Intended for
Dynegy Midwest Generation, LLC

Date
November 5, 2021

Project No.
1940101010-004

GROUNDWATER MODEL REPORT

EAST ASH POND
HENNEPIN POWER PLANT
HENNEPIN, ILLINOIS

DRAFT

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HENNEPIN POWER PLANT EAST ASH POND

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ACRONYMS AND ABBREVIATIONS

§	Section
35 I.A.C.	Title 35 of the Illinois Administrative Code
amsl	above mean sea level
AP2	Ash Pond No. 2
AP4	Ash Pond No. 4
CCWL	Coal Combustion Waste Landfill
CBR	closure-by-removal
CCR	coal combustion residual
CIP	closure-in-place
cm/s	centimeter per second
DMG	Dynegy Midwest Generation, LLC
EAP	East Ash Pond
EAPS	East Ash Pond System
ft/d	feet per day
Geosyntec	Geosyntec Consultants, Inc.
GWPS	groundwater protection standards
HCR	Hydrogeologic Site Characterization Report
HELP	Hydrologic Evaluation of Landfill Performance
HDPE	high density polyethylene
HPP	Hennepin Power Plant
ID	identification
IEPA	Illinois Environmental Protection Agency
in/yr	inches per year
LDPE	low density polyethylene
mg/L	milligrams per liter
mil	One thousandth of an inch
NAVD88	North American Vertical Datum of 1988
NID	National Inventory of Dams
No.	number
NPDES	National Pollutant Discharge Elimination System
Part 845	35 I.A.C. § 845: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments
Ramboll	Ramboll Americas Engineering Solutions, Inc.
SI	surface impoundment
SP	stress period
TDS	total dissolved solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

EXECUTIVE SUMMARY

Ramboll Americas Engineering Solutions, Inc. (Ramboll) has prepared this Groundwater Model Report on behalf of Hennepin Power Plant (HPP), operated by Dynegy Midwest Generation, LLC (DMG), in accordance with requirements of Title 35 of the Illinois Administrative Code (35 I.A.C.) Section (§) 845: Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments (Part 845) (Illinois Environmental Protection Agency [IEPA], April 15, 2021). This document presents the results of predictive groundwater modeling simulations for proposed closure scenarios for the East Ash Pond (EAP; Vistra identification [ID] number [No.] 803, IEPA ID No. W1550100002-05, and National Inventory of Dams [NID] No. IL50363) at HPP in Hennepin, Illinois..

The EAP is one of three coal combustion residuals (CCR) surface impoundments (SI), and two non-CCR units (Leachate Pond and the Polishing Pond) that are collectively known as the East Ash Pond System (EAPS). The Coal Combustion Waste Landfill (CCWL; Vistra ID No. 801) is located adjacent to and north of the EAP. Ash Pond No. 2 (AP2; Vistra ID No. 802) and Ash Pond No. 4 (AP4; Vistra ID No. 804) are located adjacent to each other and to the north and west of the EAP, respectively. Both AP2 and AP4 were closed in-place in 2020, in accordance with closure and post-closure care plans approved by IEPA (Civil & Environmental Consultants, Inc., 2017). The HPP property is bordered to the north by the Illinois River, to the south and east by industrial property, and to the west by agricultural land and the Donnelly WMA. The EAP is a lined unit constructed in 1995 to 1996.

Groundwater at the EAPS is encountered in unconsolidated alluvial and glacial outwash materials which overlie a shale bedrock. CCR material at the EAP and CCWL are located above the water table and described in the *Hydrologic Site Characterization Report* for the EAP (Ramboll, 2021a). The *History of Potential Exceedances* (Ramboll, 2021b) indicated that there are no potential groundwater exceedances of applicable groundwater standards attributable to the EAP.

Groundwater flow and transport at the EAP was simulated using site-specific MODFLOW and MT3DMS models, which were modified from pre-existing models developed to simulate unit closure at AP2 and AP4 in 2017. Modifications to the 2017 models generally consisted of the following:

- Changes to the recharge distributions for the EAP and the polishing ponds for the years 1996-present
- Incorporation of changes in recharge for AP2 and AP4 to reflect closure of those units (completed in November 2020)
- Alterations to the time discretization to extend the second stress period from 2017 to November 2020
- Addition of a third stress period to represent conditions following closure of AP2 and AP4 up to the present.

A qualitative calibration was performed to compare simulated concentrations following closure of AP2 and AP4 to observed boron concentrations from 2020 and 2021. Results of the qualitative calibration indicated the modified MODFLOW and MT3DMS models were appropriate for simulation of proposed closure scenarios at the EAP.

Predictive simulations were performed to evaluate the effects of the proposed capping system on surrounding groundwater quality. Three predictive source control scenarios were evaluated for the EAP:

- No-action.
- Closure-in-place (CIP).
- Closure-by-removal (CBR).

Infiltration rates for each predictive scenario were calculated using the Hydrologic Evaluation of Landfill Performance software (HELP), according to proposed design parameters and specifications. Predictive simulations of EAP closure scenarios indicated boron concentrations at monitoring network wells will remain below 2 milligrams per liter (mg/L) (maintaining compliance with the groundwater protection standards [GWPS]) for no action, CIP, and CBR remedial actions. Both closure scenarios (CIP and CBR) demonstrate maintained compliance with the GWPS beyond the post-closure care period of 30 years.

1. BACKGROUND

1.1 Overview

In accordance with Part 845 (IEPA, 2021), Ramboll has prepared this Groundwater Model Report on behalf of HPP, operated by DMG. This document was prepared to present the results of predictive groundwater modeling simulations for proposed closure scenarios for the EAP at the HPP in Hennepin, Illinois.

Site hydrogeology, and groundwater quality are summarized in **Section 1**, and described in detail in the Hydrogeologic Site Characterization Report (HCR; Ramboll, 2021a). The HCR was completed and submitted with the Initial Operating Permit for the EAP as required by 35 I.A.C. § 845.230(d)(2)(I)(i).

Previously-developed site-specific MODFLOW and MT3D flow and transport models were modified and used to assess the effects of the proposed capping system on surrounding groundwater quality, documented in **Section 2**. The details of model calibration and prediction results are presented in **Sections 3 and 4**, respectively. **Section 5** presents a summary of the report with an emphasis on results of predictive modeling of closure scenarios for the EAP.

1.2 Site Description and Hydrogeology

1.2.1 Site Description

The HPP is located in northcentral Illinois in Putnam County, approximately four miles northeast of the Village of Hennepin. The EAP is located in the northeast quarter of Section 26, Township 33 North, Range 2 West, Putnam County, Illinois. The EAP is located south of the Illinois River and approximately one mile east of the Big Bend, where the river shifts course from predominantly west to predominantly south. Existing CCR impoundments and other site structures border the EAP to the north, west, and east. Surrounding areas include industrial properties to the east and south of the EAPS, agricultural land to the southwest, and the retired HPP to the west.

The HPP had two coal-fired units constructed in 1953 and 1959 with capacities of 70 and 210 megawatts, respectively. The plant initially burned high-sulfur Illinois coal and switched to sub-bituminous Powder River Basin coal in 1999.The plant ceased operations in November of 2019 when the plant was retired.

The CCR Units located adjacent to each other in the eastern portion of the HPP are AP2, AP4, and the EAP (referred to as the Primary East Ash Pond in previous documents), and non-CCR units including the Leachate Pond (formerly Pond 2E) and the Polishing Pond (formerly Secondary Pond); all of which comprise the East Ash Pond System (EAPS) (**Figure 1**). The CCWL was constructed on a portion of AP2 and is included in the extent of the EAPS. The CCR Units associated with the EAPS are situated south and adjacent to the Illinois River. The area is also bounded to the east and south by industrial properties owned by Tri-Con Materials and Washington Mills, respectively. The HPP provides the western boundary for the CCR Units with agricultural land to the southwest. Additionally, a 9-acre parcel between the HPP property and Washington Mills (south of the CCR Units) was previously occupied by Advanced Asphalt but operations are no longer active, and the property contains several buildings. The current owner of this parcel is listed as Tri-Con Materials.

Figure 1 depicts the location of the CCR Units and non-CCR Units within the EAPS. The four Hennepin EAPS CCR units consist of the following: one existing landfill (CCWL), one existing SI (EAP), and two IEPA-approved, closed SIs (AP2 and AP4). A detailed history of the EAPS is presented in the HCR (Ramboll, 2021a). Operational changes and relevant site activities are described below:

- The EAP was completed in 1996, and used to store bottom ash, fly ash, and other non-CCR waste. Discharge from the EAP was routed to the adjacent non-CCR Leachate Pond and Polishing Pond prior to its discharge to the Illinois River in accordance with the plant's National Pollutant Discharge Elimination System (NPDES) permit. The pond is approximately 21 acres in size, and was constructed with a 4-foot thick clay liner at the base; containment dikes surrounding the unit were raised in 2003. Disposal of CCR waste in the EAP stopped in 2019 when the power plant was retired from service.
- AP4 is a former unlined impoundment. This unit was closed in place with final cover completed in November 2020.
- The Polishing Pond was constructed in 1995 with a 48-inch thick compacted clay liner having a vertical hydraulic conductivity of 1×10^{-7} centimeters per second (cm/s).
- AP2 is a former unlined impoundment constructed in 1958 and used to store fly ash, bottom ash, and other non-CCR waste streams (*e.g.,* coal pile runoff). The pond was removed from service in 1996. Groundwater modeling of this unit was conducted in 2017 and 2020 in support of unit closure, and this unit was closed-in-place in November 2020.
- The easternmost portion of AP2 was removed from service in 2010 to facilitate construction of the Leachate Pond. The Leachate Pond is lined with 60-millimeter high density polyethylene (HDPE) overlying three feet of compacted clay with a vertical hydraulic conductivity of 1×10^{-7} cm/s.
- Between the Leachate Pond and closed AP2 is the CCWL (Phase I), an overfill with geomembrane liner and leachate collection system that was completed in 2010. The CCWL (**Figure 1**) was completed in February 2011 but never used to store CCR actively generated at HPP. Approximately 7,000 cubic yards of bottom ash was placed over the liner system to provide ballast and freeze-thaw protection for the liner, but no other material has been placed in the CCWL since that time. Although additional landfill cells (*i.e.,* Phases II, III, IV) and a future bottom ash pond were planned in 2009, it was subsequently decided that no further construction of lined ash disposal units (landfill or bottom ash pond) would be undertaken because of decreased ash disposal due to beneficial reuse of CCR.

1.2.2 Site Hydrogeology

The hydrogeology of the EAP is described in detail in the Hydrologic Site Characterization Report (Ramboll, 2021a). A short summary is provided below.

The principal stratigraphic layers (from top to bottom) encountered at the EAP and adjacent areas are:

- Fill comprised of CCR, fly ash, bottom ash, and other non-CCR waste streams, including coal pile runoff
- Alluvial fine-grained silts and clays, classified as Cahokia Alluvium

- Sand and gravel with boulders, deposited by glacial meltwaters and classified as Henry Formation
- Shale Bedrock

The river is immediately adjacent to the lower terrace, east of the EAPS, and there is minimal alluvium between the pond system and the river. The highly permeable Henry Formation sands and gravels make up the upper and lower terraces, and fill the valley beneath the alluvium. The sand and gravels of the two terraces are indistinguishable, consisting of a heterogeneous mixture of silty-sandy gravel, with cobble zones and with boulders up to several feet in diameter. The Henry Formation is more than 100 feet thick in the river valley and at least 130 feet thick on the upper terrace.

The Henry Formation and alluvium comprise the uppermost aquifer at the EAPS and extend from the water table to the bedrock. This uppermost aquifer extends about 7,000 feet upgradient from the pond system to the south where clay-rich glacial till is encountered. Clay-rich glacial tills typically yield little water, especially compared with the high permeability Henry Formation.

The Henry Formation deposits are underlain by shale bedrock. The Pennsylvanian-age bedrock consists of interbedded layers of shale with thin limestone, sandstone, and coal beds. The shale bedrock unit has low hydraulic conductivity and defines the lower boundary of the uppermost aquifer.

Regional groundwater flow in the unlithified deposits above the shale bedrock discharges into the Illinois River. The primary flow direction of groundwater flow beneath the EAP is north (Ramboll, 2021a). Depth to the water table is typically greater than 20 feet below ground surface around the EAPS. The water table elevation can vary due to changes in river stage. During flood stages, exfiltration from the river may temporarily recharge groundwater close to the river, increasing the elevation of the water table beneath the EAPS and adjacent areas of the floodplain. Generally, groundwater elevations vary with river stage.

The lowest elevation of the ash within the lined EAP is 464 feet North American Vertical Datum of 1988 (NAVD88). Saturation of ash in the EAP due to flooding in the Illinois River is not expected to occur based upon historic observed river stage, the 100-year FEMA flood elevation of 462 ft amsl, and the presence of the liner system below the CCR material.

1.3 Groundwater Quality

There are no potential groundwater exceedances of applicable groundwater standards attributable to the EAP as described below.

