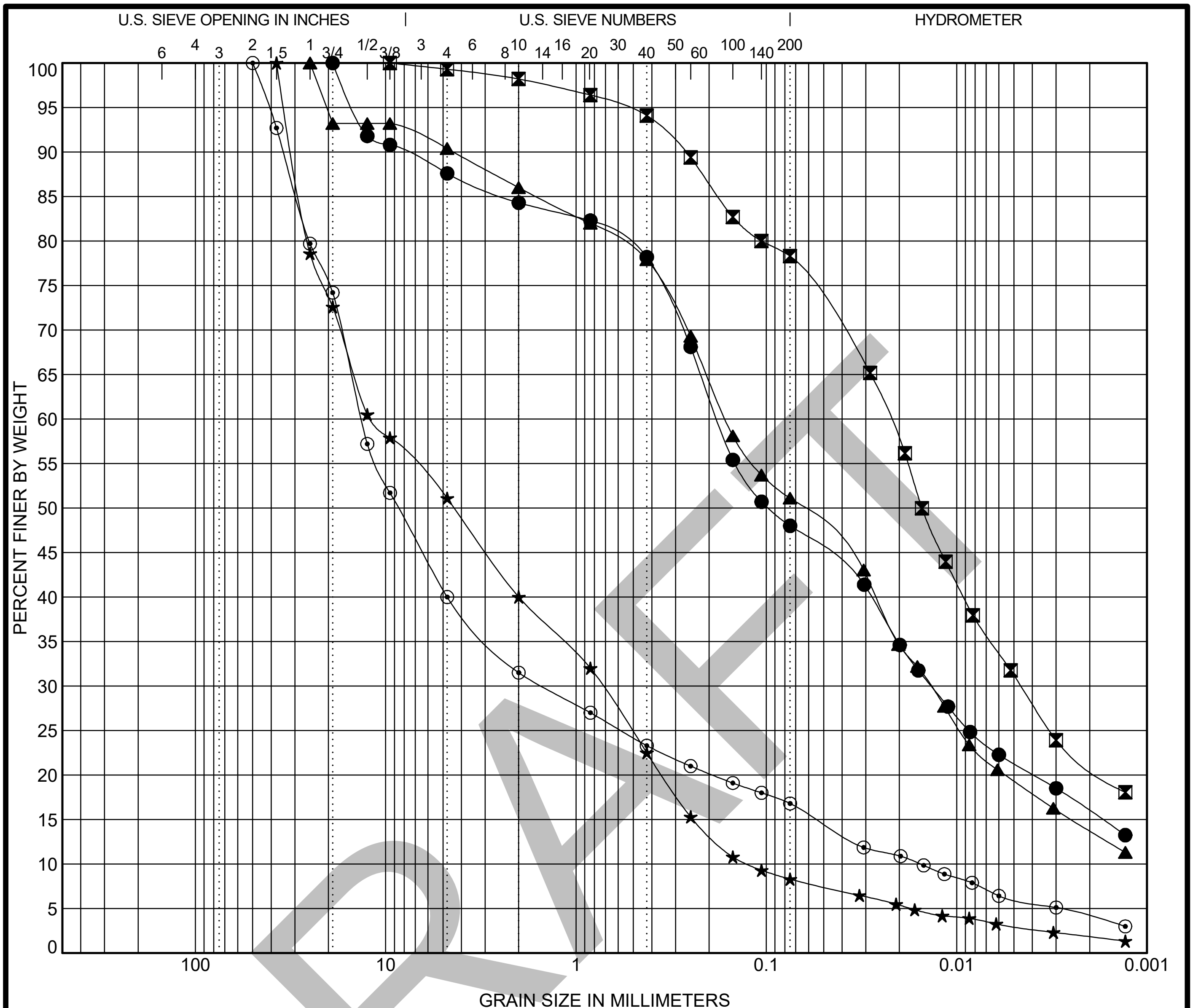

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COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (ft.)	Sample Description	LL	PL	PI	Cc	Cu
●	MW55	15.0	**CLAYEY SAND(SC)**	32	19	13		
⊠	SB52	4.0	**LEAN CLAY with SAND(CL)**	32	17	15		
▲	SB53	2.0	**SANDY LEAN CLAY(CL)**	29	16	13		
★	SB53	56.0					0.36	95.13
⊙	SB55	50.0	**SILTY, CLAYEY GRAVEL with SAND(GC-GM)**	21	15	6	10.79	862.67

	Boring	Depth (ft.)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	MW55	15.0	19	0.18	0.01		12.4	39.6	26.7	21.3
⊠	SB52	4.0	9.5	0.02	0		0.7	21.0	47.1	31.2
▲	SB53	2.0	25	0.16	0.01		9.6	39.3	31.8	19.3
★	SB53	56.0	37.5	11.86	0.73	0.125	48.9	42.8	5.3	3.0
⊙	SB55	50.0	50	13.39	1.5	0.016	60.0	23.2	10.7	6.1

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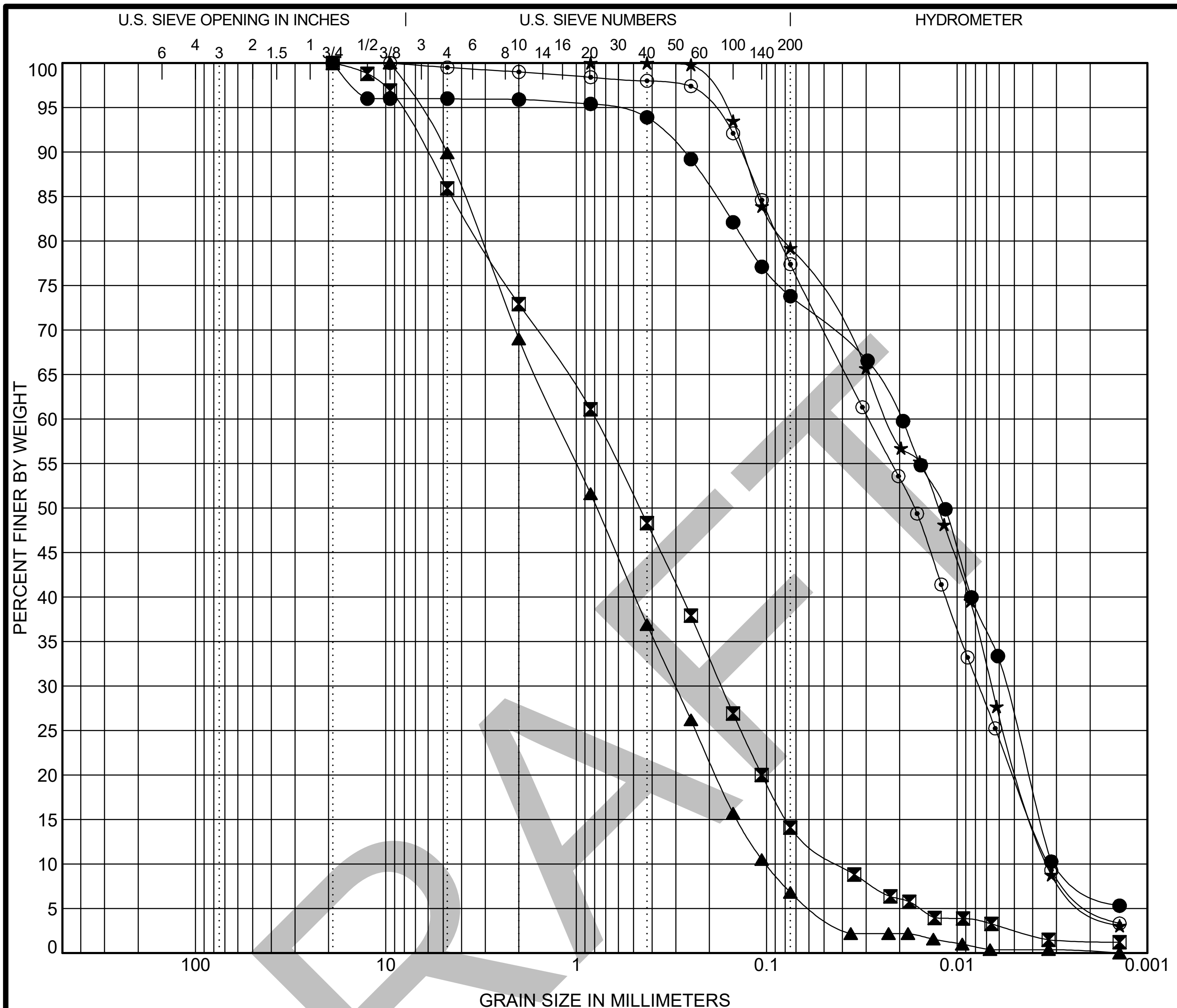
FROM THE GROUND UP

GRAIN SIZE DISTRIBUTION

Vistra Energy
Hennepin, Illinois
J037936.01

GRAIN SIZE 2018 J037936.01 - VISTRA HENNEPIN.GPJ 00 CLONE ME.GPJ 3/26/21



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (ft.)	Sample Description	LL	PL	PI	Cc	Cu
●	XPW01	10.0					0.52	6.37
⊠	XPW01	12.0					0.92	19.28
▲	XPW01	15.0					0.71	12.62
★	XPW02	14.0	SILT with SAND(ML)	NP	NP	NP	0.57	6.89
⊙	XPW02	16.0	SILT with SAND(ML)	NP	NP	NP	0.62	8.84

	Boring	Depth (ft.)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	XPW01	10.0	19	0.02	0.01	0.003	4.0	22.2	47.6	26.2
⊠	XPW01	12.0	19	0.79	0.17	0.041	14.1	71.8	11.5	2.6
▲	XPW01	15.0	9.5	1.28	0.3	0.101	10.1	83.1	6.4	0.4
★	XPW02	14.0	0.84	0.02	0.01	0.003	0.0	20.8	57.7	21.5
⊙	XPW02	16.0	9.5	0.03	0.01	0.003	0.5	22.1	57.6	19.8

GEOTECHNOLOGY INC
FROM THE GROUND UP

GRAIN SIZE DISTRIBUTION

Vistra Energy
Hennepin, Illinois
J037936.01

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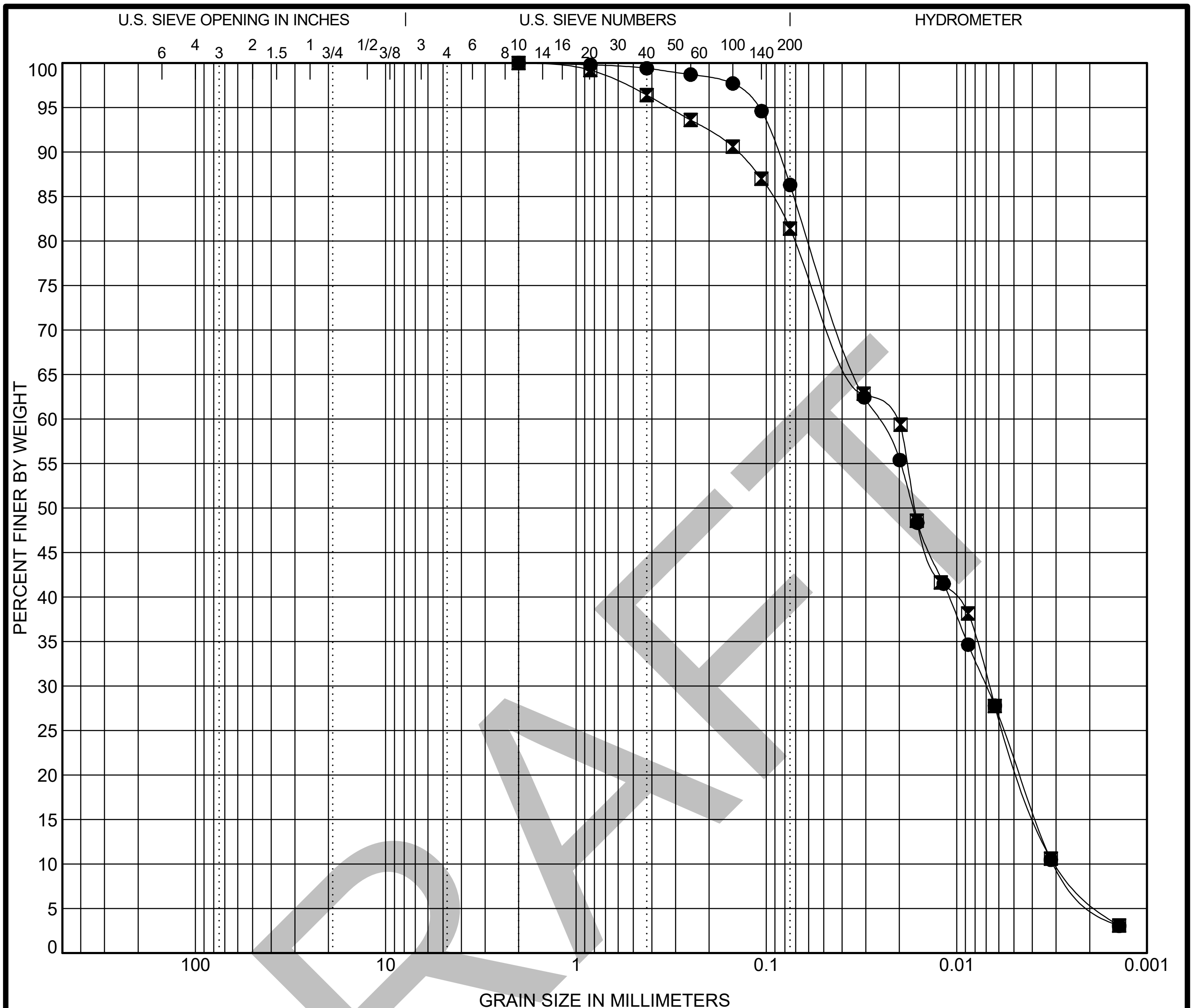
GRAIN SIZE 2018 J037936.01 - VISTRA HENNEPIN.GPJ 00 CLONE ME.GPJ 3/26/21



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring	Depth (ft.)	Sample Description	LL	PL	PI	Cc	Cu
●	**XPW03**	**14.0**	**SILT(ML)**	**NP**	**NP**	**NP**	**0.61**	**8.69**
⧗	**XPW03**	**18.0**	**SILT with SAND(ML)**	**NP**	**NP**	**NP**	**0.71**	**7.14**

