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Removal Site Evaluation Report / Engineering Evaluation / Cost Analysis for Trichloroethylene Plumes Discharging to Steel Creek in P-Area Groundwater Operable Unit (NBN) (U)

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U.S. Department of Energy
and
Savannah River Nuclear Solutions, LLC
Aiken, South Carolina

EXECUTIVE SUMMARY

The U.S. Department of Energy (USDOE) is proposing to perform a non-time critical (NTC) removal action for the trichloroethylene (TCE) plumes discharging to Steel Creek from the P-Area Groundwater (PAGW) Operable Unit (OU). This Removal Site Evaluation Report/Engineering Evaluation/Cost Analysis (RSER/EE/CA) presents and evaluates NTC removal action alternatives developed to address the TCE plumes discharging to Steel Creek from the PAGW OU and has been developed to combine the reporting requirements of 40 Code of Federal Regulations (CFR) 300.410 Removal Site Evaluation and 40 CFR 300.415 Removal Action.

Groundwater is contaminated with chlorinated volatile organic compounds (cVOCs) (primarily TCE) and tritium, at concentrations above maximum contaminant levels (MCLs). Plumes originating from the northwest side of the P-Area Reactor Building Complex are migrating westward within the Upper Aquifer Zone and Lower Aquifer Zone of the Upper Three Runs Aquifer and are intersecting Steel Creek. A NTC removal action is warranted in the groundwater in an effort to reduce the amount of TCE in groundwater that will eventually discharge into Steel Creek. Tritium plumes in groundwater that discharge to Steel Creek above the MCL are also problems warranting action; however, the tritium plumes and related surface water exceedances will be addressed at a later time as part of the final remedy at the OU.

The United States Environmental Protection Agency, South Carolina Department of Health and Environmental Control, and USDOE have agreed that the PAGW OU is a candidate for an early action to reduce risk to human health and the environment. The elevated levels of TCE in the groundwater and surface water meet the criteria in 40 CFR Section 300.415(b) (2) (i): *Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances or pollutants or contaminants*.

The removal action objective for the NTC removal action is to reduce the TCE mass in the groundwater plumes so that the mass flux to Steel Creek will ultimately be reduced in order to reach the MCL in surface water. Two alternatives to reduce the TCE mass in the groundwater plumes that are discharging into Steel Creek include removal actions that are considered for two separate areas. The alternatives evaluated include the following:

- Alternative 1 – No Action
- Alternative 2A – Permeable Reactive Barrier (PRB) in the Neck Area of the TCE Plumes
- Alternative 2B – PRB in the Elbow Portion of the Distal Area of the TCE Plumes
- Alternative 3A – In Situ Chemical Oxidation (ISCO) in the Neck Area of the TCE Plumes
- Alternative 3B – ISCO in the Elbow Portion of the Distal Area of the TCE Plumes

The table below summarizes the results from the alternative evaluation.

Alternative	Effectiveness	Implementability	Cost*
Alternative 1 No Action	Low	High	$ 0
Alternative 2A PRB in the Neck Area of the TCE Plumes	Medium-High	Medium-High	$ 4.61 M
Alternative 2B PRB in the Elbow Portion of the Distal Area of the TCE Plumes	High	Medium	$ 6.03 M
Alternative 3A ISCO in the Neck Area of the TCE Plumes	Medium	Medium-High	$ 4.92 M
Alternative 3B ISCO in the Elbow Portion of the Distal Area of the TCE Plumes	Medium-High	Low	$ 9.09 M

*Million (M)

The preferred action is Alternative 2A, PRB at the Neck Area of the TCE Plumes. This alternative involves the installation of a zero-valent iron PRB in the neck area of the plumes where cVOC concentrations are high and the geologic formation restricts groundwater flow through a relatively narrow area of high permeability sediments. Installing a PRB in the well-defined highly permeable sediments in the neck area of the TCE plumes will truncate the source area of the plumes from the distal portion and will provide long-term effectiveness by reducing TCE mass in groundwater through in situ destruction, and eventually reduce the TCE discharge to surface water to concentrations below the MCL. This alternative will allow surface water concentrations in Steel Creek to achieve applicable or relevant and appropriate requirements once the remnant plumes have attenuated.

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LIST OF ABBREVIATIONS AND ACRONYMS

>	greater than
<	less than
~	approximate, approximately
ac	acre
ARAR	applicable or relevant and appropriate requirement
amsl	above mean sea level
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cis-1,2-DCE	cis-1,2-dichloroethylene
CFR	Code of Federal Regulations
cVOC	chlorinated Volatile Organic Compound
DPT	direct push technology
EE/CA	Engineering Evaluation/Cost Analysis
FFA	Federal Facility Agreement
ft	feet
ft^3	cubic feet
GA	Gordon Aquifer
ha	hectare
IDW	investigation-derived waste
ISCO	In situ Chemical Oxidation
km	kilometer
km^2	square kilometer
L	liter, liters
LAZ	Lower Aquifer Zone
LLC	Limited Liability Company
M	million
m	meter
m^3	cubic meter
MCL	maximum contaminant level
mi	mile
mi^2	square mile
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NTC	non-time critical
O&M	operation and maintenance
OU	Operable Unit
PAGW	P-Area Groundwater
PAOU	P-Area Operable Unit
PCE	tetrachloroethylene
PRB	permeable reactive barrier
PRSB	P-Area Reactor Seepage Basins
P-RBC	P-Area Reactor Building Complex
PSA	Potential Source Area

LIST OF ABBREVIATIONS AND ACRONYMS (*Continued/End)*

RAO	removal action objectives
RSER	Removal Site Evaluation Report
SCDHEC	South Carolina Department of Health and Environmental Control
SAP	Sampling and Analysis Plan
sec	second
SRNS	Savannah River Nuclear Solutions, LLC
SRS	Savannah River Site
SVE	Soil Vapor Extraction
TBC	to be considered
TCE	trichloroethylene
UAZ	Upper Aquifer Zone
µg/L	micrograms per liter
UIC	underground injection control
USDOE	U.S. Department of Energy
USEPA	U.S. Environmental Protection Agency
UTRA	Upper Three Runs Aquifer
WSRC	Washington Savannah River Company LLC (October 2005-present)
WSRC	Westinghouse Savannah River Company LLC (before October 2005)
ZVI	Zero-Valent Iron

1.0 INTRODUCTION

The U.S. Department of Energy (USDOE) is proposing to perform a non-time critical removal (NTC) removal action at the P-Area Groundwater (PAGW) Operable Unit (OU) to address the trichloroethylene (TCE) plumes discharging to Steel Creek. This Removal Site Evaluation Report (RSER)/Engineering Evaluation/Cost Analysis (EE/CA) identifies the objectives of the removal action and evaluates NTC removal action alternatives developed to address the TCE plumes discharging to Steel Creek from the PAGW OU. Other chlorinated volatile organic compounds (cVOCs) groundwater plumes are collocated with the TCE groundwater plumes, but are not discharging to Steel Creek at concentrations above their MCLs. Tritium plumes in groundwater and their discharge to Steel Creek are not the focus of this RSER/EE/CA. This document also provides a vehicle for public comment in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) 300.415.

The Savannah River Site (SRS) encompasses 803 km^2 (310 mi^2) of land adjacent to the Savannah River, principally in Aiken and Barnwell counties of South Carolina. SRS is located approximately (~) 40 km (25 mi) southeast of Augusta, Georgia, and 32-km (20 mi) south of Aiken, South Carolina (Figure 1). SRS is owned by USDOE while Savannah River Nuclear Solutions, LLC (SRNS) provides management and operating services. SRS has historically produced tritium, plutonium, and other special nuclear materials for national defense. Chemical and radioactive wastes are by-products of nuclear material production processes. Hazardous substances, as defined by Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), are present in the SRS environment.

The public is encouraged to comment on the alternatives presented in this RSER/EE/CA. Following the public comment period, an Action Memorandum will be prepared by USDOE and added to the SRS Administrative Record, which is accessible by the public. All responses to the public comments will be included in the Action Memorandum.

Copies of this RSER/EE/CA and the Administrative Record for SRS are available at the following locations:

U.S. Department of Energy
Public Reading Room
Gregg Graniteville Library
University of South Carolina-Aiken
471 University Parkway
Aiken, South Carolina 29803
(803) 641–3504

Thomas Cooper Library
Government Information and Maps Department
University of South Carolina
1322 Green Street
Columbia, SC 29208
(803) 777–4841

Hard copies of this RSER/EE/CA are available at the following locations:

Reese Library
Government Information Department
Augusta University
2500 Walton Way
Augusta, GA 30904
(706) 737–1744

Asa H. Gordon Library
Savannah State University
2200 Tompkins Road
Savannah, GA 31404
(912) 358–4324

To submit comments or request a public meeting during the public comment period, contact:

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2.0 SITE CHARACTERIZATION

2.1 Site Description and Background

P Area is located in the central portion of SRS ~4.0-km (2.5 mi) east-southeast of the geographical center of SRS and about 6.4 km (4 mi) west of the nearest site boundary (Figure 2). P Area consists of a closed nuclear reactor building complex and several surface OUs and structures that were characterized and identified as sources to soil and groundwater contamination. The PAGW OU encompasses the groundwater beneath P Area, northwest to Steel Creek, northeast toward

PAR Pond and SRS Road F, and southeast to Meyers Branch and is established for the purposes of groundwater modeling (Figure 3). Groundwater over portions of the PAGW OU areal extent has been impacted by reactor and facility operations between 1954 and 1991.

A scoping meeting was held with the USDOE, U.S. Environmental Protection Agency (USEPA) and South Carolina Department of Health and Environmental Control (SCDHEC) in January 2017 to discuss the PAGW OU characterization data and discern impact of TCE contaminated groundwater discharging to the nearby surface water in Steel Creek. During the interactive scoping meeting held in May 2017, USDOE, USEPA and SCDHEC, agreed to consider Permeable Reactive Barriers (PRB) or the application of *In Situ* Chemical Oxidation (ISCO) as possible removal action alternatives to address TCE concentrations in groundwater at the neck and distal areas in an effort to reduce discharges of TCE contaminated groundwater to surface water in Steel Creek.

2.2 Previous Action

The P Area surface units identified as posing a risk to human health, environment, and contributing to groundwater contamination were remediated as part of the P-Area Operable Unit (PAOU), including the P-Area Reactor Building Complex (P-RBC) (105-P). Remedial actions associated with surface units included in the PAOU have been completed and are documented in the PAOU Post Construction Report (SRNS 2012a). One surface unit, Potential Source Area (PSA)-3A was determined to be the source of the TCE plumes that are discharging to Steel Creek (Figure 4). PSA-3A was remediated in 2011 and the remedial goals were met using soil vapor extraction (SVE) enhanced with soil fracturing and ISCO injection. PSA-3B, a source for the tetrachloroethylene (PCE) contamination in the PAGW OU, was also remediated using SVE (SRNS 2012b). All remedial actions of surface units in P-Area that had the potential to impact groundwater in the future are summarized in Table 1. No remedial, interim, or removal actions have been conducted specific to the PAGW OU.

A treatability study at the PAGW OU to assess the viability of biostimulation and bioaugmentation using a microbe (MicroCED) found in SRS groundwater was conducted in 2009 on the TCE groundwater plumes downgradient of PSA-3A (SRNS 2010b). Biodegradation of TCE was mostly exhibited in the injection wells with little to no impact exhibited at the nearby piezometers (Amidon et al, 2013). Subsequent sampling further supported the notion of localized treatment with little impact to nearby piezometers. No follow-on work has been conducted since completion of the study.

A description of the previous groundwater investigations at the PAGW OU is provided in the Sampling and Analysis Plan (SAP) for the PAGW OU (SRNS 2013a). Table 2 provides a summary of the previous groundwater characterizations. In addition to these investigations, monitoring wells in P Area have been installed and sampled since as early as 1979 through 2016. Section 2.5 of this document discusses the extent of characterization data and sample locations performed as described in the SAP.

2.3 Land Use

The area encompassed by the PAGW OU includes zones currently designated for industrial use as well as areas with no current use restrictions. No current or projected future development of P Area is planned. The Upper Three Runs Aquifer (UTRA), which is the aquifer where the majority of the plumes are located, is not currently used as a drinking water source at SRS. There are no identified area(s) or structure(s) that are considered to have historical value. Land use of the entire PAGW OU area will be controlled as part of a future remedial decision in accordance with the SRS Land Use Control Assurance Plan to prevent use of groundwater or surface water that exceeds MCLs (WSRC 1999).

2.4 Environmental Setting

The PAGW OU is bounded by Meyers Branch to the southeast, PAR Pond to the northeast, and Steel Creek to the northwest (Figure 3). Topography ranges from 101-meters (m) (330-feet [ft]) above mean sea level (amsl) near P Area to 57.9-m (190-ft) amsl at the downstream end of Meyers Branch and Steel Creek. The area near the P-RBC (105-P) is higher in elevation (>101 m [330 ft]) than the surrounding land. Surface drainage on the west side of the P-RBC is to the west, towards Steel Creek. Surface drainage on the east side of the P-RBC drains to unnamed tributaries that drain to PAR Pond while surface drainage on the south side drains to wetlands and unnamed tributaries to Meyers Branch.

Shallow groundwater flow in the Upper Aquifer Zone (UAZ) and Lower Aquifer Zones (LAZ) of the UTRA mirrors local area topography. P Area resides on a groundwater divide in which the shallow water-bearing units exhibit diverging flow paths to the east and west of the P-RBC (Figures 5 and 6).

Prior to construction of P Area, the headwater of Steel Creek, as defined by the United States Geological Society, was determined approximately 305-m (1,000-ft) downstream from the current location. During the course of P Area reactor operations, process water with flows reaching 11.3 m^3/sec (400 ft^3/sec) scoured and impacted the area resulting in the development of a canyon with steep sides, depth of ~6.1 m (20 ft), and varying width of 24.3 m to 61 m (80 ft to 200 ft). Over the course of more than 30 years of operations, this scouring resulted in the intersection of the UAZ further upstream and therefore changing the location of the headwater of Steel Creek. To date, natural flow exists within Steel Creek, and natural vegetation has repopulated the banks and streambed, none of which are typical of wetland hydric soil vegetation.

The headwaters of Steel Creek sit at an elevation of 73-m (240-ft) amsl and incise down to ~61-m (~200-ft) amsl where Steel Creek enters L Lake. Steel Creek is likely the largest drain influence from shallow water-bearing units within the area of interest. During most of the year, the elevation of the UAZ near the headwaters of Steel Creek is approximately the same as the elevation of the Steel Creek streambed. Consequently, Steel Creek, which is a perennial stream, is a discharge point for the shallow water-baring units. Groundwater contamination from the west side of P Area and the P-Area Reactor Seepage Basins (PRSBs) is known to be discharging into Steel Creek.

2.5 Nature and Extent of Contamination

As part of the work to characterize PAGW under CERCLA, soil and groundwater samples were taken throughout the area. Characterization data have been collected from groundwater samples collected from P Area monitoring wells and numerous direct push technology (DPT) locations as well as surface water collected from various locations along Steel Creek. The sample locations from the characterization efforts are shown on Figures 7 through 10.

Groundwater in P Area has been found to be contaminated with tritium and cVOCs: PCE, TCE, and cis-1,2-dichloroethlynene (cis-1,2-DCE). Nearly all of groundwater contamination is exhibited in the UAZ and LAZ; however, one well in the Gordon Aquifer (GA) located at the PRSBs contains tritium only. The cVOC groundwater plumes are present to the north of the P-RBC and extend to the west toward Steel Creek and to the east toward PAR Pond. Groundwater plumes to the east are limited in areal extent and currently do not impact surface water.

Plumes on the west side of the P-RBC are impacting Steel Creek with discharges of tritium and TCE contaminated groundwater exceeding their respective MCL. Tritium plumes and related surface water exceedances will be addressed at a later time as part of the final remedial decision for the PAGW OU. The focus of this NTC removal action is to address TCE groundwater plumes that are discharging to Steel Creek. The extent of the TCE and PCE groundwater plumes is described in the following subsections. Other cVOCs, such as PCE and cis-1,2-DCE, that are also present in the groundwater in exceedance of their MCLs will also be addressed by any removal action implemented due to collocation of the groundwater plumes within the TCE plumes. The extent of cis-1,2-DCE contamination is limited and is encompassed by the larger TCE groundwater plumes.

TCE Plumes discharging to Steel Creek

In the UAZ, TCE contaminated groundwater extends from the north of P-RBC westward to Steel Creek (Figure 11). The highest exhibited TCE concentration of 7,440 µg/L is located near Steel Creek. TCE is present in the LAZ on the west side of the P-RBC and extends to Steel Creek with concentrations over 7,000 µg/L (Figure 12). Distribution of TCE concentrations in exceedance of 1,000 µg/L in the LAZ is three (3) times greater than in the overlying UAZ. This is primarily due to the almost stagnant horizontal groundwater flow associated with the groundwater divide and subsequent increased vertical migration of TCE from the UAZ into the LAZ north of the P-RBC.

MCL exceedances in groundwater occur in ~8.9 hectares (ha [22 acres {ac}]) in the UAZ plume and 8.5 ha (21 ac) in the LAZ plume.

PCE Plumes

PCE groundwater contamination has been delineated similarly in the UAZ into two distinct plumes. The PCE plume northeast of the P-RBC is not collocated with groundwater plumes in P Area due to the location of the source area being in a different area in P Area (Figure 4). On the west side of the P-RBC, as the plume migrates west, the PCE plume in the UAZ is collocated with the TCE groundwater plume and extends towards Steel Creek. PCE contamination also exists in the LAZ and extends toward Steel Creek. PCE groundwater concentrations are in the range of 100 µg/L, significantly less than the TCE concentrations. The PCE plume geometries in the UAZ and LAZ are shown in Figures 13 and 14. MCL exceedances in groundwater occur in ~6.1 ha (15 ac) in the UAZ plume and 3.2 ha (8 ac) in the LAZ plume.

Surface Water Contamination

TCE is the only cVOC that has been detected in Steel Creek at concentrations exceeding the MCL. Uncertainties exist to the exact location and overall areal impact of TCE-contaminated groundwater discharges to Steel Creek between surface water locations SC-02 and SC-04 (Figure 10). Based on existing surface water data, it is known that at surface water location SC-02 TCE has not been detected in over 12 years (Figure 15). This could be in part due to only the upper portion of the UAZ being intersected by the creek at this location, resulting in less contaminated groundwater discharging than exhibited in the lower portion of the UAZ (Figure 16). This would lead to limited groundwater discharges in this area while the plumes continue to migrate further downstream to an area of greater discharge. Downstream of SC-02, surface water location SC-03 has exhibited TCE concentrations above the MCL since late 2004 with the maximum detection of 28.3 µg/L in 2013 (Figure 15). As expected and based on flow rate data, flow along Steel Creek increases downstream as more of the UAZ is intersected. Additionally, other surface water bodies (e.g., Carolina Bays) provide a continual source of water to the creek. At SC-04, ~305 m (~1,000-ft) downstream of SC-03, TCE concentrations have not been detected.

Groundwater Contamination Summary

Groundwater contamination associated with cVOCs is primarily exhibited in a narrow band north of the P-RBC and extends to the west to Steel Creek, where impact is known, and east towards an unnamed tributary to PAR Pond. The cVOC groundwater plumes can be described in three parts: 1) source area, 2) neck area, and 3) distal area (Figures 16 and 17). As represented in Figure 17, the estimated volume of contaminated groundwater above 1 ppm TCE combined in the UAZ and LAZ is 124 million (M) L (32.8M gallons [gal]) in the source area, 12.9M L (3.4M gal) in the neck area, and 62.6M L (16.5M gal) in the distal area. The source area represents the majority of the groundwater contamination and is centered north of the P-RBC within the P Area facility area. The neck area represents the area where the cVOC groundwater plumes are controlled by a buried geologic feature thus creating a narrowing of the groundwater plumes and is located to the west just outside of the P Area facility area. The distal area represents the area where the plumes are closest to Steel Creek. Alternatives associated with treating the distal area of the plumes are focused on the highest TCE concentrations (above ~5,000 µg/L) in this area and are referred to as the elbow portion of the distal plumes area. Table 3 lists the maximum reported concentrations for TCE, PCE, and cis-1,2-DCE in the UAZ and LAZ at the three areas during the fourth quarter sampling event in 2016.

3.0 REMOVAL ACTION SCOPE AND OBJECTIVES

The NTC removal action proposed at the PAGW OU is associated with TCE-contaminated groundwater discharging into Steel Creek above the MCL (5 µg/L). The neck and the elbow portion of the distal plume area will be evaluated for this removal action. Alternatives associated with treating the source area of the plumes were discussed in the May 2017 scoping meeting. Due to the very slow rate of groundwater movement in this area and extensive contamination in both the UAZ and LAZ, treatment would likely be ineffective despite very high costs. Therefore, conducting a removal action in the source area of the plumes was not considered further.