Groundwater quality at the EAPS has been monitored since 1983. At this time, groundwater monitoring is being conducted to meet requirements of several overlapping programs for the IEPA and United States Environmental Protection Agency (USEPA). Generally, monitoring to identify groundwater impacts due to operation of the EAPS consists of chemical constituents related to CCR products and disposal, specifically for metals and general groundwater quality indicators (pH, sulfate, chloride, and total dissolved solids [TDS]). A full history and summary of groundwater monitoring at the EAPS is presented in the HCR (Ramboll, 2021a). Groundwater concentrations from 2015 to 2021 presented in HCR Table 4-1 and summarized in the History of Potential Exceedances (attached to the Operating Permit Application) are considered potential exceedances because the methodology used to determine them is proposed in the Statistical

Analysis Plan (Appendix A to Groundwater Monitoring Plan [GMP]) which has not been reviewed or approved by IEPA at the time of submittal of the Part 845 Operating Permit application.

Table 1 of the *History of Potential Exceedances* (Ramboll, 2021b) summarizes how potential exceedances were identified following the proposed Statistical Analysis Plan. No potential exceedances were identified for the EAP. This includes monitoring data for boron, which was selected as the constituent for transport modeling. The applicable GWPS for boron is 2 mg/L.

2. GROUNDWATER MODELING APPROACH

This section describes the approach to the modeling task documented in this report.

2.1 Modeling objectives

Under current conditions, the groundwater protection standards are being met for the EAP. Proposed plans for Closure-in-place (CIP) and Closure-by-removal (CBR) are effective source control measures that further mitigate future groundwater impacts by minimizing the hydraulic head on the CCR in the lined unit; or, through removal of the CCR. While no potential exceedances of GWPS have been identified in the monitoring well network for this unit (**Section 1.3**); and, source control will mitigate future groundwater impacts, groundwater modeling of closure alternatives was completed to demonstrate that closure will maintain compliance with applicable groundwater quality standards following construction.

Boron was selected for groundwater transport modeling. Boron is commonly used as an indicator parameter for contaminant transport modeling for CCR because: (i) it is commonly present in coal ash leachate; (ii) it is mobile and typically not very reactive but conservative (*i.e.*, low rates of sorption or degradation) in groundwater; and (iii) it is less likely than other constituents to be present in background groundwater from natural or other anthropogenic sources.

Previously, contaminant fate and transport modeling for boron was performed to support closure of AP2 and AP4 using MODFLOW and MT3D (O'Brien and Gere Engineers, Inc. [OBG], 2017). The EAP is present within the previous model domain and was simulated as part of AP2 and AP4 models. Groundwater elevation and concentration data from wells located between AP2 and the EAP are consistent with previously simulated values and have not consistently exceeded GWPS for boron.

2.2 Model Code Selection

This section describes the model codes used to provide site-specific prediction estimates for the EAP.

2.2.1 MODFLOW

For the construction and calibration of the numerical groundwater flow model for the site, Ramboll selected the model code MODFLOW, a publicly-available groundwater flow simulation program developed by the United States Geological Survey (USGS) (McDonald and Harbaugh, 1988). MODFLOW is thoroughly documented, widely used by consultants, government agencies and researchers, and is consistently accepted in regulatory and litigation proceedings. MODFLOW uses a finite difference approximation to solve a three-dimensional head distribution in a transient, multi-layer, heterogeneous, anisotropic, variable-gradient, variable-thickness, confined or unconfined flow system. User-supplied inputs are hydraulic conductivity, aquifer/layer thickness, recharge, wells, and boundary conditions. The program also calculates water balance at wells, rivers, and drains. Principal assumptions governing groundwater flow simulation include: 1) groundwater flow is governed by Darcy's law; 2) the formation behaves as a continuous porous medium; 3) flow is not affected by chemical, temperature, or density gradients; and 4) hydraulic properties are constant within a grid cell.

This groundwater flow modeling used MODFLOW-96 (Harbaugh and McDonald, 1996), with Groundwater Vistas 7 software for model pre- and post- processing tasks (Environmental Simulations, Inc, 2017).

2.2.2 MT3DMS

MT3DMS (Zheng and Wang, 1998) is an update of MT3D. It calculates concentration distribution for a single dissolved solute as a function of time and space. Concentration is distributed over a three-dimensional, non-uniform, transient flow field. Solute mass may be input at discrete points (wells, drains, river nodes, constant head cells), or distributed evenly or unevenly over the land surface (recharge).

MT3DMS accounts for advection, dispersion, diffusion, first-order decay and sorption. Sorption can be calculated using linear, Freundlich, or Langmuir isotherms. First-order decay terms may be differentiated for the adsorbed and dissolved phases.

The program uses the standard finite difference method, the particle-tracking-based Eulerian-Lagrangian methods, and the higher-order finite-volume total-variation-diminishing TVD method for the solution schemes. The finite difference solution can be prone to numerical dispersion for low-dispersivity transport scenarios, and the particle-tracking method has problems in conserving mass-balance. The TVD solution is not subject to numerical dispersion and conserves mass well, but is computationally intensive. For this modeling, the TVD solution was used.

Major assumptions include: (i) changes in the concentration field do not affect the flow field; (ii) changes in the concentration of one solute do not affect the concentration of another solute; (iii) chemical and hydraulic properties are constant within a grid cell; and (iv) sorption is instantaneous and fully reversible, while decay is not reversible.

2.2.3 HELP

Percolation through the cap system was calculated using the HELP model, version 4.0 (Tolaymat and Krause, 2020). The HELP model was developed by USEPA in the 1990s to estimate the head and water balance expected for landfill liner or cover design specifications.

2.3 Description of Existing Model

Site-specific MODFLOW and MT3DMS models were developed to provide simulation results at AP2 in 2010, and updated in 2017 to provide predictive simulations for AP2 closure (OBG, 2017). The 2017 models were used as the base for the EAP closure modeling.

The 2017 models consisted of the following:

- Steady-state MODFLOW/MT3DMS models were developed to represent site conditions prior to 1996. This model was calibrated to a set of groundwater elevation data and concentrations collected in September 1995.
- Calibrated transient MODFLOW and MT3DMS models which simulated groundwater flow and transport at the EAPS from 1996 to 2017. Groundwater elevations and boron concentrations collected throughout this period were used to calibrate the models.

- Predictive simulations to estimate future boron concentrations for a number of closure scenarios for AP2 and AP4. Closure action was modeled over a period of 20 years, beginning in January 2018.

2.4 Modeling Approach

The 2017 flow and transport models were retained and revised as appropriate to perform simulations for the EAP.

EAP Current Conditions

Modifications to the 2017 model were required to simulate conditions at the EAP from initial operations at the EAPS to the current time ("current conditions" model). The existing model used one steady-state period and two transient stress periods to simulate and calibrate historical/current conditions through 2017. Recalibration of the flow and transport model was not performed; however, model results were compared to site concentration and groundwater elevation data collected in 2020 and 2021 to confirm that model simulation results were overall reasonable for assessment of current conditions at the EAPS.

Modifications to the 2017 model are detailed in **Section 3**, but generally consisted of changes to the recharge distributions for the EAP and the polishing ponds for the years 1996 to present, incorporation of changes in recharge for AP2 and AP4 to reflect closure of those units in November 2020, alterations to the time discretization to extend the second stress period from 2017 to November 2020, and addition of a third stress period to represent conditions following closure of AP2 and AP4 up to the present time.

Predictive Modeling

The EAP current conditions model was then used as a starting point for the predictive modeling, which simulates changes in boron concentrations for 50 years following unit closure. These scenarios are intended to represent proposed closure alternatives for the EAP (including anticipated changes to the CCWL) and utilize the design specifications from the *Draft CCR Final Closure Plan*, which is Appendix I of the Draft Construction Permit Application (Geosyntec, 2021) to which this report is also attached. No action, CIP, and CBR scenarios were simulated:

- No Action – Assumes no closure at the EAP (current conditions retained). Closure of the CCWL was simulated with an estimated completion on February 1, 2025.
- EAP CIP – The EAP will be graded and covered with a geomembrane and soil layers. The CCWL will also be closed, with an estimated completion on December 22, 2023.
- EAP CBR – CCR materials from the EAP will be removed. The existing liner system and 1 foot of material beneath the side slope and bottom liner will be excavated. Closure of the CCWL will also be performed, with the estimated completion date of October 24, 2025.

Details and results of predictive simulations are presented in **Section 4**.

3. MODEL DEVELOPMENT AND CALIBRATION

This section describes the development and calibration of the EAP current conditions MODFLOW and MT3DMS models. The calibrated 2017 model, which was developed to simulate historical flow and transport for AP2, was used as the base for the current conditions model for the EAP. This section describes the overall construction and components of the EAP flow and transport model. Since most of the components of the existing model were retained, this section provides a brief summary of model components that were not changed, with more detail for the modifications made to the model for EAP simulation. Refer to the AP2 model report (OBG, 2017) for further documentation.

3.1 Flow Model Development

The development process for a numerical groundwater flow model consists of construction of a finite-difference grid for the model area, specification of model structure, assignment of boundary conditions, specification of hydraulic parameter values and zones, and selection of appropriate water-level measurements for calibration of the model. These features represent elements of the conceptual site model, which provides the basis for the construction and calibration of the numerical model to observed groundwater flow conditions at the site.

3.1.1 Model Discretization

The model domain is approximately 8,000 feet by 6,000 feet, and encompasses the area of the EAPS and sufficient surrounding areas to accurately simulate flow near the EAP. The northern boundary of the model domain is located beyond the Illinois River, which is the natural discharge for the model domain. The southern edge of the model domain extends approximately 3,500 feet south of the EAPS, and the model domain extends approximately 2,500 feet to the east and west of the EAPS. Vertically, the model domain extends from the water table to top of bedrock. The shale bedrock is relatively impermeable compared to the overlying unconsolidated sediments, and provides a base for the model.

The model grid is rotated 9 degrees from true north to match the approximate alignment of the southern bank of the Illinois River at the site, and consists of a rectangular grid of 157 columns and 112 rows (**Figure 2**). Grid spacing is variable; a uniform 25 by 25 foot grid was specified for the EAPS, with increasing grid spacing moving from the EAPS to the edge of the model domain. The largest grid dimension is 500 feet, at the upgradient (southern) edge of the model domain.

Four model layers were specified to represent the alluvium and glacial outwash materials above bedrock. Natural vertical stratigraphic divisions are not present in the unconsolidated materials beneath the EAPS, so uniform layer bottom elevations were selected. Model layer 1 is unconfined, with the water table representing the top of the layer; the bottom elevation of model layer 1 is 430 feet above mean sea level (amsl), which gives it an approximate, spatially variable saturated thickness of 15 to 20 feet. Layers 2, 3, and 4 were specified with uniform thicknesses of 8 feet, with bottom elevations of 422, 412, and 406 feet amsl, respectively. Bedrock is encountered at an elevation of 400 to 410 feet amsl beneath the EAP.

3.1.1.1 Time Discretization and Stress Periods

The simulation length was revised from the existing model to extend to the current time (2021), and a third stress period was added to simulate closure of AP2 and AP4 in November 2020. The time discretization and stress periods are summarized in **Table A** below.

Table A. Time Discretization and Stress Periods

Date	Operational Change	Previous model	Current Conditions Model
1958-1989	Operation of AP2, with multiple embankment increases	Steady-State initial conditions simulation	Steady-state initial conditions simulation. Heads and concentrations generated were used for initial conditions.
1996-2010	Operation of AP2 and EAP	Stress Period 1	Stress Period 1 (5,099 days)
2010-2020	AP2 was reconfigured with construction of the Leachate Pond and CCWL	Stress Period 2	Stress Period 2, extended from 2017-2020 (3,623 days)
November 2020	Closure of AP2 and AP4 completed	Not applicable	Current Conditions: Stress Period 3 (1,146; 1,553; or 1,818 days for simulation of current conditions until EAP closure remedy completed)
Predictive Scenarios (2023 or 2025 + 50 years)	No Action, EAP CIP, EAP CBR	Not applicable	18,250 days (50 years) for model predictions. Completed as new transient model simulations, using results of current conditions simulation as starting concentrations for the appropriate final closure date

3.1.2 Boundary Conditions

Groundwater flow directions at/near the EAPS are generally aligned with the model grid, from south to north. The upgradient (southern) edge of the model is represented as a constant head boundary, located at sufficient distance from the site to produce a groundwater flow field consistent with observed groundwater elevations at the EAP. The northern edge of the active model domain is defined by river cells which represent the Illinois River in model layer 1, with inactive (no-flow) cells between the edge of the river and the model domain. Boundary conditions are shown on **Figure 2**.

The river cells and constant head cells which define the downgradient and upgradient edges of the model were not modified from the 2017 model. The constant head cells were specified in model layer 1 with an elevation of 458 feet amsl. River cells are specified with an elevation of 444 feet amsl, which represents an average stage of the Illinois River. These values were selected during the 2017 model construction and calibration.

Variation in stage of the Illinois River was not incorporated into the current conditions model for the EAP; since the objective of model simulations for unit closure is to estimate long-term concentrations, steady-state, average stage was used to represent the river. However, periodic flooding of the river can create short-term reversals in groundwater flow direction near the river, which is documented in site reports. The potential effects of river floods on groundwater flow and boron concentrations in Site groundwater were evaluated as part of the AP2 closure process, using a transient model developed specifically to represent these conditions (Ramboll, 2020). As documented in the modeling report, saturation of ash at the former AP2 due to high river stage is unlikely to occur for any but the most extreme flood events, and does not result in appreciable increases in boron concentrations in groundwater compared to current concentration levels. The base of ash at the EAP is higher than at AP2 and does not have the potential for saturation during even extreme recorded flood events.