	Boring	Depth (ft.)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**XPW03**	**14.0**	**2**	**0.03**	**0.01**	**0.003**	**0.0**	**13.7**	**64.4**	**21.9**
⧗	**XPW03**	**18.0**	**2**	**0.02**	**0.01**	**0.003**	**0.0**	**18.6**	**59.5**	**21.9**

GEOTECHNOLOGY INC
FROM THE GROUND UP

GRAIN SIZE DISTRIBUTION

Vistra Energy
Hennepin, Illinois
J037936.01

GRAIN SIZE 2018 J037936.01 - VISTRA HENNEPIN.GPJ 00 CLONE ME.GPJ 3/26/21

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APPENDIX D

Test Report

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Geotechnology, Inc.
11816 Lackland Road, Suite 150
St. Louis, MO 63146
314-997-7440

TEST REPORT

Prepared For:
Geosyntec Consultants, Inc.
941 Chatham Lane Suite 103
Columbus, Ohio 43221

Project No.:	**J037936.01**	**March 29, 2021**
Project Name:	**Vistra Energy - Hennepin**	**Page 1 of 1**
Sampled By:	**Geotechnology, Inc.**	
Attention:	**Ms. Allison Kreinberg**	

HYDRAULIC CONDUCTIVITY (PERMEABILITY) TEST & DENSITY DETERMINATION (UNIT WEIGHT) ASTM D5084 & D7263

Sample ID	Moisture Content (%)	Initial Wet Density (pcf)	Initial Dry Density (pcf)	Hydraulic Conductivity (cm/s)
MW55-(15-17.5)	14.4	124.5	108.8	1.5×10^{-7}
SB52-(6-8)	24.8	118.8	95.2	7.1×10^{-8}
SB53-(2-4)	13.6	136.4	120.1	2.4×10^{-8}
XPW02-(14-16)	123.3	79.9	35.8	2.9×10^{-4}
XPW03-(14-16)	177.0	76.9	27.8	1.7×10^{-4}
XPW03-(18-20)	138.8	80.4	33.7	2.0×10^{-4}

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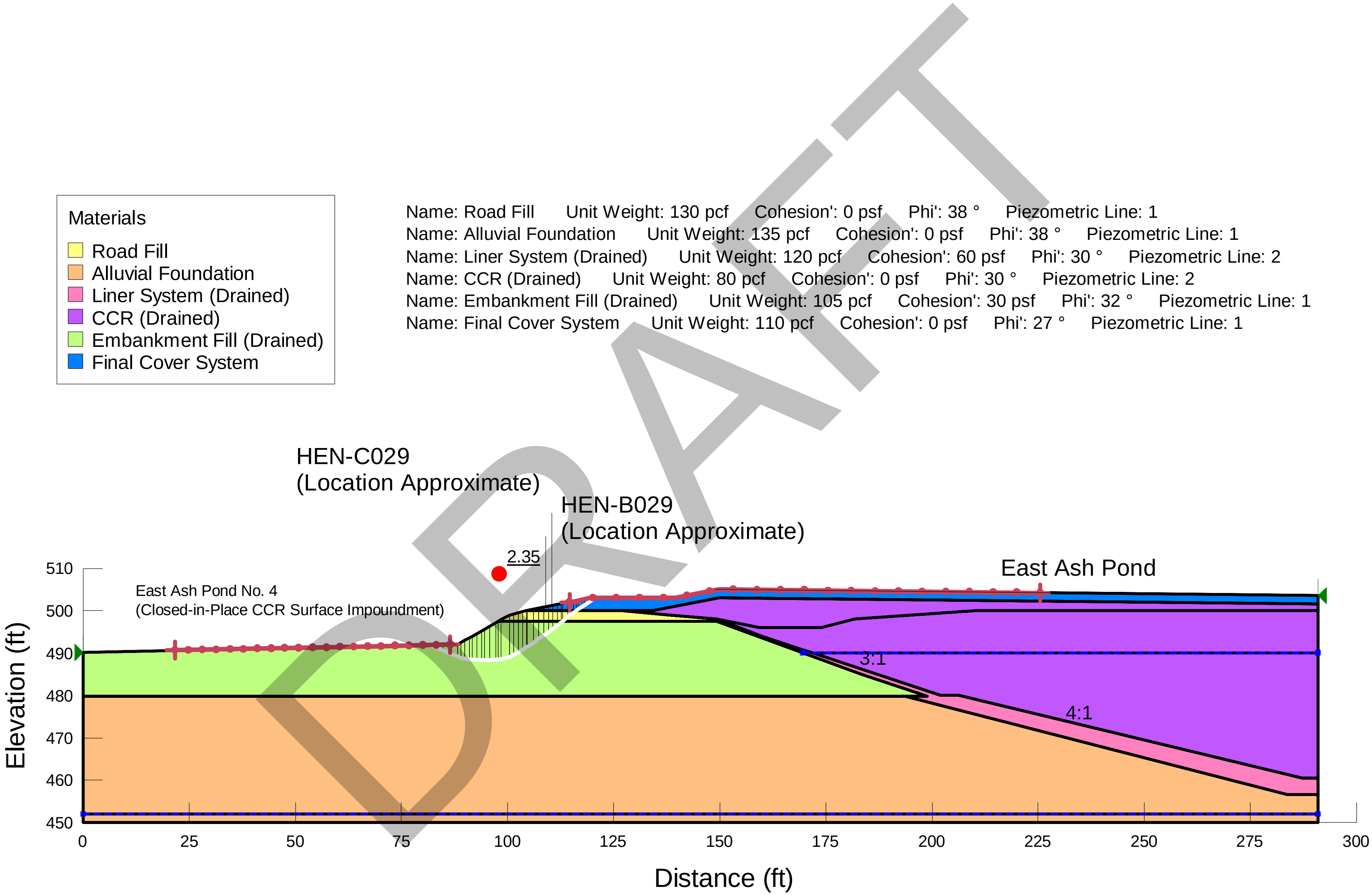
APPENDIX C

Global Slope Stability Analysis Output

Hennepin East Ash Pond
Cross Section SL-10
Long-Term Static

Calculated By: IJV/LPC Date: 10/27/2021

Checked By: ZJF Date: 11/1/2021



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Hennepin East Ash Pond
Cross Section SL-10
End-of-Construction

Calculated By: IJV/LPC Date: 10/27/2021

Checked By: ZJF Date: 11/1/2021

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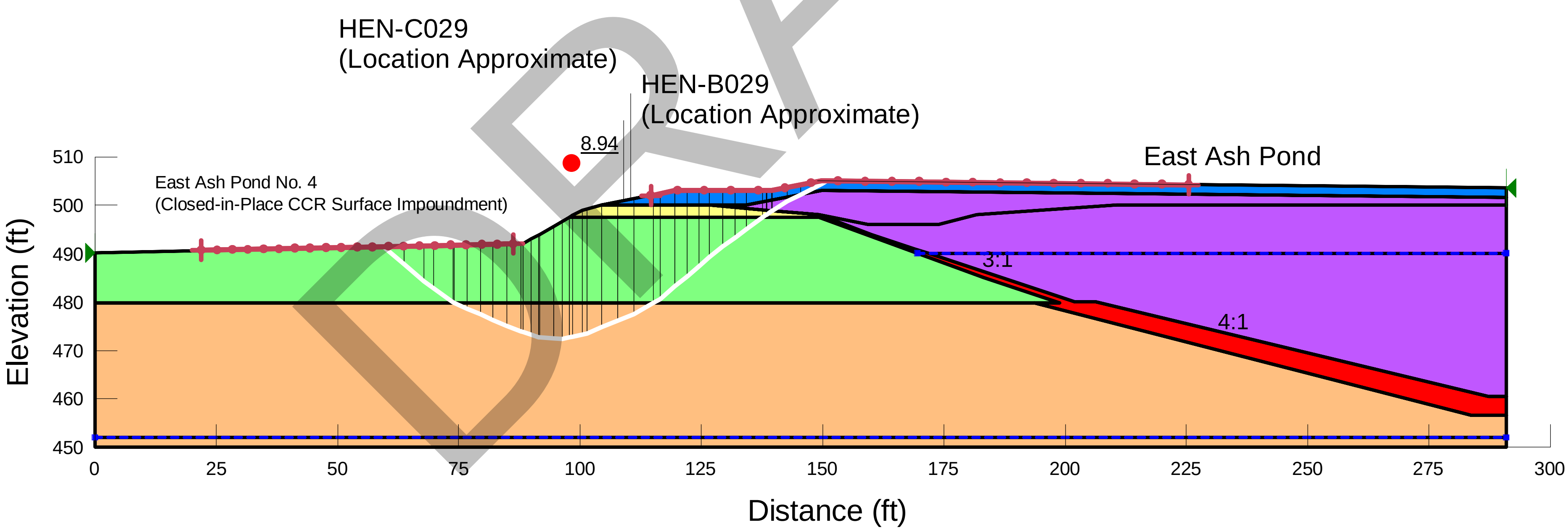
Materials

- Road Fill
- Alluvial Foundation
- Liner System (Undrained)
- CCR (Drained)
- Embankment Fill (Undrained)
- Final Cover System

Name: Road Fill Unit Weight: 130 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 1
Name: Alluvial Foundation Unit Weight: 135 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 1
Name: Liner System (Undrained) Unit Weight: 120 pcf Cohesion': 2,500 psf Phi': 0 ° Piezometric Line: 2
Name: CCR (Drained) Unit Weight: 80 pcf Cohesion': 0 psf Phi': 30 ° Piezometric Line: 2
Name: Embankment Fill (Undrained) Unit Weight: 105 pcf Cohesion': 2,500 psf Phi': 0 ° Piezometric Line: 1
Name: Final Cover System Unit Weight: 110 pcf Cohesion': 0 psf Phi': 27 ° Piezometric Line: 1



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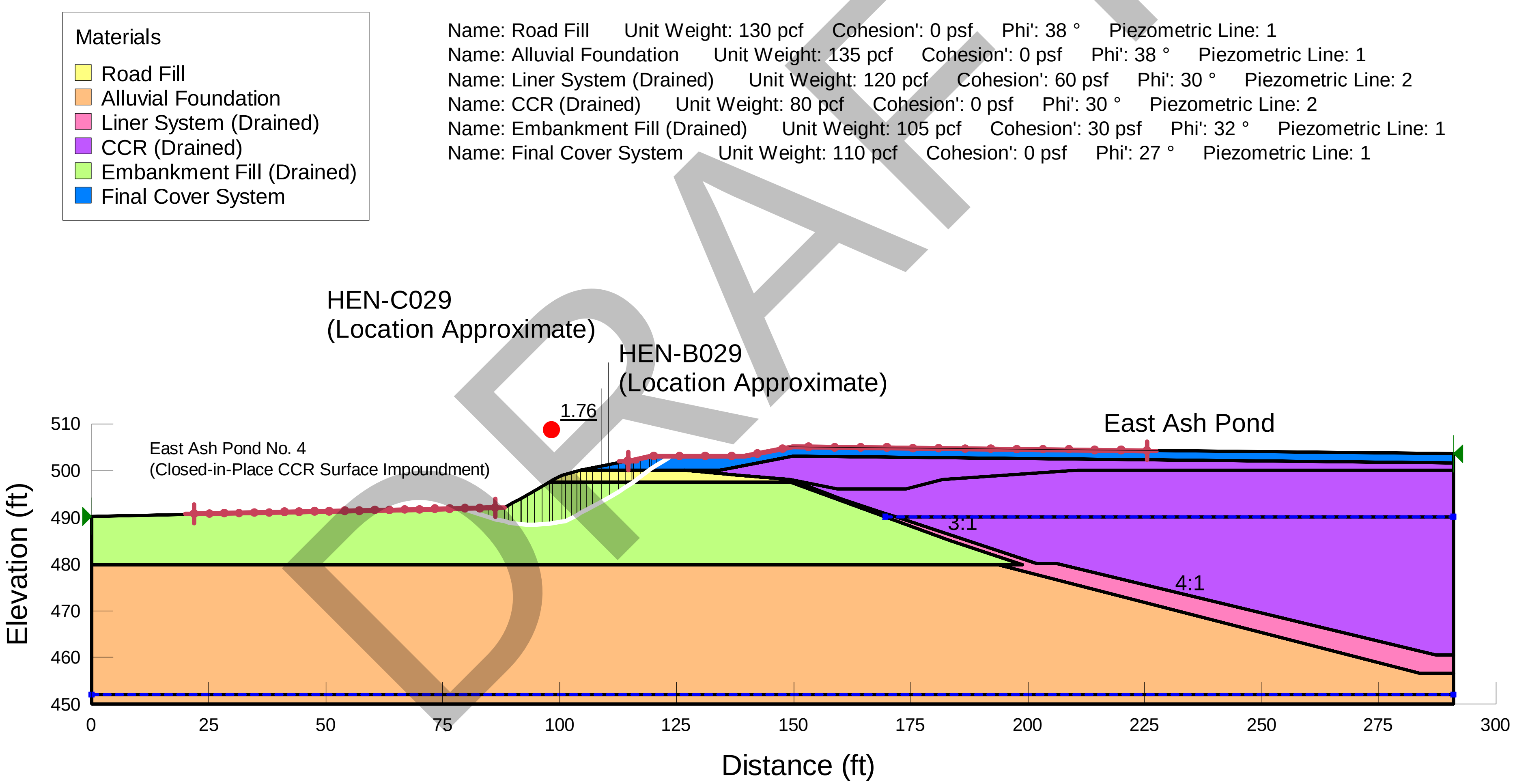
Hennepin East Ash Pond
Cross Section SL-10
Pseudostatic Seismic - Drained Emb.

Calculated By: IJV/LPC Date: 10/27/2021

Checked By: ZJF Date: 11/1/2021



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Hennepin East Ash Pond
Cross Section SL-10
Pseudostatic Seismic - Undrained Emb.