An effectiveness monitoring plan, specific to this removal action, will be developed to evaluate the short- and long-term impacts of this NTC removal action on the groundwater and surface water.

3.1 Justification for the Proposed Removal Action

USDOE, as lead agency, is mandated to take action to reduce the adverse effects of man-made contamination on human health and the environment. The NCP states that if the lead agency determines a release or potential release poses a threat to public health or welfare or the environment, the lead agency may take any appropriate removal action to abate, prevent, minimize, stabilize, mitigate, or eliminate the release or threat of release. This determination should be based on the factors identified in 40 CFR Section 300.415(b) (2).

The May 2017 scoping meeting among USEPA, SCDHEC and USDOE identified the TCE plumes associated with the PAGW as candidates for a removal action to address TCE contamination in the groundwater that is discharging to surface water at levels exceeding the MCL. The elevated levels of TCE in the groundwater and surface water above the MCL meet the criteria in 40 CFR Section 300.415(b) (2) (i): *"Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances or pollutants or contaminants"*.

3.2 Removal Action Objectives

The removal action objective (RAO) for the NTC removal action is to reduce the TCE mass in the groundwater plumes so that the mass flux to Steel Creek will ultimately be reduced in order to reach the MCL in the stream. TCE concentrations measured in Steel Creek at location SC-03 (see Figure 10) between 2012 and 2016 average ~20 µg/L. Based on these observed TCE concentrations in Steel Creek, a TCE mass flux reduction of 80% or greater should achieve the MCL in Steel Creek. Alternatives were evaluated that reduce TCE mass flux across the treatment zone resulting in reduced mass in the groundwater plumes that are discharging to Steel Creek. The removal actions evaluated will also address other cVOCs present, PCE and cis-1,2-DCE, in the groundwater due to the extent and collocation of these groundwater plumes with the TCE plumes. TCE mass removal in groundwater is consistent with the final remedial action objective of reducing the cVOC concentrations in groundwater and surface water to their MCLs. This removal action will not address tritium in the groundwater or surface water and will leave hazardous substances in place that pose a potential future risk. However, the residual risk will be minimal because there is no current or projected future use of groundwater or surface water as a drinking water source at the PAGW OU. Site access is currently controlled by SRS facility security and administrative controls. Site specific land use controls are expected to be part of the final remedial action for the PAGW OU.

4.0 IDENTIFICATION OF REMOVAL ACTION ALTERNATIVES

The following alternatives for the PAGW OU removal action were examined:

- **Alternative 1 — No Action**: The No Action alternative is required to be evaluated by the NCP.

- **Alternative 2 — PRB**: This alternative involves the installation of a zero-valent iron PRB to intercept and dechlorinate the TCE groundwater plumes. This reactive medium degrades the TCE into nontoxic dehalogenated organic compounds and inorganic chloride. This alternative will reduce the TCE contamination in the PAGW that is in the UAZ and LAZ and extends from north of P-RBC westward to Steel Creek. Pre-design geotechnical and geochemical characterization might be needed to better define groundwater characteristics that could limit PRB effectiveness, such as the precise location of the low-permeability zone depth which the wall must join to minimize underflow. This alternative is consistent with any additional remediation activities that will be conducted within the PAGW OU as a part of the final remedy. This alternative will also treat PCE and cis-1,2-DCE in addition to TCE, but will not treat tritium. This removal action is not considered a final remedy for the entire PAGW OU.

  Two areas are considered for this technology alternative: A) the neck area and B) the elbow portion of the distal area of the plumes. These locations are evaluated as a subset of Alternative 2.

  Alternative 2A — PRB in the Neck Area of the TCE Plumes: The purpose of the removal action in the neck area is to reduce TCE mass flux from the source area and allow the distal area TCE groundwater plumes to eventually attenuate, thus reducing TCE flux to Steel Creek. Conceptually, a zero-valent iron PRB across the 45.7-m (150-ft) width of the TCE groundwater plumes with two angled impermeable walls installed from 15.2-m to

44.2-m (50-ft to 145-ft) below ground surface (Figure 18) would be installed. The base of the PRB would be set into a low- permeability unit or aquitard to ensure there is minimal underflow and bypass of the PRB. Extensive characterization data already exists in this area and the plume geometry and subsurface geologic conditions are well defined. Some additional pre-design data might be needed to confirm the details of the design for implementation of this alternative. Various methods are available for installation of the PRB. However, based on the depth of the PRB, installation of the PRB is assumed to use injection as the means for placement of the PRB for the purposes of evaluating the cost. Installation of the PRB will be by a commercial vendor subcontracted by SRNS. The actual method of installation of the PRB will be determined upon review of all vendor conceptual designs, ensuring that the RAO is met.

Alternative 2B — PRB in the Elbow Portion of the Distal Area of the TCE Plumes: The purpose of this alternative is to reduce the high TCE mass in this portion of the groundwater plumes, thus reducing the TCE mass flux to Steel Creek. This alternative includes significant additional characterization to define the extent of the distal portion of the plumes and impact to Steel Creek, in the area of monitoring well clusters PGW026 and PGW027, where the highest concentration of TCE has been observed (elbow portion). The characterization of this area is scheduled to begin in fiscal year 2018. Based on existing data, it is assumed that the PRB would extend 122 m (400 ft) along the bluff overlooking Steel Creek to a depth of ~21.3 m to 44.2 m (70 ft to 145 ft) (Figure 19). The base of the PRB would be set into a low-permeability unit or aquitard to ensure there is minimal underflow and bypass of the PRB. Various methods are available for installation of the PRB. However, based on the depth of the PRB, installation of the PRB could likely use injection as the means for placement of the PRB. The actual method of installation of the PRB will be determined upon review of all vendor conceptual designs, ensuring that the RAO is met.

- **Alternative 3 — ISCO**: This alternative involves the injection of a chemical oxidant (sodium persulfate), an activator (if needed), and pH buffer. Sodium persulfate oxidizes the TCE in the groundwater plumes and converts the contaminant to non-toxic compounds. The purpose of this action is to reduce the TCE mass flux into Steel Creek. Since the oxidant has limited residence time in the aquifer, periodic injections of oxidant through permanent injection wells will be needed. Pre-design characterization and lab studies would be needed to support design of the oxidant geochemistry and injection details. Addition of a pH buffer is needed to limit acidification of the aquifer associated with the persulfate oxidation. This alternative is consistent with any additional remediation activities that will be conducted within the PAGW as a part of the final remedy. This alternative will treat PCE and cis-1,2-DCE in addition to TCE but will not treat tritium. This removal action is not a final remedy for the entire PAGW OU.

Two areas are considered for this technology alternative: A) the neck area and B) the elbow portion of the distal area of the plumes. These locations are evaluated as a subset of Alternative 3.

Alternative 3A — ISCO in the Neck Area of the TCE Plumes: The purpose of ISCO treatment in the neck area is to reduce TCE mass flux from source area and allow the distal area TCE plumes to eventually attenuate, thus reducing TCE flux to Steel Creek. Implementation in the neck area would include installation of injection wells in two rows, spaced ~6.1-m (20-ft) apart. The injection wells would be installed perpendicular to groundwater flow to support long-term injections (Figure 20). Approximately 47 injection wells would be installed and screened in the UAZ and LAZ. Each cluster would be installed ~3-m (10-ft) apart and the treatment depth would range from 21.3-m to 44.2-m (70-ft to 145-ft) below ground surface. An additional 12 injection wells would be installed in the LAZ only to ensure adequate coverage for treatment. Groundwater monitoring wells would also be installed to support effectiveness monitoring of the action. Because the oxidant must be in contact with the contaminant to be effective, periodic injections must be administered. Based on data collected from the monitoring network, it is assumed that four injection campaigns would be required every three years over the course of 10 years in order to sufficiently reduce the mass of TCE in the groundwater in order to be effective at eventually achieving the MCL in Steel Creek.

Alternative 3B — ISCO in the Elbow Portion of the Distal Area of the TCE Plumes: The purpose of this alternative is to reduce the TCE mass in this portion of the groundwater plumes, thus reducing the TCE mass flux to Steel Creek. This alternative would involve injections along two transects near the elbow portion of the distal area of the plumes. Consideration of ISCO in this larger area would be based on the results of the characterization data. The characterization of this area is scheduled to begin in fiscal year 2018. Based on existing data, it is assumed that one transect would be installed along the bluff at Steel Creek to separate the TCE plumes from the up-gradient groundwater source area and another transect is proposed to treat the remaining TCE plumes south of the first transect (Figure 21). The transect along the bluff would be ~131-m (430-ft) long and the other ~76.2-m (250-ft) long. Injections would occur in 66 injection well clusters in the UAZ and the LAZ for a total of 132 injection wells. Each cluster would be installed ~3-m (10-ft) apart and the treatment depth would range from 21.3-m to 44.2-m (70-ft to 145-ft) below ground surface. Due to increased groundwater gradients in the area, it is assumed that five separate injection campaigns will be conducted every 2 years over the course of 10 years.

5.0 ANALYSIS AND COMPARISON OF REMOVAL ACTION ALTERNATIVES

Three alternatives are presented in this RSER/EE/CA for evaluation. According to the NCP, the No Action Alternative, Alternative 1, must be evaluated as a baseline. Alternative 2 involves the installation of a zero-valent iron PRB to intercept and dechlorinate the TCE plumes that are migrating toward Steel Creek. Alternative 3 proposes ISCO (sodium persulfate) injections in a series of wells to oxidize TCE in the plumes migrating to Steel Creek. The application areas (i.e., neck or elbow portion) of Alternatives 2 and 3 are evaluated and compared separately as the environmental setting influences the effectiveness, implementability, and cost.

Guidance on conducting NTC removal actions under CERCLA recommends that each alternative be reviewed against three broad criteria: effectiveness, implementability, and cost.

Regulatory acceptance and community acceptance are usually not known until after the comment periods. However, during the alternative analysis a judgment as to acceptance may be included based on previous regulatory decisions or on public comment to other related documents. The final impact of these modifying criteria can be assessed only after the comment period and subsequent responses are developed.

5.1 Effectiveness

Alternative 1 — No Action: This alternative does not meet the effectiveness criteria. Leaving the TCE plumes associated with the PAGW OU in place does not reduce the impact of TCE contaminated discharge of groundwater to Steel Creek above MCLs and thus does not provide overall protection to the environment. This alternative does not contribute to a reduction of toxicity, mobility, or volume through treatment. The No Action Alternative is not effective in meeting the removal action objectives.

Alternative 2 — PRB: This alternative meets the effectiveness criteria. Installation of the PRB will reduce the toxicity of the TCE via chemical reduction resulting from contact with zero-valent iron. This alternative will reduce the TCE mass in the plumes as they migrate through the PRB, which will eventually reduce the TCE mass flux to Steel Creek.

This alternative is effective at contaminant reduction in a single pass of the reactive barrier and results are permanent. Once installed, the PRB is a passive treatment process, requiring no operation and little to no maintenance of the remediation system. Groundwater monitoring and reporting will be conducted prior to, during, and after installation to validate the performance of the system.

Alternative 2A — PRB in the Neck Area of the TCE Plumes: This alternative would be effective at separating the source area from the distal area, reducing the TCE mass flux across the neck area. The anticipated long-term effectiveness of this alternative is high, because the extent of contamination and the subsurface conditions are well defined in this area. There is a relatively narrow area of high permeability sediments through which the contaminated TCE plumes are traveling. Installing a PRB in this area would significantly reduce TCE mass in the plumes from the source area as they travel downgradient through the reactive zone. Although this alternative rapidly destroys TCE in the treatment zone, it is not very effective in the short term in reducing TCE mass flux to Steel Creek, as the distance from the treatment zone to surface water is significant (about 457 m [1,500 ft]). Thus, this alternative would leave the remnant downgradient TCE plumes to attenuate while continuing to discharge to Steel Creek in exceedance of the MCL. Near-term effects in reducing TCE mass within the treatment zone in the neck of the plume provide for control of the source of this plume, which is key in curtailing the continued migration of TCE-contaminated groundwater that discharges to Steel Creek.

Alternative 2B — PRB in the Elbow Portion of the Distal Area of the TCE Plumes: This alternative would be effective in the long term in addressing the westward-migrating TCE plumes. Although this alternative rapidly destroys TCE in the treatment zone, it is somewhat effective in the short term in reducing TCE mass flux to Steel Creek, as the distance from the treatment zone to surface water (SC-03) is about 244 m (800 ft). A portion of the downgradient TCE plumes will continue to discharge to Steel Creek in exceedance of the MCL. There is greater uncertainty with regard to the potential for the groundwater to bypass the PRB in this portion of the plumes due to the wider, less defined area of high permeability sediments and overall extent of the TCE groundwater plumes. In order to address this uncertainty and ensure minimal bypass flow, pre-design characterization would be needed. Such data might indicate that the elbow is not well suited to placement of a PRB; it could also lead to consideration of placement of the PRB farther downgradient, which would improve the short-term effectiveness in reducing TCE discharge to Steel Creek.

Alternative 3 — ISCO: This alternative meets the effectiveness criteria. Similar to the PRB alternative (Alternative 2), this alternative will significantly reduce TCE mass in the treatment zone, thus eventually reducing the TCE mass flux to surface water (Steel Creek). ISCO injection is effective in the long term and is permanent. However, because the oxidant must remain in contact with the contaminant, rebound is likely; thus, several injections over several years will be necessary. An activator may also be necessary to ensure the most effective residence time. There is uncertainty associated with competing scavengers present in the subsurface which could reduce the effectiveness. Also, with multiple injections and subsequent chemical oxidation, it is expected that there will be an increase in metal and sulfate concentrations in groundwater and surface water. Pre-design characterization and lab studies would be needed to better define geotechnical and geochemical implications that could limit the success of the action. Groundwater monitoring and reporting would be conducted prior to, during, and after installation to validate the performance of the system.

Alternative 3A — ISCO in the Neck Area of the TCE Plumes: For ISCO injection to be effective in the long term, several injections over several years will be necessary in order to keep the oxidant in contact with the TCE as it moves downgradient towards Steel Creek from the source area. It is assumed that a total of four injections (every three years) will be needed over a 10-year period. In practice, performance monitoring would be required to monitor the effectiveness of the alternative and provide indication for the required frequency of continued injections. ISCO has the potential to dissolve naturally occurring metals in the sediments and there is uncertainty as to whether this technology would result in exceedance of MCLs in groundwater associated with repetitive injections. Therefore, a pH buffer is planned to prevent the release of naturally occurring metals, which could exceed MCLs for those metals. Also, with multiple injections and subsequent chemical oxidation, it is expected that there will be an increase in sulfate concentration in groundwater. Although this alternative rapidly destroys TCE in the treatment zone, it is not very effective in the short term in reducing TCE mass flux to Steel Creek, as the distance from the treatment zone to surface water is significant (about 457 m [1,500 ft]). Thus, this alternative would leave the remnant downgradient TCE plumes to continue to discharge to Steel Creek in exceedance of the MCL while the TCE plumes attenuate. Near-term effects in reducing TCE mass within the treatment zone in the neck of the plume provide for control of the source of this plume, which is key in curtailing the continued migration of TCE contaminated groundwater that discharges to Steel Creek.

Alternative 3B — ISCO in the Elbow Portion of the Distal Area of the TCE Plumes: This alternative would be a long-term action and would be effective in addressing the westward migrating plumes and mitigating impact to Steel Creek. In the elbow portion of the distal area of the plumes, injections are assumed to be required in two transects with ~132 injection wells. Five injection campaigns would be required every 2 years over a 10-year period to ensure the effectiveness of this alternative. In practice, performance monitoring would be required to monitor the effectiveness of the alternative and provide indication for the required frequency of continued injections. ISCO has the potential to dissolve naturally-occurring metals in the sediments and there is uncertainty as to whether this technology would result in discharge of those metals to Steel Creek above the Ambient Water Quality Criteria and MCLs as well as an increase in sulfate from chemical oxidation due to the proximity of the injection wells to Steel Creek. Although this alternative rapidly destroys TCE in the treatment zone, it is only somewhat effective in the short term in reducing TCE mass flux to Steel Creek, as the distance from the treatment zone to surface water (SC-03) is about 244 m (800 ft). A portion of the downgradient TCE plumes will continue to discharge to Steel Creek in exceedance of the MCL while the TCE plumes attenuate.

5.2 Identification of Applicable or Relevant and Appropriate Requirements (ARARs)

In accordance with 40 CFR § 300.415(j) of the NCP, on-site removal actions conducted under CERCLA of 1980, as amended, are required to attain ARARs to the extent practicable, considering the exigencies of the situation. In determining whether compliance with ARARs is practicable, the lead agency may consider appropriate factors, including 1) the urgency of the situation; and 2) the scope of the removal action. ARARs include only Federal and State environmental or facility siting laws/regulations; they do not include occupational safety or worker protection requirements. Compliance with Occupational Safety and Health Administration standards is required by 40 CFR § 300.150. For purposes of ease of identification, the USEPA has created three categories of ARARs: Chemical-, Location- and Action-Specific. Additionally, per 40 CFR § 300.405(g)(3), other advisories, criteria, or guidance may be considered in determining remedies [to-be-considered (TBC) category]. USDOE, the lead agency at the SRS, is expected to comply with ARARs and TBC guidance as set forth in the RSER/EE/CA, to the extent practicable, when conducting this non-time critical removal action. However, the selected removal action will be an interim measure with respect to federal groundwater ARARs (MCLs in groundwater). The attainment of the groundwater ARARs will be addressed as part of the remedial goals of the final remedial decision for the PAGW OU.

Applicable requirements, as defined in 40 CFR § 300.5, means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal environmental or State environmental or facility siting laws that specifically address a hazardous substance, pollutant, or contaminant, remedial action, location, or other circumstance at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable. Relevant and appropriate requirements, as defined in 40 CFR § 300.5, means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal environmental or State environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, or contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at a CERCLA site that their use is well suited to the particular site. Only those State standards that are identified by the State in a timely manner and that are more stringent than Federal requirements may be relevant and appropriate.

Under Section 121 of CERCLA, any material remaining on site must reach a level or standard of control equal to that of any other ARAR promulgated under any Federal or more stringent State environmental statute. The term "promulgated" means that the requirement generally is applicable and legally enforceable. The ARAR concept is pertinent only to onsite actions; offsite actions must comply with all applicable Federal and State requirements. A requirement under other environmental laws may be either "applicable" or "relevant and appropriate," but not both. The first step in identifying ARARs is to determine if a requirement is applicable.

This RSER/EE/CA identifies ARARs in Appendix A and does not propose to waive any ARARs. The final condition of the site after the removal action will leave some contaminants in the groundwater that are not being addressed by this removal action. The final disposition of all PAGW OU groundwater plumes will be addressed under a separate remedial action(s) as defined in the Record of Decision for the OU, which will likely include land use controls until MCLs in groundwater are met. Existing administrative controls will remain in place until the final disposition of the PAGW OU. Completion activities are identified in the Federal Facility Agreement (FFA), a legally binding and enforceable tri-party agreement between USDOE and the two regulatory agencies, USEPA and SCDHEC (FFA, 1993).

Consideration of NEPA Values

This RSER/EE/CA conforms to USDOE policy (i.e., DOE Order 451.1B, *National Environmental Policy Act Compliance Program* [NEPA]) to incorporate NEPA values in USDOE CERCLA documents. NEPA values include consideration of socioeconomic, demographic, environmental justice, archaeological, historical, cultural, natural resources, protected species, floodplains, wetlands, and cumulative impacts of the proposed removal action.

Any potential environmental releases resulting from implementation of the preferred alternative (such as a hydraulic fluid leak) would be minimal and limited to the vicinity of the project area in P Area. Work controls will be in place to contain any spills of chemicals used in the proposed action. Given the potential alternatives and distance to the SRS boundary, no impacts beyond the SRS boundary could occur, ensuring that there are no environmental justice concerns associated with the proposed removal action.

The PAGW OU is located near an established industrial landscape. The location of the proposed removal action for the TCE groundwater plumes discharging to Steel Creek within the PAGW OU is not within any jurisdictional waters of the United States (i.e., wetlands). The proposed removal action will not result in adverse impacts to the wetlands or floodplains. Implementation of the proposed removal action would have a negligible impact on SRS archaeological, cultural, historical, or natural resources.

Six plant and animal species on SRS are afforded protection by the Federal government under the Endangered Species Act of 1973. None of these species has been identified within the footprint of the proposed removal action; therefore, this action is not anticipated to adversely affect the protected species identified at SRS.

Implementation of this removal action would reduce TCE (as well as PCE and cis-1,2-DCE) mass in the groundwater at the application area. Therefore, the removal action would contribute cumulatively to reducing risk to site workers and the public. Additionally, the expenditure of funds for the proposed removal action would contribute cumulatively to an overall positive economic impact within the Site's region of influence. It would also represent progress toward the completion of the 515 waste units and 15 areas where environmental restoration work is required under the FFA at SRS.

