CO_2 SPARGING PHASE 2 FULL-SCALE IMPLEMENTATION AND MONITORING REPORT

LCP CHEMICALS SITE, BRUNSWICK, GA

Prepared for Honeywell

Prepared by:

Mutch Associates, LLC

360 Darlington Avenue

Ramsey, NJ 07446

In collaboration with:

Parsons

3577 Parkway Lane, Suite 100

Norcross, GA 30309

June 19, 2015

EXECUTIVE SUMMARY

In-situ carbon dioxide (CO_2) sparging was designed and implemented to treat a subsurface caustic brine pool (CBP) formed by historical production of industrial chemicals at the LCP Chemicals Site, Brunswick, GA (Site). Phase 1 of CO_2 sparging was conducted between October 2013 and February 2014 in accordance with the *CO_2 Sparging Work Plan, LCP Chemicals Site, Brunswick, GA* dated April 24, 2013 (Sparging Work Plan) and approved by the U.S. Environmental Protection Agency, Region 4 (EPA). Phase 2 of CO_2 sparging was conducted in October 2014 and April 2015 in accordance with the Sparging Work Plan and *Technical Approach for Phase 2 CO_2 Sparging, LCP Chemicals Site, Brunswick GA (Revision 1)* dated September 11, 2014 (Phase 2 Memo). The CBP is being addressed under an Administrative Settlement Agreement and Order on Consent (AOC), which was entered into between Honeywell and EPA on April 18, 2007. The remedial action objectives (RAOs) that are defined in the AOC and include: 1) reducing the pH of the CBP to between 10 and 10.5 and 2) reducing the density of the CBP. This report describes the results of Phase 2 sparging.

Phase 2 Well Network and Sparge Protocol

Based on the average radius of influence (ROI) observed during Phase 1 of 33 feet (ft), the final layout of Phase 2 sparge wells within the Phase 1 sparging footprint was designed to form sparge "columns," with consideration given to overlap. A total of 58 Phase 2 sparge wells were installed within the Phase 1 footprint (SW-66 through SW-123).

Prior to the Phase 2 sparging, the southern boundary of the CBP was better defined via Geoprobe sampling program that further delineated the extent of the high pH plume to the south. This newly delineated "southern area" was added to the sparging program, bringing the total area to 13.9 acres. This southern area was treated for the first time as part of Phase 2 sparging, utilizing 22 new wells.

Required CO_2 Mass

During Phase 1 sparging, an overall mass of at least 8,000 to 9,000 lb of CO_2 per sparge well was required to treat groundwater with moderate alkalinity (< 4,000 mg/L $CaCO_3$), with adjustments for higher and lower alkalinity areas. For Phase 2 wells, a modified method for calculating CO_2 dosage was used, resulting in target doses ranging from 8,000 lb to 40,000 lb for specific sparge wells. This method of calculating required CO_2 mass was also retroactively applied to Phase 1 sparge wells.

Sparging Activity

Phase 2 sparging was initiated on October 17, 2014 and continued through April 28, 2015. Sparge wells were placed on an approximate once per week regimen with a 4-hour duration to start, with adaptive

management to optimize well-specific performance. The total amount of CO_2 injected during Phase 2 was 1,521,000 lb. All sparge wells received their target CO_2 mass. By comparison, 783,000 lb was sparged during Phase 1.

Changes in pH in the Phase 1 Footprint

Groundwater monitoring results for the deep Satilla from 2011-2012 serve as an appropriate pre-sparge baseline for the CBP because sparging began in late 2013 as part of the Proof of Concept Test. Deep Satilla groundwater during this period was characterized as consistently having pH values between 10.5 and 12.0, with many wells exhibiting a pH of greater than 11.5. After Phase 2 sparging**,** the majority (22 out of 30) of deep Satilla monitoring points (monitoring wells and extraction wells) had pH less than 7.5, with the vast majority with a pH of under 10.0 (26 out of 30 wells).[1]

Changes in pH in the Southern Area

A total of 16 groundwater samples in the southern area were collected via Geoprobe after Phase 2 sparging concluded. The pH in groundwater that was collected from within 30 ft of a sparge well was consistently less than 10.5, and in most cases less than 7.5. At distances of 30 ft or greater, pH was between 7.14 and 11.67, with several locations with pH less than 10.0. These results are consistent with the observed average ROI of 33 ft within the Phase 1 footprint. Since the Phase 2 sparge wells were placed on a coarse hexagonal grid, there are several areas that have yet to be treated by CO_2 sparging.

Changes in Mercury (Hg) Concentrations

Although Hg concentrations are not a component of the AOC, we monitored the performance of the CO_2 sparging with respect to the reduction of Hg concentrations associated with the Phase 2 work. Groundwater monitoring results for Hg in the deep Satilla from 2011-2012 serve as an appropriate pre-sparge baseline for the CBP because sparging began in late 2013 as part of the Proof of Concept Test. During this period, deep Satilla groundwater within the Phase 1 sparging footprint exhibited Hg concentrations between 35.7 and 2,530 µg/L. After sparging, Hg concentrations in monitoring points were considerably lower within the sparging footprint, with a range of 0.95 to 470 µg/L. Overall, 24 out of 27 monitoring points showed a decrease in Hg after sparging. The majority of monitoring points (18 out of 27) showed Hg concentrations less than 20 µg/L with three points having Hg concentrations less than 2.0 µg/L. The mean Hg concentration in all Phase 2 monitoring points was lowered from 118 to 42.8 µg/L, a 64%

[1] The only deep Satilla monitoring points within the sparging footprint that remained above pH 10.5 at the end of Phase 2 were EW-5, MW-516B, MW-352B and MW-513B. Throughout this report, the term monitoring point is used to refer to monitoring wells and extraction wells.

decrease. For monitoring points where the pH was less than 10.5, the mean Hg concentration was 12.4 µg/L.

All 16 Phase 2 sparge wells sampled for Hg exhibited a decrease in dissolved concentrations from pre- to post-sparging. The mean Hg concentration in Phase 2 sparge wells was lowered from 150 to 16.8 µg/L, an 89% decrease. The mean concentration in sparge wells post treatment (16.8 µg/L) was similar in magnitude to the mean in monitoring points where the pH was less than 10.5 (12.4 µg/L).

Co-located Geoprobe locations in the southern area that showed improvement in pH to near-neutral levels also showed a substantial decrease in dissolved Hg concentrations. The mean Hg concentration after Phase 2 in the southern area was 42.3 µg/L, a 57% reduction compared to pre-sparge levels. However, this includes contributions from many locations that have not been treated yet by CO_2 sparging. Considering only locations where the pH is less than 8.0, the post-sparge mean Hg concentration was 25.6 µg/L.

Conclusions

- CO_2 sparging has been very successful in lowering pH levels in the Satilla aquifer.
- The mean Hg concentration in Phase 2 monitoring points where the pH was less than 10.5 was 12.4 µg/L, an 89% reduction from pre-Phase 1 levels.
- Only four deep Satilla monitoring points within the sparging footprint have a pH above 10.5.
- Post-sparge Geoprobe groundwater sampling in the southern area supports the selected ROI of 33 ft within the Phase 1 footprint.
- Hg measurements throughout the entire sparging program show that additional reductions in Hg should occur over time as groundwater remains at neutral pH.

Recommendations

- Given that the 33 ft average ROI was substantiated in Phase 2, the coarse spacing in the southern area should be filled in with additional sparge wells on a 66 ft spacing.
- Add new sparge wells east of wells MW-352B and MW-513B to lower pH along the eastern edge of the sparging footprint.
- Add new sparge wells near wells EW-5 and MW-510B to correct for the slight increase measured in post-sparge pH.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AOC	Agreement and Order on Consent
ARCO	Atlantic Refining Company
As	Arsenic
bgs	Below ground surface
CBP	Caustic brine pool
$CaCO_3$	Calcium carbonate
CO_2	Carbon dioxide
CO_3^{2-}	Carbonate ion
Cr	Chromium
Cr(III)	Trivalent chromium
Cr(VI)	Hexavalent chromium
CPT	Cone Penetrometer Test
DOM	Dissolved organic matter
DP	Distribution Panel
EPA	Environmental Protection Agency
EW	Extraction Well
ft	Feet
ft/d	Feet per day
gpm	Gallons per minute
Hg	Mercury
HDPE	High-density polyethylene
kW	Kilowatt
lb	Pounds
LCP	Linden Chemicals and Plastics
MW	Monitoring well
n	Sample size
NAVD	North American Vertical Datum
NA	Not available
NM	Not measured
NTU	Nephelometric turbidity unit
ORP	Oxidation reduction potential
P&ID	Process and instrumentation drawing
ppmv	Part per million by volume
psi	Pounds per square inch (gauge)
psia	Pounds per square inch – absolute
PVC	Poly vinyl chloride
PZ	Piezometer
RAO	Remedial Action Objective
RI	Remedial Investigation
ROI	Radius of influence
scfm	Standard cubic feet per minute
Si	Silica
SG	Specific gravity
SW	Sparge well
TDS	Total dissolved solids
µg/L	Microgram per liter

1 INTRODUCTION

Mutch Associates, LLC (Mutch), in collaboration with Parsons Corporation (Parsons), have prepared this report of Phase 2 of carbon dioxide (CO_2) sparging at the LCP Chemicals Site in Brunswick, Georgia (Site). Phase 2 of CO_2 sparging was conducted in accordance with the *CO_2 Sparging Work Plan, LCP Chemicals Site, Brunswick, GA* dated April 24, 2013 (Sparging Work Plan) (Mutch Associates and Parsons, 2013a) and the *Technical Approach for Phase 2 CO_2 Sparging, LCP Chemicals Site, Brunswick GA (Revision 1)* dated September 11, 2014 (Phase 2 Memo). Formal approval of the Sparging Work Plan and Phase 2 Memo were granted by the U.S. Environmental Protection Agency, Region 4 (EPA) on May 1, 2013 and September 12, 2014, respectively. Sparging was designed to remediate a subsurface caustic brine pool (CBP) formed by historical production of industrial chemicals on the Site. The CBP is being addressed under an Administrative Settlement Agreement and Order on Consent (AOC) entered into between EPA and Honeywell on April 18, 2007. The remedial action objectives (RAO) were defined in the AOC and included reducing the pH of the CBP to between 10 and 10.5 and reducing the density of the CBP.

This report is organized in the following manner:

- Section 1 – Introduction and background;
- Section 2 – Describes the sparge well installation and sparge system construction;
- Section 3 – Describes the specific procedures and protocols employed during sparging;
- Section 4 – Presents the results of sparging on pH and mercury (Hg), other geochemical parameters, and groundwater levels; and
- Section 5 – Conclusions and recommendations.

1.1 Site Description

The Site is located at 4125 Ross Road,[2] in the City of Brunswick, in Glynn County, Georgia, and is bordered by the Turtle River marshes to the west and south and the urban populations of Brunswick to the north and east. The Site encompasses approximately 813 acres, of which 684 acres are tidally influenced salt marsh. A Site location map is provided in Figure 1-1.

Industrial operations were conducted by multiple parties from approximately 1919 until 1994. The Site was originally owned and operated by the Atlantic Refining Company (ARCO) who operated a petroleum refinery from 1919 until 1930 and a petroleum storage facility until approximately 1955.

[2] We understand that a site address was developed as part of the County's upgrade to its 911-emergency system.

Portions of the Site were also owned by Georgia Power Company and the Dixie O'Brien Paint Company. In 1955, the property was purchased by Allied Chemical, Inc. (Allied). From 1956 to 1979, chlorine, hydrochloric acid, and sodium hydroxide were produced by Allied by the electrolysis of sodium chloride using Hg cells (the chlor-alkali chemical manufacturing process). In 1979, LCP Chemicals purchased the property and continued to operate the chlor-alkali process until operations ceased in 1994. Honeywell (formerly Allied) repurchased most of the property that constitutes the Site in 1998 and currently still owns most of the property.[3]

During chemical production activities at the Site, a portion of the shallow aquifer was contaminated by residuals of chlor-alkali-manufacturing operations and a subsurface CBP formed. The CBP is characterized by elevated pH, elevated total dissolved solids, and elevated concentrations of dissolved metals. The CBP is defined in the AOC as groundwater with a pH above 10.5. Figure 1-2 shows the location and extent of the CBP based on pH data collected in 2012.[4] The area within the 10.5 contour was 8.6 acres.

In July and August of 2014, Honeywell performed groundwater sampling via Geoprobe at the base of the Satilla aquifer along the southern boundary of the CBP as mapped in 2012. The purpose of this sampling was to improve delineation of the extent of the high pH (> 10.5) plume. Further details on this sampling are provided in Section 2.1.2. Results of the re-mapping of the pH > 10.5 plume are shown in Figure 1-3. Addition of the southern area increased the area of the CBP to 13.9 acres.

1.2 Summary of Proof of Concept Test

Full-scale CO_2 sparging was preceded by a Proof of Concept Test. The Proof of Concept Test was conducted from October 29, 2012 to November 17, 2012 in accordance with the *Final Work Plan for CO_2 Sparging Proof of Concept Test, LCP Chemicals Site, Brunswick, GA* (Proof of Concept Test Work Plan) dated September 11, 2012 (Mutch Associates, 2012). EPA approved the Proof of Concept Test Work Plan in a letter dated September 10, 2012. The Proof of Concept Test was designed to evaluate the feasibility of CO_2 sparging to remediate the CBP.

---

[3] A portion of the property was sold to Glynn County in 2012 for its Glynn County Sheriff's Office, which became operational in October 2014.

[4] The mapping of the CBP (Figure 1-2) was created by kriging pH data from deep Satilla monitoring wells (MW series) from the May/June 2012 monitoring event, supplemented with data from September 2011 for extraction wells (EW series). For most wells, field pH values were used for the mapping. The only exceptions were MW-357A, MW-357B, MW-512B and MW-516B, where laboratory pH was conservatively used because field pH was considerably lower than historic values. Well MW-113C was not included in kriging because of poor resolution in this area of the site.

Key observations from the Proof of Concept Test that are relevant to the design and implementation of full-scale sparging, as described in the Proof of Concept Test report (Mutch Associates and Parsons, 2013b) are:

1. Significant pH reductions from pH 11-12 in the deep Satilla were achievable in 5 to 7 days sparging at circa 50 standard cubic feet per minute (scfm).
2. A radius of influence (ROI) of at least 20 feet was achieved in the deep Satilla and greater than 60 feet (ft) at the water table surface.
3. Hg levels in the high pH CBP waters fully-impacted by the sparging declined from 110-120 µg/L to 11-33 µg/L (70 to 90% reductions).
4. During sparging, significant mounding of the potentiometric surface was observed. Shallow Satilla wells within the 20-ft radius of sparge wells increased to within 1 ft of the ground surface.
5. Significant rebound of pH or Hg was not observed based on results from groundwater monitoring conducted three months after completion of sparging.

The Proof of Concept Test indicated that CO_2 sparging is an effective, innovative technology, suitable for full-scale implementation at the Site (Figure 1-4). Observations made during testing further indicated that full-scale implementation of CO_2 sparging should be conducted over a multiple-year, sequential effort. The principal drivers for this sequential implementation were:

- Management of groundwater mounding caused by superposition of multiple, closely-spaced sparge wells; and
- Maximization of sparging efficiency.

The Proof of Concept Test indicated that managing groundwater mounding during full-scale implementation would be critical. The groundwater table rose to within 1 ft of the ground surface during the testing. This potential for mounding could be exacerbated by superposition of mounding from multiple nearby sparging wells and by seasonal rises of the groundwater table. Moreover, in some areas of the CBP, the water table is even closer to the surface than at the test site. These factors could impose a practical limit on the spacing of wells and the number of wells that could be sparged simultaneously. Conducting the implementation over multiple years would allow active sparge wells to be further apart, thereby reducing the superposition of groundwater mounding.

The Proof of Concept Test suggested that CO_2 sparge efficiency could be enhanced by a sparge regimen that emphasizes short bursts of sparging (anywhere from ½ to 4 hr) followed by rest periods. The rest periods would allow CO_2 gas residual saturation remaining in the formation to both dissolve and diffuse into the surrounding CBP waters. The Proof of Concept Test Report concluded that different sparge regimens should be tested during the first year of sparging in an effort to optimize sparge efficiency.

The Proof of Concept Test results also showed that the pH reached target levels in the deep Satilla at least 20 ft away from sparge well MW-1C (Mutch Associates and Parsons, 2013b). This indicated an effective ROI of at least 20 ft in the deep Satilla. Modest decreases in pH in deep Satilla wells were observed at radial distances greater than 20 ft, indicating some consumption of CO_2 demand. The ROI in the intermediate and shallow Satilla was significantly larger than 20 ft. For example, gas channels extended all the way from MW-1C to MW-517A, which is a distance of approximately 100 ft. As a result, there was some uncertainty regarding the ROI that would be achieved during full-scale implementation. The Proof of Concept Test Report indicated that further evaluation of ROI could be achieved by using an initial coarse grid spacing for sparge wells during the first year of sparging, followed by filling-in with a denser well spacing in future efforts based on observed results.

Although Hg concentrations are not a component of the AOC, during the Proof of Concept Test we did monitor the performance of the CO_2 sparging with respect to its impact on Hg concentrations. The Proof of Concept Test showed that post-sparge deep Satilla wells show a clear trend of decreasing Hg concentrations with decreasing pH. Furthermore, monitoring in these same wells showed a gradual lowering of dissolved Hg concentrations over time at a given pH (Mutch Associates and Parsons, 2013c). This effect appeared after three months and was sustained through 6 months after sparging was completed.

1.3 Summary of Phase 1 of Full-Scale Sparging

As described in the EPA-approved Sparging Work Plan (Mutch Associates and Parsons, 2013a), the technical objectives of Phase 1 of full-scale sparging were the following:

- Reduce pH as determined by measurements in deep Satilla monitoring wells and extraction wells;
- Determine the average ROI of sparging to develop a technical approach for Phase 2 of CO_2 sparging;
- Determine the optimal sparging regimen to maximize CO_2 utilization efficiency; and
- Reduce Hg concentrations as determined by comparison of pre- and post-sparging concentrations in mid and deep Satilla monitoring wells.

Phase 1 of CO_2 sparging at the Site is described in detail in the *CO_2 Sparging Phase 1 Full-scale Implementation and Monitoring Report, Revision 1* (Phase 1 Report), dated June 20, 2014 (Mutch Associates and Parsons, 2014). Phase 1 sparge wells were placed approximately 80 ft apart on a coarse, semi-regular, hexagonal grid pattern (Mutch Associates, Parsons, 2013). This layout provided flexibility for various final sparge well spacings by placing additional sparge wells on the grid (Figure 1-5). Sparging was performed from November 8, 2013 to February 13, 2014.

A summary of the key results from Phase 1 is presented below:

- All of the technical objectives of Phase 1 of CO_2 sparging were met.
- Sparging was effective in reducing the pH of the CBP groundwater. Following Phase 1 of sparging, 14 out of 15 deep Satilla monitoring points within a radial distance of 30 ft from a sparge well had a post-sparge pH < 10.0, and 13 out of 15 monitoring points had a post-sparge pH < 7.5. Many wells at distances greater than 30 ft showed significant decreases in pH.
- An average ROI of 32.9 ft was estimated from the pH versus distance data. This is considerably larger than the approximate 20 ft ROI measured in the Proof of Concept Test.
- The optimal sparging regimen was Regimen A (once per week). Some sparge wells required longer sparge durations of 8 to 24 hr to provide adequate flow.
- The efficiency of CO_2 sparging was evaluated by comparing the CO_2 demand of the CBP with the amount of CO_2 mass required to lower the pH to circumneutral and found to be 29%. This efficiency was approximately three times larger than the efficiency estimated from the Proof of Concept Test (9.7%).
- CO_2 sparging resulted in a significant decline in aqueous-phase Hg concentrations. In monitoring points where post-sparge pH was less than 7.5, the mean Hg concentration decreased from 94 μg/L to 21 μg/L (n = 22), a decrease of 78%.
- The pre-and post-sparging aquifer testing showed no sharp loss of aquifer transmissivity. The mean of six pre-sparge well specific capacities was 0.011 gpm/ft. The mean of ten post-sparge specific capacities measured approximately 2 weeks after sparging was 0.035 gpm/ft.
- The pre-sparge aquifer testing indicated that the basal Satilla varies in hydraulic conductivity within the CBP from 2 to 17 ft/d, with a mean value of 9.9 ft/d. The Proof of Concept pre-sparging aquifer test had previously measured a hydraulic conductivity of 8.9 ft/d in that area of the Site.
- A significant fraction of the injected CO_2 remained in the formation as residual CO_2 saturation and was not vented to the atmosphere. The emplacement of CO_2 residual saturation into the Satilla provides a long-term source of pH-neutralization and Hg immobilization for water flowing from upgradient locations. This may also serve as protection against pH rebound.
- As the CO_2 residual saturation dissolves into the surrounding groundwater, a process that could take months or years, aquifer properties such as hydraulic conductivity and storativity should concomitantly approach pre-sparge levels, except for whatever impact the minimal reduction in

porosity may have on these properties. Our experience during the Proof of Concept Test and Phase 1 suggest that these latter impacts are not of particular concern.

1.4 Phase 2 of Full-scale Sparging

1.4.1 Technical Objectives

The technical objectives of Phase 2 sparging were similar to that of Phase 1. For the Phase 1 footprint, the objectives were the following:

- Install additional sparge wells to arrive at a final grid pattern that is reflective of the average 33-ft ROI determined during Phase 1; and
- Complete the CO_2 treatment by lowering pH values and Hg concentrations in deep Satilla monitoring wells and extraction wells.

For the southern area (Figure 1-3), the objectives were the following:

- Reduce pH as determined by measured pH via post-sparge Geoprobe groundwater sampling;
- Confirm that CO_2 sparging produces a similar average ROI as the Phase 1 footprint (33 ft) via post-sparge Geoprobe groundwater sampling; and
- Reduce Hg concentrations as determined by comparison of pre- and post-sparging concentrations in selected sparge wells and Geoprobe groundwater samples.

1.4.2 Reporting

Data collected during Phase 2 sparging is compiled and evaluated in this report. Specifically, this report contains the following information:

- A summary of Pre-Phase 2 Geoprobe sampling in the southern area of the Site to delineate the extent of the high pH (> 10.5) plume;
- Borings / well construction logs for sparge wells installed prior to Phase 2 sparging;
- A tabular summary of injection activities at each well, including mass of CO_2 injected per event;
- Changes in pH observed in the monitoring well network;
- Pre- and post-sparge groundwater monitoring results of other constituents such as Hg, total dissolved solids (TDS), silica (Si), arsenic (As) and chromium (Cr);
- Recommendations regarding the next phase of sparging activities.

2 SYSTEM CONSTRUCTION

2.1 Sparge Well Construction

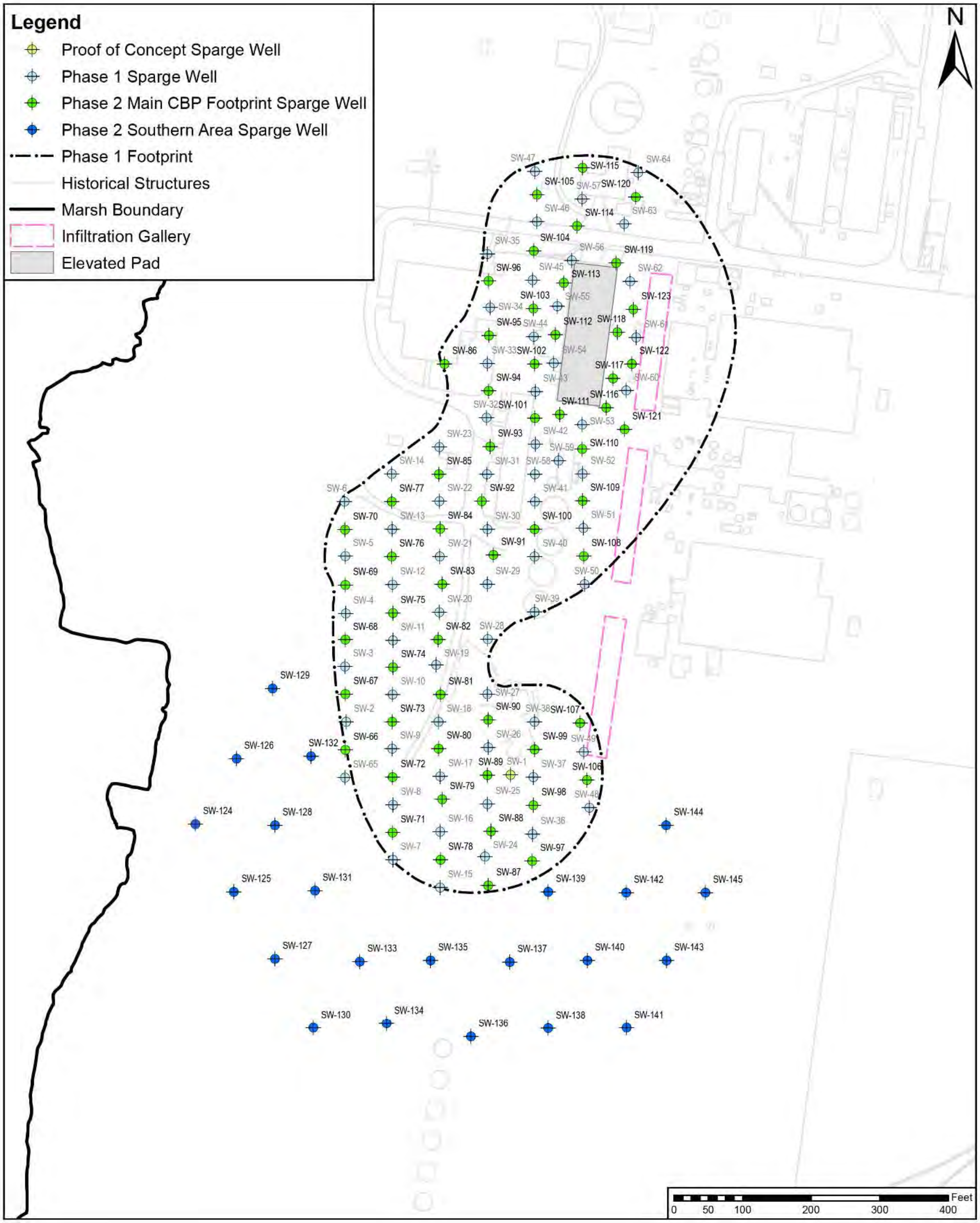
2.1.1 Sparge Well Locations within the Phase 1 Footprint

Phase 1 sparge wells were placed approximately 80 ft apart on a coarse, semi-regular, hexagonal grid pattern (Mutch Associates and Parsons, 2014). This pattern allowed for various final sparge well spacings by adding future sparge wells to the grid. The conceptual layout of Phase 2 sparge wells within the Phase 1 footprint is shown in Figure 2-1. Phase 1 sparge and Phase 2 sparge wells and their associated ROI form sparge "columns." There is overlap of Phase 1 and Phase 2 sparging radii within each column, and a small amount of non-overlap in-between columns. The columns of sparge wells are oriented perpendicular to the direction of groundwater flow. Thus, groundwater within these areas of non-overlap will travel through sparged areas and interact with residual saturation of CO_2 that will continue to treat groundwater. The positioning of the Phase 1 and 2 wells is such that the final sparge well spacing is 69.3 ft in the x-direction and 40 ft in the y-direction.

Shown on Figure 2-2 is the physical layout of 58 sparge wells within the Phase 1 sparging footprint using the conceptual layout described above. Consistent with the conceptual layout, Phase 2 sparge wells (shown in green) are between Phase 1 sparge wells (shown in light blue). Additional Phase 2 sparge wells were placed to the areas east, south and west of the elevated pad (e.g. SW-111 to SW-113 and SW-116 to SW-118) to treat groundwater underneath the pad. Phase 2 sparge wells were not placed in the area near SW-28 and SW-40 because pH monitoring prior to Phase 1 indicated that this location had pH < 10.5.

2.1.2 Sparge Well Locations in Southern Area

In accordance with the *Post-sparge pH Monitoring and Geoprobe Transects* technical memorandum (Mutch Associates, 2014), dated June 20, 2014, Geoprobe sampling for pH and Hg was conducted on July 7 – 9, 2014 and August 7 – 8, 2014 to provide further definition of the CBP in the southern area of the Site. A total of 19 Geoprobe samples (GP-01 through GP-19) were taken from the base of the Satilla aquifer. In addition, the pH of 38 deep Satilla monitoring wells within and just outside the Phase 1 footprint was also collected. The results of this sampling (Figure 2-3) indicated that deep Satilla groundwater with pH > 10.5 was present approximately 220 ft west of SW-2, 320 ft southwest of SW-7, and 350 ft southeast of SW-36.



Above: Layout of Phase 1 and 2 sparge wells.

The conceptual layout for the southern area is shown in Figure 2-4. This layout featured a coarse hexagonal grid pattern, similar to what was employed in Phase 1. The coarse layout allows for placement of additional sparge wells on the hexagonal grid in future phases, pending the results of Phase 2 sparging. The spacing of 114.3 ft was selected because it results in a final spacing of 66 ft when additional sparge wells (shown as the grey circles on Figure 2-4) are placed at the geometric center of triangles formed by the Phase 2 wells.

The physical layout of sparge wells in the southern area is shown above and in Figure 2-5. A total of 22 wells were installed (SW-124 through SW-145). Consistent with the conceptual layout, Phase 2 sparge wells in the southern area are on a coarse grid, approximately 114.3 ft on center. This coarse grid provides more separation between sparge wells and helps mitigate excessive mounding and surfacing.

2.1.3 Sparge Well Installation and Development

Sparge wells were constructed with 2 ft of 2-inch diameter, 0.010-inch slotted Schedule 40 PVC screen with a 2-inch Schedule 40 PVC riser. In general, the well screen was set at the top of the variably-cemented sandstone which forms the base of the Satilla, except where a clay stratum was encountered or determined to be directly above the variably cemented sandstone. If the clay was penetrated greater than 6 in, the boring was grouted (95% Type 2 Portland / 5% bentonite) to the top of clay, and the screen was set just above the clay. Well construction was completed with a 20/30 sand pack to 2 ft above the top of screen, followed by a 2-ft bentonite seal, and cement grout to the surface. Boring logs / well construction diagrams are included in Appendix A.

Following installation, sparge wells were developed by removing an average of 70 gallons of water with the goal of achieving a turbidity of 50 Nephelometric Turbidity Units (NTU). During well development, yields less than 0.5 gallons per minute (gpm) were observed in a number of sparge wells; these wells were surged with a surge block to improve yield. Final yields and water quality data (i.e. pH, specific conductance) obtained during well development are included in the summary table provided in Appendix B.

The pH measured in Phase 2 sparge wells, deep Satilla monitoring wells and pre-sparge Geoprobe locations was contoured to develop a pH 10.5 boundary for the southern area (Figure 2-6). Addition of the southern area increased the areal extent of the CBP from 8.6 to 13.9 acres.

2.1.4 Piezometer Installation

Consistent with the EPA-approved Sparging Work Plan and the Phase 2 Memo, shallow (7-ft bgs) piezometers were installed at the locations shown on Figure 2-7 to supplement the existing shallow Satilla monitoring wells to measure water depth during sparging. 15 piezometers were installed prior to Phase 1 and 20 additional were installed prior to Phase 2. Piezometers were constructed with 5 ft of 2-inch diameter, 0.010-inch slotted Schedule 40 PVC screen with a 2-ft PVC riser. Piezometer construction was completed with a 20/30 sand pack to 0.5 ft above the top of screen, followed by a 0.5-ft bentonite seal, and cement grout to the surface. Piezometer construction diagrams are included in Appendix C.

2.1.5 Monitoring Well Completions

To reduce the potential for groundwater surfacing, threaded plugs were installed on all monitoring wells within the sparging footprint to contain the possible rise of water. The monitoring well network is shown on Figure 2-8. Similar to Phase 1, the monitoring wells were outfitted with fittings and ports to allow for instrumentation cables and manual pressure measurements (Mutch Associates and Parsons, 2014).

2.1.6 Top of Sandstone and Clay Isopach Mappings

A mapping of the top of the variably-cemented sandstone was developed prior to Phase 2 sparge well installation to estimate its depth from ground surface at planned Phase 2 sparge well locations (Figure 2-9). Field data for the elevation of the top of the variably-cemented sandstone was gathered from Phase 1 sparge well boring logs, boring logs from Site monitoring wells and extraction wells, Geoprobe drilling reports, Cone Penetrometer Tests (CPTs), and exploratory borings from the Remedial Investigation (RI). The elevation data was catalogued and consolidated into a master database and used as the basis for interpolation of the top of variably-cemented sandstone elevation over the entire Site. The interpolation was accomplished using Ordinary Kriging with 2nd order trend removal with the Geostatistical Analyst package of ArcGIS (ESRI).[5] The map (Figure 2-9) shows the variably-cemented sandstone as a continuous unit at elevations varying from −39.5 to −43.0 ft (NAVD 88). The variably-cemented sandstone surface generally deepens moving north-northwest (NNW) across the sparging footprint.

A clay isopach map was prepared in order to estimate the location and thickness of clay deposition to assist in well screen placement (Figure 2-10). Data used for the clay isopach map was obtained from the same sources as the top elevation of the variably-cemented sandstone described above. Clay thickness was interpolated over the entire sparging footprint using inverse-distance weighting interpolation with the

---

[5] Ordinary Kriging was performed using an experimental semivariogram (lag size: 43.3 ft, number of lags: 12) modeled with a Gaussian function optimized to reduce root mean square error (nugget: 1.84, major range: 346.6, partial sill: 0.453). Kriging was performed using a search neighborhood of 4 sectors with 45 degree offset (min/max neighbors: 10/15).

Geostatistical Analyst package of ArcGIS. Clay is not pervasive in the subsurface, and is typically thicker in the northern portion of the sparging footprint.

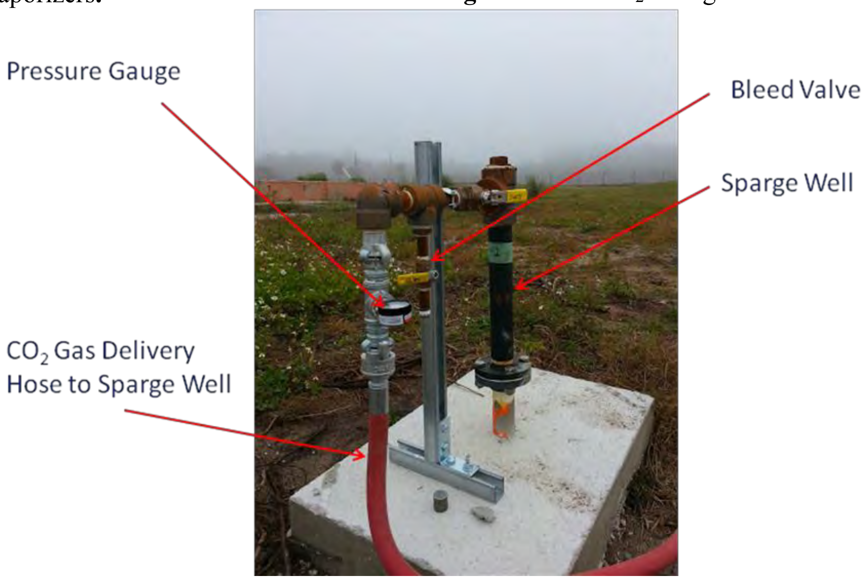
2.2 CO_2 Storage, Vaporization, and Distribution System

Equipment to store, vaporize, and distribute CO_2 to the Phase 1 sparge wells was installed at the Site in October and November 2013, as summarized below.

- Storage and vaporization equipment included two 50-ton refrigerated bulk tanks for liquid CO_2 storage, two 105-kW process vaporizers to convert liquid CO_2 to gaseous form, pressure regulators to reduce CO_2 line pressure from 300 pounds per square inch (psi) to a field delivery pressure of approximately 50 psi, a trim heater to adjust the final temperature of the gaseous CO_2, a flow meter, and other instrumentation and controls.
- Distribution system equipment included distribution piping, eight distribution panels (DPs), portable hoses, and instrumentation. The distribution panels included three 1-inch branch lines following the upstream pressure regulator; each branch line included a downstream pressure regulator and a flow meter (rotameter). A temperature gauge also was provided at each distribution panel. Temperature measurements, together with the flow and pressure measurements, were used to estimate CO_2 mass sparged into each sparge well.

Further detail regarding the equipment installed to support Phase 1 sparging is described in the Phase 1 Report (Mutch Associates and Parsons, 2014). Various system components installed during Phase 1 are also illustrated below.

Left: 105-kW process vaporizers**.** **Right:** 50-ton CO_2 storage tanks



Above: Typical distribution panel. **Below:** Typical sparge wellhead installation

Based on the investigations described in Section 2.1, the sparging footprint for Phase 2 was expanded to the south as shown on Figure 2-5. To accommodate sparging in this area, three additional distribution panel locations were established (DP-9, DP-10, and DP-11), and approximately 800 ft of additional distribution piping was installed at the Site in September and October 2014, as shown on Figure 2-11. On January 7, 2015, distribution panels were shifted from locations DP-1, DP-5, and DP-8 (following substantial completion of sparging at these locations), to locations DP-11, DP-10, and DP-9, respectively, to allow for sparging in the south and southwest. A process and instrumentation drawing (P&ID) illustrating the additional piping and distribution panels is provided as Figure 2-12.

3 PROCEDURES AND PROTOCOLS

3.1 Groundwater Sampling

3.1.1 Monitoring Wells and Extraction Wells

Prior to and following CO_2 sparging, specific monitoring and extraction wells were sampled to provide baseline and post-sparge groundwater quality data. Post-sparge sampling of Satilla monitoring wells occurred approximately 2 weeks after the end of Phase 2 sparging. The monitoring wells and extraction wells that were sampled are presented on Table 3-1. The locations of deep Satilla monitoring wells are shown in Figure 3-1; mid Satilla monitoring wells are shown in Figure 3-2.

Table 3-1: Monitoring Points for Phase 2 CO_2 Sparging

Deep Satilla Monitoring Wells			
MW-105C(b)	MW-357B	MW-507B(a)	MW-515B
MW-112C(a,b)	MW-358B(a)	MW-508B(a)	MW-516B(b)
MW-113C(a,b)	MW-501B(b)	MW-510B(a)	MW-517B
MW-115C(b)	MW-502B(b)	MW-511B(b)	MW-518B(b)
MW-352B	MW-503B(a,b)	MW-512B(b)	MW-519B
MW-353B(a)	MW-504B(b)	MW-513B(b)	MW-1C
MW-357A	MW-505B	MW-514B(b)	MW-2C
Deep Satilla Extraction Wells			
EW-1	EW-4	EW-8	EW-11
EW-2	EW-5	EW-9	
EW-3	EW-6	EW-10	
Mid Satilla Monitoring Wells			
MW-352A	MW-504A	MW-513A	MW-517A
MW-502A	MW-505A	MW-514A	

(a) Indicates a well outside of the sparging area which served as a background monitoring well.
(b) Indicates well was selected for measurement of specific gravity in the field pre-and post-sparging.

Wells were purged and sampled using the low flow "Tubing-in-Screened-Interval" method, pursuant to US EPA Region IV Environmental Investigations Standard Operating Procedure (SOP) – March 2013 (USEPA, 2013). The guidance document *Groundwater Sampling Guidelines for Superfund and RCRA Project Managers* (Yeskis and Zavala, 2002) was also referenced for additional technical support. Per the method, the tubing intake was lowered to the middle of the screened interval of the well, and a peristaltic pump was used to purge the groundwater at a low flow rate. Throughout the purge process, depth-to-water measurements were collected to assess and maintain stable drawdown. A minimum one equipment volume was purged prior to stabilization parameters (pH, specific conductivity, dissolved oxygen, and turbidity). Although not considered stabilization parameters, temperature and oxidation reduction potential were also recorded. Once the required parameters were stable for three consecutive readings, and goals for turbidity had been reached,[6] groundwater samples were collected for laboratory analysis as described in Table 3-2.

Table 3-2: Water Quality Analytes and Associated Laboratory Methods

Analyte	Method	Description
pH	EPA SW-846 9040B	Ion selective electrode
Alkalinity	SM 2320B	Potentiometric titration
Total Hg Filtered/dissolved Hg[(a)]	EPA SW-846 7470A	Cold-vapor atomic absorption spectrophotometry
Total dissolved solids	SM 2540C	Gravimetric
Total metals & silica[(b)]	EPA SW-846 6010B	Inductively Coupled Plasma – Atomic Emission Spectroscopy

(a) If after 2 hours of purging or 5 well volumes had been purged, and turbidity was still greater than 50 NTUs, a filtered sample for Hg was also collected.
(b) Total metals included aluminum, arsenic, barium, beryllium, calcium, cobalt, chromium, iron, potassium, magnesium, manganese, sodium, nickel, selenium, vanadium, zinc.

The groundwater samples were preserved on ice and submitted to TestAmerica Laboratories in Savannah, GA for analysis. Once the groundwater samples had been collected, approximately 900 mL of groundwater were pumped into a graduated cylinder and the specific gravity was determined using a hydrometer for those wells indicated on Table 3-1. Purge logs, including a summary of stabilization parameters and specific gravity measurements, are provided in Appendix D. All of the water quality data collected as part of Phase 2 sampling is presented in Appendix E.

A subset of groundwater samples collected from extraction wells (EWs) had sodium concentrations and specific conductance values much lower than historical values. The well casing of extraction wells are in subsurface vaults that are susceptible to infiltration from rainwater or shallow groundwater when there is a high groundwater table. This infiltration of rain water or shallow groundwater likely resulted in some samples from extraction wells that are not entirely representative of the CBP. For the purpose of this assessment, when measured sodium concentration or specific conductance values from Phase 2 sampling were less than 40% of historical averages, the groundwater samples were considered non-representative of deep Satilla groundwater. Extraction wells sampled during pre-Phase 2 monitoring that were affected by dilution were EW-2, EW-4, EW-5, EW-6, and EW-9, based upon comparison with historical sodium concentrations. The same analysis was done on the Phase 1 data. EW-3 and EW-4 were affected by dilution in the pre-Phase 1 and EW-9 was affected in post-Phase 1. During post-Phase 2 sampling, EW-8, EW-9

[6] Goals for turbidity were: less than 10 NTUs or a minimum 1-hr purge with turbidity less than 50 NTUs and with turbidity measurements within 10%; or a minimum 5-well volume purge or 2-hr purge, whichever occurred first.

and EW-10 were determined to be affected by dilution based upon specific conductance recorded during well purging. As a result, samples from these wells were not submitted to the laboratory for analysis of other parameters. Water quality measurements (i.e. Hg, Si and TDS, etc.) from extraction wells that were suspected to be affected by dilution are not displayed on figures or used to calculate averages or percent removals. It should be noted that pH values collected in these extraction wells were considered to be not significantly affected by this dilution because of the logarithmic scale of pH. A 10:1 dilution of deep Satilla is required to bias measured pH values low by one standard unit. The pH measured in the extraction wells listed above were included in figures and included in summary tables of this report.

3.1.2 Geoprobe Sampling

Pre-sparge Geoprobe sampling of groundwater in the southern area is discussed in Section 2.1.2. Post-sparge Geoprobe sampling in the southern area was also performed to provide groundwater quality data after sparging. The post-sparge Geoprobe sampling program consisted of 16 locations along the pre-sparge Geoprobe transects to allow for pre-sparge and post-sparge comparisons of water quality. Also, the locations were placed at varying distances from sparge wells to provide information on the radius of influence in the southern area. Each location was sampled using a 4-ft screen set approximately 1 ft above the estimated depth to sandstone, with the exception of GP-27a, where the screen was set 3 ft above the estimated depth to sandstone. A location in-between GP-16 and SW-142 (Figure 2-6) was repeatedly met with refusal and therefore a groundwater sample was not collected in this area. Samples were measured for pH in the field and field-filtered using a 0.45 μm filter. The samples were then sent to TestAmerica Laboratories in Savannah, GA for analysis of dissolved Hg using EPA method SW-846 7470A.

3.2 Monitoring During Sparging

Groundwater pH and conductivity were measured throughout the sparging program in all monitoring points within the sparging footprint. A portable peristaltic pump was used to pump water to the surface. Tubing was lowered to the mid-point of the screen and water was pumped with a flow rate that ranged from 0.25 to 2.50 L/min. The water passed through a flow cell equipped with a YSI Professional Plus multi-parameter probe that measured pH, specific conductance, barometric pressure, and temperature. The probe was set to take readings every 30 seconds. Wells were pumped until all parameters were stabilized over three consecutive readings. The final stabilized reading was used as the data point of record. The data was recorded on the internal memory of the meter and was reported at the end the day.

Field measurements of pH and conductivity occurred at a frequency of approximately once per week in deep Satilla monitoring points within the sparging footprint. Several wells to the west of the sparging footprint were sampled approximately once per month to assess lateral migration of the CBP. In addition, wells screened in the Coosawhatchie A/B formation (HWEast2, HWEast3, HWEast5, MW-352D, MW-115, and MW-360D) were sampled two times during Phase 2 operations to assess effect of sparging on pH (Figure 3-3). Shallow Satilla monitoring wells were not monitored as part of Phase 2 sparing effort.

All pH electrodes were calibrated daily to ensure accuracy of results. A three point standard curve using pH 4.01, 7.00, and 10.01 was used. A valid pH calibration curve was obtained only when the slope was within 5% of the theoretical value of −59 mV/pH. Specific conductance was also calibrated daily. A calibration check was performed at least once per day to ensure electrode stability.

3.3 Sparge Operations

3.3.1 Sparge Regimens

Phase 1 of CO_2 sparging tested four sparging regimens to optimize CO_2 efficiency (Mutch Associates and Parsons, 2014). The Phase 1 Report recommended a once per week regimen with a 4-hr duration to start, with adaptive management to optimize well-specific performance. Phase 1 sparging also indicated that specific wells needed longer sparging intervals (e.g. 8 or 24 hr) to provide adequate mass flows of CO_2. Since this approach was successful in Phase 1, the same procedures were applied throughout Phase 2 of CO_2 sparging.

3.3.2 Required CO_2 Mass Per Well

During Phase 1 sparging, an overall mass of at least 8,000 to 9,000 lb of CO_2 per sparge well was required in moderate alkalinity groundwater (< 4,000 mg/L $CaCO_3$). Areas of higher alkalinity were sparged at approximately 1.5-times (12,000 lb) to 2-times (16,000 lb) this amount to account for the increased demand. To prepare for Phase 2, alkalinity was measured in select sparge wells and Geoprobe locations. This information was combined with deep Satilla alkalinity data collected prior to Phase 1 to interpolate alkalinity across the entire sparging footprint (Figure 3-4).[7] The interpolated alkalinity map shows high alkalinity areas in the northern portion of the Site near the elevated pad, and in the southwestern area of the Site.

To determine CO_2 dosing in high alkalinity areas, the total mass of CO_2 was scaled from the 8,000 lb baseline established in Phase 1 using the following procedure. First, the average alkalinity within a 33-

[7] This map was created using the radial basis function interpolator in ArcGIS Geostatistical Analyst. Data used for the interpolation are indicated on Figure 3-4. Phase 2 sparge wells with a pH <10.5 were excluded from the interpolation data set because they were assumed to have been influenced by Phase 1 sparging. MW-105C was replaced with March 2014 data because of an error in reporting of alkalinity from the lab. The data set was supplemented with alkalinity values from 2010 (MW-101C, MW-106C, MW-304C, MW-306B, MW-351B, MW-355B), 2006 (MW-307B), and 2003 (MW-114C and MW-116C).

ft radius of each sparge well was estimated using the interpolated alkalinity map (Figure 3-4) and the zonal statistics toolbox of ArcGIS (version 10.3). Second, an alkalinity multiplier was calculated for each sparge well by dividing the average alkalinity by 4,000 mg/L as $CaCO_3$ (the baseline alkalinity from Phase 1). Finally, the required CO_2 dose was determined by scaling up the baseline in a linear fashion according to Table 3-3. For example, the area within 33 ft of SW-94 had a mean alkalinity of 12,510 mg/L. It therefore had an alkalinity multiplier of 3.13 which resulted in a CO_2 dose of 28,000 lb. The CO_2 mass requirements for each Phase 2 sparge well are shown on Figure 3-5.

Table 3-3: Alkalinity-CO_2 Dose Relationship

Average Alkalinity within ROI (mg/L as $CaCO_3$)	Alkalinity Multiplier	CO_2 dose (lb)
Less than 4,000	Less than 1.00	8,000
4,001 to 6,000	1.01 to 1.50	12,000
6,001 to 8,000	1.51 to 2.00	16,000
8,001 to 10,000	2.01 to 2.50	20,000
10,001 to 12,000	2.51 to 3.00	24,000
12,001 to 14,000	3.01 to 3.50	28,000
14,001 to 16,000	3.51 to 4.00	32,000
16,001 to 18,000	4.01 to 4.50	36,000
18,001 to 20,000	4.51 to 5.00	40,000

This method of calculating required CO_2 mass was also retroactively applied to Phase 1 sparge wells (Figure 3-6). In light of the new alkalinity data, many Phase 1 sparge wells had less than the required CO_2 mass using the linear scale-up method described above. Therefore, these wells were sparged during Phase 2 to achieve the revised target. In addition, Phase 1 sparge wells that had already met the new mass requirements received approximately 2,000 lb of CO_2 during Phase 2. The purpose of the additional sparging was to treat high pH groundwater that may have moved into the zone of influence of a Phase 1 well during sparging of Phase 2 sparge wells. A secondary benefit of sparging all Phase 1 sparge wells was the replenishment of the residual saturation of CO_2 which helps protect against long-term rebound of pH.

The only sparge well that was an exception to the CO_2 dosing described above was SW-124. Pre-sparge sampling of SW-124 indicated pH < 10.5 (9.82) and low Hg (8 µg/L), indicating this area is not part of the CBP. Therefore, this well was not sparged during Phase 2 and its target CO_2 was effectively set to zero. All of the other southern wells outside the 10.5 boundary were sparged because of either their close proximity to the boundary (e.g. SW-141) or elevated Hg in the area (e.g. SW-136).

3.3.3 Maximum Wellhead Pressures

Fractures can be generated in geologic formations if air or any other gas is injected at a pressure that exceeds the sum of the natural strength of the formation and the in-situ stresses present (Suthersan, 1997). The pressure required to fracture a consolidated geologic formation is a function of the cohesive or tensile strength of the formation and the pressure exerted by the weight of soil and water. Because the Satilla aquifer is primarily composed of non-cohesive sands, cohesive strength was conservatively assumed to be zero. Therefore, considering only the weight of the water and soil, the minimum pneumatic fracture initiation pressure, P_i is:

$$P_i > d_w(\gamma_w \phi + \gamma_{soil}(1-\phi)) + (d_{tot} - d_w)\gamma_{soil}(1-\phi) \qquad (3\text{-}1)$$

where d_w is the depth of water (saturated thickness), d_{tot} is the total depth of soil, ϕ is the soil porosity, γ_w is the specific weight of water (62.4 lb/ft^3) and γ_{soil} is the specific weight of soil.

Sparge wells (enumerated below in the tables as SWs) at the Site were screened at different intervals and therefore would have their own unique minimum pneumatic fracture initiation pressures. Table 3-4 and Table 3-5 provides calculated minimum pneumatic fracture initiation pressures for all Phase 1 and Phase 2 sparge wells, respectively.

The calculations of P_i presented in Tables 3-4 and 3-5 assumed a 5-ft unsaturated zone, porosity of 0.30, and a specific gravity of soil equal to 2.65 (specific weight of soil equal to 116 lb/ft^3). The 5 ft of unsaturated zone provides a conservative estimate of P_i (the actual depth of the unsaturated zone varies from approximately 3 to 4 ft). There is also additional head loss from the well head to the base of the sparge well screen, resulting in lower effective pressures at the well screen. Therefore, actual field conditions at a particular sparge well would yield a slightly larger value of P_i, which could allow for slightly higher sparging pressures at the well head. During sparging implementation, pressure applied to individual sparge wells was gradually increased until a satisfactory flow was achieved or until pressures were no more than 2 to 3 psi of P_i.

Table 3-4: Calculated Minimum Pneumatic Fracture Initiation Pressure for Phase 1 Sparge Wells

Sparge Well	Top of Screen, d_{tot} (ft bgs)	Depth of water, d_w (ft)	P_i (psi)	Sparge Well	Top of Screen, d_{tot} (ft bgs)	Depth of water, d_w (ft)	P_i (psi)
SW-2	47.5	42.5	32.3	SW-34	42.0	37.0	28.4
SW-3	46.0	41.0	31.2	SW-35	42.0	37.0	28.4
SW-4	48.5	43.5	32.9	SW-36	47.0	42.0	31.9
SW-5	48.5	43.5	32.9	SW-37	49.0	44.0	33.3
SW-6	48.5	43.5	32.9	SW-38	49.5	44.5	33.6
SW-7	48.0	43.0	32.6	SW-39	49.5	44.5	33.6
SW-8	48.0	43.0	32.6	SW-40	50.0	45.0	34.0
SW-9	47.5	42.5	32.3	SW-41	48.5	43.5	32.9
SW-10	47.5	42.5	32.3	SW-42	49.5	44.5	33.6
SW-11	49.5	44.5	33.6	SW-43	46.0	41.0	31.2
SW-12	49.0	44.0	33.3	SW-44	47.0	42.0	31.9
SW-13	49.5	44.5	33.6	SW-45	42.0	37.0	28.4
SW-14	47.0	42.0	31.9	SW-46	42.0	37.0	28.4
SW-15	47.0	42.0	31.9	SW-47	44.0	39.0	29.8
SW-16	49.0	44.0	33.3	SW-48	45.0	40.0	30.5
SW-17	48.5	43.5	32.9	SW-49	50.5	45.5	34.3
SW-18	50.5	45.5	34.3	SW-50	49.0	44.0	33.3
SW-19	44.0	39.0	29.8	SW-51	50.0	45.0	34.0
SW-20	49.0	44.0	33.3	SW-52	49.5	44.5	33.6
SW-21	44.0	39.0	29.8	SW-53	46.5	41.5	31.6
SW-22	48.0	43.0	32.6	SW-54	42.0	37.0	28.4
SW-23	48.0	43.0	32.6	SW-55	40.5	35.5	27.4
SW-24	48.5	43.5	32.9	SW-56	45.5	40.5	30.9
SW-25	51.0	46.0	34.7	SW-57	46.0	41.0	31.2
SW-26	50.0	45.0	34.0	SW-58	49.0	44.0	33.3
SW-27	49.5	44.5	33.6	SW-59	49.5	44.5	33.6
SW-28	49.5	44.5	33.6	SW-60	45.5	40.5	30.9
SW-29	50.0	45.0	34.0	SW-61	47.0	42.0	31.9
SW-30	50.0	45.0	34.0	SW-62	45.0	40.0	30.5
SW-31	47.0	42.0	31.9	SW-63	47.6	42.6	32.3
SW-32	47.5	42.5	32.3	SW-64	50.5	45.5	34.3
SW-33	46.0	41.0	31.2	SW-65	48.0	43.0	32.6

Table 3-5: Calculated Minimum Pneumatic Fracture Initiation Pressure for Phase 2 Sparge Wells

Sparge Well	Top of Screen, d_{tot} (ft bgs)	Depth of water, d_w (ft)	P_i (psi)	Sparge Well	Top of Screen, d_{tot} (ft bgs)	Depth of water, d_w (ft)	P_i (psi)
SW-66	48	43	32.6	SW-106	49	44	33.3
SW-67	46.5	41.5	31.6	SW-107	51	46	34.7
SW-68	49	44	33.3	SW-108	48.75	43.75	33.1
SW-69	49	44	33.3	SW-109	49	44	33.3
SW-70	46.5	41.5	31.6	SW-110	49	44	33.3
SW-71	47.5	42.5	32.3	SW-111	46	41	31.2
SW-72	47	42	31.9	SW-112	43	38	29.1
SW-73	48	43	32.6	SW-113	42	37	28.4
SW-74	49	44	33.3	SW-114	45	40	30.5
SW-75	48	43	32.6	SW-115	47	42	31.9
SW-76	45.7	40.7	31.0	SW-116	46	41	31.2
SW-77	46	41	31.2	SW-117	45.5	40.5	30.9
SW-78	48	43	32.6	SW-118	44	39	29.8
SW-79	49.5	44.5	33.6	SW-119	45	40	30.5
SW-80	49.5	44.5	33.6	SW-120	50	45	34.0
SW-81	48.5	43.5	32.9	SW-121	48	43	32.6
SW-82	49	44	33.3	SW-122	50	45	34.0
SW-83	43.5	38.5	29.5	SW-123	43	38	29.1
SW-84	46.5	41.5	31.6	SW-124	44.5	39.5	30.2
SW-85	47.5	42.5	32.3	SW-125	46	41	31.2
SW-86	45	40	30.5	SW-126	46	41	31.2
SW-87	50	45	34.0	SW-127	48.5	43.5	32.9
SW-88	48	43	32.6	SW-128	47	42	31.9
SW-89	49	44	33.3	SW-129	46.5	41.5	31.6
SW-90	49	44	33.3	SW-130	47	42	31.9
SW-91	48.5	43.5	32.9	SW-131	48.5	43.5	32.9
SW-92	43	38	29.1	SW-132	48.5	43.5	32.9
SW-93	46	41	31.2	SW-133	49	44	33.3
SW-94	44	39	29.8	SW-134	47.5	42.5	32.3
SW-95	42.5	37.5	28.8	SW-135	46	41	31.2
SW-96	41	36	27.8	SW-136	46	41	31.2
SW-97	49	44	33.3	SW-137	48	43	32.6
SW-98	49	44	33.3	SW-138	48	43	32.6
SW-99	50	45	34.0	SW-139	48.5	43.5	32.9
SW-100	49	44	33.3	SW-140	49.5	44.5	33.6
SW-101	42.5	37.5	28.8	SW-141	49	44	33.3
SW-102	43	38	29.1	SW-142	49	44	33.3
SW-103	42	37	28.4	SW-143	48	43	32.6
SW-104	41.5	36.5	28.1	SW-144	47	42	31.9
SW-105	44	39	29.8	SW-145	48	43	32.6

3.3.4 Sequence of Operations

Phase 2 sparging was initiated on October 17, 2014 and continued through April 28, 2015, with sparge operations suspended over the 2-week holiday period between December 19, 2014 and January 4, 2015. The sparge well commissioning process entailed gradually applying pressure to individual wells to understand well-specific pressure / flow relationships, while at the same time making observations and collecting shallow groundwater elevations to understand the potential for groundwater mounding and surfacing. Initial guidelines for sparge well sequencing included the following:

- Two sparge wells per distribution panel would be sparged simultaneously, initially for approximately 4-hr periods.
- Extended duration sparging would be applied to areas with high alkalinity.
- When possible, sparging would occur from adjacent distribution panels, and focus on contiguous portions of the Site, to reduce operator travel time between distribution panels.
- During sparging, water levels were monitored in piezometers. Superposition of mounding was not significant at a 160-ft spacing; groundwater levels generally never rose to within 1 ft of the ground surface with the exception being the northern portion of the Site near SW-112 and SW-113 (discussed below). Therefore, sparging into adjacent sparge wells (approximately 80 ft apart) was tested with close monitoring of nearby piezometers. This closer spacing did not result in significant superposition of mounding and therefore sparging into adjacent sparge wells was incorporated into the schedule over most of the Site.
- After consecutive rain events in late November 2014, the groundwater levels in the northern portion of the Site were within 1 to 2 ft of the ground surface. Consequently, the northern sparge wells adjacent to the road were shifted to shorter sparge durations (1 to 4 hr) to minimize groundwater rise.

