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GROUNDWATER MODELING REPORT

GYPSUM MANAGEMENT FACILITY POND
DUCK CREEK POWER PLANT
CANTON, ILLINOIS

DRAFT

GROUNDWATER MODELING REPORT DUCK CREEK POWER PLANT GYPSUM MANAGEMENT FACILITY POND

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ACRONYMS AND ABBREVIATIONS

§	Section
±	plus or minus
35 I.A.C.	Title 35 of the Illinois Administrative Code
bgs	below ground surface
CBR	closure by removal
CCR	coal combustion residuals
CIP	closure in place
cm/s	centimeters per second
CSM	conceptual site model
DCPP	Duck Creek Power Plant
ft^2/d/ft	square feet per day per foot
ft^3/d	cubic feet per day
ft/d	feet per day
GMF	Gypsum Management Facility
GMP	Groundwater Monitoring Plan
GMR	Groundwater Modeling Report
GWL	groundwater elevation
GWPS	groundwater protection standard
Hanson	Hanson Professional Services, Inc.
HCR	Hydrogeologic Site Characterization Report
HDPE	high-density polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
HUC	Hydrologic Unit Code
ID	identification
IEPA	Illinois Environmental Protection Agency
IPRG	Illinois Power Resources Generating, LLC
K	hydraulic conductivity
K_{eff}	effective hydraulic conductivity
mil	Millimeter
msl	above mean sea level
NA	not applicable
NID	National Inventory of Dams
No.	Number
NRT/OBG	Natural Resource Technology, an OBG Company
oz/yd^2	ounce per square yard
Part 845	Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: 35 I.A.C. § 845
PMP	potential migration pathway
Ramboll	Ramboll Americas Engineering Solutions, Inc
RMSE	root mean squared error
RQD	rock quality designation
SI	surface impoundment

std	standard deviation
TVD	total-variation-diminishing
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

EXECUTIVE SUMMARY

This Groundwater Modeling Report (GMR) has been prepared to show how proposed closure solutions for the Gypsum Management Facility (GMF) Pond will maintain compliance with the applicable groundwater standards at the Duck Creek Power Plant (DCPP), Fulton County, Illinois. This report integrates existing site data and information with the latest hydrogeology and groundwater quality data to generate a conceptual and numerical model of the GMF Pond. The conceptual site model (CSM) includes hydrogeologic and groundwater quality data specific to the GMF Pond, which has been collected between 2015 and 2021.

The GMF Pond (Vistra identification [ID] number [No.] 203, Illinois Environmental Protection Agency [IEPA] ID No. W0578010001-04, and National Inventory of Dams [NID] No. IL50573) is located at the DCPP southwest of Canton, Illinois (**Figure 1-1**). The DCPP is located near the Duck Creek Cooling Pond, which was used as a source of cooling water for the power plant when it was active, and several small ponds which are remnants of the area's surface mining history. Prior to construction of the power plant and associated facilities, strip mining of coal took place within the property boundary of the DCPP. Currently, land use adjacent to the DCPP is agriculture, pasture, and forest with minimal development.

The GMF Pond is a 1,500-foot by 900-foot earthen berm double-lined coal combustion residual (CCR) surface impoundment (SI) located north of the former power plant. The GMF Pond decant water discharges to the lined GMF Recycle Pond. In addition to the CCR within the lined GMF Pond, there are five layers of unlithified material present above the Pennsylvanian-age shaley siltstone and silty shale bedrock (Carbondale Formation). These materials have been categorized into three hydrostratigraphic units presented below in descending order:

- **Uppermost Aquifer:** this unit includes the Peoria/Roxanna Loess, the upper Radnor Till, and the shallow sands. These units are hydraulically connected and underlain by a thick till sequence of the Radnor Till (Natural Resource Technology, an OBG Company [NRT/OBG], 2017a).
- **Lower Radnor Till/Lower Confining Unit:** Underlying the uppermost aquifer, the lower Radnor Till is approximately 42 to 58 feet thick.
- **Bedrock Confining Unit:** The thick and low permeability shaley siltstone, silty shale, and coal beds of the Carbondale Formation, are estimated to have a thickness of approximately 300 to 400 feet.

While the primary migration pathway is the shallow sand of the uppermost aquifer, the groundwater within the overlying Peoria/Roxanna Loess has the potential to be impacted and is considered a potential migration pathway (PMP).

Groundwater migrates downward through the loess and upper Radnor Till into the shallow sands of the uppermost aquifer. Groundwater flow in the sands is generally in a northwest to southeast direction. Seasonal variation of groundwater levels at the GMF Pond are present and may fluctuate approximately 1 to 10 feet. There is no observable seasonal variation of groundwater flow direction at the GMF Pond associated with the elevation changes. Groundwater flows toward the Duck Creek Cooling Pond located approximately 2,100 feet east of the GMF Pond. The surface water elevation of the Cooling Pond is estimated to range from 562.5 to 565 feet North American

Vertical Datum of 1988 (NAVD88), which is approximately 20 feet lower than water elevations at the GMF Pond.

The CSM for modeling the GMF Pond is as follows:

- All hydrostratigraphic layers are laterally continuous across the area. The flat to gently rolling uplands are dissected by deeply incised streams (into the materials of the uppermost aquifer and lower confining unit) that are tributaries to major river systems in areas that have not been disturbed by strip mining activity.
- The GMF Pond is constructed such that the double liner system is in direct contact with the lower confining unit or backfill of similar properties (i.e., removal of the uppermost aquifer sand below the footprint of the GMF Pond).
- Groundwater migrates vertically through the upper portions of the uppermost aquifer and horizontally within the sands above the lower confining unit to the southeast towards the Duck Creek Cooling Pond. The stage in Duck Creek Cooling Pond is managed with minimal (less than 3 feet) variability throughout the year.
- Vertical gradients measured between the bedrock and uppermost aquifer are generally downward near the GMF Pond, indicating that it is a recharge area.

Groundwater quality parameters were monitored in the shallow sands and the PMP monitoring wells at the GMF Pond as part of the groundwater quality investigations performed between 2015 and 2021. The History of Potential Exceedances attached to the Operating Permit Application summarizes all potential groundwater exceedances following the proposed statistical analysis plan. The following potential exceedances were identified:

- Arsenic and lead – determined from a single sample from well P60 screened in the loess (PMP).
- pH – values less than the lower limit were determined in wells G52L and G60L which are also screened in the loess (PMP).

Multiple lines of evidence that these limited potential groundwater protection standard (GWPS) exceedances are not related to the GMF Pond is provided in the technical memorandum attached to this report, *Evaluation of potential GWPS Exceedances* (Golder, 2021a). Based on statistical analysis and evaluation of subsequent potential exceedances it has been determined there are no potential groundwater exceedances of applicable groundwater standards attributable to the GMF Pond.

All available hydrological information were used to construct a conceptual model and numerical model of the GMF Pond. A steady state, 5-layer numerical model was constructed to characterize the long-term groundwater flow conditions at the site. Calibration of the model focused on simulating mean groundwater elevations for 59 wells at the site by modifying hydraulic parameters for the different hydrostratigraphic units, alongside drain and general head boundary conductance. The calibrated model represents a reasonable match to the observed data given the simplicity of the model. Particle tracking was used both for the closure scenario and sensitivity analysis to provide a quantitative estimate of the distance a potential contaminant from the GMF Pond may travel in 100 years.

Particle tracking for the CIP scenario for a 100-year period indicates that contaminants will not migrate beyond the liner system, maintaining compliance with the applicable groundwater standards post closure.

1. INTRODUCTION

1.1 Overview

In accordance with requirements of the Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments: 35 I.A.C. § 845 (Part 845) (IEPA, 2021), Ramboll Americas Engineering Solutions, Inc. (Ramboll) has prepared this GMR on behalf of the DCPP (**Figure 1-1**), operated by Illinois Power Resources Generating, LLC (IPRG). This report will apply specifically to the CCR Unit referred to as the GMF Pond. However, information gathered to evaluate other CCR units in the vicinity regarding geology, hydrogeology, and groundwater quality is included, where appropriate.

1.2 Previous Groundwater Reports

Numerous hydrogeologic investigations have been performed at the DCPP. The information presented in this GMR includes data collected as part of a 2021 field investigation and previous investigations summarized and presented in the Hydrogeologic Site Characterization Report (HCR) (Ramboll, 2021a) which was provided as an attachment to the Initial Operating Permit application required by 35 I.A.C. § 845.230.

1.3 Site Location and Background

The DCPP is located in Fulton County, Illinois and approximately 6 miles southeast of the town of Canton. The GMF Pond is located north of the power plant in Section 18 of Township 6 North, Range 5 East (**Figure 1-1**). The GMF Recycle Pond is located just south of the GMF Pond (**Figure 1-2**). The DCPP is located near the Duck Creek Cooling Pond, which was used as a source of cooling water for the power plant when it was active, and several small ponds which are remnants of the area's surface mining history. The Landfill is located due north of the GMF Pond and the closed units, Ash Pond No. 1 and Ash Pond No. 2, are located south of the GMF Recycle Pond. Prior to construction of the power plant and associated facilities, strip mining of coal took place within the property boundary of the DCPP (**Figure 1-1**). Currently, land use adjacent to the DCPP is agriculture, pasture, and forest with minimal development. The area is flat to gently rolling uplands that are dissected by deeply incised streams that are tributaries to major river systems in areas that have not been disturbed by strip mining activity.

1.4 Site History and CCR Units

Surface preparation for the GMF Pond began in 2007 and construction took place from 2008 to 2009. The GMF Recycle Pond was constructed at the same time.

The GMF Pond, also referred to as the gypsum stack/management system, operates under an IEPA permit (#2017-E0-62640) issued in December 2017. It consists of a 1,500-foot by 900-foot earthen berm with 3.5:1 side slopes, a maximum elevation of 620 feet, a double geomembrane liner consisting of a 60-millimeter (mil) high-density polyethylene (HDPE) geomembrane liner, 12-inch clay cushion, 4 ounce per square yard (oz/yd^2) non-woven geotextile filter fabric, 12-inch highly permeable granular drainage (sand), 10 oz/yd^2 non-woven geotextile filter fabric, 60-mil HDPE geomembrane liner, reinforced bentonite mat, 36-inch compacted clay, all installed over in-situ foundation soil, and all pipes, pumps, and appurtenances necessary for the storage of approximately 3.6 million tons of gypsum at a maximum elevation of 715 feet with discharge to the GMF Recycle Pond.

During construction, shallow sand was encountered and completely removed from underneath the northeast corner and southwest corner of the GMF Pond, putting the liner in contact with clay of the lower Radnor Till. Sand outside the GMF Pond footprint remains. The GMF Pond decant water discharges to the GMF Recycle Pond, which has a capacity of 32.6 million gallons. The GMF Recycle Pond is lined with a 60-mil HDPE geomembrane liner, reinforced bentonite mat and 36 inches of compacted clay (Ramboll, 2021a).

2. SITE GEOLOGY AND HYDROGEOLOGY

2.1 Stratigraphy

The hydrogeology of the GMF Pond is described in detail in the Hydrological Characterization Report (Ramboll, 2021a). A short summary is provided below.

The unlithified stratigraphy within and immediately surrounding the GMF Pond consists of the following in descending order: fill material and CCR; silt and clayey silt loess (Peoria/Roxanna Loess); weathered till (upper Radnor Till); shallow, medium-grained sand to silt zone within the Radnor Till; and till (lower Radnor Till). The unlithified units overlay Pennsylvanian-age shaley siltstone and silty shale bedrock (Carbondale Formation).

CCR (gypsum) is present within the GMF Pond at a maximum thickness of approximately 22 feet, as estimated from topography and the elevation of the base of the liner from available construction details (AECOM, 2016). The range of gypsum thickness is estimated from less than 1 to 22 feet. The thickest areas of gypsum are to the north and west within the GMF Pond and thin toward the south end of the GMF Pond. The base of the liner rests on top of the lower Radnor Till.

The Wisconsinan Stage Peoria/Roxanna Loess extends from beneath the topsoil developed in the loess to depths ranging from 11 to 21 feet. The loess consists predominantly of silt and clayey silt with minor amounts of sand. The loess exhibits iron staining, concretions, and some fracturing. The Loess Unit is saturated below depths varying from approximately 3.5 to 11 feet.

The loess is generally underlain by a relatively thin till sequence consisting of the Berry Clay (where present) and the Illinoian Stage upper Radnor Till. The till sequence ranges in thickness from 9 to 21 feet in the area of the GMF Pond. This shallow till is generally weathered and exhibits signs of oxidation and fracturing. The till is primarily clayey silt with minor amounts of sand and gravel.

The shallow sand zone is laterally extensive within the Radnor Till across the site and varies in thickness from less than 1 to 18 feet near the GMF Pond; the top of the shallow sand zone is generally located at an elevation of 570 to 590 feet msl. The shallow sand zone exhibits lateral facies changes across the site and varies from a medium-grained sand to a silt and often contains intercalated till seams. The shallow sand zone is saturated.

Till sequences underlying the shallow sand zone consist of clay, silt, and sand of the Illinoian Stage lower Radnor Till. The till ranges in thickness from 42 to 58 feet. In some areas of the site, including the area near the GMF Pond, the till sequences typically extend from the base of the shallow sand to the bedrock surface. In other areas of the site, the till sequences extend to intermediate or deep sands. The till sequences are typically high in silt content with varying amounts of clay, sand, and gravel, and are often calcareous.

Pennsylvanian bedrock was encountered at greatly varying depths across the site. Bedrock depths ranged from a minimum of 52 feet to a maximum of 108 feet below ground surface (bgs). The bedrock shows little compositional variation across the site and consists primarily of shaley siltstone and silty shale. The shale bedrock unit is typically weathered near the surface, has low hydraulic conductivity, and underlies the glacial till sequences. These units often contain thin dolomite ledges and nodules and some fractures.

2.2 Hydrogeology

Three distinct water-bearing layers have been identified at the site based on stratigraphic relationships and common hydrogeologic characteristics, which are summarized below:

- **The Uppermost Aquifer**: This unit includes the Peoria/Roxanna Loess, the upper Radnor Till, and the shallow sands described in detail in **Section 2.5.1**. These units are hydraulically connected and underlain by a thick till sequence of the Radnor Till (NRT/OBG, 2017a). The shallow sands are laterally extensive across the site, vary in thickness from less than 1 to 18 feet, and are generally located at an elevation of 570 to 590 feet above mean sea level (msl). The shallow sand is saturated. During construction of the GMF Pond, sand was completely removed everywhere it was encountered (mainly the northeast corner and southwest corner of the pond), putting the base of liner in contact with clay of the lower Radnor Till. Sand outside the GMF Pond footprint remains in place.
- **Lower Radnor Till/Lower Confining Unit**: Underlying the uppermost aquifer, the lower Radnor Till is approximately 42 to 58 feet thick. Previous hydrogeologic studies indicate discontinuous sand lenses observed within the till are not hydraulically connected to the shallow sand unit (NRT/OBG, 2017a).
- **Bedrock Confining Unit**: The thick and low permeability shaley siltstone, silty shale, and coal beds of the Carbondale Formation are estimated to have a thickness of approximately 300 to 400 feet.

2.2.1 Groundwater Flow

Groundwater flow around the GMF Pond is generally in a southeast direction. The Peoria/Roxanna Loess (PMP) and shallow sands of the uppermost aquifer are hydraulically connected. The groundwater flow in the Peoria/Roxanna Loess is expected to be primarily vertical, with the majority of the horizontal migration expected to occur within the shallow sand unit. Groundwater flow across the GMF Pond within the uppermost aquifer (well locations adjacent to the pond are shown in **Figure 2-1**) is consistently in a southeast direction toward the Duck Creek Cooling Pond (as shown by groundwater elevation contours from April 14, 2021, **Figure 2-2**). Groundwater elevations of the uppermost aquifer vary seasonally although flow directions are generally consistently downward (Ramboll, 2021a). Surface water elevations within the GMF Pond are higher than the groundwater. The elevation difference between the phreatic surface and groundwater elevations, in addition to no observations of radial flow, provide evidence that the GMF Pond does not impact groundwater flow directions via recharge to groundwater. Given the low permeability of the liner system, it is more likely that the GMF Pond is a barrier to groundwater flow within the uppermost aquifer, deflecting flow from upgradient areas around the perimeter of the pond toward the downgradient areas.

2.2.2 Hydraulic Properties

Field estimates of the hydraulic properties of the uppermost aquifer (including both the loess and the shallow sand zones) indicated hydraulic conductivities from 3.0×10^{-5} to 3.9×10^{-3} centimeters per second (cm/s) (equivalent to 0.085 to 11.1 feet per day [ft/d]) with a geometric mean of 3.6×10^{-4} cm/s (1.02 ft/d), based on field tests conducted on 12 wells (5 wells were screened in the loess and 7 wells were screened in the sand) (Ramboll, 2021a).

Hydraulic properties for the Loess ranged from 3.0 x 10^{-5} to 2.3 x 10^{-3} cm/s (0.085 to 6.5 ft/d) with a geometric mean of 2.2 x 10^{-4} cm/s (0.62 ft/d). Shallow sand wells ranged from 6.5 x 10^{-5} to 3.9 x 10^{-3} cm/s (0.18 to 11.0 ft/d) with a geometric mean of 4.9 x 10^{-4} cm/s (1.4 ft/d).

Additional laboratory analysis of seven samples from the loess, upper Radnor Till and shallow sand provided vertical hydraulic conductivities ranging from 7.1 x 10^{-8} to 2.3 x 10^{-6} cm/s (0.0002 to 0.0065 ft/d).

Laboratory estimates for the Lower Radnor Till based on two samples indicated a vertical hydraulic conductivity ranging from 4.1 x 10^{-8} to 5.4 x 10^{-6} cm/s (0.00012 to 0.015 ft/d).

Results of field hydraulic conductivity tests conducted in 2021 in the bedrock confining unit by Hanson Professional Services, Inc. (Hanson) at monitoring well G54C ranged from 1.4 x 10^{-4} to 1.6 x10^{-4} cm/s, with a geometric mean of 1.5 x 10^{-4} cm/s. This is high in comparison to the horizontal hydraulic conductivity range of 1.3 x 10^{-6} cm/s to 1.3 x 10^{-9} cm/s, established by Hanson in 2015, which used pressure testing on borehole OM32. The higher values observed at G54C are attributed to the highly weathered nature of the bedrock in the screen interval, which is supported by the low rock quality designation (RQD) N values ranging from 14 to 22 (lower numbers indicating lower percentage of intact rock core recovered).

2.2.3 Groundwater Elevation Data

There are 59 wells located around the GMF Pond, with most wells located around the perimeter of the GMF Pond and the GMF RP. In most of these wells, water level measurement are available from 2004 to 2021 (**Table 2-1**). The data are summarized in **Table 2-2**. The observed range in groundwater elevation (GWL) within the data set is 41.6 feet. For wells with more than 1 reading, the mean variation in GWL within each well is 13.9 feet (mean GWL variation), with an observed minimum and maximum variation of 4.8 and 28.4 feet, respectively.

2.2.4 Mining Activity

Strip mining has occurred in this area since the 1930s. Strip mining in the site vicinity extracted coal from the Springfield (No. 5) coal seam. Mining operations in the area have ceased (NRT/OBG, 2017a). Strip mining has completely disrupted the natural stratigraphy down to the Springfield (No. 5) coal unit at some portions of the site. Previous investigations completed outside of the GMF Pond at the site also indicated that bedrock in the area is overlain by mine spoil ranging in thickness from approximately 10 feet to 75 feet. The mine spoil consists of excavated bedrock (weathered shale, shale fragments, and some coal fines) mixed with the sand, silts, and silty clays of the unconsolidated glacial and aeolian deposits. The GMF Pond is located immediately adjacent to several former large surface mining areas (**Figure 2-3**).

3. GROUNDWATER QUALITY

3.1 Groundwater Classification

Per 35 I.A.C. § 620.210, groundwater within the uppermost aquifer at the GMF Pond meets the definition of a Class I – Potable Resource Groundwater based on the following criteria:

- Groundwater in the uppermost aquifer extends 10 feet or more below the land surface.
- Hydraulic conductivity exceeds the 1 x 10^{-4} cm/s criterion.

Field hydraulic conductivity tests performed on the unlithified geologic materials that include loess and shallow sand at the GMF Pond had geometric mean hydraulic conductivities exceeding 1 x 10^{-4} cm/s. Based on this information groundwater is classified as Class I – Potable Resource Groundwater.

However, background (upgradient) groundwater originates from areas north and west of the GMF Pond that have been surface mined and present a significant alternative source for groundwater impacts.

3.2 Potential Groundwater Exceedances

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

Groundwater concentrations from 2015 to 2021 presented in the HCR Table 4-1 (Ramboll, 2021a), and evaluated and summarized in the History of Potential Exceedance tables (Ramboll, 2021b), 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]; Ramboll, 2021c), which has not been reviewed or approved by IEPA at the time of submittal of 35 I.A.C. § 845 Operating Permit application.

The History of Potential Exceedances attached to the Operating Permit Application summarizes all potential groundwater exceedances following the proposed Statistical Analysis Plan. The following potential exceedances were identified:

- Arsenic and lead – determined from a single sample from well P60 screened in the loess (PMP)
- pH – values less than the lower limit were determined in wells G52L and G60L, which are also screened in the loess (PMP)

Multiple lines of evidence that these limited potential GWPS exceedances are not related to the GMF Pond is provided in the *Evaluation of potential GWPS Exceedances* (**Appendix A**, Golder, 2021a) and summarized below:

- The ionic composition of groundwater collected from G52L, G60L, and P60 is similar to groundwater collected from background wells G02S, G50S, and G52S.
- Concentrations of key GMF Pond constituents differ significantly in GMF Pond pore water samples when compared to groundwater samples from monitoring wells G52L, G60L, and P60.
- High turbidity was recorded on the groundwater sampling record for the one sample collected from P60 that had elevated arsenic and lead concentrations.

- A peat layer ranging in thickness from 1 to 14 feet is present in the immediate vicinity of P60, resulting in lower pH.
- Arsenic and lead are not typical CCR indicators and are not present in GMF Pond porewater and surface water at concentrations above the GWPS.
- The GMF Pond liner was constructed with a dual composite liner system with a leak detection system, has undergone rigorous construction quality assurance, and has indicated strong performance.

4. GROUNDWATER MODEL

4.1 Overview

Data collected at the Site from 2004 to the recent 2021 field investigation were used to construct a groundwater model of the GMF Pond. The model was then used to evaluate how the proposed closure plan would maintain compliance with the applicable groundwater standards following the closure construction. The modeling results are summarized and evaluated in this GMR. A disk containing the associated model files is included as **Appendix B**.

4.2 Conceptual Model

The HCR (Ramboll, 2021a) forms the foundation of the GMF Pond hydrogeological setting. The GMF Pond overlies the recharge area for the underlying transmissive geologic media, which are composed of unlithified deposits.

4.2.1 Hydrogeology

As discussed in **Section 2.2**, groundwater flow around the GMF Pond is generally in a southeast direction. The Peoria/Roxanna Loess and Shallow Sands are hydraulically connected. The groundwater flow in the Peoria/Roxanna Loess is expected to be primarily vertical, with the majority of the horizontal migration expected to occur within the Shallow Sands unit. The geological conceptual model for the site consisted of the following layers:

- Loess - silt and clayey silt of the Wisconsinan Stage Peoria/Roxanna Loess which extends beneath the topsoil.
- Upper Radnor Till - a thin layer of low permeability till consisting of the Berry Clay and the Illinoian Stage upper Radnor Till.
- Shallow Sands – glacial outwash and re-worked glacial deposits at the base of the Upper Radnor Till formation is the lowermost, laterally extensive coarse grained unlithified deposit identified beneath the site.
- Lower Radnor Till – composed of clay, silt, and sand of the Illinoian Stage lower Radnor Till.
- Bedrock Confining Unit - lowermost unit identified at the site and underlies all unlithified deposits. This unit, composed of low permeability shaley siltstone, silty shale, and coal beds, occurs within the Carbondale Formation of the Kewanee Group.

Surfaces for each of the four major geological units (Loess, Upper Radnor Till, shallow sand, and lower Radnor Till) was made by interpolating contacts between the units interpreted from boring logs. Since all boring log information is centered around the ponds, the surfaces were extended to the full model domain by extrapolation. During construction of the pond, it was noted that sand was removed so that the liner was in contact with the Lower Radnor Till or backfill of similar properties.

4.2.2 Extent and Boundaries

The United States Geological Survey (USGS) National Map places the DCPP within the lower Illinois-Lake Chautauqua watershed subbasin (Hydrologic Unit Code [HUC] 07130003). The GMF Pond CSM extent is bounded by a hydrological catchment (watershed) divide to the east based on watershed data from USGS. Along the north, south, and east, the model boundary has been placed along known waterbodies as much as possible. As such, it is assumed groundwater inflow from adjacent watersheds is negligible through both the uppermost aquifer and lower confining unit.