In summary, the cumulative impacts associated with the proposed removal action would be so small that their potential contribution to an overall cumulative effect on- or offsite would be negligible.

5.3 Implementability

Implementability of each alternative was assessed against the criteria below:

- Technical feasibility with regard to available techniques and demonstrated methods for accomplishing the proposed alternative;
- Administrative feasibility with regard to operations personnel and other resources to complete the alternative's implementation; also, the availability of specific equipment and technical specialists;
- Regulatory acceptance of the preferred alternative; and

- Community acceptance of the preferred alternative. USDOE–Savannah River will provide for a public comment period, and comments concerning the proposed remedy will be considered and incorporated into the comment responses and included with the action memorandum as appropriate.

Alternative 1 — No Action, is the current condition and, therefore, would not require any additional resources to implement. The levels of TCE in the plumes discharging to Steel Creek at the PAGW exceed MCLs so the No Action alternative would not be acceptable to DOE-Savannah River, USEPA and SCDHEC.

Alternative 2 — Installation of a PRB, could be implemented without major technical or administrative concerns. Personnel are readily available and technologies for PRB are well defined. PRBs are widely used to intersect contaminated plumes at other waste units outside of SRS and this remedial method has wide acceptance from the regulatory community. Traditional methods of PRB installation including trenching and deep soil mixing may not be feasible for the depth of the wall needed to intersect the TCE plumes associated with PAGW. Another common method of installation, soil fracturing with zero-valent iron injection, may be the most effective for the site-specific conditions in P Area. An Underground Injection Control (UIC) Permit will be required for the installation of the PRB. The installation of the wall will be performed consistent with SRS safety and health procedures to ensure minimal impact to the remediation worker during implementation. Waste associated with the installation of the PRB will be limited. Any soil cuttings generated will be disposed of in accordance with the investigation-derived waste (IDW) guidance. Other waste material generated will be disposed of at the solid waste landfill on USDOE property; cost and transportation would not be a significant issue. PRB installation utilizes standard commercial equipment readily available to SRS.

Alternative 2A — PRB in the Neck Area of the TCE Plumes: Is most easily implemented in the neck portion because the area of application is flat, easily accessible by equipment, and requires little to no tree clearing/grubbing. Minimal land disturbance is expected. Conceptually, the PRB in the neck area of the plumes will include impermeable subsurface walls (funnel) to help direct the groundwater through the PRB (gate).

Installation of subsurface walls is common and is easily achievable to the required depths. The amount of soil cuttings and waste associated with the installation of the walls will be dependent on the installation technology selected. Disposal of waste associated with the installation of the funnel walls is not a significant issue.

Alternative 2B — PRB in the Elbow Portion of the Distal Area of the TCE Plumes: Is easily implemented from a technology standpoint, however some uncertainty remains with respect to implementability of the PRB at the Distal Area to ensure minimal by-pass flow conditions. In the elbow area of the plumes, this alternative includes a significantly longer wall through wooded terrain which will require substantial site preparation work. Clearing and grubbing of existing vegetation over an area of ~2.02 ha (5 ac) is anticipated to gain access for the PRB installation. A stormwater pollution prevention plan and grading permit would be required to establish the necessary controls associated with land disturbance, as this area is much closer to down slopes that lead to Steel Creek. Figure 22, an aerial view of the alternative implementation areas, illustrates the implementation issues regarding accessibility, clearing and grubbing requirements, and proximity to Steel Creek.

Alternative 3 — ISCO, could be implemented without major technical or administrative concerns. Personnel are readily available and technologies for chemical oxidation are well defined. Well drilling equipment and subcontractors are readily available and have extensive experience at SRS. A UIC permit will be required for the injection of sodium persulfate, pH buffer and activator (if needed). Waste generated from this technology is typical of well installation wastes including drilling cuttings and fluids. Waste disposal, in accordance with the IDW Plan, is not considered to be a significant issue. Well installation and the injection of materials uses standard drilling rigs and scientific equipment readily available at SRS. Drilling and land clearing activities would comply with regulations to prevent sediment discharges to surface water and runoff. The installation of injection wells and chemical injection will be performed consistent with SRS safety and health procedures to ensure minimal impact to the remediation workers during implementation.

Alternative 3A — ISCO in the Neck Area of the TCE Plumes: Is most easily implemented in the neck area because the area of application is flat, easily accessible by equipment, and requires little to no tree clearing/grubbing.

Alternative 3B — ISCO in the Elbow Portion of the Distal Area of the TCE Plumes: Is easily implemented from a technology standpoint. However, in the elbow portion of the distal area of the plumes, this alternative includes installation of significantly more wells through wooded terrain which will require significant site preparation work. Clearing and grubbing of existing vegetation over an area of ~2.02 ha (5 ac) is anticipated to gain access for the ISCO well installation and to establish an area of operation to support routine injections. A stormwater pollution prevention plan and grading permit would be required to establish the necessary controls associated with land disturbance, as this area is much closer to down slopes that lead to Steel Creek. Figure 22, an aerial view of the alternative implementation areas, illustrates the implementation issues regarding accessibility, clearing and grubbing requirements, and proximity to Steel Creek.

5.4 Cost

The cost is $0 for the No Action alternative. Two other alternatives evaluated, PRB and ISCO, each include two application areas, the neck area and the elbow portion of the distal area of the plumes. Each alternative in each area is estimated separately.

The lowest cost alternative (besides the No Action alternative) is PRB at the Neck Area of the TCE Plumes at ~$4.61M. This estimate includes capital costs for construction of a PRB with zero-valent iron in the permeable sediments (gate) along with two impermeable subsurface walls (funnels) intended to direct groundwater flow and mitigate bypass. Since the system is designed to operate passively, once installed, operation and maintenance (O&M) costs are associated only with monitoring and reporting. These O&M costs are included in the estimate. In comparison, the cost of implementing ISCO in the neck area is slightly higher, ~$4.92M. Also included in the capital costs for the ISCO action is the installation of 36 injection and 10 monitoring wells, along with design, testing and laboratory studies. The increased cost is largely due to the recurrent injections of chemicals every three years, resulting in higher O&M.

The estimated cost for installing a PRB in the elbow portion of the distal area of the plumes is $6.03M. The increase as compared to alternative 2A is related to the size of the wall needed. This estimate may be low if the results of the distal area characterization indicate that a larger PRB is needed.

The highest cost alternative evaluated is ISCO at the elbow portion of the distal area of the plumes, estimated to be ~$9.09M. Capital costs for this estimate include the clearing and grubbing for access to the area and construction costs associated with the installation of 132 injection wells and 18 monitoring wells. O&M costs are significant for this alternative because they include a total of five injections of chemicals over a 10-year period. Groundwater monitoring and reporting costs are also included in the O&M estimate. It should be noted that costs for both alternatives in the distal portion of the plumes could increase if characterization data indicate that the higher concentration portion of the plume extends farther downgradient. Additional characterization will be performed in the distal area of the plume in 2018. The cost for this additional characterization is not included in the estimate for Alternatives 2B or 3B.

Cost estimate details are provided in Appendix B and are summarized for direct and indirect capital costs as well as direct and indirect O&M costs. Capital costs include site preparation, materials, construction, drilling, and soil analyses, design, engineering, project management, health and safety, overhead and contingency. O&M costs include groundwater monitoring at frequencies ranging from monthly and semimonthly beginning in the first year after installation to biannually beginning in the third year. For Alternatives 3A and 3B, O&M costs also include additional injections of chemicals.

- Alternative 1, No Action, $0 estimated cost
- Alternative 2A, PRB in the Neck Area of the TCE Plumes, $4.61M estimated cost
- Alternative 2B, PRB in the Elbow Portion of the Distal Area of the TCE Plumes, $6.03M estimated cost

- Alternative 3A, ISCO in the Neck Area of the TCE Plumes, $4.92M Estimated
- Alternative 3B, ISCO in the Elbow Portion of the Distal Area of the TCE Plumes, $9.09M estimated cost

5.5 Comparison of Removal Action Alternatives

A comparative analysis of the alternatives is summarized in the table below. The effectiveness of Alternative 2A, PRB in the Neck Area of the TCE Plumes, was qualitatively given a score of medium-high because, while it will be very effective in reducing TCE mass in the groundwater, the removal action performed at this location will leave remnant plumes downgradient that will continue to discharge to Steel Creek until the untreated TCE contaminated groundwater attenuates. While the effectiveness of Alternative 2B was considered to be high, there is greater uncertainty associated with the conceptual design due to the lack of characterization data in this area. This uncertainty is not accounted for in the qualitative ranking of the alternatives. The ISCO alternatives (3A and 3B) were scored slightly lower for effectiveness than the PRB alternatives because of the potential to dissolve naturally occurring metals in the sediments, the potential to form increased sulfate concentrations as a by-product of chemical oxidation, and the need for multiple injections over the ten-year period. The frequency of injections may be higher if the treatment zone is re-contaminated more quickly than assumed. Both PRB and ISCO are relatively easy to install in the neck area of the plumes, because this area is well characterized and the TCE plumes narrow in a geologic feature that restricts flow through an area of high permeability sediments. The PRB was considered to be more favorable from an implementability standpoint, because once installed the O&M costs would likely be limited to monitoring and reporting, while the ISCO alternatives will require multiple injections over a period of several years. ISCO in the elbow portion of the distal area would require significant labor and time to both install and inject oxidant, as 132 injection wells are assumed in the conceptual design.

The following table summarizes the alternatives evaluated.

	Effectiveness	Implementability	Cost
Alternative 1 No Action	Low	High	$ 0
Alternative 2A PRB in the Neck Area of the TCE Plumes	Medium High	Medium-High	$ 4.61 M
Alternative 2B[1] PRB in the Elbow Portion of the Distal Area of the TCE Plumes	High	Medium	$ 6.03 M
Alternative 3A ISCO in the Neck Area of the TCE Plumes	Medium	Medium-High	$ 4.92 M
Alternative 3B[1] ISCO in the Elbow Portion of the Distal Area of the TCE Plumes	Medium-High	Low	$ 9.09 M

[1] Additional characterization scheduled for 2018 is not included in the estimate.

6.0 PREFERRED REMOVAL ACTION ALTERNATIVE

The preferred action is **Alternative 2A, PRB at the Neck Area of the TCE Plumes**. Installing a PRB in the well-defined narrow band of highly permeable sediments in the neck area of the TCE plumes will cut off the source area of the plumes and prevent their migration to the distal portion, reduce contaminant mass, and provide long term effectiveness by ultimately reducing the TCE mass flux to surface water above the MCL. This alternative will ultimately allow surface water concentrations in Steel Creek to achieve the MCL once the remnant plumes have attenuated. Characterization of this area is extensive and the subsurface geologic conditions and plume geometry in the neck area are favorable to this technology. This action could be easily implemented as the surface conditions are flat, clear of vegetation and accessible without clearing and grubbing. This alternative is preferred over Alternative 2B, PRB at the Elbow Portion of the Distal Area of the TCE Plumes, because it can be implemented quickly, at a lower cost, and provide a significant benefit by reducing TCE mass in the upgradient portions of the plumes.

The field application and effectiveness of the preferred action could be evaluated to consider applying this technology at a much larger scale at the elbow portion of the distal area of the plumes at a later time, subsequent to additional characterization of that area.

Alternative 2A, PRB at the Neck Area of the TCE Plumes is preferred over the ISCO technology because of its proven success at other waste sites outside of SRS and minimal O&M activities (sampling and reporting) and associated costs. In comparison, O&M for ISCO would be much higher as multiple injections with continued procurement of chemicals and injection equipment would be required. Additionally, with ISCO, there is the possibility for increased concentrations of naturally-occurring metals and sulfate that will affect groundwater quality and possibly impact surface water in Steel Creek.

Regulatory acceptance of this alternative is anticipated, as it will reduce TCE mass in groundwater and ultimately (long term) mitigate the discharge of TCE to surface water in Steel Creek. This technology has been employed at other commercial sites within South Carolina and has been considered by USDOE, USEPA and SCDHEC during two scoping summary meetings as a possible removal action alternative in addressing TCE mass in groundwater.

This alternative will not preclude any additional remediation of the PAGW OU and is consistent with the current and future land use.

7.0 IMPLEMENTATION SCHEDULE

This RSER/EE/CA will be submitted to USEPA and SCDHEC for review and comment. The RSER/EE/CA will be available for public comment following this review. The removal action schedule is presented below:

Submit Revision 0 RSER/EE/CA for Regulatory Comment	October 30, 2017
Issue RSER/EE/CA for Public Comment	April 10, 2018
Submit Final Action Memorandum and Responsiveness Summary to USEPA and SCDHEC	May 15, 2018
Submit Revision 0 Removal Action Design Plan	November 30, 2018
Submit Revision 0 Effectiveness Monitoring Plan	November 30, 2018
Removal action start of RSER/EE/CA activity	April 30, 2019
Anticipated construction completion of RSER/EE/CA activity	September 20, 2019
Submit Revision 0 Removal Action Report	January 10, 2020

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8.0 REFERENCES

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9.0 GLOSSARY

Applicable or Relevant and Appropriate Requirement (ARAR): The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) requires compliance with any promulgated standard requirements, criteria, or limitation under Federal and more stringent State environmental laws. Examples include the Clean Water Act, Endangered Species Act, etc.

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA): A Federal law, known as Superfund passed in 1980 and reauthorized by the Superfund Amendments and Reauthorization Act (SARA) in 1986. The law authorizes the Federal government to respond directly to releases of hazardous substances that may endanger public health or the environment.

National Oil and Hazardous Substances Pollution Contingency Plan (NCP): The federal government's blueprint for responding to both oil spills and hazardous substance releases. The NCP is the result of our country's efforts to develop a national response capability and promote overall coordination among the hierarchy of responders and contingency plans.

Non-Time Critical Removal Action: This is a type of response action recognized by the USEPA as appropriate for addressing hazardous substance threats where a planning horizon of six months or more is appropriate. Under an USEPA/USDOE agreement, USDOE uses a non-time critical removal action approach tailored for decommissioning USDOE facilities. That approach is comprised of: a threat assessment; identification, analysis, and documentation of decommissioning alternatives; opportunities for public participation in the decommissioning decision; and planning and performance of decommissioning activities.

Removal Action: When USDOE identifies a threat of exposure to, or migration of, hazardous substances that poses a risk to health, welfare, or the environment, USDOE is authorized by CERCLA to exercise removal action authority to implement an appropriate response to the risks posed. Activities that may be taken under CERCLA removal action authority include any activity that reduces risks or potential risks in a relatively short time frame and can be identified as appropriate with a relatively limited analysis of alternatives. Removal actions are not limited to immediate action, or action in response to an emergency. (See non-time critical removal action.)

Surveillance and Maintenance: These activities are conducted through-out the facility life cycle phase including when a facility is not operating and is not expected to operate again and continues until phased out during decommissioning. Activities include providing in a cost effective manner periodic inspections and maintenance of structures, systems and equipment necessary for the satisfactory containment of contamination and protection of workers, the public and the environment.

Operable Unit: A physical area consisting of structure or land areas of specified size and shape for which a separate decision will be made as to whether or not that area exceeds the release criterion. The size and shape of the operable unit are based on factors, such as the potential for contamination, the expected distribution of contamination, and any physical boundaries (e.g., buildings, fences, soil type, surface water body) at the site.

