Prepared for

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PLANT HAMMOND
ASH POND 3 (AP-3)
ADVANCED ENGINEERING METHODS
FEASIBILITY REPORT

GEORGIA POWER COMPANY
Rome, Floyd County, Georgia

Submitted by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1. INTRODUCTION

1.1 Background and Purpose

Plant Hammond (the Plant) is a four-unit, coal-fired electric generating facility located in Rome, Floyd County, Georgia. The Plant is located along the Coosa River, approximately 10 miles west of Rome, GA and is owned by Georgia Power Company (Georgia Power). The Plant operated from 1954 to 2019 and when operating, had a capability of producing 843 megawatts of electricity. The Plant occupies about 1,100 acres and is bordered by Georgia Highway 20 (GA-20) on the north, the Coosa River on the south, Cabin Creek and an industrial land on the east, and a sparsely populated, forested, rural and industrial land on the west. **Figure 1-1** shows a plan view of the Plant along with the four CCR surface impoundments at the Plant (i.e., AP-1 through AP-4). **Figure 1-2** shows the area in the immediate vicinity of Ash Pond 3 (AP-3).

On 17 April 2015, the United States Environmental Protection Agency (USEPA) published regulations on the disposal of Coal Combustion Residuals (CCR) titled "*40 CFR Parts 257 and 261: Hazardous and Solid Waste Management System; Disposal of Coal Combustible Residuals from Electric Utilities; Final Rule*" (the USEPA CCR Rule). The USEPA CCR Rule became effective on 19 October 2015, which established regulations regarding closure and continued operation and monitoring of both existing and new CCR surface impoundments and landfills. In November 2016, the Georgia Environmental Protection Division (GA EPD) adopted amendments to the state's Rules for Solid Waste Management that address CCR (GA EPD 391-3-4-.10, i.e., the State CCR Rule). The State CCR Rule incorporates by reference most of the provisions of the USEPA CCR Rule.

Georgia Power closed AP-3 in compliance with USEPA and State CCR Rules in the second quarter of 2018 by capping in place and plans to close the remaining three (AP-1, AP-2, and AP-4) CCR surface impoundments at the Plant. The AP-3 closure is described in greater detail in Section 3, and the remaining three impoundments will be closed by removal. This report presents an evaluation of advanced engineering method (AEM) options considered for implementation in connection with the in-place closure (capping) of AP-3. Here, the term AEM is used to refer to technologies or measures that are designed to enhance the protection of groundwater and closure effectiveness, and/or further minimize future maintenance of the unit.

This document is Geosyntec's report on its evaluation of AEM feasibility for AP-3 at Plant Hammond. The report summarizes the conceptual site model (CSM) for AP-3 and then presents an initial screening of AEMs that evaluates the feasibility of certain technologies and measures. Then, considering the overall plan for and anticipated effects from CCR surface impoundment closures at Plant Hammond, the list of AEM options is refined and evaluated in detail by comparing AEM relative effectiveness using a groundwater numerical flow model, implementability, and potential impacts associated with construction.

1.2 Report Organization

Following this introductory section, the remaining part of this report is organized as follows:

- Section 2 presents a summary of the CSM. A detailed discussion of the CSM is provided in the *Hydrogeologic Assessment Report for Ash Pond 3 Revision 1* (HAR Rev 01) (Geosyntec, 2019);
- Section 3 discusses the AP-3 closure, as well as the anticipated effects on post-closure conditions from Georgia Power's election to close AP-1 by removal;
- Section 4 presents the initial screening and focused evaluation of the various AEMs considered for AP-3;
- Section 5 presents a comparative discussion of the evaluated AEM options; and
- Section 6 provides a list of references.

2. CONCEPTUAL SITE MODEL

The Plant is located in the Valley and Ridge Physiographic Province (Valley and Ridge) of northwest Georgia, which is characterized by Paleozoic sedimentary rocks that have been folded and faulted into the ridges and valleys that gave this region its name. The topography of the valleys and ridges reflects the underlying geology of the variably eroded and folded layers of alternating bedrock units. Ridges are composed of relatively erosion-resistant rocks such as sandstone, conglomerate, or chert whereas valley floors are underlain by more-easily eroded rocks such as limestone, dolomite, and shale.

Previous subsurface investigations identified five (5) lithologic units in the area of AP-3. From top to bottom, these units are: fill, terrace alluvium, residuum, highly weathered/fractured limestone bedrock, and unweathered limestone bedrock. The characteristics of these units are described in greater detail in the *HAR Rev 01* (Geosyntec, 2019). The uppermost aquifer is unconfined and occurs primarily in the terrace alluvium, highly weathered limestone, and in the solution-enhanced joints in the competent bedrock. The aquifer is recharged from infiltration of precipitation and from release of stored water in the lower permeability residuum to the underlying units. Localized preferential flow may also occur in the coarse facies of the terrace alluvium, but this unit is not laterally extensive across AP-3. Groundwater flow in the vicinity of AP-3 generally flows from west to east. The geologic and hydrogeologic characteristics near AP-3 are described in greater detail in the *HAR Rev 01* (Geosyntec 2019).

The limestone observed in the vicinity of AP-3 is associated with the middle units of the Cambrian age Conasauga Formation (Ccls), which consists of mostly shaley or argillaceous limestone (referred to as limestone). A review of 7.5-minute USGS topographic maps (Rock Mountain, GA and Livingston, GA) of the area containing the Plant did not exhibit the typical surface expressions of karst features, such as sinkholes and sinking or disappearing streams. The discrete, discontinuous, and mostly filled solution openings observed in subsurface borings, through drilling and borehole geophysical investigation, were likely formed by dissolution of limestone along the bedding planes and joints. The openings are mostly filled with mud and, based on collective review of AP-3 boring logs, are not laterally continuous or representative of extensive open cavities within the bedrock formation. Due to the discrete and discontinuous nature of these solution features, linear preferential flow pathways for groundwater are not expected. With respect to karst processes, it should be noted that dissolution of the limestone bedrock takes place over geologic time, on the order of hundreds of thousands of years. The solution features present at AP-3 are not expected to be actively enlarging, further they are not laterally continuous or representative of extensive open cavities within the bedrock formation across the footprint of the unit. Mechanisms that, if present, could contribute to displacement of the residuum and surface soils at AP-3 due to karst include (i) an elevated water table resulting in increased head pressure and downward seepage gradients; (ii) the collapse or erosion of residuum into the solution-enhanced joint system due to the downward seepage forces and gravity; and (iii) the progressive upward propagation of downward soil collapse or erosion under the forces of downward seepage and gravity. When all these mechanisms are present, displacement (in the form of sinkholes or drop-outs) is possible. However, if one or more of these conditions are mitigated, then these mechanisms are decoupled from the process and the risk of displacement is substantially reduced. The rapid increase and decrease of groundwater levels via periodic pumping of groundwater or the raising and lowering of surface water in unlined impoundments may promote this process by increasing these erosional forces and therefore increasing the risk of these events occurring (Sinclair, 1982; Sowers, 1996).

For example, documented historical water loss from AP-3 during the early stages of operation (late 1970s) were related to wet-sluicing (creating an elevated water table) and the likely presence of solution-enhanced joints and fractures in the underlying bedrock. These conditions were mitigated with repair of the area of water loss and conversion to dry-handling operations at AP-3 in 1982. No additional seeps, water loss, suspected cavities, or other issues have been encountered since the conversion to dry handling in 1983. Additionally, the final engineered closure measures, including installation of a low permeability cover to minimize or eliminate infiltration, were designed and constructed in a manner that will both lower groundwater levels and minimize the potential for adverse effects on the structural components of the unit due to sinkholes or drop-outs.

3. OVERVIEW OF AP-3 CLOSURE MEASURES

The AP-3 unit was closed in place in accordance with the State CCR Rule and the USEPA CCR Rule. This was accomplished by ensuring liquid removal to support the construction of a stable final cover system. The final cover system consists of a 60-mil High-Density Polyethylene (HDPE) liner, geo-composite drainage media, protective soil cover, and a vegetative cover. The cover system is graded to promote positive drainage and shed stormwater away from AP-3 via riprap drainage ditches toward three outfall locations around AP-3. The final closure of the unit with this low-permeability cover system minimizes or eliminates infiltration, to the maximum extent feasible, resulting in lower groundwater levels in the area of the closed unit. Prior to installation of the cover system, the sub-grade was stabilized sufficiently to support the final cover system and the CCR met appropriate compaction and moisture content standards in accordance with the final design criteria. Details of the engineering and design components of the AP-3 closure and cover system are included in the *Engineering Report* included in Part B of the Permit Application (Stantec 2018).

In addition to the closure of AP-3, Georgia Power opted to close nearby AP-1 by removal of the CCR material from the unit. The planned closure by removal activities at AP-1 will include the removal of all standing water and CCR from the unit. The removal of this water will be managed in a way so as not to create conditions or mechanisms leading to displacement of soil and is expected to result in beneficial reductions in groundwater levels and lower hydraulic gradients, including in the AP-3 footprint. The engineering measures that have been implemented at AP-3 and those planned for AP-1 have and will continue to mitigate the mechanisms that could contribute to karst-related displacement of soils as discussed in Section 2.

Groundwater model scenarios were evaluated to compare the relative effects of potential AEM measures for AP-3 and are discussed in the subsequent sections. The following groundwater model scenarios were considered: (i) the AP-3 closure measures as a standalone condition without the effects of the AP-1 closure by removal, (ii) the combined effects of the AP-3 and AP-1 closures, and (iii) the additional effects of various AEM technologies. The groundwater modeling results are presented in **Appendices A** and **B.**

4. EVALUATION OF ADVANCED ENGINEERING METHODS

4.1 Overview

The purpose of this section is to provide an overview of various AEMs that were considered to enhance in-place closure of AP-3 and present their evaluation. For the purpose of this report, AEMs are grouped into two categories: (i) low-permeability barriers (e.g., slurry walls, cutoff walls, etc.)[1], and (ii) groundwater extraction systems (extraction wells, interceptor trenches, TreeWells®, etc.). Based on groundwater data collected at AP-3 to date, there are no exceedances of maximum contaminant levels (MCLs) or regional screening levels (RSLs).

The selection and design of an AEM generally depends on various factors, including effectiveness, implementation challenges, and long-term operation and maintenance. Below, technologies and concepts are initially screened on effectiveness and implementability at AP-3. Through the initial screening process, four options were selected and evaluated in more detail to compare the relative effects on the potentiometric surface resulting from each AEM.

4.2 Initial Screening of Technologies

Based on the conceptual site model, the uppermost portion of the weathered limestone is the predominant groundwater flow zone within the uppermost aquifer at AP-3. Localized preferential flow may also occur in the coarse facies of the terrace alluvium, but this unit is not laterally extensive across AP-3. To be effective, an AEM for AP-3 would need to affect groundwater flow in the highly weathered limestone and potentially in coarse facies of terrace alluvium (if present).

The multiple technical measures considered include five types of low-permeability barriers and three types of groundwater extraction systems. Initial screening was based on implementability and expected effectiveness given the existing infrastructure and hydrogeologic conditions at the AP-3. These considerations are briefly discussed below.

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[1] Permeable reactive barriers and in-situ soil stabilization of the CCR material were considered, however, only those AEMs that have the potential to reduce groundwater elevation and flux were carried forward and evaluated.

The five barrier types include slurry walls, grout curtains, deep soil mix (DSM) walls, sheet pile walls, and geomembrane barriers. The major design considerations for low-permeability barriers are:

- Plan alignment of the wall will be limited by factors such as the property boundaries, accessibility, overhead and underground utility locations, and distance from any existing slopes;
- For most subsurface walls, a working platform or bench (25 to 60 feet wide) is needed along the entire alignment of the wall; and
- Construction of cutoff walls to target depths below ground surface near AP-3 and into very stiff soils or unweathered limestone bedrock could pose challenges and may require specialized equipment.

Based on the understanding of the site conditions, the use of grout curtains, DSM walls, sheet pile walls, and geomembrane barriers are screened out due to one or more major implementability challenges associated with these AEMs. For example, the sheet piles could not physically be driven into the target zone within the bedrock, and the DSM measure would also be limited to the unconsolidated soils above the bedrock. Similar issues preclude the use of geomembrane barriers. The slurry wall option was considered to be the most constructible of the barrier technologies. Two configurations were carried forward for further evaluation, a half slurry wall and full slurry wall.

The three groundwater extraction systems screened were (i) a groundwater extraction well array installed between AP-1 and AP-3, (ii) an interceptor trench on the upgradient side of AP-3, and (iii) a *TreeWell* system downgradient of AP-3. The groundwater extraction well option presents a potential issue of fluctuating groundwater levels and localized steep gradients resulting from pumping in the vicinity of the extraction wells. Rapid lowering of water levels and the fluctuations associated with cycling of the extraction system presents the potential for adverse effects on the underlying karst bedrock by providing a mechanism for erosion of the residuum soils into the solution-enhanced fracture system in the bedrock. While the interceptor trench option would also require pumping, the effect would be dispersed across the entire length of the trench alignment rather than localized in an area near AP-1, and therefore would result in less steep groundwater gradients and fluctuations. The extraction well option was screened out, and the interceptor trench and *TreeWell* options were carried forward for further evaluation. The more detailed evaluation included an assessment of relative effectiveness of AEM scenarios using a groundwater flow model.

4.3 Groundwater Model

The groundwater numerical model developed for the AP-3 area is described in detail in the *Groundwater Model Calculation Package* included as **Appendix A**. The additional model scenarios that were used to evaluate the AEMs are documented in a separate report, the *Groundwater Model Calculation Package Addendum*, included as **Appendix B**. The model represents steady state conditions, and transient conditions were not evaluated. The particle tracking scenarios represent the estimated amount of time it would take a conservative tracer (a water particle) to travel from the location of the greatest thickness of CCR below the potentiometric surface to the AP-3 permit boundary. Groundwater flux is estimated by the volume of water modeled as flowing through the bottom of each model cell within the CCR model layer, and the percent reduction is for each scenario relative to the baseline pre-closure conditions.

Groundwater flow models are necessarily simplified mathematical representations of complex natural systems. Therefore, all groundwater models have limits to their accuracy and associated uncertainties in model predictions. The goal of this model was not to predict precise outcomes, but to provide relative groundwater elevation and flow information to facilitate a comparative evaluation of AEM options. For example, as discussed in **Appendix A**, the mean head error of the calibrated model is -0.06 feet. However, that error ranged from +4.27 feet to -3.20 feet across the model domain. This indicates that while the model's uncertainty is low on average, in some places the calibrated model groundwater elevation could vary up to four feet from the observed conditions.

4.4 Detailed Evaluation of Technologies

Following the initial screening and the development of the groundwater flow model, the selected low permeability barrier (slurry walls) and extraction system scenarios were further evaluated using the predictive model. The following criteria were considered:

- the maximum thickness of CCR below the potentiometric surface;

- volume of CCR below the potentiometric surface;
- groundwater flux through the AP-3 unit;
- time taken for a water particle to travel from the location of the greatest thickness of CCR below the potentiometric surface to the AP-3 permit boundary; and
- implementability considerations such as constructability and potential impacts or adverse effects of the measure.

As a basis of comparison, results of the modeled closure simulations for AP-3 alone as well as the combined effects of closing AP-3 and AP-1 are provided in Section 4.4.1. **Table 4-1** presents a summary of the predictive scenario results obtained from the groundwater flow modeling simulations. These are discussed in greater detail below.

4.4.1 AP-3 Closure Conditions

Results of groundwater modeling included in **Appendices A** and **B** of this report indicate that the closure and capping of AP-3 with a low permeability cover system alone will meaningfully lower the groundwater table, reducing the volume of CCR below the potentiometric surface by nearly 65% and groundwater flux through the CCR in AP-3 by 92.2% relative to the pre-closure conditions. Modeling indicates that capping of AP-3 combined with the planned drainage of AP-1 will have an even more significant effect on the groundwater elevations within AP-3 and its immediate vicinity, reducing the volume of CCR below the potentiometric surface by 91% and groundwater flux by 97.7% relative to the pre-closure conditions.

4.4.2 Low Permeability Barriers

Slurry walls are the most common type of vertical hydraulic barriers and typically include soil-bentonite, cement-bentonite, and soil-cement-bentonite mixtures to construct the below-grade barrier. Methods for the design and construction of slurry walls are well established and when properly designed and installed, they are considered an effective long-term solution for inhibiting groundwater migration (Gerber and Fayer, 1994).

For the AP-3 area, two measures were evaluated for the installation of a slurry wall. The first considered a wall constructed on the upgradient (west) side of AP-3, in order to mitigate groundwater movement toward the unit, and the second considered a fully encompassing wall encircling the entire boundary of AP-3. For both cases, the actual slurry materials were not differentiated, and it was assumed that a hydraulic conductivity of 1 x 10^{-7} centimeters per second would be achieved, which is within the normal expected range of a slurry wall. Also, for both wall alignment options, the depth of the wall was variable, but extended from the ground surface, through the terrace alluvium, residuum, and highly weathered/fractured limestone bedrock, keyed into the top of the unweathered limestone bedrock. This depth ranged from approximately 50 to 75 feet below ground surface (ft bgs).

4.4.2.1 Half Slurry Wall

The potential half slurry wall configuration, along the upgradient (west) half of AP-3 is shown on **Figure 4-1**. This configuration was evaluated using the groundwater numerical flow model developed for AP-3. The resulting steady state conditions using this AEM in conjunction with the combined effects of the AP-3 and AP-1 closures indicated an approximate maximum potentiometric surface height above the bottom of the unit of 3.1 feet and an approximate total volume of CCR below the potentiometric surface of 6,360 cubic yards (CY). This represented a 94% reduction in the total volume of CCR below the potentiometric surface and a 98.6% reduction in groundwater flux compared to the pre-closure conditions. The particle tracking scenarios estimated a travel time of over 100 years for a particle of water originating at the highest point of the CCR below the potentiometric surface to exit the permit boundary of AP-3.

4.4.2.2 Full Slurry Wall

The potential full slurry wall configuration, along the entire perimeter of AP-3 is shown on **Figure 4-2**. This configuration was also evaluated using the groundwater numerical flow model. The resulting steady state conditions using this AEM in conjunction with the combined effects of the AP-3 and AP-1 closures indicated an approximate maximum potentiometric surface height above the bottom of the unit of 4.3 feet and an approximate total volume of CCR below the potentiometric surface of 16,800 CY. This represented an 83% reduction in the total volume of CCR below the potentiometric surface and a 98.7% reduction in groundwater flux compared to the pre-closure conditions, but an increase in the volume of CCR below the potentiometric surface as compared to the effect of the closures of AP-3 and AP-1 alone. The particle tracking scenarios estimated a travel time of over 100 years for a particle of water originating at the highest point of the CCR below the potentiometric surface to exit the permit boundary of AP-3.

4.4.2.3 Low Permeability Barrier Implementability Considerations

The slurry wall configurations that were considered yielded variable results, with the partial upgradient wall alignment resulting in greater reductions in the total volume of CCR below the potentiometric surface and groundwater flux than the fully encompassing wall alignment. This is likely due to groundwater mounding predicted in the interior of AP-3 with the full slurry wall, while the partial slurry wall along the upgradient side allows for groundwater flow out of the system. The full slurry wall option would likely require hydraulic control (via groundwater extraction) within the unit in order to relieve head pressures due to the fully encompassing wall. This may lead to the same concerns that resulted in exclusion of the extraction well system discussed in Section 4.2. For these reasons, the fully encompassing slurry wall option is not advanced to the comparative analysis presented in Section 5.

The upgradient slurry wall alignment also results in groundwater mounding, along the upgradient portion of AP-3, as shown in Figure 4 of **Appendix B**. This modeled mounding (on the order of one to four feet) may be problematic in areas to the west of AP-3 where groundwater levels are commonly less than ten feet below ground surface.

In order to achieve the conditions predicted in the model scenarios (2 and 3), the conceptual slurry wall design would require a depth range of 50 to 75 feet and installed into the top of the limestone bedrock. Construction of a slurry wall to this depth and into the fractured bedrock would require specialized equipment such as a large one-pass system or hydromill trench cutter and may not be feasible due to implementability challenges, such as the large working platform (approximately 30 feet) required to operate such equipment and property boundaries. Currently the crest of the AP-3 embankment is approximately 12 to 15 feet wide, and the distance from the toe of the western embankment to the adjacent property boundary is less than 20 feet. One-pass and hydromill trenching systems would not be able to access the western portion of AP-3 without modification to the embankment or access to the neighboring property for construction of the working platform. Therefore, the slurry wall option presents significant implementability concerns.

4.4.3 Groundwater Extraction Systems

Conventional groundwater extraction systems generally involve installing an array of vertical extraction wells designed to pump groundwater to the surface, treating the water if needed, and discharging it to surface water or reinjecting it into the subsurface. This is an active approach used to remove, divert, or contain groundwater. These extraction systems would be intended to reduce groundwater flux through AP-3 by lowering the groundwater elevation rather than by impeding groundwater flow.

An alternative to conventional vertical extraction wells is to install an interceptor trench rather than an array of wells, in order to capture a continuous linear cross-section of the groundwater flow. As the groundwater flows into the trench, elevation-controlled pumps or sumps allow for the extraction of the groundwater from the trench, thereby resulting in a locally lower groundwater elevation. Extracted water is then treated (if needed) and conveyed to a permitted discharge. While this method may also result in fluctuations in groundwater levels, these fluctuations are likely to be less extreme and localized as compared to those expected from vertical extraction wells.

A second alternative to conventional vertical extraction wells is the use of a *TreeWell* system, which is a patented engineered system that uses the aggressive rooting ability of selected trees and other vegetation to capture and remove groundwater from the subsurface. The *TreeWell* system utilizes a specialized lined planting unit constructed with optimum planting media designed to promote downward root growth and focus groundwater extraction from a targeted depth interval. This type of system mirrors a conventional vertical mechanical extraction system using the trees as pumps, providing hydraulic control (Goldemund and Gestler, 2019). While this method may also result in slight fluctuations in groundwater levels due to the growing season of the trees, these fluctuations are very limited compared to those expected from conventional vertical extraction wells or interceptor trenches. There is also the added benefit of minimal long-term operation and maintenance of the system once the trees are established and the canopy develops, while providing longer-term hydraulic control without the need for above-ground water treatment.

4.4.3.1 Interceptor Trench

The alignment of a potential upgradient interceptor trench is shown on **Figure 4-3**. For modeling purposes, the trench was extended at least five feet into the highly fractured bedrock (between 50 and 65 feet below ground surface) over the entire length of the alignment. For modeling purposes, the drain elevation for the trench was set at 565 feet mean sea level and an estimated pumping rate of 13 gallons per minute (gpm), or approximately 20,000 gallons per day (gpd), would be required at steady state to maintain the effectiveness of the trench. The resulting steady state conditions using this AEM in conjunction with the combined effects of the AP-3 and AP-1 closures indicated an approximate maximum potentiometric surface height above the bottom of the unit of 1.3 feet and an approximate total volume of CCR below the potentiometric surface of 780 CY. This represented a 99% reduction in the total volume of CCR below the potentiometric surface and a 99.9% reduction in groundwater flux compared to the pre-closure conditions. The particle tracking scenarios estimated a travel time of over 100 years for a particle of water originating at the highest point of the CCR below the potentiometric surface to exit the permit boundary of AP-3.

4.4.3.2 TreeWell Systems

The location of a potential *TreeWell* field (conceptually designed and modeled as 107 *TreeWell* units) to the east of AP-3 is shown on **Figure 4-4**. For modeling purposes, the *TreeWell* units are installed in the highly fractured limestone unit and are estimated to "pump" at approximately 40 gpd per tree, or an approximate 4,300 gpd for the entire field. This water is drawn into the vascular system of the tree and then subject to evapotranspiration. Therefore, no effluent is generated, avoiding potential long-term discharge management and associated permitting. The resulting steady state conditions using this AEM in conjunction with the combined effects of the AP-3 and AP-1 closures indicated an approximate maximum potentiometric surface height above the bottom of the unit of 3.7 feet and an approximate total volume of CCR below the potentiometric surface of 8,140 CY. This represented a 92% reduction in the total volume of CCR below the potentiometric surface and a 97.8% reduction in groundwater flux compared to the pre-closure conditions. The particle tracking scenarios estimated a travel time of over 100 years for a particle of water originating at the highest point of the CCR below the potentiometric surface to exit the permit boundary of AP-3. The modeling results presented herein do not capture additional beneficial effects on groundwater quality, reductions of the potentiometric surface, or groundwater flux expected in the vicinity of the *TreeWell* field outside of the AP-3 permit boundary.