The Duck Creek Cooling Pond water levels are managed such that they remain at an elevation between 562.5 and 565 feet NAVD88. The Duck Creek Cooling Pond is the receiving body of water for the area encompassed by the CSM.

Infiltration of precipitation to the groundwater table is applied as recharge at the site. Groundwater in the loess and upper Radnor Till migrates downward into the shallow sands (the primary horizontal migration pathway) (discussed in **Section 2.2.1**). Groundwater flow through the loess and upper Radnor Till above the sand zone adjacent to the GMF Pond is considered a PMP.

4.2.3 GMF Pond

The GMF Pond is a 1,500-foot by 900-foot earthen berm and has a double liner system which acts as a low permeability interface (**Table A**) between the gypsum contained within the GMF Pond and the ambient groundwater system. The double liner system was installed along the inner faces of the pond (sides and base of the excavated area).

Table A. Double Liner System Properties from Top to Bottom

Liner Component	Thickness (feet)	Hydraulic Conductivity (ft/d)
HDPE geomembrane	0.005	5.7 x 10^{-10}
Cushion of soil	1	16.4
4 oz/yd^2 non-woven geotextile filter fabric	NA	high
Drainage layer (sand)	1	28.4
10 oz/yd^2 non-woven geotextile filter fabric	NA	high
HDPE geomembrane	0.005	5.7 x 10^{-10}
Geosynthetic clay liner (bentonite)	0.005	1 x 10^{-10} *
Compacted Clay	3	2 x 10^{-3}
Vertical Harmonic Mean of double-liner system	**5.015**	**2.8 x 10^{-7}**

* Estimated based on available information
NA = not applicable

Estimates of the hydraulic properties of each of the components within the double-liner system were derived using values from the Hydrologic Evaluation of Landfill Performance (HELP) model Tolaymat and Krause, 2020); see **Section 5-1** for more information about HELP. For flow perpendicular to the layer orientation, as is the case in the liner where the hydraulic gradient is vertical for the base and horizontal for the sides of the pond, the harmonic mean was used to obtain the effective hydraulic conductivity (K_{eff}) (Fetter, 1988). The harmonic mean was determined by:

$$K_{eff} = \frac{\sum b}{\sum \frac{b}{K}}$$

where b is the layer thickness and K is the horizontal hydraulic conductivity.

Findings from the HCR (Ramboll, 2021a) indicate that the GMF Pond does not appear to impact groundwater flow directions via recharge to groundwater. Given the low permeability of the liner system and the removal of sand below the unit, it is more likely that the GMF Pond is a barrier to groundwater flow within the Loess and Shallow Sands aquifers, directing flow from upgradient areas around the perimeter of the pond toward the downgradient areas south and east of the pond toward the Duck Creek Cooling Pond.

If a release to groundwater were to occur, this would be detected by increased boron concentrations (or other parameters included in 35 I.A.C. § 845.600(a)(1)) in the uppermost aquifer or PMP wells. 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. Groundwater quality data shows no boron levels above background levels, therefore there is no meaningful data to use in model calibration. Contaminant transport is therefore modeled with particle tracking, which allows for evaluation of transport times and directions.

4.3 Model Approach

A three-dimensional groundwater flow model was calibrated to represent the conceptual flow system described above. A steady state model was used to simulate the mean groundwater flow conditions at the site. The model was calibrated to match mean groundwater elevations observed between 2004 to 2021 (**Table 2-2**). Prediction simulations were then performed to evaluate the potential impacts to groundwater from closure in place as presented in the *Draft CCR Final Closure Plan, which is Appendix H of the Draft Construction Permit Application* (Golder, 2021b) to which this report is also attached.

Three model codes were used to simulate groundwater flow and contaminant transport:

- Groundwater flow was modeled in three dimensions using MODFLOW 2005.
- Contaminant transport was modeled in three dimensions using MODPATH.
- Percolation (recharge) was modeled using the results of the HELP model.

5. MODEL SETUP AND CALIBRATION

5.1 Model Descriptions

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—given user-supplied inputs of hydraulic conductivity, aquifer/layer thickness, recharge, wells, and boundary conditions. The program also calculates water balance at wells, rivers, and drains.

MODFLOW was developed by the USGS (McDonald and Harbaugh, 1988) and has been updated several times since. Major assumptions of the code are: (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. Other assumptions concerning the finite difference equation can be found in McDonald and Harbaugh (1988). MODFLOW 2005 was used for these simulations with Groundwater Vistas 7 software for model pre- and post- processing tasks (Environmental Simulations, Inc, 2017).

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 has numerical dispersion for low-dispersivity transport scenarios but conserves good mass balance. The particle-tracking method avoids numerical dispersion but was not accurate in conserving mass. Groundwater quality data indicates negligible transport of contaminants from the GMF Pond; therefore, the particle-tracking method was used to provide estimates of groundwater transport in the event of leakage through the pond liner.

The HELP model was developed by USEPA. HELP is a one-dimensional hydrologic model of water movement across, into, through and out of a landfill or soil column based on precipitation, evapotranspiration, runoff, and the geometry and hydrogeologic properties of a layered soil and waste profile. For this modeling, results of the HELP model, HELP Version 4.0 (Tolaymat and Krause, 2020) completed for the groundwater model were used to estimate the hydraulic flux from beneath the GMF Pond.

5.2 Flow and Transport Model Setup

Under current conditions, the groundwater protection standards are being met for the GMF Pond. While no potential exceedances of GWPS have been identified in the monitoring well network for this unit (**Section 3.2**); and, source control will mitigate future groundwater impacts, groundwater modeling of closure in place was completed to demonstrate that closure will maintain compliance with applicable groundwater quality standards following construction. The modeled area was approximately 7,900 feet by 9,950 feet with the GMF Pond located in the southeast quadrant. The model grid and boundary conditions for the five model layers are displayed in **Figures 5-1 through 5-5**.

Evaluation of monitoring well data for the GMF Pond has not identified statistically significant seasonal trends in groundwater flow or quality which could affect model applicability for prediction of transport. The MODFLOW model was calibrated to mean groundwater elevations from 2004 to 2021. Multiple iterations of MODFLOW calibration were performed to achieve an acceptable match to observed flow data. For the GMF Pond, the calibrated flow model was used in predictive modeling to evaluate closure in place (CIP). Because no groundwater impacts attributable to the CCR unit have been observed, there is no need to simulate a closure by removal (CBR) option because no future exceedances would be expected. Details of the proposed CIP are described below:

- The CCR within the GMF Pond will be consolidated in the north end of the pond, graded, and covered with a geomembrane and soil layers with an estimated timeline of completion of 12 months.

5.2.1 Grid and Boundary Conditions

A five-layer, 340 x 220 node grid was established with 25-foot grid spacing (**Figure 5-1 through 5-5**), with a total number of 200,732 active cells. The northern and western edges of the model are no-flow boundaries in all layers of the model. For both the southern and eastern boundaries, where the model boundary is the Duck Creek Cooling Pond, a constant head boundary was placed equal to the surface elevation of the Duck Creek Cooling Pond. In areas where the model boundary deviates inland from the Duck Creek Cooling Pond, a general head boundary with a conductance estimate based on the distance to the Duck Creek Cooling Pond was placed. The southern and eastern boundaries are only present in layer 5 due to the change in elevation.

The bottom of the model was also a no-flow boundary. The top of the model was a time-dependent specified flux boundary, with specified flux rates equal to the mean recharge rate.

Natural (streams) and man-made (associated with the railroad) drainage features are present in the modeled area; these are represented as drains in the model.

5.2.1.1 Layer Top/Bottom

A digital elevation model of the area was used to assign the top of layer one. The elevations for the base of each hydrostratigraphic layer were interpolated from boring log data primarily from logs provided in the HCR (Ramboll, 2021a) and imported as grid data into MODFLOW. The silts and clays of the Upper Radnor Till unit was divided into two layers to accommodate the explicit inclusion of the GMF Pond liner system (see **Section 5.2.1.4**). The Loess, Shallow sands, and Lower Radnor Till were all represented as single layers within the model.

Flow model layer description and parameters are summarized in **Table B** below.

Table B. Flow Model Layer Descriptions

Layer	Hydrostratigraphic unit name	Hydrostratigraphic unit used to determine layer thickness	Top Elevation (feet)	Bottom Elevation (feet)	Thickness (feet)
			Mean (Minimum – Maximum)		
1	uppermost aquifer (PMP)	Loess	616.2 (594.7-663.0)	597.7 (585.0-604.5)	18.6 (0.5-65.6)

2 & 3	uppermost aquifer	Silts and clays of the Upper Radnor Till	597.7 (585.0-604.5)	587.0 (577.0-597.5)	10.2 (1.0-19.8)
4	uppermost aquifer	Shallow sands	587.0 (577.0-597.5)	582.8 (566.8-595.4)	4.2 (0.5-14.3)
5	lower confining unit	Lower Radnor till	582.8 (566.8-595.4)	527.7 (517.3-547.7)	54.9 (34.0-67.1)

PMP = potential migration pathway

5.2.1.2 Hydraulic Conductivity

The spatial distribution of the hydraulic conductivities within each layer was considered homogenous. With the exception that in the strip-mining area to the south of the GMF Pond described in **Section 2.2.4** (**Figure 2-3**), where all hydrostratigraphic units were excavated and the area back-filled, resulting in what is assumed to be a more homogenous fill in the strip-mining area. Therefore, the hydraulic conductivity values for each layer in the mine spoil area are uniform. **Figures 5-6 through 5-11** show the spatial distribution of the hydrostratigraphic units, as well as the mining spoils associated with the strip mining activity, GMF Pond and GMF Recycle Pond, and the GMF Pond liner for each of the model layers.

Where available, hydraulic conductivity values were derived from field measured values reported in the HCR (Ramboll, 2021a) (**Section 2.2.2**). During calibration it became clear that tested values in general were low and therefore hydraulic conductivities for the hydrostratigraphic layers were further refined through model calibration and tend to be greater than the tested values. No horizontal anisotropy was assumed. Vertical anisotropy with ratios between 1/10 and 1/3 were applied to the Loess, Upper Radnor Till, Shallow sands, Lower Radnor Till, and the mine spoils to simulate preferential flow in the horizontal direction in these materials.

5.2.1.3 Recharge

Recharge rates were determined through calibration of the model to observed groundwater elevations. For the calibration model, recharge was applied uniformly across the model. Model inputs are summarized in **Table C** in **Section 5.4**.

5.2.1.4 GMF Pond Parameters

Implementation of the GMF Pond into the model used hydraulic flow barriers to represent the double liner system on the sides of the pond. The bottom of the liner is implemented by assigning the liner system hydraulic conductance to model layer 2 within the footprint of the pond. The base elevation of layer 2 within the footprint of the GMF Pond simulates the base elevation of the liner. The thickness of model layer 2 within the footprint of the pond was set to five feet. Removal of the Shallow Sands below the GMF Pond (as described Section 4.2.3) means that the liner is in direct contact with the Upper Radnor Till or backfill of similar characteristics.

A drain was placed in model layer 1, where the elevation of the base of the drain was equal to the water level monitored in the pond. The drain was included to represent flow to the GMF Recycle Pond. The GMF Recycle Pond was implemented in the same way. The actual recharge to the ponds is unknown, but for simplicity the same values as were used for the surrounding area were applied. The drain conductance was adjusted to allow for enough “runoff” from the ponds to fit expected water levels in both ponds.

The vertical hydraulic conductivity of the double liner system was calculated as 2.8 x 10^{-7} ft/d (horizontal hydraulic conductivity of 2.8 x 10^{-6} ft/d) based on the harmonic mean of the hydraulic conductivities for the different components within the liner (**Table A** in **Section 4.2.3**). These values were assigned to model layer 2 within the footprint of the GMF Pond representing the liner system.

5.2.2 Transport Model Input Values

Particle tracking was used both for the sensitivity analysis (discussed in **Section 6.2.1**) and the closure scenario to provide a quantitative estimate of the distance a potential contaminant from the GMF Pond may travel in 100 years.

5.2.2.1 Effective Porosity

MODPATH uses estimates of the effective porosity of the hydrostratigraphic unit to calculate Darcy velocities, which strongly impact the movement of particles. Estimates of porosity for the hydrostratigraphic units provided in the HCR (Ramboll, 2021a) and summarized below:

- Loess - Average total porosity of 37 percent (range of 32.4 to 41.8 percent).
- Upper Radnor Till - Average total porosity of 36.8 percent (range of 30.7 to 41.4 percent).
- Shallow sands - Average total porosity of 29.5 percent (range of 27.4 to 31.4 percent).
- Lower Radnor Till - Average total porosity of 22.3 percent (range of 20.6 to 23.5 percent)

The values from the HCR are based on laboratory testing and are not expected to represent effective porosities, but rather be at the upper level of possible values. The values used in the modeling were chosen based on expected values for the hydrostratigraphic units; the chosen values are shown in **Table C** in **Section 5.4**.

5.2.2.2 Particles

Particles represent a given mass of contaminant and are initially placed within the GMF Pond at the top of model layer 2 (representing the top of the liner). At each cell within the GMF Pond, one particle was started at the top of model layer 2 and allowed to travel for 100 years.

Simplifying assumptions were made while developing this model:

- Except for changes induced by cap construction and ash fill consolidation/removal, the groundwater flow system is at steady state.
- Natural recharge is constant over the long term.
- Fluctuations in Duck Creek Cooling Pond stage do not affect groundwater flow and transport over the long term.
- Hydraulic conductivity is consistent within hydrostratigraphic units.
- The conductance term used to simulate the GMF Pond double liner system adequately represents a composite estimate of the permeability of the liner system.
- Particles represent a mass of Boron which leaves the GMF Pond and enters the groundwater system.
- Boron is not adsorbed and does not decay, and mixing and dispersion are the only attenuation mechanisms.

5.3 Calibration Flow Model

The groundwater model was manually calibrated to best approximate the mean groundwater elevations in 59 wells at the site. The mean elevations used for calibration and locations of wells within the flow model are summarized in **Table 2-2**. Well locations are shown in **Figure 2-1**. This involved modifying the hydraulic conductivities of the different hydrostratigraphic units, recharge rate, and conductance of the drains and general head boundaries within the model to minimize the difference between the mean observed groundwater elevation and simulated groundwater elevation. Where possible, the range of the parameter values used during calibration were based on observed values (*i.e.,* for the range in hydraulic conductivity estimates from the HCR). Where this was not possible, such as for the drain and general head boundary conductance, the range of parameter values were based on other site information or inferred from knowledge from similar sites. Where data were limited, the parameter values were less constrained during calibration (*e.g.,* parameter values had wider ranges). The root mean squared error (RMSE) was used as a metric to identify the optimal values for the different parameters.

The groundwater model is steady state and is therefore only able to simulate the long term mean groundwater flow conditions. It is unable to capture seasonal variability in groundwater elevations. There may be a bias in the groundwater elevation data used to quantify the mean groundwater elevation for the wells, based on the temporal distribution of the data and the frequency of the data collection. The potential for deviation away from mean conditions can be integrated into the calibration process by using the standard deviation of the groundwater levels as an additional metric (**Table 2-2**). This assumes that all groundwater data have a gaussian distribution (normal distribution) such that 95 percent of the observed groundwater elevation would fall within plus or minus (±) 2 standard deviations (std) from the average groundwater elevation. If a simulated groundwater level was within ±2 std of the mean observed groundwater level, the simulation may be considered reasonable.

5.4 Calibration Flow Model Results

Results of the MODFLOW modeling are presented below. A disk containing the model files is attached to this report (**Attachment A**). **Table C** shows the calibrated hydraulic conductivity for the different units shown in **Figures 5-6** to **5-11**.

Groundwater model calibration results are presented in **Figure 5-12** and **Figure 5-13**, which shows the observed GWL and simulated groundwater elevations. The RMSE of the GWL across all wells was 6.22 feet. The mass balance error for the flow model was 0.001 percent and the ratio of the residual std to the range of heads was 20.9 percent, which is above the desired target value of 10 percent. The simulated groundwater elevations within the Loess (**Figure 5-12A**) are generally in good agreement with the observed groundwater elevations. Most of the simulated groundwater elevations fall within ±1 std of the observed groundwater elevation. The simulated groundwater elevations in the shallow sands have a greater tendency to be overestimated relative to the observed groundwater levels. **Figure 5-13** shows the observed versus simulated concentrations within the model. Overestimation of groundwater elevation in the model is more pronounced in the shallow sands at lower groundwater elevations.

Table C. Calibrated Flow Model Layer Hydraulic Parameters

Parameter	Type	Units	Calibrated Value	Ratio Kh to Kv	Porosity
Recharge	Rate	ft/d	0.001	NA	NA
Layer 1: Uppermost Aquifer (PMP)	Hydraulic conductivity	ft/d	5	7	0.37
Layer 2 & 3: Uppermost Aquifer	Hydraulic conductivity	ft/d	1	5	0.37
Layer 4: Uppermost Aquifer (Sand)	Hydraulic conductivity	ft/d	30	3	0.17
Layer 5: Lower Confining Unit	Hydraulic conductivity	ft/d	0.7	10	0.22
Strip mining area	Hydraulic conductivity	ft/d	5	5	0.20
GMF Pond Base Liner	Hydraulic conductivity	ft/d	2.8×10^{-6}	10	0.20
GMF Pond Horizontal Flow Barrier	Hydraulic conductivity	ft/d	5.68×10^{-7}	NA	NA
General Head	Conductance	ft^2/d/ft	1.5	NA	NA
Drains: railway	Conductance	ft^2/d/ft	1.8×10^{-2}	NA	NA
Drains: stream	Conductance	ft^2/d/ft	8.0×10^{-2}	NA	NA
Drains: GMF Pond	Conductance	$ft^2/d/ft^2$	5.0×10^{-3}	NA	NA

ft^2/d/ft = square feet per day per foot
NA = not applicable
Kh = horizontal Hydraulic Conductivity
Kv = Vertical Hydraulic Conductivity

Figure 5-14 and **Figure 5-15** show the simulated groundwater elevations for layers 1 (Loess) and 4 (Shallow Sands), respectively. In both the Loess and Shallow Sands, the model is able to simulate the groundwater levels around the GMF Pond within 1 standard deviation. This indicates that the model is adequate to simulate the hydraulic head between the GMF Pond and the surrounding groundwater in the uppermost aquifer, which is an important driver of groundwater flow from the pond into the aquifer. The largest errors tend occur in wells to the north and south of the GMF Pond. In general, the flow patterns are comparable to those shown in **Figure 2-2** interpreted from the site well data for May 2021. The GMF Pond forms a barrier to groundwater flow, directing groundwater to flow around the unit in layer 1 of the model. Some impact of the GMF Pond on groundwater flow can be seen in **Figure 5-14**, where the groundwater contours are deflected along the GMF Pond's footprint. **Table D** provides an overview of the GMF Pond water balance. The estimated particle travel distances after 100 years are also provided as a no action scenario for comparison to the proposed closure scenario.

Table D. Water Balance Results from Calibrated GMF Pond and Particle Travel Distances after 100 years for Current Conditions (no action scenario)

Water Balance Components	Calibrated Model
Inflow: Recharge (ft^3/d)	942.5
Outflow: Drain Flow (ft^3/d)	941.0
Outflow: Leakage (ft^3/d)	0.62
Mean distance travelled by particles (feet) ± (std)	0.123±0.039
Mean distance travelled by particles in z direction (feet) ± (std)	0.121±0.035

ft^3/d = cubic feet per day

K = hydraulic conductivity

Review of the model calibration indicates good agreement with observed conditions in the local area around the GMF Pond. The elevated ratio of the residual std to the range of heads suggests that sitewide subsurface heterogeneity (the uppermost aquifer is located in glacial deposits that grade laterally from sand to silt) is not optimally represented by the homogenous layers used in the model. Further, because the shallow sand layer is less than 5-feet thick in most locations, wells monitoring the shallow sand are screened across the shallow sand and into the overlying and/or underlying finer grained deposits of the Radnor Till, which are represented in the model as separate layers. Based on the objective of the model to estimate potential impacts from the GMF Pond, a homogenous representation in hydraulic properties within layers was maintained.

6. CLOSURE SCENARIO MODEL

As discussed in **Section 5.2**, because no groundwater impacts attributable to the CCR unit have been observed, there is no need to simulate a CBR option because no future exceedances would be expected. Modeling for the CIP closure scenario was conducted using particle tracking for a period of 100 years, based on a steady state model of the site under closure conditions. HELP (Version 4.0; (Tolaymat and Krause, 2020) was used to estimate percolation through GMF Pond capping solution (described below). HELP modeling input and output values can be found in **Appendix C**.

The following simplifying assumptions were made for the simulation:

- Cap construction has an instantaneous and constant effect on recharge and percolation through surface materials.
- In the CIP scenario, average annual percolation rates through the cap system were estimated from a 100-year HELP model run. There was no significant change in percolation rates over the 100-year timeframe of HELP-simulated values. This 100-year HELP-calculated percolation rate remained constant over the duration of the closure scenario prediction model runs.
- The design for CIP for the GMF Pond involves pumping out ponded water from the GMF Pond, construction of a berm mid-way (east-west orientation) across the pond (also lined with 60-mil HDPE geomembrane), and collection of all gypsum south of the berm to be deposited north of the berm. The existing double-liner system south of the berm will be disposed.
- Cap construction in the scenario was assumed to be completed with a cover system consisting of the following (listed from ground surface down): a vegetative cover (6 inches thick), protective layer of compacted soil (36 inches thick), geo-composite drainage layer, and 60-mil HDPE geomembrane.
- Final grade of the capping system was assumed at or above current top of berms. Proper storm water control systems were assumed to remove excess water from the surface of the capped areas based on design drawing (Golder, 2021b).
- Predicted recharge rates for the GMF Pond cover system can be estimated based on the HELP cap system percolation rates.
- All saturated gypsum is consolidated into the designed footprint of the CIP closure scenario. This assumes all gypsum is placed within the final footprint of the caps for the closure-in-place scenario. Local fill materials were assumed to replace the compacted clay liner.
- Local fill materials applied to the CIP models have similar hydraulic properties as the Upper Radnor Till used in the calibrated model.

6.1 Closure in Place Model Setup

Both the HELP and a modified version of the calibrated groundwater flow models were used to evaluate the impact of the CIP scenario. The scenario was simulated as steady state flow model and particle tracking was used to estimate contaminant travel distances from the capped unit. In the modified version of the steady state flow model the horizontal flow boundary and liner properties of layer 1 and 2 are only applied within the CIP footprint.

HELP input data and results are provided in **Appendix C**. The CIP scenario was modeled for a period of 100 years. Climatic inputs were synthetically generated using default equations developed for Indianapolis, Indiana (the closest weather station included in the HELP database), 100-year average precipitation and temperature values recorded at the Peoria, Illinois weather station, and the latitude of the GMF Pond. Soil layering was developed for the CIP scenario using data provided in the closure scenario designs documented in the Golder (2021b) report described above.

HELP model results indicated that an average of 0.00025 inches/year (2.1×10^{-5} foot/year) of leakage occurs through the CIP cap system (**Appendix C**). The CIP scenario footprint is shown in **Figure 6-1**, the HELP calculated cap system percolation rate was applied to the CIP footprint as recharge, the recharge rate for the area outside this footprint was set the same as in the calibrated model (**Table C**). The CIP plan also includes surface drainage in the southern area of the GMF Pond footprint, therefore the drainage in this area was simulated with drain cells set equal to the planned surface elevation. The Recycle Pond was removed as part of the CIP model scenario. The CIP scenario model was run as steady state. A particle was placed in each cell in the CIP footprint (**Figure 6-2**) to simulate advective transport.

The groundwater flow from the CIP GMP Pond footprint is correlated to the conductivity of the liner system; therefore, a sensitivity analysis was performed for the CIP scenario to determine the impact of the liner system's hydraulic properties on the leakage from the CIP GMP Pond footprint. The conductance values of the horizontal hydraulic barriers and liner of the pond were increased by an order of magnitude. This simulation approach represents the upper bounds of potential flow rates through the liner and results are presented in **Section 6.2.1**. All other hydraulic parameters were unchanged from the calibrated model in the CIP scenario model.

6.2 Closure in Place Model Results

The simulation of the CIP scenario resulted in dry cells within the CIP footprint in both layer 1 (the gypsum) and layer 2 (the basal liner) indicating water is not expected to accumulate in the closed unit following placement of the cap. Low levels of saturation within the capped CIP scenario are anticipated due the unwatering and dewatering of the GMF pond prior to capping and the low infiltration rate through the cap. However, in order to use MODPATH to determine the travel distance of particles through the basal liner, cells are required to be saturated (active). To get saturated cells in the CIP footprint, the horizontal and vertical hydraulic conductivities of the gypsum unit (see **Table C**) were reduced to 0.1 ft/d and 0.01 ft/d respectively, thus allowing for MODPATH simulations. All water balance and particle tracking results provided below pertain to the groundwater model with the reduced gypsum hydraulic conductivity.

