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September 1, 2016

Delivered via FedEx

Ms. Bobbi Coleman
South Carolina Department of Health and Environmental Control
Assessment Section, UST Management Division
Bureau of Land and Waste Management
2600 Bull Street
Columbia, South Carolina 29201

Subject: Corrective Action Plan
Plantation Pipe Line Company
Lewis Drive Release Site, Belton, South Carolina
Site ID #18693, "Kinder Morgan Belton Pipeline Release"

Dear Ms. Coleman,

On behalf of Plantation Pipe Line Company (Plantation), CH2M HILL Engineers, Inc. (CH2M) has prepared the enclosed Corrective Action Plan (CAP) for the Lewis Drive Site located in Belton, Anderson County, South Carolina. This CAP describes the proposed remedial approach to address impacts to soil, groundwater, and surface water at the site.

If you have any further questions or concerns, please contact me at (919) 760-1777 or Mr. Jerry Aycock with Plantation at (770) 751-4165.

Regards,
CH2M HILL Engineers, Inc.

William M. Waldron, P.E.
Senior Project Manager

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File

REPORT

Corrective Action Plan
Lewis Drive Release Site
Belton, South Carolina

Site ID Number 18693
(“Kinder Morgan Belton Pipeline Release”)

Prepared for

Plantation Pipe Line Company

September 1, 2016

CH2M HILL Engineers, Inc.
6600 Peachtree Dunwoody Road
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Atlanta, Georgia 30328

Corrective Action Plan
Lewis Drive Release Site
Belton, South Carolina
Site ID Number 18693
(“Kinder Morgan Belton Pipeline Release”)

PREPARED FOR

PLANTATION PIPE LINE COMPANY

PREPARED BY

ch2m

ATLANTA, GEORGIA

SEPTEMBER 1, 2016

I affirm that this report was prepared under my direct supervision.

No. 32547
SCOTT F. POWELL

Scott F. Powell

Scott Powell, P.E.
South Carolina Registered Professional Engineer #32547

9/1/2016
Date

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Acronyms and Abbreviations

µg/L	micrograms per liter
1,2-DCA	1,2-dichloroethane
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAP	corrective action plan
CH2M	CH2M HILL Engineers, Inc. (a CH2M HILL company)
CSA	Comprehensive Site Assessment
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
HDD	horizontal directional drilling
LEL	lower explosive limit
MTBE	methyl tertiary butyl ether
Plantation	Plantation Pipe Line Company
PTE	potential to emit
PVC	polyvinyl chloride
RSL	regional screening level
SCDHEC	South Carolina Department of Health and Environmental Control
scfm	standard cubic feet per minute
SVE	soil vapor extraction
UST	underground storage tank
VOC	volatile organic compound

SECTION 1

Introduction

CH2M HILL Engineers, Inc. (a CH2M HILL company, herein referred to as CH2M) has prepared this Corrective Action Plan (CAP) on behalf of Plantation Pipe Line Company (Plantation) for the remediation of a pipeline release discovered December 8, 2014, at the Lewis Drive site in Belton, Anderson County, South Carolina (Figure 1). This site has been designated by the South Carolina Department of Health and Environmental Control (SCDHEC) as Site Number 18693 ("Kinder Morgan Belton Pipeline Release"). The CAP has been prepared in accordance with correspondence from SCDHEC stamped January 26, 2015, March 21, 2016, June 13, 2016, and June 29, 2016, using results reported in the Comprehensive Site Assessment (CSA) Report submitted to SCDHEC on July 15, 2016 (CH2M, 2016a). This CAP supersedes the Interim CAP (CH2M, 2015a) and the Interim Free-Product Recovery Plan (CH2M, 2016b) previously approved by SCDHEC. This CAP incorporates the surface water protection measures documented in a letter to SCDHEC dated April 19, 2016 (CH2M, 2016c) and subsequently approved June 13, 2016. Those measures are currently being implemented.

On December 8, 2014, a release of an estimated 8,800 barrels (369,600 gallons) of gasoline and a small amount of diesel fuel (Plantation, 2015) was discovered from a sleeve on Plantation's 26-inch product pipeline near Lewis Drive, Belton, South Carolina (Figure 1). The site is located on the pipeline right-of-way between Lewis Drive, a rural two-lane undivided asphalt road, to the east and a hayfield to the west. The release location and site features (including the locations of monitoring wells, recovery sumps, temporary wells, recovery trenches, and so on) are shown on Figure 2.

The purpose of this CAP is to describe the proposed comprehensive plan to remediate soil and groundwater impacted by the release, which included the previously approved measures to protect the nearby surface water bodies, Brown's Creek and Cupboard Creek. The proposed approach includes using a series of means to conduct sparging for the purpose of increasing the oxygen content of the soil and groundwater and stimulating *in situ* aerobic biodegradation of hydrocarbons. In addition, some stripping of contaminants from impacted soil and groundwater will occur but should be minimal.

In accordance with Section 280.66 (d) of the SCDHEC Underground Storage Tank (UST) Control Regulations R. 61-92 Part 280 (SCDHEC, 2008), Plantation has already proceeded with implementing pertinent remedial actions prior to finalizing this CAP. In accordance with Plantation's letter to SCDHEC dated March 10, 2016, and as agreed during a meeting with SCDHEC on May 2, 2016, Plantation initiated remedial system construction activities in June 2016. Activities currently complete or underway include the following:

- A total of 27 vertical sparging wells have been drilled in the area of groundwater impacts to Brown's Creek.
- A total of 19 vertical sparging wells have been installed in the area of potential groundwater impacts to Cupboard Creek.
- One of three future horizontal sparging wells is currently being drilled.
- A steel-framed equipment building is being manufactured off-site to house remediation equipment.

This CAP is organized as follows:

- **Section 1, Introduction** – Provides an introduction to the site, as well as an overview of the purpose and organization of this CAP.
- **Section 2, Response Actions and Comprehensive Site Assessment** – Summarizes the response actions, site assessment activities completed, and key findings.

- **Section 3, Conceptual Model of Hydrocarbon Transport** – Summarizes the conceptual site model.
- **Section 4, Corrective Action Objectives** - Lists the proposed remedial objectives.
- **Section 5, Proposed Remedial Approach** – Describes the remedial approach selected to achieve the proposed objectives.
- **Section 6, Regulatory Permits and Approvals** – Lists the permits and agreements that will be obtained for the remediation system.
- **Section 7, Operation and Maintenance** – Outlines the operation, maintenance, and reporting activities that will be performed during system start-up and system operation.
- **Section 8, Monitoring and Reporting** – Summarizes the monitoring program that will be implemented to monitor remedial performance and related reporting.
- **Section 9, Waste Management** – Describes how waste generated during construction will be managed.
- **Section 10, Schedule** – Lists the proposed dates for completing the design, construction, and start-up of the remediation system.
- **Table and Figures** – The supporting table and figures are provided in sections following the text.
- **Appendix A, Bioscreen Modeling** – Presents the methodology and results of fate and transport modeling to aid in identifying relevant cleanup criteria being proposed.

SECTION 2

Response Actions and Comprehensive Site Assessment

This section provides a summary of the work performed as part of the initial response action, subsequent site assessment activities, and related findings. Detailed descriptions are presented in the CSA report (CH2M, 2016a).

As the site assessment and remediation have progressed, it has become convenient to subdivide the site into the following three zones, each with unique geologic and hydrogeological characteristics:

1. **Surface Water Protection Zone** – This zone encompasses the lowland areas adjacent to Brown's Creek and Cupboard Creek.
2. **Hayfield Zone** – The Hayfield Zone encompasses the upland hayfield north of Lewis Drive.
3. **Shallow Bedrock Zone** – The Shallow Bedrock Zone encompasses the upland area south of Lewis Drive.

These zones are depicted on Figure 2, and their unique characteristics will be described in detail in Section 3.

2.1 Response Actions

Following discovery of the pipeline release, Plantation implemented initial response actions consisting of pipeline repair, soil removal, product recovery, and abatement of surface water impacts. These actions were performed between December 8, 2014, and June 10, 2015, and are documented in the Interim CAP (CH2M, 2015a) submitted to SCDHEC on March 5, 2015.

Initial response actions included the following measures:

- Installed 98 temporary wells to delineate the extent of product and to determine the depth to groundwater.
- Installed 20 product recovery sumps.
- Installed 15 product recovery wells.
- Installed two product recovery trenches to protect Brown's Creek and Cupboard Creek.
- Installed a network of seven hard impermeable booms and 10 soft absorbent booms in Brown's Creek to mitigate downstream impacts and to recover product from surface water.
- Excavated approximately 2,800 tons of petroleum-impacted soil and disposed of the soil off-site.

2.2 Site Assessment Activities

Between June 11, 2015, and June 30, 2016, the following work was performed to delineate the extent of hydrocarbons in soil, groundwater, and surface water:

- Conducted receptor and utility surveys to determine potential receptors and principal utilities in the vicinity of the release.
- Installed 36 residuum monitoring wells, 14 bedrock monitoring wells, and one transition zone monitoring well to determine the horizontal and vertical extent of hydrocarbons in groundwater.

- Collected 69 groundwater samples to evaluate the presence of hydrocarbons in groundwater.
- Collected 71 soil samples to evaluate the horizontal and vertical extent of hydrocarbons in soil.
- Collected 22 surface water samples from monthly sampling events at Brown's Creek and Cupboard Creek to monitor surface water quality.
- Installed five soil vapor probes and collected soil vapor samples to evaluate the potential for vapor intrusion for the former residence nearest the site (112 Lewis Drive).
- Completed 10 aquifer slug tests to evaluate the hydraulic conductivity of the residuum and bedrock.
- Collected residential tap water samples from the former residence (at 112 Lewis Drive) nearest the site for analysis.

Major findings obtained from the CSA are summarized below and serve as the basis for the approach and subsequent design of the proposed remedial action for the site.

2.3 Site Location and Setting

The site is located in a rural area approximately 450 feet northeast of the intersection of Lewis Drive and West Calhoun Road, approximately 1 mile northwest of Belton, South Carolina (Figure 1). Lewis Drive is a rural, two-lane undivided asphalt road. Impacts from the release extend in three directions from the release point: to the north approximately 900 feet into an adjacent hay field; to the northeast approximately 1,000 feet to Brown's Creek; and to the south approximately 300 feet to West Calhoun Road (Figure 2). Another hayfield lies to the west of the site and Cupboard Creek lies to the southwest (Figure 2).

The site is located within the Piedmont physiographic province of northwestern South Carolina. The Piedmont province is characterized locally by relatively low, rolling hills where topographic relief is typically a few hundred feet. The land adjacent to the release point has relatively low relief and is atop a northwest-trending ridge that slopes to the northeast toward an unnamed tributary of Brown's Creek, and to the southwest toward Cupboard Creek. Much of the surrounding area has been developed and is primarily used for agricultural purposes.

2.4 Site Geology and Hydrogeology

The geology of the release site is depicted on cross-sections A-A' and B-B' (Figures 3 and 4, respectively). Site geology is characterized by competent mica schists and biotite gneiss bedrock that is overlain by reddish brown silty sand saprolitic soil. A thin, partially weathered rock transition zone is present above the bedrock, and marks the transition between competent bedrock and the saprolitic soil. Bedrock beneath the site is competent, with little to no transition zone, and has a fairly low density of fractures. The fractures encountered do transmit groundwater, but produce low volumes questionable for use in residential supply and insufficient for agricultural or industrial supply.

Groundwater recharge occurs near the center of the site, resulting in groundwater flows southwest toward Cupboard Creek, north through the Hayfield Zone to Brown's Creek, and northeast more directly toward Brown's Creek (Figure 5). Brown's Creek and Cupboard Creek are discharge boundaries for groundwater flow.

The water table generally is present in the saprolite in most of the area of impact. In some areas south of Lewis Drive, the water table is within shallow bedrock with little to no saturated soil (e.g., at MW-19 and MW-22). The water table in the Shallow Bedrock Zone is generally around 10 feet below grade. Bedrock depths deepen as one moves away from the release point, and they are depicted on Figure 6.

In the Hayfield Zone, the water table is approximately 10 to 15 feet below grade, and bedrock is generally deeper, on average more than 20 feet below the groundwater interface and up to 50 feet in some locations. Therefore, there is generally more saturated soil in the Hayfield Zone compared to the Shallow Bedrock Zone.

2.5 Gasoline Occurrence and Recovery

Primarily gasoline and a small amount of diesel fuel released at the site, referred to as product throughout this report, has been recovered from the subsurface. From December 9, 2014, to June 17, 2016, 4,978 barrels (approximately 209,000 gallons) of product were recovered using high-vacuum extraction methods from a network of recovery wells, trenches, and sumps. Product recovery volumes have decreased since December 2015 due to a rise in the water table caused by large volumes of precipitation in October and November 2015 (a 500-year event). The decrease also suggests that the majority of recoverable product has been collected. The extent of product as of May 2016 is shown on Figure 7.

2.6 Key Findings

Impacts to groundwater have been contained to the subsurface, with the exception of an area where impacted groundwater flows into a small section of Brown's Creek. Soil and groundwater analytical data show that the vertical and horizontal extents of petroleum hydrocarbons in soil and groundwater have been defined. The lateral distribution of hydrocarbons in groundwater extends in three directions from the release point: to the north approximately 900 feet into an adjacent hayfield; to the northeast approximately 1,000 feet to Brown's Creek; and to the south approximately 300 feet to Calhoun Road. The vertical extent of hydrocarbons outside the plume boundaries is defined by bedrock monitoring wells located to the north, south, east, and west.

The results of a well survey performed in December 2014 indicate that no public or private water wells are being used within a 1,000-foot radius of the edge of the dissolved hydrocarbon plume. Potable water is supplied to the surrounding area by the City of Belton. A 10-inch water supply main runs along West Calhoun Road. Groundwater yield at the site is likely too low for use in residential supply and insufficient for agricultural or industrial supply.