3.3.5 Sparge Well and Monitoring Well Maintenance

Basic maintenance was required on sparge wells and monitoring wells. Notably:

- Approximately seven sparge wells were briefly decommissioned and repaired by affixing a new flange to connect the well pipe to the sparge well completion head.
- After two sparge events, SW-102 had evidence of short circuiting within 10 ft below ground surface. To mitigate the short circuiting, an approximately 12 ft 1-in diameter pipe slip with a 2-in packer was installed inside of SW-102. The pipe slip was an effective fix, bypassing the first 10 ft of well and allowed SW-102 to reach its CO_2 mass requirement.

- The coupling that connected the well pipe to the well stick up was replaced on eight monitoring wells. The monitoring well maintenance did change the elevations of the following monitoring wells: MW-504B, MW-507B, MW-513B, MW-517A, MW-517B, MW-518B, MW-519A, and MW-519B. The tops of casing of these wells were resurveyed.
- MW-112C and MW-112B were outfitted with the same well completions as described in Section 2.1.5. In addition, these wells were encircled with two layers of sandbags as an added precaution to control potential surfacing of groundwater as a result of their position west of the marsh access road in the southwest portion of the Site. During SW-126 sparge events, MW-112B showed evidence of minor upwelling of groundwater in the annular space between the inner and outer casing of the well. To mitigate this occurrence, quick-dry cement was added to the inside of the annular space of MW-112B, the sparging durations for SW-126 were shortened, and MW-112B was checked approximately every half-hour while SW-126 was sparged.

3.4 Field Measurements During Sparging

During sparging of a well, measurements of temperature, flow rate and pressure were made at the distribution panel. Pressure was measured at a gauge just downstream of the rotameter. These measurements were collected at periodic intervals, typically every half hour during normal sparging operations. The collected measurements were recorded in electronic spreadsheets stored on waterproof tablets and copied to a master spreadsheet for calculation of total mass sparged (see Section 3.5). A summary of these measurements for each sparge well is provided in Appendix F.

3.5 Measurement and Calculation of Flowrates and CO_2 Mass

The flow rate of gas to the sparge well was read from a distribution panel rotameter upstream of the well head. Rotameters report accurate flow rates only when the operating conditions (temperature and pressure) are the same as the conditions under which the rotameter was calibrated. When operating and calibration conditions differ, flow readings from a rotameter must be corrected. The rotameter correction equation for gases is:

$$Q^*(\text{scfm}) = Q_{\text{rotameter}} \sqrt{\left(\frac{T_{std}}{T_{act}}\right)\left(\frac{P_{act}}{P_{std}}\right)} \qquad (3\text{-}2)$$

where $Q_{rotameter}$ is the flow reading from the rotameter, Q^* is the gas volumetric flow rate (in scfm), P_{act} is the actual pressure (in psia), T_{act} is the actual temperature (in °R), P_{std} is the standard pressure (in psia), T_{std} is the standard temperature (530 °R) of the rotameter correction. Rotameters installed on the permanent system were calibrated for carbon dioxide, so an additional specific gravity correction was not required. For CO_2 sparging, Equation 3-2 becomes:

$$Q^*(\text{scfm } CO_2) = Q_{\text{rotameter}} \sqrt{\left(\frac{530^\circ R}{T_{act} + 460}\right)\left(\frac{P_{act} + 14.7}{14.7 \text{ psi}}\right)} \tag{3-3}$$

The rotameter used for the portable system was not calibrated for CO_2. Therefore, a specific gravity correction was also required:

$$Q^*(\text{scfm } CO_2) = Q_{\text{rotameter}} \sqrt{\left(\frac{530^\circ R}{T_{act} + 460}\right)\left(\frac{P_{act} + 14.7}{14.7 \text{ psi}}\right)\left(\frac{1}{SG}\right)} \tag{3-4}$$

The mass of CO_2 injected into sparge wells was calculated by numerically integrating the flow versus time data for each sparge well (Appendix F). The trapezoidal method of integration was employed and the equation used to calculate the mass for each well is shown below:

$$M_{\text{sparged}} = \rho^*_{gas} \int Q^* dt \approx \rho^*_{gas} \sum \bar{Q}^* \Delta t \tag{3-5}$$

where ρ^*_{gas} represents the density of carbon dioxide equal to 0.1144 lb/ft^3 at standard temperature and pressure (70 °F and 14.7 psi). A correction factor (C_F) of 1.136 was used to modify Equation 3-4 to more accurately account for the mass to each sparge well (Mutch Associates and Parsons, 2014):

$$Q^*(\text{scfm } CO_2) = C_F Q_{\text{rotameter}} \sqrt{\left(\frac{530^\circ R}{T_{act} + 460}\right)\left(\frac{P_{act} + 14.7}{14.7 \text{ psi}}\right)} \tag{3-6}$$

3.6 Piezometric Surface and Groundwater Table

The 20 shallow piezometers installed prior to Phase 2, the 15 piezometers installed prior to Phase 1, and the shallow Satilla monitoring wells were checked for water level rise via manual measurement with an electronic water level meter.

A total of 11 pressure transducers (Solinst, Levelogger) were used throughout the sparging program for one piezometer and select deep Satilla monitoring wells. The transducers were used to obtain information on piezometric surface rise in the deep Satilla and shallow groundwater level rise throughout the sparging program. Five transducers were placed within the sparging footprint: PZ-46, MW-501B, MW-513B, MW-516B and MW-2C. Six transducers were placed to the west of the sparging footprint: MW-112C, MW-113C, MW-353B, MW-503B, MW-507B and MW-508B. Each transducers was set to a designated depth within the well and securely affixed to prevent any movement. Automatic data loggers connected to each transducer were synchronized for time and programmed to record water levels at 5-minute intervals during the CO_2 sparging period. All transducers were installed by October 21, 2014 and collected data through May 5, 2015.

3.7 Air Monitoring

Ambient air monitoring during sparging consisted of grab sample monitoring for carbon dioxide, oxygen, and hydrogen sulfide using a MultiRae IR Plus multi-gas meter, and for Hg using a Jerome Model 431X meter. The air space near representative sparge wells were selected over the course of the program for sampling. Typically, measurements were collected at the sparge wells and approximately 10 ft north, south, east, and west of the sparge wells (i.e., five locations per sparge well).

Approximately 270 sampling events (five locations each) were conducted over the course of the program; sample results are reported on the forms provided in Appendix G; a summary of the results is provided below (Table 3-6). No exceedances of action levels for the four air constituents monitored were observed.

Table 3-6: Summary of Air Monitoring Results

Air Constituent	Units	Action Level	Minimum Observed Level	Maximum Observed Level	Notes
CO_2	ppmv	2,500	330	1,270	
O_2	% by volume	> 19.5% and < 22.0%	20.9	20.9	
H_2S	ppmv	10	0	6	Only 15 samples above 0
Hg	mg/m^3	0.05	0	0.005	Only 13 samples above 0.000

4 RESULTS OF PHASE 2 SPARGING

4.1 Sparge Well Flow Rates and Total CO_2 Mass

4.1.1 CO_2 Flow Rates

The first two weeks of sparging operations involved a “break-in” period where CO_2 was injected into each Phase 2 sparge well for the first time. These first injections provided critical information on injection pressures required to achieve flow. All Phase 2 wells had measureable flow at moderate pressures (30 to 35 psi) indicating that they were functional sparge wells. The average flow rates for each Phase 2 sparge well over the entire duration of sparging varied from 15.5 scfm (SW-88) to 54.1 scfm (SW-73) (Figure 4-1). The average flow rate for all Phase 2 sparge wells was 29.2 scfm. As described in Section 3.3.2, all Phase 1 sparge wells received CO_2 during the Phase 2 sparging effort. The average flow rates for each Phase 1 sparge well over the entire duration of sparging varied from 3.4 scfm (SW-43) to 42.4 scfm (SW-22) (Figure 4-2). The average flow rate for all Phase 1 sparge wells during Phase 2 was 22.7 scfm, which was similar to that observed during Phase 1 (26.0 scfm).

4.1.2 CO_2 Total Mass

The total amount of CO_2 injected during Phase 2 was 1,521,000 lb. Phase 2 sparge wells received 1,199,000 lb while Phase 1 sparge wells received additional 321,000 lb. By comparison, 783,000 lb was sparged during Phase 1.

The sparged mass and target mass of CO_2 for each of the Phase 2 sparge wells are shown in Figure 4-3. As described earlier in Section 3.3.2, sparge well target masses ranged from 8,000 to 40,000 lb of CO_2. All Phase 2 sparge wells received their target mass. The sparged mass and target mass of CO_2 for each Phase 1 sparge wells are shown in Figure 4-4. All Phase 1 sparge wells received their target mass. As described earlier, all Phase 1 sparge wells (SW-2 through SW-65) received at least 2,000 lb during Phase 2 of CO_2 sparging.

4.1.3 CO_2 Mass Balance

A system-wide mass balance was performed to determine the total mass of CO_2 injected and to verify the masses injected into each sparge well. The total mass delivered to the Site must be equal to the sum of the CO_2 mass sparged, the CO_2 left in inventory and any major losses during start-up:

$$M_{delivered} = M_{sparged} + M_{inventory} + M_{major\ losses} \quad (4\text{-}1)$$

The total mass delivered to the Site by Airgas was 1,542,000 lb (771.0 tons). The storage tanks had 30,000 lb (15 tons) remaining in inventory at conclusion of sparging. During system start-up, the tank telemetry system indicated that approximately 7,000 lb (3.5 tons) was used, effectively setting $M_{major\ losses}$. The mass of CO_2 sparged, calculated using numerical integration of the flow versus time data (Equation 3-5), was 1,521,000 (760.5 tons). The mass balance error was calculated according to:

$$\text{Error }\% = \frac{(M_{sparged} + M_{inventory} + M_{major\ losses}) - M_{delivered}}{M_{delivered}} \times 100\% \qquad (4\text{-}2)$$

The mass balance error calculated using this approach was 1.0%:

$$\text{Error }\% = \frac{(1{,}521{,}000 + 30{,}000 + 7{,}000) - 1{,}542{,}000}{1{,}542{,}000} \times 100\% = 1.0\% \qquad (4\text{-}3)$$

This is an acceptable level of error for this type of system mass balance.

4.2 Effect of Sparging on pH

4.2.1 Pre-sparge pH

Groundwater monitoring results for the deep Satilla from 2011-2012 (Figure 4-5) serve as an appropriate pre-sparge baseline for the CBP because sparging began in late 2013 as part of the Proof of Concept Test. The CBP during this period was characterized as consistently having pH between 10.5 and 12.0, with many values greater than 11.5. As described in Section 2.1, the Phase 1 sparging footprint was determined via interpolation of these pH values.

The pH in deep Satilla monitoring locations prior to the start of Phase 2 sparging is shown in Figure 4-6. In general, pH within the sparging footprint varied from 6.44 (MW-502B) to 12.00 (MW-352B). Many (22 out of 30) deep Satilla monitoring points within the sparging footprint were below pH 7.5 as a result of Phase 1 sparging. Only MW-352B (12.00), MW-112C (10.83) and MW-516B (11.62) had pre-sparge pH greater than 10.5.

Pre-sparge pH in Phase 2 sparge wells (Figure 4-7) varied from 6.58 (SW-138) to 12.08 (SW-86). Phase 2 sparge wells were not expected to have pH less than 10.5, since they are generally located at least 40 ft from their nearest Phase 1 sparge well. However, three Phase 2 sparge wells within the Phase 1 footprint had pH $\leq$ 7.5 (SW-83, SW-84 and SW-100), indicating that groundwater in these areas was completely treated during Phase 1 sparging and that sparging radii at select locations were at least 40 ft. This is consistent with the average 33 ft ROI determined in Phase 1 and the observation of neutral pH in monitoring well/sparge well pairs that were greater than 35 ft apart during Phase 1. Several other sparge wells had pH ≤ 10.5, suggesting partial treatment during Phase 1 sparging.

A composite map showing pH in deep Satilla monitoring locations (monitoring wells, extraction wells, select Phase 1 sparge wells, Phase 2 sparge wells, and Geoprobe locations) is provided as Figure 4-8. This map displays all information that was known about deep Satilla pH prior to the start of Phase 2 sparging. Alternating low pH (blue to green colors) and high pH (yellow to red colors) is noticeable in neighboring sparge wells along the western edge of the sparging footprint. This is a reflection of the low-pH areas created at Phase 1 sparge wells that persisted for months after sparging.

The pH in mid Satilla monitoring wells is generally lower than in the deep Satilla, consistent with the conceptual model of the CBP as a dense plume that moved to the bottom of the Satilla aquifer. Mid Satilla pH within the sparging footprint from 2011-2012 (Figure 4-9) varied from 6.38 (MW-501A) to 11.60 (MW-514A). Only MW-512A and MW-514A had pH greater than 10.5, indicating that these wells are screened at elevations that is representative of the CBP. After Phase 1, the pH in MW-512A and MW-514A had decreased to 8.59 and 6.86, respectively (Mutch Associates and Parsons, 2014). Prior to Phase 2, mid Satilla wells showed pH from 6.13 (MW-502A) to 10.01 (MW-352A) (Figure 4-10).

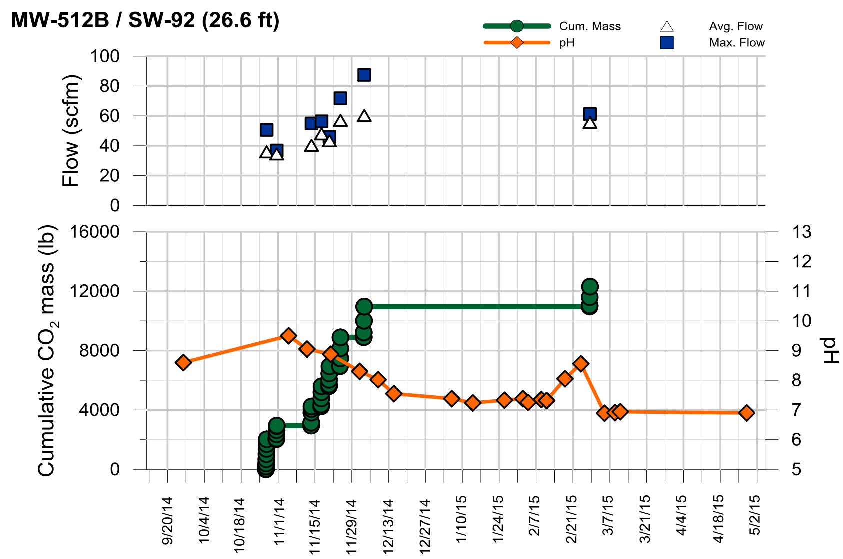
4.2.2 pH Monitoring Results During Sparging

Periodic monitoring pH results for all 28 deep Satilla monitoring points within 50 ft of a sparge well are shown in Figures 4-11 through 4-24. These figures are arranged in order of increasing radial distance from sparge well to deep Satilla monitoring point. As illustrated below for MW-512B, each figure shows pH versus time data for the monitoring point along with the identity of its nearest sparge well, the distance to the sparge well, the sparge well average and maximum flow rates, and the cumulative CO_2 mass injected.

As shown below and on Figure 4-19, MW-512B had a pre-sparge pH of 8.60. During sparging into SW-92 which is 26.6 ft away, the pH increased slightly and then gradually decreased, and then eventually stabilized at pH 6.90 at the end of Phase 2. The gradual lowering of pH during Phase 2 shown above for MW-512B was observed in many deep Satilla monitoring wells including MW-511B (Figure 4-15), EW-8 (Figure 4-16), MW-512B (Figure 4-19), MW-357B (Figure 4-19), EW-3 (Figure 4-20) and MW-105C (Figure 4-22).

Several deep Satilla monitoring points had pH near 7.0 prior to start of Phase 2 sparging. During Phase 2 sparging, the pH in these wells did not change appreciably. Examples of this behavior are MW-502B (Figure 4-11), MW-518B (Figure 4-11), MW-505B (Figure 4-14), EW-9 (Figure 4-15), EW-1 (Figure

4-17), MW-519B (Figure 4-17), MW-517B (Figure 4-18), MW-504B (Figure 4-18), MW-357A (Figure 4-20), MW-1C (Figure 4-21) and EW-11 (Figure 4-21).



Above: pH as a function of time in MW-512B, and CO_2 flow and CO_2 mass as a function of time in SW-92 (26.6 ft away from MW-512B)

Two deep Satilla monitoring points showed a decrease in pH, followed by an increase in pH back to pre-sparge levels. This behavior was observed for MW-352B (Figure 4-12) and MW-513B (Figure 4-13). MW-516B was the only deep Satilla monitoring point within 50 ft of a sparge well that did not show an appreciable change in pH during Phase 2 sparging (Figure 4-23). MW-352B, MW-513B and MW-516B are discussed in more detail in Section 4.2.3.

Deep Satilla pH in monitoring points at distances larger than 50 ft are shown in Figure 4-25 (MW-515B and EW-5). These monitoring points are at considerable distances from sparge wells and were not expected to show large improvements in pH. The pH in MW-515B was unchanged for most of Phase 2 with the exception of the last 6 weeks where it decreased from 9.11 to 6.45 and then increased to a final pH of 8.66. The pH in EW-5 was highly variable during Phase 2 sparging, varying from approximately pH 9 to 11.

As described earlier, pH was monitored in eight deep Satilla monitoring wells west of the sparging footprint to assess lateral movement of the CBP during sparging (Figure 4-26 through Figure 4-28). Seven of these wells (MW-353B, MW-358B, MW-503B, MW-507B, MW-508B, MW-112C and MW-113C) exhibited little change in pH during Phase 2 sparging. MW-510B (Figure 4-27), which was closest to the sparging footprint, was the only well to show an increase in pH (10.9) at the end of Phase 2.

A subset of mid Satilla monitoring wells that had historic high pH were measured for pH during Phase 2 sparging (Figure 4-29 through Figure 4-31). These wells showed either a decrease in pH to near-neutral levels (MW-352A, MW-514A and MW-517A) or sustained a near-neutral pH through the entire duration of Phase 2 (MW-502A, MW-504A, MW-505A and MW-513A).

Table 4-1: Summary of Pre- and Post-Sparge pH in Deep Satilla Monitoring Points within the Phase 1 Sparging Footprint

Monitoring Point	Pre-sparge 2011-2012	Pre-Phase 1	Post-Phase 1	Pre-Phase 2	Post-Phase 2	ΔpH
EW-1	11.33	11.28	6.27	6.50	6.32	−5.01
EW-2	11.20	10.50	6.57	7.26	6.47	−4.73
EW-3	11.78	11.01	9.84	9.79	7.01	−4.77
EW-4	11.73	11.20	7.01	8.50	9.69	−2.04
EW-5	11.02	10.50	10.74	9.06	11.22	0.20
EW-6	11.49	11.75	7.41	6.96	6.78	−4.71
EW-8	10.88	10.50	9.09	7.52	6.59	−4.29
EW-9	11.44	10.90	6.73	7.30	6.68	−4.76
EW-10	11.23	11.10	7.34	7.41	7.67	−3.56
EW-11	11.72	8.62	6.49	6.85[b]	6.39	−5.33
MW-105C	11.50	11.08	6.68	7.3	6.38	−5.12
MW-115C	12.00	10.70	6.68	9.83	8.63	−3.37
MW-1C	11.61[a]	8.98	6.54	6.61	6.55	−5.06
MW-2C	11.78[a]	8.71	6.49	6.70	6.65	−5.13
MW-352B	11.50	11.53	12.89	12.00	11.39	−0.11
MW-357A	11.20	10.20	6.54	6.79	6.46	−4.74
MW-357B	11.60	11.08	8.82	8.78	6.20	−5.40
MW-501B	11.47	11.30	6.81	6.79	6.73	−4.74
MW-502B	11.53	11.13	6.93	6.44	6.50	−5.03
MW-504B	11.43	11.20	6.49	6.62	6.40	−5.03
MW-505B	11.35	10.04	6.76	6.91	6.59	−4.76
MW-511B	11.74	12.28	9.81	8.66	6.58	−5.16
MW-512B	11.58	11.73	6.93	8.60	6.90	−4.68
MW-513B	11.61	11.34	6.51	9.30	11.69	0.08
MW-514B	11.71	10.37	6.31	6.77	6.11	−5.60
MW-515B	10.31	11.24	8.8	9.39	8.66	−1.65
MW-516B	11.60	11.30	11.48	11.62	11.60	0.00
MW-517B	10.73	9.81	6.48	6.57	6.54	−4.19
MW-518B	10.42	10.87	7.18	6.82	6.53	−3.89
MW-519B	11.71	7.35	6.54	6.57	6.61	−5.10
Mean:	**11.41**	**10.65**	**7.64**	**7.91**	**7.48**	**−3.92**

(a) Indicates pH value was measured in 2012 prior to the Proof of Concept Test
(b) Indicates value was collected shortly after the start of Phase 2 sparging

4.2.3 Post-sparge pH Results

A summary of the changes in pH in deep Satilla monitoring points within the Phase 1 footprint after sparging is provided in Table 4-1. Post-sparge pH results are shown in plan view for deep Satilla monitoring points in Figure 4-32. The majority (22 out of 30) of deep Satilla monitoring points had pH less than 7.5 after Phase 2, with the vast majority of monitoring points (26 out of 30) with a pH of less than 10.0.

The only deep Satilla monitoring points within the sparging footprint that remained above pH 10.5 at the end of Phase 2 were EW-5, MW-516B, MW-352B and MW-513B. EW-5 is 69.0 ft from the nearest Phase 2 sparge well and appears to be beyond the influence of the existing sparge well network. MW-516B is in between two columns of sparge wells (Figure 2-8) and likely represents a small area of high pH water, surrounded by groundwater with low pH on four sides as evident from post-sparge pH in Phase 1 and Phase 2 sparge wells (Figure 4-33). Both MW-352B and MW-513B have had their pH driven down to near-neutral at various points during sparging, but the final pH returned to near pre-sparge values despite continued sparging with CO_2. Both monitoring wells are on the eastern edge of the sparge well network (Figure 2-8) and it is possible that untreated groundwater from the east is continually replenishing the area with high-pH groundwater.

Post-sparge pH values in sparge wells (shown in Figure 4-33) were all near-neutral with the exception of SW-95 (pH 8.95) which is on the outer-edge of the sparging footprint. The near-neutral pH in the large majority of sparge wells was expected since these wells all received considerable masses of CO_2 during sparging.

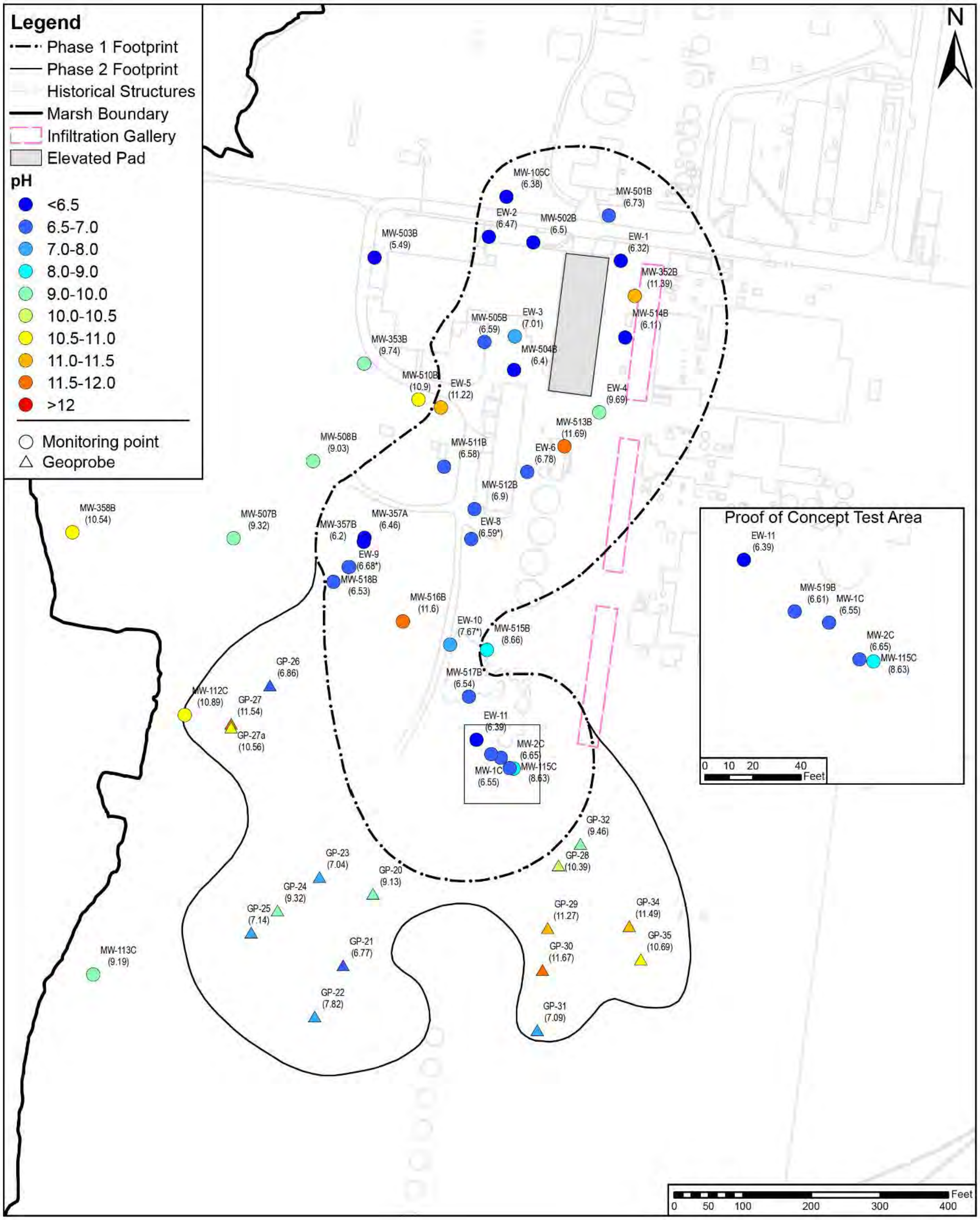
As described in Section 3.1.2, a total of 16 groundwater samples were collected via Geoprobe after sparging concluded in the southern area (Table 4-2). The pH measurements of deep Satilla groundwater at these Geoprobe locations are shown in Figure 4-34 along with 33-ft radii extended outward from southern area Phase 2 sparge wells. The pH in groundwater that was collected from within 30 ft was consistently less than 8.0. At distances 30 ft or greater, pH was between 7.14 and 11.67, with several locations with pH less than 10.0. These results are consistent with the observed average ROI of 33 ft within the Phase 1 footprint.

Table 4-2: Summary of Post-Sparge Geoprobe Sampling of Deep Satilla Groundwater in the Southern Area

Geoprobe ID	Distance from Geoprobe to nearest SW (ft)	Nearest SW	pH	Hg (µg/L)
GP-26	14.9	SW-129	6.86	13
GP-22	15.0	SW-130	7.82	33
GP-31	20.0	SW-138	7.09	17
GP-23	20.0	SW-131	7.04	7
GP-21	25.1	SW-133	6.77	21
GP-25	29.9	SW-127	7.14	26
GP-35	30.0	SW-143	10.69	5.7
GP-27a	30.0	SW-126	10.56	45
GP-27	34.9	SW-126	11.54	41
GP-28	35.1	SW-139	10.39	13
GP-34	53.6	SW-143	11.49	14
GP-29	54.7	SW-140	11.27	37
GP-24	56.0	SW-127	9.32	62
GP-30	61.9	SW-140	11.67	170
GP-20	68.4	SW-7	9.13	75
GP-32	69.2	SW-048	9.46	2.9

The pH in all deep Satilla monitoring locations (monitoring wells, extraction wells, sparge wells and Geoprobe locations) is shown below and in Figure 4-35. The Phase 1 footprint has a few isolated areas that have pH greater than 10.5. These areas are mostly along the eastern edge or western edge of the sparging footprint. Since the southern area has received only one round of CO_2 injections, there are several areas far from the influence of sparging which have elevated pH.

Results for post-sparge pH in mid Satilla monitoring points are shown in Figure 4-36. All mid Satilla wells sampled during Phase 2 had pH between approximately 6.0 and 6.5 as a result of sparging. Most notably, MW-352A pH decreased from pH 10.01 (Figure 4-10) to 6.46 (Figure 4-36).



Above: Post-sparge (Phase 2) pH in all deep Satilla monitoring locations

4.2.4 Effect of Sparging on Coosawhatchie pH

The effect of sparging on pH in the Coosawhatchie A/B aquifer was assessed by monitoring six wells screened in this aquifer. MW-352D, MW-115, MW-360D, HW-East2, HW-East3, HW-East5 were sampled seven weeks into the Phase 2 sparging effort on December 11, 2014, and near the conclusion of sparging on April 8 - 9, 2015. This data, along with measurements made on May 31, 2012, which serve as a pre-sparge baseline and measurements made during Phase 1 sparging, are summarized in Table 4-3. The Phase 2 post-sparge values for all six wells were within 0.25 units of the post-Phase 1 values. Further, five of the six wells remain within 0.5 units of the pre-sparge 2012 values. The only large difference in pH was observed in HW-East5 where the pH decreased from 9.00 to 7.29. The relatively small changes in pH in Coosawhatchie wells indicate that sparging in the deep Satilla has not had a significant effect on water quality in the Coosawhatchie A/B aquifer. This is an expected result given the separation of these units by the variably-cemented sandstone.

Table 4-3: Summary of pH Data Collected in Monitoring Wells Screened in the Coosawhatchie A/B Aquifer

Monitoring Point	May 31, 2012	January 15, 2014	February 21-22, 2014	December 11, 2014	April 8-9, 2015
MW-115D	10.22	10.10	10.14	10.17	9.99
MW-352D	6.35	6.80	6.84	6.81	6.78
MW-360D	9.92	10.09	10.15	10.46	10.34
HW-East2	6.58	-	6.38	6.44	6.44
HW-East3	6.63	-	6.32	6.65	6.50
HW-East5	9.00	-	7.13	7.18	7.29

4.3 Effect of Sparging on Mercury

4.3.1 Pre-Sparge Mercury

Groundwater monitoring results for Hg in the deep Satilla from 2011-2012 (Figure 4-37) serve as an appropriate pre-sparge baseline for the CBP because sparging began in late-2013 as part of the Proof of Concept Test. During this period deep Satilla groundwater within the Phase 1 sparging footprint exhibited Hg concentrations between 35.7 and 2,530 µg/L. In general, groundwater in the northern part of the Phase 1 footprint had the highest Hg concentrations, typically greater than 200 µg/L. Concentrations in the southern part of the Phase 1 footprint typically had concentrations approximately between 100 and 200 µg/L.

Pre-sparge (Phase 2) results for Hg in deep Satilla monitoring locations are shown in Figure 4-38. These results represent a combination of monitoring locations (i.e. monitoring wells, extraction wells, sparge wells and Geoprobe locations). Groundwater Hg concentrations within the entire sparging footprint (Phase 1 and 2) ranged from 1.6 to 790 μg/L. The low concentrations in specific monitoring wells (e.g. MW-105C and EW-8) are reflective of reductions in Hg concentrations as a result of Phase 1 sparging. The high concentrations observed in many of the sparge wells (e.g. SW-113 and SW-108) and Geoprobe locations (e.g. GP-02 and GP-05) reflect areas that had not yet been treated by CO_2 sparging.

Groundwater monitoring results for Hg in the mid Satilla from 2011-2012 (Figure 4-39) show concentrations between 0.64 and 522 μg/L. Hg concentrations in mid Satilla monitoring wells are generally lower than in the deep Satilla, consistent with the conceptual model of the CBP as a dense plume that moved to the bottom of the aquifer. The highest concentrations were observed in MW-352A (522 μg/L) and MW-514A (503 μg/L), located west of the former cell buildings and east of the elevated pad. These wells are in the same area as MW-352B, which had very high concentrations in the deep Satilla (discussed above). The Hg in mid Satilla monitoring wells prior to Phase 2 are shown in Figure 4-40. All mid Satilla monitoring wells sampled prior to Phase 2 showed significant decreases in Hg as a result of Phase 1 CO_2 sparging.

4.3.2 Post-Sparge Mercury

Post-sparge (Phase 2) Hg concentrations for all deep Satilla monitoring locations (monitoring wells and extraction wells, sparge wells and Geoprobe locations) are shown below and in Figure 4-41. The majority (18 out of 27) of monitoring points (monitoring wells and extraction wells) within the Phase 1 footprint showed Hg concentrations less than 20 μg/L, with three points having Hg concentrations less than 2.0 μg/L.

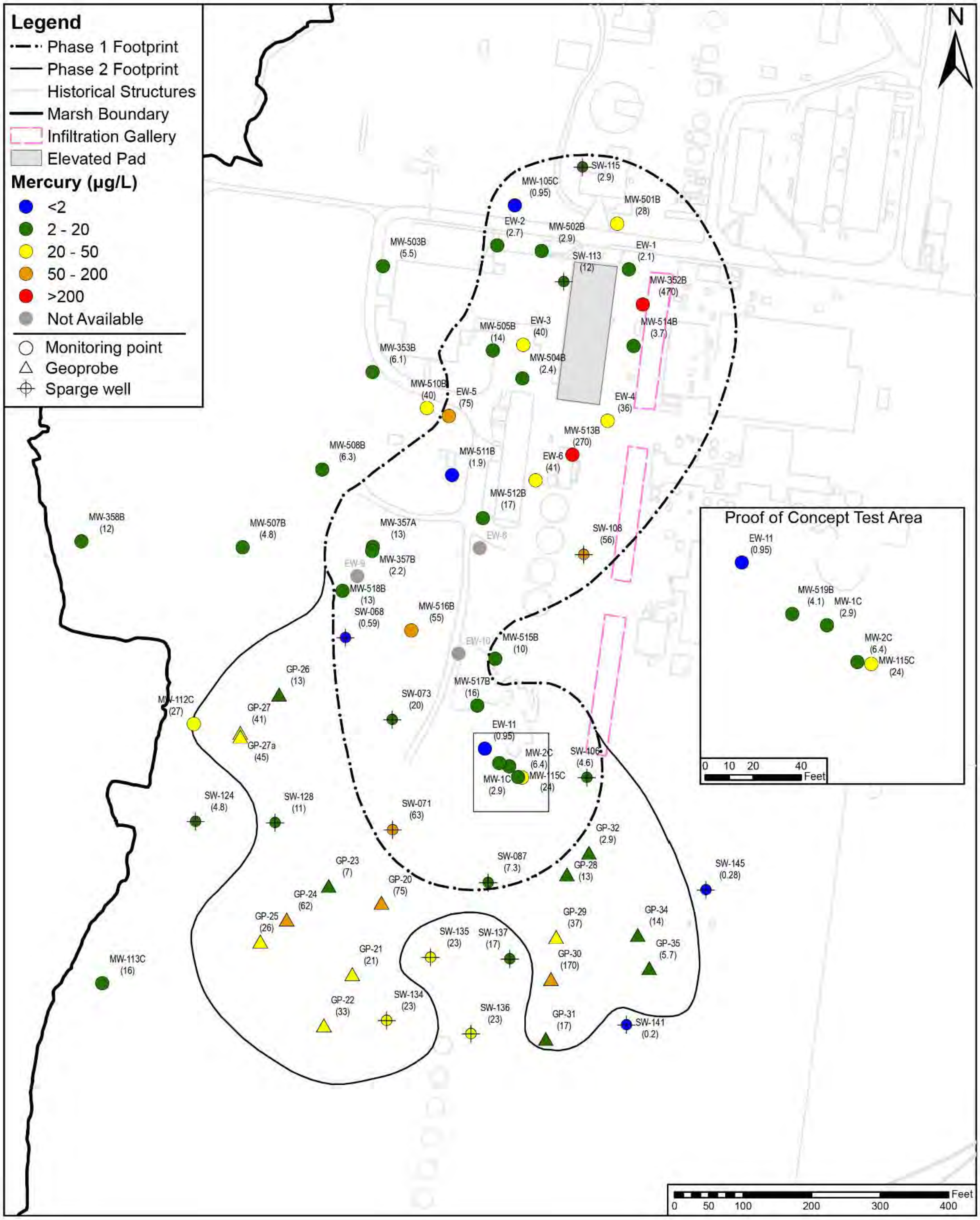
Deep Satilla monitoring well and extraction well Hg results are summarized in Table 4-4. Historical data from 2011-2012, before the Proof of Concept Test, is also included. Overall, 29 out of 30 monitoring points have decreased in Hg when compared to 2011-2012 levels. The mean Hg concentration in all Phase 2 monitoring points was lowered from 232 to 43 μg/L, a percent decrease of 87%. Moreover, where the Phase 2 post-sparge pH was less than 10.5, the mean Hg concentration was 12.4 μg/L.

The decrease in Hg in deep Satilla monitoring points is shown graphically in Figure 4-42 in the form of box plot using the data from Table 4-4. The boundary of the box closest to zero indicates the 25th percentile, a line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile. The error bars above and below the box indicate the 95th and 5th percentiles values, respectively. Points represent values outside of the 5^{th} and 95^{th} percentile, respectively. The box plot shows that the large decrease in median concentrations after Phase 1 sparging was sustained through the end of Phase 2. 25^{th} and 5^{th} percentile concentrations were lower after Phase 2, consistent with the observed decrease in select monitoring points after Phase 2. The highest Hg concentration throughout the sparging program has been consistently observed in MW-352B which has not yet been lowered to neutral pH.

Table 4-4: Summary of Pre- and Post-Sparge Hg in Deep Satilla Monitoring Wells Within the Sparging Footprint

Monitoring Point	Historical (2011-2012)	Pre-Phase 1	Post-Phase 1	Pre-Phase 2	Post-Phase 2	Hg Change (µg/L)	Hg % Change from 2011-2012
EW-1	56	50	0.53	3.8	2.1	−54	−96%
EW-2	110	60	6.7	NA[(b)]	2.7	−107	−98%
EW-3	270	NA[(b)]	71	170	40	−230	−85%
EW-4	210	NA[(b)]	20	NA[(b)]	36	−174	−83%
EW-5	370	300	180	NA[(b)]	75[(a)]	−295	−80%
EW-6	820	430	180	NA[(b)]	41	−779	−95%
EW-8	110	48	2.7	1.6	NA[(b)]	NA	NA
EW-9	160	120	NA[b]	NA[(b)]	NA[(b)]	NA	NA
EW-10	110	68	35	32	NA[(b)]	NA	NA
EW-11	160	48	3	NA	0.95	−159	−99.4%
MW-105C	60	58	2.4	1.6	0.95	−59	−98%
MW-115C	98	62	19	26	24	−74	−76%
MW-1C	110[(c)]	43	11	3.7	2.9	−107	−97%
MW-2C	110[(c)]	49	34	5.3	6.4	−104	−94%
MW-352B	1080	690	260	390	470[(a)]	−610	−56%
MW-357A	111	71	4.1	50	13	−98	−88%
MW-357B	178	180	5.7	45	2.2	−176	−99%
MW-501B	46	48	13	25	28	−18	−39%
MW-502B	109	120	4.4	18	2.9	−106	−97%
MW-504B	885	320	7.7	6	2.4	−883	−99.7%
MW-505B	175	53	32	32	14	−161	−92%
MW-511B	244	160	82	31	1.9	−242	−99.2%
MW-512B	239	85	30	120	17	−222	−93%
MW-513B	531	12	11	78	270[(a)]	−261	−49%
MW-514B	73	40	4.1	26	3.7	−69	−95%
MW-515B	55	30	10	30	10	−45	−82%
MW-516B	40	34	37	64	55[(a)]	15	39%
MW-517B	109	92	14	6.9	16	−93	−85%
MW-518B	129	53	4.8	4.5	13	−116	−90%
MW-519B	191	31	15	7.7	4.1	−187	−98%
Mean:	**232**	**120**	**38**	**49**	**43**	**−201**	**−87%**

(a) Indicates pH was above 10.5 at the end of Phase 2
(b) Sample result not representative of deep Satilla groundwater (see Section 3.1.1)
(c) Indicates pH value was measured in 2012 prior to the Proof of Concept Test



Above: Post-sparge (Phase 2) Hg in deep monitoring locations (monitoring wells, extraction wells, Geoprobe locations and sparge wells).

Dissolved Hg results for Phase 2 sparge wells are summarized in Table 4-5 and are shown on Figure 4-41. All 16 Phase 2 sparge wells sampled for Hg exhibited a decrease in dissolved concentrations from pre- to post-sparging. The mean Hg concentration in Phase 2 sparge wells was lowered from 150 to 16.8 µg/L, a percent decrease of 89%. The largest decrease on a concentration basis was SW-108 which decreased from 790 to 56 µg/L. Percent decreases of 99% were observed in SW-68, SW-115 and SW-145. The mean concentration in sparge wells post treatment (16.8 µg/L) is similar in magnitude to the mean in monitoring points where the pH was less than 10.5 (12.4 µg/L).

Table 4-5: Summary of Pre- and Post-Sparge Hg in Deep Satilla Sparge Wells within the Sparging Footprint

Sparge Well	Pre-Phase 2	Post-Phase 2	Hg Change (µg/L)	Hg % Change
SW-106	150	4.6	−145	−97%
SW-108	790	56	−734	−93%
SW-113	620	12	−608	−98%
SW-115	240	2.9	−237	−99%
SW-124	7.5	4.8	−2.7	−36%
SW-128	28	11	−17	−61%
SW-134	66	23	−43	−65%
SW-135	31	23	−8	−26%
SW-136	76	23	−53	−70%
SW-137	63	17	−46	−73%
SW-141	1.7	0.2	−1.5	−88%
SW-145	24	0.28	−24	−99%
SW-68	54	0.59	−53	−99%
SW-71	110	63	−47	−43%
SW-73	120	20	−100	−83%
SW-87	13	7.3	−6	−44%
Mean:	**150**	**16.8**		**−89%**

Dissolved Hg results for post-Phase 2 Geoprobe locations are summarized in Table 4-6 and are shown below and on Figure 4-41. Table 4-6 is organized by co-located Geoprobe locations to examine the effect of CO_2 sparging on Hg concentrations in a given area. In general, locations that showed improvement in pH to near-neutral levels also showed a substantial decrease in dissolved Hg. Considering only locations where the pH is less than 8.0, the mean post-sparge Hg concentration was 25.6 µg/L. The reduction in Hg in co-located Geoprobe locations are also shown graphically in the form of a box plot in Figure 4-42. A summary of all Hg results in deep Satilla monitoring locations is presented in Table 4-7.

Table 4-6: Summary of Pre- and Post-Sparge Hg in Co-located Pairs of Geoprobe Points within the Sparging Footprint

Geoprobe pair	Pre-Phase 2	Post-Phase 2	Hg Change (µg/L)	Hg % Change
GP-01/GP-20	N/A	75	N/A	N/A
GP-02/GP-21	180	21	−159	−88%
GP-03/GP-22	110	33	−77	−70%
GP-04/GP-23	160	7.0	−153	−96%
GP-05/GP-24	220	62	−158	−72%
GP-06/GP-25	78	26	−52	−67%
GP-09/GP-26	74	13	−61	−82%
GP-10/GP-27	42	41[(a)]	−1	−2%
GP-12/GP-29	160	37[(a)]	−123	−77%
GP-13/GP-30	25	170[(a)]	+145	+580%
GP-14/GP-31	33	17	−16	−49%
GP-17/GP-35	5.0	5.7[(a)]	+0.7	+14%
Mean:	**98.8**	**42.3**		**−57%**

(a) Indicates pH was above 10.5 at the end of Phase 2

As discussed earlier, Hg concentrations generally decreased as the pH was lowered to near-neutral as a result of CO_2 sparging. The Proof of Concept Test showed that Hg concentrations decreased sharply when the pH was lowered below pH 8.0 (Mutch Associates and Parsons, 2013b). A similar dependence was present in the Phase 1 data except that there was inherently more variability because the entire CBP was represented. The post-sparge Phase 2 relationship between Hg and pH for deep Satilla monitoring locations is shown in Figure 4-43. The Hg versus pH relationship is not as obvious in the Phase 2 data because most of the groundwater samples were between pH 6.0 and 7.5 as a result of sparging. Within this pH interval, Hg concentrations vary from 0.2 µg/L (SW-141) to 63 µg/L (SW-71). Some of the higher concentrations in this interval were measured in Phase 2 sparge wells. These Hg concentrations are expected to continue to decrease because of the kinetic effect of Hg immobilization in the CBP after sparging has ended (Mutch Associates and Parsons, 2013c).

The CBP is generally a sulfide-rich, reducing environment. Dissolved Hg speciation in the presence of sulfide is dominated by: complexes with sulfide such as $HgHS^-$, HgS_2^{2-}; complexes with polysulfides such as $Hg(S_x)_2^{2-}$ and HgS_xOH^-; complexes with thiol groups present on dissolved organic matter (DOM); and HgS(s) precipitated as metacinnabar or cinnabar (Skyllberg, 2008). The geochemical conceptual model for Hg within the CBP is discussed in the RI (GeoSyntec Consultants, 1997) and in the Proof of Concept Test Final Report (Mutch Associates and Parsons, 2013b). Solubility of Hg in the presence of sulfide generally decreases with decreasing pH as a result of precipitation of Hg sulfide, HgS(s) (Jay et al., 2000).

Table 4-7: Summary of Mercury Results

Monitoring Points							
		Sample Size (n)	Mean	Standard Deviation	Median	Average Difference	Average Percent Change
Hg (µg/L)	2011-2012	28	240	267	145	−197	−82%
	Pre-Phase 1	28	120	146	59		
	Post-Phase 1	29	37.9	61.6	13		
	Pre-Phase 2	24	49.9	80.9	26		
	Post-Phase 2	27	42.8	98.2	13		
Selected Sparge Wells							
		Sample Size (n)	Mean	Standard Deviation	Median	Average Difference	Average Percent Change
Hg (µg/L)	Pre-Phase 2	16	150	228	64.5	−132.8	−89%
	Post-Phase 2	16	16.8	18.7	11.5		
Co-Located Geoprobe Pairs							
		Sample Size (n)	Mean	Standard Deviation	Median	Average Difference	Average Percent Change
Hg (µg/L)	Pre-Phase 2	11	98.8	71.9	78.0	−59.5	−60%
	Post-Phase 2	11	39.3	46.4	26.0		

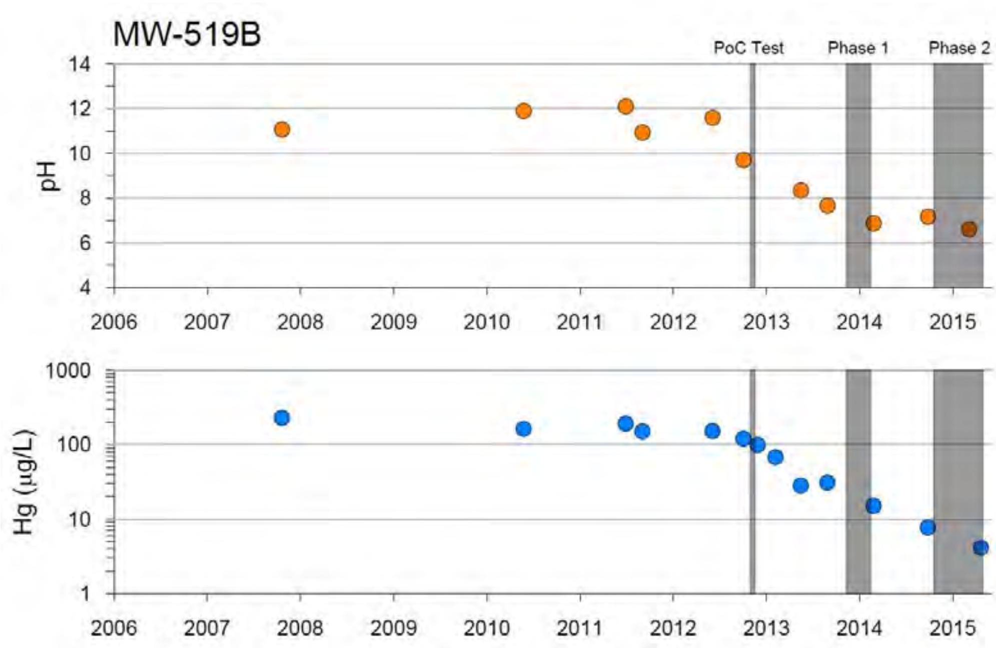
Note: average difference and average percent change for monitoring points was calculated using mean values from 2011-2012 to post-sparge Phase 2.

Post-sparge Hg concentrations are shown in plan view for the mid Satilla in Figure 4-44. Concentrations ranged from 2.3 to 53 µg/L with more than half of concentrations less than 20 µg/L. The mean Hg concentration after Phase 2 in the mid-Satilla wells was 21.1 µg/L. In general, Hg concentrations in the mid Satilla continue to decrease with each sparging event. For example, MW-352A and MW-514A, the two mid Satilla monitoring wells with the highest pre-Phase 1 Hg concentrations (both were ≥ 300 µg/L), showed large decreases after Phase 1 to 11 and 47 µg/L, respectively. After Phase 2 (Figure 4-44), these two wells now have concentrations of 3.3 and 3.2 µg/L, respectively.

4.3.3 Historical Mercury Concentrations Versus Time

The historical Hg concentrations and pH values for wells MW-519B and MW-115C, and EW-6 and EW-11 are shown in Figures 4-45 and 4-46, respectively. As discussed above, a significant reduction in Hg concentration is expected when groundwater reaches a neutral pH. The historical plots show that continued reductions in Hg concentrations occur over time as groundwater maintains a neutral pH. For example, MW-519B (shown below and in Figure 4-45) shows a steady linear decrease in Hg concentration since sparging neutralized the pH during the Proof of Concept Test. Similarly, both EW-6 and EW-11

(Figure 4-46) show continued reductions in Hg concentrations since reaching a neutral pH. EW-6 is noteworthy because concentrations were at or above 1,000 µg/L for a long time and as high as 2,530 µg/L in July 2012. The Hg concentrations in EW-6 after Phase 2 was 41 µg/L, and may continue to decline over time. The historical plot of MW-115C (Figure 4-45) shows that the reduction in Hg concentration due to lowering the pH is not immediately reversible when a slight rise in pH occurs. The Proof of Concept Test, Phase 1 and Phase 2 sparging influenced the pH of groundwater near MW-115C. As expected, Hg concentrations decreased. However, when the pH increased slightly after Phase 2, the Hg concentrations remained at lower levels and did not rebound. This suggests that Hg reductions are not easily or quickly reversible.



Above: MW-519B historical pH and Hg

4.4 Effect of Sparging on Additional Geochemical Parameters

4.4.1 Effect of Sparging on Silica

Silica concentrations in the deep Satilla measured through Phase 1 and 2 of CO_2 sparging are summarized in Table 4-8. Silica concentrations from pre-Phase 1, pre-Phase 2 and post-Phase 2 are shown in Figures 4-47 through 4-49. Prior to Phase 1 sparging, silica values within the sparging footprint (Figure 4-47) ranged from 75 mg/L (MW-1C) to 17,000 mg/L (MW-352B). High silica areas generally greater than 1,000 mg/L were west of the EW-6 area and in an isolated area near MW-352B. A low silica area existed near the Proof of Concept Test, as a result of prior sparging in this area. After Phase 1, most deep Satilla monitoring points showed a decrease in silica to less than 200 mg/L as a result of the lower pH (Figure 4-

48). As discussed in the Phase 1 Report, dissolved silica concentrations decrease with decreasing pH to maintain equilibrium with amorphous SiO_2.

Table 4-8: Summary Statistics for Constituents in Deep Satilla Monitoring Points

Chemical Constituent		Sample Size (n)	Mean	Median	Standard Deviation
Alkalinity (mg/L as $CaCO_3$)	Pre-Phase 1	25[a]	3,604	2,700	3,328
	Post-Phase 1	29	5,645	4,500	3,353
	Pre-Phase 2	23	5,074	4,400	2,592
	Post-Phase 2	27	5,604	4,200	4,200
Total Dissolved Solids, TDS (mg/L)	Pre-Phase 1	28	16,436	12,000	12,939
	Post-Phase 1	29	12,990	11,000	7,962
	Pre-Phase 2	24	12,825	11,000	7,940
	Post-Phase 2	27	13,865	9,700	11,335
Arsenic, As (µg/L)	Pre-Phase 1	28	96	44	162
	Post-Phase 1	29	76	22	194
	Pre-Phase 2	24	56	13	179
	Post-Phase 2	27	122	9	388
Chromium, Cr (µg/L)	Pre-Phase 1	28	235	185	178
	Post-Phase 1	29	255	210	237
	Pre-Phase 2	24	179	165	142
	Post-Phase 2	27	216	130	300
Silica, Si (mg/L as SiO_2)	Pre-Phase 1	28	1,439	395	3,243
	Post-Phase 1	29	756	75	2,553
	Pre-Phase 2	24	716	120	2,378
	Post-Phase 2	27	928	93	2,336

Note: When measured values were below the MDL (i.e. "U" qualified), half the MDL was used in calculation of the mean.
(a) Three samples omitted due to improper "U" qualification for alkalinity from analytical lab.

Results for silica after Phase 2 are shown in Figure 4-49. Silica concentrations in most monitoring points that were low at the end of the Phase 1 were relatively unchanged. For those wells where pH was reduced, silica decreased slightly (e.g. MW-357B, EW-3 and MW-51B). There were a few increases in silica concentration (e.g. MW-513B and MW-510B), consistent with the observed increase in pH in these monitoring wells. Overall, changes in silica concentrations parallel changes in pH measured in deep Satilla monitoring points.

As discussed in more detail in the Phase 1 report, amorphous silica precipitates when the pH is decreased as a result of CO_2 sparging. Pre-and post-sparging aquifer testing during Phase 1 showed no sharp loss of aquifer transmissivity. Therefore, silica precipitation does not appear to cause a loss in aquifer permeability.

4.4.2 Effect of Sparging on Total Dissolved Solids

TDS measured in deep Satilla monitoring points through Phase 1 and 2 of CO_2 sparging are summarized in Table 4-8. TDS concentrations from pre-Phase 1, pre-Phase 2 and post-Phase 2 are shown in plan view on Figures 4-50 through 4-52. Prior to Phase 1 sparging, TDS in deep Satilla monitoring points within the sparging footprint (Figure 4-50) ranged from 2,600 mg/L (MW-105C) to 56,000 mg/L (MW-352B), with a mean of 16,436 µg/L (n = 28). Note that MW-352B had the highest TDS and silica prior to Phase 1 (see Section 4.4.1). TDS concentrations appear to have large spatial variability; monitoring points showing the highest concentrations are often near points with relatively low concentrations. For example, MW-352B (56,000 mg/L) is neighbored by EW-1 (3,500 mg/L) and MW-514B (5,300 mg/L).