The results of simulated CIP for the GMP Pond at DCPP are shown in **Table E** below. All particles remain within the CIP footprint (liner and gypsum), indicating the proposed closure method is not expected to result in exceedances of the GWPS. The mean travel distance of all particles within the liner system and gypsum was 0.29 feet horizontally and 0.03 feet vertically after 100 years. Reduced head within the closed pond creates variable hydraulic gradients with the surrounding groundwater. This results in simulated groundwater inflow into the CIP footprint and outflow from the CIP footprint. Approximately 57 percent of the particles (in the north-western corner of the unit) move upward from the liner system into the over lying gypsum. The remaining 43 percent move downward while remaining within the liner system.

Estimated vertical flow rates are reduced compared to the calibration model. In the calibrated model, vertical flow is 0.62 ft^3/d (**Table D**); whereas, in the CIP scenario this is reduced to 0.07 ft^3/d (**Table E**).

Of primary interest is the simulation of particles moving downwards within the liner which could potentially enter the groundwater system. Comparison of the downwards advective travel distance of the particles for the calibration model (no action) and CIP scenario show a reduction in travel distance after 100 years. In the calibrated model, the mean distance traveled by the particles was 0.12 feet (**Table D**) into the liner system; whereas, in the CIP scenario this is reduced to 0.04 feet (**Table E**) into the liner system.

Table E. Water Balance Results from Closure-in-Place Scenario and Particle Travel Distances after 100 Years

Water Balance components	CIP Scenario	CIP Increase liner K by 10^1
Inflow: Recharge (ft^3/d)	0.027	0.027
Inflow: Groundwater inflows (ft^3/d)	0.042	0.75
Outflow: Leakage (ft^3/d)	0.068	0.78
Mean distance travelled by all particles (feet)	0.285±0.46	17.21±18.12
Mean distance travelled by all particles in z direction (feet)	0.025±0.019	0.326±0.2
Percentage of particles which moved downward	43	42
Mean distance travelled by downward moving particles in z direction (feet)	0.035±0.02	0.226±0.127
Percentage of particles which moved upward	57	58
Mean distance travelled by upward moving particles in z direction (feet)	0.017±0.0	0.4±0.21

ft^3/d = cubic feet per day

K = hydraulic conductivity

6.2.1 GMF Pond Sensitivity

The impact of changes to the liner conductivity, on the simulated CIP GMP Pond groundwater outflows and particle tracking are shown in **Table E** above. Increasing the hydraulic conductivity of the liner system by an order of magnitude results in a similar increase in outflow from 0.07 to 0.78 ft^3/day. There is a significant lateral component to the particle movement in this sensitivity test leading to an increase in mean distance traveled by particles from 0.0.29 to 17.21 feet. However, the downward movement of particles only increases from 0.04 feet to 0.23 feet. In both simulations the particles remain within the CIP unit and pond liner system, which is 5 feet thick.

7. CONCLUSIONS

There are no potential groundwater exceedances of applicable groundwater standards attributable to the GMF Pond. This GMR has been prepared to show how proposed CIP for the GMF Pond will maintain compliance with the applicable groundwater standards at the DCPP. This report integrates existing site data and information with the latest hydrogeology and groundwater quality data to generate a conceptual and numerical model of the GMF Pond.

The calibrated numerical model of the GMF Pond successfully simulated the groundwater flows and elevations around the GMF Pond. The water balance for the GMF Pond and particle tracking simulations indicated that the outflow from the GMF Pond will decrease as compared to current conditions and that all particles representing potential contaminant mass will remain within the CIP unit and liner system after 100 years.

In the CIP scenario, estimated vertical flow rates through the GMF Pond liner system were reduced from 0.62 ft^3/day in the calibration model to 0.07 ft^3/day. Particle tracking showed that the hydraulic gradient between the CIP unit and the groundwater in the aquifer moved particles a mean distance of 0.29 feet horizontally and 0.04 feet downward after 100 years and remained within the model layers representing the liner system and gypsum unit. Increasing the conductivity of the liner system for sensitivity testing influenced both the water balance and the travel distances of the particles. With the liner conductivity in the CIP model increased by one order of magnitude for testing, the flow out of the pond increased from 0.07 ft^3/day to 0.8 ft^3/day; likewise, the downwards distance travelled by the particles increased from 0.04 feet to 0.22 feet. This indicates that in both the CIP scenario and sensitivity test simulations, the particles do not migrate beyond the liner system which is 5 feet thick.

Particle tracking for the CIP scenario for a 100-year period indicates that contaminants will not migrate beyond the liner system, maintaining compliance with the applicable groundwater standards post closure.

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TABLES

TABLE 2-1. GROUNDWATER ELEVATION TIMESERIES DATA

GROUNDWATER MODELING REPORT
DUCK CREEK POWER PLANT
GMF POND
CANTON, ILLINOIS

	Uppermost Aquifer / PMP (Peoria and Roxana Loess)																														
Date	**G50L**	**G51L**	**G52L**	**G53L**	**G54L**	**G55L**	**G56L**	**G57L**	**G58L**	**G59L**	**G60L**	**G61L**	**G62L**	**G63L**	**G64L**	**G65L**	**G66L**	**G67L**	**G68L**	**G69L**	**G70L**	**G71L**	**G72L**	**G73L**	**P57L**	**R61L**	**P01L**	**G02L**	**P40L**	**P41L**	**P42L**
1/9/2004																												613.73	610.22		
3/12/2004																												614.26	610.29		
7/21/2004																												612.27	609.69	602.99	
10/18/2004																												607.24	602.12		
1/28/2005																												616.13	615.3	606.31	612.39
4/11/2006																												614.51	616.49	606.33	613.74
3/29/2007	615.07																								584.97						
5/17/2007	614.03																								588.35						
6/19/2007	613.02																								587.68						
9/18/2007	606.69																								585.66						
11/27/2007	604.67																								584.47						
1/30/2008	609.25	606.31	587.79								591.38					587.77									584.7						
3/26/2008	611.2	609.08	589.31								590.33														585.14						
5/15/2008	611.53	609.21	591.14								589.46					587.79									586.03						
6/24/2008	611.28	607.9	591.85								589.23														586.41						
9/15/2008	612.67	610.68	590.46																						593.64						
11/5/2008	611.28	606.17	591.29																						586.27						
2/16/2009																											616.89	613.96	608.6	605.99	608.48
3/4/2009	611.8	608.4	592.59	603.4		589.29															588.94				586.76						
4/21/2009	613.44	611.62	596.41	607.24	583.7	589.84							590.87			587.87	597.5	597.46	588.78	589.77	590.29				590.51		618.48	615.33	616.27	603.98	610.42
6/8/2009	612.92	610.29	597.01	606.53	583.47	590.1							590.83			587.88	603.4	600.25		590.54	591.24			582.13	588.94		617.76	614.21	614.42	604.61	610.05
4/30/2013	613.62	610.99	595.09	604.59	583.27	590.16	596.96	595.36	589.57	587.74	588.73	600.79	597.74	599.1	593	587.84	596.84	599.3	588.76	589.52	588.19	584.79	589.88	581.53	609.39	600.79					
7/23/2013																												611.86			
10/16/2013																												606.16			
1/20/2014																												613.26			
1/30/2014																															
4/21/2014																												614.5			
4/22/2014																															
7/14/2014																											616.73	614.21			607.95
7/16/2014																															
10/14/2014																											617.01	614.31	616.23	605.22	609.72
2/24/2015																											616.35	614.04	613.15	605.43	611.27
2/25/2015																															
4/15/2015																											611.2	613.81	611.85	605.41	611
4/16/2015																															
7/21/2015																											617.84	614.69	617.3	606.03	610.08
7/22/2015																															
10/12/2015																											614.59	611.59	612.77		603.95
10/15/2015																															
12/10/2015																															

TABLE 2-1. GROUNDWATER ELEVATION TIMESERIES DATA
GROUNDWATER MODELING REPORT
DUCK CREEK POWER PLANT
GMF POND
CANTON, ILLINOIS

	Uppermost Aquifer / PMP (Peoria and Roxana Loess)																													
Date	**G50L**	**G51L**	**G52L**	**G53L**	**G54L**	**G55L**	**G56L**	**G57L**	**G58L**	**G59L**	**G60L**	**G61L**	**G62L**	**G63L**	**G64L**	**G65L**	**G66L**	**G67L**	**G68L**	**G69L**	**G70L**	**G71L**	**G72L**	**G73L**	**P57L**	**R61L**	**P01L**	**G02L**	**P40L**	**P41L**	**P42L**
25/01/2016	614	609.8	599.63	614.2		597.26	603.05	602.98	596.01	600.46			599.53	600.06	599.02	595.86	606.19	606.3		606.12	598.93	589.84	595.23	591.05			618.11	615.51	617.38	606.05	610.18
18/04/2016	611.88	606.81	594.89	611.68		596.57	602.96	600.93	594.87	591.16	589.99		594.03	597.89	600.14	592.18	600.88	603.2	593.13	600.16	596.55	586.6	590.53	589.45			615.25	612.01	612.84		604.44
09/08/2016	612.77	610.26	599.7	614.48	584.55	597.28	603.29	602.42	595.53	599.56	589.85		599.38	599.15	598.93	590.1	606	606.46	589.38	606.69	599.1	586.1	589.87	589.41			615.39	612.48	612.82		606.1
08/09/2016																															
14/10/2016	610.07	605.4	597.28	613.29	586.47	598.88	599.36	602.9	597.28	601.7	590.03		600	599.35	597.12	593.96	604.69	604.92	588.41	606.22	598.73	589.13	589.83	589.57			615.67	614.22	613.08		604.09
09/01/2017	609.05	605.49	594.91	610.14	589.18	596.58	600.82	598.92	592.48	588.03	589.77		595.56	596.3	598.17		602.01	602.2	591.34	604.95	597.67	586.39		586.28			614.89	614.76	612.33		603.14
04/02/2017																															
10/02/2017																															
02/04/2017	613.47	609.21	598.63	614.03	587.35	599.27	599.88	601.57	598.08	601.5	589.44		597.5	599.65	599.64	593.71	605.46	606.07	593.5	606.01	604.32	588.84	593.74	590.13			617.44	615.36	617.11	605.63	609.82
26/07/2017	614.09	610.26	600.87	614.55	588.67	598.08	599.42	599.87	598.84	602.7	590.41		598.58	600.25	600.09	594.18	605.86	606.11	595.34	606.45	605.18	588.64	589.73	592.08		601.52	617.45	615.51	617.18	605.64	610.24
01/09/2017																															
02/10/2017			590.67	604.5	586.85	595.78	598.26	595.47	590.83		588.23		593.83	594.51	596.77	588.86			594.36	595.64	593.87	586.29		586.95		591.29	612.71		607.25		600.97
02/01/2018		603.81	588.46	606.1	584.19	592.28					589.5		593.56	594.19	596.84		TOP		590.37	598	591.2			587.08			614.9		612.23		603.14
01/02/2018																															
07/02/2018																															
10/02/2018																															
06/03/2018																											615.77	606.41	612.45		603.19
10/04/2018	614.39	610.65	596.62	614.12	583.65	594.68	600.32	603.39	598.12	598.86	589.94		597.62	599.97	599.92	589.49	604.52	604.89	593.96	606.02	595.77			585.37			617.32	615.51	616.87	605.28	609.65
03/06/2018																															
02/07/2018	606.86	604.9	588.58	606.43	585.71	594.04	597.47	593.79	590.13	587.32	589.34		593.87	594.15	596.62	587.55	599.04	591.39	590.55	598.12	592.06	584.69	589.79	588.03		591.38	616.84	612.31	616.41	604.26	610.19
02/10/2018	610.77	608.61	592.48	604.41	586.34	594.18		593.52			589.73		595.18	594.14	595.31	587.69	598.74	600.22	590.32	598.18	592.83	584.64		585.13		591.29	616.05	607.93	616.35	605.53	610.134
04/10/2018																															
11/01/2019	607.18	604.98	589.9	607.35	585.76	593.78	597.48	593.95	590.29	587.45	589.48		594.5	594.59	597.16	587.88	598.08	599.37	591.45	598.24	592.55	584.92		588.05		591.32	616.56	612.79	617.38	604.33	610.17
04/04/2019	603.94	600.18	594.28	604.14	587.55	598.17	600.29	597.86	592.44	596.5	592.42		596.29	601.06	596.26	590.74	601.95	605.01	592.46	599.57	597.21	586.2	589.78	587.33		593.79	616.89	616.48	618.56	604.8	610.14
01/07/2019	613.15	607.19	593.65	603.06	588.06	598.16	604.92	603.92	598.49	595.27	592.53		597.95	599.05	600.9	589.84	603.09	604.55	597.81	599.52	599.87	588.55	591.79	583.01		593.14	617.24	609.77	616.73	605.98	610.14
11/11/2019	612.09	608.44	594.53	611.17	589.22	597.64	602.09	600.08	595.74	595.37	599.53		599.4	596.92	598.56	592.48	602.26	603.58	596.24	601.63	598.2	589.34	590.51	589.91		597.07	617.06	612.43	611.91	608.39	610.3
03/01/2020	613.17	610.1	591.63	614.03	591.56	598.31	603.26	601.75	596.44	596	602.53		601.19	598.37	599.97	592.08	604.26	604.88	597.2	602.71	598.9	589.23	589.91	590.51		599.16	617.52	615.78	614.73	607.73	613.71
13/04/2020	612.97	609.82	596.88	613.8	591.01	600.31	605.64	604.11	600.59	602.76	605.49		605.03	611.32	603.52	596.36	604.14	605.58	598.91	604.34	601.69	591.48	591.71	593.52		604.89	616.68	614.51	614.65	608.44	613.87
06/08/2020	609.55	603.54	593.79	610.48	592.39	600.19	602.74	600.58	596.31	597.2	599.81		601.8	599.58	599.98	593.83	599.93	602.69	598.92	600.26	597.43	589.34	590.51	591.48		602.25	611.94	608.31	610.34		610.43
16/11/2020	606.36	602.25	591.67	605.38	592.56	597.8	598.92	596.16	592.08	590.7	593.44		597.64	596.31	596.91	590.2				596.14	594.57	587.72	589.88	588.05		596.68	608.45		601.99		606.24
18/02/2021	611.29	606.99	593.46	607.98	591.56	595.81	597.55	595.8	591.42	589.15	593.7		595.71	595.35	596.57	588.6	597.77	599.69		595.36	593.5	587.08	589.89	586.66		594.89	615.33	613.55	606.5		607.74

TABLE 2-1. GROUNDWATER ELEVATION TIMESERIES DATA

GROUNDWATER MODELING REPORT
DUCK CREEK POWER PLANT
GMF POND
CANTON, ILLINOIS

	Uppermost Aquifer (Shallow Sand)																											
Date	**G02S**	**P01S**	**P40S**	**P41S**	**P42S**	**G50S**	**G51S**	**G52S**	**G53S**	**G54S**	**G55S**	**G56S**	**G57S**	**G58S**	**G59S**	**G60S**	**G61S**	**G63S**	**G64S**	**G65S**	**G66S**	**G67S**	**G68S**	**G69S**	**G71S**	**G72S**	**R72S**	**P57S**
1/9/2004																												
3/12/2004																												
7/21/2004																												
10/18/2004																												
1/28/2005																												
4/11/2006																												
3/29/2007						614.94																						585.925
5/17/2007						613.91																						588.775
6/19/2007						612.95																						588.215
9/18/2007						606.56																						586.355
11/27/2007						603.67																						584.955
1/30/2008						607.7	606.43	583.95								582.43				584.6								585.265
3/26/2008						609.64	609.28	584.79								582.24				584.39								585.635
5/15/2008						609.9	609.35	585.11								581.93				585								586.775
6/24/2008						609.54	608.03	585.16								581.47				585.18								586.945
9/15/2008						611.59	610.87	587.55								584.29				584.79								586.575
11/5/2008						610.2	606.37	585.78								582.7				585.08								586.805
2/16/2009																												
3/4/2009						610.74	608.5	586.45	602.49	583.75	589.7	592.19	591.24	585.59	581.91	581.75	590.22	589.63	590.65	584.08	593.54	594.01	586.17	587.34	580.38			585.415
4/21/2009						612.31	611.51	588.79	604.2	583.47	589.71	592.54	591.87	586.99	582.25	583.02	590.06	590.29	591.44	584.82	598.13	597.24	586.15	588.75	581.29			586.905
6/8/2009						611.82	610.27	588.13	604.77	583.32	590.12	593.19	593.49	587.75	582.81	583.67	589.87	591.14	592.53	586.31	601.71	599.62	586.23	588.93	581.9			588.135
4/30/2013						612.43	611.34	590.21	604.88	582.97	589.69	592.49	592.1	591.71	587.27	588.42	588.37	592.4	593.82	584.2	596.06	595.72	586.51	586.07	584.73	583.6		609.705
7/23/2013																												
10/16/2013																												
1/20/2014																												
1/30/2014						607.77	603.88	587.9	600.4	582.88	589.87	592.24	591.42	586.95	584.3	584.69	586.87	591.5	592.64	584.83	591.94	593.18	586.86	585.48	582.4	584.05		
4/21/2014																												
4/22/2014						607.77	603.88	587.9	600.4	582.88	589.87	592.24	591.42	586.95	584.3	584.69	586.87	591.5	592.64	584.83	591.94	593.18	586.86	585.48	582.4	584.05		
7/14/2014																												
7/16/2014						611.03	609.08	589.59	604.58	583.05	590.39	593.57	592.88	586.03	585.83	586.63	587.37	592.88	594.28	585.45	598.79	598.29	586.94	586.85	584.08	585.88		
10/14/2014						611.6	610.59	590.62	606.97	583.42	591.55	595.61	595.58	591.01	586.83	587.93	588.04	593.93	595.52	588.72	601.8	600.14	587.88	588.58	585.66	589.91		
2/24/2015																												
2/25/2015						611.3	609.66	589.84	606.09	583.2	591.33	595.42	594.52	589.46	585.84	586.63	587.28	593.59	594.94	587.8	598.18	597.79	587.6	588.3	584.02			
4/15/2015																												
4/16/2015						610.54	607.06	589.62	606.85	583.33	591.62	596.29	595.95	590.15	585.86	586.69	587.74	594.13	595.45	587.9	598.38	598.32	587.44	588.46	584.32			
7/21/2015																												
7/22/2015						612.65	610.07	591.37	610.9	584.35	596.51	600.97	601.61	596.81	588.79	590.82	590.02	596.97	598.42	594.45	605.34	605.57	592.96	599.23	588.77	593.79		
10/12/2015																												
10/15/2015						608.15	604.08	589	606.7	584.87	596.13	600.04	597.19	590.61	585.28	586.07	589.2	595.21	596.06	592.02	600.09	601.71	592.36	595	586.34	588.41		
12/10/2015	611.53	614.27	612.3	600.64	603.95																							

TABLE 2-1. GROUNDWATER ELEVATION TIMESERIES DATA
GROUNDWATER MODELING REPORT
DUCK CREEK POWER PLANT
GMF POND
CANTON, ILLINOIS

	Uppermost Aquifer (Shallow Sand)																											
Date	**G02S**	**P01S**	**P40S**	**P41S**	**P42S**	**G50S**	**G51S**	**G52S**	**G53S**	**G54S**	**G55S**	**G56S**	**G57S**	**G58S**	**G59S**	**G60S**	**G61S**	**G63S**	**G64S**	**G65S**	**G66S**	**G67S**	**G68S**	**G69S**	**G71S**	**G72S**	**R72S**	**P57S**
25/01/2016						612.71	610.01	591.84	611.37	586.14	596.89	603.05	601.64	596.89	588.65	590.78	589.27	597.73	597.97	596.05	605.92	605.84	591.96	598.87	590.6	595.24		
18/04/2016						610.93	606.85	589.93	609.24	585.58	596.45	602.68	600.86	594.28	586.91	588.42	590.05	597.27	597.74	592.16	600.59	602.81	592.15	595.65	586.83	586.9		
09/08/2016						612.91	610.67	591.69	611.32	584.43	596.99	603.14	602.02	596.07	585.31	586.57	589.66	595.95	597.97	594.07	605.37	605.69	593.01	599.58	588.81			
08/09/2016	612.18	614.87	612.63	601.35	605.61																							
14/10/2016						608.63	605.6	589.92	608.65	586.46	598.82	599.84	602.32	598.08	589.8	591.86	590.49	597.21	598.77	593.96	604.16	604.75	592.8	598.51	589.35		589.57	
09/01/2017						606.55	605.53	589.6	608.37	588.84	596.77	600.84	598.79	593.01	586.65	587.37	591.35	596	596.62	590.63	599.56	601.67	594.64	596.5	586.97		585.71	
04/02/2017	614.9	617.15	616.67	605.75	608.2																							
10/02/2017	603.72	612.77	606.85	594.76	598.97																							
02/04/2017						612.06	609.47	606.84	610.72	584.57	596.26	600.7	600.83	594.8	589.16	591.78	591.16	597.97	598.96	593.61	605.27	605.36	592.46	599.11	589.76		594.05	
26/07/2017						609.36	609.98	608.1	610.46	585.5	596.13	600.72	601.68	597.95	591.75	593.09	592.33	597.8	597.78	594.07	605.46	605.72	592.93	600.18	589.96		594.97	
01/09/2017	612.45	616.13	611.64	600.82	602.2																							
02/10/2017						603.07	599.59	587.48	602.36	586.82	595.47	597.49	594.79	590.14	584.81	588.88	597.8	593.29	595.74	588.78	594.15	597	587.97	593.19	585.9		585.79	
02/01/2018						607.7	601.94	584.78	605.99	583.17	591.82	597.49	599.66	594.99	582.01	590.17	587.88	593.1	598.79	586.97	596.36	598.14	583.05	589.86	583.08		583.96	
01/02/2018	610.56	615.52	611.12	599	603.29																							
07/02/2018	612.97	616.52	615.83	604.57	608.09																							
10/02/2018	610.03	616.42	613.89	604.49	607.97																							
06/03/2018																												
10/04/2018						613.55	611.14	591.82	611.17	586.47	594.59	601.37	601.83	597.86	587.16	591.97	590.9	598.11	599.21	589.24	603.9	604.11	592.81	599.28	587.8		585.61	
03/06/2018	614.38	615.67	611.14	598.47	603.62																							
02/07/2018						607.87	605.67	586.41	606.41	585.61	591.71	597.1	598.82		581.8	590.47	587.85	593.06	598.77		597.11	598.29	581.95	580.08	583.09		583.99	
02/10/2018						610.4	608.94	588.8	603.14	586.21	593.99	596.87	595.02	589.68	584.73	585.43	590.9	593.22	593.97	587.01	598.11	599.5	580.82	588.58	586.2		585.17	
04/10/2018	614.88	616.93	616.49	605.91	608.14																							
11/01/2019						608.2	605.98	589.92	607.34	584.05	591.85	597.14	599.33	595.32	581.81	590.62	589	593.12	598.86	587.3	598.09	599.1	582.11	590.13	583.2		584.15	
04/04/2019								598.42	598.54	587.55	598.66	599.81	597.89	595.46	588.81	590.07	590.02	588.1	593.38	588.17	601.77	605.19	586.9	593.19	589.1		589.77	
01/07/2019						611.99	607.79	591.08	602.97	597.14	587.87	599.05	603.74	604.46	597.2	589.95	592.55	597.12	599.77	588.07	602.66	604.33	596.78	590.09	590.05		588.6	
11/11/2019						611.23	608.69	590.57	608.88	588.58	597.55	602.01	599.92	595.58	587.19	588.4	596.35	596.47	597.24	592.3	601.78	603.06	595.31	597.64	589.28		588.68	
03/01/2020						612.35	610.4	591.65	611.15	589.33	598.19	603.44	601.29	596.73	587.95	589.35	598.96	597.7	598.51	592.68	603.82	604.44	596.35	598.4	589.35		588.35	
13/04/2020						611.99	610.08	591.27	611.31	590.13	600.31	605.46	604.51	600.08	588.73	590.98	604.67	601.11	600.84	596.17	603.73	605.34	597.83	600.47	591.12		591.56	
06/08/2020						608.42	603.77	599.58	608.14	591.46	599.97	602.36	600.61	596.06	587.77	589.02	601.19	598.3	598.63	593.73	599.35	602.26	598.06	597.26	589.25		589.11	
16/11/2020						605.68	602.23	588.69	603.77	591.54	597.54	598.52	596.24	591.88	587.02	587.8	595.95	595.38	596.18	590.11	595.58	598.31	596.29	593.88	587.72		586.38	
18/02/2021						610.4	607.17	589.63	606.58	590.59	595.68	598.09	596.17	591.62	586.45	587.49	594.21	595.22	596.04	588.65	597.52	599.43	594.94	593.14	587.12		585.42	

[O:BP June 2021; C: NLN 10/25/21; C: BGH 10/29/21]