Impacts to surface water in Brown's Creek have occurred in the area where impacted groundwater discharges to Brown's Creek. Surface water analytical data indicate that benzene is the only compound present at a concentration exceeding SCDHEC surface water screening criteria. These exceedances are limited to locations SW-01 and SW-02, an area that represents an approximate length of 300 feet in Brown's Creek. Numerous downstream sampling locations have been tested and dissolved hydrocarbons have not been detected since the discovery of the release. To date, sample results from Cupboard Creek have not exceeded the SCDHEC or U.S. Environmental Protection Agency (EPA) screening levels.

Soil vapor analytical data indicate two locations where sample concentrations exceeded the EPA Vapor Intrusion Screening Level for benzene (EPA, 2014). However, one location is in an open field and the other is near the former residence (112 Lewis Drive), which is no longer occupied and is being relocated to another property away from the site. Thus, there is not a complete exposure pathway for vapor intrusion at the site.

SECTION 3

Conceptual Model of Hydrocarbon Transport

The source of residual soil, groundwater, and surface water contamination is from a release of product that occurred at a sleeve on Plantation's 26-inch product pipeline. The release was discovered on December 8, 2014. Plantation estimates that approximately 8,800 barrels (369,600 gallons) of product were released. Of this, approximately 4,978 barrels (209,000 gallons) have been recovered to date using high-vacuum extraction equipment from a network of product recovery wells, sumps, and trenches.

The release occurred in an upland area of the site where precipitation recharges the underlying aquifer. Groundwater flows radially from the release point. Impacts to groundwater extend laterally in three directions from the release point: to the north approximately 900 feet into an adjacent hayfield; to the northeast approximately 1,000 feet to Brown's Creek; and to the south approximately 300 feet to Calhoun Road (Figure 5). Cupboard Creek flows intermittently, indicating that the majority of flow from the Lewis Drive ridge is to the northeast, toward Brown's Creek.

The vertical extent of impacts at the site are defined by bedrock monitoring wells located to the north, south, east, and west. Due to the low porosity of bedrock at the site, there is little infiltration of hydrocarbons into bedrock, except through fractures. The majority of hydrocarbon impacts occur in the overlying residuum.

These data are consistent with the standard conceptual model of groundwater flow and contaminant migration in the Piedmont physiographic province. In this model, groundwater recharge occurs in upland areas, and continued recharge causes the dissolved hydrocarbon plume to migrate downward within the aquifer until groundwater discharge causes the plume to emerge in lowland areas at creeks, streams, and rivers.

For remediation purposes, the site can be subdivided into three zones with unique geologic and hydrogeological characteristics:

1. **Surface Water Protection Zone** – This zone encompasses the lowland areas adjacent to Brown's Creek and Cupboard Creek. The Surface Water Protection Zone is characterized by moderately thick saturated zones and varying depths to bedrock. Near Cupboard Creek, the average depth to groundwater is approximately 5 to 10 feet below ground surface (bgs) and the average depth to bedrock is approximately 20 feet bgs. Near Brown's Creek, the average depth to groundwater is approximately 10 to 15 feet bgs and the average depth to bedrock is approximately 45 feet bgs. Product and dissolved hydrocarbons in the aquifer in these lowland areas have acted as a source for surface water impacts to Brown's Creek during periods of high precipitation. Although similar impacts are not observed at Cupboard Creek, measures must be taken to protect both surface water bodies.
2. **Hayfield Zone** – The Hayfield Zone encompasses the upland hayfield north of Lewis Drive. The Hayfield Zone is characterized by a consistently deep bedrock and a relatively large saturated thickness that starts at 22 feet at Lewis Drive and extends up to 57 feet at the northern extent of impacts to groundwater, approximately 900 feet north of the release point (Figure 5). The depth to groundwater in this zone ranges from 5 to 15 feet bgs.
3. **Shallow Bedrock Zone** – The Shallow Bedrock Zone encompasses the upland area south of Lewis Drive. The Shallow Bedrock Zone is characterized by a thin saturated zone less than 5 feet thick due to shallow bedrock (typically present 5 to 10 feet below grade). Fractures in the bedrock may be sufficient to transmit groundwater, which is evidenced by dissolved hydrocarbon concentrations present in groundwater samples collected from bedrock monitoring wells in some areas.

Although high-vacuum product recovery efforts have continued twice weekly at the site through July 2016, the amount of mobile product recovered has decreased significantly, with less than 150 gallons of product having been recovered cumulatively since January 2016. In 2015, 16,000 gallons of product were recovered on average each month. The significant decrease in product recovery volume suggests that the majority of recoverable product has been collected. The remaining product will act as a continuing hydrocarbon source to groundwater as seasonal fluctuations of the water table continue to flush hydrocarbons from the smear zone. Therefore, a comprehensive corrective action must remediate both free-phase and dissolved hydrocarbons through *in situ* treatment means.

SECTION 4

Corrective Action Objectives

The corrective action objectives for the site are as follows:

1. Remove product to the maximum extent practicable in accordance with UST Control Regulations 61-92 Section 280.64 (SCDHEC, 2008).
2. Abate surface water impacts to maintain the following surface water criteria:

   - Benzene: 2.2 micrograms per liter (µg/L)
   - Toluene: 1,000 µg/L
   - Ethylbenzene: 530 µg/L
   - Xylenes: 190 µg/L
   - Naphthalene: 0.17 µg/L
   - Methyl tertiary butyl ether (MTBE): 14 µg/L

   These treatment criteria for benzene, ethylbenzene, and toluene are based on SCDHEC Water Classifications and Standards [R.61-68] for Human Health, for consumption of water and organisms (SCDHEC, 2012). Because surface water criteria for xylenes, naphthalene, and MTBE are not listed in the SCDHEC regulations, EPA Regional Screening Levels (RSLs) for tap water (EPA, 2016) (based on hazard quotient = 1 and cancer risk = 1 x 10^{-6}) were used for these constituents.

3. Reduce concentrations of dissolved hydrocarbons in groundwater to be protective of surface water quality, in accordance with the criteria listed above. CH2M performed fate and transport modeling to calculate these target groundwater treatment criteria. A description of the model, input parameters, and results is presented in Appendix A. The following treatment objectives were calculated and are illustrated on Figure 8:

   - Along the path from the release point northeast toward Brown's Creek, 20 µg/L of benzene requires a horizontal separation of approximately 400 feet in order to naturally attenuate to the surface water standard of 2.2 µg/L at the interface with Brown's Creek.

   - North through the hayfield, 20 µg/L of benzene requires a horizontal separation of approximately 225 feet in order to naturally attenuate to the surface water standard of 2.2 µg/L at the interface with Brown's Creek.

   - Along the path south toward Cupboard Creek, 20 µg/L of benzene requires approximately 480 feet of separation in order to attenuate to the surface water standard of 2.2 µg/L at the interface with Cupboard Creek (assuming hydraulic continuity between the release point and Cupboard Creek).

SECTION 5

Proposed Remedial Approach

This section describes the proposed remedial approach for the site. Biosparging has been selected as the preferred approach to achieve the remedial objectives outlined above in Section 3.

5.1 Biosparging Technology

Biosparging is a remediation technology that involves the low-flow injection of atmospheric air into the saturated zone to increase the oxygen content of the soil and groundwater to stimulate the *in situ* aerobic biodegradation of hydrocarbons. The biosparging process is similar to air sparging; however, air sparging removes constituents primarily through volatilization, whereas biosparging focuses on oxygen replenishment to promote biodegradation of constituents. In a biosparging application, the rate of air injection is controlled to stimulate biodegradation and minimize the potential for generating soil vapor, to the extent practical, thereby precluding the need for soil vapor extraction (SVE).

Ultimately, flow rates will be increased from biosparging levels into the range of low to medium air sparging levels. Therefore, the generic term “sparging” will be used in the remainder of this CAP to describe operation at either level.

Sparging was selected for use at the site for the following reasons:

- Product recovery volumes have plateaued using high-vacuum extraction, and the majority of the residual product that remains is sorbed in soil and is non-mobile.
- Numerous case studies show that sparging effectively reduces product levels and concentrations of petroleum-related hydrocarbons in soil and groundwater. Additionally, Plantation has successfully used sparging in numerous nearly identical geologic settings to remove residual product and reduce hydrocarbon concentrations in soil and groundwater within the Piedmont physiographic province of South and North Carolina.
- Sparging equipment (air compressors and associated controls) is fairly simple, relatively low maintenance, and reliable. Typically, runtime efficiency for a sparging system exceeds 90 percent.
- Sparging eliminates the need for removal, treatment, storage, or discharge of groundwater. Minimal volumes of (treated) condensate will be generated.
- During the initial stages of operation, sparging will be conducted at low flow rates to limit volatilization of hydrocarbons. As biodegradation and mass removal proceeds, flow rates will be gradually increased while monitoring ambient vapor concentrations.

The proposed layout of the sparging system is illustrated on Figure 9. The system components are described in the following subsections, broken out by zone.

5.1.1 Surface Water Protection Zone

In accordance with the Surface Water Protection Plan proposed in a letter to SCDHEC dated April 19, 2016 (CH2M, 2016c) and approved August 5, 2016 (SCDHEC, 2016), the following actions will be taken to prevent hydrocarbon impacts to Brown’s Creek and Cupboard Creek:

- Nineteen (19) vertical sparging wells divided among two injection rows (VAS-1 through VAS-19) have already been installed as a precautionary measure to protect Cupboard Creek from potential impacts (hydrocarbons have not been detected in Cupboard Creek to date) (Figure 9). The available saturated thickness in this area is relatively limited: the average depth to groundwater is approximately 5 to 10 feet bgs and the average depth to bedrock is approximately 20 feet bgs. A well spacing of 30 feet was used due to the relatively limited saturated thickness; each sparging well was installed to the maximum depth possible at each location (top of bedrock surface), ranging in depths from 13 to 32 feet bgs (on average, 19 feet bgs).

- A total of 27 vertical sparging wells divided among three injection rows (VAS-20 through VAS-46) have been installed to mitigate impacts to Brown's Creek (Figure 9). A greater number of sparging wells was installed upgradient of Brown's Creek due to historical hydrocarbon detections at this location, and a wider area of impacted soil and groundwater compared to Cupboard Creek. The available saturated thickness in this area is greater than Cupboard Creek; the average depth to groundwater is approximately 10 to 15 feet bgs and the average depth to bedrock is approximately 45 feet bgs. A well spacing of 40 feet was used; each sparging well was installed to the maximum depth possible at each location ranging in depths from 16.5 to 72.5 feet bgs (on average, 44 feet bgs).
- In addition to the vertical sparging wells, two segments of diffusion aerators (self-sinking injection piping from Air Diffusion Supply) will be installed along a 200-foot section of Brown's Creek to aerate surface water in the creek (Figure 9). The diffusion lines will be 1-inch-outer-diameter high-density polyethylene slotted pipes that have a specially designed wall thickness that allows the pipes to naturally sink to the bottom of the stream without any anchoring. It is proposed that two lines, each 200 feet long, will be installed in parallel approximately 30 feet apart and a minimum of 2 to 3 feet below the water surface, where feasible. The lines will be installed by hand and will not require any cut or fill of the streambed or banks. After installing the diffusion lines and feeder tubes, the lines will be connected to conveyance piping that will distribute the injection air from air compressors within the system compound (shown on Figure 9 about 1,000 feet from the stream).
- The current surface water boom layout in Brown's Creek will remain until surface water samples no longer show impacts from impacted groundwater. Once two rounds of surface water sampling no longer show impacts, the booms will be removed. SCDHEC will be contacted prior to removing the booms.

5.1.2 Hayfield Zone

Three horizontal directional drilling (HDD) sparging wells (HAS-1, HAS-2, and HAS-3) will be installed in the Hayfield Zone because the bedrock is deep and the saturated thickness is greater than 20 feet (Figure 9). The use of HDD in this area will significantly reduce impacts to that property, particularly to the north of Lewis Drive, because trenching or piping will not be required. Additionally, the use of HDD wells eliminates the need to install compressed air conveyance piping in conduits below Lewis Drive and Plantation's pipeline right-of-way.

Drilling has already begun south of Lewis Drive, and the borings will be advanced northwest beneath Lewis Drive and Plantation's pipelines. The three wells will be spaced on 90-foot centers, and will be constructed using approximately 220 feet of 40-inch-diameter Schedule 80 polyvinyl chloride (PVC) well casing and a varying length feet of custom slotted well screen (600 feet on average). A total of 2,400 feet of horizontal drilling is proposed, including 1,800 feet of screened pipe. The well screens will be positioned 20 feet below the water table (approximately 40 to 45 feet bgs, depending on drilling conditions encountered), and the screened intervals of the north hayfield wells will be positioned to encompass the leading edge of the hydrocarbon plume.

5.1.3 Shallow Bedrock Zone

For the area of the site with shallow bedrock and a thin saturated zone, sparging will be conducted within the bedrock layer to allow the injected air to be distributed via the same fracture network that transmitted impacts to groundwater in this zone. An estimated 13 vertical sparging wells will be installed into fractured bedrock in this area, which is bounded by the vertical sparging barriers protecting

Cupboard Creek to the southwest and Brown’s Creek to the northeast (Figure 9). This layout of vertical sparging wells in bedrock assumes a radius of influence of 100 feet through the bedrock fractures.

Phased implementation of the bedrock sparging wells will be conducted to (1) demonstrate that the fractures are sufficient to accept a suitable amount of air for successful sparging, (2) evaluate the radius of influence from the bedrock sparging wells, and (3) evaluate where injected air propagates upward into the saprolite and its distribution. The first phase will be conducted on the three proposed bedrock sparging wells closest to Cupboard Creek (the southwest corner of the Shallow Bedrock Zone). Results from the first phase will be evaluated to determine the final spacing. Figure 9 shows 13 bedrock sparging wells using an assumed spacing of 100 feet on center.