After Phase 1, many deep Satilla monitoring points either showed a significant decrease in TDS (e.g. MW-352B, MW-519B, MW-115C, MW-1C, MW-512B) or stayed relatively constant (e.g. MW-511B, MW-357B, MW-516B) (Figure 4-52). The overall effect was a slight decrease in mean TDS from 16,436 mg/L (n = 28) to 12,990 mg/L (n = 29) (Table 4-8). Median TDS also decreased from 12,990 to 11,000 mg/L. TDS concentrations post-Phase 1 were very similar to that pre-Phase 2.

After Phase 2, mean TDS increased slightly from 12,825 mg/L (n = 24) to 13,865 mg/L (n = 27), but median TDS decreased from 11,000 mg/L to 9,700 mg/L. The increase in mean TDS is largely due to MW-352B, which increased from 32,000 to 50,000 mg/L and the inclusion of EW-5 (44,000 mg/L) in the calculation (pre-Phase 2 TDS was not available for this well). As discussed earlier in Section 4.2.2, the pH in MW-352 decreased during Phase 2 sparging, but returned to pre-sparge levels at the end of Phase 2. MW-352B is located on the eastern edge of the sparging network. The increase in TDS at the end of Phase 2 provides additional evidence that untreated groundwater from the east is continually entering the area near MW-352B.

Overall, mean and median TDS in deep Satilla monitoring points within the sparging footprint decreased from pre-Phase 1 to post-Phase 2. The mean TDS decreased from 16,436 mg/L to 13,865 mg/L, for a percent decrease of 16%. The median TDS decreased from 12,000 mg/L to 9,700 mg/L, for a percent decrease of 19%.

There are numerous geochemical reactions occurring during CO_2 sparging which can affect TDS. However, CO_2 sparging is not expected to have a large effect on TDS since sodium and chloride are the major components of TDS within the CBP, and these ions generally behave conservatively (i.e. do not precipitate or adsorb). The most important process that may lower TDS is silica precipitation. Conversely, increases in bicarbonate ion concentration as a result of CO_2 sparging is expected to increase TDS.

4.4.3 Effect of Sparging on Specific Gravity

Specific gravity of groundwater is a manifestation of the presence of dissolved solids. Specific gravity measurements during Phase 1 and 2 are summarized in Table 4-9. The majority of specific gravity measurements recorded during Phase 1 were between 1.01 and 1.02. A more precise field hydrometer was used to record specific gravity during Phase 2 sparging. The pre- and post-Phase 2 mean specific gravity values were nearly identical. The difference between paired means (pre- to post-sparge) for both Phase 1 and Phase 2 are not statistically significant ($p > 0.025$). In other words, the difference in the mean values of the two groups is not great enough to reject the possibility that the difference is due to random sampling variability.

The specific gravity of any water is dictated by the concentrations of dissolved solids. Similar to TDS (Section 4.4.2), a large change in specific gravity was not expected after CO_2 sparging. Also, like TDS, the specific gravity of the CBP is largely a function of sodium and chloride ions, which generally behave conservatively. The lack of change in the CBP specific gravity upon CO_2 sparging is inconsequential with respect to Hg since the density of the water does not affect Hg immobilization which is driven by the change in pH. Furthermore, there is no significant harm expected from specific gravity, which in many cases only slightly exceeds that of fresh water and in almost all cases is less than that of typical seawater (SG = 1.025).

Table 4-9: Pre- and Post-Sparge Specific Gravity

Monitoring Point	Pre-Phase 1	Post-Phase 1	Pre-Phase 2	Post-Phase 2	ΔSG[c]
MW-105C	NM[a]	1.01	1.0045	1.0050	0.0005
MW-112C	NM	NM[b]	1.0225	1.0280	0.0055
MW-113C	NM	NM[b]	1.0240	1.0250	0.0010
MW-115C	1.03	1.045	1.0240	1.0220	−0.0020
MW-501B	NM[a]	1.02	1.0105	1.0160	0.0055
MW-502B	1.02	1.023	1.0050	1.0075	0.0025
MW-503B	1.00	1.01	1.0005	1.0025	0.0020
MW-504B	1.02	1.02	1.0155	1.0070	−0.0085
MW-511B	1.02	1.02	1.0150	1.0110	−0.0040
MW-512B	1.025	1.01	1.0130	1.0180	0.0050
MW-513B	1.01	1.02	1.0020	1.0165	0.0145
MW-514B	1.00	1.01	1.0040	1.0045	0.0005
MW-516B	1.02	1.02	1.0180	1.0180	0.0000
MW-518B	1.03	1.02	1.0085	1.0050	−0.0035
Mean:	1.018	1.019	1.0119	1.0133	0.0014

(a) MW-105C and MW-501B were inadvertently not measured (NM) in the field for the Pre-Phase 1 sample period.
(b) MW-112C and MW-113C were not measured in the field for Phase 1.
(c) ΔSG were calculated from Pre-Phase 2 and Post-Phase 2 sparge measurements.

4.4.4 Effect of Sparging on As and Cr

Pre-Phase 1 sparge As concentrations in deep Satilla monitoring points ranged from 20 to 790 µg/L, with a mean of 96 µg/L (n = 28). The post-Phase 2 As concentrations ranged from 4.6 to 1800 µg/L, with a mean of 122 µg/L (n = 27). The best indication of the overall change in As concentrations due to sparging is the downward trend in median values over time. As shown in Table 4-8, the median As decreased from 44 µg/L (pre-Phase 1) to 9 µg/L (post-Phase 2) for a reduction of 80%. As concentrations are lower in almost all wells throughout the deep Satilla, except in EW-5 and MW-352B where sparging has not yet neutralized the pH. From pre-Phase 1 to post-Phase 2, there was a 27% increase in the mean As concentration in the deep Satilla monitoring points (Table 4-8). However, the mean was highly influenced by EW-5, a statistical outlier with a value (1800 µg/L) more than four standard deviations above the mean.

Pre-Phase 1 Cr concentrations in deep Satilla monitoring points ranged from 30 to 720 µg/L, with a mean of 235 µg/L (n = 28). Post-Phase 2 Cr concentrations ranged from 5.5 to 1600 µg/L, with a mean Cr concentration of 216 µg/L (n = 27). The best indication of the overall change in Cr concentrations due to sparging is the downward trend in the median values over time. As shown in Table 4-8, median Cr concentrations decreased from 185 µg/L (pre-Phase 1) to 130 µg/L (post-Phase 2), for a decrease of 30%. The mean Cr concentration pre-Phase 1 to post-Phase 2 decreased by 8%. As was the case with As, the post-Phase 2 mean was heavily influenced by EW-5, a statistical outlier with a value of 1600 µg/L. Cr speciation in the CBP is most likely trivalent (as opposed to hexavalent) because of the large concentrations of ferrous iron and dissolved sulfide which are both known to reduce Cr(VI) to Cr(III) (Pettine et al., 1994; Pettine et al., 1998).

4.5 Effect of Sparging on Piezometric Surfaces

Similar to the Proof of Concept Test and Phase 1 sparging, the piezometric surface in the deep Satilla Aquifer and the groundwater table in the Satilla Aquifer were influenced during Phase 2 sparging. The mounding of the groundwater table in the Satilla, as observed in the hydrograph of PZ-46, is shown in Figure 4-53. The water elevation in PZ-46 represents the potentiometric surface 5 to 7 ft below the water table, not the water table itself. As expected, the water elevation in PZ-46 fluctuated as a function of flow rate and radial distance to nearby operating sparge wells. The general behavior of the water level within PZ-46 during a sparge event was as follows. After a sparge event was initiated, the water level in the piezometer increased quickly, reaching a peak of 1 to 4 ft above the original water elevation approximately 4 hours after the start of sparging. Once sparging concluded, it took approximately 8 hours for the water level to return to the pre-sparge water elevation. A detailed description of this process accompanied with figures is available in the Phase 1 Report (Mutch Associates and Parsons, 2014).

The water levels in the 35 shallow piezometers on site were checked periodically while sparging into the accompanying sparge wells. From November 16th – 30th 2014, the Site received approximately 4 inches of rain. The heavy rains, accompanied with sparging, resulted in an upward shift in water levels as measured in the piezometers. The water elevations before November 16th were typically 3 to 4 ft below ground surface. However, after November 30th, they were often 1 to 2 ft below ground surface, as shown in the hydrograph of PZ-46 (Figure 4-53). After this increase in the water table, sparging resulted in several instances when shallow groundwater surfaced in low-lying areas of the Site. These typically occurred in the northern portion of the Site adjacent to the access road. This area was particularly sensitive because the elevation of the road was low relative to the ground, and the high density of the sparge network in the northern area. These instances were often preceded by periods of precipitation and resulted in localized standing water that either evaporated or percolated back into the ground within the sparge footprint. The sparging procedures were adjusted to shorten sparging durations in the northern portion of the Site in an effort to minimize or preclude additional instances of the groundwater table surfacing on the road. The long-term effect of sparging on the groundwater table was an increase in water level elevation during sparging, followed by a gradual return to pre-sparge levels.

As in Phase 1, the piezometric surface in the deep Satilla monitoring wells within the sparge footprint was strongly influenced by sparging. The piezometric surface changed as a function of sparge well flow rates and radial distance from the sparge well. Four monitoring wells within the Phase 1 footprint were outfitted with transducers that recorded the piezometric surface throughout the sparging program. The long term hydrographs for all deep Satilla monitoring wells are provided in Appendix H. The general behavior of the piezometric surface in a deep Satilla monitoring well under the influence of sparging is as follows: The piezometric surface increased in a matter of minutes after sparging began and steadily increased with the sparge flow rate throughout the sparging event. Near the end of the sparge period, the piezometric surface reached a maximum value. The piezometric surface declined immediately after sparging ended, often to a lower elevation then pre-sparge. The water level then returned to pre-sparge conditions approximately 7 hours after sparging ended. A detailed description of this process accompanied with figures is available in the Phase 1 Report (Mutch Associates, Parsons, 2014).

As discussed in Section 2.1.5, monitoring wells and piezometers within the sparging footprint were fitted with threaded caps prior to sparging. These threaded caps were largely effective in containing the rising waters in monitoring wells and piezometers. There were, however, a few instances where an open sample port or loose fitting allowed small amounts of deep Satilla groundwater to reach the surface as water or foam. In all cases, the water or foam evaporated or percolated into the ground within the sparging footprint. There were no apparent long term effects of sparging on the piezometric surface in the deep

Satilla. The piezometric surface elevation rose and fell during sparge operations but gradually returned to pre-sparge levels during rest periods. The Phase 2 hydrographs for all deep Satilla monitoring wells outfitted with transducers can be found in Appendix H. Appendix H also contains hydrographs for deep Satilla monitoring wells along the western edge of the Site that span the post-Phase 1 to pre-Phase 2 rest period.

Table 4-10: Difference in Water Levels in Selected Well Pairs

	North End of Site MW-501B to MW-503B (347 feet apart)	Center of Site MW-513B to MW-508B (366 feet apart)	South End of Site MW-516B to MW-112C (346 feet apart)
Historical Period			
July 2007	1.4	2.3	1.4
October 2009	1.4	4.3	1.2
Historical Average:	**1.4**	**3.3**	**1.3**
Phase 1			
Beginning of Sparging	1.3	2.5	1.9
Winter Rest Period	1.3	3.1	1.6
End of Sparging	1.3	3.9	1.2
Average During Sparging:	**1.3**	**3.1**	**1.5**
Phase 2			
Beginning of Sparging	1.5	4.3	1.8
Winter Rest Period	1.4	4.2	1.6
End of Sparging	1.2	4.0	1.3
Average During Sparging:	**1.3**	**4.1**	**1.6**

Notes:
1. All values in units of feet (ft)
2. A positive number indicates the well within the sparging footprint had a higher water level than the well west of the sparging footprint
3. The first well in each pair is the well within the sparging footprint and the second well is located west of the sparging footprint. i.e. MW-501B is within the sparging footprint

The water levels in three pairs of monitoring wells were measured with transducers to evaluate change in head differences during Phase 2 sparging efforts to assess migration of deep Satilla water outside the sparging footprint. One well within each pair is located within the sparging footprint and one well is located west of the sparging footprint, adjacent to the marsh. The selected well pairs were MW-501B and MW-503B, MW-513B and MW-508B, and MW-516B and MW-112C. Available groundwater levels from July 2007 and October 2009 (provided by EPS Planning Specialists, Inc.) and data from Phase 1 operations were used to calculate the historical averages of pre-sparge head differences in each monitoring well pair, as shown in Table 4-9. Hydrographs of these paired water levels (in ft NAVD 88) are shown in Figures 4-

54 through Figure 4-56. A least squares regression, linear trend line was fit to water levels obtained from monitoring well transducer data and the difference between the trend lines was taken at three points during the sparging period and then averaged. For each monitoring pair, the average head difference during sparging was not significantly different from the historical average as shown in Table 4-9. Therefore, the data indicate that Phase 2 sparging had an insignificant impact on deep Satilla groundwater migration as the average westerly hydraulic gradient did not appreciably change during the sparging activities.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

A summary of the key results of Phase 2 sparging is presented below:

- A total of 1,521,000 lb of CO_2 was sparged during Phase 2.
- CO_2 sparging has been extremely successful in lowering pH levels in the Satilla aquifer. The majority (22 out of 30) of deep Satilla monitoring points had pH less than 7.5 after Phase 2, with an the vast majority of monitoring points (26 out of 30) with a pH of less than 10.0.
- The only deep Satilla monitoring points within the sparging footprint that remained above pH 10.5 at the end of Phase 2 were MW-513B, MW-516B, MW-352B, and EW-5. MW-352B and MW-513B are both along the eastern edge of the sparge well network, while EW-5 is along the western edge.
- Post-sparge Geoprobe groundwater sampling in the southern area indicated that pH within 30 ft of a sparge well was consistently less than 10.5, and in most cases less than 7.5. At distances 30 ft or greater, pH was between 7.14 and 11.67, with several locations with pH less than 10.0. These results are consistent with the observed average ROI of 33 ft within the Phase 1 footprint.
- The mean Hg concentration in Phase 2 monitoring points where the pH was less than 10.5 was 12.4 µg/L. This concentration is similar to that observed post-sparge in Phase 2 sparge wells (16.8 µg/L), and is a significant reduction from 2011-2012 levels which averaged 232 µg/L.
- Hg and pH measurements throughout the entire sparging program show that additional reductions in Hg may occur over time as groundwater remains at neutral pH. This suggests that groundwater Hg concentrations within the sparging footprint may continue to decrease into the future. Additionally, pH data collected throughout the Proof of Concept Test, Phase 1 and Phase 2 suggests that slight increases in pH do not reverse reductions in Hg concentrations.

5.2 Recommendations

Based upon the results of Phase 2, the following actions are recommended:

- Given that ROI achieved in the southern area was consistent with the ROI determined in the Phase 1 footprint (approximately 33 ft), the coarse spacing established in the southern area during Phase 2 should be filled in with additional sparge wells on a 66-ft spacing to achieve a final pattern suitable for completing the treatment.

- Two deep Satilla monitoring points on the eastern edge of the sparge well network (MW-352B and MW-513B) were not able to sustain near-neutral pH after Phase 2. Sparge wells should be installed east of these wells to lower pH along the eastern edge of the sparging footprint.
- Two deep Satilla monitoring points on the western edge of the sparge well network (EW-5 and MW-510B) experienced slight increase in pH during sparging such that their post-sparge pH was greater than 10.5. Sparge wells should be installed near these monitoring wells on the existing grid pattern to lower the pH in this area.

6 REFERENCES

GeoSyntec Consultants, 1997. Remedial Investigation Report Ground Water Operable Unit Volume I LCP Chemicals Brunswick, Georgia.

Jay, J.A., Morel, F.M.M., Hemond, H.F., 2000. Mercury speciation in the presence of polysulfides. Environ. Sci. Technol. 34, 2196-2200.

Mutch Associates, 2012. Final Work Plan for CO_2 Sparging Proof of Concept Test.

Mutch Associates, 2014. Post-sparge pH monitoring and Geoprobe transects.

Mutch Associates, Parsons, 2013a. CO_2 Sparging Work Plan, LCP Chemicals Site, Brunswick, GA.

Mutch Associates, Parsons, 2013b. CO_2 Sparging Proof of Concept Test Report.

Mutch Associates, Parsons, 2013c. CO_2 Sparging Proof of Concept: 6 month post-sparge monitoring results.

Mutch Associates, Parsons, 2014. CO_2 Sparging Phase 1 Full-Scale Implementation And Monitoring Report.

Pettine, M., Barra, I., Campanella, L., Millero, F.J., 1998. Effect of Metals on the Reduction of Chromium(VI) with Hydrogen Sulfide. Water Res. 32, 2807-2813.

Pettine, M., Millero, F.J., Passino, R., 1994. Reduction of chromium(VI) with hydrogen-sulfide in NaCl media. Marine Chem. 46, 335-344.

Skyllberg, U., 2008. Competition among thiols and inorganic sulfides and polysulfides for Hg and MeHg in wetland soils and sediments under suboxic conditions: Illumination of controversies and implications for MeHg net production. J. Geophys. Res. 113, G00C03.

Suthersan, S.S., 1997. Remediation Engineering: Design Concepts. CRC Press.

USEPA, 2013. SESD Operating Procedure Groundwater Sampling.

Yeskis, D., Zavala, B., 2002. Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers. USEPA.

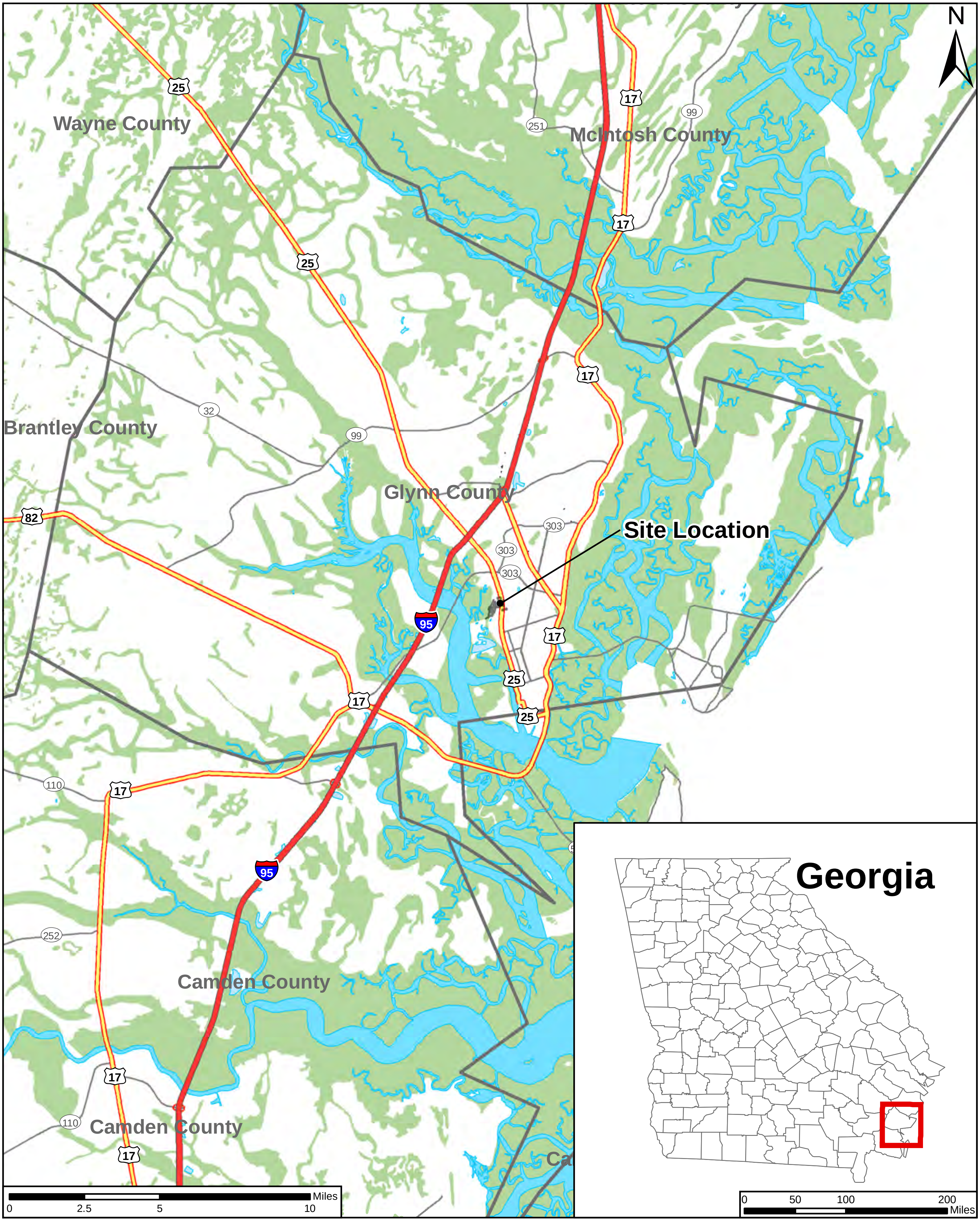


Figure 1-1: Site location map.
LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

Figure 1-2: Contour of pH> 10.5 showing the location of the CBP using 2012 data.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

Figure 1-3: Updated location of the CBP using 2014 Geoprobe pH data.
LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

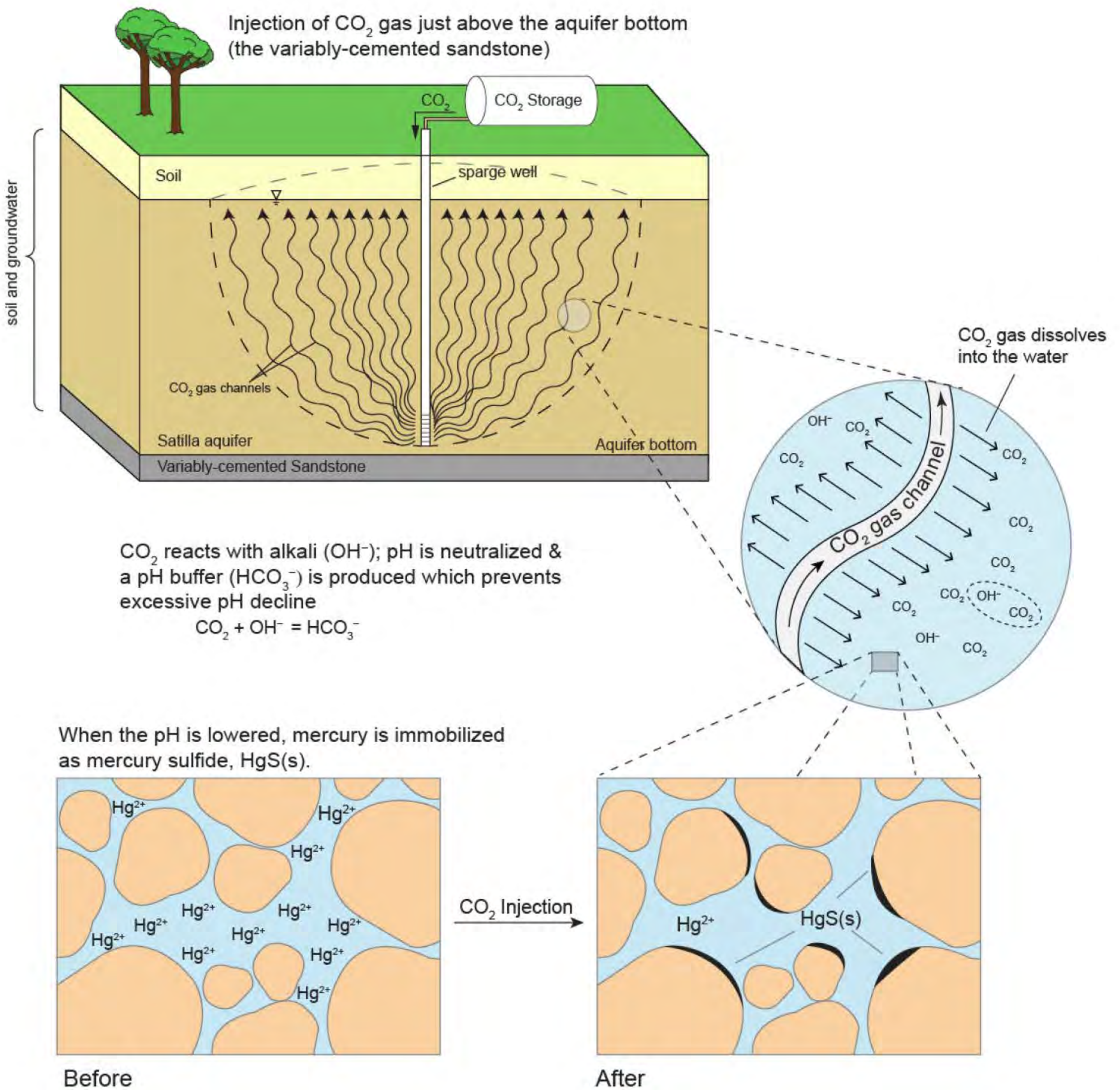


Figure 1-4: Conceptual model of CO_2 sparging.

LCP Chemicals Site, Brunswick, GA

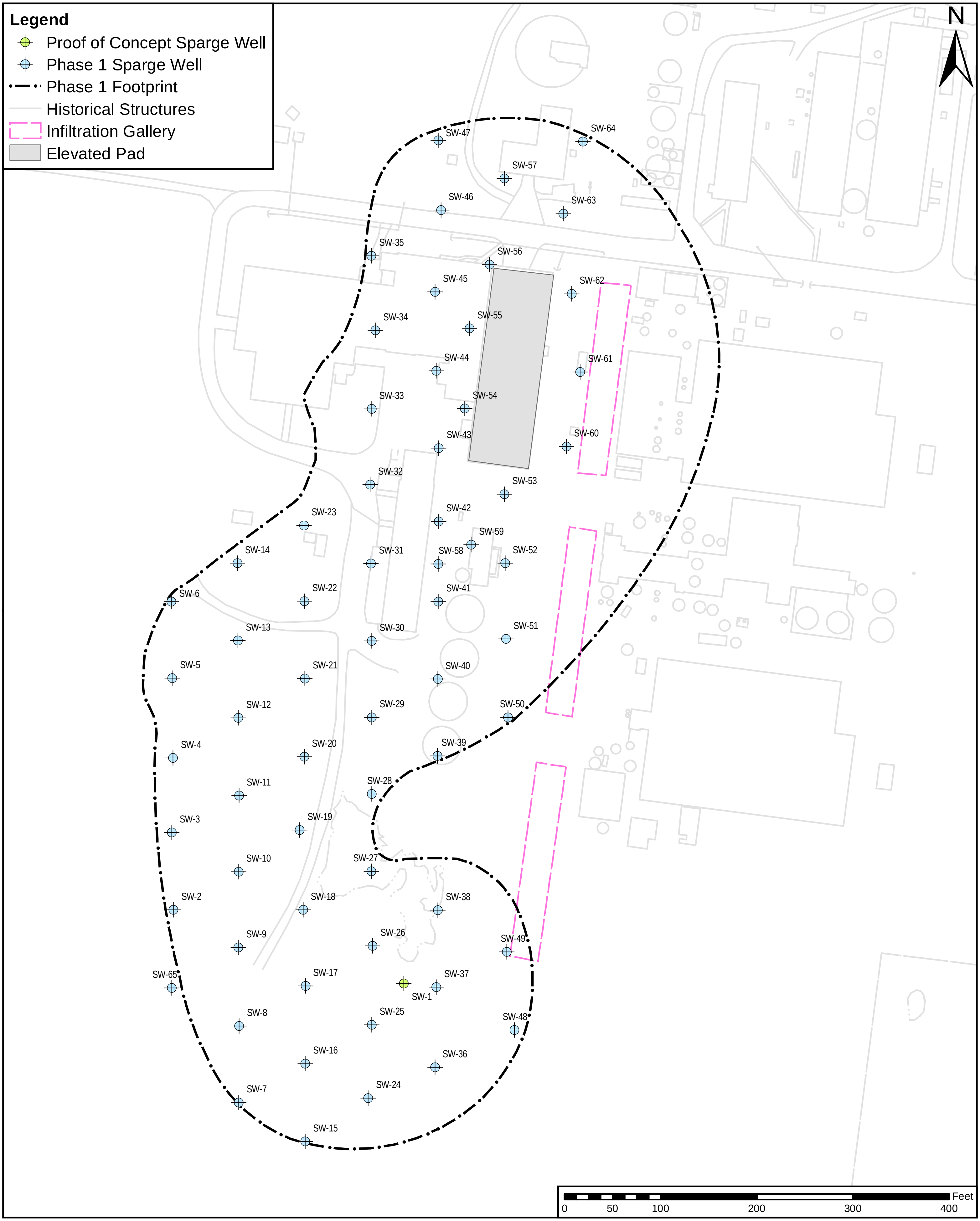


Figure 1-5: Locations of 64 sparge wells installed as part of Phase 1 of CO_2 sparging.
LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

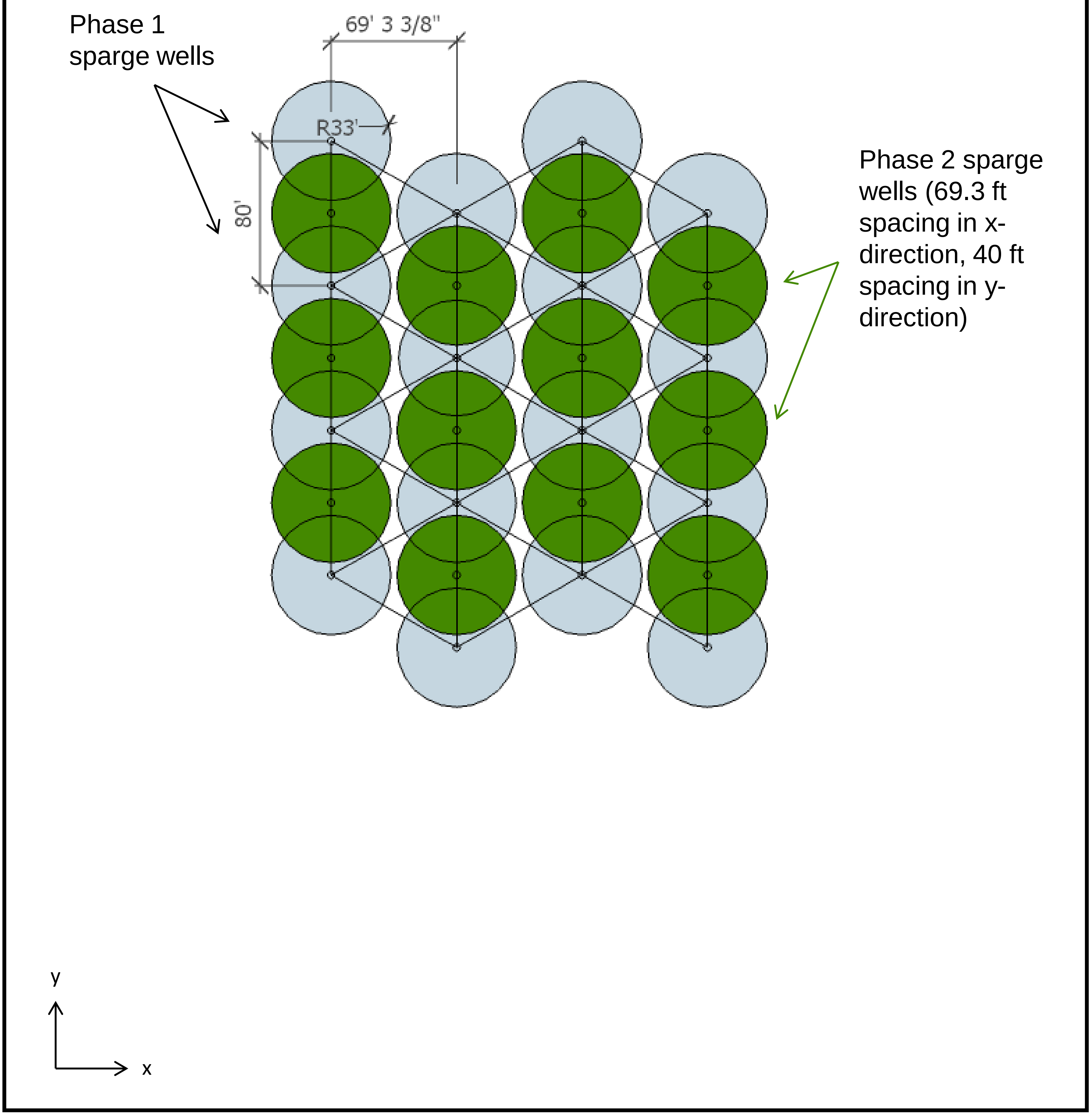


Figure 2-1: Conceptual Phase 2 sparge well layout for the Phase 1 footprint.
LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

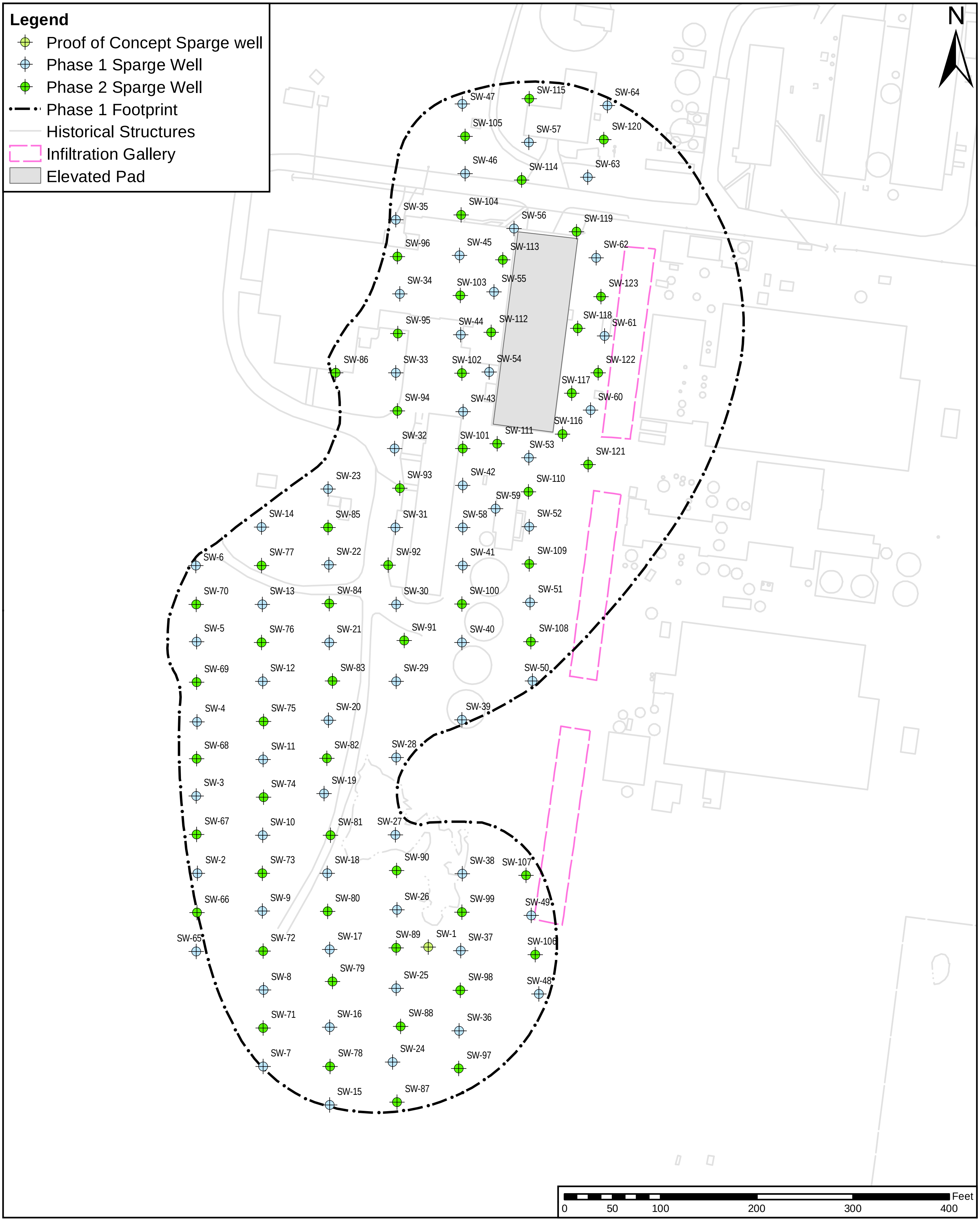


Figure 2-2: Locations of 58 Phase 2 sparge wells installed within the Phase 1 footprint.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

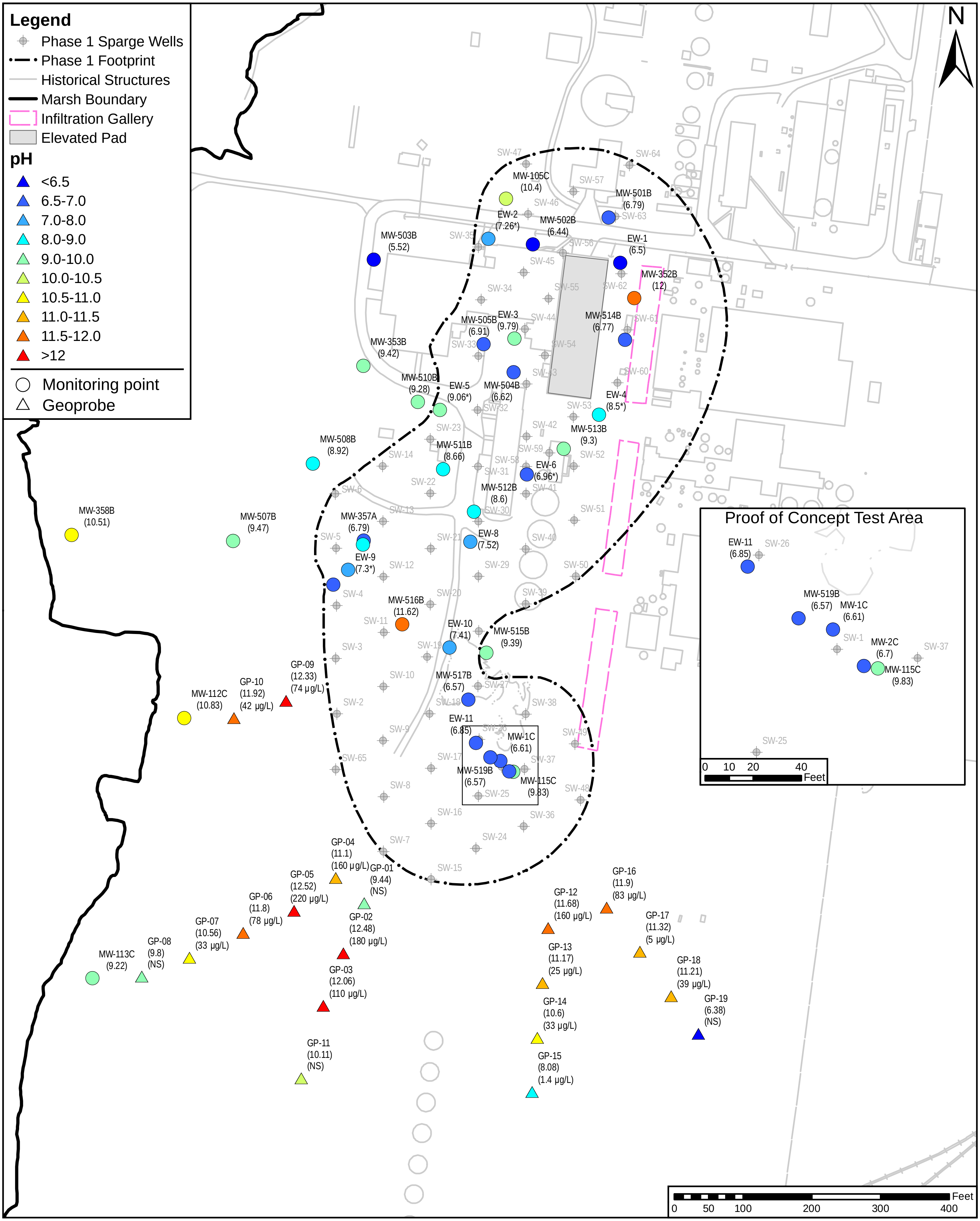


Figure 2-3: Pre-Phase 2 Geoprobe and monitoring well sampling results.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

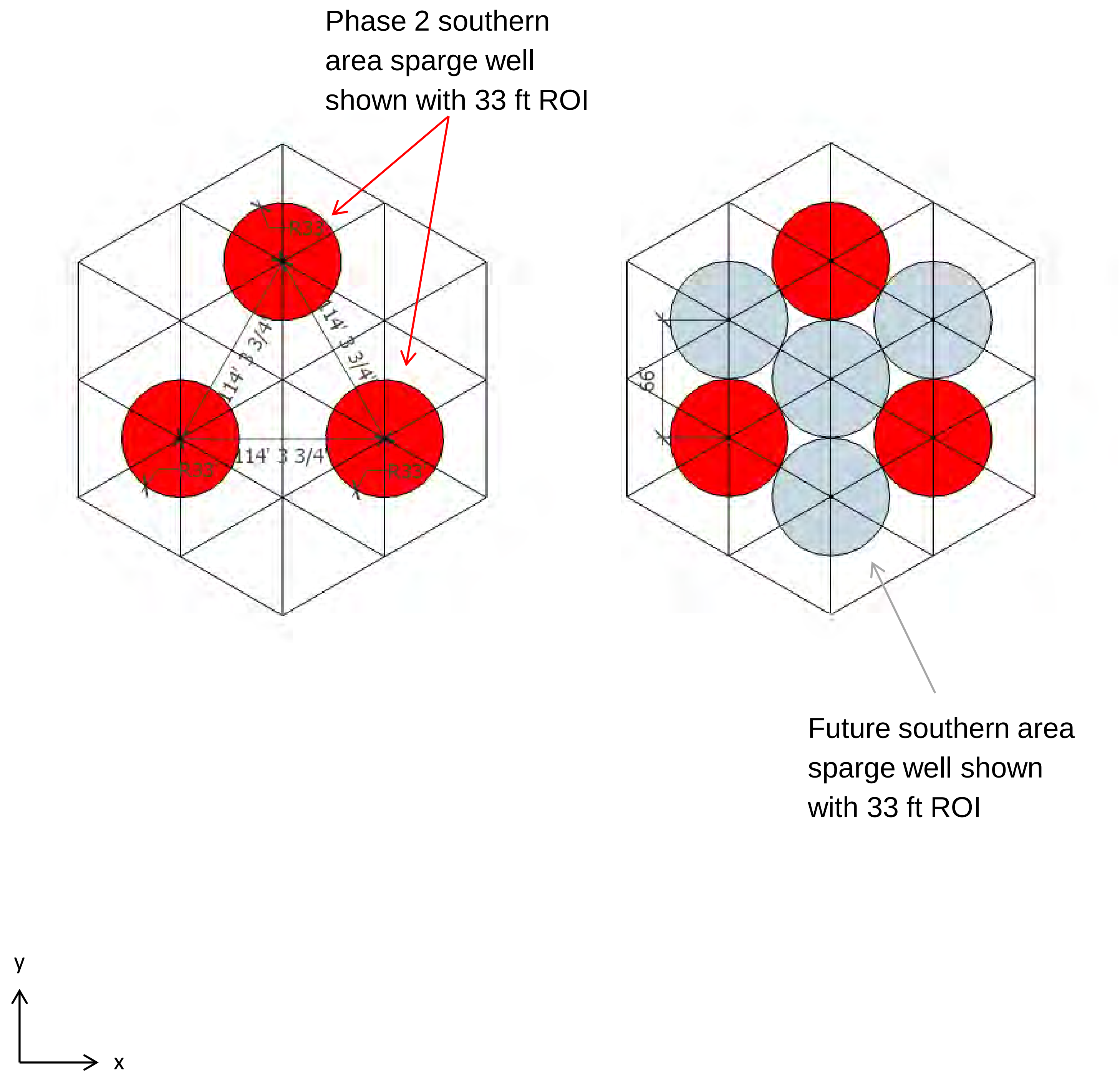
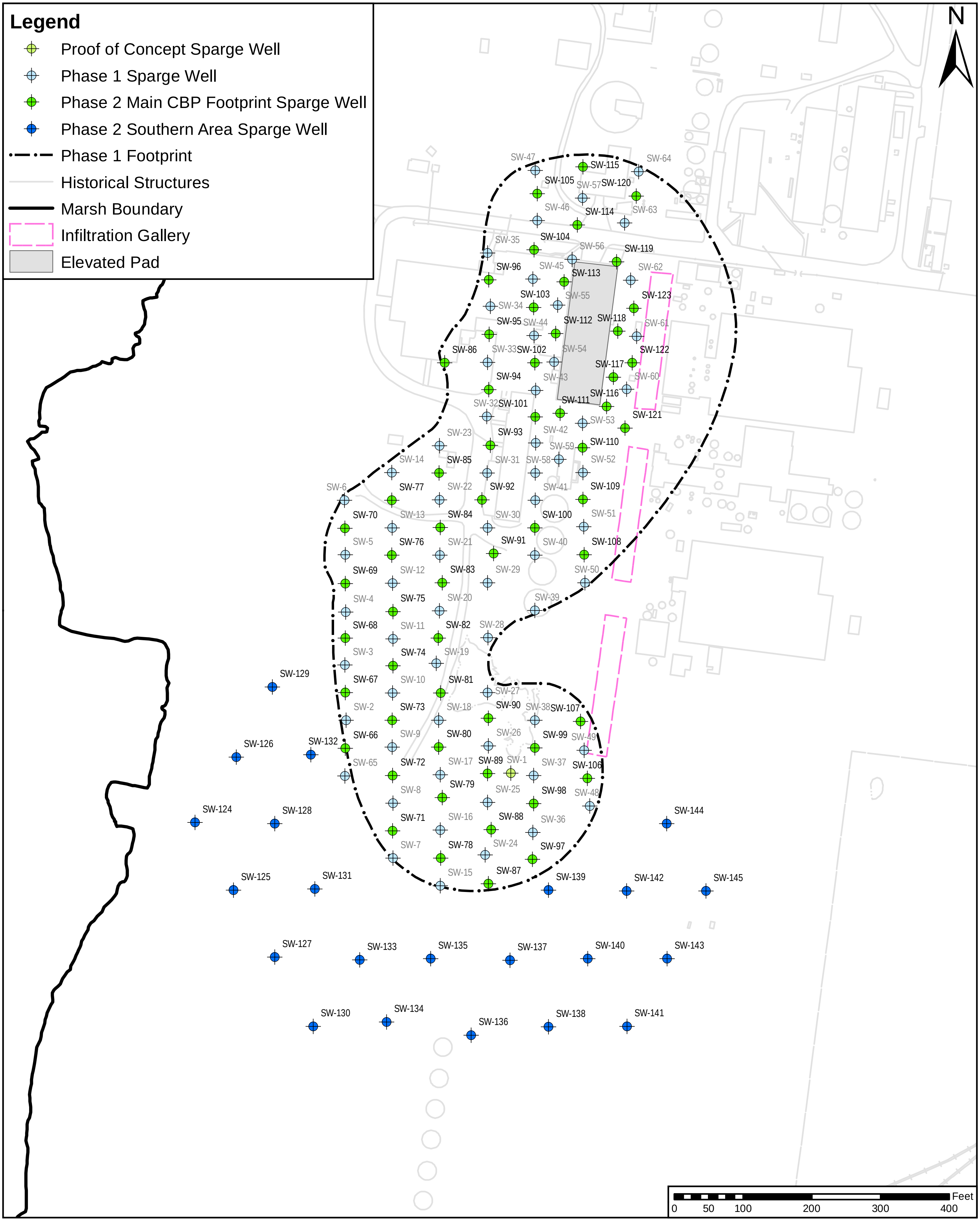


Figure 2-4: Conceptual Phase 2 sparge well layout for the southern area.
LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists



Legend
Proof of Concept Sparge Well
Phase 1 Sparge Well
Phase 2 Main CBP Footprint Sparge Well
Phase 2 Southern Area Sparge Well
Phase 1 Footprint
Historical Structures
Marsh Boundary
Infiltration Gallery
Elevated Pad
N
SW-47
SW-115
SW-64
SW-105
SW-57
SW-120
SW-46
SW-114
SW-63
SW-35
SW-104
SW-56
SW-119
SW-96
SW-45
SW-113
SW-62
SW-103
SW-55
SW-123
SW-34
SW-95
SW-44
SW-112
SW-118
SW-61
SW-86
SW-33
SW-102
SW-54
SW-122
SW-117
SW-94
SW-43
SW-60
SW-116
SW-111
SW-32
SW-101
SW-53
SW-121
SW-23
SW-93
SW-42
SW-59
SW-110
SW-14
SW-85
SW-31
SW-58
SW-52
SW-6
SW-77
SW-22
SW-92
SW-41
SW-109
SW-70
SW-13
SW-84
SW-30
SW-100
SW-51
SW-5
SW-76
SW-21
SW-91
SW-40
SW-108
SW-69
SW-12
SW-83
SW-29
SW-50
SW-4
SW-75
SW-20
SW-39
SW-68
SW-11
SW-82
SW-28
SW-129
SW-3
SW-74
SW-19
SW-67
SW-10
SW-81
SW-27
SW-2
SW-73
SW-18
SW-90
SW-38
SW-107
SW-126
SW-132
SW-66
SW-9
SW-80
SW-26
SW-99
SW-49
SW-65
SW-72
SW-17
SW-89
SW-1
SW-37
SW-106
SW-8
SW-79
SW-25
SW-98
SW-48
SW-124
SW-128
SW-144
SW-71
SW-16
SW-88
SW-36
SW-7
SW-78
SW-24
SW-97
SW-15
SW-87
SW-125
SW-131
SW-139
SW-142
SW-145
SW-127
SW-133
SW-135
SW-137
SW-140
SW-143
SW-130
SW-134
SW-136
SW-138
SW-141
Feet
0
50
100
200
300
400

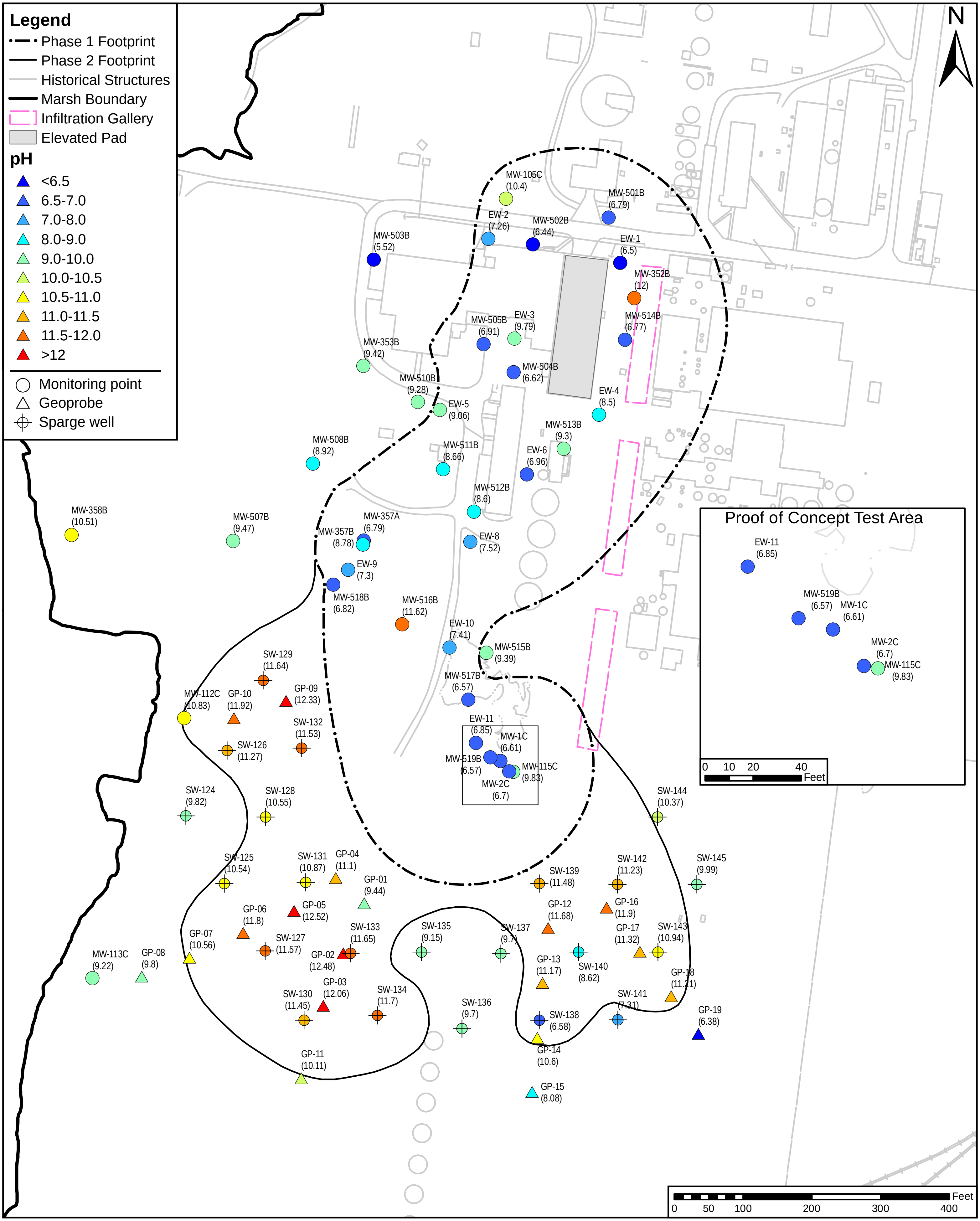


Figure 2-6: Pre-sparge (Phase 2) pH in Phase 2 sparge well and Geoprobe locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

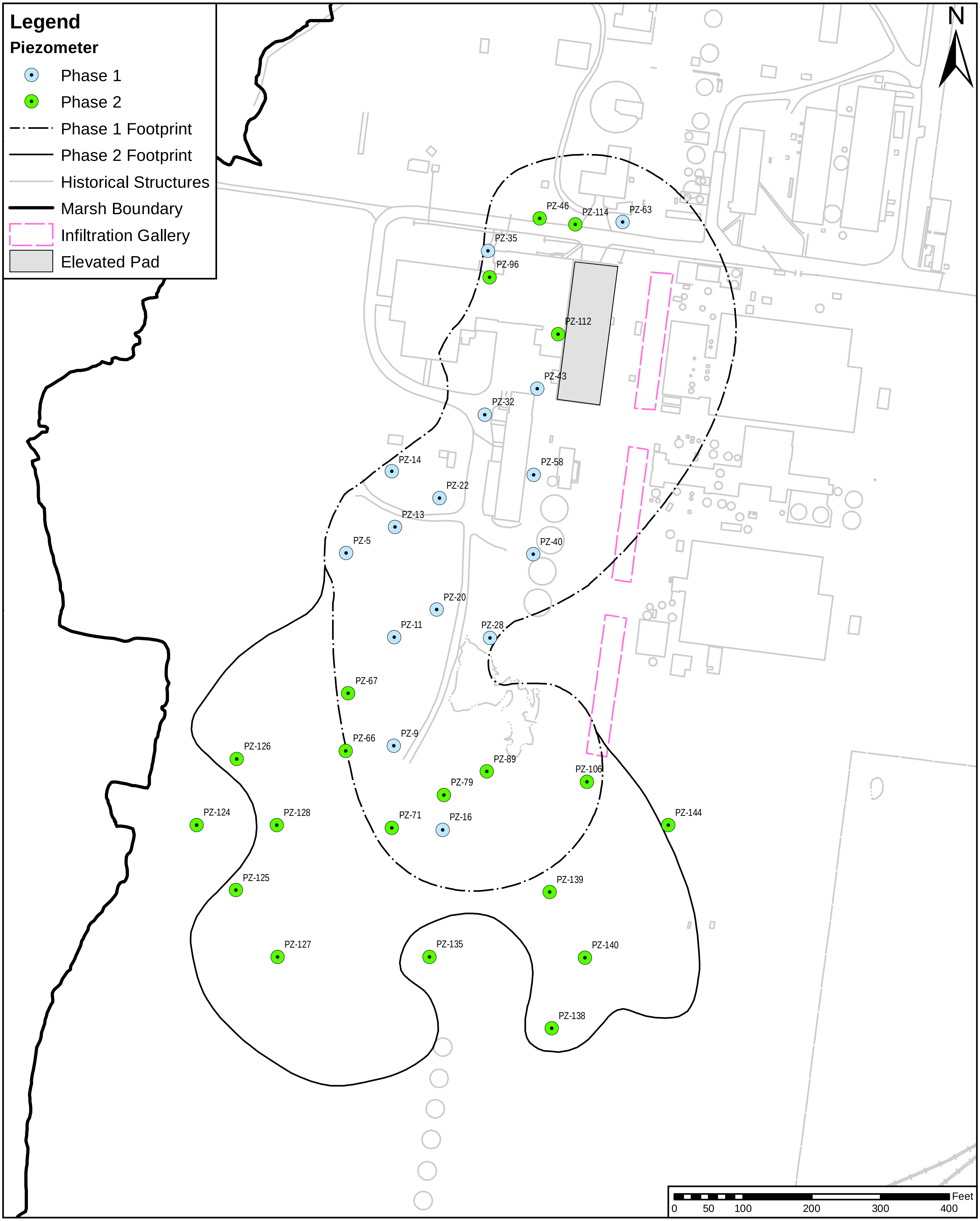


Figure 2-7: Locations of piezometers installed as part of Phase 2 CO_2 sparging.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