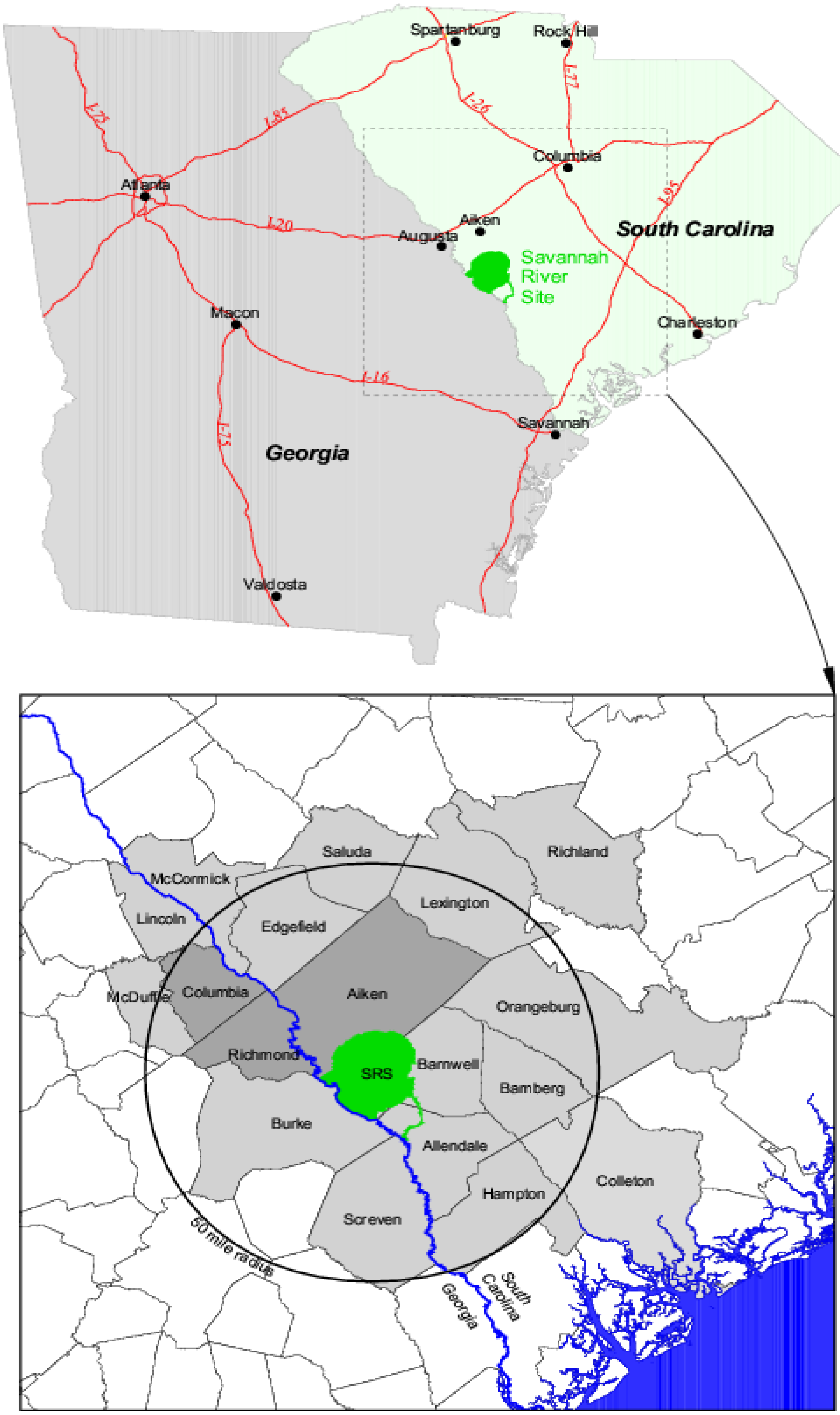

Figure 1. Geographic Proximity of the Savannah River Site

Figure 2. SRS Site Map Showing the Relative Location of P Area

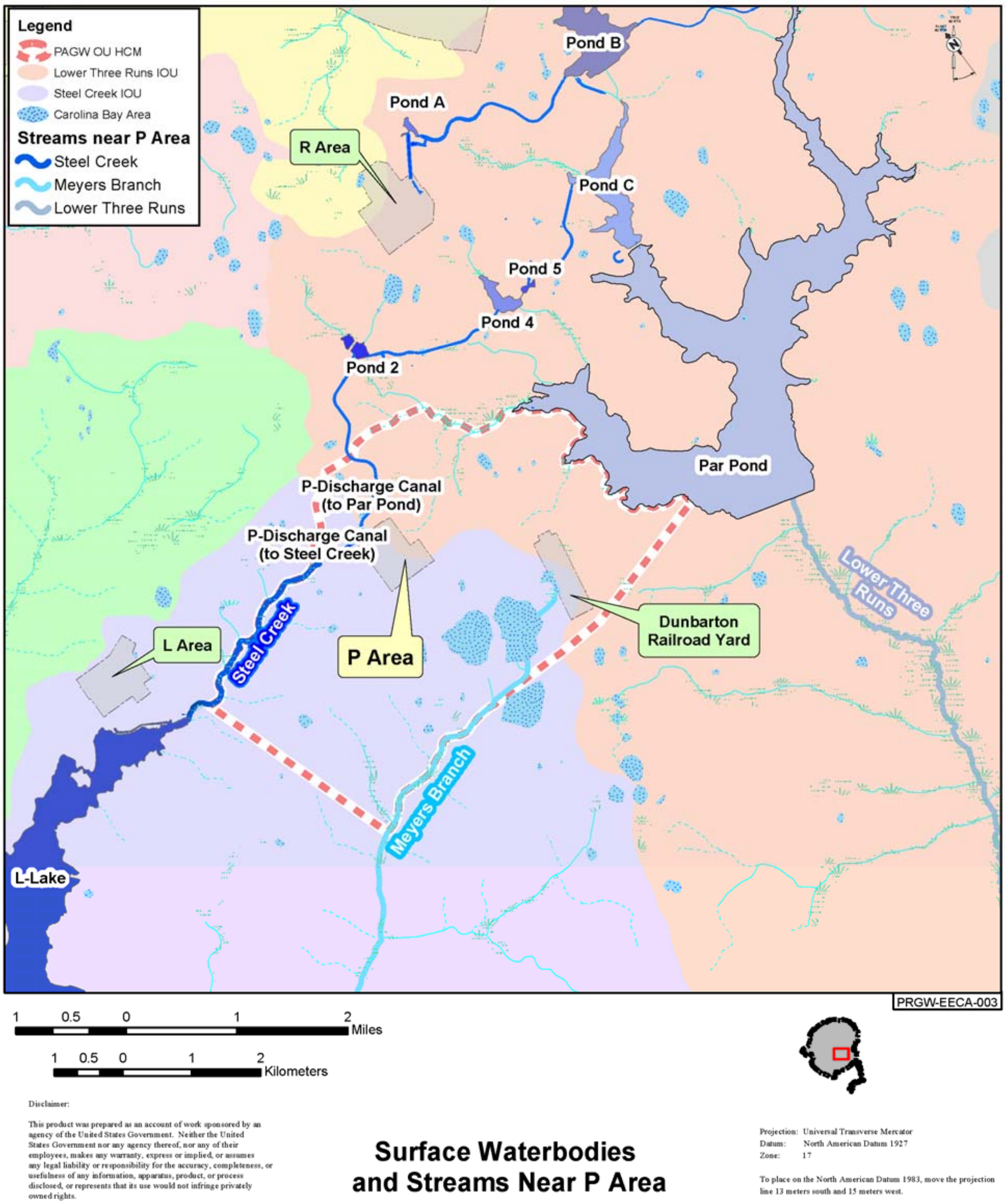

Figure 3. Boundaries of PAGW OU

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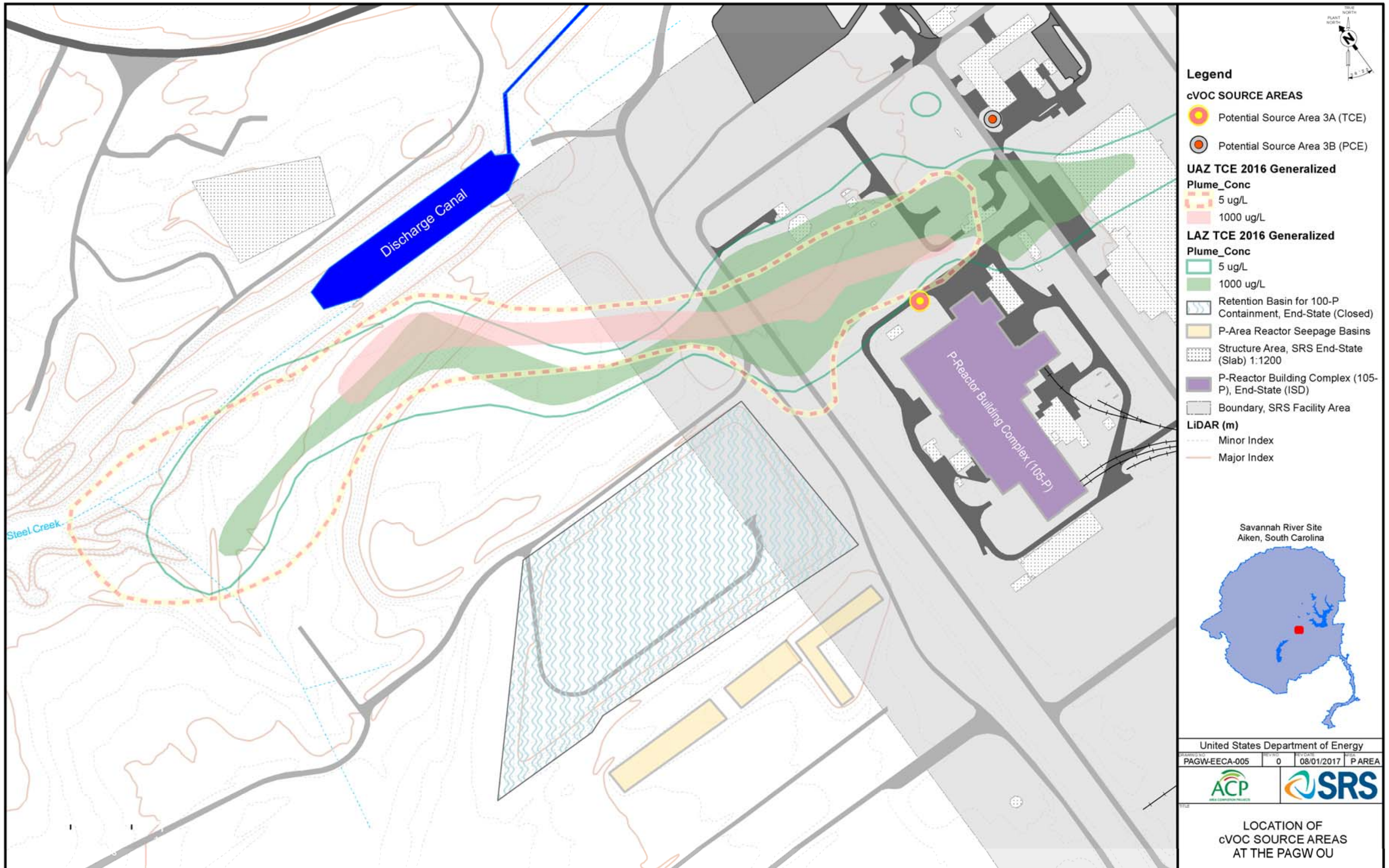

Figure 4. **TCE Plumes Discharging to Steel Creek in Relation to PAOU Surface Subunits (e.g., PSAs)**

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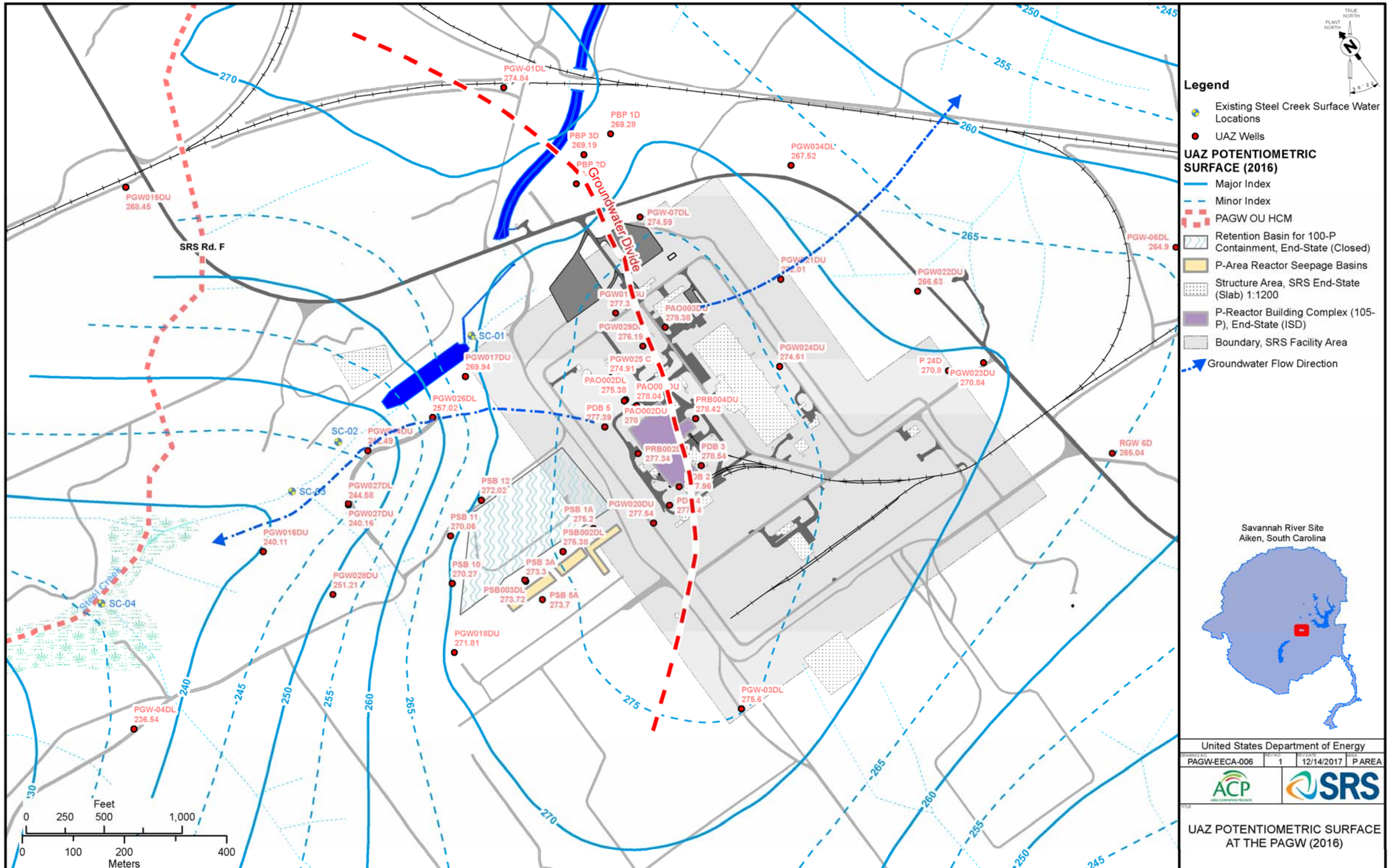

Figure 5. UAZ Potentiometric Surface at the PAGW OU

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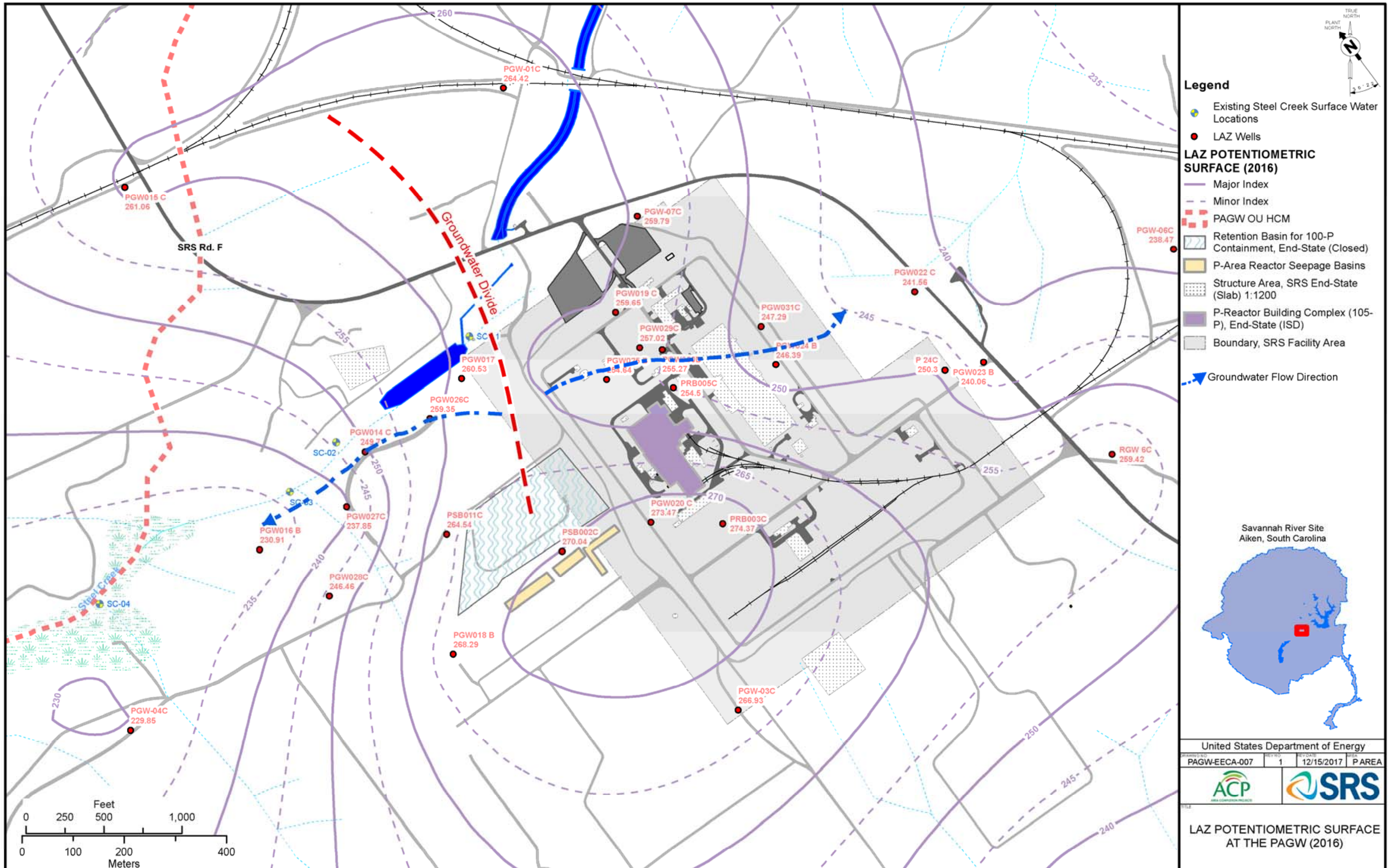

Figure 6. LAZ Potentiometric Surface at the PAGW OU

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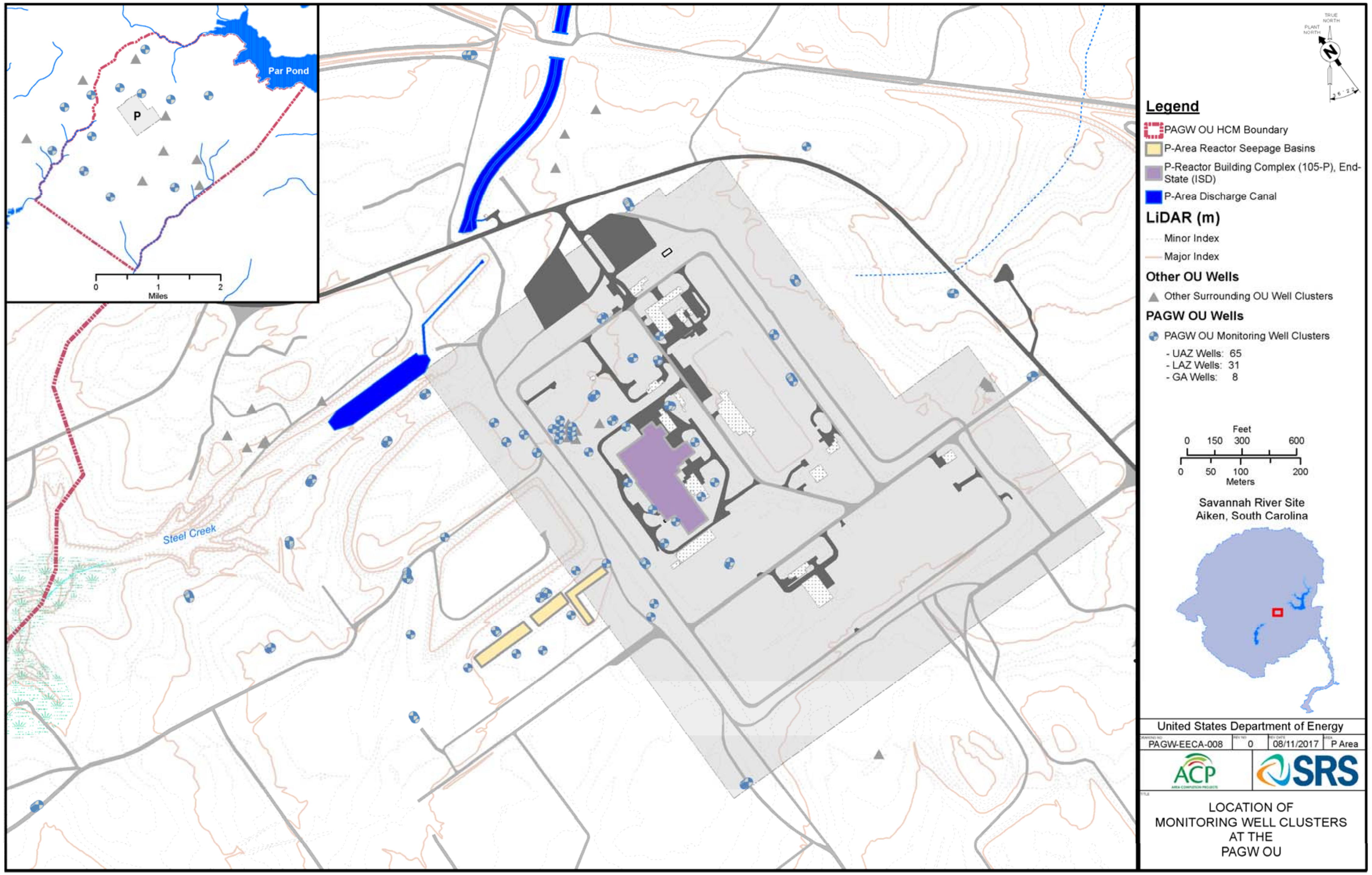

Figure 7. Monitoring Well Clusters at the PAGW OU

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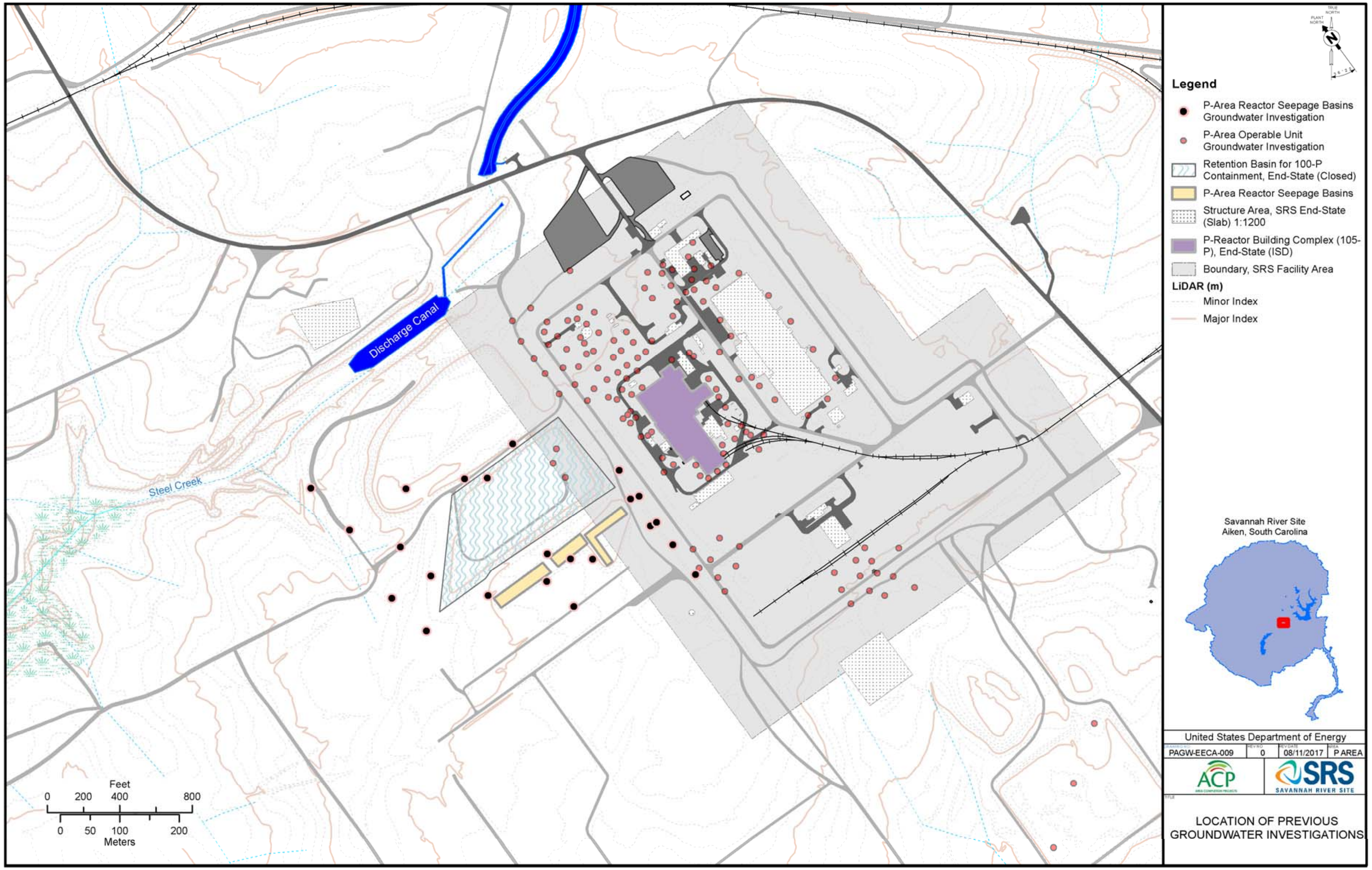