5.2 Sparging Well Construction Details

The vertical saprolite sparging wells have been constructed as follows:

- The wells were installed using hollow-stem auger drilling methods.
- The vertical sparging wells were constructed of 2-inch-diameter Schedule 40 PVC riser with 0.006-inch slotted Schedule 40 well screen. The 2.5-foot well screens were installed as deep as practical (anticipated to be 15 to 20 feet bgs at Cupboard Creek and 40 to 45 feet bgs at Brown’s Creek) with a 1-foot sump at the base of each well.
- The annular space around the well screen was filled with a fine sand filter pack, which extended approximately 1 foot above the top of the well screen.
- A 5-foot-thick bentonite seal was installed above the filter pack, and the vertical sparging wells were sealed with cement-bentonite grout to approximately 2 feet bgs.
- Each vertical saprolite sparging well will be piped individually back to the sparging system compound, allowing each well to be controlled individually.

The horizontal sparging wells will be installed as follows:

- The wells will be installed using HDD methods using “blind” or single-entry completion.
- A pilot hole will be drilled, and then the drill rods will be withdrawn to attach a succession of reamers to enlarge the borehole. Reaming is accomplished in a forward direction, the same as drilling the pilot hole. Finally, all rods will be withdrawn, and the riser and slotted pipe will be pulled into the borehole using the smaller diameter rods. The HDD drilling fluid will be a biopolymer fluid with a non-toxic enzyme breaker solution. Drilling fluids will be recycled to minimize waste.
- Tracking and steering the drill head will be via walkover navigation methods in which a battery-operated downhole transmitter, or sonde, transmits a constant electromagnetic signal to a receiver operated on the surface by a drilling technician.
- The horizontal sparging wells will be constructed of 4-inch-diameter Schedule 80 PVC riser and slotted pipe, installed at a depth of approximately 40 to 45 feet bgs (as measured from the drill rig). The exact as-built depth of each horizontal well will depend on conditions encountered during drilling, particularly the angle of the initial drill rods as they advance through rock.
- The HDD sparging wells will be sealed from 3 feet bgs to at least 20 feet bgs using cement-bentonite grout.
- Each horizontal sparging well will be piped individually back to the sparging system compound to allow the wells to be controlled separately.

The vertical bedrock sparging wells will be installed as follows:

- The wells will be installed using an air rotary rig, and boreholes will be initially advanced 5 to 10 feet into competent bedrock.
- A steel casing will be installed in the borehole and grouted to the ground surface in order to seal the unsaturated zone from the bedrock borehole.
- The drill rig will then advance a bit from within the surface casing into bedrock until a water-producing fracture is encountered. It is anticipated that the bedrock sparging wells will be installed approximately 20 to 40 feet into bedrock at each location (to a similar depth as the monitoring wells).
- Sparging will be implemented within the open-hole bedrock well by installing a PVC pipe down the open hole and sealing off the design injection interval with a K-packer or suitable equivalent.

5.3 Proposed Sparging Equipment

The sparging system compound will be installed on the recently acquired property (at 112 Lewis Drive) and will be secured. An existing driveway will be used to access the system; therefore, equipment or infrastructure will not be installed on the neighboring property. Some clearing will be required on the neighboring property for drill rig staging, as well as trench routes for compressed air conveyance piping.

A preliminary process and instrumentation diagram for the sparging system is shown on Figures 10 and 11. As shown, two 200-horsepower rotary screw compressors, each capable of producing approximately 1,050 standard cubic feet per minute (scfm) at 100 pounds per square inch gauge, will be used to inject air to the wells. The compressor will be staged outside on concrete pads underneath a protective canopy.

Additional sparging equipment will consist of piping manifolds, an air receiver tank, filters, gauges, valves, and flowmeters, as well as a control panel for on-site and remote control of the system. The sparging manifolds, instrumentation, and controls will be installed within a steel frame building. Each sparging well will be controlled by a dedicated manifold leg in the equipment building that will include a pressure regulator and throttling valve. Electrical service, provided by Duke Energy, will be established at the equipment compound.

SECTION 6

Regulatory Permits and Approvals

The following permits and agreements have been/will be obtained for the proposed remedial system:

- **Minor Source Air Permit Exemption** – In accordance with South Carolina Code of Regulations Chapter 61, Article 62 (SCDHEC Regulation 61-62: Air Pollution Control Regulations and Standards, December 2015), groundwater remediation systems are exempt from obtaining a construction permit if both of the following conditions are met:
    - A total uncontrolled potential to emit (PTE) of less than 5 tons per year each of particulates, sulfur dioxide, nitrogen oxides, and carbon monoxide; and a total uncontrolled PTE of less than 1,000 pounds per month of volatile organic compounds (VOCs) (Regulation 1, Section II, [B][2][h])
    - A total uncontrolled PTE of less than 1,000 pounds per month of a toxic air pollutant such as benzene, toluene, and so on (Regulation 5, Standard No. 8, [I][B])

  Documentation demonstrating that the system meets these conditions was submitted to SCDHEC on April 12, 2016. A letter confirming that the proposed system was exempt from new permit requirements was received on April 28, 2016.

- **Underground Injection Control Permits-to-Construct and Permits-to-Operate** – The permit-to-construct the vertical and horizontal sparging wells was received on May 12, 2016. The permit-to-operate will be received after submittal of the Form 1903 well completion records to SCDHEC. A permit-to-construct and permit-to-operate for the Shallow Bedrock Zone sparging wells will need to be obtained.
- **Encroachment Permits** – Encroachment permits from Anderson County were received (1) on June 2, 2016, for minor site work proposed near the Lewis Drive right-of-way (temporary construction entrance) and (2) on July 13, 2016, for horizontal drilling under Lewis Drive.
- **U.S. Army Corps of Engineers** – A letter requesting confirmation that no permit will be required was submitted to the U.S. Army Corps of Engineers on August 5, 2016, in reference to the surface water aerators proposed for Brown’s Creek.
- **Stormwater Pollution Prevention Plan** – A major modification to the Stormwater Pollution Prevention Plan was approved on August 5, 2016, to include the additional site disturbance from remediation activities described in this plan.
- **Building Permit** – A site plan was approved by Anderson County Development Services on August 23, 2016, to approve construction of the proposed treatment system building and associated site work. A building permit application will be submitted in September 2016.

SECTION 7

Operation and Maintenance

After the system is constructed, the following operational concepts will be implemented.

7.1 System Checks and Commissioning

The system equipment will be tested by the equipment vendor prior to shipment to the site. Before the initial start-up of the system, equipment commissioning activities will be conducted and the following items will be confirmed in a commissioning checklist:

- Inspections required by Anderson County and/or the City of Belton have been completed.
- Sparging system building and equipment have been positioned and anchored.
- All interior piping and connections to exterior piping have been connected and leak tested.
- Final electrical connection is completed, and rotation of motors has been checked.

During the start-up and commissioning phase, the equipment vendor's representative will be on-site to ensure that the completed system is fully operational.

7.2 Initial System Operational Concepts

The general operational concept for the complete system will be continuous air injection 24 hours a day, 7 days a week, with the exception of periodic downtime for scheduled maintenance. A more detailed breakdown of operations by zone is as follows:

1. **Surface Water Protection Zone** – The 46 vertical sparging wells will initiate at 2 to 4 scfm per well in half the wells (initial total injection of 46 to 92 scfm). The initial proposed injection sequence for these wells will be to alternate flow between half the wells every 24 hours (i.e., pulsing) using solenoid valves and control programming. This sequence may be adjusted depending on performance monitoring results. The surface water aerators will initiate at 5 scfm in each 200-foot line (10 scfm total), per manufacturer recommendation, and will run 24 hours a day, 7 days a week.
2. **Hayfield Zone** – The three horizontal wells will initiate at 0.05 scfm per foot of screen (90 scfm total) and will run continuously. These wells will take potentially several days to achieve the target flow rate, so they will not be shut down unless equipment or power failure occurs.
3. **Shallow Bedrock Zone** – The initial three bedrock sparging wells will initiate at 2 to 4 scfm per well and will run continuously at first. Depending on observations, these wells may be placed in a pulsing mode.

The proposed initial flow rates described above are biosparging rates, to limit volatilization of hydrocarbons. Injected air transferred to the vadose zone will be assimilated through aerobic respiration of residual sorbed contamination. Ambient vapor concentrations will be routinely monitored during start-up.

Air injection is planned to be gradually increased over time to optimize system performance. As biodegradation and mass removal proceeds, flow rates will be gradually increased to air sparging levels. It is anticipated that it may take a month or so before the flow rates in the Surface Water Protection Zone sparging wells can be increased. Up to 1 year may be required before flow rates in the Hayfield Zone horizontal sparging wells can be increased. These decisions will be made based on monitoring data collected in each of the zones at the site. Changes will be documented and reported to SCDHEC.

7.3 System Operational Checks

Several process components will include transmitters that feed an analog signal to a programmable logic controller, which will relay these readings through a wireless modem to provide remote monitoring. Routine on-site system operational checks will be performed monthly and will focus on process elements that are not able to be remotely monitored, including the following:

- Air pressure for each sparging well from the manifold system
- Receiver tank pressure and temperature
- Dissolved oxygen (DO) measurements at key monitoring wells in the vicinity of the sparging system

Monthly system operational checks may be changed to every 6 weeks, to bi-monthly, and to potentially quarterly checks once the system’s operations have stabilized. Monitoring locations also may change, in response to the data, as remediation progresses.

The services of an air compressor technician will be procured to perform routine compressor maintenance at scheduled intervals. Oil changes are recommended every 8,000 hours. Air filters will be changed every other month, or as needed based on visual inspection.

SECTION 8

Monitoring and Reporting

This section provides the proposed monitoring and reporting program for the site following construction and start-up of the remedial system.

8.1 Monitoring

Aspects of visual observations, field measurements, and analytical results used to monitor the effectiveness of the sparging system are described below.

8.1.1 Visual Observations

During visits to the site (monthly after start-up), visual inspections will be performed for evidence of a petroleum sheen on surface waters, odors in the area, and/or distressed vegetation. Visual inspections will be conducted prior to start-up, and monthly thereafter within the area of the site and specifically along a 3,000-foot section of Brown's Creek and a 600-foot section of Cupboard Creek. The route of inspection is indicated on Figures 12 and 13.

8.1.2 Zone of Influence

DO concentrations will be measured in 20 wells listed on Table 1 using an optical DO probe to assess the zone of influence from sparging. These measurements will be conducted while the system remains operational to evaluate the maximum potential zone of influence from injection air. These measurements will be conducted in the select group of monitoring wells monthly during the first year of operations. After the first year, these measurements will be conducted quarterly for a year and then semiannually thereafter. This type of monitoring will be conducted following flow adjustments to portions of the system. After the flow rates are adjusted, DO measurements will be conducted monthly to ensure that conditions return to steady-state conditions similar to the previous flow rates. Monitoring frequencies outside of those outlined above will be adjusted as needed in consultation with SCDHEC.

8.1.3 Contaminant Reduction Evaluation

Performance monitoring will be conducted by groundwater sampling in the existing monitoring well network at the site. A baseline monitoring event will be performed prior to start-up using low-flow sampling techniques. The data collected during this baseline event will be compared to sampling results collected after system start-up to determine the effectiveness of sparging. The groundwater samples will be analyzed for key site contaminants as listed in Table 1. The field parameters DO, oxidation-reduction potential, pH, temperature, specific conductance, and turbidity will be measured during well purging at all sample locations.

Performance monitoring for contaminant reduction will be conducted as follows:

- During Year 1, the 53 wells listed in Table 1 and shown on Figure 12 will be sampled quarterly. The samples will be analyzed for benzene, toluene, ethylbenzene, and xylenes (BTEX), naphthalene, MTBE, and 1,2-dichloroethane (1,2-DCA) by EPA Method 8260B (ethylene dibromide is not proposed in this sampling list because it has not been detected at the site in previous sampling events [CH2M, 2016a]).

During Year 2 and following, the same 53 wells will be sampled annually. A 37-well subset listed in Table 1 (and shown on Figure 12) will also be sampled semiannually. The samples will be analyzed for BTEX by EPA Method 8260B. Groundwater analytical results will be compared to the fate and transport modeling results described in Appendix A. Isoconcentration contours of benzene will be plotted on figures presented in the annual reports. These contours will be compared to the contours presented on Figure 8 shown to be protective of surface water at Brown's Creek and Cupboard Creek:

8.1.4 Biodegradation Evaluation Parameters

Natural attenuation parameters will be analyzed periodically to evaluate the progress of biodegradation. Groundwater samples will be collected prior to start-up and annually thereafter from the 21 wells listed in Table 1. These samples will be analyzed for nitrate by EPA Method SM2320B, sulfate by EPA Method D516-9002, ferrous iron by EPA Method SM3500 FE D, carbon dioxide and methane by EPA Method RSK-175, and alkalinity by Method SM2320B.

8.1.5 Air Monitoring

Prior to start-up of the sparging system and when airflow rates are adjusted, air monitoring will be conducted to screen for potential exceedances of the lower explosive limit (LEL) and for VOCs. LEL monitoring will be conducted with an LEL detector at the City of Belton water branch line valve to the former residence at 112 Lewis Drive.

Ambient air monitoring will also be conducted in the breathing zone with a photoionization detector at MW-19 near Cupboard Creek, at MW-40 near Brown's Creek, and at MW-09 in the Hayfield Zone.

8.1.6 Surface Water Monitoring

Surface water samples will be collected quarterly for the first year of operations and semiannually thereafter from each of the 16 locations indicated on Figure 13. Since the purpose of the remedial action and the related sampling is to monitor the performance of the measures being implemented, the diffusion aerators in Brown's Creek will not be shut off prior to sampling. Samples will be analyzed for BTEX and naphthalene using EPA Method 8260B. Samples will be collected in accordance with the Quality Assurance Project Plan (CH2M, 2015b) and EPA Region 4 protocol.

During these same surface water sampling events, DO measurements will also be taken to evaluate the performance of the Brown's Creek diffusion aerators. DO measurements will be taken upstream and downstream of the diffusion aerators at surface water sampling locations SW-03 (upstream) and at SW-01 and SW-13 (downstream). DO will be measured using a Hach LDO Probe, Model 2 or equivalent.