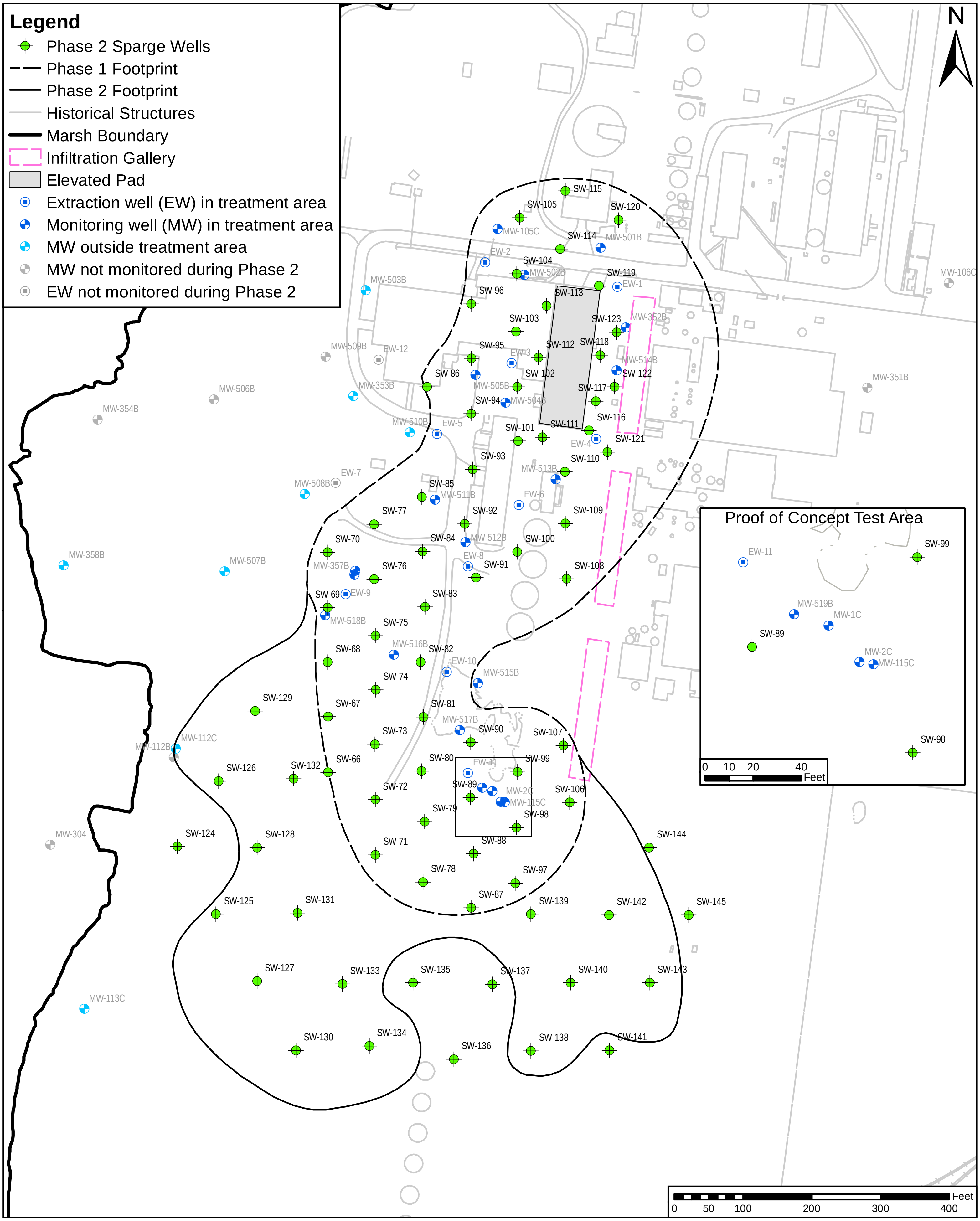


Figure 2-8: Monitoring well network used to evaluate Phase 2 CO_2 sparging.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

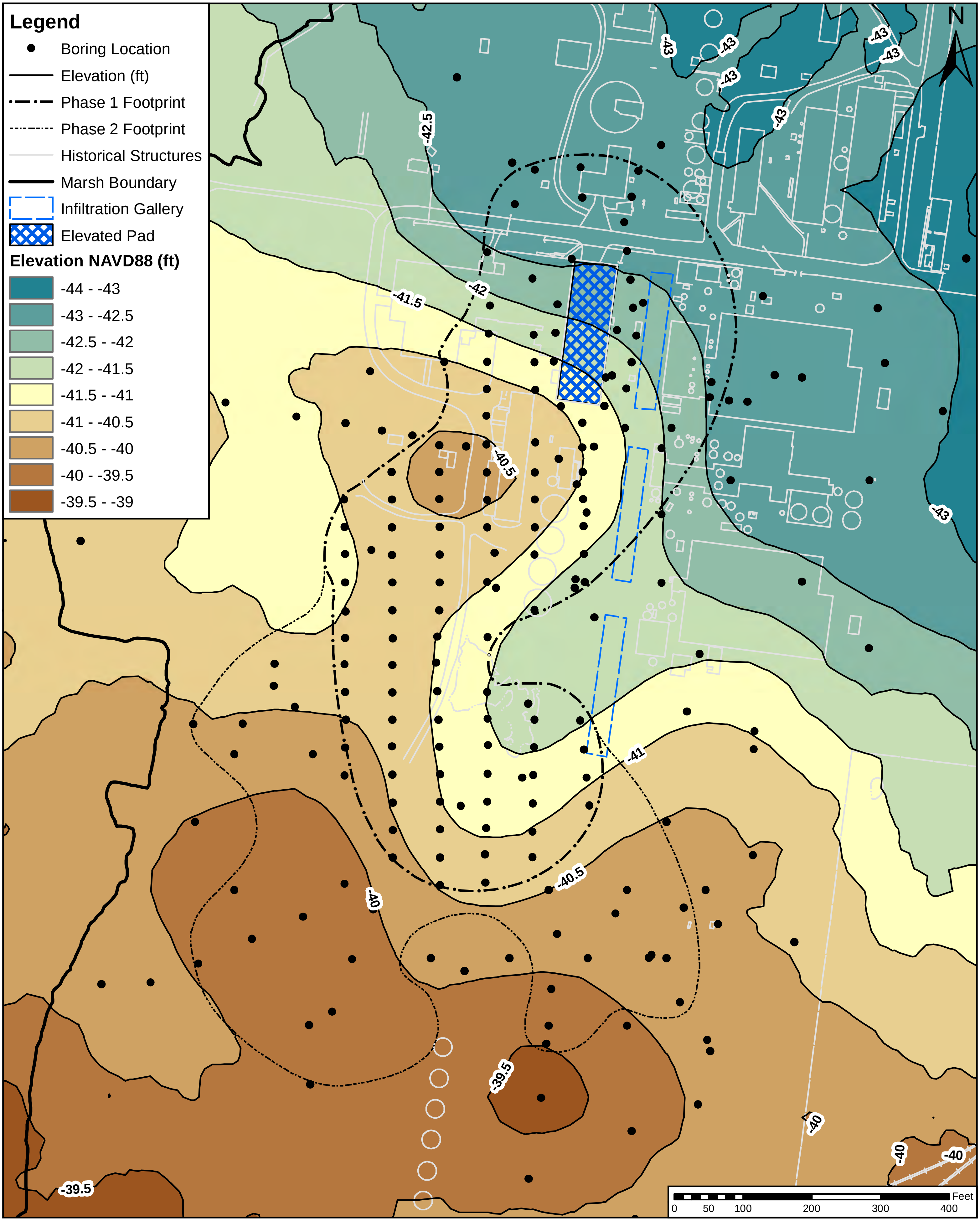


Figure 2-9: Structural contours of the top of variably-cemented sandstone.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

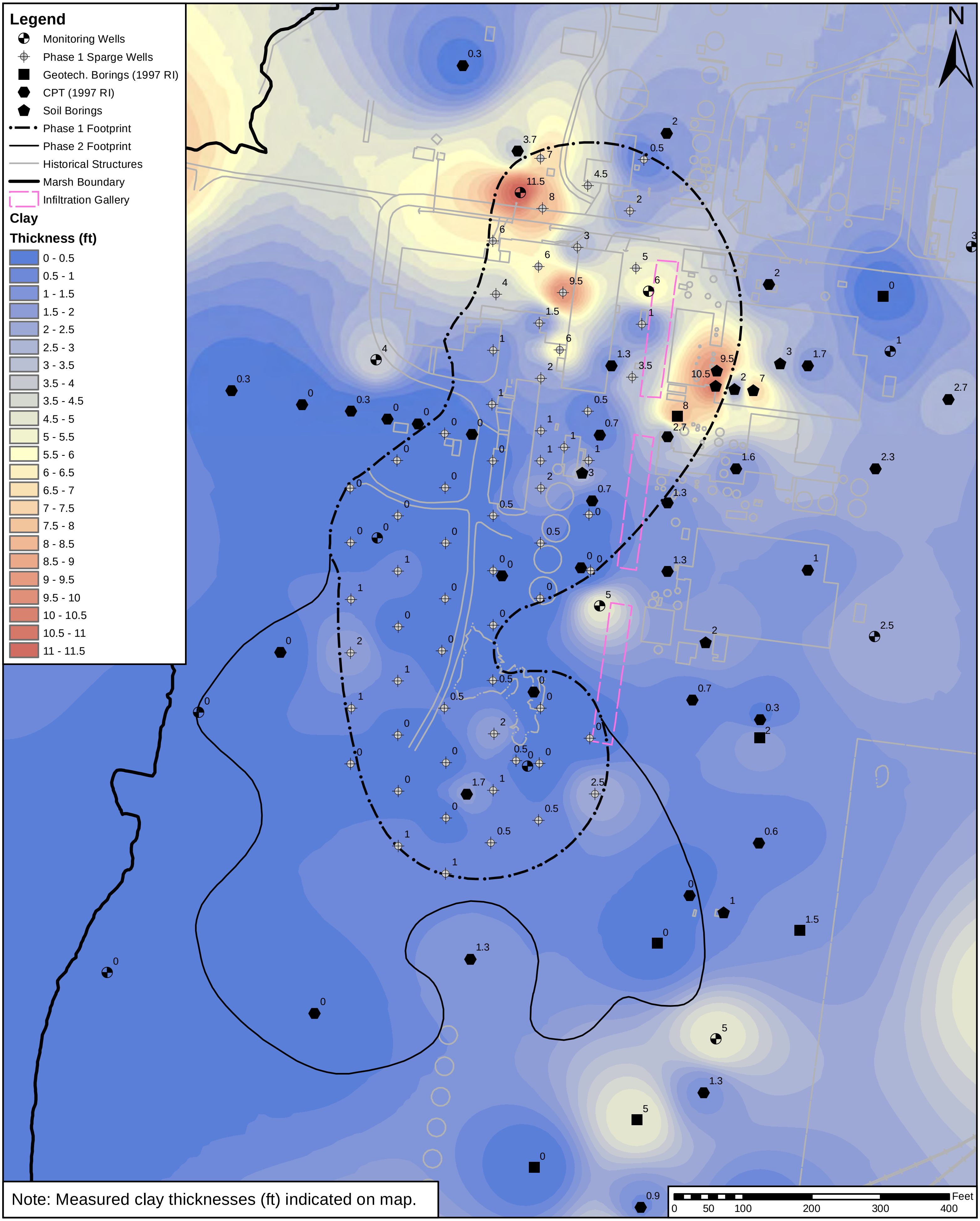


Figure 2-10: Clay isopach map.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

REV.	DESCRIPTION	DATE	DRAWN	CHK'D	APPV'D
B	FOR INFORMATION ONLY	4/15/14	JTS		
A	FOR INFORMATION ONLY	10/23/13	JTS		

PROJECT TITLE

Honeywell

LCP CHEMICALS SITE

CARBON DIOXIDE SPARGING SYSTEM

BRUNSWICK, GEORGIA

PARSONS

ENVIRONMENT AND INFRASTRUCTURE

OFFICE
301 PLAINFIELD ROAD
SYRACUSE, NY 13212
(315) 451-9560

JOB 448434

WBS

DRAWING TITLE

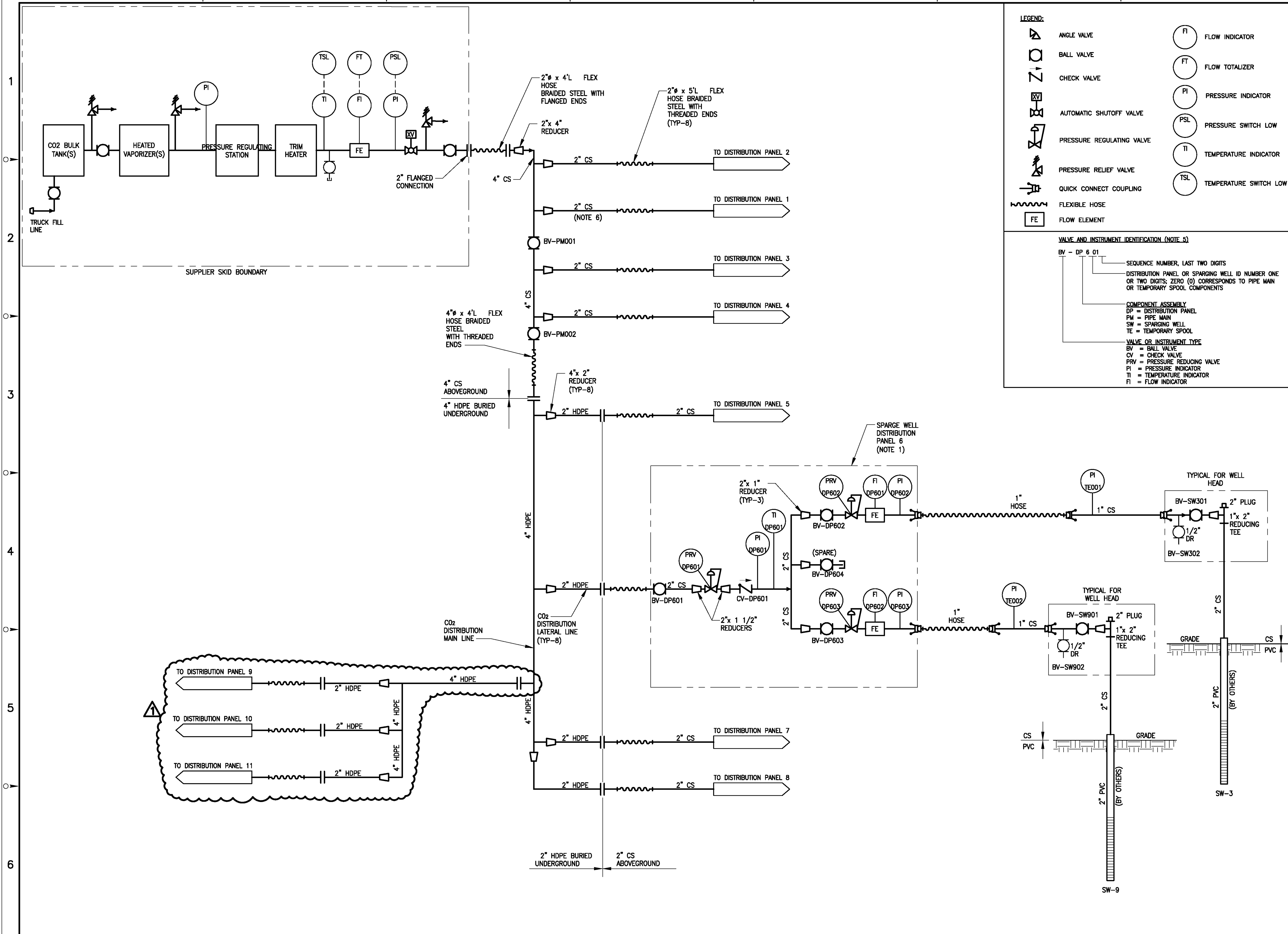
FIGURE 2-11

SITE OPERATIONS PLAN

SCALE 1"=40'-0"

DRAWING NO. SK-448434-C-001

REV. B



NOTES:

1. TYPICAL DISTRIBUTION PANEL FOR EACH SPARGE AREA.
2. CARBON STEEL PIPE SHALL BE ASTM A53 GRADE B STD WALL PIPE.
3. 4" HDPE PIPE SHALL BE DR-17.
4. 2" HDPE PIPE SHALL BE DR-11 OR LOWER.
5. VALVE AND INSTRUMENT IDENTIFICATION NUMBERS HAVE BEEN SHOWN FOR DISTRIBUTION PANEL 6 AND SPARGING WELLS SW-3 AND SW-9, THE OTHER DISTRIBUTION PANEL PANELS AND SPARGING WELLS WILL BE NAMED IN THE SAME FORMAT.
6. PORTION OF 2" CS PIPE TO DISTRIBUTION PANEL 1 SHALL BE BURIED FOR ROAD CROSSING.
7. SEE SPECIFICATION 15060 FOR PIPING, VALVES AND INSTRUMENTATION REQUIREMENTS.

NO.	DESCRIPTION	DATE	DRAWN	CHK'D	APP'VD
1	REVISED FOR 2014 CONSTRUCTION	08/15/14	RR	JMO	JMO
0	ISSUED FOR CONSTRUCTION	9/13/13	JTS	AN	JMO

	DATE
DRAWN BY JTS	9/13/13
CHECKED BY AN	9/13/13
APPROVED BY JMO	9/13/13
PROJECT MGR. JMO	9/13/13

SEAL

PARSONS
ENVIRONMENT AND INFRASTRUCTURE

OFFICE
301 PLAINFIELD ROAD
SYRACUSE, NY 13212
(315) 451-9560

JOB 447567
WBS 02127

PROJECT TITLE
Honeywell
LCP CHEMICALS SITE
CARBON DIOXIDE SPARGING SYSTEM
BRUNSWICK, GEORGIA

DRAWING TITLE
FIGURE 2–12
PROCESS & INSTRUMENTATION DIAGRAM

SCALE NO SCALE

DRAWING NO. FIGURE 2–12 REV. 1

FILE NAME: P:\PIT\PROJECTS\HONEYWELL\448354 BRUNSWICK LCP CO2 SPARGING\10 TECHNICAL CATEGORIES\ENGR\CAD\FIGURE 2-8.DWG
PLOT DATE: 5/20/2015 1:54 PM PLOTTED BY: RABUFFETTI, RICHARD

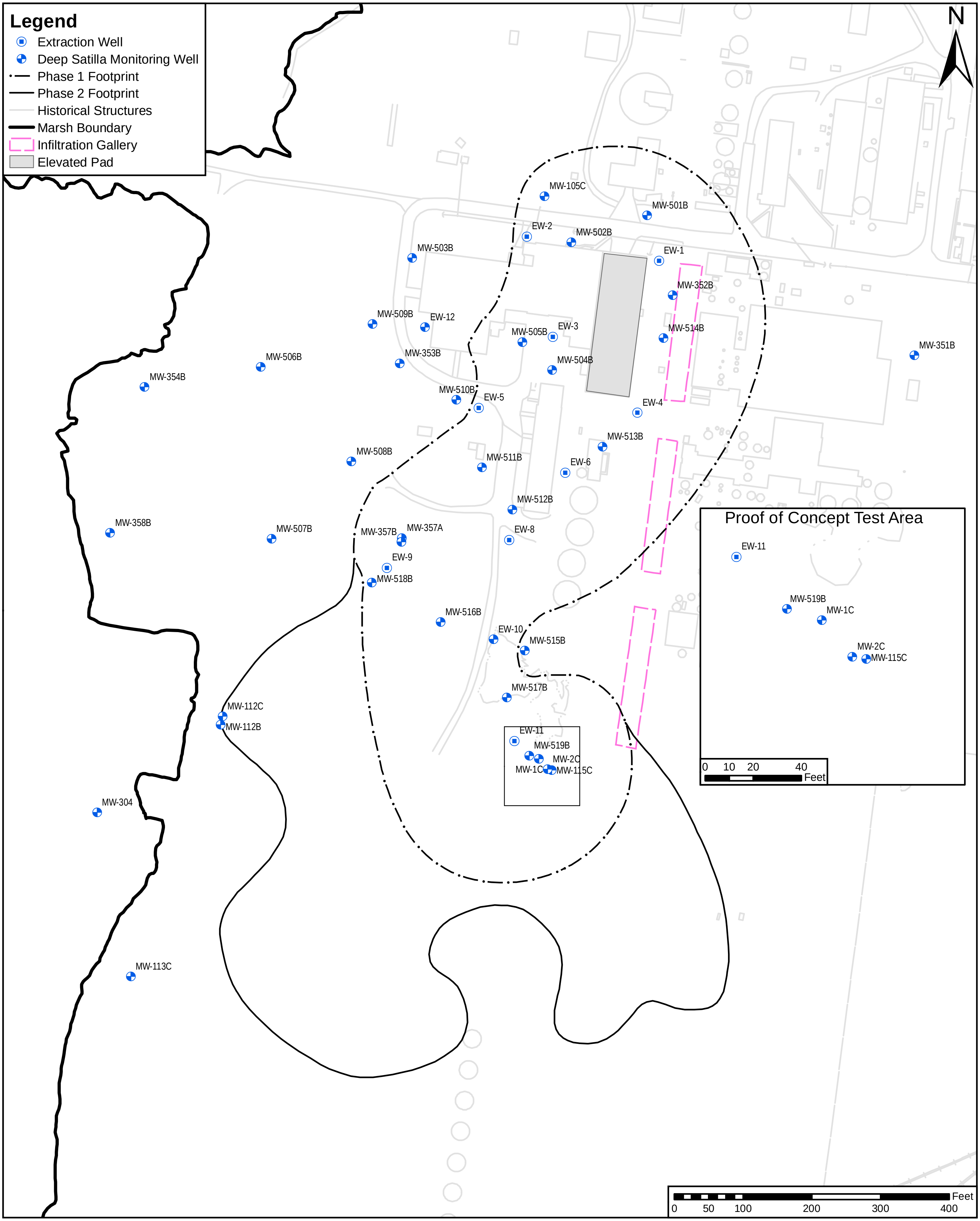


Figure 3-1: Locations of deep Satilla monitoring points.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

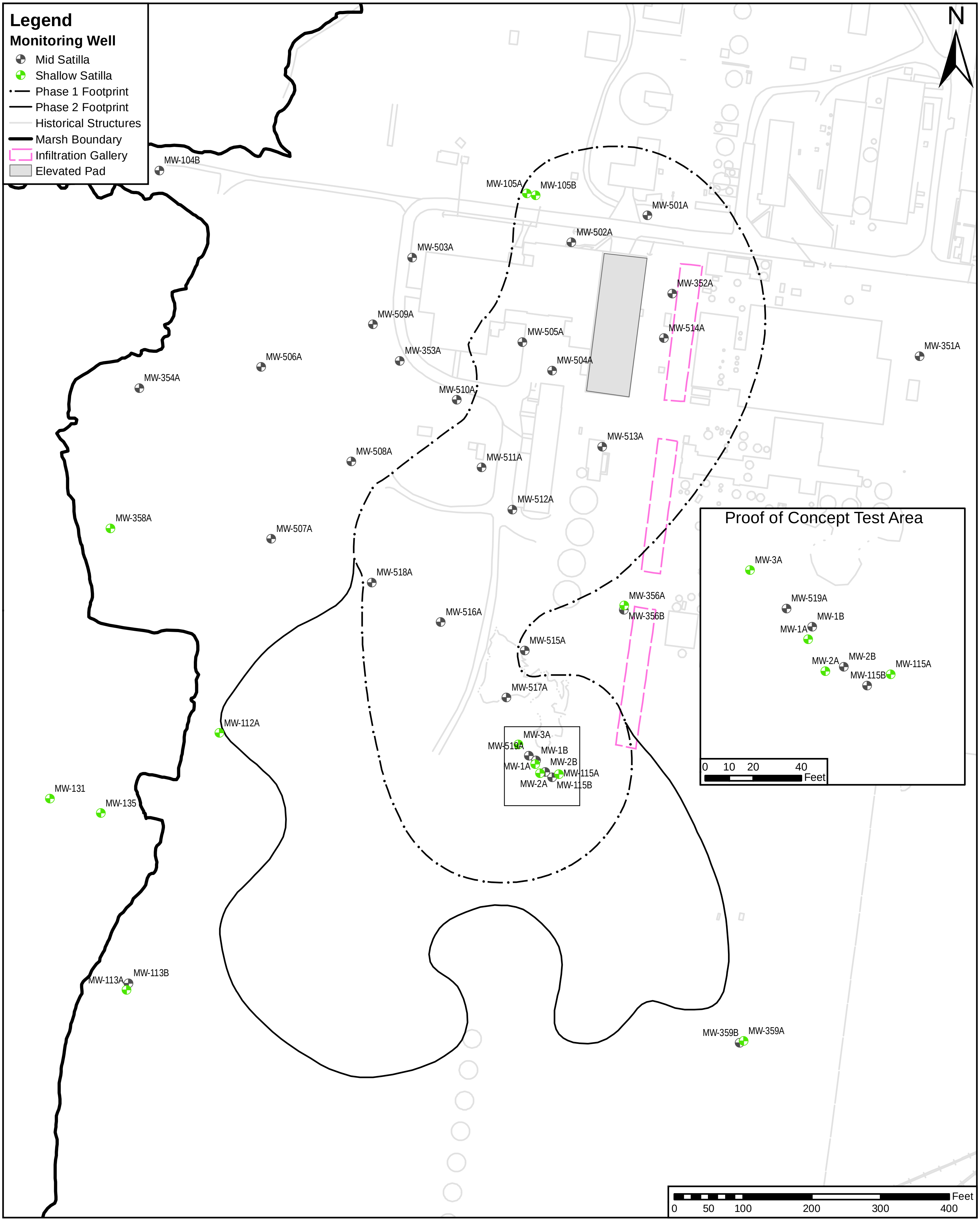


Figure 3-2: Locations of mid and shallow Satilla monitoring wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

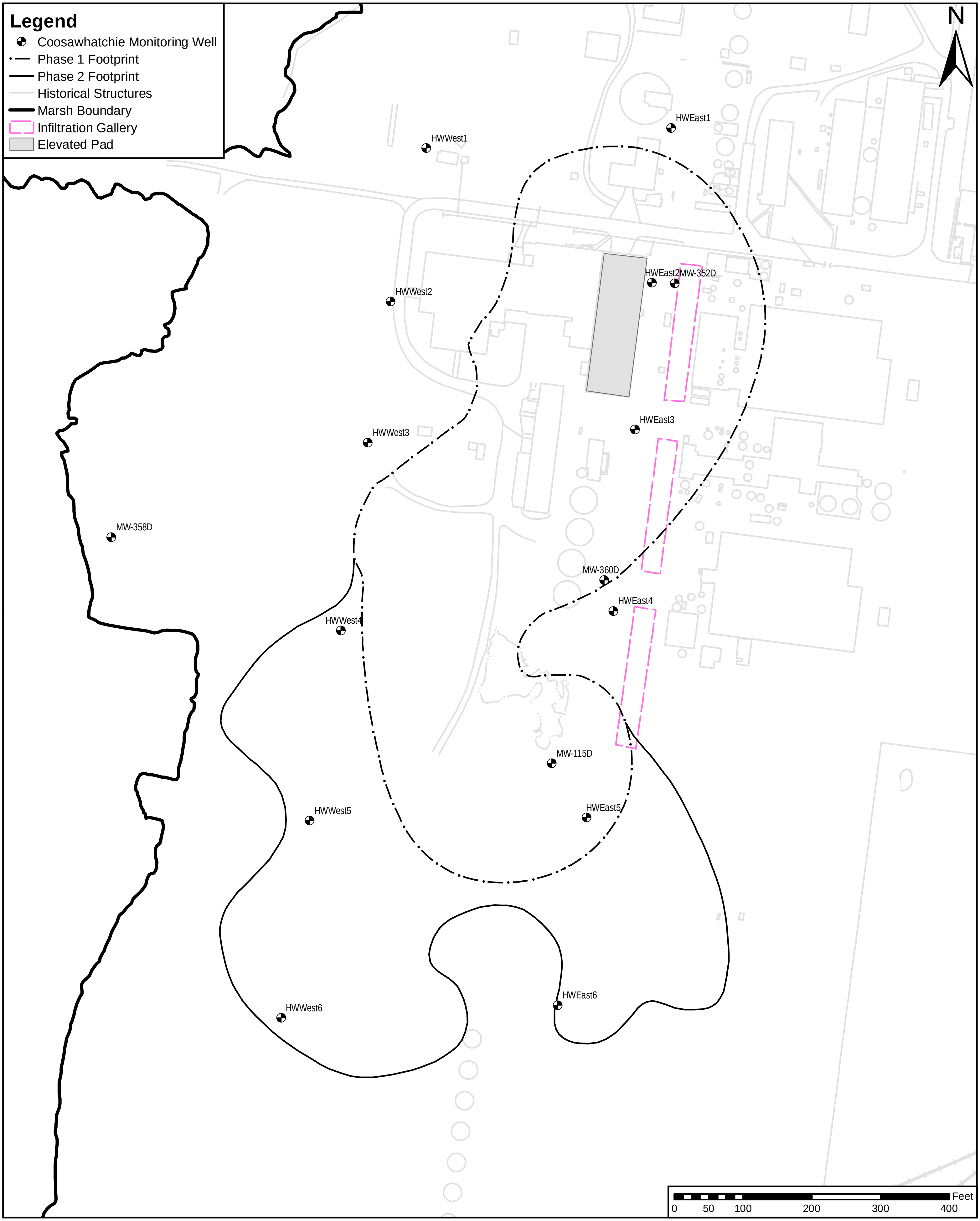


Figure 3-3: Locations of Coosawhatchie A/B monitoring wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

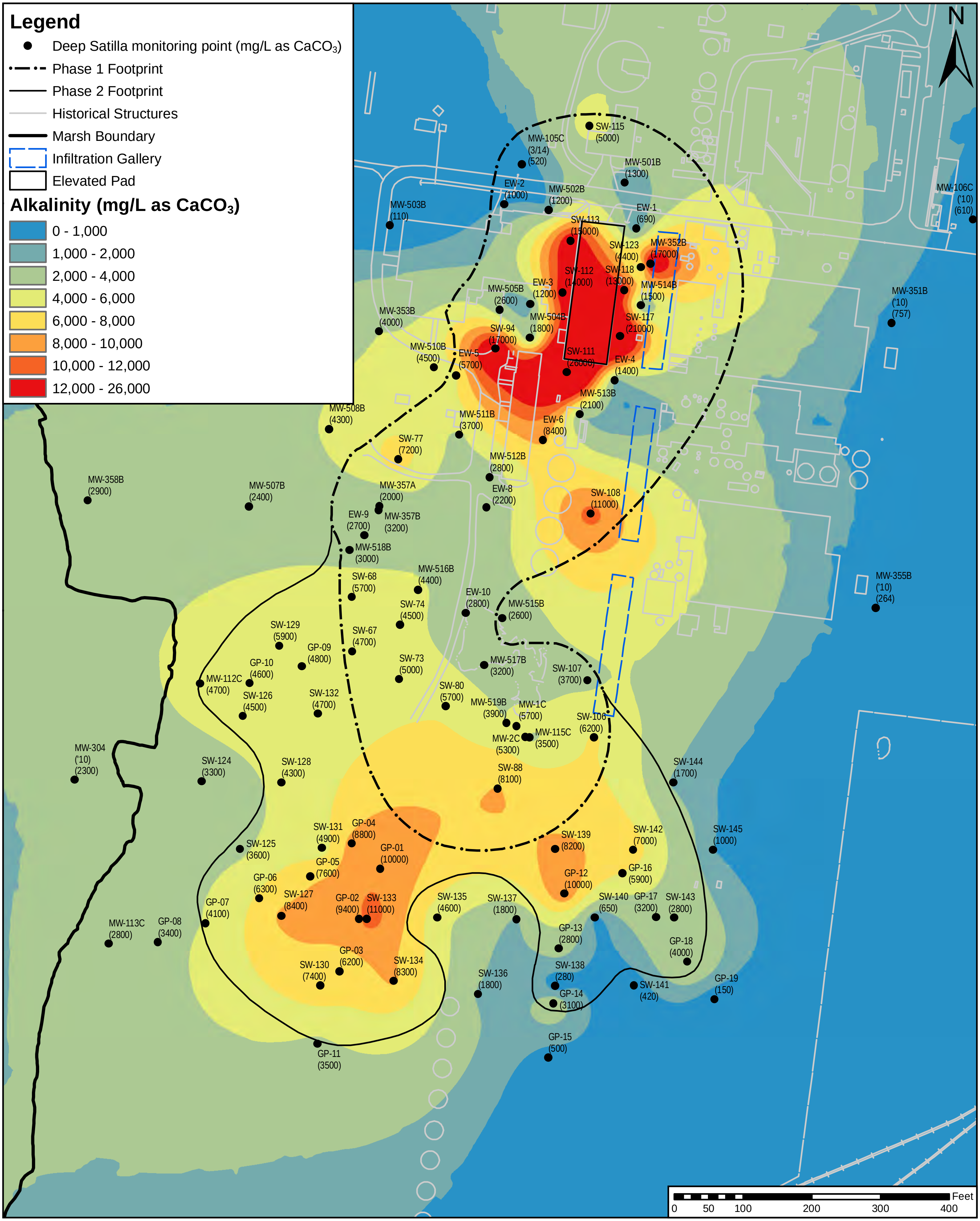


Figure 3-4: Interpolated alkalinity in the Satilla using data from deep monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

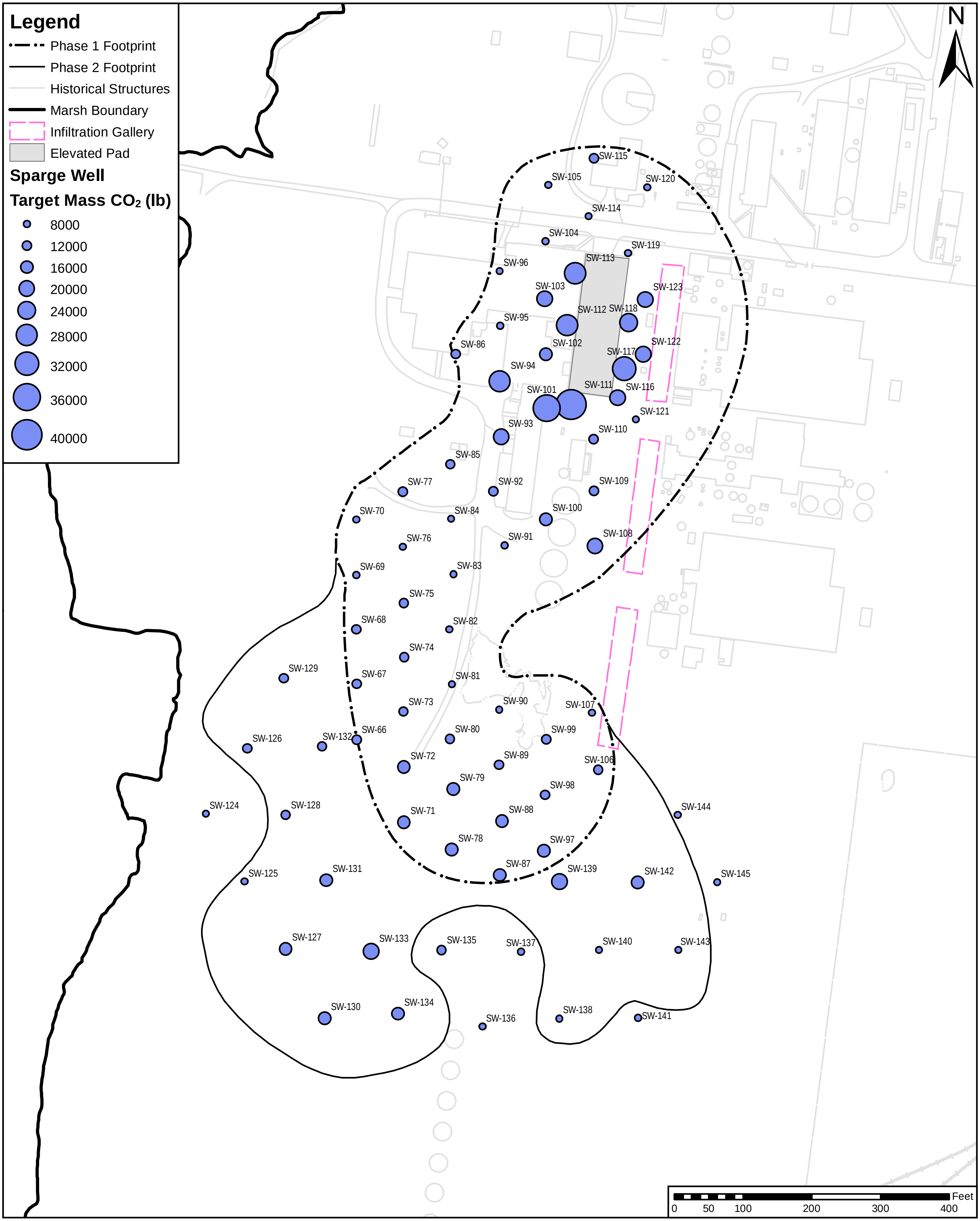


Figure 3-5: Target CO_2 sparging mass for Phase 2 sparge wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

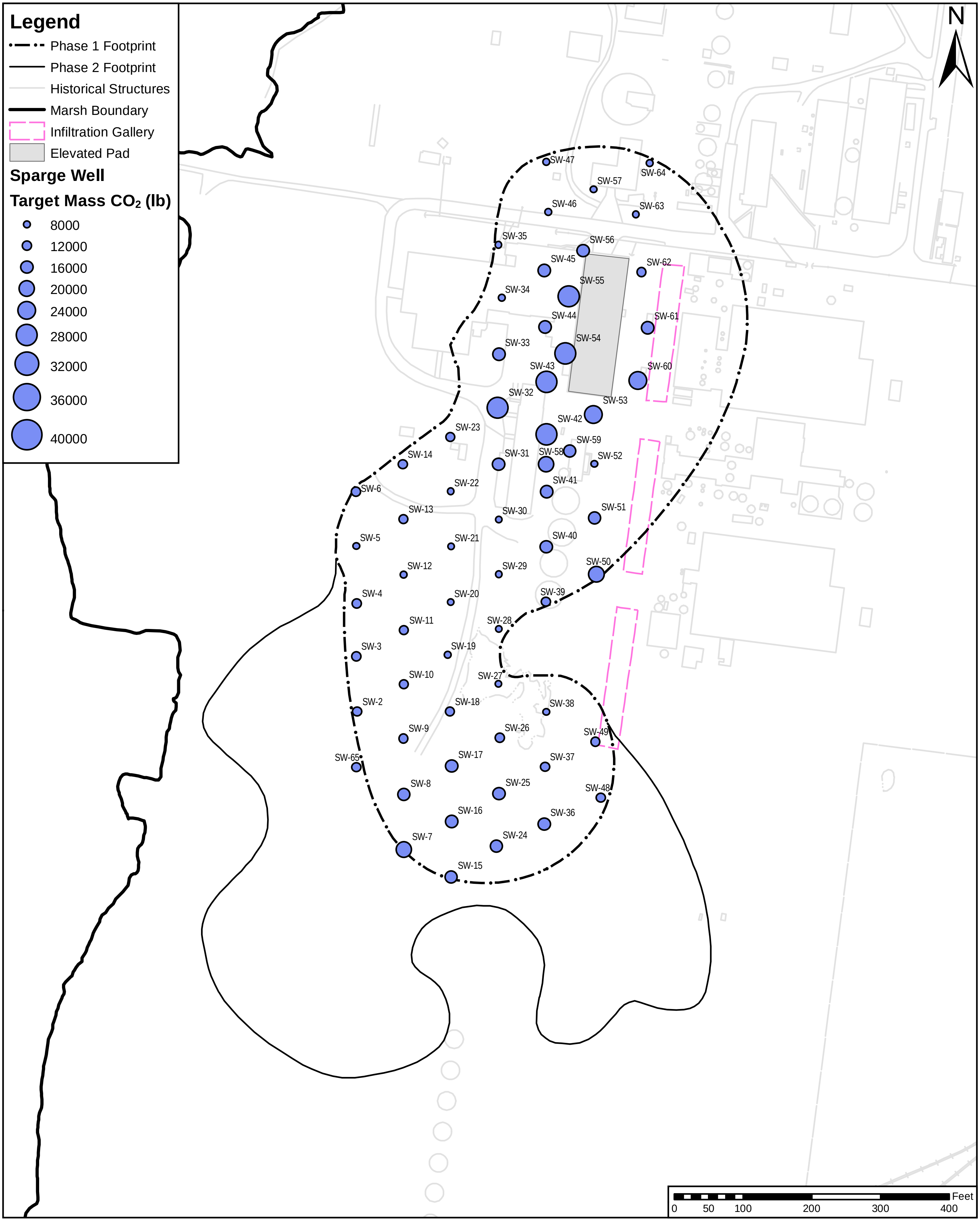


Figure 3-6: Target CO_2 sparging mass for Phase 1 sparge wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

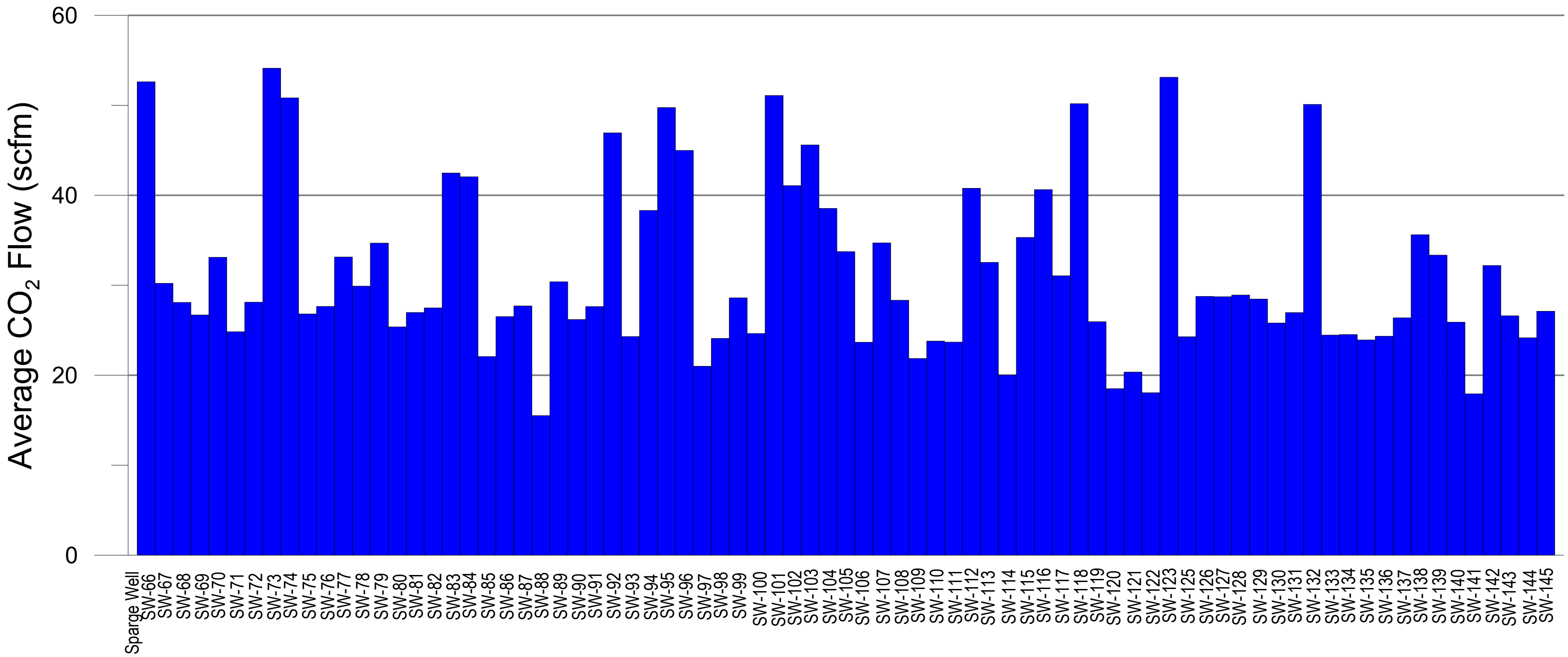


Figure 4-1: Average flow rates for Phase 2 sparge wells.

LCP Chemicals Site, Brunswick, GA

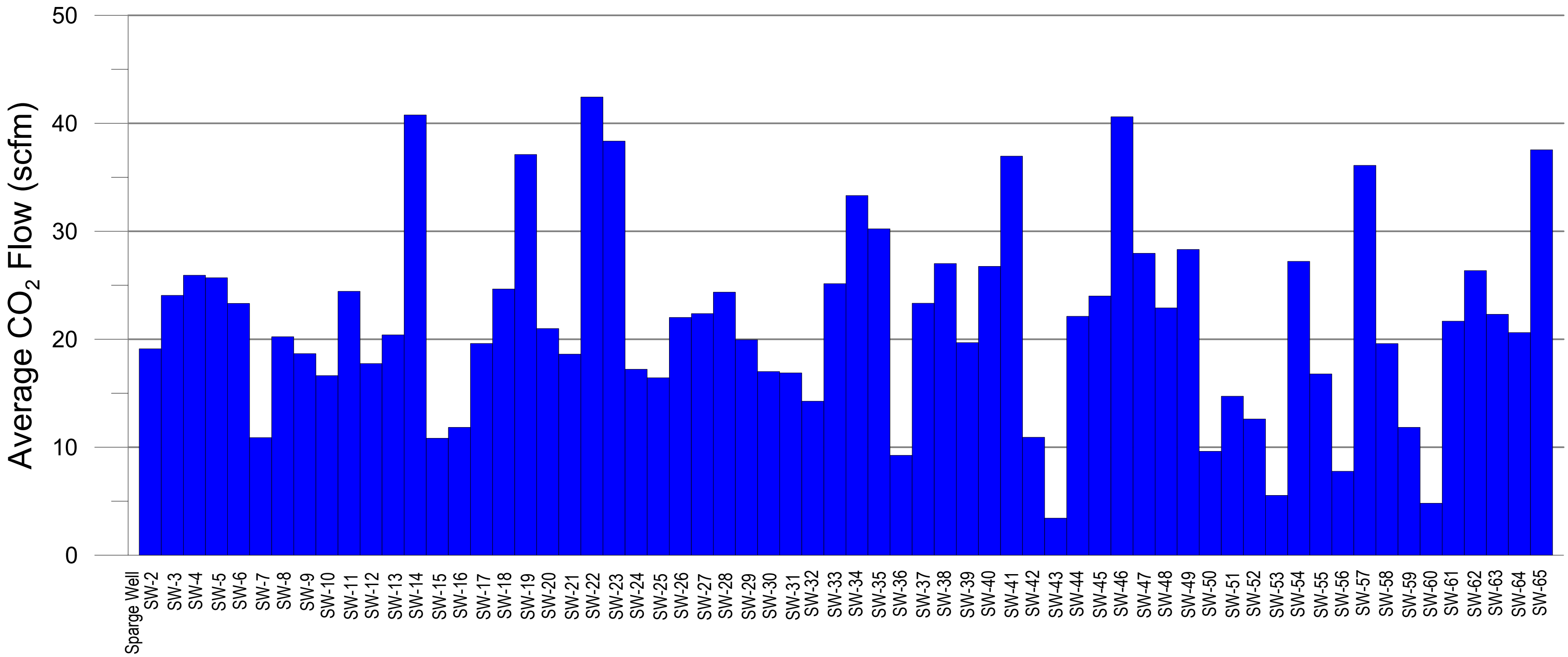


Figure 4-2: Average flow rates for Phase 1 sparge wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

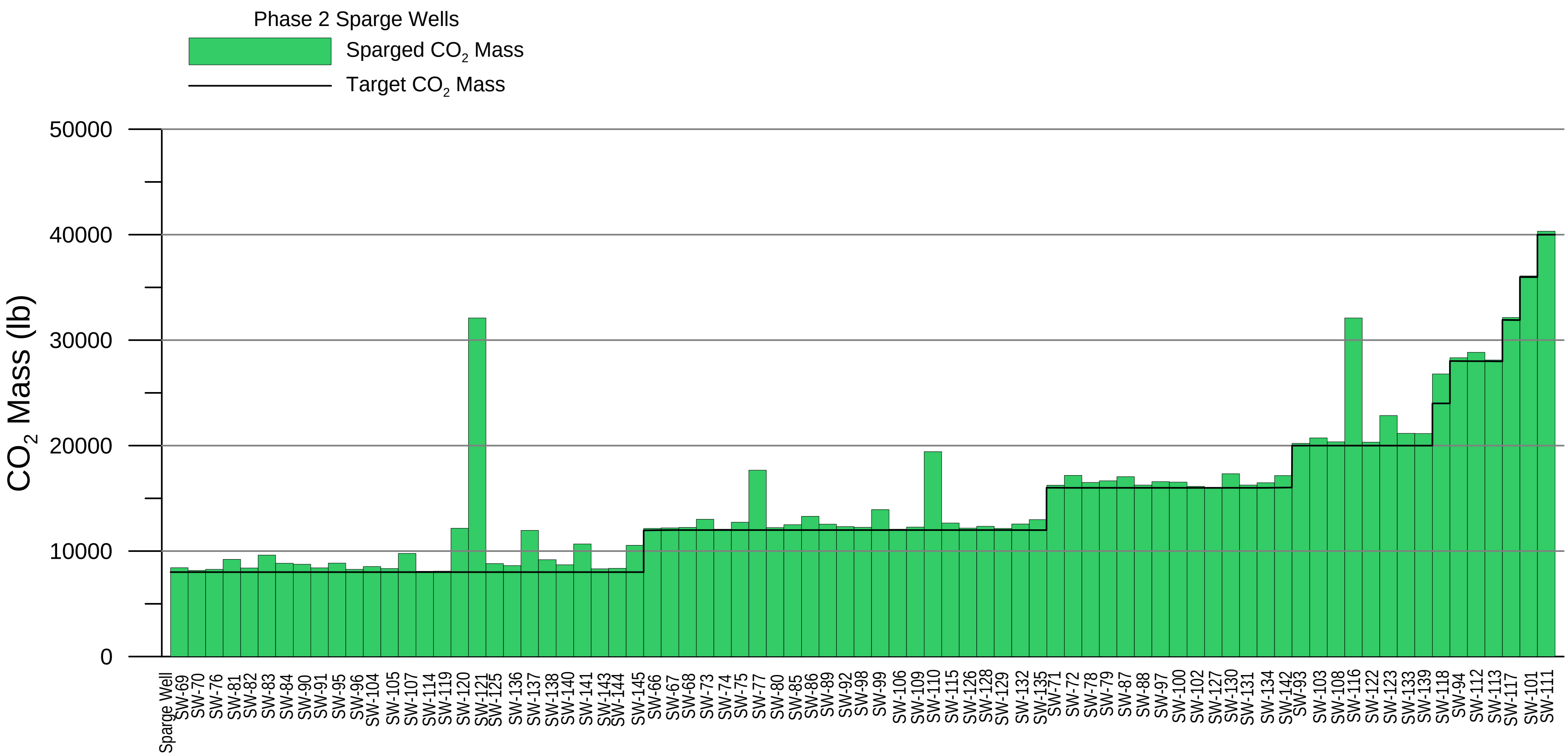


Figure 4-3: Total CO_2 mass for Phase 2 sparge wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

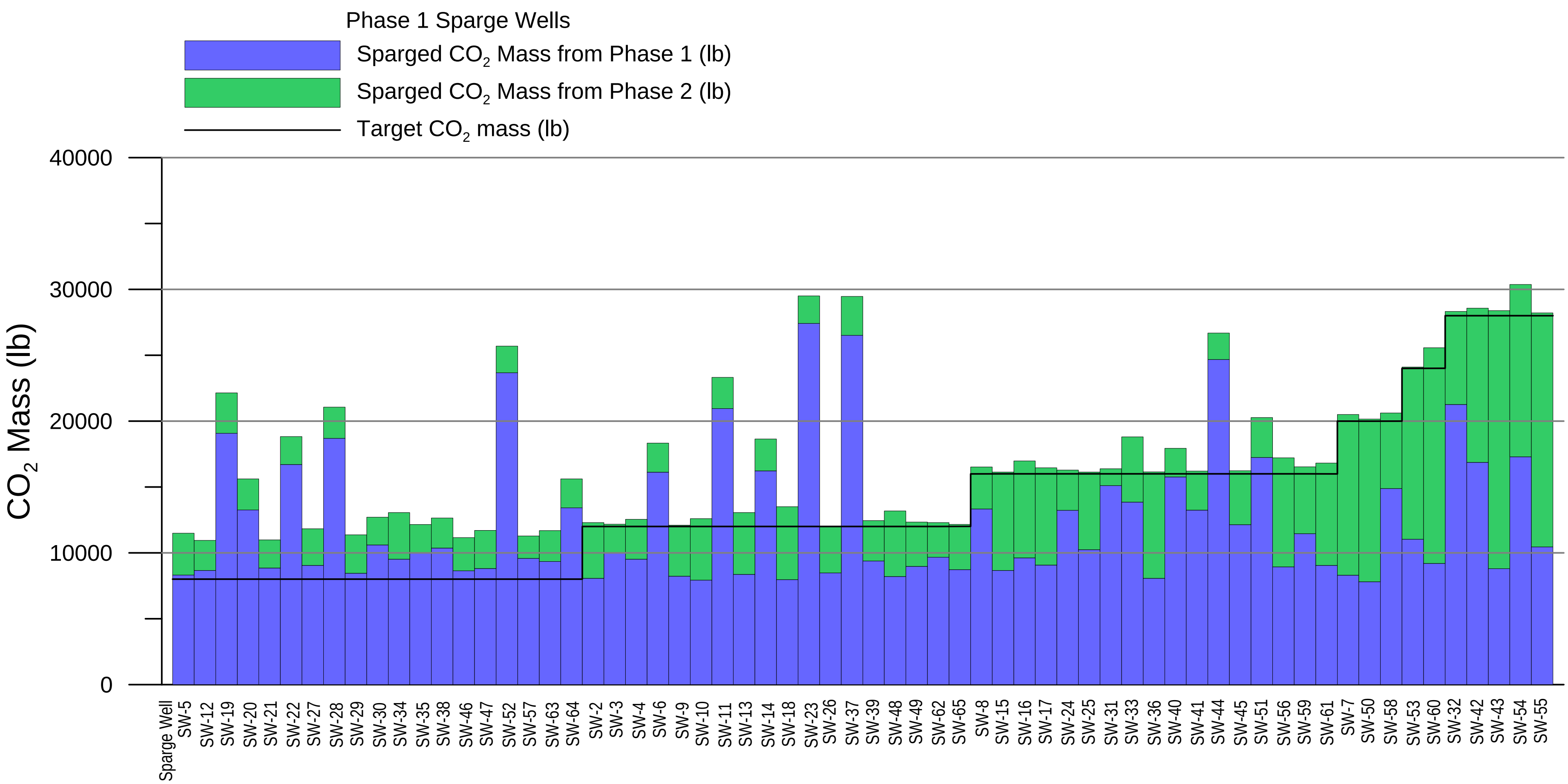


Figure 4-4: Total CO_2 mass for Phase 1 sparge wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

