



United States Department of Energy

Savannah River Site

**Treatability Study Work Plan for Groundwater Injection and Discharge
Canal Treatment at the D-Area Groundwater (OU) (U)**

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LIST OF ACRONYMS AND ABBREVIATIONS

bgs	below ground surface
CPRB	Coal Pile Runoff Basin
DAG	D-Area Groundwater
ft	feet
gpm	gallons per minute
m	meters
µg/L	microgram per liter
MCL	maximum contaminant level
OU	operable unit
psi	pounds per square inch
SCDHEC	South Carolina Department of Health and Environmental Control
SRNS	Savannah River Nuclear Solutions LLC
SRS	Savannah River Site
USEPA	U.S. Environmental Protection Agency
UTRA	Upper Three Runs aquifer
WSRC	Westinghouse Savannah River Company LLC (before October 2005)
WSRC	Washington Savannah River Company LLC (October 2005- July 2008)

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1.0 INTRODUCTION

D Area is located on an alluvial terrace in the southwest quadrant of the Savannah River Site (SRS) approximately 915 meters (m) (3,050 feet [ft]) east of the Savannah River (Figure 1) at an elevation approximately 37.5 m (125 ft) above mean sea level (msl). Local topography is relatively flat with a general slope from the northeast to southwest.

The coal-fired 484-D Powerhouse provided electricity and steam for the D-Area facilities and other areas at SRS. The power plant was put into operation in 1952. The major ancillary facilities associated with the powerhouse are the former Coal Storage Area (484-17D), the 489-D Coal Pile Runoff Basin (CPRB), and four ash basins (Figure 2). For over 60 years, the 484-17D Coal Storage Area was a staging area for coal prior to its use in the powerhouse. Exposure of the coal to rainwater has allowed the degradation of iron sulfide (pyrite; a mineral commonly found in coal) to sulfuric acid. As a result, the soils underneath the 484-17D Coal Storage Area, associated storm water runoff, and groundwater underlying the area have been acidified. The acidification lead to leaching of metals from both the coal and the natural minerals in the underlying soils in the vadose zone and aquifer have resulted in a sulfate and metals groundwater plume in the Upper Three Runs Aquifer (UTRA) (Figure 3). Currently, acidic groundwater is discharging downgradient into the D-Area Discharge Canal at pH levels generally below 4.

Maintenance actions conducted in 2012 and 2013 removed the majority of coal present at the 484-17D Coal Storage Area; however, the vadose zone soils beneath the storage area remain acidified. A non-time critical removal action for neutralization of the soils at the 484-17D Coal Storage Area is currently in development and an Engineering Evaluation/Cost Analysis is scheduled for submittal in September 2018. This treatability study is designed to address the acidic pH conditions in the groundwater beneath the 484-17D Coal Storage Area and 489-D CPRB and the discharge to surface water in the D-Area Discharge Canal.

2.0 PROJECT DESCRIPTION

The vadose zone and groundwater beneath the 484-17D Coal Storage Area and the 489-D CPRB are impacted by low pH conditions (< pH of 4) from approximately 60 years of coal fed power

plant operations. The presence of a low-pH plume in the groundwater is expected to last for decades under natural groundwater conditions. The low-pH groundwater is currently discharging into the D-Area Discharge Canal which later converges with Beaver Dam Creek and flows through the Savannah River floodplain to the Savannah River. If the pH of the aquifer can be raised to more normal, less acidic conditions, the groundwater and surface water conditions in the D-Area Discharge Canal would improve.

This project proposes to test the viability of an approach to remediation that contains two relatively simple elements:

- Inject potable water into the aquifer upgradient of the low-pH, metals, and sulfate plume to flush the aquifer.
- Adjust the low-pH surface water in the D-Area Discharge Canal with calcium carbonate (CaCO_3) reactive structure(s).

Injection of Potable Groundwater

The method of pH adjustment is to simply flush the aquifer from the top of the water table with groundwater injections of a more neutral pH potable water. Two potable water wells (PW 3D and PW 136D) are present in D-Area northwest of the 484-D Powerhouse that produce groundwater with a pH of approximately 6.0. Both wells were used for operations and are screened approximately 152 m (500 ft) below the surface. The wells are artesian and are estimated to produce over 60 gallons per minute (gpm) each without the assistance of pumps. The well head pressure of the wells is approximately 5 to 10 pounds per square inch (psi) and is expected to support enough flow and pressure to deliver large volumes of water to the proposed injection field.

The artesian groundwater will be piped to the 484-17D Coal Storage Area and 489-D CPRB and injected into the UTRA water table with a series of injection wells. Creating a water mound of 1.5 m (5 ft) above current conditions is expected to increase the groundwater discharge into the D-Area Discharge Canal. It is estimated that the production wells could supply enough water to fill the pore space volume (the space between the sediment grains in the vadose zone) to create the 1.5 m (5 ft) water mound in approximately 100 days. A total of 10 pore space volumes of injected

potable groundwater could significantly flush and raise the pH levels in the upper water table within a three-year study period. The artesian conditions of the production wells are expected to support the groundwater injection study in addition to future remedial activities if needed. (SRNS 2016a)

Reactive Structures in D-Area Discharge Canal

An increase in the amount of acidic water discharging to the D-Area Discharge Canal is expected to occur when the aquifer system is flushed. Titration test results using water from the D-Area Discharge Canal indicate that contact of surface water with a high purity CaCO_3 reactive structure will raise the pH of the surface water to over 6.0 (SRNS 2016b). Figure 4 shows the carbonate consumption rates associated with the neutralization of the sulfuric acid and illustrates a titration curve of the test. CaCO_3 marble chips engineered in two sections downgradient of the acidic groundwater discharge point within the D-Area Discharge Canal are expected to allow enough contact time with the surface water for pH adjustment to natural conditions (Figure 4 and Figure 6). The use of high purity CaCO_3 (typically greater than 90% CaCO_3) limits the introduction of undesirable constituents into the surface water (silt, clay, reactive minerals, etc.). A source for high purity CaCO_3 marble chips is available in northern Georgia.