8.2 Reporting

Site reporting will be conducted as follows:

- An installation report will be prepared following system installation.
- Quarterly data transmittals and a comprehensive annual report will be prepared for the first year of operations. The fourth quarterly report will serve as the comprehensive annual report.
- Semiannual data transmittals and a comprehensive annual report will be prepared during the second and subsequent year(s) of operation.

Reports will include a summary of sparging and groundwater extraction and treatment system operations, monitoring results, groundwater contour maps, isoconcentration contour maps, and analytical laboratory reports. Quarterly data transmittals will be submitted within 60 days following the quarter end. The comprehensive annual report for the first year of operations will be provided 90 days following the quarter end. Semiannual data transmittals will be provided 60 days following the monitoring event, and the annual report will be provided within 90 days following the calendar year end.

SECTION 9

Waste Management

Investigation-derived waste and remediation-derived waste (including but not limited to soil cuttings, drilling fluids, well development fluids, decontamination fluids, and water generated during system installation and performance monitoring) will be managed with oversight by Kinder Morgan Environmental Health and Safety. Waste streams will be managed according to SCDHEC guidelines as follows:

- Soil cuttings generated during the construction of sparging wells will be containerized in roll-off containers and disposed off-site at an appropriate facility.
- Purge water generated during groundwater monitoring will be containerized in a poly tank secured in the sparging system compound for eventual transport and disposal off-site.
- Drilling fluids generated during well development will be containerized and disposed off-site.

Sparging operation eliminates the need for removal, treatment, storage, or discharge of groundwater. Condensate water generated from the air compressor will be treated with carbon filters and discharged to the ground surface. The compressor will be equipped with a particulate filter, compressed air filters, and condensate treatment system; treated condensate will be released through the side of the building onto the ground.

SECTION 10

Schedule

This section provides an overview of the proposed schedule and anticipated performance for the site.

10.1 Proposed Schedule

The proposed implementation schedule for remedial design through construction is summarized below. This schedule is subject to change based on the time required for permitting, lead time for equipment manufacturing, or other unforeseen circumstances.

Activity	Schedule
Design	December 2015 – April 2016
Permitting	March – August 2016
Procurement	May – August 2016
Surface Water Protection Zone vertical drilling	June – July 2016
Hayfield Zone horizontal drilling	August – October 2016
Equipment fabrication, delivery to site, and installation	June – November 2016
Site work installation	September – December 2016
Start-up	December 2016
Shallow Bedrock Zone vertical drilling	Mid 2017 (in order to provide at least 3 months of monitoring before proceeding with permitting, procurement, and installation)

10.2 Anticipated Performance

Due to the inherent heterogeneity of the site geology, ecology, and microbial community, it is difficult to forecast the time required to achieve remedial endpoints. However, based on past experience with similar sparging projects in the Piedmont geography, the following performance is expected:

- **Surface Water Protection Zone** – It is anticipated that impacts to surface water should abate within a few months after system start-up. Sparging will continue until the upgradient plume reaches the target configuration for monitored natural attenuation (see Table 1 and Figure 8).
- **Hayfield** – Measureable reductions in groundwater concentrations in the hayfield should be observed within 6 months to 1 year following system start-up. Sparging within the main core of the plume is anticipated to be operated up to or beyond 10 years.
- **Shallow Bedrock Zone** – The time to reduce groundwater concentrations in the Shallow Bedrock Zone depends greatly on the number and size of bedrock fractures in this zone. This zone may take less time than the Hayfield Zone, but more specific timing can be approximated once the system has operational experience.

In all zones, performance time frames cannot be reasonably projected until system performance can be evaluated. As remediation progresses and more is learned about the performance of each zone, performance time frames will be reevaluated and refined.

SECTION 11

References

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Table

Table 1. Proposed Groundwater Monitoring Plan

Corrective Action Plan

Lewis Drive Release, Belton, South Carolina

Site ID #18693 "Kinder Morgan Belton Pipeline Release"

Frequency:	**Contaminant Reduction Evaluation**				**Biodegradation Evaluation**		**Zone of Influence**	**Notes**
	Baseline	**Quarterly (Year 1)**	**Annual (Year 2 and following)**	**Semiannual (Year 2 and following)**	**Baseline**	**Annual**	**Monthly (Year 1)[1]**	
Analytes: **Well ID**	**BTEX, Naphthalene, MTBE, and 1,2-DCA[2]**			**BTEX[3]**	**Nitrate, Sulfate, Ferrous Iron, Carbon Dioxide, Methane, and Alkalinity[4]**		**Dissolved Oxygen**	
MW-01	Y	Y	Y	Y	Y	Y		
MW-01B	Y	Y	Y	Y				
MW-02	Y	Y	Y	Y	Y	Y	Y	Typically contains product
MW-02B	Y	Y	Y	Y			Y	
MW-03	Y	Y	Y	Y	Y	Y	Y	
MW-04	Y	Y	Y	Y	Y	Y	Y	
MW-05	Y	Y	Y					
MW-06	Y	Y	Y	Y				
MW-07	Y	Y	Y	Y				
MW-08	Y	Y	Y	Y	Y	Y	Y	
MW-09	Y	Y	Y	Y	Y	Y	Y	Typically contains product
MW-10	Y	Y	Y	Y	Y	Y	Y	
MW-11	Y	Y	Y	Y	Y	Y		Typically contains product
MW-12	Y	Y	Y	Y	Y	Y	Y	Typically contains product
MW-12B	Y	Y	Y	Y			Y	
MW-13	Y	Y	Y	Y				
MW-13B	Y	Y	Y	Y				
MW-14	Y	Y	Y					
MW-14B	Y	Y	Y					
MW-15	Y	Y	Y	Y	Y	Y	Y	
MW-15B	Y	Y	Y	Y			Y	
MW-16	Y	Y	Y	Y	Y	Y	Y	Typically contains product
MW-17	Y	Y	Y					
MW-17B	Y	Y	Y					
MW-18	Y	Y	Y	Y	Y	Y	Y	Typically contains product
MW-19	Y	Y	Y	Y	Y	Y	Y	
MW-20	Y	Y	Y	Y	Y	Y	Y	Typically contains product
MW-21	Y	Y	Y					
MW-22	Y	Y	Y	Y	Y	Y		
MW-23	Y	Y	Y	Y				
MW-23B	Y	Y	Y	Y				
MW-24	Y	Y	Y					
MW-24B	Y	Y	Y					
MW-25	Y	Y	Y	Y	Y	Y	Y	
MW-25B	Y	Y	Y	Y			Y	
MW-26	Y	Y	Y					
MW-26B	Y	Y	Y					
MW-27	Y	Y	Y					
MW-27B	Y	Y	Y					
MW-28	Y	Y	Y	Y	Y	Y	Y	
MW-29	Y	Y	Y	Y			Y	
MW-30	Y	Y	Y	Y			Y	
MW-31	Y	Y	Y	Y				
MW-31B								
MW-32	Y	Y	Y		Y	Y		
MW-33								
MW-33T								
MW-35	Y	Y	Y	Y	Y	Y		
MW-36	Y	Y	Y	Y				
MW-36B	Y	Y	Y	Y				
MW-37	Y	Y	Y	Y				
MW-38	Y	Y	Y					
MW-39	Y	Y	Y					
MW-40	Y	Y	Y	Y	Y	Y		
MW-41	Y	Y	Y					
MW-42	Y	Y	Y	Y	Y	Y		

Table 1. Proposed Groundwater Monitoring Plan

Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

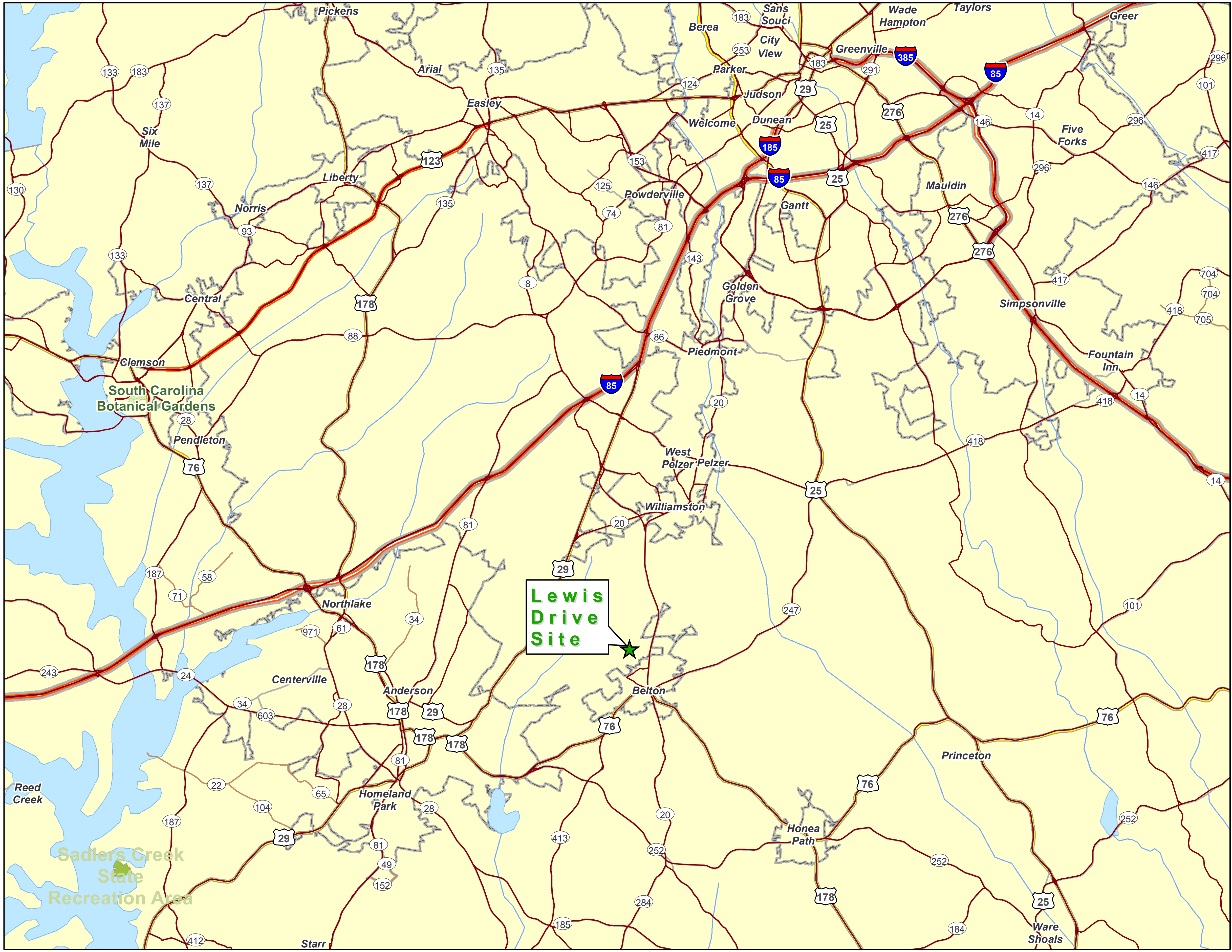
	Contaminant Reduction Evaluation				**Biodegradation Evaluation**		**Zone of Influence**	**Notes**
Frequency:	**Baseline**	**Quarterly (Year 1)**	**Annual (Year 2 and following)**	**Semiannual (Year 2 and following)**	**Baseline**	**Annual**	**Monthly (Year 1)**[1]	
Analytes: **Well ID**	**BTEX, Naphthalene, MTBE, and 1,2-DCA**[2]			**BTEX**[3]	**Nitrate, Sulfate, Ferrous Iron, Carbon Dioxide, Methane, and Alkalinity**[4]		**Dissolved Oxygen**	
TW-55							Y	
TW-59							Y	
TW-60							Y	
TW-64							Y	
TW-66							Y	
TW-67							Y	
TW-73							Y	
TW-96							Y	
Totals:	53	53	53	37	21	21	20	

Notes:

1. Zone of influence monitoring for dissolved oxygen will be performed monthly for Year 1 and as-needed thereafter as air sparge flow rates are adjusted.
2. Contaminant Reduction Evaluation: BTEX, naphthalene, MTBE, and 1,2-DCA by EPA Method 8260B
3. Contaminant Reduction Evaluation (semiannual event): BTEX by EPA Method 8260B
4. Biodegradation Evaluation: nitrate by EPA Method SM2320B, sulfate by EPA Method D516-9002, ferrous iron by EPA Method SM3500 FE D, carbon dioxide and methane by EPA Method RSK-175, and alkalinity by Method SM2320B

1,2-DCA = 1,2-dichloroethane
BTEX = benzene, toluene, ethylbenzene, and xylenes
DCA = dichloroethane
EPA = U.S. Environmental Protection Agency
MTBE = methyl tertiary butyl ether