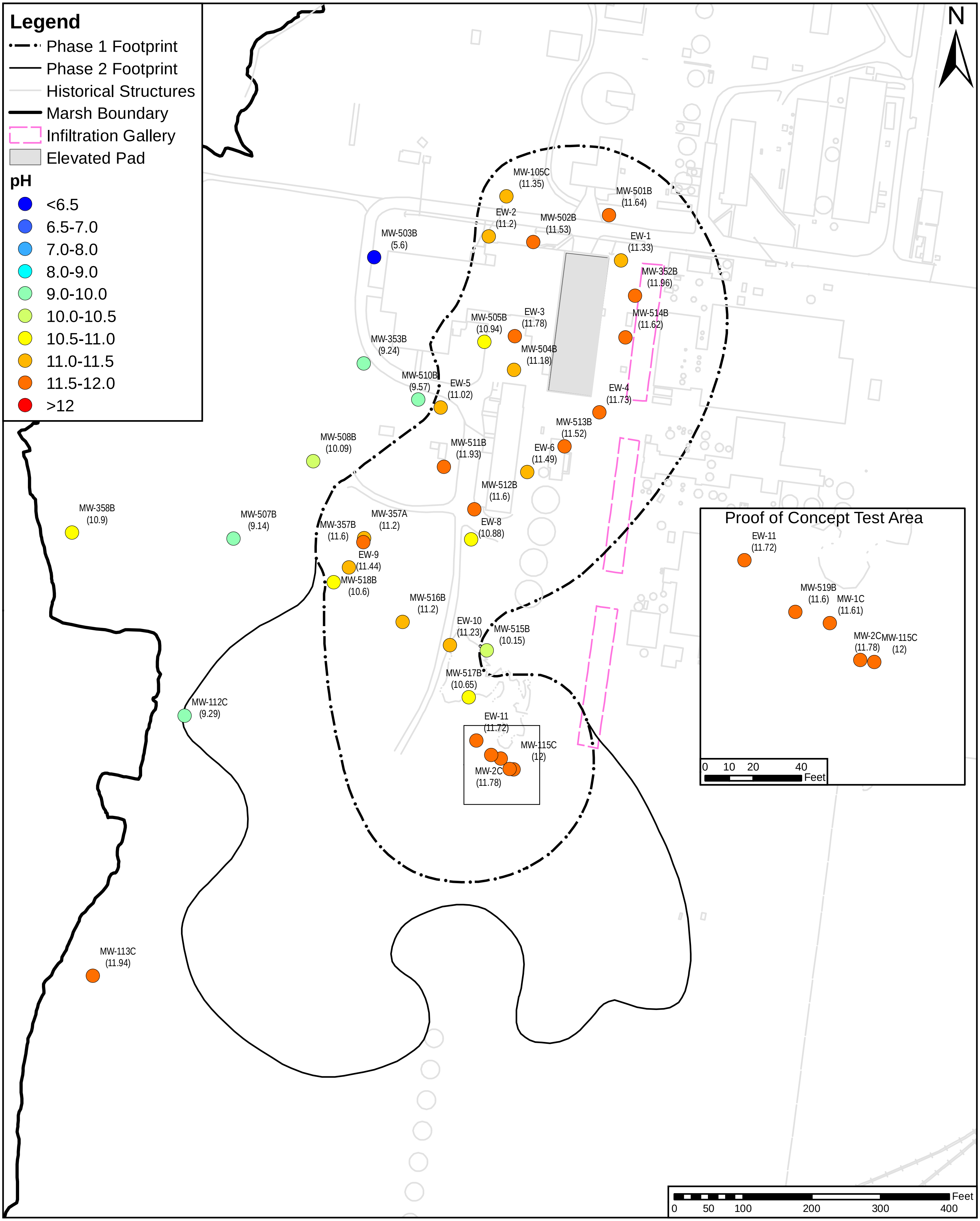


Figure 4-5: Pre-sparge (2011-2012) pH in deep Satilla monitoring and extraction wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

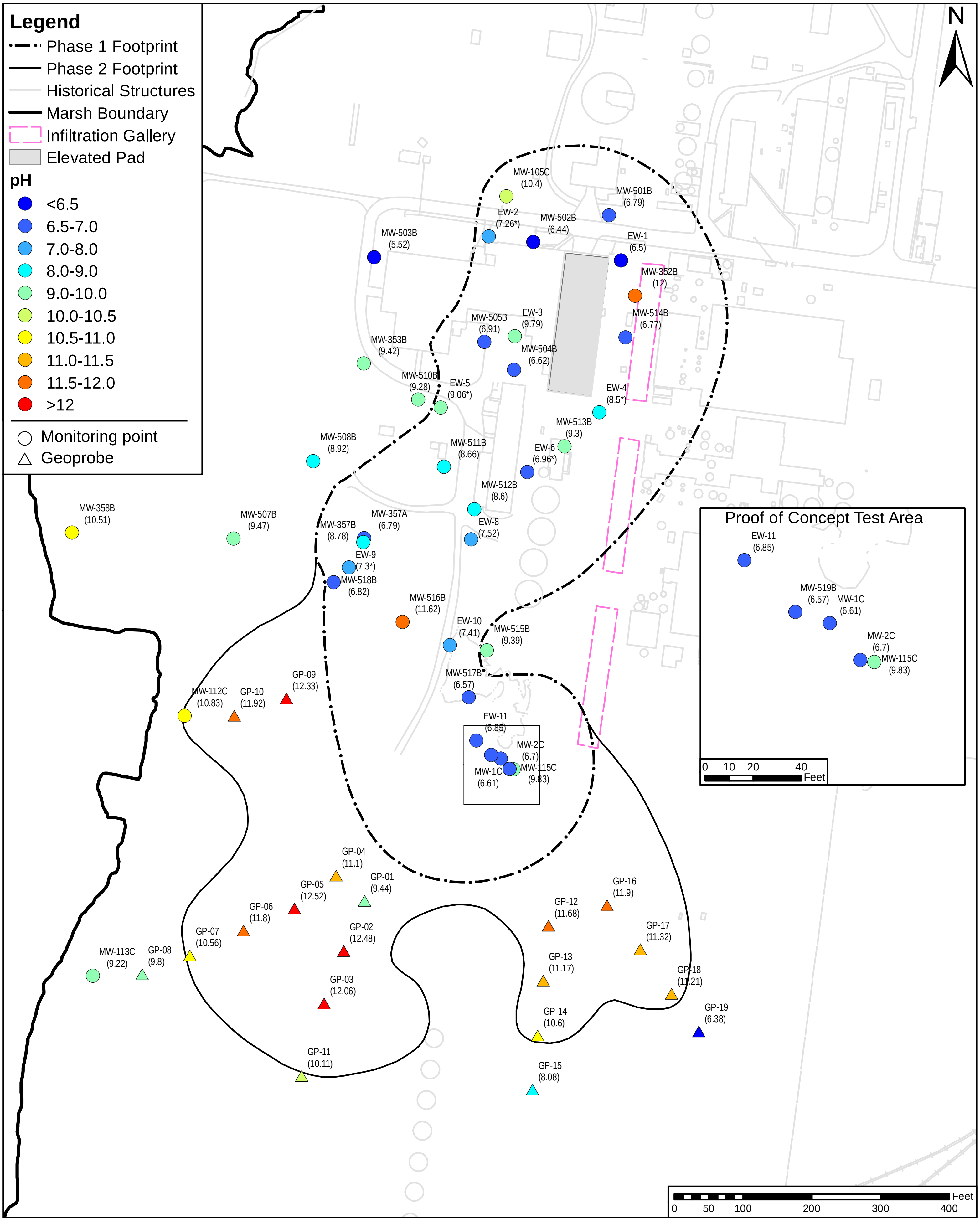


Figure 4-6: Pre-sparge (Phase 2) pH in deep Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

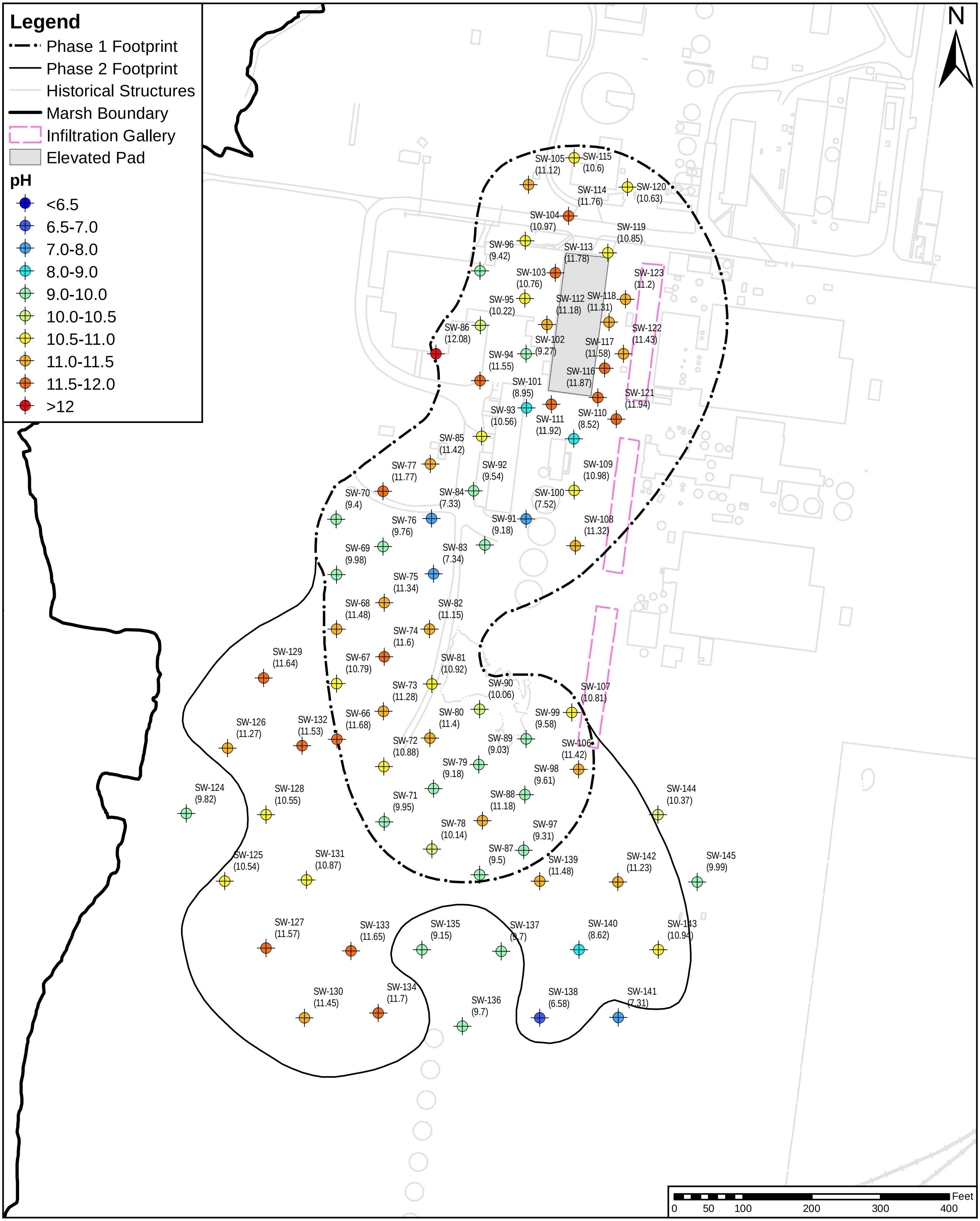


Figure 4-7: Pre-sparge (Phase 2) pH in sparge wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

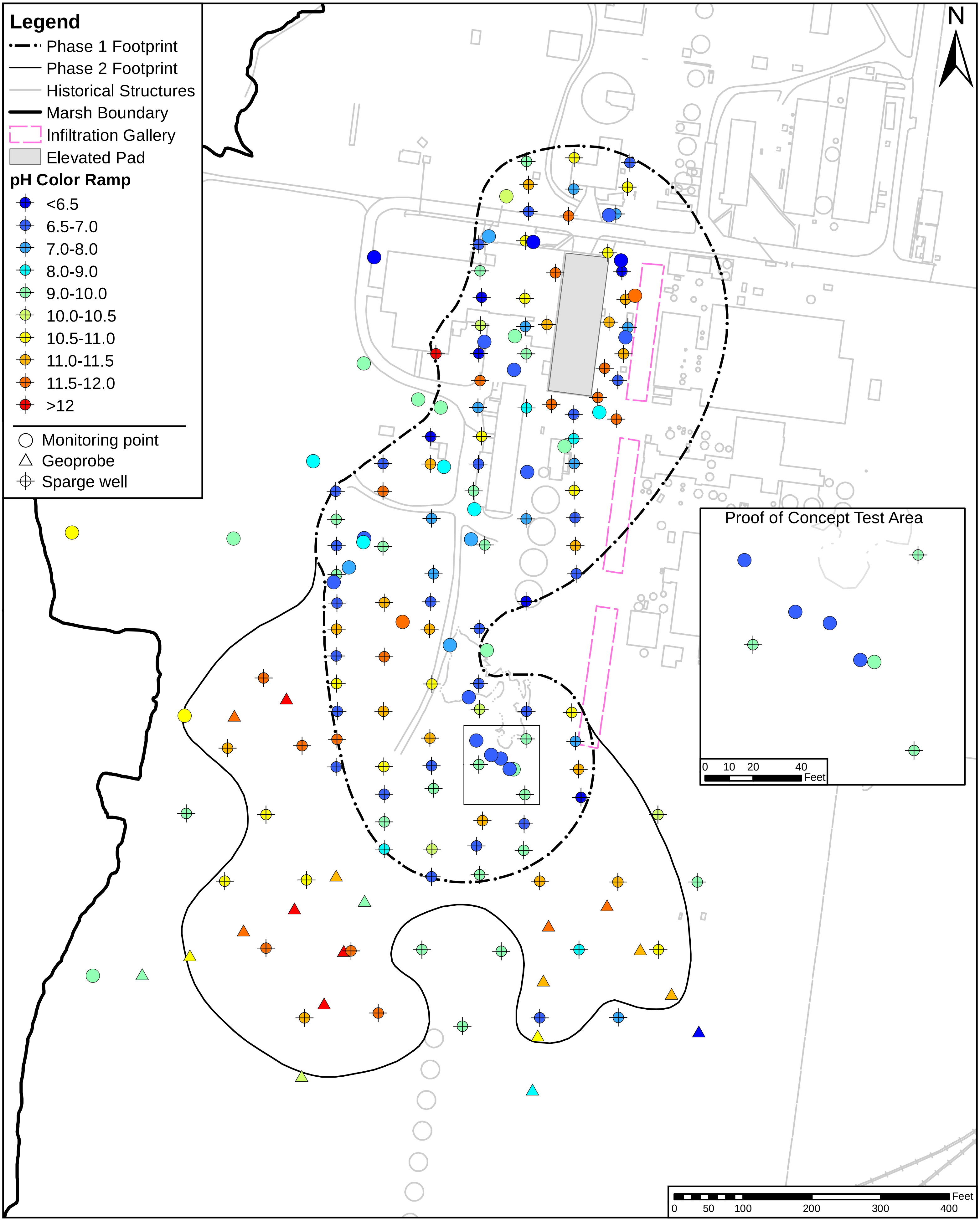


Figure 4-8: Pre-sparge (Phase 2) pH in deep Satilla monitoring locations.
LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

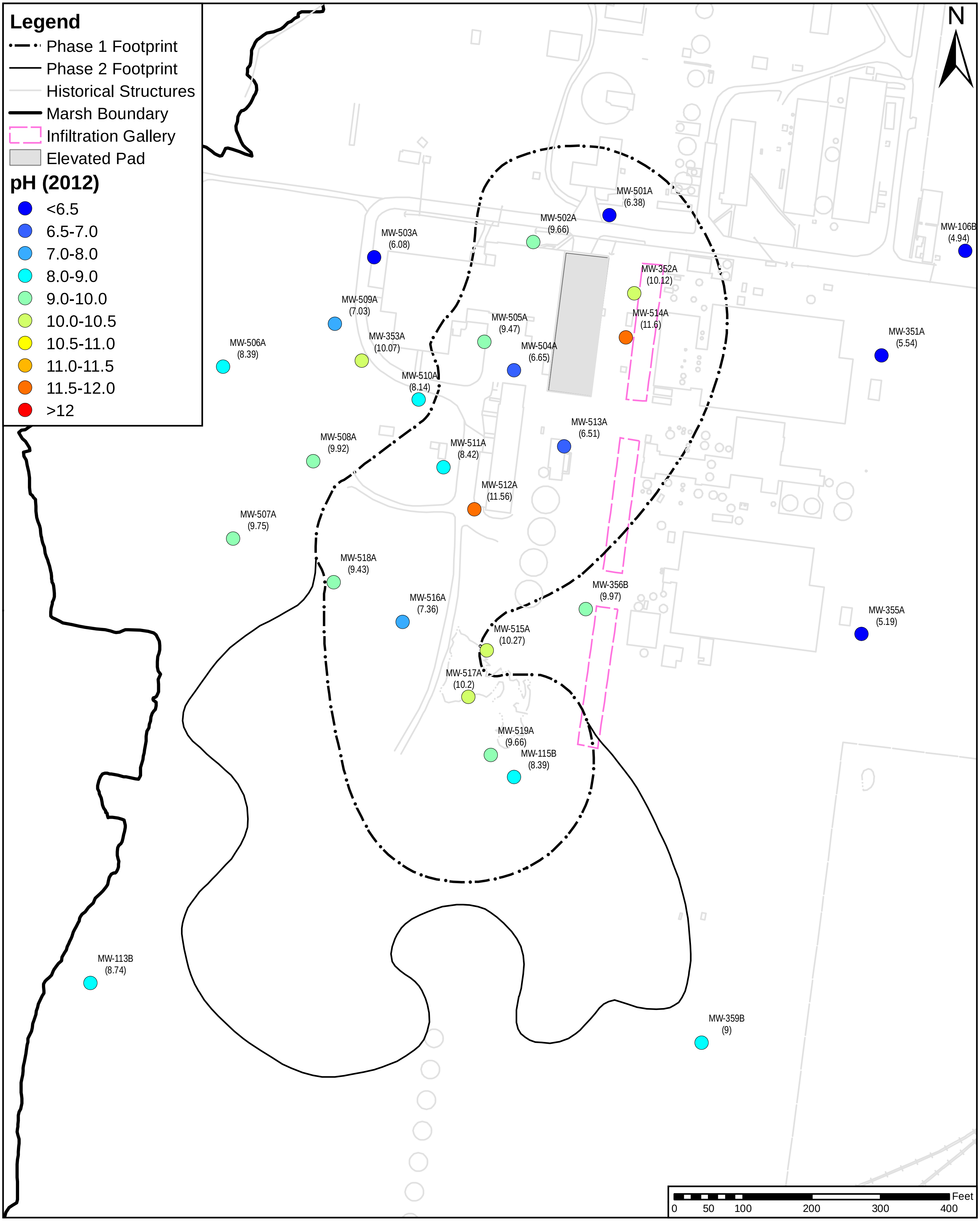


Figure 4-9: Pre-sparge (2012) pH in mid Satilla monitoring wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

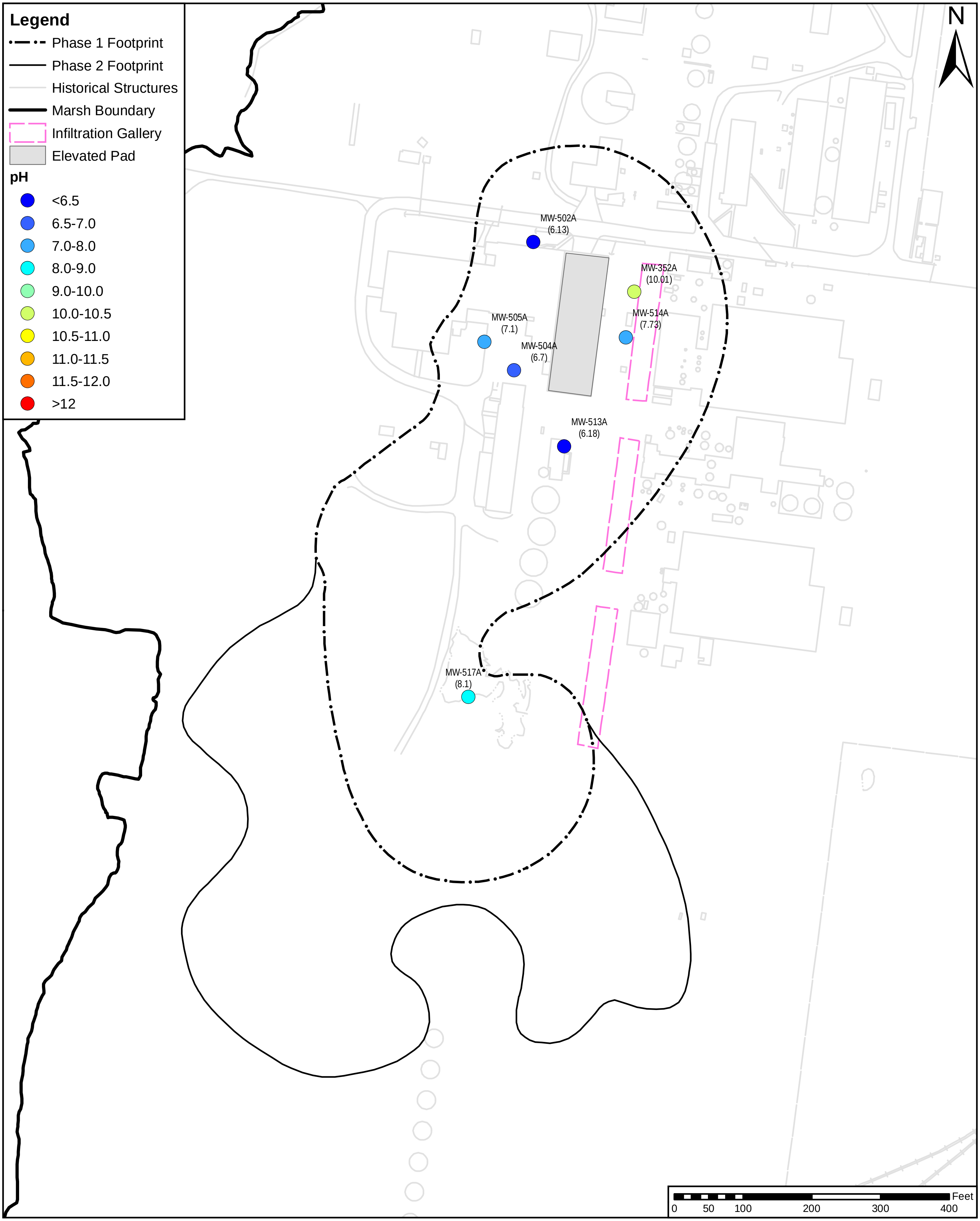


Figure 4-10: Pre-sparge (Phase 2) pH in mid Satilla monitoring wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

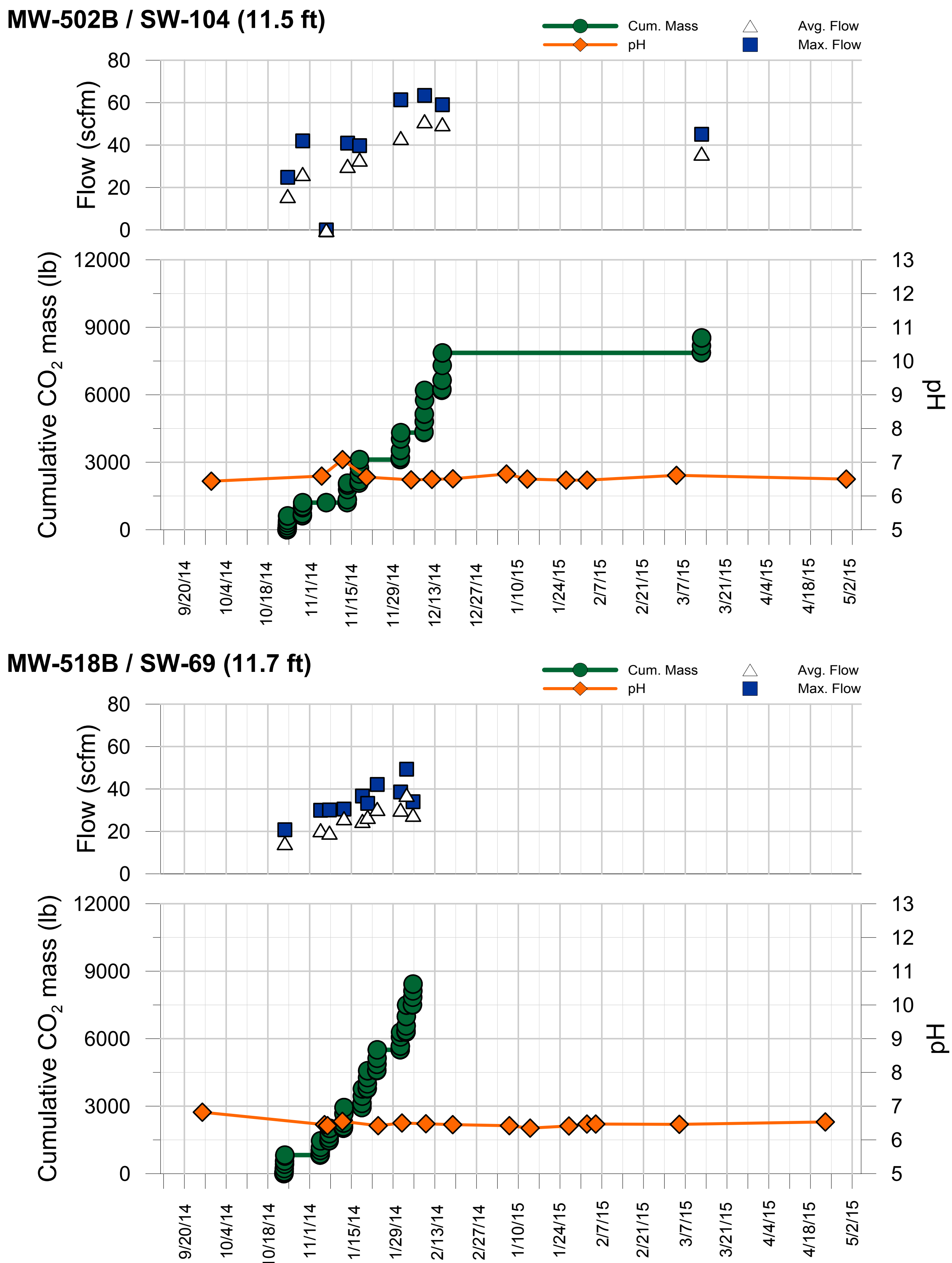


Figure 4-11: CO_2 flow, mass and pH as a function of time for MW-502B and MW-518B

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

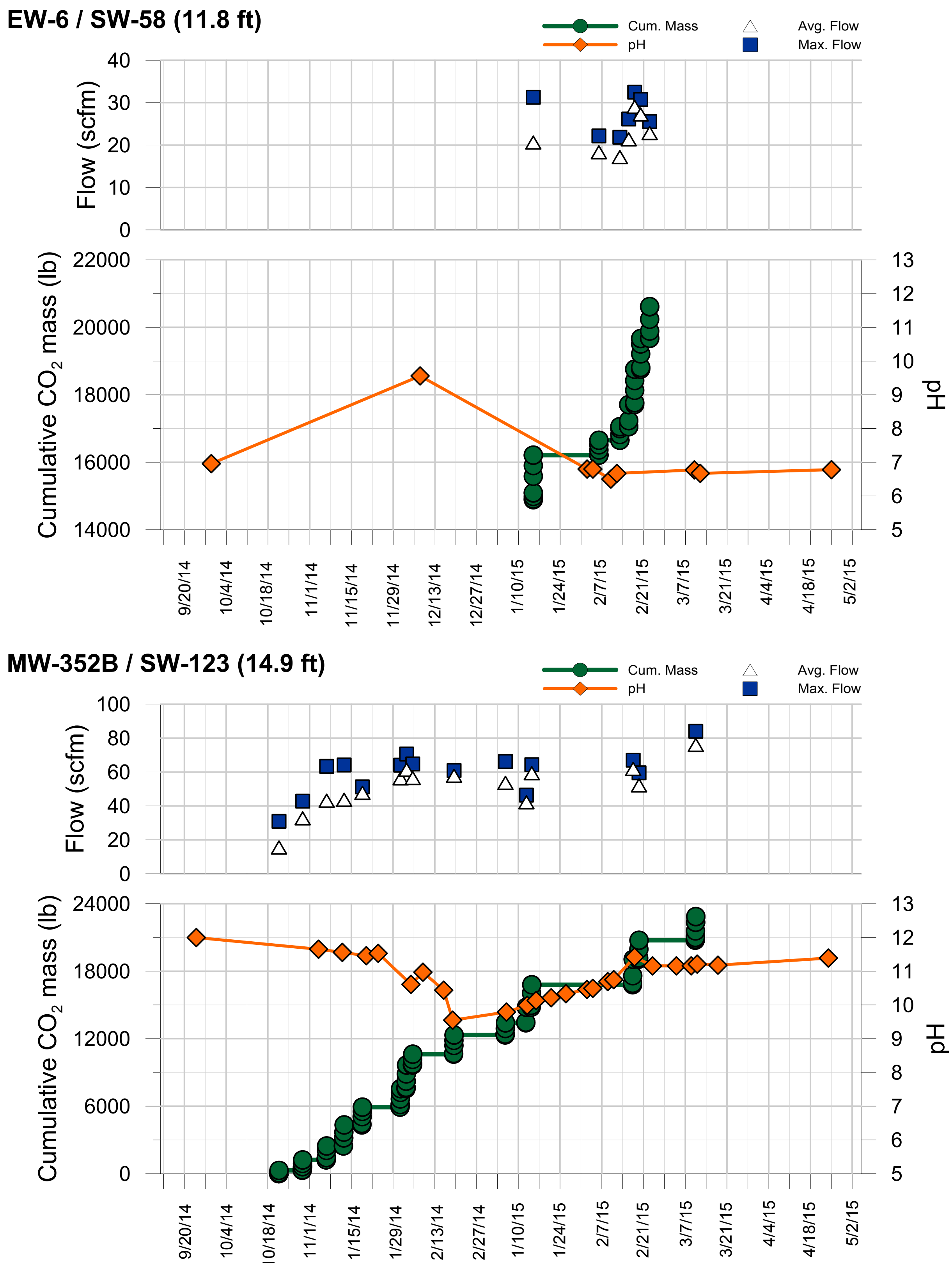


Figure 4-12: CO_2 flow, mass and pH as a function of time for EW-6 and MW-352B

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

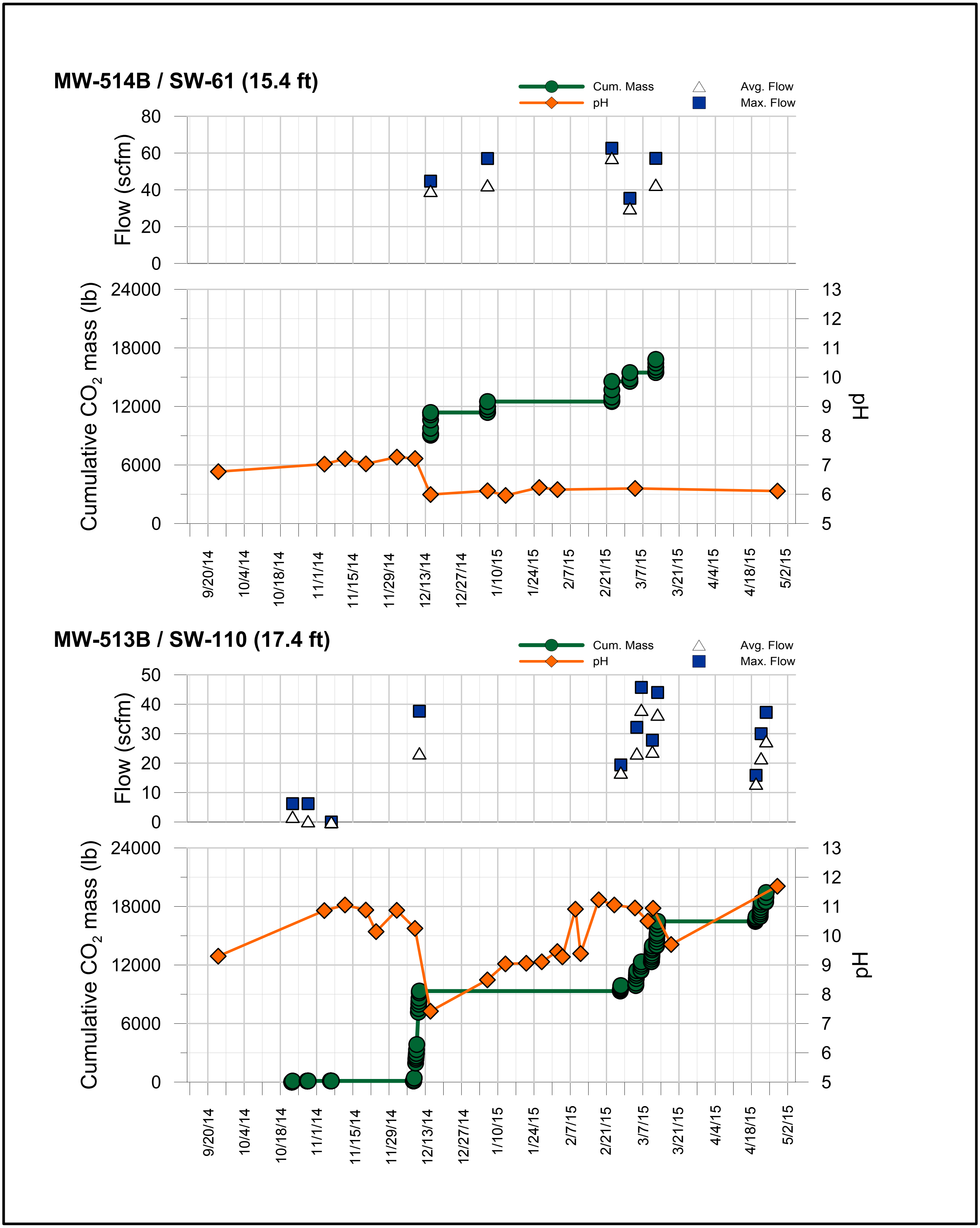


Figure 4-13: CO_2 flow, mass and pH as a function of time for MW-514B and MW-513B

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

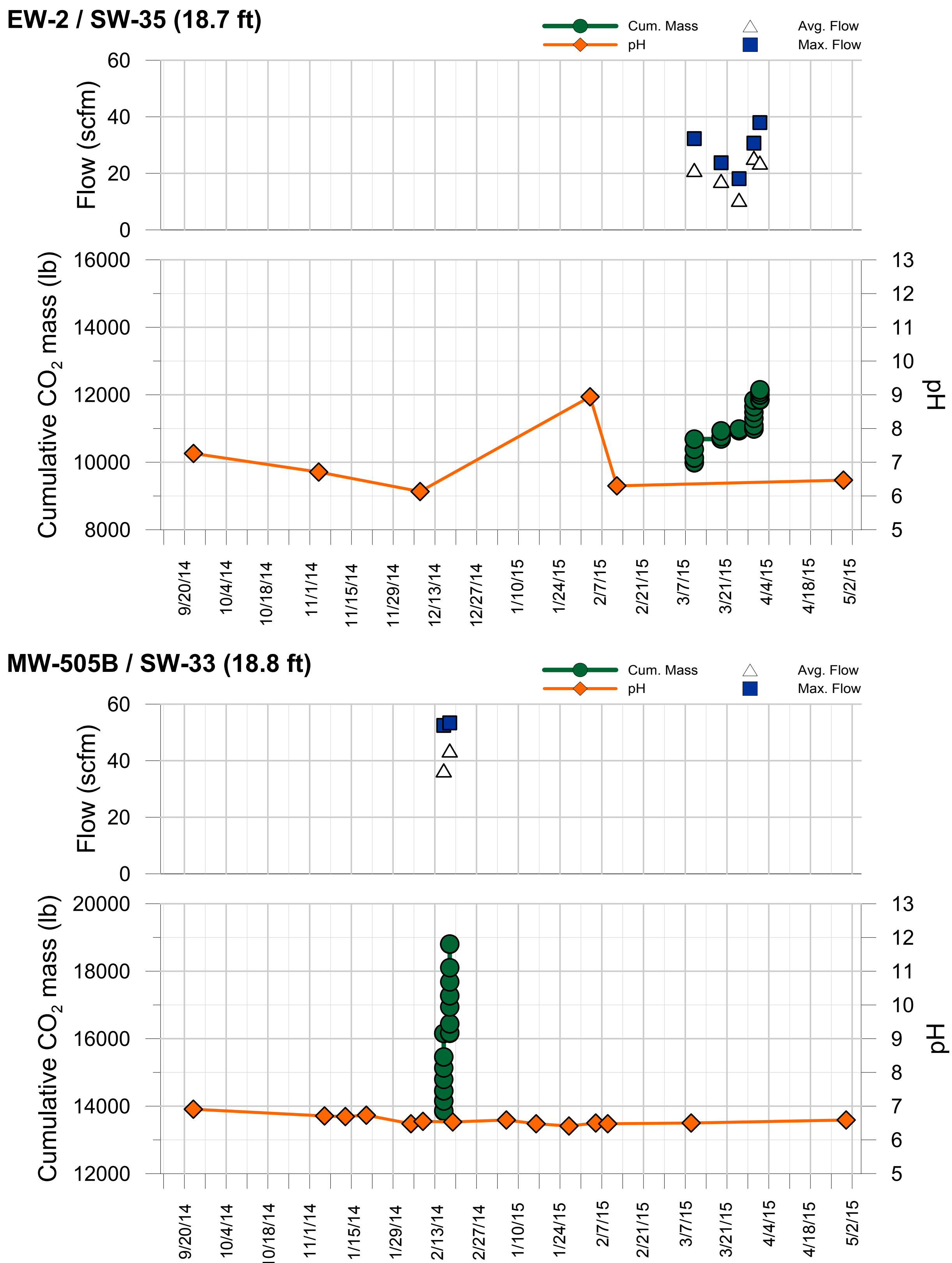


Figure 4-14: CO_2 flow, mass and pH as a function of time for EW-2 and MW-505B

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

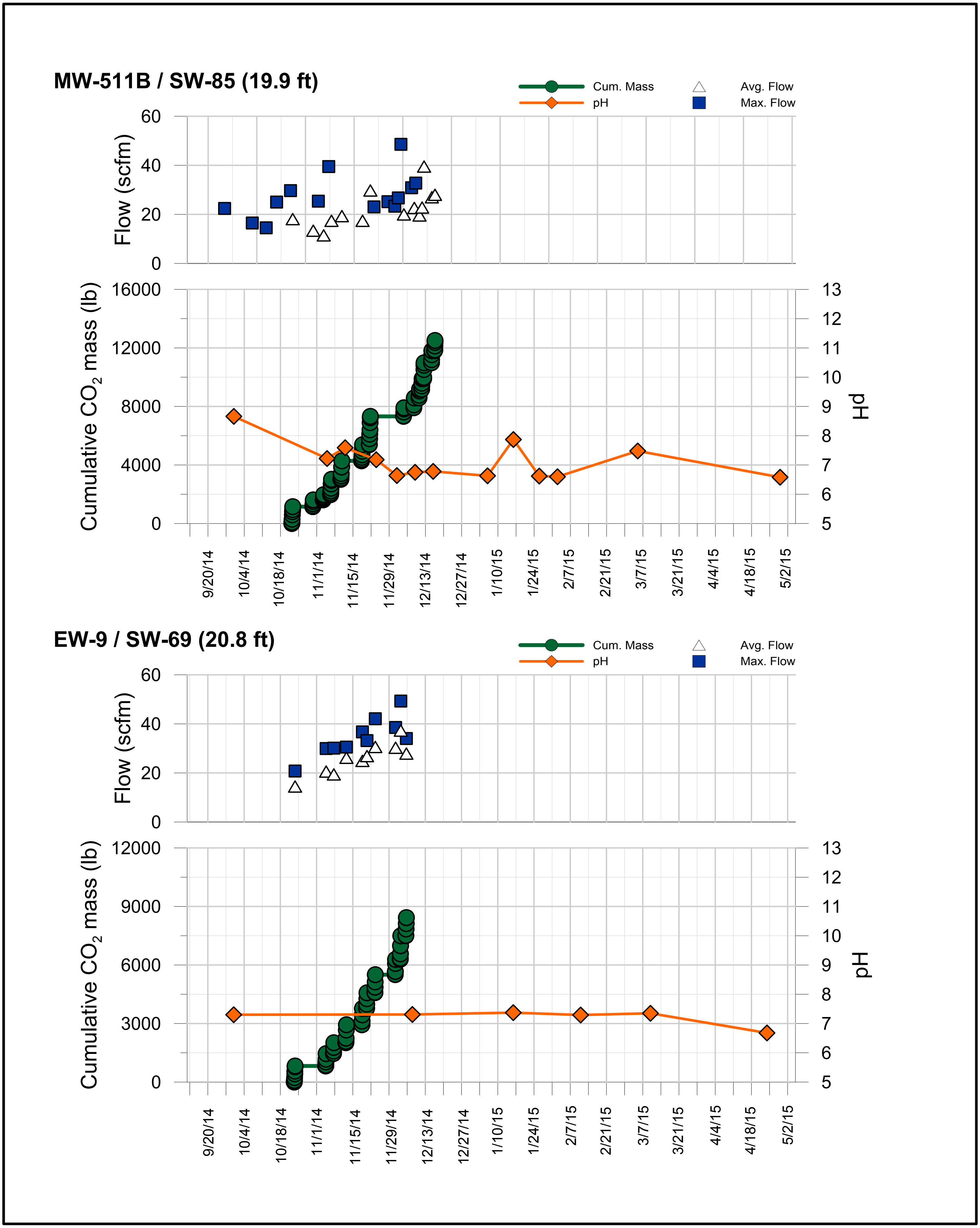


Figure 4-15: CO_2 flow, mass and pH as a function of time for MW-511B and EW-9

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

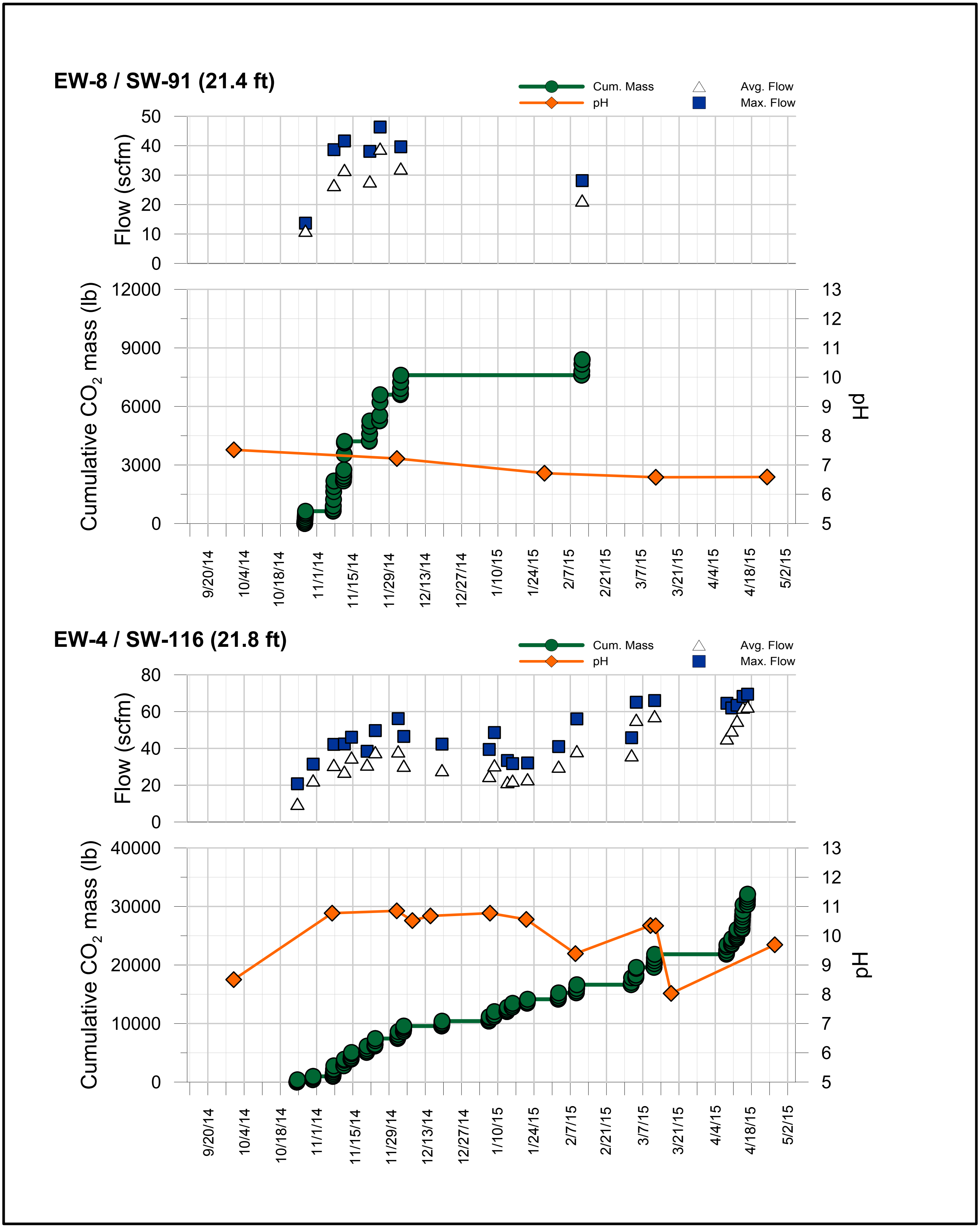


Figure 4-16: CO_2 flow, mass and pH as a function of time for EW-8 and EW-4

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

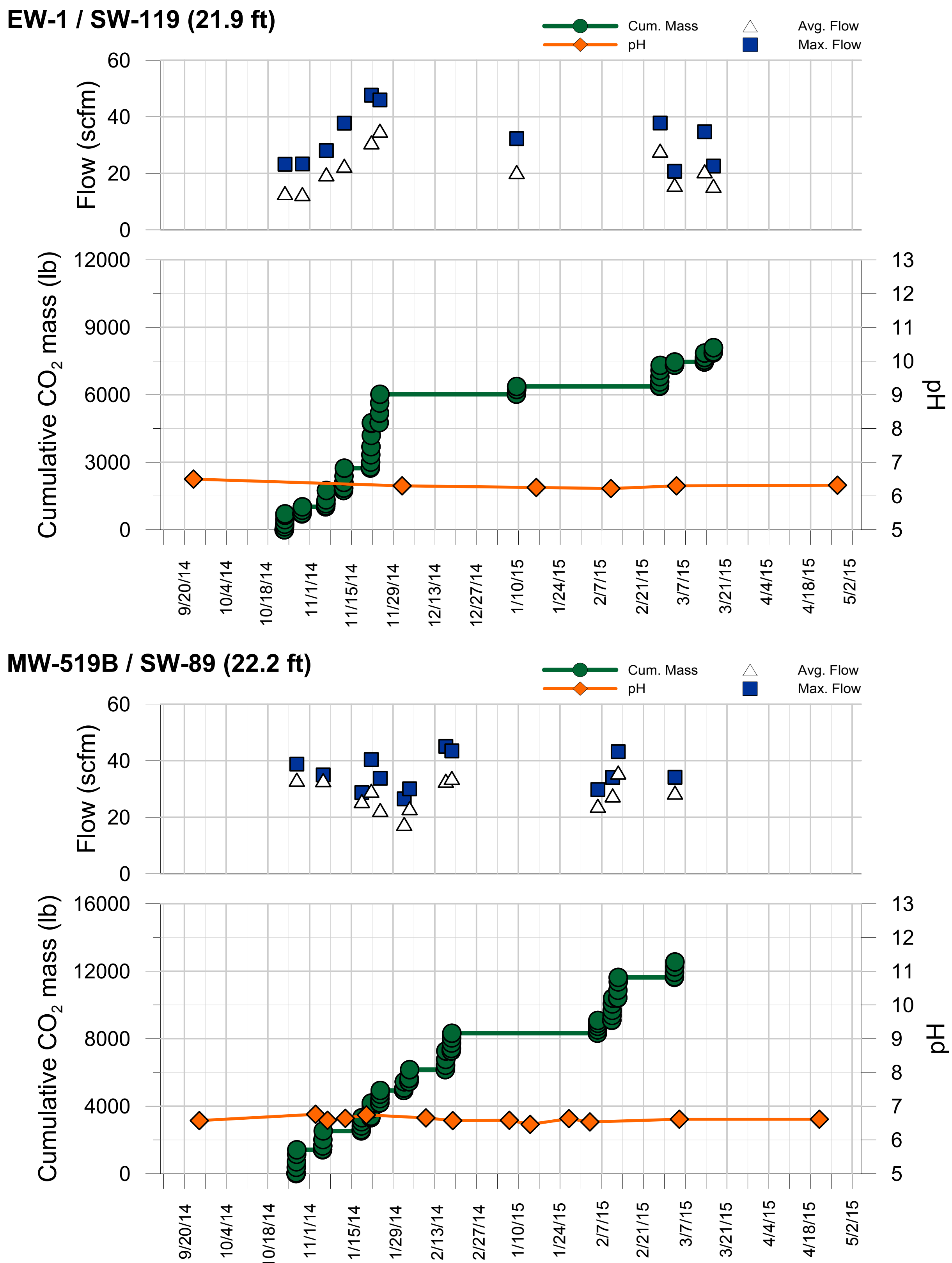
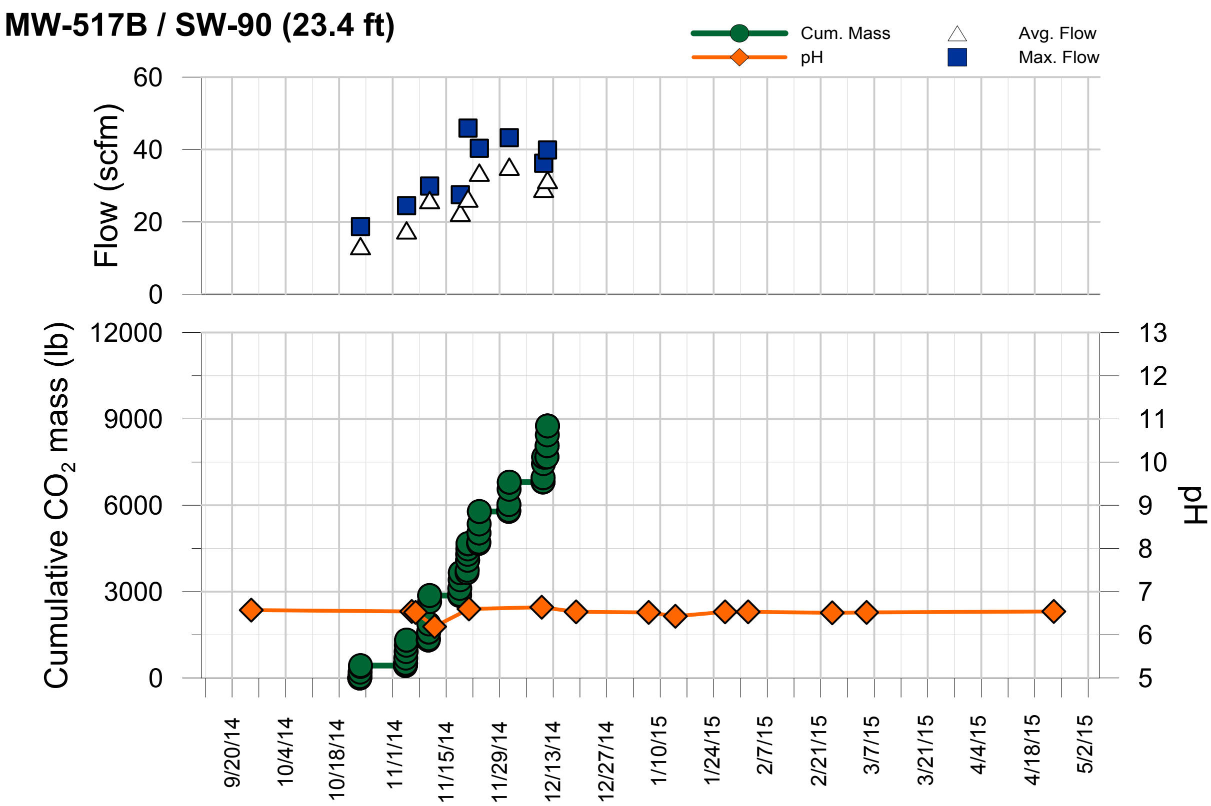


Figure 4-17: CO_2 flow, mass and pH as a function of time for EW-1 and MW-519B

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists



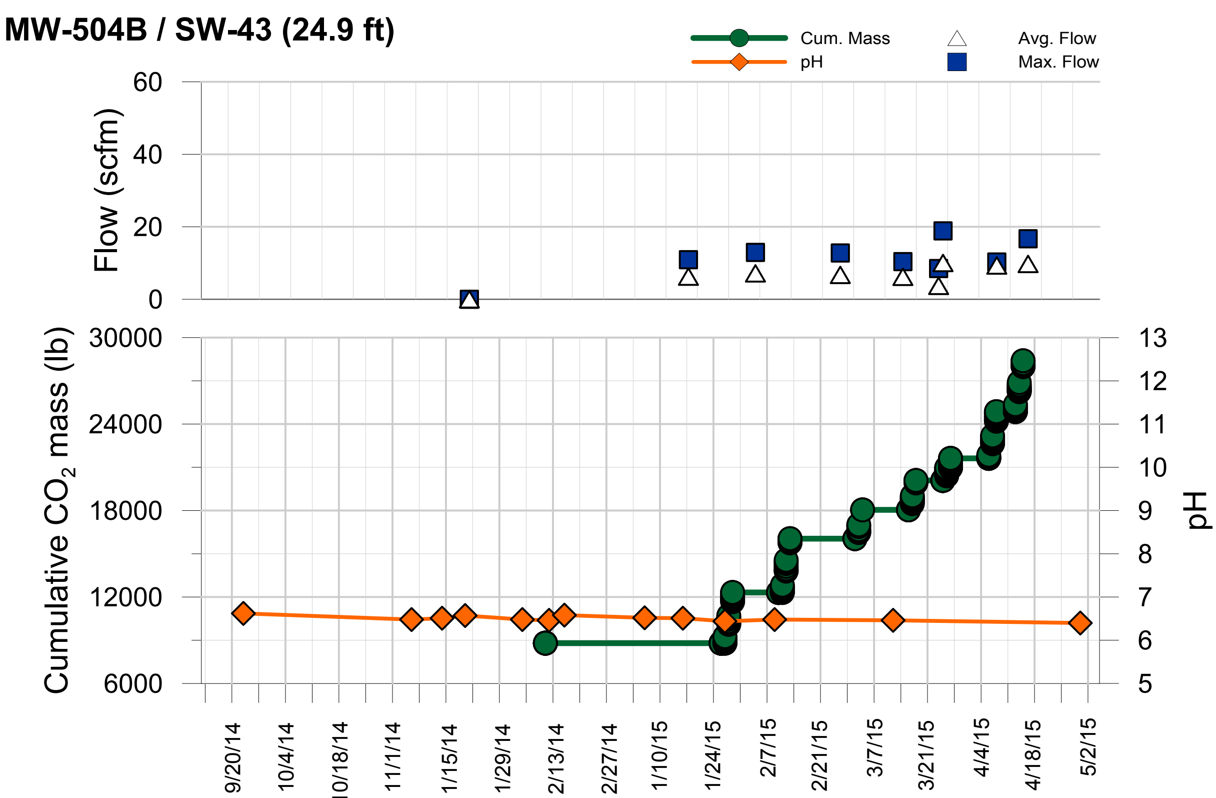


Figure 4-18: CO_2 flow, mass and pH as a function of time for MW-517B and MW-504B