4.4.3.3 Groundwater Extraction System Implementability Considerations

Predictive model scenarios evaluated in this report indicate that the upgradient trench drain concept would need to be installed five feet into the highly weathered rock to effectively reduce the upgradient groundwater flow coming into AP-3 and thereby reduce the volume of CCR below the potentiometric surface. Like the slurry wall concept, a trench installed to this depth and into the weathered bedrock would require specialized trenching equipment that may not be feasible due to implementability challenges, the large working platform (approximately 30 feet) required to operate such equipment and property boundaries. Currently the crest of the AP-3 embankment is approximately 12 to 15 feet wide, and the distance from the toe of the western embankment to the adjacent property boundary is less than 20 feet. One-pass and hydromill trenching systems would not be able to access the western portion of AP-3 without modification to the embankment or access to the neighboring property for construction of the working platform.

Long-term pumping and management of groundwater from the trench would be required in perpetuity in order for the trench option to remain effective. The cycling of the pumps needed to actively dewater the trench would result in fluctuations in groundwater levels in the vicinity of the trench. These effects would likely be dispersed over the entire length of the trench, have less steep localized gradients, and would not cycle as frequently as in the case of conventional vertical extraction wells discussed in Section 4.2. This does not, however, preclude the increased risk of potential adverse effects on soil stability due to karst conditions in the bedrock.

The field of *TreeWell* units that would be considered is located along the downgradient side (east) of AP-3 and would be intended to locally lower the water table and create an inward hydraulic gradient toward the *TreeWell* field. This would also slightly reduce the volume of CCR below the potentiometric surface in the unit. This location is outside of the AP-3 footprint and therefore would not require disturbance of the AP-3 cover system or existing dike construction. Subsurface conditions (soil and groundwater geochemistry) at AP-3 are not expected to pose any significant issues for the trees to thrive. Possible concerns regarding constructability include the technical challenges of drill rig access in the floodplain of Cabin Creek for the purpose of installing the 4-foot diameter boreholes to the target zone within highly weathered bedrock; however, this may be addressed with minor surface improvements and grading.

Initially, the trees will require three to four growing seasons for full canopy closure to achieve optimal groundwater extraction rates, but some positive effects on groundwater levels are expected to occur after about two growing seasons. During the initial establishment period, more frequent site inspections (i.e., semi-annually) would be appropriate to monitor plant vigor and identify any potential issues (such as an insect infestation) that may require active intervention. Following the initial establishment period (3 to 4 years), only minor operation and maintenance activities such as pruning of the trees, occasional fertilization, and mowing of undergrowth may be needed.

5. COMPARISON OF OPTIONS

5.1 Overview

Based on the CSM, the uppermost portion of the highly fractured and weathered limestone is the predominant groundwater flow zone within the uppermost aquifer at AP-3. The terrace alluvium may act as a localized flow zone, but this unit is not laterally extensive across the AP-3 area. Controlling groundwater flux through AP-3 requires mitigation of the flow in the highly fractured limestone unit, and potentially in the coarse facies of the terrace alluvium (if present).

Georgia Power has closed AP-3 in-place, including the installation of a low permeability cover system, and has opted to close AP-1 by removal of the ponded water and CCR. As discussed in Section 4.1.1 the closure and capping of AP-3 alone has a positive effect on the groundwater conditions. When combined with the closure and surface water improvements at AP-1 the volume of CCR below the potentiometric surface is reduced by 91% and groundwater flux by 97.7% relative to the pre-closure conditions. The combined closure of AP-3 and AP-1 also resulted in a modeled travel time of 100 years or more for a water particle to reach the permit boundary of AP-3, a significant improvement over pre-closure conditions, which is estimated to have been on the order of 20 years.

Thus, the in-place closure of AP-3 and the surface water improvements associated with closure of AP-1 provide a substantial improvement to the groundwater elevation and flux at AP-3. As compared to pre-closure conditions or closure of AP-3 alone, a high degree of enhanced groundwater protection is modeled to be achieved without the use of an AEM. However, Georgia Power may consider employing an AEM to provide further reductions of (i) the volume of CCR below the potentiometric surface within AP-3 and (ii) groundwater flux through AP-3. To facilitate Georgia Power's AEM decision making for AP-3, this section presents a comparative discussion of the evaluated AEM options based on effectiveness and implementability considerations.

5.2 Relative Comparison of AEMs

Based on the modeled scenarios presented in **Appendix B**, some additional reduction of groundwater elevations and flux in AP-3 could be achieved by each of the AEM options (slurry wall, *TreeWells*, and interceptor trench). Below, each of these three AEM options is compared to the combined closure of AP-3 and AP-1 and each other in terms of effectiveness and implementability.

5.2.1 Slurry Walls

While the half slurry wall AEM could reduce the volume of CCR below the potentiometric surface (modeled to be an additional 3%) the full slurry wall is modeled to increase the volume of CCR below the potentiometric surface (modeled to be a reduction of 8%). Both slurry wall measures (half and full) were predicted to further reduce groundwater flux (i.e., 1% or less) and inhibit water particle travel (i.e., similar to the combined closure of AP-3 and AP-1 – 100 years or more).

Implementability considerations for this measure include:

- Target depths of 50 to 75 feet below ground surface and cutting into competent bedrock to key the slurry wall into a low permeability layer would require hydromill technology. The minimum working platform requirements for construction is larger than the available space at the toe or along the crest of the embankment. Property boundary easements and significant modifications to AP-3 embankments would be required.

- Groundwater mounding may occur on the upgradient (west) side of the AP-3 embankment, potentially bringing groundwater levels close to the ground surface. This condition may create saturated shallow soils, drainage problems, and potential flooding of the upgradient areas, especially after significant storm events.

5.2.2 Interceptor Trench

The upgradient interceptor trench drain option could reduce the volume of CCR below the potentiometric surface (modeled to be an additional 8%). Also, it is modeled to reduce groundwater flux (i.e., approximately 2.1%) and water particle travel (i.e., similar to the combined closure of AP-3 and AP-1 – 100 years or more).

Implementability considerations for this measure include:

- Target depths of 50 to 65 feet below ground surface and cutting into the weathered and fractured bedrock would require large one-pass trenching or hydromill technologies, and minimum working platform is larger than the available space at the toe or along the crest of the embankment. Property boundary easements and significant modifications to AP-3 embankments would be required.

- Requires long term management of intercepted and pumped groundwater, as well as long-term maintenance of pumping equipment.

- Fluctuations in groundwater levels due to cycling of pumps and occasional maintenance may have unfavorable effects on erosion of soils into the solution-enhanced fracture system beneath the AP-3.

5.2.3 TreeWells

The *TreeWell* field installed downgradient of AP-3 was modeled to reduce the volume of CCR below the potentiometric surface (i.e., approximately 1%) and groundwater flux from the CCR (i.e., approximately 0.1%) relative to the combined closure of AP-3 and AP-1. Like the combine closure of AP-3 and AP-1, the *TreeWell* field was also modeled to achieve water particle travel time of 100 years or more. Further, the modeled results presented herein do not capture additional beneficial effects on groundwater quality, reductions of the potentiometric surface, or groundwater flux expected in the vicinity of the *TreeWell* field outside of the AP-3 permit boundary. Additionally, the *TreeWells* would require minimal long-term maintenance, offer the beneficial long-term hydraulic control without the need for above-ground water treatment, and would not impact the cover system or dikes of the AP-3 embankment.

Implementability considerations for this measure include:

- Drilling equipment and cutting heads needed to advance 4-foot diameter boreholes to target depths in the highly fractured limestone. The Cabin Creek floodplain presents some challenges for equipment access.

- Effectiveness relies on the established vegetation of the trees and may take multiple growing seasons (3 to 4 years) to achieve.

- Minor fluctuation in groundwater levels are expected due to seasonal growth cycles of the trees.

5.3 Conclusions

Based on the evaluations presented in this report, the in-place closure of AP-3 along with the effects of removal of AP-1, provides significant reductions in the volume of CCR below the potentiometric surface, groundwater flux through the unit, and water particle travel time for AP-3. This combination is expected to enhance the overall groundwater quality in the vicinity of AP-3. The three AEM options advanced for this comparative analysis are each predicted to offer some additional improvements in comparison to the combined closure of AP-3 and AP-1, as noted above, and would enhance the protection of groundwater and closure effectiveness for AP-3.

While each of the AEM options are predicted to offer some benefit to groundwater quality, implementation challenges differentiate the AEM options evaluated. The slurry wall and interceptor trench options present significant implementation challenges. Access is very limited along the western and northern portion of AP-3 and therefore, the slurry wall and interceptor trench AEMs would require property boundary easements and significant modifications to the AP-3 embankments. Potential adverse impacts may result from the slurry wall and trench AEMs including mounding of groundwater (slurry wall) and groundwater fluctuation and increased risk of karst-related soil loss (interceptor trench), and long-term operation and maintenance for water removal to ensure the effectiveness of these two options.

In comparison, the implementation considerations of the *TreeWell* option are manageable, and the primary concerns discussed in section 5.2.3 are not likely to pose critical challenges for the project. Access and drilling concerns can be addressed with surface improvements such as clearing and grading of the area. Tree survival/mortality is a common factor in any plant-based system, but as previously mentioned, conditions are not expected to adversely affect the trees, and this can be evaluated by compatibility studies prior to planting. The fluctuations in groundwater due to seasonal patterns (summer growth, winter dormancy) are expected to be small, evenly distributed, and relatively insignificant.

While the implementation challenges and potential impacts do not necessarily preclude any of the AEM options, the magnitude of those challenges and impacts for purposes of AEM evaluation may be considered relative to the effect that will otherwise be achieved by the combined closure of AP-3 and AP-1. Additionally, groundwater quality at AP-3 is currently not impacted above MCLs or RSLs by CCR-related constituents. The potential for such impacts in the future will be further reduced significantly by the current closure of AP-3 and Georgia Power's decision to close AP-1 by removal. Groundwater quality at AP-3 is and will continue to be monitored in accordance with federal and state requirements, and will be addressed, as necessary, through the regulatory assessment of corrective measures (ACM) process.

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TABLE

Table 4-1
Summary of Focused AEM Evaluation
Plant Hammond, Floyd County, Georgia

Scenario No.	AP-3 Conditions	AP-1 Pool Elevation	Enhancement	Description of Enhancement	Effectiveness					Implementability Considerations	
					Maximum Height of Potentiometric Surface Above Bottom of Unit (ft)	Volume of CCR Below Potentiometric Surface (CY)	% Reduction in Volume of CCR Below the Potentiometric Surface	% Reduction in Groundwater Flux	Time for Particles to Cross AP-3 Permit Boundary (years)	Constructability	Potential Impacts
0	Partial Cover Installed	Historical Elevation	-	-	9.6	101,585	-	-	20	-	-
AP-3 Closure Conditions											
1a	Cover installed	Historical Elevation	AP-3 Closure	Engineered cover at AP-3 Stormwater diverted away from AP-3	6.5	36,438	64%	92.2%	52	(i) cover system is already installed at AP-3	-
1b	Cover installed	Removed	AP-1 Closure	Engineered cover at AP-3 Stormwater diverted away from AP-3 Eliminates hydraulic influence of historical AP-1 pool	3.7	8,657	91%	97.7%	>100	(i) cover system is already installed at AP-3 (ii) free water will be removed from AP-1 during closure by removal of that unit	-
AEM Scenarios											
2	Cover installed	Removed	Half Slurry Wall	Slurry wall installed on the upgradient side of AP-3 Wall extends 50-75 ft bgs, keyed into the bedrock	3.1	6,361	94%	98.6%	>100	(i) specialized equipment is required for depths exceeding 40 feet. (ii) large surface areas are required during installation for excavated soil storage, slurry mixing, material storage, etc. (iii) special equipment needed for cutting into bedrock	(i) The full slurry wall option may inhibit groundwater flow out of the unit and limit the intended reduction of water levels; hydraulic control wells may be required (ii) the half slurry wall may potentially create unintended mounding of groundwater on the upgradient side of AP-3
3	Cover installed	Removed	Full Slurry Wall	Fully encompassing slurry wall around entire AP-3 area Wall extends 50-75 ft bgs, keyed into bedrock	4.3	16,807	83%	98.7%	>100		
4	Cover installed	Removed	Interceptor Trench	Trench at upgradient side of AP-3. Drain Installed to Bottom of Highly Fractured Zone (5 feet below residuum) Layer. Drain Collection Set at El. 565 ft	1.3	778	99%	99.9%	>100	(i) high operation and maintenance costs associated with possible treatment of groundwater. (ii) specialized equipment needed to cut the trench into the fractured bedrock	(i) fluctuations in groundwater levels due to cycling of pumps and occasional maintenance may have unfavorable effects on erosion of soils into the solution-enhanced fracture system
5	Cover installed	Removed	TreeWells®	107 *TreeWells* Screened in HFR/Fractured Limestone and "Pumping" at 40 GPD/tree (collectively 3 gpm for the entire field)	3.7	8,143	92%	97.8%	>100	(i) access for drilling equipment in the floodplain area (ii) establishing the trees/vegetation can take some time (3-4 years); favorable growing conditions needed	-

Notes:
1. These values were obtained from groundwater flow modeling results. It is noted that groundwater flow models are necessarily simplified mathematical representations of complex natural systems. Because of this, all groundwater models have limits to their accuracy.
2. These model results were intended for use as relative comparisons between scenarios, and not as precise predictions of post-closure conditions.
3. Particle tracking represents a theoretical particle of water traveling by advection only, and does not account for geochemistry, retardation, or diffusion.
4. Flux estimates were calculated in the model by the volume of water passing through the bottom of model cells in the CCR layer.

FIGURES

Cabin Creek

Notes:
1. Aerial Photograph approximate date - February 2018
Source: Google Earth.

Plant Hammond Site Map

Georgia Power Company
Plant Hammond AP-3
Rome, Floyd County, Georgia

Geosyntec consultants

Kennesaw, GA | May 2020

Figure 1-1

N:\GA Power\Plant Hammond GW Mon-Rpt Proposal\Siting and Hydrogeo Reports\AP-3\Combined Siting and HydroGeo\GIS\mxd\Figure1-1_SiteMap.mxd 11/9/2018 11:15:42 AM

Aerial Photograph approximate date - August 2019 Source: Google Earth.

AP-3 Site Map

Georgia Power Company
Plant Hammond AP-3
Rome, Floyd County, Georgia

Geosyntec consultants

Kennesaw, GA | April 2020

Figure 1-2

N:\GA Power\Plant Hammond AP3\AEM Evaluation Report\03_Figures\MXD\Figure 1-1 AP-3 Plant Hammond Site Map.mxd 4/13/2020 4:54:34 PM

Aerial Photograph approximate date - August 2019 Source: Google Earth.

Upgradient (Half) Slurry Wall Layout

Georgia Power Company
Plant Hammond AP-3
Rome, Floyd County, Georgia

Geosyntec consultants

Kennesaw, GA | April 2020

Figure 4-1

N:\GA Power\Plant Hammond AP3\AEM Evaluation Report\03_Figures\MXD\Figure 4-1 AP-3 Upgradient (Half) Slurry Wall Layout.mxd 4/13/2020 4:55:32 PM

Full Slurry Wall

N

0 150 300 600 Feet

Aerial Photograph approximate date - August 2019 Source: Google Earth.

Full Slurry Wall Layout

Georgia Power Company
Plant Hammond AP-3
Rome, Floyd County, Georgia

Geosyntec consultants

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Figure 4-2

N:\GA Power\Plant Hammond AP3\AEM Evaluation Report\03_Figures\MXD\Figure 4-2 AP-3 Full Slurry Wall Layout.mxd 4/13/2020 4:56:40 PM

Interceptor Trench

N

0 150 300 600 Feet

Aerial Photograph approximate date - August 2019 Source: Google Earth.

Upgradient Interceptor Trench Layout

Georgia Power Company
Plant Hammond AP-3
Rome, Floyd County, Georgia

Geosyntec consultants

Kennesaw, GA | April 2020

Figure 4-3

N:\GA Power\Plant Hammond AP3\AEM Evaluation Report\03_Figures\MXD\Figure 4-3 AP-3 Upgradient Interceptor Trench Layout 4.13.20.mxd 4/13/2020 4:57:44 PM

Tree Wells

N

0 150 300 600
Feet

Aerial Photograph approximate date - August 2019 Source: Google Earth.

Tree Wells Layout

Georgia Power Company
Plant Hammond AP-3
Rome, Floyd County, Georgia

Geosyntec consultants

Kennesaw, GA | April 2020

Figure 4-4

N:\GA Power\Plant Hammond AP3\AEM Evaluation Report\03_Figures\MXD\Figure 3-4 AP-3 Tree Wells Layout.mxd 4/13/2020 4:44:23 PM

APPENDIX A

Groundwater Model Calculation Package

Prepared for

Southern Company
241 Ralph McGill Blvd NE
Atlanta, Georgia 30308

GROUNDWATER MODEL CALCULATION PACKAGE PLANT HAMMOND AP-3

GEORGIA POWER COMPANY
Floyd County, Georgia

Submitted by

Geosyntec consultants

engineers | scientists | innovators

1255 Roberts Boulevard, Suite 200
Kennesaw, Georgia 30144

Project Number: GR6242
November 2019

Geosyntec consultants

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

3D	three dimensional
AP	ash pond
cm/s	centimeters per second
EVS	Environmental Visualization System
ft	feet
$ft^2/d/ft$	square feet per day per foot
Geosyntec	Geosyntec Consultants
GPC	Georgia Power Company
HAR	Hydrogeologic Assessment Report
NAVD88	North American Vertical Datum of 1988
NRMSE	normalized root mean square error
PEST	Parameter Estimation Software
REV	Representative Elementary Volume
SCS	Southern Company Services
USGS	United States Geologic Survey

1.0 INTRODUCTION

This *Groundwater Model Calculation Package* (Report) was prepared to document the construction and calibration of the finalized three-dimensional (3D), steady-state, groundwater numerical flow model used to evaluate the groundwater flow conditions in the vicinity of Ash Pond 3 (AP-3 or Site) at the Georgia Power Company (GPC) owned and operated Plant Hammond (the Plant) near Rome, GA. This Report documents the findings and conclusions of the calibrated groundwater flow model, which was used to simulate existing condition and capping of AP-3 with dewatering of AP-1 and evaluate the impacts of pond closure on the groundwater flow system at the Plant. The Report has been prepared by Geosyntec Consultants, Inc. (Geosyntec) on behalf of Southern Company Services (SCS).

1.1 Model Objectives

The objectives of the numerical groundwater flow modeling were three-fold:

- Construct a steady-state groundwater model of the Site that is calibrated to representative groundwater conditions recorded in the field;
- Simulate groundwater conditions within AP-3 under the current closure scenario using the calibrated model;
- Using the simulated results to evaluate the post-closure groundwater conditions.

2.0 MODEL CONSTRUCTION

2.1 Model Design

Based on the geologic information described in Section 3.0 of the *Hydrogeologic Assessment Report (Revision 01) – Ash Pond 3 (AP-3)* (HAR Rev. 01), the numerical groundwater flow model is conceptualized as being a single aquifer system, composed of five geologic layers (i.e. fill, terrace alluvium material, residuum, highly weathered rock, and unweathered limestone). The geological layers were further vertically discretized to better evaluate flow in the model domain **(Table 1)**. Generally, the geological layers, in addition to ash, were assigned to the numerical model layers as follows:

- Fill: Layer 1 and 2
- Ash: Layer 1 and 2
- Terrace Alluvium Material: Layer 3
- Residuum: Layer 4
- Highly weathered Rock: Layer 5
- Highly Fractured Rock (i.e. top 5 feet of Limestone): Layer 6
- Unweathered Limestone: Layers 7-9

Based on information provided in boring logs and a microgravity survey, the hydraulic properties of the geologic materials within the terrace alluvium material, highly weathered rock, and highly fractured rock were altered to more appropriately represent the materials (e.g., gravel or fractures that may indicate a greater than average hydraulic conductivity value than suggested by the geometric mean of measured values) found in these zones. These zones are shown in **Figures 1** through **9** and the justification for each zonation is provided in **Table 1**.

The bottoms of AP-1 and AP-3 were determined using historical as-built drawings published to GPC's webpage. Data from these sources were imported into the 3D visualization software Environmental Visualization System (EVS) and used to create the bottom of ash for AP-1 and AP-3.

The modular, 3D, finite difference groundwater flow model (MODFLOW), created by the United States Geological Survey (USGS), was used as the modeling program to simulate groundwater flow. Specifically, a Newton formulation of MODFLOW, MODFLOW-NWT (Niswonger, et al., 2011) was utilized because of its capabilities in solving non-linear equations associated with unconfined aquifers and non-linear boundary conditions, conditions relevant to the Site. The constant head package and the drain package (Niswonger, 2011) were used to simulate rivers/creeks and ephemeral steams, respectively. The recharge package (Niswonger, et al., 2011) was used to simulate recharge. Parameter estimation software (PEST) is a model independent parameter estimation program (Watermark Numerical Computing, 1994) that was used during the calibration process to assist in estimating model parameters such as hydraulic conductivity.

For the purposes of the MODFLOW groundwater flow model, the aquifer is assumed to act as an equivalent porous medium. However, a portion of the model domain is comprised of fractured rock. One rationale for this assumption is based on observed historical water levels and associated potentiometric surface maps that indicate a relatively smooth potentiometric surface without angular or sharp changes in the groundwater table.

Geophysical borehole logs were reviewed to evaluate the average open fracture spacing (**Table 3**). The evaluation indicated that in the borings where geophysics data were available that the average open fracture spacing varied from 0.25 to 0.65 fractures per foot with an average of 0.45 fractures per foot. These fracture spacings were used to calculate a representative elementary volume (REV). A REV is the smallest volume over which a measurement can be made that will yield a value representative of a whole. Since MODFLOW assumes groundwater flow in a porous medium (not fractures), it is necessary to understand the scale of the fractured rock system where groundwater flow is the same as in a porous medium. Generally, a REV of equivalent porous media flow occurs at scales of 30 to 50 times grain size diameter on a side. This same concept has been applied to fractured rock systems and for this Site would indicate that a REV for the portion of the limestone evaluated would range from a cube with sides measuring 7.5 feet to a cube with sides measuring 32.5 feet.

2.2 Model Grid and Layering

The model domain consists of 344 rows, 344 columns, and 9 vertical layers. The model cell size varies from approximately 10 ft by 10 ft Near AP-3 and telescopes outward toward the model boundary.

Model layers represent the 5 geologic units described in the HAR Rev. 01 and **Table 1** herein. Ground surface elevations were based on a combination of actual ground surface topography from publicly-available regional LIDAR data and a Site topo map provided by SCS. Lithology and layer elevations were based on subsurface lithologic/geologic boring log descriptions from Site-specific field investigation data, and historical maps of AP-3 construction. Data from these sources were imported using EVS and interpolated to create surfaces for the top and bottom of each model layer. The top of layer 1 is land surface and the elevations are based on LIDAR elevation data provided by the USGS (USGS, 2017) and a Site topo map[1]. Elevations for the bottoms of layer 1 through 9 were based on geological boring log data from the Site. The bottom of layer 9 (bottom of bedrock) was assumed to be at an elevation of 375 ft North American Vertical Datum of 1988 (NAVD88), which varies between 160 to 190 feet below the bottom of the highly fractured rock zone. **Figure 10b** though **Figure 15** show examples of EVS model layering along the cross section lines presented on **Figure 10a.**

In general, a minimum model layer thickness of 0.1 ft was applied to areas where interpolation of artificial pinch-outs were created due to a lack of geological data control points, or where physical pinch-outs of geologic units were observed (e.g. terrace alluvium material directly beneath AP-3). This minimum thickness was enforced because MODFLOW-NWT does not allow for a zero layer thickness in the model grid. For areas where a unit pinches out, cells with a minimum thickness of 0.1 ft were assigned hydraulic conductivity zones to match the geologic unit in the layer below. For example, the terrace alluvium material pinches out underneath AP-3, resulting in small layer thicknesses in model layer 3 beneath AP-3. Those cells were therefore assigned a hydraulic conductivity equal to that of the residuum in model layer 3.