3.1.3 Recharge Rates

Recharge specified in model layer 1 represents infiltration of precipitation and vertical influx from ash pond operation. A number of recharge rates are used to represent variable infiltration from portions of the EAPS, with changes in time (per stress period) representing changes in the EAPS. Most of the recharge assignments from the 2017 model were maintained for stress periods 1 and 2, although new values were assigned for the EAP and the polishing pond.

Stress period 3 incorporated revisions to the recharge rates for AP2 and AP4, to represent post-closure conditions at these units. The recharge values for the closed units were originally calculated using HELP as part of the 2017 predictive modeling; since construction specifications were consistent with predictive simulations, the original calculated infiltration rate of 1.9 in/yr was assigned to AP2 and AP4.

Figures 3 through 5 present simulated recharge distributions and values for stress periods 1, 2, and 3.

3.1.3.1 Polishing Pond

The infiltration rate and the recharge extent (area) for the polishing pond was revised from the 2017 model to better represent current conditions. The polishing pond was not used for disposal of CCR materials. The pond is lined and currently impounding water, to a constant (managed) elevation of 476 feet amsl. The base of the pond is at 462 feet, and is underlain by four feet of clay placed atop native material. The water table is 16 feet below the base of the pond.

The constant head maintained in the impoundment indicated a head-based calculation of infiltration (Darcy's Law) was more appropriate than a runoff/water balance model (HELP). Site-specific values of hydraulic conductivity were used where appropriate, with values from the HELP model database (Tolaymat and Krause, 2020) used where site specific data were not available. Calculated infiltration from the pond to the water table is 9.3 inches per year (in/yr). Calculation details are presented in **Appendix A**.

3.1.3.2 EAP

Although the infiltration rate at the EAP in its current configuration was previously calculated and simulated in the 2017 model, the focus on the EAP for this modeling effort warranted recalculation of infiltration at the EAP for current conditions. The EAP has been slowly accumulating CCR materials over time and is currently impounding water, with standing water in a portion of the total footprint at an elevation of 487 feet amsl. A constant water level is maintained in the EAP through draining of water into the polishing pond. The EAP is lined and was constructed at its base with a 4-foot clay layer, underlain by 1 foot of sand, atop the native glacial outwash material. The base of ash within the EAP is 464 feet amsl and the base of the surface impoundment (i.e. clay) is 460. The approximately 23.5 feet of saturation within the pond indicates that the liner is competent, and the normal water table is encountered approximately 10 to 14 feet below the base of the clay liner.

The constant head maintained in the EAP indicated a head-based calculation of infiltration (Darcy's Law) was more appropriate that a runoff/water balance model (HELP). Site-specific values of hydraulic conductivity were used where appropriate, with values from the HELP model database used where site specific data were not available. Calculated infiltration from the impoundment is 12.9 in/yr. Calculation details are presented in **Appendix A**.

3.1.4 Hydraulic Conductivity

In constructing the model for the site, representative values for horizontal and vertical hydraulic conductivity of various hydrogeologic units were selected based on the results of hydraulic testing conducted at the site as well as regional information. The hydraulic conductivities specified in the existing MODFLOW model were selected from site data and were carefully adjusted during calibration and sensitivity testing; these values were retained for the EAP modeling. Uniform hydraulic conductivity zones were specified in model layers 1 through 4 to represent different materials.

The highly-permeably glacial outwash deposits present in the northern portion of the model domain were simulated with hydraulic conductivities of 100, 500, and 1,000 feet per day (ft/d); the finer-grained sands present in the southern portion of the model domain was simulated with a hydraulic conductivity of 35 ft/d in all model layers. Two new estimates of hydraulic conductivity of the glacial outwash were obtained from slug tests performed at new wells MW-53 and MW-54 (Ramboll, 2021a), and the averaged results of these wells are consistent with the hydraulic conductivity distribution in the existing model.

Hydraulic conductivity values used in the model were not modified to reflect changes in ash pond operation, since the ash ponds and associated structures (berms, clean water ponds) are located above the water table. **Figure 6** presents the hydraulic conductivity distributions for model layers 1 through 4.

3.2 Transport Model Development

The development process for an MT3DMS transport model consists of construction of a finite-difference grid for the model area, specification of model structure, assignment of boundary conditions, specification of hydraulic parameter values and zones, and selection of appropriate chemical concentrations for calibration of the model. These features represent elements of the conceptual site model, which provides the basis for the construction and calibration of the numerical model to observed groundwater concentration data.

The MT3DMS model for boron developed for AP2 was adapted for the EAP model. Changes made to the 2017 model are detailed below, with summary information provided for the retained model characteristics. A full description of model construction and calibration is presented in the 2017 model report (OBG, 2017).

Since the ash fill is above the water table, the conceptual model for transport assumes the only source of boron to the system originates from boron that leaches to infiltration of process water or rainwater as it percolates through the CCR above the water table. The conceptual transport model assumes that boron concentration in leachate does not vary as a function of time, although the volume of leachate decreases over time as a function of pond dewatering and capping. There is no removal of mass from the groundwater system via adsorption or decay.

3.2.1 Initial Concentration

Initial concentrations for the current conditions model were generated from the 1997 steady-state model which represents the early operation of the EAPS (1958-1996). Simulated boron concentrations in groundwater used to represent 1996 concentrations varied from 0 to 21 mg/L.

3.2.2 Source Concentration

Concentrations of boron in leachate (recharge from the EAPS) were specified for AP2, AP4, and the EAP in Stress Periods 1, 2, and 3. The CCWL and leachate pond also have specified concentrations of boron recharge due to their construction above portions of the former AP2. A few of the recharge concentration settings were modified from the 2017 model to better represent current conditions. In the 2017 model, the polishing pond had been simulated with the same recharge concentration as the EAP (4 mg/L). Since the polishing pond was not used for CCR disposal, the recharge boron concentration at the polishing pond was set to zero in all stress periods. Stress Period 3 incorporated removal of a small portion of the embankments for AP2 nearest the Illinois River, so recharge for this area was set to zero for this period. Boron recharge concentrations are summarized in **Table B** below.

Table B. Boron Recharge Concentrations, mg/L

	SP1	SP2	SP3
Western portion of AP2 (closed in 2020)	9	9	9
Portion of AP2 embankment near the river	5	5	5
AP4 (closed in 2020)	5	5	5
Central portion of AP2 (closed in 2010)	16	16	16
CCWL (formerly AP2)	16	16	16
Leachate Pond (formerly AP2)	16	16	16
Narrow Zone within central/eastern AP2	10/20	10/16	10/16
EAP	4	4	4

SP = stress period

A total of nine porewater samples were collected in 2020 from three new wells completed into ash materials within the EAP (Ramboll, 2021a). Boron concentrations in these samples varied from 2.3 to 4.21 mg/L, which indicates that the 4 mg/L boron recharge concentration simulated for the EAP in the 2017 model is appropriate.

3.2.3 Storage and Effective Porosity

The storage and effective porosity values specified in the 2017 model were retained without modification. Zonation of storage/porosity was coincident with the distribution of hydraulic conductivity, with two zones in each layer and summarized in **Table C** below.

Table C. Storage, Specific Yield, and Effective Porosity Values

Location	Storativity	Specific Yield	Effective Porosity
L1/L4: near river	1×10^{-4}	0.2	0.15
Away from river (all layers)	1×10^{-3}	0.18	0.1
L2/L3: near river	1×10^{-5}	0.25	0.2

3.2.4 Dispersivity and Diffusion

Longitudinal dispersivity was 35 feet, with transverse and vertical dispersion coefficients assuming a ratio of 1/10 and 1/100, respectively (Gelhar et al., 1992). Sensitivity testing performed in 2017 indicated negligible to low sensitivity of model results to dispersivity. Diffusion was set to 0 for the entire model domain.

3.2.5 Retardation and Decay

A distribution coefficient of zero was selected to yield a retardation factor of 1.0. A decay coefficient of zero was modeled, as is appropriate for inorganic constituents. Therefore, this modeling assumed no adsorption and no decay.

3.3 Qualitative Calibration to Current Conditions

Calibration of a groundwater flow or transport model refers to the iterative process of adjusting model parameters and boundary conditions to obtain a reasonable match between observed conditions and simulation results. The calibration of a groundwater flow model should rely on discrete measurements of groundwater elevation to avoid the potential for interpretive bias that may result from attempting to match a contoured potentiometric surface (Konikow, 1978; Anderson and Woessner, 1992). The primary criterion for evaluating the calibration of a groundwater flow model is the difference between observed and simulated water levels at a set of calibration targets. Groundwater transport models are calibrated using concentration targets, with application of the same principles.

Extensive calibration and parameter sensitivity testing was performed during the 2017 model development. Traditional calibration (*i.e.,* residuals and statistics) was not conducted for the minor model revisions of the historical model. A qualitative calibration was performed to evaluate results of stress period 3 (current conditions) and confirm an adequate agreement between observed and simulated groundwater elevations and concentrations.

3.3.1 Groundwater Elevations

Due to the high conductivity of the materials at the site and the flow system geometry, with parallel flux boundaries (constant head cells and river cells), simulated groundwater elevations are relatively uniform across the EAPS, with a gradient consistent with average conditions. This is also true for observed values over time; at any given measurement date, measured groundwater elevations are relatively uniform. However, while groundwater elevations at the site are generally uniform for any particular date, the actual elevations can vary by 8 to 10 feet due to the high sensitivity of groundwater elevation to river stage. Groundwater elevations simulated in the EAP model are within the range of measured groundwater elevations at the site, and maintain the appropriate gradient across the EAPS.

3.3.2 Boron Concentrations

The calibration of the 2017 transport model was limited to data before 2017. Measured boron concentrations from 2020 and 2021 were compared to model results from Stress Period 3 to assess accuracy of transport calibration to the current time. This is important due to the closure of AP2 and AP4 in November 2020.

Table 1 presents a summary of observed boron concentration data for wells at the EAPS in 2020-2021 versus simulated concentrations. Simulated concentrations at the 11 EAP monitoring wells are within 0.1 mg/L of average observed concentrations at six of the wells and are within 0.4 to 0.6 mg/L at the other five wells. Generally, simulated concentrations for SP3 are slightly lower than observed values, but this is not universal. A number of wells show decreasing concentrations during SP3 following closure of AP2 and AP4 (**Figure 7**). Agreement between simulated and observed concentrations is sufficient to enable use of this model as a basis for prediction of concentrations after closure of the EAP.

3.4 Flow and Transport Model Assumptions and Limitations

Simplifying assumptions are necessary when numerically representing the natural environment in a groundwater flow and transport model. Outside of assumptions inherent to the codes used to develop the model, several simplifying assumptions were made, including:

- Leachate instantaneously migrates to groundwater (*e.g.,* rapid migration through the unsaturated zone).
- Fluctuations in river stage are short in duration and do not significantly affect groundwater flow and transport (supported by Ramboll, 2020).
- Hydraulic parameters such as hydraulic conductivity, storage, and recharge, can be represented using homogeneous zones that cover large areas of the model domain.
- Recharge rate outside the impoundment is constant over time.
- Source concentrations remain constant over time.
- Boron minimally adsorbs and does not decay, and mixing and dispersion are the primary attenuation mechanisms in groundwater.
- Cap construction has an instantaneous effect on recharge and percolation because it is constructed over a brief period relative to the length of the model simulation.

The model is limited by the data used for calibration, which adequately define the local groundwater flow system and the source and extent of the plume. Since data used for calibration are near to the EAP, model predictions of transport distant from the impoundment will not be as reliable as predictions of transport near the impoundment.

4. PREDICTIVE SIMULATIONS

The current conditions model for the EAP was extended in time and modified to simulate future conditions and groundwater concentrations of boron for proposed closure alternatives for the EAP. A total of three scenarios were simulated: no action, EAP CIP, and EAP CBR. Simulations were performed for a total of fifty years following completion of closure.

The results of the current conditions simulation, extended through the estimated completion date of each closure scenario, were used as initial conditions (heads and concentrations) for the predictive models. Previous model simulations for impoundment closure assumed instantaneous changes to the impoundment conditions at the time of closure (*i.e.,* the end date for the unit closure represents the step-change in conditions for each simulation), and this convention was retained for the EAP closure predictive modeling. The design specifications and parameters used to simulate EAP closure are described in detail in the Draft CCR Final Closure Plan (Geosyntec, 2021), which is Attachment I to the Draft Construction Permit Application to which this report is also attached.

Simulated changes in boron concentration for each of the EAP closure scenarios were evaluated by plotting predicted boron concentration at the 11 groundwater wells in the proposed EAP compliance monitoring network (Ramboll, 2021c).

4.1 No Action

A no-action scenario was simulated to predict boron concentrations if closure of the EAP is not completed, and to provide a baseline for evaluation of other closure options. It was assumed that no action was taken to cover or remove existing ash within the EAP; however, closure of the CCWL, which will be performed in conjunction with EAP closure, was simulated.

4.1.1 Landfill Closure

The CCWL was constructed in 2011 above the CCR in the eastern portion of AP2, with a geomembrane liner and leachate collection system installed to limit infiltration. A total of 7,500 cubic yards of bottom ash were placed into the CCWL to protect the liner system; however, no additional CCR or non-CCR materials have been placed into the CCWL since that time. The current configuration of the CCWL was simulated in the 2017 model and the EAP current conditions model with an infiltration rate of 0.3 in/yr and a boron concentration of 16 mg/L.