Calculated By: IJV/LPC Date: 10/27/2021

Checked By: ZJF Date: 11/1/2021

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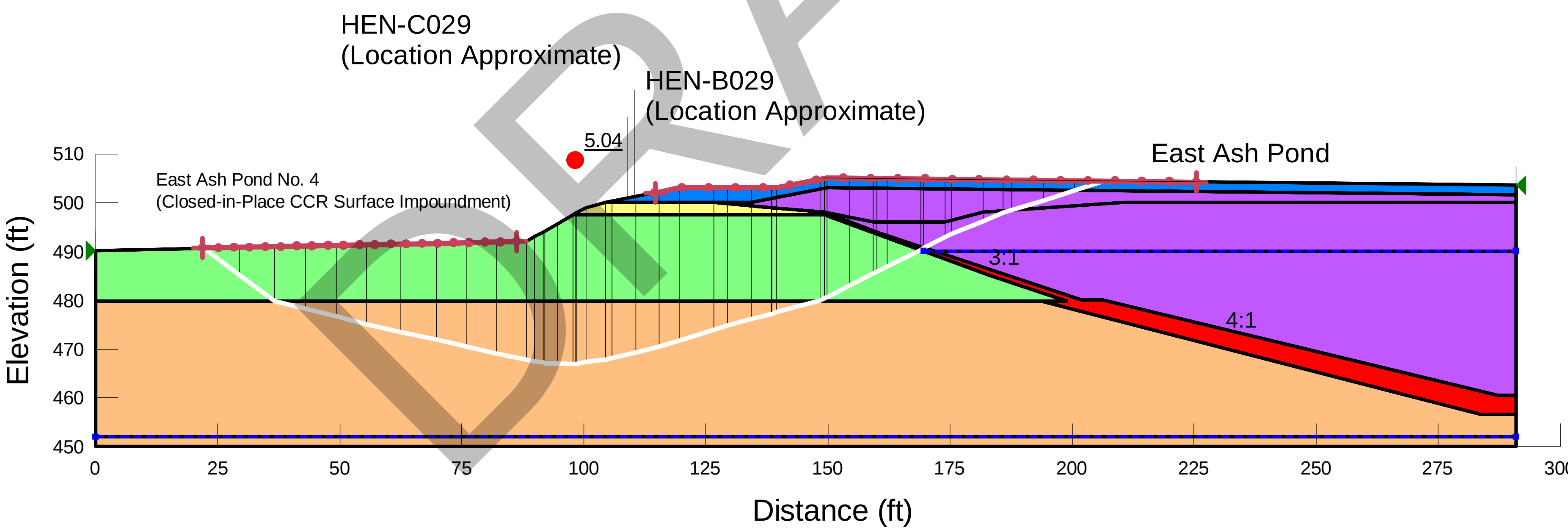
Materials
- Road Fill
- Alluvial Foundation
- Liner System (Undrained)
- CCR (Drained)
- Embankment Fill (Undrained)
- Final Cover System

Name: Road Fill Unit Weight: 130 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 1
Name: Alluvial Foundation Unit Weight: 135 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 1
Name: Liner System (Undrained) Unit Weight: 120 pcf Cohesion': 2,500 psf Phi': 0 ° Piezometric Line: 2
Name: CCR (Drained) Unit Weight: 80 pcf Cohesion': 0 psf Phi': 30 ° Piezometric Line: 2
Name: Embankment Fill (Undrained) Unit Weight: 105 pcf Cohesion': 2,500 psf Phi': 0 ° Piezometric Line: 1
Name: Final Cover System Unit Weight: 110 pcf Cohesion': 0 psf Phi': 27 ° Piezometric Line: 1



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Hennepin East Ash Pond
Cross Section SL-10
Post-Earthquake - Drained Emb.

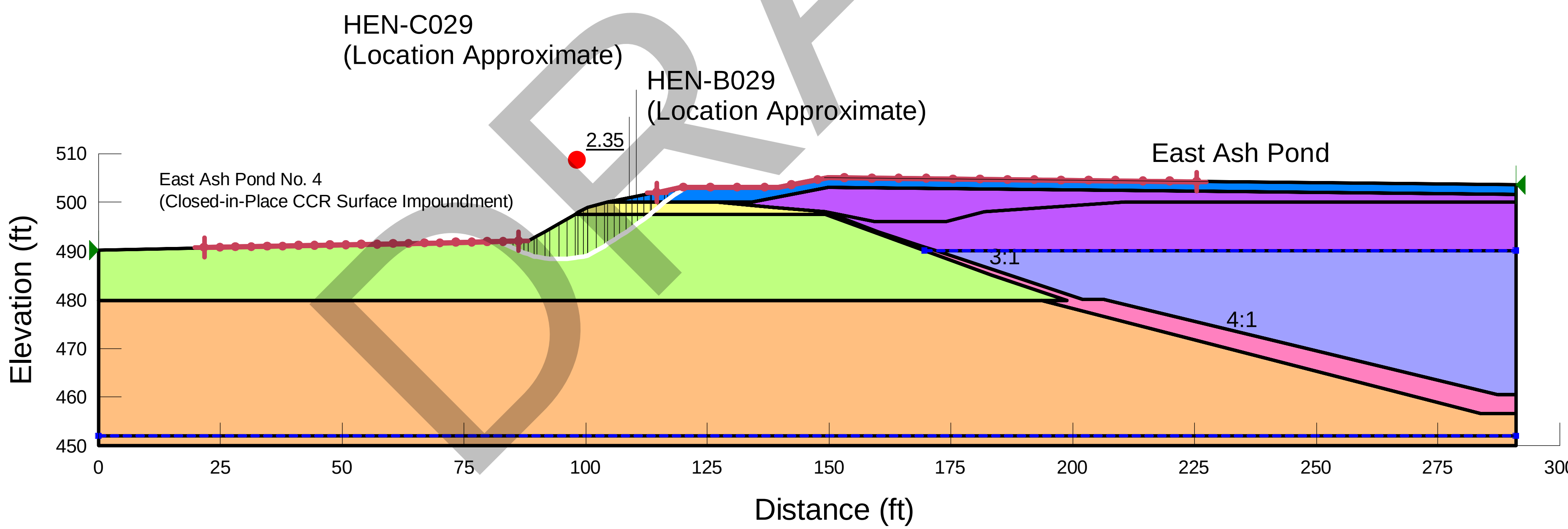
Calculated By: IJV/LPC   Date: 10/27/2021

Checked By: ZJF   Date: 11/1/2021

DRAFT

Materials
- Road Fill
- Alluvial Foundation
- Liner System (Drained)
- CCR (Drained)
- Embankment Fill (Drained)
- Final Cover System
- CCR (Liquefied)

Name: Road Fill   Unit Weight: 130 pcf   Cohesion': 0 psf   Phi': 38 °   Piezometric Line: 1
Name: Alluvial Foundation   Unit Weight: 135 pcf   Cohesion': 0 psf   Phi': 38 °   Piezometric Line: 1
Name: Liner System (Drained)   Unit Weight: 120 pcf   Cohesion': 60 psf   Phi': 30 °   Piezometric Line: 2
Name: CCR (Drained)   Unit Weight: 80 pcf   Cohesion': 0 psf   Phi': 30 °   Piezometric Line: 2
Name: Embankment Fill (Drained)   Unit Weight: 105 pcf   Cohesion': 30 psf   Phi': 32 °   Piezometric Line: 1
Name: Final Cover System   Unit Weight: 110 pcf   Cohesion': 0 psf   Phi': 27 °   Piezometric Line: 1
Name: CCR (Liquefied)   Unit Weight: 80 pcf   Tau/Sigma Ratio: 0.05   Minimum Strength: 0 psf   Piezometric Line: 2



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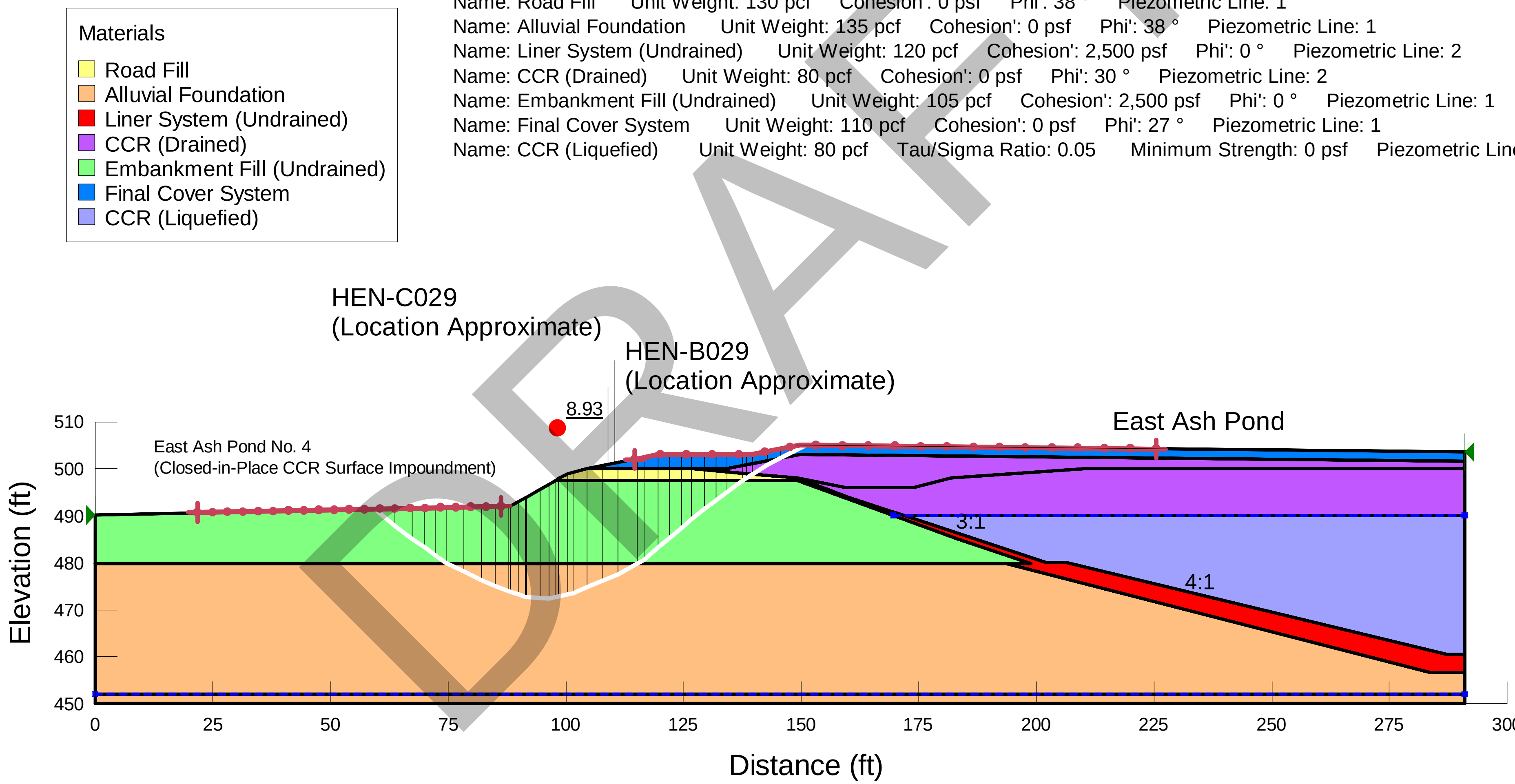
Hennepin East Ash Pond
Cross Section SL-10
Post-Earthquake - Undrained Emb.

Calculated By: IJV/LPC Date: 10/27/2021

Checked By: ZJF Date: 11/1/2021

Name	Unit Weight	Cohesion' / Tau/Sigma Ratio	Phi' / Minimum Strength	Piezometric Line
Road Fill	130 pcf	Cohesion': 0 psf	Phi': 38 °	1
Alluvial Foundation	135 pcf	Cohesion': 0 psf	Phi': 38 °	1
Liner System (Undrained)	120 pcf	Cohesion': 2,500 psf	Phi': 0 °	2
CCR (Drained)	80 pcf	Cohesion': 0 psf	Phi': 30 °	2
Embankment Fill (Undrained)	105 pcf	Cohesion': 2,500 psf	Phi': 0 °	1
Final Cover System	110 pcf	Cohesion': 0 psf	Phi': 27 °	1
CCR (Liquefied)	80 pcf	Tau/Sigma Ratio: 0.05	Minimum Strength: 0 psf	2



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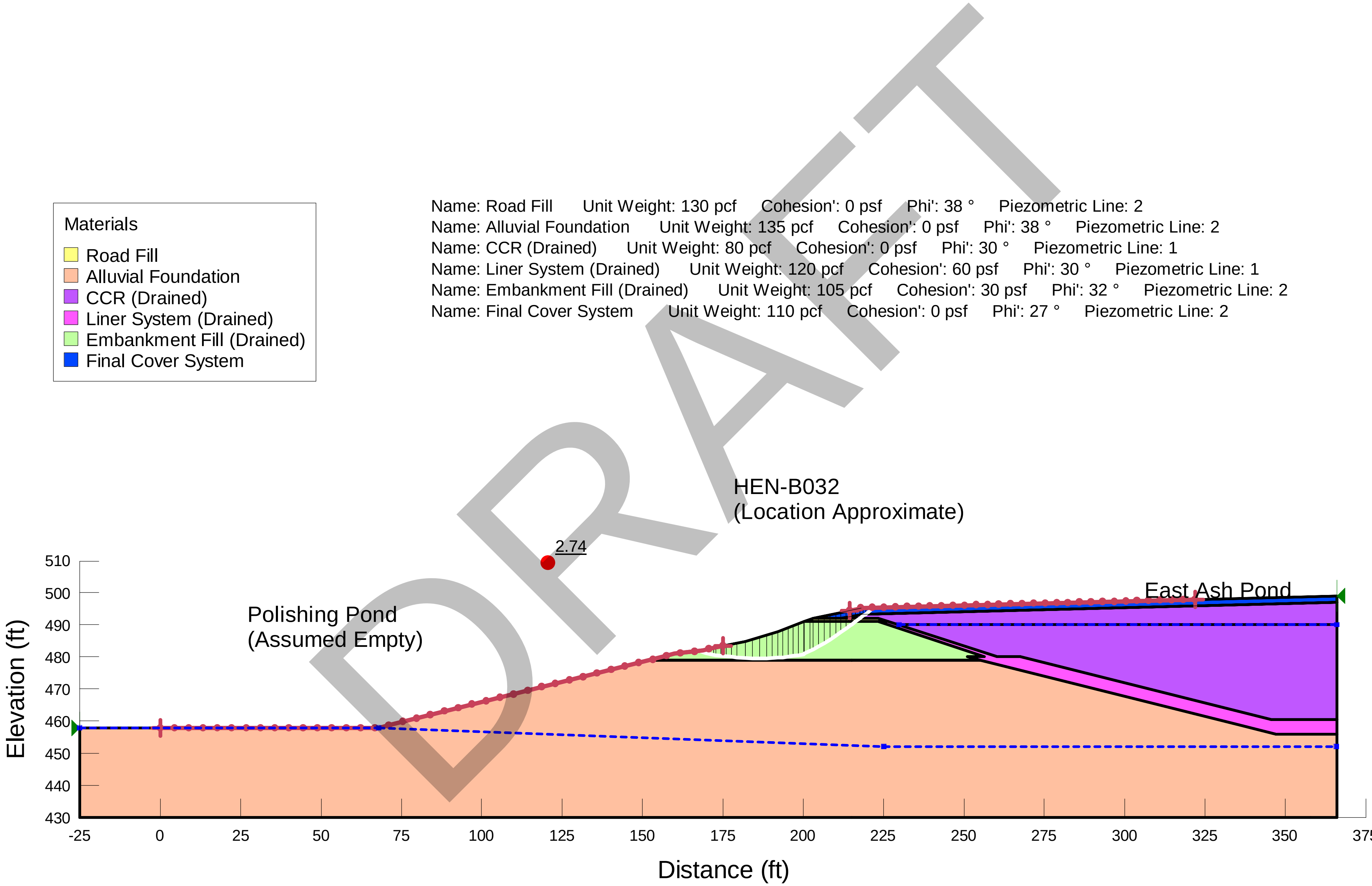
East Ash Pond
Cross Section SL-12
Long-Term Static