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

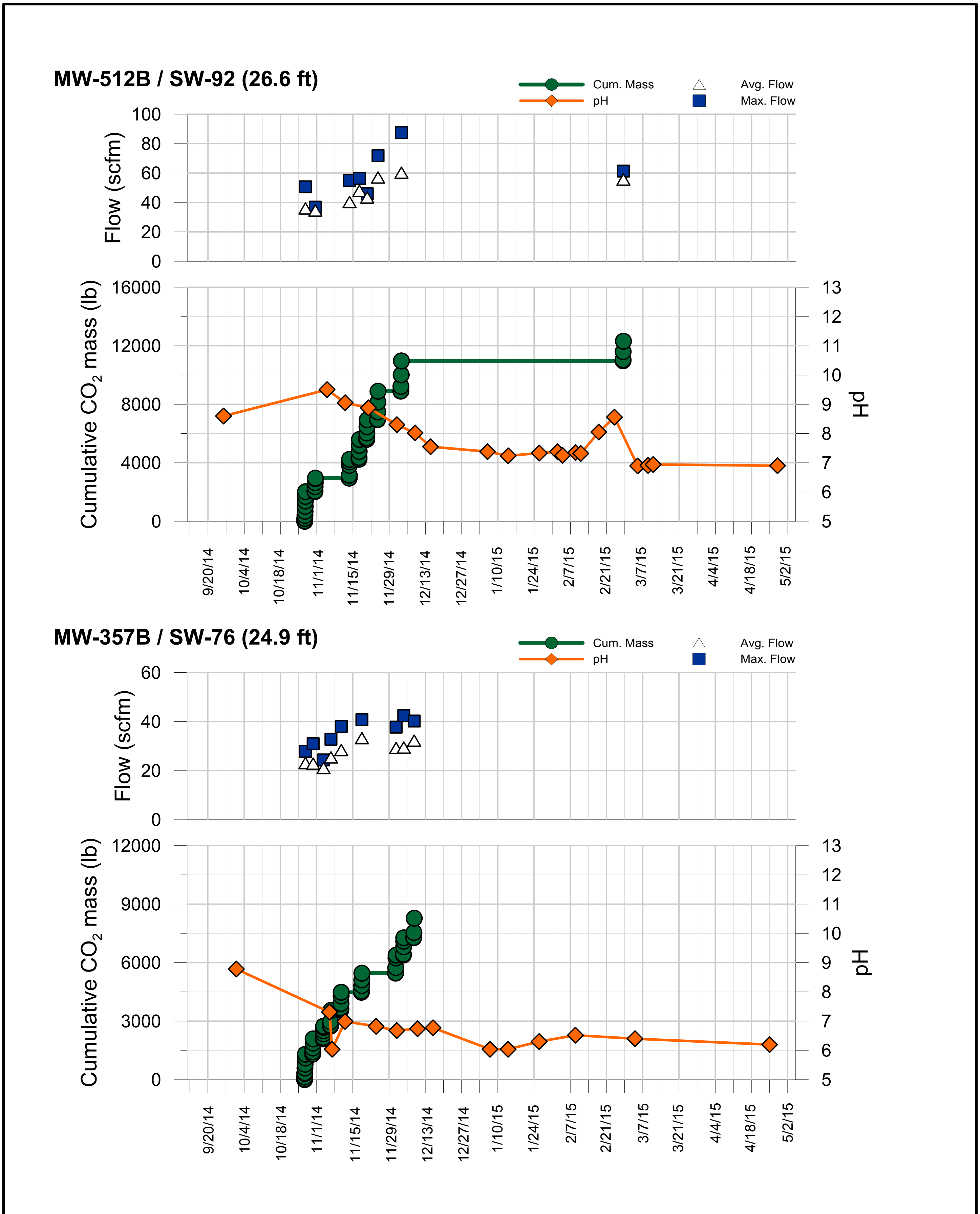
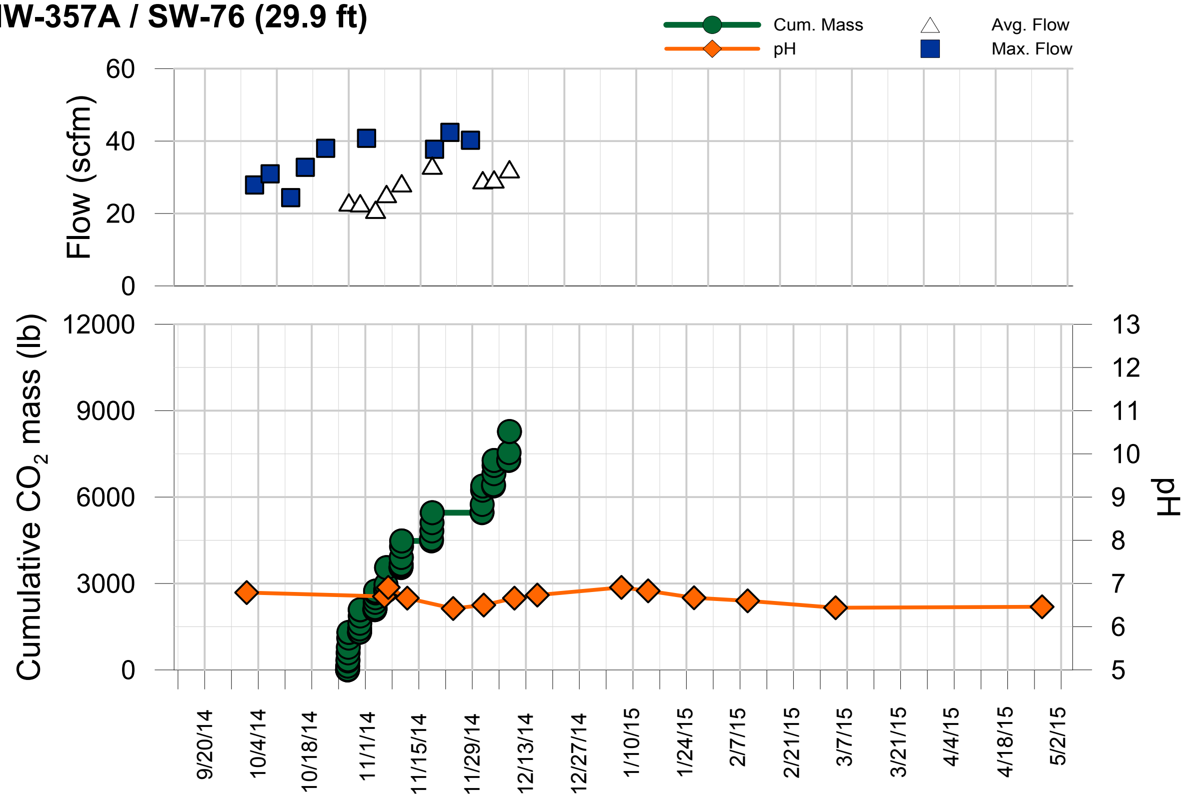


Figure 4-19: CO_2 flow, mass and pH as a function of time for MW-512B and MW-357B

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

MW-357A / SW-76 (29.9 ft)



EW-3 / SW-102 (30.5 ft)

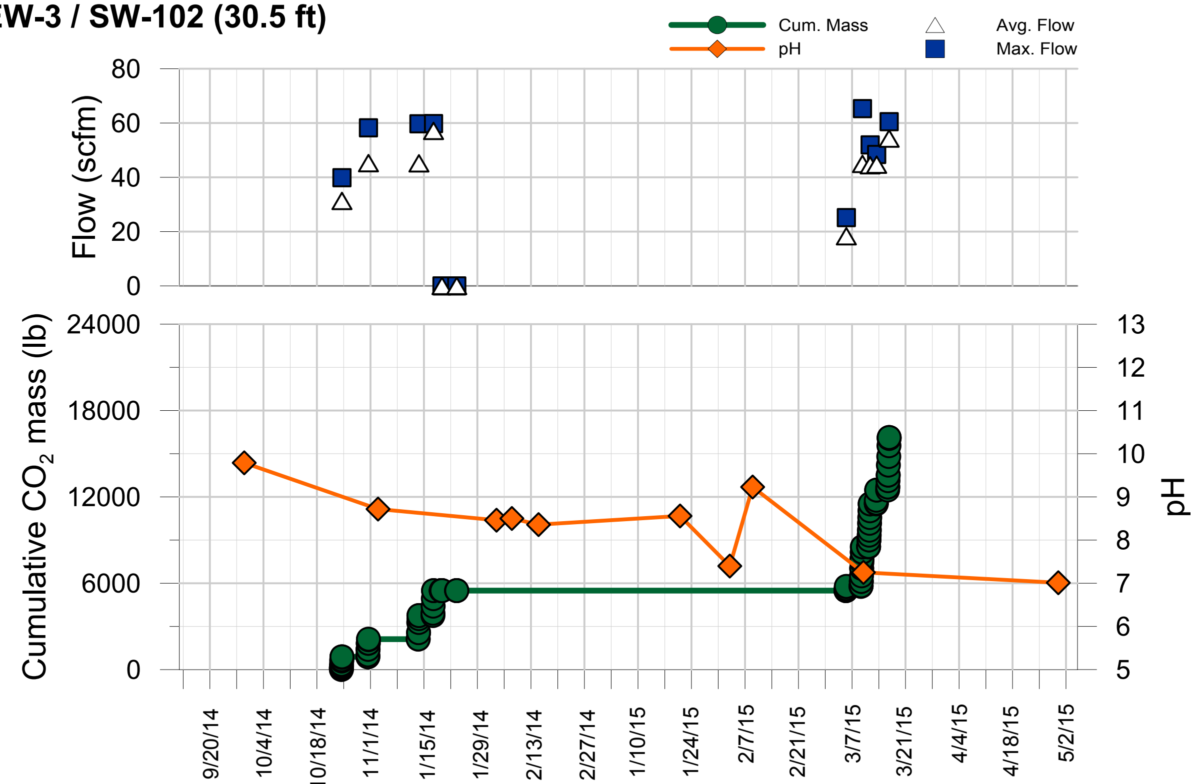


Figure 4-20: CO_2 flow, mass and pH as a function of time for MW-357A and EW-3

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

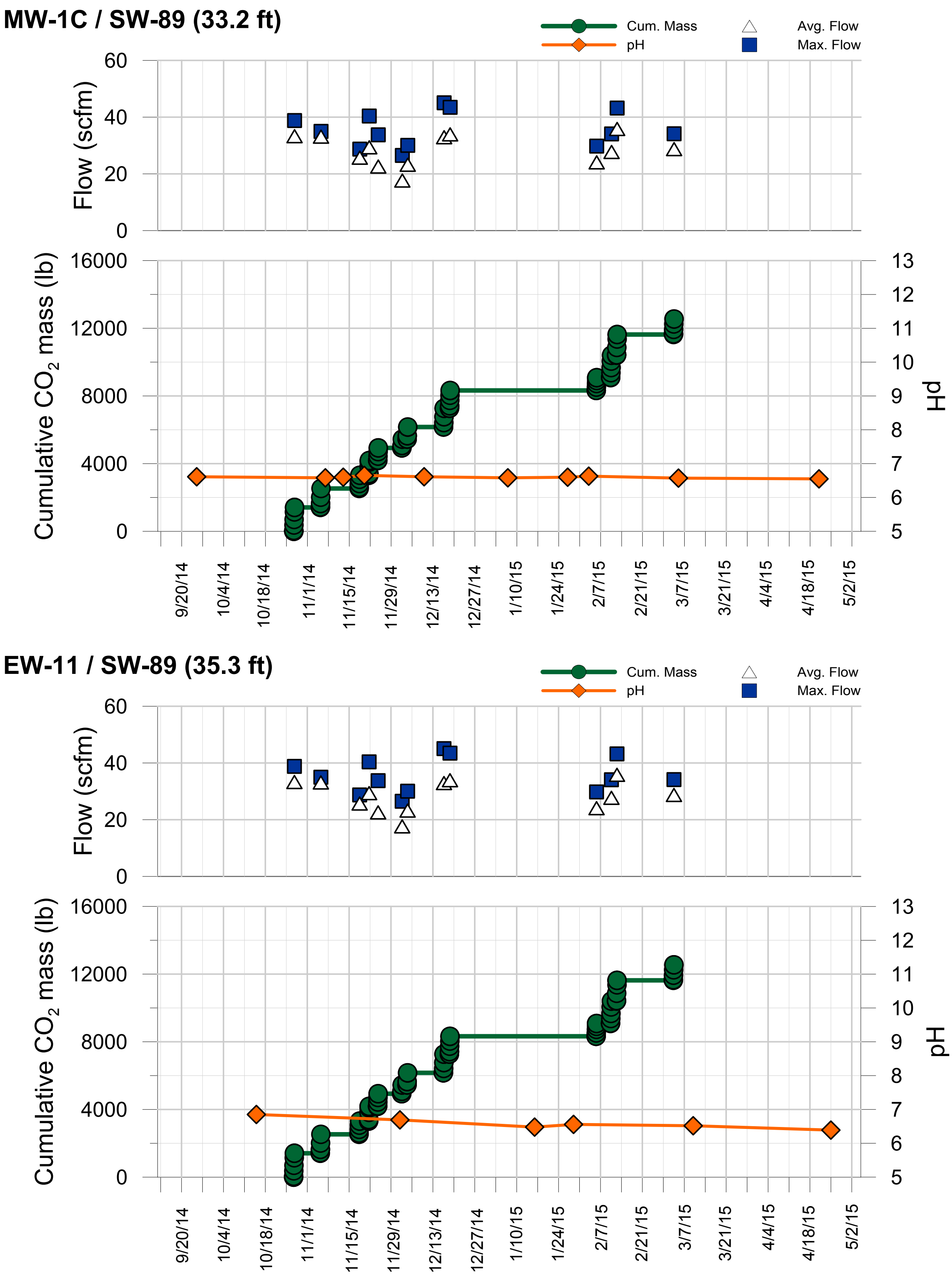


Figure 4-21: CO_2 flow, mass and pH as a function of time for MW-1C and EW-11

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

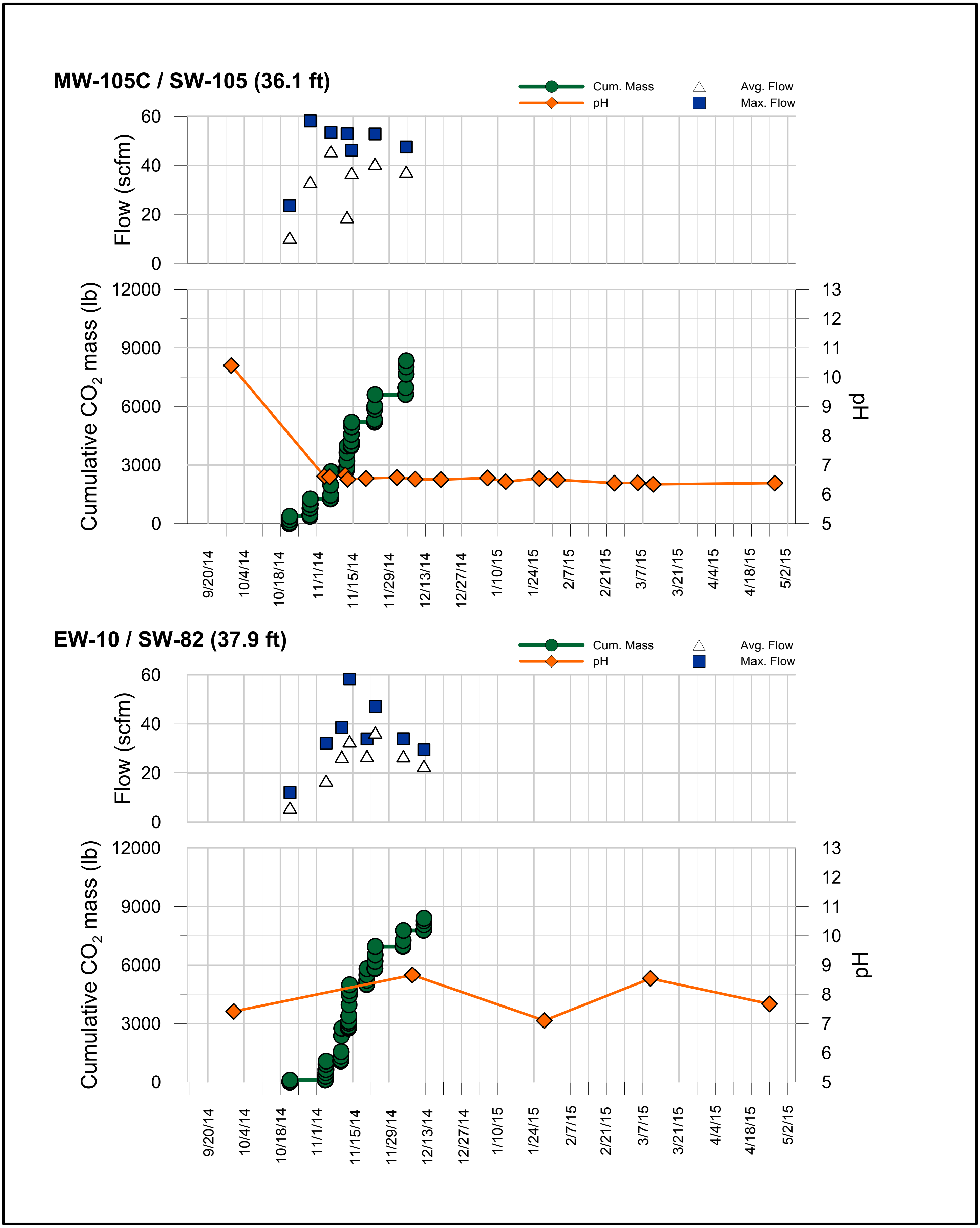


Figure 4-22: CO_2 flow, mass and pH as a function of time for MW-105C and EW-10

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

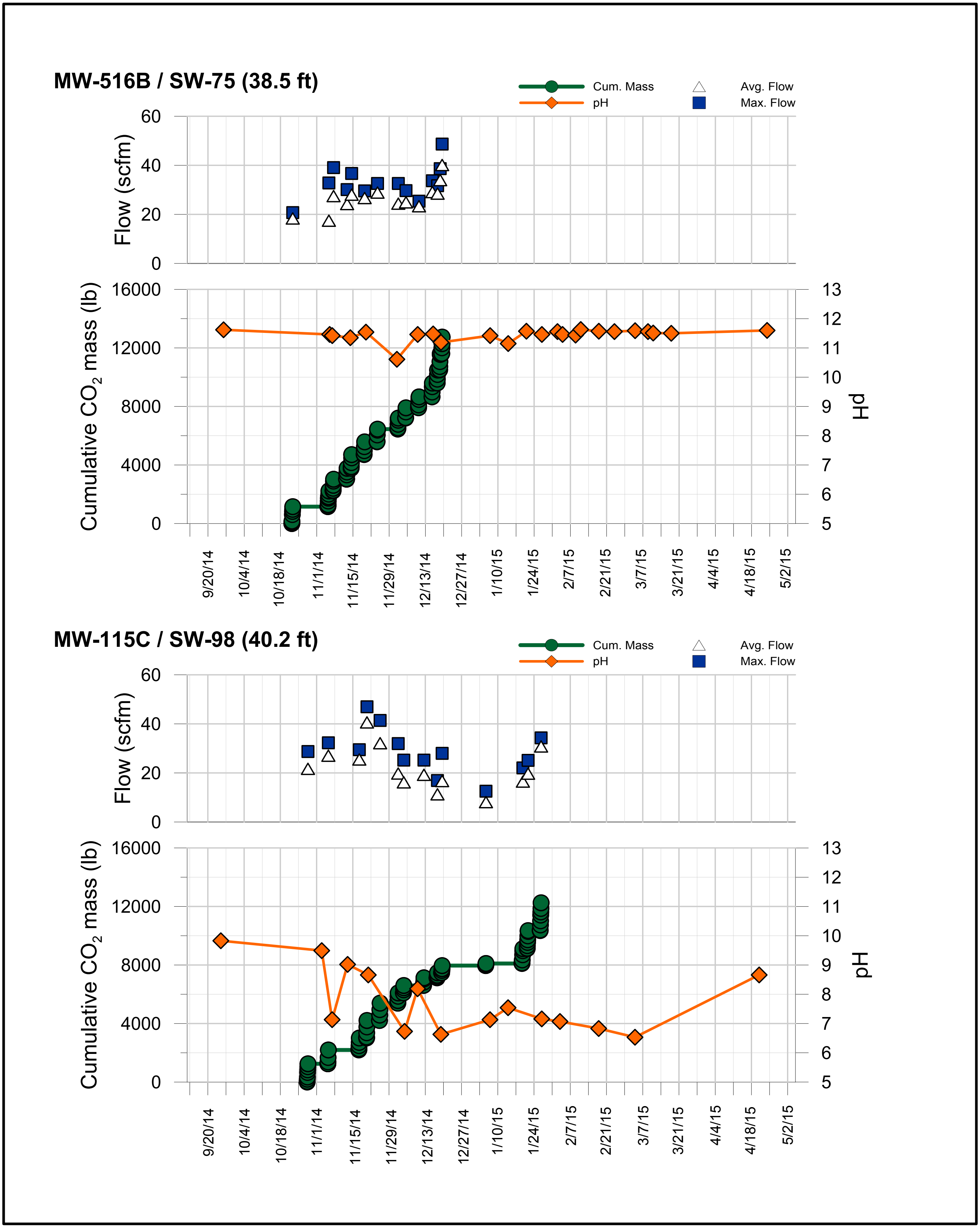


Figure 4-23: CO_2 flow, mass and pH as a function of time for MW-516B and MW-115C

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

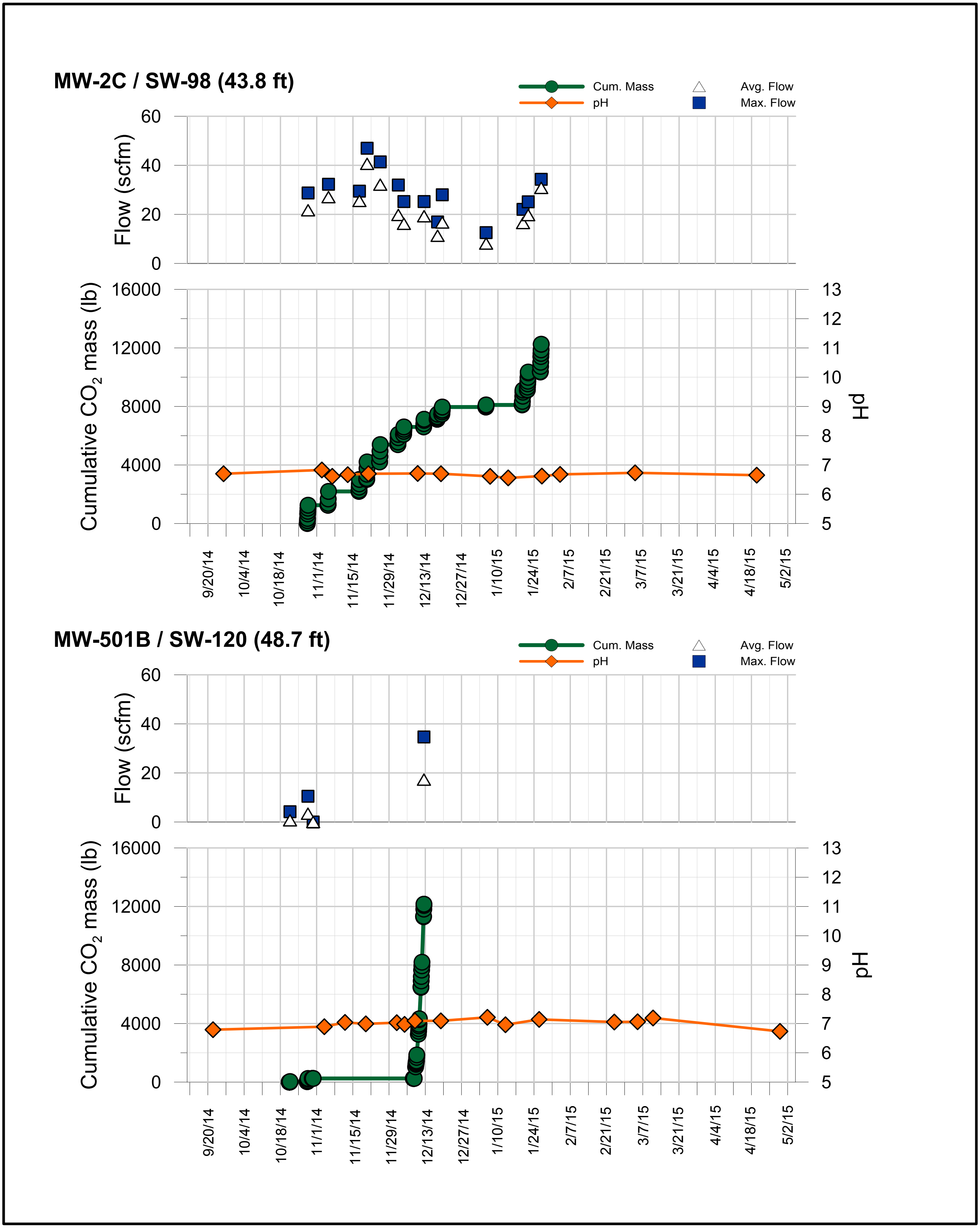
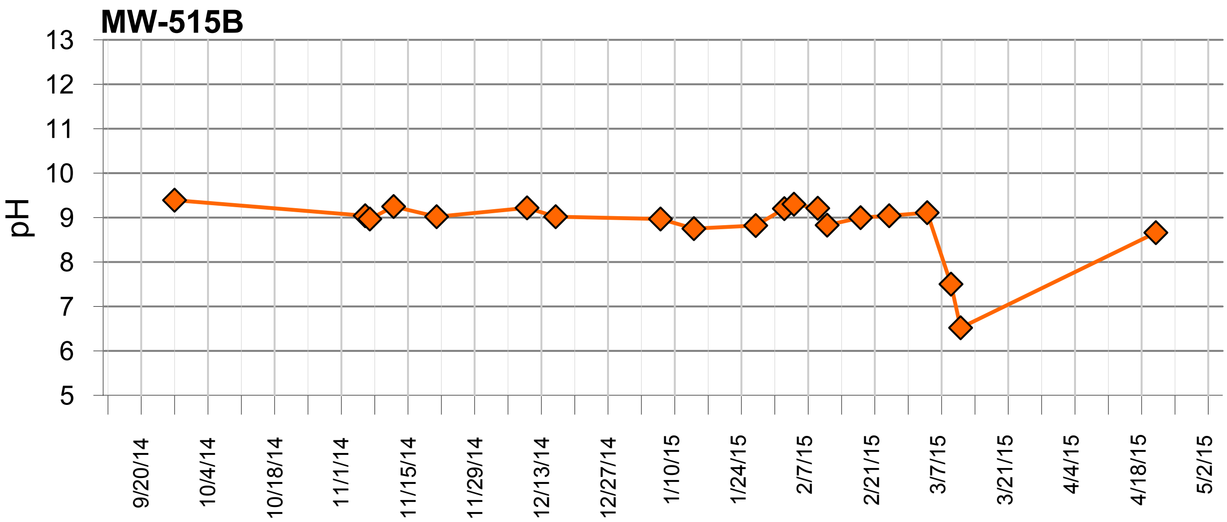


Figure 4-24: CO_2 flow, mass and pH as a function of time for MW-2C and MW-501B

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists



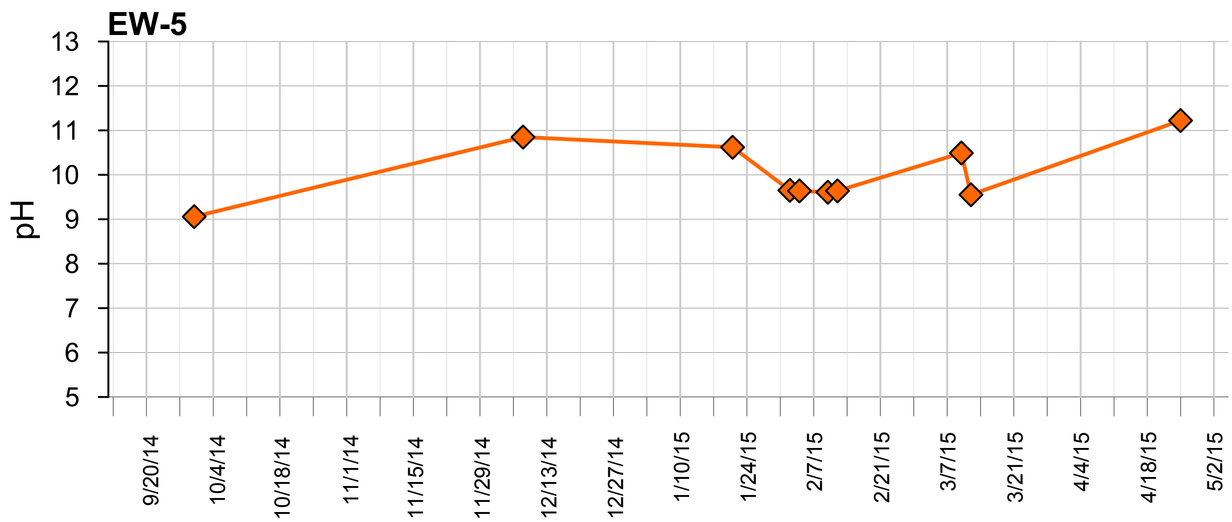


Figure 4-25: pH as a function of time for MW-515B and EW-5 during Phase 2 sparging

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

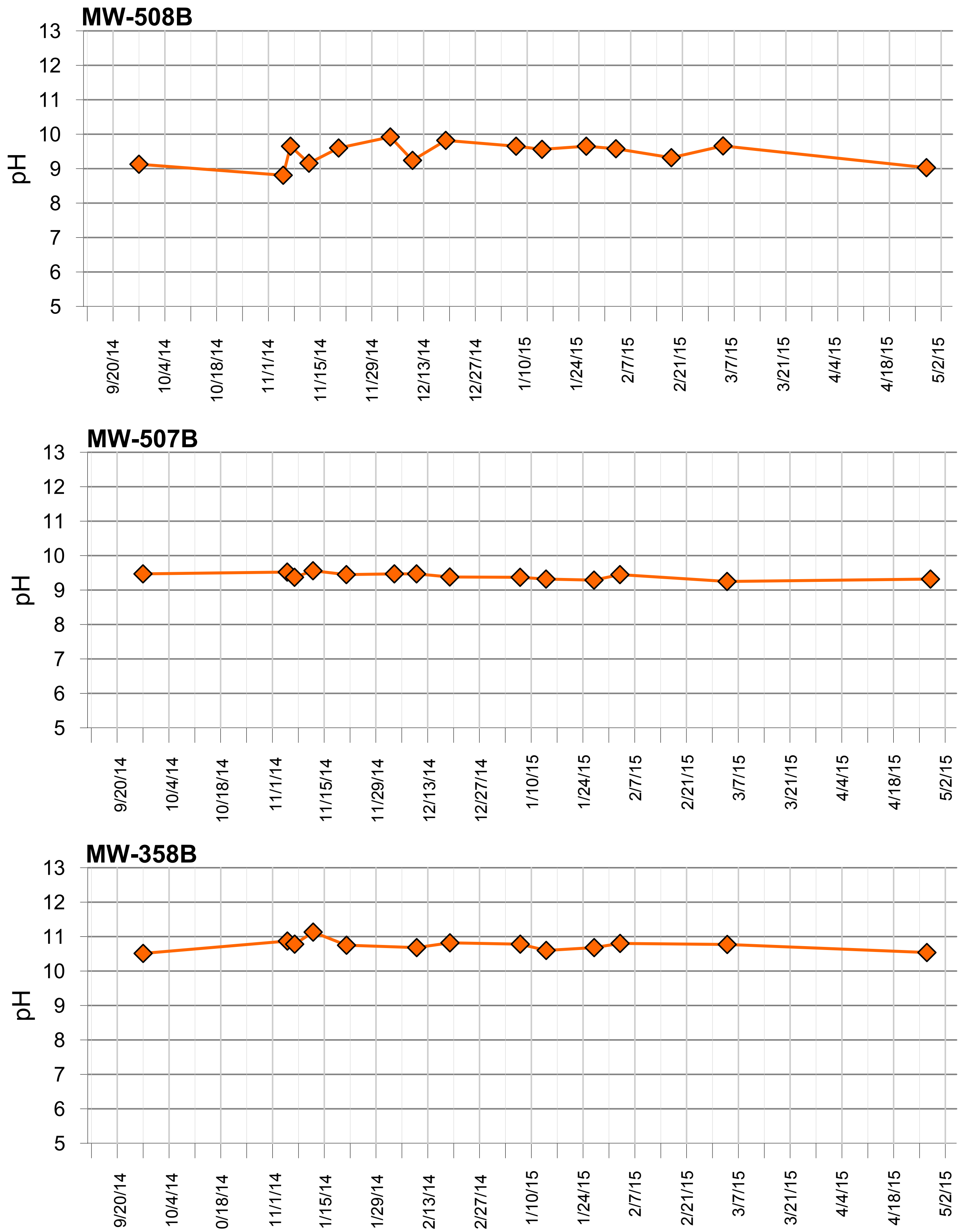


Figure 4-26: pH as a function of time for MW-508B, MW-507B, and MW-358B during Phase 2 sparging

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

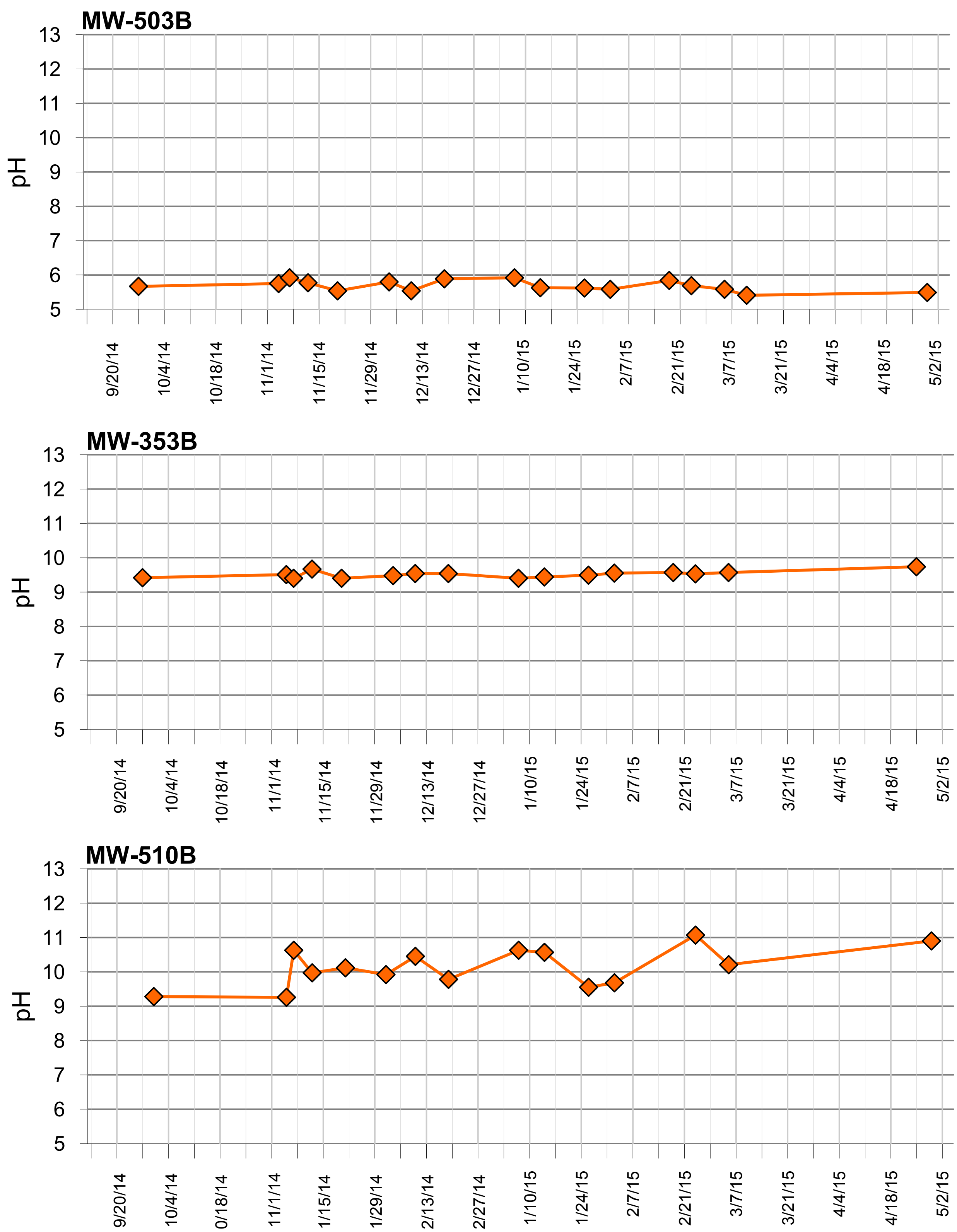
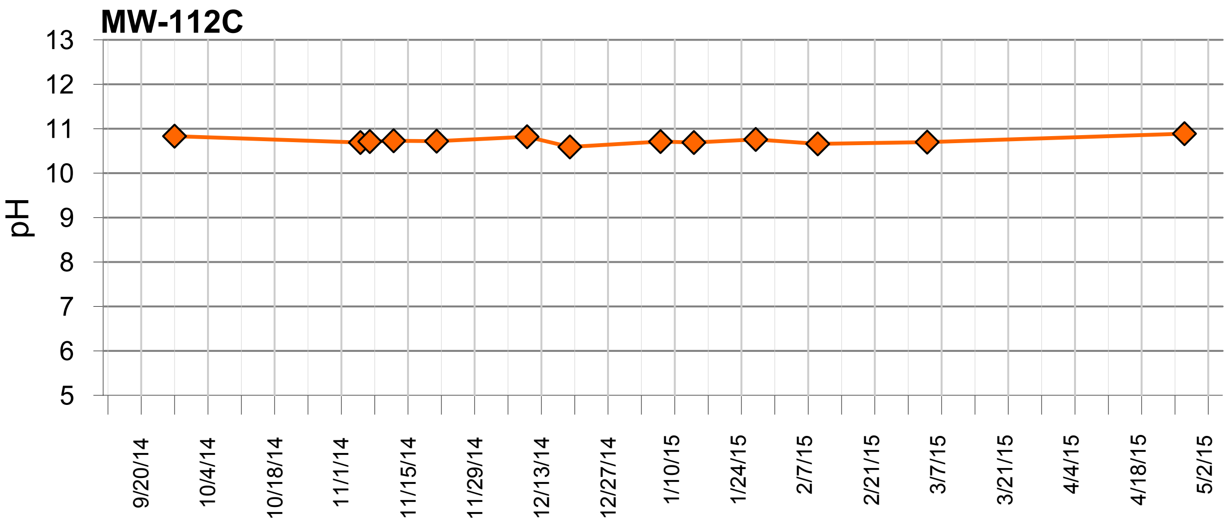


Figure 4-27: pH as a function of time for MW-503B, MW-353B, and MW-510B during Phase 2 sparging

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists



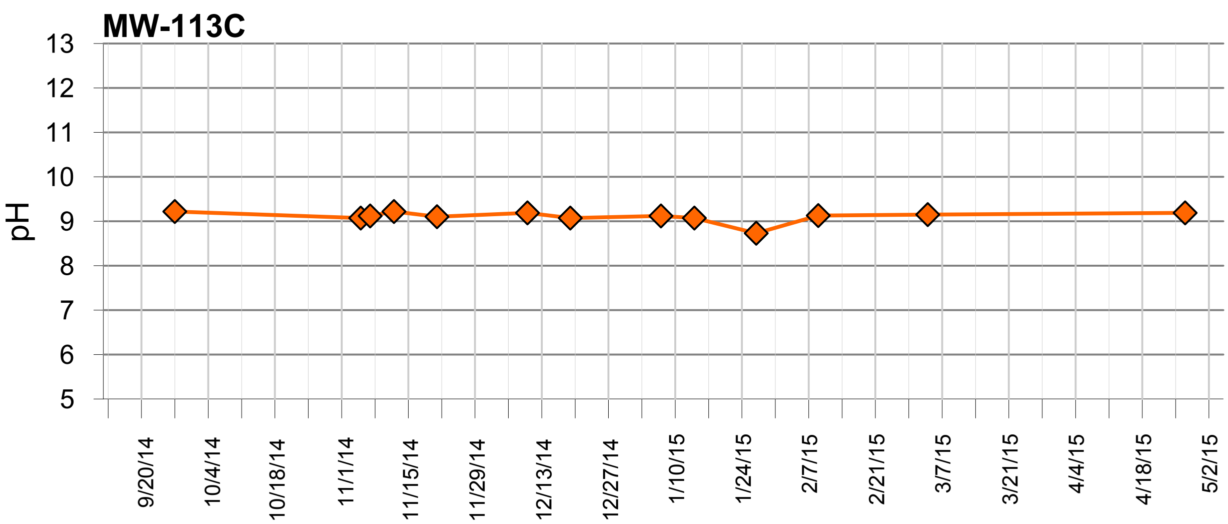


Figure 4-28: pH as a function of time for MW-112C and MW-113C during Phase 2 sparging

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

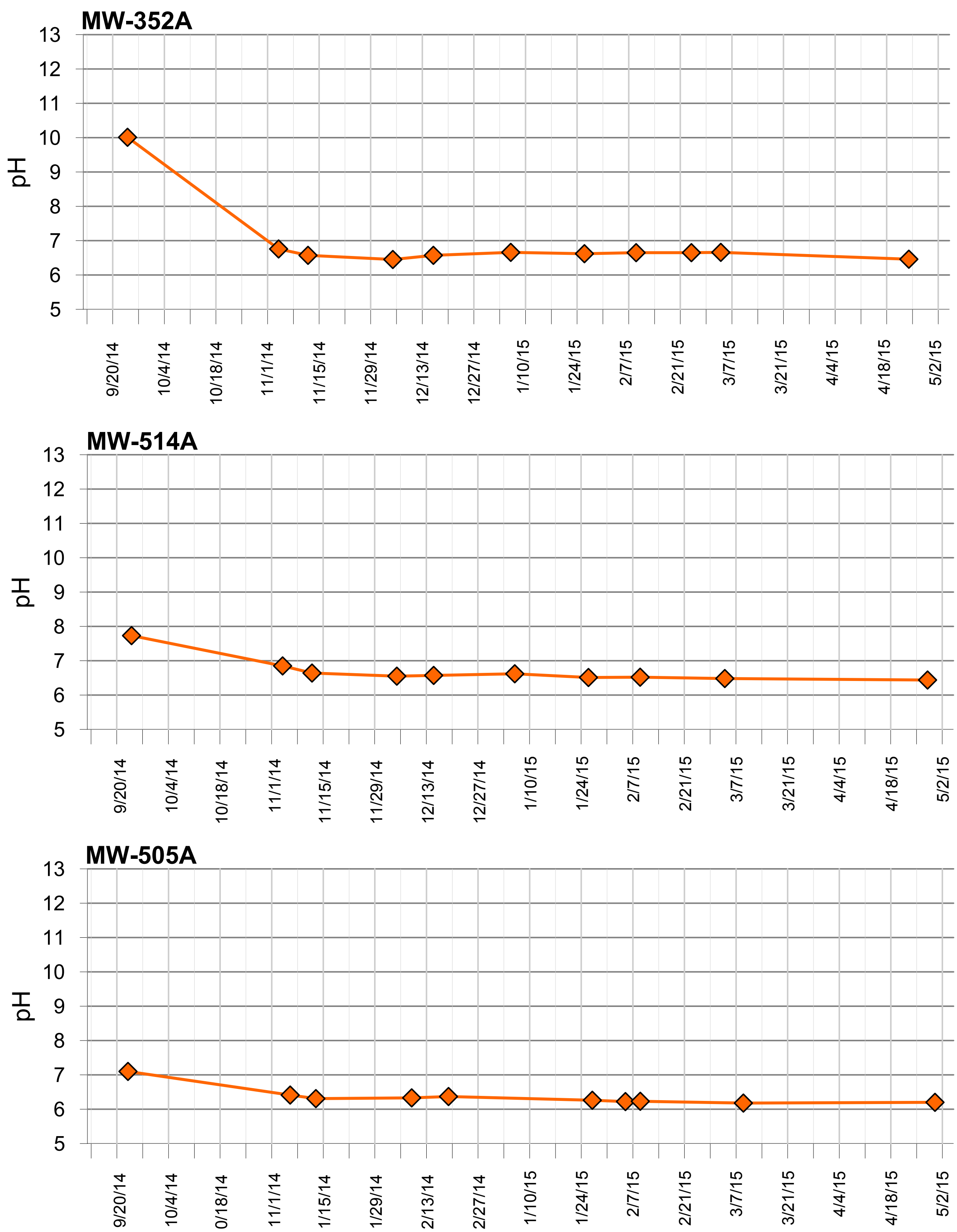


Figure 4-29: pH as a function of time for MW-352A, MW-514A, and MW-505A during Phase 2 sparging

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

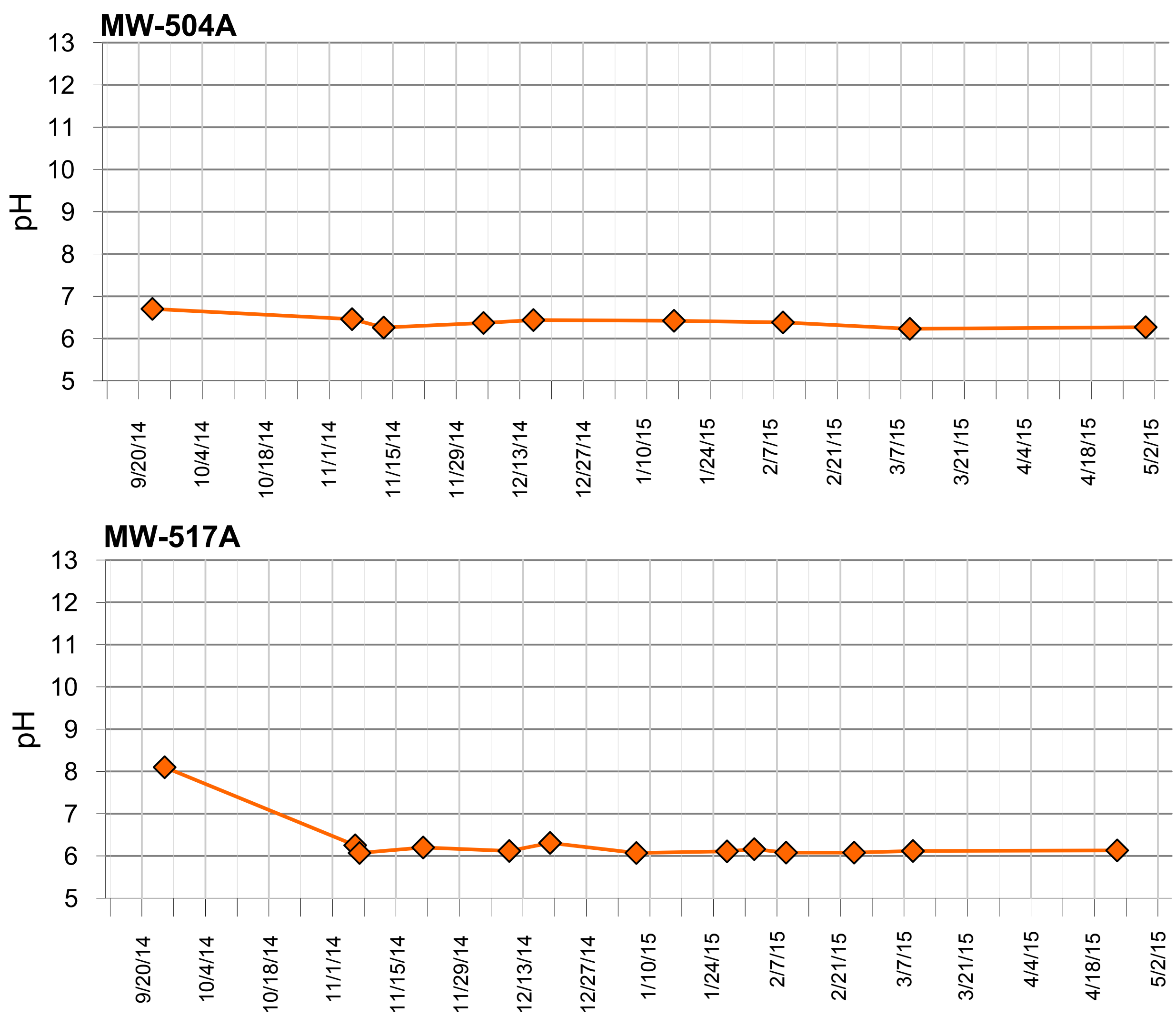
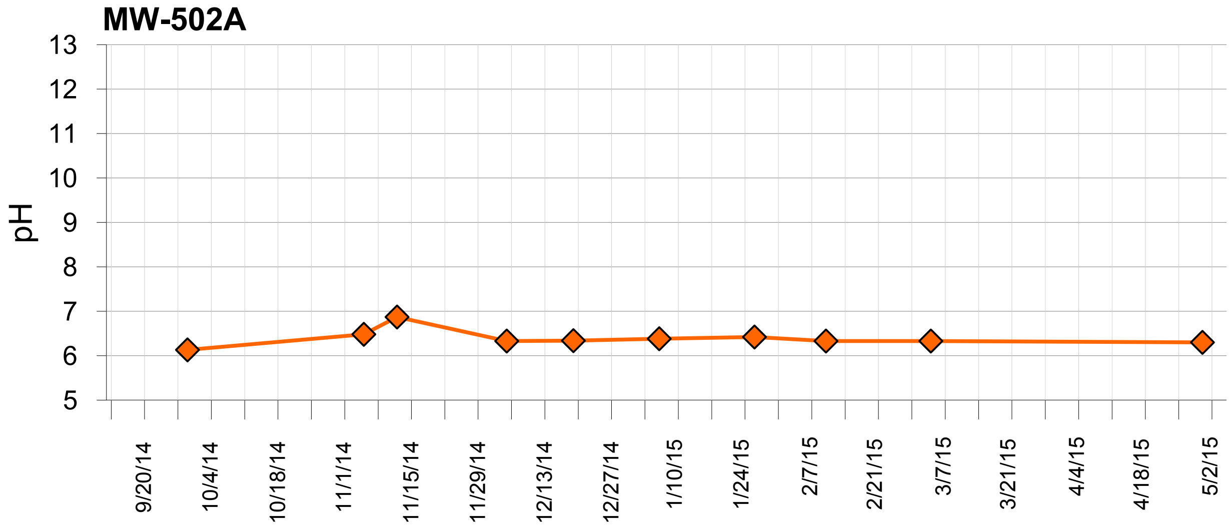


Figure 4-30: pH as a function of time for MW-504A and MW-517A during Phase 2 sparging

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists



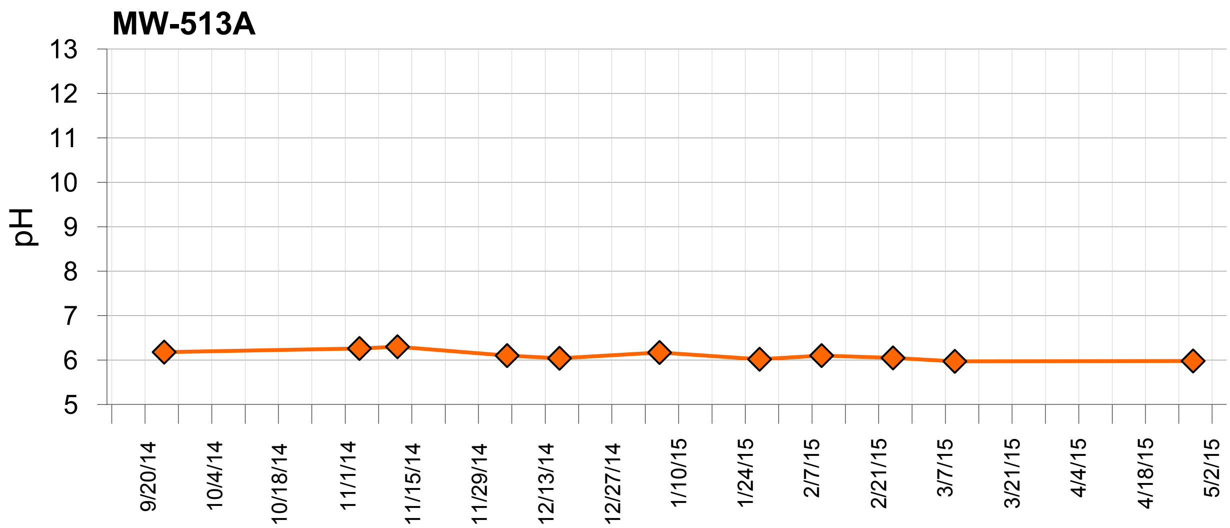


Figure 4-31: pH as a function of time for MW-502A and MW-513A during Phase 2 sparging

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

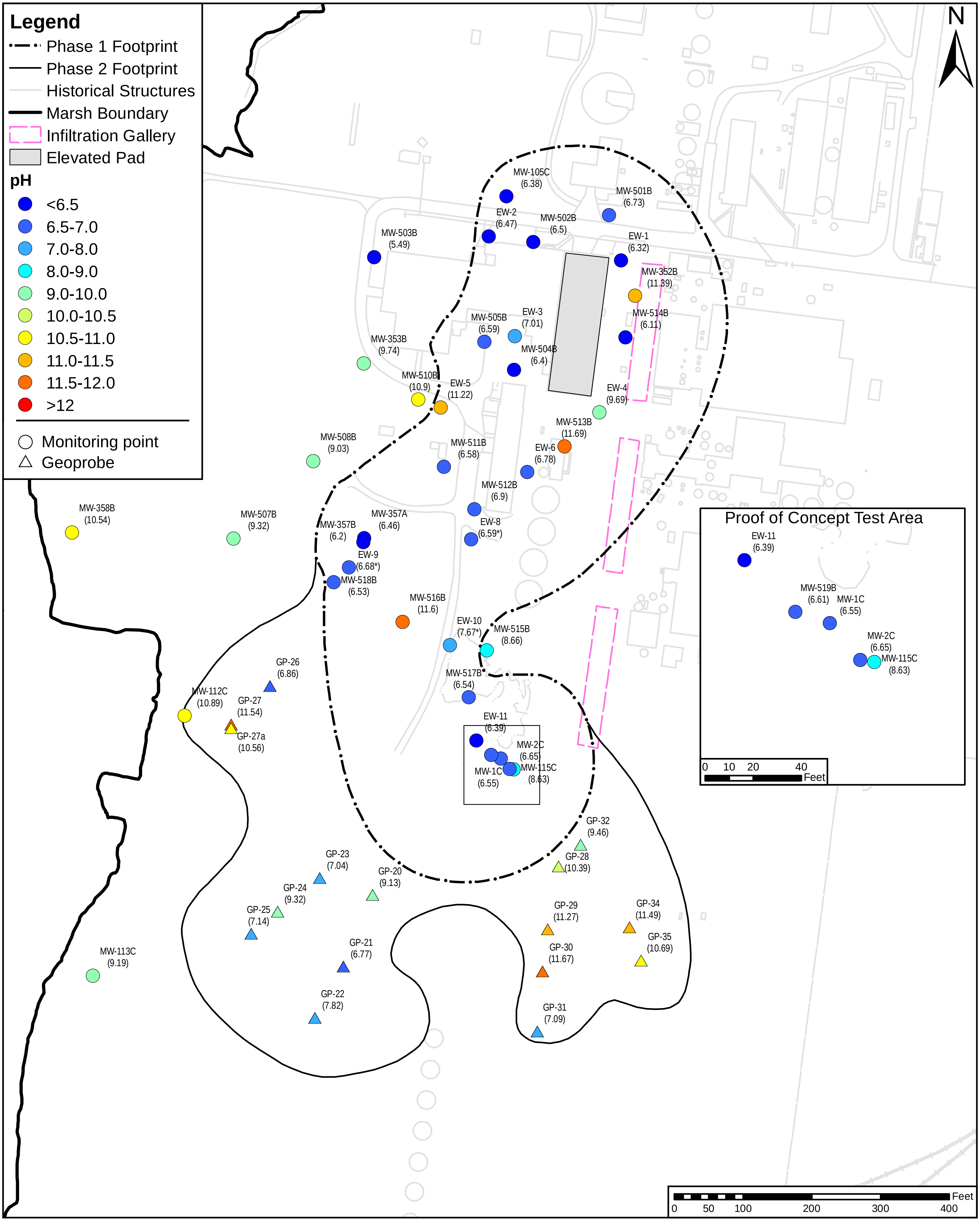


Figure 4-32: Post-sparge (Phase 2) pH in deep Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

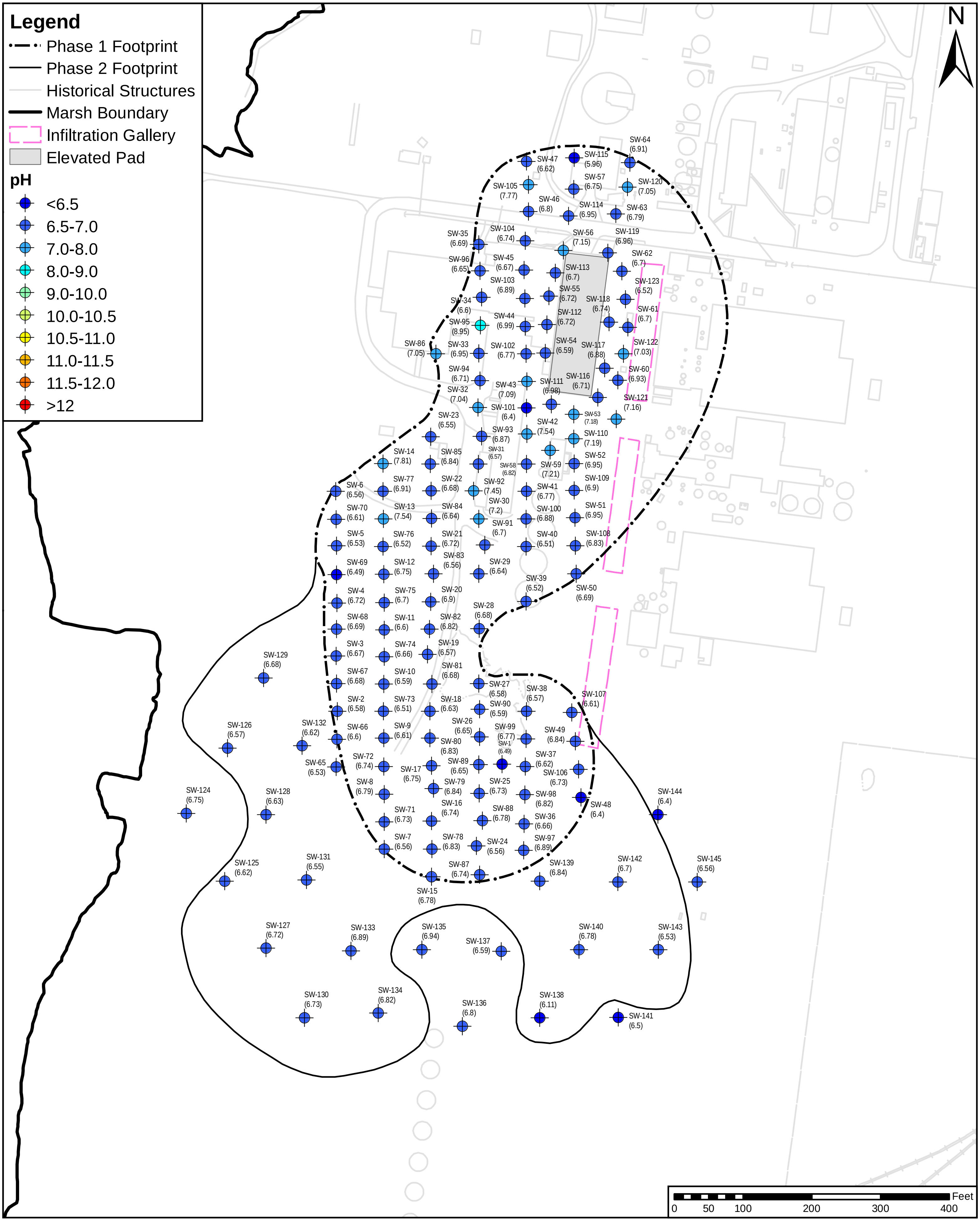


Figure 4-33: Post-sparge (Phase 2) pH in sparge wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC

Environmental Engineers and Scientists

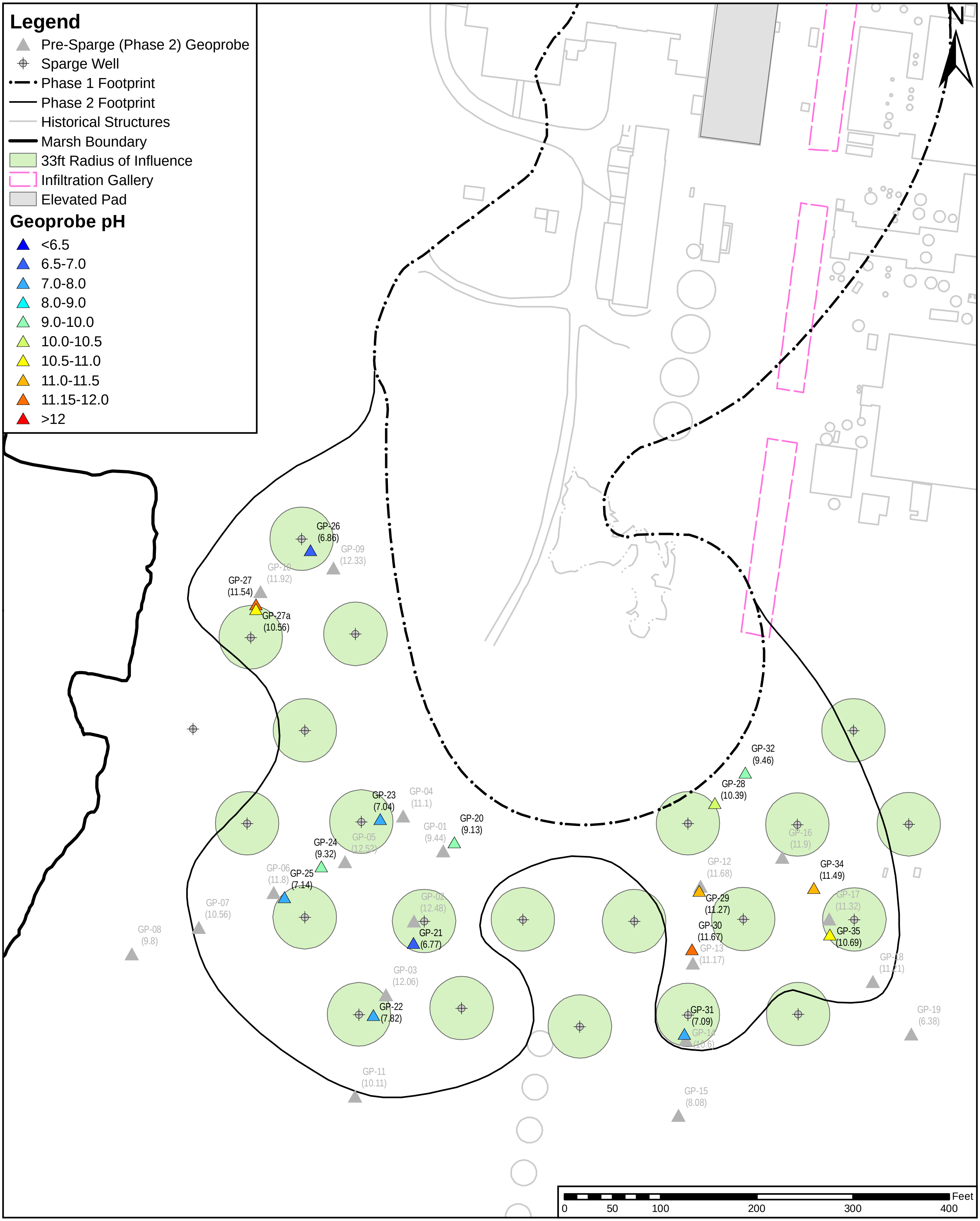


Figure 4-34: Post-sparge (Phase 2) pH southern area Geoprobe locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

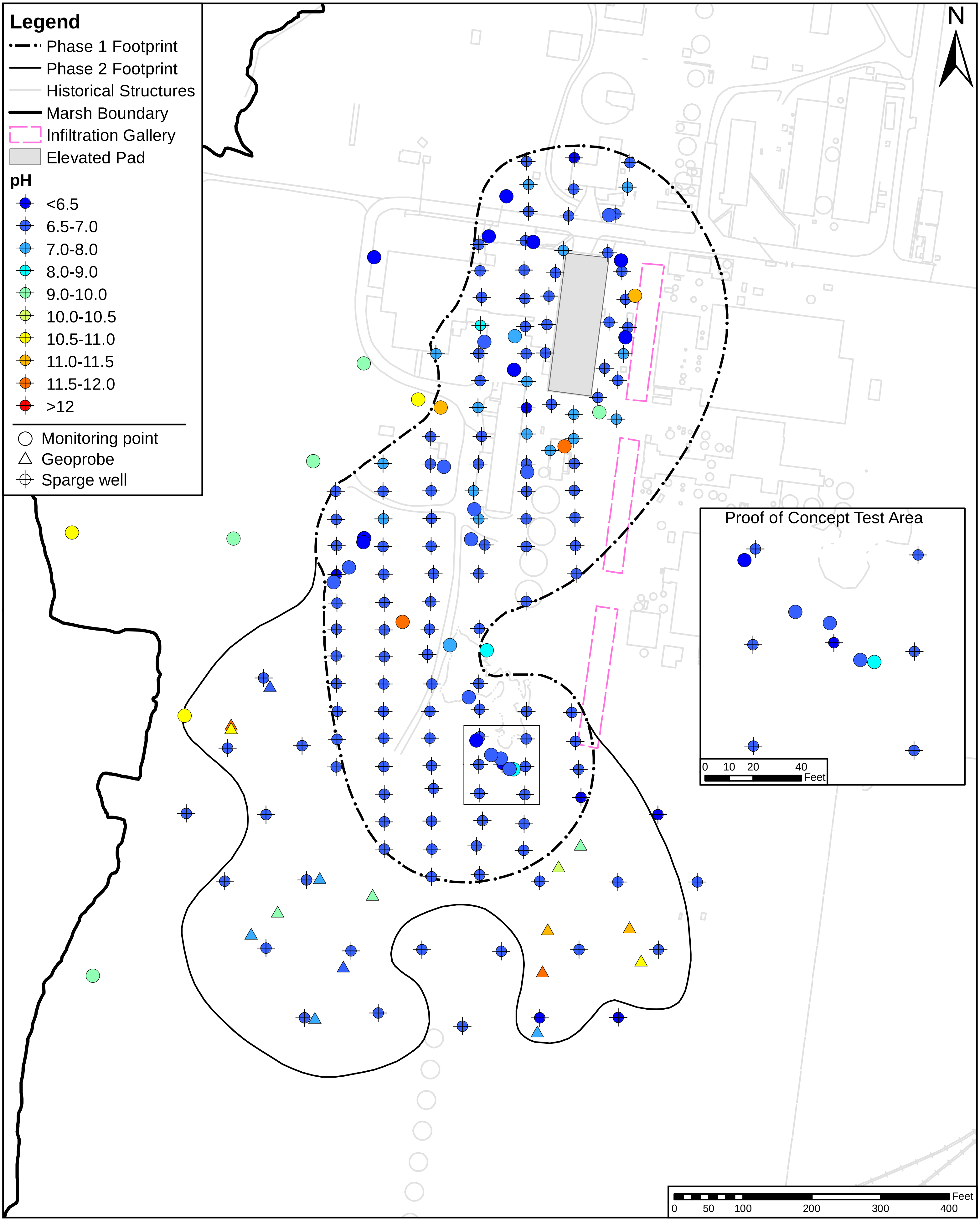


Figure 4-35: Post-sparge (Phase 2) pH in all deep Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

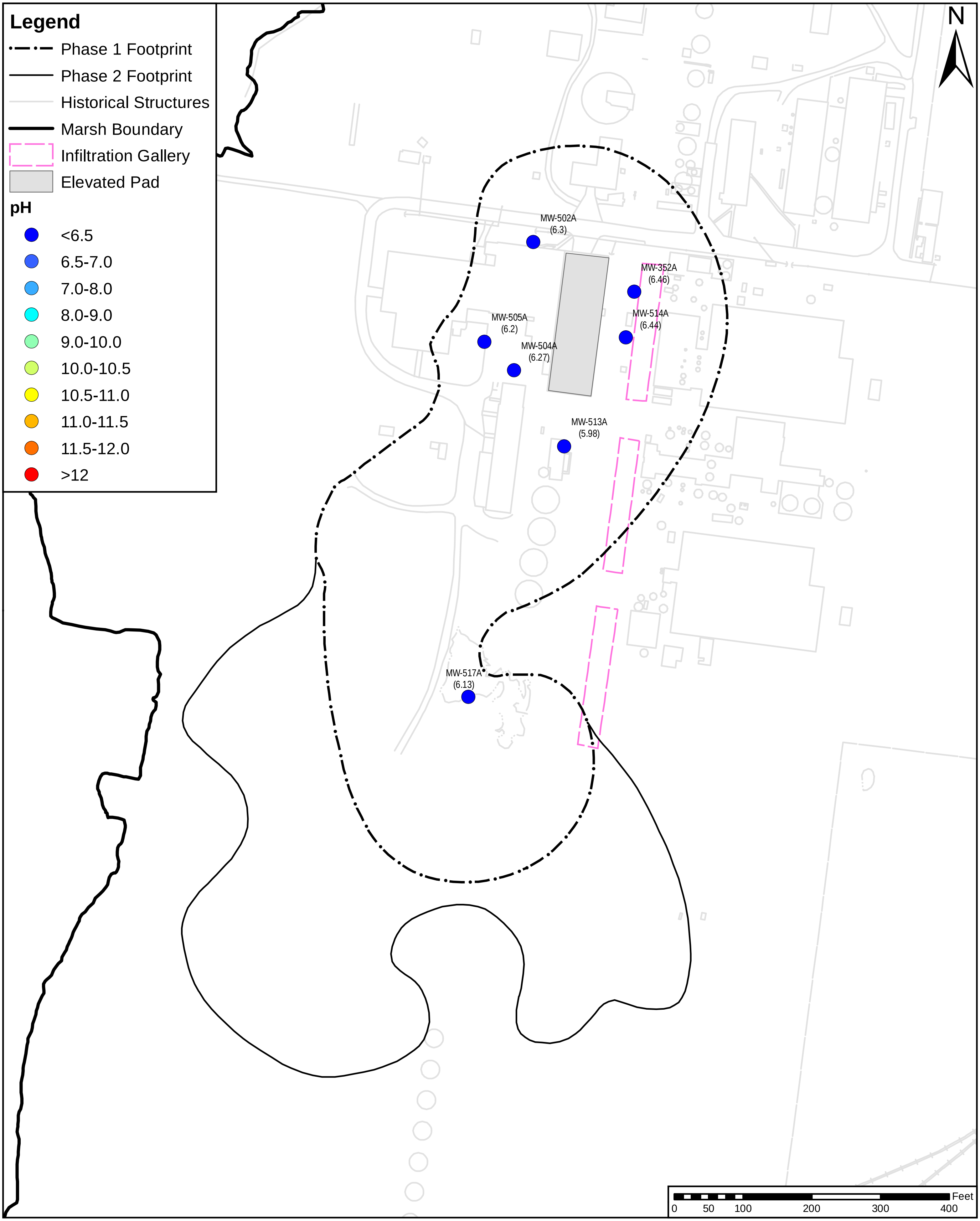


Figure 4-36: Post-sparge (Phase 2) pH in mid Satilla monitoring wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

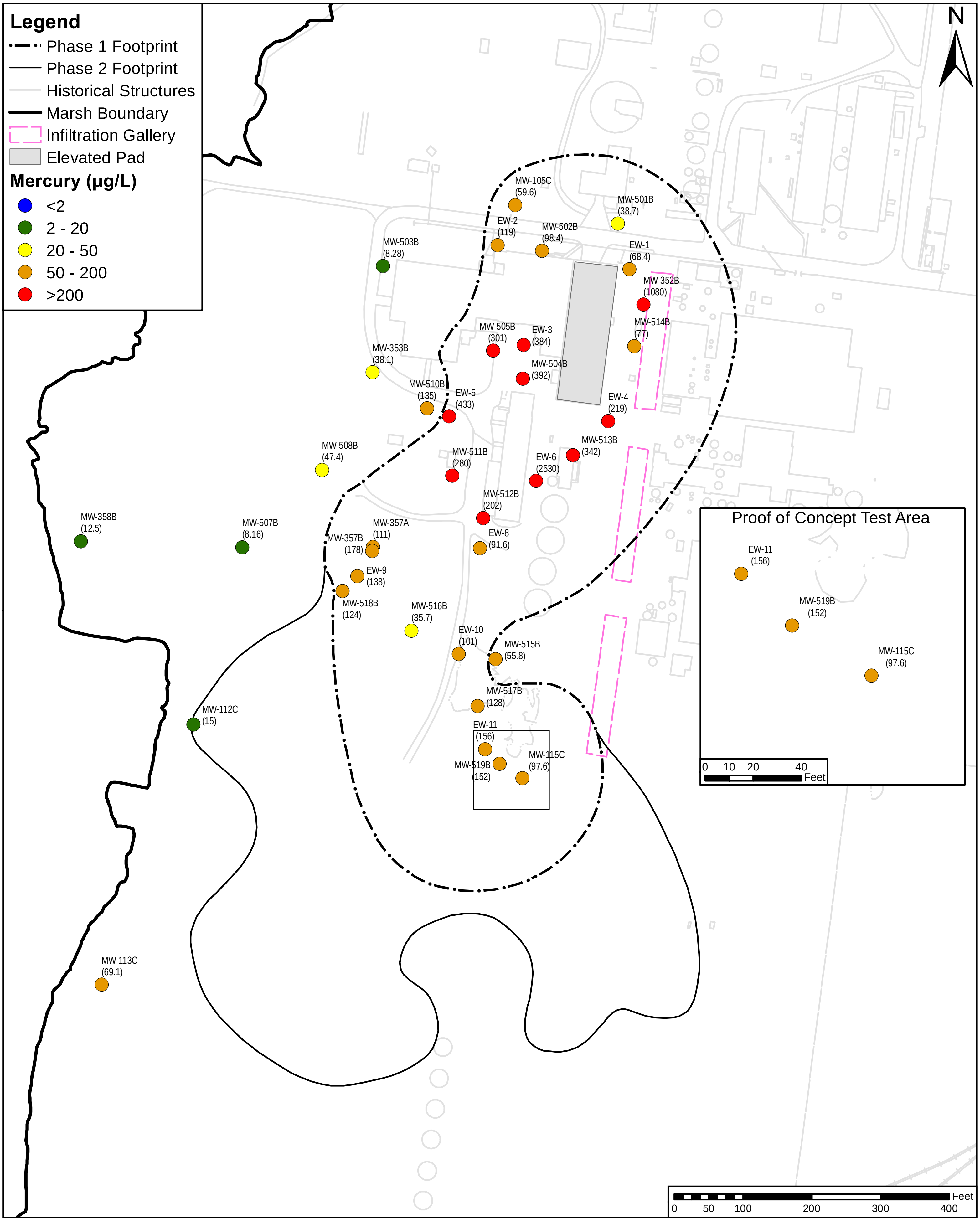


Figure 4-37: Pre-sparge (2011-2012) mercury in deep Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

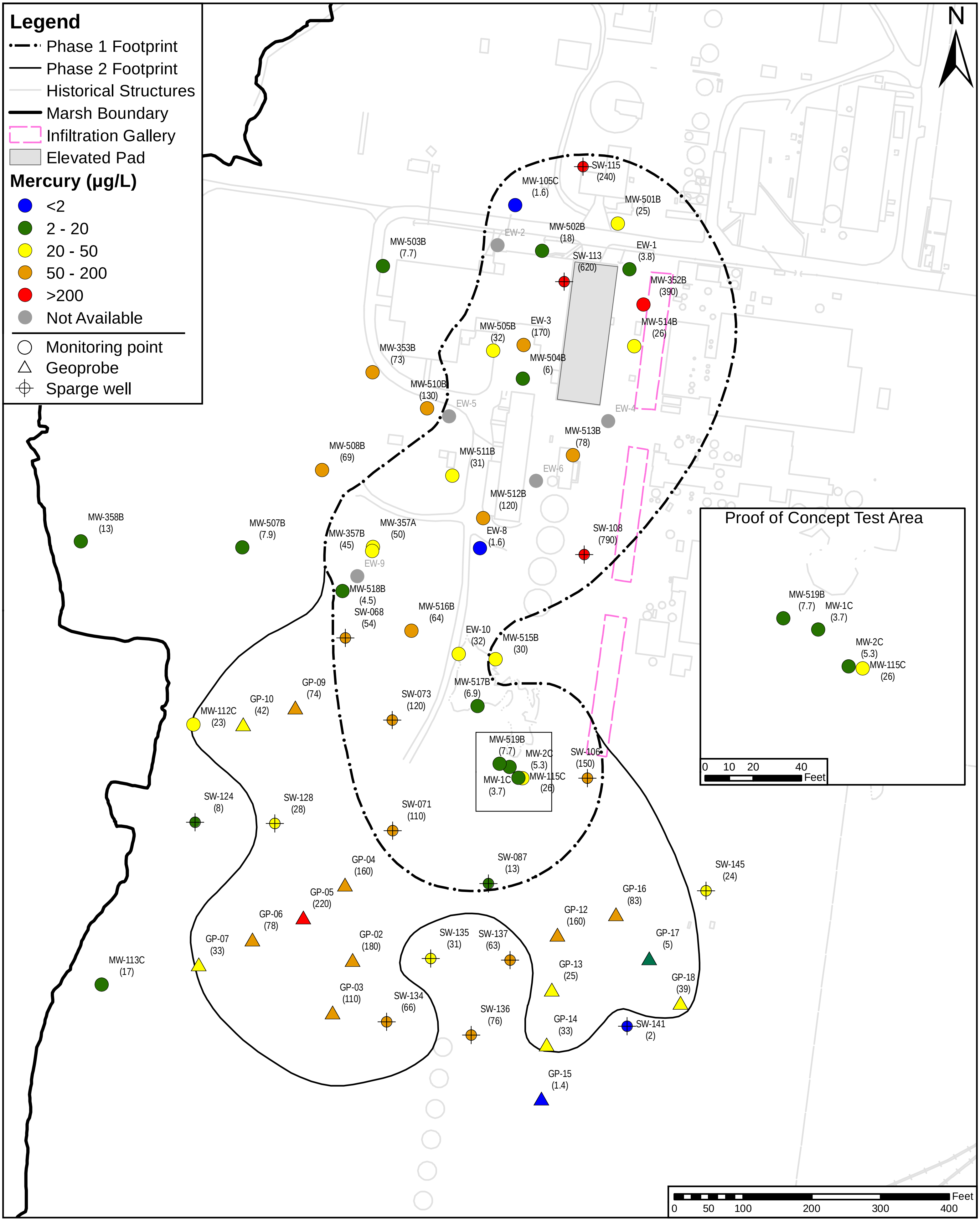


Figure 4-38: Pre-sparge (Phase 2) mercury in deep Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

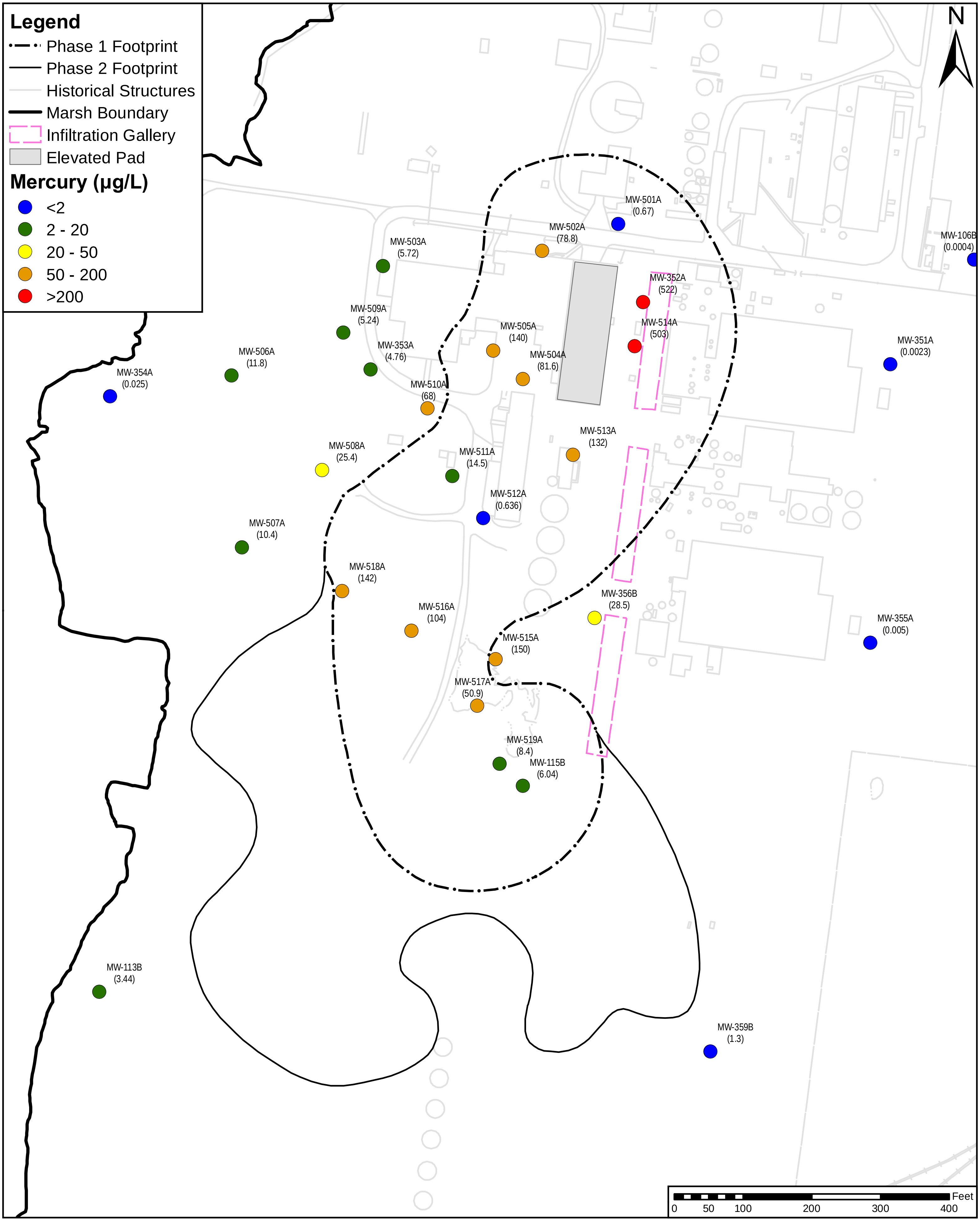


Figure 4-39: Pre-sparge (2012) mercury in mid Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

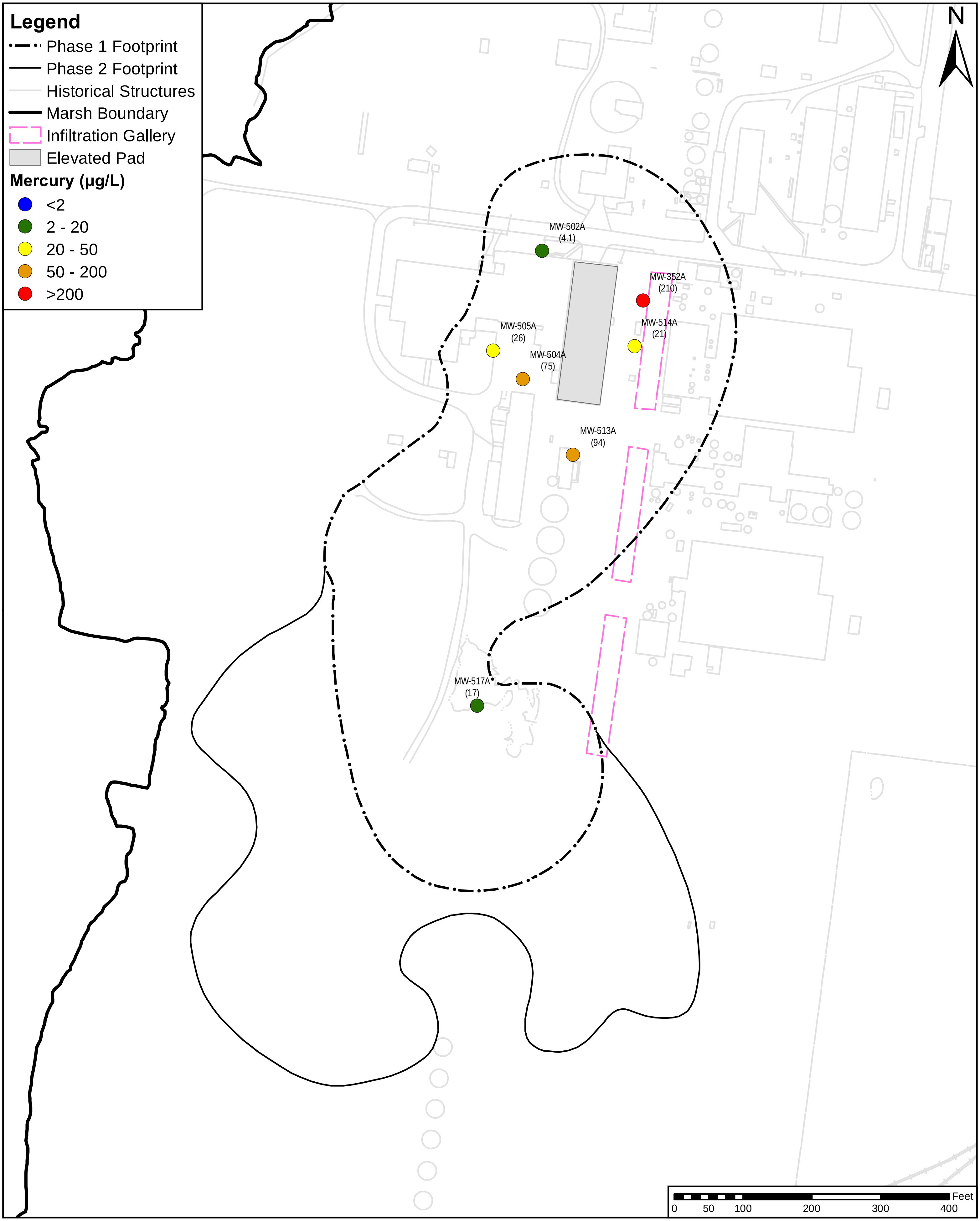


Figure 4-40: Pre-sparge (Phase 2) mercury in mid Satilla monitoring wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

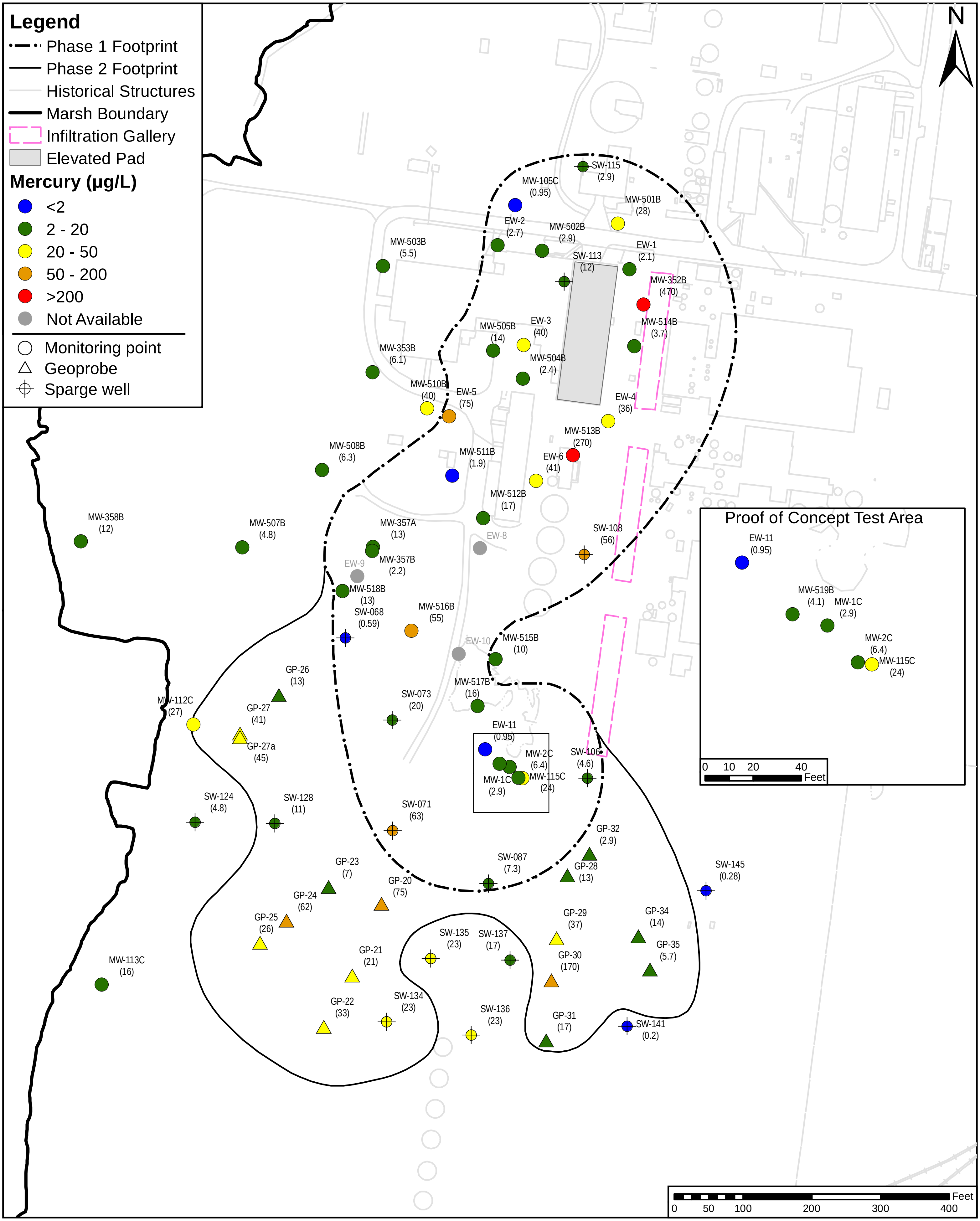


Figure 4-41: Post-sparge (Phase 2) mercury in deep Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

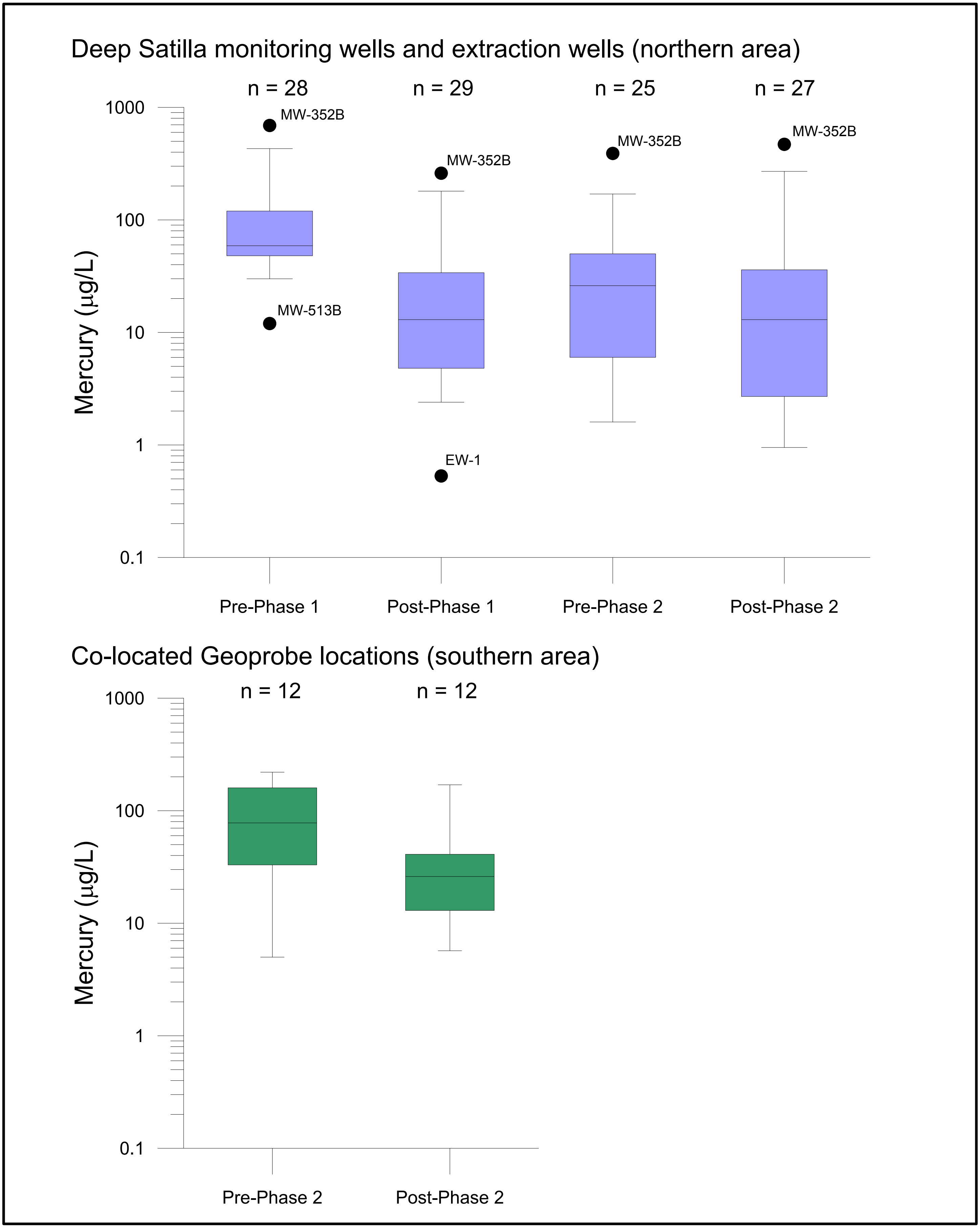


Figure 4-42: Box plot of mercury concentrations in deep Satilla monitoring locations

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

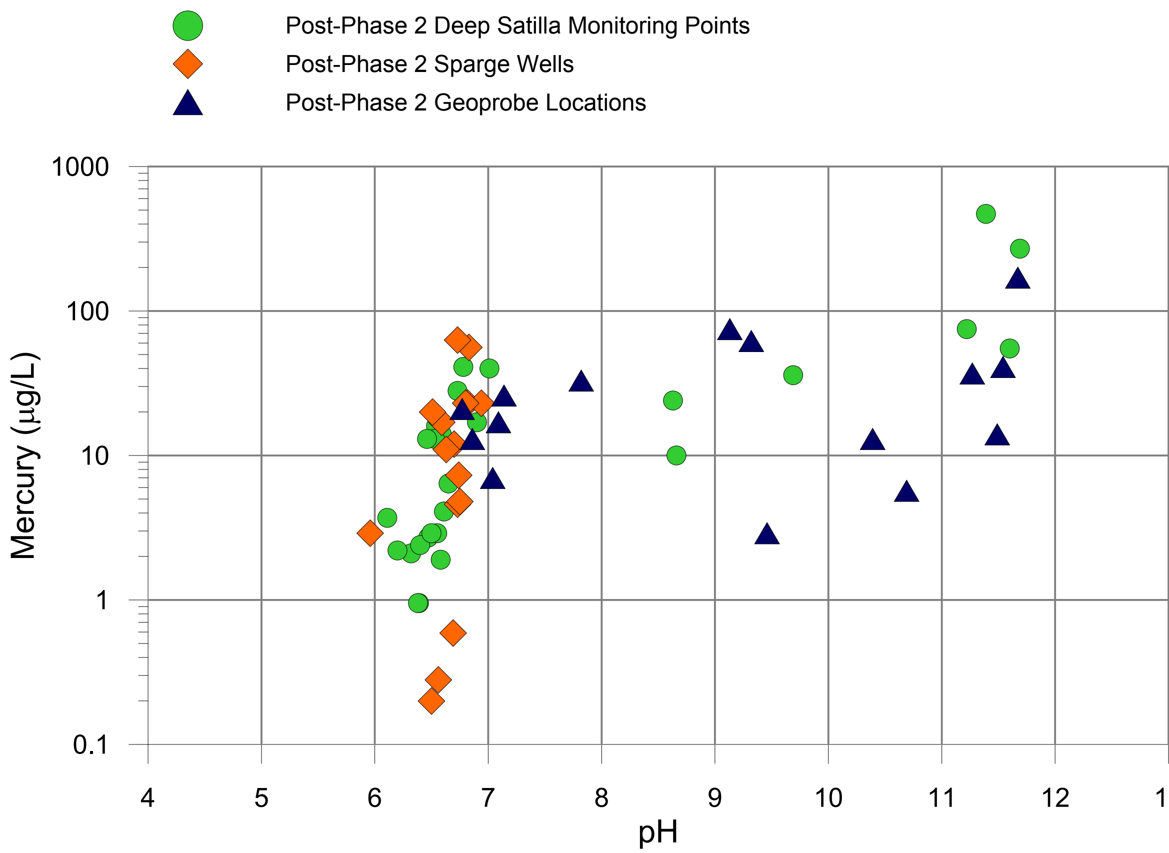


Figure 4-43: Relationship between Hg and pH in deep Satilla monitoring locations

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

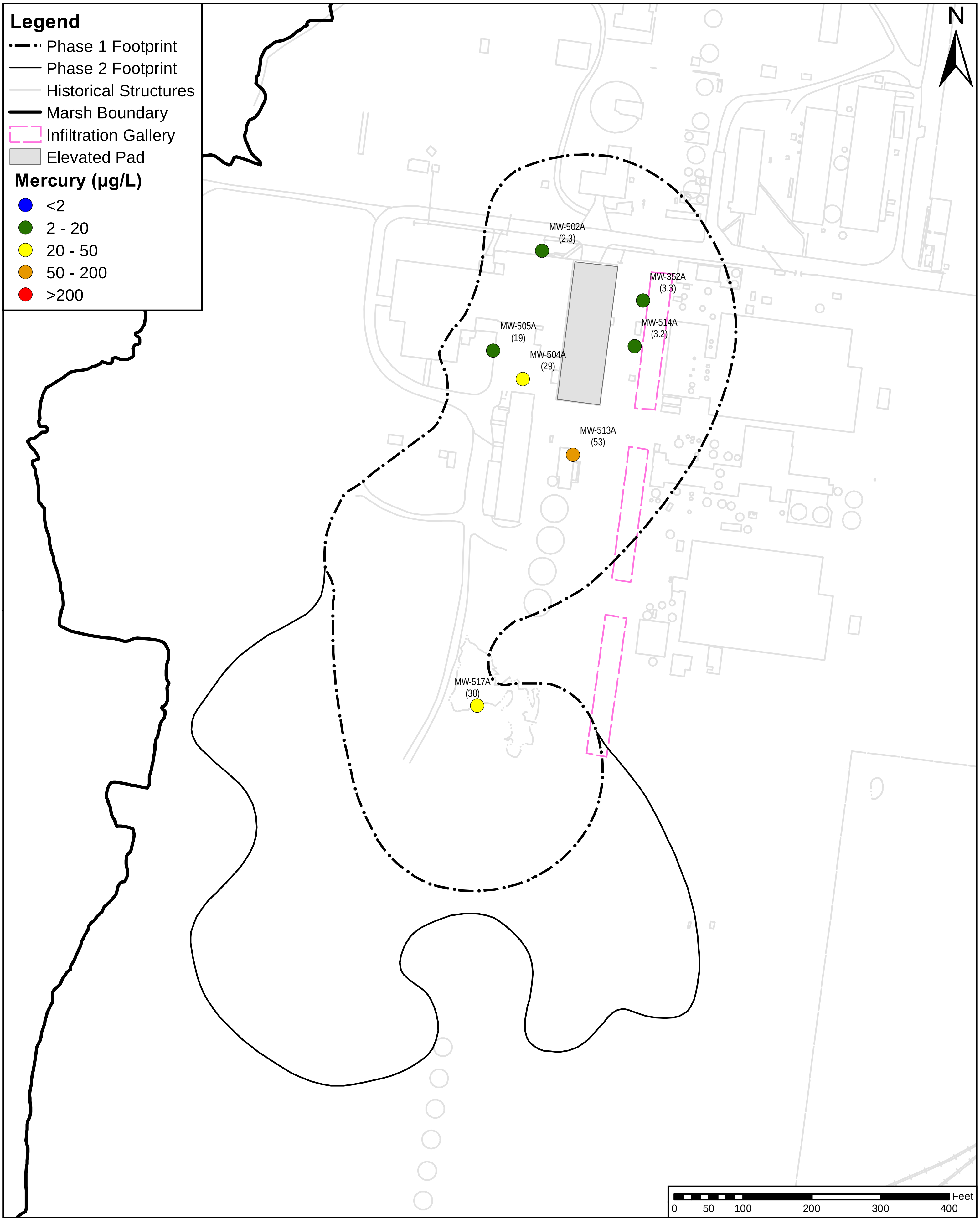


Figure 4-44: Post-sparge (Phase 2) mercury in mid Satilla monitoring wells.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

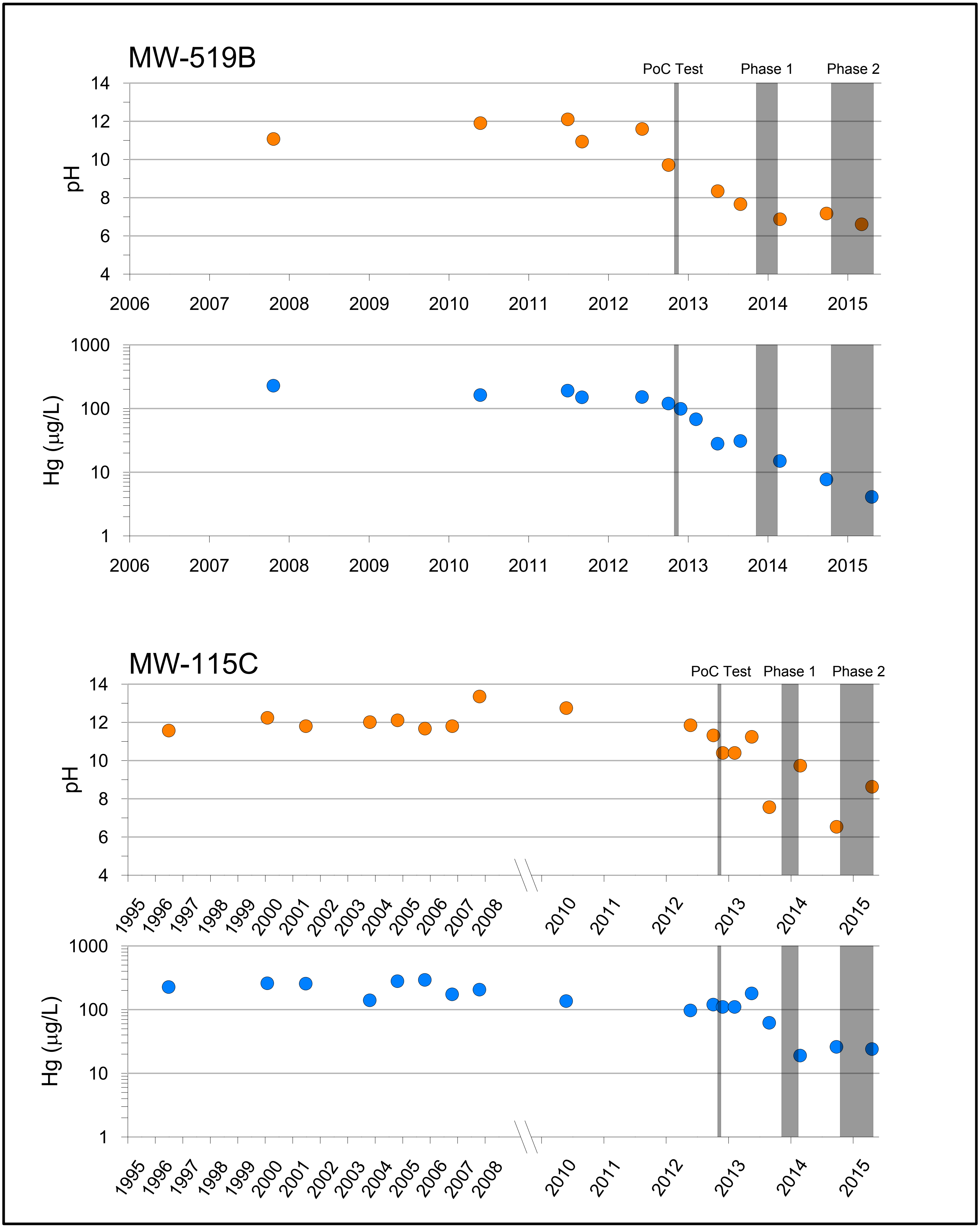


Figure 4-45: Historical pH and Hg in MW-519B and MW-115C

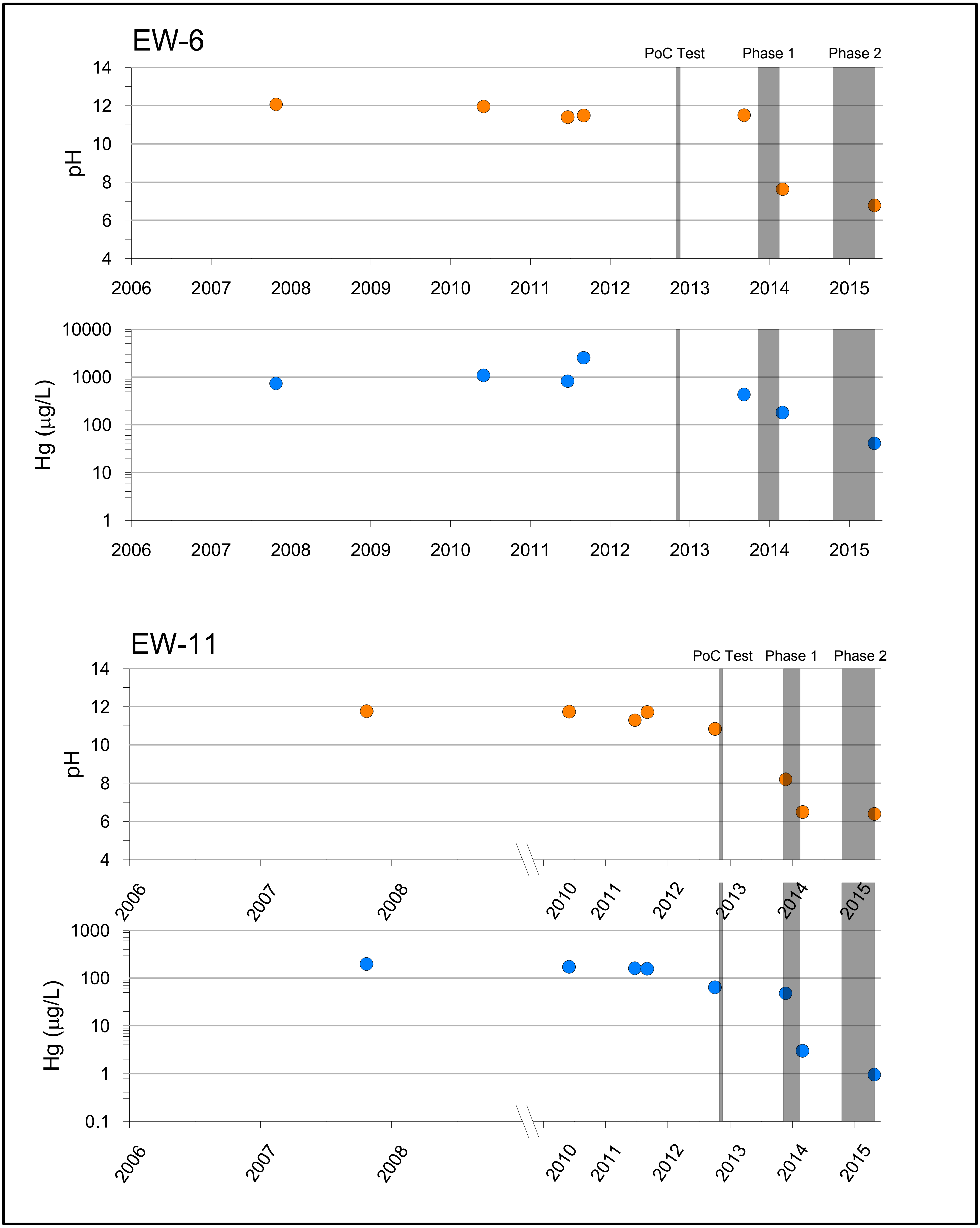


Figure 4-46: Historical pH and Hg in EW-6 and EW-11

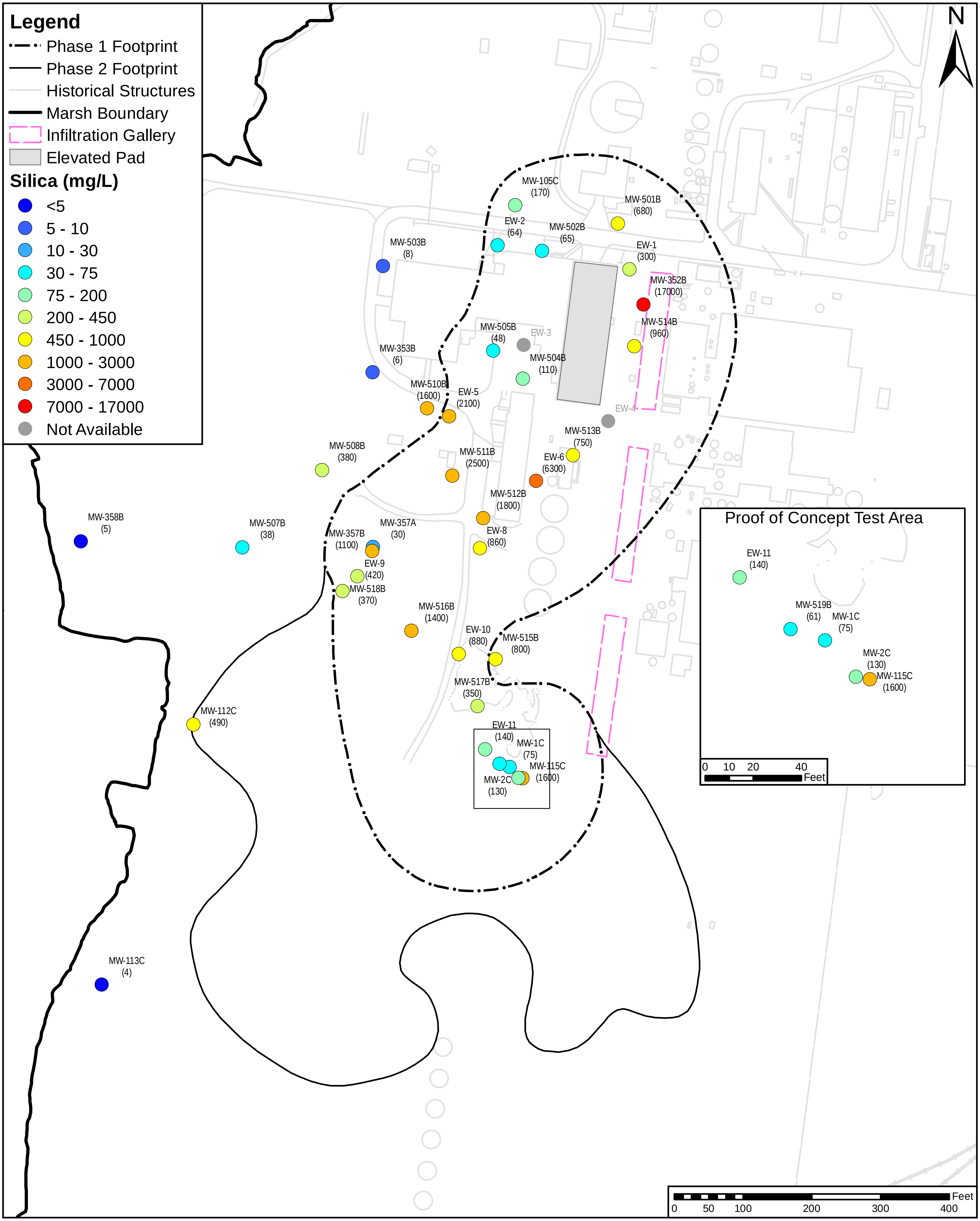


Figure 4-47: Pre-sparge (Phase 1) silica in deep Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

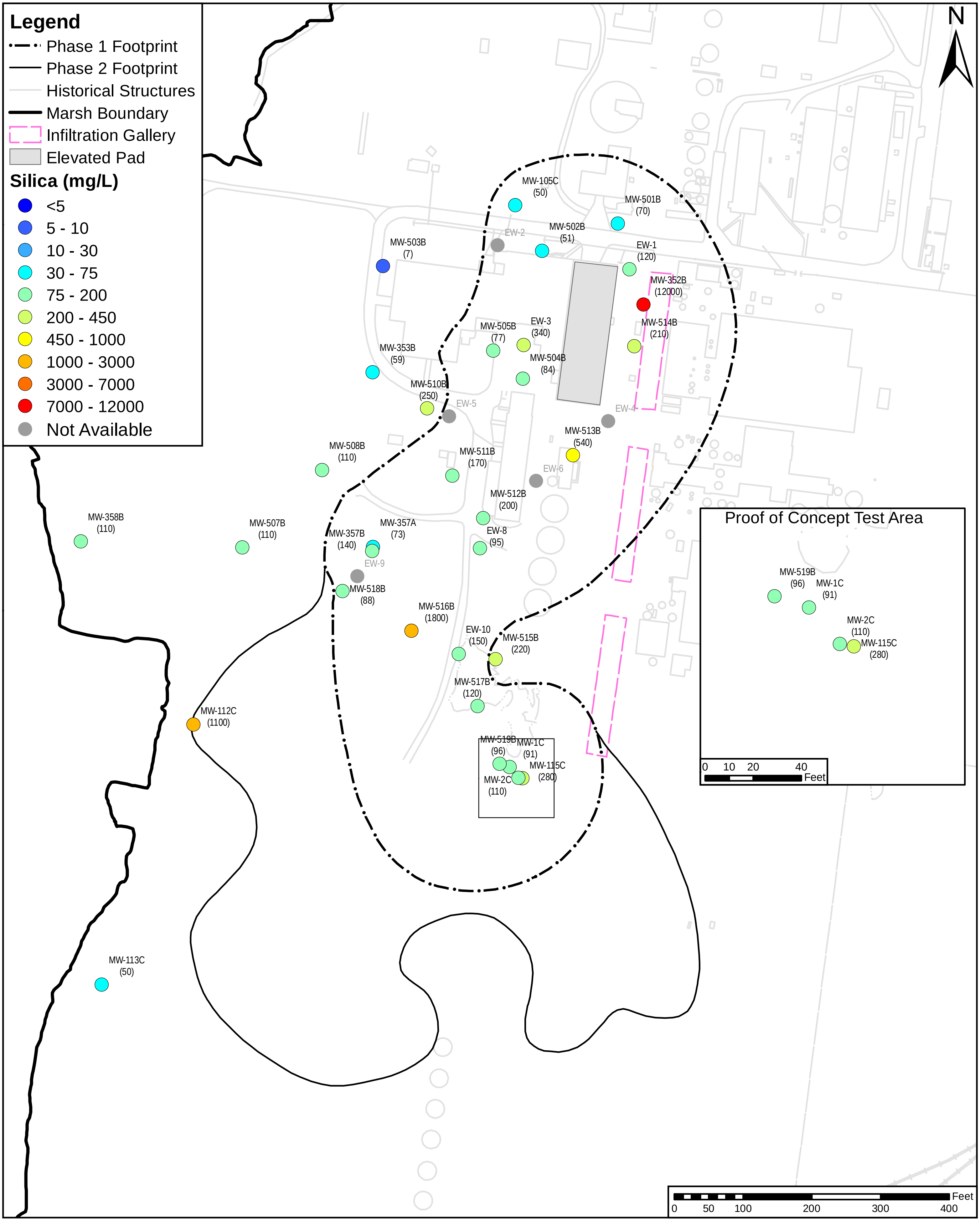


Figure 4-48: Pre-sparge (Phase 2) silica in deep Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