3.0 TEST OBJECTIVES

The objective of this treatability study is to determine the ability of injected clean groundwater to:

- Flush the acidity (increase the pH) out of the upper water table aquifer of the UTRA in the vicinity of and downgradient of the 484-17D Coal Storage Area and 489-D CPRB to improve the aquifer conditions and reduce or eliminate the dissolved metal groundwater plumes.
 - Increase the pH level of the D-Area Discharge Canal surface water to approximately 6.0 with CaCO_3 reactive structures prior to discharge into Beaver Dam Creek and the Savannah River floodplain and river.
-

This treatability study will be used to support the development of the D-Area Groundwater OU Feasibility Study.

Monitoring of water table elevations and pH measurements in surrounding monitoring wells and streams, as well as metal analyses of groundwater and surface water, will be used to determine the impact of the groundwater injections. Stream flow measurements will document the increase in flow in the D-Area Discharge Canal from the groundwater injections.

4.0 EXPERIMENTAL DESIGN AND PROCEDURES

It is estimated that 10 pore space volumes are sufficient to flush the aquifer with an estimated duration of three years to meet treatability study objectives. However, actual observation of field conditions and data collected will help determine the exact impact and potential timeframes and feasibility of the action.

Water from the D-Area Discharge Canal was used in titration tests to estimate the amount of CaCO₃ material required to successfully raise the pH of the acidic surface water to more natural levels (pH of ~ 6.0) (SRNS 2016b). Monitoring of stream conditions upgradient and downgradient of the CaCO₃ reactive structures will determine if more CaCO₃ material is needed or is feasible.

Measurements of water table elevations, stream flow, pH, and sample collection for metal analyses will be conducted following the SRS 3Q1 Manual, *Environmental Requirements and Program Documents*, similar to other routine sampling and monitoring events at SRS such as the D-Area Groundwater (DAG) Operable Unit (OU) monitoring. Locations to be sampled are described in Section 6.0, *Sampling and Analysis*.

Testing of the artesian flow rates of the two production wells will occur before the field start date of the Treatability Study (January 31, 2020). Groundwater samples from the two production wells will also be collected to support the application for an Underground Injection Control permit. Slug tests in one or both of the existing monitoring wells to be used as part of the injection field (see section 5.0 *Equipment and Materials*) will also occur before the field start date to measure the aquifer characteristics during injection.

5.0 EQUIPMENT AND MATERIALS

The two production wells already exist northwest of the 484-17D Coal Storage Area and 489-D CPRB. Approximately 7,100 feet of pipes/hoses will be installed to transport the potable groundwater to the injection field (Figure 4). Due to little change in elevation, enough natural pressure from the artesian conditions is expected to be sufficient to feed the injection field of approximately 22 injection wells without the use of mechanical pumps. Two separate pipe runs will be made, one from each of the production wells. Each production well will supply half of the injection wells; i.e., well PW 3D will supply the western injection field and well PW 136D will supply the eastern injection field. Adjustments to the configuration of the injection field may be made based on the actual field conditions to optimize performance once the action is underway.

The injection wells will be screened in the upper water table of the UTRA. The water table is approximately 3 m (10 ft) below ground surface (bgs). Actual screen placement will be determined based on the geologic core collected during drilling activities for the installation of the injection wells. Screens are to be placed in higher permeability (sandy) zones preferable for injection. Screen lengths between 1.5 m (5 ft) and 3 m (20 ft) are expected to be used based on lithology. Two existing monitoring wells screened within the upper water table (well DCB 43A in the western field and well DCB 2A in the eastern field) will be used as injection wells. Valves will be placed on all injection wells to control injection flow.

The two CaCO₃ reactive structure areas will be constructed of high grade marble chips sourced from a facility in northern Georgia and placed directly in the D-Area Discharge Canal. Riprap will be placed on the downstream side of the marble chips to prevent erosion. Construction equipment will aid in the placement of the marble chips and riprap. The trees and vegetation north of the CaCO₃ reactive structures will be cleared and a sampling platform will be constructed to aid in the safe collection of surface water samples upstream of and downstream of each of the two structures (Figure 6).

Measurements of water table elevations, stream flow, pH, and sample collection for metal analyses will be conducted following the SRS 3Q1 Manual, *Environmental Requirements and Program*

Documents, similar to other routine sampling and monitoring events at SRS such as the DAG OU monitoring.

6.0 SAMPLING AND ANALYSIS

Table 1 and Figure 7 show the locations of the monitoring network and the sampling schedule for the treatability study. Water table elevations will be measured at the injection wells and numerous wells surrounding the 484-17D Coal Storage Area and the 489-D CPRB to adjust the injection well flow and monitor the effects of the groundwater injections. Stream flow measurements will be collected at all surface water station locations within the D-Area Discharge Canal and the tributary to the east. Groundwater and surface water samples will be monitored for the metals that are part of the DAG OU monitoring network (Table 2). Field pH measurements, and other routine field measurements will be taken (Table 3). One round of sampling will occur before groundwater injections begin. Sampling of the two production wells will analyze for metals and other common groundwater constituents prior to beginning injection campaigns. A total of 34 wells and 9 surface water stations outside of the injection field will be monitored. Twenty monitoring wells and all 9 surface water stations will include metal, pH and other routine field analyses.