Closure of the CCWL will consist of excavation of landfilled bottom ash within the CCWL, installation of a geotextile cushion overtop the existing geomembrane and leachate collection system to protect the geomembrane, backfill with 5.5 feet of protective cover soil, and 0.5 feet of vegetative cover soil. The CCWL final surface will be graded to produce slopes of 1 to 2.5 percent. The existing liner and leachate collection system will remain in place. Construction was simulated to be completed on February 1, 2025.

The HELP program was used to estimate infiltration after landfill closure using the specifications from the Draft CCR Final Closure Plan. The estimated recharge rate at the CCWL after closure is 0.013 in/yr. Details of the HELP model simulation are presented in **Appendix A**.

4.2 Closure-in-Place

The proposed plan for CIP of the EAP consists of draining standing water from the EAP, backfilling and grading of the existing CCR materials, and installation of a final cover. The final cover will consist of a 40-mil low density polyethylene (LDPE) geomembrane with protective geotextile cushion, 1.5 feet of sand and gravel fill, and 0.5 feet of sandy clay soil as a vegetative cover layer. CIP of the EAP is predicted to be completed on December 22, 2023. The CCWL will also be closed during this time, as described above.

The HELP model was used to estimate the infiltration rate through the final cover. Cap and cover specifications for the EAP CIP simulation were based upon the current construction of the EAP and the information in the Draft CCR Final Closure Plan. HELP model inputs and outputs are detailed in **Appendix A**. An infiltration rate of 0.32 in/yr was calculated for the proposed EAP CIP remedy.

The EAP CIP scenario was simulated by changing infiltration rates for the EAP and the CCWL to 0.32 in/yr and 0.013 in/yr, respectively, starting on December 22, 2023. The 4 mg/L boron recharge rate specified for the EAP was retained for simulation of CIP.

A requirement for capping of CCR units with a geomembrane is that the calculated hydraulic flux through the liner be equivalent or less than calculated hydraulic flux for a 3-foot clay final cover system. The HELP calculated percolation/leakage through proposed CIP sequence with the 40-mil, linear low-density polyethene (LDPE) low-permeability layer for CIP is 0.32 in/yr. A hypothetical CIP sequence with the liner replaced by a 3-foot clay low-permeability layer with a hydraulic conductivity of 1×10^{-7} cm/sec was simulated in HELP to provide a basis for comparison. The calculated infiltration rate through the hypothetical CIP sequence with clay liner was 1.4 in/yr, which is higher than the calculated rate for the LDPE liner. Therefore, the proposed LDPE cover provides greater reduction of infiltration than an equivalent 3-ft thick clay final cover system. This HELP simulation is detailed in **Appendix A**.

4.3 Closure by Removal

The proposed plan for CBR of the EAP consists of unwatering, dewatering, and excavation of the CCR materials within the EAP, and excavation and removal of the 4-foot clay liner from the base and 1 foot of material beneath the liner system. The construction sequence is anticipated to require approximately 31 months to complete and will take place from March 13, 2023 to October 24, 2025. Closure of the CCWL will also be completed during this timeframe.

The HELP model was used to estimate the infiltration rate through base of the EAP following closure. Cap and cover specifications for the EAP CBR simulation were based upon the current construction of the EAP and the information in the Draft Basis of Design report (Geosyntec, 2021). HELP model inputs and outputs are detailed in **Appendix A**. An infiltration rate of 9.2 in/yr was calculated for the proposed EAP CBR remedy.

The EAP CBR scenario was simulated by changing infiltration rates for the EAP and the CCWL to 9.2 in/yr and 0.013 in/yr, respectively, starting on October 24, 2025. The boron concentration recharge for the EAP was changed to 0 mg/L to reflect removal of CCR material from the impoundment.

4.4 Evaluation of EAP Closure Scenarios

Boron concentrations were simulated for fifty years after EAP closure. Predicted boron concentrations at the 11 wells in the proposed EAP closure network are summarized below. The highest predicted concentration for the well network in 2020-2021 is 0.89 mg/L prior to unit closure, which is lower than the GWPS of 2 mg/L. **Figure 8** presents predicted boron concentrations over time for CIP and CBR, and indicates that boron concentrations decline rapidly after unit closure and stabilize after approximately 2 to 3 years in both scenarios. Results are summarized in **Table D** below.

Table D. Boron Concentrations at Monitoring Wells after Closure

Well ID	Boron Concentrations (mg/L)			
	Initial Concentration at Closure	No Action - 5 years	CIP - 5 years	CBR - 5 years
7	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00
12	0.89	0.88	0.03	0.00
13	0.41	0.41	0.01	0.00
16	0.06	0.06	0.00	0.00
17	0.00	0.00	0.00	0.00
46	0.87	0.86	0.03	0.00
47	0.63	0.62	0.11	0.08
52	0.17	0.17	0.11	0.11
54	0.49	0.49	0.02	0.00
08D	0.00	0.00	0.00	0.00

The simulated changes in infiltration rates at the CCWL and EAP did not result in any appreciable changes in groundwater elevation from current conditions in either of the three scenarios. Predicted boron concentrations in both scenarios decline rapidly from a maximum concentration of 0.89 mg/L to 0.2 mg/L or less within 5 years and remain at or below 0.2 mg/L until the end of the simulation at 50 years. Both closure scenarios demonstrate maintained compliance with the GWPS beyond the post-closure care period of 30 years.

Evaluation of monitoring well data for the EAP has not identified statistically significant seasonal trends in groundwater quality which could affect model applicability for prediction of boron transport.

5. SUMMARY

There are no potential groundwater exceedances of applicable groundwater standards attributable to the EAP. Groundwater flow and transport modeling of the EAP was completed to provide information for assessment of proposed closure alternatives of the EAP.

Groundwater flow and transport at the Hennepin EAP was simulated using site-specific MODFLOW and MT3DMS models, which were modified from the 2017 models used to simulate unit closure at AP2. Predictive source control simulations of EAP closure scenarios indicated boron concentrations at monitoring network wells will remain below 2 mg/L (maintaining compliance with the GWPS) for no action, CIP, and CBR remedial actions. Predicted boron concentrations in both CIP and CBR scenarios decline rapidly from a maximum observed concentration of 0.89 mg/L to 0.2 mg/L or less within 5 years and remain at or below 0.2 mg/L. Both closure scenarios demonstrate maintained compliance with the GWPS beyond the post-closure care period of 30 years.

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TABLES

Table 1. Model Calibration to Boron Concentrations, 2020-2021

Groundwater Model Report

East Ash Pond

Hennepin Power Plant

Hennepin, Illinois

Observed Boron Concentrations					Simulated Boron Concentrations
Well ID	**Number of observations 3/1/2020-7/1/2021**	**Minimum observed concentration (mg/L)**	**Maximum observed concentration (mg/L)**	**Average observed concentration (mg/L)**	**Simulated concentrations, Current Conditions Model 11/1/2020-11/1/2021 (mg/L)**
EAP Monitoring Well Network					
7	9	0.06	0.16	0.1	0
8	10	0.11	0.18	0.1	0
12	5	0.20	0.86	0.5	0.9
13	5	0.30	1.34	1	0.4
16	7	0.10	0.13	0.1	0.1
17	7	0.07	0.14	0.1	0
46	3	0.25	0.41	0.3	0.9
47	**3**	**0.15**	**0.19**	**0.2**	**Decreases (1.2 to 0.7)**
52	**6**	**0.12**	**0.23**	**0.2**	**Decreases (0.9 to 0.2)**
54	6	0.68	1.09	0.9	0.5
08D	10	0.09	0.13	0.1	0
Other EAPS Monitoring Wells					
03R	**5**	**0.62**	**1.96**	**1.4**	**Decreases (1.1 to 0.2)**
04R	1	1.67	1.67	1.7	0
05R	6	0.78	4.31	1.8	0.7
6	1	0.26	0.26	0.3	0.1
10	**2**	**0.15**	**0.19**	**0.2**	**Decreases (0.9 to 0.1)**
15	1	0.52	0.52	0.5	0.1
18S	**5**	**3.29**	**5.30**	**4**	**Decreases (3.1 to 0.8)**
18D	**5**	**1.54**	**1.80**	**1.7**	**Decreases (1.3 to 0.6)**
19S	5	1.02	6.21	4	0.6
19D	5	3.45	4.65	4	0.5
40S	5	1.30	4.30	2.2	0.7
05DR	6	0.94	1.17	1	0.6

Notes:

Simulated concencentrations for Model Current Conditions reflect concentrations following the closure of AP2 and AP4 in November 2020. Concentrations remain steady throughout the simulation at a number of wells; however **bolded rows** and a notation of "Decreases" indicates simulated concentrations at the well location decreased during SP3 due to simulated closure of AP2 and AP4.

EAP = East Ash Pond

EAPS = East Ash Pond System

mg/L = milligrams per liter

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FIGURES

MONITORING WELL
PART 845 REGULATED UNIT (SUBJECT UNIT)
SITE FEATURE
LIMITS OF FINAL COVER
PROPERTY BOUNDARY

0 175 350 Feet

SITE LOCATION MAP

GROUNDWATER MODEL REPORT
EAST ASH POND
HENNEPIN POWER PLANT
HENNEPIN, ILLINOIS

FIGURE 1

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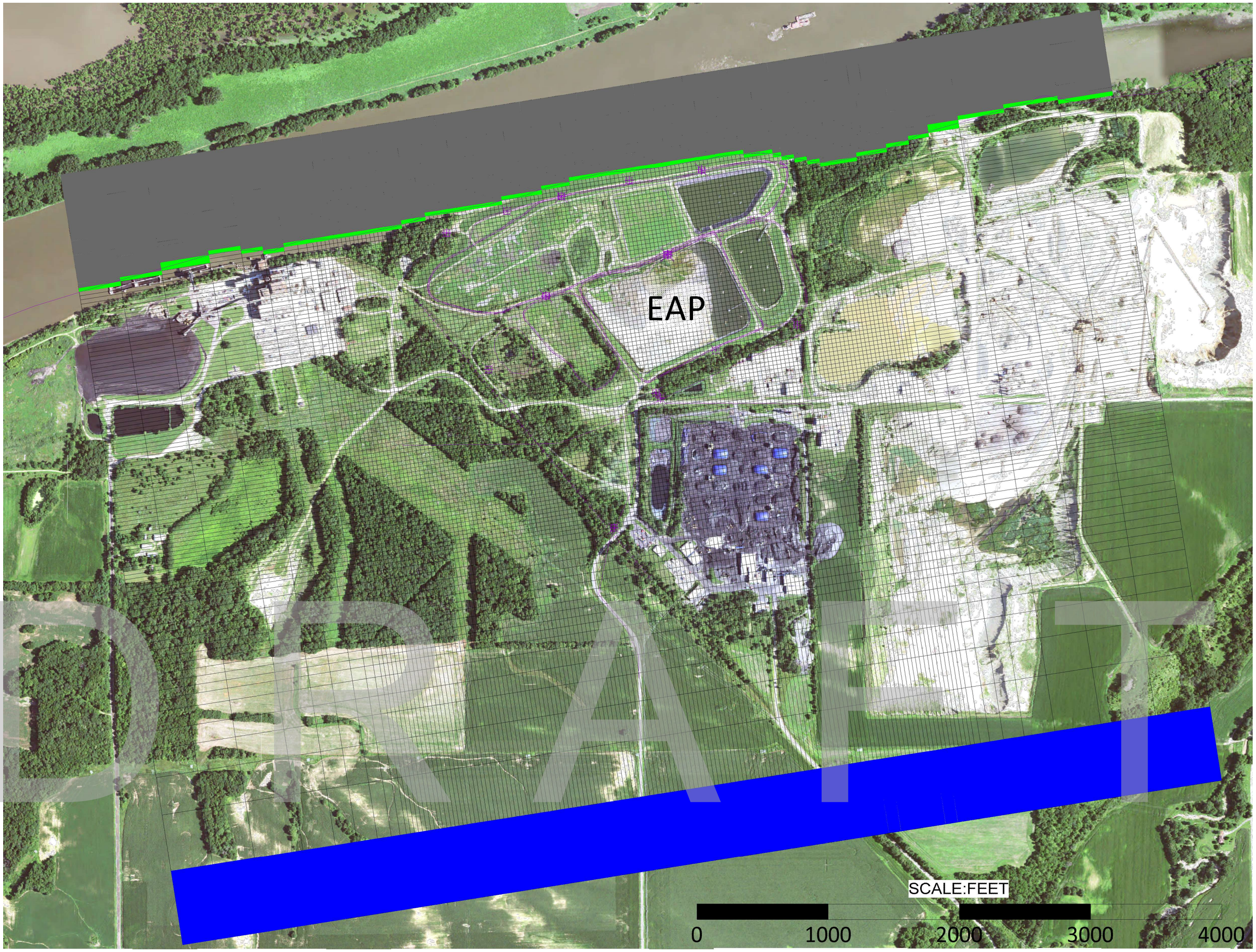
Y:\Mapping\Projects\22\2285\MXD\MISC\Figure 1_HEN EAP Site Location Map.mxd

PROJECT: 169000XXXX | DATED: 10/13/2021 | DESIGNER: STOLZSD



LEGEND

Constant Head Boundary, Model Layer 1

River Boundary, Model Layer 1

Inactive Area (No-Flow Boundary, all layers)

Model Grid (variable spacing of 25 to 300 feet)