TABLE 2-2. GROUNDWATER ELEVATION DATA
GROUNDWATER MODELING REPORT
DUCK CREEK POWER PLANT
GMF POND
CANTON, ILLINOIS

Well ID	Easting (feet)	Northing (feet)	X model (feet)	Y model (feet)	Top of Screen (feet)	Bottom of Screen (feet)	Center of Screen (feet)	Standard Deviation (feet)	Number of Readings	Minimum GWL (feet)	Maximum GWL (feet)	Mean GWL (feet)	GWL Variation (feet)
G02L	2345393.92	1400757.03	2543.92	6707.03	609.5	604.5	607.00	2.67	38	606.16	616.48	613.04	10.32
G02S	2345396.37	1400748.81	2546.37	6698.81	596.18	591.18	593.68	2.70	18	603.72	615.5	612.70	11.78
G50L	2345538.178	1399222.503	2688.178	5172.503	609.24	604.53	606.89	2.85	34	603.94	615.07	611.16	11.13
G50S	2345538.017	1399216.604	2688.017	5166.604	591.66	586.85	589.26	4.36	44	586.56	614.94	609.57	28.38
G51L	2345467.956	1398451.651	2617.956	4401.651	604.8	600.01	602.41	2.81	30	600.18	611.62	607.64	11.44
G51S	2345468.02	1398447.042	2618.02	4397.042	592.82	588.04	590.43	4.29	39	587.69	611.51	607.17	23.82
G52L	2345467.443	1397701.96	2617.443	3651.96	587.49	582.9	585.20	3.46	31	587.79	600.87	593.72	13.08
G52S	2345467.996	1397697.133	2617.996	3647.133	577.41	572.63	575.02	5.07	39	583.95	608.1	590.25	24.15
G53L	2346049.245	1399242.023	3199.245	5192.023	603.37	594.02	598.70	4.07	25	603.06	614.55	609.08	11.49
G53S	2346053.266	1399241.972	3203.266	5191.972	589.72	585.23	587.48	3.52	33	598.54	611.37	606.58	12.83
G54L	2346007.979	1397706.511	3157.979	3656.511	592.86	583.43	588.15	2.97	22	583.27	592.56	587.41	9.29
G54S	2346004.479	1397706.819	3154.479	3656.819	576.75	572.28	574.52	3.26	33	582.88	597.14	586.11	14.26
G55L	2346248.805	1397709.746	3398.805	3659.746	584.33	583.85	584.09	3.24	25	589.29	600.31	595.78	11.02
G55S	2346248.641	1397706.061	3398.641	3656.061	579.07	574.62	576.85	3.51	33	587.87	600.31	594.24	12.44
G56L	2346522.917	1397750.899	3672.917	3700.899	606.19	597.85	602.02	2.55	20	596.96	605.64	600.73	8.68
G56S	2346522.742	1397747.224	3672.742	3697.224	586.67	582.18	584.43	3.77	33	592.19	605.46	598.30	13.27
G57L	2346531.002	1398106.794	3681.002	4056.794	604.05	594.6	599.33	3.52	21	593.52	604.11	599.30	10.59
G57S	2346531.145	1398102.358	3681.145	4052.358	590.55	586.02	588.29	3.92	33	591.24	604.51	597.79	13.27
G58L	2346532.815	1398246.776	3682.815	4196.776	599.48	590.07	594.78	3.27	20	589.57	600.59	594.78	11.02
G58S	2346533.675	1398242.523	3683.675	4192.523	588.74	584.26	586.50	4.80	33	582	604.46	592.82	22.46
G59L	2346536.298	1398385.852	3686.298	4335.852	597.2	587.78	592.49	5.45	19	587.32	602.76	595.23	15.44
G59S	2346536.3	1398381.765	3686.3	4331.765	582.73	578.23	580.48	3.13	33	581.8	597.2	586.45	15.4
G60L	2346593.584	1398516.878	3743.584	4466.878	592.57	587.78	590.18	4.53	25	588.23	605.49	592.17	17.26
G60S	2346593.887	1398511.868	3743.887	4461.868	581.21	576.42	578.82	3.27	39	581.47	593.09	587.35	11.62
G61L	2346537.794	1398682.764	3687.794	4632.764	610.56	601.2	600.30	1.00	1	600.79	600.79	600.79	NA
G61S	2346538.331	1398687.195	3688.331	4637.195	589.92	585.48	587.70	4.23	33	586.87	604.67	591.35	17.8
G62L	2346538.232	1398827.136	3688.232	4777.136	600.06	590.71	595.39	3.33	24	590.83	605.03	596.98	14.2
G63L	2346541.313	1398970.834	3691.313	4920.834	601.8	592.38	597.09	3.64	22	594.14	611.32	598.24	17.18
G63S	2346541.905	1398966.566	3691.905	4916.566	585.46	580.97	583.22	2.91	33	588.1	601.11	594.74	13.01
G64L	2346539.146	1399111.488	3689.146	5061.488	602.12	592.76	597.44	2.21	22	593	603.52	598.25	10.52
G64S	2346538.063	1399106.875	3688.063	5056.875	585.75	581.26	583.51	2.60	33	590.65	600.84	596.37	10.19
G65L	2346463.961	1397028.352	3613.961	2978.352	593.01	588.21	590.61	2.78	24	587.55	596.36	590.61	8.81
G65S	2346458.347	1397027.185	3608.347	2977.185	583.17	578.39	580.78	4.16	39	576.99	596.17	588.59	19.18
G66L	2346509.483	1397282.853	3659.483	3232.853	605.14	595.71	600.43	3.02	21	596.84	606.19	602.03	9.35
G66S	2346509.006	1397278.215	3659.006	3228.215	579.94	575.45	577.70	3.96	33	591.94	605.92	599.88	13.98
G67L	2346472.782	1397569.814	3622.782	3519.814	607.41	598.05	602.73	3.66	21	591.39	606.46	602.58	15.07
G67S	2346469.268	1397572.438	3619.268	3522.438	583.72	579.23	581.48	3.84	33	593.18	605.84	600.76	12.66
G68L	2346152.97	1397593.263	3302.97	3543.263	598.8	589.43	594.12	3.36	20	588.41	598.92	593.06	10.51
G68S	2346148.944	1397592.398	3298.944	3542.398	579.49	575.02	577.26	4.81	33	580.82	598.06	590.15	17.24
G69L	2345830.273	1397585.849	2980.273	3535.849	599.25	589.88	594.57	5.25	24	589.52	606.69	600.01	17.17
G69S	2345834.433	1397585.858	2984.433	3535.858	578.6	574.1	576.35	5.40	33	580.08	600.47	592.79	20.39
G70L	2345701.108	1397413.265	2851.108	3363.265	594.89	585.54	590.22	4.41	25	588.19	605.18	595.95	16.99
G71L	2345823.223	1397148.551	2973.223	3098.551	595.33	585.84	590.59	1.94	20	584.64	591.48	587.49	6.84
G71S	2345821.255	1397152.559	2971.255	3102.559	581.28	577.28	579.28	3.02	33	580.38	591.12	586.39	10.74
G72L	2346054.09	1396946.871	3204.09	2896.871	600.21	590.85	595.53	1.55	16	589.73	595.23	590.79	5.5
G72S	2346049.117	1396947.026	3199.117	2897.026	584.87	580.39	582.63	4.49	10	580.12	595.24	587.20	15.12
G73L	2346343.387	1396966.704	3493.387	2916.704	590.15	580.8	585.48	3.04	23	581.53	593.52	587.94	11.99
P01L	2345348.87	1399791.97	2498.87	5741.97	611.71	602.36	607.04	2.17	31	608.45	618.48	615.88	10.03
P01S	2345348.93	1399796.61	2498.93	5746.61	599.35	594.87	597.11	1.21	18	612.77	617.59	616.01	4.82
P40L	2346652.35	1400805.34	3802.35	6755.34	611.81	601.81	606.81	4.05	36	601.99	618.56	613.11	16.57
P40S	2346652.52	1400812.95	3802.52	6762.95	590.68	585.68	588.18	2.71	18	606.85	617.13	613.66	10.28
P41L	2346634.94	1399638.11	3784.94	5588.11	606.47	601.47	603.97	3.00	34	595.48	608.44	603.67	12.96
P41S	2346638.49	1399645.38	3788.49	5595.38	592.83	582.83	587.83	3.20	18	594.76	606.35	602.72	11.59

TABLE 2-2. GROUNDWATER ELEVATION DATA
GROUNDWATER MODELING REPORT
DUCK CREEK POWER PLANT
GMF POND
CANTON, ILLINOIS

Well ID	Easting (feet)	Northing (feet)	X model (feet)	Y model (feet)	Top of Screen (feet)	Bottom of Screen (feet)	Center of Screen (feet)	Standard Deviation (feet)	Number of Readings	Minimum GWL (feet)	Maximum GWL (feet)	Mean GWL (feet)	GWL Variation (feet)
P42L	2346018.89	1399640.95	3168.89	5590.95	609.03	599.03	604.03	3.31	33	600.97	613.87	608.70	12.9
P42S	2346012.93	1399640.29	3162.93	5590.29	591.21	586.21	588.71	3.10	18	598.97	610.88	606.31	11.91
P57L	2346672.501	1397040.105	3822.501	2990.105	589.44	584.74	587.09	6.05	15	584.469	609.389	588.59	24.92
P57S	2346669.285	1397043.518	3819.285	2993.518	579.92	575.21	577.57	5.86	15	584.955	609.705	588.16	24.75
R61L	2346537.97	1398692.52	3687.97	4642.52	601.12	591.49	596.31	4.50	14	591.29	604.89	596.39	13.6
R72S	2346044.05	1396948.06	3194.05	2898.06	584.98	580.32	582.65	3.21	18	583.96	594.97	587.82	11.01

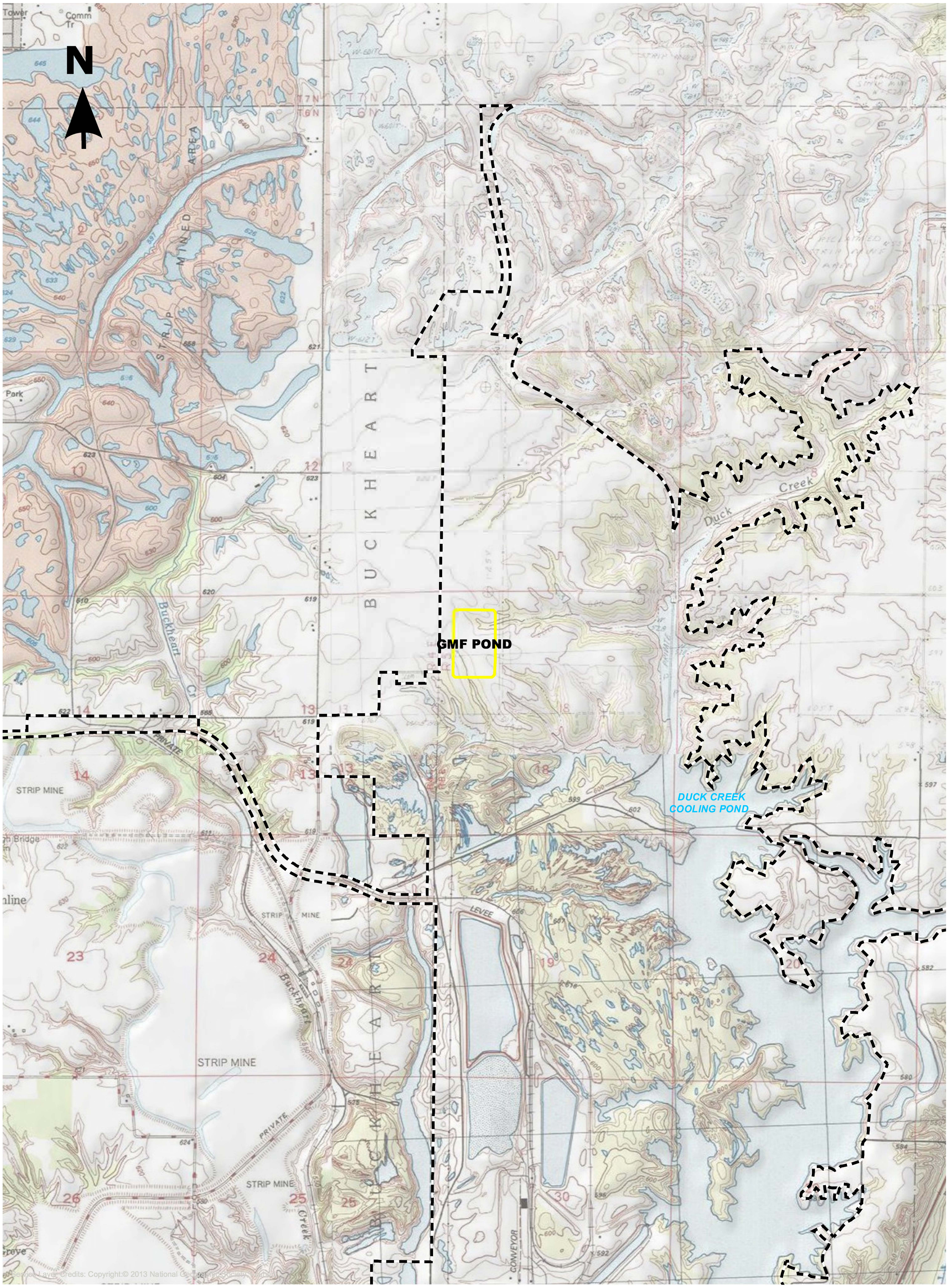
[O:BP June 2021; C: NLN 10/25/21; C: BGH 10/29/21]

Notes:
GMF - Gypsum Management Facility
GWL = groundwater elevation
NA = Not Applicable
NAVD88 = North American Vertical Datum of 1988

FIGURES

PROJECT: 169000XXXX | DATED: 9/21/2021 | DESIGNER: STOLZSD

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Duck_Creek\GMF_Pond\Figure 1-1_Site Location Map.mxd



🟨 PART 845 REGULATED UNIT (SUBJECT UNIT)

▭ PROPERTY BOUNDARY

0 1,000 2,000 Feet

SITE LOCATION MAP

FIGURE 1-1

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK POWER PLANT
CANTON, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

🟨 PART 845 REGULATED UNIT (SUBJECT UNIT)
☐ SITE FEATURE
⬚ PROPERTY BOUNDARY

0 150 300 Feet

SITE MAP

FIGURE 1-2

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK POWER PLANT
CANTON, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

■ MONITORING WELL
▭ PART 845 REGULATED UNIT (SUBJECT UNIT)
▭ SITE FEATURE
▭ PROPERTY BOUNDARY

0 150 300
Feet

MONITORING WELL LOCATION MAP

FIGURE 2-1

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK POWER PLANT
CANTON, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

🟧 BACKGROUND WELL
■ MONITORING WELL
🟩 SOURCE SAMPLE LOCATION
— GROUNDWATER ELEVATION CONTOUR (5-FT CONTOUR INTERVAL, NAVD88)
🟨 PART 845 REGULATED UNIT (SUBJECT UNIT)
☐ SITE FEATURE
⬚ PROPERTY BOUNDARY

0 150 300
Feet

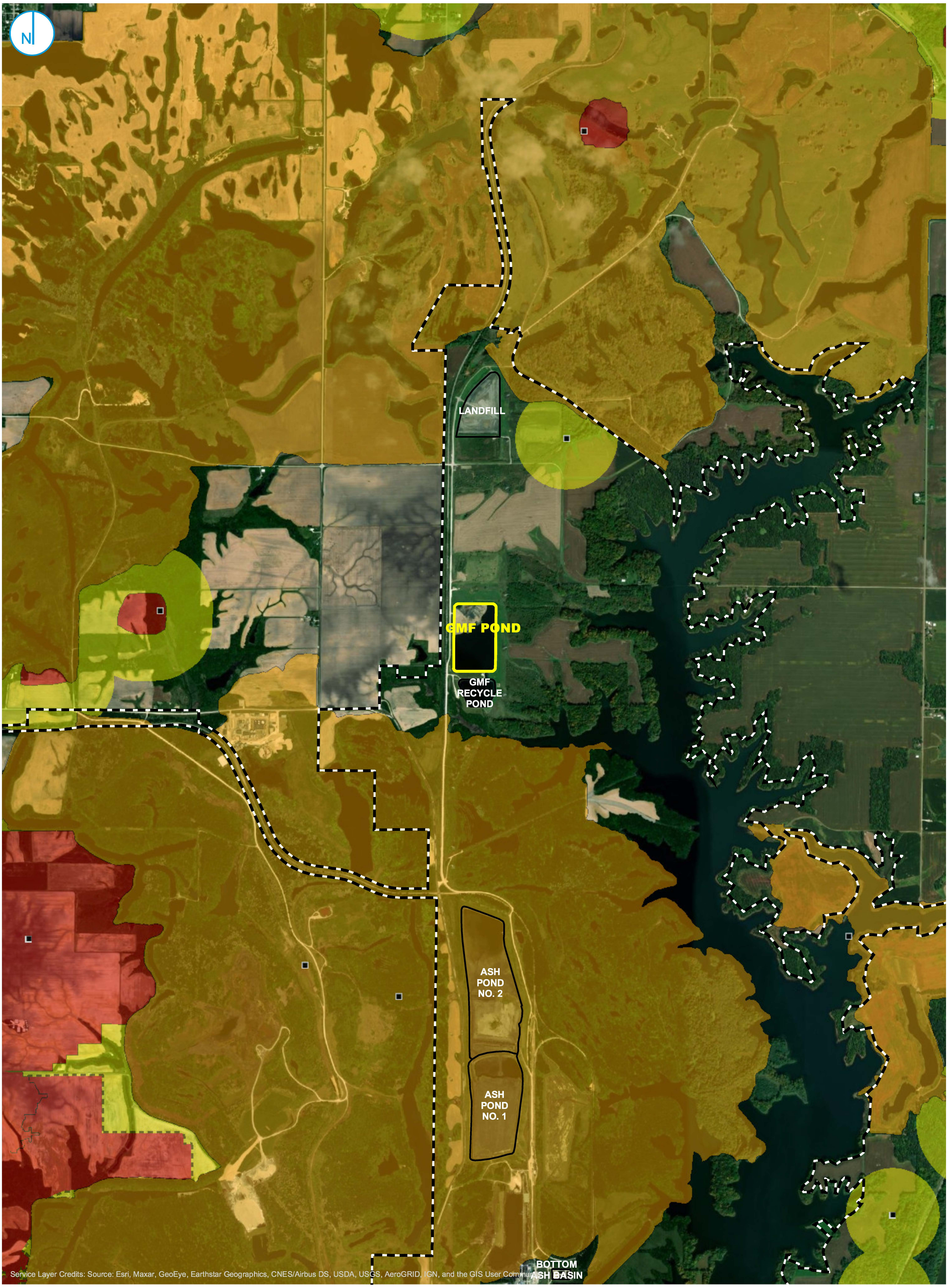
UPPERMOST AQUIFER GROUNDWATER ELEVATION CONTOURS
APRIL 14, 2021

FIGURE 2-2

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK POWER PLANT
CANTON, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL



Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

- ■ COAL MINE SHAFT
- 🟧 SURFACE COAL MINE
- 🟥 UNDERGROUND COAL MINE
- 🟨 UNDERGROUND MINE BUFFER REGION
- ▢ PART 845 REGULATED UNIT (SUBJECT UNIT)
- ▢ SITE FEATURE
- ⬚ PROPERTY BOUNDARY

0 1,000 2,000 Feet

COAL MINE COVERAGE AREA

FIGURE 2-3

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK POWER PLANT
CANTON, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

