AECOM

Pilot Study Work Plan

Columbia Fuel Fabrication Facility
Hopkins, Richland County, South Carolina

Westinghouse Electric Company, LLC

Project Number: 60691645

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Acronyms

bgs	below ground surface
BRA	Baseline Risk Assessment
CA	Consent Agreement
CAD	computer-aided design
cDCE	cis-1,2-dichloroethene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cf	cubic feet
CFFF	Columbia Fuel Fabrication Facility
COC	chain-of-custody
COPCs	constituents of potential concern
CSM	Conceptual Site Model
CVOCs	chlorinated volatile organic compounds
DCGL	derived concentration guidance level
DI	de-ionized
DO	dissolved oxygen
DPT	direct push technology
ERD	enhanced reductive dechlorination
ERD+ZVI	Enhanced reductive dechlorination supplemented with zero-valent iron
EPA	United States Environmental Protection Agency
eZVI	Ferox Plus Emulsified Zero Valent Iron
FS	Feasibility Study
ft	feet
gals	gallons
GEL	GEL Laboratories LLC
Geo Lab	Geo Lab Drilling
GPR	ground penetrating radar
Hepure	Hepure Technologies, LLC.
HF	hydrofluoric acid
HSA	hollow-stem auger
IDW	investigation derived waste
ISCR	in-situ chemical reduction
LEAF	Leaching Environmental Assessment Framework
MCL	maximum contaminant level
mrem/yr	millirem per year
MS	matrix spike
MSD	matrix spike duplicate
NRC	Nuclear Regulatory Commission
NTU	nephelometric turbidity units
ORP	oxidation reduction potential
OU	operable unit
PCE	tetrachloroethene
PPE	personal protective equipment
PSI	pounds per square inch
PRB	permeable reactive barrier
QA	quality assurance
QC	quality control
RAO	Remedial Action Objective
RG	Remedial Goal
RI	Remedial Investigation
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SC	South Carolina
SCDES	South Carolina Department of Environmental Services
SDS	safety data sheets

Sf	square feet
SNM	special nuclear material
SOF	sum of fractions
SOP	standard operating procedure
SU	standard units
S-MZVI	sulfidated micro-scale ZVI
TCE	trichloroethene
Tc-99	technetium-99
U +IV	tetravalent uranium
U +VI	hexavalent uranium
ug/L	micrograms per liter
UIC	underground injection control
VC	vinyl chloride
Westinghouse	Westinghouse Electric Company, LLC
WL II	West Lagoon II
WWTP	wastewater treatment plant
ZVI	zero-valent iron

1. Introduction

The Westinghouse Electric Company, LLC (Westinghouse) Columbia Fuel Fabrication Facility (CFFF) is located at 5801 Bluff Road (site or property) in Hopkins, approximately 15 miles southeast of Columbia, South Carolina (SC, **Figure 1**). The site includes approximately 1,151 acres, with the operational area encompassing approximately 75 acres centrally located, thereby creating substantial buffers from adjoining properties. The property is primarily surrounded by rural forested and agricultural property with some low-density residential development. CFFF was opened in 1969 and manufactures fuel assemblies and components for the commercial nuclear power industry. Site features are shown on **Figure 2**.

The South Carolina Department of Environmental Services (SCDES) and CFFF entered into a Consent Agreement (CA) on February 26, 2019. The CA requires Westinghouse to comprehensively assess potential environmental impacts from current and historical operations at the CFFF by following the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) process. The CERCLA process requires the following incremental steps: Remedial Investigation (RI), Feasibility Study (FS), Record of Decision (ROD), Remedial Design/Remedial Action, and Remedial Action Completion.

RI activities were conducted from June 2019 through October 2021. The *Final Remedial Investigation Report* (AECOM, 2023) was submitted to SCDES in February 2023. The results of the RI confirm the presence of constituents of potential concern (COPCs) in environmental media including soil, groundwater, sediment, and surface water. The COPCs identified in one or more media included chlorinated volatile organic compounds (CVOCs), nitrate, fluoride, technetium-99 (Tc-99), and uranium. The RI did not identify any sources of ongoing impacts. The identified impacts were limited to these media, and the extent of impact in each media is within the facility property boundary with no identified mechanism for future migration offsite. Additionally, the Baseline Risk Assessment (BRA) conducted as part of the RI indicated that the identified impacts posed no unacceptable risk to human health or the environment.

Based on the results of the RI, the following was recommended: 1) Conduct an FS to assess appropriate cleanup options for CFFF and 2) Develop a groundwater fate and transport model to predict when COPCs in groundwater will attenuate and/or remain in a steady state condition. Additional details can be found in the *Final Remediation Investigation Report* (AECOM, 2023).

On August 1, 2024, SCDES, Westinghouse, and AECOM met virtually to present and discuss the progress of the CFFF FS. During the meeting, AECOM presented the list of considered remedial technologies and the screening processes used to retain technologies for further evaluation. AECOM also presented the list of remedial alternatives being evaluated in the FS, which were developed using the remedial technologies retained from the screening process. During the meeting, the SCDES indicated that certain retained remedial technologies should be confirmed to be effective at the site prior to inclusion in the final alternative. This could prevent a circumstance in which the ROD included a technology that turns out to be ineffective at the site. Therefore, pilot testing was deemed necessary to assess the effectiveness of the remedial technologies and eliminate an inadequate technology from consideration for the ROD. The SCDES also directed that the pilot testing be completed prior to the submittal of the FS Report.

As a result, the initial schedule as presented in the FS Work Plan, submitted to the SCDES in July 2023, no longer applies. A notification letter (LTR-RAC-24-48) was submitted to the SCDES on September 19, 2024 (Westinghouse, 2024), to request permission to conduct pilot studies, defer the submittal of the FS, and submit this Work Plan by January 30, 2025. This request was approved by SCDES on September 20, 2024.

Additional activities resulting from the August 1, 2024 SCDES meeting include the pilot test work plan, bench-scale treatability testing, and pilot test work plan implementation. This document presents the pilot test work plan for the following remedial technologies and their target COPC:

- Enhanced reductive dechlorination supplemented with zero-valent iron (ERD+ZVI) for CVOCs;
- ZVI for Tc-99; and
- ZVI for uranium.

This Pilot Study Work Plan and the FS reference the data collected during the RI as the standard for conditions at the site, unless noted otherwise. However, all applicable and relevant information collected since the RI is considered and evaluated as it becomes available.

2. Regulatory Framework

CFFF is regulated by the Nuclear Regulatory Commission (NRC) and SCDES. The NRC regulates radiological safety and decommissioning in accordance with NRC regulations and special nuclear material (SNM) license SNM-1107. In accordance with SNM-1107, CFFF has set aside closure funding to remove radiologically impacted environmental media when the facility is decommissioned (Westinghouse, 2022). SCDES has the authority to require Westinghouse to investigate and clean up any historical radiologic or non-radiologic releases to the environment.

3. Site Description, Background, and Physical Setting

3.1 Facility Description and Operational Background

Figures 1 through 3 illustrate the site features discussed below. The CFFF property is located on Bluff Road (SC Highway 48), approximately 15 miles southeast of Columbia, SC, and includes approximately 1,151 acres as identified by Richland County Tax Map Series numbers 18600-01-01 and 18601-01-02. The property is surrounded by rural forested and agricultural properties with some residential properties located north and east of the site.

The primary plant building is located approximately 2,700 feet (ft) southwest of Bluff Road on the northern portion of the property, with the wastewater treatment plant (WWTP) located near the southwest corner of the plant building. Treated wastewater is piped to the Congaree River approximately 3 miles south of the property boundary, where it is discharged under National Pollutant Discharge Elimination System permit SC0001848. A 30 to 40 ft bluff separates the northern, partially developed portion of the property from the southern floodplain portion of the property. Notable features in the floodplain include Mill Creek (including Upper and Lower Sunset Lakes, **Figure 2**), a man-made canal, and man-made stormwater ditches. **Figure 3** presents a site map including the location of all monitoring wells associated with the project.

Westinghouse purchased the property in 1968, and construction of the CFFF was completed in 1969. Prior to construction, the property consisted of farmland and woodlands. The main manufacturing activity is the fabrication of low-enriched uranium fuel assemblies and components for the commercial nuclear power industry. The manufacturing process generates multiple wastewater streams, which are treated by various physical, chemical, and biological processes prior to discharge to the Congaree River.

CFFF has been divided into eight operable units (OUs) in recognition of the different types of site activities and potential sources of impact. The OUs are identified as the Northern Storage Area, Mechanical Area (of the plant building), Chemical Area (of the plant building), West Lagoons Area, Wastewater Treatment Area, Sanitary Lagoon Area, Southern Storage Area, and Western Storage Area. The OUs are depicted on **Figure 4** and are described in detail in the *Final Remedial Investigation Work Plan* (AECOM, 2019).

Releases of COPCs have occurred from the WWTP and manufacturing operations. CFFF has assessed known releases, installed an extensive groundwater monitoring network (beginning in the early 1980s), and initiated various remediation efforts in response to historic events. An additional comprehensive site assessment of groundwater, surface water, sediment, and soils has been performed from 2019 to 2021 under the CA. These assessment activities have determined that environmental impacts from historical operations are largely confined to the immediate plant area and there are no offsite impacts. Additional facility background and operational information is included in the *Final Remedial Investigation Report* (AECOM, 2023).

3.2 Historical Investigations

As mentioned above, previous environmental investigations were performed from 1980 to 2019. Summaries of and excerpts from the investigation reports are included in the *Final Remedial Investigation Report* (AECOM, 2023).

3.3 Historical Remediation Activities

Environmental remediation activities were performed beginning in 1998. Summaries of and excerpts from remediation activities are included in the *Final Remedial Investigation Report* (AECOM, 2023).

3.4 Site Geology

CFFF is located within the Upper Coastal Plain physiographic province of SC. The SC Coastal Plain is a southeasterly thickening wedge of sediment overlying the bedrock of the North American craton. Thicknesses of this wedge of sediment range from zero ft at the Fall Line (the furthest transgression of the ocean along the southeastern US coast readily evident in the geologic record) to over 3,500 ft in southeastern SC (Colquhoun, et al., 1983). The Upper Coastal Plain of SC lies between the Fall Line near Columbia to the northeast and the Orangeburg Scarp to the southwest.

Sediments north of CFFF are a series of northwest to southeast trending, Tertiary aged river terraces (fluvial depositional environment), with the oldest Pliocene Epoch (5.33 million to 2.58 million years ago) sediments being located south of the boundary of the Fort Jackson Army base. Sediments comprising the vadose zone and surficial aquifer of the property are a Quaternary Age, Pleistocene Epoch (2.58 million to 11,700 years ago) river terrace. In contrast, the sediment in the floodplain portion of the site was deposited during the late Pleistocene Epoch (130,000 to 11,700 years ago) to Holocene Epoch (11,700 years ago to present day). The river terrace and floodplain sediment were deposited by the Congaree River, which is located approximately three miles south-southwest of the southern property boundary.

Surficial aquifer sediments generally occur to a depth of 30 to 40 ft below ground surface (bgs) at the site, depending on topography, and can be differentiated into overbank deposits consisting of clayey silt, clayey sand, silt, sandy silt to silty sand (approximately 8 to 10 ft thick) and a coarsening downward sand (approximately 20 to 30 ft thick) river channel deposit. Silt and clay lenses and lower permeability silty or clayey sands occur at varying depths within the coarsening downward sands of the surficial aquifer. Geologic cross-sections depicting site lithologies are included in the *Final Remedial Investigation Report* (AECOM, 2023).

Sediments of the surficial aquifer unconformably overlie the Upper Cretaceous, late Campanian Age sediments (83.6 million to 72.1 million years ago, a gap of approximately 70 million years) comprising the Black Creek Formation (Nystrom, Jr. et al., 1991). The upper portion of the Black Creek Formation beneath the site is a confining bed composed of dry silt/clay and brittle shale that is encountered throughout the site. This confining clay varies in thickness from 38 to 83 ft based on data gathered during the installation of the four Black Creek Aquifer wells (W-3A, W-49, W-50, and W-71). The elevation of the top of the Black Creek confining clay is undulating but is generally highest west of the plant building in the operational portion of the property and decreases radially in all directions, with the lowest elevations being within the floodplain. The surface of this clay is undulating due to the amount of time that this formation was exposed to precipitation and subsequent erosion. Beneath the clay confining unit is a sand aquifer within the lower Black Creek Formation known as the Black Creek Aquifer, which is artesian in some areas of SC. These sediments were deposited in an upper delta plain, fluvial environment. Beneath the Black Creek Aquifer is the Middendorf Aquifer, which unconformably overlies the crystalline bedrock of the North American craton.

3.5 Site Hydrogeology

CFFF is underlain by three hydrogeologic units: the surficial aquifer, the Black Creek Aquifer, and the Middendorf Aquifer. The predominant direction of groundwater flow in the surficial aquifer is to the southwest with flow components to the west and south. The inferred groundwater flow direction in the Black Creek Aquifer is to the southwest. **Figures 5**, **6**, and **7** illustrate the locations of monitoring wells at the site and groundwater elevation contour (potentiometric) maps for the surficial aquifer – upper zone, surficial aquifer – lower zone, and the Black Creek Aquifer, respectively, for October 2024. Wells installed on top of or within five ft of the Black Creek confining clay are designated as surficial aquifer - lower zone monitoring wells with the rest of the surficial aquifer comprising the upper zone.

Groundwater velocity was calculated using Darcy's Law which incorporates hydraulic gradient, hydraulic conductivity and effective porosity. Using an assumed effective porosity of 30 percent (0.30), the average hydraulic gradient, and the average hydraulic conductivity, a groundwater flow velocity for the surficial aquifer at CFFF of 150 ft per year was calculated. Additional details for the groundwater flow calculations are provided in the *Final Remedial Investigation Report* (AECOM, 2023).

Although groundwater flow velocities above the bluff and down the bluff are calculated to be higher than those in the floodplain, the slower groundwater flow velocity in the floodplain inhibits groundwater in a connected aquifer system from flowing faster than the slowest portion of the aquifer. Slower groundwater flow rates in the floodplain cause groundwater from above the bluff and down the bluff to push against slower moving groundwater in the floodplain. Therefore, groundwater flow velocities in the floodplain limit the overall flow rate in the surficial aquifer.

3.6 Site Ecology

The *Baseline Risk Assessment* (AECOM, 2022) documents that the site is comprised of two main ecological communities: 1) a maintained, herbaceous community within the developed area of the facility and 2) a swamp community associated with the Congaree River floodplain. There are extensive areas for planted pines to the north, south, east, and west of these communities.

Vegetation within the developed area includes various grasses, rushes, sedges, and ruderal, weedy herbs. The herbaceous community within the developed area is limited in height due to periodic mowing, which prevents the growth of shrubs or trees. Because this site maintenance limits the flora and the industrial use of the property, the fauna of this community is expected to be limited. Terrestrial wildlife that may use this area includes but is not limited to rodents, birds, reptiles, and amphibians. Wild boar, whitetail deer, fox, bobcat, and other animals that reside in the planted pines or swamp community may periodically visit this area to feed. Aquatic wildlife that may occur within the ditches includes but is not limited to minnows, tadpoles, and insects.

The swamp community within the property extends along Mill Creek and includes densely forested wetlands, bottomland hardwood forests, and the open waters of Lower Sunset Lake and the Gator Pond. The forest canopy within Mill Creek is dominated by tupelo but also includes cypress, whereas the upland portions are dominated by pine, maple, and oak. Periodic flooding of this area deposits nutrient rich sediment across the entire community. Due to this, there is an abundance of flora within the floodplain, and this area is highly suitable for its former use as farmland. Subsequently, this area hosts a wide variety of birds, mammals, reptiles, amphibians and obligately aquatic animals such as fish, tadpoles, crayfish, and insects.

There are five federal and five state species listed as threatened and endangered within Richland County based on information from the SC Heritage Trust website in conjunction with the SC Department of Natural Resources. None of the federally or state-listed species known to occur in Richland County have been observed at the CFFF property. Based on the known ranges and the habitat requirements of these species, their occurrence on or adjacent to the facility is unlikely except for two species that have a moderate potential for occurrence. These species are the Rafinesque’s big-eared bat and the spotted turtle.

4. Conceptual Site Model

This Conceptual Site Model (CSM) was previously developed in the *Final Remedial Investigation Report* (AECOM, 2023). The pilot studies described in this work plan will be evaluating technologies which involve treatment of COPCs in groundwater. For this purpose, the CSM has been summarized in the following sections to include only relevant information pertaining to groundwater at the site.

4.1 Summary

The shallow subsurface of CFFF consists of overbank deposits underlain by coarsening downward sand comprising the surficial aquifer both above and below the bluff, thereby forming one continuous surficial aquifer with differing ages of deposition. These sediments were deposited by the Congaree River, which is currently located approximately 3 miles southwest of the site. The Black Creek Aquifer confining clay underlies the coarsening downwards sands across the entire site.

Groundwater beneath the site generally flows to the south-southwest with components of flow to the west, south, and southeast. Groundwater near West Lagoon II (WL II) flows both north and south in the lower zone of the surficial aquifer due to a hydraulic barrier created by a ridge in the confining clay and lower than typical permeability of the aquifer sands. Historical releases in the operational areas of CFFF impacted groundwater, but the vadose zone sources of these impacts are either so depleted that they no longer can impact groundwater or are in inaccessible areas of the site (e.g., beneath the plant building). Inaccessible vadose zone sources for groundwater impact will be removed during the future decommissioning of CFFF. The on-site groundwater impacts that are the subject of this Pilot Study are confined to the surficial aquifer only.

Within the operating area of the facility, stormwater drains from the site via the Eastern Ditch and the Middle Ditch, which converges with the Eastern Ditch southwest of the Sanitary Lagoon. From there, drainage traverses a deeply incised section of the Eastern Ditch, eventually discharging to Upper Sunset Lake (part of Mill Creek) south of the bluff. In the deeply incised section of the Eastern Ditch, groundwater is understood to discharge to surface water in the vicinity of MW-41, resulting in exceedances of the tetrachloroethene (PCE) maximum contaminant level (MCL) in surface water.

The Gator Pond and Mill Creek deflect the transport of COPCs in groundwater. The Gator Pond receives discharge of COPC impacted groundwater, particularly fluoride, in the northeastern portion of the pond with the remainder of the pond recharging the surficial aquifer with surface water due to its excavation into the permeable subsurface sands. The near constant head in the Gator Pond causes most of the groundwater flowing in its vicinity to migrate around it to the east or the west due to groundwater mounding.

Mill Creek is lined with a low permeability clayey silt that acts as an aquitard to the communication between surface water and groundwater. Impoundment of Mill Creek has resulted in the surface water elevation being consistently above that of the water table upstream of the Lower Sunset Lake Dike. The surface water that seeps through the aquitard may cause minimal groundwater mounding beneath Mill Creek (Upper and Lower Sunset Lakes), which locally deflects groundwater migration to the east.

Below the Lower Sunset Lake Dike, Mill Creek is not impounded. The aquitard underlying Mill Creek would inhibit, if not prevent, discharge of groundwater to Mill Creek if/when the groundwater elevation is higher than surface water and vice versa. Because the canal was excavated, the surface water in the canal is in direct contact with the surficial aquifer. Groundwater discharges to the canal when its elevation is higher than the surface water in the canal and vice versa.

The hydraulic gradient in the floodplain is much lower than the hydraulic gradient above the bluff. This inhibits the overall rate of groundwater flow and may increase the deflection effect of COPC transport in the area north of Lower Sunset Lake.

Impacted groundwater will remain within the property boundary as a result of:

- the slow groundwater flow velocity in the floodplain,
- the groundwater fate and transport properties of the COPCs, such as diffusion, adsorption, and advection,

- the natural breakdown of CVOCs in the floodplain, and
- the distance to the closest property boundary.

4.2 Groundwater COPCs

The lateral extent of groundwater impacts for the COPCs exceeding their respective MCLs at CFFF, as delineated in the RI, are illustrated in **Figure 8** for reference in the following sections.

4.2.1 Chlorinated Volatile Organic Compounds

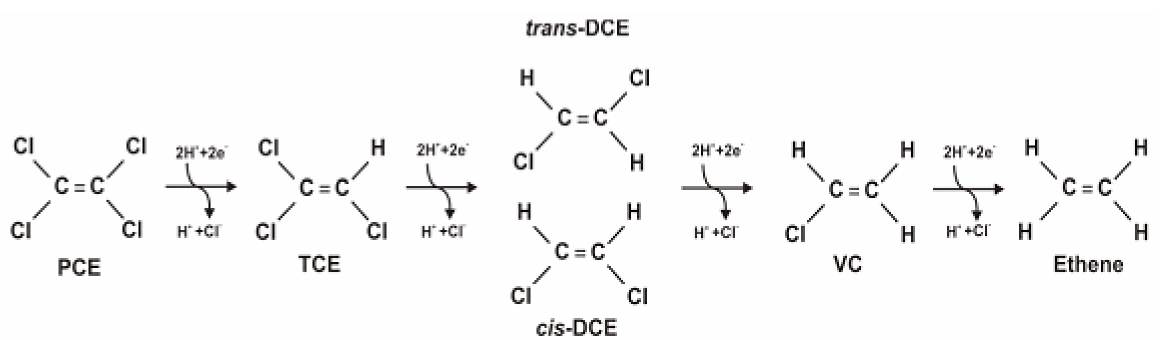
The RI fully delineated the extent of PCE in groundwater in the surficial aquifer and documented that there were no residual sources of CVOCs identified in soil that could impact groundwater in the future. Additionally, PCE was eliminated from use at the facility in 2020, so future releases are not expected.

As described in the RI, there are two PCE plumes in the upper zone of the surficial aquifer, referred to as the main and southern plumes. The main plume is the only PCE plume in the surficial aquifer – lower zone. The main PCE plume in the surficial aquifer – upper and lower zones is located within an area between WLII and the plant building and extends to areas west, southwest, and south-southeast (lower zone only). The main PCE plume appears to have originated in the Western Storage Area OU between WLII and the plant building. The highest concentrations of PCE have consistently been detected in groundwater from well pair W-65 and W-66 (**Figure 3**) with detections ranging from 200 to 810 micrograms per liter (ug/L) since January 2019.

The western lobe of the main plume extends to an area beneath Upper Sunset Lake. The middle lobe of the main plume in the surficial aquifer – lower zone is located closer to the developed area of the site and initially flows southwest before turning south and extends to Upper Sunset Lake near the Upper Sunset Lake Dike. The eastern lobe of the main plume extends from the area of the southwestern corner of the plant building to the south-southeast into the floodplain.

The southern PCE plume in the surficial aquifer – upper zone is located from the southern extent of the developed area at the bluff and extends to the southeast below the bluff, barely into the floodplain near monitoring well W-97. It is believed that the PCE in the southern plume in the surficial aquifer - upper zone near the bluff may be part of the PCE plume in the surficial aquifer – lower zone, rather than the result of a source in the southern area of the plant near the bluff since PCE was not formerly used in the vicinity of these wells.

Chlorinated ethenes such as PCE can undergo biotic (biological) and abiotic (physical) transformations under both aerobic and anaerobic conditions. Natural, biotic degradation of PCE to produce daughter products at CFFF follows the reductive dechlorination pathway. This pathway is as follows:



(Source: Parsons Corporation, 2004)

Exceedances of the MCL of trichloroethene (TCE) exist within the PCE plume and is understood to represent reductive dechlorination PCE rather than a plume from a different source. cis-1,2-Dichloroethylene (cDCE) concentrations have been detected at CFFF, but there have been no exceedances of the MCL for this compound. Vinyl chloride (VC) has been detected above the MCL in groundwater from two monitoring wells (W-95 and W-107) south of Upper and Lower Sunset Lake. Neither PCE nor TCE were present in the groundwater from these wells indicating that reductive dechlorination to cDCE and VC occurred naturally while the groundwater flowed beneath these surface water bodies.

Currently, the VC plume is contained within the CFFF property boundary and, in the downgradient direction, is approximately 2,100 ft from the southern CFFF property boundary.

4.2.2 Nitrate

The primary sources of the nitrate plume exceeding the MCL in the surficial aquifer is the Wastewater Treatment Area and WL II. As shown on **Figure 8**, the aerial extent of the nitrate plume extends to areas to the southwest and southeast from these source areas. Nitrate concentrations exceeding the MCL are in monitoring wells above the bluff. Detected concentrations below the bluff are significantly lower than the MCL. Nitrate concentrations in groundwater from wells south of Upper Sunset Lake and Lower Sunset Lake are one to two orders of magnitude below the MCL. The lateral extent of nitrate MCL exceedances is contained within the CFFF property boundary and, in the downgradient direction, is approximately 2,800 ft from the southern CFFF property boundary.

4.2.3 Fluoride

The fluoride plume exceeding the MCL in the surficial aquifer is primarily south of the plant building and in the vicinity of the WWTP as shown on **Figure 8**. The greatest fluoride concentrations have been detected in the groundwater from the surficial aquifer - upper zone wells located at the south end of the plant building (W-77 and W-78) and downgradient in well pair W13R and W-123 (**Figure 3**). Concentrations of fluoride above the MCL are also detected south of the WWTP, but at lesser concentrations.

The potential sources for fluoride are the WWTP and the plant area north of well W-77, including uranium hexafluoride storage areas and operations and the hydrofluoric acid (HF) Spiking Stations 1 and 2 in the Chemical Storage Area OU. The lateral extent of fluoride MCL exceedances is contained within the CFFF property boundary and, in the downgradient direction, is approximately 2,900 ft from the southern CFFF property boundary.

4.2.4 Uranium

As shown on **Figure 8**, the uranium plume exceeding the MCL in the surficial aquifer is localized to two areas adjacent to the plant building. The northern plume, located on the west side of the building near the southwest corner, includes monitoring wells W-55 and W-56 and the southern plume, on the south side of the building, includes monitoring well W-77. The greatest total uranium concentration in groundwater is currently detected in surficial aquifer - upper zone well W-56. Both uranium groundwater plumes are localized near the plant building and are delineated by the existing monitoring well network.

The potential sources for the northern and southern uranium plumes are historical 2008/2011 underground line breaches, solvent extraction operations, and the plant area north of well W-77, which includes uranyl nitrate storage and off-loading, uranium hexafluoride storage areas, and the HF Spiking Stations 1 and 2.

4.2.5 Technetium-99

As shown on **Figure 8**, the Tc-99 plume exceeding the MCL in the surficial aquifer is to the south of the WWTP lagoons within the Wastewater Treatment Area and extends to the southwest into the Southern Storage Area. Only groundwater from the surficial aquifer – lower zone monitoring wells W-6 and W-11 (**Figure 3**) have historically exceeded Tc-99's MCL.