GROUNDWATER MODEL REPORT
EAST ASH POND
HENNEPIN POWER PLANT
HENNEPIN, ILLINOIS

FIGURE 2
BOUNDARY CONDITIONS AND MODEL GRID

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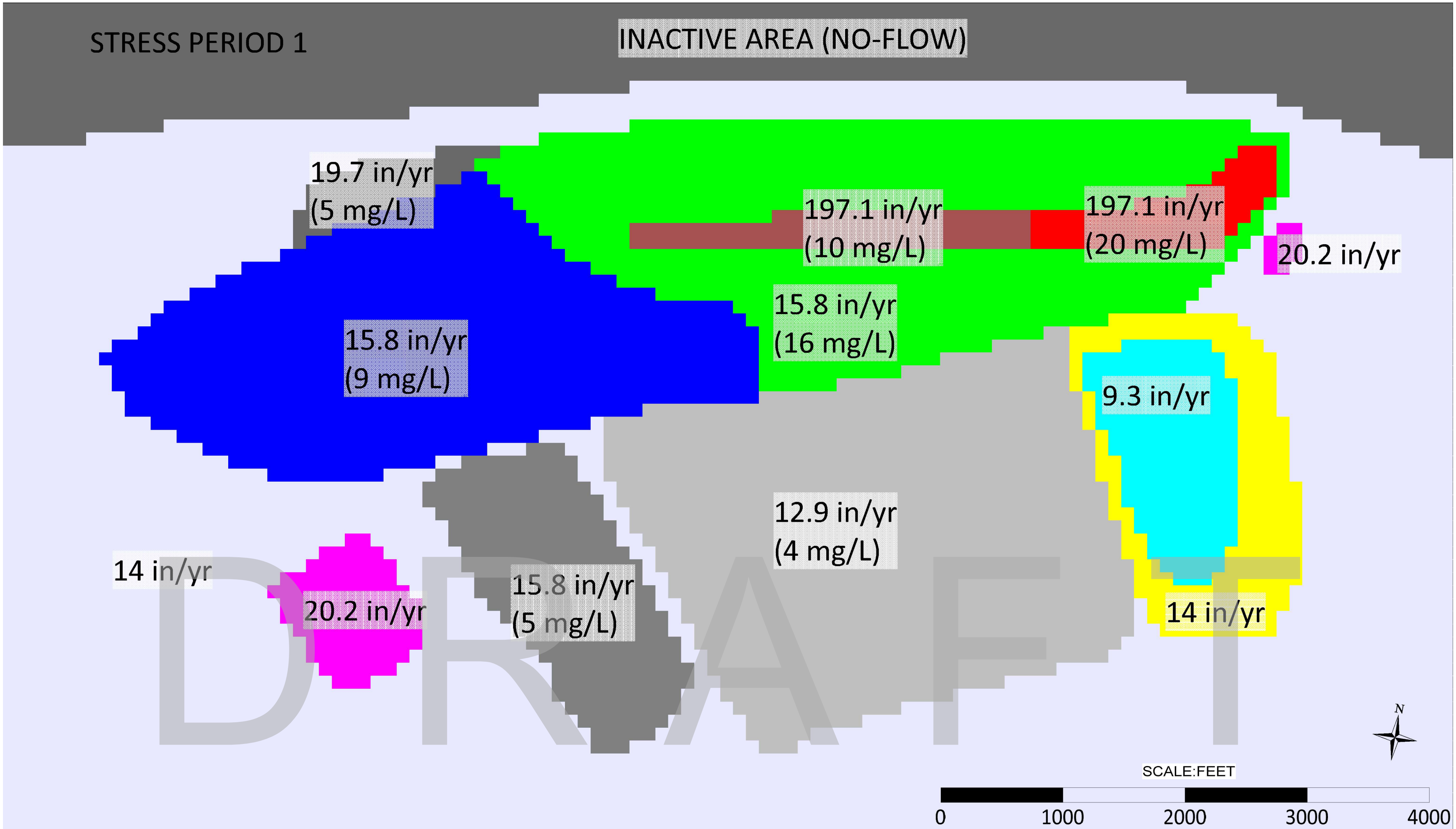

LEGEND

Inactive Area (No-Flow Boundary, all layers)

14 in/yr (0 mg/L) — Model recharge, in/yr (Boron concentration recharge, mg/L)

Notes
Stress Period 1 represents conditions present from 1996-2010

GROUNDWATER MODEL REPORT
EAST ASH POND
HENNEPIN POWER PLANT
HENNEPIN, ILLINOIS

FIGURE 3
MODEL RECHARGE
(STRESS PERIOD 1)

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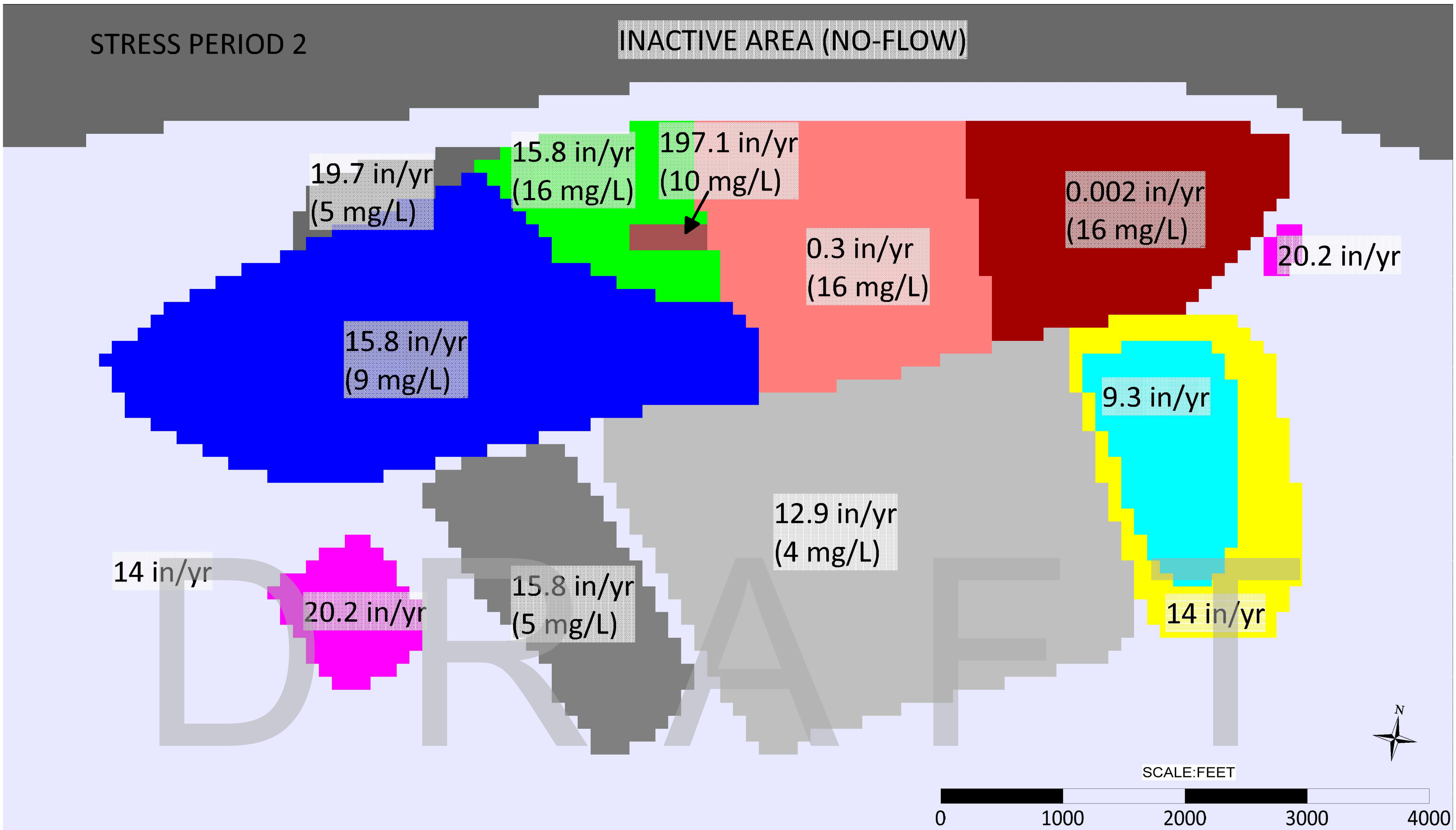

LEGEND

Inactive Area (No-Flow Boundary, all layers)

14 in/yr (0 mg/L) — Model recharge, in/yr (Boron concentration recharge, mg/L)

Notes

Stress Period 2 represents conditions present from 2010-2020

GROUNDWATER MODEL REPORT
EAST ASH POND
HENNEPIN POWER PLANT
HENNEPIN, ILLINOIS

FIGURE 4
MODEL RECHARGE
(STRESS PERIOD 2)

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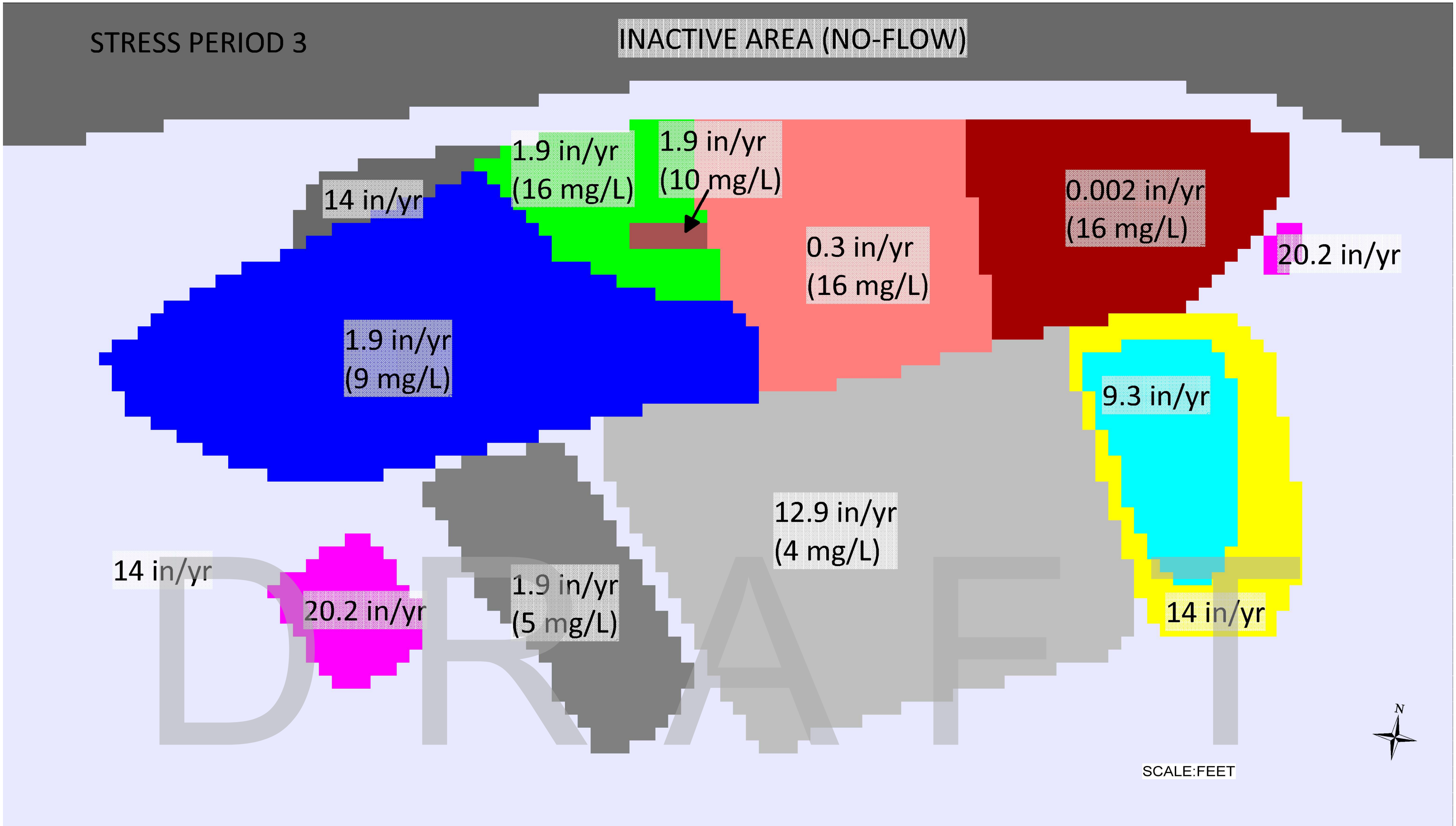

LEGEND

Inactive Area (No-Flow Boundary, all layers)

14 in/yr (0 mg/L) Model recharge, in/yr (Boron concentration recharge, mg/L)

Notes

Stress Period 3 represents conditions following closure of AP2 and AP4 (November 2020-present)

GROUNDWATER MODEL REPORT
EAST ASH POND
HENNEPIN POWER PLANT
HENNEPIN, ILLINOIS

FIGURE 5
MODEL RECHARGE
(STRESS PERIOD 3)