Figure 8. Groundwater Sampling Investigation Locations for Impacts from Surface Units

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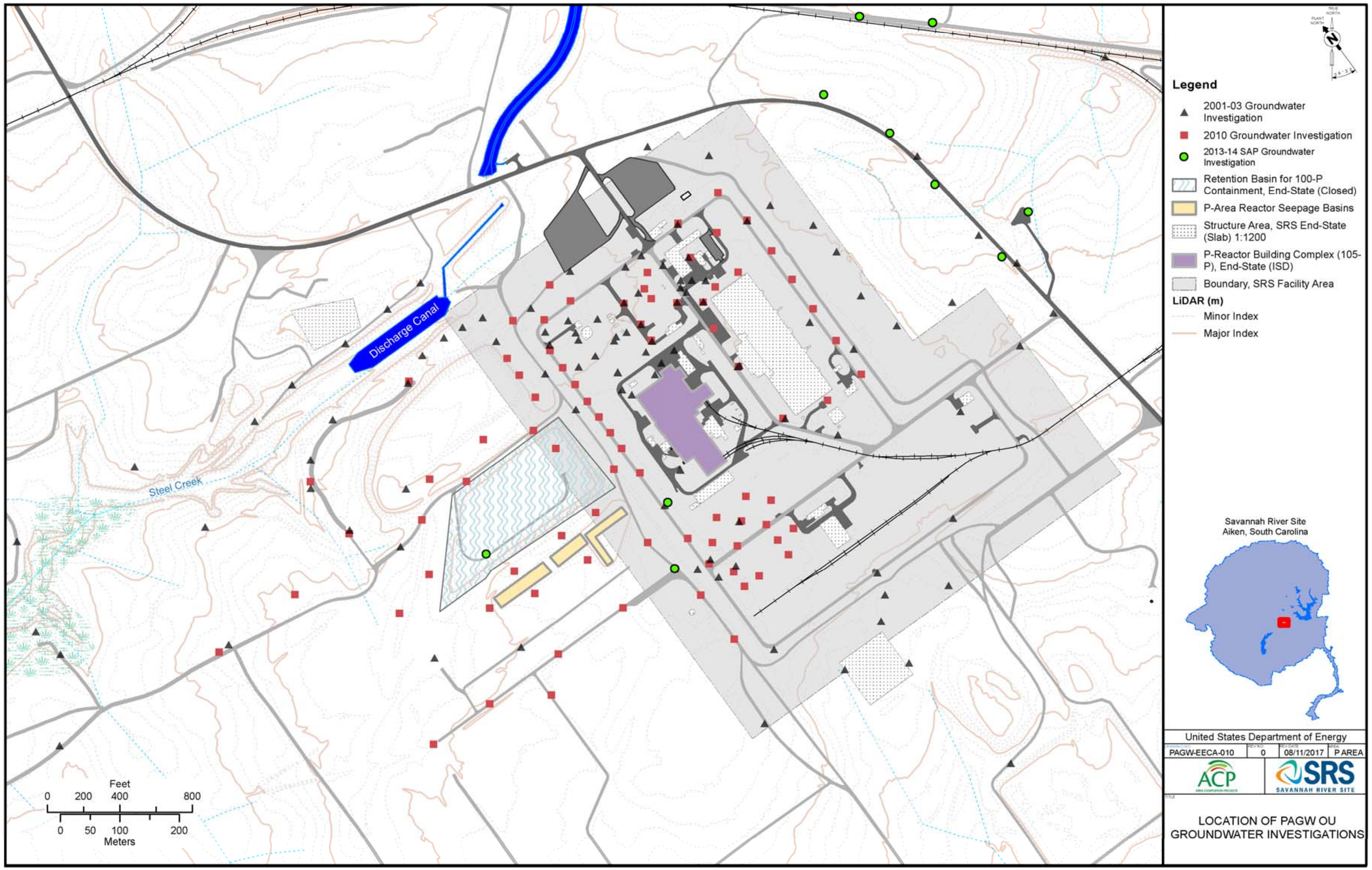

Figure 9. PAGW OU Investigation Locations

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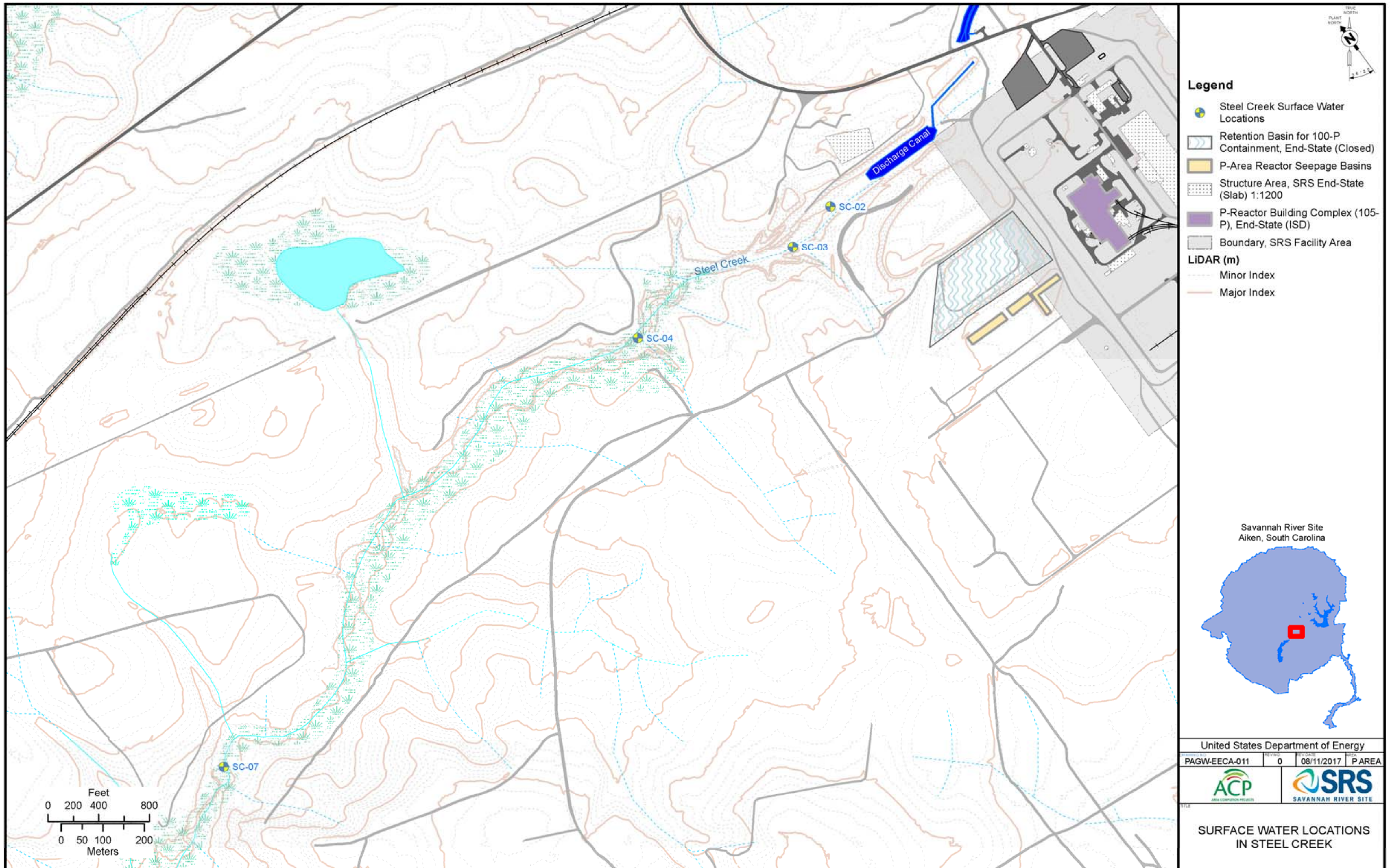

Figure 10. Surface Water Sampling Stations at Steel Creek

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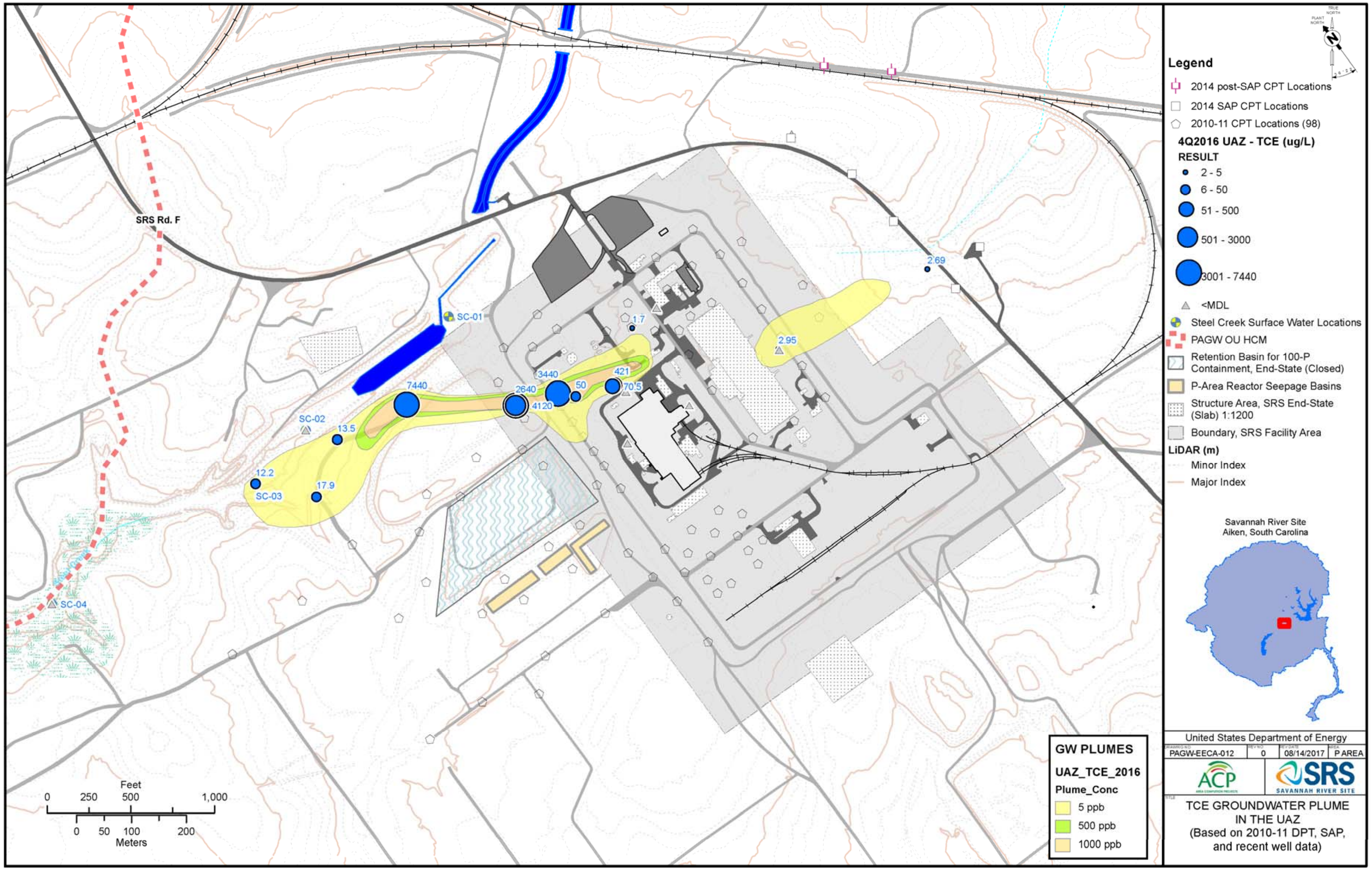

Figure 11. TCE Groundwater Plumes in the UAZ

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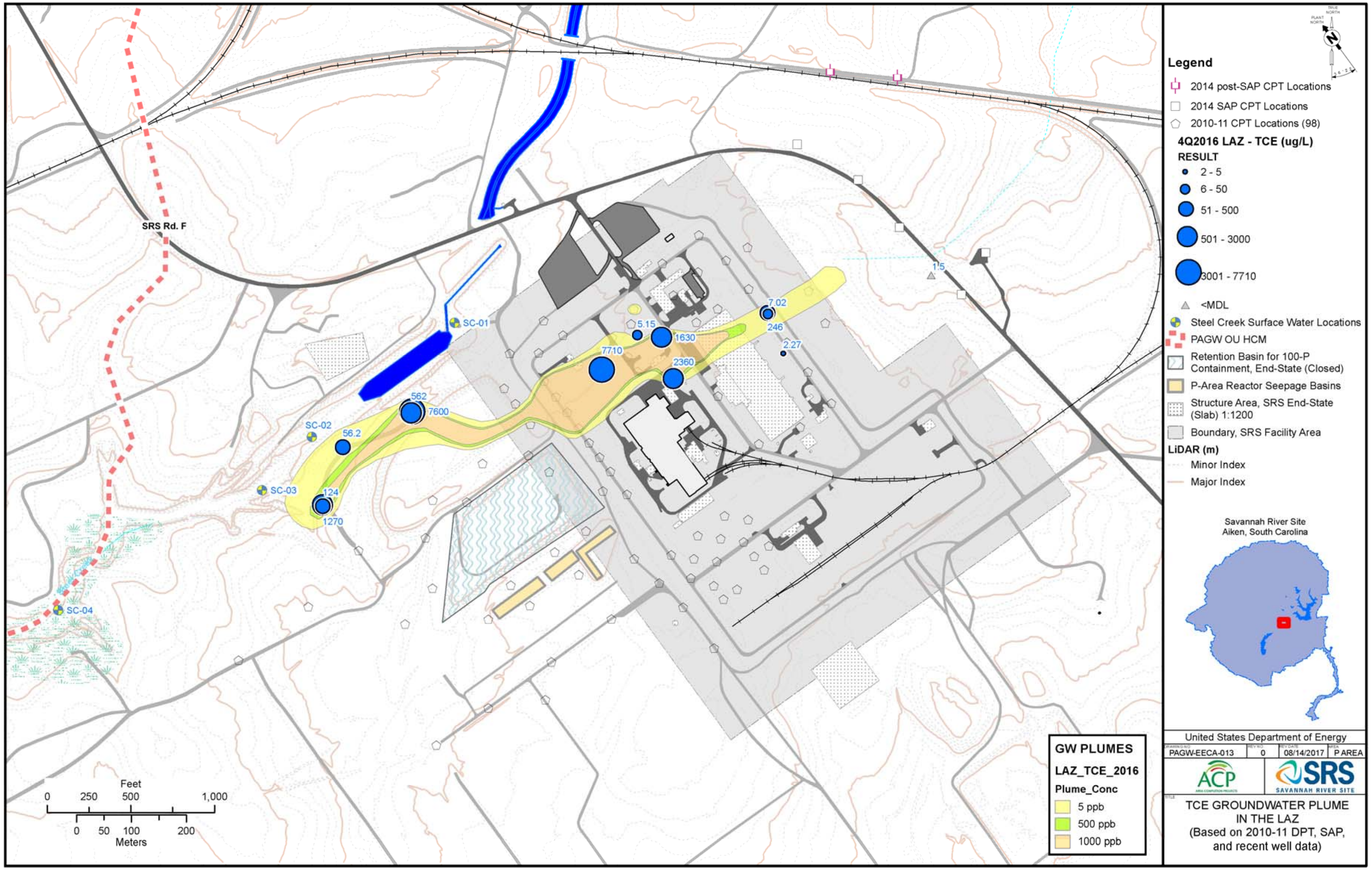

Figure 12. TCE Groundwater Plume in the LAZ

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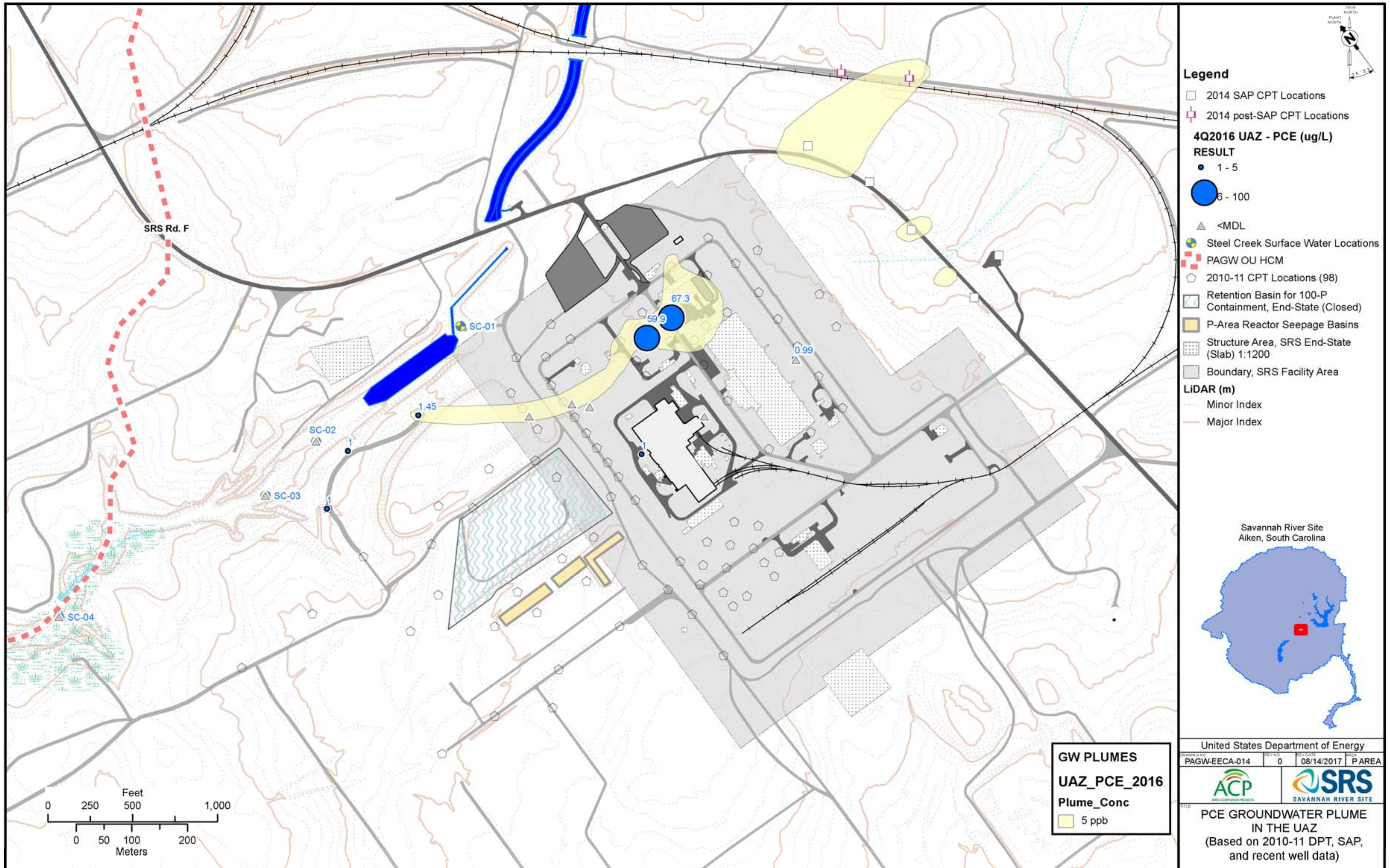