Calculated By: IJV/LPC Date: 10/27/2021

Checked By: ZJF Date: 11/1/2021



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East Ash Pond
Cross Section SL-12
End-of-Construction

Calculated By: IJV/LPC Date: 10/27/2021

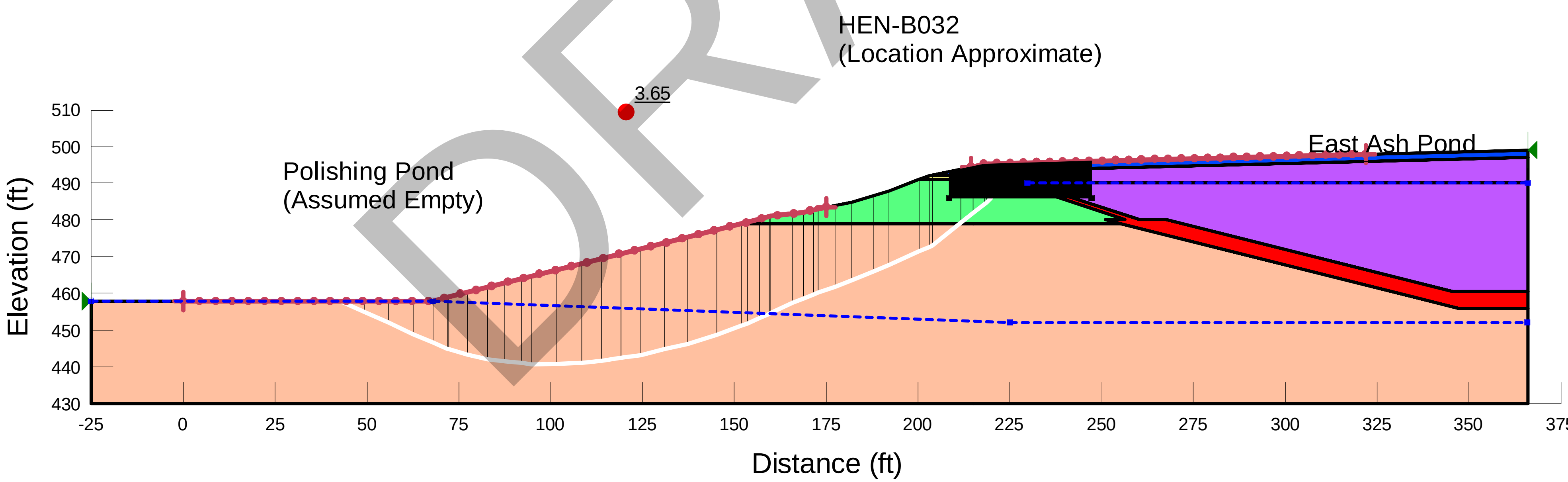
Checked By: ZJF Date: 11/1/2021

DRAFT

Materials

- Road Fill
- Alluvial Foundation
- CCR (Drained)
- Liner System (Undrained)
- Embankment Fill (Undrained)
- Final Cover System

Name: Road Fill Unit Weight: 130 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 2
Name: Alluvial Foundation Unit Weight: 135 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 2
Name: CCR (Drained) Unit Weight: 80 pcf Cohesion': 0 psf Phi': 30 ° Piezometric Line: 1
Name: Liner System (Undrained) Unit Weight: 120 pcf Cohesion': 2,500 psf Phi': 0 ° Piezometric Line: 1
Name: Embankment Fill (Undrained) Unit Weight: 105 pcf Cohesion': 2,500 psf Phi': 0 ° Piezometric Line: 2
Name: Final Cover System Unit Weight: 110 pcf Cohesion': 0 psf Phi': 27 ° Piezometric Line: 2



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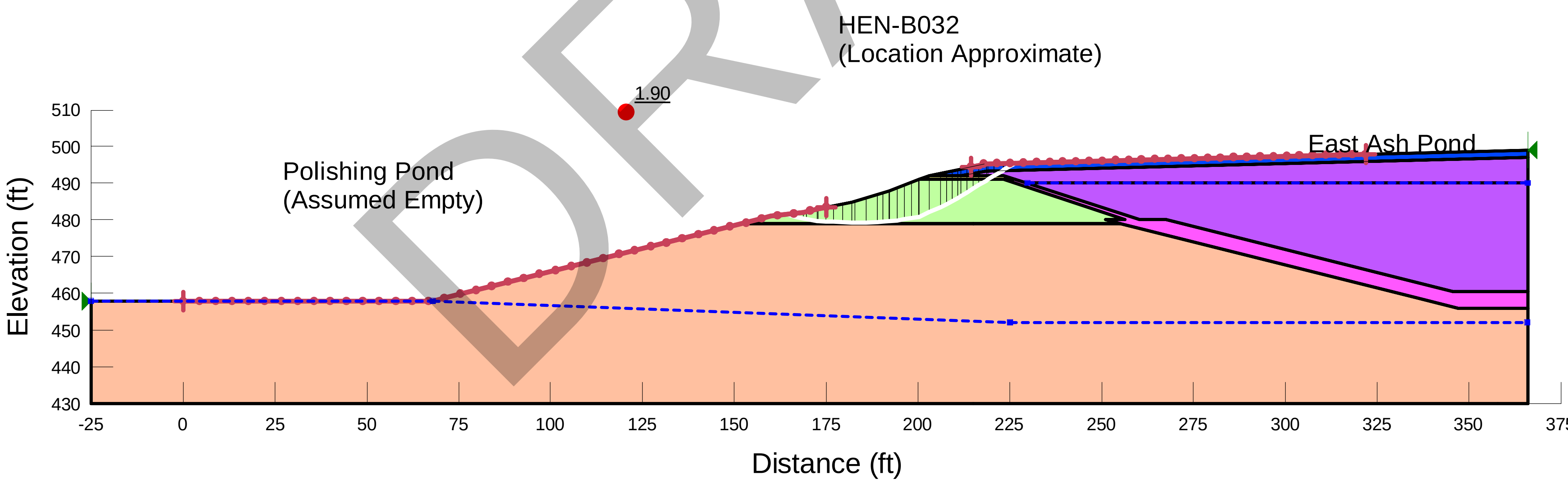
East Ash Pond
Cross Section SL-12
Pseudostatic Seismic - Drained Embankment

Calculated By: IJV/LPC Date: 10/27/2021

Checked By: ZJF Date: 11/1/2021

Materials
Road Fill
Alluvial Foundation
CCR (Drained)
Liner System (Drained)
Embankment Fill (Drained)
Final Cover System

Name: Road Fill Unit Weight: 130 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 2
Name: Alluvial Foundation Unit Weight: 135 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 2
Name: CCR (Drained) Unit Weight: 80 pcf Cohesion': 0 psf Phi': 30 ° Piezometric Line: 1
Name: Liner System (Drained) Unit Weight: 120 pcf Cohesion': 60 psf Phi': 30 ° Piezometric Line: 1
Name: Embankment Fill (Drained) Unit Weight: 105 pcf Cohesion': 30 psf Phi': 32 ° Piezometric Line: 2
Name: Final Cover System Unit Weight: 110 pcf Cohesion': 0 psf Phi': 27 ° Piezometric Line: 2



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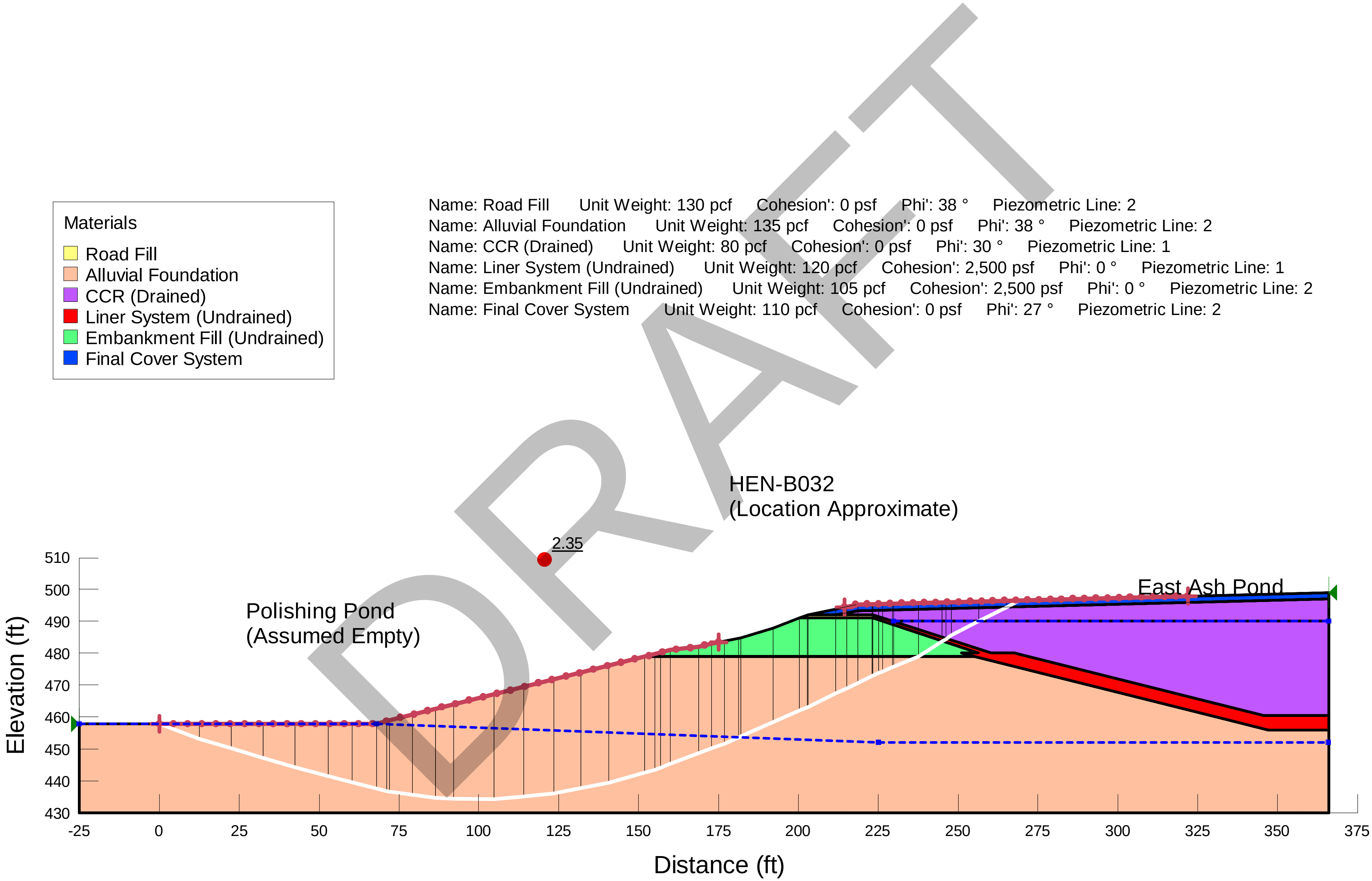
East Ash Pond
Cross Section SL-12
Pseudostatic Seismic - Undrained Embankment

Calculated By: IJV/LPC Date: 10/27/2021

Checked By: ZJF Date: 11/1/2021



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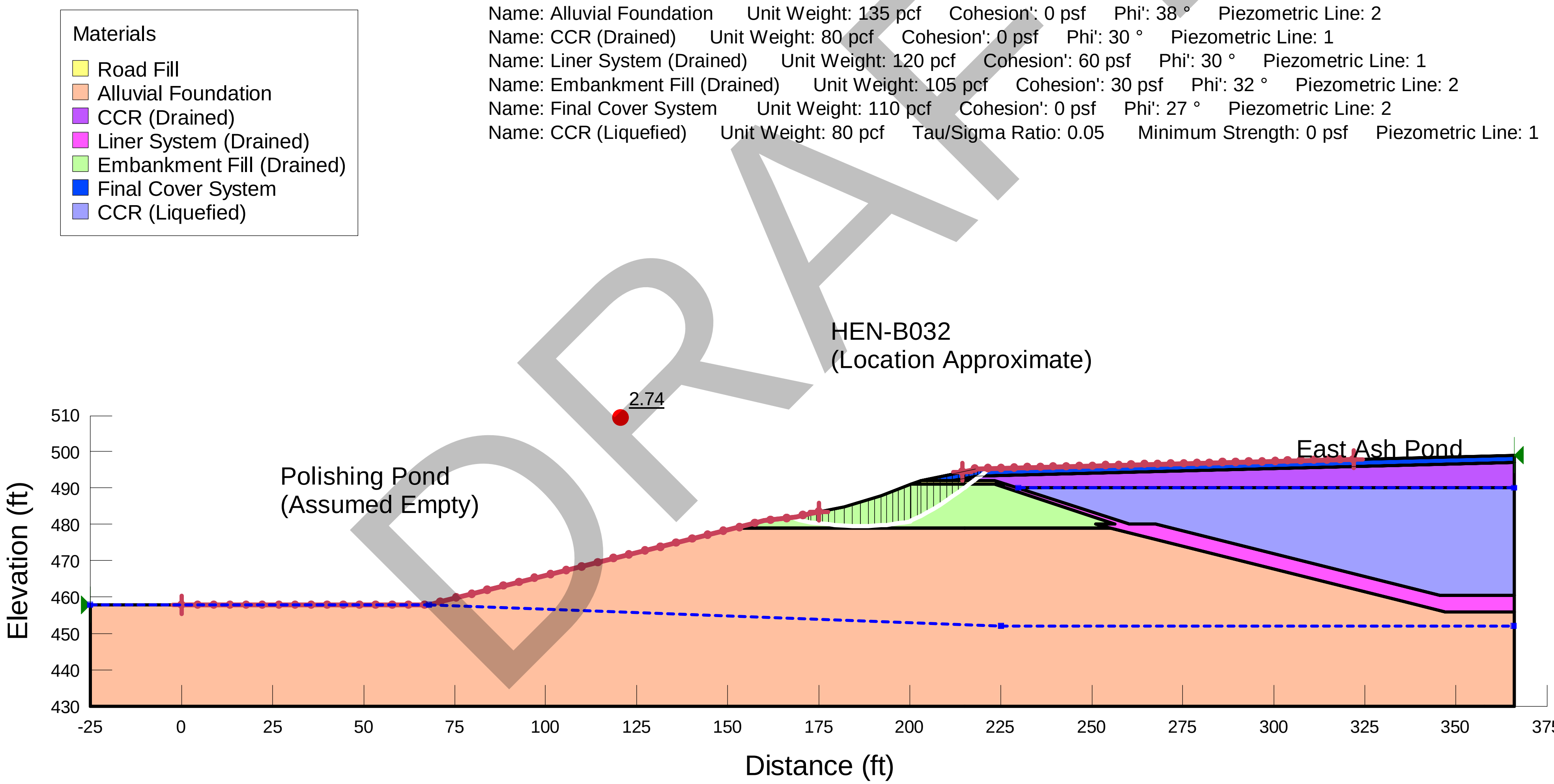
East Ash Pond
Cross Section SL-12
Post Earthquake - Drained Embankment