---

[1] The topographic contours and details shown inside of the Dike limits were obtained from the stamped as-built final cover survey conducted by Martin Survey and Associates, Inc. of Holly Springs, GA for Salla Construction Company, LLC of Birmingham, AL, Dated 25 October 2012, as provided by Southern Company Services in the CAD file titled “PH-Final 12-4-12.”

2.3 Model Boundaries

A conceptual level map of the boundary conditions is shown in **Figure 16** and the boundary conditions assigned to the model are shown in **Figure 16a**. The Coosa River was modeled by assigning a constant head boundary condition elevation of 561.45 ft NAVD88 to Layers 1-5. It should be noted that based on surface water elevation data collected by the USGS from 1 October 2007 until 20 May 2017 at a staff gauge located approximately eight miles east of Plant Hammond, the Coosa River stage has historically varied by 21.7 feet[2]. The depth of the Coosa River is not known adjacent to the Plant and was assumed to be approximately 17 feet deep and extend to the top of the highly-fractured limestone.

Cabin Creek is shown on the USGS topo (USGS, 1967) in **Figure 16** to be continually present and was also modeled as a constant head boundary condition. However, observations made during Site visits indicated that Cabin Creek is shallow. Furthermore, the elevation of Cabin Creek changes from approximately 570 ft to 561.45 ft NAVD88. Therefore, the constant head boundary condition that represents Cabin Creek is assigned to the uppermost active layer. For example, in one portion of the model the boundary condition would be assigned to layer 1. However, as Cabin Creek cuts down through the terrain, it reaches a point where it influences layer 2 and layer 1 is now dry. In these instances, the constant head boundary condition would be assigned to layer 2 instead of layer 1.

The USGS topo map indicates an ephemeral stream along the western portion of the model. Due to the ephemeral nature of the unnamed stream, it was assigned as a drain boundary condition. The drain elevations were derived from the Site-specific topo data and USGS topo and ranged from 590.6 ft NAVD88 near the northern edge of the model to the southern terminus of the Coosa River with a 9 February 2017 measured elevation of 561.45 ft NAVD88. The drain conductance was a calibrated value and set at 10 square feet per day per foot ($ft^2/d/ft$). Like Cabin Creek, this unnamed stream is shallow, and therefore the drain boundary condition was only assigned to the uppermost active layer.

---

2 https://nwis.waterdata.usgs.gov/usa/nwis/uv/?cb_00065=on&format=rdb&site_no=02397000&period=&begin_date=2007-10-01&end_date=2017-05-21

The USGS topo map in **Figure 16** shows that a topographic ridge is located north and west of the Site. It was assumed that this ridge functions as a no flow boundary condition as surface water runoff appears to collect in streams or water bodies on either site of the ridge.

AP-1 and AP-2 were both modeled as constant head boundary conditions. Ash was present in layers 1 and 2 in AP-1. Therefor the 9 February 2017 measured constant head boundary condition (585.09 ft NAVD88) was applied to both layers 1 and 2 in AP-1. Less information is available regarding AP-2 therefore the 9 February 2017 measured constant head boundary condition of 596.43 ft NAVD88 was applied only to the uppermost active cell. Similarly, little information is known regarding the industrial wastewater ponds to the east of Cabin Creek, which are not owned by GPC. Therefore, the surface water elevation derived from LIDAR data (588 ft NAVD88) was assigned to the uppermost active cell in these locations.

2.3.1 Model Recharge

The USGS performed a recharge study for the Coosa River basin (USGS, 1996). The study evaluated average recharge for the 4,040 square mile drainage basin that is represented by streamflow measurements made at a point on the Coosa River approximately 8 miles east of the Site. The recharge study estimated that the average recharge rate for the entire basin was 13.2 inches per year, but may be as low as 3.2 inches per year during droughts. It should be mentioned that these estimates are averages. Actual recharge will vary locally based on topography, surface water, run-off, man-made drainage features, rainfall intensity, etc. Therefore, these two recharge estimates were used as the upper and lower bounds for estimating recharge assigned to various zones within the model domain during model calibration. As shown in **Figure 17**, four recharge zones were assigned to the Site. The area south of the railroad tracks does not receive recharge as much of the area is covered with pavement or buildings and the remainder of the area is close to the Coosa River and is therefore in a discharge area. The area north of the railroad tracks was assigned a recharge value of 6.38 inches per year. This reflects the lower amount of recharge expected in the area due to runoff from relatively steep topography and the presence of man-made stormwater ditches. The area north of Cabin Creek was assigned a recharge of 13.2 inches per year as it is the headwaters area for Cabin Creek. Additionally, AP-3 was assigned a recharge rate of 3.7 inches per year in stormwater runoff is directed to an inner perimeter stormwater collection system. This recharge rate depicts baseline conditions for when the AP-3 cover system was incomplete (i.e., February 9, 2017). It should be noted that 0.57 inches of precipitation fell on nearby Rome, GA on February 8, 2017 (wunderground.com, 2017). This is one day before Geosyntec personnel were on Site collecting static groundwater and surface water measurements that were used to calibrate the model.

2.4 Hydraulic Conductivity Zones

In general, hydraulic conductivity zonation was based on a specific geologic material, which represented a layer in the model. The range, geometric mean and model calibrated hydraulic conductivity values for each geologic material are presented in **Table 1**. If available, well-specific hydraulic conductivity values were incorporated into the model (**Table 4**). However, model calibration was not possible using a single hydraulic conductivity for each geologic material as this produced unacceptable residuals in the residuum, highly weathered rock, and highly fractured rock. Therefore, the boring logs of monitoring wells with relatively high residuals were evaluated for the presence of material within the well screen that may be hydraulically different than that of the main geologic unit. Additionally, a microgravity survey was evaluated for the presence of bedrock zones that may contain open fractures/ solution voids (low density materials) or lower hydraulic conductivity zones (high density materials). Finally, where available, the measured hydraulic conductivity in wells with relatively high residuals were evaluated for differences from the value used in the model for the geologic unit. **Figures 1 through 9** show the hydraulic conductivity zones used in layers 1 through 9. A table of hydraulic conductivity zones is shown in **Table 1**.

2.5 Model Calibration

The model was calibrated to groundwater elevation targets based on measurements at monitoring wells and surface water locations made by Geosyntec on February 9, 2017. These measurements, well screen elevations, calibrated modeled values for each well are shown on **Table 5**. Wells were assigned to model layers based on their screen elevations. The groundwater flow model was calibrated to the actual on-site groundwater conditions by setting drain conductance to 10 ft^2/d/ft and then modifying recharge and hydraulic conductivity using PEST version 13.6 (Watermark, 1994) to allow the named parameters to vary within measured ranges until the best statistical fit between measured and observed head elevations was obtained. Following the use of PEST, zones within select geologic materials were adjusted according to available data as described in Section 2.4 to obtain a satisfactory fit. The model was considered calibrated once simulated output closely approximated observed field conditions (e.g. inferred groundwater flow directions, groundwater gradients, groundwater elevations at monitoring wells observed on Site), and when calibration statistics indicated a low residual mean error and a normalized root mean square error (NRMSE) less than 10%. NRMSE is used to measure the difference between observed groundwater values and model predicted values. The smaller the difference between observed and predicted values, the smaller the NRMSE percentage. Typically, groundwater models are considered calibrated when NRMSE is less than 10%.

Simulated groundwater elevation contours of the calibrated model are shown in **Figure 18** for the highly fractured rock zone and **Figure 19** for the terrace alluvium material. These zones were selected because most of the wells near AP-3 are screened in the highly weathered zone/highly fractured zone and most of the wells near AP-1 are screened at least partially in the terrace alluvium material. Simulated contours and flow directions generally matched historical potentiometric contour and flow direction maps generated from measured groundwater elevations. The simulated and the observed groundwater elevations were compared at the 36 monitoring well targets incorporated into the model by calculating the residual (observed groundwater elevation minus simulated groundwater elevation) for each well target (**Table 5**). The minimum residual head value was -3.81 ft and the maximum residual head value was 3.20 ft, over a range in observed head values of 20.76 ft. Comparison statistics for the well targets in **Table 5** show a residual mean error (ME) of -0.15 ft and a NRMSE of 9.9%); the proximity of these statistics to zero indicates a good match between observed and simulated heads and that the model is reasonably calibrated. The computed mass water balance error for the model was also small (-2.0 E-04%). **Figure 20** plots observed versus simulated head values for the 36 targets, and shows a good match between observed and simulated heads based on proximity of the results to the 1:1 correlation line. **Figure 21** shows observed head versus model residuals and shows that there is no strong bias to the residuals. Combined with the comparison statistics and negligible mass balance error, **Figure 20** and **Figure 21** support the conclusion that the flow model is a reasonable representation of actual Site conditions. Overall, simulated head contours, flow directions, calibration statistic, and model residuals indicates that the model is reasonably calibrated.

3.0 PREDICTIVE SIMULATIONS

After calibration, the groundwater model was used to evaluate the predictive scenario for pre-closure conditions (i.e., calibration run) and final closure design at steady state.

3.1 Scenario 1: Baseline Condition (Base Case, Pre-Closure)

This scenario is the calibrated model representing the conditions present at the Site before completion of the cover system, i.e. the "existing condition" at the time of model construction (i.e., February 9, 2017). **Figure 22** shows the baseline groundwater elevation contours generated from the model simulation.

3.2 Scenario 2: Install Cover at AP-3; AP-1 at Baseline Pool Level (Post-Closure)

Scenario 2 represents the conditions at the Site following completion of the cover system at AP-3 but prior to the dewatering and closure of AP-1. Under this scenario, recharge over AP-3 was reduced to zero and the constant head boundary condition at AP-1 was set at 585.09 ft to represent the pool water level measured February 9, 2017. **Figure 23** shows model predicted groundwater elevation contour map.

3.3 Scenario 3: Install Cover at AP-3 and Drain AP-1 (Post-Closure)

Scenario 3 represents the conditions at the Site following completion of the cover system at AP-3 and the anticipated closure of AP-1. Under this scenario, recharge over AP-3 was reduced to zero and the constant head boundary condition at AP-1 is removed to represent the removal of free water and closure of that unit. **Figure 24** shows model predicted groundwater elevation contour map.

Groundwater flow models are necessarily simplified mathematical representations of complex natural systems. Therefore, all groundwater models have limits to their accuracy and associated uncertainties in model predictions. The goal of this model was not to define precise predictive scenarios, but to provide relative groundwater elevation and flow information. The supporting calibration statistics and representative flow simulations provide an acceptable degree of confidence that the model is calibrated and suitable for its intended purpose.

4.0 SENSITIVITY ANALYSIS

A sensitivity analysis was performed to evaluate the effect that decreased horizontal and vertical hydraulic conductivity of the residuum would have on the calibration of the model. This parameter was chosen as the residuum is present beneath the ash in AP-3 and the hydraulic conductivity of the residuum plays a role in the feasibility of closure options. For the sensitivity analysis, the horizontal hydraulic conductivity of the residuum was reduced from 2.20 x 10^{-4} centimeters per second (cm/s) to 2.20 x 10^{-5} cm/s and the vertical hydraulic conductivity was reduced from 9.15 x 10^{-5} cm/s to 1.46 x 10^{-6} cm/s. The residuals between the calibrated head values and the sensitivity head values are shown in **Table 6**. The relatively small residuals (average residual is -0.06 ft and absolute average residual is 0.12 ft) between the simulations indicates that the model is not very sensitive to the hydraulic conductivity of the residuum. The implies that the potential for natural fluctuation of hydraulic conductivity within the residuum will not negatively impact the constructed model's ability to accurately predict scenarios.

5.0 CONCLUSIONS

A three-dimensional steady state groundwater flow model was constructed to simulate various scenarios at the Site. Once calibrated, the model was used to simulate the groundwater flow conditions that would result from constructing a cap at AP-3 and draining AP-1 (Scenario 3). Under this scenario, the model predicts approximately a four-foot reduction in the groundwater elevation across the Site relative to the modeled pre-closure baseline conditions (Scenario 1).

6.0 REFERENCES

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TABLES

Table 1. Geologic Zones and Hydraulic Conductivity Values

Geologic Unit	Assigned Groundwater Model Layer	Data Source	Horizontal Hydraulic Conductivity, K_h (cm/s)				Vertical Hydraulic Conductivity, K_v (cm/s)			
			Geometric Mean	Model	Range of Values	Number of Observations	Geometric Mean	Model	Range of Values	Number of Observations
Residuum	**4**	Law Engineering (1977), Southern Company (2014) - K_h Golder (2016) & Geosyntec (2017) - K_v	2.01E-04	2.20E-04	6.10E-07 to 2.35E-02	13	2.91E-07	9.15E-05	1.00E-07 to 1.40E-06	6
Fill	**1, 2**	Law Engineering (1977) - K_h Golder (2016) & Geosyntec (2017) - K_v	3.33E-06	1.02E-05	7.62E-07 1.02E-05	8	4.12E-08	1.5E-07 at berm; 1.85E-06 elsewhere	1.50E-08 to 1.50E-07	4
Terrace Material	**3**	Law Engineering (1977) - K_h Golder (2016) & Geosyntec (2017) - K_v	1.21E-04	1.11E-03	4.27E-05 to 3.76E-04	4	9.47E-08	2.14E-04	6.40E-08 to 1.40E-07	2
Rock (+ some residuum)	**5, 6**	Law Engineering (1977) - K_h	3.38E-04	3.38E-03	5.08E-05 to 2.13E-03	3	-	3.38E-04	-	-
Limestone	**7, 8, 9**	Geosyntec (2017) - K_h	4.99E-04	3.53E-04	6.22E-05 to 2.82E-03	7	-	3.53E-05	-	-

Notes:
1) The samples tested for vertical hydraulic conductivity of the terrace material contained more clay than average and likely underestimate the vertical hydraulic conductivity.
2) The following additional hydraulic conductivity zones are shown on Figures 1 through 9. The hydraulic conductivities (cm/s) and rationale for changing the hydraulic conductivity are shown below:

Low Density Limestone Kh=1.76E-02 Kv=1.76E-03 Calibrated based on assumed increased fracture density from microgravity survey
High Density Limestone Kh=3.53E-05 Kv=3.53E-06 Calibrated based on assumed decreased fracture density from microgravity survey
High K Terrace Material Kh=5.00E-02 Kv=5.00E-03 Calibrated based on relatively high K values measured at AP1-MW6 and AP1-MW7, sand lense in APC1-5S, and sandy gravel in AP1-C4.
Low K residuum Kh=8.82E-0 6Kv=8.82E-07 Used lower range of K for residuum based on presence of only clay in this boring.
East of AP1 Low K Residuum Kh=3.38E-05 Kv=3.38E-06 Used lower range of K for residuum based on presence of only clay in this boring.
East of AP1 High K Residuum Kh=7.06E-03 Kv=7.06E-04 Calibrated based on presence of sandy gravel in well screen of AP1C-1
SW of AP1 Sand Kh=5.00E-02 Kv=5.00E-03 Calibrated based on sand seam in residuum at AP1C-6
SW of AP3 Highly Weathered Limestone Kh=8.42E-02 Kv= 8.42E-03 Calibrated based on partially weathered rock (shale gravel) AP3-MW21 and AP1-MW-1
SW of AP3 High K Highly Fractured Zone Kh=2.68E-02 Kv=2.68E-03 Calibrated based on partially weathered rock (shale gravel) AP3-MW21 and AP1-MW-1
water Kh=3.53E+00 Kv=3.53E+00 High K used to simulate water in Coosa River and Cabin Creek.

Table 2. Groundwater Elevations Near AP3-B-11 - February 9, 2017

Monitoring Well Name	Easting (ft)	Northing (ft)	Distance from AP3-B-11	Groundwater Elevation 2/9/17 (ft)	Reduction in Groundwater Elevation from AP3-B-11 (ft)
AP3-B-4	1942920.34	1550709.19	320	567.14	16.98
AP3-B-5	1942521.24	1550275.29	295	570.48	13.64
AP3-B-9	1942654.24	1550662.39	120	567.00	17.12
AP3-B-10	1942345.89	1550500.71	300	568.89	15.23
AP3-B-11	1942643.26	1550545.31	0	584.12	0.00

Notes:
1) Elevations are referenced to NAVD88
2) Northing and Easting reference the Georgia State Plane West (NAD83)

Table 3. Fracture Spacing Evaluation

Borehole Name	Length of Borehole Geophysics Data (ft)	Total Number of Open Fractures	Total Open Space (ft)	Fractures per Foot	Open Space per length (ft/ft)
AP3-B-2	59	32	2.85	0.54	0.048
AP3-B-3	44.5	11	1.03	0.25	0.023
AP3-B-4	3.1	2	0.50	0.65	0.161
AP3-B-9	2.75	1	0.65	0.36	0.236

Table 4. Well-Specific Measured Hydraulic Conductivity Values

Monitoring Well Name	Easting (ft)	Northing (ft)	Well Screen Midpoint Elevation (ft)	Model Layer	Measured Horizontal Hydraulic Conductivity (cm/s)		Measured Vertical Hydraulic Conductivity (cm/s)	
AP1-MW-1	1941590.75	1549936.41	563.10	6	2.68E-03	e	-	
AP1-MW-5	1942445.49	1548430.84	555.60	6	1.84E-03	e	-	
AP1-MW-6	1941686.57	1548381.22	554.30	6	1.14E-02	e	-	
AP1-MW-7	1941084.33	1548230.08	556.50	4	2.35E-02	e	-	
APA-4 (HGWA-4MW-19)	1939386.06	1549932.71	567.90	3	9.74E-04	e	-	
APA-2 (HGWA-1MW-20)	1940773.28	1550423.59	568.40	7	1.41E-03	e	-	
AP3-MW-21	1941812.40	1550265.01	565.50	5	8.42E-03	e	-	
HGWA-122 (AP3-MW-22)	1941892.64	1551247.62	565.70	6	2.50E-02	e	-	
AP3-MW-23	1942503.03	1551636.22	558.10	6	5.04E-02	e	-	
HGWC-124 (AP3-MW-24)	1942787.04	1551618.74	552.70	7	1.27E-03	e	-	
HGWC-8 (AP1C-2)	1942392.75	1549114.34	559.43	3	-		6.40E-08	e
HGWC-9 (AP1C-3)	1942215.01	1548692.82	538.62	5	-		1.50E-08	e
HGWC-11 (AP1C-5S)	1941146.65	1548477.54	560.33	4	-		6.10E-08	e
AP3-B-1	1942043.87	1550918.48	530.63	7	5.70E-04	b	1.40E-06	c
AP3-B-2	1941995.70	1551318.19	493.00	8	2.34E-04 (496.80'-491.80')	b	1.10E-07	c
AP3-B-3	1942862.68	1551280.14	507.00	7	2.82E-03 (549.15'-544.15')	b	2.90E-07	c
AP3-B-4	1942920.34	1550709.19	552.39	6	9.25E-04	b	2.10E-08	d
AP3-B-5	1942521.24	1550275.29	542.83	7	6.95E-04	b	7.60E-07	c
AP3-B-6S	1942122.65	1550542.92	581.95	1	4.13E-02	a	-	
AP3-B6I	1942123.35	1550538.41	546.48	5	9.75E-05	a	1.00E-07	c
AP3-B6D	1942124.44	1550530.98	523.76	7	6.22E-05	a	-	
AP3-B-8	1942521.40	1551323.29	519.59	7	5.15E-04	b	1.80E-07	c

Notes:
"-" = data unavailable
Source citation of hydraulic conductivity values:
a) Measured via slug test by Geosyntec, 2017
b) Measured via packer test by Geosyntec, 2017
c) Laboratory measurement of residuum vertical hydraulic conductivity by Geosyntec, 2017
d) Laboratory measurement of fill vertical hydraulic conductivity by Geosyntec, 2017
e) Provided by others

Elevations are referenced to NAVD88

Table 5. Observed and Modeled Groundwater Elevations February 9, 2017

Monitoring Well Name	Easting (ft)	Northing (ft)	Well Screen Midpoint Elevation (ft)	Model Layer	Observed Groundwater Elevation (ft)	Simulated Groundwater Elevation (ft)	Residual (ft)
AP1-MW-1	1941590.75	1549936.41	563.10	6	581.53	579.23	2.30
AP1-MW-5	1942445.49	1548430.84	555.60	6	562.79	562.23	0.56
AP1-MW-6	1941686.57	1548381.22	554.30	6	563.41	563.49	-0.08
AP1-MW-7	1941084.33	1548230.08	556.50	4	562.66	563.54	-0.88
APA-4 (HGWA-4MW-19)	1939386.06	1549932.71	567.90	3	583.42	582.87	0.55
APA-2 (HGWA-1MW-20)	1940773.28	1550423.59	568.40	7	580.12	583.39	-3.27
AP3-MW-21	1941812.40	1550265.01	565.50	5	581.45	578.25	3.20
HGWA-122 (AP3-MW-22)	1941892.64	1551247.62	565.70	6	578.57	579.14	-0.57
AP3-MW-23	1942503.03	1551636.22	558.10	6	574.61	574.37	0.24
HGWC-124 (AP3-MW-24)	1942787.04	1551618.74	552.70	7	570.50	570.83	-0.33
HGWA-1 (APA-2MW-20)	1940773.31	1550423.69	568.30	7	580.12	583.39	-3.27
HGWA-2 (APA-3S)	1939845.20	1549796.40	565.23	3	581.02	582.86	-1.84
HGWA-3 (APA-3D)	1939833.46	1549793.93	548.19	5	581.20	581.40	-0.20
HGWA-4 (APA-4MW-19)	1939386.17	1549932.76	567.90	3	583.42	582.87	0.55
HGWC-7 (AP1C-1)	1942319.97	1549520.39	556.32	5	575.77	572.93	2.84
HGWC-8 (AP1C-2)	1942392.75	1549114.34	559.43	3	577.42	574.39	3.03
HGWC-9 (AP1C-3)	1942215.01	1548692.82	538.62	5	566.10	566.85	-0.75
HGWC-10 (AP1C-4)	1941644.41	1548469.51	561.66	3	565.15	566.38	-1.23
HGWC-11 (AP1C-5S)	1941146.65	1548477.54	560.33	4	564.80	567.55	-2.75
HGWC-12 (AP1C-5D)	1941152.08	1548475.82	550.33	6	564.80	568.61	-3.81
HGWC-13 (AP1C-6)	1940900.41	1548628.52	554.76	4	576.53	573.48	3.05
HGWC-120 (P20-2016)	1942907.17	1551082.00	552.76	7	566.60	567.11	-0.51
AP1A-1	1941613.87	1550080.50	571.17	3	581.59	581.51	0.08
AP3-B-1	1942043.87	1550918.48	530.63	7	577.63	575.12	2.51
AP3-B-2	1941995.70	1551318.19	493.00	8	578.20	577.11	1.09
AP3-B-3	1942862.68	1551280.14	507.00	7	564.50	568.30	-3.80
AP3-B-4	1942920.34	1550709.19	552.39	6	567.14	566.28	0.86
AP3-B-5	1942521.24	1550275.29	542.83	7	570.48	568.80	1.68
AP3-B-6S	1942122.65	1550542.92	581.95	1	574.80	577.15	-2.35
AP3-B6I	1942123.35	1550538.41	546.48	5	574.70	572.83	1.87
AP3-B6D	1942124.44	1550530.98	523.76	7	572.87	573.11	-0.24