After groundwater injection begins, monthly measurements and sampling will be collected for the first eight months, followed by quarterly monitoring. Monitoring of the D-Area Discharge Canal surface water pH upgradient and downgradient of the CaCO₃ reactive structures will occur monthly after the initial eight-month monitoring ends. Adjustments to the monitoring may be made based on field conditions or monitoring results. The second quarter (2Q) and fourth quarter (4Q) DAG OU monitoring will not be impacted by the treatability study and will continue as normally scheduled.

7.0 DATA MANAGEMENT

Similar to other routine sampling events for groundwater and surface water, field measurements and sample data will be entered into the SRS Environmental Restoration Data Management System (ERDMS). Other field observations, including notes on the production well performance, drilling activities, system performance, field observations, etc., will be recorded in field notebooks or daily

activities sheets. Photographs of the injection field components and CaCO₃ reactive structures will be taken periodically to document the treatability study action.

8.0 DATA ANALYSIS AND INTERPRETATION

Data (field measurements, sample results, flow rates, etc.) will be collected and presented in a combination of tabular form, graphs, and time-series plots. Maps depicting the water table will also be created. All these items and an interpretation will be supplied in data reports (see section 11.0 *Data Reports*).

9.0 HEALTH AND SAFETY

A site-specific health and safety plan and work package will be prepared before work begins for the treatability study. Hazards including, but not limited to, heat stress or frostbite, hand safety, harmful plants and animals, heavy construction equipment, tripping hazards, hearing protection, personal protective equipment, etc. will be examined.

10.0 RESIDUALS MANAGEMENT

Since the injections are of potable groundwater, many of the physical components of the treatability study will be sanitary waste once the action is complete. There is a possibility that metal cladding could occur on the CaCO₃ reactive structures marble chips due to the reactive pH adjustment of surface water and dissolution of metals. Based on field observations and measurements, the disposal of and replacement of marble chips may be required. Analysis of field and sample data and visual observation of the CaCO₃ reactive structures will help determine the action required, if any. Additional residuals will attempt to be identified in the development of the site-specific health and safety plan and work package.

11.0 REPORTS

A treatability study report will be submitted one year after field start. Currently, the field start date is planned for January 31, 2020. The first report is expected to be submitted by January 31, 2021. Future reports will be proposed at a later date based on the initial performance of the treatability study, but will be no later than a year following the initial report.

12.0 SCHEDULE

The anticipated length of the treatability study is approximately three years of groundwater injection. Analysis of the production well flow rates, injection operation, aquifer acceptance, field data, sample data, and performance of the CaCO₃ reactive structures will help determine the actual length of the treatability study. Construction of the CaCO₃ reactive structures and installation of the injection wells and associated piping from the production wells is not expected to occur until the field start date of January 31, 2020.

13.0 REFERENCES

SRNS, 2016a. *Remediation of the Acidic Groundwater Impacting the Discharge Canal in D Area*; Interoffice Memo, Savannah River Site, October, Savannah River Nuclear Solutions LLC, Aiken, SC

SRNS, 2016b. *Feasibility Study of the Reactive Structures for the D-Area Discharge Canal*; ERD-EN-2016-0042, Savannah River Site, Rev. 0, October, Savannah River Nuclear Solutions LLC, Aiken, SC

SRNS, 2017a. *2016 Groundwater Monitoring Report for the D-Area Groundwater OU (U)*, SRNS-RP-2017-00383, Savannah River Site, Rev. 0, July, Savannah River Nuclear Solutions LLC, Aiken, SC

Table 1. Proposed D-Area Treatability Study Monitoring Network and Sampling Schedule

Station	Station Type	Before Injection	After Injections Start		
			Monthly - First 8 months	Monthly	Quarterly
PW 3D	Production Well	M	WL		WL
PW 136D	Production Well	M	WL		WL
DCB 3A	Monitoring Well	WL	WL		WL
DCB 4A	Monitoring Well	M	M		M
DCB 5A	Monitoring Well	WL	WL		WL
DCB 6	Monitoring Well	M	M		M
DCB 7	Monitoring Well	WL	WL		WL
DCB 8	Monitoring Well	M	M		M
DCB 9	Monitoring Well	WL	WL		WL
DCB 10	Monitoring Well	M	M		M
DCB 21A	Monitoring Well	M	M		M
DCB 21B	Monitoring Well	M	M		M
DCB 21C	Monitoring Well	M	M		M
DCB 22A	Monitoring Well	M	M		M
DCB 23A	Monitoring Well	WL	WL		WL
DCB 23B	Monitoring Well	M	M		M
DCB 23C	Monitoring Well	M	M		M
DCB 26AR	Monitoring Well	WL	WL		WL
DCB 33B	Monitoring Well	WL	WL		WL
DCB 34A	Monitoring Well	M	M		M
DCB 34C	Monitoring Well	M	M		M
DCB 35A	Monitoring Well	M	M		M
DCB 35C	Monitoring Well	M	M		M
DCB 36A	Monitoring Well	M	M		M
DCB 36C	Monitoring Well	M	M		M
DCB 37A	Monitoring Well	M	M		M
DCB 41A	Monitoring Well	WL	WL		WL
DCB 44A	Monitoring Well	WL	WL		WL
DCB 45A	Monitoring Well	WL	WL		WL
DCB 49	Monitoring Well	WL	WL		WL
DCB 53	Monitoring Well	WL	WL		WL
DCB 70A	Monitoring Well	M	M		M
DCB077	Monitoring Well	M	M		M
DCB078	Monitoring Well	M	M		M
DSWM-4	Surface Water Station	M	M		M
DSWM-4A	Surface Water Station	M	M		M
DSWM-4B	Surface Water Station	M	M		M
DSWM-4C	Surface Water Station	M	M		M
DSWM-5	Surface Water Station	M	M		M
DSWM-6	Surface Water Station	M	M		M
DSWM-7	Surface Water Station	M	M	pH	M
DSWM-8	Surface Water Station	M	M	pH	M
DSWM-9	Surface Water Station	M	M	pH	M