Figure 13. PCE Groundwater Plumes in the UAZ

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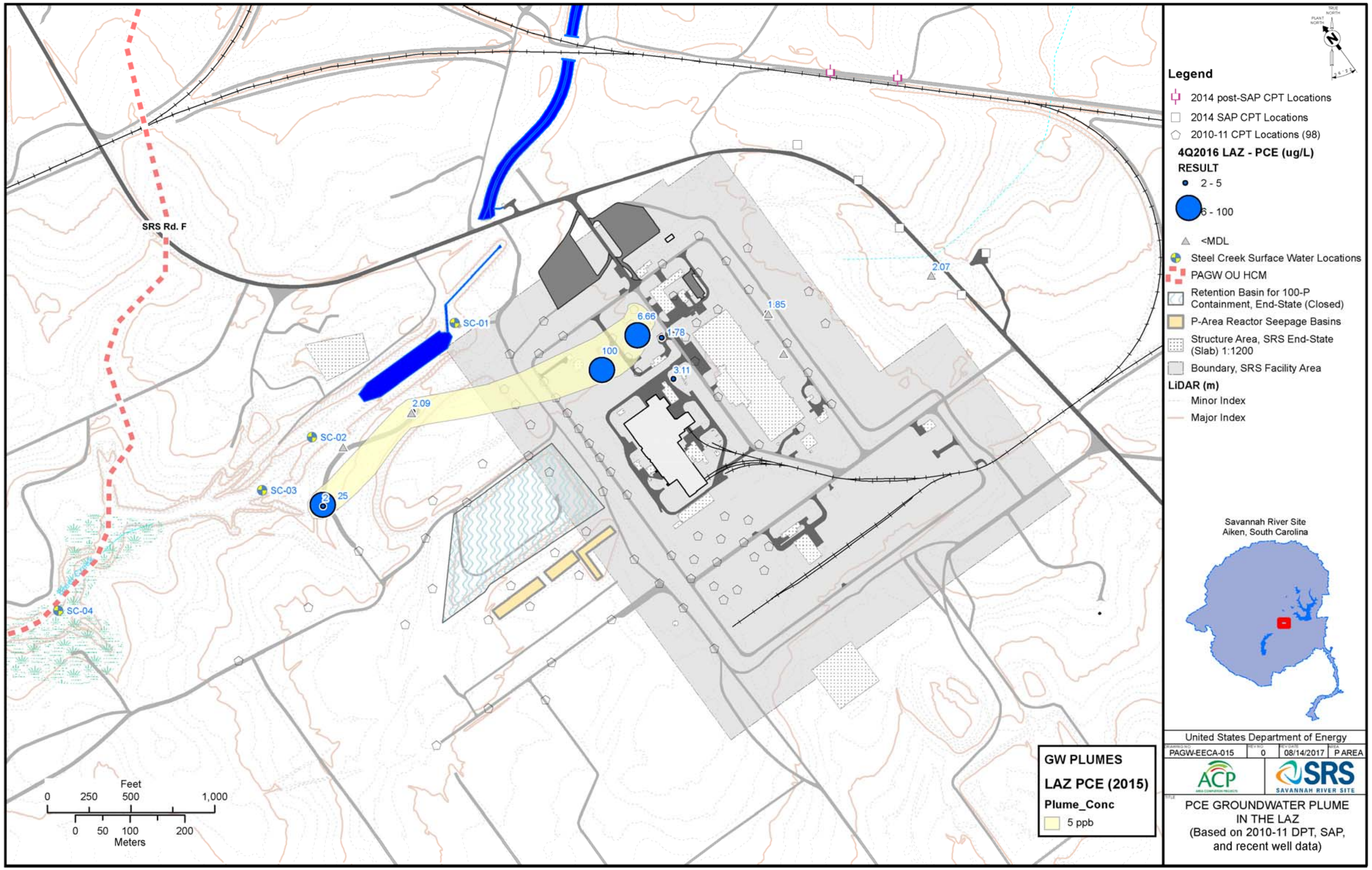

Figure 14. PCE Groundwater Plume in the LAZ

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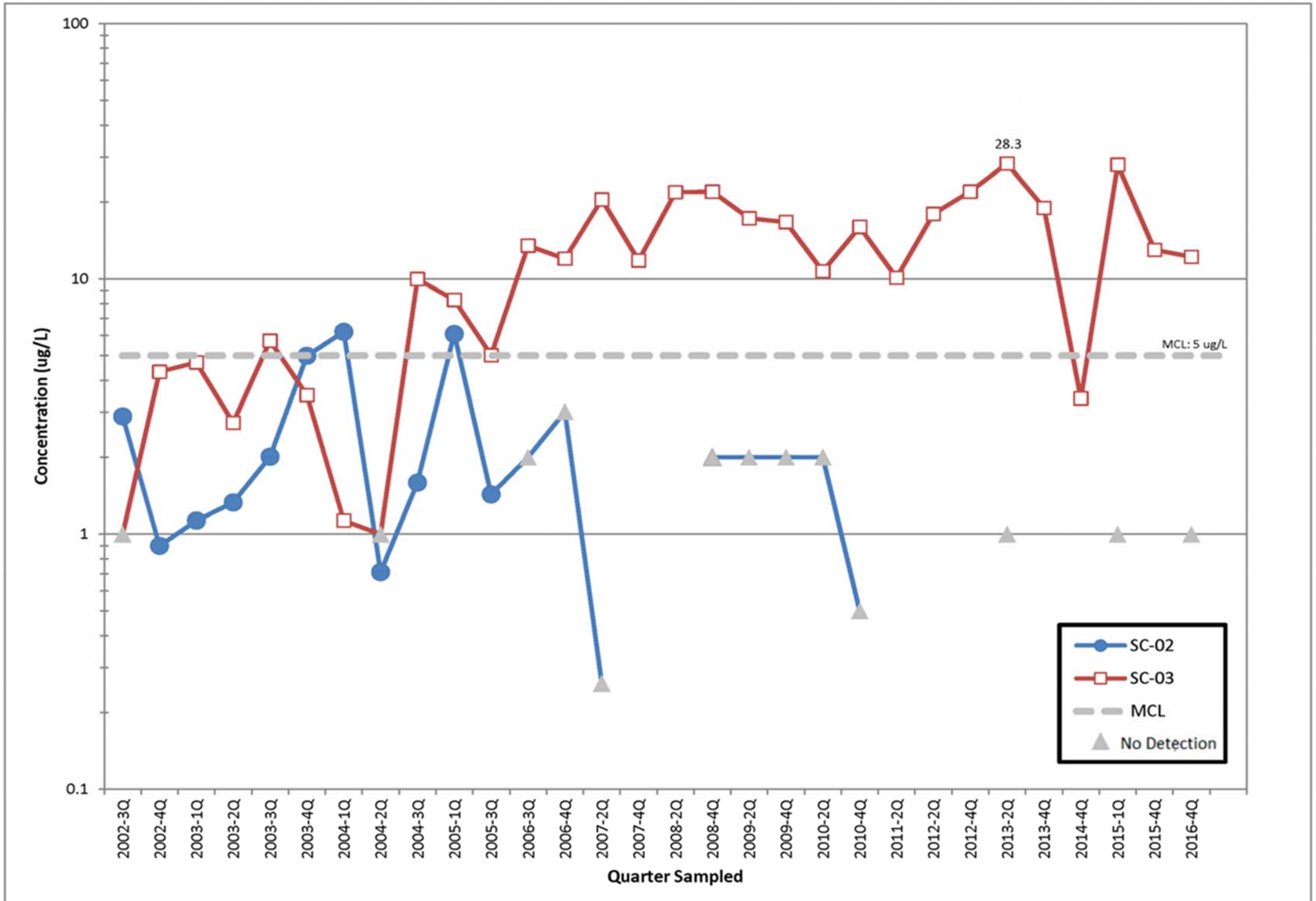

Figure 15. TCE Time-Trends at Steel Creek Surface Water Locations SC-02 and SC-03

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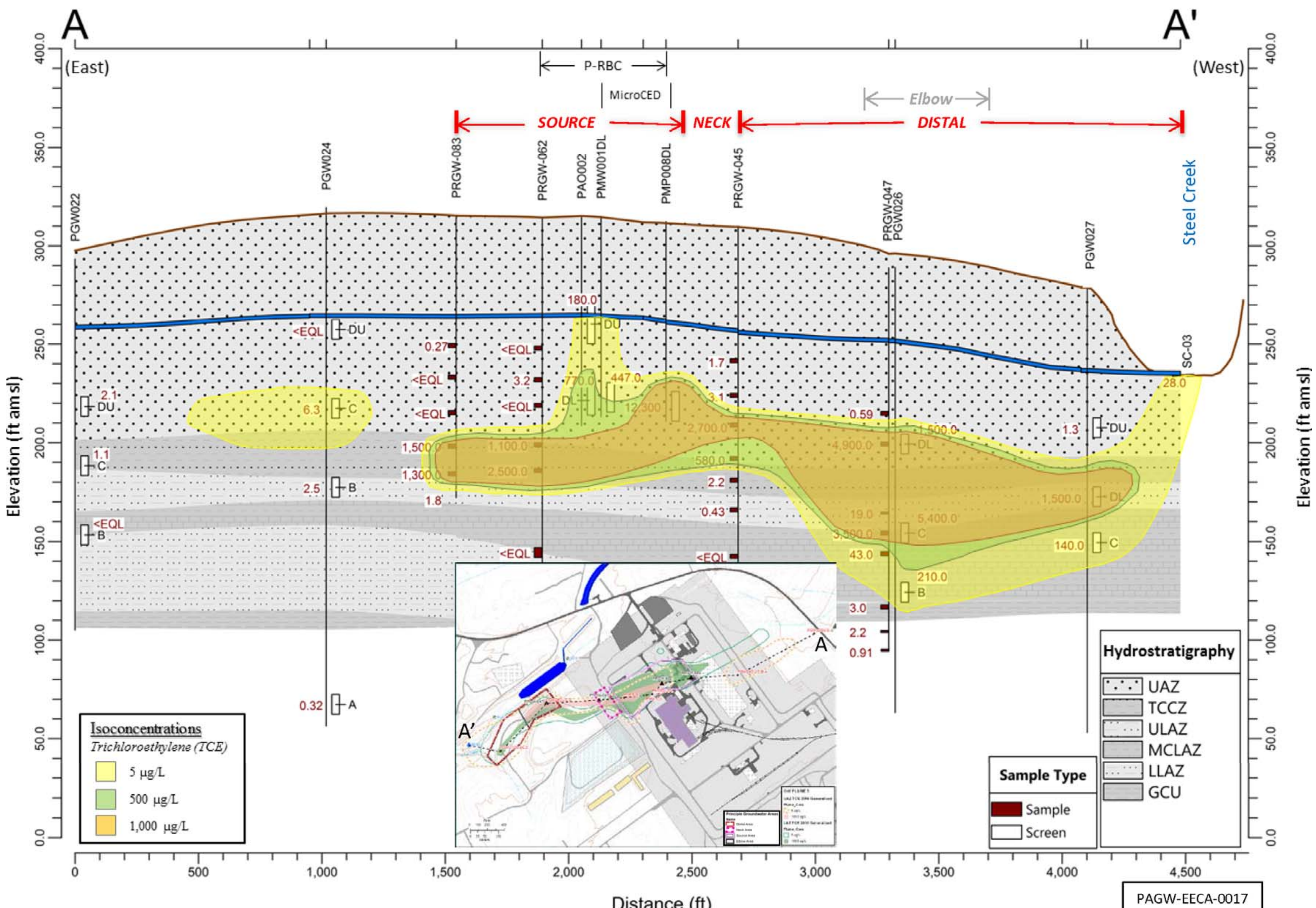

Figure 16. Cross Section A-A' of TCE Groundwater Plumes from East of P Area West towards Steel Creek

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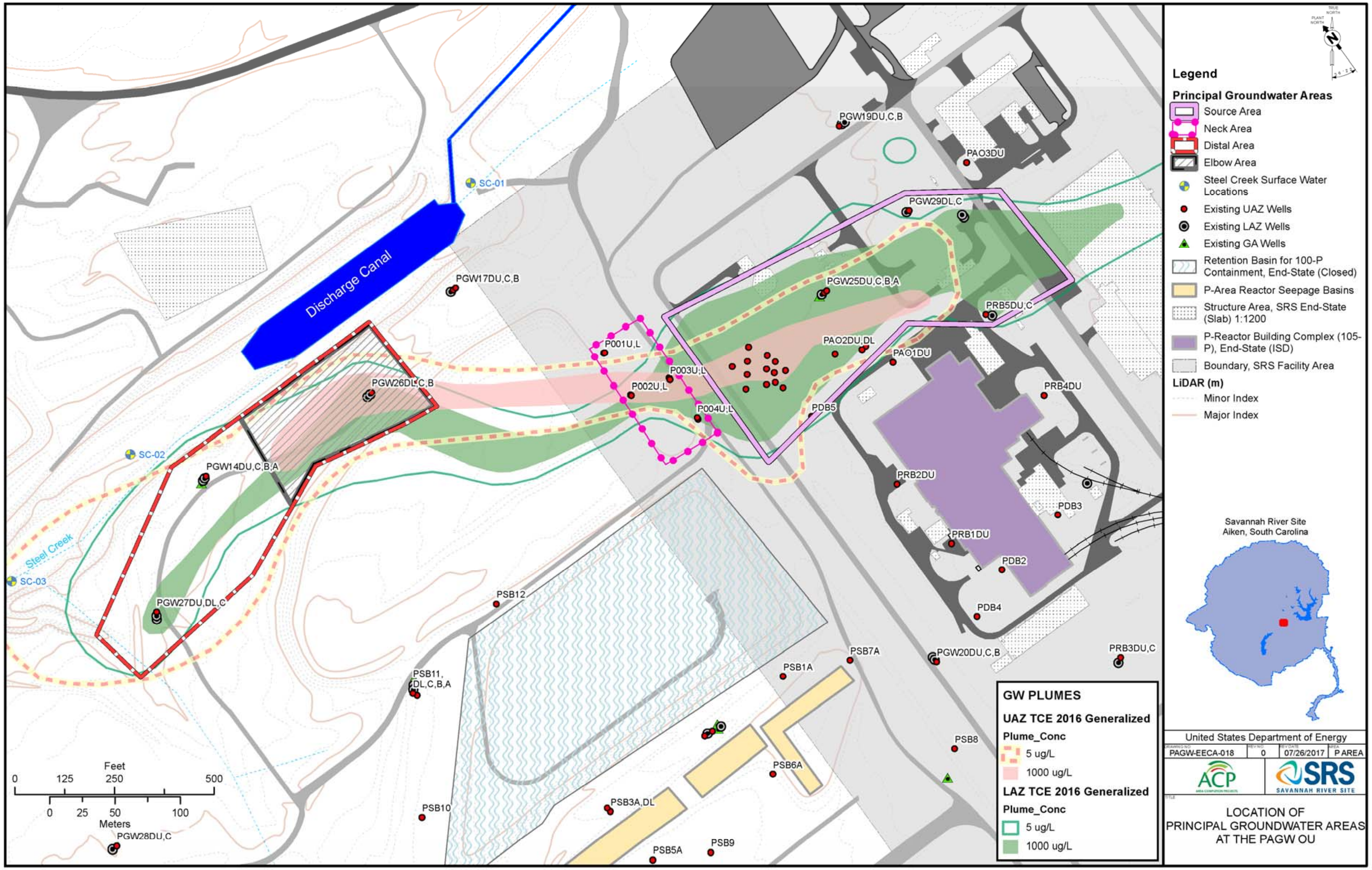

Figure 17. Principal Areas within the TCE Groundwater Plumes

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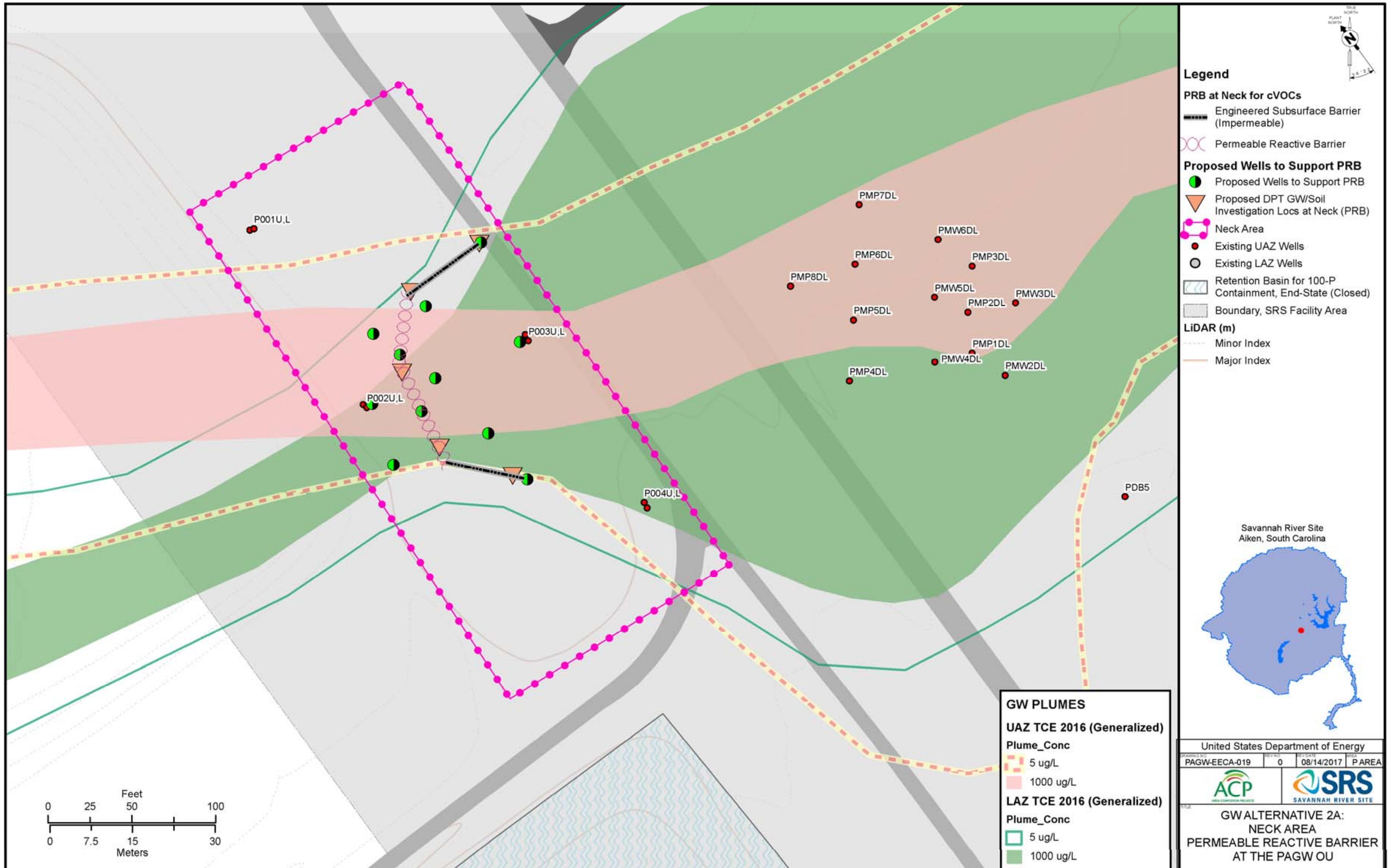

Figure 18. Alternative 2A: PRB in the Neck Area of the TCE Plumes

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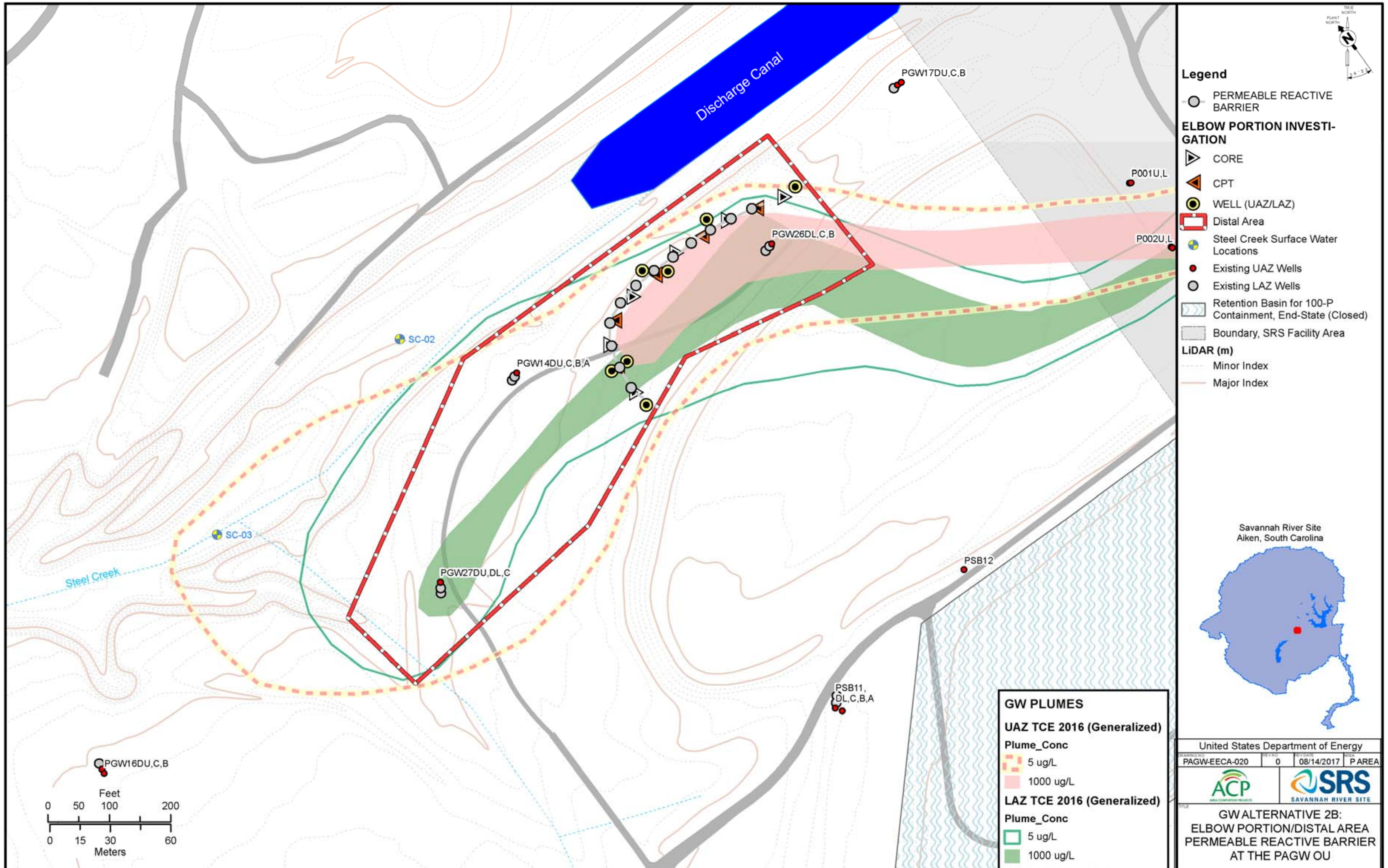