The source of the Tc-99 plume is believed to be historic releases that occurred within the Wastewater Treatment Area and Chemical Area OUs. As stated in the RI, current site operations do not have the potential to introduce significant quantities of Tc-99 into the environment. The Tc-99 plume is contained within the CFFF property boundary and, in the downgradient direction, is approximately 3,200 ft from the southern CFFF property boundary.

5. Feasibility Study

As discussed in **Section 1.0,** an FS is currently being performed to assess appropriate cleanup options for the site. As part of the FS, remedial action objectives (RAOs) and remedial goals (RGs) were established for the COPCs identified in the RI. **Table 1** summarizes the COPCs and their respective media. The RAOs were to mitigate potential risks based on the current industrial use and the conservative future residential use of the site. A summary of the RGs for each COPC based on the RAOs is provided in **Table 2.**

Based on the COPCs present at the site, a list of applicable remedial technologies was developed as a preliminary screening step in the evaluation process. The candidate technologies were then screened based on specific criteria including applicability and appropriateness to the site, technical feasibility and implementability, and relative cost. The remedial technologies that passed the screening process were retained for further evaluation and development into remedial alternatives. The resulting remedial alternatives developed for the FS are as follows:

- Remedial Alternative 1 - No Action
- Remedial Alternative 2 - Excavation, ZVI, ERD+ZVI, Fluoride Sequestration
- Remedial Alternative 3 - Excavation, Permeable Reactive Barrier of liquid activated carbon (PRB), Fluoride Sequestration
- Remedial Alternative 4 - Excavation, ZVI, ERD+ZVI, Groundwater Extraction
- Remedial Alternative 5 - Excavation, PRB, Groundwater Extraction

A summary of the Remedial Alternatives and their respective target COPCs is provided in **Table 3**. Additional details of the remedial technology screening and remedial alternatives development processes will be included in the FS Report.

6. Pilot Studies

As previously stated, select remedial technologies require confirmation of effectiveness prior to inclusion in the final list of remedial alternatives. Therefore, pilot testing was deemed necessary to assess the effectiveness of the remedial technologies prior to submittal of the FS Report and to possibly eliminate an ineffective technology from consideration for the ROD. The following sections detail the proposed pilot study activities for ERD+ZVI treatment of CVOCs and ZVI treatment for Tc-99 and Uranium. The locations of the pilot study areas at the site are illustrated in **Figure 9.**

6.1 CVOC

Enhanced reductive dechlorination (ERD) involves modifying the chemical, physical, and biological conditions of an aquifer to stimulate microbial degradation of contaminants under anaerobic conditions. This process can prove more difficult when compared to other remedial technologies as it can be affected by several site-specific variables. Therefore, a pilot study is necessary to assess if the aquifer conditions can be successfully altered on a pilot-scale and demonstrate the effectiveness of the remediation technology prior to submittal of the FS Report. Since ERD and ZVI have been proven successful in treating CVOCs as remedial technologies, a bench-scale treatability test is not necessary prior to pilot test implementation. The following sections detail the proposed pilot study objectives, requirements, and design for the treatment of CVOCs in groundwater.

6.1.1 Description of Remedial Technology

In-situ enhanced anaerobic bioremediation is a remedial technology that involves the development of subsurface geochemical conditions that allow indigenous microorganisms to biodegrade target constituents. For CVOCs, this typically involves the addition of an electron donor (e.g., carbon source) within the subsurface to stimulate anaerobic microorganisms to biodegrade contaminants via reductive dechlorination.

During ERD, carbon is used as an energy source by the anaerobic microbes in the subsurface, while chlorinated hydrocarbons act as respiratory substrates (electron acceptors) during metabolism. Chlorine atoms are sequentially removed from the chlorinated compounds and replaced with hydrogen atoms. As described in **Section 4.2.1,** PCE at the site is being degraded under anaerobic conditions via reductive dechlorination, resulting in the sequential dechlorination to TCE, cDCE, and VC. Incomplete conversion of the parent compounds can occur, resulting in an accumulation of the daughter products (cDCE and/or VC). Under favorable geochemical conditions, PCE can be degraded completely to the innocuous end-product, ethene.

In-situ chemical reduction (ISCR) enhanced bioremediation can be combined with ERD to accelerate the degradation of CVOCs. ISCR utilizes technologies such as ZVI to chemically reduce CVOCs by providing electrons that break the chemical bonds in chlorinated compounds, resulting in their reduction to less harmful products. ZVI is a reagent that promotes the destruction of a variety of organic and inorganic pollutants. It can destroy certain compounds by direct chemical reaction and can also promote anaerobic biological degradation by creating a reducing environment that favors anaerobic bacteria.

ERD combined with ZVI (ERD+ZVI) would involve the injection of reagents through direct push or permanent injection points at a targeted depth interval. There are several remedial amendment vendors that offer varying reagents for ERD. The vendors and their specific reagents included in this work plan are for example purposes only and are subject to change prior to implementation. An example of such reagents is Ferox Plus Emulsified Zero Valent Iron (eZVI) provided by Hepure Technologies, LLC. (Hepure), which consists of nano/micro scale ZVI, surfactant, food grade vegetable oil (carbon source), and water. Additional details for eZVI are provided in the safety data sheet (SDS) which is included as **Appendix A**. Similar to ERD alone, multiple injection events are typically necessary to reach RAOs. Subsequent groundwater monitoring would be performed to assess whether adequate distribution is obtained, proper geochemical conditions are developed, and that biological reductive dechlorination is occurring.

6.1.2 Objectives

The objectives of the CVOC pilot study are to assess if aquifer conditions can be successfully modified to demonstrate the effectiveness of in-situ bioremediation in reducing CVOC concentrations at the site as well as provide design data necessary for full-scale implementation.

6.1.3 Permit Requirements

SCDES approval is required for the installation of all monitoring wells. A monitoring well application will be completed, submitted, and approved prior to construction of any monitoring well at the site. AECOM will use the information included in this work plan to complete the required well permit application through the appropriate SCDES channels. A copy of the monitoring well application form is included as **Appendix B.**

SCDES requires an underground injection control (UIC) permit to inject any fluid into the subsurface through a well or boring. Since direct push technology (DPT) borings satisfy the classification requirements for a Class V.A. well as defined by the SCDES, a UIC permit will be required prior to initiating the pilot test activities. AECOM will use the information included in this Work Plan to complete the required UIC permit application through the appropriate SCDES channels. A copy of the UIC permit application form is included as **Appendix C.**

6.1.4 Well Installation

The CVOC pilot test will target monitoring wells W-120 and W-121, located west of the main plant building (**Figure 9**). These wells were selected based on their location, depths, and elevated PCE concentrations. Although the highest PCE concentrations have been detected in wells W-65 and W-66 (200 to 810 ug/L), their proximity to the middle ditch and plant infrastructure makes them less accessible than wells W-120 and W-121 which exhibit the second highest PCE concentrations (5.66 to 340 ug/L). Monitoring well W-120 is installed in the lower zone of the surficial aquifer with a screen depth interval of 29 to 34 ft bgs and W-121 is installed in the upper zone of the surficial aquifer with a screen depth interval of 12 to 22 ft bgs. To assess injection performance and gather data for the design of a larger-scale injection, six performance monitoring well pairs (PMW-1A/B through PMW-6A/B) will be installed up-, cross-, and down-gradient of the injection grid. The proposed locations for the performance monitoring well pairs are shown in **Figure 10**.

The performance monitoring wells will be constructed at previously specified locations in accordance with the United States Environmental Protection Agency (EPA) Region 4 SESDGUID-101-R2 Design and Installation of Monitoring Wells protocol (EPA, 2018) and SC Well Standards R.61-71 (SCDES, 2016).

Each performance monitoring well pair will consist of one well installed within the upper zone of the surficial aquifer, designated by the letter “A”, and one well installed within the lower zone of the surficial aquifer, designated by the letter “B”. The “A” wells wills be installed to target a total depth of 22 ft bgs and the “B” wells will be installed to target a total depth of approximately 34 ft bgs. In the case that the Black Creek confining unit is encountered prior to reaching the 34-foot target depth, the well will be installed at the depth at which the confining unit was encountered. The “A” wells will be constructed with 10-foot screens to match W-121 and assess injection performance in the upper zone of the surficial aquifer. The “B” wells will be constructed with 5-foot screens to match W-120 and assess injection performance in and the lower zone of the surficial aquifer. Construction details for the pilot study wells are summarized in **Table 4**. For each performance monitoring well pair, both wells will be installed equidistant from the target treatment area as shown in **Figure 10.**

Each monitoring well will be constructed using two-inch diameter, flush threaded, Schedule 40 PVC casing, and 0.010-inch slotted screen installed through the rotosonic casing or hollow-stem auger (HSA) annulus. Filter sand will be placed in the annular space surrounding the well screen to a depth of approximately two feet above the top of the well screen. A bentonite clay seal with a minimum thickness of two feet will be placed above the filter pack and hydrated. As the filter sand and bentonite clay are added, the rotosonic casing or HSA will be pulled from the borehole to ensure the annulus is completely filled. Depths to sand and bentonite will be monitored with a weighted tape measure as the installation progresses. The monitoring wells will be grouted using bentonite-cement (up to 5% bentonite) or high solids bentonite (minimum 20% solids). The grout will be pumped from above the bentonite seal to land surface via a tremie pipe as the rotosonic casing or HSA core barrel is pulled.

Surface completions for the monitoring wells will be above-grade and consist of a 4-inch square protective casing with a lockable lid, constructed of either steel or aluminum and set approximately 2.5 feet above land surface. Each protective casing will be set into a 2-foot by 2-foot square by 6-inch-thick concrete pad. Typical construction details for the performance monitoring wells are included as **Appendix D** and will be submitted with the monitoring well permit application.

Per SC Well Standards R.61-71 (SCDES, 2016), monitoring wells will be properly labeled with an identification plate immediately upon well completion. The identification plate will be constructed of a durable, weatherproof, rustproof, material. The identification plate will be permanently secured to the well casing or enclosure floor around the casing where it is readily visible. The identification plate will be permanently marked to show:

- Company name and certification number of the driller who installed the well;
- Date that the well was completed;
- Total depth (feet) of the well;
- Casing depth (feet);
- Screened interval; and
- Designator and/or identification number.

The performance monitoring wells will be developed by AECOM personnel to remove sediment generated during well installation and to allow the sand filter packs to settle and compact around the screens. Well development will be conducted no sooner than 24 hours after grouting has been completed. The monitoring wells will be developed by alternatively surging and then pumping with an electric submersible pump. Groundwater indicator parameters (e.g., pH, temperature, specific conductivity, dissolved oxygen [DO], oxidation reduction potential [ORP], and turbidity) will be measured periodically during development using a water quality meter and recorded on Monitoring Well Development Logs. Development of monitoring wells will continue until parameters have stabilized to within approximately 10% (0.2 standard units [SU] for pH) and the turbidity is reduced to <10 nephelometric turbidity units (NTUs) unless a higher NTU is specifically approved by the AECOM project manager on a well-by-well basis. Total well depth will also be measured and recorded during development.

6.1.5 Baseline Groundwater Sampling

Groundwater samples will be collected from the existing monitoring wells (W-120 and W-121) and the 12 newly installed performance monitoring wells (PMW-1A through PMW-6B) to establish baseline conditions prior to the pilot test implementation. The performance monitoring wells will be sampled no sooner than 24 hours following development. Prior to sampling, water levels will be measured in the wells using an electric water level indicator and recorded on a Groundwater Sample Collection Record.

The wells will be purged and sampled by low-flow, low-volume procedures using either a peristaltic pump or a variable speed submersible pump and dedicated polyethylene or Teflon™ tubing. Low-flow purging will be completed with the tubing or pump intake installed at the approximate monitoring well screen-interval midpoint in accordance with EPA Region 4 LSASDPROC-301-R6 Groundwater Sampling (EPA, 2023a). Water quality parameters will be measured approximately every five minutes using a water quality meter equipped with a flow-through cell. The water quality parameters will include temperature, pH, specific conductivity, DO, ORP, and turbidity. Field water quality meters will be calibrated prior to delivery to the site and in accordance with the manufacturers' recommendations. Additional calibrations will be performed as warranted (e.g., if the instrument is behaving erratically). Calibration details will be recorded on calibration log forms.

Purging will proceed until pH is within 0.1 SU, specific conductivity varies no more than 5%, and the turbidity is <10 NTUs or stable within 10% and only if specifically approved by the AECOM project manager on a well-by-well basis. Once parameter stabilization is achieved, groundwater samples will be collected in accordance with EPA Region 4 LSASDPROC-301-R6 Groundwater Sampling (EPA, 2023a) using the disposable polyethylene or Teflon™ tubing. All in-field measurements will be recorded on groundwater sampling logs.

To provide quantitative data on the precision and accuracy of the sampling and analysis program, quality assurance (QA) and quality control (QC) samples consisting of duplicate, matrix spike (MS)/matrix spike duplicate (MSD), equipment blank, and trip blank samples will be collected during environmental sampling. Field QA/QC samples will be collected, handled, preserved, documented, packaged, and shipped using the same procedures as for other samples of the same media. In summary, the QA/QC samples will be collected as specified below:

- Duplicate – one duplicate sample per 20 samples
- MS/MSD – one MS and one MSD sample per 20 samples
- Equipment Blank – one equipment blank from sampling equipment requiring field decontamination for each 20 samples
- Trip Blank – one trip blank for each cooler containing samples that require CVOC analysis

Each environmental sample, including field samples and QA/QC samples will be assigned a unique identification based on the sample media/type. This naming convention will facilitate proper linking of sample data (field and laboratory) to the electronic database and to map locations. Where practical, performance monitoring will coincide with routine, semi-annual groundwater monitoring. If these campaigns align, groundwater samples from the monitoring well network will retain their standard sample nomenclature. Pilot study samples will have unique suffixes where baseline samples will be designated as PSBL and post-injection samples will have the unique suffix PS and associated timeframe (e.g., 14 days will be PS14D and one month will be PS1M). Sample nomenclature is listed below:

- Groundwater samples from monitoring wells will be identified as the well identification (e.g., W-120-PSBL or W-120-PS3M).
- Groundwater samples from performance monitoring wells will be identified as the well identification (e.g., PMW-1A-PSBL or PMW-1A-PS6M).
- Duplicate and MS/MSD samples will be identified with the sample identification (ID) followed by the codes “DUP”, “MS”, or “MSD” (e.g., W-120-DUP-PSBL, W-120-MS-PS9M, W-120-MSD-PS9M).
- Equipment blanks and trip blanks will be identified with “EB” or “TB”-{sequence number}-{yyyymmdd date} (e.g., EB-01-PSBL-20250419, TB-01-PS1M-20251017).

Groundwater samples will be analyzed by GEL Laboratories LLC (GEL) in Charleston, SC, unless specified otherwise by Westinghouse, according to the analytes and methods listed below:

- Select CVOCs by EPA Method 8260B; and
- Total organic carbon (TOC) by SW-846 Test Method 9060A.

A Sampling and Analysis Plan (SAP) summarizing the CVOC pilot study baseline sampling is provided in **Appendix E.**

From the time of collection through transportation and delivery to the laboratory, sample handling will follow proper chain-of-custody (COC) procedures. Sample containers will be surrounded by bubble wrap or equivalent packing material and placed in coolers with ice upon collection. Once samples are collected and placed on ice, a COC form(s) will be filled out completely, including information specific to the project and each sample. Each COC will be cooler-specific. Personnel packing the cooler will verify that the samples listed on the COC match the samples in the cooler, then sign and date the completed COC. A copy of the COC will be retained in the files, and the original completed COC will be enclosed in a sealable plastic bag and placed inside the cooler for shipment.

Sample handling, packaging, and shipping activities will follow the procedures outlined in the EPA Region 4 FSBPROC-209-R6 Packing, Marking, Labeling, and Shipping of Environmental and Waste Samples (EPA, 2024). Samples will be delivered to a commercial carrier to be shipped overnight to GEL or via the site’s regularly scheduled GEL courier. The laboratory will be alerted if shipments are scheduled for weekend delivery, to ensure that personnel are available to receive the samples.

Data will be collected and recorded in a variety of ways including standardized field forms, electronically recorded field measurements, and laboratory-generated data. Information about locations, field measurements, samples, laboratory tests, and data results will be maintained in the project database. Access will be restricted to project personnel, and the ability to view and/or add or change data will be granted to only those individuals identified to perform those tasks. Original data documents and electronic files will be archived in the appropriate hardcopy and computerized project filing system.

Numerical analyses, instrument readings and recordings, measurements, and tests will be documented and subjected to internal review. Field records will be legible and sufficiently complete to permit reconstruction of data gathering activities by a qualified individual other than the originator, if necessary. Field generated data sheets and other field documents will be collected and reviewed daily for accuracy and completeness by the AECOM field project manager or his/her designee.

6.1.6 ERD+ZVI Injection Design

The following sections detail the ERD+ZVI injection design for the CVOC pilot test.

6.1.6.1 Target Treatment Area

The target treatment area measures approximately 100 ft (north to south) by 100 ft (east to west) and is focused on the vicinity of monitoring wells W-120 and W-121. The CVOC pilot test will target a depth interval of approximately 9 to 34 ft bgs. The resulting target treatment volume is estimated to be 250,000 cubic feet (cf). The target treatment area is illustrated in **Figure 10**. Based on the target treatment volume of 250,000 cf and assuming an effective porosity of 20%, the effective pore volume of the treatment zone is approximately 374,000 gallons (gals).

6.1.6.2 Estimated Injection Volumes

Approximately 20,000 pounds (lbs), or 1,460 gals, of eZVI provided by Hepure will be mixed with approximately 14,000 gals of freshwater to create a total amendment volume of 15,460 gals. The amendment will be injected into the subsurface across 25 injection point locations (618 gals per point) at five depth intervals per point. Note: the product and vendor are subject to change prior to implementation. Vendors and products listed in this work plan are provided for example purposes, only. If another product is selected a revised pilot test work plan will be submitted. The proposed injection point locations are illustrated in **Figure 10**. A summary of the CVOC pilot test injection volumes is included in **Table 5**.

6.1.6.3 Implementation

Prior to conducting any intrusive subsurface activities, a private utility locator with ground penetrating radar (GPR) capabilities will also be mobilized to the site to identify any subsurface utilities and other unknown anomalies within the target treatment area. A private locating event utilizing GPR was performed in November 2024 within the target treatment area to identify subsurface utilities and revealed the presence of one underground electric utility within the target treatment area. Additionally, one overhead electric utility was observed within the area. The approximate locations of the two electric utilities are illustrated in **Figure 10**. The locations of the utilities are not anticipated to affect the proposed injection point locations.

Caution tape, snow/silt fencing, traffic cones, traffic barrels, or a combination of which, with appropriate signage will be utilized to establish an exclusion zone around the target treatment area. The exclusion zone will prevent unauthorized pedestrian and/or vehicle traffic from entering the work area. Additionally, the exclusion zone will be set up in a manner that will not block any vehicle traffic routes or access to the plant facilities. Note that 10 injection points (two northern-most rows of injection points) are located within the controlled access area.

Fresh water will be sourced locally from a fire hydrant located on Bluff Road approximately 1.4 miles from the target treatment area. A water truck or towable water trailer will be utilized to transfer water from the Bluff Road hydrant to an on-site storage tank. Prior to amendment application, a pre-application injection test using only fresh water will be performed to assess how much volume the formation will accept at the specified depth intervals as well as injection flow rate and pressure information. The pre-application test should consist of a freshwater volume that is 15 to 20 percent (%) greater than the single-point design volume. For the CVOC pilot test, the freshwater volume for the pre-application test should be between approximately 711 to 742 gals for a single injection point.

An SC certified drilling contractor (e.g., Geo Lab Drilling [Geo Lab]) will be subcontracted to perform the injection activities. The eZVI will be delivered to the site in granular form in 50-lb bags and an appropriately sized forklift will be utilized to unload and handle the delivered material. Geo Lab will utilize a custom injection system to prepare, batch, mix, and inject 15,460 gals of the eZVI amendment into 25 injection point locations.

Injections will begin at the proposed locations along the outside of the treatment area and progress in the direction of monitoring wells W-120 and W-121 (center of the target treatment area). An appropriate distance will be maintained between consecutive injection locations to avoid localized overloading of the formation and to minimize mounding of the groundwater table. A geoprobe rig utilizing DPT will be mobilized to the Site to administer the amendment injections. At each location, the geoprobe rig will advance injection rods to five separate injection depths utilizing a “top-down” approach. The injection rods will be advanced to depths of 11.5, 16.5, 21.5, 26.5 and 31.5 ft bgs to target 5-foot intervals at each injection depth. Approximately, 123.7 gals of the eZVI amendment will be injected into each targeted depth interval. Injection volumes, flowrates, and pressures will be monitored throughout the duration of the pilot test (**Section 6.1.8**). As a standard operating procedure, injection pressures are to be maintained within 0 to 30 psi, and not to exceed 50 psi at any time, to minimize the potential for hydraulic fracturing and/or daylighting of the amendment to the surface through the injection rod annulus.

Once the required amendment volume has been injected into each targeted depth interval, fresh water will be used to flush through the pump, flowmeter, hoses, and injection rods to ensure all amendment has been displaced into the formation. Geo Lab will provide enough equipment to leave injection tooling in-place to allow complete subsurface depressurization prior to removal. Upon completion of each injection point, the DPT bore-hole will be abandoned with bentonite and six inches, at minimum, of Portland grout cement at the surface. Any disturbed areas will be restored to match pre-existing conditions. Disturbed vegetative cover will be seeded and strawed upon completion of the work.

6.1.7 Performance Monitoring

During injection, in-field parameters will be recorded by the drilling subcontractor to evaluate performance. Injection pressures, flow rates, and volumes at each location will be recorded at a frequency of once per hour, at minimum. The injection monitoring data will be recorded and documented in daily injection reports which will be submitted to the AECOM designated engineer(s) for review prior to beginning injections the following day. Depth to water measurements will be recorded by AECOM field staff from monitoring wells W-120, W-121, and PMW-1 through PMW-6. The frequency of the depth to water measurements will initially be each day prior to beginning injection, once per hour during injection, and after injection is completed which may be adjusted depending on in-field observations after the first full day of injection. Groundwater field parameters including conductivity, pH, temperature, DO, turbidity, and ORP will be field measured with a water quality meter at the select monitoring wells each day prior to beginning injection and after the injection is completed.

After the injection has been completed, several groundwater sampling events will be performed to evaluate the ERD+ZVI performance overtime. The groundwater sampling will be performed using the same procedures as the baseline sampling (**Section 6.1.6**) and will occur at a frequency of every three months following injection completion. After the 12-month sampling event, results from the routine, semi-annual groundwater sampling at the site may be relied upon for further evaluation of the ERD+ZVI performance. A Sampling and Analysis Plan (SAP) summarizing the CVOC pilot study post-injection sampling is provided in **Appendix E.**

6.2 Tc-99

Due to the rarity of Tc-99 impacts to groundwater, there is limited information available regarding in-situ remediation. Another concern is to remain below the dose criteria for radionuclides during future site decommissioning activities. Therefore, further evaluation and testing consisting of both a bench-scale treatability test and field-scale pilot test are recommended to prove the proposed remedial technology is successful prior to submittal of the FS Report. Currently, two remedial technologies are being considered for the in-situ treatment of Tc-99 in groundwater: ZVI and PRB. During the FS remedial alternative evaluation process, ZVI received a better evaluation score when compared to PRB. However, the two technologies will be re-evaluated after the results of the bench-scale treatability test. Therefore, the following sections detail the proposed pilot study objectives, requirements, and design if ZVI were to be selected as the choice remedial technology. If PRB is selected as the choice remedial technology, a revised pilot test work plan will be submitted.

6.2.1 Description of Remedial Technology

ZVI has been proven successful in the removal of Tc-99 from aqueous solutions (Korte, N, 2001). ZVI acts as a reducing agent, chemically converting the radionuclide from a soluble oxidation state (Tc-99 +VII) to a less soluble oxidation state (Tc-99 +IV) through a redox reaction which results in Tc-99 precipitating onto the ZVI particles or being incorporated into newly formed iron oxide minerals (Boglaienko, D., et al., 2019). This process is often referred to as reductive immobilization. Under reducing conditions with little oxygen present, Tc-99 exists as Tc-99 +IV, which has low environmental mobility and poor aqueous solubility (Emerson, H., et al., 2020). Additionally, the incorporation of Tc-99 +IV in iron oxidation products may decrease the likelihood of long-term release of Tc-99 as compared to other Tc-99 precipitates due to the reduced likelihood of re-oxidation (Emerson, H., et al., 2020).

ZVI is available in multiple forms which are engineered to meet a range of specific site requirements. For example, ZVI can be injected into an impacted groundwater source area or installed as a permeable barrier wall downgradient across the flow path of the plume. When injected, the technology relies on the same passive distribution technique and dispersive mechanisms which typically require a high density of injection points.

6.2.2 Objectives

The objectives of the Tc-99 pilot study are to evaluate the effectiveness of ZVI as a remedial technology in treating Tc-99 impacted groundwater at the site and to provide design data for full-scale implementation, if necessary.