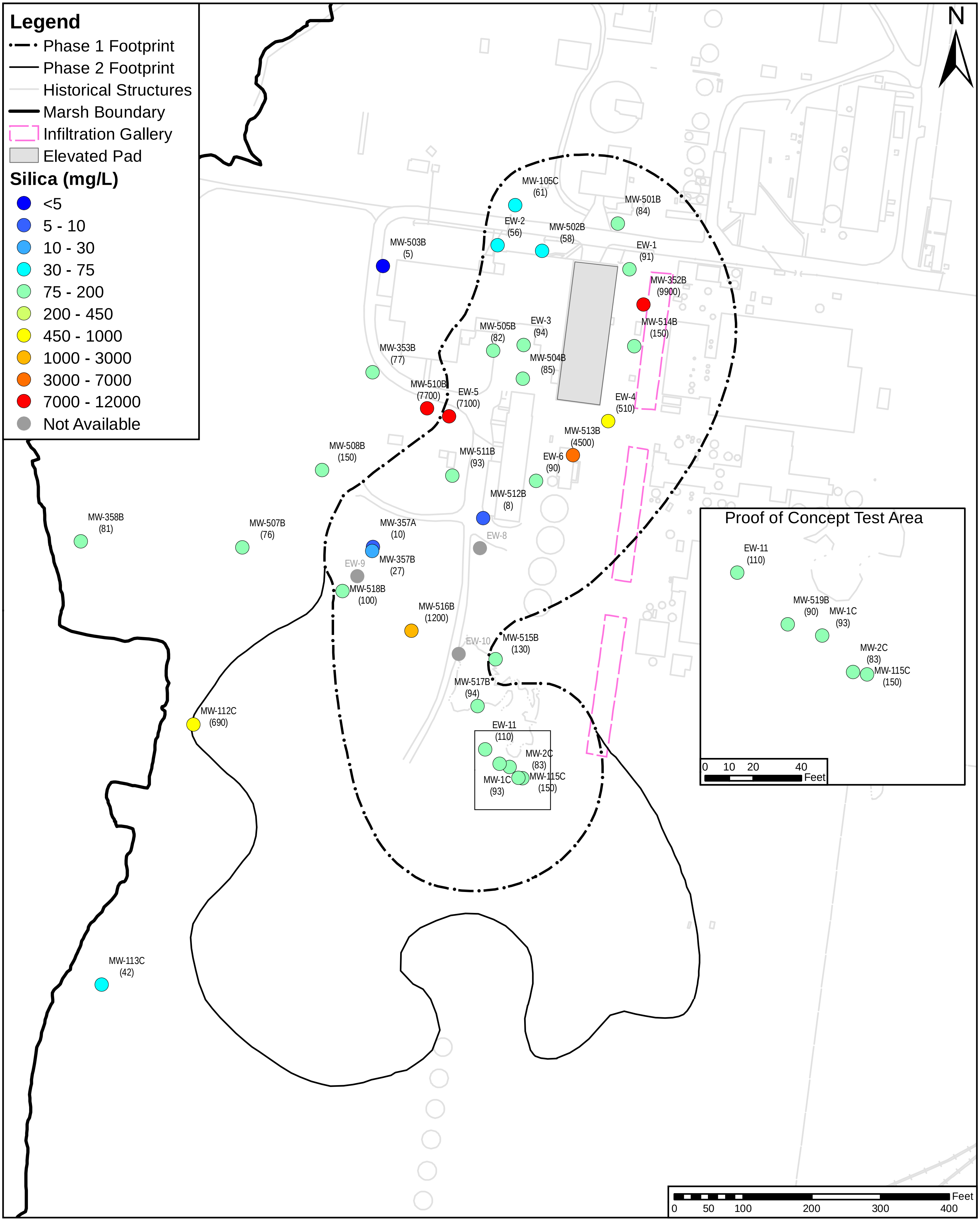


Figure 4-49: Post-sparge (Phase 2) silica in deep Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

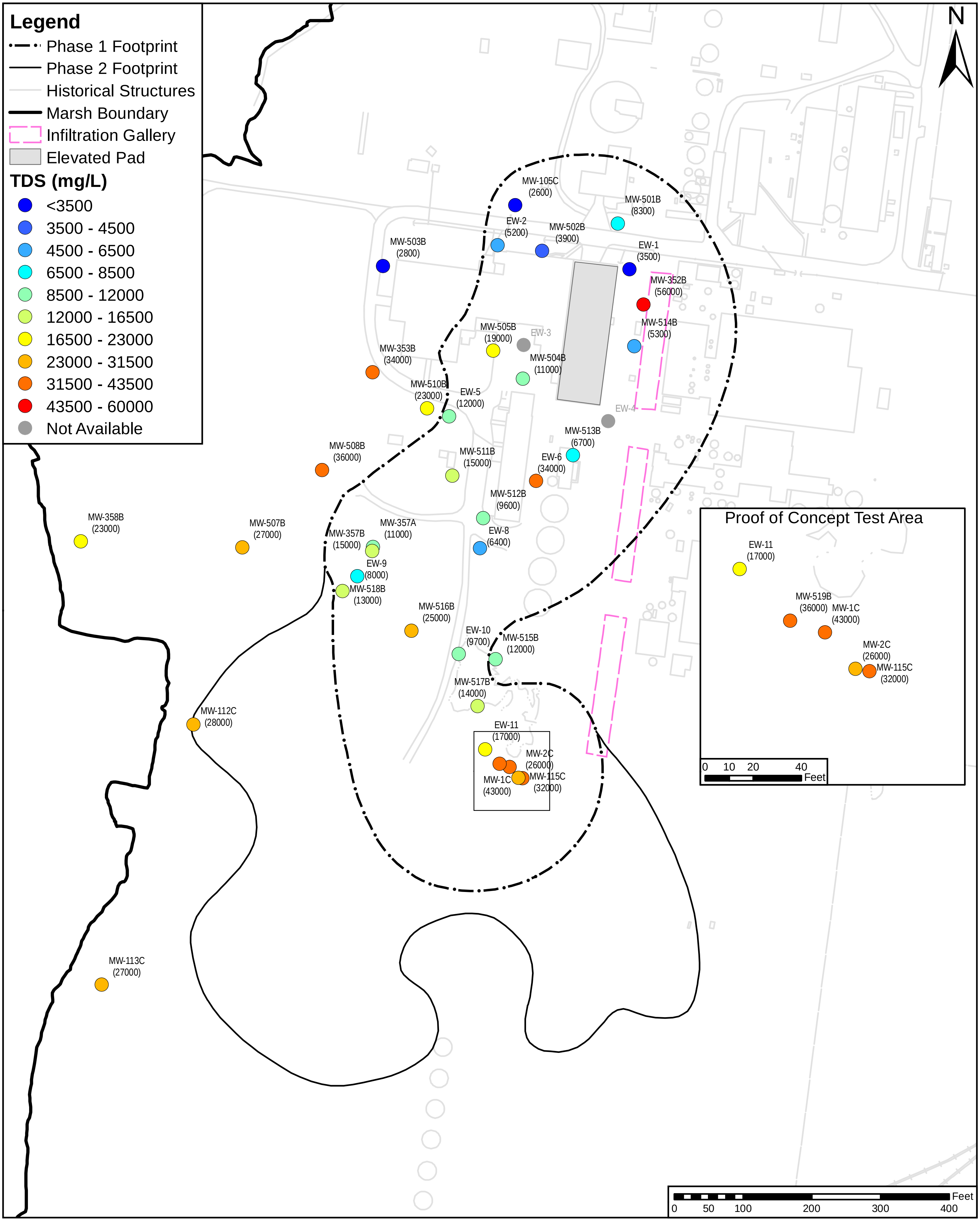


Figure 4-50: Pre-sparge (Phase 1) TDS in deep Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

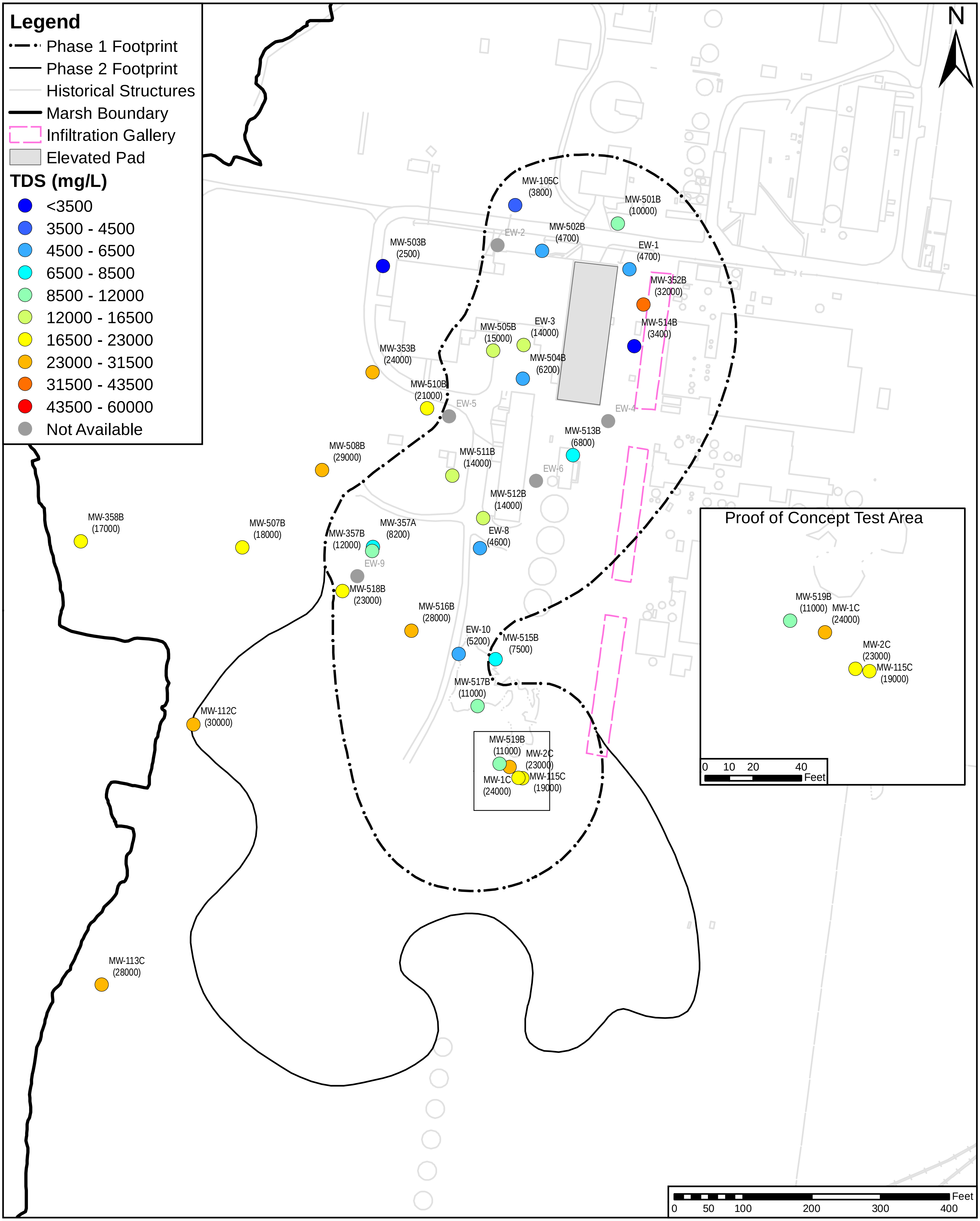


Figure 4-51: Pre-sparge (Phase 2) TDS in deep Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

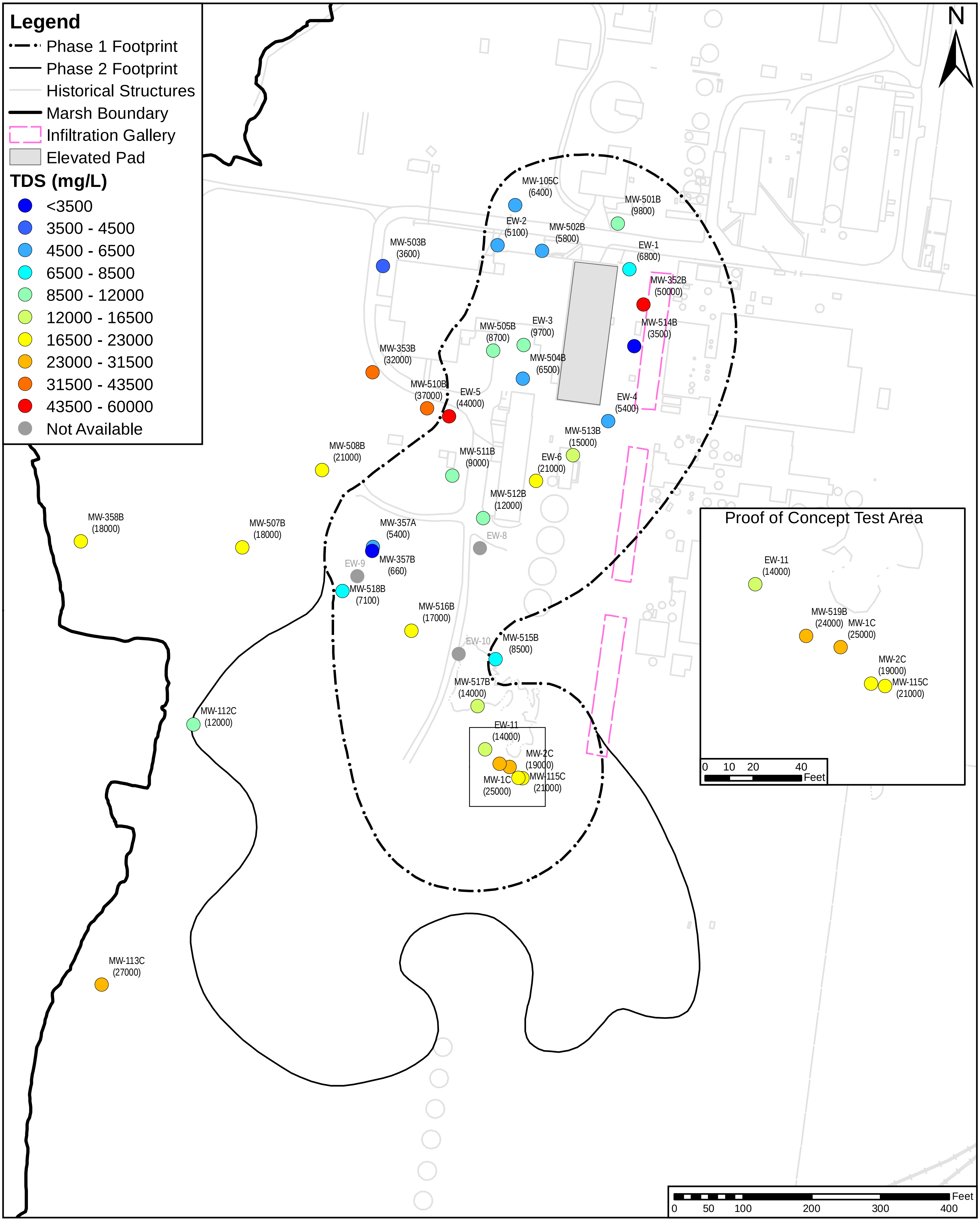


Figure 4-52: Post-sparge (Phase 2) TDS in deep Satilla monitoring locations.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

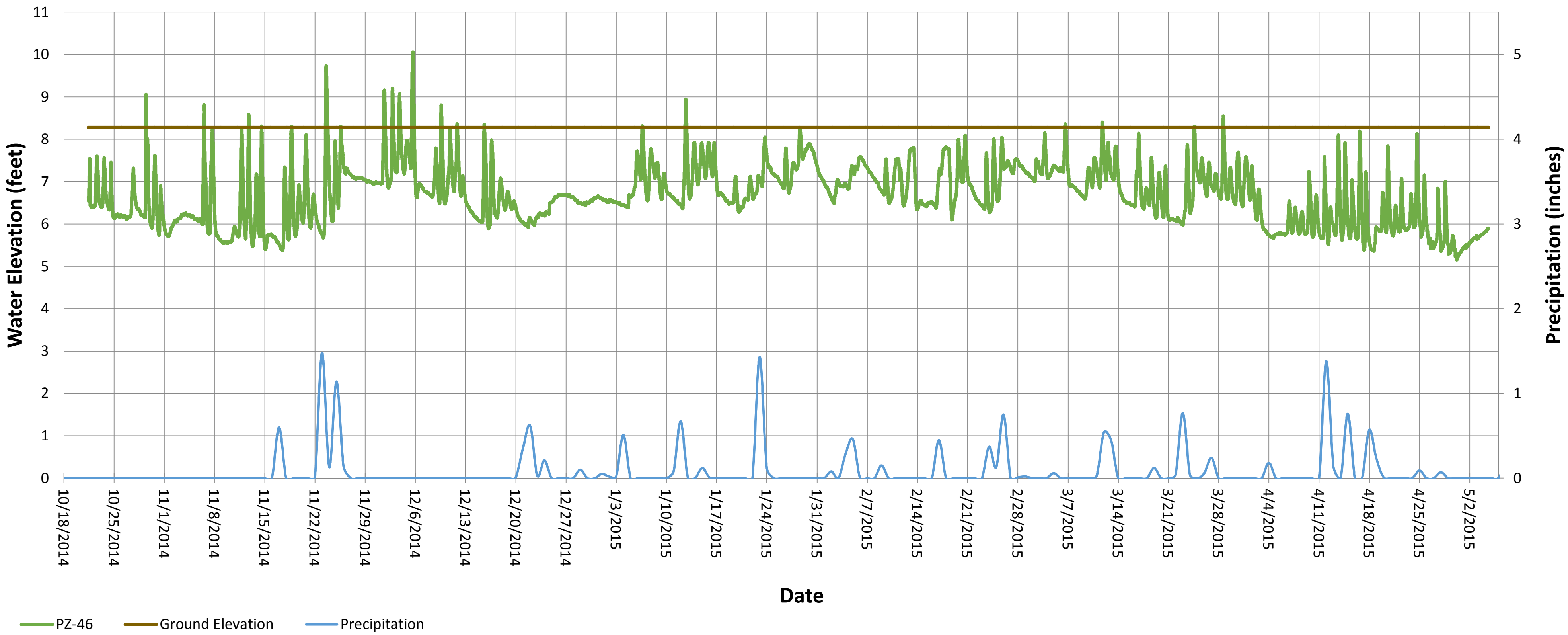


Figure 4-53: PZ-46 hydrograph and daily precipitation data.

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

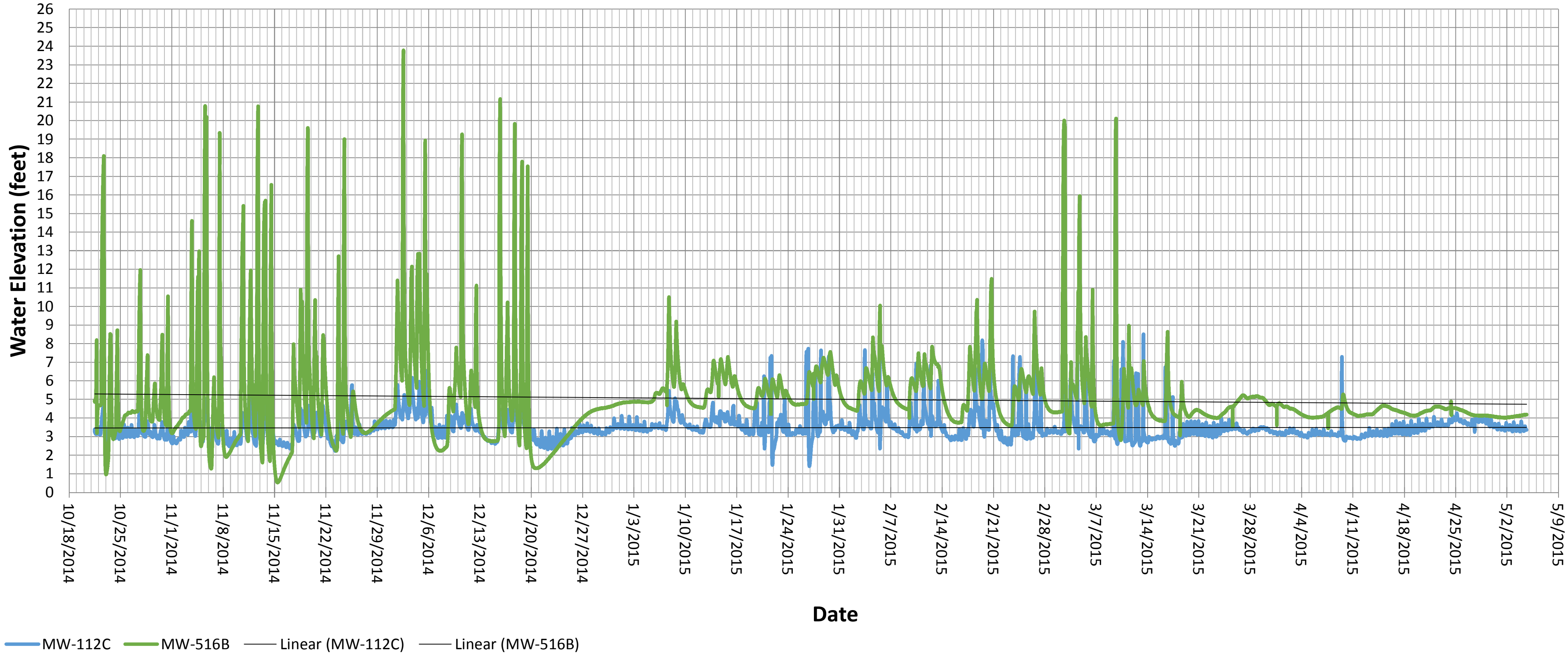


Figure 4-54: MW-516B and MW-112C Hydrograph

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

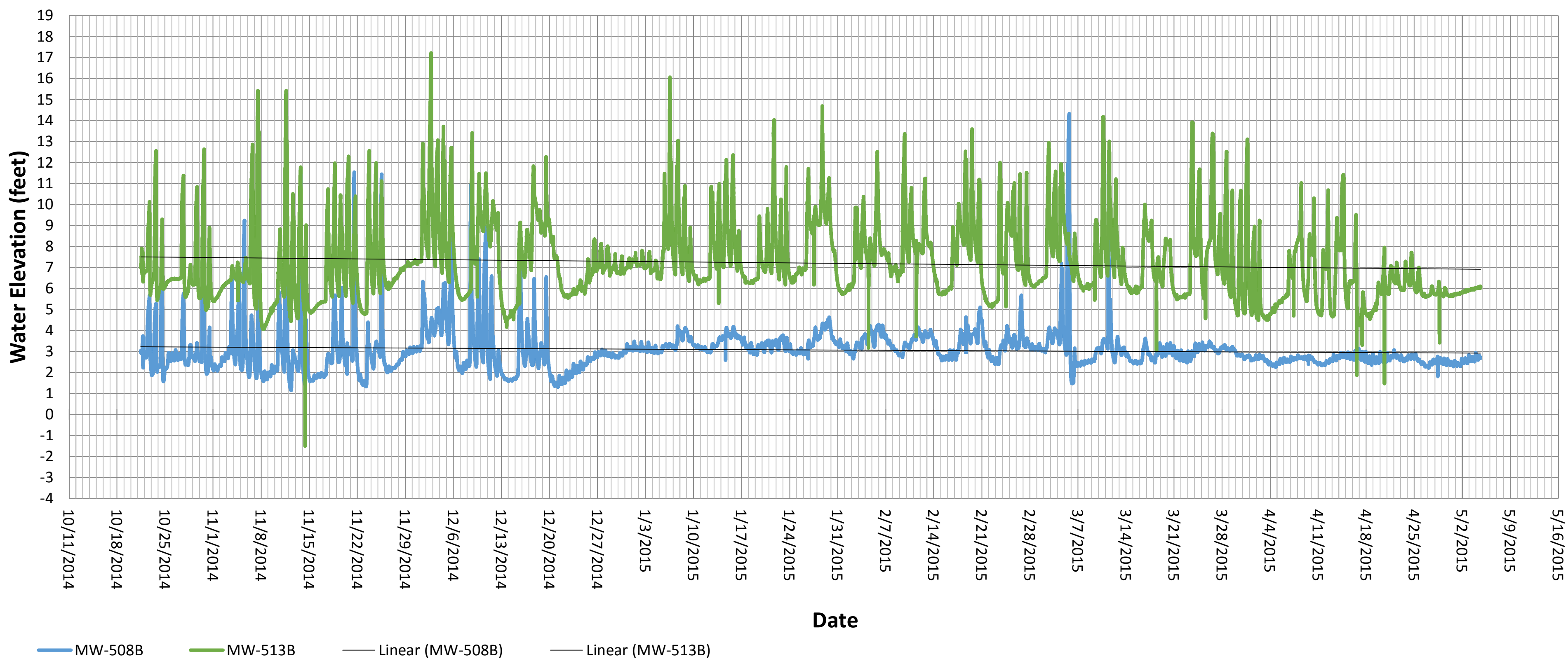


Figure 4-55: MW-513B and MW-508B Hydrograph

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC

Environmental Engineers and Scientists

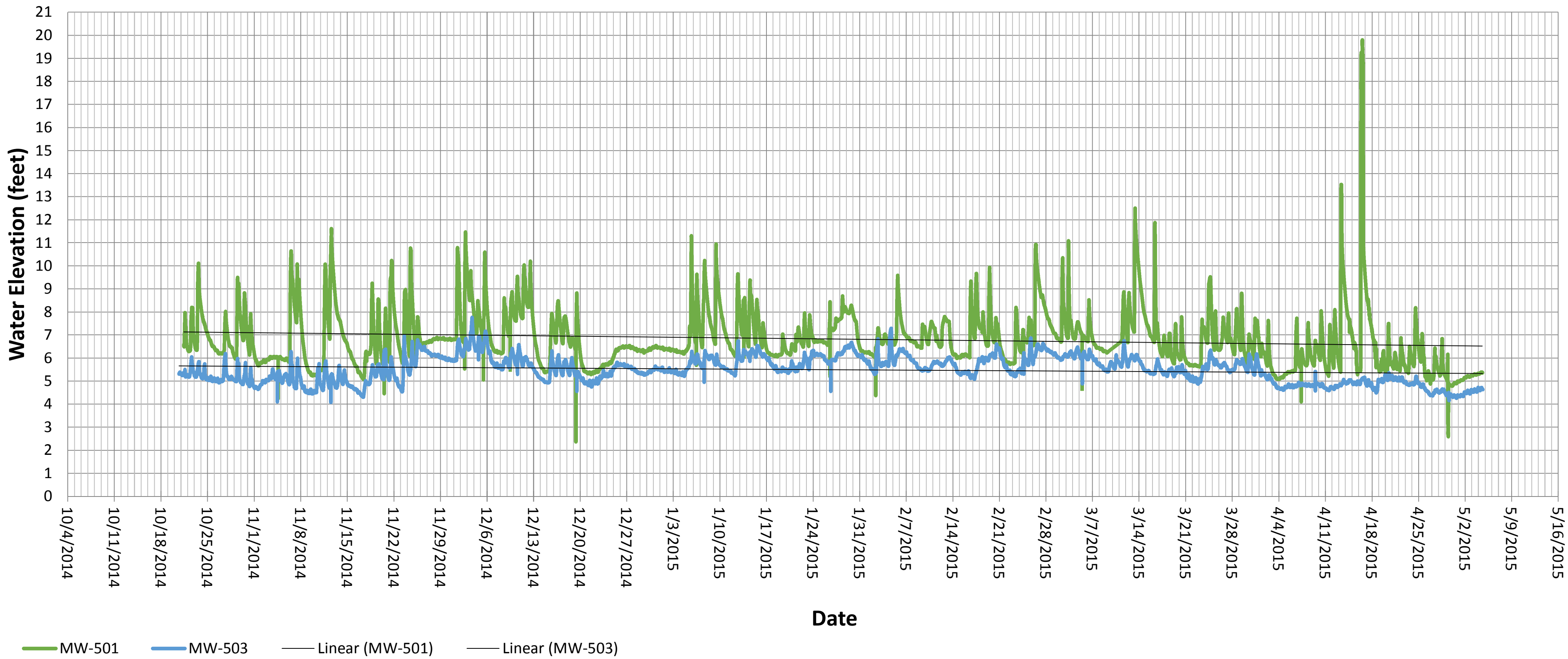


Figure 4-56: MW-501B and MW-503B Hydrograph

LCP Chemicals Site, Brunswick, GA

Mutch Associates, LLC
Environmental Engineers and Scientists

Appendix A:

Boring Logs/Well Construction Diagrams

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-66
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431554.12	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861478.48	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 10.09	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.2 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0							Hand cleared to 5 feet. Brown-gray SAND. 5-44 ft. pH=7, VOCs=0.0, Hg= 0.0.	
5								
10				0.0	0.000			
15								

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-66
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431554.12	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861478.48	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 10.09	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.2 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
				0.0	0.000			
25								
30								

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-66
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431554.12	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861478.48	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 10.09	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.2 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35								
				0.0	0.000			
40								
			15-19-29-31	0.0	0.000		Gray, fine-medium SAND, trace silt, trace shells.	
45								

BORING LOG

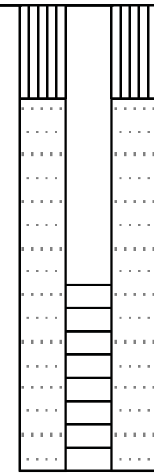
Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-66
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431554.12	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861478.48	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 10.09	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.2 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description
45			15-19-29-31	0.0	0.000		Gray, fine-medium SAND, trace silt, trace shells.
			16-25-33-38	0.0	0.000		As above
			16-23-24-38	0.0	0.000		Gray, fine-medium SAND, trace silt.
50 / 50.2			50/2	0.0	0.000		Variably cemented SANDSTONE. Refusal at 50.2 ft.

Well Construction Diagram



BORING LOG

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-67
Diameter: 8 Inches
Date: 09/03/2015

Northing (ft): 431635.36	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861478.33	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.50	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 49.5 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0							Hand cleared to 5 feet. 5-44 ft. pH= 7, VOC= 0.0, Hg= 0.0	
5								
10				0.0	0.000			
15								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-67
Diameter: 8 Inches
Date: 09/03/2015

Northing (ft): 431635.36 Easting (ft): 861478.33 Elevation (ft): 9.50 Total Depth: 49.5 Ft	Driller: Groundwater Protection Inc Method: Mud Rotary Consultant: Mutch Associates Project No: 448517	Datum: NAVD88 **Coordinate System:** **NAD 1983 State Plane Georgia East / FIPS 1001**

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
				0.0	0.000			
25								
30								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-67
Diameter: 8 Inches
Date: 09/03/2015

Northing (ft): 431635.36	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861478.33	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.50	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 49.5 Ft	Project No: 448517	

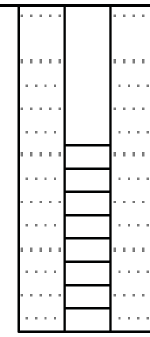
Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35								
				0.0	0.000			
40								
			13-11-14-19	0.0	0.000		Gray, fine-medium SAND, trace silt, trace shells.	
45								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-67
Diameter: 8 Inches
Date: 09/03/2015

Northing (ft): 431635.36	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861478.33	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.50	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 49.5 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
45			13-11-14-19	0.0	0.000		Gray, fine-medium SAND, trace silt, trace shells.	
			16-24-26-32	0.0	0.000		As above.	
49.5			11-39-50/6	0.0	0.000		As above over gray fine-medium SAND, some silt, trace pieces of mudstone, variably cemented sandstone Bedrock in tip.	

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-68
Diameter: 8 Inches
Date: 09/03/2014

Northing (ft): 431714.34	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861478.08	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.08	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 51.0 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0							Hand cleared to 5 ft. Mud rotary to 44 ft. pH= 7, VOCs= 0.0, Hg= 0.0.	
5								
10				0.0	0.000			
15								

BORING LOG

Honeywell

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-68
Diameter: 8 Inches
Date: 09/03/2014

Northing (ft): 431714.34	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861478.08	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.08	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 51.0 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
				0.0	0.000			
25								
30								

BORING LOG

Honeywell

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-68
Diameter: 8 Inches
Date: 09/03/2014

Northing (ft): 431714.34
Easting (ft): 861478.08
Elevation (ft): 9.08
Total Depth: 51.0 Ft

Driller: Groundwater Protection Inc
Method: Mud Rotary
Consultant: Mutch Associates
Project No: 448517

Datum: NAVD88
Coordinate System:
NAD 1983 State Plane Georgia East / FIPS 1001

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35								
				0.0	0.000			
40								
			22-23-27-30	0.0	0.000		Gray fine-medium SAND, trace silt, trace shells.	
45								

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-68
Diameter: 8 Inches
Date: 09/03/2014

Northing (ft): 431714.34 Easting (ft): 861478.08 Elevation (ft): 9.08 Total Depth: 51.0 Ft	Driller: Groundwater Protection Inc Method: Mud Rotary Consultant: Mutch Associates Project No: 448517	Datum: NAVD88 **Coordinate System:** **NAD 1983 State Plane Georgia East / FIPS 1001**

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
45			22-23-27-30	0.0	0.000		Gray fine-medium SAND, trace silt, trace shells.	
			21-23-28-38	0.0	0.000		As above	
			18-16-X-X	0.0	0.000		As above	
50			50/6	0.0	0.000		Grey, fine to coarse SAND, some silt, variably cemented SANDSTONe bedrock in tip of spoon.	
51.0								

BORING LOG

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-69
Diameter: 8 Inches
Date: 09/02/2014 - 09/03/2014

Northing (ft): 431794.01	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861478.05	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.49	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 51.5 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0							Hand cleared to 5 feet. Mud rotary 5-44 ft. pH= 7, VOCs= 0.0, Hg= 0.0.	
5								
10				0.0	0.000			
15								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-69
Diameter: 8 Inches
Date: 09/02/2014 - 09/03/2014

Northing (ft): 431794.01	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861478.05	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.49	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 51.5 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
				0.0	0.000			
25								
30								

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-69
Diameter: 8 Inches
Date: 09/02/2014 - 09/03/2014

Northing (ft): 431794.01
Easting (ft): 861478.05
Elevation (ft): 9.49
Total Depth: 51.5 Ft

Driller: Groundwater Protection Inc
Method: Mud Rotary
Consultant: Mutch Associates
Project No: 448517

Datum: NAVD88
Coordinate System:
NAD 1983 State Plane Georgia East / FIPS 1001

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35								
				0.0	0.000			
40								
			17-25-33-34	0.0	0.000		Gray, fine-medium SAND, trace silt, trace shells.	
45								

BORING LOG

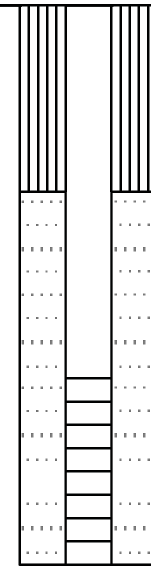
Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-69
Diameter: 8 Inches
Date: 09/02/2014 - 09/03/2014

Northing (ft): 431794.01	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861478.05	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.49	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 51.5 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description
45			17-25-33-34	0.0	0.000		Gray, fine-medium SAND, trace silt, trace shells.
			30-30-50+	0.0	0.000		Gray, fine to coarse SAND, trace silt, trace shells at bottom.
			17-16-17-X	0.0	0.000		Gray, fine to medium SAND, trace silt, trace shells.
50			13-20-50/2	0.0	0.000		Gray fine-medium SAND, trace-little silt, trace shells. Variably cemented SANDSTONE in tip.
51.5							

Well Construction Diagram



Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-70
Diameter: 8 Inches
Date: 09/10/2014

Northing (ft): 431874.53	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861477.72	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 8.44	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 48.9 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0							Hand cleared with post hole digger. SAND. pH = 7 5-20 ft and pH = 8 20-42 ft.	
5								
10				0.1	0.000			
15								

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-70
Diameter: 8 Inches
Date: 09/10/2014

Northing (ft): 431874.53	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861477.72	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 8.44	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 48.9 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
				0.1	0.000			
20								
25				0.1	0.000			
30								

BORING LOG

Honeywell

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-70
Diameter: 8 Inches
Date: 09/10/2014

Northing (ft): 431874.53	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861477.72	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 8.44	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 48.9 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35				0.1	0.000			
40								
			3-6-10-15	0.0	0.000		Wet, fine-medium SAND, trace clay. Clay in 2-inch lenses at base of sample. Hg=0.0 mg/m3 VOCs= 0.0 ppm.	
			7-9-17-17	0.0	0.000		Wet, fine-medium SAND, trace clay, widely scattered thin clay lenses. Hg= 0.0 mg/m3, VOCs= 0.0 ppm	
45								

BORING LOG

Honeywell

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-70
Diameter: 8 Inches
Date: 09/10/2014

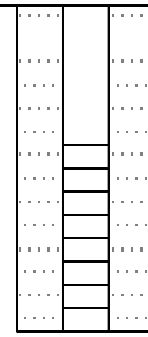
Northing (ft): 431874.53
Easting (ft): 861477.72
Elevation (ft): 8.44
Total Depth: 48.9 Ft

Driller: Groundwater Protection Inc
Method: Mud Rotary
Consultant: PARSONS
Project No: 448517

Datum: NAVD88
Coordinate System:
NAD 1983 State Plane Georgia East / FIPS 1001

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description
45			7-9-17-17	0.0	0.000		Wet, fine-medium SAND, trace clay, widely scattered thin clay lenses. Hg= 0.0 mg/m3, VOCs= 0.0 ppm
			3-4-7-6	0.0	0.000		Wet, fine SAND, little medium sand, trace clay. Hg= 0.0 mg/m3, VOCs= 0.0 ppm
48.9			30-50/5	0.0	0.000		Wet, fine-medium SAND, over gray fine sand, trace fine gravel, trace shells, trace silt. Hg= 0.0 mg/m3 VOCs= 0.0 ppm Refusal at 48.9 feet.

Well Construction Diagram



BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-71
Diameter: 8 Inches
Date: 09/05/2015

Northing (ft): 431434.05	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861547.33	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.87	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 49.75 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0			Hand Dug				SAND	
5								
10								
15								

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-71
Diameter: 8 Inches
Date: 09/05/2015

Northing (ft): 431434.05	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861547.33	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.87	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 49.75 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
25								
30								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-71
Diameter: 8 Inches
Date: 09/05/2015

Northing (ft): 431434.05
Easting (ft): 861547.33
Elevation (ft): 9.87
Total Depth: 49.75 Ft

Driller: Groundwater Protection Inc
Method: Mud Rotary
Consultant: PARSONS
Project No: 448517

Datum: NAVD88
Coordinate System:
NAD 1983 State Plane Georgia East / FIPS 1001

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35								
40								
			6-3-7-16	0.0	0.000		Wet, gray medium to fine SAND, little shells, trace silt. Hg=0.0 VOCs= 0.0	
45								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-71
Diameter: 8 Inches
Date: 09/05/2015

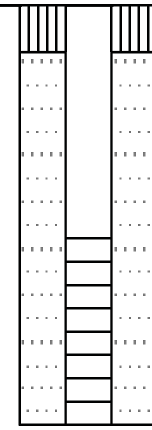
Northing (ft): 431434.05
Easting (ft): 861547.33
Elevation (ft): 9.87
Total Depth: 49.75 Ft

Driller: Groundwater Protection Inc
Method: Mud Rotary
Consultant: PARSONS
Project No: 448517

Datum: NAVD88
Coordinate System:
NAD 1983 State Plane Georgia East / FIPS 1001

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description
45			6-3-7-16	0.0	0.000		Wet, gray medium to fine SAND, little shells, trace silt. Hg=0.0 VOCs= 0.0
			13-24-40-50	0.0	0.000		As above. Hg= 0.0 VOCs=0.0
49.75			13-15-24-50/3	0.0	0.000		As above, less shells (trace) over black/gray medium to fine SAND, little silt, little coarse sand. Hg= 0.0 VOCs= 0.0. Refusal at 49.75 ft.

Well Construction Diagram



BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-72
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431514.43 Easting (ft): 861547.22 Elevation (ft): 9.53 Total Depth: 49.5 Ft	Driller: Groundwater Protection Inc Method: Mud Rotary Consultant: PARSONS Project No: 448517	Datum: NAVD88 **Coordinate System:** **NAD 1983 State Plane Georgia East / FIPS 1001**

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0–5			Hand Dug				SAND 5-20 Hg= 0.0 mg/m3, VOCs= 0.0, SAND 20-40 ft Hg= 0.0m VOCs= 0.0, pH=8	
10				0.0	0.000			
15								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-72
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431514.43	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861547.22	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.53	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 49.5 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
				0.0	0.000			
25								
30								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-72
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431514.43	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861547.22	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.53	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 49.5 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35				0.0	0.000			
40								
				0.0	0.000			
			10-10-14-16	0.0	0.000		Wet, gray medium to fine SAND, little to trace silt, trace shells. Hg= 0.0 mg/m3 VOCs= 0.0, pH= 9	
45								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-72
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431514.43	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861547.22	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.53	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 49.5 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
45			10-10-14-16	0.0	0.000		Wet, gray medium to fine SAND, little to trace silt, trace shells. Hg= 0.0 mg/m3 VOCs= 0.0, pH= 9	
			6-15-20-23	0.0	0.000		As above	
			10-17-15-50/6	0.0	0.000		As above 48-48.5. Weathered bedrock, dark gray, medium to fine SAND, some silt, little coarse gravel. Hg= 0.0 mg/m3 VOCs= 0.0	
50.0								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-73
Diameter: 8 Inches
Date: 09/04/2014

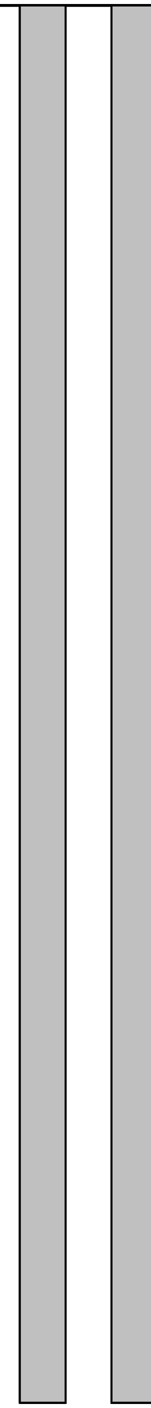
Northing (ft): 431594.87
Easting (ft): 861546.61
Elevation (ft): 9.43
Total Depth: 50.75 ft

Driller: Groundwater Protection Inc
Method: Mud Rotary
Consultant: PARSONS
Project No: 448517

Datum: NAVD88
Coordinate System:
NAD 1983 State Plane Georgia East / FIPS 1001

Depth ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description
0							SAND hand dug 0-5 ft. mud rotary 5-20 ft. VOCs= 0.0, Hg= 0.0, pH=8 SAND 20-44 ft VOCs=0.0, Hg= 0.0, pH= 8
5							
10				0.0	0.000		
15							

Well Construction Diagram



BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-73
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431594.87	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861546.61	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.43	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.75 ft	Project No: 448517	

Depth ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
				0.0	0.000			
25								
30								

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-73
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431594.87	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861546.61	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.43	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.75 ft	Project No: 448517	

Depth ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35				0.0	0.000			
40								
				0.0	0.000			
			13-7-7-6	0.0	0.000		Wet, gray fine to medium SAND, trace silt and clay, trace shells.	
45								

BORING LOG

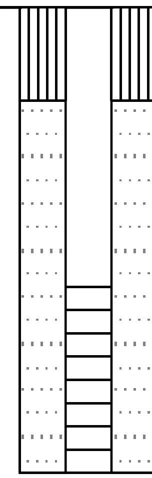
Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-73
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431594.87	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861546.61	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.43	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.75 ft	Project No: 448517	

Depth ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description
45			13-7-7-6	0.0	0.000		Wet, gray fine to medium SAND, trace silt and clay, trace shells.
			3-2-3-5	0.0	0.000		As above
			4-3-5-6	0.0	0.000		Wet gray, fine to medium SAND, trace-little silt.
50			40-50/3	0.0	0.000		Wet brown-gray, fine to medium SAND, little coarse sand, some silt.
50.75							

Well Construction Diagram



BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-74
Diameter: 8 Inches
Date: 09/03/2014

Northing (ft): 431674.12	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861547.67	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.20	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 52.0 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0							Hand cleared to 5 feet. SAND 0-10 ft. pH=7, VOCs=0.0, Hg= 0.0. Mud rotary to 44 feet.	
5								
10				0.0	0.000			
15								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-74
Diameter: 8 Inches
Date: 09/03/2014

Northing (ft): 431674.12 Easting (ft): 861547.67 Elevation (ft): 9.20 Total Depth: 52.0 Ft	Driller: Groundwater Protection Inc Method: Mud Rotary Consultant: PARSONS Project No: 448517	Datum: NAVD88 **Coordinate System:** **NAD 1983 State Plane Georgia East / FIPS 1001**

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
				0.0	0.000			
25								
30								

BORING LOG

Honeywell

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-74
Diameter: 8 Inches
Date: 09/03/2014

Northing (ft): 431674.12	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861547.67	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.20	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 52.0 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35				0.0	0.000			
40								
44–45			14-24-28-33				Wet, gray fine to medium SAND, trace to little silt, little shells.	
45								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-74
Diameter: 8 Inches
Date: 09/03/2014

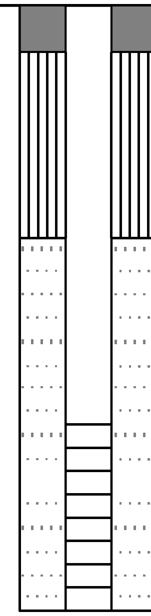
Northing (ft): 431674.12
Easting (ft): 861547.67
Elevation (ft): 9.20
Total Depth: 52.0 Ft

Driller: Groundwater Protection Inc
Method: Mud Rotary
Consultant: PARSONS
Project No: 448517

Datum: NAVD88
Coordinate System:
NAD 1983 State Plane Georgia East / FIPS 1001

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description
45			14-24-28-33				Wet, gray fine to medium SAND, trace to little silt, little shells.
			11-21-44-48				As above
			20-24-30-28				As above
50			13-16-15-50/5				Wet-moist, black-gray fine-medium SAND, some silt, trace coarse sand, lense of silt. Refusal at 5' 11".
52.0							

Well Construction Diagram



BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-75
Diameter: 8 Inches
Date: 09/03/2014

Northing (ft): 431752.81	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861547.61	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 8.92	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.0 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0							Hand cleared to 5 feet. pH= 8 Mud rotary to 44 feet. pH= 8.	
5								
10								
15								

BORING LOG

Honeywell

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-75
Diameter: 8 Inches
Date: 09/03/2014

Northing (ft): 431752.81 Easting (ft): 861547.61 Elevation (ft): 8.92 Total Depth: 50.0 Ft	Driller: Groundwater Protection Inc Method: Mud Rotary Consultant: PARSONS Project No: 448517	Datum: NAVD88 **Coordinate System:** **NAD 1983 State Plane Georgia East / FIPS 1001**

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
25								
30								

BORING LOG

Honeywell

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-75
Diameter: 8 Inches
Date: 09/03/2014

Northing (ft): 431752.81	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861547.61	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 8.92	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.0 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35								
40								
			17-41-42-47	0.0	0.000		Wet, gray, fine-medium SAND, trace-little silt, little shells.	
45								

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-75
Diameter: 8 Inches
Date: 09/03/2014

Northing (ft): 431752.81	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861547.61	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 8.92	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.0 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
45			17-41-42-47	0.0	0.000		Wet, gray, fine-medium SAND, trace-little silt, little shells.	
			36-38-36-31	0.0	0.000		As above	
50.0			18-20-29-50	0.0	0.000		As above	

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-76
Diameter: 8 Inches
Date: 09/02/2014 - 09/03/2014

Northing (ft): 431834.99	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861545.73	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 8.87	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 47.75 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0							SAND Hand cleared to 5 feet. pH=7, VOCs= 0.0, Hg= 0.0. Mud rotary to 44 ft. pH= 7 at 40 ft.	
5								
10				0.0	0.000			
15								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-76
Diameter: 8 Inches
Date: 09/02/2014 - 09/03/2014

Northing (ft): 431834.99	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861545.73	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 8.87	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 47.75 Ft	Project No: 448517	

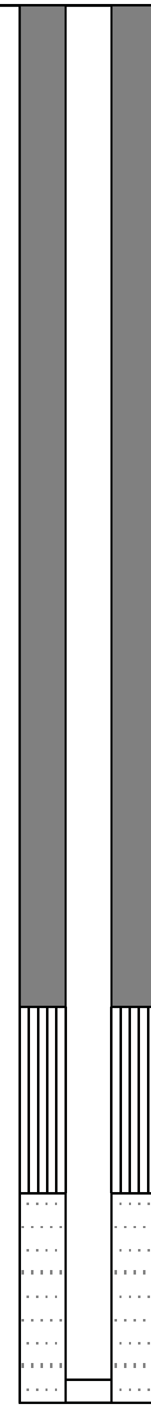
Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
				0.0	0.000			
25								
30								

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-76
Diameter: 8 Inches
Date: 09/02/2014 - 09/03/2014

Northing (ft): 431834.99	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861545.73	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 8.87	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 47.75 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description
30							
35				0.0	0.000		
40							
				0.0	0.000		
			6-12-13-48	0.0	0.000		Wet, gray , fine-medium SAND, little shells, trace silt. Shells increasing with depth.
45							

Well Construction Diagram



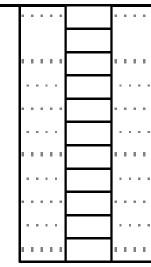
BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-76
Diameter: 8 Inches
Date: 09/02/2014 - 09/03/2014

Northing (ft): 431834.99	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861545.73	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 8.87	Consultant: PARSONS	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 47.75 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
45			6-12-13-48	0.0	0.000		Wet, gray , fine-medium SAND, little shells, trace silt. Shells increasing with depth.	
			40-42-60-60/0	0.0	0.000		As above. Refusal at 47.75.	
48.0								



BORING LOG

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-77
Diameter: 8 Inches
Date: 08/26/2014

Northing (ft): 431915.06	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861545.71	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 8.75	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 48.3 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0							Hand cleared to 5 feet. Brown organic soil and white road packed GRAVEL over gray-brown fine-medium SAND, trace silt. 5-44 ft. pH=8, VOCs= 0.0, Hg= 0.0	
5								
10				0.0	0.000			
15								

BORING LOG

Honeywell

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-77
Diameter: 8 Inches
Date: 08/26/2014

Northing (ft): 431915.06 Easting (ft): 861545.71 Elevation (ft): 8.75 Total Depth: 48.3 Ft	Driller: Groundwater Protection Inc Method: Mud Rotary Consultant: Mutch Associates Project No: 448517	Datum: NAVD88 **Coordinate System:** **NAD 1983 State Plane Georgia East / FIPS 1001**

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
				0.0	0.000			
25								
30								

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-77
Diameter: 8 Inches
Date: 08/26/2014

Northing (ft): 431915.06
Easting (ft): 861545.71
Elevation (ft): 8.75
Total Depth: 48.3 Ft

Driller: Groundwater Protection Inc
Method: Mud Rotary
Consultant: Mutch Associates
Project No: 448517

Datum: NAVD88
Coordinate System:
NAD 1983 State Plane Georgia East / FIPS 1001

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35								
				0.0	0.000			
40								
			50-64-	0.0	0.000		Gray fine-medium SAND, trace silt, trace little shells. Mud rotary 45-46 ft.	
45								

BORING LOG

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-77
Diameter: 8 Inches
Date: 08/26/2014

Northing (ft): 431915.06
Easting (ft): 861545.71
Elevation (ft): 8.75
Total Depth: 48.3 Ft

Driller: Groundwater Protection Inc
Method: Mud Rotary
Consultant: Mutch Associates
Project No: 448517

Datum: NAVD88
Coordinate System:
NAD 1983 State Plane Georgia East / FIPS 1001

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
45			50-64-	0.0	0.000		Gray fine-medium SAND, trace silt, trace little shells. Mud rotary 45-46 ft.	
			51-48-58-	0.0	0.000		Gray tine-medium SAND, trace silt, trace-little shells.	
48.3			50/4	0.0	0.000		Gray,fine-medium SAND. Sandstone bedrock in tip of spoon.	

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-78
Diameter: 8 Inches
Date: 09/04/2014 - 09/05/2014

Northing (ft): 431394.06	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861617.02	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 10.10	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.0 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0							Hand cleared to 5 feet. Mud rotary to 44 ft. pH= 8, VOCs= 0.0, Hg= 0.0.	
5								
10				0.0	0.000			
15								

BORING LOG

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-78
Diameter: 8 Inches
Date: 09/04/2014 - 09/05/2014

Northing (ft): 431394.06	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861617.02	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 10.10	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.0 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
				0.0	0.000			
25								
30								

BORING LOG

Honeywell

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-78
Diameter: 8 Inches
Date: 09/04/2014 - 09/05/2014

Northing (ft): 431394.06	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861617.02	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 10.10	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 50.0 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35								
				0.0	0.000			
40								
44–45			14-17-23-21	0.0	0.000		Gray, fine-medium SAND, trace silt 44-45.5 ft. Gray silt and clay , little sand 45.5-46 ft.	
45								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-78
Diameter: 8 Inches
Date: 09/04/2014 - 09/05/2014

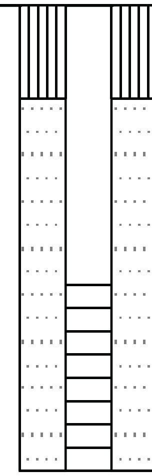
Northing (ft): 431394.06
Easting (ft): 861617.02
Elevation (ft): 10.10
Total Depth: 50.0 Ft

Driller: Groundwater Protection Inc
Method: Mud Rotary
Consultant: Mutch Associates
Project No: 448517

Datum: NAVD88
Coordinate System:
NAD 1983 State Plane Georgia East / FIPS 1001

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description
45			14-17-23-21	0.0	0.000		Gray, fine-medium SAND, trace silt 44-45.5 ft. Gray silt and clay , little sand 45.5-46 ft.
			12-17-20-18	0.0	0.000		As above 46-46.5 ft. 46.5 -47 ft. Gray fine-medium SAND, SILT, and CLAY. 47-48 ft. Gray fine to medium SAND, trace silt.
50.0			13-25-35-50	0.0	0.000		Gray fine-medium SAND, trace silt, trace shells, trace mudstone bedrock in bottom of sample.

Well Construction Diagram



BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***

Boring No: SW-79

Diameter: 8 Inches

Date: 09/04/2014

Northing (ft): 431482.47

Easting (ft): 861619.34

Elevation (ft): 9.90

Total Depth: 51.7 Ft

Driller: Groundwater Protection Inc

Method: Mud Rotary

Consultant: Mutch Associates

Project No: 448517

Datum: NAVD88

Coordinate System:

NAD 1983 State Plane Georgia East / FIPS 1001

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0							Hand cleared to 5 feet. Mud rotary to 45 feet. pH= 8, VOCs= 0.0, Hg= 0.0.	
5								
10				0.0	0.000			
15								

Site: *LCP Chemicals Site, Brunswick GA*
Boring No: SW-79
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431482.47	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861619.34	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.90	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 51.7 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
15								
20								
				0.0	0.000			
25								
30								

BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-79
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431482.47 Easting (ft): 861619.34 Elevation (ft): 9.90 Total Depth: 51.7 Ft	Driller: Groundwater Protection Inc Method: Mud Rotary Consultant: Mutch Associates Project No: 448517	Datum: NAVD88 **Coordinate System:** **NAD 1983 State Plane Georgia East / FIPS 1001**

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
30								
35								
				0.0	0.000			
40								
45								

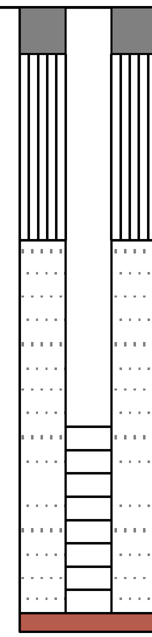
BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-79
Diameter: 8 Inches
Date: 09/04/2014

Northing (ft): 431482.47	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861619.34	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 9.90	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 51.7 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
45			8-8-11-17	0.0	0.000		Gray SILT and CLAY, little fine to medium sand. Lower sample gray fine-medium SAND, trace silt.	
			12-18-21-22	0.0	0.000		Gray, fine-medium SAND, trace silt.	
50			12-17-18-17	0.0	0.000		As above.	
51.7			30-50/2	0.0	0.000		Sand as above. 1 inch of variably cemented SANDSTONE.	



BORING LOG

Honeywell

Site: ***LCP Chemicals Site, Brunswick GA***
Boring No: SW-80
Diameter: 8 Inches
Date: 09/05/2014

Northing (ft): 431555.62	Driller: Groundwater Protection Inc	Datum: NAVD88
Easting (ft): 861614.35	Method: Mud Rotary	**Coordinate System:**
Elevation (ft): 10.23	Consultant: Mutch Associates	**NAD 1983 State Plane Georgia East / FIPS 1001**
Total Depth: 51.5 Ft	Project No: 448517	

Depth Ft	Recov	Sample ID	Blow Count	PID Reading	Mercury	USCS Code	Soil Description	Well Construction Diagram
0							Hand cleared to 5 feet. SAND. Mud rotary to 46 feet. pH= 8, VOCs= 0.0, Hg= 0.0	
5								
10				0.0	0.000			
15								