Calculated By: IJV/LPC Date: 10/27/2021

Checked By: ZJF Date: 11/1/2021

Name: Road Fill Unit Weight: 130 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 2
Name: Alluvial Foundation Unit Weight: 135 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 2
Name: CCR (Drained) Unit Weight: 80 pcf Cohesion': 0 psf Phi': 30 ° Piezometric Line: 1
Name: Liner System (Drained) Unit Weight: 120 pcf Cohesion': 60 psf Phi': 30 ° Piezometric Line: 1
Name: Embankment Fill (Drained) Unit Weight: 105 pcf Cohesion': 30 psf Phi': 32 ° Piezometric Line: 2
Name: Final Cover System Unit Weight: 110 pcf Cohesion': 0 psf Phi': 27 ° Piezometric Line: 2
Name: CCR (Liquefied) Unit Weight: 80 pcf Tau/Sigma Ratio: 0.05 Minimum Strength: 0 psf Piezometric Line: 1



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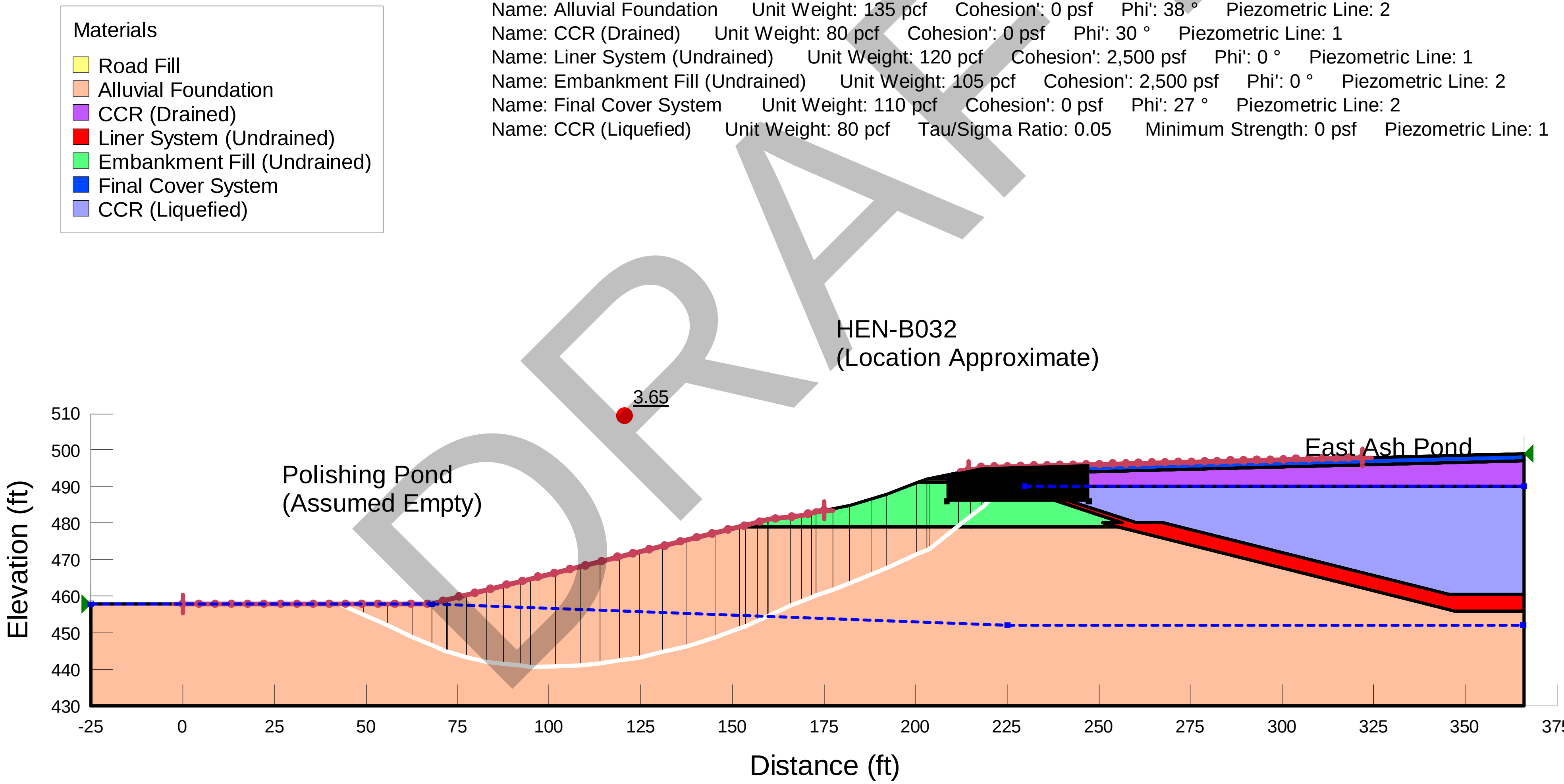
East Ash Pond
Cross Section SL-12
Post Earthquake - Undrained Embankment

Calculated By: IJV/LPC Date: 10/27/2021

Checked By: ZJF Date: 11/1/2021

Name: Road Fill Unit Weight: 130 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 2
Name: Alluvial Foundation Unit Weight: 135 pcf Cohesion': 0 psf Phi': 38 ° Piezometric Line: 2
Name: CCR (Drained) Unit Weight: 80 pcf Cohesion': 0 psf Phi': 30 ° Piezometric Line: 1
Name: Liner System (Undrained) Unit Weight: 120 pcf Cohesion': 2,500 psf Phi': 0 ° Piezometric Line: 1
Name: Embankment Fill (Undrained) Unit Weight: 105 pcf Cohesion': 2,500 psf Phi': 0 ° Piezometric Line: 2
Name: Final Cover System Unit Weight: 110 pcf Cohesion': 0 psf Phi': 27 ° Piezometric Line: 2
Name: CCR (Liquefied) Unit Weight: 80 pcf Tau/Sigma Ratio: 0.05 Minimum Strength: 0 psf Piezometric Line: 1



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APPENDIX D

Interface Friction Testing Data

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Table K.1 - Summary of Interface Friction CQA Testing Results

Material	Sample ID	Friction Angle (°)[1]	Adhesion (psf)	Large Displacement Friction Angle (°)[2]	Pass/ Fail[1,2]
Clay Cover Soil	CB-03	23.4	142	17.1*	Pass
Skaps DSGC TN 270-2-10	-				
Skaps 40 mil LLDPE TXGM	-				
CCR	CF-02 (CCR-1)				
Clay Cover Soil	CB-03	27.8	81	21.5*	Pass
Skaps NWGT GE116	-				
Skaps 40 mil LLDPE TXGM	-				
CCR	CF-02 (CCR-1)				
Clay Cover Soil	CB-03	19.0	190	10.8	Pass[3]
Skaps DSGC TN 270-2-10	-				
Skaps 40 mil LLDPE TXGM	-				
Coal	CY-01				
Clay Cover Soil	CB-03	24.9	158	15.0	Pass
Skaps NWGT GE116	-				
Skaps 40 mil LLDPE TXGM	-				
Coal	CY-01				
Sand and Gravel Cover Soil	SCS-03	41.3*	-*	35.5*	Pass
Skaps DSGC TN 270-2-10	-				
Sand and Gravel Cover Soil	SCS-03	26.9	102	27.5	Pass
Skaps NWGT GE116	-				
Sand and Gravel Cover Soil	SCS-03	25.3	51	18.9*	Pass
Skaps 40 mil LLDPE TXGM	-				

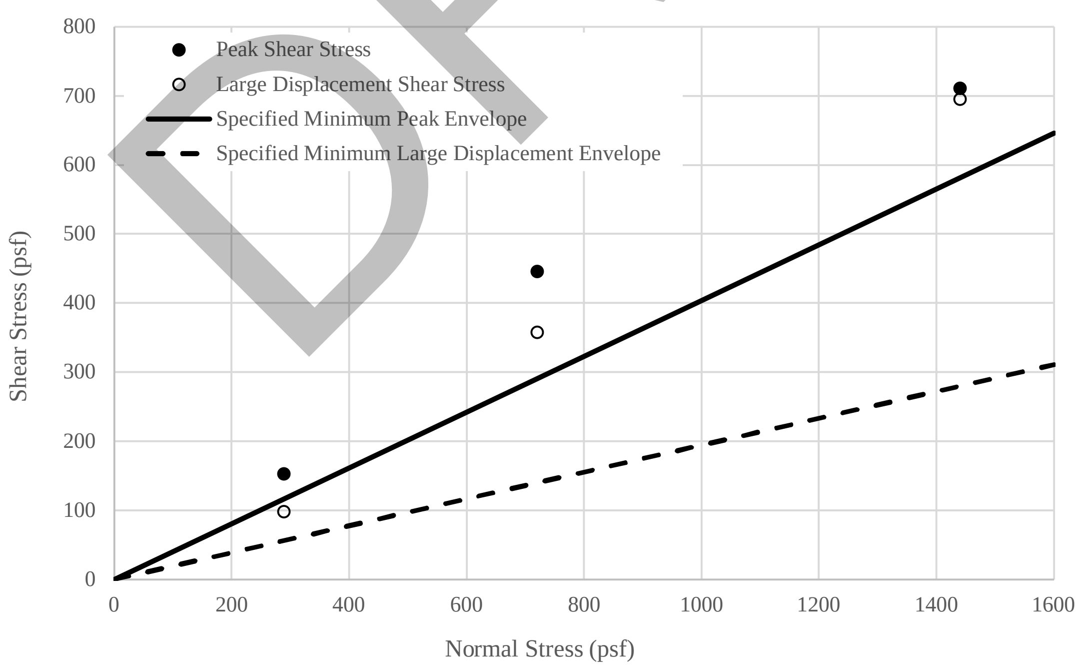
* Minimum Secant Angle results reported.

[1] Minimum Required Friction Angle = 22 degrees per Specification 31 05 19 03.01A

[2] Minimum Required Large Displacement Friction Angle = 11 degrees per Specification 31 05 19 03.01B

[3] Interface shear strength is in excess of specified values when adhesion is considered.

Figure K.1 - Interface Friction Testing Results Plot



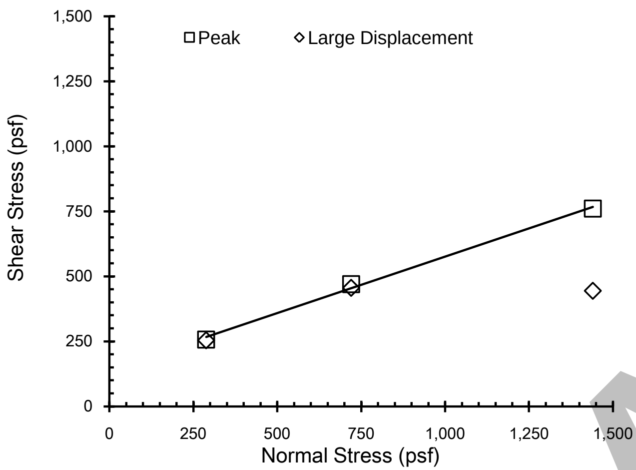
DRAFT

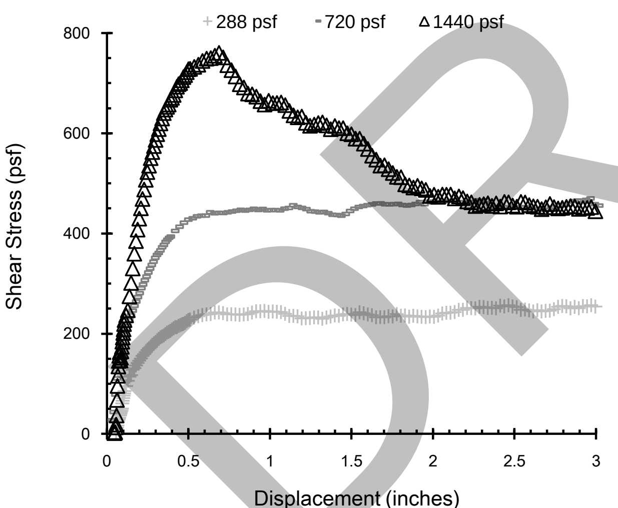
Multi-Layered Interface Friction Test (ASTM D5321 Modified)

Client: Geosyntec Consultants
Project: Dynegy Energy
Hennepin West Ash Pond System Closure

TRI Log #: 53888-3
Richard S. Lacey, P.E. 3/9/2020
Analysis & Quality Review/Date

CB-03 (Clay) vs. Skaps DSGC TN 270-2-10 (95161010001) vs. Skaps 40 mil LLDPE TXGM (3111002301) vs. CCR-1(coal ash) - Tamp





Test Results, Linear Regression				
Mohr-Coulomb Parameters		Peak	Large Displacement
Friction Angle	Degrees	23.4	*Various failure modes Refer to per normal stress secant friction angles*
Y-intercept or Adhesion	psf	142	
Minimum Secant Angle	Degrees	27.8	17.1

Note - Large Displacement Values Reported for 3.0 inches of Displacement

Test Conditions					
Upper Box	CB-03 (Clay) ω = 17.0 % γ_d = 104.0 pcf				
Floating	Skaps DSGC TN 270-2-10 (95161010001)				
	Skaps 40 mil LLDPE TXGM (3111002301)				
Lower Box	CCR-1(coal ash) Tamped in place				
Conditioning	Wet - Loading applied and Interface flooded for a minimum of 16 hours prior to shear.				
Shearing Rate	inches/minute	0.04			

Test Notes

Shearing occurred at the TXGM vs Ash interface at 288 psf and 720 psf, and at the NWGT vs. TXGM interface at 1,440 psf.