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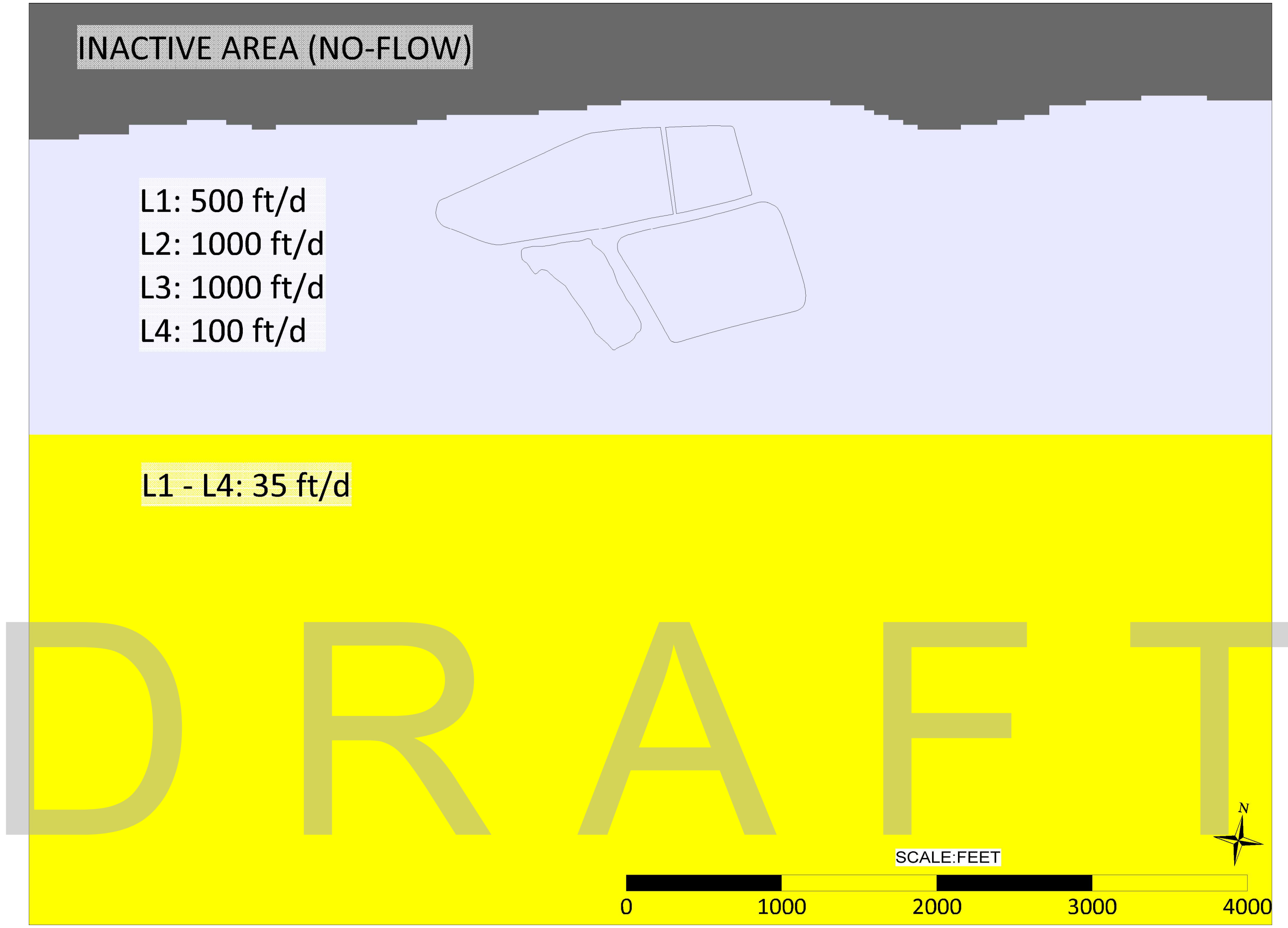

Notes

Model conductivity zones are set with anisotropy of 1 (Kz/Kr=1)

GROUNDWATER MODEL REPORT
EAST ASH POND
HENNEPIN POWER PLANT
HENNEPIN, ILLINOIS

FIGURE 6
MODEL HYDRAULIC CONDUCTIVITY

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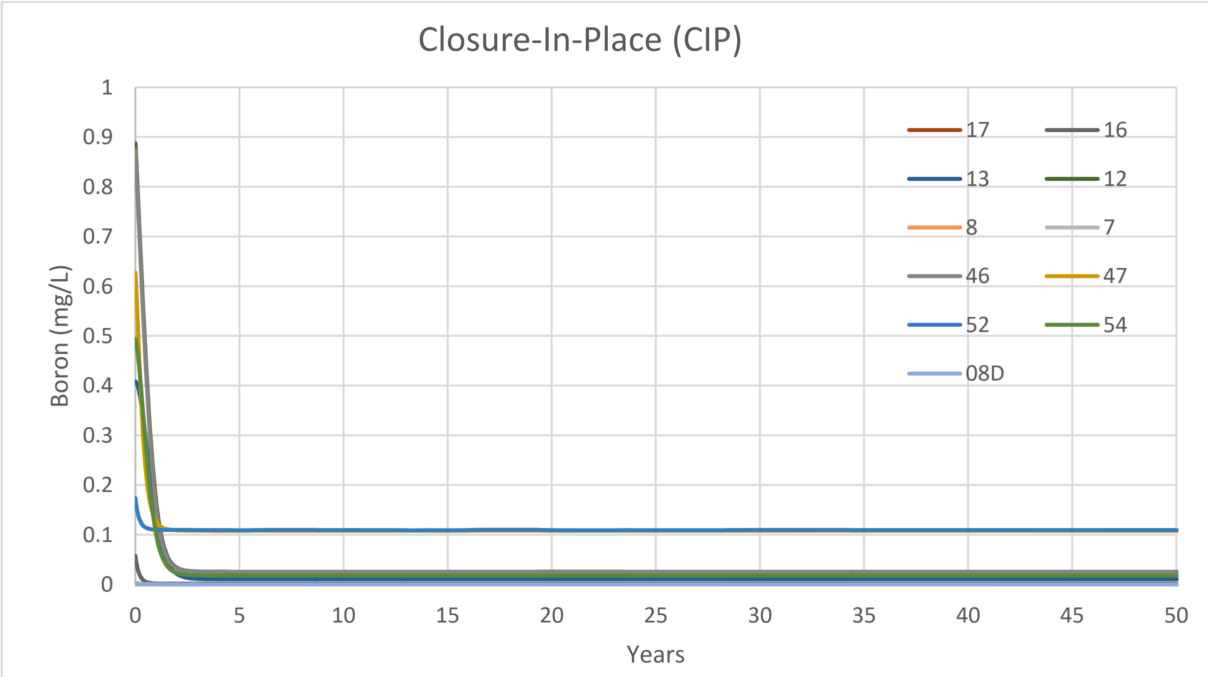
Figure 7

Selected Simulated vs Observed Concentrations, 2020-2021

Groundwater Model Report
Hennepin East Ash Pond
Hennepin Power Plant
Hennepin, Illinois

Notes

All concentrations are boron, in mg/L



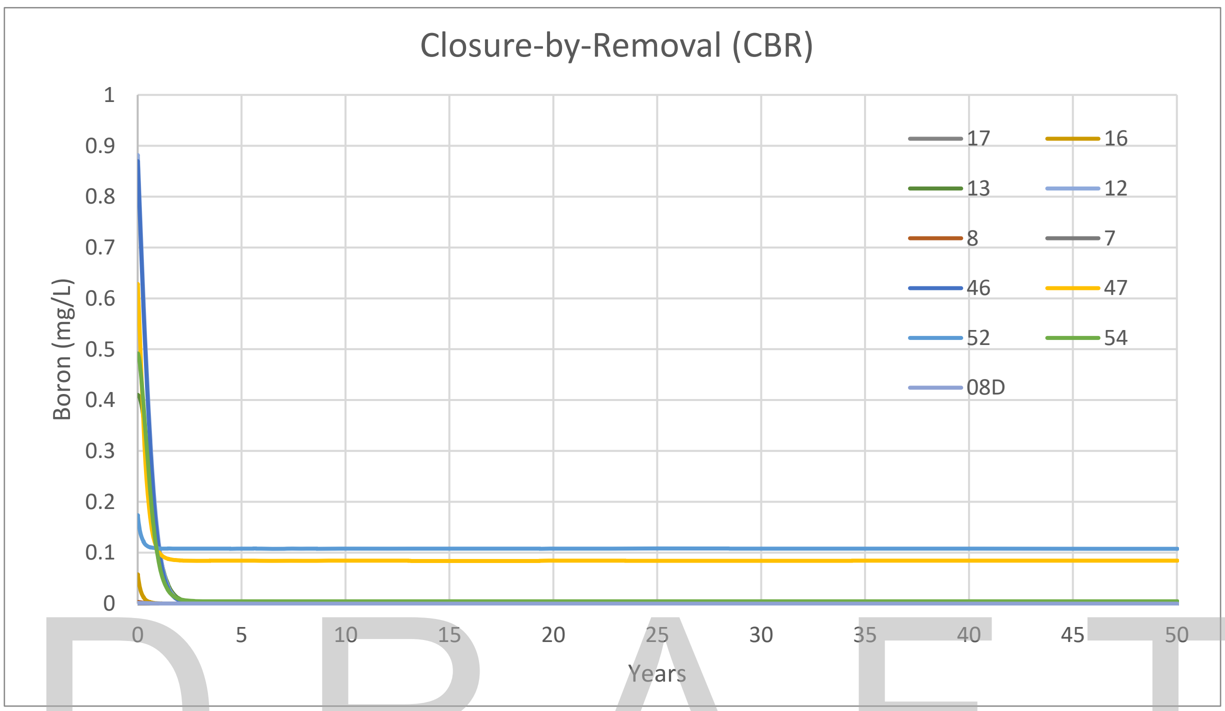


Figure 8

Predicted Boron Concentrations - CIP and CBR

Groundwater Model Report

Hennepin East Ash Pond

Hennepin Power Plant

Hennepin, Illinois

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APPENDIX A
INFILTRATION CALCULATIONS

Appendix A
Infiltration Calculations

This appendix describes the calculation of infiltration rates for different portions of the EAPS. Infiltration rates were estimated using the HELP model or Darcy's Law. Calculation sheets and HELP model output are provided in this appendix.

1. Polishing Pond current conditions – Darcy's Law

   The polishing pond was not used for disposal of CCR materials. The pond is lined and currently impounding water, to a constant (managed) elevation of 476 ft amsl. The base of the pond is at 462 feet, and is underlain by four feet of clay placed atop native material. The water table is 16 feet below the base of the impoundment. The constant head maintained in the impoundment indicated a head-based calculation of infiltration (Darcy's Law) was more appropriate that a runoff/water balance model (HELP). Site-specific values of hydraulic conductivity were used where appropriate, with values from the HELP model database (Tolaymat and Krause, 2020) used where site specific data were not available. Calculated infiltration from the impoundment to the water table is 9.3 in/yr. Ths value was incorporated into the current conditions MODFLOW model and predictive scenarios.

2. EAP current conditions – Darcy's Law

   The EAP has been slowly accumulating CCR materials over time and is currently impounding water, with standing water in a portion of the total footprint at an elevation of 487 ft amsl. The impoundment is lined – it was constructed with a 4-foot clay layer, underlain by 1 foot of sand, atop the native glacial outwash material. The base of the impoundment is 464 ft amsl. The approximately 23.5 feet of saturation within the pond indicates that the liner is competent, and the water table is encountered more than ten feet below the base of the liner.

   The constant head maintained in the impoundment indicated a head-based calculation of infiltration (Darcy's Law) was more appropriate that a runoff/water balance model (HELP). Site-specific values of hydraulic conductivity were used where appropriate, with values from the HELP model database used where site specific data were not available. Calculated infiltration from the impoundment is 12.9 in/yr. This value was incorporated into the current conditions MODFLOW model and the no-action predictive simulation.

3. Landfill closure – HELP Model

   Closure of the CCWL will consist of excavation of landfilled bottom ash within the landfill, installation of a geotextile cushion overtop the existing geomembrane and leachate collection system to protect the geomembrane, backfill with 5.5 feet of protective cover soil, and 0.5 feet of vegetative cover soil. The landfill final surface will be graded to produce slopes of 1% to 2.5%. The HELP program was used to estimate infiltration after landfill closure using the specifications from the Draft CCR Final Closure Plan. The calculated recharge rate at the landfill after closure is 0.013 in/yr. This value was used in the predictive MODFLOW simulations.

4. EAP CIP – HELP – 2 feet of cover soil

   The proposed plan for CIP of the EAP consists of draining standing water from the EAP, backfilling and grading of the existing CCR materials, and installation of a final cover. The final cover will consist of a 40-mil LLDPE geomembrane with protective geotextile cushion, 1.5 feet of sand and gravel fill, and 0.5 feet of sandy clay soil as a vegetative cover layer. The HELP model was used to estimate the infiltration rate through the final cover. Cap and cover specifications for the EAP CIP simulation were based upon the current construction of the EAP and the information in the Draft CCR Final Closure Plan. An infiltration rate of 0.32 in/yr was calculated for CIP. This value represents the final simulated infiltration rate used for the EAP CIP predictive MODFLOW model scenario.

5. EAP CIP Sensitivity analysis – HELP – 2 feet of cover soil and clay liner
   A requirement for capping of CCR units with a geomembrane is that the calculated hydraulic flux through the liner be equivalent or less than calculated hydraulic flux for a 3-foot clay liner. The HELP calculated percolation/leakage through the CIP sequence with a 3-foot clay liner replacing the LDPE, and 2 feet of cover soil, is 1.4 in/yr. This is greater than the calculated rate for the LDPE liner scenario (4). This infiltration value was not incorporated into the MODFLOW model.