Table 5. Observed and Modeled Groundwater Elevations February 9, 2017

Monitoring Well Name	Easting (ft)	Northing (ft)	Well Screen Midpoint Elevation (ft)	Model Layer	Observed Groundwater Elevation (ft)	Simulated Groundwater Elevation (ft)	Residual (ft)
AP3-B-7	1942387.32	1551042.74	518.36	7	571.56	571.48	0.08
AP3-B-8	1942521.40	1551323.29	519.59	7	573.14	572.01	1.13
AP3-B-9	1942654.24	1550662.39	538.00	7	567.00	568.55	-1.55
AP3-B-10	1942345.89	1550500.71	552.69	4	568.89	572.44	-3.55
AP3-B-11 *	*1942643.26*	*1550545.31*	*539.62*	*6*	*584.12*	*568.90*	*15.22*
						Min Residual	-3.81
						Max Residual	3.20
						Range	20.76
						Mean Error	-0.15
						NRMSE	9.9%

Notes:
*AP3-B-11 was not included in the statistical evaluations. The measured groundwater elevation in this well is approximately 15 feet higher than it's nearest neighbors

1) Elevations are referenced to NAVD88. Northing and Easting reference the Georgia State Plane West (NAD83)

Table 6. Sensitivity Evaluation

Monitoring Well Name	Calibrated Head (ft)	Sensitivity Analysis Head (ft)	Residual
AP1-MW-1	579.25	579.35	-0.10
AP1-MW-5	562.26	562.23	0.04
AP1-MW-6	563.58	563.51	0.06
AP1-MW-7	564.08	563.70	0.39
HGWA-4 (APA-4MW-19)	582.95	583.15	-0.20
APA-2 (HGWA-1MW-20)	583.43	583.58	-0.16
AP3-MW-21	578.26	578.40	-0.13
HGWA-122 (AP3-MW-22)	579.15	579.36	-0.20
AP3-MW-23	574.38	574.53	-0.15
HGWC-124 (AP3-MW-24)	570.83	570.90	-0.07
HGWA-1 (APA-2MW-20)	583.43	583.58	-0.16
HGWA-2 (APA-3S)	582.93	583.10	-0.17
HGWA-3 (APA-3D)	581.47	581.60	-0.13
HGWA-4 (APA-4MW-19)	582.95	583.15	-0.20
HGWC-7 (AP1C-1)	572.94	573.07	-0.13
HGWC-8 (AP1C-2)	574.40	574.45	-0.06
HGWC-9 (AP1C-3)	566.90	566.89	0.02
HGWC-10 (AP1C-4)	566.68	566.37	0.31
HGWC-11 (AP1C-5S)	567.75	567.60	0.15
HGWC-12 (AP1C-5D)	568.73	568.62	0.10
HGWC-13 (AP1C-6)	573.55	573.53	0.03
HGWC-120 (P20-2016)	567.11	567.12	0.00
AP1A-1	581.53	581.64	-0.11
AP3-B-1	575.14	575.29	-0.16
AP3-B-2	577.13	577.29	-0.16
AP3-B-3	568.30	568.30	0.00
AP3-B-4	566.28	566.30	-0.02
AP3-B-5	568.81	568.90	-0.09
AP3-B-6S	577.17	577.61	-0.45
AP3-B6I	572.84	572.94	-0.10
AP3-B6D	573.12	573.23	-0.11
AP3-B-7	571.49	571.53	-0.04
AP3-B-8	572.02	572.09	-0.08
AP3-B-9	568.55	568.59	-0.04
AP3-B-10	572.45	572.38	0.06
AP3-B-11	568.91	568.95	-0.05
		Average	-0.06
		Abs. Average	0.12