Specimen No.		-	1	2	3
Normal Stress		psf	288	720	1,440
Box Edge Dimension		in	12	12	12
Bearing Slide Resistance		lbs	11	15	22
Peak	Shear Stress	psf	257	470	760
	Secant Angle	deg.	41.7	33.1	27.8
Large Displacement	Shear Stress	psf	254	456	444
	Secant Angle	deg.	41.4	32.3	17.1
Asperity Height, Avg. of 5 Meas.		mils	32	33	32

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The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

TRI Environmental, Inc.
9063 Bee Caves Rd. – Austin, TX 78733 – USA | Ph: 800.880.TEST or 512.263.2101

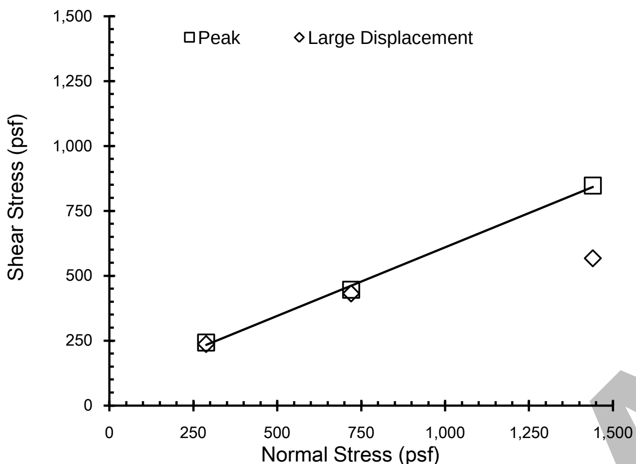
Multi-Layered Interface Friction Test (ASTM D5321 Modified)

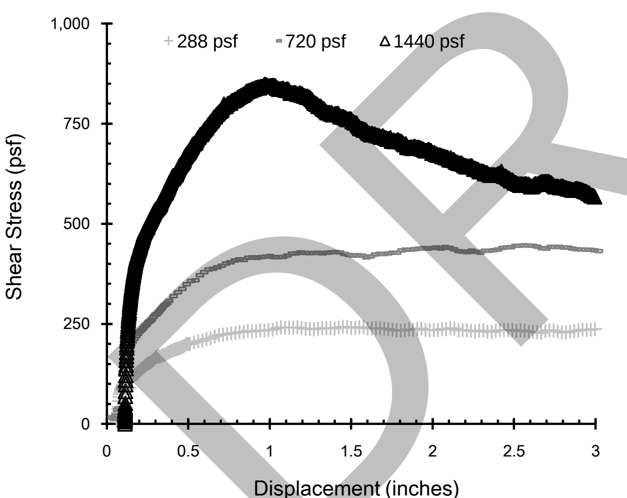
Client: Geosyntec Consultants — TRI Log #: 53888-1

Project: Dynegy Energy — Richard S. Lacey, P.E. 3/10/2020

Hennepin West Ash Pond System Closure — Analysis & Quality Review/Date

CB-03 (Clay) vs. Skaps NWGT GE116 (60771.1) vs.
Skaps 40 mil LLDPE TXGM (3111002301) vs.
CCR-1(coal ash) - Tamp





Test Results, Linear Regression			
Mohr-Coulomb Parameters		Peak	Large Displacement
Friction Angle	Degrees	27.8	*Various failure modes Refer to per normal stress secant friction angles*
Y-intercept or Adhesion	psf	81	
Minimum Secant Angle	Degrees	30.5	21.5

Note - Large Displacement Values Reported for 3.0 inches of Displacement

Test Conditions		
Upper Box	CB-03 (Clay) ω = 17.0 % γ$_d$ = 104.0 pcf	
Floating	Skaps NWGT GE116 (60771.1)	
	Skaps 40 mil LLDPE TXGM (3111002301)	
Lower Box	CCR-1(coal ash) Tamped in place	
Conditioning	Wet - Loading applied and Interface flooded for a minimum of 16 hours prior to shear.	
Shearing Rate	inches/minute	0.04

Test Notes

Shearing occurred at the TXGM vs Ash interface at 288 psf and 720 psf, and at the NWGT vs. TXGM interface at 1,440 psf.

Specimen No.		-	1	2	3
Normal Stress		psf	288	720	1,440
Box Edge Dimension		in	12	12	12
Bearing Slide Resistance		lbs	11	15	22
Peak	Shear Stress	psf	243	446	847
	Secant Angle	deg.	40.1	31.8	30.5
Large Displacement	Shear Stress	psf	237	432	567
	Secant Angle	deg.	39.4	30.9	21.5
Asperity Height, Avg. of 5 Meas.		mils	32	32	31

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TRI Environmental, Inc.
9063 Bee Caves Rd. – Austin, TX 78733 – USA | Ph: 800.880.TEST or 512.263.2101

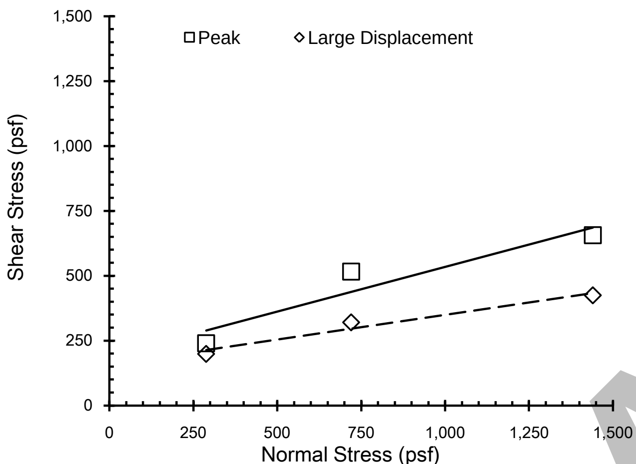
Multi-Layered Interface Friction Test (ASTM D5321 Modified)

Client: Geosyntec Consultants — TRI Log #: 53888-4

Project: Dynegy Energy - Hennepin West Ash Pond System C — Richard S. Lacey, P.E. 3/10/2020

Analysis & Quality Review/Date

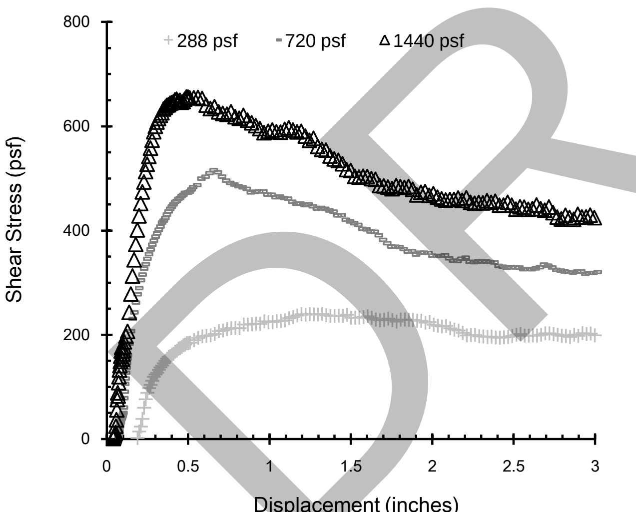
CB-03 (Clay) vs. Skaps DSGC TN 270-2-10 (95161010001) vs. Skaps 40 mil LLDPE TXGM (3111002301) vs. CY-01 (Coal) - Tamp



Test Results, Linear Regression			
Mohr-Coulomb Parameters		Peak	Large Displacement
Friction Angle	Degrees	19.0	10.8
Y-intercept or Adhesion	psf	190	159
Minimum Secant Angle	Degrees	24.5	16.4

Note - Large Displacement Values Reported for 3.0 inches of Displacement

Test Conditions		
Upper Box	CB-03 (Clay) ω = 17.0 % γ_d = 104.0 pcf	
FLOATING	Skaps DSGC TN 270-2-10 (95161010001)	
	Skaps 40 mil LLDPE TXGM (3111002301)	
Lower Box	CY-01 (Coal) Tamped in place	
Conditioning	Wet - Loading applied and Interface flooded for a minimum of 16 hours prior to shear.	
Shearing Rate	inches/minute	0.04



Test Notes

Shearing occurred at the DSGC vs. TXGM interface at all stresses.

Specimen No.		-	1	2	3
Normal Stress		psf	288	720	1,440
Box Edge Dimension		in	12	12	12
Bearing Slide Resistance		lbs	11	15	22
Peak	Shear Stress	psf	240	516	656
	Secant Angle	deg.	39.8	35.6	24.5
Large Displacement	Shear Stress	psf	199	320	425
	Secant Angle	deg.	34.6	24.0	16.4
Asperity Height, Avg. of 5 Meas.		mils	33	33	34

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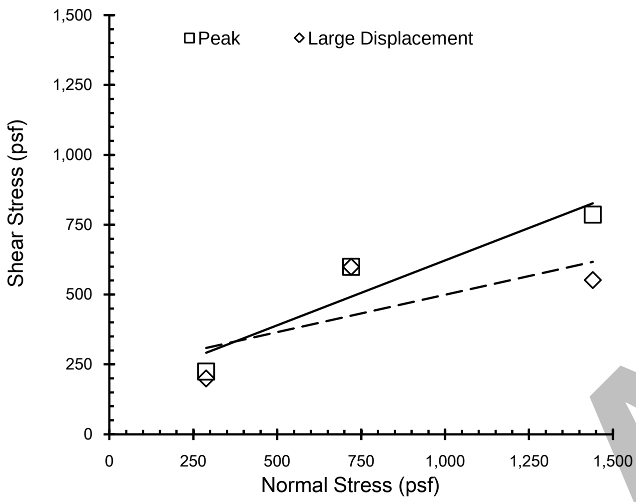
Multi-Layered Interface Friction Test (ASTM D5321 Modified)

Client: Geosyntec Consultants — TRI Log #: 53888-2
Project: Dynegy Energy — Richard S. Lacey, P.E. 3/3/2020
Hennepin West Ash Pond System Closure — Analysis & Quality Review/Date

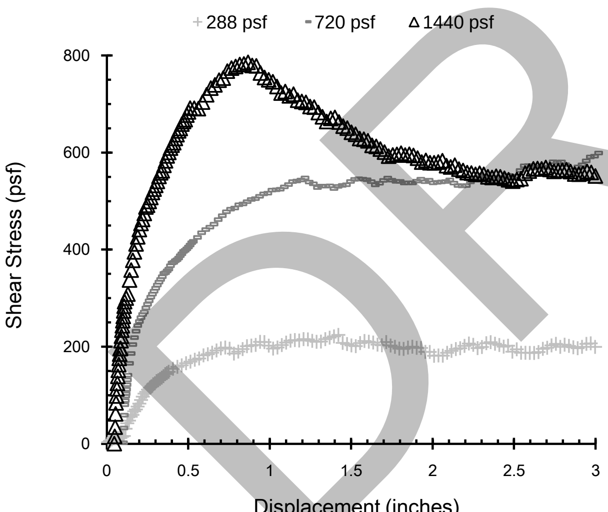
CB-03 (Clay) vs. Skaps NWGT GE116 (60771.1) vs. Skaps 40 mil LLDPE TXGM (3111002301) vs. CY-01 (Coal)



Test Results, Linear Regression			
Mohr-Coulomb Parameters		Peak	Large Displacement
Friction Angle	Degrees	24.9	15.0
Y-intercept or Adhesion	psf	158	232
Minimum Secant Angle	Degrees	28.6	21.0

Note - Large Displacement Values Reported for 3.0 inches of Displacement

Test Conditions		
Upper Box	CB-03 (Clay) ω = 17.0 % γ_d = 104.0 pcf	
Floating	Skaps NWGT GE116 (60771.1) Skaps 40 mil LLDPE TXGM (3111002301)	
Lower Box	CY-01 (Coal) Tamped in place	
Conditioning	Wet - Loading applied and Interface flooded for a minimum of 16 hours prior to shear.	
Shearing Rate	inches/minute	0.04



Test Notes

Shearing occurred at the Clay vs. NWGT interface at all stresses.

Specimen No.		-	1	2	3
Normal Stress		psf	288	720	1,440
Box Edge Dimension		in	12	12	12
Bearing Slide Resistance		lbs	11	15	22
Peak	Shear Stress	psf	224	599	786
	Secant Angle	deg.	37.9	39.8	28.6
Large Displacement	Shear Stress	psf	200	599	552
	Secant Angle	deg.	34.7	39.8	21.0
Asperity Height, Avg. of 5 Meas.		mils	32	33	31

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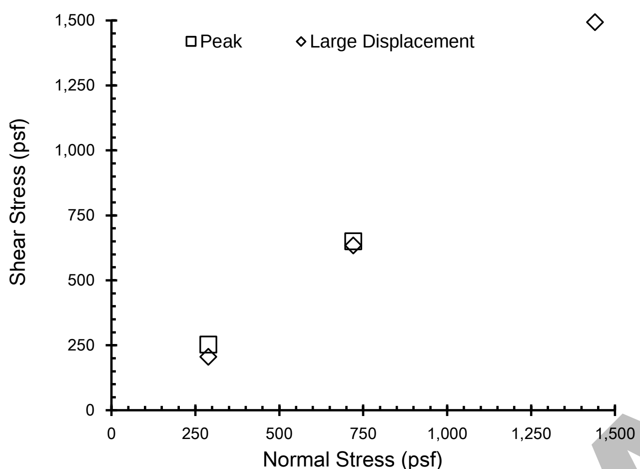
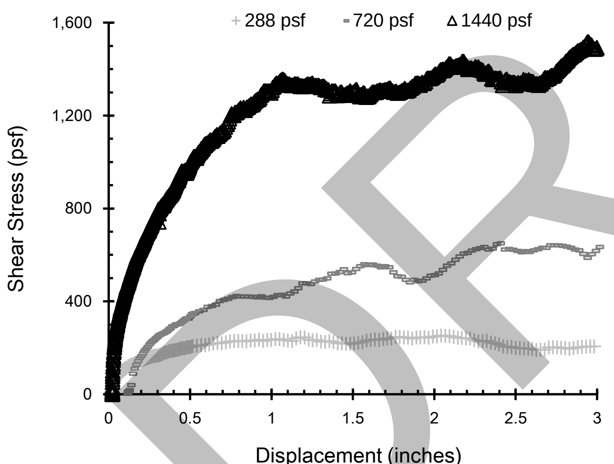
Shear Strength of Geosynthetic-Geosynthetic Interface by Direct Shear (ASTM D5321)

Client: Geosyntec Consultants
Project: Dynegy Energy - Hennepin
West Ash Pond System Closure

TRI Log #: 53888-7
Richard S. Lacey, P.E. 5/26/2020
Analysis & Quality Review/Date

SCS-03 vs.
Skaps DSGC TN 270-2-10 (95161010001)





Test Results, Linear Regression			
Mohr-Coulomb Parameters		Peak	Large Displacement
Friction Angle	Degrees	Negative Intercept *Refer to per-normal-stress secant angles*	
Y-intercept or Adhesion	psf		
Minimum Secant Angle	Degrees	41.3	35.5

Note - Large Displacement Values Reported for 3.0 inches of Displacement

Test Conditions		
Upper Box	SCS-03 Tamped in place	
Lower Box	Skaps DSGC TN 270-2-10 (95161010001)	
Conditioning	Wet - Loading applied and Interface flooded for a minimum of 24 hours prior to shear.	
Shearing Rate	inches/minute	0.04

Test Notes

Shearing occurred at the interface at all stresses.