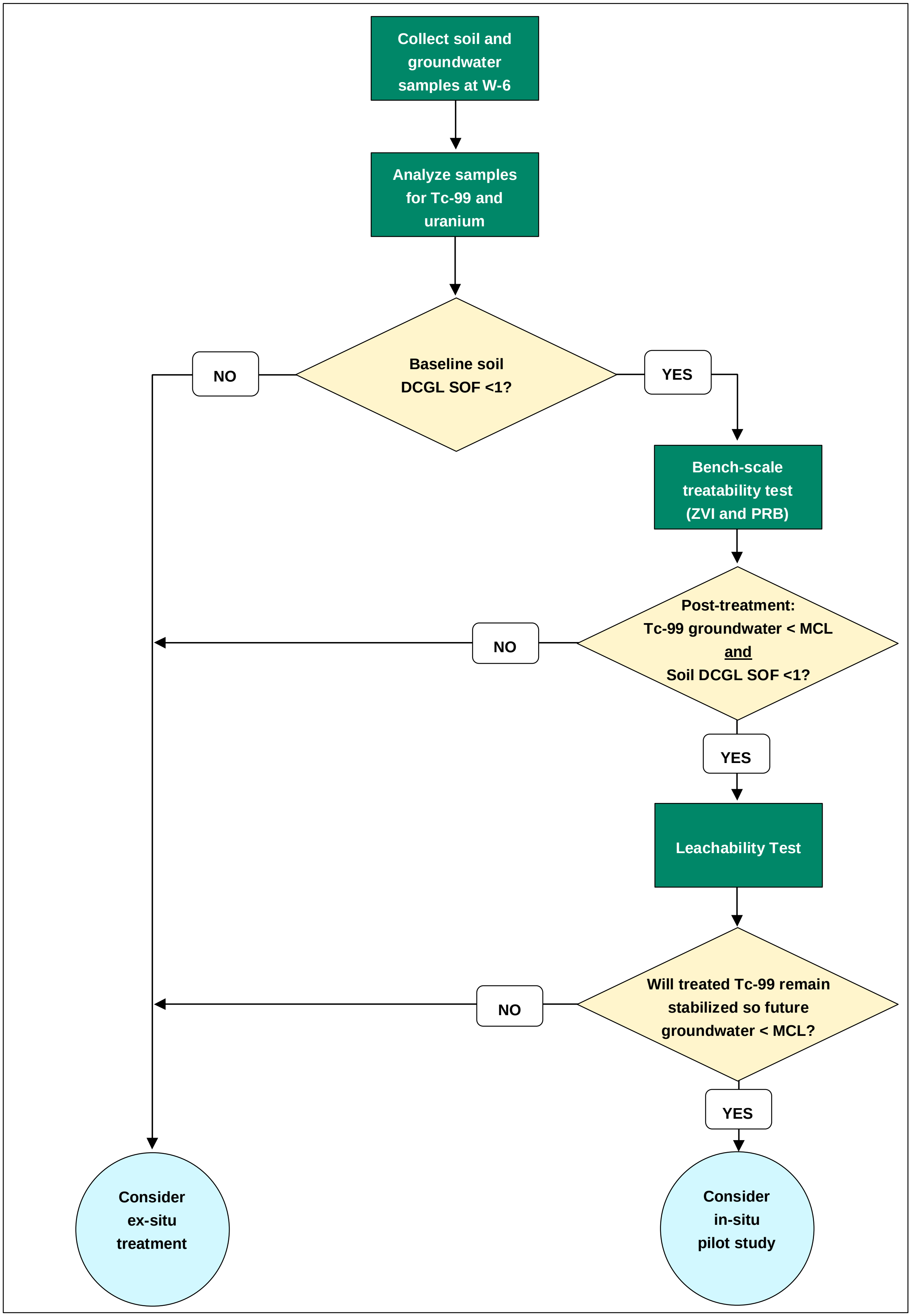
6.2.3 Bench-Scale Treatability Test

During the FS screening process, in-situ treatment of Tc-99 was deemed a more feasible remedial technology at achieving groundwater MCLs when compared to an ex-situ technology such as groundwater extraction based on the implementability, cost, and duration. However, the in-soluble Tc-99 remaining in the saturated soil may create complications during future decommissioning based on the 25 millirem per year (mrem/yr) dose criteria in 10 CFR Part 20.1402 required by the NRC. Because of these concerns, the bench-scale treatability test for Tc-99 includes testing to both verify the effectiveness of the proposed remedial technologies in treating Tc-99 in groundwater and assessing if the Tc-99 concentrations in pre- and post-bench scale testing could potentially result in decommissioning issues.

Currently, three different ZVI products are being considered for the in-situ treatment of Tc-99 in groundwater. These three products differ in particle size, chemical make-up, and are generated by differing manufacturing methods. Additionally, one PRB product consisting of colloidal liquid activated carbon is being considered at the bench-scale. The bench-scale treatability test will evaluate which of the three ZVI products is the most effective and then which is the most effective remedial technology when comparing the best performing ZVI product and PRB. Additionally, a leachability test will be conducted utilizing the EPA Leaching Environmental Assessment Framework (LEAF) methods to evaluate the desorption rate of the stabilized Tc-99 post-treatment. The bench-scale treatability test, leachability test, and subsequent pilot study will be performed in a stepwise approach according to the following scenarios:

- Soil and groundwater samples will be collected from the area historically exhibiting the highest Tc-99 concentrations (monitoring well W-6 area). A drill rig utilizing rotary sonic technology will be mobilized to the site to collect approximately 20 lbs of soil sample from a location immediately adjacent to W-6 at depth matching the W-6 screen interval (23 to 28 ft bgs). Additionally, approximately 10 gals of groundwater sample will be collected from monitoring well W-6. The samples will then be sent to a select lab to perform further testing including analysis of Tc-99 and uranium to establish baseline conditions prior to treatment.
- The pre-treatment (baseline) Tc-99 and uranium concentrations in soil will be compared to the derived concentration guidance level (DCGL, Leidos, 2023) sum of fractions (SOF). An SOF is used to assess the cumulative potential dose of radiation exposure of the uranium isotopes and Tc-99 by adding the fractions of individual uranium isotopes and Tc-99 divided by their respective screening levels. A DCGL SOF greater than one (>1) indicates that the calculated dose limit for CFFF would be exceeded and a DCGL SOF less than one (<1) indicates that the dose limit has not been exceeded. If the baseline soil concentrations exceed the calculated dose limit (DCGL SOF >1), then ex-situ treatment (e.g., groundwater extraction) would be considered in place of in-situ treatment and no further testing would be required.
- If baseline Tc-99 and uranium concentrations in soil do not exceed the calculated does limit (DCGL SOF <1), then the bench-scale treatability test would be performed to determine if the in-situ treatment reduces Tc-99 groundwater concentrations below the MCL while not increasing Tc-99 and uranium soil concentrations above the calculated dose limit post-treatment.
- If Tc-99 and uranium concentrations in soil exceed the calculated does limit post-treatment, then ex-situ treatment would be considered in place of in-situ treatment and no further testing would be required.
- If Tc-99 and uranium concentrations in soil remain below the calculated dose limit post-treatment, then the leachability test would be performed using the better performing remedial technology (e.g., ZVI or PRB) to assess the potential desorption rate of the insoluble Tc-99.
- If the leachability test ascertains that the stabilized Tc-99 will eventually desorb into groundwater at a rate that would result in concentrations that could exceed the MCL in the future, then ex-situ treatment would be considered in place of in-situ treatment and no further testing would be required.
- If the leachability test ascertains that the desorption rate is low enough that Tc-99 concentrations in groundwater will remain below the MCL, then in-situ treatment would remain a viable option, and the site would consider proceeding to the pilot study phase.

A decision tree illustrating the stepwise approach is provided in the diagram below:


Collect soil and groundwater samples at W-6
Analyze samples for Tc-99 and uranium
Baseline soil DCGL SOF <1?
NO
YES
Bench-scale treatability test (ZVI and PRB)
Post-treatment: Tc-99 groundwater < MCL and Soil DCGL SOF <1?
NO
YES
Leachability Test
Will treated Tc-99 remain stabilized so future groundwater < MCL?
NO
YES
Consider ex-situ treatment
Consider in-situ pilot study

In summary, results from the saturated soil tests will evaluate the current amount of Tc-99 in soil below the groundwater table within the impacted Tc-99 groundwater plume and how treatment will affect that amount. Results from the bench-scale treatability test will determine which remedial technology is the most effective in treating Tc-99 in groundwater and at what dosing rates. Results from the leachability test will assist in evaluating the long-term effectiveness and permanence of the Tc-99 treatment. Additional details are provided in the standard operating procedures (SOP) for the bench-scale treatability test which is included as **Appendix F**.

6.2.4 Permit Requirements

If the site proceeds to the pilot study phase, a UIC permit will be required prior to initiating the Tc-99 pilot test activities. In such case, AECOM will use the information included in this Work Plan to complete the required UIC permit application through the appropriate SCDES channels. A copy of the UIC permit application form is included as **Appendix C.** Additionally, an electronic draft of the completed UIC permit application will be provided to Westinghouse for review prior to submittal to SCDES.

6.2.5 Well Installation

Historically, Tc-99 concentrations exceeding the groundwater MCL have been localized to monitoring wells W-6 and W-11. Because W-6 and W-11, along with the co-located wells W-22 and W-32, are within the target treatment areas, these wells can be utilized in combination with the current groundwater monitoring program to evaluate performance of the Tc-99 pilot test. Therefore, additional well installations will not be required to support the pilot study.

6.2.6 Baseline Groundwater Sampling

Results from the historical groundwater monitoring will be used to establish baseline conditions prior to the Tc-99 pilot test implementation. Specific results include parameters such as pH, ORP, DO, and Tc-99 concentrations from select monitoring wells including W-6, WW-11, W-22, and W-32.

6.2.7 ZVI Injection Design

The following sections describe the design of the Tc-99 pilot test if sulfidated micro-scale ZVI (S-MZVI), provided by Regenesis, were to be selected as the choice product for the ZVI remedial technology. If another product is selected or in-situ treatment methods are not viable (pending the results of the bench-scale treatability test), a revised pilot test work plan will be submitted. The SDS for S-MZVI is included in **Appendix A.**

6.2.7.1 Target Treatment Area

The target treatment area for Tc-99 consists of two areas within the MCL exceedance plume as shown in **Figure 11**. There will be two injection areas, one within the upgradient portion of the plume to target the monitoring well W-6 area, and one within the downgradient portion of the plume to target the W-11 area. Each injection area measures approximately 4,000 square feet (sf) and a target depth interval of 11 to 31 ft bgs. The injection areas will each consist of 40 injection point locations (four rows of ten) with 10-foot spacing.

6.2.7.2 Estimated Injection Volumes

For each target treatment area, approximately 10,000 lbs, or 662 gals, of S-MZVI will be mixed with 31,959 gals of freshwater to create an amendment volume of 32,621 gals (20,000 lbs of ZVI and 65,242 gals of amendment, total for both target areas). The amendment will be injected into the subsurface across the 40 injection point locations at each target treatment area (816 gals per point). The proposed injection point locations are illustrated in **Figure 11**. A summary of the Tc-99 pilot test injection volumes is included in **Table 6**.

6.2.7.3 Implementation

As described in **Section 6.1.6.3,** a private locate will be performed with GPR prior to conducting any subsurface activities. Based on historical computer-aided design (CAD) drawings and photos provided by Westinghouse and previous GPR events, there are several underground utilities including storm sewer, power, and wastewater discharge lines that extend through the target treatment areas at depths less than five ft bgs. Approximate locations of the known underground utilities, which were generated from a combination of on-site locating and CAD drawings provided by Westinghouse, are illustrated in **Figure 11.**

Exclusion zones will be established in the same manner as described in **Section 6.1.6.3** to prevent unauthorized pedestrian and/or vehicle traffic from entering the work area.

Fresh water will be obtained in the same manner as described in **Section 6.1.6.3.** A pre-application test will also be performed for the Tc-99 pilot test which will consist of approximately 938 to 979 gals for a single injection point.

Regenesis will be subcontracted to perform the injection activities. The S-MZVI will be delivered to the site in 500-lb poly drums. An appropriately sized forklift will be used to unload and handle the delivered material. The S-MZVI will be delivered as a concentrated slurry, or colloidal suspension, of 40% ZVI by weight in glycerol. A mechanical paddle mixer will be used to mix the slurry and adequately disturb any settled material to ensure even distribution prior to any dilution mixing. The S-MZVI slurry will be mixed with freshwater on-site in a conical or flat-bottomed mixing tank in a specific order prior to injection into the subsurface. The specific order is as follows:

1) The required batch volume of freshwater will be added to the mixing tank;
2) The mixing mechanism (recirculation pump or paddle mixer) will be engaged prior to adding the S-MZVI slurry;
3) The required batch volume of the S-MZVI slurry will be transferred from the drums or tote to the mixing tank via drum pump or double-diaphragm pump;
4) The S-MZVI and freshwater will be mixed vigorously initially prior to injection; and
5) Continue to gently mix the batch volume of amendment while it is being injected to prevent settling.

Two mixing tanks will be available so the next batch can be mixed during injection of the previously mixed batch to eliminate downtime and promote continuous injection throughout the pilot test.

Due to the limited success in locating the wastewater discharge utilities in the northern injection area, a vacuum-truck operated by Westinghouse personnel will be utilized to remove the overburden via soft-excavation techniques to a depth of five ft bgs for any injection points located near anticipated underground utilities, otherwise known as “potholing”. Potholing will not be required in the southern injection area since the underground power utilities were easily identified during previous GPR locating events. Soil removed during the potholing will be containerized and handled by Westinghouse personnel. Planned injection point locations that overlap with located utilities will be shifted accordingly.

Injections will begin at the proposed locations in the W-6/W-22 area and progress north to south (downgradient). The injections will be administered in the same manner as described in **Section 6.1.6.3**. For the Tc-99 pilot test, the injection rods will be advanced to depths of 13.5, 18.5, 23.5, 28.5 ft bgs to target 5-foot intervals at each injection depth. Approximately, 204 gals of the mixed S-MZVI amendment will be injected into each targeted depth interval following the same standard operating procedures as described in **Section 6.1.6.3.** Injection flowrates and pressures will be monitored throughout the duration of the pilot test (**Section 6.2.8**).

A freshwater flush will be performed after each injection depth interval as described in **Section 6.1.6.3.** Upon completion, each injection point will be abandoned, and the disturbed area will be restored as described in **Section 6.1.6.3.**

6.2.8 Performance Monitoring

During injection, in-field parameters will be recorded in the same manner as described in **Section 6.1.7** to evaluate performance. Depth to water measurements will be recorded from select monitoring wells including W-6, W-11, W-22, and W-32 at the same frequencies as described in **Section 6.1.7.** Groundwater field parameters will also be measured in the same manner as described in **Section 6.1.7.**

After the injection has been completed, groundwater sampling will be performed at the select monitoring wells including W-6, W-11, W-22, and W-32 and results of which will be utilized to evaluate performance over a minimum time period of one year, post-injection. The groundwater sampling, packing, marking, labeling, and shipping will be performed using the same procedures as described in **Section 6.1.5.** GEL will analyze the samples for Tc-99 via DOE EML HASL-300 (Tc-02-RC Modified).

The groundwater sampling will occur at a frequency of 14 days, one month, three months, and six months following injection completion. The post-injection sample frequency is dependent upon the bench-scale treatability and leachability test results and, therefore, may be subject to change as results are received. Post-injection monitoring events may be supplemented with the routine groundwater monitoring events performed at the site if they happen to occur within the schedule timeframe. A SAP summarizing the Tc-99 pilot study post-injection sampling is provided in **Appendix E.**

6.3 Uranium

Unlike Tc-99, there is sufficient information regarding in-situ remediation of uranium to evaluate if the proposed remedial technologies would be successful if implemented at the site. Therefore, a pilot study for uranium is not required prior to submittal of the FS Report. However, since the remedial technology that would be selected for treatment of Tc-99 would be the same as for Uranium, Westinghouse requested to proactively perform the uranium pilot study concurrently with the Tc-99 pilot study. The following sections detail the proposed pilot study objectives, requirements, and design for uranium.

6.3.1 Description of Remedial Technology

Like Tc-99, ZVI remediates uranium in groundwater by acting as a reducing agent, chemically converting the radionuclide from a soluble oxidation state to a less soluble, relatively immobile oxidation state. In the case of uranium, ZVI converts toxic hexavalent uranium (U +VI) into tetravalent uranium (U +IV) through reductive immobilization. Reductive immobilization of U +VI can be achieved by reducing media such as mixed ferrous/ferric hydroxides, goethite, lepidocrocite, mackinawite, amorphous iron sulfide, hydrogen sulfide, sulfide minerals, sulfate-reducing bacteria, and bare ZVI particles. Of these materials, ZVI aggregates have been widely tested for reductive immobilization of redox sensitive metals, metalloids and radionuclides (Zhao, X., et al., 2020).

6.3.2 Objectives

It is understood that potential sources for uranium impacts to groundwater at the site exist in inaccessible areas underneath the plant building. However, these potential sources will be addressed during site decommissioning in accordance with the site's NRC license. Therefore, the objectives of the uranium pilot study are to further evaluate the effectiveness of ZVI as a remedial technology in mitigating potential risks outside of the inaccessible areas based on the current industrial use and the conservative future residential use of the site. Additionally, the pilot study should provide design data necessary for a potential full-scale uranium remediation to address groundwater impacts, if necessary.

Since historical groundwater monitoring has demonstrated that the uranium exceedances in monitoring wells W-55 and W-56 are highly isolated to the uppermost portion of the surficial aquifer, the pilot test will focus on reducing uranium groundwater concentrations in these wells.

6.3.3 Permit Requirements

Similar to the CVOC and Tc-99 pilot tests, a UIC permit will be required prior to initiating the uranium pilot test activities. AECOM will use the information included in this Work Plan to complete the required UIC permit application through the appropriate SCDES channels. A copy of the UIC permit application form is included as **Appendix C.** An electronic draft of the completed UIC permit application will be provided to Westinghouse for review prior to submittal to SCDES.

6.3.4 Well Installation

Due to the abundance of monitoring wells located in the vicinity of the uranium pilot study focus area, these wells can be used in combination with the current groundwater monitoring program to evaluate performance of the uranium pilot test. Therefore, additional well installations are not required to support the pilot study.

6.3.5 Baseline Groundwater Sampling

Results from the historical groundwater monitoring will be used to establish baseline conditions prior to the uranium pilot test implementation. Specific parameter results include pH, ORP, DO, and total uranium concentrations from select monitoring wells including W-37, W-54, W-55, W-56, W-57, W-72, and W-73.

6.3.6 ZVI Injection Design

The following sections detail the injection design of the uranium pilot test utilizing S-MZVI provided by Regenesis.

6.3.6.1 Target Treatment Area

The target treatment area measures approximately 4,000 sf and is focused on monitoring wells W-55 and W-56. The uranium pilot test will target a depth interval of approximately nine to 15 feet bgs. The injection area will consist of 40 injection point locations with 10-foot spacing. The target treatment area and injection point locations are illustrated in **Figure 12.**

6.3.6.2 Estimated Injection Volumes

Approximately 3,000 lbs, or 199 gals, of S-MZVI will be mixed with 9,588 gals of freshwater to create a total amendment volume of 9,787 gals. The amendment will be injected into the subsurface across 40 injection point locations (245 gals per point) at two depth intervals per point. The proposed injection point locations are illustrated in **Figure 12.** A summary of the uranium pilot test injection volumes is included in **Table 7.**

6.3.6.3 Implementation

As described in **Section 6.1.6.3,** a private locate will be performed with GPR prior to conducting any subsurface activities. Private locating events utilizing GPR have been performed in the past with limited success in locating underground utilities related to plant processes within the target treatment area. Specifically, the contaminated waste line, the sanitary sewer line, and process sewer line. This may be due to the depths bgs at which these process lines were installed. Based on historical CAD drawings provided by Westinghouse, in respect to the target treatment area, the contaminated waste line and sanitary sewer line are 8-inch diameter pipes that ranges from approximately 4.3 to 6.1 and 8.1 to 10.6 feet bgs, respectively, and the process sewer line is a 4-inch diameter pipe that ranges from approximately 9.3 to 11.3 feet bgs. A cross-section view illustrating the underground process utilities and their respective approximate depths is provided as **Appendix G.** Approximate locations of the known underground utilities, which were generated from a combination of on-site locating and CAD drawings provided by Westinghouse, are illustrated in **Figure 12.**

Exclusion zones will be established in the same manner as described in **Section 6.1.6.3** to prevent unauthorized pedestrian and/or vehicle traffic from entering the work area.

Due to the limited success in locating the process utilities, two overburden excavations will be performed to pinpoint exact locations by providing direct line of sight to each process utility. This process is commonly referred to as “daylighting”. One excavation will be performed near the northern extent of the target treatment area and the other will be performed near the southern extent to project a straight line above ground connecting the two daylighted locations for each process utility.

For the southern excavation, a section of concrete, perpendicular to the process utilities and measuring approximately one foot wide by 16 ft (at minimum), will be saw-cut and removed to expose the subsurface overburden. A vacuum-truck operated by Westinghouse personnel will then be utilized to remove the overburden via soft-excavation techniques to a depth ranging from approximately 4.3 to 11.3 feet bgs. These methods will be repeated for the northern excavation, however, concrete saw-cutting and removal is not anticipated as the northern area is covered by gravel and/or vegetation. Additional caution tape/fencing and signage will be utilized to create barriers around the open excavation.

Once each utility has been daylighted at both ends, semi-permanent rebar stakes will be installed to mark each end and will be utilized for connection of nylon string for the straight-line projections. Each projected straight line will be marked with paint on the ground surface so the nylon strings can be removed during the pilot test to allow access for injection equipment and personnel. However, the rebar stakes will remain in-place for the duration of the pilot test should the straight-line projections need to be re-marked. Utility manholes within and surrounding the target treatment area will also be used to confirm utility locations and depths. Soil removed during the overburden excavations will be containerized and handled by Westinghouse personnel.

After the semi-permanent stakes have been installed and the straight-line projections are completed, the excavations will be backfilled and compacted in 6-inch lifts with rock screenings to six inches below the natural grade. In the northern excavation, the remaining six inches will be filled with a compacted base course. In the southern excavation, the remaining six inches will be filled with a compacted base course and the removed section of concrete will be patched with 3,500 pounds per square inch (psi) concrete with fiber mesh to match the surrounding surfaces. Depending on the thickness of the surrounding concrete, rebar dowels may be installed prior to pouring the concrete patch to improve stability. Locations of the proposed overburden excavations are illustrated in **Figure 12.**

Fresh water will be obtained in the same manner as described in **Section 6.1.6.3.** A pre-application test will also be performed for the uranium pilot test which will consist of approximately 281 to 294 gals for a single injection point.

Regenesis will be subcontracted to perform the injection activities following the same methods as described in **Section 6.2.7.3**.

Injections will begin at the proposed locations furthest from the plant and progress in direction of the plant (e.g., west to east). The injections will be administered in the same manner as described in **Section 6.1.6.3**. For the uranium pilot test, the injection rods will be advanced to a depth of 10.5 feet bgs to target a depth interval of 9 to 12 feet bgs and then to a second depth of 13.5 feet bgs to target a depth interval of 12 to 15 feet bgs. Proposed depths and spacing of the DPT injection points are illustrated in the cross-section provided as **Appendix G.** Approximately, 122.5 gals of the mixed S-MZVI amendment will be injected into each targeted depth interval following the same rule-of-thumb as described in **Section 6.1.6.3**. Injection volumes, flowrates, and pressures will be monitored throughout the duration of the pilot test (**Section 6.3.8**).

A freshwater flush will be performed after each injection depth interval as described in **Section 6.1.6.3.** Upon completion, each injection point will be abandoned, and the disturbed area will be restored as described in **Section 6.1.6.3.**

6.3.7 Performance Monitoring

During injection, in-field parameters will be recorded in the same manner as described in **Section 6.1.7** to evaluate performance. Depth to water measurements will be recorded from monitoring wells W-37, W-54, W-55, W-56, W-57, W-72, and W-73 at the same frequencies as described in **Section 6.1.7.** Groundwater field parameters will also be measured in the same manner as described in **Section 6.1.7.**

After the injection has been completed, results of the routine groundwater sampling events from the select monitoring wells including W-37, W-54, W-55, W-56, W-57, W-72, and W-73 will be utilized to evaluate performance over a minimum time period of one year, post-injection. Specific parameters to be monitored include pH, ORP, DO, and total uranium concentrations. The groundwater sampling will be performed using the same procedures as described in **Section 6.1.5.** GEL will analyze the samples for isotopic uranium by EPA Method 200.8/200.2. A SAP summarizing the uranium pilot study post-injection sampling is provided in **Appendix E.**

7. Decontamination and Investigation Derived Waste

Drilling equipment and reusable equipment will be cleaned between borings/samples. Equipment cleaning will be performed in accordance with the EPA Region 4 LSASDPROC-205-R4 Field Equipment Cleaning and Decontamination (EPA, 2020). Drilling equipment will be decontaminated with a pressure washer using potable water between target treatment areas. For groundwater sampling, single-use, factory-cleaned sampling equipment will generally be used when possible. Hand auger buckets and water level meters will be washed with a detergent (e.g., Liqui-Nox®) solution and rinsed with de-ionized (DI) water between boreholes and monitoring wells, respectively. Probes used for field measurements will be rinsed with DI water between each sample location. Flow-thru cells will be rinsed with DI water between sampling locations and washed with the detergent solution and DI water at the end of the day.

Investigation derived waste (IDW) generated during the well installation and pilot test implementation will be managed in accordance with CFFF procedures and the EPA Region 4 LSASDPROC-202-R5 Management of Investigation Derived Waste (EPA, 2023b). Materials which may become IDW include personal protective equipment (PPE), disposable equipment, soil cuttings from drilling or hand auguring, drilling fluids, groundwater obtained through well development or well purging, and cleaning/decontamination fluids.

Groundwater well sampling and development IDW was authorized for on-site treatment at CFFF in a Letter of Authorization (LOA 005504) issued by SCDES on October 27, 2020 (SCDES, 2020). Liquids generated from these activities will be collected in 275-gal totes labeled as Groundwater IDW. When the tote is full, it will be transferred to Uranium Recovery and Recycling Services for introduction into the wastewater treatment process.

Solid IDW will be containerized in Department of Transportation approved 55-gal drums or roll-off containers and temporarily staged at a central location pending selection of final disposal method(s). Each drum will contain IDW from one location. IDW from multiple locations will not be mixed in drums. Generated IDW is anticipated to be characterized using previous analytical results and handled/disposed under existing waste profiles for the site. If required, composite samples may be collected to characterize the IDW. IDW composite samples will be collected in general accordance with EPA Region 4 LSASDPROC-300-R5 Soil Sampling (EPA, 2023c). CFFF personnel will coordinate the profiling and disposal of the IDW materials.

8. Reporting

Following completion of the pilot test injections, AECOM will submit an Injection Completion Report which will detail the baseline groundwater monitoring results, the bench-scale treatability test results, the final injection designs, and the injection implementations. Following completion of the post-injection performance monitoring, AECOM will submit a Pilot Study Completion Report which will detail the results and findings of the CVOC, Tc-99, and uranium pilot studies.