FIGURES

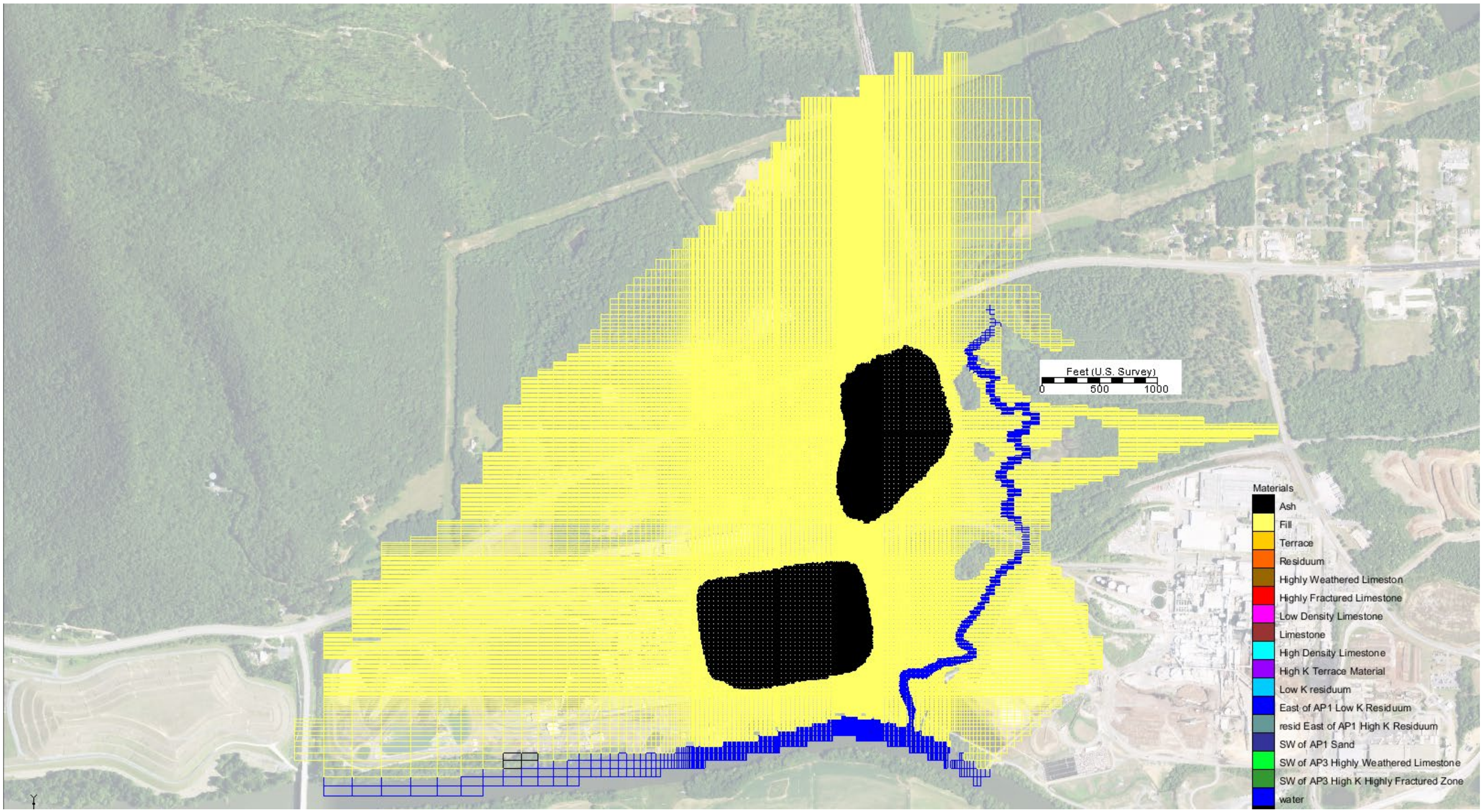

Figure 1: Layer 1 Hydraulic Conductivity Zones

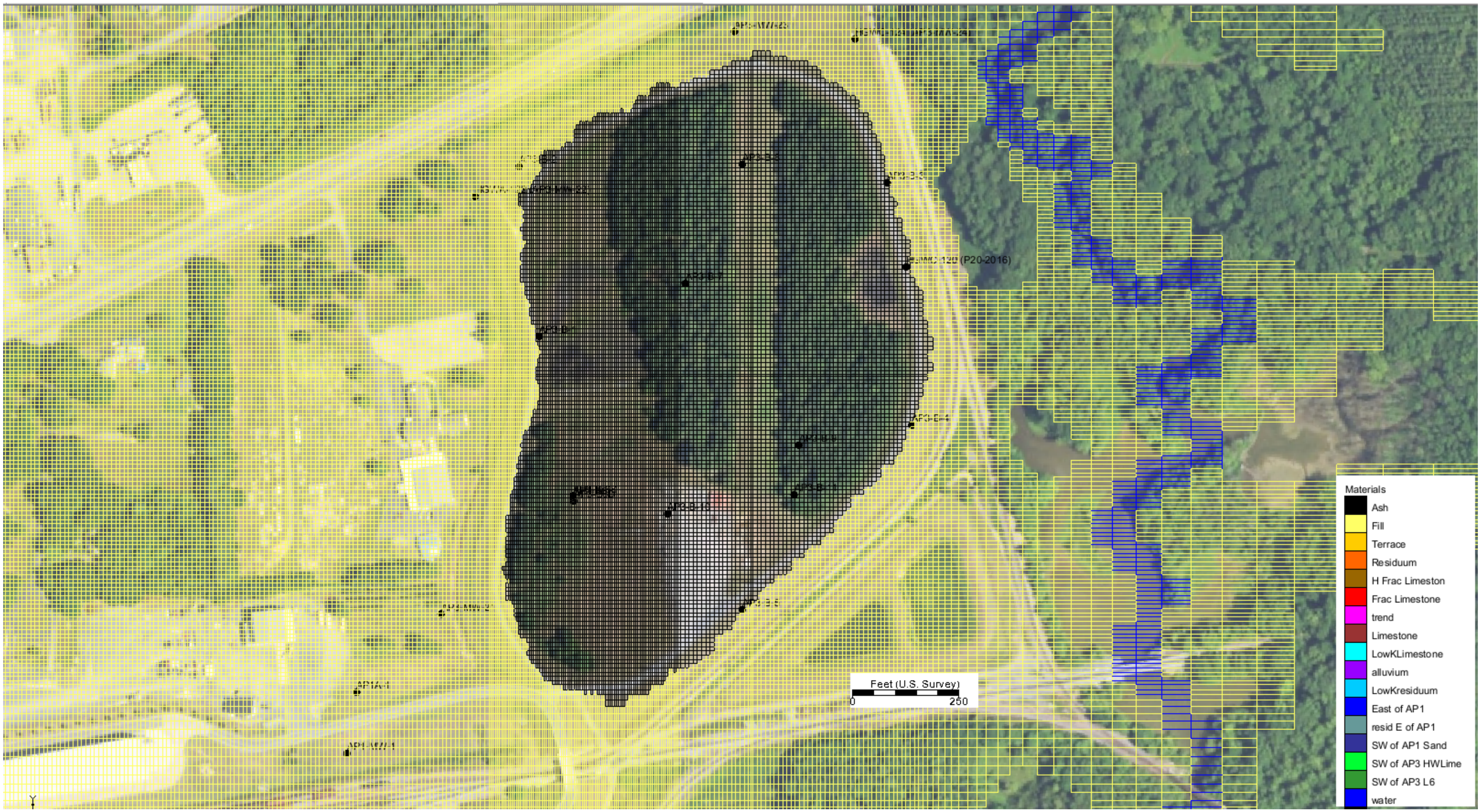

Figure 1a: Layer 1 Hydraulic Conductivity Zones Near AP-3

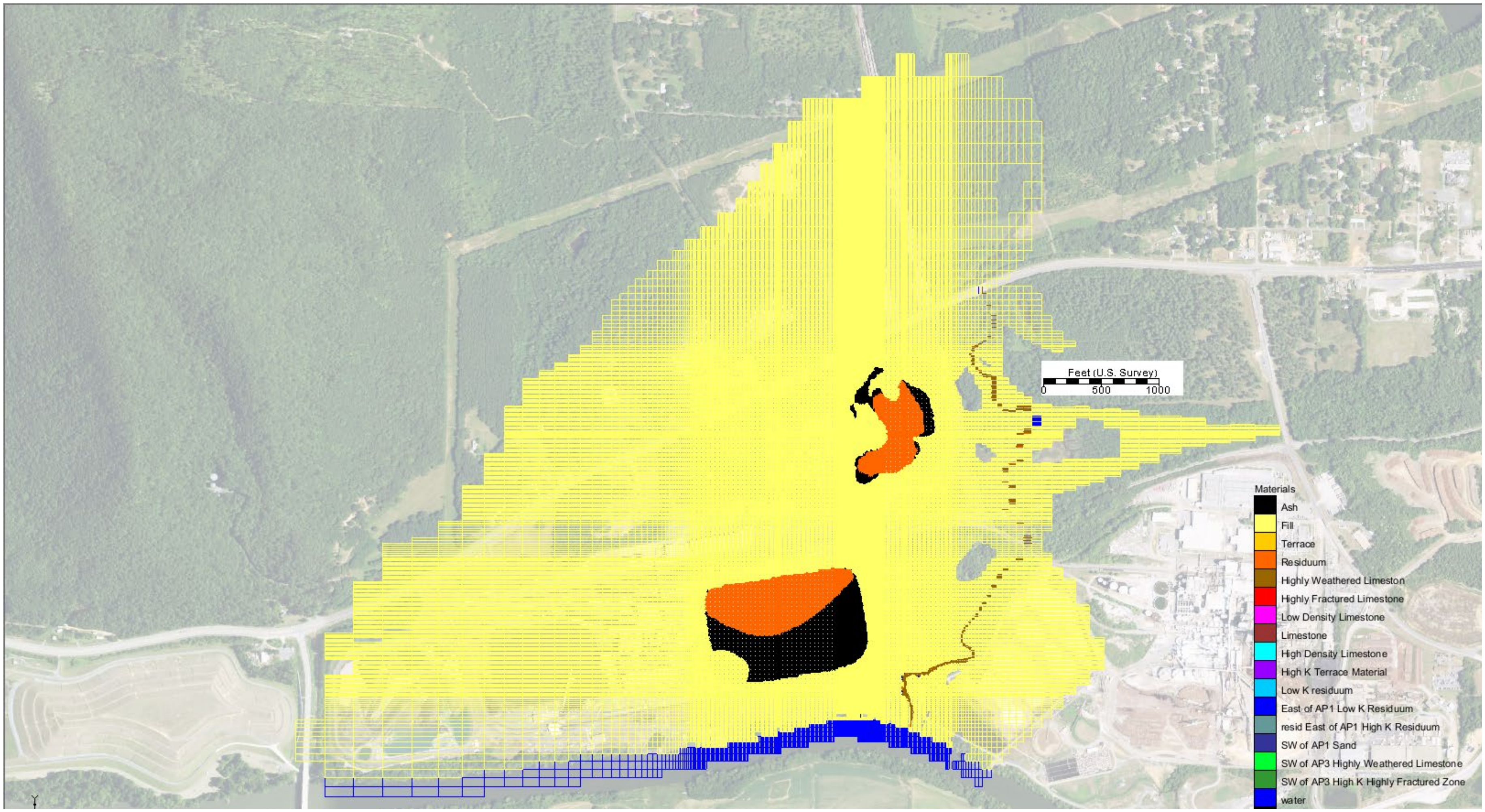

Figure 2: Layer 2 Hydraulic Conductivity Zones

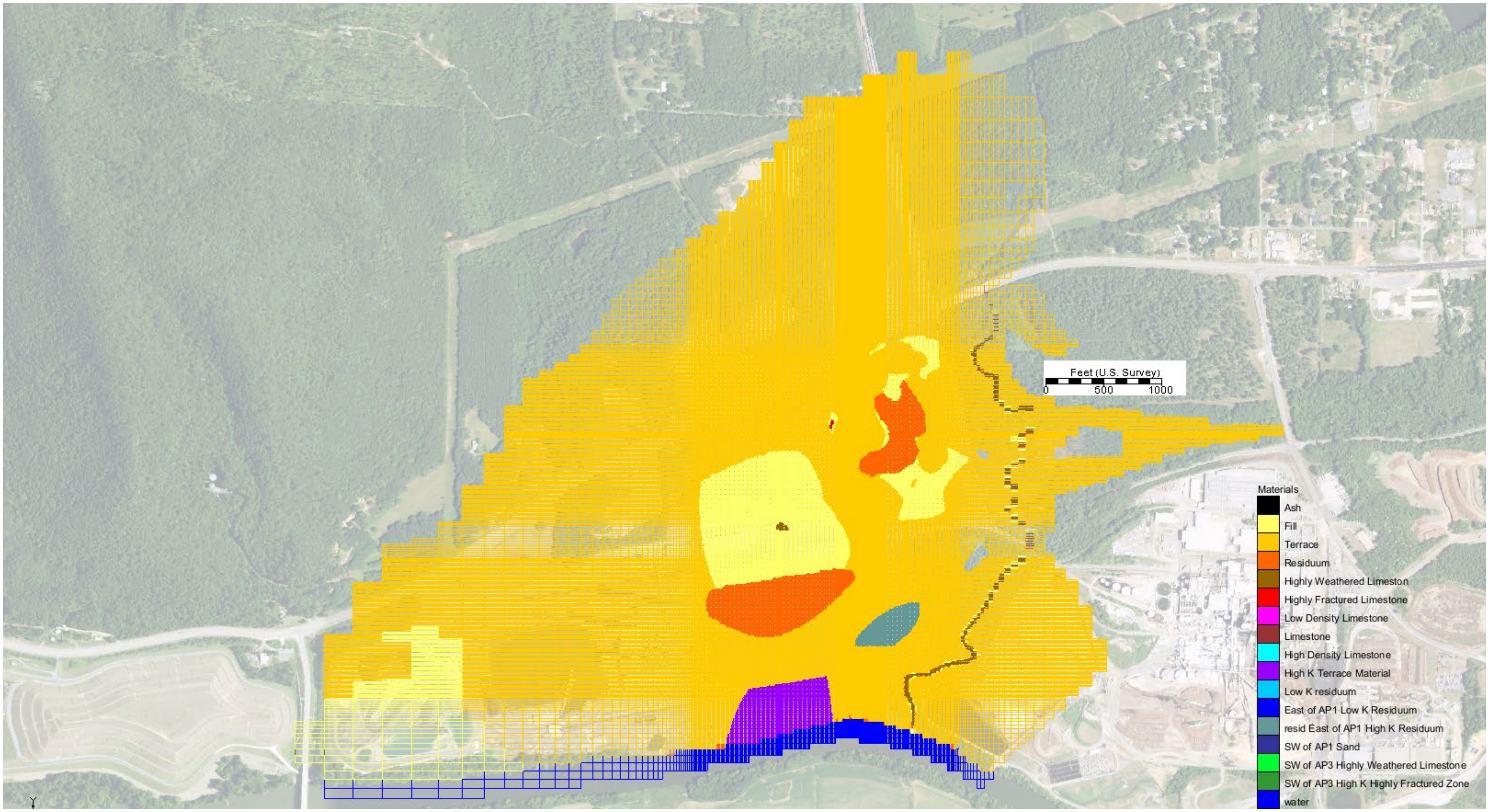

Figure 3: Layer 3 Hydraulic Conductivity Zones

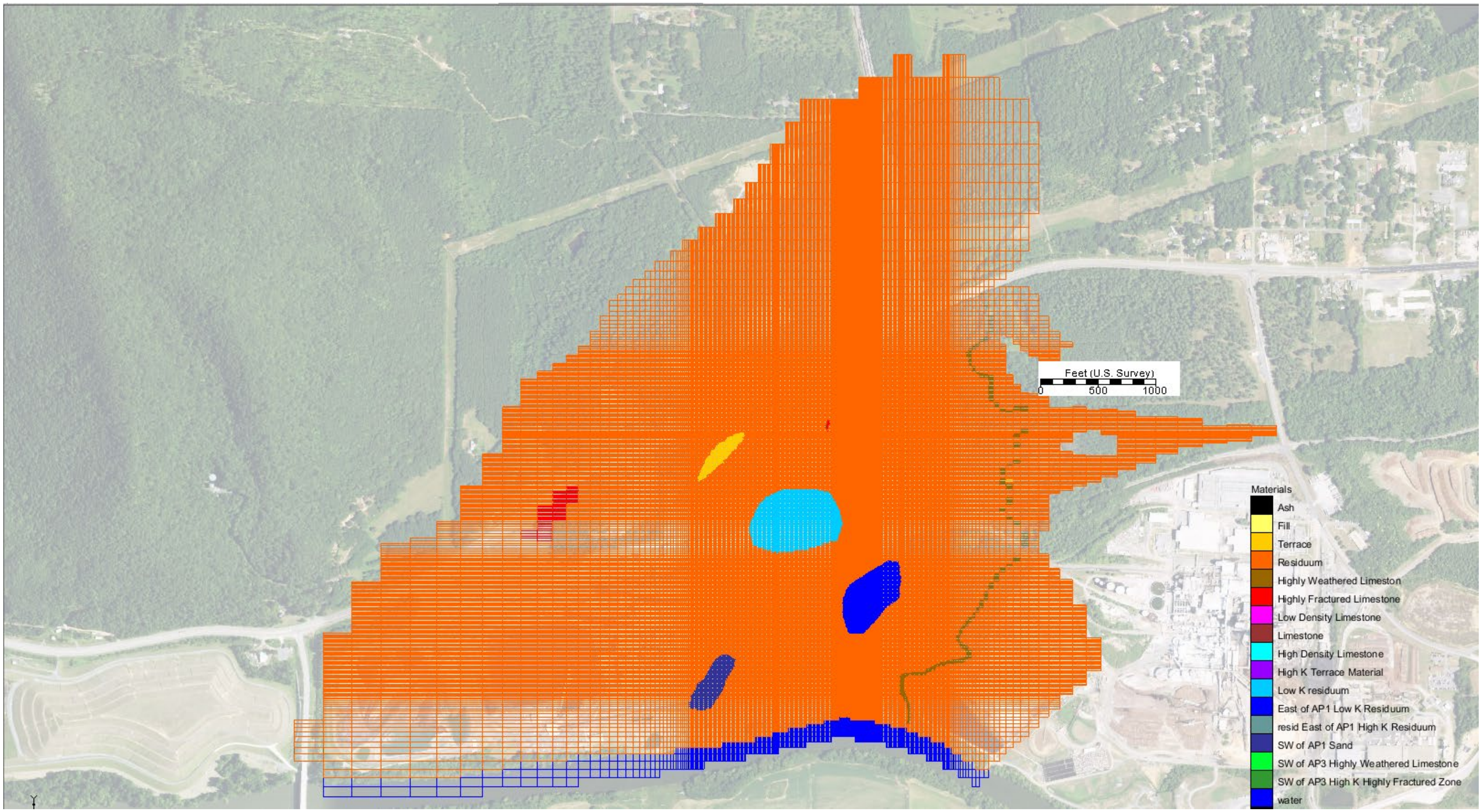

Figure 4: Layer 4 Hydraulic Conductivity Zones

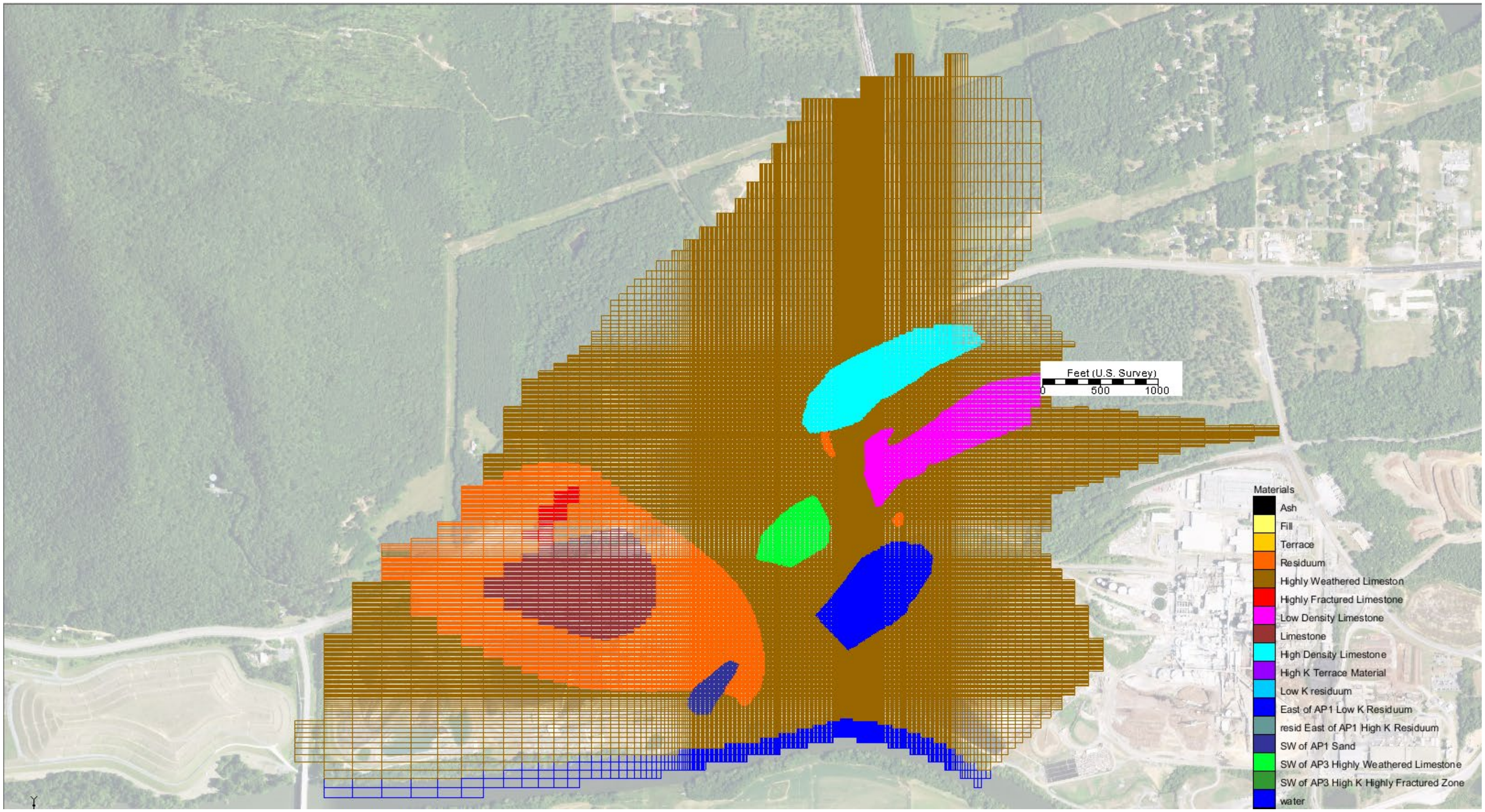

Figure 5: Layer 5 Hydraulic Conductivity Zones

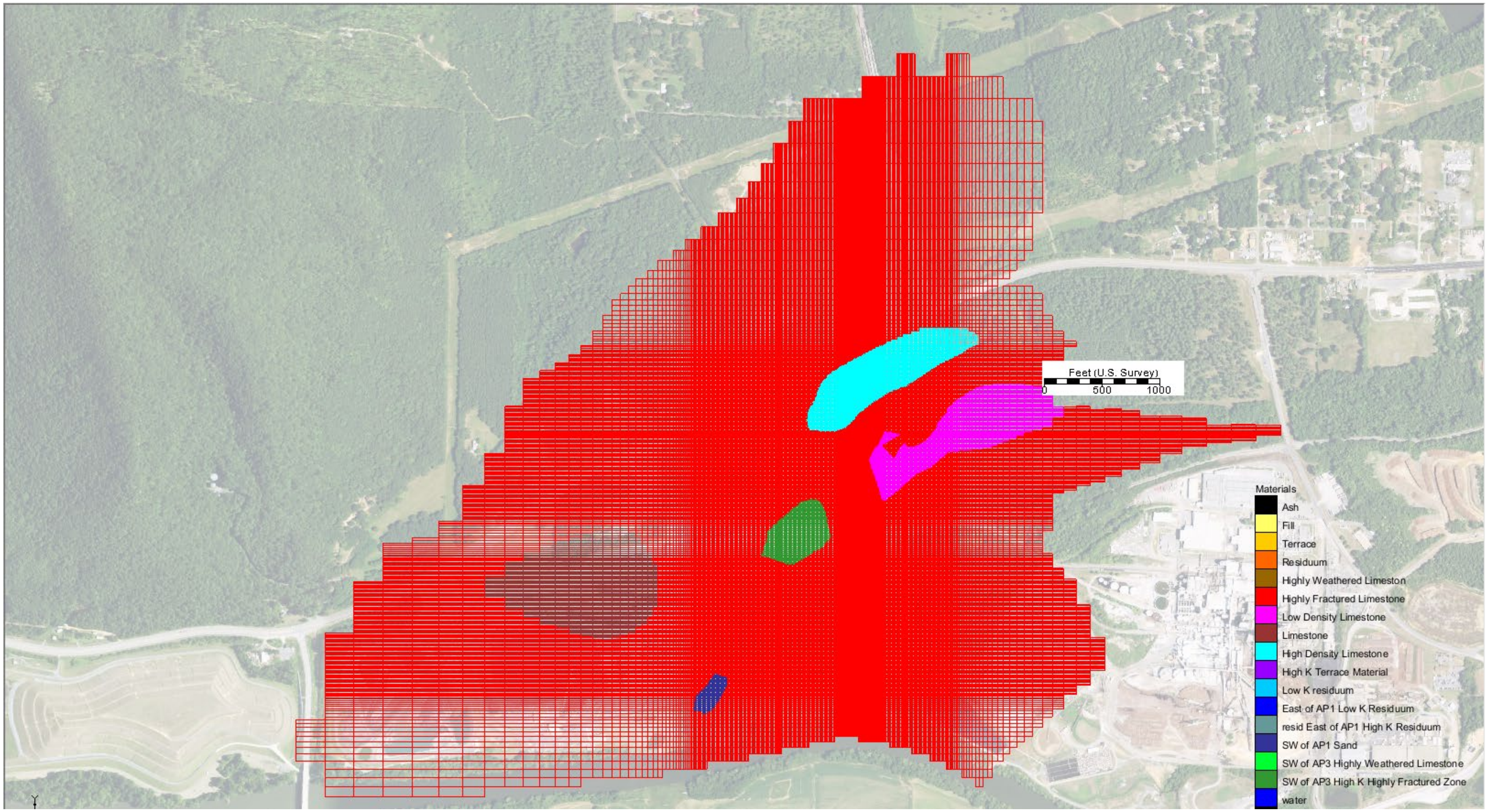

Figure 6: Layer 6 Hydraulic Conductivity Zones

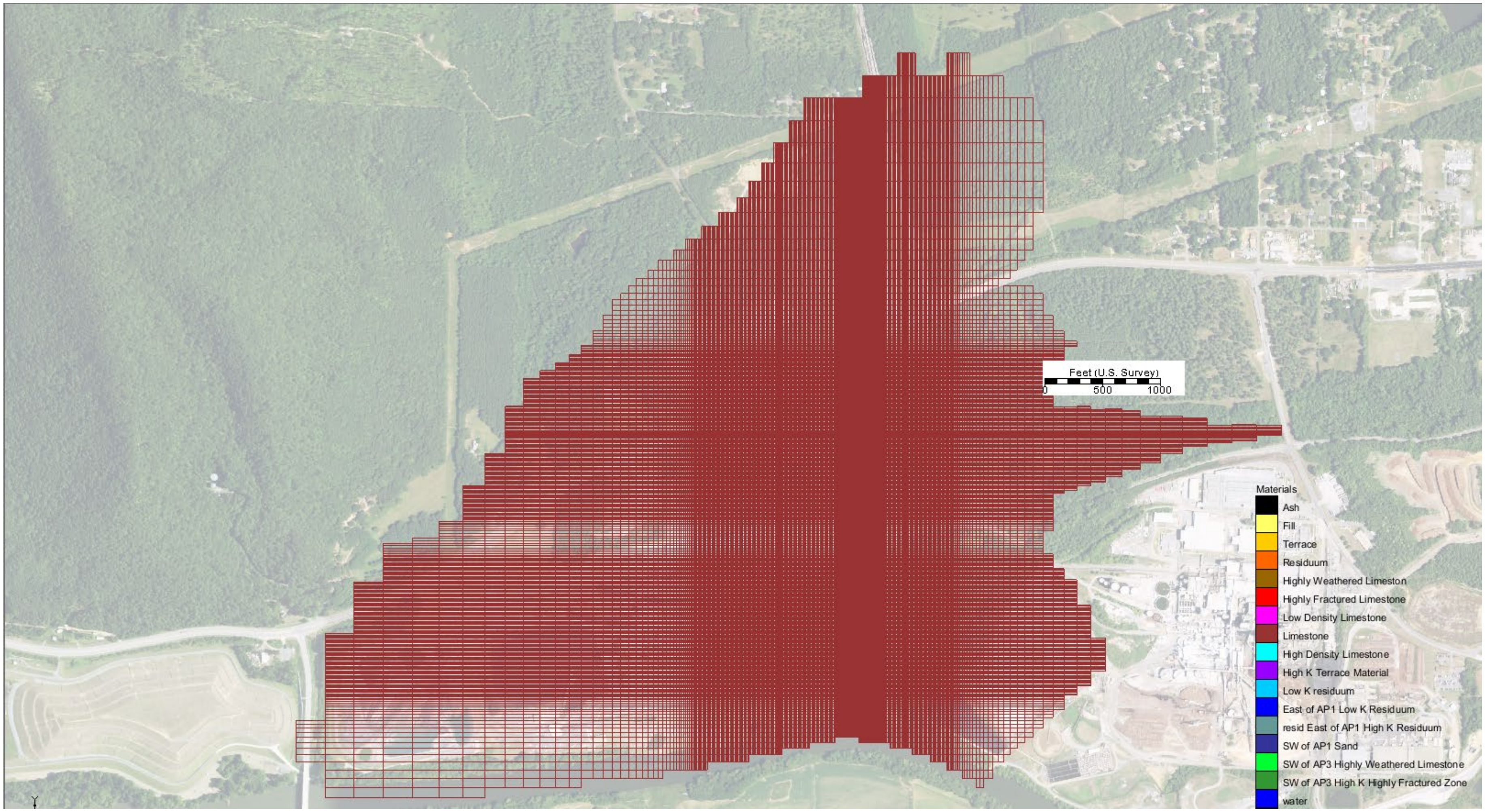

Figure 7: Layer 7 Hydraulic Conductivity Zones

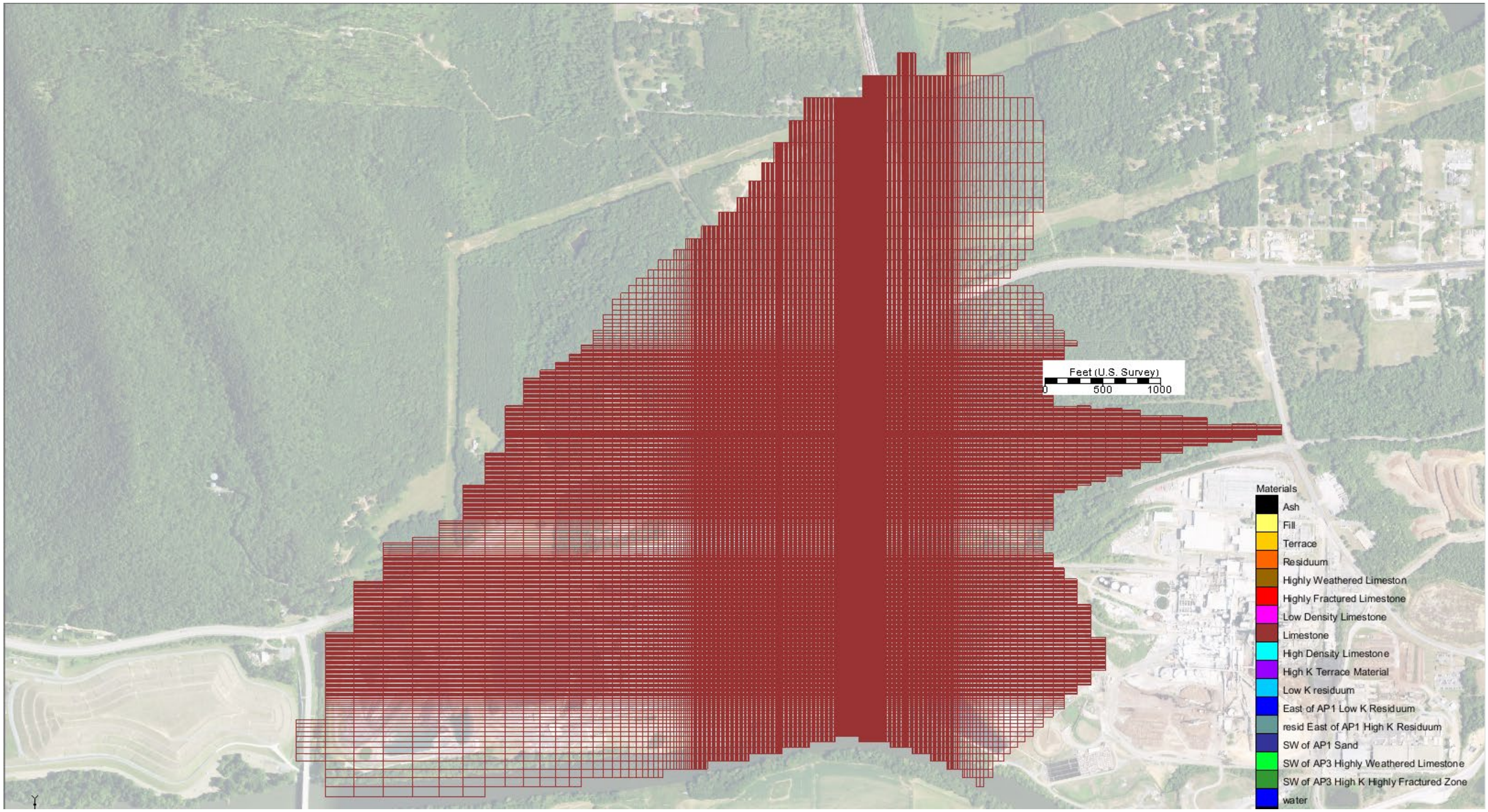

Figure 8: Layer 8 Hydraulic Conductivity Zones

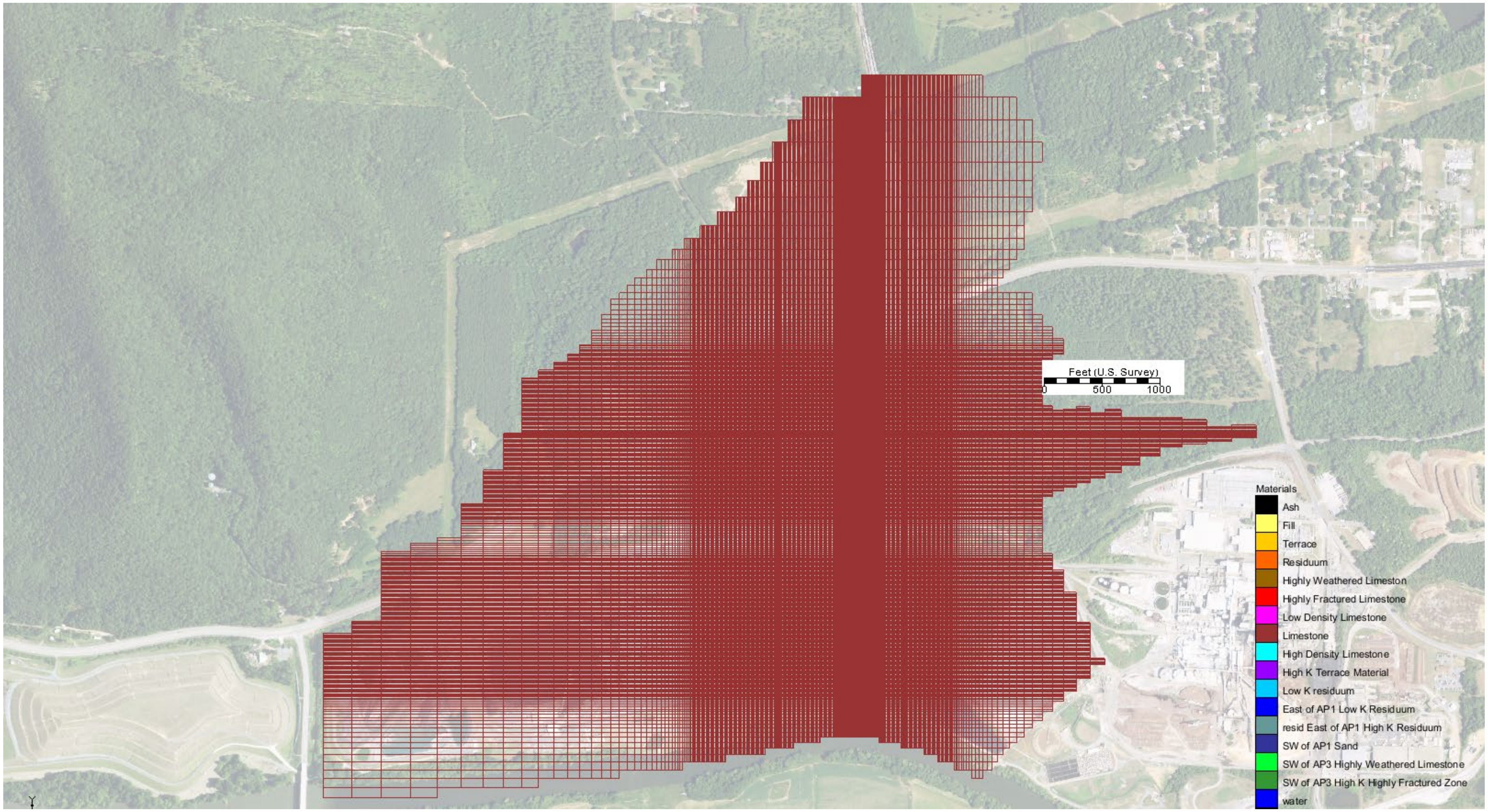

Figure 9: Layer 9 Hydraulic Conductivity Zones

Boring (Installed 2017)	Ground Surface Elevation (5 ft interval)
Boring (Installed 2015)	Georgia Power Property Boundary
Boring (Installed 1976-1977)	
Well/Piezometer (Installed 2016)	
Monitoring Well (Installed 2015)	
Well/Piezometer (Installed 2014)	
Piezometer (Installed 2010)	
Piezometer (Installed 1976-1977)	
Observation Well (Installed 1976-1977)	

Notes:
1. Aerial Photograph approximate date - February 2017
Source: Google Earth.
2. Topographic Contour Source: City of Rome and Floyd County, Georgia and a site topographic map provided by Southern Company Services.
3. AP3-1, AP3-2, AP3-3, AP1-MW-2, AP1-MW-3, AP1-MW-4, AP3-MW-25 through AP3-MW-27, and HGWC-121 were abandoned.

N

0 580 Feet

Plan View of Geologic Sections in EVS (A-A', B-B', C-C', D-D', D'-D'', E-E', and F-F')

Georgia Power Company
Plant Hammond AP3
Rome, Floyd County, Georgia

Geosyntec consultants

Kennesaw, GA | July 2017

Figure 10a

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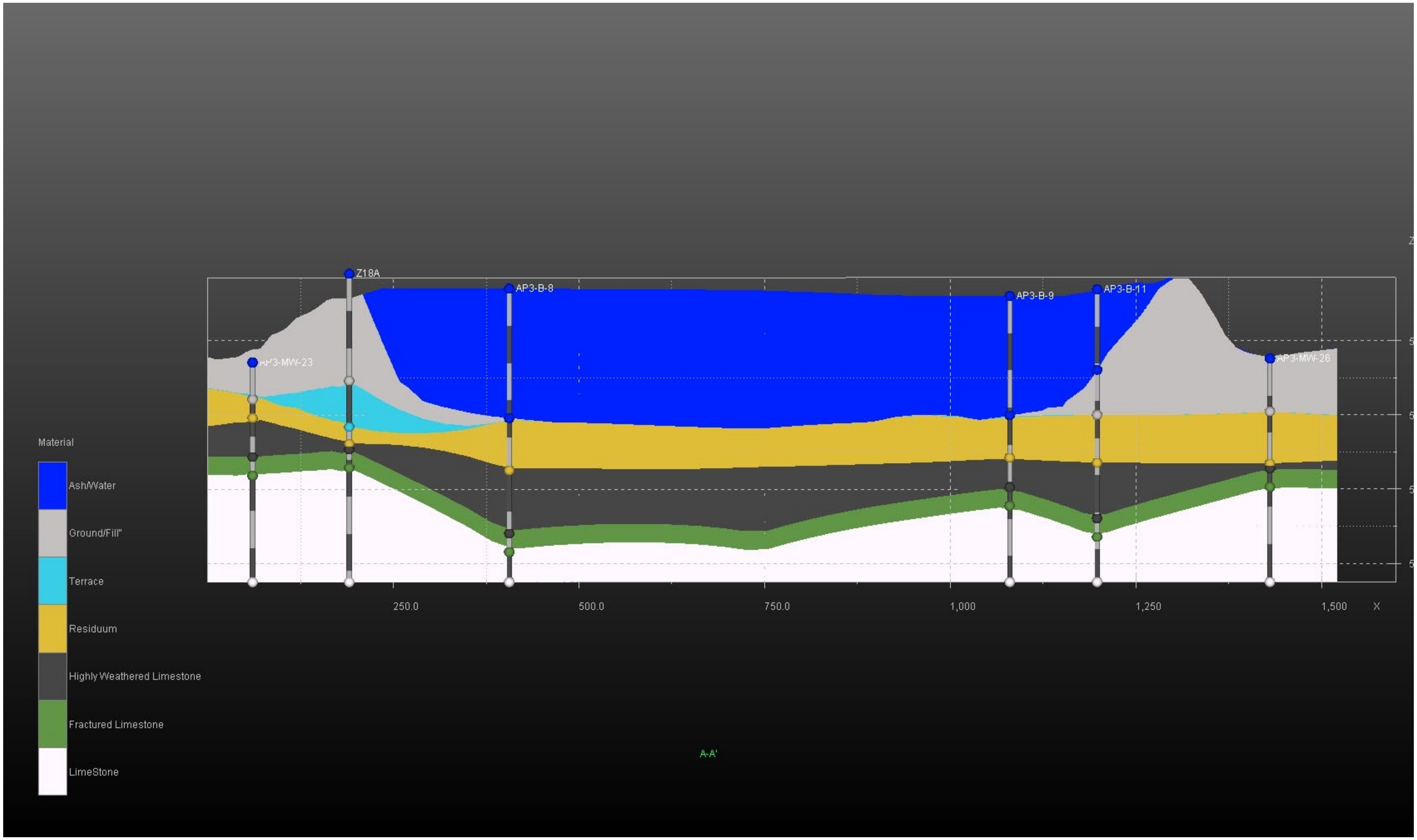

Figure 10b: EVS Cross-Section A-A’