M = Metals and field parameters including pH

WL = Water table elevation measurement only

pH = pH reading of surface water only for performance monitoring of the reactive structures

Table 2. Proposed Metals Included in Sample Analyses

ALUMINUM
ANTIMONY
ARSENIC
BARIUM
BERYLLIUM
CADMIUM
CALCIUM
CHROMIUM, TOTAL
CHROMIUM, HEXAVALENT*
COBALT
COPPER
IRON
LEAD
MAGNESIUM
MANGANESE
MERCURY
NICKEL
POTASSIUM
SELENIUM
SILVER
SODIUM
SULFATE
THALLIUM
URANIUM
VANADIUM
ZINC

*if chromium exceeds 100 µg/L, chromium-6+ will be analyzed during the next sampling event

Table 3. Proposed Field Measurements

OXIDATION/REDUCTION POTENTIAL
DISOLVED OXYGEN
PH
SPECIFIC CONDUCTANCE
TOTAL ALKALINITY (AS CaCO ₃)
TURBIDITY
WATER TEMPERATURE
WATER ELEVATION (Wells)
STREAM FLOW MEASUREMENT (Surface Water)

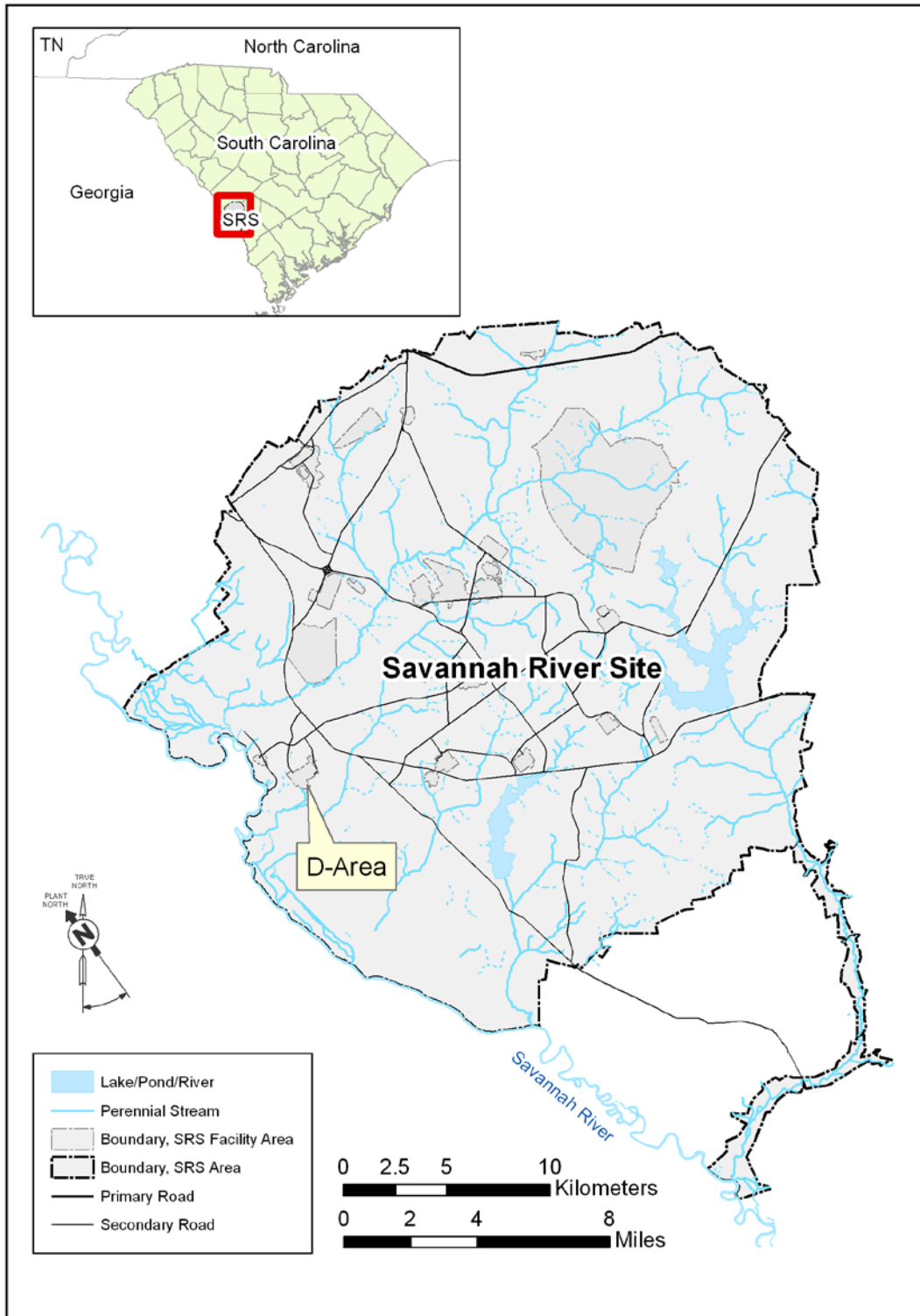


Figure 1. Location of D-Area at SRS

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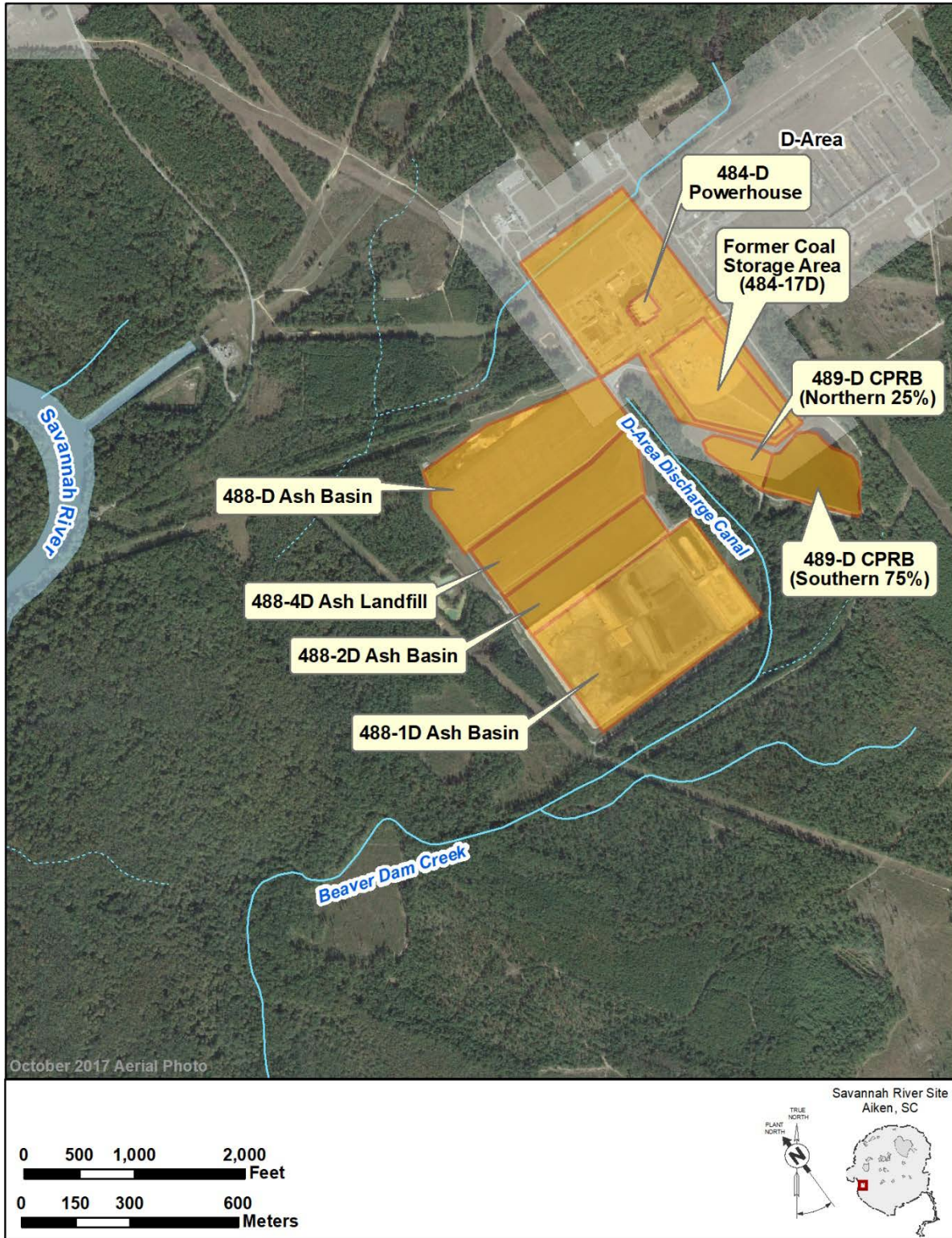