Figures



VICINITY MAP

LEGEND

★ Lewis Drive Site

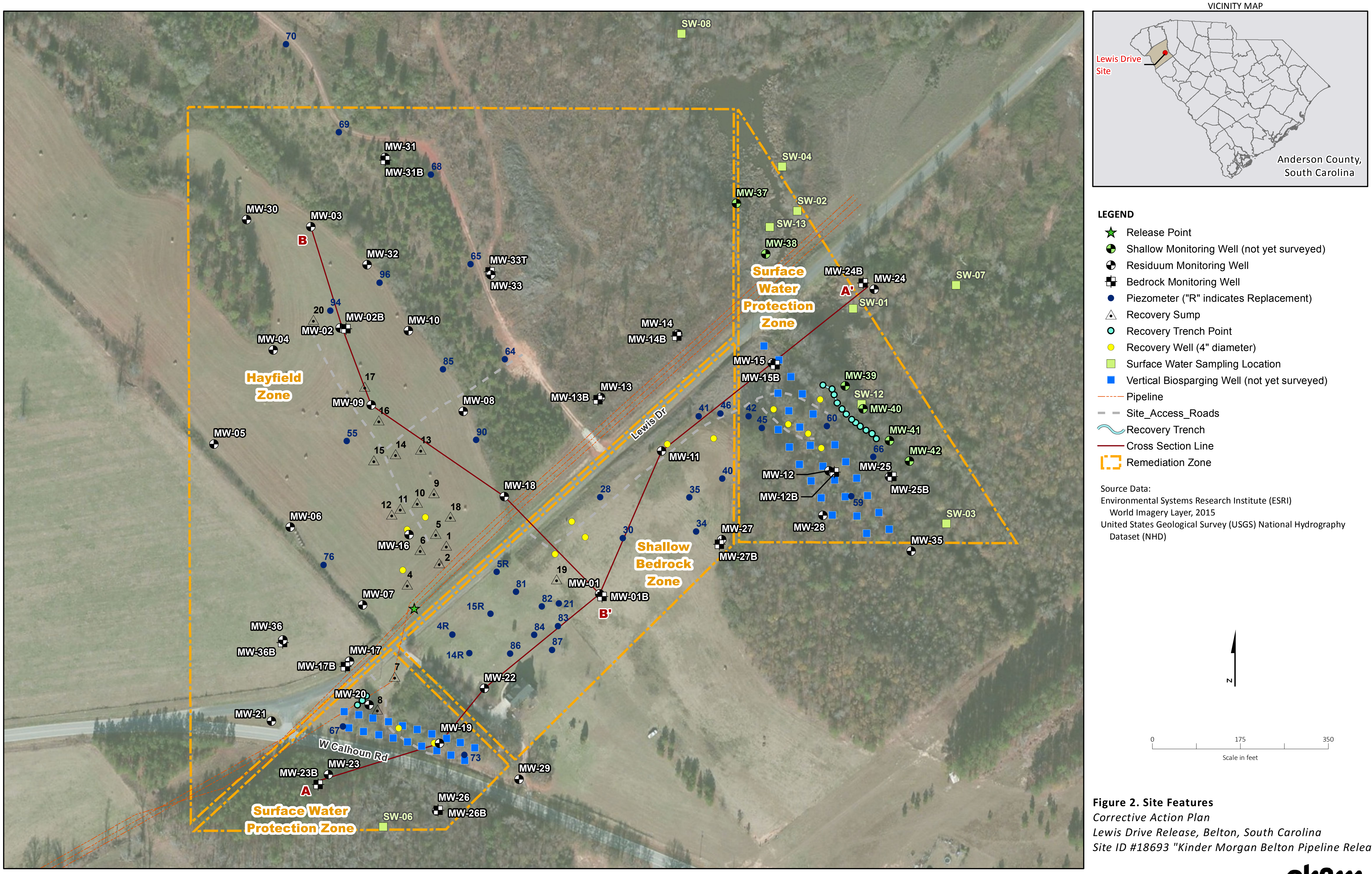
BASE MAP SOURCE:
ESRI, Arcmap Imagery - USA Thematic Map

N

0 3.5 7
Approximate scale in miles

Figure1. Location of Lewis Drive Release Site
Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

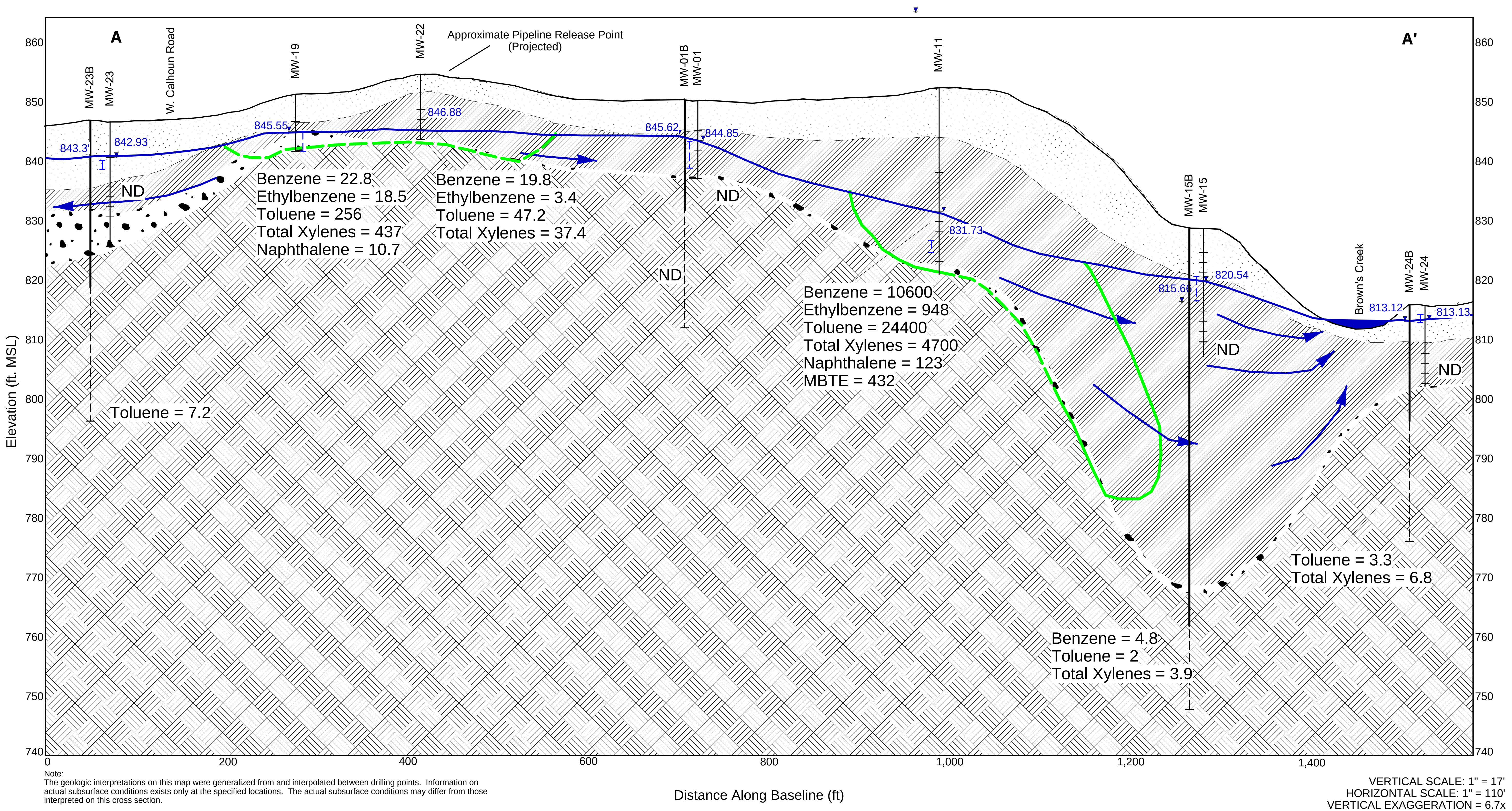
\\CANOPUS\GROUPS\GIS\00_PROJ\K\KINDER_MORGAN\654558LEWISDR_ER\GIS\MAPS\CORRECTIVE_ACTION_PLAN\FIGURE1_SITE_LOCATION.MXD SASELAGE 8/15/2016



Source Data:
Environmental Systems Research Institute (ESRI)
World Imagery Layer, 2015
United States Geological Survey (USGS) National Hydrography Dataset (NHD)

Figure 2. Site Features
Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

ch2m:

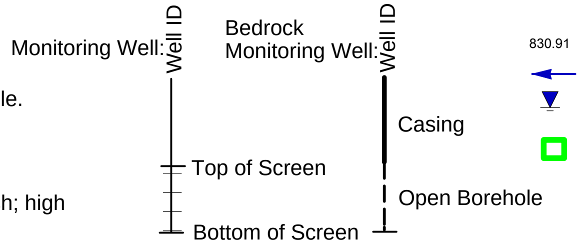


Note:
The geologic interpretations on this map were generalized from and interpolated between drilling points. Information on actual subsurface conditions exists only at the specified locations. The actual subsurface conditions may differ from those interpreted on this cross section.

VERTICAL SCALE: 1" = 17'
HORIZONTAL SCALE: 1" = 110'
VERTICAL EXAGGERATION = 6.7x

LEGEND

- ░ **SOIL**: Completely weathered; clayey.
- ▨ **SAPROLITE** Completely weathered with relict rock structure visible.
- ● **TRANSITION ZONE** Mixed soil and rock fragments.
- ▧ **FRESH BEDROCK** Few open fractures may be weathered or fresh; high rock-quality designation (RQD); competent rock.



830.91 Groundwater Elevation (feet amsl)
← Groundwater Flow Direction
▼ Water Table (May 6, 2016)
🟩 Estimated Dissolved Benzene Plume Extent (5 µg/L) Concentrations are given in micrograms per liter (µg/L)
ND = Groundwater was collected and analyzed, but no analytes were detected above the reported sample quantitation limit.

MTBE = methyl tertiary butyl ether

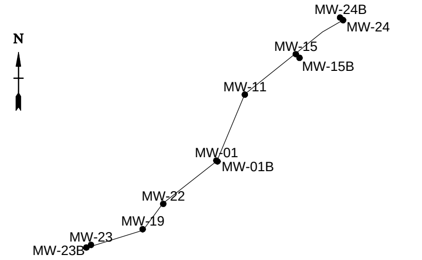
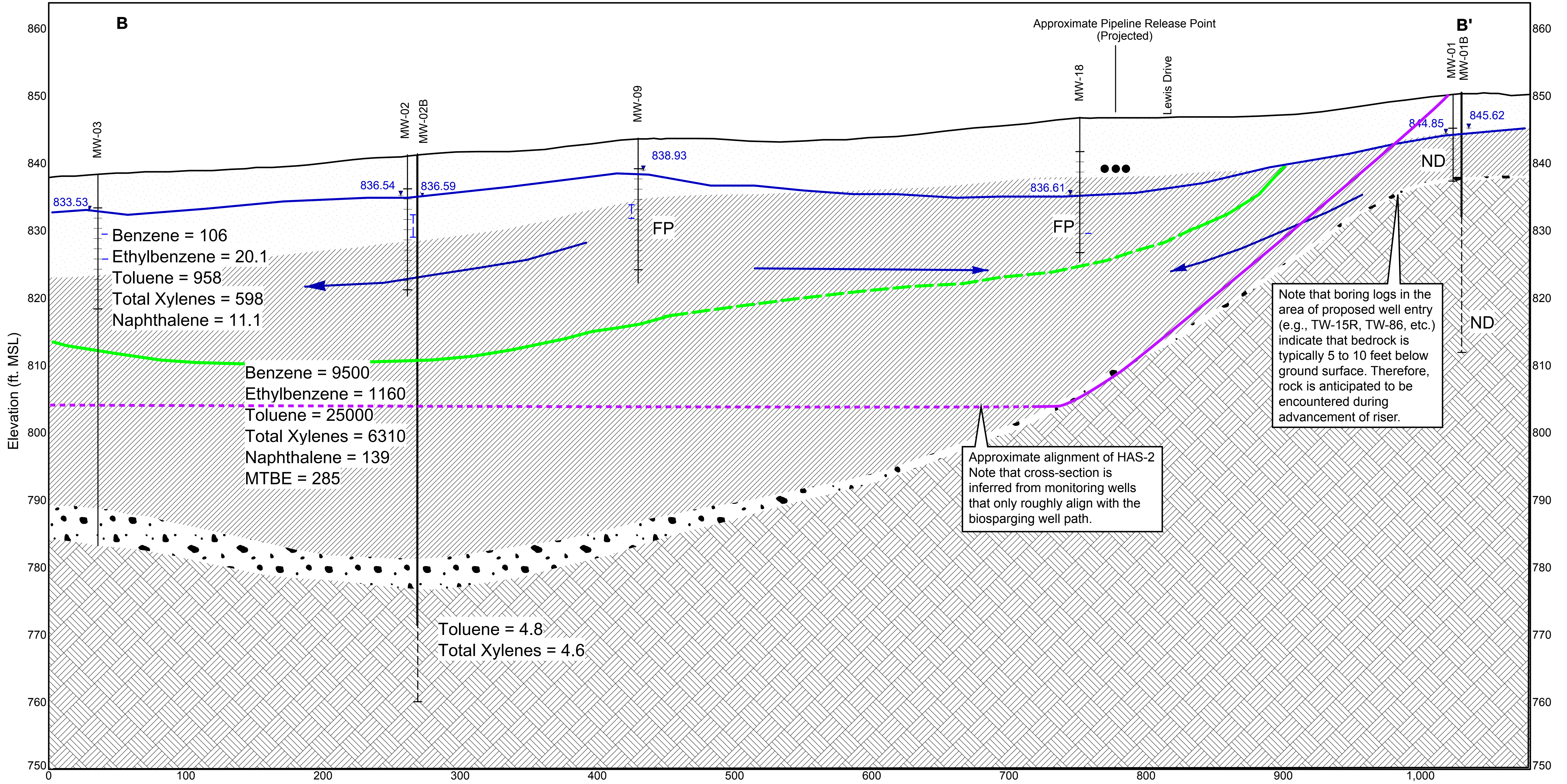


Figure 3. Cross-Section A-A'

Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693
"Kinder Morgan Belton Pipeline Release"

ch2m

LEWISDRIVEBASE LEWIS DRIVE ISA BORING LOGS.GPJ CH2M GEOTECH.GDT 8/18/15



Note that boring logs in the area of proposed well entry (e.g., TW-15R, TW-86, etc.) indicate that bedrock is typically 5 to 10 feet below ground surface. Therefore, rock is anticipated to be encountered during advancement of riser.

Approximate alignment of HAS-2 Note that cross-section is inferred from monitoring wells that only roughly align with the biosparging well path.

Note:
The geologic interpretations on this map were generalized from and interpolated between drilling points. Information on actual subsurface conditions exists only at the specified locations. The actual subsurface conditions may differ from those interpreted on this cross section.