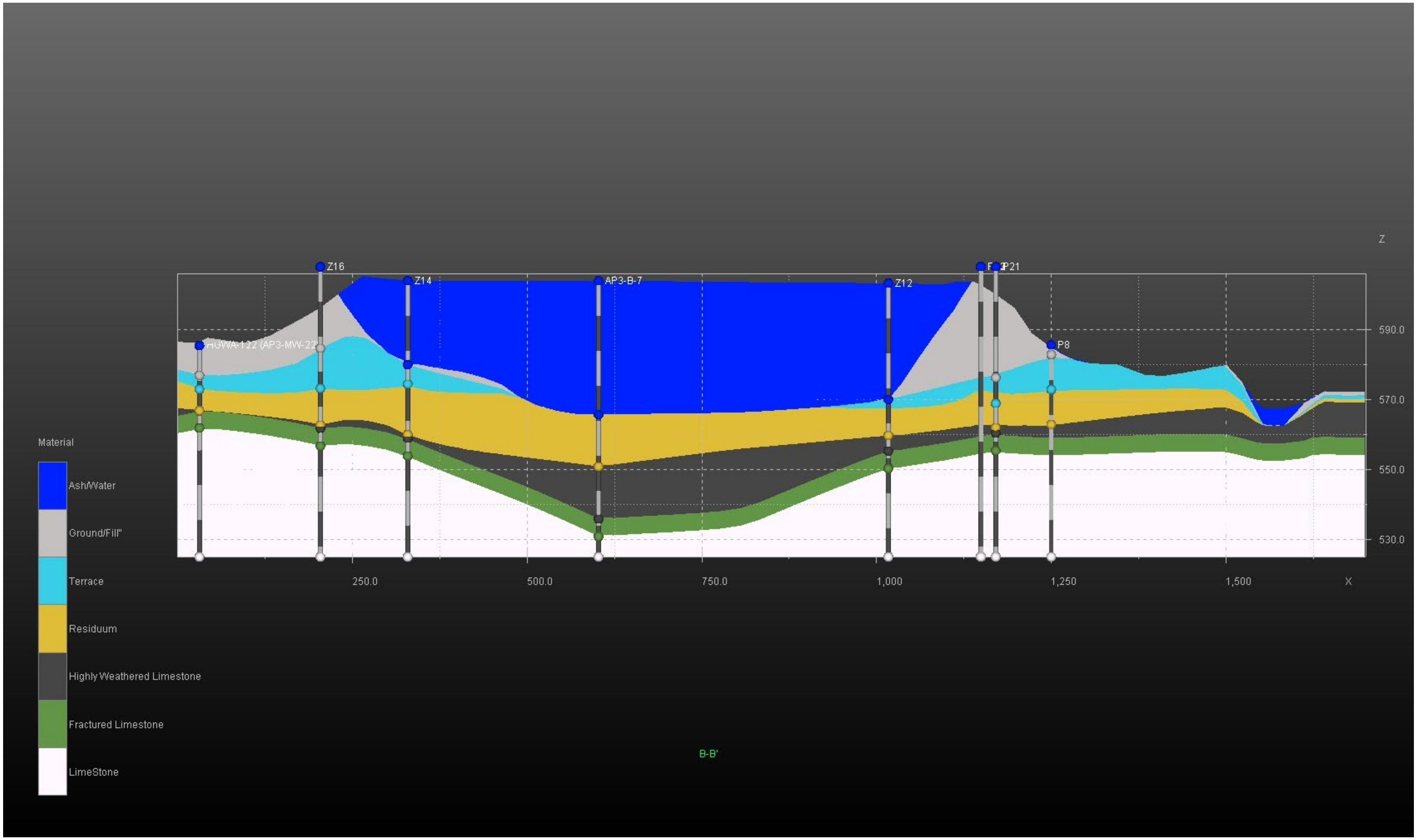

Figure 11: EVS Cross-Section B-B’

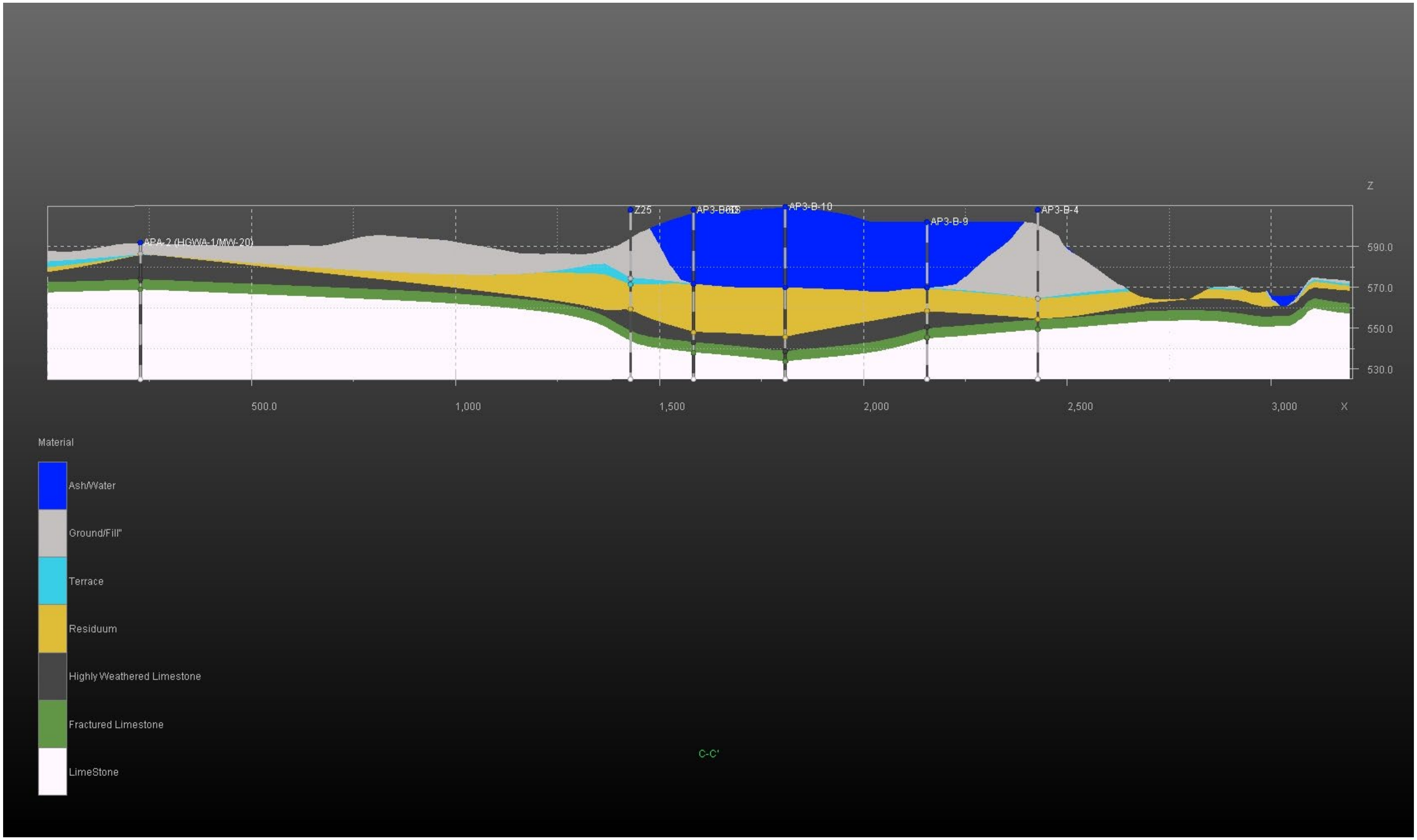

Figure 12: EVS Cross-Section C-C’

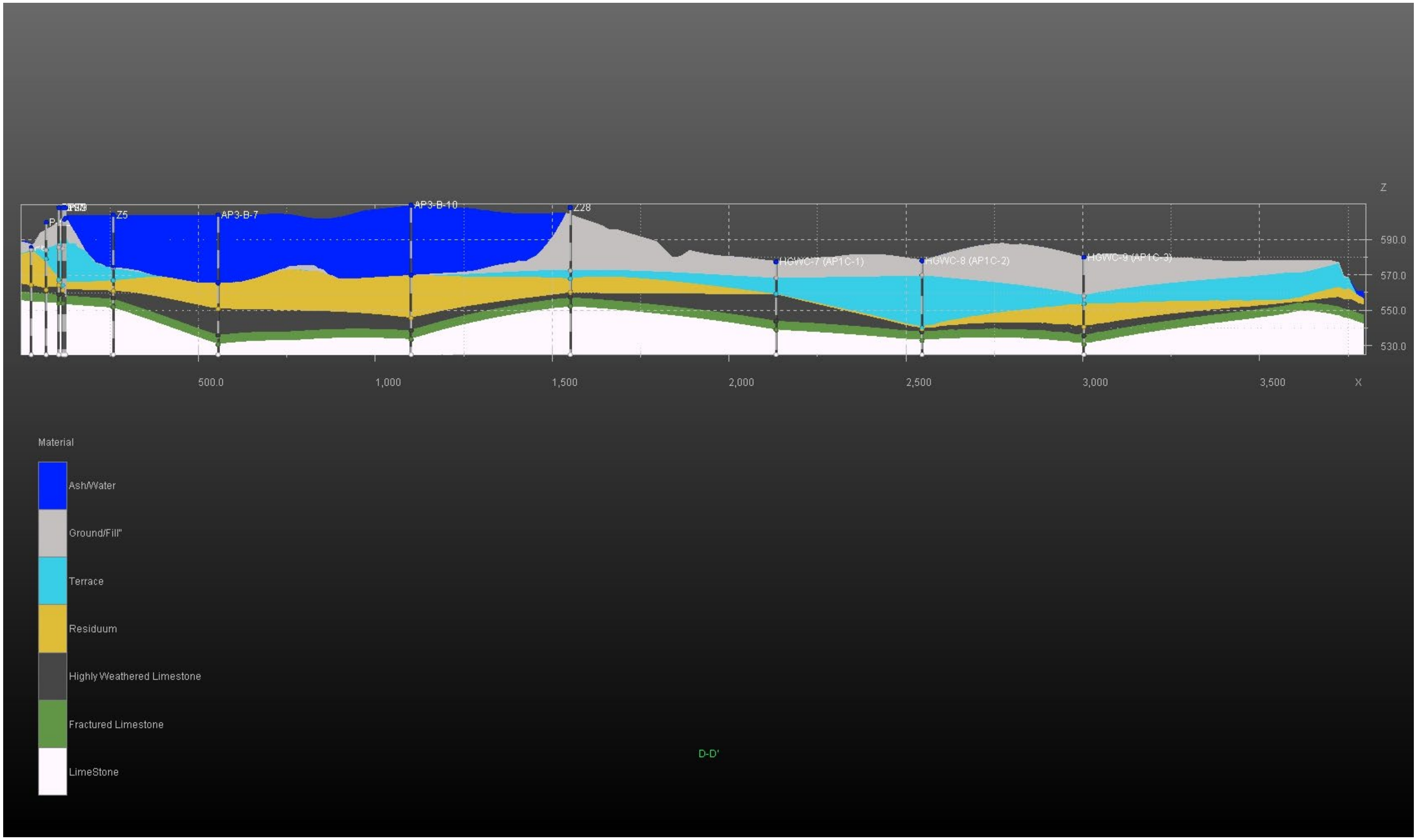

Figure 13: EVS Cross-Section D-D'

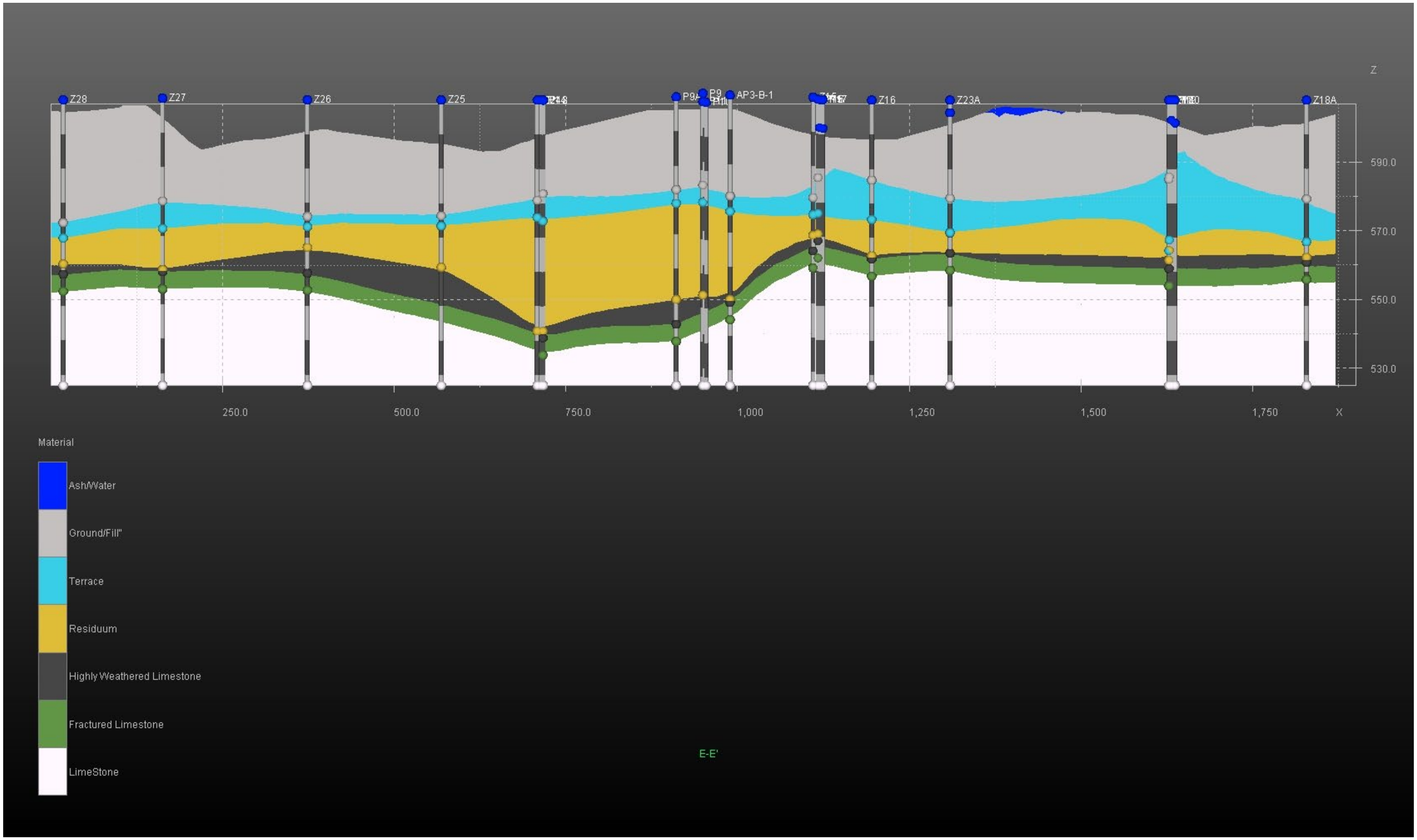

Figure 14: EVS Cross-Section E-E'

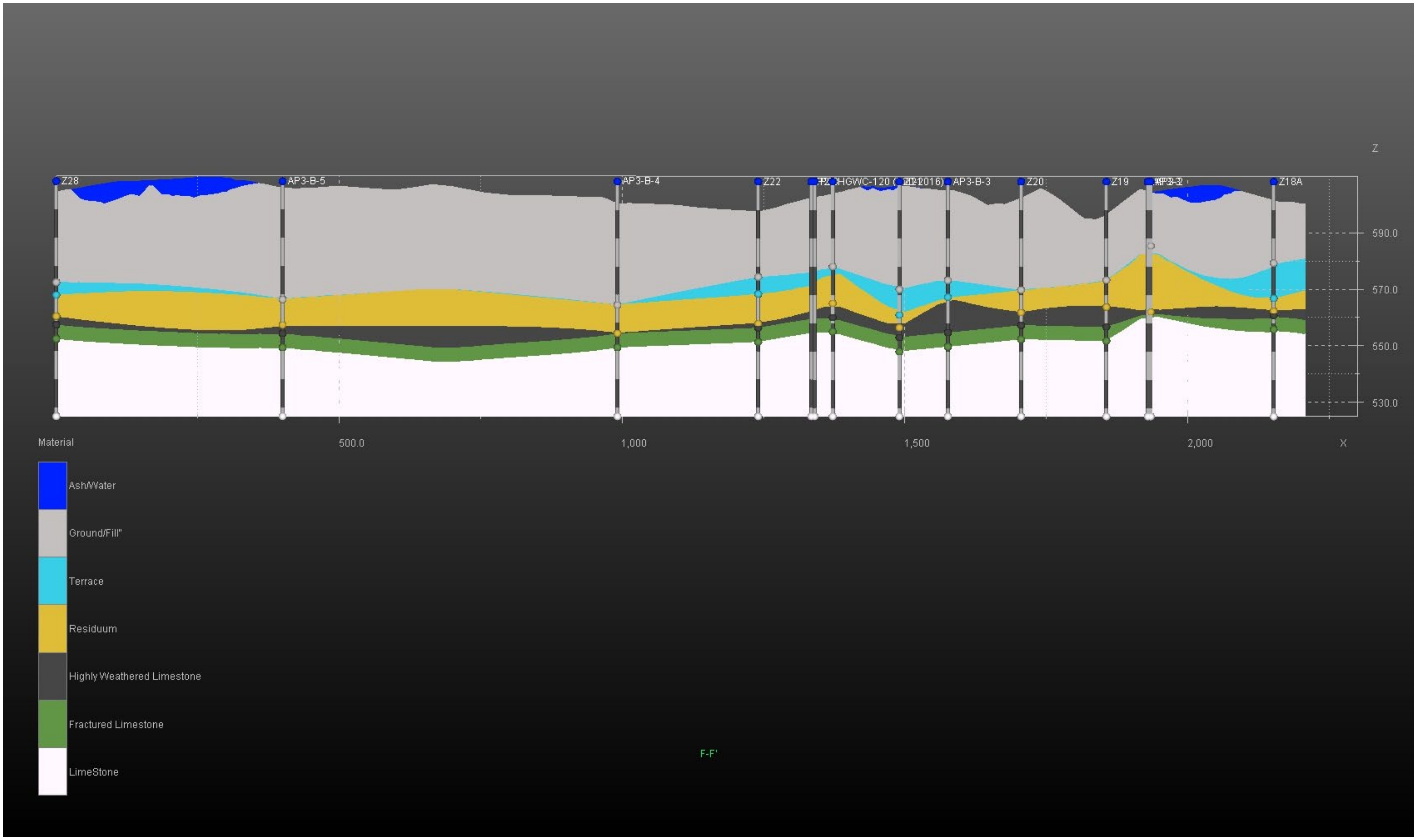

Figure 15: EVS Cross-Section F-F’