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Tables

Table 1
Constituents of Potential Concern by Media
Pilot Study Work Plan
Westinghouse Columbia Fuel Fabrication Facility
Hopkins, South Carolina

Media	Primary COPC				
	CVOCs	Nitrate	Fluoride	Uranium	Tc-99
Groundwater	FS	FS	FS	FS	FS
Surface Water	FS	NE	FS	NE	NE
Soil/Sediment	NE	NE	NE	FS	FS

Notes:
COPC - Constituents of potential concern
CVOCs - Chlorinated volatile organic compounds
Tc-99 - Technetium-99
FS - To be evaluated in Feasibility Study
NE - No exceedances in Remedial Investigation

Table 2
Remedial Goals for Site-Specific COPCs
Pilot Study Work Plan
Westinghouse Columbia Fuel Fabrication Facility
Hopkins, South Carolina

COPC	Groundwater				Surface Water					Soil/Sediment				
	Long-term Goal	Maximum Detection[1]			Short-term Goal	Long-term Goal	Maximum Detection[1]			Short-term Goal[2]	Long-term Goal[2]	Maximum Detection[1]		
	µg/L	µg/L	Location	Date	µg/L	µg/L	µg/L	Location	Date	pCi/g	pCi/g	µg/L	Location	Date
PCE	5	370	W-65	Q2-2024	53	5	16	SW-17	7/18/2019	NA	NA	NA	NA	NA
TCE	5	50	W-65	Q2-2024	220	5	1	SW-17	7/18/2019	NA	NA	NA	NA	NA
Vinyl Chloride	2	3.2	W-107	Q2-2024	930	2	<1.0	NA	NA	NA	NA	NA	NA	NA
Nitrate	10,000	330,000	W-18R	Q2-2024	NA	10,000	7,300	SW-23	7/16/2019	NA	NA	NA	NA	NA
Fluoride	4,000	9,800	W-78	Q2-2024	4,000	4,000	5,100	SW-GATORPOND	2/28/2024	NA	NA	NA	NA	NA
Total Uranium	30	302	W-56	Q2-2024	NA	30	2.38	SW-LOWERSUNSETLAKE	5/29/2024	NA	NA	NA	NA	NA
Tc-99	900 pCi/L	2,840 pCi/L	W-6	Q2-2024	NA	900 pCi/L	44.7	SW-GATORPOND	2/28/2024	89,400	42.8	312	SED-65	1/3/2024
Uranium 233/234	NA	NA	NA	NA	NA	NA	NA	NA	NA	3,310	209.7	435	SED-44	12/1/2020
Uranium 235/236	NA	NA	NA	NA	NA	NA	NA	NA	NA	39	36.9	24.3	SED-44	12/1/2020
Uranium 238	NA	NA	NA	NA	NA	NA	NA	NA	NA	179	111.3	98.7	SED-44	12/1/2020

Notes:
[1] - Maximum detections reflect the most recent set of data, where applicable.
[2] - Soil/Sediment goals are based upon the updated Derived Concentration Guidance Levels (DCGLs) from NUREG-1575.

COPC - Constituents of potential concern
PCE - Tetrachloroethene
TCE - Trichloroethene
Tc-99 - Technetium-99
µg/L - Micrograms per Liter
pCi/L - Pico curies per Liter
pCi/g - Pico curies per gram
NA - Not applicable

Table 3
Summary of Remedial Alternatives
Pilot Study Work Plan
Westinghouse Columbia Fuel Fabrication Facility
Hopkins, South Carolina

Remedial Alternative 1		Remedial Alternative 2		Remedial Alternative 3		Remedial Alternative 4		Remedial Alternative 5	
Remedial Technology	Targeted COPC	Remedial Technology	Targeted COPC	Remedial Technology	Targeted COPC	Remedial Technology	Targeted COPC	Remedial Technology	Targeted COPC
No Action	None	Excavation (Hydraulic Dredging)	Uranium (sediment) Tc-99 (sediment)	Excavation (Hydraulic Dredging)	Uranium (sediment) Tc-99 (sediment)	Excavation (Hydraulic Dredging)	Uranium (sediment) Tc-99 (sediment)	Excavation (Hydraulic Dredging)	Uranium (sediment) Tc-99 (sediment)
		ZVI (injection)	Uranium (groundwater) Tc-99 (groundwater)	PRB (liquid activated carbon injection)	Uranium (groundwater) Tc-99 (groundwater) CVOCs Nitrate	ZVI (injection)	Uranium (groundwater) Tc-99 (groundwater)	PRB (liquid activated carbon injection)	Uranium (groundwater) Tc-99 (groundwater) CVOCs Nitrate
		ERD+ZVI (injection)	CVOCs Nitrate			ERD+ZVI (injection)	CVOCs Nitrate		
		Fluoride Sequestration (injection)	Fluoride	Fluoride Sequestration (injection)	Fluoride	Groundwater Extraction	Fluoride	Groundwater Extraction	Fluoride

Notes:

COPC - Constituents of potential concern

Tc-99 - Technetium-99

CVOCs - Chlorinated Volatile Organic Compounds

ZVI - Zero Valent Iron

ERD - Enhanced Reductive Dechlorination

PRB - Permeable Reactive Barrier

Table 4
Pilot Study Well Construction Summary
Pilot Study Work Plan
Westinghouse Columbia Fuel Fabrication Facility
Hopkins, South Carolina

Well Number	Northing	Easting	Date Installed	Ground Surface Elevation (ft msl)	Top of Casing Elevation (ft msl)	Casing Stickup (ft)	Well Diameter (in)	Casing Type	Total Depth (ft bgs)	Screen Length (ft)	Screen Interval (ft bgs)	Classification
Existing Monitoring Wells												
W-6	744963.2941	2024109.6154	5/15/1980	136.96	136.46	-0.50	2.0	PVC	27.80	5	23-28	Surficial - Lower Zone
W-11	744743.0468	2023914.5566	5/14/1980	138.45	140.76	2.31	2.0	PVC	24.97	3	22-25	Surficial - Upper Zone
W-22	744960.9243	2024116.3963	7/12/1980	137.08	136.51	-0.57	2.0	PVC	15.10	5	10-15	Surficial - Upper Zone
W-32	744742.1011	2023919.8088	7/15/1980	138.33	140.34	2.01	2.0	PVC	21.89	5	17-22	Surficial - Upper Zone
W-37	745407.3901	2024230.7318	2/11/1992	136.58	139.04	2.46	2.0	PVC	20.41	5	15.5-20.5	Surficial - Upper Zone
W-54	745442.5511	2024229.9796	9/19/2018	136.79	136.52	-0.27	2.0	PVC	15.82	5	11-16	Surficial - Upper Zone
W-55	745397.6509	2024214.0049	9/20/2018	136.90	136.63	-0.27	2.0	PVC	15.24	5	10-15	Surficial - Upper Zone
W-56	745351.3097	2024203.7460	9/20/2018	136.83	136.68	-0.15	2.0	PVC	15.13	5	10-15	Surficial - Upper Zone
W-57	745307.4270	2024190.7853	9/20/2018	136.90	136.73	-0.17	2.0	PVC	15.12	5	10-15	Surficial - Upper Zone
W-73	745339.3056	2024166.2500	6/30/2019	136.85	136.45	-0.40	2.0	PVC	16.00	10	6-16	Surficial - Upper Zone
W-74	745325.1257	2024067.1720	9/17/2019	136.64	139.93	3.29	2.0	PVC	30.60	5	25.5-30.5	Surficial - Lower Zone
W-120	745967.1436	2024014.3529	7/29/2021	139.26	142.34	3.08	2.0	PVC	33.80	5	29-34	Surficial - Lower Zone
W-121	745966.7263	2024008.0883	7/29/2021	139.12	142.24	3.11	2.0	PVC	22.12	10	12-22	Surficial - Upper Zone
Proposed Performance Monitoring Wells												
PMW-1A	--	--	--	--	--	2.50	2.0	PVC	22.00	10	12-22	Surficial - Upper Zone
PMW-1B	--	--	--	--	--	2.50	2.0	PVC	34.00	5	29-34	Surficial - Lower Zone
PMW-2A	--	--	--	--	--	2.50	2.0	PVC	22.00	10	12-22	Surficial - Upper Zone
PMW-2B	--	--	--	--	--	2.50	2.0	PVC	34.00	5	29-34	Surficial - Lower Zone
PMW-3A	--	--	--	--	--	2.50	2.0	PVC	22.00	10	12-22	Surficial - Upper Zone
PMW-3B	--	--	--	--	--	2.50	2.0	PVC	34.00	5	29-34	Surficial - Lower Zone
PMW-4A	--	--	--	--	--	2.50	2.0	PVC	22.00	10	12-22	Surficial - Upper Zone
PMW-4B	--	--	--	--	--	2.50	2.0	PVC	34.00	5	29-34	Surficial - Lower Zone
PMW-5A	--	--	--	--	--	2.50	2.0	PVC	22.00	10	12-22	Surficial - Upper Zone
PMW-5B	--	--	--	--	--	2.50	2.0	PVC	34.00	5	29-34	Surficial - Lower Zone
PMW-6A	--	--	--	--	--	2.50	2.0	PVC	22.00	10	12-22	Surficial - Upper Zone
PMW-6B	--	--	--	--	--	2.50	2.0	PVC	34.00	5	29-34	Surficial - Lower Zone

Notes:

ft = feet ft msl = feet above mean sea level

in = inches ft bgs = feet below ground surface

Top of casing and ground surface elevations surveyed by AECOM during November 2018, November 2019, April 2021 and August 2021.

Horizontal coordinates are referenced to the State Plane Coordinate System and the North American Datum of 1983 (NAD 83).

Vertical locations are referenced to the North American Vertical Datum of 1988 (NAVD 88).

Table 5
CVOC Pilot Test Design Summary
Pilot Study Work Plan
Westinghouse Columbia Fuel Fabrication Facility
Hopkins, South Carolina

Injection Design Summary		
Monitoring Well Information		
Target Monitoring Wells	W-120	W-121
Screen Interval (ft bgs)	29-34	12-22
COPC Concentration (ug/L)		
PCE	340	82
TCE	17	2.4
Aquifer Geochemistry		
pH (S.U.)	5.91	5.21
ORP (mV)	176	263
DO (mg/L)	0.53	2.42
Temperature (^{o}C)	20.6	18.7
Specific Conductivity (uS/cm)	145.3	66.2
Natural Attenuation Parameters (ug/L) *		
Chloride	5400	NA
Total Iron	64	NA
Nitrate	3900	NA
Sulfate	4000	NA
Manganese	160	NA
Methane	110	NA
Treatment Zone Information		
Target Treatment Area (sf)	10,000	
Top Target Treatment Depth (ft bgs)	9	
Bottom Target Treatment Depth (ft bgs)	34	
Targeted Treatment Thickness (ft)	25	
Estimated Effective Porosity	20%	
Average Aquifer Hydraulic Conductivity (ft/day)	4.08 (W-120) - 10.63 (W-121)	
Total Number of Injection Points	25	
Injection Point Grid	5x5	
Injection Point Spacing (ft)	20	
Injection Depth Interval (ft)	5	
Number of Depth Intervals per Injection Point	5	
Injection Point Depths (ft bgs)	11.5, 16.5, 21.5, 26.5, 31.5	
Injection Information		
Injection Method	DPT (top-down approach)	
Product	eZVI	
Product Amount (lbs)	20,000	
Product Volume (gals)	1,460	
Make-up Water Volume (gals)	14,000	
Pre-Application Test - 15% (gals fresh water)	711	
Pre-Application Test - 20% (gals fresh water)	742	
Total Amendment Volume (gals)	15,460	
Amendment ZVI by Weight	15%	
Amendment Volume per Point (gals)	618	
Amendment Volume per Depth Interval (gals)	124	
Estimated Days to Complete	9	

Notes:

COPC = constituent of potential concern
ug/L = micrograms per liter
PCE = tetrachloroethylene
TCE = trichloroethylene
S.U. = standard units
ORP = oxidation reduction potential in millivolts (mV)
DO = dissolved oxygen in milligrams per liter (mg/L)
^{o}C = degrees Celsius

lbs = pounds
gals = gallons
uS/cm = microsiemens per centimeter
NA = not analyzed
sf = square feet
ft bgs = feet below ground surface
DPT = direct-push technology
eZVI = Ferox Plus Zero-Valent Iron

Table 6
Tc-99 Pilot Test Design Summary
Pilot Study Work Plan
Westinghouse Columbia Fuel Fabrication Facility
Hopkins, South Carolina

Injection Design Summary				
Monitoring Well Information				
Target Monitoring Wells	W-6	W-22	W-11	W-32
Screen Interval (ft bgs)	23-28	10-15	22-25	17-22
COPC Concentration (pCi/L)				
Tc-99	2,500	31.1	1,230	231
Aquifer Geochemistry				
pH (S.U.)	5.53	5.9	5.62	6.94
ORP (mV)	206	152	156	147
DO (mg/L)	0.3	0.3	1.58	0.73
Temperature (^oC)	19.6	19.4	21.2	20.4
Specific Conductivity (uS/cm)	585.0	2421.0	154.0	1062.0
Natural Attenuation Parameters (ug/L) *				
Chloride	24,000	7,100	8,400	7,400
Total Iron	330	140	<50	<50
Nitrate	295,000	83,500	27,000	130,000
Sulfate	47,000	170,000	4,200	32,000
Manganese	250	960	49	290
Methane	<10	74	<10	<10
Treatment Zone Information				
Location	Northern Treatment Area		Southern Treatment Area	
Target Treatment Area (sf)	4,000		4,000	
Top Target Treatment Depth (ft bgs)	11		11	
Bottom Target Treatment Depth (ft bgs)	31		31	
Target Treatment Thickness (ft)	20		20	
Effective Porosity	20%		20%	
Average Aquifer Hydraulic Conductivity (ft/day)	0.51 (W-6)		0.06 (W-11)	
Total Injection Points	40		40	
Injection Point Grid	4x10		4x10	
Injection Point Spacing (ft)	10		10	
Injection Depth Interval (ft)	5		5	
Number of Depth Intervals per Injection Point	4		4	
Injection Point Depths (ft bgs)	13.5, 18.5, 23.5, 28.5		13.5, 18.5, 23.5, 28.5	
Injection Information				
Injection Method	DPT (top-down approach)		DPT (top-down approach)	
Product	S-MZVI		S-MZVI	
Product Amount (lbs)	10,000		10,000	
Product Volume (gals)	662		662	
Make-up Water Volume (gals)	31,959		31,959	
Pre-Application Test - 15% (gals fresh water)	938		938	
Pre-Application Test - 20% (gals fresh water)	979		979	
Total Amendment Volume (gals)	32,621		32,621	
Amendment ZVI by Weight	4%		4%	
Amendment Volume per Point (gals)	816		816	
Amendment Volume per Depth Interval (gals)	163		163	
Estimated Days to Complete	12		12	

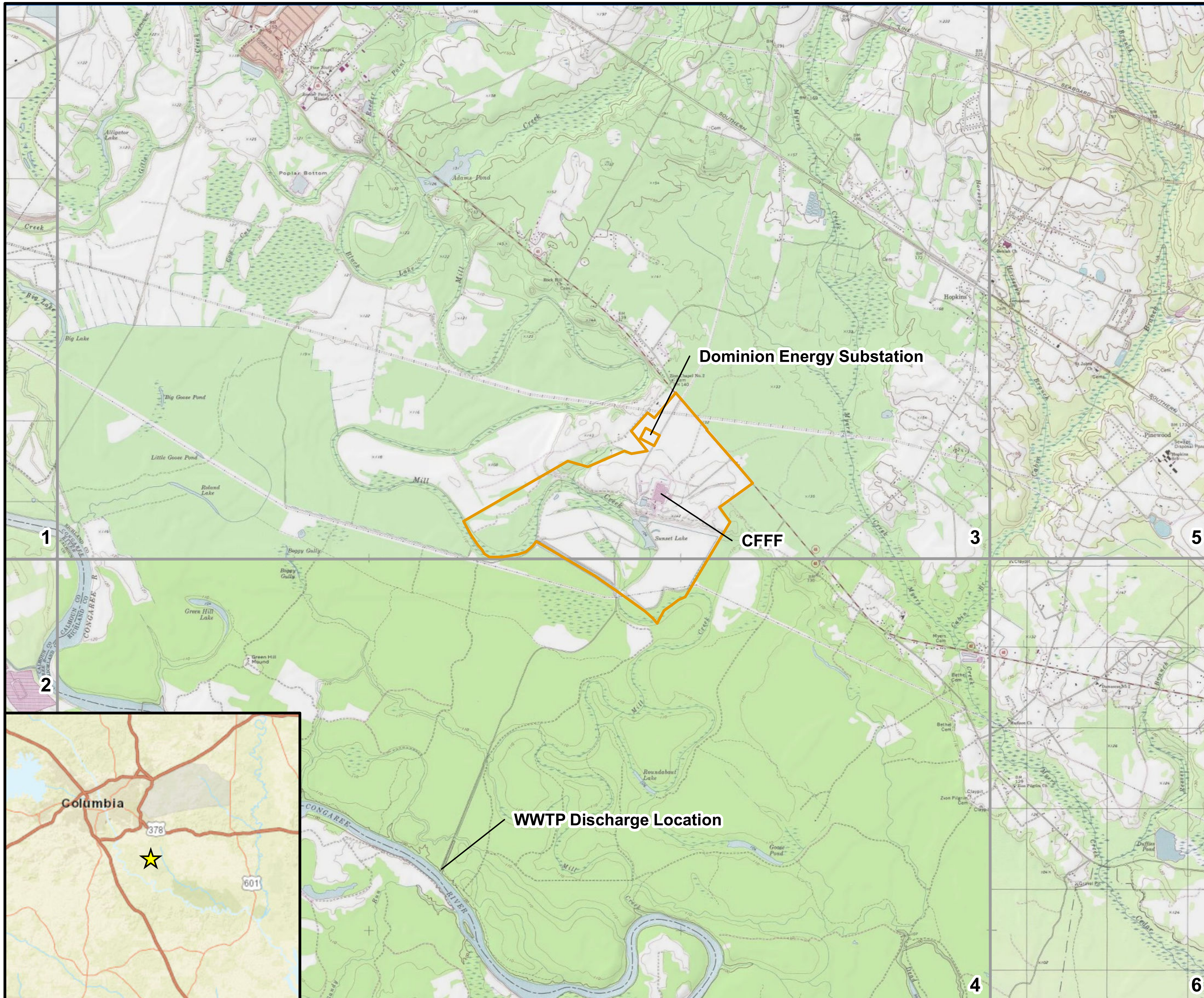
Notes:
COPC = constituent of potential concern
pCi/L = picocuries per liter
ug/L = micrograms per liter
S.U. = standard units
ORP = oxidation reduction potential in millivolts (mV)
DO = dissolved oxygen in milligrams per liter (mg/L)
^oC = degrees Celsius
uS/cm = microsiemens per centimeter
sf = square feet
ft bgs = feet below ground surface
DPT = direct-push technology
S-MZVI = sulfidated micro-scale zero-valent iron
lbs = pounds
gals = gallons

Table 7
Uranium Pilot Test Design Summary
Pilot Study Work Plan
Westinghouse Columbia Fuel Fabrication Facility
Hopkins, South Carolina

Injection Design Summary		
Monitoring Well Information		
Target Monitoring Wells	W-55	W-56
Screen Interval (ft bgs)	10-15	10-15
COPC Concentration (ug/L)		
Total Uranium	121	143
Aquifer Geochemistry		
pH (S.U.)	6.05	5.97
ORP (mV)	196	195
DO (mg/L)	5.49	3.32
Temperature (^{o}C)	19.3	19.4
Specific Conductivity (uS/cm)	122.0	132.0
Natural Attenuation Parameters (ug/L) *		
Chloride	5,300	7,800
Total Iron	71	75
Nitrate	1,500	2,500
Sulfate	28,000	18,000
Manganese	<5	<5
Methane	<10	<10
Treatment Zone Information		
Target Treatment Area (sf)	4,000	
Top Target Treatment Depth (ft bgs)	9	
Bottom Target Treatment Depth (ft bgs)	15	
Target Treatment Thickness (ft)	6	
Estimated Effective Porosity	20%	
Average Aquifer Hydraulic Conductivity (ft/day)	9.04*	
Total Number of Injection Points	40	
Injection Point Grid	4x10 (modified)	
Injection Point Spacing (ft)	10	
Injection Depth Interval (ft)	3	
Number of Depth Intervals per Injection Point	2	
Injection Point Depths (ft bgs)	10.5 and 13.5	
Injection Information		
Injection Method	DPT (top-down approach)	
Product	S-MZVI	
Product Amount (lbs)	3,000	
Product Volume (gals)	199	
Make-up Water Volume (gals)	9,588	
Pre-Application Test - 15% (gals fresh water)	281	
Pre-Application Test - 20% (gals fresh water)	294	
Total Amendment Volume (gals)	9,787	
Amendment ZVI by Weight	4%	
Amendment Volume per Point (gals)	245	
Amendment Volume per Depth Interval (gals)	122	
Estimated Days to Complete	4	

Notes:
COPC = constituent of potential concern
ug/L = micrograms per liter
S.U. = standard units
ORP = oxidation reduction potential in millivolts (mV)
DO = dissolved oxygen in milligrams per liter (mg/L)
S-MZVI = sulfidated micro-scale zero-valent iron
* - Slug test data taken from nearest wells (W-35 and W-39)
sf = square feet
ft bgs = feet below ground surface
DPT = direct-push technology
lbs = pounds
gals = gallons
uS/cm = microsiemens per centimeter
^{o}C = degrees Celsius

Figures



Legend

Locations

Property Line

Topographic Quadrangle Boundary

ID	Topographic Quadrangle Name
1	Southwest Columbia
2	Gaston
3	Fort Jackson South
4	Saylors Lake
5	Congaree
6	Gadsden

0 2,000 4,000 Feet

1:48,000

Map Projection: NAD 1983, South Carolina State Plane, FIPS 3900, Feet

Datum: North American 1983

Data Source: Esri/USGS

AECOM

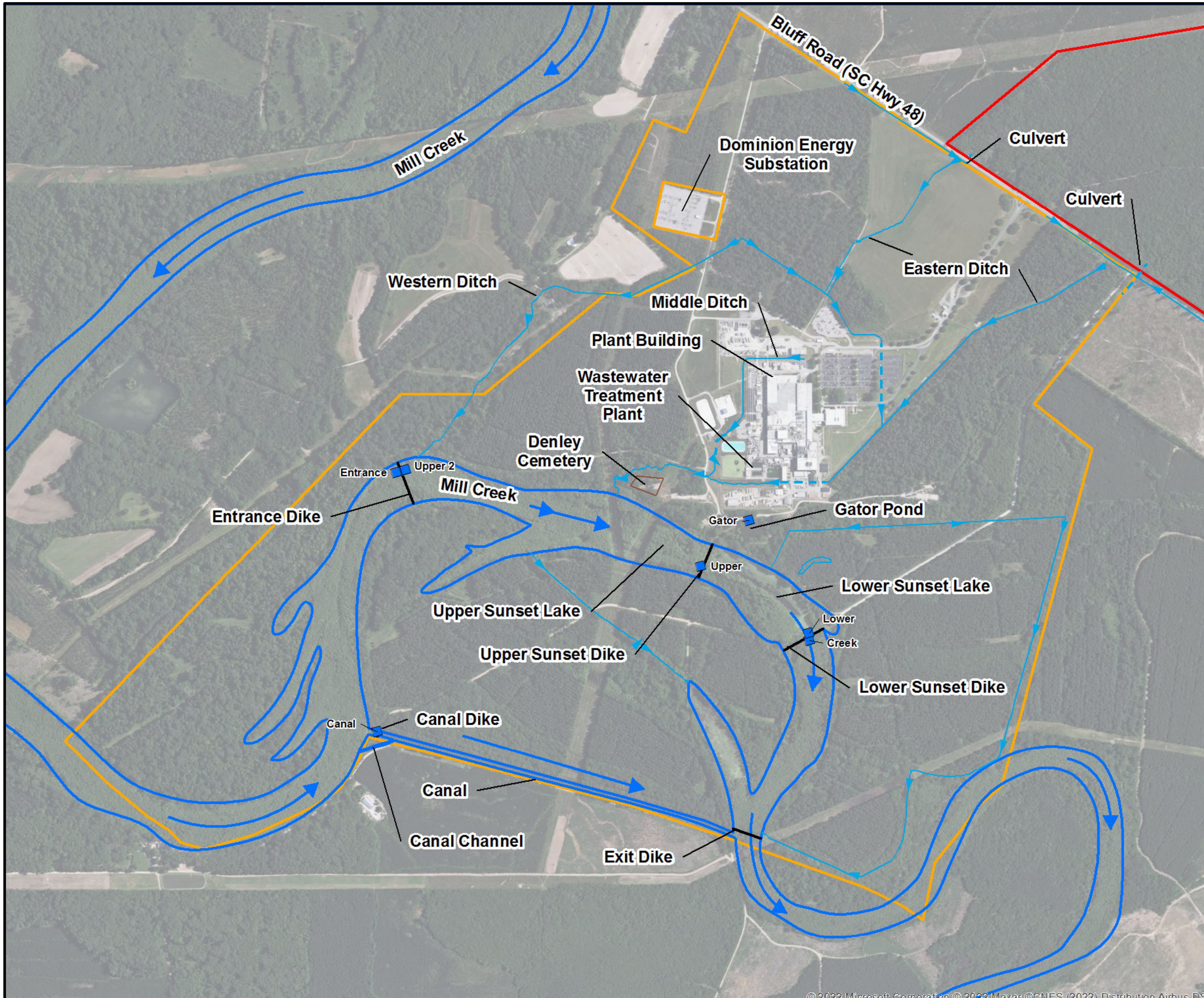
5438 Wade Park Blvd,
Raleigh, NC 27607
T: (919) 461-1100 F: (919) 464-1415

Site Location Map

WESTINGHOUSE COLUMBIA FUEL FABRICATION FACILITY
HOPKINS, SOUTH CAROLINA

PROJECT NO.	PREPARED BY:	DATE:	
60691645	CCS	January 2025	FIGURE 1

Path: M:\EnvDataViz\Westinghouse\mxd\2021 RI Report\F1 Site Location Map.mxd



Legend

- Staff Gage Location
- Mill Creek Flow Direction
- Ditch
- Culvert
- Property Line
- SCRDI Bluff Road (Superfund Site)
- Mill Creek
- Dike Location