Figure 19. **Alternative 2B: PRB in the Elbow Portion of the Distal Area of the TCE Plumes**

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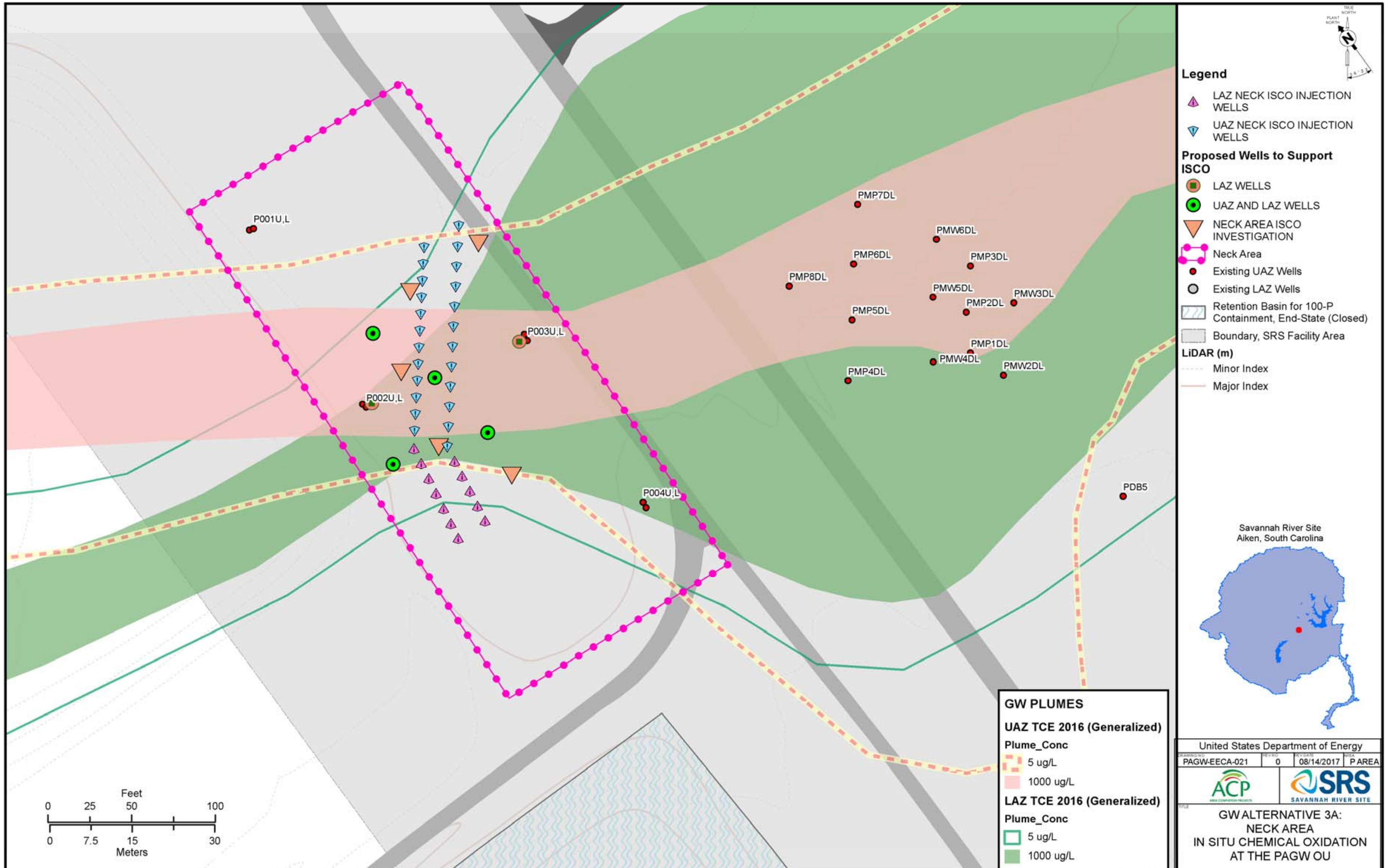

Figure 20. Alternative 3A: ISCO in the Neck Area of the TCE Plumes

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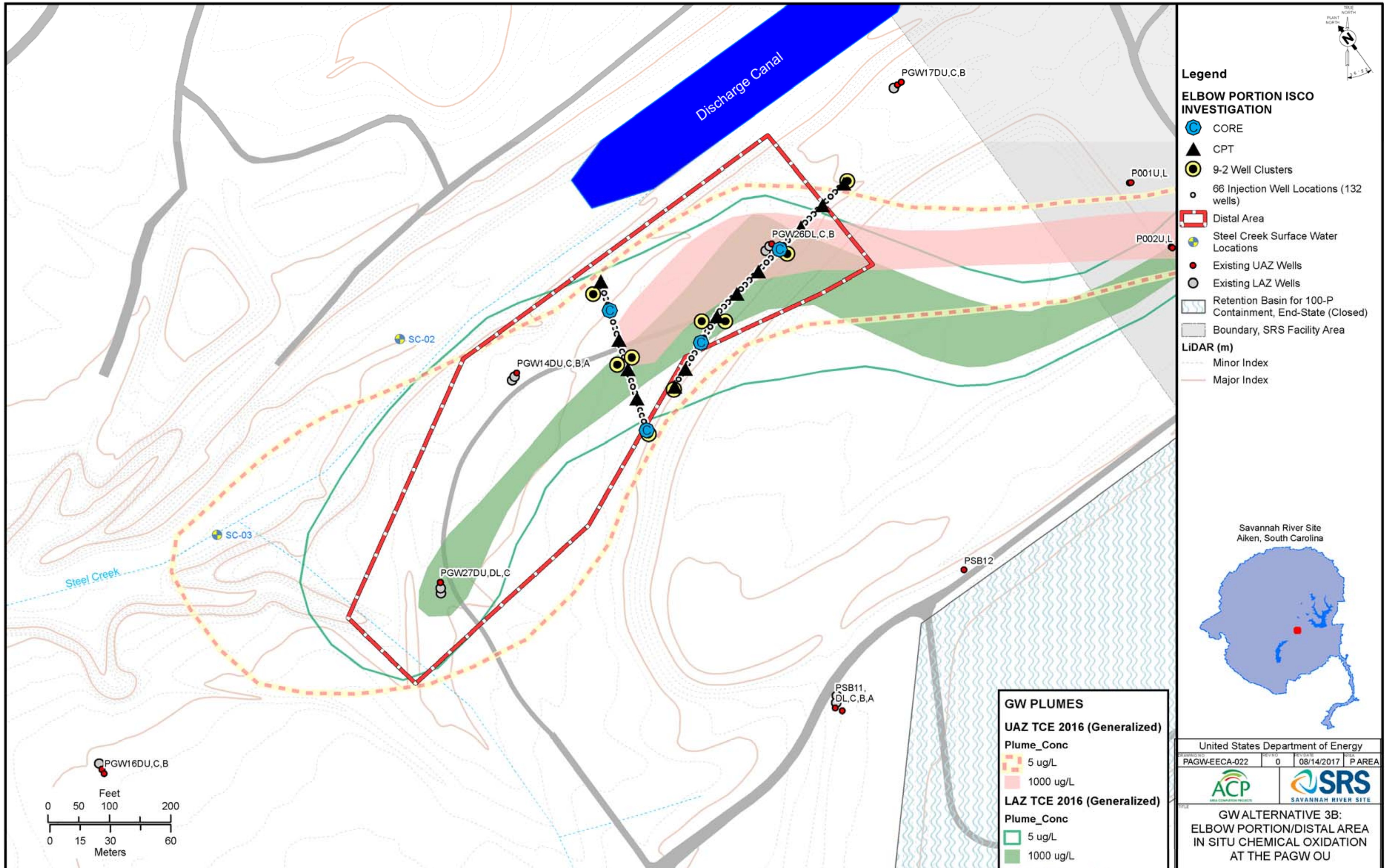

Figure 21. Alternative 3B: ISCO in the Elbow Portion of the Distal Area of the TCE Plumes

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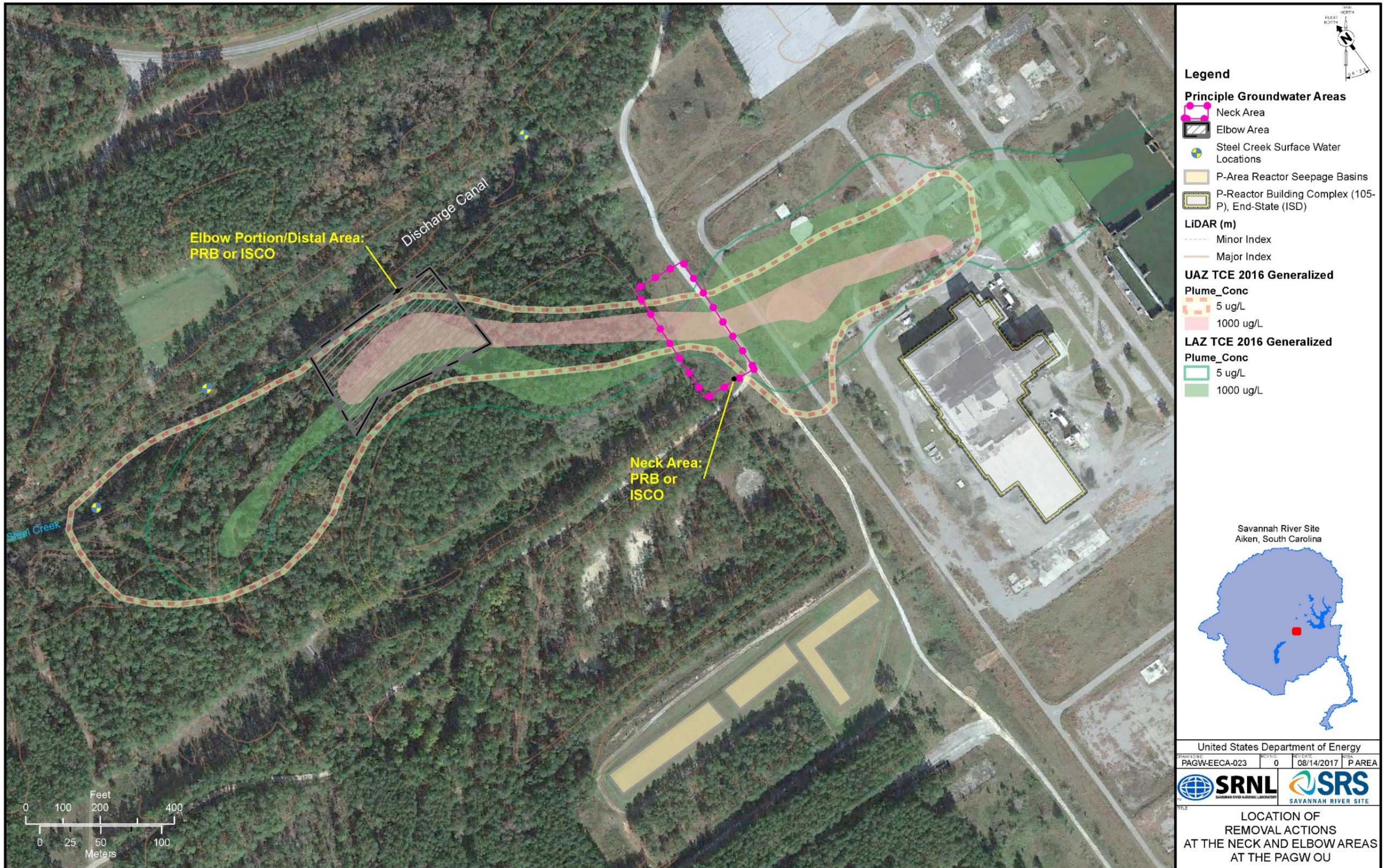

Figure 22. Aerial View of Alternative Areas to Illustrate Implementability Issues

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Table 1. Previous Actions for Surface Units that had the Potential to Impact Groundwater in the Future

Surface Unit Previous Actions	Remedy Implemented	Completion Date (Reference)
• PAOU (the following sub units are included in the PAOU)	Land Use Controls	2012 (2012a)
1. PSA-3A	SVE enhanced with soil fracturing and ISCO injection.	2011 (SRNS 2012b)
2. PSA-3B	SVE	2011 (SRNS 2012b)
3. P-Area Process Sewer Lines (PSLs) Combined Subunit	Isolation and plugging of PSLs, grouting of the associated underground structures, manholes, weirs, and boxes; select removal of process equipment external to the P-RBC; sealing/plugging of outfalls.	2010 (SRNS 2012a)
4. P-Reactor Building (105-P) Building Complex	In Situ Decommissioning	2011 (SRNS 2012a)
• P-Area Reactor Seepage Basins (PRSB)	In situ stabilization with a low-permeability soil cover system and Institutional Controls (Land Use Controls).	2005 (WSRC 2006)

Table 2. Previous Groundwater Investigations

Focus Area of Investigation	Time Frame	Summary
P-Reactor Seepage Basins (PRSB)	1998 & 2001	Groundwater impacted by the PRSBs is comingled with the larger P Area plumes and groundwater associated with this closed surface unit is included in the PAGW OU. The PRSB surface unit has been closed using In-Situ Stabilization. Details of the closure are provided in the PCR/Final Remediation Report for the PRSBs (WSRC 2006).
P-Area Burning Rubble Pit (PBRP) OU	1998 & 2001	Groundwater impacted from operations of the PBRP OU was determined to be localized to a small area north of Steel Creek and was not comingling with plumes originating in P Area. Therefore, groundwater impacted by former PBRP operations is not included in the PAGW OU.
PAGW OU	2001-2003	Groundwater sampling of existing wells, sampling by DPT, and installation of 36 new wells and 54 piezometers supplied data to support development of a fate and transport groundwater model. The characterization efforts revealed multiple contaminant plumes with multiple sources in the PAGW OU. Primary contaminants were determined to be tritium, TCE, and PCE. Potential sources of the TCE plumes were determined to originate north and east of P-Reactor (PSA-3A) and a potential source to the PCE plumes was determined to originate west of the Administrative/Maintenance Building (PSA-3B).
PAGW OU	2005-2006	The cVOC source areas, including PSAs 3A and 3B along with the PSLs were investigated to define extent of contamination.
PAGW OU	2010	A comprehensive groundwater investigation of the PAGW OU was conducted via DPT (Cone Penetrometer Testing) and IsoFlow^{TM}). Subsequent to this investigation, 21 new monitoring wells were installed in 2011 to provide groundwater monitoring at locations where deeper aquifer monitoring was needed. Outcome resulted in a comprehensive extent of groundwater impact at PAGW OU. Previously unknown, tritium contamination was determined to be localized and present in the GA at the PRSBs.
PAGW OU	2014	Focused groundwater characterization based on details described in PAGW OU SAP. Work entailed investigation to extent of localized tritium contamination at the PRSBs in the GA, extent of cVOC groundwater plumes to the east of P-RBC, and installation of seven new wells. Localized GA tritium contamination at the PRSBs was confirmed to be present in only one well. PCE groundwater contamination determined east of SRS Rd. F not associated with other PCE plumes in P Area.
PAGW OU	2015	Additional work was performed to delineate extent of newly identified PCE plumes to the east of P Area. One new well was installed to provide long-term monitoring.

Table 3. Maximum cVOC Concentrations at the Three Areas

		Maximum Concentration (µg/L) in UAZ			Maximum Concentration (µg/L) in LAZ		
Contaminant	**MCL**	**Source Area**	**Neck Area**	**Distal Area**	**Source Area**	**Neck Area***	**Distal Area**
TCE	5	3,140	4,120	7,440	7,710	1,500	7,600
PCE	5	260	50	25	100	<MDL	2.09
Cis-1,2-DCE	70	4,720	107	432	104	400	200

Based on 4Q2016 unless otherwise noted
MDL – minimum detection limit
*Based on 2011 DPT data since there are no LAZ wells in this area

APPENDIX A

Potential ARARs and TBC Criteria for the TCE Plumes Discharging to Steel Creek in PAGW OU

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Action	Requirements*	Prerequisite	Citation	Alt 2A	Alt 2B	Alt 3A	Alt 3B
Action Specific ARARs							
Underground Injection Well Installation, Operation, and Abandonment							
Monitoring of Class V underground injection wells	Monitoring requirements shall, at a minimum, specify: Monitoring of the nature of injected fluids with metering and daily recording of injected and produced fluid volumes as appropriate; Monitoring of injection pressure and either flow rate or volume semimonthly, or metering and daily recording of injected and produce fluid, volumes as appropriate; Demonstration of mechanical integrity at least once every five years during the life of the well; Monitoring of the fluid level in the injection zone semimonthly, where appropriate and monitoring of the parameters chosen to measure water quality in the monitoring wells semimonthly	Monitoring into the injection zone of ground waters of the State of South Carolina - **applicable**	SCDHEC R.61-87.14(G)(3)	✓	✓	✓	✓
Operation and maintenance of Class V underground injection wells	Shall at all times properly operate and maintain all facilities and systems of treatment and controls which are installed or used.	Operation of well for underground injection of any fluids into the subsurface or ground waters of the State of South Carolina – **applicable**	SCDHEC R.61-87.13(X)	✓	✓	✓	✓
	Shall report malfunction of injection system which may cause fluid migration into or between underground sources of drinking water; shall immediately stop injection upon determination that the injection system has malfunctioned and could cause fluid migration into or between underground sources of drinking water; shall not restart the injection system until the malfunction has been corrected.		SCDHEC R.61-87.13(EE)	✓	✓	✓	✓
Closure of Class V underground injections wells	Wells must be closed in a manner that complies with the prohibition of fluid movement in 40 CFR 144.82(a)(l). Also, any soil, gravel, sludge, liquids, or other materials removed from or adjacent to the well must be disposed or otherwise managed in accordance with substantive applicable Federal, State, and local regulations and requirements.	Closure of Class V wells [as defined in 40 CFR 144.6(e)] – **applicable**	40 CFR 144.82(b)	✓	✓	✓	✓

\

Action	Requirements*	Prerequisite	Citation	Alt 2A	Alt 2B	Alt 3A	Alt 3B
***Action Specific ARAR** (cont'd)*							
Monitoring Well Installation, Operation, and Abandonment							
Installation or Abandonment of Permanent and Temporary Monitoring Wells	All monitoring wells shall be drilled, constructed, maintained, operated, and/or abandoned to ensure that underground sources of drinking water are not contaminated. Abandonment of permanent conventionally installed monitoring wells 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 with neat cement, bentonite-cement, or 20% high solids sodium bentonite grout, from the bottom of the well to the land surface.	Construction of permanent and temporary monitoring wells (including non-standard installation, as defined in R.61-71B (2)) – Removal and abandonment of wells - **applicable**	SC R.61-71H.1(b) SC R.61-71H.2(e)	✓	✓	✓	✓
Transportation of Samples (i.e., Solid Waste, Soils and Wastewaters)	Samples are not subject to any requirements of 40 CFR Parts 261 through 268 or 270 when: • The sample is being transported to a laboratory for the purpose of testing; or • The sample is being transported back to the sample collector after testing. In order to qualify for the exemption in paragraphs (d)(1)(i) and (ii), a sample collector shipping samples to a laboratory must: • Comply with U.S. DOT, U.S. Postal Service, or any other applicable shipping requirements • Assure that the information provided in (1) thru (5) of this section accompanies the sample. • Package the sample so that it does not leak, spill, or vaporize from its packaging.	Water samples for purpose of conducting testing to determine its characteristics or composition will occur as part of the groundwater monitoring program - **applicable**	40 CFR 261.4(d)(1)(i)-(iii) SC R.61-79 261.4*(d)* (1) 40 CFR 261.4(d)(2)(i) 40 CFR 261.4(d)(2)(i)(A) and (B) SC R.61-79 261.4*(d)* (2)(i)(A) and (B)	✓	✓	✓	✓