VERTICAL SCALE: 1" = 15'
HORIZONTAL SCALE: 1" = 75'
VERTICAL EXAGGERATION = 4.9x

LEGEND

SOIL: Completely weathered; clayey.

SAPROLITE Completely weathered with relict rock structure visible.

TRANSITION ZONE Mixed soil and rock fragments.

FRESH BEDROCK Few open fractures may be weathered or fresh; high rock-quality designation (RQD); competent rock.

Monitoring Well: Well ID
Top of Screen
Bottom of Screen

Bedrock Monitoring Well: Well ID
Casing
Open Borehole

FP = sample not collected due to the presence of free product
MTBE = methyl tertiary butyl ether
830.91 Groundwater Elevation (feet amsl)
← Groundwater Flow Direction
▼ Water Table (May 6, 2016)
🟩 Estimated Dissolved Benzene Plume Extent (5 µg/L)
Concentrations are given in micrograms per liter (µg/L)
ND = Groundwater was collected and analyzed, but no analytes were detected above the reported sample quantitation limit.
Horizontal well casing
Horizontal well screen

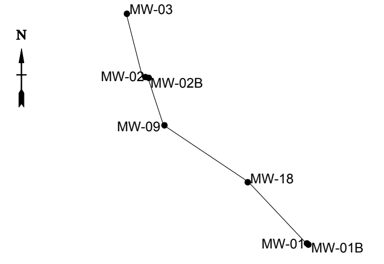
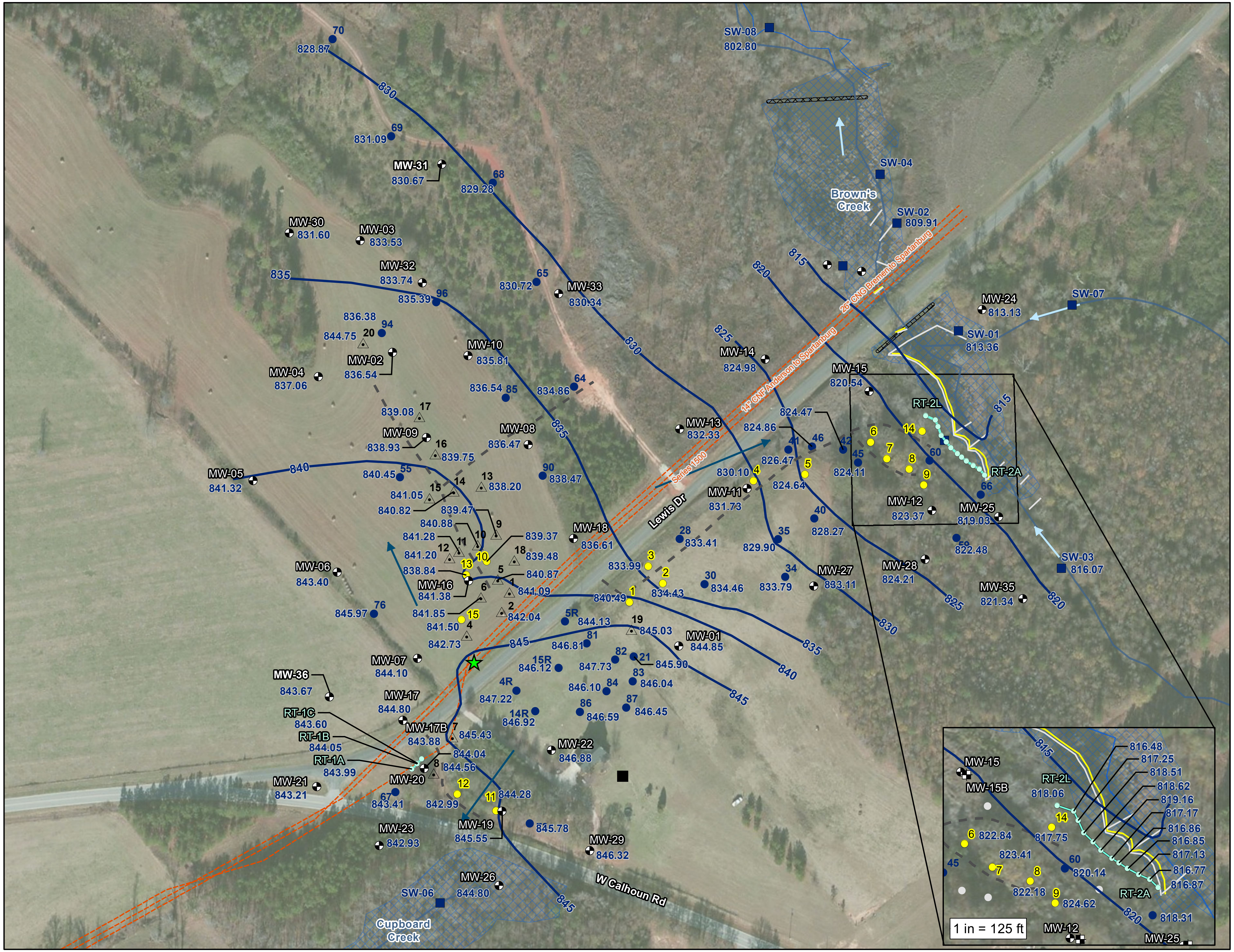


Figure 4. Cross-Section B-B'

Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693
"Kinder Morgan Belton Pipeline Release"

LEWISDRIVEBASE LEWIS DRIVE ISA BORING LOGS.GPJ CH2M GEOTECH.GDT 8/19/15



LEGEND

- ★ Release Point
- Monitoring Well
- △ Recovery Sump
- ● Piezometer ("R" indicates Replacement)
- ● Recovery Well (4" diameter)
- ■ Surface Water Sampling Location
- ■ Septic Tank
- ○ Recovery Trench Point
- Recovery Trench
- Surface Water Flow Direction
- Groundwater Flow Direction
- Potentiometric Surface (5' contour interval)
- Pipeline
- Access Route
- Soft Boom
- Hard Boom
- Stream (NHD)
- Delineated Wetland
- Beaver Dam
- Detail Area
- **843.19** Corrected Groundwater/Surface Water Elevation as of 5/06/2016 and 5/10/2016 in feet above mean sea level

Source Data:
ESRI World Imagery Layer, 2015
USGS National Hydrography Dataset (NHD)

N

0 175 350
Scale in Feet

Figure 5. Water Table Map, May 2016
Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

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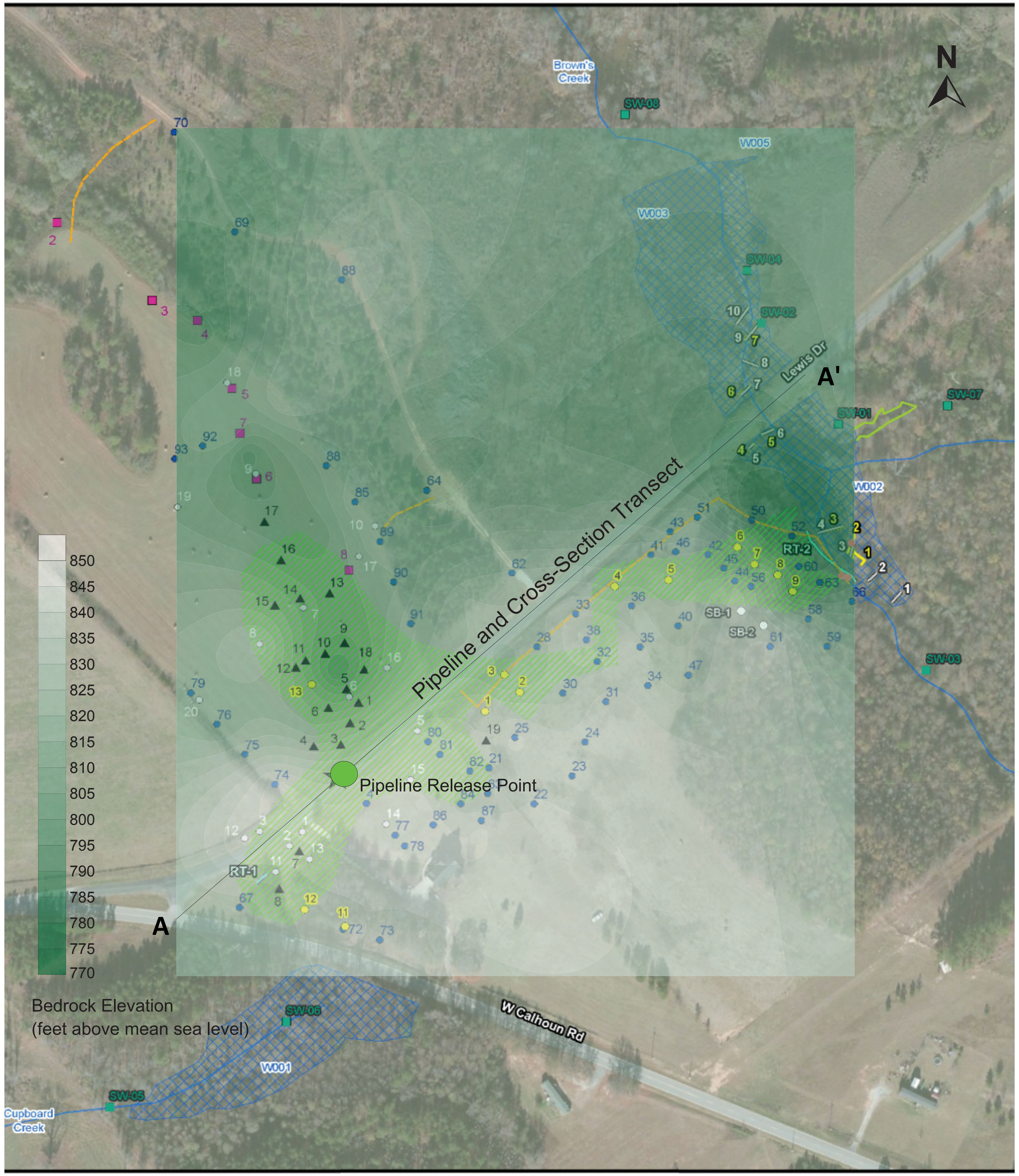
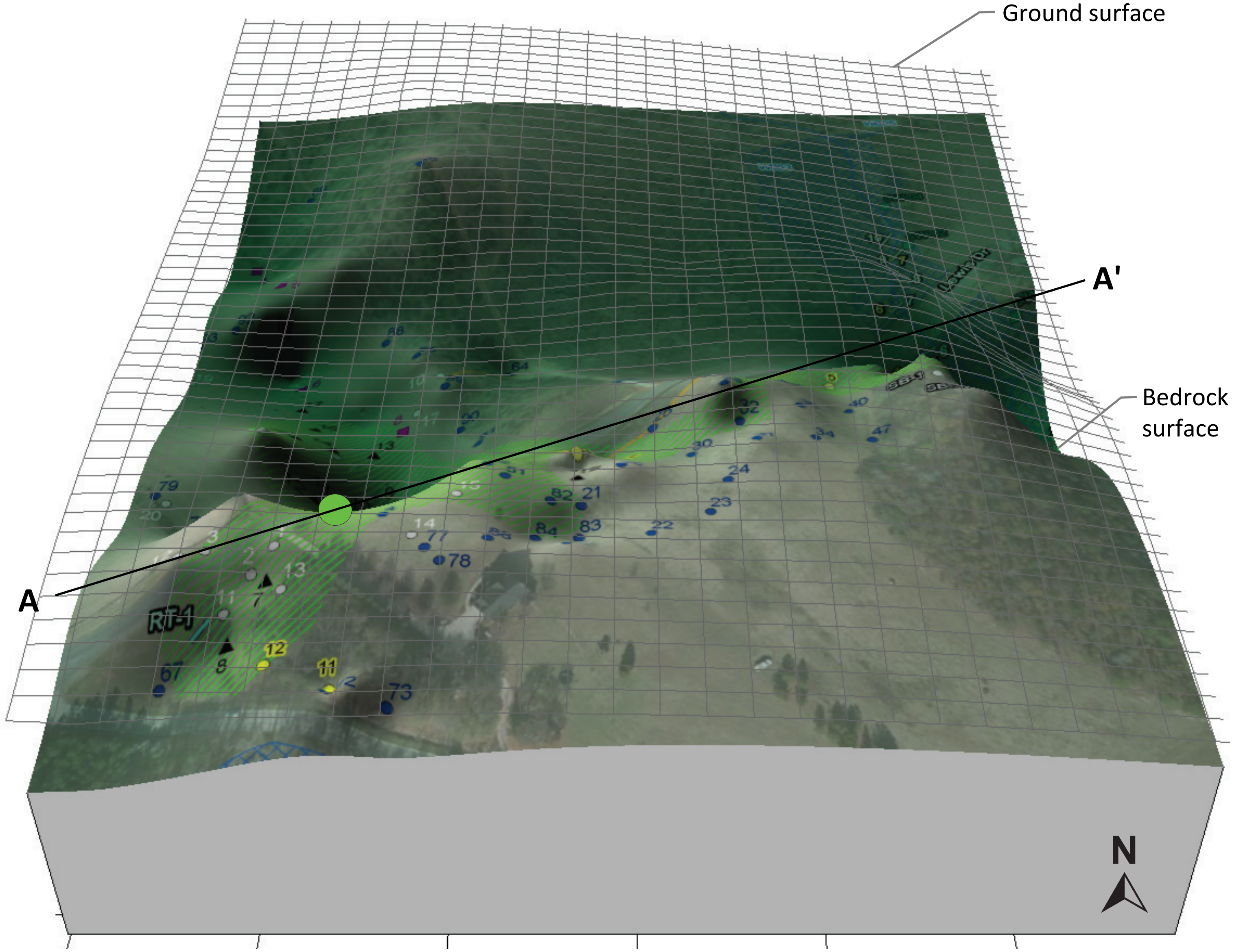
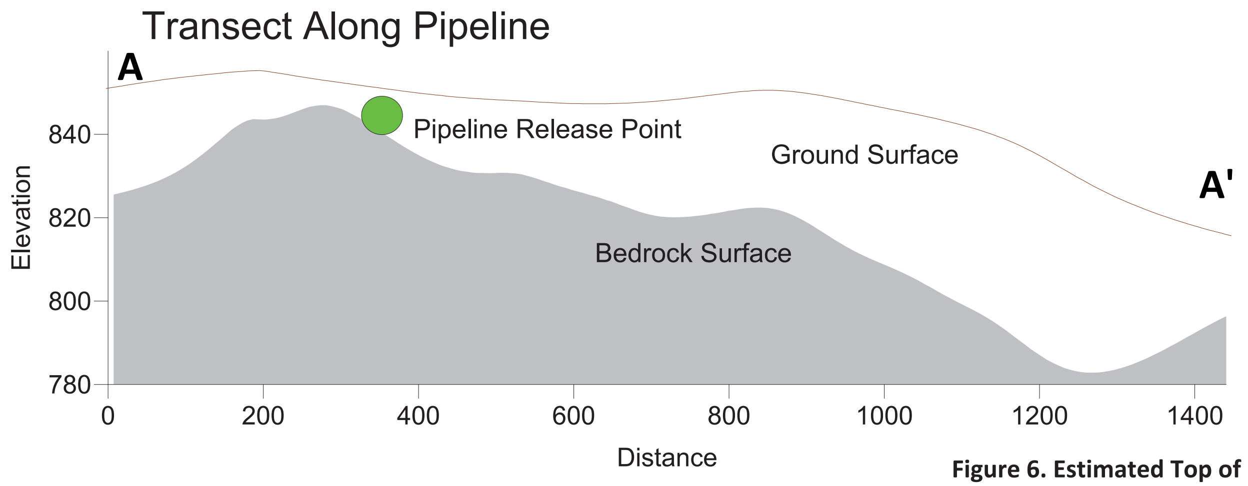
ch2m