0 500 1,000 Feet

1:12,000

Map Projection: NAD 1983, South Carolina State Plane, FIPS 3900, Feet

Datum: North American 1983

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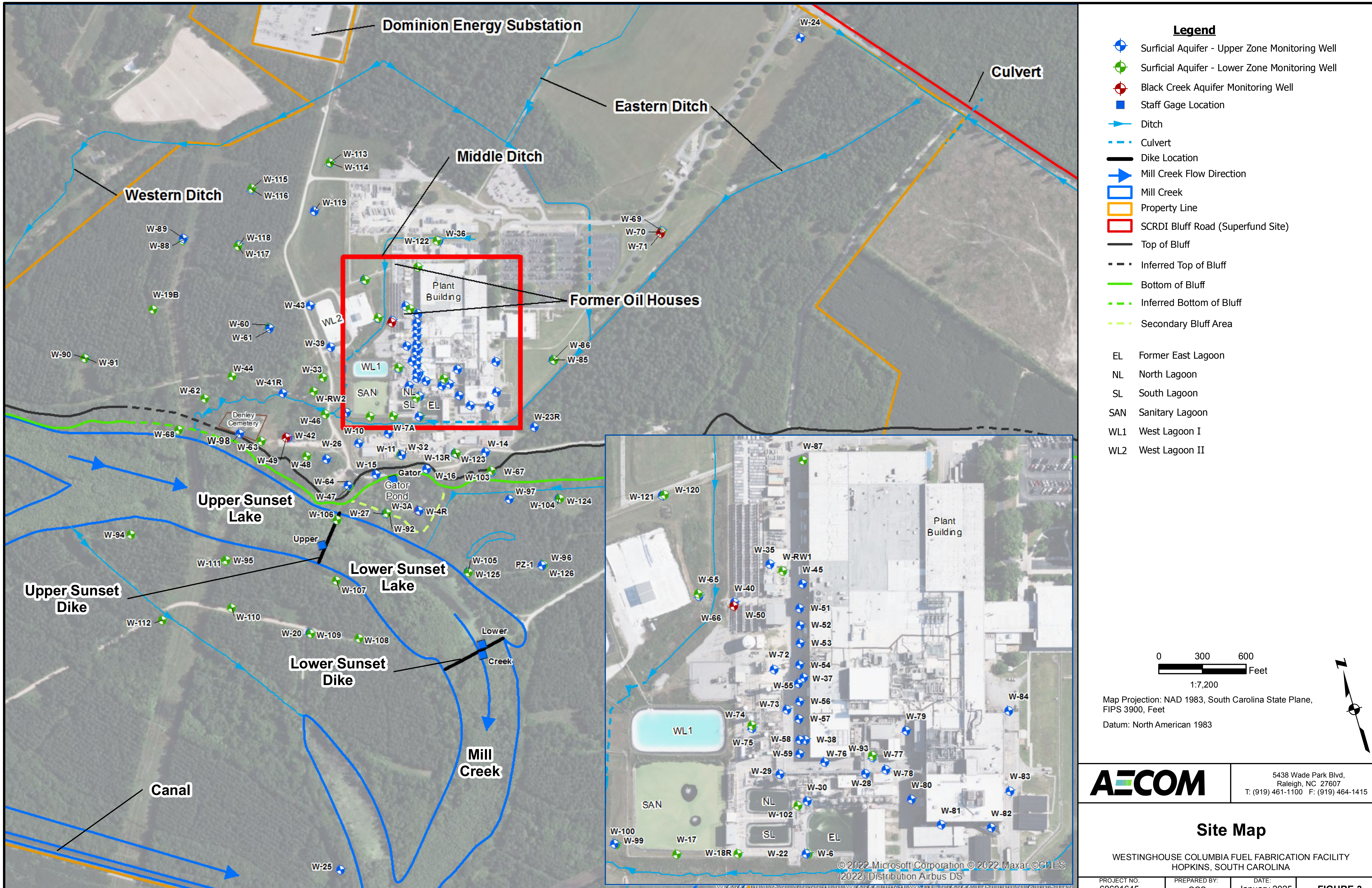
Property Map

WESTINGHOUSE COLUMBIA FUEL FABRICATION FACILITY
HOPKINS, SOUTH CAROLINA

PROJECT NO.	PREPARED BY:	DATE:	
60691645	CCS	January 2025	FIGURE 2

Path: M:\EnvDataViz\Westinghouse\mxd\2021 RI Report\F2 Property Map.mxd



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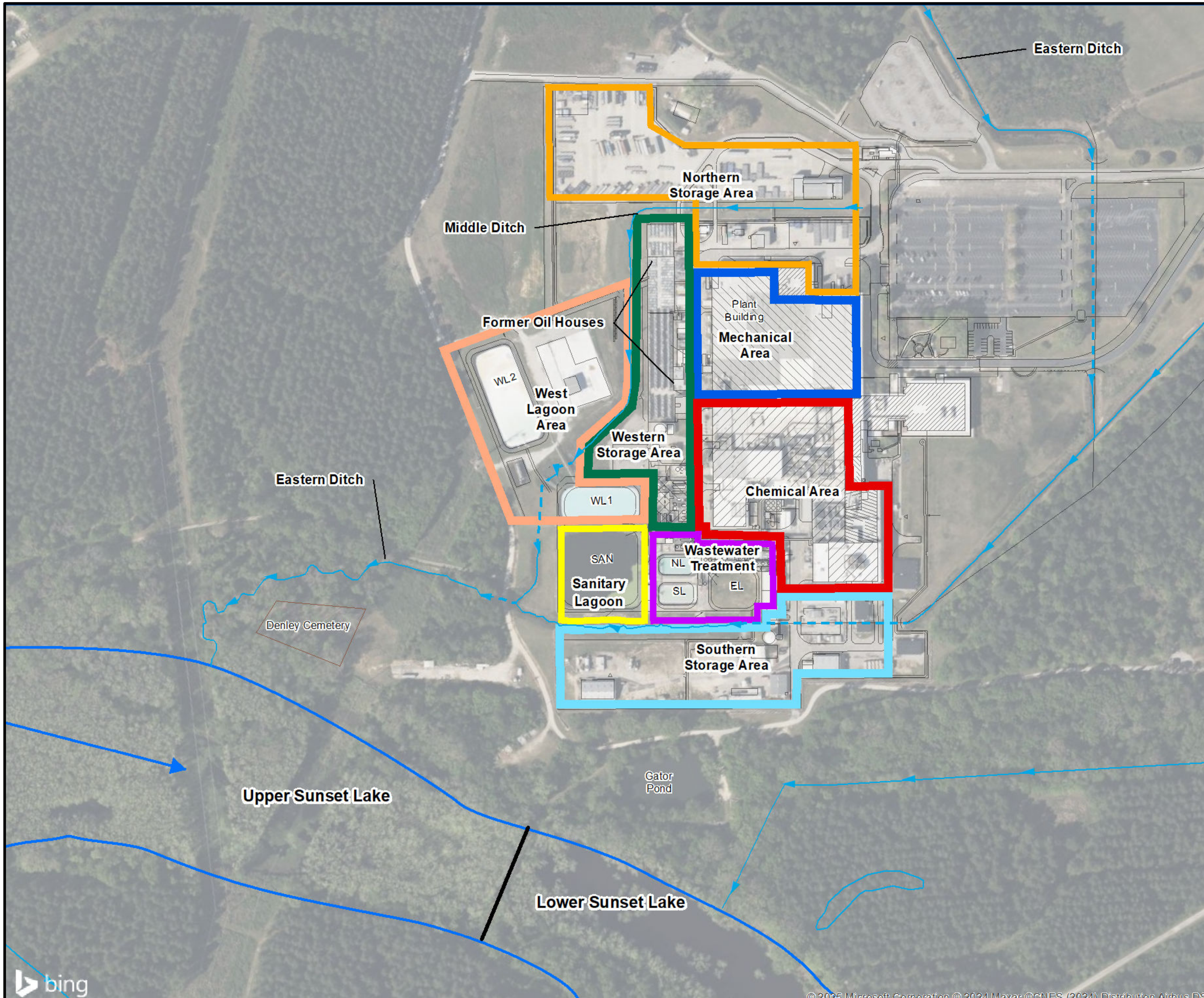

Legend

- Ditch
- Culvert
- Mill Creek Flow Direction
- EL Former East Lagoon
- NL North Lagoon
- SL South Lagoon
- SAN Sanitary Lagoon
- WL1 West Lagoon I
- WL2 West Lagoon II
- Mill Creek
- Dike Location

Operable Units

- Chemical Area
- Mechanical Area
- Northern Storage Area
- Sanitary Lagoon Area
- Southern Storage Area
- Wastewater Treatment Area
- West Lagoons Area
- Western Storage Area

0 150 300 Feet

1:3,600

Map Projection: NAD 1983, South Carolina State Plane, FIPS 3900, Feet

Datum: North American 1983

AECOM

2151 Pickens Street, Suite 301
Columbia, SC 29201
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Operational Units Map

WESTINGHOUSE COLUMBIA FUEL FABRICATION FACILITY
HOPKINS, SOUTH CAROLINA

PROJECT NO.	PREPARED BY:	DATE:	
60691645	CCS	January 2025	FIGURE 4

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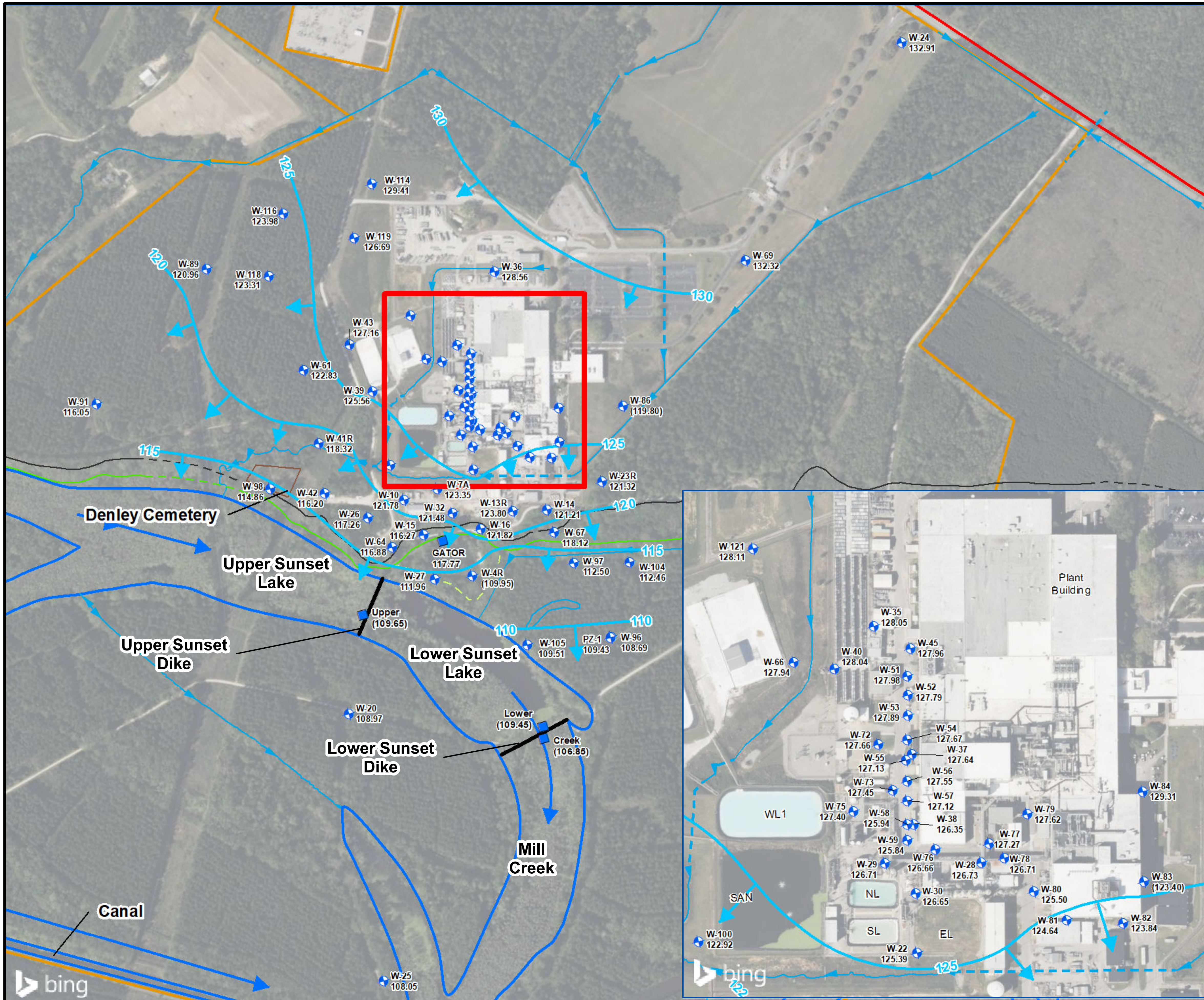

Legend

- Surficial Aquifer - Upper Zone Monitoring Well
- Mill Creek
- Property Line
- SCRDI Bluff Road (Superfund Site)
- Culvert
- Ditch
- Mill Creek Flow Direction
- Dike Location
- Staff Gauge Location
- Top of Bluff
- Inferred Top of Bluff
- Bottom of Bluff
- Inferred Bottom of Bluff
- Secondary Bluff Area
- EL Former East Lagoon
- NL North Lagoon
- SL South Lagoon
- SAN Sanitary Lagoon
- WL1 West Lagoon I
- WL2 West Lagoon II
- Potentiometric Line (C.I. = 5 feet)
- Direction of Groundwater
- 132.91 Groundwater Elevation
- (120.88) Elevation for illustrative purposes only

Based upon data collected on October 21, 2024

0 300 600 Feet

1:7,200

Map Projection: NAD 1983, South Carolina State Plane, FIPS 3900, Feet

Datum: North American 1983

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Surficial Aquifer - Upper Zone Potentiometric Map October 2024

WESTINGHOUSE COLUMBIA FUEL FABRICATION FACILITY
HOPKINS, SOUTH CAROLINA

PROJECT NO.	PREPARED BY:	DATE:	
60691645	CCS	January 2025	FIGURE 5

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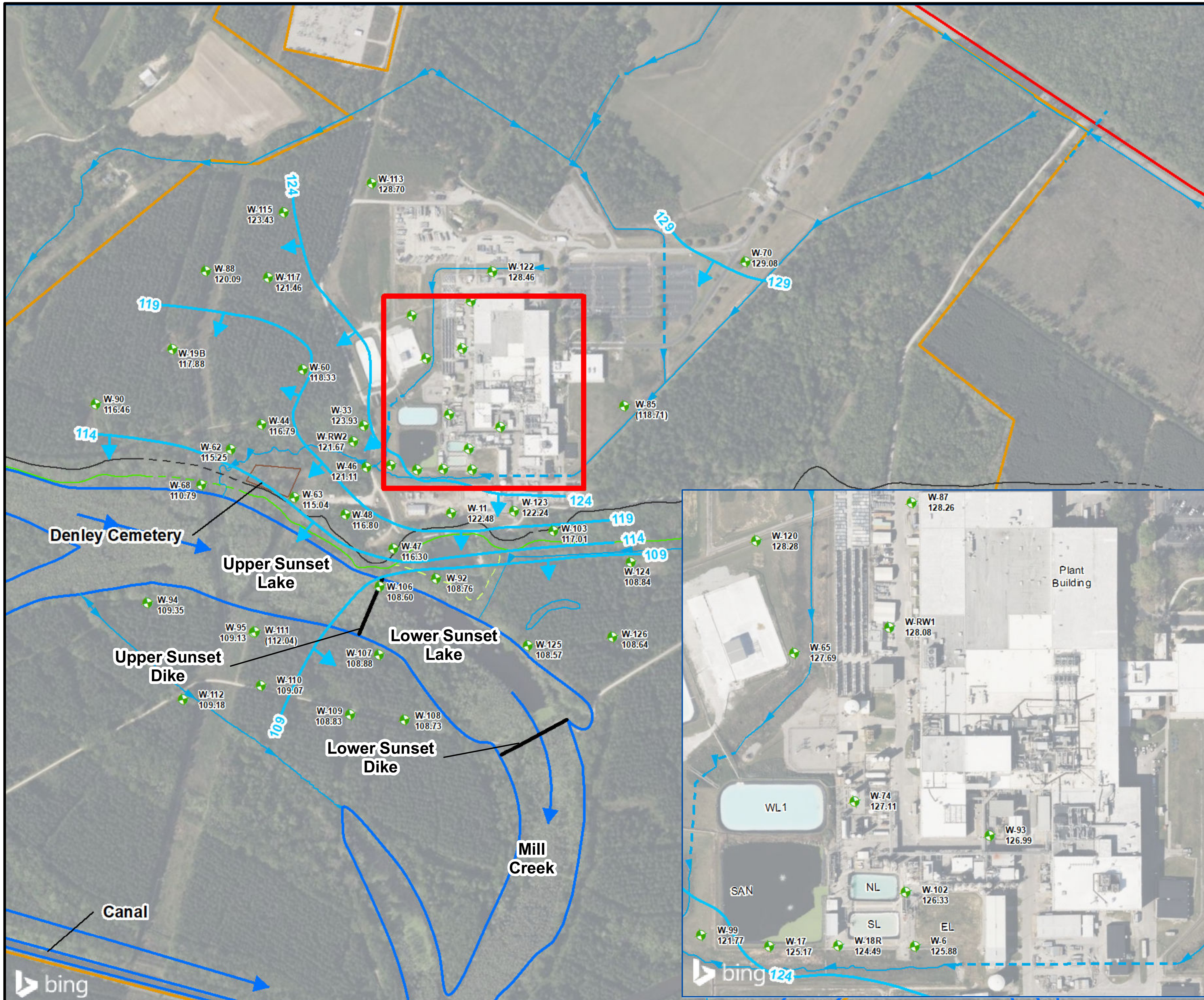

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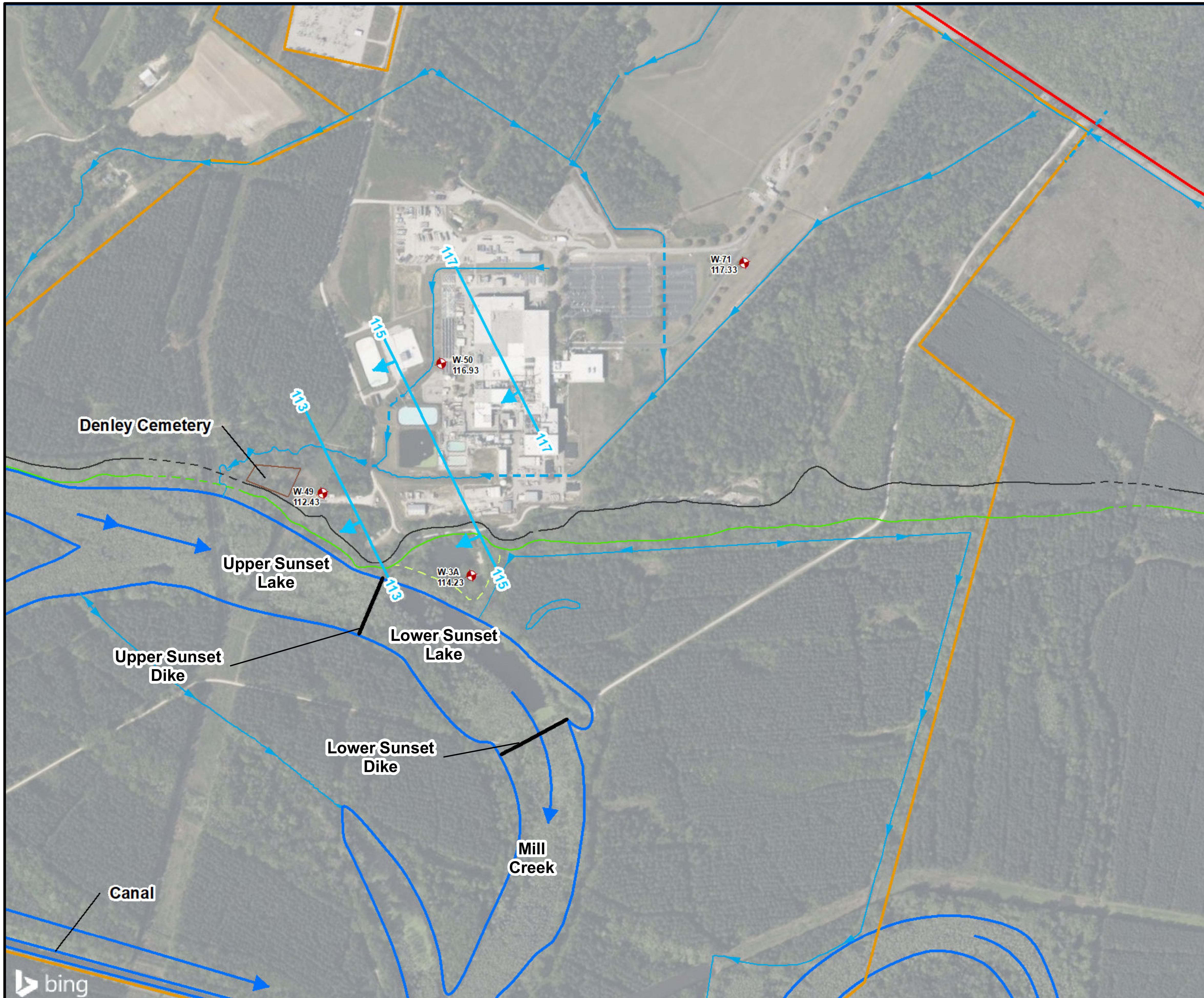
Surficial Aquifer - Lower Zone Potentiometric Map October 2024

WESTINGHOUSE COLUMBIA FUEL FABRICATION FACILITY
HOPKINS, SOUTH CAROLINA

PROJECT NO.	PREPARED BY:	DATE:	
60691645	CCS	January 2025	FIGURE 6

Path: M:\EnvDataViz\Westinghouse\mxd\2024 RI Report\F9 Lower Pot Map October 2024.mxd



Legend

- Black Creek Aquifer Monitoring Well
- Mill Creek
- Property Line
- SCRDI Bluff Road (Superfund Site)
- Culvert
- Ditch
- Mill Creek Flow Direction
- Dike Location
- Top of Bluff
- Inferred Top of Bluff
- Bottom of Bluff
- Inferred Bottom of Bluff
- Secondary Bluff Area

EL	Former East Lagoon
NL	North Lagoon
SL	South Lagoon
SAN	Sanitary Lagoon
WL1	West Lagoon I
WL2	West Lagoon II

- Potentiometric Line (C.I. = 2 feet)
- Direction of Groundwater

117.33 Groundwater Elevation

Based upon data collected on October 21, 2024

0 300 600 Feet

1:7,200

Map Projection: NAD 1983, South Carolina State Plane, FIPS 3900, Feet

Datum: North American 1983

N

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Black Creek Aquifer Potentiometric Map October 2024

WESTINGHOUSE COLUMBIA FUEL FABRICATION FACILITY
HOPKINS, SOUTH CAROLINA

PROJECT NO.	PREPARED BY:	DATE:	
60691645	CCS	January 2025	FIGURE 7

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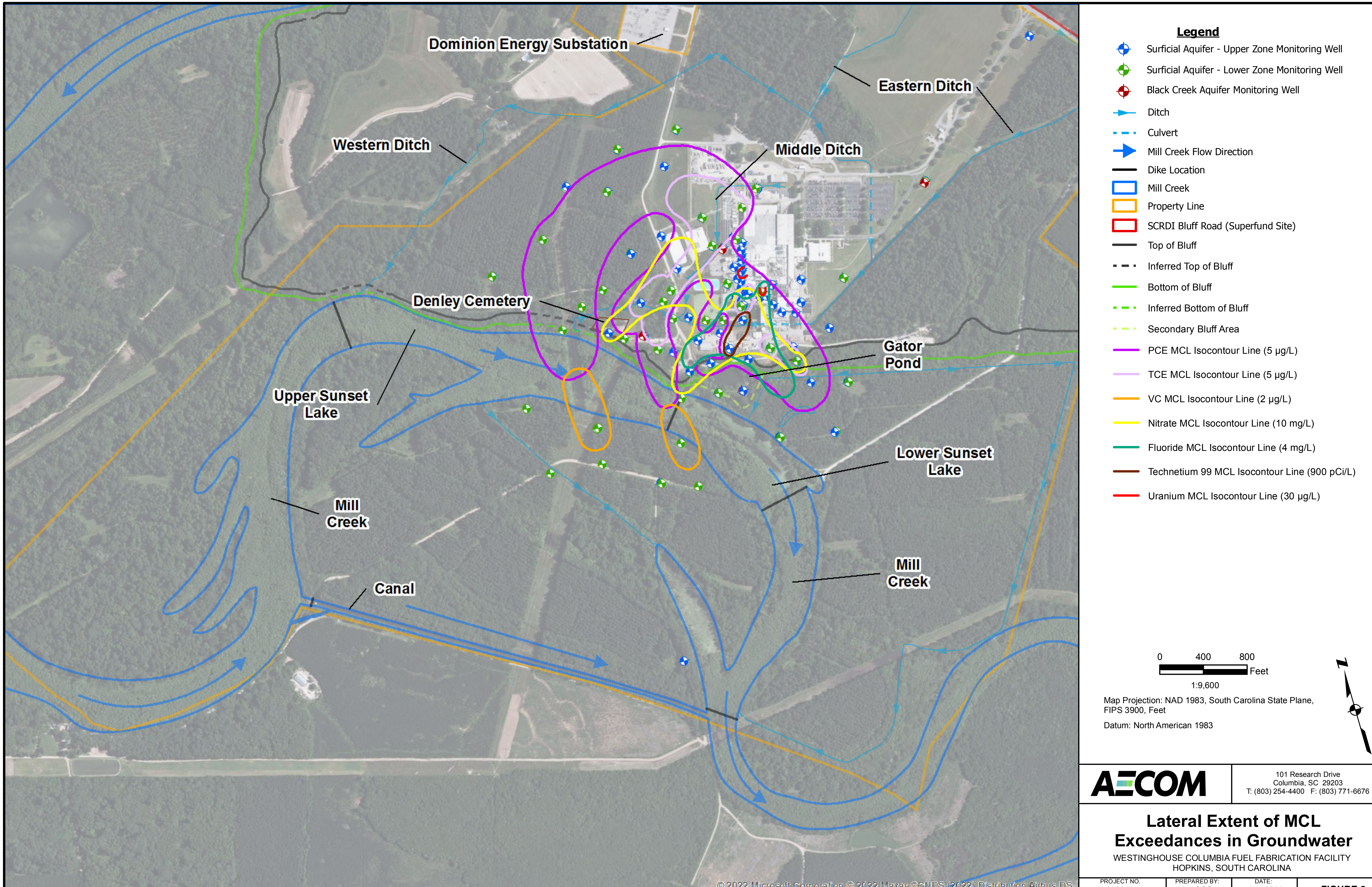