6. EAP CIP Sensitivity analysis – HELP (alternate scenario with 3 feet of cover soil)
   A sensitivity analysis of the EAP CIP proposed cap was performed to evaluate effects of increasing the thickness of the cover soil layer from 2 to 3 feet. An infiltration rate of 0.8 in/yr was calculated for this sequence. This analysis was performed for comparison of different specifications and not included in the MODFLOW model.

7. EAP CIP Sensitivity analysis – HELP (alternate scenario with 3 feet of cover soil and clay liner)
   A sensitivity analysis of the EAP CIP proposed cap was performed to evaluate effects of increasing the thickness of the cover soil layer from 2 to 3 feet, with the replacement of the LDPE membrane with a 3 foot layer of clay barrier soil. This analysis was performed for comparison of different specifications and not included in the MODFLOW model. The calculated infiltration rate through this alternate CIP sequence was 1.7 in/yr. This evaluation was performed for comparison only and results were not used in MODFLOW modeling.

8. EAP CBR – HELP
   The proposed plan for closure-by-removal of the EAP consists of dewatering and excavation of the CCR materials within the EAP, and excavation and removal of the 4-foot clay liner and 1 foot of underlying material. The HELP model was used to estimate the infiltration rate through base of the EAP following closure. Cap and cover specifications for the EAP CBR simulation were based upon the current construction of the EAP and the information in the Draft CCR Final Closure Plan. An infiltration rate of 9.2 in/yr was calculated for the proposed EAP CBR remedy.

1. Polishing Pond Current Conditions

Darcy's Law Calculation

Equivalent K for flow at right angles to layer stratification from Domenico and Schwartz, 1990, equation 3.22 (page 69)

Head Information		
Water Level (Pool)	475.97	ft amsl
Base of pond (as built)	462	ft amsl
Groundwater Elevation beneath pond	446	ft amsl
Darcy's Law Calculations		
Head difference (dh)	29.97	feet
Travel distance (dL)	16	feet
Calculated Hydraulic Conductivity (K)	4.00E-07	cm/s
Calculated Hydraulic Conductivity (K)	1.13E-03	ft/d
specific discharge (infiltration rate)	2.12E-03	ft/d
specific discharge (infiltration rate)	**9.30**	in/yr
Stratigraphic Detail		
Layer 1 - Clay Liner		
thickness of layer 1	4	ft
K1	1.00E-07	cm/s
Layer 2 - glacial outwash (native)		
thickness of layer 2	12	ft
K2	1.80E-01	cm/s

2. East Ash Pond Current Conditions

Darcy's Law Calculation
Equivalent K for flow at right angles to layer stratification from Domenico and Schwartz, 1990, equation 3.22 (page 69)

Head Information		
Water Level (Pool)	487.48	ft amsl
Base of pond (as built)	464	ft amsl
Groundwater Elevation beneath pond	446	ft amsl
Darcy's Law Calculations		
Head difference (dh)	41.48	feet
Travel distance (dL)	18	feet
Calculated Hydraulic Conductivity (K)	4.50E-07	cm/s
Calculated Hydraulic Conductivity (K)	1.28E-03	ft/d
specific discharge (infiltration rate)	2.94E-03	ft/d
specific discharge (infiltration rate)	**12.87**	in/yr
Stratigraphic Detail		
Layer 1 - Clay Liner		
thickness of layer 1	4	ft
K1	1.00E-07	cm/s
Layer 2 -fill sand		
thickness of layer 2	1	ft
K2	5.80E-03	cm/s
Layer 3 - glacial outwash (native)		
thickness of layer 3	13	ft
K3	1.80E-01	cm/s

3. Landfill Closure

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: HEN Landfill - Closure **Simulated On:** 8/30/2021 14:44

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
SCL - Sandy Clay Loam
Material Texture Number 10

Thickness	=	6	inches
Porosity	=	0.398	vol/vol
Field Capacity	=	0.244	vol/vol
Wilting Point	=	0.136	vol/vol
Initial Soil Water Content	=	0.2488	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-04	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer
CoS - Coarse Sand
Material Texture Number 1

Thickness	=	66	inches
Porosity	=	0.417	vol/vol
Field Capacity	=	0.045	vol/vol
Wilting Point	=	0.018	vol/vol
Initial Soil Water Content	=	0.1045	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-02	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
S - Sand
Material Texture Number 2

Thickness	=	12	inches
Porosity	=	0.437	vol/vol
Field Capacity	=	0.062	vol/vol
Wilting Point	=	0.024	vol/vol
Initial Soil Water Content	=	0.4212	vol/vol
Effective Sat. Hyd. Conductivity	=	5.80E-03	cm/sec
Slope	=	0.5	%
Drainage Length	=	900	ft

Layer 4

Type 4 - Flexible Membrane Liner

HDPE Membrane

Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	4	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5

Type 3 - Barrier Soil Liner

Liner Soil (High)

Material Texture Number 16

Thickness	=	36	inches
Porosity	=	0.427	vol/vol
Field Capacity	=	0.418	vol/vol
Wilting Point	=	0.367	vol/vol
Initial Soil Water Content	=	0.427	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07	cm/sec

Layer 6

Type 1 - Vertical Percolation Layer

G - Gravel

Material Texture Number 21

Thickness	=	18	inches
Porosity	=	0.397	vol/vol
Field Capacity	=	0.032	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.032	vol/vol
Effective Sat. Hyd. Conductivity	=	3.00E-01	cm/sec

Layer 7

Type 1 - Vertical Percolation Layer (Waste)

High-Density Electric Plant Coal Fly Ash

Material Texture Number 30

Thickness	=	480	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.187	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 8

Type 1 - Vertical Percolation Layer

Glacial Outwash

Material Texture Number 44

Thickness	=	420	inches
Porosity	=	0.417	vol/vol
Field Capacity	=	0.045	vol/vol
Wilting Point	=	0.018	vol/vol
Initial Soil Water Content	=	0.045	vol/vol
Effective Sat. Hyd. Conductivity	=	1.80E-01	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	80.8	
Fraction of Area Allowing Runoff	=	0	%
Area projected on a horizontal plane	=	5	acres
Evaporative Zone Depth	=	8	inches
Initial Water in Evaporative Zone	=	1.696	inches
Upper Limit of Evaporative Storage	=	3.222	inches
Lower Limit of Evaporative Storage	=	0.852	inches
Initial Snow Water	=	0.274951	inches
Initial Water in Layer Materials	=	138.054	inches
Total Initial Water	=	138.329	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	41.3	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	120	days
End of Growing Season (Julian Date)	=	300	days
Average Wind Speed	=	9	mph
Average 1st Quarter Relative Humidity	=	70	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	74	%
Average 4th Quarter Relative Humidity	=	77	%

Note: Evapotranspiration data was obtained for , Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
1.665246	1.874612	2.254818	3.099339	4.449317	4.12829
3.29051	4.017539	3.401471	3.029886	2.510213	1.863762

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
27.4	35	40.3	50	69.5	78.4
83	79.7	71.5	56.9	46.3	33.6

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31

Average Annual Totals Summary

Title: HEN Landfill - Closure
Simulated on: 8/30/2021 14:47

	Average Annual Totals for Years 1 - 50*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	35.59	[5.14]	645,867.8	100.00
Runoff	0.000	[0]	0.0000	0.00
Evapotranspiration	23.120	[3.256]	419,627.5	64.97
Subprofile1				
Lateral drainage collected from Layer 3	12.1502	[2.1307]	220,526.2	34.14
Percolation/leakage through Layer 5	0.013513	[0.001837]	245.3	0.04
Average Head on Top of Layer 4	67.8086	[8.7079]	---	---
Subprofile2				
Percolation/leakage through Layer 8	**0.012941**	[0.002404]	234.9	0.04
Water storage				
Change in water storage	0.3019	[3.564]	5,479.3	0.85

* Note: Average inches are converted to volume based on the user-specified area.

4. EAP CIP - 2 feet of cover soil

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: HEN EAP CIP (2 ft cover) **Simulated On:** 10/28/2021 14:14

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
SCL - Sandy Clay Loam
Material Texture Number 10

Thickness	=	6	inches
Porosity	=	0.398	vol/vol
Field Capacity	=	0.244	vol/vol
Wilting Point	=	0.136	vol/vol
Initial Soil Water Content	=	0.3947	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-04	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer
CoS - Coarse Sand
Material Texture Number 1

Thickness	=	18	inches
Porosity	=	0.417	vol/vol
Field Capacity	=	0.045	vol/vol
Wilting Point	=	0.018	vol/vol
Initial Soil Water Content	=	0.4166	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-02	cm/sec

Layer 3
Type 4 - Flexible Membrane Liner
LDPE Membrane
Material Texture Number 36

Thickness	=	0.04	inches
Effective Sat. Hyd. Conductivity	=	4.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	1	Holes/Acre
FML Placement Quality	=	3	Good

Layer 4

Type 1 - Vertical Percolation Layer (Waste)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	372	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.1873	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 5

Type 1 - Vertical Percolation Layer
Clay - moderate
Material Texture Number 43

Thickness	=	48	inches
Porosity	=	0.451	vol/vol
Field Capacity	=	0.419	vol/vol
Wilting Point	=	0.332	vol/vol
Initial Soil Water Content	=	0.4207	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07	cm/sec

Layer 6

Type 1 - Vertical Percolation Layer
S - Sand
Material Texture Number 2

Thickness	=	12	inches
Porosity	=	0.437	vol/vol
Field Capacity	=	0.062	vol/vol
Wilting Point	=	0.024	vol/vol
Initial Soil Water Content	=	0.0649	vol/vol
Effective Sat. Hyd. Conductivity	=	5.80E-03	cm/sec

Layer 7

Type 1 - Vertical Percolation Layer
Glacial Outwash
Material Texture Number 44

Thickness	=	156	inches
Porosity	=	0.417	vol/vol
Field Capacity	=	0.045	vol/vol
Wilting Point	=	0.018	vol/vol
Initial Soil Water Content	=	0.045	vol/vol
Effective Sat. Hyd. Conductivity	=	1.80E-01	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	80.6	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	510	acres
Evaporative Zone Depth	=	8	inches
Initial Water in Evaporative Zone	=	3.196	inches
Upper Limit of Evaporative Storage	=	3.222	inches
Lower Limit of Evaporative Storage	=	0.852	inches
Initial Snow Water	=	0.274951	inches
Initial Water in Layer Materials	=	107.552	inches
Total Initial Water	=	107.827	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	41.3	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	120	days
End of Growing Season (Julian Date)	=	300	days
Average Wind Speed	=	9	mph
Average 1st Quarter Relative Humidity	=	70	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	74	%
Average 4th Quarter Relative Humidity	=	77	%

Note: Evapotranspiration data was obtained for , Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
1.665246	1.874612	2.254818	3.099339	4.449317	4.12829
3.29051	4.017539	3.401471	3.029886	2.510213	1.863762

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
27.4	35	40.3	50	69.5	78.4
83	79.7	71.5	56.9	46.3	33.6

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31
Solar radiation was simulated based on HELP V4 weather simulation for:

Lat/Long: 41.3/-89.31

Average Annual Totals Summary

Title: HEN EAP CIP (2 ft cover)
Simulated or 10/28/2021 14:16

	Average Annual Totals for Years 1 - 50*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	35.59	[5.14]	65,878,515.6	100.00
Runoff	8.075	[3.311]	14,948,903.1	22.69
Evapotranspiration	27.017	[3.834]	50,016,380.0	75.92
Subprofile1				
Percolation/leakage through Layer 3	0.529518	[0.021507]	980,296.3	1.49
Average Head on Top of Layer 3	18.5065	[0.739]	---	---
Subprofile2				
Percolation/leakage through Layer 7	**0.319267**	[0.207637]	591,059.7	0.90
Water storage				
Change in water storage	0.1740	[0.9142]	322,172.8	0.49

* Note: Average inches are converted to volume based on the user-specified area.