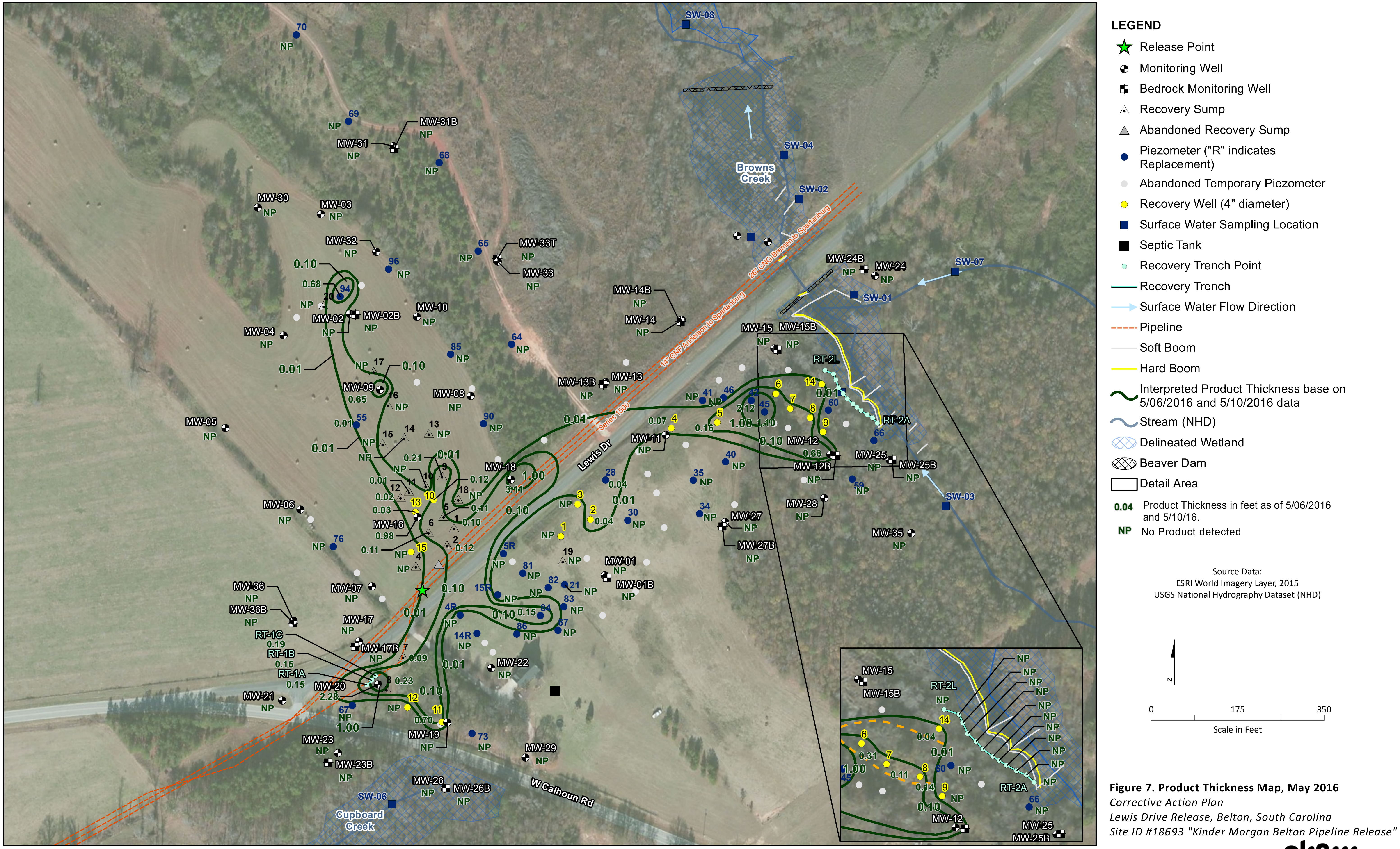






Note:
The geologic interpretations on this map were generalized from and interpolated between drilling points. Information on actual subsurface conditions exists only at the specified locations. The actual subsurface conditions may differ from those interpreted on this figure.

Figure 6. Estimated Top of Bedrock Map
Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

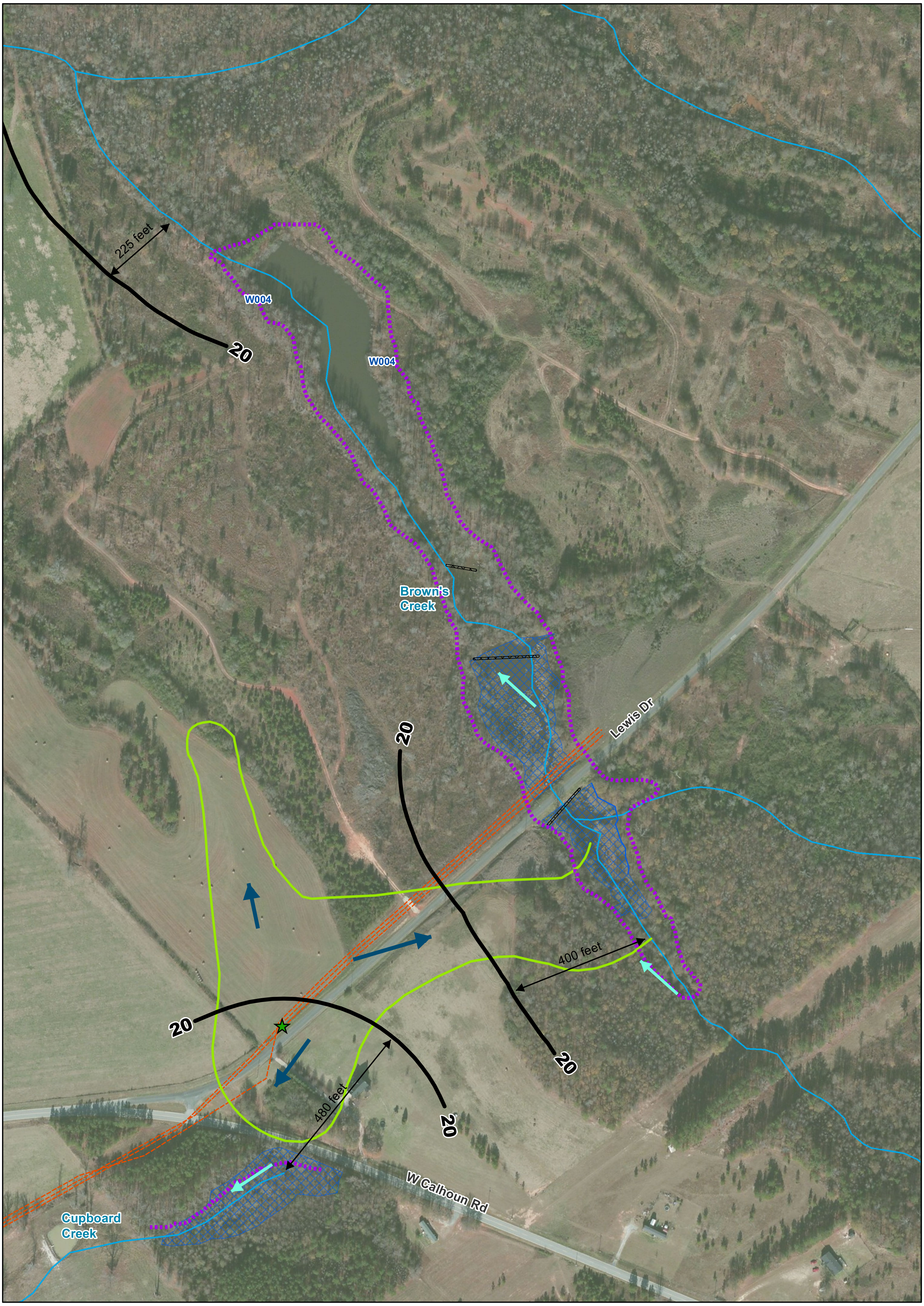


Source Data:
ESRI World Imagery Layer, 2015
USGS National Hydrography Dataset (NHD)

Figure 7. Product Thickness Map, May 2016
Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

ch2m.

\\CANOPUS\GROUPS\GIS\00_PROJ\K\KINDER_MORGAN\654558LEWISDR_ER\GIS\MAPS\CORRECTIVE_ACTION_PLAN\FIGURE7_PRODUCT_THICKNESS_MAP.MXD SASELAGE 9/1/2016



LEGEND

- ★ Release Point
- Pipeline
- Inspection Route for Sheen or Distressed Vegetation
- Dissolved Benzene Plume Extent (5 µg/L, as of May 2016)
- Surface Water Flow Direction
- Groundwater Flow Direction
- Topographic Contour (5-foot Interval)
- National Hydrography Dataset Stream
- Delineated Wetland
- Beaver Dam
- 20 Target maximum concentration for natural attenuation of benzene (micrograms per liter)

Base Map Source:
*Environmental Systems Research Institute (ESRI) ArcMap World Imagery, 2015
*United States Geological Survey (USGS) National Hydrography Dataset (NHD)

Figure 8. Modeled Benzene Groundwater Concentrations Protective of Surface Water
Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693
"Kinder Morgan Belton Pipeline Release"

ch2m

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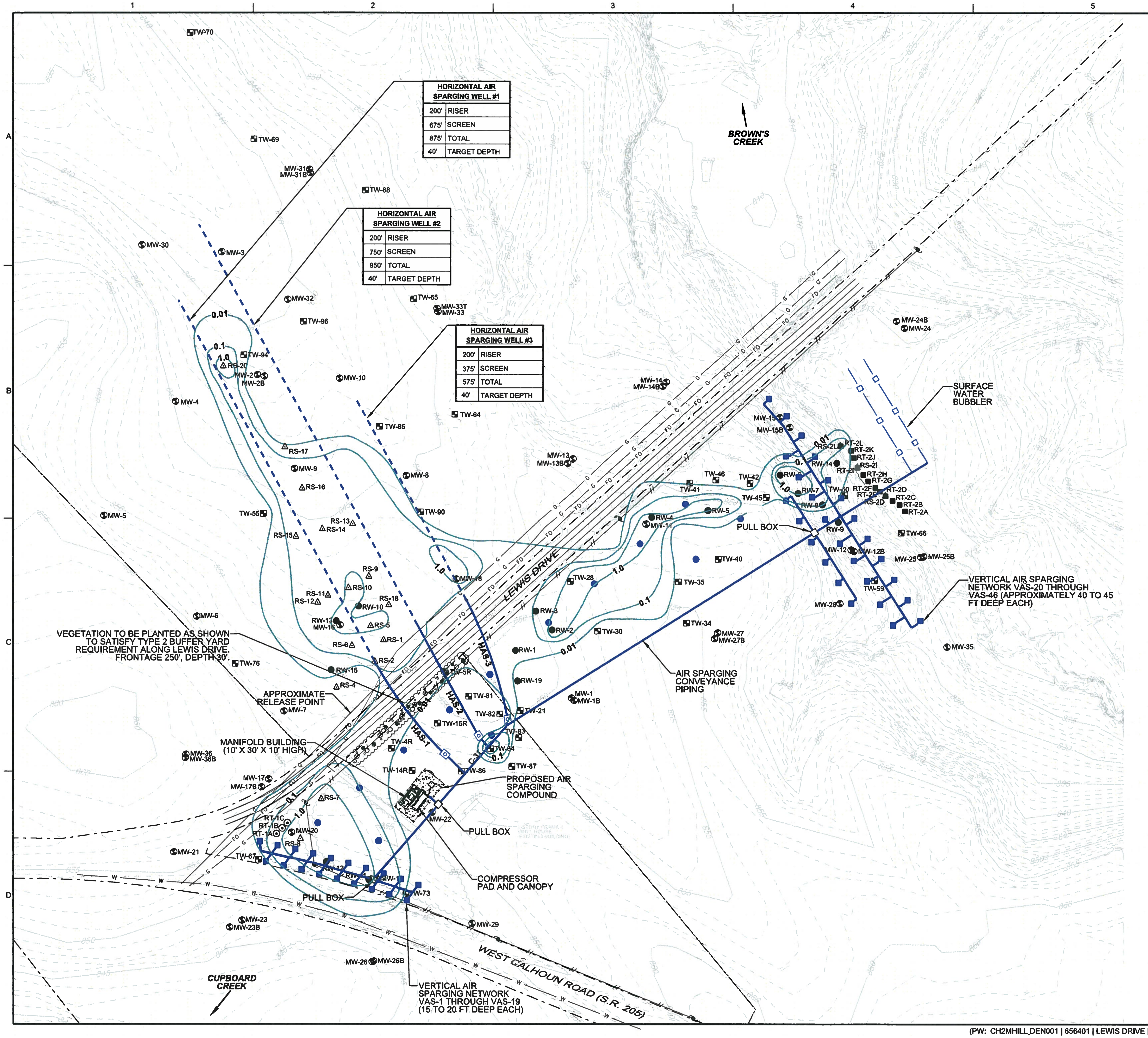