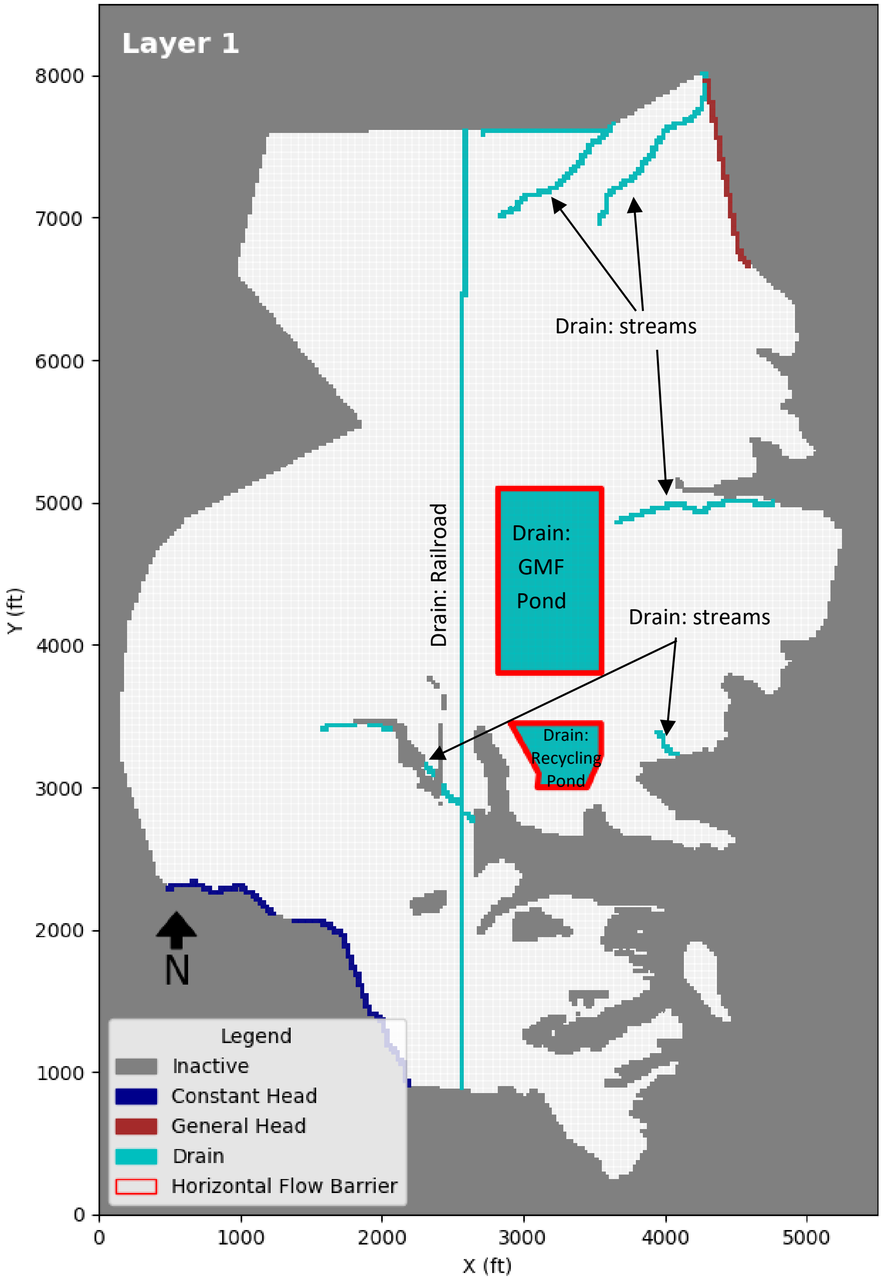


FIGURE 5-1 BOUNDARY CONDITIONS FOR LAYER 1 OF THE CALIBRATED NUMERICAL MODEL

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK SITE
CANTON, ILLINOIS

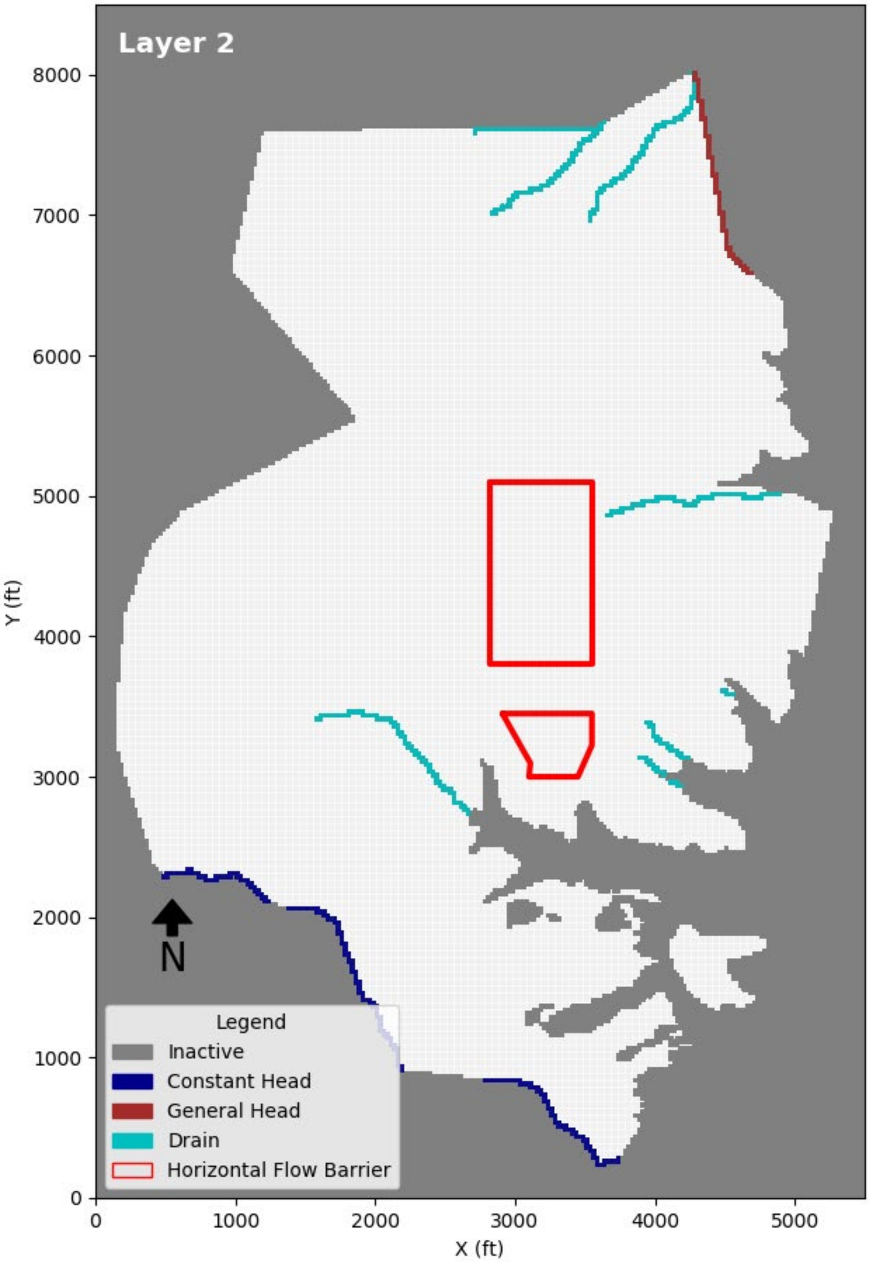


FIGURE 5-2 BOUNDARY CONDITIONS FOR LAYER 2 OF THE CALIBRATED NUMERICAL MODEL

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK SITE
CANTON, ILLINOIS

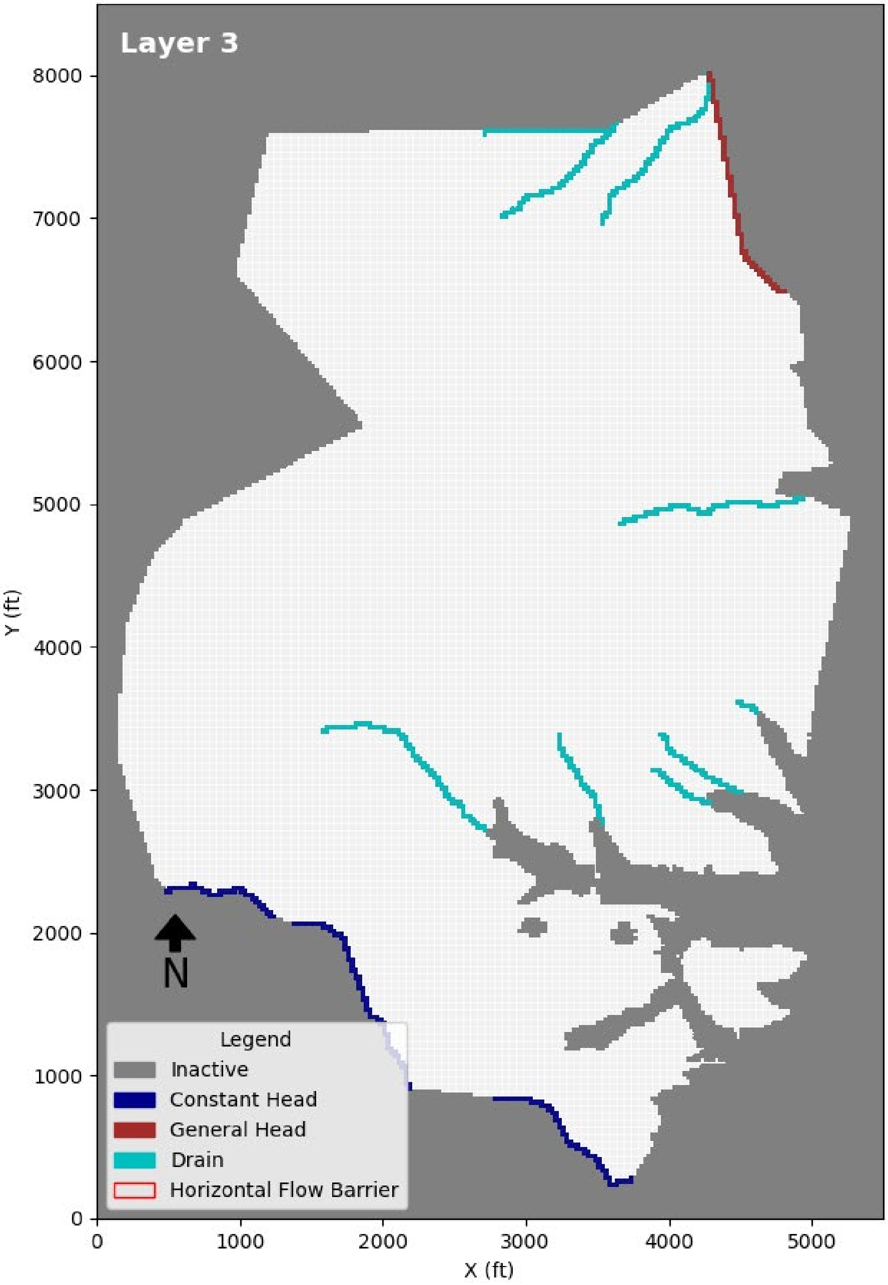


FIGURE 5-3 BOUNDARY CONDITIONS FOR LAYER 3 OF THE CALIBRATED NUMERICAL MODEL

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK SITE
CANTON, ILLINOIS

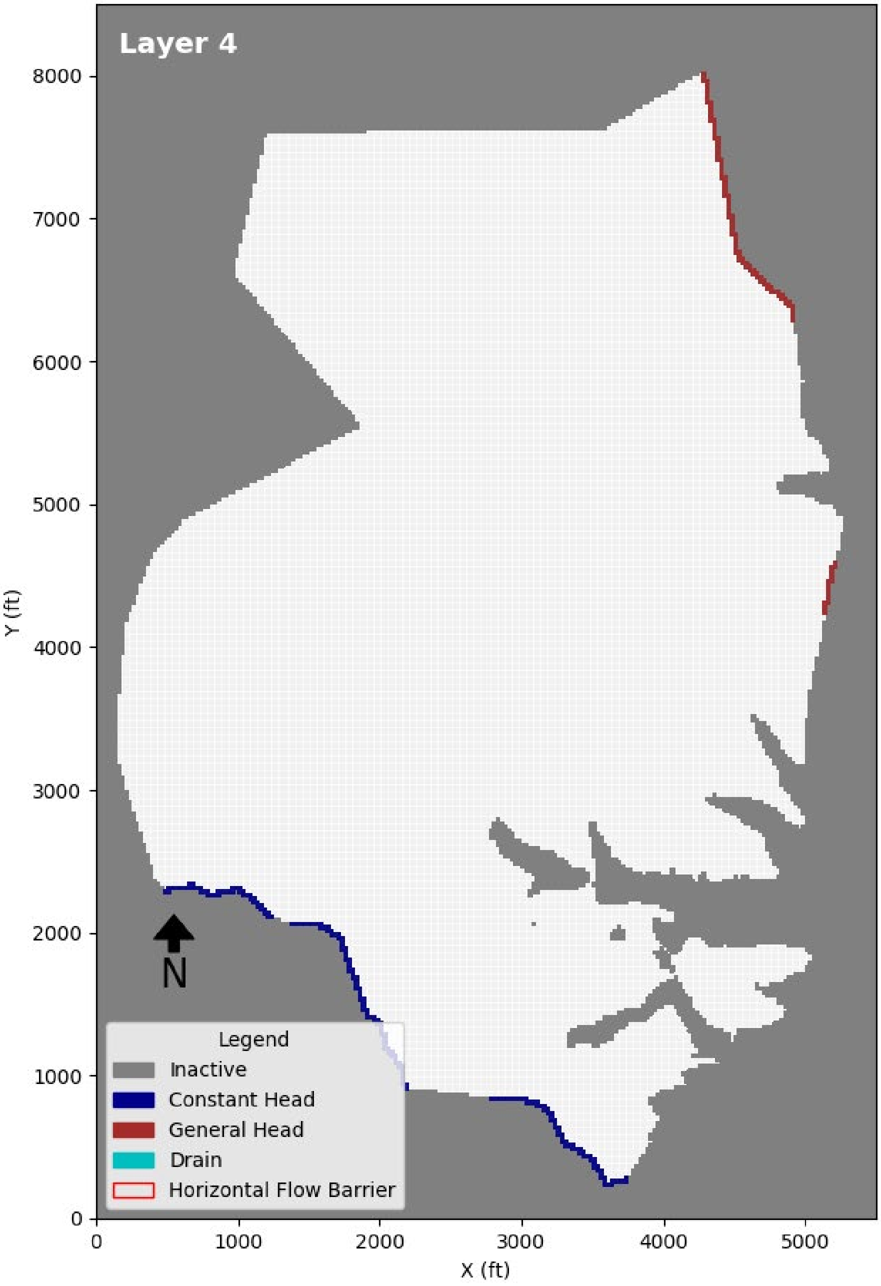


FIGURE 5-4 BOUNDARY CONDITIONS FOR LAYER 4 OF THE CALIBRATED NUMERICAL MODEL

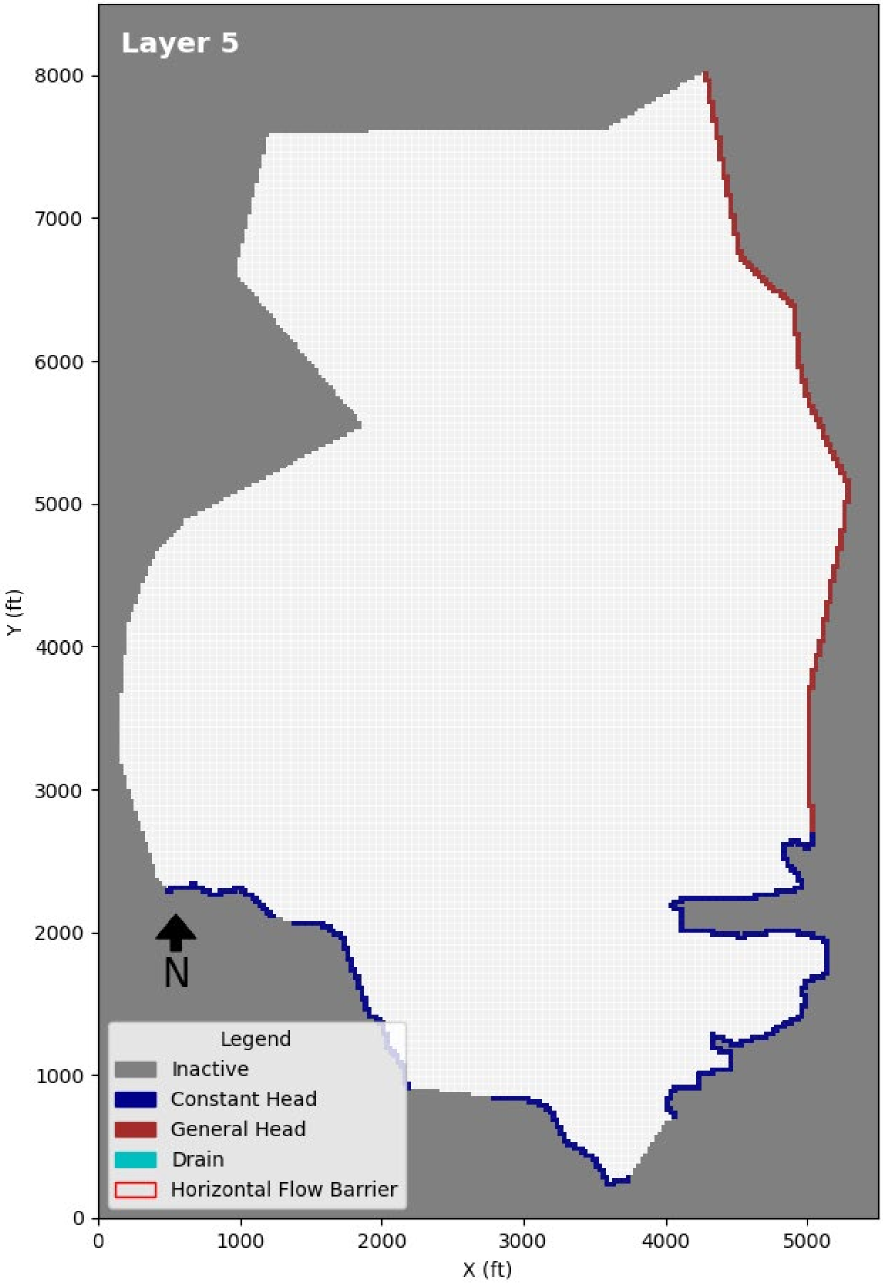


FIGURE 5-5 BOUNDARY CONDITIONS FOR LAYER 5 OF THE CALIBRATED NUMERICAL MODEL

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK SITE
CANTON, ILLINOIS

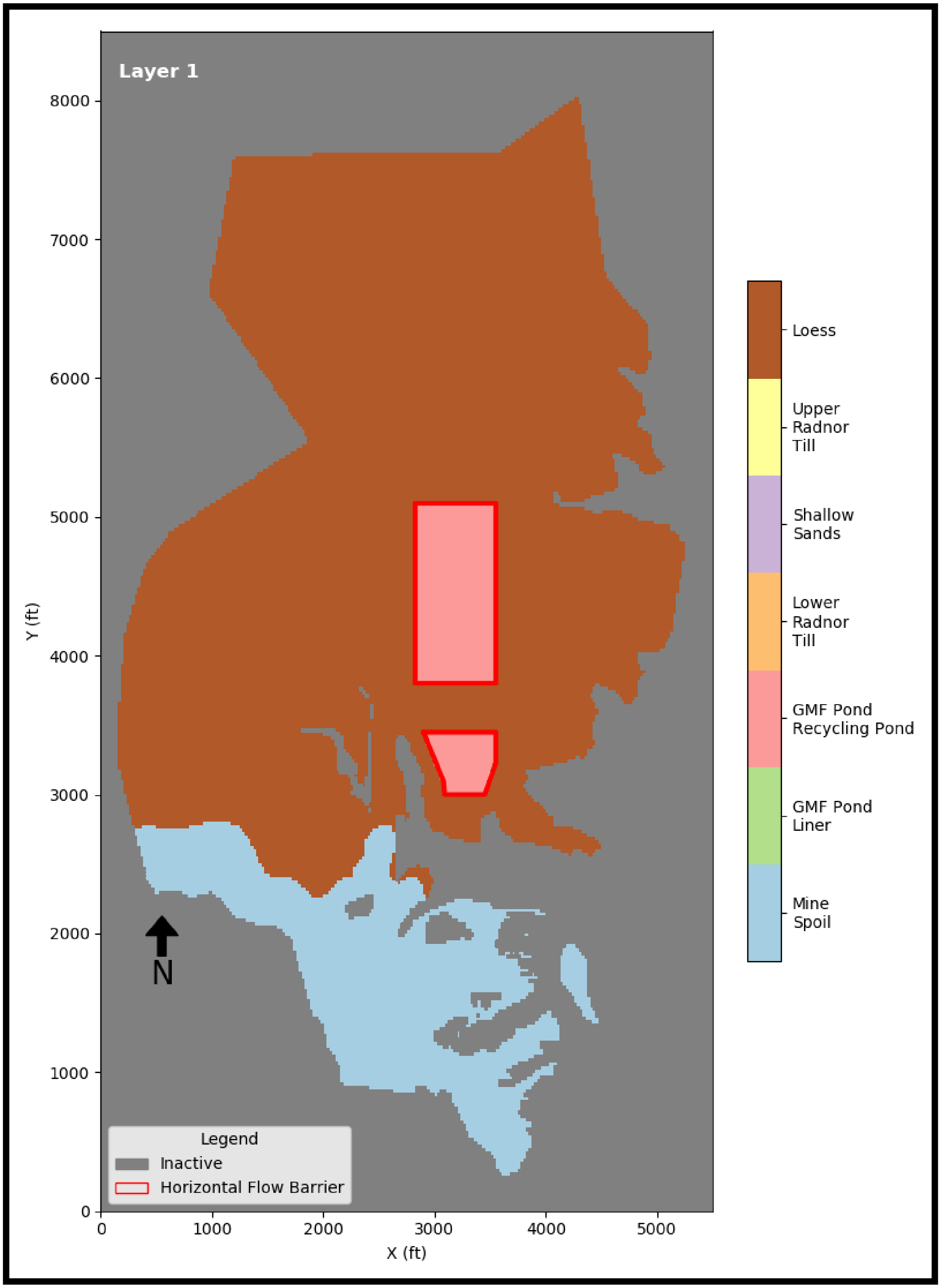


FIGURE 5-6 SPATIAL DISTRIBUTION OF HYDROSTRATIGRAHPIC LAYERS FOR LAYER 1 IN THE NUMERICAL MODEL

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK SITE
CANTON, ILLINOIS

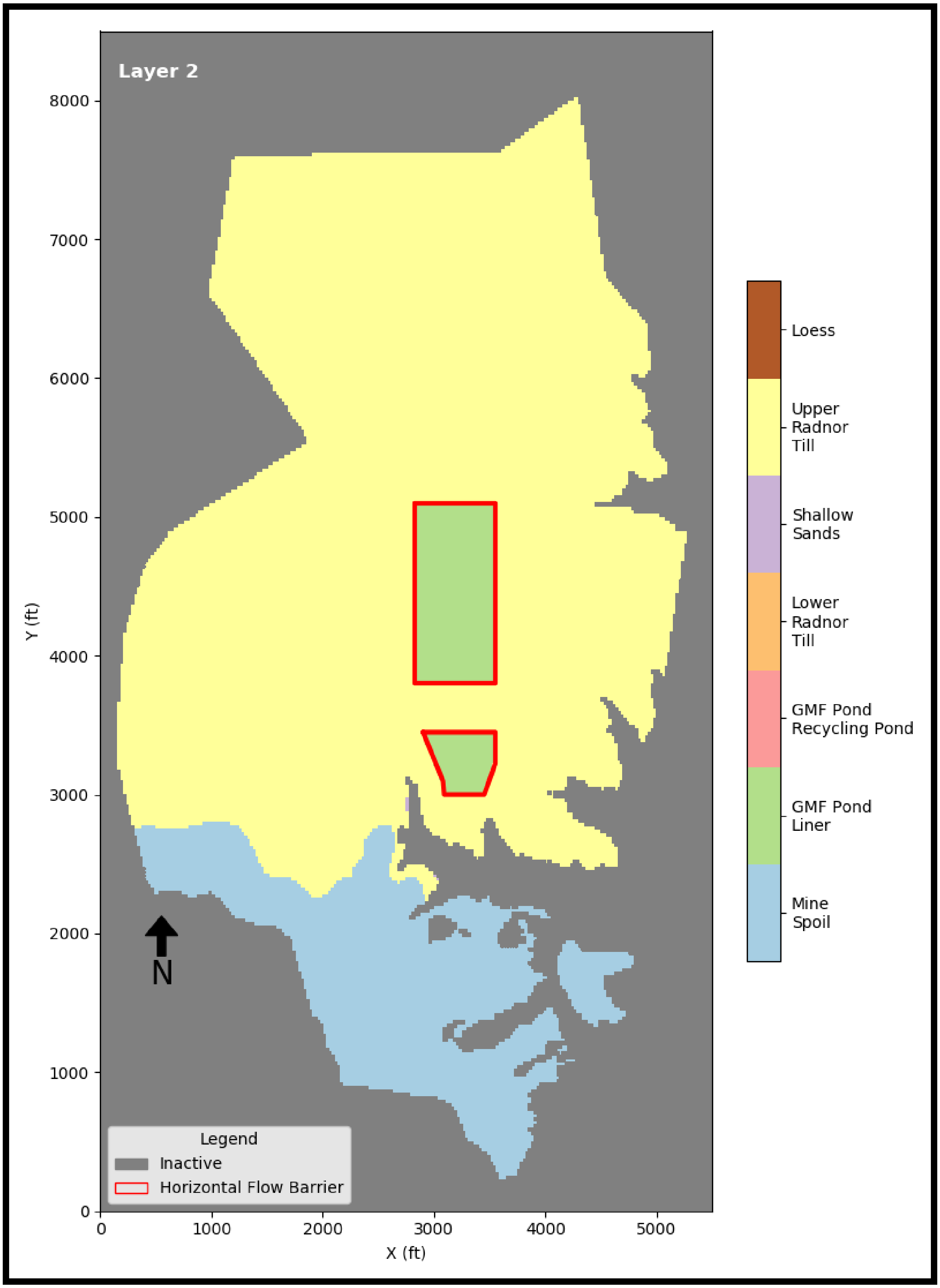


FIGURE 5-7 SPATIAL DISTRIBUTION OF HYDROSTRATIGRAHPIC LAYERS FOR LAYER 2 IN THE NUMERICAL MODEL

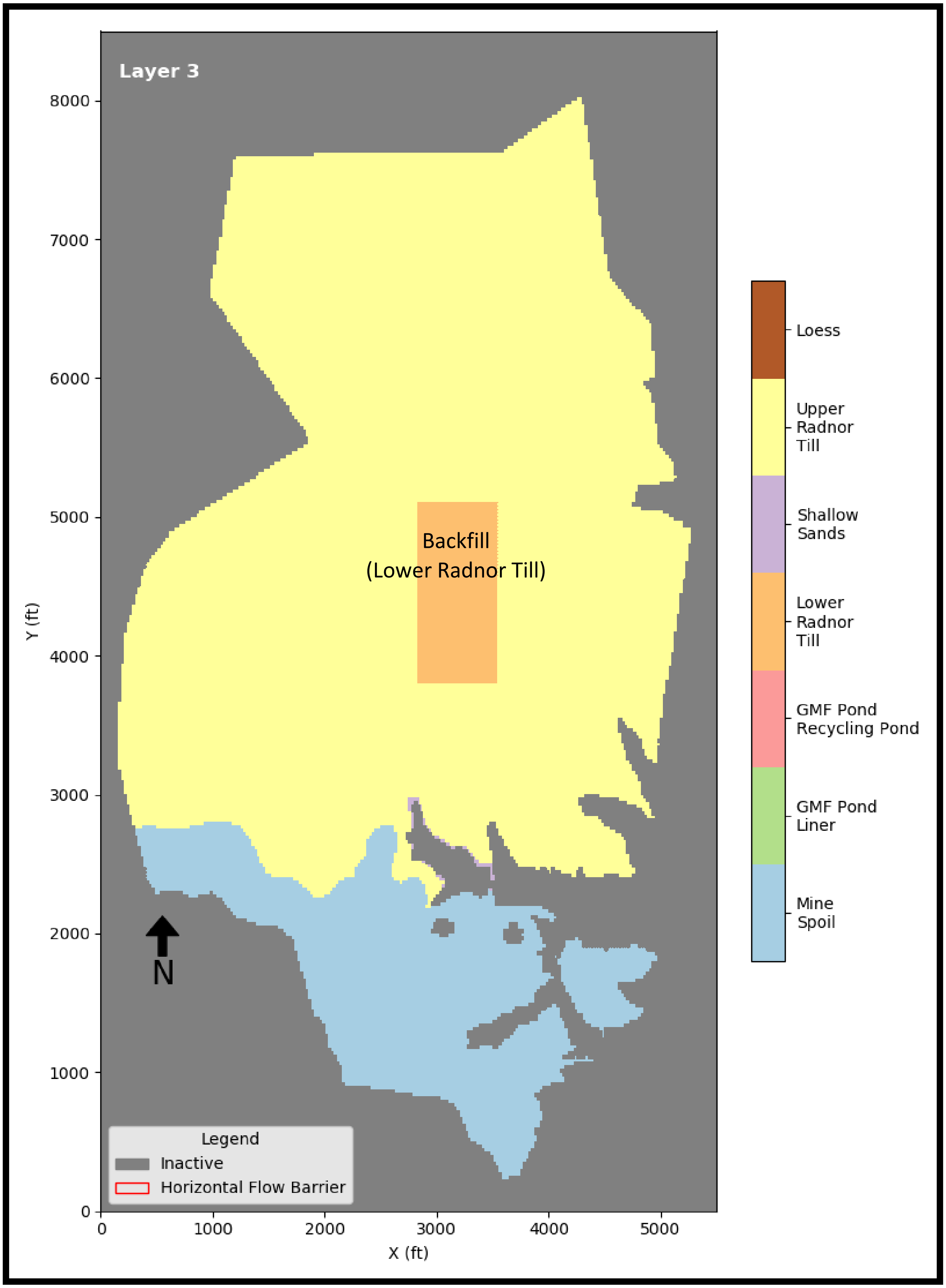


FIGURE 5-8 SPATIAL DISTRIBUTION OF HYDROSTRATIGRAHPIC LAYERS FOR LAYER 3 IN THE NUMERICAL MODEL

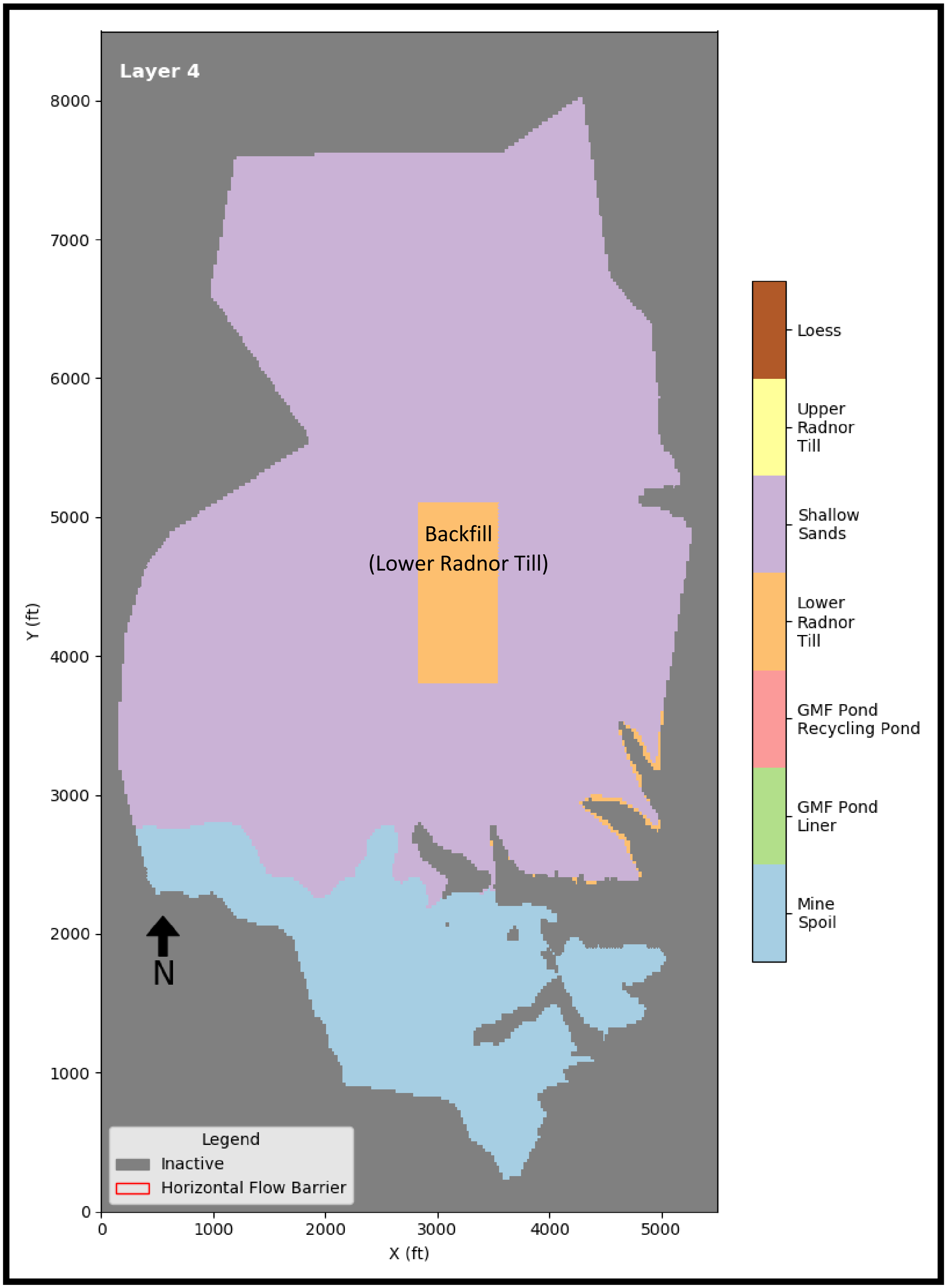


FIGURE 5-9 SPATIAL DISTRIBUTION OF HYDROSTRATIGRAHPIC LAYERS FOR LAYER 4 IN THE NUMERICAL MODEL

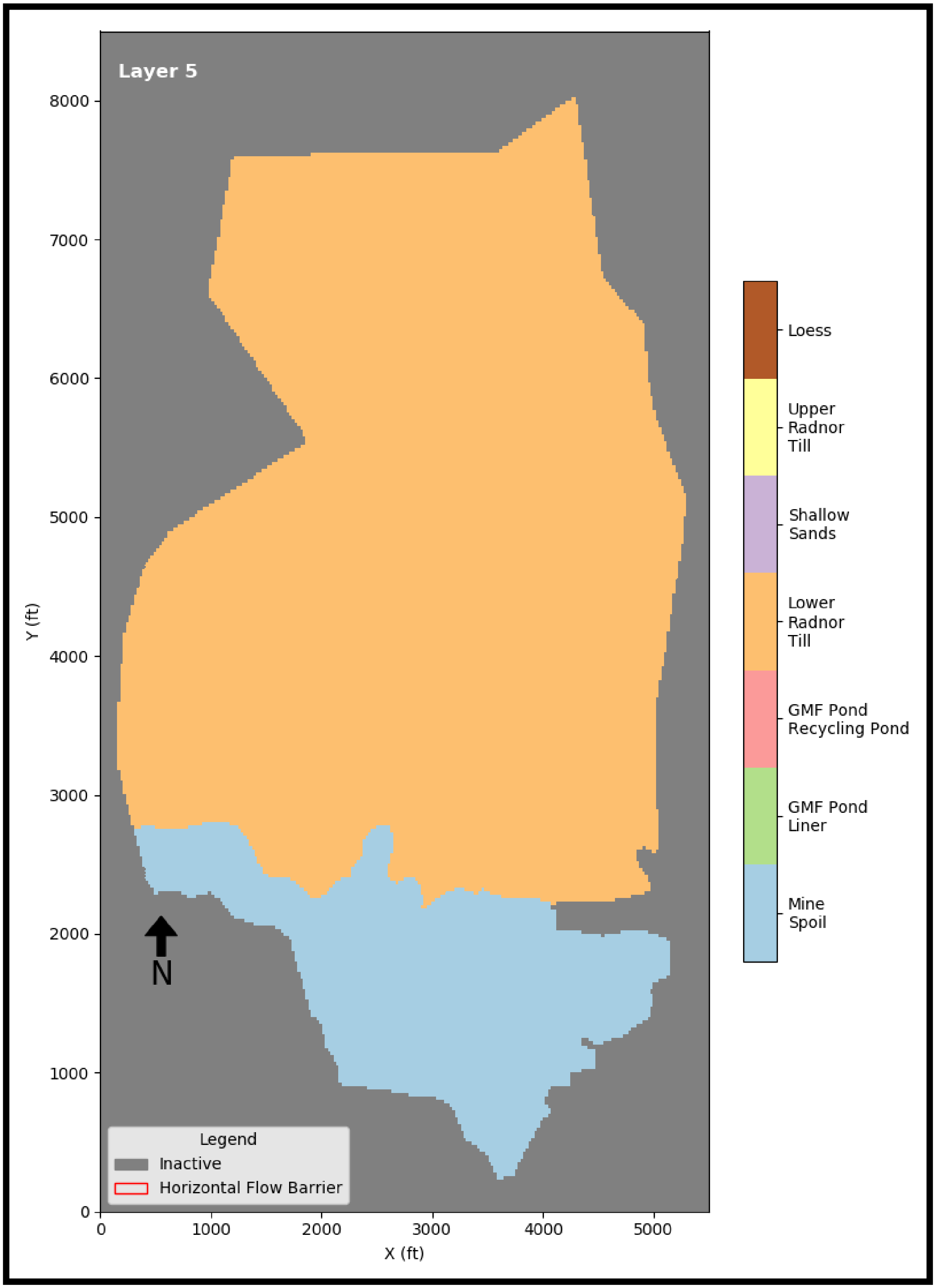


FIGURE 5-10 SPATIAL DISTRIBUTION OF HYDROSTRATIGRAHPIC LAYERS FOR LAYER 5 IN THE NUMERICAL MODEL