AECOM

101 Research Drive
Columbia, SC 29203
T: (803) 254-4400 F: (803) 771-6676

Lateral Extent of MCL Exceedances in Groundwater

WESTINGHOUSE COLUMBIA FUEL FABRICATION FACILITY
HOPKINS, SOUTH CAROLINA

PROJECT NO.	PREPARED BY:	DATE:	
60691645	CCS	July 2022	FIGURE 8

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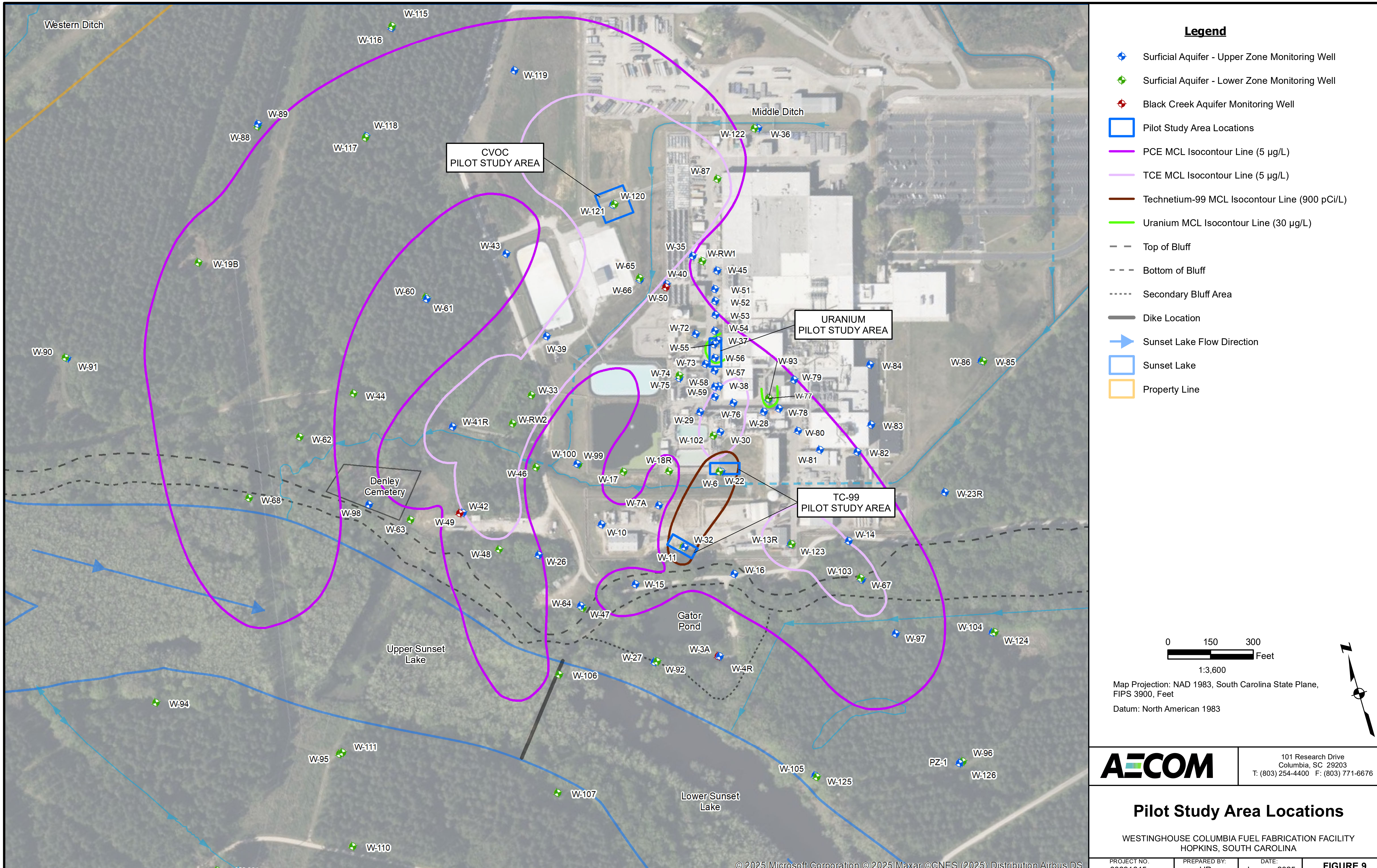

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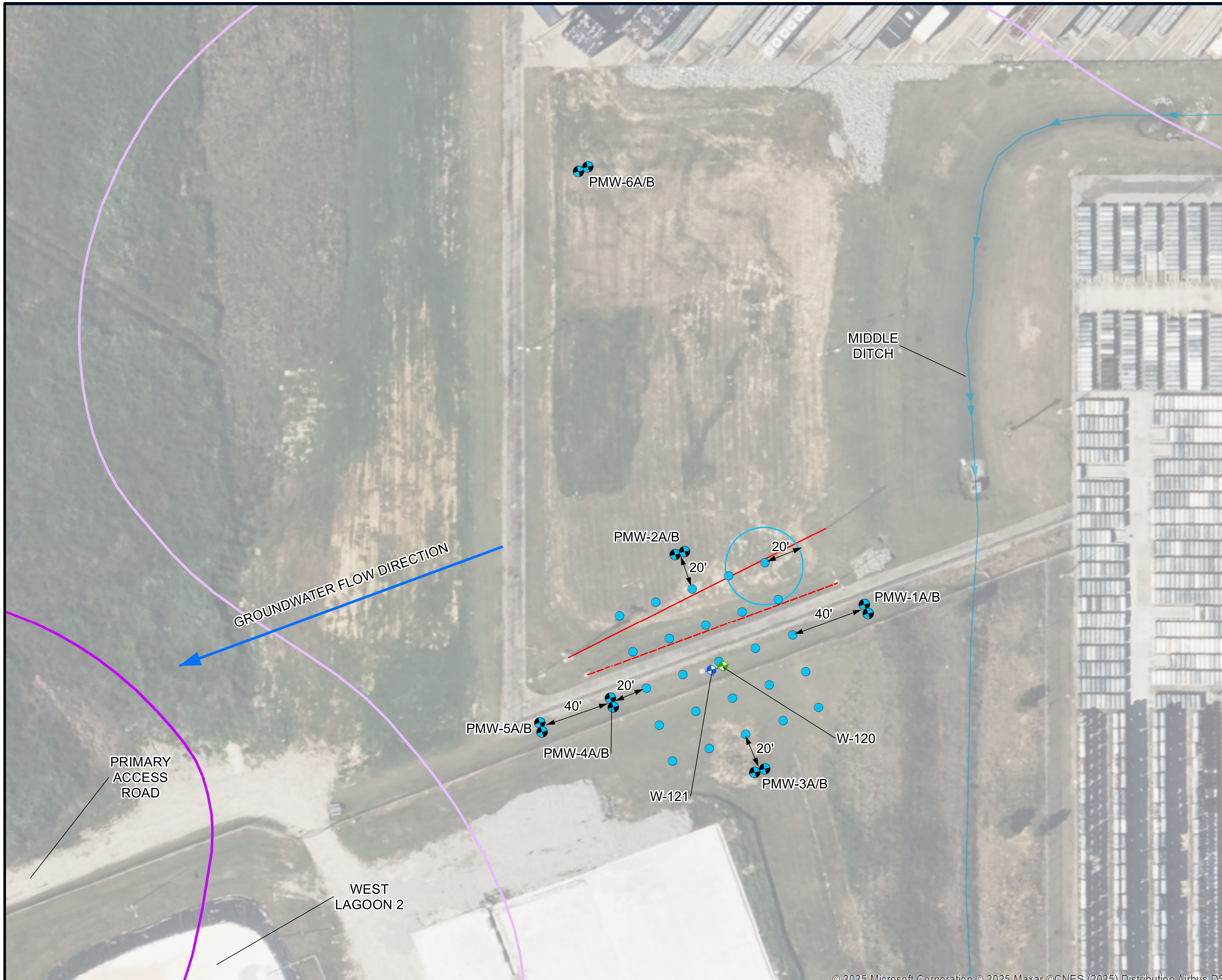

Legend

- Surficial Aquifer - Upper Zone Monitoring Well
- Surficial Aquifer - Lower Zone Monitoring Well
- Performance Monitoring Well
- ERD+ZVI Injection Point
- Target Radius of Influence
- PCE MCL Isocontour Line (5 µg/L)
- TCE MCL Isocontour Line (5 µg/L)
- Ditch
- Culvert
- Underground Electric Utility
- Overhead Electric Utility

0 25 50 Feet

1:600

Map Projection: NAD 1983, South Carolina State Plane, FIPS 3900, Feet

Datum: North American 1983

N

AECOM

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T: (803) 254-4400 F: (803) 771-6676

CVOC Pilot Test Layout

WESTINGHOUSE COLUMBIA FUEL FABRICATION FACILITY
HOPKINS, SOUTH CAROLINA

PROJECT NO.	PREPARED BY:	DATE:	
60691645	IJR	January 2025	FIGURE 10

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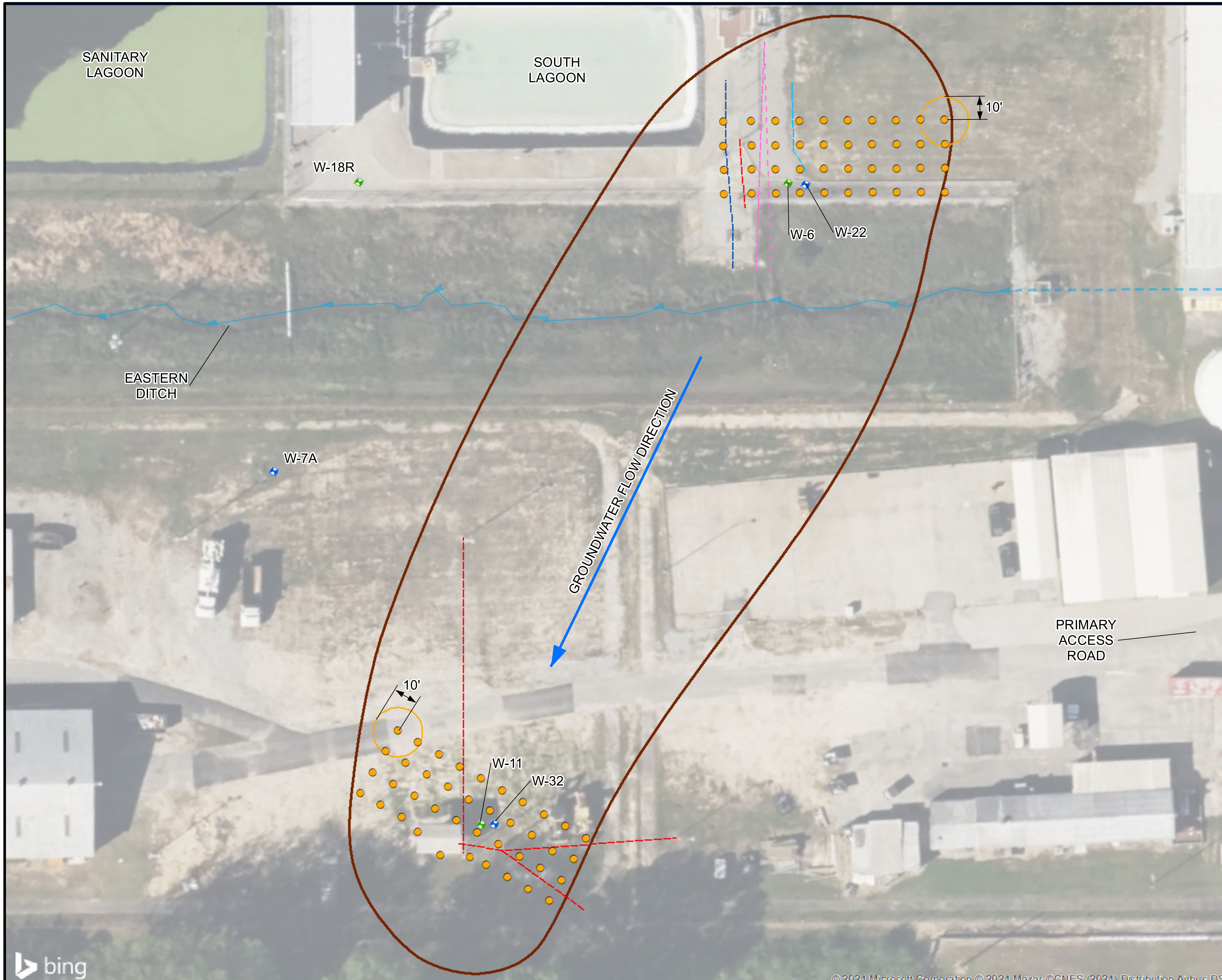

Legend

- Surficial Aquifer - Upper Zone Monitoring Well
- Surficial Aquifer - Lower Zone Monitoring Well
- ZVI Injection Point
- Target Radius of Influence
- Technetium-99 MCL Isocontour Line (900 pCi/L)
- Ditch
- Culvert

Underground Utilities

- Electric
- WWTP Discharge (New)
- WWTP Discharge (Old)
- Water
- Storm Sewer

0 20 40 Feet

1:480

Map Projection: NAD 1983, South Carolina State Plane, FIPS 3900, Feet

Datum: North American 1983

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Tc-99
Pilot Test Layout

WESTINGHOUSE COLUMBIA FUEL FABRICATION FACILITY
HOPKINS, SOUTH CAROLINA

PROJECT NO.	PREPARED BY:	DATE:	
60691645	IJR	January 2025	FIGURE 11

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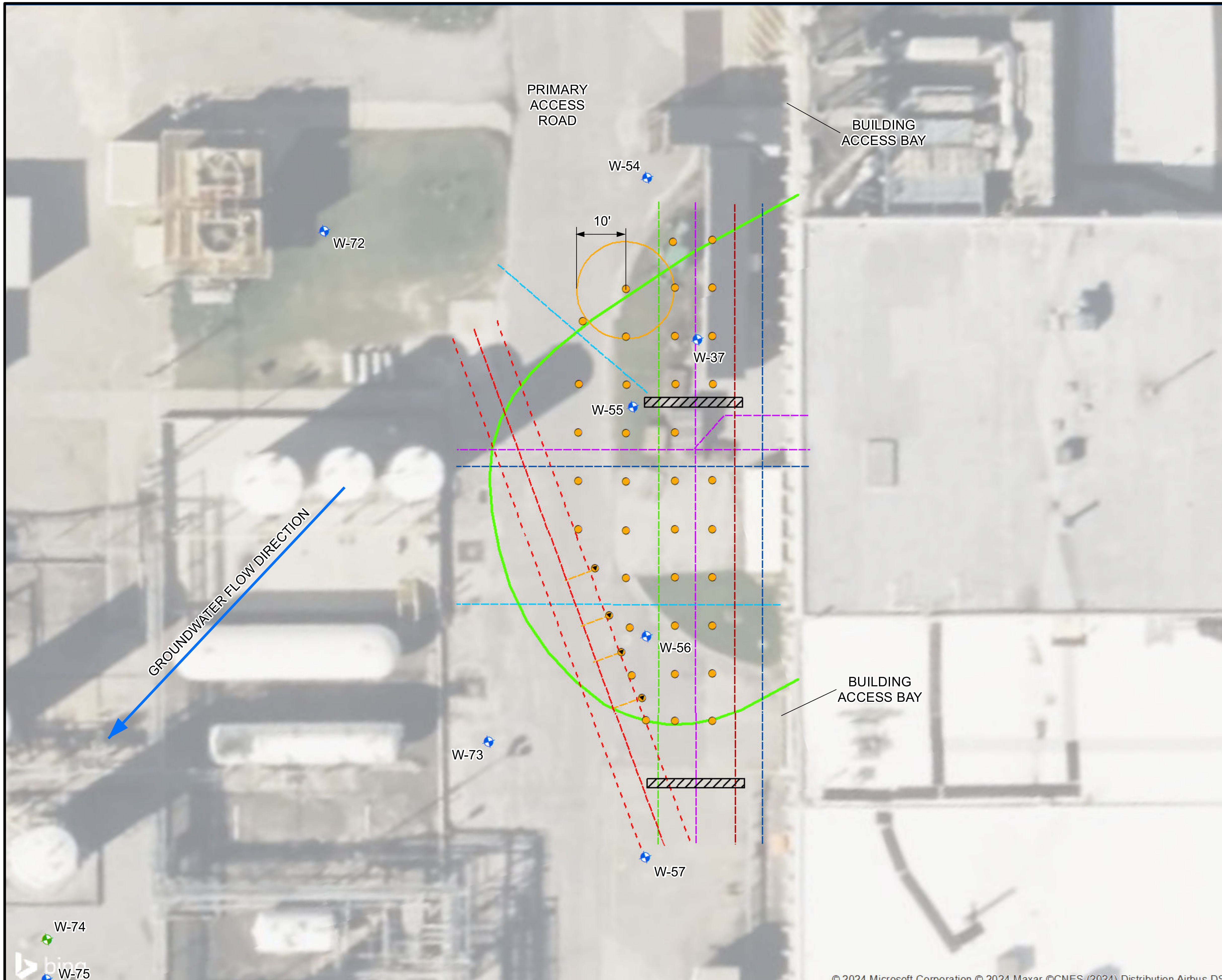

Legend

- Surficial Aquifer - Upper Zone Monitoring Well
- Surficial Aquifer - Lower Zone Monitoring Well
- Vertical ZVI Injection Point
- Angled ZVI Injection Point (30-Degree)
- Angled DPT Extent
- Target Radius of Influence
- Utility Overburden Excavation Area
- Uranium MCL Isocontour Line (30 µg/L)

Underground Utilities

- Electric
- Electric Buffer (5')
- Water
- Storm Sewer
- Contaminated Waste
- Sanitary Sewer
- Process Sewer

0 10 20 Feet

1:240

Map Projection: NAD 1983, South Carolina State Plane, FIPS 3900, Feet

Datum: North American 1983

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Columbia, SC 29203
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Uranium Pilot Test Layout

WESTINGHOUSE COLUMBIA FUEL FABRICATION FACILITY
HOPKINS, SOUTH CAROLINA

PROJECT NO.	PREPARED BY:	DATE:	
60691645	IJR	January 2025	FIGURE 12

Path: \\nadtc1vfp172\data\EnvDataViz\Westinghouse\mxd\2024 Feasibility Study\Pilot_Test_Figures\U_Interim_Measure_Layout_Rev.mxd

Appendix A
Safety Data Sheets

Hepure Technologies Inc

Committed to Comprehensive Environmental Solutions

Ferox Plus

MATERIAL SAFETY DATA SHEET

According to OSHA and ANSI

Reviewed on 5/1/2013

1. Identification of Substance

Trade Name: Ferox Plus

Supplier: Hepure Technologies, Inc.
63 Main Street, Suite 203B
Flemington, NJ 08822

Emergency Information: 908-510-3835 Dr. Robert Kelley

2. Composition/Data on Components

Ingredient	CAS #	Weight%	Hazardous
Food grade edible soy bean oil	8001-22-7	30-40%	No
Iron	7439-89-6	10-40%	No
Emulsifiers, thickeners, and proprietary nutrient package containing nitrogen, phosphorus and vitamin B_{12}	Mixture	3 - 6%	No
Sodium Lactate	867-56-1	2 - 4%	Yes
Water	7732-18-5	10 - 55%	No

3. Hazards Identification

Hazard Description:
Information pertaining to particular dangers for man and environment

R 36/37 Irritating to eyes and respiratory system.

4. First Aid Measures

After inhalation
Supply fresh air. If required, provide artificial respiration. Keep patient warm. Seek medical advice.

After skin contact
Immediately wash with water and soap and rinse thoroughly. Seek immediate medical advice.

After eye contact
Rinse opened eye for several minutes under running water. Then consult a doctor.

After swallowing
Seek immediate medical advice.

Information for doctor
The following symptoms may occur: Nausea, Cramp, Gastric or intestinal disorders

5. Fire Fighting Measures

Suitable extinguishing agents: Extinguishing powder, dry chemical, sand, or graphite to smother fire. Use water only in mist/fog application to avoid spreading power/acclimated dust in surrounding area.

For safety reasons unsuitable extinguishing agents: Water, Carbon dioxide, Halogenated extinguisher

Protective equipment: Wear self-contained respirator. Wear fully protective impervious suit.

6. Accidental Release Measures

Person-related safety precautions:
Wear protective equipment. Keep unprotected persons away. Ensure adequate ventilation. Keep away from ignition sources.

Measures for cleaning/collecting:
Ensure adequate ventilation.
Keep away from ignition sources.

Additional information:
See section 7 for information on safe handling.
See section 8 for information on personal protection equipment.
See section 13 for disposal information.

7. Handing and Storage

Handling
Information for safe handling:
Keep container tightly sealed.
Store in cool, dry place in tightly closed containers.
Ensure good ventilation at the workplace.

Information about protection against explosions and fires:
Keep ignition sources away.

Storage
Requirements to be met by storerooms and receptacles:
No special requirements.

Information about storage in one common facility:
Do not store together with oxidizing and acidic materials.
Store away from halogens.
Further information about storage containers:
Keep container tightly sealed.
Store in cool, dry conditions in well sealed containers.

8. Exposure Controls and Personal Protection

Additional information about design of technical systems:
Properly operating chemical fume hood designed for hazardous chemicals and having an average face velocity of at least 100 feet per mile.

Components with limit values that require monitoring at the workplace: None required.

Additional Information: No data

Personal protective equipment

General protective and hygienic measures
The usual precautionary measures for handling chemicals should be followed.

Keep away from foodstuffs, beverages, and feed.
Remove all soiled and contaminated clothing immediately.
Wash hands before breaks and at the end of work.
Avoid contact with the eyes and skin.

Breathing Equipment: Use suitable respirator when high concentrations are present.

Protection of hands: Impervious gloves

Eye protection: Safety glasses, full face protection.

Body protection: Protective work clothing.

9. Physical and Chemical Properties

Form: Viscous Liquid
Color: Grey
Odor: Odorless

Change in condition
Melting point / Melting range: - 20º C
Boiling point / Boiling range: >300º C
Sublimation temperature / start: Not determined
Flash point: >250º C
Ignition temperature: Not determined
Decomposition temperature: Not determined

Explosion limits:
Lower: Not determined
Upper: Not determined

Vapor pressure at 20º C: 1 mm Hg
Density at 20º C (68º F): 1.44 g/cc

Solubility in / Miscibility with water: Insoluble

10. Stability and Reactivity

Thermal decomposition / conditions to be avoided:
Decomposition will not occur if used and stored according to specifications.
Materials to be avoided:
Acids, Water / moisture, Oxidizing agents, Halogens

Reacts with strong oxidizing agents
Dangerous products of decomposition: Metal oxide fume

11. Toxicological Information

Acute toxicity:

LD / LC50 values that are relevant for classification:		
Oral	LD50	20000 mg/kg (gpg) 30000 mg/kg (rat)
	LDLo	20 mg/kg (rbt)

Primary irritant effect:

On the skin: Irritant to skin and mucous membranes.
On the eye: Irritating effect.
Sensitization: No sensitizing effects known.

Other information (about experimental toxicity):

Tumorigenic effects have been observed with laboratory animals.

Subacute to chronic toxicity:

Iron compounds may cause vomiting, diarrhea, pink urine, black stool, and liver damage. May cause damage to the kidneys. Irritating to the respiratory tract, they may cause pulmonary fibrosis if dusts are inhaled.

Additional toxicological information:

To the best of our knowledge the acute and chronic toxicity of this substance is not fully known.
The Registry of Toxic Effects of Chemical Substances (RTECS) contains tumorigenic and/or carcinogenic and/or neoplastic data for components in this product.
No classification data on carcinogenic properties of this material is available from the EPA, IARC, NTP, OSHA, or ACGIH.

12. Ecological Information

General notes:

Do not allow material to be released to the environment without proper governmental permits.

13. Disposal Considerations

Product:
Recommendation:

Consult state, local or national regulations for proper disposal.

Uncleaned Packagings:

Recommendation:

Disposal must be made according to official regulations.

14. Transport Information

Shipping Information:
Not regulated as a hazardous material by DOT, IMO, or IATO.
Proper shipping-name (technical name): Emulsified Zero Valent Iron

15. Regulations

Product related hazard information:

Hazard symbols:

IX	Irritant

Risk phrases:

36 / 37	Irritating to eyes and respiratory system.

Safety phrases:

26	In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.

National regulations
All components of this product are listed in the U.S. Environmental Protection Agency Toxic Substances Control Act Chemical Substance Inventory.

Information about limitation of use:

For use only by technically qualified individuals.

16. Other Information

Employees should use this information only as a supplement to other information gathered by them, and should make independent judgment of suitability of this information to ensure proper use and protect the healthy and safety of employees. This information is furnished without warranty, and any use of the product not in conformance with this Material Safety Data Sheet, or in combination with any other product or process, is the responsibility of the user.

SAFETY DATA SHEET

1. Identification

Product identifier	**S-MicroZVI or S-MZVI**
Other means of identification	None.
Recommended use	Remediation of contaminants in soil and groundwater.
Recommended restrictions	None known.

Manufacturer/Importer/Supplier/Distributor information

Company Name	REGENESIS
Address	1011 Calle Sombra San Clemente, CA 92673 USA
General information	949-366-8000
E-mail	CustomerService@regenesis.com

Emergency phone number	For Dangerous Goods Incidents ONLY (spill, leak, fire, exposure or accident), call CHEMTREC 24/7 at:
USA, Canada	1-800-424-9300
International	+1 703-741-5970

2. Hazard(s) identification

Physical hazards	Not classified.
Health hazards	Not classified.
OSHA defined hazards	Not classified.

Label elements

Hazard symbol	None.
Signal word	None.
Hazard statement	The mixture does not meet the criteria for classification.
Precautionary statement	
Prevention	Observe good industrial hygiene practices.
Response	Wash hands after handling.
Storage	Store away from incompatible materials.
Disposal	Dispose of waste and residues in accordance with local authority requirements.
Hazard(s) not otherwise classified (HNOC)	None known.
Supplemental information	Contact with acids liberates very toxic gas.

3. Composition/information on ingredients

Mixtures

Chemical name	CAS number	%
Glycerol	56-81-5	40 - 50
Zero valent iron	7439-89-6	30 - 50
Iron(II) sulfide	1317-37-9	1 - 4

Composition comments	All concentrations are in percent by weight unless otherwise indicated. Components not listed are either non-hazardous or are below reportable limits.

4. First-aid measures

Inhalation	Move to fresh air. Call a physician if symptoms develop or persist.
Skin contact	Wash off with soap and water. Get medical attention if irritation develops and persists.
Eye contact	Rinse with water. Get medical attention if irritation develops and persists.

Ingestion	Rinse mouth. Get medical attention if symptoms occur.
Most important symptoms/effects, acute and delayed	Direct contact with eyes may cause temporary irritation.
Indication of immediate medical attention and special treatment needed	Treat symptomatically.
General information	Ensure that medical personnel are aware of the material(s) involved, and take precautions to protect themselves. Show this safety data sheet to the doctor in attendance.

5. Fire-fighting measures

Suitable extinguishing media	Use fire-extinguishing media appropriate for surrounding materials.
Unsuitable extinguishing media	None known.
Specific hazards arising from the chemical	During fire, gases hazardous to health may be formed. Combustion products may include: carbon oxides, iron oxides.
Special protective equipment and precautions for firefighters	Self-contained breathing apparatus and full protective clothing must be worn in case of fire.
Fire fighting equipment/instructions	Move containers from fire area if you can do so without risk.
Specific methods	Use standard firefighting procedures and consider the hazards of other involved materials.
General fire hazards	This material will not burn until the water has evaporated. Residue can burn.