Specimen No.		-	1	2	3
Normal Stress		psf	288	720	1,440
Box Edge Dimension		in	12	12	12
Bearing Slide Resistance		lbs	11	15	22
Peak	Shear Stress	psf	253	649	1,517
	Secant Angle	deg.	41.3	42.1	46.5
Large Displacement	Shear Stress	psf	206	634	1,493
	Secant Angle	deg.	35.5	41.4	46.0

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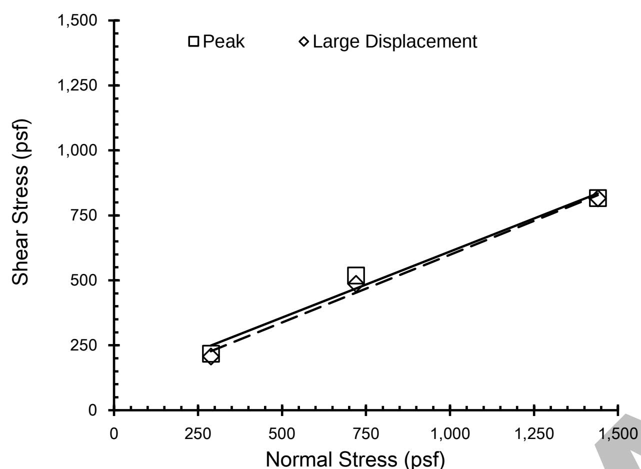
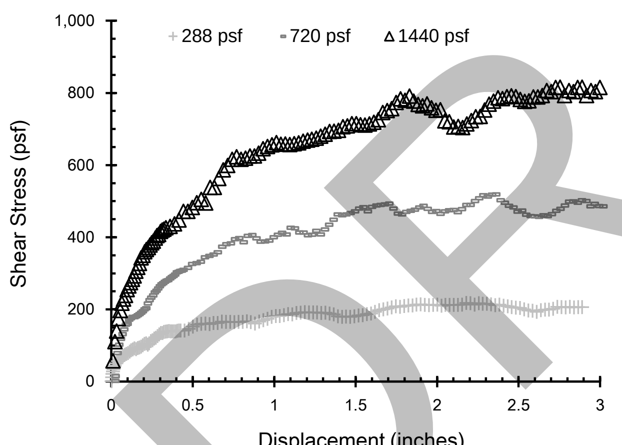
Shear Strength of Soil-Geosynthetic Interface by Direct Shear (ASTM D5321)

Client: Geosyntec Consultants
Project: Dynegy Energy - Hennepin
West Ash Pond System Closure

TRI Log #: 53888-5
Richard S. Lacey, P.E. 5/26/2020
Analysis & Quality Review/Date

SCS-03 vs.
Skaps NWGT GE116 (60771.30)





Test Results, Linear Regression			
Mohr-Coulomb Parameters		Peak	Large Displacement
Friction Angle	Degrees	26.9	27.5
Y-intercept or Adhesion	psf	102	77
Minimum Secant Angle	Degrees	29.5	29.5

Note - Large Displacement Values Reported for 3.0 inches of Displacement

Test Conditions		
Upper Box	SCS-03 Tamped in place	
Lower Box	Skaps NWGT GE116 (60771.30)	
Conditioning	Wet - Loading applied and Interface flooded for a minimum of 24 hours prior to shear.	
Shearing Rate	inches/minute	0.04

Test Notes
Shearing occurred at the interface at all stresses.

Specimen No.		-	1	2	3
Normal Stress		psf	288	720	1,440
Box Edge Dimension		in	12	12	12
Bearing Slide Resistance		lbs	11	15	22
Peak	Shear Stress	psf	218	518	816
	Secant Angle	deg.	37.1	35.8	29.5
Large Displacement	Shear Stress	psf	206	486	815
	Secant Angle	deg.	35.6	34.0	29.5

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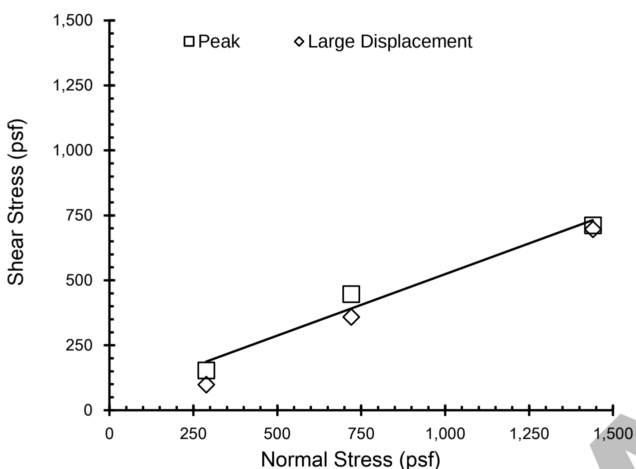
Shear Strength of Soil-Geosynthetic Interface by Direct Shear (ASTM D5321)

Client: Geosyntec Consultants
Project: Dynegy Energy - Hennepin
West Ash Pond System Closure

TRI Log #: 53888-6
Richard S. Lacey, P.E. 5/28/2020
Analysis & Quality Review/Date

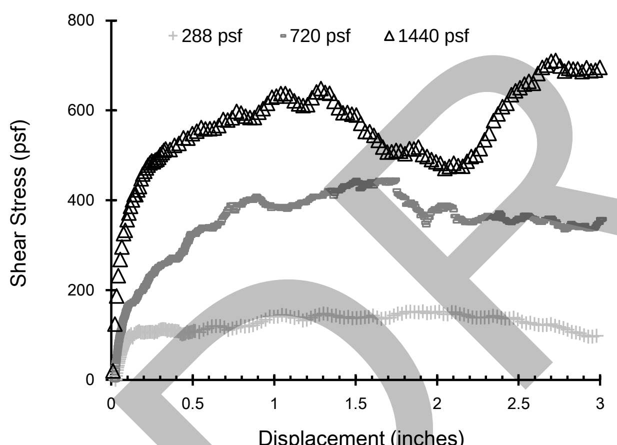
SCS-03 vs.
Skaps 40 mil LLDPE TXGM (3111002301) - shiny side up



Test Results, Linear Regression			
Mohr-Coulomb Parameters		Peak	Large Displacement
Friction Angle	Degrees	25.3	Negative Intercept *Refer to per-normal-stress secant angles*
Y-intercept or Adhesion	psf	51	
Minimum Secant Angle	Degrees	26.3	18.9

Note - Large Displacement Values Reported for 3.0 inches of Displacement

Test Conditions		
Upper Box	SCS-03 Tamped in place	
Lower Box	Skaps 40 mil LLDPE TXGM (3111002301) - shiny side up	
Conditioning	Wet - Loading applied and Interface flooded for a minimum of 24 hours prior to shear.	
Shearing Rate	inches/minute	0.04



Test Notes
Shearing occurred at the interface at all stresses.

Specimen No.		-	1	2	3
Normal Stress		psf	288	720	1,440
Box Edge Dimension		in	12	12	12
Bearing Slide Resistance		lbs	11	15	22
Peak	Shear Stress	psf	153	446	711
	Secant Angle	deg.	27.9	31.8	26.3
Large Displacement	Shear Stress	psf	98	358	695
	Secant Angle	deg.	18.9	26.4	25.8
Asperity Height, Avg. of 5 Meas.		mils	29	32	32

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APPENDIX E

Veneer Stability Analysis Output

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VENEER SLOPE STABILITY CALCULATIONS - 40H:1V SLOPE

Inputs in purple.

Internal Slope Failure (Unsaturated Static)

Analysis of all lower interfaces (subgrade-to-geomembrane, geomembrane-to-geocomposite, geocomposite-to-cover soil)

(Conversion of degrees to radians are performed for Excel spread sheet calculations)

2.5% (40H:1V slope) β =	1.43	degrees =	*0.02 radians*
Interface Friction, δ =	**25.30**	**degrees =**	*0.44 radians*
Interface Adhesion, a =	**51.00**	**psf**	
Thickness of soil above geomembrane, t =	**2.00**	**ft**	
Thickness of Saturation (water) t_w =	0.021	ft	
t_w* =	0.021	ft	
Height of slope, h =	6.0	ft	
Total Unit Weight of Soil Above Geomembrane, γ_t =	**110.00**	**pcf**	
Effective Unit Weight, γ_b =	57.60	pcf	
Saturated Unit Weight of Soil Above Geomembrane, γ_{sat} =	120.00	pcf	
Friction Angle of Soil Above Geomembrane, ϕ =	**27.00**	**degrees =**	*0.47 radians*
Cohesion of Soil Above Geomembrane, c =	**0.00**	**psf**	
Seismic Coeffecient, k_s =	0.000	g	

A	*B*	*C*	
[γ_t x (t-t_w) + γ_b x t_w]	**[γ_t x (t-t_w) + γ_{sat} x t_w]**	**tanδ/tanβ**	**[A/B] x C**
218.900	220.210	18.908	18.795

D	
[a/sinβ]	**D/B**
2040.637	**9.266778986**

E	*F*	*G*	
γ_t x (t-t_w*) + γ_b x t_w*]/B	**[tanϕ/(2sinβcos$^2\beta$)]/(1-tanβtanϕ)**	**t/h**	**E x F x G**
0.994	10.332	0.333	3.423

H	*I*	*J*	
1/B	**[1/(sinβcosβ)]/[1-tanβtanϕ]**	**ct/h**	**H x I x J**
0.005	40.541	0.000	0.000

A'	*B'*	*C'*	*D'*	**[A'+B'-C']/D'**
a/[γ_t x t x cos^2(β)]	**tanϕ x [1-(γ_w x t_w)/(γ_t x t)]**	**n_q x tanβ x tanϕ**	**n_q + tanβ**	28.074
0.232	0.470	0.000	0.025	

FS (Static)
31.486

DRAFT

VENEER SLOPE STABILITY CALCULATIONS - 40:1V SLOPE

Inputs in purple.

Internal Slope Failure (Unsaturated Seismic)

Analysis of all lower interfaces (subgrade-to-geomembrane, geomembrane-to-geocomposite, geocomposite-to-cover soil)

(Conversion of degrees to radians are performed for Excel spread sheet calculations)

2.5% (40H:1V slope) β =	1.43	degrees =	*0.02 radians*
Interface Friction, δ =	**25.30**	**degrees =**	*0.44 radians*
Interface Adhesion, a =	**51.00**	**psf**	
Thickness of soil above geomembrane, t =	**2.00**	**ft**	
Thickness of Saturation (water) t_w =	0.021	ft	
t_w* =	0.021	ft	
Height of slope, h =	6.0	ft	
Total Unit Weight of Soil Above Geomembrane, γ_t =	**110.00**	**pcf**	
Effective Unit Weight, γ_b =	57.60	pcf	
Saturated Unit Weight of Soil Above Geomembrane, γ_{sat} =	120.00	pcf	
Friction Angle of Soil Above Geomembrane, ϕ =	**27.00**	**degrees =**	*0.47 radians*
Cohesion of Soil Above Geomembrane, c =	**0.00**	**psf**	
Seismic Coeffecient, k_s =	0.078	g	

A	***B***	***C***	
[γ_t x (t-t_w) + γ_b x t_w]	**[γ_t x (t-t_w) + γ_{sat} x t_w]**	**tanδ/tanβ**	**[A/B] x C**
218.900	220.210	18.908	18.795

D	
[a/sinβ]	**D/B**
2040.637	**9.266778986**

E	***F***	***G***	
γ_t x (t-t_w*) + γ_b x t_w*]/B	**[tanϕ/(2sinβcos$^2\beta$)]/(1-tanβtanϕ)**	**t/h**	**E x F x G**
0.994	10.332	0.333	3.423

H	***I***	***J***	
1/B	**[1/(sinβcosβ)]/[1-tanβtanϕ]**	**ct/h**	**H x I x J**
0.005	40.541	0.000	0.000

A'	***B'***	***C'***	***D'***	**[A'+B'-C']/D'**
a/[γ_t x t x cos^2(β)]	**tanϕ x [1-(γ_w x t_w)/(γ_t x t)]**	**n_q x tanβ x tanϕ**	**n_q + tanβ**	6.805
0.232	0.470	0.001	0.103	

FS (Seismic)
6.805

DRAFT

VENEER SLOPE STABILITY CALCULATIONS - 40H:1V SLOPE

Inputs in purple.