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK SITE
CANTON, ILLINOIS

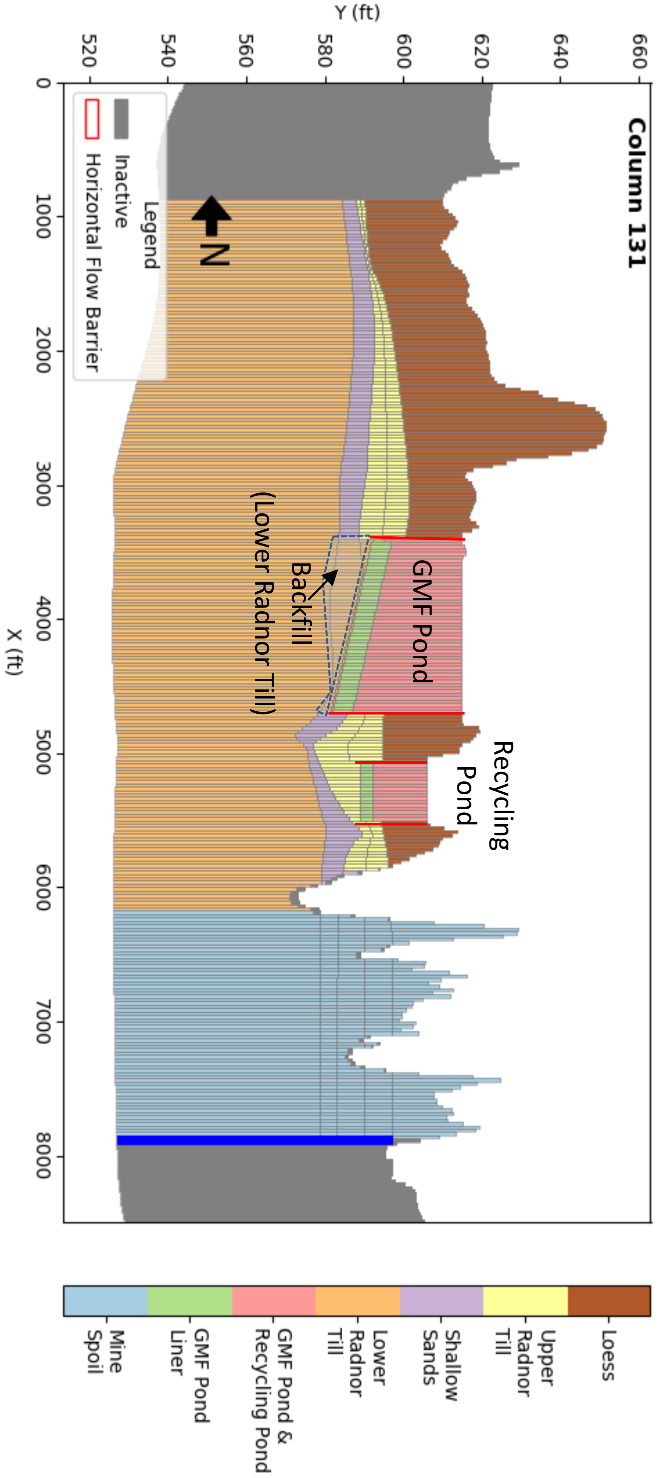
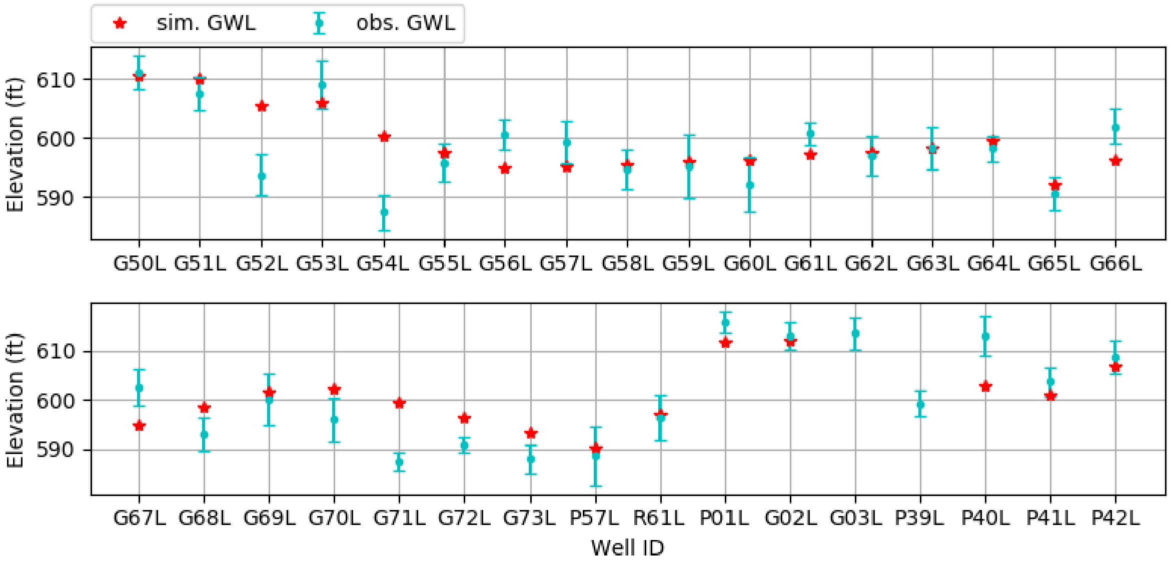


FIGURE 5-11 CROSS SECTION OF THE OF HYDROSTRATIGRAHPIC LAYERS FOR COLUMN 131 IN THE NUMERICAL MODEL

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK SITE
CANTON, ILLINOIS

A. Loess



B. Shallow Sands

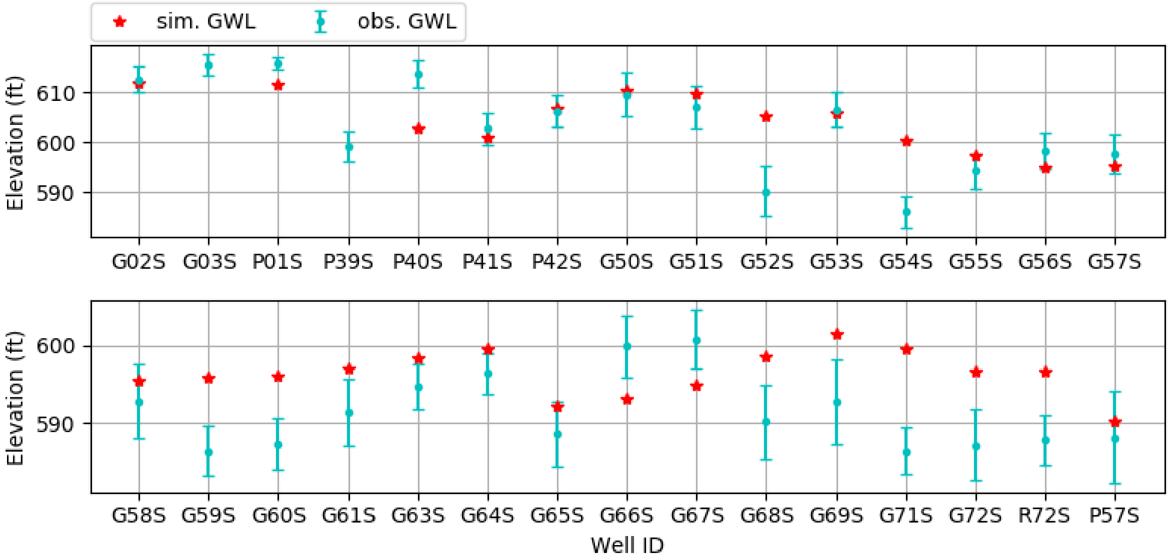


FIGURE 5-12 OBSERVED AND SIMULATED GROUNDWATER LEVELS FROM THE CALIBRATED MODEL FOR WELLS SCREENED IN **A** THE LOESS AND **B** THE SHALLOW SANDS.

(ERROR BARS REPRESENT 1 STANDARD DEVIATION)

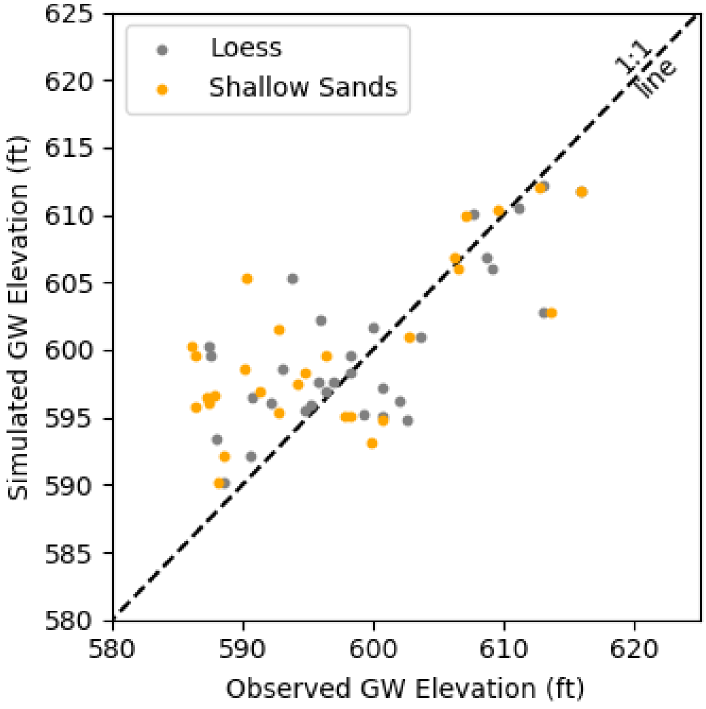


FIGURE 5-13 OBSERVED VERSUS SIMULATED GROUNDWATER ELEVATIONS FROM THE CALIBRATED MODEL

WELLS SCREENED IN THE LOESS ARE GRAY AND THE SHALLOW SANDS ARE ORANGE

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK SITE
CANTON, ILLINOIS

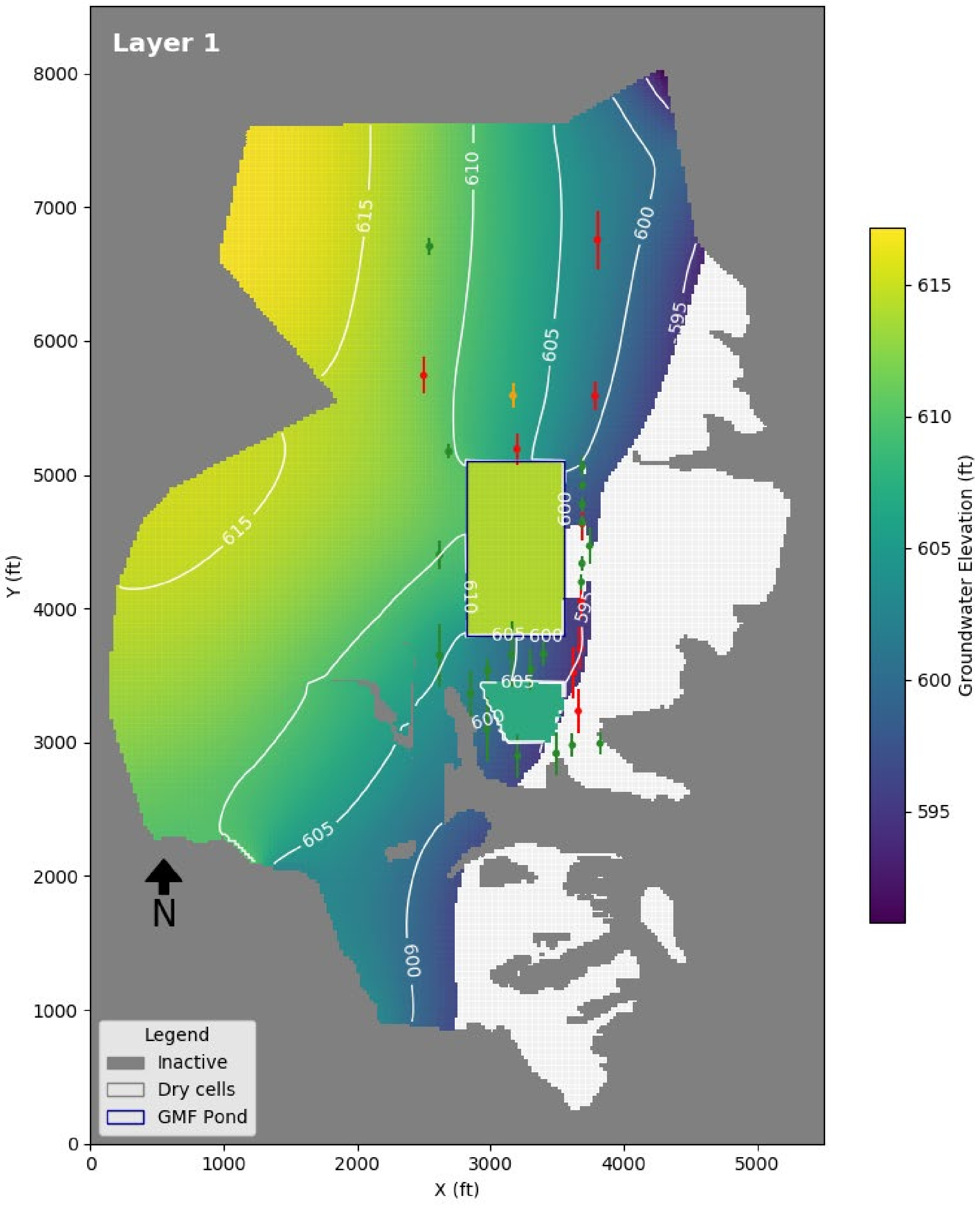


FIGURE 5-14 GROUNDWATER ELEVATION CONTOURS FOR LAYER 1 OF THE CALIBRATED NUMERICAL MODEL. WELL ERROR BARS INDICATE THE SIZE OF THE RESIDUAL BETWEEN SIMULATED AND OBSERVED GROUNDWATER LEVEL (GWL), AND THE COLOR INDICATES IF THE SIMULATED GWL IS ±1 (GREEN), ±2 (ORANGE) OR GREATER THAN ±3 (RED) STANDARD DEVIATIONS FROM THE OBSERVED GWL DATA

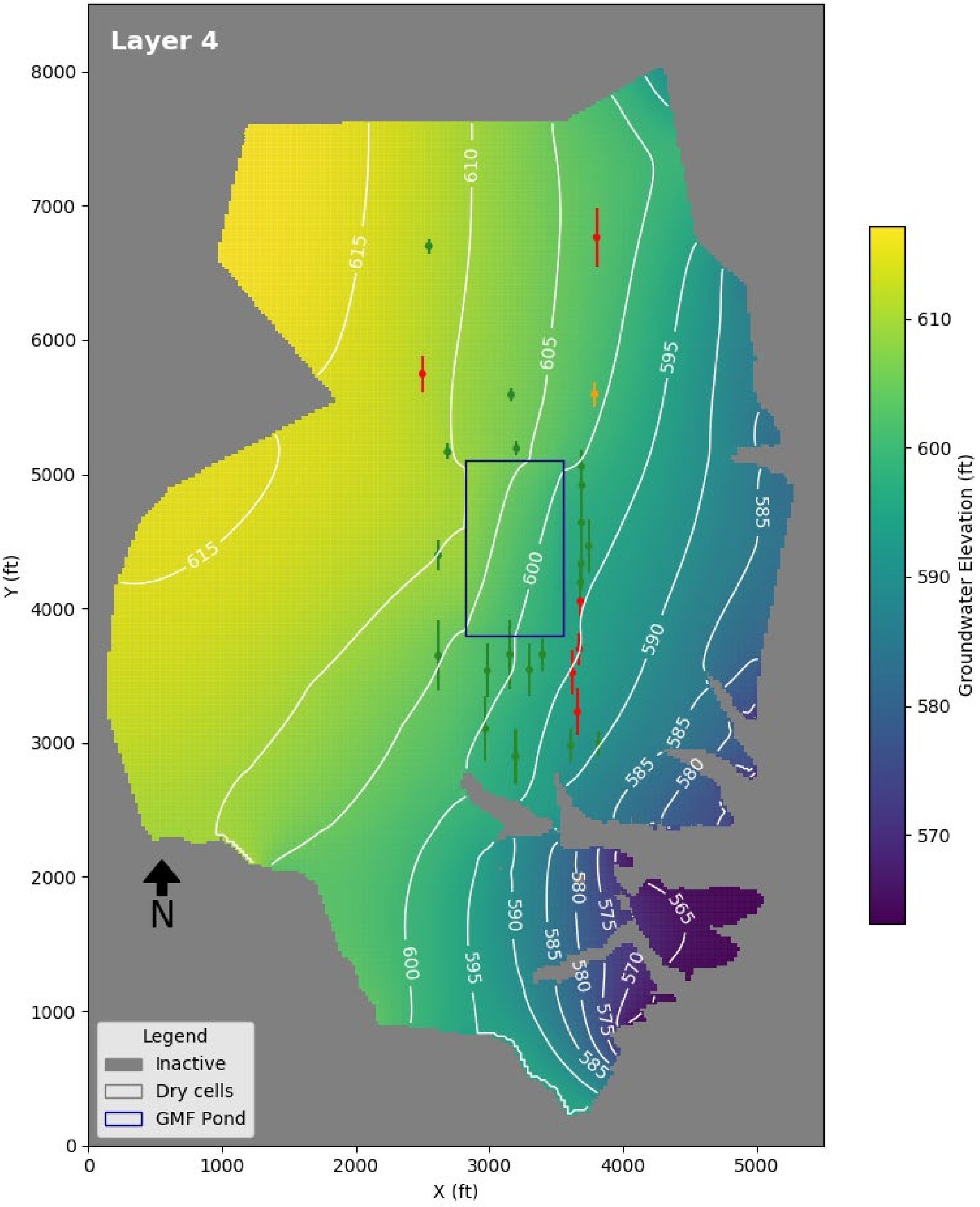


FIGURE 5-15 GROUNDWATER ELEVATION CONTOURS FOR LAYER 4 OF THE CALIBRATED NUMERICAL MODEL. WELL ERROR BARS INDICATE THE SIZE OF THE RESIDUAL BETWEEN SIMULATED AND OBSERVED GROUNDWATER LEVEL (GWL), AND THE COLOR INDICATES IF THE SIMULATED GWL IS ±1 (GREEN), ±2 (ORANGE) OR GREATER THAN ±3 (RED) STANDARD DEVIATIONS FROM THE OBSERVED GWL DATA