6. Accidental release measures

Personal precautions, protective equipment and emergency procedures	Keep unnecessary personnel away. For personal protection, see section 8 of the SDS.
Methods and materials for containment and cleaning up	Large Spills: Stop the flow of material, if this is without risk. Dike the spilled material, where this is possible. Absorb in vermiculite, dry sand or earth and place into containers. Following product recovery, flush area with water. Small Spills: Wipe up with absorbent material (e.g. cloth, fleece). Clean surface thoroughly to remove residual contamination. Never return spills to original containers for re-use. For waste disposal, see section 13 of the SDS.
Environmental precautions	Avoid discharge into drains, water courses or onto the ground.

7. Handling and storage

Precautions for safe handling	Avoid prolonged exposure. Observe good industrial hygiene practices.
Conditions for safe storage, including any incompatibilities	Store in original tightly closed container. Store away from incompatible materials (see Section 10 of the SDS).

8. Exposure controls/personal protection

Occupational exposure limits

US. OSHA Table Z-1 Limits for Air Contaminants (29 CFR 1910.1000)

Components	Type	Value	Form
Glycerol (CAS 56-81-5)	PEL	5 mg/m3	Respirable fraction.
		15 mg/m3	Total dust.

US. OSHA Table Z-3 (29 CFR 1910.1000)

Components	Type	Value	Form
Glycerol (CAS 56-81-5)	TWA	5 mg/m3	Respirable fraction.
		15 mg/m3	Total dust.
		50 mppcf	Total dust.
		15 mppcf	Respirable fraction.

Biological limit values	No biological exposure limits noted for the ingredient(s).

Appropriate engineering controls	Good general ventilation should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level.

Individual protection measures, such as personal protective equipment

Eye/face protection	Wear safety glasses with side shields (or goggles).
Skin protection	
Hand protection	Wear appropriate chemical resistant gloves. Suitable gloves can be recommended by the glove supplier.
Skin protection	
Other	Wear suitable protective clothing.
Respiratory protection	In case of insufficient ventilation, wear suitable respiratory equipment.
Thermal hazards	Wear appropriate thermal protective clothing, when necessary.
General hygiene considerations	Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants.

9. Physical and chemical properties

Appearance	
Physical state	Liquid.
Form	Viscous metallic suspension.
Color	Dark gray
Odor	Slight.
Odor threshold	Property has not been measured.
pH	10 (As shipped) 7 - 8 (When mixed with water)
Melting point/freezing point	Property has not been measured.
Initial boiling point and boiling range	Property has not been measured.
Flash point	Property has not been measured.
Evaporation rate	Property has not been measured.
Flammability (solid, gas)	Not applicable.
Upper/lower flammability or explosive limits	
Explosive limit - lower (%)	Property has not been measured.
Explosive limit - upper (%)	Property has not been measured.
Vapor pressure	Property has not been measured.
Vapor density	Property has not been measured.
Relative density	Property has not been measured.
Solubility(ies)	
Solubility (water)	Property has not been measured.
Partition coefficient (n-octanol/water)	Property has not been measured.
Auto-ignition temperature	Property has not been measured.
Decomposition temperature	Property has not been measured.
Viscosity	3000 cP (77 °F (25 °C))
Other information	
Density	Property has not been measured.
Explosive properties	Not explosive.
Kinematic viscosity	Property has not been measured.
Oxidizing properties	Not oxidizing.

10. Stability and reactivity

Reactivity	The product is stable and non-reactive under normal conditions of use, storage and transport.

Chemical stability	Material is stable under normal conditions.
Possibility of hazardous reactions	Contact with acids will release highly flammable and highly toxic hydrogen sulfide gas. Can react with some acids with the evolution of hydrogen.
Conditions to avoid	Contact with incompatible materials. Avoid drying out product.
Incompatible materials	Strong oxidizing agents. Acids.
Hazardous decomposition products	No hazardous decomposition products are known.

11. Toxicological information

Information on likely routes of exposure

Inhalation	Spray mist may irritate the respiratory system. For dry material: Dust may irritate respiratory system.
Skin contact	Prolonged or repeated exposure may cause minor irritation.
Eye contact	Direct contact with eyes may cause temporary irritation.
Ingestion	May cause discomfort if swallowed.
Symptoms related to the physical, chemical and toxicological characteristics	Direct contact with eyes may cause temporary irritation.

Information on toxicological effects

Acute toxicity Not expected to be acutely toxic.

Components	Species	Test Results
Glycerol (CAS 56-81-5)		
Acute		
Dermal		
LD50	Rabbit	> 18700 mg/kg
Oral		
LD50	Rat	27200 mg/kg

Skin corrosion/irritation	Prolonged skin contact may cause temporary irritation.
Serious eye damage/eye irritation	Direct contact with eyes may cause temporary irritation.

Respiratory or skin sensitization

Respiratory sensitization	Not a respiratory sensitizer.
Skin sensitization	This product is not expected to cause skin sensitization.
Germ cell mutagenicity	No data available to indicate product or any components present at greater than 0.1% are mutagenic or genotoxic.
Carcinogenicity	Not classifiable as to carcinogenicity to humans.

IARC Monographs. Overall Evaluation of Carcinogenicity

Not listed.

NTP Report on Carcinogens

Not listed.

OSHA Specifically Regulated Substances (29 CFR 1910.1001-1053)

Not listed.

Reproductive toxicity	This product is not expected to cause reproductive or developmental effects.
Specific target organ toxicity - single exposure	Not classified.
Specific target organ toxicity - repeated exposure	Not classified.
Aspiration hazard	Not an aspiration hazard.
Further information	Contains an ingredient known to produce adverse effects in a small percentage of hypersensitive individuals exhibited as respiratory distress and allergic skin reactions.

12. Ecological information

Ecotoxicity The product is not classified as environmentally hazardous. However, this does not exclude the possibility that large or frequent spills can have a harmful or damaging effect on the environment.

Components		Species	Test Results
Glycerol (CAS 56-81-5)			
Aquatic			
Acute			
Crustacea	EC50	Daphnia magna	> 10000 mg/l, 24 Hours

Persistence and degradability No data is available on the degradability of this product.

Bioaccumulative potential No data available.

Partition coefficient n-octanol / water (log Kow)

Glycerol (CAS 56-81-5) -1.76

Mobility in soil No data available.

Other adverse effects None known.

13. Disposal considerations

Disposal instructions Collect and reclaim or dispose in sealed containers at licensed waste disposal site.

Local disposal regulations Dispose in accordance with all applicable regulations.

Hazardous waste code The waste code should be assigned in discussion between the user, the producer and the waste disposal company.

Waste from residues / unused products Dispose in accordance with local regulations. Empty containers or liners may retain some product residues. This material and its container must be disposed of in a safe manner (see: Disposal instructions).

Contaminated packaging Since emptied containers may retain product residue, follow label warnings even after container is emptied. Empty containers should be taken to an approved waste handling site for recycling or disposal.

14. Transport information

DOT

Not regulated as dangerous goods.

IATA

Not regulated as dangerous goods.

IMDG

Not regulated as dangerous goods.

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code Not established.

15. Regulatory information

US federal regulations This product is not known to be a "Hazardous Chemical" as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200.

TSCA Section 12(b) Export Notification (40 CFR 707, Subpt. D)

Not regulated.

CERCLA Hazardous Substance List (40 CFR 302.4)

Not listed.

SARA 304 Emergency release notification

Not regulated.

OSHA Specifically Regulated Substances (29 CFR 1910.1001-1053)

Not listed.

Toxic Substances Control Act (TSCA) All components of the mixture on the TSCA 8(b) inventory are designated “active”.

Superfund Amendments and Reauthorization Act of 1986 (SARA)

SARA 302 Extremely hazardous substance

Not listed.

SARA 311/312 Hazardous chemical No

SARA 313 (TRI reporting)

Not regulated.

Other federal regulations

Clean Air Act (CAA) Section 112 Hazardous Air Pollutants (HAPs) List

Not regulated.

Clean Air Act (CAA) Section 112(r) Accidental Release Prevention (40 CFR 68.130)

Not regulated.

Safe Drinking Water Act (SDWA) Not regulated.

FEMA Priority Substances Respiratory Health and Safety in the Flavor Manufacturing Workplace

Glycerol (CAS 56-81-5) Other Flavoring Substances with OSHA PEL's

US state regulations

US. Massachusetts RTK - Substance List

Glycerol (CAS 56-81-5)

US. New Jersey Worker and Community Right-to-Know Act

Glycerol (CAS 56-81-5)

US. Pennsylvania Worker and Community Right-to-Know Law

Glycerol (CAS 56-81-5)

US. Rhode Island RTK

Glycerol (CAS 56-81-5)

California Proposition 65

California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65): This material is not known to contain any chemicals currently listed as carcinogens or reproductive toxins. For more information go to www.P65Warnings.ca.gov.

US. California. Candidate Chemicals List. Safer Consumer Products Regulations (Cal. Code Regs, tit. 22, 69502.3, subd. (a))

Zero valent iron (CAS 7439-89-6)

International Inventories

Country(s) or region	Inventory name	On inventory (yes/no)*
Australia	Australian Inventory of Industrial Chemicals (AICIS)	Yes
Canada	Domestic Substances List (DSL)	Yes
Canada	Non-Domestic Substances List (NDSL)	No
China	Inventory of Existing Chemical Substances in China (IECSC)	Yes
Europe	European Inventory of Existing Commercial Chemical Substances (EINECS)	No
Europe	European List of Notified Chemical Substances (ELINCS)	No
Japan	Inventory of Existing and New Chemical Substances (ENCS)	No
Korea	Existing Chemicals List (ECL)	Yes
New Zealand	New Zealand Inventory	Yes
Philippines	Philippine Inventory of Chemicals and Chemical Substances (PICCS)	Yes
Taiwan	Taiwan Chemical Substance Inventory (TCSI)	Yes
United States & Puerto Rico	Toxic Substances Control Act (TSCA) Inventory	Yes

*A "Yes" indicates that all components of this product comply with the inventory requirements administered by the governing country(s)
A "No" indicates that one or more components of the product are not listed or exempt from listing on the inventory administered by the governing country(s).

16. Other information, including date of preparation or last revision

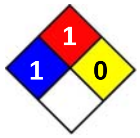
Issue date 27-December-2018

Revision date 25-May-2022

Version # 02

HMIS® ratings Health: 1
Flammability: 1
Physical hazard: 0
Personal protection: B

NFPA ratings



Disclaimer

Regenesis cannot anticipate all conditions under which this information and its product, or the products of other manufacturers in combination with its product, may be used. It is the user's responsibility to ensure safe conditions for handling, storage and disposal of the product, and to assume liability for loss, injury, damage or expense due to improper use. The information in the sheet was written based on the best knowledge and experience currently available.

Appendix B
Monitoring Well Application Form

Monitoring Well Application

1. Proposed Location of Monitoring Well(s):

Street Address:

City (including Zip):

County:

Please attach Scaled Map or Plat

2. Well Owner's Information:

Name (Last then First):

Company:

Complete Address:

Telephone Number:

3. Property Owner's Information:

☐ Check if same as Well Owner

Name (Last then First):

Company:

Address:

Telephone Number:

4. Proposed Drilling Date:

5. Intended Purpose of Well(s):

Pre-Purchase ☐

Investigation ☐

NOTE: If this request is for an existing DHEC project, please enter the Program area and ID number below.

Program Area:
Project or Site ID #:

6. Proposed number of monitoring wells:

7. Proposed parameters to be analyzed (check all that apply), please specify analytical method beside check box:

VOCs ☐
BTEX ☐
MtBE ☐
Naphthalene ☐
PAHs ☐
Metals ☐
Nitrates ☐
Base, Neutral & Acid Ex. ☐
Pesticides/Herbicides ☐
Phenols ☐
Radionuclides ☐
PCBs ☐
Other (specify below) ☐

8. Proposed construction details (complete and attach proposed monitoring well schematics):

South Carolina Department of Health and Environmental Control (SCDHEC) summary of standards for monitoring well construction (per South Carolina Well Standards and Regulations R. 61-71)

Approval and License Requirements

Prior Department approval is required for the installation or abandonment of all monitoring wells including direct push, geoprobe or other temporary type monitoring wells. The attached monitoring well approval document should be completed, submitted and approved prior to construction of any monitoring well. A monitoring well is any well used to obtain water samples for water quality analyses or to measure groundwater levels. There are no fees for approvals. All monitoring wells must be drilled by a driller that is registered in South Carolina with the Board of Certification of the Environmental Systems Operators. If any of the information on the application including the proposed drilling date, well construction details or well placement changes, the Department (i.e. project manager issuing the well approval) must be notified 24 hours prior to well construction.

Location

Due to the nature and purpose of a monitoring well, the depth and location requirements in respect to surface water bodies, potential contamination sources, etc., are variable, and shall be approved on a case by case basis by the Department.

Construction and Material

Casing should be of sufficient strength to withstand normal forces encountered during and after well installation and be composed of material so as to minimally affect water quality analyses. Casing should have a sufficient diameter to allow for efficient sample collection (i.e., to provide access for sampling equipment). The diameter of the drilled hole needs to be large enough on all sides (1.5 inches of annular space) to allow forced injection of grout through a tremie pipe. All monitoring wells should have a cement pad or aggregate reinforced concrete at the ground surface which extends at least six inches beyond the bore hole diameter and six inches below ground surface to prevent infiltration between the surface casing and the bore hole. All monitoring wells should be grouted from the top of the bentonite seal to the surface with a neat cement, high solids bentonite or neat cement, bentonite mixture approved by the Department. A hydrated bentonite seal with a minimum thickness of 12 inches is to be placed above the filter pack to prevent infiltration of grout if the well has a filter pack. The monitoring well intake or screen design should minimize the amount of formational materials entering the well. The gravel pack should be utilized opposite the well screen as appropriate so that parameters analyses will be minimally affected. All monitoring wells should have a locking cap or other security device to prevent damage and/or vandalism. Any monitoring well which is destroyed, rendered unusable or is abandoned should be reported to the Department and be properly abandoned, revitalized or replaced as appropriate or required by permit or regulation.

Development

Monitoring wells shall be properly developed. Development shall include the removal of formation cuttings and drilling fluids from the well bore hole. Development shall be complete when the well produces water typical of the aquifer being monitored.

Reporting Requirements

A monitor well record form (1903) or equivalent to include the following should be completed and submitted to the Department within 30 days after completion of the monitoring wells:

Name and address of facility/owner;
Surveyed or global positioning system location of monitor well(s) on a scaled map or plat;
Driller and certification number;
Date drilled;
Driller's or Geologist's log;
Total depth;
Screened interval;
Diameter and construction details;
Depth to water table with date and time measured;
Surveyed elevation of measuring point with respect to established benchmark;
Monitoring well approval number issued by the Department.

Additionally, the groundwater and soil (if taken) analytical results should be submitted to the Department within 30 days of receipt from the laboratory.

Abandonment

All monitoring wells shall be properly abandoned, when deemed appropriate by the Department. Any well that acts as a source of contamination shall be repaired or permanently abandoned immediately after receipt of notice from the Department. Abandonment shall be by forced injection of grout or pouring through a tremie pipe starting at the bottom of the well and proceeding to the surface in one continuous operation. The well shall be filled with either neat cement, bentonite-cement, or 20% high solids sodium bentonite grout, from the bottom of the well to the land surface.

* This summary of standards for monitoring well construction may not include a listing of all information necessary to obtain an approval to install monitoring wells. Final approval of monitoring well installation will be dependant upon the regulatory requirements for the Department program area for which the monitoring wells are to be installed.

* Some areas of the Department may require a detailed justification of the placement of monitoring wells and the depth of monitoring well screened zones prior to granting installation approval.

Appendix C
UIC Permit Application Form

Reset Form

Form I UIC	SC DEPARTMENT of ENVIRONMENTAL SERVICES Underground Injection Control Permit Application Division of Water Resources (Collected under the Authority of Title 48 Chapter I of the 1976 South Carolina Code of Laws)	I. EPA ID NUMBER	T/A	C
		U		

Read attached instructions before starting.

For OfficialUse Only

Application Approved month day year			Date Received month day year			Permit Well Number

Comments

II. Facility Name and Address

Facility Name

Street Address

City | State | Zip Code

III. Owner/Operator and Address

Owner/OperatorName

Street Address

City | State | Zip Code

IV. Ownership Status (Select One)

☐ A. Federal ☐ B. State ☐ C. Private

☐ D. Public ☐ E. Other (Explain)

V. SIC Codes

VI. Well Status (Select A, B or C)

☐ A. Operating | Date Started *(MM/DD/YYYY)* | ☐ B. Modification/Conversion | ☐ C. Proposed

VII. Type of Permit Requested - Class and Type of Well (see reverse)

A. Class(es) enter code(s)	B. Type(s) enter code(s)	C. If class is "other" or type is code 'Y', explain	D. Number of Wells per type

VIII. Location of Wells or Approximate Center of field or Project

C	A. Latitude				B. Longitude			
I		Deg	Min	Sec		Deg	Min	Sec

IX. Attachments

Complete the following questions on a separate sheet(s) and number accordingly; see instructions for **Classes 11, 111, and V, complete and submit on a separate sheet(s) attachments A-U as appropriate. Attach maps where required. List attachments by letter which are applicable and include with your application.**

X. Certification

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of a fine and imprisonment.

A. Name (Type or Print)	Title	B. Phone No.
C. Signature		D. Date Signed (MM/DD/YYYY)

Well Class and Type Codes

Class I	Industrial, municipal, and other injection wells for the subsurface disposal of fluids. (Prohibited)		
Class II	Oil and gas production and storage related injection wells.		
	Type	"D"	Produced fluid disposal well
		"R"	Enhanced recovery well
		"R"	Hydrocarbon storage well (excluding natural gas)
		"X"	Other Class II wells
Class III	Special process injection wells.		
	Type	"G"	Solution mining well
		"S"	Sulfur mining well by frasch process
		"U"	Uranium mining well (excluding solution mining of conventional mines)
		"X"	Other Class III wells
Class IV	Hazardous or radioactive waste disposal injection wells. (Prohibited)		
Class V.A	Injection wells not included in Class I, II, III, IV or V.B		
	Type	"A"	Storm runoff drainage wells
		"B"	Aquifer recharge wells
		"C"	Salt-water intrusion barrier wells
		"D"	Subsidence control wells
		"E"	Backfill wells associated with subsurface mining
		"F"	Geothermal energy recovery wells
		"G"	Experimental technology well
		"H"	Natural gas storage wells
		"I"	Corrective action wells
Class V.B	Non-contact return flow system wells		
	Type	"A"	Heat pump return flow wells
	Type	"B"	Cooling water return flow wells

Instructions for Attachments to Form 1
Underground Injection Control
for Corrective Action Wells
(effective 01/91)

The following ATTACHMENTS should be submitted with an underground injection control (UIC) permit application for Class V.A. corrective action wells associated with aquifer remediation that are to be used to inject fluid whose chemical constituents are below all drinking water standards, as established under R.61-58.5.

Attachment A: Activity for Review

Submit a brief description of the activities to be conducted that require a UIC permit.

Attachment B: Well Construction Details

Submit schematic or other appropriate drawings of the surface and subsurface construction details of the recovery and injection wells.

Attachment C: Operating Data

Submit the following proposed operating data for each injection well:

1) Average and maximum daily rate and volume of fluid to be injected. In addition, indicate the average and maximum daily rate and volume of fluid to be withdrawn from each recovery well. Verification of the aquifer's hydraulic ability to produce and accept the quantities proposed should be presented.

2) Average and maximum injection pressure.

3) Pumping schedule (i.e. continuous, alternating cycles, etc.).

4) Proposed ranges in the concentration of all contaminant constituents within the injection fluid. Include comprehensive ground-water quality data from a "worst case" well sample.

5) Length of time the project is expected to require injection to complete remediation (to ensure the effective dates of the permit will allow sufficient time to complete the project).

Attachment D: Monitoring Program

Discuss the planned monitoring program in detail:

1) Include a discussion of monitoring devices, sampling frequency (sufficient to verify treatment system efficiency), sampling protocol, sampling location, parameters to be analyzed, and proposed method(s) of analysis.

2) This plan should indicate how, through monitoring, the proposed contaminant levels in the injectate will be verified.

3) This plan should also clearly illustrate exactly how hydraulic control of the contaminant plume (and injectate, where relevant) will be verified through monitoring (i.e., piezometers, quality analyses, etc.).

Attachment E: Existing or Pending State/Federal Permits

List the program and permit number of any existing State or Federal permits for the facility (i.e., NPDES, RCRA, UST, etc.).

Attachment F: Description of Business

Give a brief description of the nature of the business of the facility and any immediately adjacent facilities.

Attachment G: Area of Review

1) The area of review should be a fixed radius of 1/4 mile from the injection well, the outermost injection wells (if a wellfield).

2) If a fixed radius is not selected, the methods and the calculations used to determine the size of the area of review should be submitted.

Attachment H: Maps of Wells and Area of Review

1) Submit a topographic map of the area, extending one mile beyond the project property boundaries. This map should show all hazardous waste treatment, storage, or disposal facilities, and all intake and discharge structures associated with the project facility. Any known areas of soil and/or ground-water contamination within a one mile radius should be indicated. Also indicate all surface bodies of water, springs, mines (surface and subsurface), quarries, and other pertinent surface features such as residences, roads, and geologic faults (known or suspected).

2) A scaled map(s) should be included which shows the name and/or number and the location of ALL production, injection, monitoring, abandoned and dry wells within the area of review. This should be accomplished by file and field surveys. Information regarding the construction (i.e., total depth, diameter, casing/screened intervals, grouting, etc.) and the current status (i.e., actively used, temporarily abandoned, permanently abandoned) of ALL wells within the area of review should be submitted. If any wells have been abandoned, details on the method the wells were abandoned (i.e., cemented/grouted, filled with sand, etc.) should be included.

3) A potentiometric map of the project site should be submitted which accurately locates all monitoring wells and proposed recovery and injection wells and outlines the horizontal extent of both the free-phase contaminant (where applicable) and dissolved contaminant plumes. Include all water level and product thickness data. The date and time that water levels and product thicknesses were measured should be indicated.

Attachment I: Cross Sections/Diagrams

1) Geologic cross sections indicating the lithology and stratigraphy of the site and the horizontal and vertical extent of the contaminant plume, should be submitted. At least two stratigraphic cross sections, one parallel and one perpendicular to the horizontal ground-water flow direction, should be submitted. In areas where the site stratigraphy is complex, additional cross sections should be submitted to clearly illustrate the local conditions.

2) A schematic diagram, in the form of a cross section, showing the proposed remediation system with the components of flow (above and below ground) and all associated appurtenances (i.e., stripping tower, piping, wells, etc.).

Attachment J: Name and Depth of Underground Sources of Drinking Water (USDW's)

Identify and describe all aquifers which may be affected by the injection.

Attachment K: Hydraulic Control

1) Sufficient supporting data (i.e. time/drawdown data, Theis curves and methods, calculations, etc.), used to determine aquifer characteristics to verify complete hydraulic control over the contaminant plume (and injectate, if proposed injectate quality does not conform to classified ground-water standards) during injection should be submitted. At a minimum, values should be given for transmissivity, hydraulic conductivity, effective porosity and specific yield.

2) Demonstrate the presence and magnitude of, or the absence of, any vertical hydraulic gradient at the site. If a vertical hydraulic gradient exists, show how its direction and magnitude are incorporated in the calculations demonstrating hydraulic control.

3) Ground-water flow computer models (especially 2-D map view with potentiometric and flow lines) may be utilized and submitted. All calculations should be in English units. All model-derived data and maps should be properly labeled and keyed so as to be clearly understood.

Subsequent Action

After receipt of a complete Underground Injection Control Permit Application, the Department will make a determination to deny or issue a Permit to Construct the injection well(s). After the well(s) is/are constructed, the Department should be notified in writing of the well(s) completion and sent a copy of the completed well record form(s) signed by a South Carolina certified well driller which illustrates the "as built" well construction. If the system is in compliance with the approved application, the Department may then issue an Approval to Operate. This Approval to Operate is the final permission necessary prior to injection.