Internal Slope Failure (Saturated Static)

Analysis of all lower interfaces (subgrade-to-geomembrane, geomembrane-to-geocomposite, geocomposite-to-cover soil)

(Conversion of degrees to radians are performed for Excel spread sheet calculations)

2.5% (40H:1V slope) β =	1.43	degrees =	*0.02 radians*
Interface Friction, δ =	**25.30**	**degrees =**	*0.44 radians*
Interface Adhesion, a =	**51.00**	**psf**	
Thickness of soil above geomembrane, t =	**2.00**	**ft**	
Thickness of Saturation (water) t_w =	2.000	ft	
t_w* =	2.000	ft	
Height of slope, h =	6.0	ft	
Total Unit Weight of Soil Above Geomembrane, γ_t =	**110.00**	**pcf**	
Effective Unit Weight, γ_b =	57.60	pcf	
Saturated Unit Weight of Soil Above Geomembrane, γ_{sat} =	120.00	pcf	
Friction Angle of Soil Above Geomembrane, ϕ =	**27.00**	**degrees =**	*0.47 radians*
Cohesion of Soil Above Geomembrane, c =	**0.00**	**psf**	
Seismic Coeffecient, k_s =	0.000	g	

A	*B*	*C*	
[γ_t x (t-t_w) + γ_b x t_w]	[γ_t x (t-t_w) + γ_{sat} x t_w]	tanδ/tanβ	[A/B] x C
115.200	240.000	18.908	9.076

D	
[a/sinβ]	D/B
2040.637	**8.502655835**

E	*F*	*G*	
γ_t x (t-t_w*) + γ_b x t_w*]/B	[tanϕ/(2sinβcos²β)]/(1-tanβtanϕ)	t/h	E x F x G
0.480	10.332	0.333	1.653

H	*I*	*J*	
1/B	[1/(sinβcosβ)]/[1-tanβtanϕ]	ct/h	H x I x J
0.004	40.541	0.000	0.000

A'	*B'*	*C'*	*D'*	[A'+B'-C']/D'
a/[γ_t x t x cos²(β)]	tanϕ x [1-(γ_w x t_w)/(γ_t x t)]	n_q x tanβ x tanϕ	n_q + tanβ	17.460
0.232	0.205	0.000	0.025	

FS (Static)
19.232

DRAFT

VENEER SLOPE STABILITY CALCULATIONS - 40H:1V SLOPE

Inputs in purple.

Internal Slope Failure (Unsaturated Post-EQ)

Analysis of all lower interfaces (subgrade-to-geomembrane, geomembrane-to-geocomposite, geocomposite-to-cover soil)

(Conversion of degrees to radians are performed for Excel spread sheet calculations)

2.5% (40H:1V slope) β =	1.43	degrees =	*0.02 radians*
Interface Friction, δ =	**17.10**	**degrees =**	*0.30 radians*
Interface Adhesion, a =	**0.00**	**psf**	
Thickness of soil above geomembrane, t =	**2.00**	**ft**	
Thickness of Saturation (water) t_w =	0.021	ft	
t_w* =	0.021	ft	
Height of slope, h =	6.0	ft	
Total Unit Weight of Soil Above Geomembrane, γ_t =	**110.00**	**pcf**	
Effective Unit Weight, γ_b =	57.60	pcf	
Saturated Unit Weight of Soil Above Geomembrane, γ_{sat} =	120.00	pcf	
Friction Angle of Soil Above Geomembrane, ϕ =	**27.00**	**degrees =**	*0.47 radians*
Cohesion of Soil Above Geomembrane, c =	**0.00**	**psf**	
Seismic Coeffecient, k_s =	0.000	g	

A	*B*	*C*	
[γ_t x (t-t_w) + γ_b x t_w]	**[γ_t x (t-t_w) + γ_{sat} x t_w]**	**tanδ/tanβ**	**[A/B] x C**
218.900	220.210	12.306	12.232

D	
[a/sinβ]	**D/B**
0.000	**0**

E	*F*	*G*	
γ_t x (t-t_w*) + γ_b x t_w*]/B	**[tanϕ/(2sinβcos$^2\beta$)]/(1-tanβtanϕ)**	**t/h**	**E x F x G**
0.994	10.332	0.333	3.423

H	*I*	*J*	
1/B	**[1/(sinβcosβ)]/[1-tanβtanϕ]**	**ct/h**	**H x I x J**
0.005	40.541	0.000	0.000

A'	*B'*	*C'*	*D'*	**[A'+B'-C']/D'**
a/[γ_t x t x cos^2(β)]	**tanϕ x [1-(γ_w x t_w)/(γ_t x t)]**	**n_q x tanβ x tanϕ**	**n_q + tanβ**	12.232
0.000	0.306	0.000	0.025	

FS (Post-EQ)
15.656

DRAFT

VENEER SLOPE STABILITY CALCULATIONS - 5H:1V SLOPE

Purple highlighted parameters are inputted

Internal Slope Failure (Unsaturated Static)

Analysis of all lower interfaces (subgrade-to-geomembrane, geomembrane-to-geocomposite, geocomposite-to-cover soil)

(Conversion of degrees to radians are performed for Excel spread sheet calculations)

Parameter	Value	Unit	Radians
20% (5H:1V slope) β =	11.31	degrees =	*0.20 radians*
Interface Friction, δ =	**25.30**	**degrees =**	*0.44 radians*
Interface Adhesion, a =	**51.00**	**psf**	
Thickness of soil above geomembrane, t =	**2.00**	**ft**	
Thickness of Saturation (water) t_w =	0.021	ft	
t_w* =	0.021	ft	
Height of slope, h =	10.0	ft	
Total Unit Weight of Soil Above Geomembrane, γ_t =	**110.00**	**pcf**	
Effective Unit Weight, γ_b =	57.60	pcf	
Saturated Unit Weight of Soil Above Geomembrane, γ_{sat} =	120.00	pcf	
Friction Angle of Soil Above Geomembrane, ϕ =	**27.00**	**degrees =**	*0.47 radians*
Cohesion of Soil Above Geomembrane, c =	**0.00**	**psf**	
Seismic Coeffecient, k_s =	0.000	g	

A	B	C	
$[\gamma_t \times (t-t_w) + \gamma_b \times t_w]$	$[\gamma_t \times (t-t_w) + \gamma_{sat} \times t_w]$	$\tan\delta/\tan\beta$	**[A/B] x C**
218.900	220.210	2.363	2.349

D		E	F	G	
$[a/\sin\beta]$	**D/B**	$\gamma_t \times (t-t_w^*) + \gamma_b \times t_w^*]/B$	$[\tan\phi/(2\sin\beta\cos^2\beta)]/(1-\tan\beta\tan\phi)$	t/h	**E x F x G**
260.050	**1.180918193**	0.994	1.504	0.200	0.299

H	I	J	
1/B	$[1/(\sin\beta\cos\beta)]/[1-\tan\beta\tan\phi]$	ct/h	**H x I x J**
0.005	5.790	0.000	0.000

A'	B'	C'	D'	[A'+B'-C']/D'
$a/[\gamma_t \times t \times \cos^2(\beta)]$	$\tan\phi \times [1-(\gamma_w \times t_w)/(\gamma_t \times t)]$	$n_q \times \tan\beta \times \tan\phi$	$n_q + \tan\beta$	3.555
0.241	0.470	0.000	0.200	

FS (Static)
3.829

DRAFT

VENEER SLOPE STABILITY CALCULATIONS - 5H:1V SLOPE

Purple highlighted parameters are inputted

Internal Slope Failure (Saturated Static)

Analysis of all lower interfaces (subgrade-to-geomembrane, geomembrane-to-geocomposite, geocomposite-to-cover soil)

(Conversion of degrees to radians are performed for Excel spread sheet calculations)

Parameter	Value	Unit	Radians
20% (5H:1V slope) β =	11.31	degrees =	*0.20 radians*
Interface Friction, δ =	**25.30**	**degrees =**	*0.44 radians*
Interface Adhesion, a =	**51.00**	**psf**	
Thickness of soil above geomembrane, t =	**2.00**	**ft**	
Thickness of Saturation (water) t_w =	2.000	ft	
t_w* =	2.000	ft	
Height of slope, h =	10.0	ft	
Total Unit Weight of Soil Above Geomembrane, γ_t =	**110.00**	**pcf**	
Effective Unit Weight, γ_b =	57.60	pcf	
Saturated Unit Weight of Soil Above Geomembrane, γ_{sat} =	120.00	pcf	
Friction Angle of Soil Above Geomembrane, ϕ =	**27.00**	**degrees =**	*0.47 radians*
Cohesion of Soil Above Geomembrane, c =	**0.00**	**psf**	
Seismic Coeffecient, k_s =	0.000	g	

A	*B*	*C*	
$[\gamma_t \times (t-t_w) + \gamma_b \times t_w]$	$[\gamma_t \times (t-t_w) + \gamma_{sat} \times t_w]$	$\tan\delta/\tan\beta$	**[A/B] x C**
115.200	240.000	2.363	1.134

D	
$[a/\sin\beta]$	**D/B**
260.050	**1.083541647**

E	*F*	*G*	
$\gamma_t \times (t-t_w^*) + \gamma_b \times t_w^*]/B$	$[\tan\phi/(2\sin\beta\cos^2\beta)]/(1-\tan\beta\tan\phi)$	t/h	**E x F x G**
0.480	1.504	0.200	0.144

H	*I*	*J*	
1/B	$[1/(\sin\beta\cos\beta)]/[1-\tan\beta\tan\phi]$	ct/h	**H x I x J**
0.004	5.790	0.000	0.000

A'	*B'*	*C'*	*D'*	**[A'+B'-C']/D'**
$a/[\gamma_t \times t \times \cos^2(\beta)]$	$\tan\phi \times [1-(\gamma_w \times t_w)/(\gamma_t \times t)]$	$n_q \times \tan\beta \times \tan\phi$	$n_q + \tan\beta$	2.228
0.241	0.205	0.000	0.200	

FS (Static)
2.362

DRAFT

VENEER SLOPE STABILITY CALCULATIONS - 5H:1V SLOPE

Purple highlighted parameters are inputted

Internal Slope Failure (Unsaturated Seismic)

Analysis of all lower interfaces (subgrade-to-geomembrane, geomembrane-to-geocomposite, geocomposite-to-cover soil)

(Conversion of degrees to radians are performed for Excel spread sheet calculations)

20% (5H:1V slope) β =	11.31	degrees =	*0.20 radians*
Interface Friction, δ =	**25.30**	**degrees =**	*0.44 radians*
Interface Adhesion, a =	**51.00**	**psf**	
Thickness of soil above geomembrane, t =	**2.00**	**ft**	
Thickness of Saturation (water) t_w =	0.021	ft	
t_w* =	0.021	ft	
Height of slope, h =	10.0	ft	
Total Unit Weight of Soil Above Geomembrane, γ_t =	**110.00**	**pcf**	
Effective Unit Weight, γ_b =	57.60	pcf	
Saturated Unit Weight of Soil Above Geomembrane, γ_{sat} =	120.00	pcf	
Friction Angle of Soil Above Geomembrane, ϕ =	**27.00**	**degrees =**	*0.47 radians*
Cohesion of Soil Above Geomembrane, c =	**0.00**	**psf**	
Seismic Coeffecient, k_s =	0.078	g	

A	***B***	***C***	
$[\gamma_t$ x (t-t_w) + γ_b x $t_w]$	**$[\gamma_t$ x (t-t_w) + γ_{sat} x $t_w]$**	**tanδ/tanβ**	**[A/B] x C**
218.900	220.210	2.363	2.349

D			***E***	***F***	***G***	
[a/sinβ]	**D/B**		**γ_t x (t-t_w*) + γ_b x t_w*]/B**	**[tanϕ/(2sinβcos$^2\beta$)]/(1-tanβtanϕ)**	**t/h**	**E x F x G**
260.050	**1.180918193**		0.994	1.504	0.200	0.299

H	***I***	***J***	
1/B	**[1/(sinβcosβ)]/[1-tanβtanϕ]**	**ct/h**	**H x I x J**
0.005	5.790	0.000	0.000

A'	***B'***	***C'***	***D'***	**[A'+B'-C']/D'**
a/[γ_t x t x cos^2(β)]	**tanϕ x [1-(γ_w x t_w)/(γ_t x t)]**	**n_q x tanβ x tanϕ**	**n_q + tanβ**	2.531
0.241	0.470	0.007	0.278	

FS (Seismic)
2.531

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VENEER SLOPE STABILITY CALCULATIONS - 5H:1V SLOPE

Purple highlighted parameters are inputted

Internal Slope Failure (Unsaturated Post-EQ)

Analysis of all lower interfaces (subgrade-to-geomembrane, geomembrane-to-geocomposite, geocomposite-to-cover soil)

(Conversion of degrees to radians are performed for Excel spread sheet calculations)

20% (5H:1V slope) β =	11.31	degrees =	*0.20 radians*
Interface Friction, δ =	**17.10**	**degrees =**	*0.30 radians*
Interface Adhesion, a =	**0.00**	**psf**	
Thickness of soil above geomembrane, t =	**2.00**	**ft**	
Thickness of Saturation (water) t_w =	0.021	ft	
t_w^* =	0.021	ft	
Height of slope, h =	10.0	ft	
Total Unit Weight of Soil Above Geomembrane, γ_t =	**110.00**	**pcf**	
Effective Unit Weight, γ_b =	57.60	pcf	
Saturated Unit Weight of Soil Above Geomembrane, γ_{sat} =	120.00	pcf	
Friction Angle of Soil Above Geomembrane, ϕ =	**27.00**	**degrees =**	*0.47 radians*
Cohesion of Soil Above Geomembrane, c =	**0.00**	**psf**	
Seismic Coeffecient, k_s =	0.000	g	

A	*B*	*C*	
$[\gamma_t \times (t-t_w) + \gamma_b \times t_w]$	$[\gamma_t \times (t-t_w) + \gamma_{sat} \times t_w]$	$\tan\delta/\tan\beta$	**[A/B] x C**
218.900	220.210	1.538	1.529

D		
$[a/\sin\beta]$	**D/B**	
0.000	**0**	

E	*F*	*G*	
$\gamma_t \times (t-t_w^*) + \gamma_b \times t_w^*]/B$	$[\tan\phi/(2\sin\beta\cos^2\beta)]/(1-\tan\beta\tan\phi)$	t/h	**E x F x G**
0.994	1.504	0.200	0.299

H	*I*	*J*	
1/B	$[1/(\sin\beta\cos\beta)]/[1-\tan\beta\tan\phi]$	ct/h	**H x I x J**
0.005	5.790	0.000	0.000

A'	*B'*	*C'*	*D'*	[A'+B'-C']/D'
$a/[\gamma_t \times t \times \cos^2(\beta)]$	$\tan\phi \times [1-(\gamma_w \times t_w)/(\gamma_t \times t)]$	$n_q \times \tan\beta \times \tan\phi$	$n_q + \tan\beta$	1.529
0.000	0.306	0.000	0.200	

FS (Post-EQ)
1.828

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