Figure 2. D-Area Powerhouse Associated Facilities

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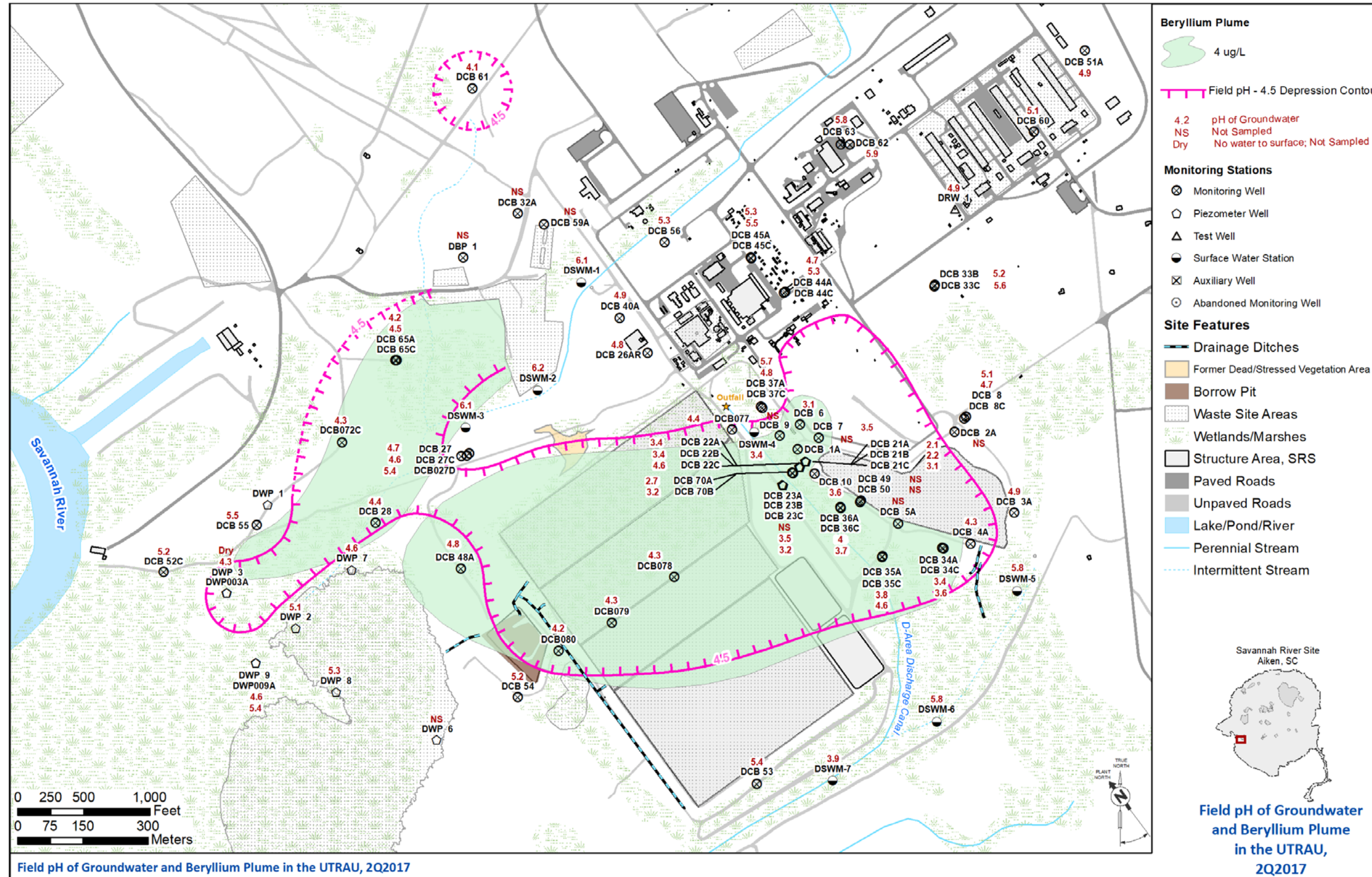


Figure 3. D-Area Groundwater 2Q2017 pH and Beryllium Plume

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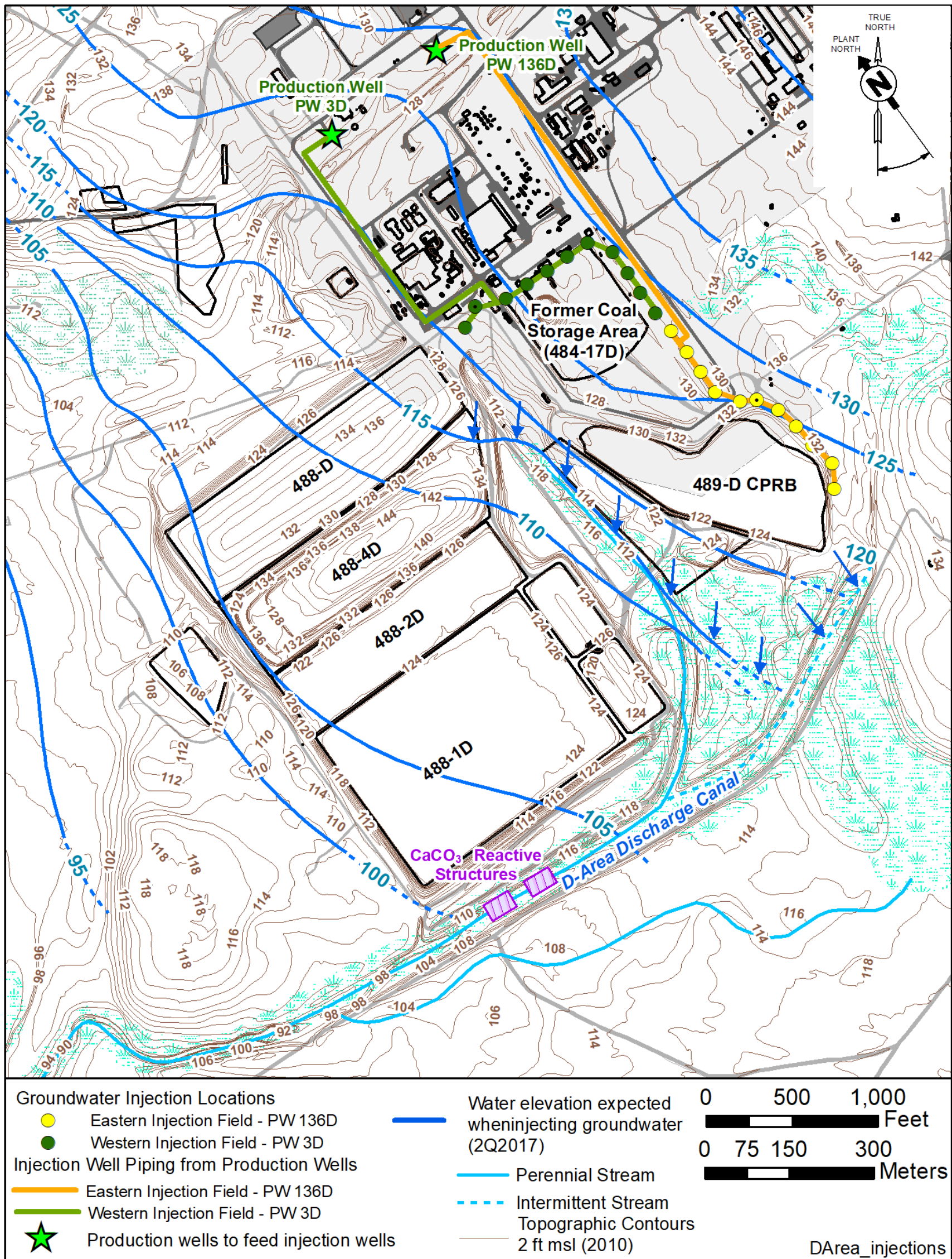