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

▭ PART 845 REGULATED UNIT (SUBJECT UNIT)
▭ SITE FEATURE
▭ PROPERTY BOUNDARY

0 150 300 Feet

CLOSURE IN PLACE MODELING SCENARIO

FIGURE 6-1

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK POWER PLANT
CANTON, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL

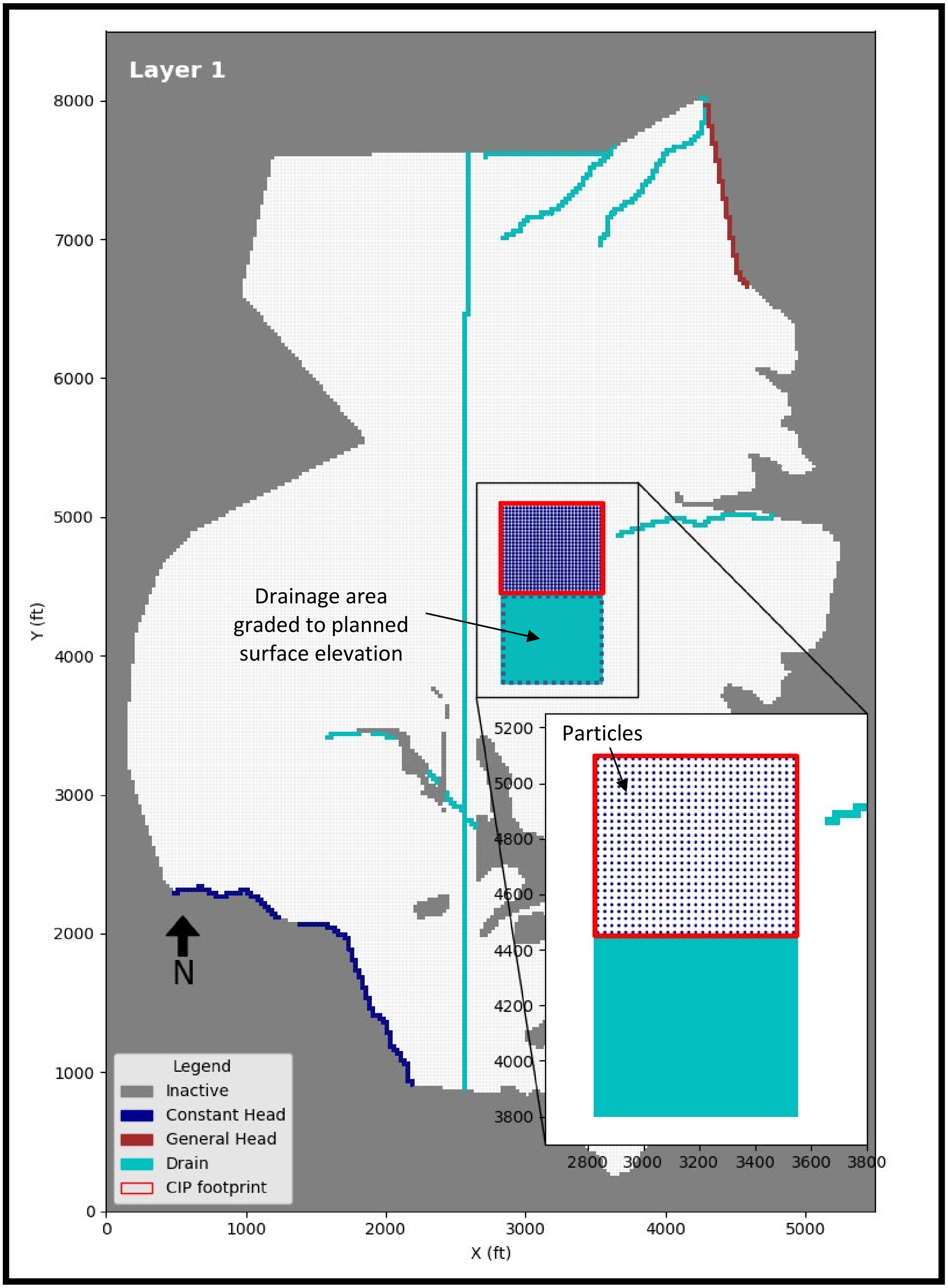


FIGURE 6-2 CLOSURE-IN-PLACE SCENARIO PARTICLE DISTRIBUTION

GROUNDWATER MODELING REPORT
GMF POND
DUCK CREEK SITE
CANTON, ILLINOIS

RAMBOLL

APPENDIX A
EVALUATION OF POTENTIAL GWPS EXCEEDANCES

TECHNICAL MEMORANDUM

DATE October 15, 2021 **Project No.** 21454831

TO David Mitchell, Stu Cravens, Vic Modeer
Illinois Power Resources Generating, LLC

CC Brian Hennings - Ramboll

FROM Roberta Russell, Jeffrey Ingram, Pat Behling -
Golder

EVALUATION OF POTENTIAL GWPS EXCEEDANCES, GYPSUM MANAGEMENT FACILITY POND, DUCK CREEK POWER PLANT, FULTON COUNTY, ILLINOIS

1.0 INTRODUCTION

Illinois Power Resource Generating, LLC (IPRG) formerly operated the Duck Creek Power Plant (DCPP) located in Fulton County, Illinois. The Gypsum Management Facility Pond (GMFP, Illinois Environmental Protection Agency [IEPA] ID No. W0578010001-04) is a surface impoundment used to manage gypsum and related coal combustion residuals (CCRs) at the DCPP. The GMFP is regulated under Part 845 *"Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments"* (State CCR Rule or Part 845) which was promulgated by the Illinois Pollution Control Board (IPCB) on April 21, 2021.

IPRG is currently preparing an Operating Permit application for the GMFP as required under Section 845.230 which requires that known exceedances of groundwater protection standards (GWPS) be documented as a part of the Operating Permit application. In October 2021, Ramboll Americas Engineering Solutions, Inc. (Ramboll) identified potential GWPS exceedances for pH, arsenic, and lead in groundwater samples collected from selected monitoring wells in the vicinity of the GMFP as presented in the Operating Permit application for the GMFP. This Technical Memorandum was developed to further evaluate these potential GWPS exceedances.

1.1 Site Setting, Geology and Hydrogeology

The Duck Creek Power Plant (Site) is an inactive power plant in Fulton County, located in central Illinois, approximately 9 miles southeast of the town of Canton. The GMFP is located north of the power plant (see Figure 1). Agricultural land surrounds the DCPP.

Regionally, the Site is positioned on the glacial uplands above the Illinois River in the Ancient Illinois Floodplain of the Till Plains Section of the Central Lowland Province. The undisturbed unlithified materials consist of loess, diamictons, and lacustrine/alluvial deposits. The area is flat to gently rolling uplands that are dissected by deeply incised streams that are tributaries to major river systems (NRT/OBG 2017).

Several large former surface coal mines are present in the vicinity; unlithified materials are present in the excavated strip mine spoils and have been mixed due to the surface mining activities. Mining operations in the area have ceased.

The uppermost bedrock stratum in the area is the Carbondale Formation of the Kewanee Group of the Pennsylvanian System. Bedrock in the area is identified as Pennsylvanian-age shale deposits. Bedrock occurs within approximately 50 feet (ft) of the ground surface in this area.

The following two unlithified water-bearing units are present beneath the GMF Pond (beginning at the ground surface):

- Loess Zone – Moderate to high permeability silts and clayey silts, including: the Peoria and Roxanna Silt (Loess Units); underlain by the low permeability clayey diamictons of the Berry Clay and upper Radnor Till Members of the Glasford Formation.
- Shallow Sand Unit – Thin to moderately thick (6 to 18 ft), moderate to high permeability, medium-grained sand to silt with intercalated till seams; underlain by till sequences of the lower Radnor Till Member of the Glasford Formation.

The Uppermost Aquifer in the area consists of the Loess and Shallow Sand. These hydraulically connected units are underlain by the lower Radnor Till Member of the Glasford Formation. As shown on Figure 1, groundwater typically flows from northwest to southeast in the Uppermost Aquifer (NRT/OBG 2017).

1.2 Gypsum Management Facility Pond Design and Operation History

The GMFP is a 1,500-foot by 900-foot earthen berm double-lined CCR surface impoundment. Construction of the dual composite liner system and a leak detection system layer was completed in 2007-2009 under a rigorous construction quality assurance program (Hanson, 2009), which is an important determinant of liner system performance. The GMFP consists of the following components from top to bottom:

- Primary Composite Liner
    - SOLMAX 460T-1000 60-mil (0.06-inch thick) textured high-density polyethylene (HDPE) geomembrane
    - 1-foot cushion soil layer (2 feet in selected areas on the side slopes)
- Leak detection layer
    - SKAPS GT-142 4-0z/yd^2 geotextile separator
    - 1-foot granular drainage layer
    - SKAPS FE-110 10-oz/yd^2 geotextile cushion
- Secondary composite liner
    - Solmax 460T-4013 60-mil texture HDPE geomembrane
    - CETCO Bentomat SDN reinforced geosynthetic clay liner (GCL)
    - 3-foot compacted clay layer placed in 8-inch lifts, compacted to at least 95% of the standard Proctor maximum dry density at a moisture content between the standard Proctor optimum moisture content (OMC) and 5% of the wet OMC

The GMFP was used to store gypsum and to clarify gypsum transport water for reuse in the wet scrubber system at the DCPP until the plants retirement in 2019. Gypsum materials are the only waste managed in the GMFP.

2.0 POTENTIAL GWPS EXCEEDANCES REVIEW

As required by Section 845.230 (d)(2)(M), an evaluation of the history of potential GWPS exceedances was competed for the Operating Permit application by Ramboll. Data collected from groundwater samples collected from the GMFP monitoring well network since January 30, 2015, were evaluated and potential exceedances of the GWPSs are summarized below.

- Field pH at monitoring well G52L: A field pH GWPS exceedance was noted in a single sample collected from this well in February 2021. The pH value of 6.4 standard units (s.u.) measured in the sample is outside the Part 845 GWPS pH range of 6.5-9.0 s.u. G52L is located cross-gradient/up-gradient from the GMF pond and the screening interval is completed within the Loess unit.
- Field pH at monitoring well G60L: Field pH GWPS exceedances were noted in this well for each of the nine samples collected from this well from March-July 2021. The average pH for the nine samples was 6.1 s.u., which is outside the Part 845 GWPS pH range of 6.5-9.0 s.u. The well is located down-gradient on the east side of the GMFP and the screening interval is completed within the Loess unit.
- Arsenic at monitoring well P60: A total arsenic GWPS exceedance was noted in a single sample collected from this well in March 2021. The arsenic concentration of 0.02 milligrams per liter (mg/L) measured in the sample slightly exceeds the Part 845 GWPS of 0.01 mg/L. P60 is located down-gradient on the east side of the GMFP and the screening interval is completed within the Loess unit.
- Lead at monitoring well P60: A total lead GWPS exceedance was noted in a single sample collected from this well in March 2021. The lead concentration of 0.036 mg/L measured in the sample slightly exceeds the Part 845 GWPS of 0.015 mg/L. P60 is located down-gradient on the east side of the GMFP and the screening interval is completed within the Loess unit.

3.0 EVIDENCE THAT POTENTIAL GWPS EXCEEDANCES ARE NOT RELATED TO THE GMFP

Groundwater data for samples collected from monitoring wells that exhibited potential GWPS exceedances, background monitoring wells and pore water samples from the GMFP were evaluated. The review of these data indicates that the GWPS exceedances are not related to the GMFP, as described in the lines of evidence (LOE) below:

- **The ionic composition of groundwater collected from G52L, G60L and P60 is similar to groundwater collected from background wells G02S, G50S and G52S.**

A Piper diagram is a graphical technique used to classify and compare different groundwater sources based on their ionic composition in aqueous solution. As shown on the Piper diagram presented as Figure 2, the ionic composition of groundwater samples collected from G52L, G60L and P60 is similar to groundwater samples collected from the background wells – both groups of samples exhibit a calcium-bicarbonate water-type. Pore and surface water samples collected from the GMFP exhibit a magnesium-chloride water-type, which is distinctly different to the background wells and monitoring wells G52L, G60L and P60. It would be expected that if there were a release from the GMFP, the ionic composition of the monitoring wells would show a mixing pattern towards the pore water ionic composition. However, as shown on Figure 2, the compositions of the monitoring wells are clustered with the background well compositions and distant from the pore and surface water compositions. These data support that the GWPS standard exceedances of pH in G52L and G60; the arsenic exceedance in P60; and the lead exceedance in P60 are not related to the GMFP.

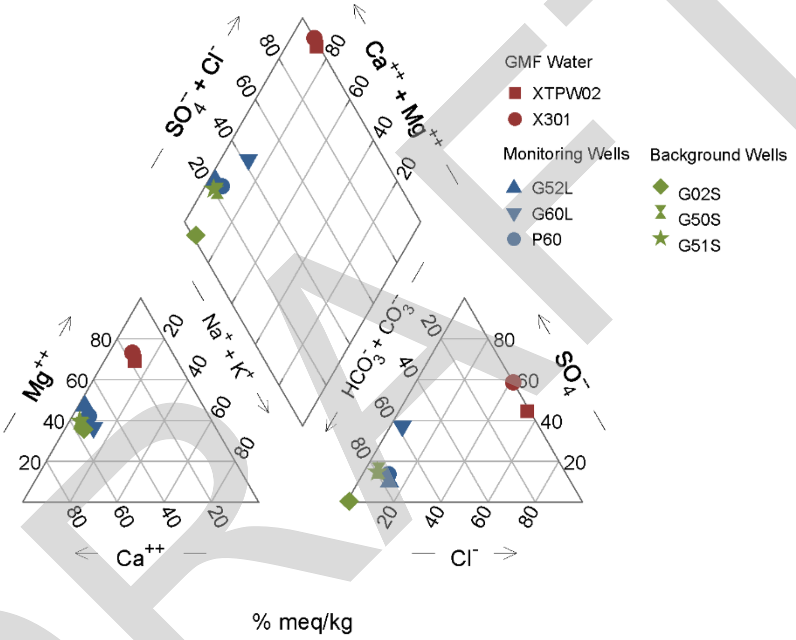


Figure 2: Piper diagram showing water chemistry of GMF Surface and Pore Water, monitoring wells G52L, G60L and P60, and background wells.

- **Concentrations of key GMFP constituents differ significantly in GMFP pore water samples and groundwater samples from monitoring wells G52L, G60L and P60.**

Concentrations of key constituents typically associated with CCR gypsum waste (boron, calcium, chloride, fluoride, sodium and sulfate) differ significantly between pore water/surface water in the GMFP and groundwater samples collected from the monitoring wells (Table 1, Figures 3 and 4). For example, boron, a typical gypsum indicator that is very mobile and non-reactive within a groundwater matrix, is elevated in GMF surface water and pore water samples (29 - 98 mg/L), whereas the monitoring wells G52L, G60L and P60 contain significantly lower concentrations (0.022 – 0.068 mg/L) that are more consistent with background results. Given the geochemical behavior of boron, it would be expected that elevated boron concentrations above background values would be observed in monitoring wells had a release occurred from the GMF pond. Similarly, fluoride and sulfate, other very mobile GMF constituents, would be expected to be observed in monitoring wells above the site GWPS in the event of a release from the GMF Pond. Figures 3 and 4 below and Table 1 show the differences in concentrations between GMF surface water/pore water and monitoring wells for other key GMF constituents. Table 1 also contains site background and the Part 845 GWPSs. These data support that the GWPS standard exceedances of pH in G52L and G60; the arsenic exceedance in P60; and the lead exceedance in P60 are not related to the GMFP.

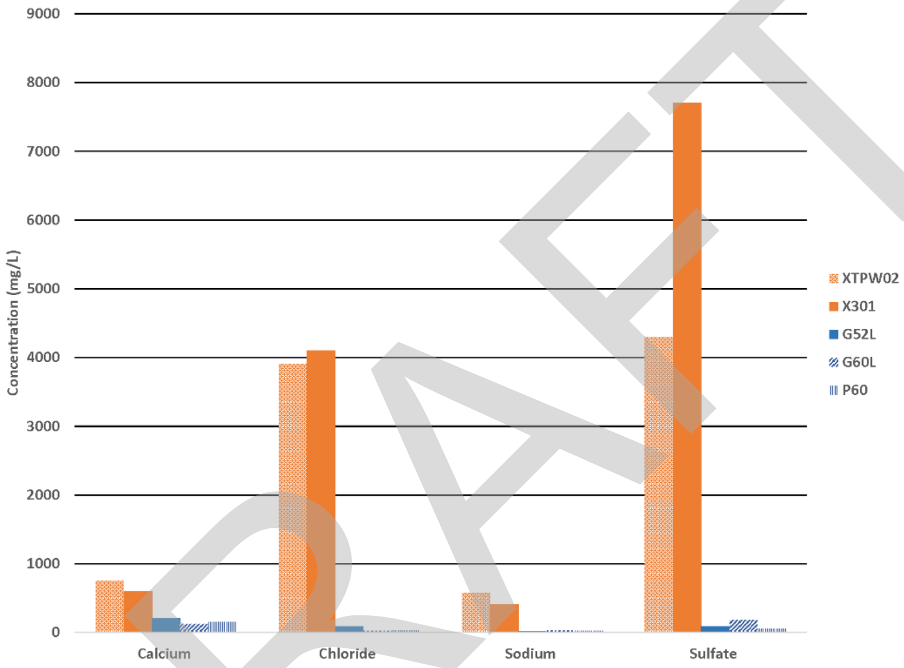


Figure 3: Bar chart showing GMFP constituent concentration comparisons between GMFP Surface and Pore Water and monitoring wells G52L, G60L and P60.

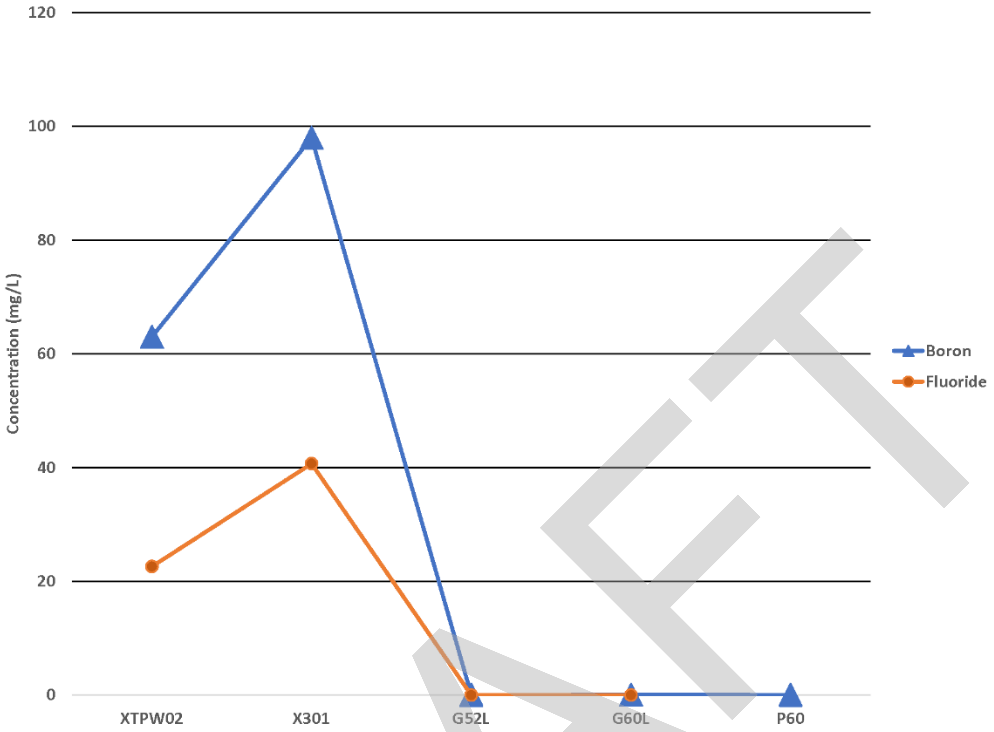


Figure 4: Line chart showing GMFP constituent concentration comparisons between GMFP Surface and Pore Water and monitoring wells G52L, G60L and P60.

- **High turbidity was recorded on the groundwater sampling record for the sample collected from P60.**

The arsenic and lead GWPS exceedances were based on a single sample collected from P60 in March 2021. The groundwater sampling record indicated an unusually high turbidity reading just before sample collection (1620 nephelometric turbidity units (NTU)). According to the sampling record, the sample did not appear to be field filtered, nor was it filtered in the lab. Thus, the arsenic and lead sample concentrations are likely elevated due to the presence of excessive soil and/or colloidal particles in the sample and are not representative of actual groundwater conditions in the vicinity of this well. These circumstances support the conclusion that GWPS standard exceedances of lead and arsenic in P60 are not related to the GMFP.

- **A peat layer ranging in thickness from 1 to 4 feet is present in the immediate vicinity of P60.**

Peat was recorded in the boring log of P60 within the saturated zone (approximately 19.5-20.5 and 24-24.2 feet below ground surface (ft bgs)), but above the screened interval of the well (approximately 29.5-34.5 feet bgs) (Appendix A). Approximately 4 feet of peat was recorded within the saturated zone in a nearby soil boring, B-55 (approximately 13.5-17.5 feet bgs). Given the interconnected nature of the unlithified water-bearing units, it is possible that the peat layer is interacting with the groundwater-bearing unit in the immediate vicinity. Peat is typically associated with low pH and is known to sequester certain metals, including arsenic and lead. In combination with a high turbidity and unfiltered sample, this may be the cause of the slightly elevated arsenic and lead concentrations in P60. Thus, the GWPS standard exceedances of pH in G60L and the arsenic lead exceedance in P60 may be associated with the peat layer encountered in the immediate vicinity of those wells.

- **Arsenic and lead are not typical CCR indicators and are not present in GMFP pore and surface water above the GWPS.**

Arsenic and lead are not typical coal ash or gypsum indicators (EPRI, 2017). As shown on Table 1, arsenic and lead have been either not detected or detected below the applicable GWPS in GMFP pore and surface water samples. In addition, concentrations in GMFP pore and surface water are lower than concentrations measured in the groundwater sample collected from P60. These data support that GWPS exceedances of lead and arsenic in P60 are not related to the GMFP, as the unit is not a source of elevated arsenic or lead.

- **The GMFP liner was constructed with a dual composite liner system with a leak detection system, has undergone rigorous construction quality assurance and has indicated strong performance**

As discussed in Section 2.0, the GMFP liner was constructed with a primary and secondary liner system with a leak detection layer between the primary and secondary liners. The construction process underwent a detailed construction quality assurance program (Hanson, 2009). The leak detection system has to date shown excellent performance of the primary liner system. Pumps in the leak detection system designed to operate to remove water from the primary liner have only run for a few hours for the lifetime of the facility (beginning in 2009). This indicates that a release from the GMFP has likely not occurred and that the GWPS standard exceedances of pH in G52L and G60; the arsenic exceedance in P60; and the lead exceedance in P60 are not related to the GMFP.

4.0 SUMMARY

The evaluation presented in this document demonstrates that the GWPS exceedances of pH in G52L and G60; the arsenic exceedance in P60; and the lead exceedance in P60 are not related to the GMFP. The following lines of evidence demonstrate the GWPS exceedances are not related to the GMFP:

- The ionic composition of groundwater collected from G52L, G60L and P60 is similar to groundwater collected from background wells G02S, G50S and G52S and not the pore water/surface water in the GMFP.
- Concentrations of key gypsum constituents differ significantly between GMFP pore water samples and groundwater samples collected from monitoring wells G52L, G60L and P60.
- High turbidity was recorded on the groundwater sampling record for the sample collected from P60, which likely resulted in arsenic and lead concentrations that are not representative of actual groundwater conditions in the vicinity of this well.
- Arsenic and lead are not CCR indicators for this CCR unit and are not present in GMFP pore and surface water above their corresponding GWPS.
- The GMFP liner was constructed with a dual composite liner system with a leak detection system, has undergone rigorous construction quality assurance and has indicated strong performance.