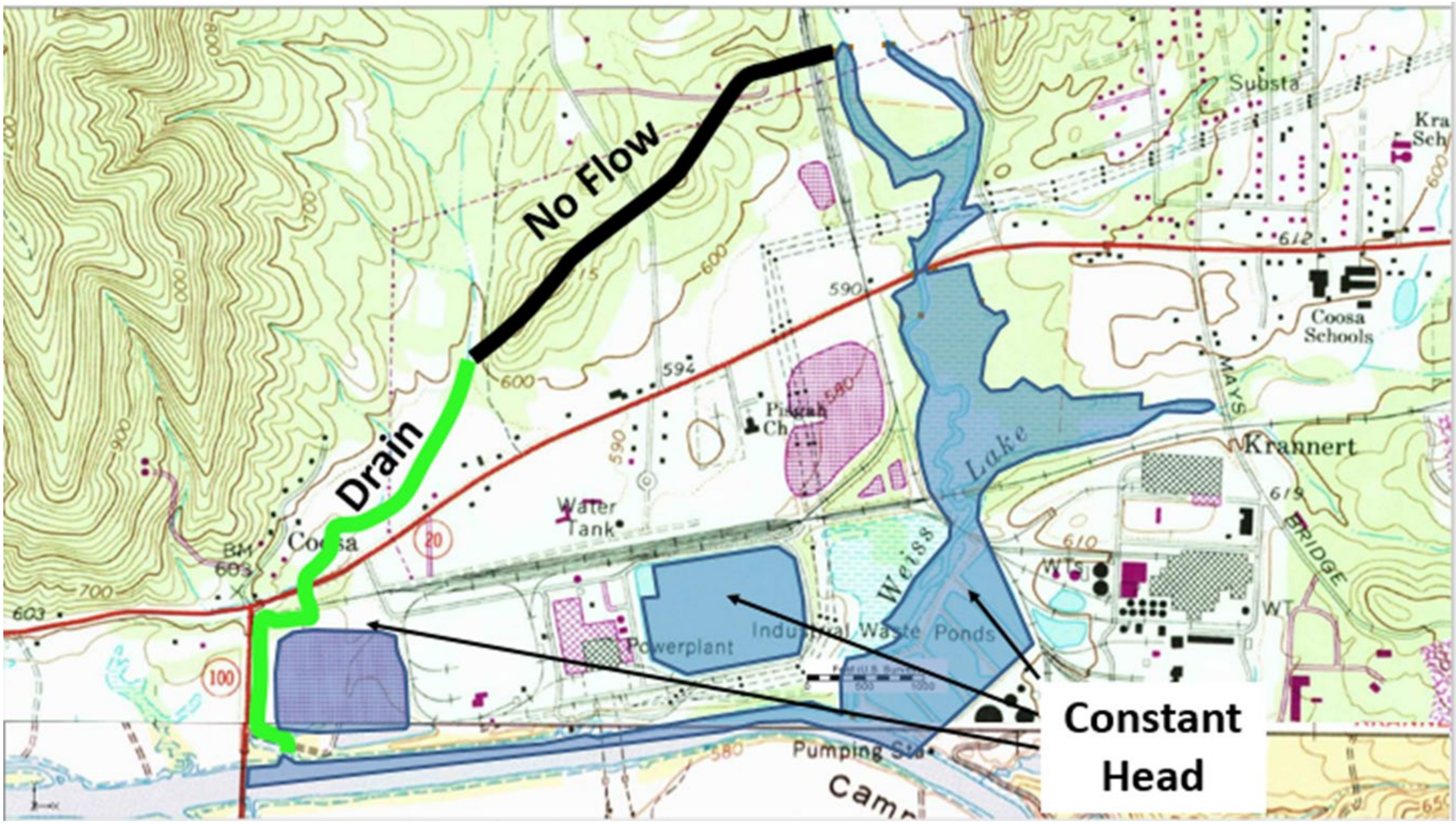

Figure 16: Conceptual Model Boundary Conditions

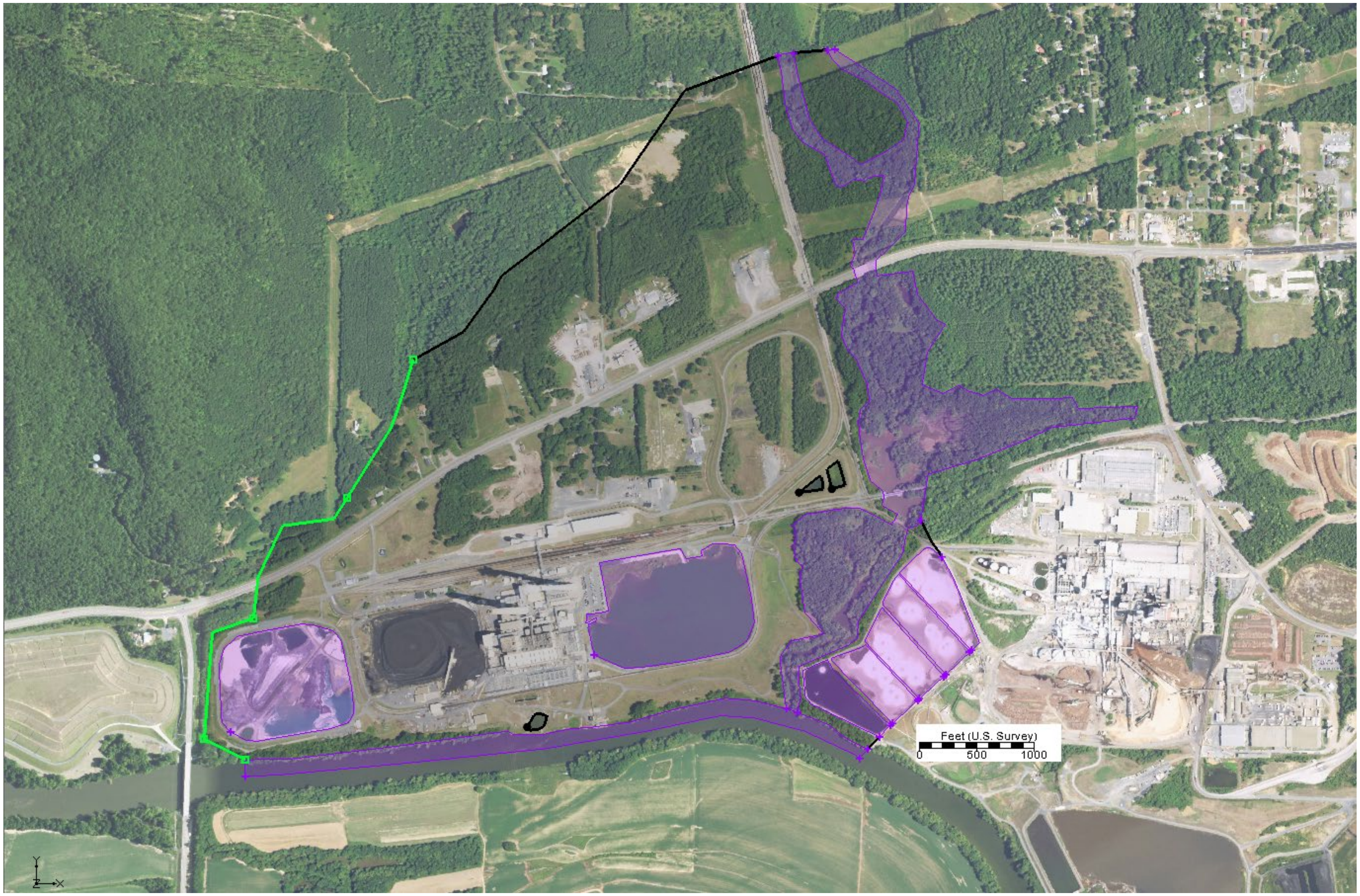

Figure 16a: Model Boundary Conditions

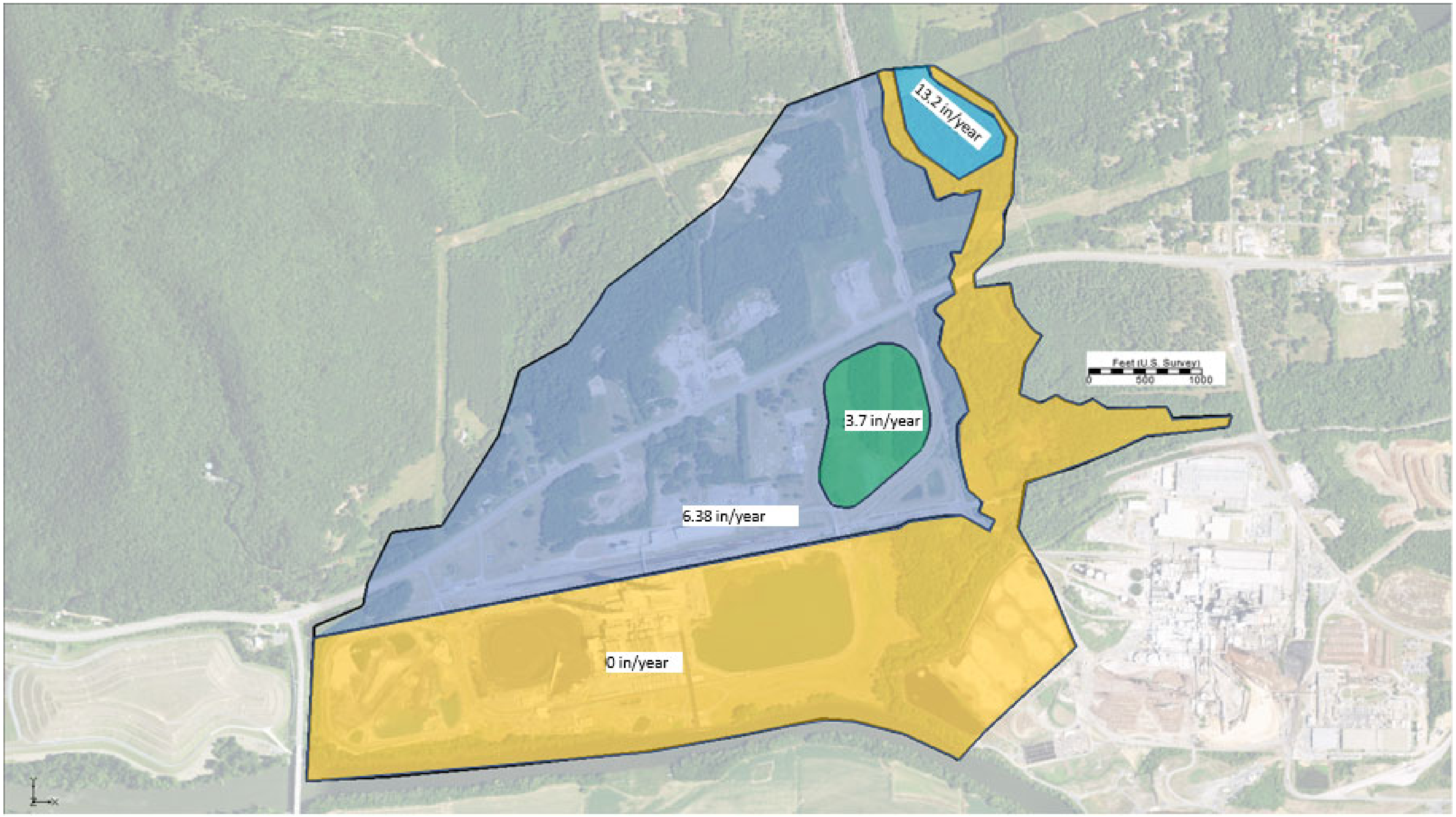

Figure 17: Model Recharge Zones

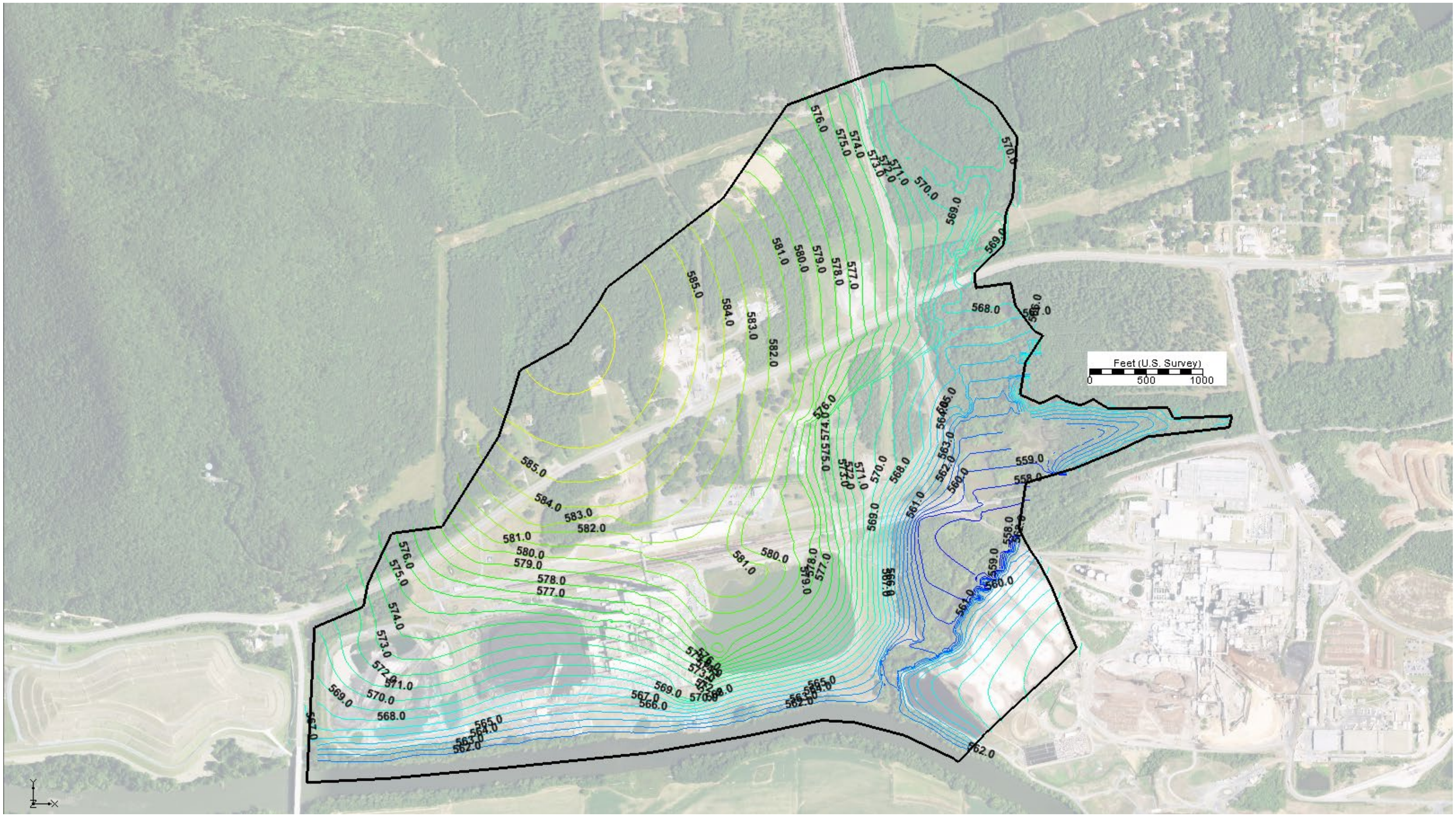

Figure 18: Modeled Groundwater Elevations for the Highly Fractured Limestone

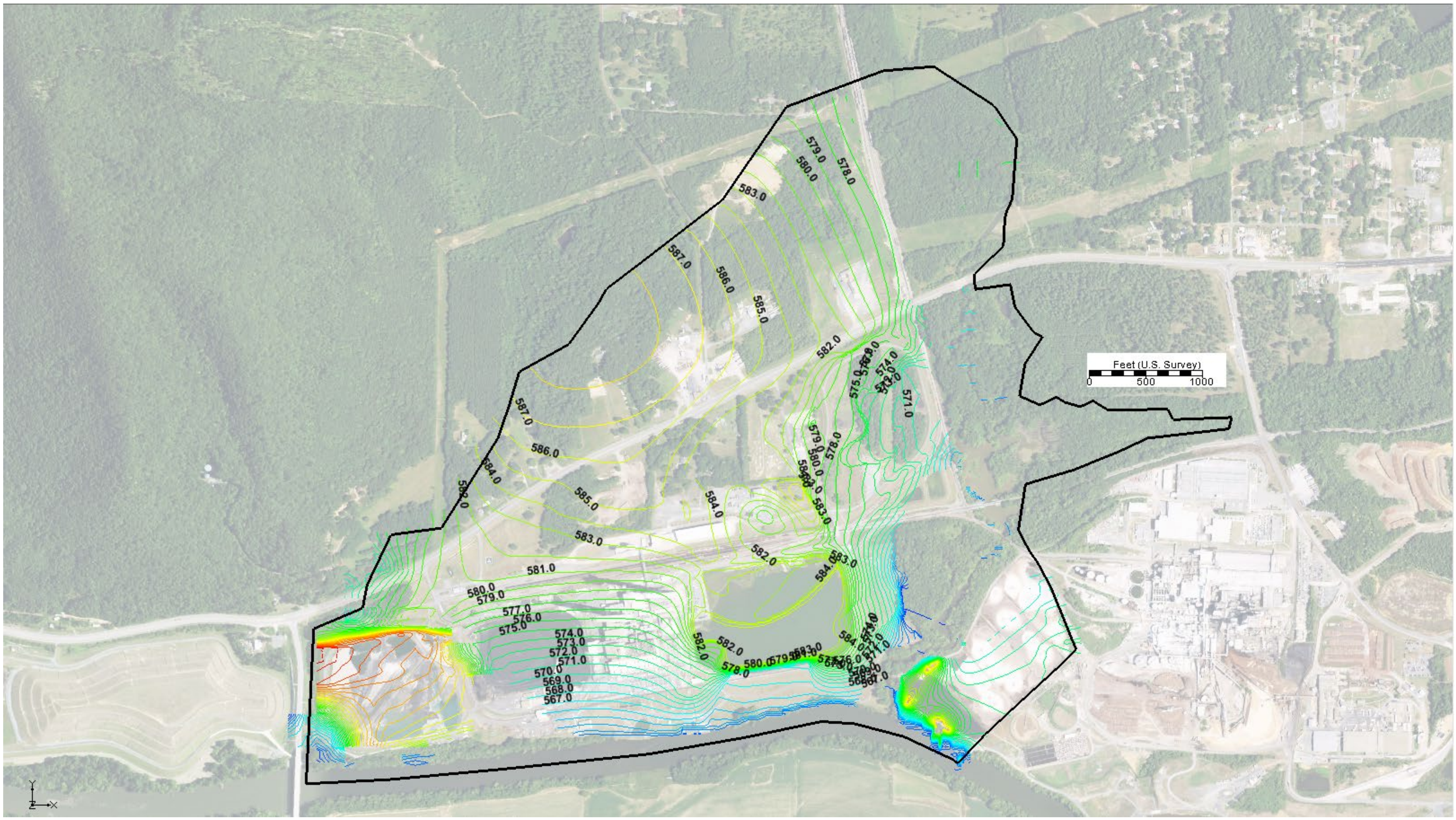

Figure 19: Modeled Groundwater Elevations for the Terrace Alluvium Material

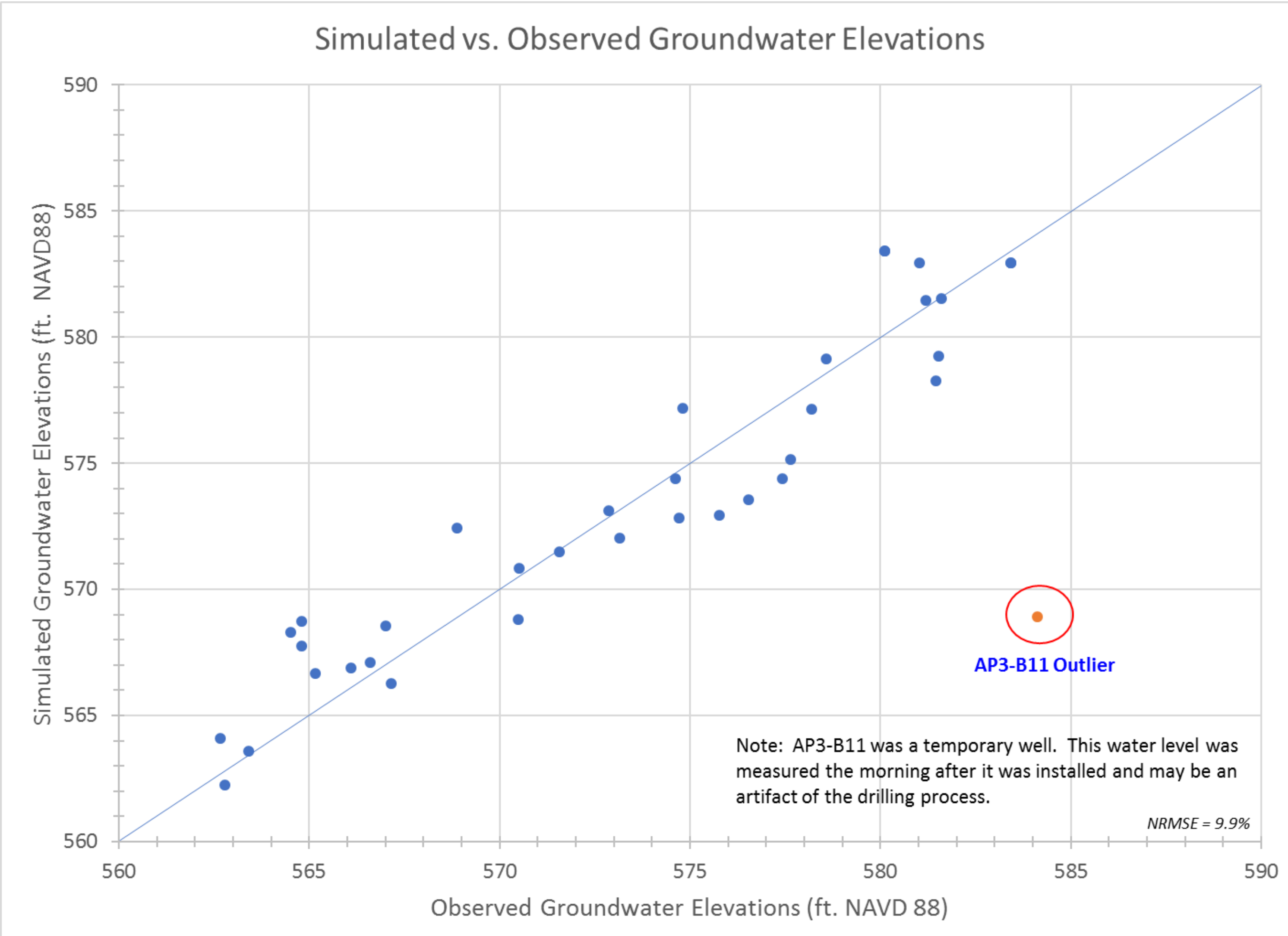

Figure 20: Simulated vs. Observed Groundwater Elevations

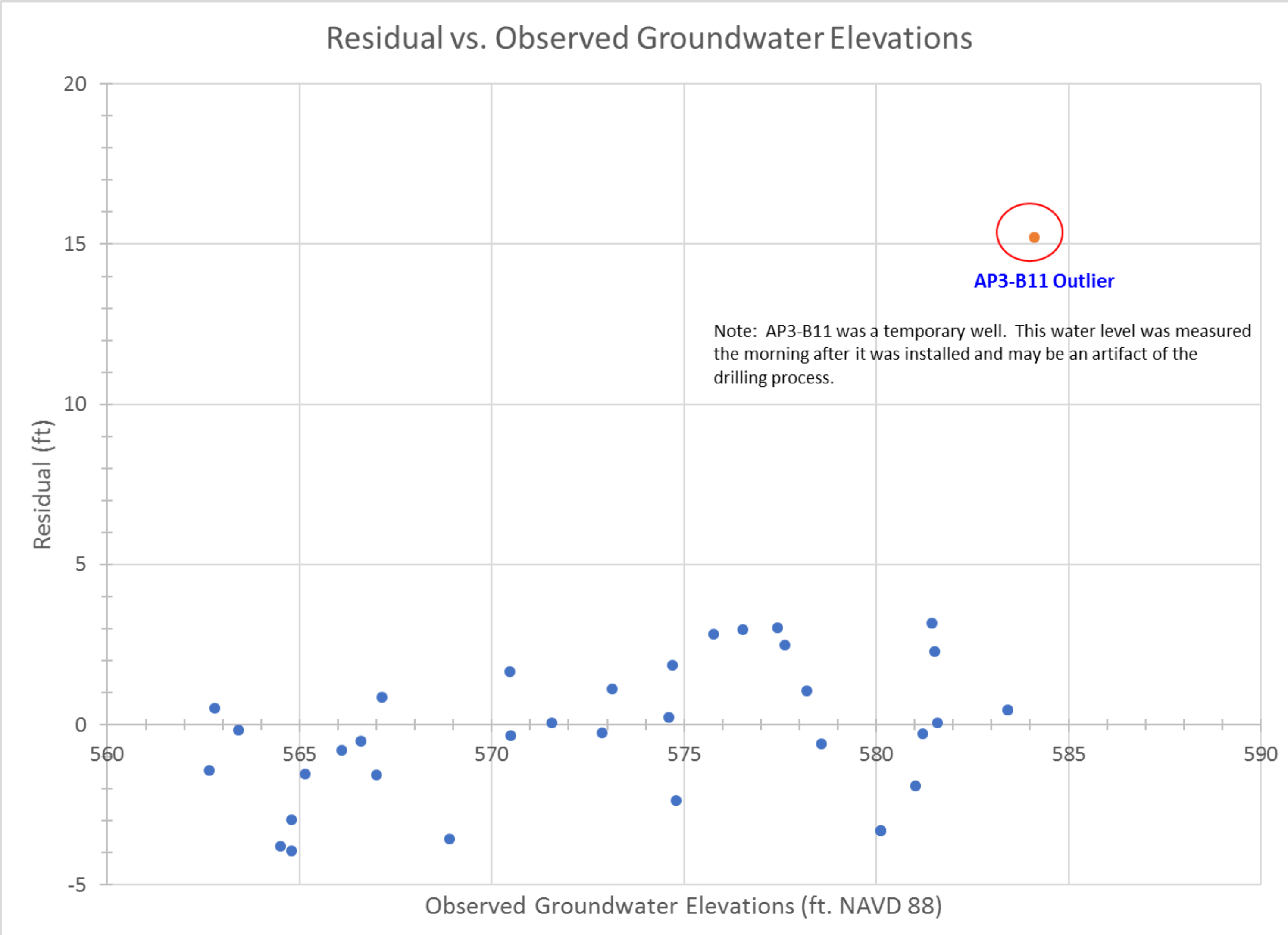

Figure 21: Residual vs. Observed Groundwater Elevations

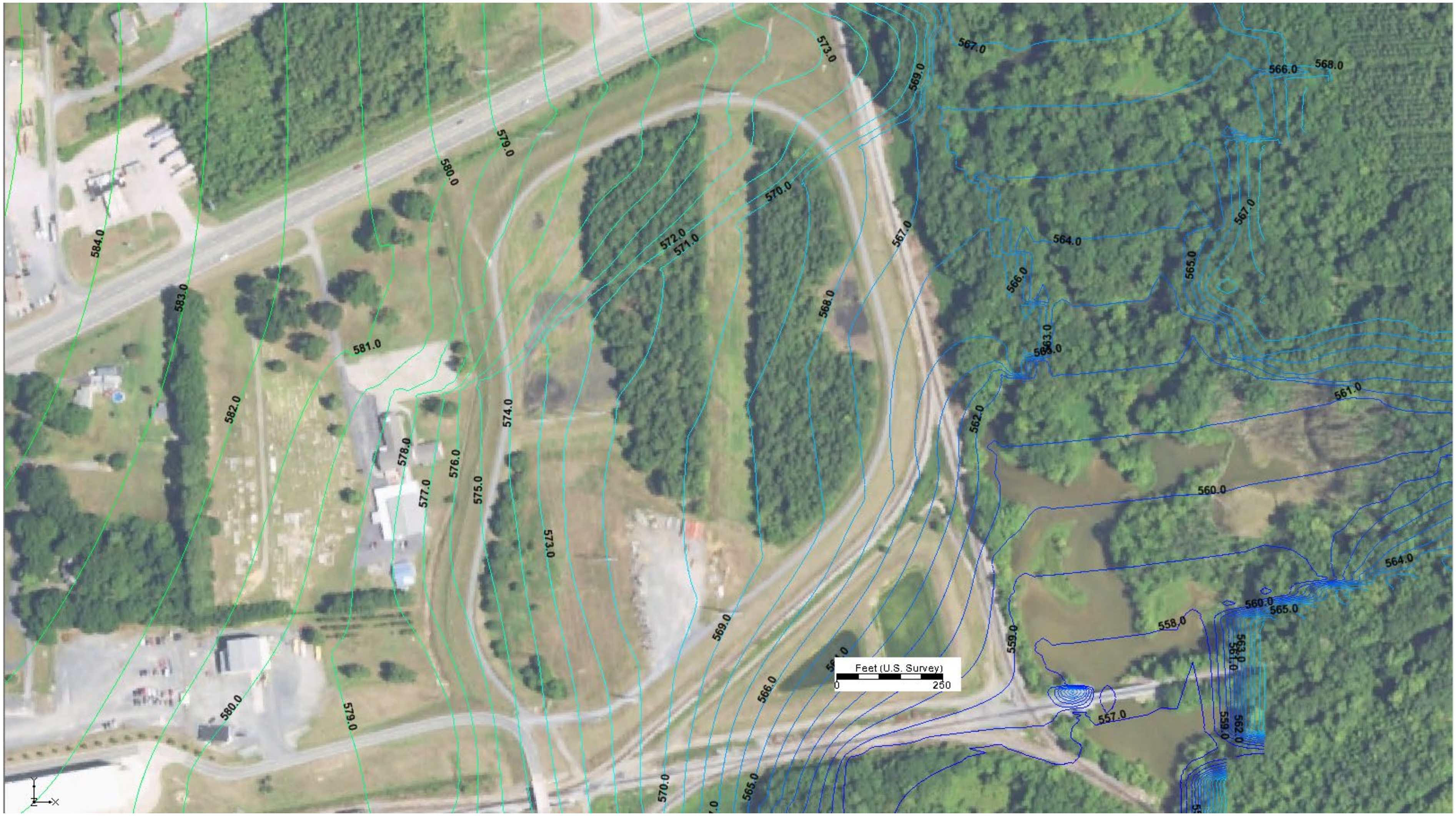

Figure 22: Scenario 1 – Model Predicted Groundwater Elevation Contour

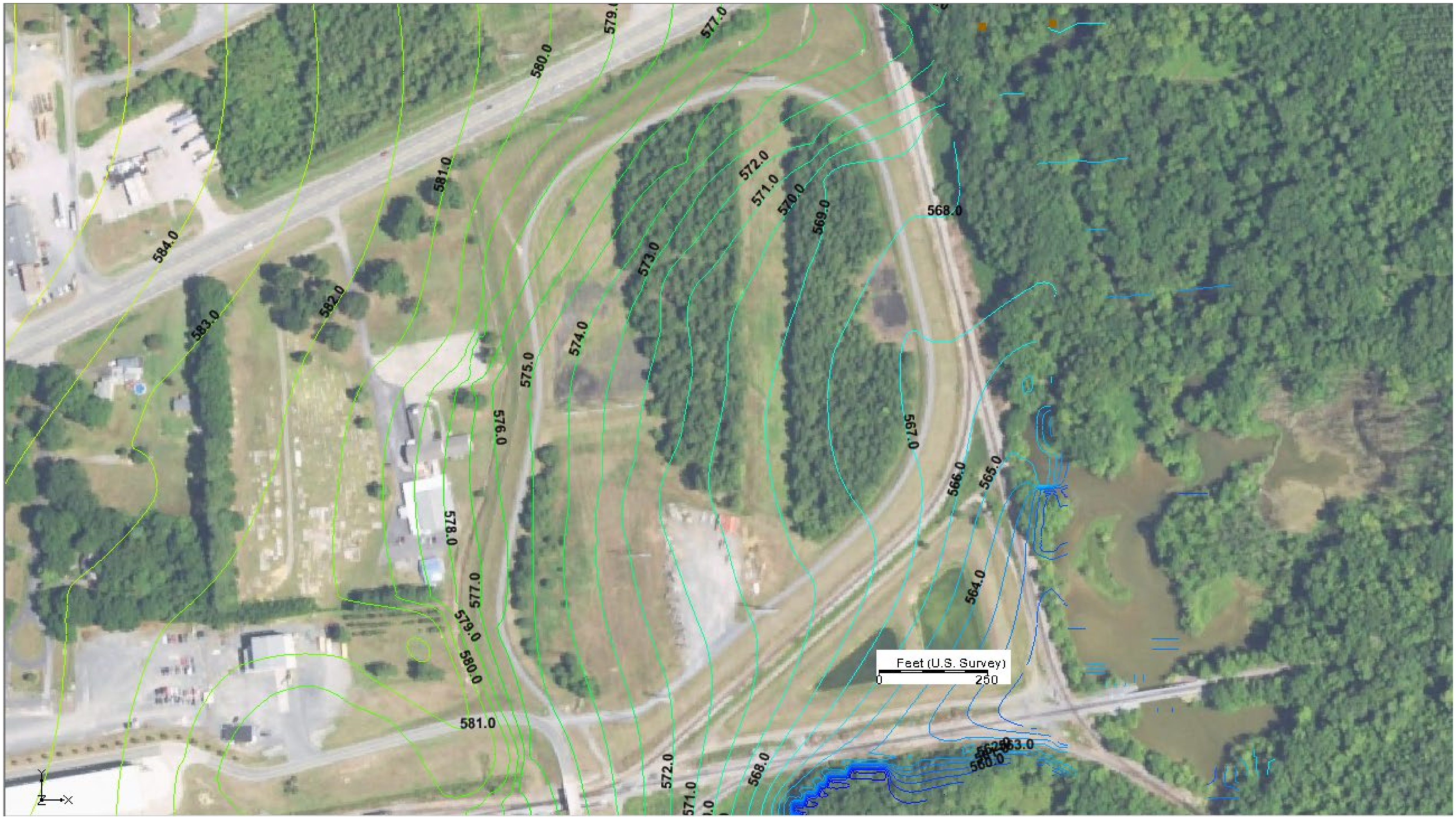

Figure 23: Scenario 2 – Model Predicted Groundwater Elevation Contour

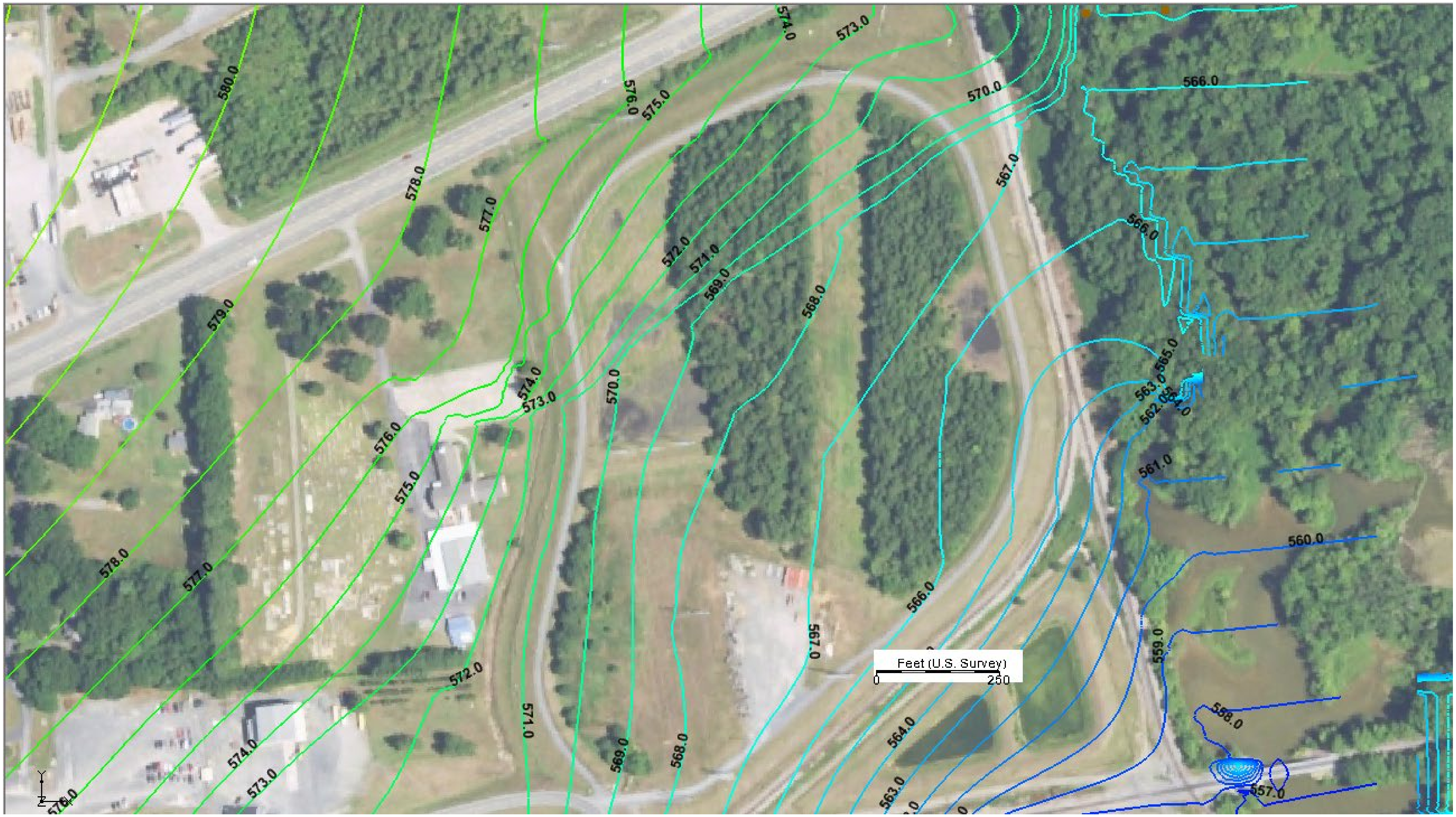

Figure 24: Scenario 3 – Model Predicted Groundwater Elevation Contour

APPENDIX B

Groundwater Model Calculation Package Addendum

Prepared for

Southern Company
241 Ralph McGill Blvd NE
Atlanta, Georgia 30308

GROUNDWATER MODEL CALCULATION PACKAGE ADDENDUM
PLANT HAMMOND ASH POND-3 (AP-3)

GEORGIA POWER COMPANY
Floyd County, Georgia

Submitted by

Geosyntec consultants

engineers | scientists | innovators

1255 Roberts Boulevard, Suite 200
Kennesaw, Georgia 30144

Project Number: GR6242
November 2020

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AEM	Advanced Engineering Method
AP	Ash Pond
CCR	Coal Combustion Residuals
CSM	Conceptual Site Model
ft	feet
Geosyntec	Geosyntec Consultants
Georgia Power	Georgia Power Company
gpd	gallons per day
SCS	Southern Company Services

1.0 INTRODUCTION

This *Groundwater Model Calculation Package Addendum* (Report) was prepared to document the results of an advanced engineering method (AEM) model scenario conducted for the groundwater flow conditions in the vicinity of Ash Pond 3 (AP-3 or Site) at the Georgia Power Company (Georgia Power) owned and operated Plant Hammond (the Plant) near Rome, GA. The AEM includes the use of *TreeWells*®. The hydrogeologic conceptual site model (CSM) and groundwater model construction and calibration were documented in the *Groundwater Model Calculation Package*, dated November 2019, and included in the *Hydrogeologic Assessment Report Revision 1*, prepared by Geosyntec Consultants (Geosyntec) and submitted to Georgia Environmental Protection Division in November 2019. This Report has been prepared by Geosyntec on behalf of Southern Company Services (SCS).

1.1 Model Objectives

The objective of the numerical groundwater flow modeling was to simulate the future conditions of groundwater near AP-3 relative to pre-closure conditions under the following scenarios:

- AP-3 closed and closure by removal of AP-1 (modeled by removing the constant head boundary conditions representing the historical pool from AP-1),
- the above conditions in conjunction with the AEM of an engineered *TreeWell* system.

The scenarios were evaluated with respect to (i) height of the potentiometric surface above the bottom of the AP-3 unit, (ii) volume of CCR below the potentiometric surface, (iii) percent reduction of CCR below the potentiometric surface relative to pre-closure conditions, (iv) the aerial extent of CCR below the potentiometric surface, (v) percent reduction in AP-3 groundwater flux, and (vi) simulated particle travel time to the permit boundary.

2.0 PREDICTIVE SIMULATIONS AND RESULTS

The calibrated groundwater model was used to predict groundwater conditions for three scenarios at steady state. These scenarios were as follows:

- Scenario 0: Pre-closure conditions with partial cover at AP-3 and AP-1 at historical pool elevation (585.09 ft, relative to North American Vertical Datum 1988, to represent the pool water level measured February 9, 2017);
- Scenario 1: Surface water improvement where AP-3 is capped by reducing recharge to zero over capped area and removing the constant head boundary conditions representing historical pool at AP-1[1]; and
- Scenario 2: 107 *TreeWells* screened in the highly fractured rock/fractured limestone and installed on the downgradient side of AP-3, each "pumping" at 40 gallons per day (gpd) per tree[2]. Modeled with the same boundary conditions as Scenario 1.

The results of the calibrated model for pre-closure conditions (Scenario 0), the post-closure conditions at AP-3 with removal of the historically present pool of AP-1 (Scenario 1), and the AEM *TreeWell* option (Scenario 2) are summarized in **Table 1**.[3] The table presents data to evaluate, per modeled scenario, (i) the maximum thickness and volume of CCR below the maximum predicted potentiometric surface; (ii) the percent reduction the calculated volume of CCR relative to pre-closure conditions; (iii) the amount of pumping modeled (specific to the *TreeWell scenario);* and (iv) the amount of time, as

---