Figure 4. D-Area Treatability Study Injection Wells, Reactive Structure, and Expected Water Table Elevation

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Water Volume, ml	CaCO ₃ Mass, g	Initial pH	Final pH	Mass CaCO ₃ per Water Volume, mg/l
Initial		3		0
200	0.018	3.08	3.99	90
200	0.05	3.05	5.75	250
200	0.1	3.02	6.15	500
50	0.1	2.98	6.64	2,000
50	0.25	2.93	6.50	5,000
50	0.5	2.90	6.60	10,000

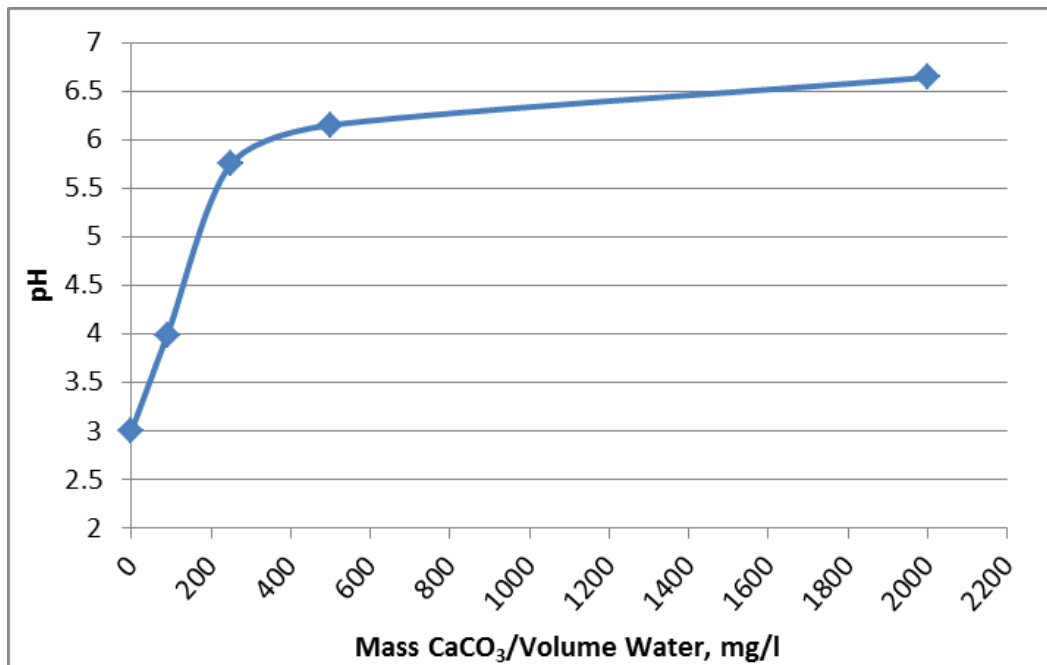


Figure 5. Titration Test Chart and Graph of D-Area Discharge Canal Acidic Surface Water with Calcium Carbonate Additions

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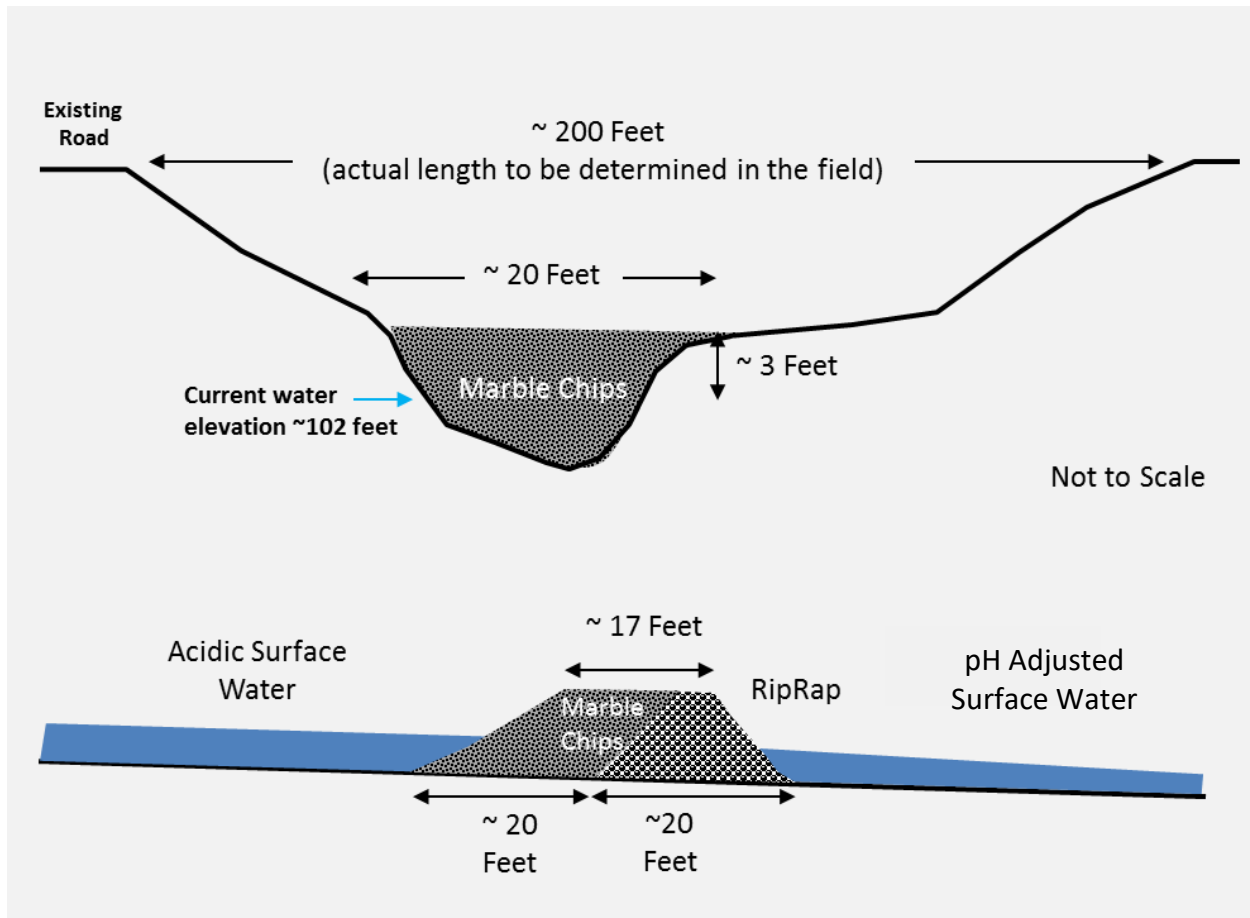