5. EAP CIP Sensitivity Analysis - 3 feet clay, 2 feet cover soil

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HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: HEN EAP CIP, clay (2 ft cover) **Simulated On:** 10/28/2021 14:22

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
SCL - Sandy Clay Loam
Material Texture Number 10

Thickness	=	6	inches
Porosity	=	0.398	vol/vol
Field Capacity	=	0.244	vol/vol
Wilting Point	=	0.136	vol/vol
Initial Soil Water Content	=	0.2644	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-04	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer
CoS - Coarse Sand
Material Texture Number 1

Thickness	=	18	inches
Porosity	=	0.417	vol/vol
Field Capacity	=	0.045	vol/vol
Wilting Point	=	0.018	vol/vol
Initial Soil Water Content	=	0.4121	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-02	cm/sec

Layer 3
Type 3 - Barrier Soil Liner
Liner Soil (High)
Material Texture Number 16

Thickness	=	36	inches
Porosity	=	0.427	vol/vol
Field Capacity	=	0.418	vol/vol
Wilting Point	=	0.367	vol/vol
Initial Soil Water Content	=	0.427	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07	cm/sec

Layer 4

Type 1 - Vertical Percolation Layer (Waste)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	372	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.1906	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 5

Type 1 - Vertical Percolation Layer
Clay - moderate
Material Texture Number 43

Thickness	=	48	inches
Porosity	=	0.451	vol/vol
Field Capacity	=	0.419	vol/vol
Wilting Point	=	0.332	vol/vol
Initial Soil Water Content	=	0.4189	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07	cm/sec

Layer 6

Type 1 - Vertical Percolation Layer
S - Sand
Material Texture Number 2

Thickness	=	12	inches
Porosity	=	0.437	vol/vol
Field Capacity	=	0.062	vol/vol
Wilting Point	=	0.024	vol/vol
Initial Soil Water Content	=	0.0632	vol/vol
Effective Sat. Hyd. Conductivity	=	5.80E-03	cm/sec

Layer 7

Type 1 - Vertical Percolation Layer
Glacial Outwash
Material Texture Number 44

Thickness	=	156	inches
Porosity	=	0.417	vol/vol
Field Capacity	=	0.045	vol/vol
Wilting Point	=	0.018	vol/vol
Initial Soil Water Content	=	0.045	vol/vol
Effective Sat. Hyd. Conductivity	=	1.80E-01	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	80.6	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	510	acres
Evaporative Zone Depth	=	8	inches
Initial Water in Evaporative Zone	=	2.333	inches
Upper Limit of Evaporative Storage	=	3.222	inches
Lower Limit of Evaporative Storage	=	0.852	inches
Initial Snow Water	=	0.2749505	inches
Initial Water in Layer Materials	=	123.162	inches
Total Initial Water	=	123.437	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	41.3	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	120	days
End of Growing Season (Julian Date)	=	300	days
Average Wind Speed	=	9	mph
Average 1st Quarter Relative Humidity	=	70	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	74	%
Average 4th Quarter Relative Humidity	=	77	%

Note: Evapotranspiration data was obtained for , Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
1.665246	1.874612	2.254818	3.099339	4.449317	4.1282902
3.29051	4.017539	3.401471	3.029886	2.510213	1.8637619

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
27.4	35	40.3	50	69.5	78.4
83	79.7	71.5	56.9	46.3	33.6

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31
Solar radiation was simulated based on HELP V4 weather simulation for:

Lat/Long: 41.3/-89.31

Average Annual Totals Summary

Title: HEN EAP CIP, clay (2 ft cover)
Simulated on: 10/28/2021 14:24

	Average Annual Totals for Years 1 - 50*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	35.59	[5.14]	65,878,515.6	100.00
Runoff	6.947	[3.224]	12,860,852.2	19.52
Evapotranspiration	26.812	[3.995]	49,637,165.1	75.35
Subprofile1				
Percolation/leakage through Layer 3	1.857393	[0.030368]	3,438,592.3	5.22
Average Head on Top of Layer 3	17.8213	[0.8728]	---	---
Subprofile2				
Percolation/leakage through Layer 7	1.350697	[0.796462]	2,500,544.5	3.80
Water storage				
Change in water storage	0.4753	[1.2945]	879,953.8	1.34

* Note: Average inches are converted to volume based on the user-specified area.

6. EAP CIP Sensitivity Analysis - alternate scenario with 3 feet of cover soil

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HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: HEN EAP - Closure-in-Place **Simulated On:** 10/14/2021 7:56

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
SCL - Sandy Clay Loam
Material Texture Number 10

Thickness	=	6	inches
Porosity	=	0.398	vol/vol
Field Capacity	=	0.244	vol/vol
Wilting Point	=	0.136	vol/vol
Initial Soil Water Content	=	0.2488	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-04	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer
CoS - Coarse Sand
Material Texture Number 1

Thickness	=	30	inches
Porosity	=	0.417	vol/vol
Field Capacity	=	0.045	vol/vol
Wilting Point	=	0.018	vol/vol
Initial Soil Water Content	=	0.3049	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-02	cm/sec

Layer 3
Type 4 - Flexible Membrane Liner
LDPE Membrane
Material Texture Number 36

Thickness	=	0.04	inches
Effective Sat. Hyd. Conductivity	=	4.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	4	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 4

Type 1 - Vertical Percolation Layer (Waste)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	372	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.1874	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 5

Type 1 - Vertical Percolation Layer
Clay - moderate
Material Texture Number 43

Thickness	=	48	inches
Porosity	=	0.451	vol/vol
Field Capacity	=	0.419	vol/vol
Wilting Point	=	0.332	vol/vol
Initial Soil Water Content	=	0.4203	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07	cm/sec

Layer 6

Type 1 - Vertical Percolation Layer
S - Sand
Material Texture Number 2

Thickness	=	12	inches
Porosity	=	0.437	vol/vol
Field Capacity	=	0.062	vol/vol
Wilting Point	=	0.024	vol/vol
Initial Soil Water Content	=	0.0643	vol/vol
Effective Sat. Hyd. Conductivity	=	5.80E-03	cm/sec

Layer 7

Type 1 - Vertical Percolation Layer
Glacial Outwash
Material Texture Number 44

Thickness	=	156	inches
Porosity	=	0.417	vol/vol
Field Capacity	=	0.045	vol/vol
Wilting Point	=	0.018	vol/vol
Initial Soil Water Content	=	0.045	vol/vol
Effective Sat. Hyd. Conductivity	=	1.80E-01	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	80.6	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	510	acres
Evaporative Zone Depth	=	8	inches
Initial Water in Evaporative Zone	=	1.696	inches
Upper Limit of Evaporative Storage	=	3.222	inches
Lower Limit of Evaporative Storage	=	0.852	inches
Initial Snow Water	=	0.274951	inches
Initial Water in Layer Materials	=	108.33	inches
Total Initial Water	=	108.605	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	41.3	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	120	days
End of Growing Season (Julian Date)	=	300	days
Average Wind Speed	=	9	mph
Average 1st Quarter Relative Humidity	=	70	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	74	%
Average 4th Quarter Relative Humidity	=	77	%

Note: Evapotranspiration data was obtained for , Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
1.665246	1.874612	2.254818	3.099339	4.449317	4.12829
3.29051	4.017539	3.401471	3.029886	2.510213	1.863762

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
27.4	35	40.3	50	69.5	78.4
83	79.7	71.5	56.9	46.3	33.6

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31

Average Annual Totals Summary

Title: HEN EAP - Closure-in-Place
Simulated on: 10/14/2021 7:58

	Average Annual Totals for Years 1 - 50*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	35.59	[5.14]	65,878,515.6	100.00
Runoff	7.423	[3.299]	13,742,412.7	20.86
Evapotranspiration	26.907	[3.866]	49,813,355.2	75.61
Subprofile1				
Percolation/leakage through Layer 3	**1.214375**	[0.044082]	2,248,172.0	3.41
Average Head on Top of Layer 3	30.0822	[0.9227]	---	---
Subprofile2				
Percolation/leakage through Layer 7	**0.796537**	[0.541572]	1,474,629.3	2.24
Water storage				
Change in water storage	0.4581	[1.2981]	848,118.3	1.29

* Note: Average inches are converted to volume based on the user-specified area.

7. EAP CIP Sensitivity Analysis - 3-foot clay liner and 3 feet of cover soil

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HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: HEN EAP - Closure-in-Place **Simulated On:** 10/13/2021 20:45

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
SCL - Sandy Clay Loam
Material Texture Number 10

Thickness	=	6	inches
Porosity	=	0.398	vol/vol
Field Capacity	=	0.244	vol/vol
Wilting Point	=	0.136	vol/vol
Initial Soil Water Content	=	0.2488	vol/vol
Effective Sat. Hyd. Conductivity	=	1.20E-04	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer
CoS - Coarse Sand
Material Texture Number 1

Thickness	=	30	inches
Porosity	=	0.417	vol/vol
Field Capacity	=	0.045	vol/vol
Wilting Point	=	0.018	vol/vol
Initial Soil Water Content	=	0.275	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-02	cm/sec

Layer 3
Type 3 - Barrier Soil Liner
Liner Soil (High)
Material Texture Number 16

Thickness	=	36	inches
Porosity	=	0.427	vol/vol
Field Capacity	=	0.418	vol/vol
Wilting Point	=	0.367	vol/vol
Initial Soil Water Content	=	0.427	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07	cm/sec

Layer 4

Type 1 - Vertical Percolation Layer (Waste)

High-Density Electric Plant Coal Fly Ash

Material Texture Number 30

Thickness	=	372	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.19	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 5

Type 1 - Vertical Percolation Layer

Clay - moderate

Material Texture Number 43

Thickness	=	48	inches
Porosity	=	0.451	vol/vol
Field Capacity	=	0.419	vol/vol
Wilting Point	=	0.332	vol/vol
Initial Soil Water Content	=	0.419	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07	cm/sec

Layer 6

Type 1 - Vertical Percolation Layer

S - Sand

Material Texture Number 2

Thickness	=	12	inches
Porosity	=	0.437	vol/vol
Field Capacity	=	0.062	vol/vol
Wilting Point	=	0.024	vol/vol
Initial Soil Water Content	=	0.0641	vol/vol
Effective Sat. Hyd. Conductivity	=	5.80E-03	cm/sec

Layer 7

Type 1 - Vertical Percolation Layer

Glacial Outwash

Material Texture Number 44

Thickness	=	156	inches
Porosity	=	0.417	vol/vol
Field Capacity	=	0.045	vol/vol
Wilting Point	=	0.018	vol/vol
Initial Soil Water Content	=	0.045	vol/vol
Effective Sat. Hyd. Conductivity	=	1.80E-01	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	80.6	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	510	acres
Evaporative Zone Depth	=	8	inches
Initial Water in Evaporative Zone	=	1.696	inches
Upper Limit of Evaporative Storage	=	3.222	inches
Lower Limit of Evaporative Storage	=	0.852	inches
Initial Snow Water	=	0.27495054	inches
Initial Water in Layer Materials	=	123.7	inches
Total Initial Water	=	123.975	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	41.3	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	120	days
End of Growing Season (Julian Date)	=	300	days
Average Wind Speed	=	9	mph
Average 1st Quarter Relative Humidity	=	70	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	74	%
Average 4th Quarter Relative Humidity	=	77	%

Note: Evapotranspiration data was obtained for , Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
1.665246	1.874612	2.254818	3.099339	4.449317	4.12829018
3.29051	4.017539	3.401471	3.029886	2.510213	1.86376189

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
27.4	35	40.3	50	69.5	78.4
83	79.7	71.5	56.9	46.3	33.6

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31

Average Annual Totals Summary

Title: HEN EAP - Closure-in-Place (CLAY)
Simulated on: 10/13/2021 20:48

	Average Annual Totals for Years 1 - 50*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	35.59	[5.14]	65,878,515.6	100.00
Runoff	6.701	[3.161]	12,404,742.9	18.83
Evapotranspiration	26.571	[4.002]	49,190,796.8	74.67
Subprofile1				
Percolation/leakage through Layer 3	**2.261741**	[0.038582]	4,187,161.3	6.36
Average Head on Top of Layer 3	29.5380	[1.1069]	---	---
Subprofile2				
Percolation/leakage through Layer 7	1.697246	[0.951224]	3,142,112.4	4.77
Water storage				
Change in water storage	0.6162	[1.663]	1,140,863.6	1.73

* Note: Average inches are converted to volume based on the user-specified area.

8. EAP CBR

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: HEN EAP - Closure By Removal **Simulated On:** 10/13/2021 20:18

Layer 1

Type 1 - Vertical Percolation Layer (Cover Soil)
Glacial Outwash
Material Texture Number 44

Thickness	=	156	inches
Porosity	=	0.417	vol/vol
Field Capacity	=	0.045	vol/vol
Wilting Point	=	0.018	vol/vol
Initial Soil Water Content	=	0.0757	vol/vol
Effective Sat. Hyd. Conductivity	=	1.80E-01	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	96.4	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	510	acres
Evaporative Zone Depth	=	8	inches
Initial Water in Evaporative Zone	=	0.472	inches
Upper Limit of Evaporative Storage	=	3.336	inches
Lower Limit of Evaporative Storage	=	0.144	inches
Initial Snow Water	=	0.274951	inches
Initial Water in Layer Materials	=	11.815	inches
Total Initial Water	=	12.09	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	41.3	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	120	days
End of Growing Season (Julian Date)	=	300	days
Average Wind Speed	=	9	mph
Average 1st Quarter Relative Humidity	=	70	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	74	%
Average 4th Quarter Relative Humidity	=	77	%

Note: Evapotranspiration data was obtained for , Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
1.665246	1.874612	2.254818	3.099339	4.449317	4.12829
3.29051	4.017539	3.401471	3.029886	2.510213	1.863762

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
27.4	35	40.3	50	69.5	78.4
83	79.7	71.5	56.9	46.3	33.6

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 41.3/-89.31

Average Annual Totals Summary

Title: HEN EAP - Closure By Removal
Simulated on: 10/13/2021 20:20

	Average Annual Totals for Years 1 - 50*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	35.59	[5.14]	65,878,515.6	100.00
Runoff	9.901	[2.412]	18,329,439.3	27.82
Evapotranspiration	16.545	[2.588]	30,628,987.6	46.49
Subprofile1				
Percolation/leakage through Layer 1	**9.153923**	[1.458283]	16,946,657.8	25.72
Water storage				
Change in water storage	-0.0144	[0.7954]	-26,569.1	-0.04

* Note: Average inches are converted to volume based on the user-specified area.

APPENDIX B
MODFLOW, MT3DMS, AND HELP MODEL FILES
(ELECTRONIC ONLY)