- Naturally occurring peat is present within the saturated zone in the immediate vicinity of P60 and G60L and may be causing naturally occurring lower pH in G60L and slightly elevated arsenic and lead concentrations in P60, particularly in a high-turbidity, unfiltered groundwater sample.

5.0 REFERENCES

Electric Power Research Institute (EPRI). 2017, Guidelines for Development of Alternative Source Demonstrations at Coal Combustion Residual Sites, Report 3002010920, October 2017

Hanson (Hanson) Professional Services Inc. 2009 Acceptance Report, Gypsum Stack, Gypsum Management Facility, AERG Duck Creek Power Generating Station. December.

Natural Resource Technology, an OBG Company (NRT/OBG), October 17, 2017b. Hydrogeologic Monitoring Plan. Duck Creek GMF Pond – CCR Unit ID 203, Duck Creek Landfill – CCR Unit ID 204. Duck Creek Power Station, Canton, Illinois. Illinois Power Resources Generating, LLC.

6.0 CLOSING

Golder appreciates the opportunity to serve as your consultant on this project. If you have any questions concerning this Technical Memorandum or need additional information, please contact the undersigned.

Golder Associates Inc.

Roberta Russell

Roberta Russell
Senior Geologist
RR/JSI/PJB

Pat Behling
Principal, Practice Leader

Attachments: Table 1 – GMF Pond Surface Water, Pore Water, and Groundwater Monitoring Data
Figure 1 – Gypsum Management Facility Pond Well Locations and Typical Groundwater Flow Direction
Appendix A – Boring Logs

Table

Table 1
GMF Pond Surface Water, Pore Water and Groundwater Monitoring Data
Duck Creek Power Plant
Canton, Illinois

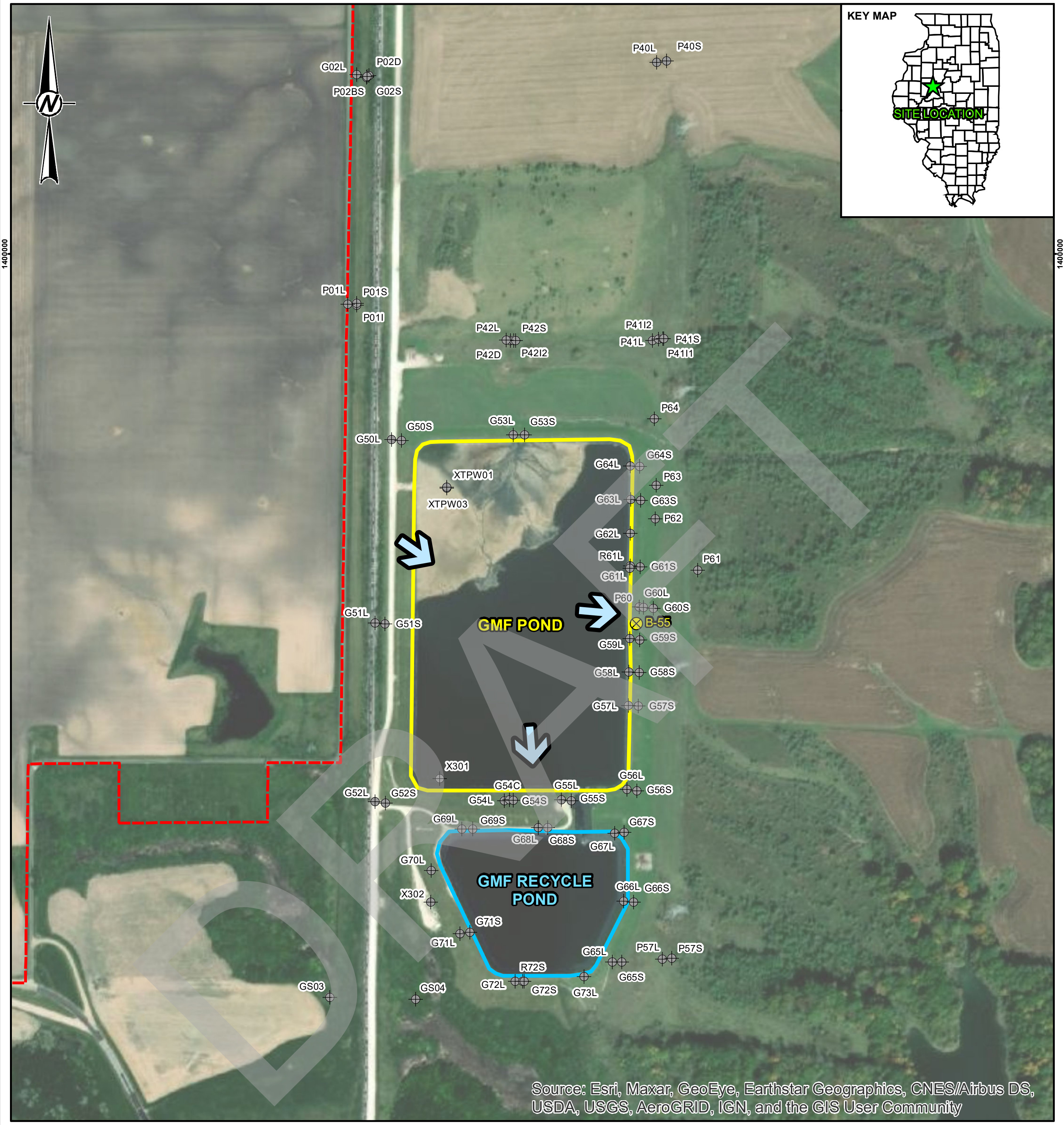
Sampling Information		Potential Exceedance Constituents			Key Flue Gas Desulfurization Material (Gypsum) Constituents					
Well ID	Sampling Date	pH	Arsenic (Total)	Lead (Total)	Boron (Total)	Calcium (Total)	Chloride (Total)	Fluoride (Total)	Sodium (Total)	Sulfate (Total)
Units		SU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Part 845 Groundwater Protection Standards										
Site Background	NA	6.6 - 7.4	0.0092	0.015	0.21	NA	17	0.5	NA	55
Part 845 Standard	NA	6.5 - 9.0	0.01	0.0075	2	NA	200	4	NA	400
Part 845 GWPS	NA	6.5 - 9.0	0.01	0.015	2	NA	200	4	NA	400
GMF Pond Surface Water and Pore Water Samples										
XTPW02	6/23/2021	6.55	0.0026	ND < 0.001	63	750	3,900	22.6	570	4,300
X301	2/24/2021	5.50	NS	NS	29	180	1,200	14.4	110	2,300
X301	4/14/2021	6.70	0.0031	0.0013	97	580	3,700	35.4	390	7,300
X301	4/29/2021	6.60	0.0025	ND < 0.001	88	560	3,600	36.9	400	7,200
X301	5/12/2021	6.48	0.0024	ND < 0.001	84	560	4,100	40.7	410	7,700
X301	6/1/2021	6.64	0.0029	ND < 0.001	98	550	3,700	36.8	400	7,300
X301	7/26/2021	6.22	0.0018	ND < 0.001	85	600	3,600	38.1	370	6,900
Monitoring Wells										
G52L*	2/19/2021	6.39	ND < 0.001	ND < 0.001	0.037	210	30	ND < 0.25	13	87
G60L	4/14/2021	6.20	ND < 0.001	ND < 0.001	0.034	110	19	ND < 0.25	29	ND < 250
G60L	4/29/2021	6.10	ND < 0.001	ND < 0.001	0.029	120	19	ND < 0.25	31	160
G60L	5/13/2021	6.19	ND < 0.001	ND < 0.001	0.025	110	19	ND < 0.25	30	180
G60L	6/1/2021	6.26	ND < 0.001	ND < 0.001	0.029	110	20	ND < 0.25	30	170
G60L	6/15/2021	6.18	ND < 0.001	ND < 0.001	0.029	110	16	ND < 0.25	32	180
G60L	6/21/2021	6.16	ND < 0.001	ND < 0.001	0.068	110	18	ND < 0.25	29	180
G60L	7/12/2021	5.98	ND < 0.001	ND < 0.001	0.027	110	18	ND < 0.25	30	180
G60L	7/28/2021	6.22	ND < 0.001	ND < 0.001	0.022	110	15	ND < 0.25	29	160
P60	3/24/2021	6.60	0.02	0.036	0.056	150	32	NS	22	53

Notes:

1) GMF - Gypsum Management Facility, SU - standard unit, mg/L - milligrams per liter,
ND - non-detect, NS - not sampled.
2) X301 samples are collected from a riser pipe from the ring drain beneath the pond.
3) XTPW02 results represent a porewater sample.
4) * - G52L data displays dissolved values.
5) Site background values based on Ramboll Determination of Potential Exceedances Table.
6) GWPS - Groundwater Protection Standard.
7) NA - Not Available.

Created by: BTT
Checked by: GM
Reviewed by: PJB

Figure



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LEGEND

⊕	WELL LOCATION
⊗	SOIL BORING LOCATION
- -	APPROXIMATE PROPERTY BOUNDARY
➚	TYPICAL GROUNDWATER FLOW DIRECTION

0 250 500 1,000
Feet

NOTE(S)

1. ALL LOCATIONS AND BOUNDARIES ARE APPROXIMATE.
2. GMF - GYPSUM MANAGEMENT FACILITY.

REFERENCE(S)

1. RAMBOLL 2020. ILLINOIS ADMINISTRATIVE CODE PART 845 DATA GAP ANALYSIS AND WORK PLAN, DUCK CREEK GYPSUM MANAGEMENT FACILITY AND RECYCLE POND - CCR UNIT 203 AND 206.

CLIENT
ILLINOIS POWER RESOURCES GENERATING, LLC.
DUCK CREEK POWER PLANT

PROJECT
MONITORED NATURAL ATTENUATION EVALUATION

TITLE
GYPSUM MANAGEMENT FACILITY POND WELL LOCATIONS AND TYPICAL GROUND WATER FLOW DIRECTION

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-10-14
DESIGNED	JSI
PREPARED	ETF
REVIEWED	BTT
APPROVED	PJB

PROJECT NO.	PHASE	REV.	FIGURE
21454831	0001	0	1

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Appendix A

Boring Logs

FIELD BORING LOG

HANSON

CLIENT: Ameren
Site: Gypsum Stack
Location: Duck Creek Generating Station
Project: 03S5010
DATES: Start: 4/1/407
Finish: 4/4/2007
WEATHER: Overcast, cool

CONTRACTOR: Testing Service Corporation
Rig mfg/model: CME-650 Track Rig
Drilling Method: 3¼" hollow stem auger w/split spoon sampler
FIELD STAFF: Driller: B. Williamson
Helper: R. Keedy
Eng/Geo: R. Hasenyager

BOREHOLE ID: B-55
Well ID: hole abandoned
Surface Elev: 611.07 ft. MSL
Completion: 20.00 ft. BGS
Station: 15,438.7N
987.3E

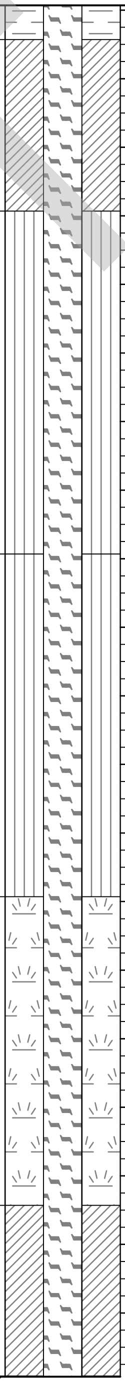
TOPOGRAPHIC MAP INFORMATION:
Quadrangle: Banner
Township: Banner
Section 18, **Tier** 6N; **Range** 5E

WATER LEVEL INFORMATION:
▼ = 13.00 - during drilling
▼ =
▽ =

SAMPLE			TESTING					
Number	Recov / Total (in) *% Recovery*	Type	*Blows / 6 in* N - Value **RQD**	Moisture (%)	Dry Den. (lb/ft^3)	Qu (tsf) *Failure Type*		
1A	15/18 *83%*	SS	*2-3* *3* N=6	29		1.75 *B*		
2A	16/18 *89%*	SS	*3-4* *5* N=9	22		0.78 *BSh*		
3A	16/18 *89%*	SS	*3-4* *4* N=8	26				
4A	15/18 *83%*	SS	*3-4* *5* N=9	26		1.94 *BSh*		
5A	18/18 *100%*	SS	*2-3* *4* N=7	33		1.32 *B*		
6A	18/18 *100%*	SS	*3-4* *5* N=9	20		1.16 *BSh*		

Depth ft. BGS	Lithologic Description	Elevation ft. MSL	Remarks
	Dark brown, clayey TOPSOIL (OL)		
2	Brown-gray, silty CLAY, trace sand (CL)	610	
4	Brown-gray, clayey SILT, trace sand (ML)	608 606	
6		604	
8 10 12	Gray-brown, clayey SILT, trace sand (ML)	602 600	
14 16	Black, PEAT (PT)	598 596 594	
18	Gray, silty CLAY, trace sand and gravel (CL)	592	
20	**End of Boring = 20.0 ft. BGS**		

Borehole Detail



NOTE(S):

FIELD BORING LOG

HANSON

CLIENT: Illinois Power Generating Company, LLC
Site: Duck Creek Power Station - Ash Landfill
Location: 17751 N. CILCO Rd., Canton, IL 61520
Project: 17E0057
DATES: Start: 3/15/2017
Finish: 3/15/2017
WEATHER: Sunny, cold (lo-30s)

CONTRACTOR: Ramsey Geotechnical Engineering, LLC
Rig mfg/model: Diedrich D-50
Drilling Method: 4¼" Hollow Stem Auger, split spoon sampler
FIELD STAFF: Driller: B. Williamson
Helper: D. Crump
Eng/Geo: R. Hasenyager

BOREHOLE ID: P60
Well ID: P60
Surface Elev: 620.12 ft. MSL
Completion: 34.62 ft. BGS
Station: 15,477.09N
992.24E

TOPOGRAPHIC MAP INFORMATION:
Quadrangle: Banner, IL
Township: Banner
Section 18, **Tier** 6N; **Range** 5E

WATER LEVEL INFORMATION:
▼ = 16.80 - During drilling
▼ = Dry - At completion
▽ =

SAMPLE			TESTING			
Number	Recov / Total (in) *% Recovery*	Type	*Blows / 6 in* N - Value **RQD**	Moisture (%)	Dry Den. (lb/ft^3)	Qu (tsf) *Qp (tsf)* Failure Type
1A	14/24 *58%*	SS	*2-3* *3-4* N=6			
2A	18/24 *75%*	SS	*3-6* *8-11* N=14	17.5		
3A	15/24 *63%*	SS	*3-4* *6-7* N=10	19.6		
4A	20/24 *83%*	SS	*6-8* *11-14* N=19	18.5		
5A	22/24 *92%*	SS	*3-5* *6-7* N=11	26.8		
6A	21/24 *88%*	SS	*2-4* *5-5* N=9	23.8		
7A	20/24 *83%*	SS	*4-4* *6-7* N=10	22.8		
8A	21/24 *88%*	SS	*5-6* *7-7* N=13	22.1		
9A	21/24 *88%*	SS	*5-5* *6-6* N=11	21.0		
10A	24/24 *100%*	SS	*2-3* *4-7* N=7	28.1		
10B				61.7		

Depth ft. BGS — Lithologic Description — Borehole Detail — Elevation ft. MSL — Remarks

Depth: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20
Elevation: 620, 618, 616, 614, 612, 610, 608, 606, 604, 602

FILL - Yellowish brown (10YR5/6), moist, medium, CLAY with some silt and trace sand.

Yellowish brown (10YR5/6), moist, medium, SILT with few clay and trace sand.

Yellowish brown (10YR5/8) with 30% gray (10YR5/1) mottles, moist, medium, SILT with few clay and trace sand.

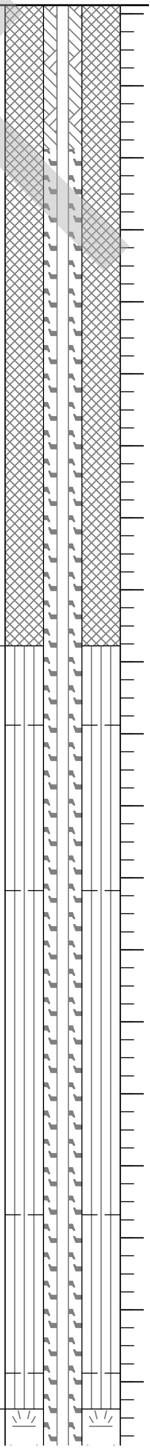
Gray (10YR5/1) with 20% yellowish brown (10YR5/8) mottles, moist, medium, SILT with few clay and trace sand.

▼

Gray (10YR5/1) with 25% yellowish brown (10YR5/8) mottles, wet, medium, SILT with few clay and trace sand.

Dark yellowish brown (10YR3/4), moist, medium, SILT with few clay and trace sand, trace organics.

Dark brown (10YR3/3), moist, medium, PEAT.



NOTE(S): P60 installed in boring.
Coordinates are on Plant (Local) grid.

FIELD BORING LOG

CLIENT: Illinois Power Generating Company, LLC
Site: Duck Creek Power Station - Ash Landfill
Location: 17751 N. CILCO Rd., Canton, IL 61520
Project: 17E0057
DATES: Start: 3/15/2017
Finish: 3/15/2017
WEATHER: Sunny, cold (lo-30s)

CONTRACTOR: Ramsey Geotechnical Engineering, LLC
Rig mfg/model: Diedrich D-50
Drilling Method: 4¼" Hollow Stem Auger, split spoon sampler
FIELD STAFF: Driller: B. Williamson
Helper: D. Crump
Eng/Geo: R. Hasenyager

BOREHOLE ID: P60
Well ID: P60
Surface Elev: 620.12 ft. MSL
Completion: 34.62 ft. BGS
Station: 15,477.09N
992.24E

TOPOGRAPHIC MAP INFORMATION:
Quadrangle: Banner, IL
Township: Banner
Section 18, **Tier** 6N; **Range** 5E

WATER LEVEL INFORMATION:
▼ = 16.80 - During drilling
▼ = Dry - At completion
▽ =

SAMPLE			TESTING			
Number	Recov / Total (in) *% Recovery*	Type	*Blows / 6 in* N - Value **RQD**	Moisture (%)	Dry Den. (lb/ft³)	Qu (tsf) *Qp (tsf)* Failure Type
11A	20/24 *83%*	SS	*2-5* *6-7* N=11	31.4		
12A	24/24 *100%*	SS	*9-8* *7-6* N=15	33.7		
13A	20/24 *83%*	SS	*4-3* *4-4* N=7	23.0		
14A	22/24 *92%*	SS	*4-5* *6-6* N=11	20.6		
15A	24/24 *100%*	SS	*3-3* *4-5* N=7	17.5		
16A	24/24 *100%*	SS	*1-3* *3-3* N=6	20.2		
17A	24/24 *100%*	SS	*5-6* *6-7* N=12	15.9		
	0/7 *0%*	BD				

Depth ft. BGS: 22, 24, 26, 28, 30, 32, 34

Elevation ft. MSL: 600, 598, 596, 594, 592, 590, 588, 586

Lithologic Description

Dark brown (10YR3/3), moist, medium, PEAT.
[Continued from previous page]

Very dark gray (10YR3/1), moist, medium, SILT with some clay and trace sand, trace organics.

Very dark gray (10YR3/1), wet, medium, SILT with some clay and trace sand, trace organics.

Dark brown (10YR3/3), moist, medium, PEAT.

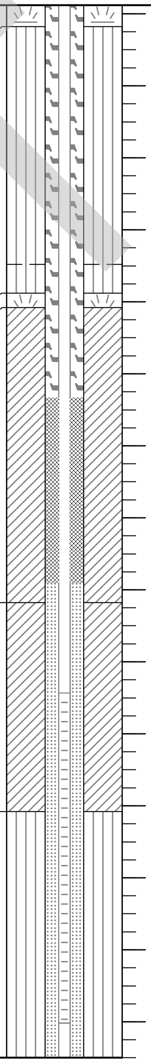
Gray (10YR5/1), moist, medium, CLAY with some silt and trace sand and gravel.

Greenish gray (5G6/1), moist, medium, CLAY with some silt and trace sand and gravel.

Greenish gray (5G6/1), wet, soft, SILT with few clay, little sand, and trace gravel.

End of Boring = 34.62 ft bgs

Borehole Detail



Remarks

NOTE(S): P60 installed in boring.
Coordinates are on Plant (Local) grid.

APPENDIX B
MODFLOW AND HELP MODEL FILES
(ELECTRONIC ONLY)

APPENDIX C
HELP MODEL INPUT AND OUTPUT

Appendix C: Inputs and Summary of HELP Closure-In-Place cap simulation

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

Title: Duck Creek Coversystem CIP **Simulated On:** 27/10/2021 21:54

Layer 1

Type 1 - Vertical Percolation Layer (Cover Soil)
SiL - Silty Loam(Moderate)
Material Texture Number 23

Thickness = 6 inches
Porosity = 0.461 vol/vol
Field Capacity = 0.36 vol/vol
Wilting Point = 0.203 vol/vol
Initial Soil Water Content = 0.4073 vol/vol
Effective Sat. Hyd. Conductivity = 9.00E-06 cm/sec

Layer 2

Type 1 - Vertical Percolation Layer
SiL - Silty Loam(Moderate)
Material Texture Number 23

Thickness = 18 inches
Porosity = 0.461 vol/vol
Field Capacity = 0.36 vol/vol
Wilting Point = 0.203 vol/vol
Initial Soil Water Content = 0.3829 vol/vol
Effective Sat. Hyd. Conductivity = 9.00E-06 cm/sec

Layer 3

Type 2 - Lateral Drainage Layer
Drainage Net (0.5 cm)
Material Texture Number 20

Thickness = 0.2 inches
Porosity = 0.85 vol/vol
Field Capacity = 0.01 vol/vol
Wilting Point = 0.005 vol/vol
Initial Soil Water Content = 0.0338 vol/vol
Effective Sat. Hyd. Conductivity = 1.00E+01 cm/sec
Slope = 4 %
Drainage Length = 450 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 = 1 Holes/Acre
FML Placement Quality = 3 Good

Layer 5

Type 1 - Vertical Percolation Layer
Gypsum waste material (Sandy Loam)
Material Texture Number 43

Thickness = 240 inches
Porosity = 0.437 vol/vol
Field Capacity = 0.105 vol/vol
Wilting Point = 0.047 vol/vol
Initial Soil Water Content = 0.105 vol/vol
Effective Sat. Hyd. Conductivity = 6.70E-04 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 = 90.1
Fraction of Area Allowing Runoff = 100 %
Area projected on a horizontal plane = 15 acres
Evaporative Zone Depth = 8 inches
Initial Water in Evaporative Zone = 3.294 inches
Upper Limit of Evaporative Storage = 3.688 inches
Lower Limit of Evaporative Storage = 1.624 inches
Initial Snow Water = 0 inches
Initial Water in Layer Materials = 34.543 inches
Total Initial Water = 34.543 inches
Total Subsurface Inflow = 0 inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude = 40.5 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 = 72 %
Average 2nd Quarter Relative Humidity = 67 %
Average 3rd Quarter Relative Humidity = 74 %
Average 4th Quarter Relative Humidity = 75 %

Note: Evapotranspiration data was obtained for ,

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.01298	1.895696	2.373253	3.597322	4.095479	4.395065163
3.769391	3.145982	3.272523	2.912689	2.788342	2.489948934

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 40.5/-89.98

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
32.4	34.2	41.9	56.4	69.6	79
83.5	81	72.5	61.4	45.9	35.6

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 40.5/-89.98
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 40.5/-89.98

Appendix C: Inputs and Summary of HELP Closure-In-Place cap simulation

Average Annual Totals Summary

Title: Duck Creek Coversystem CIP
Simulated on: 27/10/2021 21:59

	Average Annual Totals for Years 1 - 100*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	36.75	[5.46]	2,000,965.1	100.00
Runoff	12.581	[3.246]	685,044.7	34.24
Evapotranspiration	23.227	[2.957]	1,264,727.0	63.21
Subprofile1				
Lateral drainage collected from Layer 3	0.9541	[0.7929]	51,952.6	2.60
Percolation/leakage through Layer 4	0.000247	[0.00019]	13.5	0.00
Average Head on Top of Layer 4	0.0005	[0.0004]	---	---
Subprofile2				
Percolation/leakage through Layer 5	**0.000247**	[0.00019]	13.5	0.00
Water storage				
Change in water storage	-0.0142	[1.0912]	-772.6	-0.04

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