Figure 6. Conceptual Diagram of CaCO_3 Reactive Structures in the D-Area Discharge Canal

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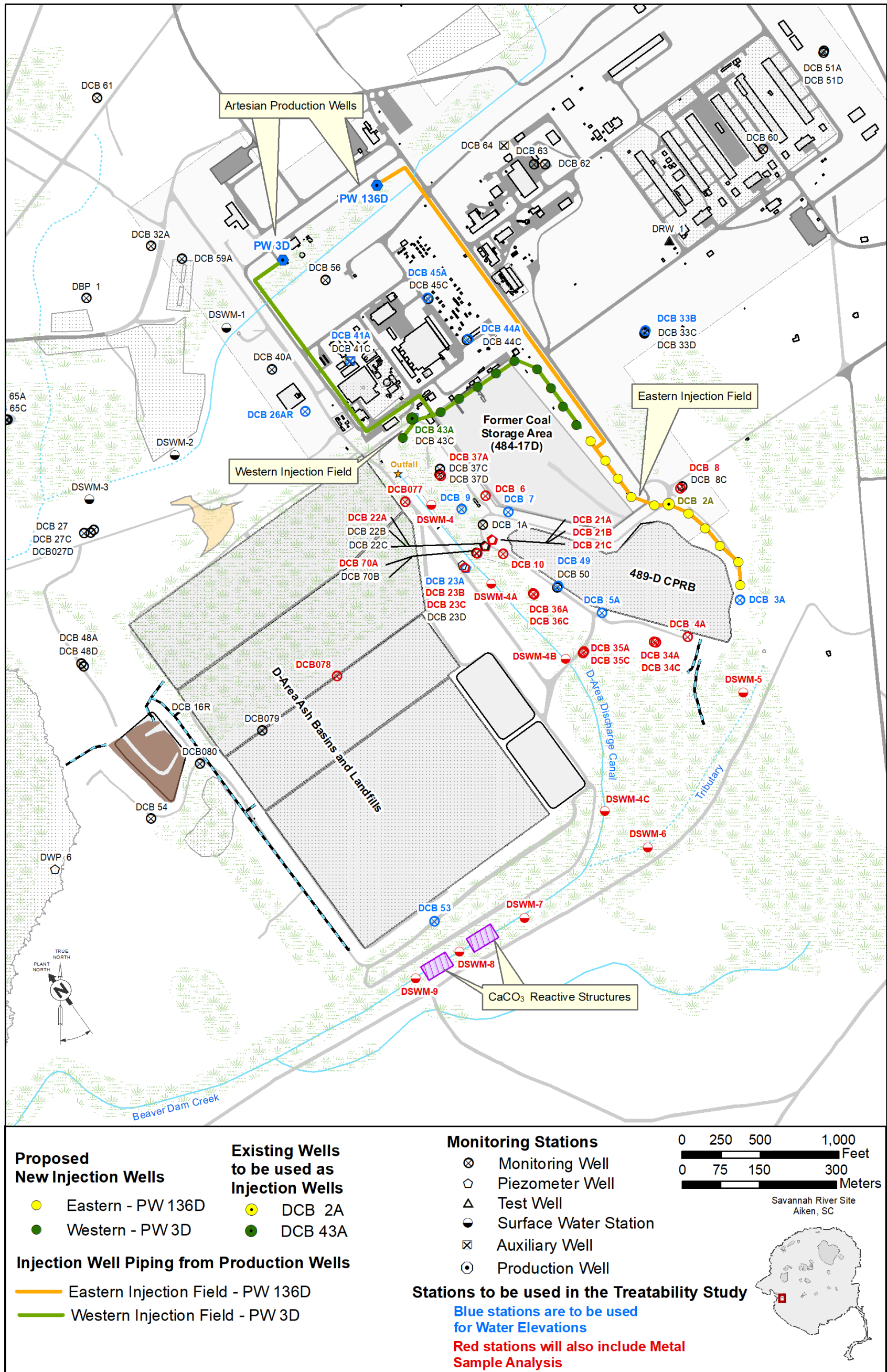


Figure 7. Proposed D-Area Treatability Study Monitoring Locations

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