Action	Requirements*	Prerequisite	Citation	Alt 2A	Alt 2B	Alt 3A	Alt 3B
***Action Specific ARAR** (cont'd)*							
General Construction Standards — All Land-disturbing Activities (i.e., excavation, clearing, grading, etc.							
Managing storm water run-off from land-disturbing activities	Must comply with the substantive requirements for stormwater management and sediment control of *NPDES General Permit No. SCR100000.*	Large and small construction activities (as defined in R.61-9) of more than 1 acre of land – **applicable**	SC R.61-9.122.26(c) NPDES General Permit No. SCR100000	✓	✓	✓	✓
	The stormwater management and sediment control plan shall contain at a minimum the information provided in the following subsections: Alternative 2B and 3B occur at the elbow area of the TCE Plumes and the land disturbance is estimated to be between 2 and 5 acres. Alternative 2A and 2B are at the neck area and the land disturbance will be less than 1 Acre)	Activities involving more than two (2) acres and less than five (5) acres of actual land disturbance which are not part of a larger common plan of development or sale – **applicable**	SC R.72-307 I. – South Carolina Storm Water Management and Sediment Reduction Regulations		✓		✓
	A plan for temporary and permanent vegetative and structural erosion and sediment control measures which specify the erosion and sediment control measures to be used during all phases of the land disturbing activity and a description of their proposed operation.		SC R.72-307 I.(3)(d)	✓	✓	✓	✓
Chemical Specific ARAR							
Organic contaminants in the groundwater	MCLs established the highest level of a contaminant that is allowed in drinking water. • Tetrachloroethylene (PCE) = 0.005 mg/L (5 µg/L) • Trichloroethylene (TCE) = 0.005 mg/L (5 µg/L) • Cis-1,2-dichlroethylene = 70 µg/L	The state of South Carolina classifies all groundwater as potential sources of drinking water and mandates that groundwater meet MCLs established by the SDWA– **applicable**	40 CFR 141.61 MCLs for organic contaminants SC R.61.58, Section 5 (N) MCLs for Volatile Synthetic Organics	✓	✓	✓	✓

Action	Requirements*	Prerequisite	Citation	Alt 2A	Alt 2B	Alt 3A	Alt 3B
***Chemical Specific ARAR** (cont'd)*							
Groundwater seep into Water of the State	Establishes South Carolina official classified water uses for all waters of the State, general rules and specific numeric and narrative criteria for protecting classified and existing water uses • Tetrachloroethylene (PCE) = 0.005 mg/L (5 µg/L) • Trichloroethylene (TCE) = 0.005 mg/L (5 µg/L) • Cis-1,2-dichlroethylene = 70 µg/L	This regulation classifies all surface water and groundwater in the state for protecting classified water uses. - **applicable**	SC R. 61-68 Water Classification and Standards SC R. 61-68 Section G.10.c Appendix	✓	✓	✓	✓
	Priority Pollutants 1-13 (SC R. 61-68 Section G.10.c Appendix) **NOTE** – These priority pollutants are the list of metals that could leach to the surface stream from the groundwater plumes as a result of lowering the pH in the groundwater plumes due to ISCO injections.	Same as above - **applicable**	Same as above			✓	✓
Location Specific ARAR							
Discharge of groundwater during well drilling operations	Discharges to the ground must not impact or reach waters of the state.	Discharges of water to the ground that will not reach surface waters – **TBC**	SRS No Discharge Permit #ND0072125	✓	✓	✓	✓
Protection of Migratory Birds	No person may take, possess, import, export, transport, sell, purchaser, barter or offer for sale, purchase or barter, any migratory bird, or the parts, nests, or eggs of such bird except as under the terms of a valid permit.	Migratory bird populations may be present in the vicinity – **applicable**	16 *USC* 703-704 – Migratory Bird Treaty Act	✓	✓	✓	✓

*Note: The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) requires compliance with ARARs during removal and remedial actions to the extent practicable.

Alt = Alternative
ARAR = applicable or relevant and appropriate requirement
CFR = *Code of Federal Regulations*
DOT = U.S. Department of Transportation
EPA = U.S. Environmental Protection Agency
SCDHEC = South Carolina Department of Health and Environmental Control
SDWA = Safe Drinking Water Act

APPENDIX B

Detailed Cost Estimates

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Alternative 2A — PRB at the Neck Area of the TCE Plumes

Item	Quantity	Units	Unit Cost	Total Cost
Direct Capital Costs				
Site Preparation				
Grading, pad construction	1	ea	$64,000	$64,000
PRB Construction				
Design	1	ea	$100,000	$100,000
Construction of Fe Wall	1	lump sum	$671,935	$671,935
Construction of Impermeable Walls	1	lump sum	$140,078	$140,078
Site Restoration	1	ea	$25,000	$25,000
Drilling				
Drilling - Groundwater Wells	16	ea	$12,226	$195,618
Drilling - Coring	5	ea	$9,164	$45,820
Soil Testing				
Geotech	14	ea	$1,849	$25,888
Soil Analyses	1	lump sum	$57,500	$57,500
Lab Study				
Studies	1	ea	$100,000	$100,000
Subtotal - Direct Capital Cost				$1,425,839
Mobilization/Demobilization	5% of subtotal direct capital			$71,292
Site Preparation/Site Restoration	5% of subtotal direct capital			$71,292
Total Direct Capital Cost	(sum of * items)			**$1,568,423**
Indirect Capital Costs				
Engineering & Design	10% of direct capital			$156,842
Project/Construction Management	20% of direct capital			$313,685
Health & Safety	5% of direct capital			$78,421
Overhead	30% of direct capital			$470,527
Contingency	20% of direct capital			$313,685
Total Indirect Capital Cost				**$1,333,160**
Total Estimated Capital Cost				**$2,901,583**
Direct O&M Costs (10 yrs; Years 2020 - 2030)				
Groundwater Monitoring Costs	1	year O&M	*Years 2020 - 2021*	
Well Sampling (yr 1) (semimonthly for 6 mos and monthly for 6 mos)	1	yr	$209,676	$209,676
Annual Reporting Costs (yr 1)	1	yr	$80,500	$80,500
Subtotal - Annual Costs				$290,176
Present Worth Annual Costs (0.1% Discount Rate)				$289,886
Groundwater Monitoring Costs	1	year O&M	*Years 2021 - 2022*	
Well Sampling (yr 2) (Quarterly)	1	yr	$45,672	$45,672
Annual Reporting Costs (yr 2)	1	yr	$41,000	$41,000
Subtotal - Annual Costs				$86,672
Present Worth Annual Costs (0.1% Discount Rate)				$86,499
Groundwater Monitoring Costs	1	year O&M	*Years 2022 - 2023*	
Well Sampling (yr 3) (Biannually)	1	yr	$22,836	$22,836
Annual Reporting Costs (yr 3)	1	yr	$35,500	$35,500
Subtotal - Annual Costs				$58,336
Present Worth Annual Costs (0.1% Discount Rate)				$58,103
Groundwater Monitoring Costs	7	years O&M	*Years 2023 - 2030*	
Well Sampling (yrs 4 - 10) (Biannually)	1	yr	$22,836	$22,836
Annual Reporting Costs (yrs 4 - 10)	1	yr	$35,500	$35,500
Subtotal - Annual Costs				$58,336
Present Worth Annual Costs (0.1% Discount Rate)				$405,506
Report	1			
RAR / IPCR	1	ea	$100,000	$100,000
Subtotal - Five Year O&M Costs				$100,000
Present Worth Five Year Costs				$99,501
Total Present Worth Direct O&M Cost				**$939,495**
Indirect O&M Costs				
Project/Admin Management	27% of direct O&M			$250,000
Health & Safety	5% of direct O&M			$50,263
Overhead	30% of direct O&M			$281,849
Contingency	20% of direct O&M			$187,899
Total Present Worth Indirect O&M Cost				**$770,010**
Total Estimated Present Worth O&M Cost				**$1,709,506**
TOTAL ESTIMATED COST				**$4,611,089**

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Alternative 2B — PRB at the Elbow Portion of the Distal Area of the TCE Plumes

Item	Quantity	Units	Unit Cost	Total Cost
Direct Capital Costs				
Site Preparation				
Grading, pad construction	1	ea	$64,000	$64,000
Stormwater Management	2500	lf	$25	$62,500
Tree Cutting, Grubbing Stumps, and Grinding Debris	5	ac	$10,000	$50,000
PRB Construction				
Design	1	ea	$100,000	$100,000
Construction of Fe Wall	1	lump sum	$1,982,554	$1,982,554
Site Restoration	1	ea	$25,000	$25,000
Drilling				
Drilling - Groundwater Wells	18	ea	$12,904	$232,273
Drilling - Coring	6	ea	$9,622	$57,732
Drilling - Cone Penetrometer Technology	5	ea	$2,592	$12,961
Soil Testing				
Geotech	30	ea	$1,797	$53,904
Soil Analyses	1	lump sum	$87,000	$87,000
Lab Study				
Studies	1	ea	$100,000	$100,000
Subtotal - Direct Capital Cost				$2,827,924
Mobilization/Demobilization	5% of subtotal direct capital			$141,396
Site Preparation/Site Restoration	5% of subtotal direct capital			$141,396
Total Direct Capital Cost	(sum of * items)			**$3,110,716**
Indirect Capital Costs				
Engineering & Design	5% of direct capital			$152,425
Project/Construction Management	10% of direct capital			$303,606
Health & Safety	2% of direct capital			$76,213
Overhead	15% of direct capital			$455,098
Contingency	10% of direct capital			$303,388
Total Indirect Capital Cost				**$1,290,729**
Total Estimated Capital Cost				**$4,401,445**
Direct O&M Costs (10 yrs; Years 2020 - 2030)				
Groundwater Monitoring Costs	1	year O&M		*Years 2020 - 2021*
Well Sampling (yr 1) (semimonthly for 6 mos and monthly for 6 mos)	1	yr	$180,612	$180,612
Annual Reporting Costs (yr 1)	1	yr	$73,500	$73,500
Subtotal - Annual Costs				$254,112
Present Worth Annual Costs (0.1% Discount Rate)				$253,858
Groundwater Monitoring Costs	1	year O&M		*Years 2021 - 2022*
Well Sampling (yr 2) (Quarterly)	1	yr	$37,368	$37,368
Annual Reporting Costs (yr 2)	1	yr	$39,000	$39,000
Subtotal - Annual Costs				$76,368
Present Worth Annual Costs (0.1% Discount Rate)				$76,215
Groundwater Monitoring Costs	1	year O&M		*Years 2022 - 2023*
Well Sampling (yr 3) (Biannually)	1	yr	$18,684	$18,684
Annual Reporting Costs (yr 3)	1	yr	$34,500	$34,500
Subtotal - Annual Costs				$53,184
Present Worth Annual Costs (0.1% Discount Rate)				$52,972
Groundwater Monitoring Costs	7	years O&M		*Years 2023 - 2030*
Well Sampling (yrs 4 - 10) (Biannually)	1	yr	$18,684	$18,684
Annual Reporting Costs (yrs 4 - 10)	1	yr	$34,500	$34,500
Subtotal - Annual Costs				$53,184
Present Worth Annual Costs (0.1% Discount Rate)				$369,693
Report	1			
RAR / IPCR	1	ea	$100,000	$100,000
Subtotal - Five Year O&M Costs				$100,000
Present Worth Five Year Costs				$99,501
Total Present Worth Direct O&M Cost				**$852,240**
Indirect O&M Costs				
Project/Admin Management	29% of direct O&M			$250,047
Health & Safety	12% of direct O&M			$100,053
Overhead	30% of direct O&M			$253,968
Contingency	20% of direct O&M			$170,448
Total Present Worth Indirect O&M Cost				**$774,516**
Total Estimated Present Worth O&M Cost				**$1,626,756**
TOTAL ESTIMATED COST				**$6,028,201**

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Alternative 3A — ISCO at the Neck Area of the TCE Plumes

Item	Quantity	Units	Unit Cost	Total Cost
Direct Capital Costs				
ISCO				
Design	1	ea	$100,000	$100,000
ISCO Material	1	lump sum	$138,369	$138,369
Drilling				
Drilling - Groundwater Wells	10	ea	$11,747	$117,471
Drilling - Coring	7	ea	$8,172	$57,204
Drilling - Injection Wells	36	ea	$9,495	$341,803
CPT	7	ea	$2,556	$17,891
Soil Testing				
Geotech	14	ea	$1,849	$25,888
Soil Analyses	1	lump sum	$80,500	$80,500
Lab Study				
Studies	1	ea	$75,000	$75,000
Subtotal - Direct Capital Cost				$954,126
Mobilization/Demobilization	5%	of subtotal direct capital		$47,706
Site Preparation/Site Restoration	5%	of subtotal direct capital		$47,706
Total Direct Capital Cost		(sum of * items)		**$1,049,539**
Indirect Capital Costs				
Engineering & Design	15%	of direct capital		$157,431
Project/Construction Management	30%	of direct capital		$314,862
Health & Safety	5%	of direct capital		$52,477
Overhead	30%	of direct capital		$314,862
Contingency	20%	of direct capital		$209,908
Total Indirect Capital Cost				**$1,049,539**
Total Estimated Capital Cost				**$2,099,078**
Direct O&M Costs (10 yrs; Years 2020 - 2030)				
Chem-Ox Reinjections (every 3 years)	3	times over 10 yrs		*Years 2020 - 2030*
Re-injections	1	ea	$138,369	$138,369
Operations Reporting Costs	1	yr	$15,000	$15,000
Subtotal - Annual Costs				$153,369
Present Worth Annual Costs (0.1% Discount Rate)				$457,357
Groundwater Monitoring Costs	1	year O&M		*Years 2020 - 2021*
Well Sampling (yr 1) (semimonthly for 6 mos and monthly for 6 mos)	1	yr	$153,624	$153,624
Annual Reporting Costs (yr 1)	1	yr	$67,000	$67,000
Subtotal - Annual Costs				$220,624
Present Worth Annual Costs (0.1% Discount Rate)				$220,404
Groundwater Monitoring Costs	1	year O&M		*Years 2021 - 2022*
Well Sampling (yr 2) (Quarterly)	1	yr	$33,216	$33,216
Annual Reporting Costs (yr 2)	1	yr	$38,000	$38,000
Subtotal - Annual Costs				$71,216
Present Worth Annual Costs (0.1% Discount Rate)				$71,074
Groundwater Monitoring Costs	1	year O&M		*Years 2022 - 2023*
Well Sampling (yr 3) (Biannually)	1	yr	$16,608	$16,608
Annual Reporting Costs (yr 3)	1	yr	$34,000	$34,000
Subtotal - Annual Costs				$50,608
Present Worth Annual Costs (0.1% Discount Rate)				$50,406
Groundwater Monitoring Costs	7	years O&M		*Years 2023 - 2030*
Well Sampling (yrs 4 - 10) (Biannually)	1	yr	$16,608	$16,608
Annual Reporting Costs (yrs 4 - 10)	1	yr	$34,000	$34,000
Subtotal - Annual Costs				$50,608
Present Worth Annual Costs (0.1% Discount Rate)				$351,787
Design/Procurement for Reinjections (every 3 yrs)	3	times over 10 yrs		*Years 2020 - 2030*
Design/Procurement	1	ea	$100,000	$100,000
Subtotal - Annual Costs				$100,000
Present Worth Annual Costs (0.1% Discount Rate)				$298,207
Report	1	time in 10 yrs		
RAR / IPCR	1	ea	$100,000	$100,000
Subtotal - Five Year O&M Costs				$100,000
Present Worth Five Year Costs				$99,501
Total Present Worth Direct O&M Cost				**$1,548,736**
Indirect O&M Costs				
Project/Admin Management	26%	of direct O&M		$400,193
Health & Safety	6%	of direct O&M		$100,203
Overhead	30%	of direct O&M		$464,621
Contingency	20%	of direct O&M		$309,747
Total Present Worth Indirect O&M Cost				**$1,274,765**
Total Estimated Present Worth O&M Cost				**$2,823,500**
TOTAL ESTIMATED COST				**$4,922,579**

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Alternative 3B — ISCO at the Elbow Portion of the Distal Area of the TCE Plumes

Item	Quantity	Units	Unit Cost	Total Cost
Direct Capital Costs				
Clearing & Grubbing				
Tree Cutting, Grubbing Stumps, and Grinding Debris	5	ac	$10,000	$50,000
Access Roads				
Access Roads	2500	lf	$15	$37,500
Stormwater Management	2500	lf	$25	$62,500
ISCO				
Design	1	ea	$100,000	$100,000
ISCO Material	1	lump sum	$307,650	$307,650
Drilling				
Drilling - Injection Wells	132	ea	$9,426	$1,244,198
Drilling - Groundwater Wells	18	ea	$12,779	$230,023
Drilling - Coring	4	ea	$9,207	$36,828
Drilling - Cone Penetrometer Technology	12	ea	$2,518	$30,216
Soil Testing				
Geotech	21	ea	$1,816	$38,145
Soil Analyses	1	lump sum	$46,000	$46,000
Lab Study				
Studies	1	ea	$100,000	$100,000
Subtotal - Direct Capital Cost				$2,283,060
Mobilization/Demobilization	5%	of subtotal direct capital		$114,153
Site Preparation/Site Restoration	5%	of subtotal direct capital		$114,153
Total Direct Capital Cost		(sum of * items)		**$2,511,366**
Indirect Capital Costs				
Engineering & Design	3%	of direct capital		$87,396
Project/Construction Management	8%	of direct capital		$188,352
Health & Safety	5%	of direct capital		$125,568
Overhead	30%	of direct capital		$753,410
Contingency	20%	of direct capital		$502,273
Total Indirect Capital Cost				**$1,656,999**
Total Estimated Capital Cost				**$4,168,365**
Direct O&M Costs (10 yrs; Years 2020 - 2030)				
Chem-Ox Reinjections (every 2 years)	5	times over 10 yrs		*Years 2020 - 2030*
Re-injections	1	yr	$307,650	$307,650
Operations Reporting Costs	1	yr	$15,000	$15,000
Subtotal - Annual Costs				$322,650
Present Worth Annual Costs (0.1% Discount Rate)				$1,598,817
Groundwater Monitoring Costs	1	year O&M		*Years 2020 - 2021*
Well Sampling (yr 1) (semimonthly for 6 mos and monthly for 6 mos)	1	ea	$180,612	$180,612
Annual Reporting Costs (yr 1)	1	ea	$73,500	$73,500
Subtotal - Annual Costs				$254,112
Present Worth Annual Costs (0.1% Discount Rate)				$253,858
Groundwater Monitoring Costs	1	year O&M		*Years 2021 - 2022*
Well Sampling (yr 2) (Quarterly)	1	yr	$37,368	$37,368
Annual Reporting Costs (yr 2)	1	yr	$39,000	$39,000
Subtotal - Annual Costs				$76,368
Present Worth Annual Costs (0.1% Discount Rate)				$76,215
Groundwater Monitoring Costs	1	year O&M		*Years 2022 - 2023*
Well Sampling (yr 3) (Biannually)	1	yr	$18,684	$18,684
Annual Reporting Costs (yr 3)	1	yr	$34,500	$34,500
Subtotal - Annual Costs				$53,184
Present Worth Annual Costs (0.1% Discount Rate)				$52,972
Groundwater Monitoring Costs	7	years O&M		*Years 2023 - 2030*
Well Sampling (yrs 4 - 10) (Biannually)	1	yr	$18,684	$18,684
Annual Reporting Costs (yrs 4 - 10)	1	yr	$34,500	$34,500
Subtotal - Annual Costs				$53,184
Present Worth Annual Costs (0.1% Discount Rate)				$369,693
Design/Procurement for Reinjections (every 2 yrs)	5	times over 10 yrs		*Years 2020 - 2030*
Design/Procurement	1	ea	$100,000	$100,000
Subtotal - Annual Costs				$100,000
Present Worth Annual Costs (0.1% Discount Rate)				$495,527
Report	1			
RAR / IPCR	1	ea	$100,000	$100,000
Subtotal - Five Year O&M Costs				$100,000
Present Worth Five Year Costs				$91,018
Total Present Worth Direct O&M Cost				**$2,938,101**
Indirect O&M Costs				
Project/Admin Management	14%	of direct O&M		$400,169
Health & Safety	4%	of direct O&M		$116,055
Overhead	30%	of direct O&M		$881,430
Contingency	20%	of direct O&M		$587,620
Total Present Worth Indirect O&M Cost				**$1,985,275**
Total Estimated Present Worth O&M Cost				**$4,923,376**
TOTAL ESTIMATED COST				**$9,091,741**

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