Appendix D
Well Construction Details

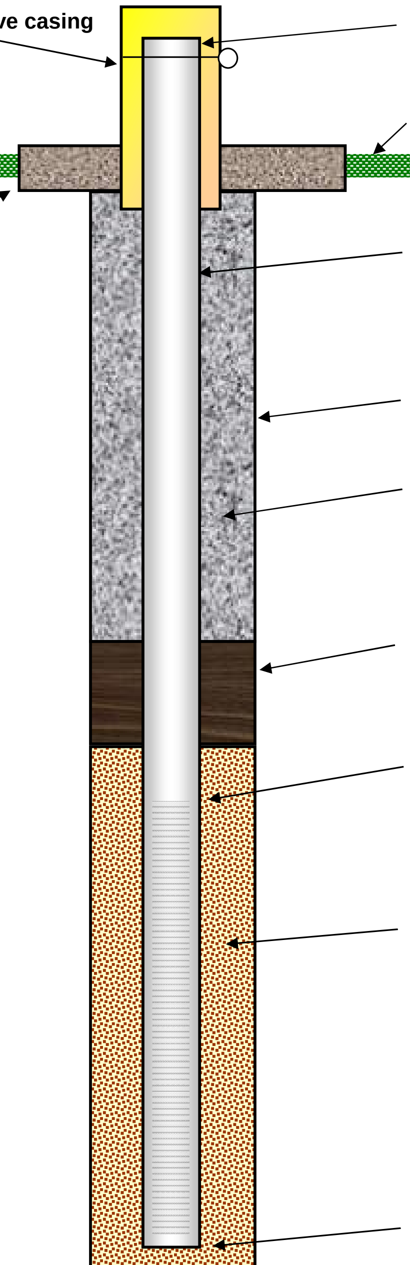
PERFORMANCE MONITORING WELL CONSTRUCTION DETAIL

Project Name: Columbia Fuel Fabrication Facility
Drilling Co: ______
Well Number: PMW-1A, 2A, 3A, 4A, 5A, and 6A

Location: Hopkins, SC
Driller: ______
Job Number: ______

Client: Westinghouse Columbia Fuel Fabrication Facility
Drilling Method: Sonic or HSA
Date Completed: ______

Geologist: ______
Static Water Level: ______ **betoc**
Survey Datum: ______



4-inch square locking protective casing

Grass, Asphalt/Concrete

Concrete Surface Pad
(2 ft x 2 ft x 6 in)

COMMENTS

Top Of Casing Elevation **TBD** ft **-2.5** ft Stickup

Land Surface Elevation **TBD** ft

Well Casing From **-2.5** ft to **12** ft
Casing Type: **SCH-40 PVC**
Inside Diameter: **2-in.**

Diameter of Borehole (nominal) **6 to 8** in

Bentonite/Cement Grout
From **0** ft to **8** ft

Bentonite Pellet Seal
Type: **PELLETS/CHIPS**
From **8** ft to **10** ft

Top of Screen Depth **12** ft
Screen Type: **SCH-40 PVC**
Screen Slot Size: **0.010-in** ID **2** in
Screen Length: **10** ft

Filter Sand for Screen
Sand Type: **#2 SAND**
From **10** ft to **22.5** ft

Bottom of Well Depth **22** ft

Bottom of Boring (estimated) Depth **22.5** ft

Total Depth of Well, b. Top of Casing Depth **24.5** ft

Note:
Drawing Not to Scale
All Depths are Referenced to Ground Surface

PERFORMANCE MONITORING WELL CONSTRUCTION DETAIL

Project Name: Columbia Fuel Fabrication Facility
Drilling Co:
Well Number: PMW-1B, 2B, 3B, 4B, 5B, and 6B

Location: Hopkins, SC
Driller:
Job Number:

Client: Westinghouse Columbia Fuel Fabrication Facility
Drilling Method: Sonic or HSA
Date Completed:

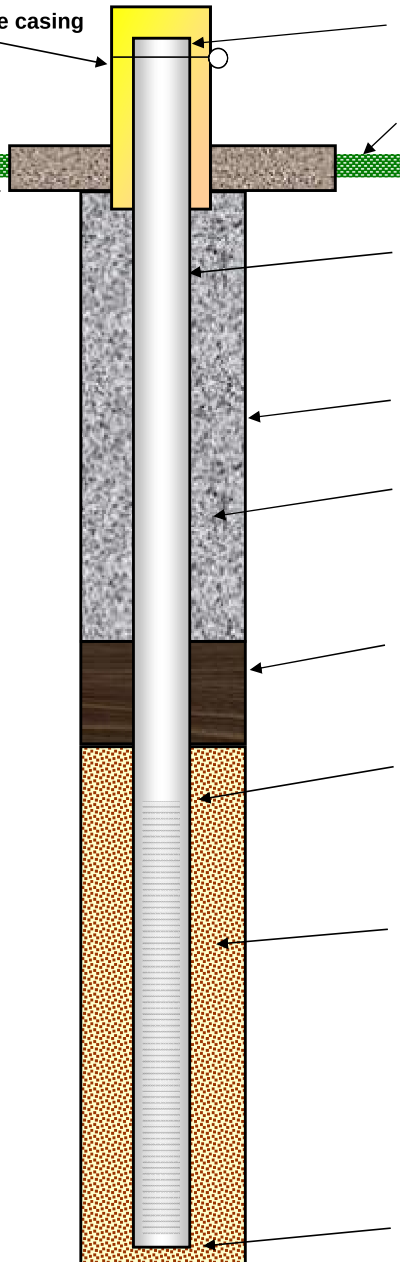
Geologist:
Static Water Level: betoc
Survey Datum:

4-inch square locking protective casing

Grass, Asphalt/Concrete

Concrete Surface Pad
(2 ft x 2 ft x 6 in)

COMMENTS



Top Of Casing Elevation **TBD** ft; **-2.5** ft Stickup

Land Surface Elevation **TBD** ft

Well Casing From **-2.5** ft to **29** ft
Casing Type: **SCH-40 PVC**
Inside Diameter: **2-in.**

Diameter of Borehole (nominal) **6 to 8** in

Bentonite/Cement Grout
From **0** ft to **25** ft

Bentonite Pellet Seal
Type: **PELLETS/CHIPS**
From **25** ft to **27** ft

Top of Screen Depth **29** ft
Screen Type: **SCH-40 PVC**
Screen Slot Size: **0.010-in** ID **2** in
Screen Length: **5** ft

Filter Sand for Screen
Sand Type: **#2 SAND**
From **27** ft to **34.5** ft

Bottom of Well Depth **34** ft

Bottom of Boring (estimated) Depth **34.5** ft

Total Depth of Well, b. Top of Casing Depth **36.5** ft

Note:
Drawing Not to Scale
All Depths are Referenced to Ground Surface

Appendix E
Sampling and Analysis Plan

Appendix E
Sampling and Analysis Plan - CVOC Pilot Study
Pilot Study Work Plan
Westinghouse Columbia Fuel Fabrication Facility
Hopkins, South Carolina

Well ID	Well Position	Approximate Distance from Nearest Injection Location (feet)	Schedule				
			Baseline	3-Months Post-Injection	6-Months Post-Injection	9-Months Post-Injection	12-Months Post-Injection
Monitoring Well Sampling							
W-120	Treatment Area	<20	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
W-121	Treatment Area	<20	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
PMW-1A	Upgradient of Treatment Area	40	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
PMW-1B	Upgradient of Treatment Area	40	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
PMW-2A	Cross-gradient of Treatment Area	20	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
PMW-2B	Cross-gradient of Treatment Area	20	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
PMW-3A	Cross-gradient of Treatment Area	20	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
PMW-3B	Cross-gradient of Treatment Area	20	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
PMW-4A	Downgradient of Treatment Area	20	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
PMW-4B	Downgradient of Treatment Area	20	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
PMW-5A	Downgradient of Treatment Area	60	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
PMW-5B	Downgradient of Treatment Area	60	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
PMW-6A	Cross-gradient of Treatment Area	225	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
PMW-6B	Cross-gradient of Treatment Area	225	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC	Field, CVOC, TOC
Quality Assurance/Quality Control Sampling							
Duplicate			CVOC, TOC	CVOC, TOC	CVOC, TOC	CVOC, TOC	CVOC, TOC
Matrix Spike			CVOC, TOC	CVOC, TOC	CVOC, TOC	CVOC, TOC	CVOC, TOC
Matrix Spike Duplicate			CVOC, TOC	CVOC, TOC	CVOC, TOC	CVOC, TOC	CVOC, TOC
Equipment Blank			CVOC, TOC	CVOC, TOC	CVOC, TOC	CVOC, TOC	CVOC, TOC
Trip Blank			CVOC	CVOC	CVOC	CVOC	CVOC
Total Count							
Total CVOC Analyses			**19**	**19**	**19**	**19**	**19**
Total TOC Analyses			**18**	**18**	**18**	**18**	**18**

Notes:
W - existing monitoring well
PMW - newly installed performance monitoring well
Field - field parameters to be collected include pH, temperature, conductivity, dissolved oxygen (DO), oxidation-reduction potential (ORP), and turbidity
CVOC - chlorinated volatile organic compounds, samples to be analyzed for select CVOCs by EPA Method 8260D
TOC - total organic carbon, samples to be analyzed by SW-846 Test Method 9060A

Appendix E
Sampling and Analysis Plan - Tc-99 Pilot Study
Pilot Study Work Plan
Westinghouse Columbia Fuel Fabrication Facility
Hopkins, South Carolina

Well ID	Well Position	Approximate Distance from Nearest Injection Location (feet)	Schedule				
			Baseline	14-Days Post-Injection	1-Month Post-Injection	3-Months Post-Injection	6-Months Post-Injection
Monitoring Well Sampling							
W-6	Northern Treatment Area	<10	Field, Tc-99	Field, Tc-99	Field, Tc-99	Field, Tc-99	Field, Tc-99
W-11	Southern Treatment Area	<10	Field, Tc-99	Field, Tc-99	Field, Tc-99	Field, Tc-99	Field, Tc-99
W-22	Northern Treatment Area	<10	Field, Tc-99	Field, Tc-99	Field, Tc-99	Field, Tc-99	Field, Tc-99
W-32	Southern Treatment Area	<10	Field, Tc-99	Field, Tc-99	Field, Tc-99	Field, Tc-99	Field, Tc-99
Quality Assurance/Quality Control Sampling							
Duplicate			Tc-99	Tc-99	Tc-99	Tc-99	Tc-99
Matrix Spike			Tc-99	Tc-99	Tc-99	Tc-99	Tc-99
Matrix Spike Duplicate			Tc-99	Tc-99	Tc-99	Tc-99	Tc-99
Equipment Blank			Tc-99	Tc-99	Tc-99	Tc-99	Tc-99
Total Count							
Total Tc-99 Analyses			**8**	**8**	**8**	**8**	**8**

Notes:
W - existing monitoring well
Field - field parameters to be collected include pH, temperature, conductivity, dissolved oxygen (DO), oxidation-reduction potential (ORP), and turbidity
Tc-99 - technetium-99, samples to be analyzed via DOE EML HASL-300 (Tc-02-RC Modified)

Appendix E
Sampling and Analysis Plan - Uranium Pilot Study
Pilot Study Work Plan
Westinghouse Columbia Fuel Fabrication Facility
Hopkins, South Carolina

Well ID	Well Position	Approximate Distance from Nearest Injection Location (feet)	Schedule		
			Baseline	Semi-Annual Groundwater Sampling Event Post-Injection	Semi-Annual Groundwater Sampling Event Post-Injection
Monitoring Well Sampling					
W-37	Treatment Area	<10	Field, Uranium	Field, Uranium	Field, Uranium
W-54	Cross-gradient of Treatment Area	<15	Field, Uranium	Field, Uranium	Field, Uranium
W-55	Treatment Area	<10	Field, Uranium	Field, Uranium	Field, Uranium
W-56	Treatment Area	<10	Field, Uranium	Field, Uranium	Field, Uranium
W-57	Cross-gradient of Treatment Area	<30	Field, Uranium	Field, Uranium	Field, Uranium
W-72	Cross-gradient of Treatment Area	<60	Field, Uranium	Field, Uranium	Field, Uranium
W-73	Downgradient of Treatment Area	<30	Field, Uranium	Field, Uranium	Field, Uranium
Quality Assurance/Quality Control Sampling					
Duplicate			Uranium	Uranium	Uranium
Matrix Spike			Uranium	Uranium	Uranium
Matrix Spike Duplicate			Uranium	Uranium	Uranium
Equipment Blank			Uranium	Uranium	Uranium
Total Count					
Total Uranium Analyses			**11**	**11**	**11**

Notes:

W - existing monitoring well
Field - field parameters to be collected include pH, temperature, conductivity, dissolved oxygen (DO), oxidation-reduction potential (ORP), and turbidity
Uranium samples to be analyzed by EPA Method 200.8/200.2

Appendix F
Bench-Scale Treatability Test SOP

WESTINGHOUSE BENCH-SCALE TREATABILITY TEST

Hyunshik Chang (12-6-24)

OBJECTIVES

This standard operating procedure (SOP) is developed by AECOM's Process and Technology Development (PTD) group in Austin, Texas specifically for the selected lab to conduct a benchtop-scale test for the Westinghouse Electric Company, LLC (Westinghouse) Columbia Fuel Fabrication Facility (CFFF) site (Site) located in Columbia, South Carolina. The goal of the test is evaluating removal efficiency of technetium-99 (Tc-99) in groundwater (GW) from the Site with four commercial products for injection application. The Tc-99 removal ratio, half-life, and maximum removal capacity of each product will be evaluated.

BACKGROUND INFORMATION

Representative water characteristics of the site GW are summarized in **Table 1**. Among the constituents of concern (COCs), Tc-99 is the major target COC with the treatment goal of <900 pCi/L. Soil effective porosity is assumed to be 0.2 based on the pilot test design.

Table 1. Representative water characteristics of the site GW.

Analytes	PCE	TCE	Nitrate	U	Tc-99	pH	ORP
Values	370 μg/L	50 μg/L	295 mg/L	302 μg/L	2840 pCi/L	5.53	206 mV

Among four test products, two injection products are manufactured by Regenesis: zero valent iron (ZVI) slurry as "S-MZVI" and colloidal activated carbon (CAC) as "PlumeStop®". Two other ZVI products are "Ferro Target" from Hepure and "Fine ZVI" from Redox Tech. Details of each product are summarized in **Table 2**. Each ZVI product needs to be diluted with water on-site and then injected into the saturated soil formation across multiple depth intervals through direct-push technology injection rods. For the test, each ZVI product will be diluted with deionized (DI) water to target 4 % ZVI concentration by weight, following the manufacturer's instruction. Total quantity of each diluted ZVI product for the test is about 500 mL. Magnetic stirrer should not be used for the product dilution step. A mechanical blander with paddles is recommended. The CAC will be applied in the identical manner at the site without dilution. Thus, the CAC will be used for this test "as-is" from the manufacturer's package after thorough mixing.

Table 2. Test product information.

Test product	ZVI-1	ZVI-2	ZVI-3	CAC
Manufacturer	Regenesis	Hepure	Redox Tech	Regenesis
Product name	S-MZVI	Ferro Target	Fine ZVI	PlumeStop
Condition	Slurry	Solid mix	Solid mix	Slurry
Solid content in package	40% ZVI	-	-	<25 % activated carbon
Test concentration	4% ZVI by weight	4% ZVI by weight	4% ZVI by weight	"as-is"
Particle size	< 5 μm	< 44 μm	< 125 μm	<2.5 μm

TEST PROCEDURE

This study is composed of three parts: baseline analysis, batch kinetic test, and batch isotherm test. AECOM will sample 20 pounds of saturated soil and 10 gallons of GW from the Site and ship to the selected lab.

1. Baseline analysis of soil and GW

As soon as the soil and GW samples are delivered to the laboratory, triplicate samples of the soil and GW will be taken for the baseline analysis for nitrate, perchloroethylene (PCE), trichloroethylene (TCE), cis-dichloroethylene (cis-DCE), vinyl chloride (VC), uranium (U), Tc-99, pH, oxidation reduction potential (ORP), background radioactivity, and soil moisture content. Based on the results of analyses, analysis list for next steps will be to be determined (TBD).

2. **Batch kinetic test**

Description: simulating the Site condition after product injection, with maintaining a constant solid to liquid ratio (1 to 2) and effective porosity of the Site (0.2).
Expected Outcome: obtaining a half-life of Tc-99 removal reaction based on a pseudo-first order reaction constant with and without the Site soil conditions. In addition, the result will be used for determining a proper reaction time for the isotherm test.

a. Dry the soil overnight in the oven with 95 ^{0}C. Sieve the dried soil with #14 mesh sieve (<1.4 mm) for collecting about 2300 g of soil passed through the sieve.
b. Each ZVI product and handling instruction will be delivered from the manufacturer to the selected lab. ZVI-1 will be a slurry form for dilution to target 4% by weight ZVI concentration (x10 dilution). ZVI-2 and ZVI-3 could be a mixture of solid with a specific instruction for adding DI water to target 4% ZVI concentration. The amount needs to be prepared for the test will be about 300 mL for each ZVI product.
c. Prepare 50 mL centrifuge vials (4 products x 2 conditions x 8 times x 3 triplicates + 27 blanks = 219 vials) as a reactor and label them according to **Table 3** with triplicates. Temporary maximum reaction time is 7 days. The Xd samples will be continuously on a reaction mode until the analysis data confirm that 7 days are enough to complete the reaction. Final reaction time for the Xd samples is TBD.

Table 3. Kinetic test sample matrix.

Reaction time	1h	3h	6h	1d	2d	4d	7d	Xd	7d
ZVI-1 (w/o soil)	Z1-1h-#	Z1-3h-#	Z1-6h-#	Z1-1d-#	Z1-2d-#	Z1-4d-#	Z1-7d-#	Z1-Xd-#	Z1-bk-#
ZVI-2 (w/o soil)	Z2-1h-#	Z2-3h-#	Z2-6h-#	Z2-1d-#	Z2-2d-#	Z2-4d-#	Z2-7d-#	Z2-Xd-#	Z2-bk-#
ZVI-3 (w/o soil)	Z3-1h-#	Z3-3h-#	Z3-6h-#	Z3-1d-#	Z3-2d-#	Z3-4d-#	Z3-7d-#	Z3-Xd-#	Z3-bk-#
CAC (w/o soil)	C-1h-#	C-3h-#	C-6h-#	C-1d-#	C-2d-#	C-4d-#	C-7d-#	C-Xd-#	C-bk-#
ZVI-1 (w/ soil)	S-Z1-1h-#	S-Z1-3h-#	S-Z1-6h-#	S-Z1-1d-#	S-Z1-2d-#	S-Z1-4d-#	S-Z1-7d-#	S-Z1-Xd-#	S-Z1-bk-#
ZVI-2 (w/ soil)	S-Z2-1h-#	S-Z2-3h-#	S-Z2-6h-#	S-Z2-1d-#	S-Z2-2d-#	S-Z2-4d-#	S-Z2-7d-#	S-Z2-Xd-#	S-Z2-bk-#
ZVI-3 (w/ soil)	S-Z3-1h-#	S-Z3-3h-#	S-Z3-6h-#	S-Z3-1d-#	S-Z3-2d-#	S-Z3-4d-#	S-Z3-7d-#	S-Z3-Xd-#	S-Z3-bk-#
CAC (w/ soil)	S-C-1h-#	S-C-3h-#	S-C-6h-#	S-C-1d-#	S-C-2d-#	S-C-4d-#	S-C-7d-#	S-C-Xd-#	S-C-bk-#

Note. # is 1, 2, or 3 (triplicates). All XX-bk-# samples are blank samples (only product or product/soil in DI water). Three additional samples (**GW-bk-#**) are GW only blank with 7 days of reaction time.

d. Record the weigh in each step: 1) vials with caps, 2) + soil, 3) + product mixture, 4) + GW with cap on. Intended solid to water ratio is approximately 1:2. Put the soil (20 g) and well mixed product (ZVI-1, ZVI-2, ZVI-3, or CAC, 5 mL) sequentially, or only the product mix, in the vials under a fume hood. Then, add the GW without headspace, and put the cap on. During the addition of product mixture and GW, N_2 gas needs to be purging the O_2 in the vials for minimum 2 minutes.
e. Put a proper number of the vials in a zip-top bag and load the bags on a mechanical shaker. Start the mixing procedure with 100 RPM and start the timer for monitoring reaction time.
f. When the vials reach to each desired reaction time, remove the corresponding vials from the shaker, and weigh the vials for confirmation of no leaking. Record the final weight of each vial.
g. Open one vial for each reaction time inside of the fume hood and measure the ORP, then pH.
h. Put the other vials in a centrifuge for 30 min with 2000 rpm. Remove the cap and filter the supernatant with a 0.22-micron syringe filter for nitrate, CVOCs, U, Tc-99 analysis (TBD). Decant the remaining supernatant. Collect the wet soil for moisture content and Tc-99 analysis.

3. **Batch isotherm test**

Description: simulating the Site condition in an equilibrium condition by using various product amount within effective porosity of the Site (0.2).
Expected Outcome: Maximum Tc-99 removal capacity of each product based on an isotherm theory (Langmuir or Freundlich constants).

a. Dry and sieve the soil with the identical procedure for about 1500 g of soil passed through the sieve.
b. ZVI-1 will be a slurry form for dilution to target 4% ZVI concentration (x10 dilution). ZVI-2 and ZVI-3 could be a mixture of solid with a specific instruction for adding DI water to target 4% ZVI concentration. The amount needs for the test will be about 200 mL for each ZVI product.
c. Prepare 50 mL centrifuge vials (4 products x 2 conditions x 5 doses x 3 triplicates + 27 blanks = 147 vials) as a reactor and label them as shown in **Table 4** in triplicates. The reaction time would be TBD based on the result of kinetic test.

Table 4. Isotherm test sample matrix.

Dosing product (mL)	1	2	3	8	10	5
ZVI-1 (w/o soil)	Z1-1mL-#	Z1-2mL-#	Z1-3mL-#	Z1-8mL-#	Z1-10mL-#	Z1-bk-#
ZVI-2 (w/o soil)	Z2-1mL-#	Z2-2mL-#	Z2-3mL-#	Z2-8mL-#	Z2-10mL-#	Z2-bk-#
ZVI-3 (w/o soil)	Z3-1mL-#	Z3-2mL-#	Z3-3mL-#	Z3-8mL-#	Z3-10mL-#	Z3-bk-#
CAC (w/o soil)	C-1mL-#	C-2mL-#	C-3mL-#	C-8mL-#	C-10mL-#	C-bk-#
ZVI-1 (w/ soil)	S-Z1-1mL-#	S-Z1-2mL-#	S-Z1-3mL-#	S-Z1-8mL-#	S-Z1-10mL-#	S-Z1-bk-#
ZVI-2 (w/ soil)	S-Z2-1mL-#	S-Z2-2mL-#	S-Z2-3mL-#	S-Z2-8mL-#	S-Z2-10mL-#	S-Z2-bk-#
ZVI-3 (w/ soil)	S-Z3-1mL-#	S-Z3-2mL-#	S-Z3-3mL-#	S-Z3-8mL-#	S-Z3-10mL-#	S-Z3-bk-#
CAC (w/ soil)	S-C-1mL-#	S-C-2mL-#	S-C-3mL-#	S-C-8mL-#	S-C-10mL-#	S-C-bk-#

Note. # is 1, 2, or 3 (triplicates). All XX-bk-# samples are blank samples (only product or product/soil in DI water). Three additional samples (**S-bk-#**) are the soil only blank with 7 days of reaction time.

d. Record the weigh in each step: labelled vials with caps, + soil, + product mixture, + GW, cap on). Put the soil (20 g) and well mixed product (ZVI-1, ZVI-2, ZVI-3, or CAC, amount in **Table 5**) sequentially, or product only in the vials under a fume hood. Then, add the GW without headspace, and put the cap on. During the addition of materials and GW, N_2 gas needs to be purging the O_2 in the vials for minimum 2 minutes.
e. Put a proper number of the vials in a zip-top bag and load the bags on a mechanical shaker. Start the mixing procedure with 100 RPM and start the timer for monitoring reaction time.
f. After determined reaction time (TBD), remove the vials from the shaker, and weigh the vials for confirmation of no leaking. Record the final weight of each vial.
g. Open one vial for each reaction time inside of the fume hood and measure ORP, then pH.
h. Put the other two vials in a centrifuge for 30 min with 2000 rpm. Remove the cap and filter the supernatant with a 0.22-micron syringe filter for nitrate, CVOCs, U, Tc-99 analysis (TBD). Decant the remaining supernatant. Collect the wet soil for moisture content and Tc-99 analysis.

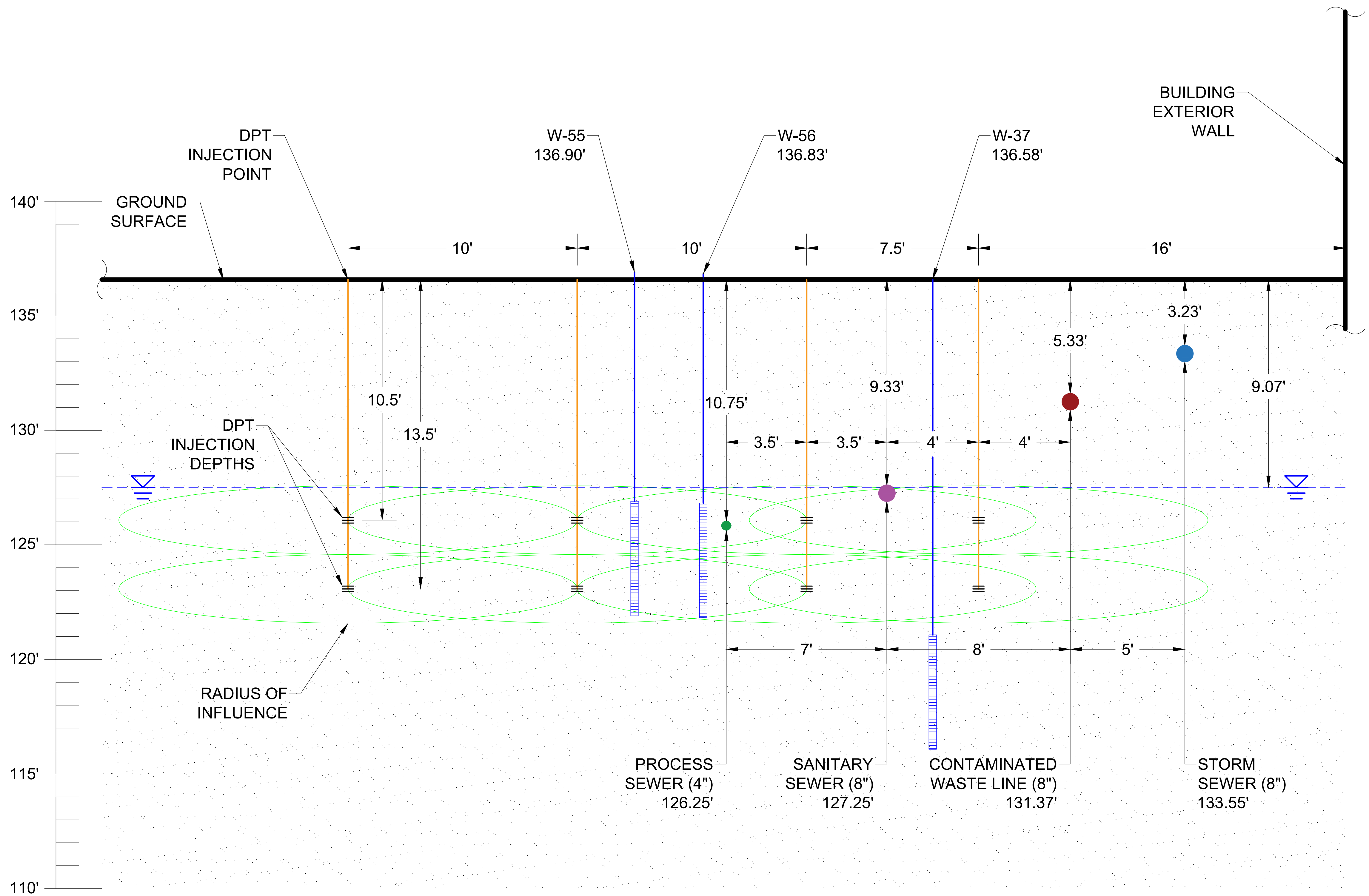
SUGGESTED ANALYTICAL METHODS

1. CVOCs: Headspace GC-MS
2. Nitrate: IC
3. U: ICP-MS
4. Tc-99: liquid scintillation counter
5. pH and ORP: probe

REQUIRED EQUIPMENT AND CONSUMABLES

1. Mechanical blender with paddles
2. Drying oven
3. #14 sieve
4. Fume hood
5. N_2 gas cylinder or in-house N_2 gas
6. Centrifuge vials (50 mL) and centrifuge
7. Balance
8. Mechanical shaker
9. Analytical instruments: GC-MS, IC, ICP-MS, liquid scintillation counter, pH / ORP meter and corresponding probes
10. 0.22-micron syringe filter and syringe
11. Pipettes and tips
12. Zip-top plastic bags

Appendix G
Uranium Pilot Test Cross-section



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1 OF 1

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