[1] The modeled hydraulic conductivities for residuum and fly ash are closely similar (i.e., 2.2 x 10^{-4} centimeters per second (cm/sec) and 5.0 x 10^{-4}cm/sec, respectively). Therefore, the model layer cells beneath AP-1 were unchanged between Scenarios 0 and 1, as reclassifying or removing the cells would not constitute a fundamental change in the modeled results. The removal of the constant head boundary (representing removal of the free liquids from AP-1) resulted in the notable changes in hydraulic conditions at AP-3.

[2] This is based on commonly accepted estimates of evapotranspiration of approximately one million gallons per year per acre of full canopy forested land (McCutcheon and Schnoor, 2003), and a planting density of approximately 60 trees per acre. This results in an estimate of 45 gpd per tree, therefore a conservative estimate of 40 gpd per tree was used for the groundwater model.

[3] The modeled effects shown in this table are focused on conditions at or within the AP-3 permit boundary. Due to the location of the *TreeWell* field downgradient of AP-3 and the current permit boundary, additional beneficial effects of the *TreeWell* system, such as reduction in the potentiometric surface and in groundwater flux, may not be evident in these model results.

predicted by the groundwater model, it would take a conservative tracer (water particle) to travel from the location of the greatest thickness of CCR below the potentiometric surface to the AP-3 permit boundary[4]. Figure 1 provides a comparison of modeled potentiometric surfaces between Scenarios 0 and 2. Figures showing the particle tracking discussed above are shown on **Figures 2** and **3.**

Table 1 also presents a conservative measurement of reduction in AP-3 groundwater flux. The baseline value was the modeled flux of groundwater per day that flowed out of the bottom of the model cells representing the CCR below the potentiometric surface in Layer 1. The modeled groundwater flux from the bottom of model cells representing CCR below the potentiometric surface for each additional scenario was also extracted from the model and compared to the baseline flux to obtain the reported reduction in flux[5].

[4] Particle tracking requires the use of MODPATH which in turn requires the user to input values of porosity. The values used for AP-3 in the area under consideration are as follows: Ash 0.2 (EPRI, 2012), Residuum 0.1 (Domenico and Schwartz, 1990), Highly Fractured Limestone 0.3 (Baedke and Krothe, 2001).

[5] It should be noted that most of the groundwater exited the ash through the bottom of the cells and only a de minimis amount exited laterally.

3.0 REFERENCES

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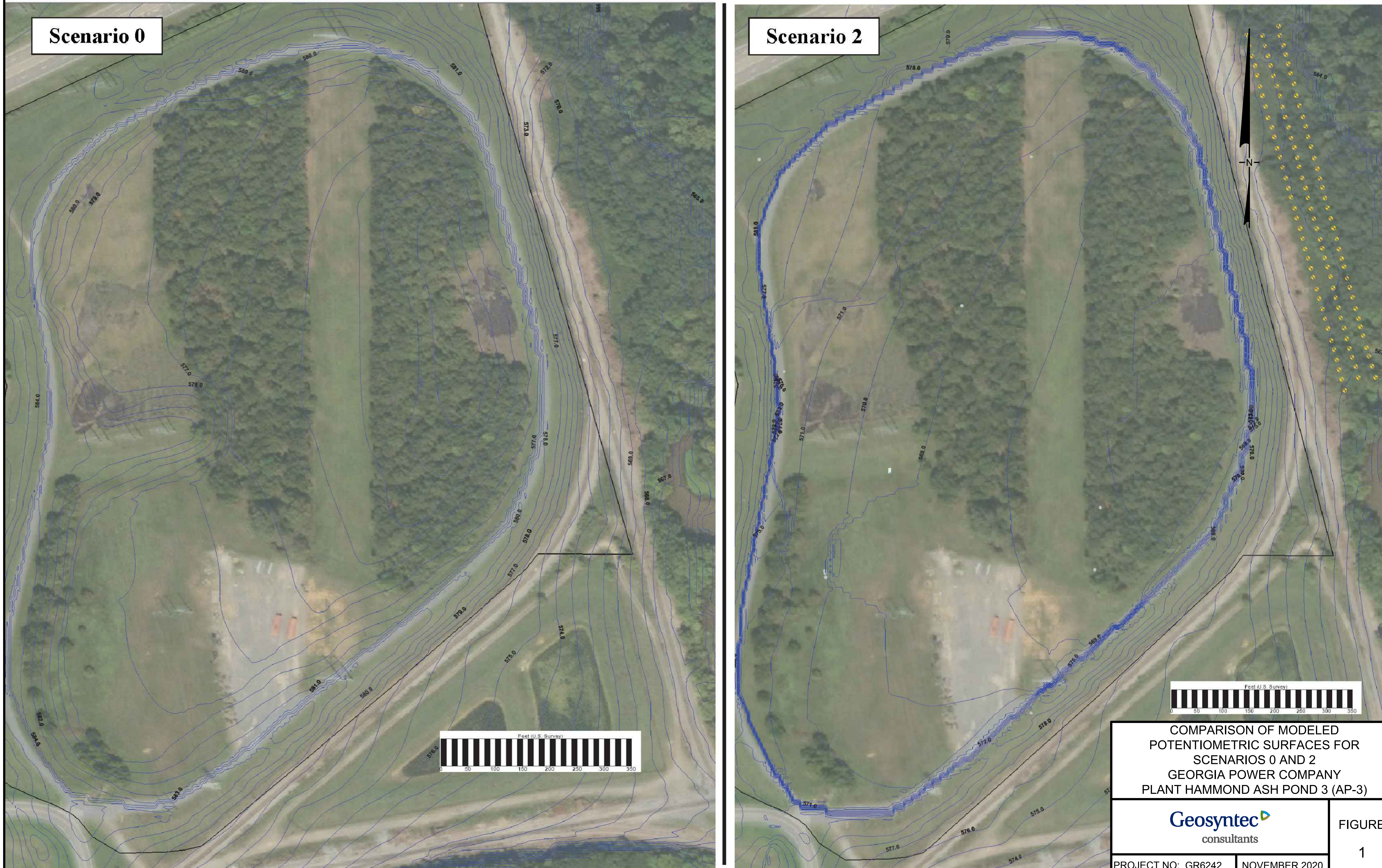
TABLE

Table 1
Summary of Modeling Results
Plant Hammond AP-3, Floyd County, Georgia

Scenario No.	AP-3 Conditions	AP-1 Pool Elevation	Enhancement	Description of Enhancement	Maximum Height of Potentiometric Surface Above Bottom of Unit (ft)	Volume of CCR Below Potentiometric Surface (CY)	% Reduction in Volume of CCR Below the Potentiometric Surface	Pumping Rate (gallons per minute)	% Reduction in Groundwater Flux	Time for Particles to Cross AP-3 Permit Boundary (years)
0	Partial Cover Installed	Historical Elevation	-	-	9.6	101,585	-	-	-	20
AP-3 Closure Conditions										
1	Cover installed	Removed	AP-1 Closure	Engineered cover at AP-3 Stormwater diverted away from AP-3 Eliminates hydraulic influence of historical AP-1 pool	3.7	8,657	91%	-	97.7%	>100
AEM Scenario										
2	Cover installed	Removed	TreeWells®	107 *TreeWells* Screened in HFR/Fractured Limestone and "Pumping" at 40 GPD/tree (collectively 3 gpm for the entire field)	3.7	8,143	92%	3.0	97.8%	>100

Notes:
1. These values were obtained from groundwater flow modeling results. It is noted that groundwater flow models are necessarily simplified mathematical representations of complex natural systems. Because of this, all groundwater models have limits to their accuracy.
2. These model results were intended for use as relative comparisons between scenarios and not as precise predictions of post-closure conditions.
3. Particle tracking represents a theoretical particle of water traveling by advection only and does not account for geochemistry, retardation, or diffusion.
4. Flux estimates were calculated in the model by the volume of water passing through the bottom of model cells in the CCR layer.

FIGURES



COMPARISON OF MODELED POTENTIOMETRIC SURFACES FOR SCENARIOS 0 AND 2
GEORGIA POWER COMPANY
PLANT HAMMOND ASH POND 3 (AP-3)

Geosyntec consultants

FIGURE 1
PROJECT NO: GR6242
NOVEMBER 2020

L:\CADD\GEORGIA POWER\PLANT HAMMOND GR6242\VOLUME\FIG 1 SCEN 2

PARTICLE TRACKING FOR SCENARIO 1
(AP-3 CAPPED, AP-1 CLOSURE)

GEORGIA POWER COMPANY
PLANT HAMMOND ASH POND 3 (AP-3)

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FIGURE 2

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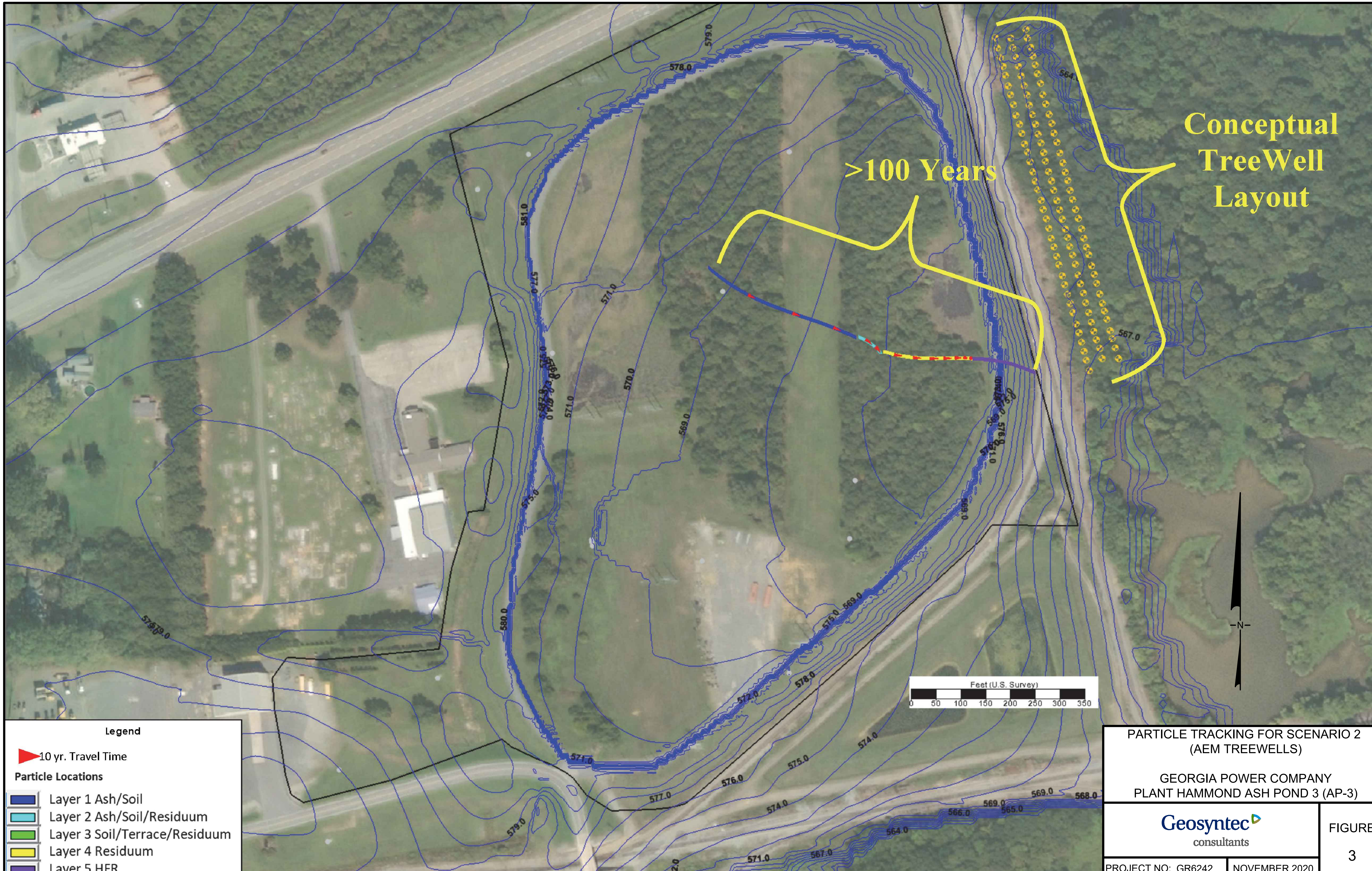

PARTICLE TRACKING FOR SCENARIO 2 (AEM TREEWELLS)

GEORGIA POWER COMPANY
PLANT HAMMOND ASH POND 3 (AP-3)

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FIGURE 3

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\\KEN-CADD\CADD\GEORGIA POWER\PLANT HAMMOND GR6242\VOLUME\FIG 6 SCEN 2