HORIZONTAL AIR SPARGING WELL #1	
200'	RISER
675'	SCREEN
875'	TOTAL
40'	TARGET DEPTH

HORIZONTAL AIR SPARGING WELL #2	
200'	RISER
750'	SCREEN
950'	TOTAL
40'	TARGET DEPTH

HORIZONTAL AIR SPARGING WELL #3	
200'	RISER
375'	SCREEN
575'	TOTAL
40'	TARGET DEPTH

N

GRAPHIC SCALE

0' 80' 160'

SOUTH CAROLINA
LICENSED PROFESSIONAL ENGINEER
No. 32547
SCOTT F. POWELL

Scott F. Powell

LEGEND

⊗	MONITORING WELL
◩	PIEZOMETER
△	RECOVERY SUMP
●	RECOVERY WELL
■	RECOVERY TRENCH POINT
⊡	HORIZONTAL BIOSPARGING ENTRY POINT
■	VERTICAL SAPROLITE BIOSPARGING WELL
●	VERTICAL BEDROCK BIOSPARGING WELL
□	PULL BOX
⊛	CANOPY
○	UNDERSTORY
✺	EVERGREEN
○	SHRUB
—	INTERPRETED PRODUCT THICKNESS BASED ON 8/7/2015 DATA
—□—	SURFACE WATER BUBBLER
—o—	PROPOSED FENCE
—⌇—	POWER LINE
—x—	EXISTING FENCE
— G —	PIPE LINE
— FO —	FIBER OPTIC LINE
— - —	PROPERTY BOUNDARY

NOTES

1. BASEMAP SURVEY PERFORMED BY TAYLOR, WISEMAN & TAYLOR; FEBRUARY 4, 2016.

NO.	DATE	REVISION	BY	APVD

DSGN	DR	CHK	APVD
C SHORES	D BELLARD-BENNETT	M STRONG	

PLANTATION PIPE LINE COMPANY
LEWIS DRIVE RELEASE
BELTON, SOUTH CAROLINA
SITE ID #18693
KINDER MORGAN BELTON PIPELINE RELEASE

ch2m.

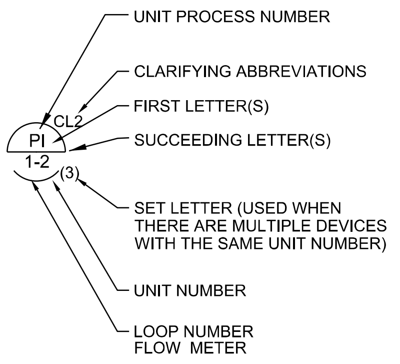
Figure 9. Proposed Sparging Layout
Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

DATE	JUNE 2016
PROJ	669228
DWG	
SHEET	

(PW: CH2MHILL_DEN001 | 656401 | LEWIS DRIVE | BOD) FILENAME: BOD-0002-656401.dgn PLOT DATE: 2016\08\31 PLOT TIME: 3:11:13 PM

INSTRUMENT IDENTIFICATION

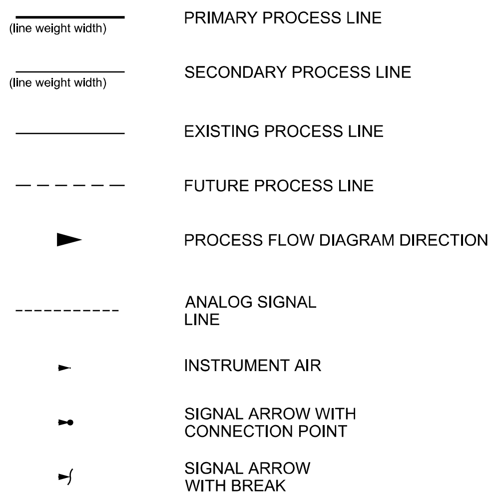
EXAMPLE SYMBOLS



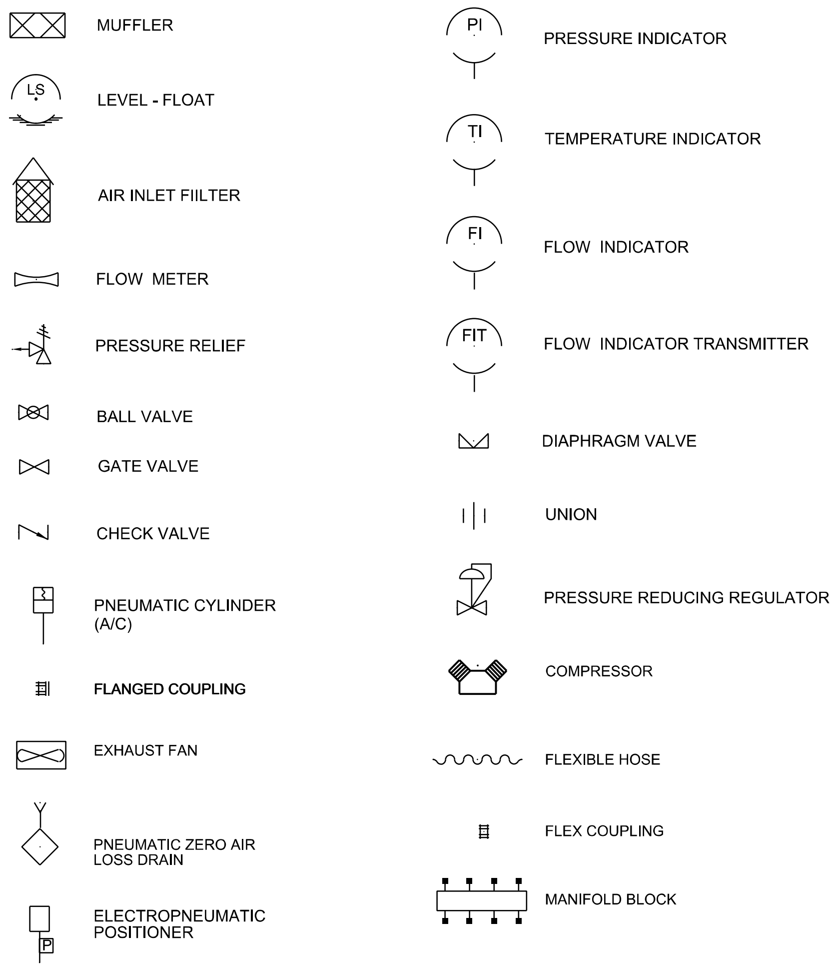
INSTRUMENT LOCATION SYMBOLS

DISCRETE FIELD MOUNTED

PID LINES and ARROWS



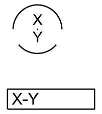
MISCELLANEOUS SYMBOLS



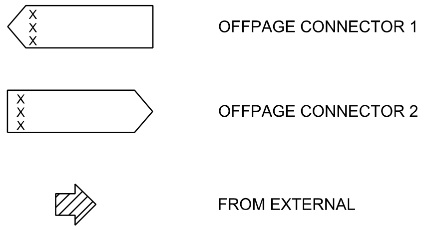
EQUIPMENT TAG NUMBERS

X: EQUIPMENT TYPE SYMBOLS
P = PUMP
T = TANK
M = MECHANICAL EQUIPMENT

Y: LOOP NUMBERS



INTERFACE SYMBOLS



ABBREVIATIONS

A/C	AIR TO CLOSE
AIT	ANALYZER INDICATING TRANSMITTER
CP	CONTROL PANEL
FI	FLOW INDICATOR
FIT	FLOW INDICATING TRANSMITTER
FY	FLOW RELAY
GAL	GALLON
HDPE	HIGH DENSITY POLYETHYLENE
I/P	CURRENT TO PNEUMATIC
LAHH	LEVEL ALARM HIGH HIGH
LEL	LOWER EXPLOSIVE LIMIT
LS	LEVEL SWITCH
LSH	LEVEL SWITCH HIGH
LSHH	LEVEL SWITCH HIGH HIGH
LSL	LEVEL SWITCH LOW
PI	PRESSURE INDICATOR
PLC	PROGRAMMABLE LOGIC CONTROLLER
PRV	PRESSURE RELIEF VALVE
SCH	SCHEDULE
STL	STEEL
TE	TEMPERATURE ELEMENT
TI	TEMPERATURE INDICATOR
V	VENT

NO.	DATE	REVISION	BY	APVD

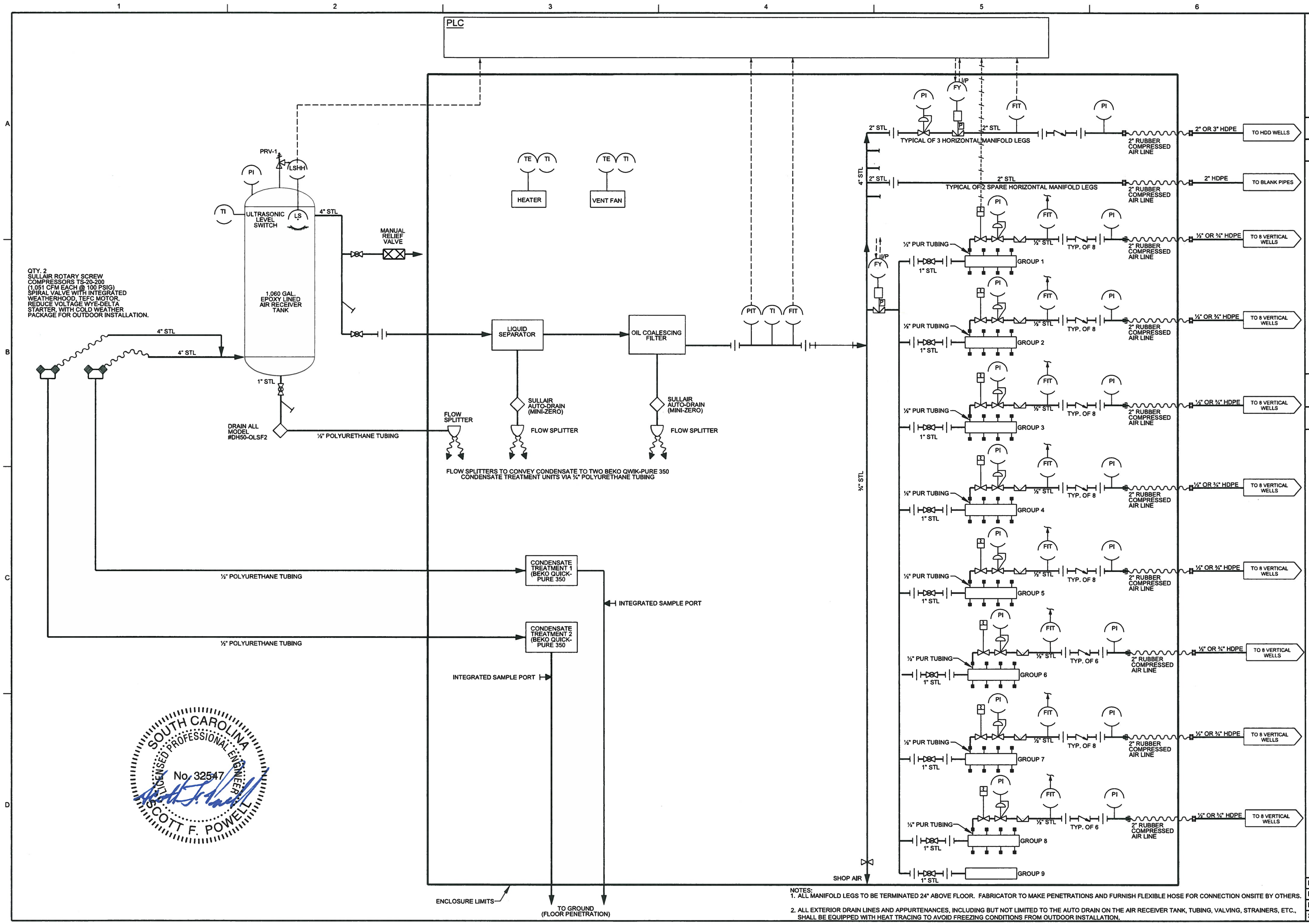
DSGN C SHORES
DR D BELLARD-BENNETT
CHK M STRONG
APVD

PLANTATION PIPE LINE COMPANY
LEWIS DRIVE RELEASE
BELTON, SOUTH CAROLINA
SITE ID #18693
KINDER MORGAN BELTON PIPELINE RELEASE

ch2m

Figure 10. Process and Instrumentation Diagram Legend
Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

DATE	JUNE 2016
PROJ	669228
DWG	
SHEET	



SOUTH CAROLINA LICENSED PROFESSIONAL ENGINEER No. 32547 SCOTT F. POWELL

NOTES:
1. ALL MANIFOLD LEGS TO BE TERMINATED 24" ABOVE FLOOR. FABRICATOR TO MAKE PENETRATIONS AND FURNISH FLEXIBLE HOSE FOR CONNECTION ONSITE BY OTHERS.
2. ALL EXTERIOR DRAIN LINES AND APPURTENANCES, INCLUDING BUT NOT LIMITED TO THE AUTO DRAIN ON THE AIR RECEIVER TANK, TUBING, VALVING, STRAINERS, ETC., SHALL BE EQUIPPED WITH HEAT TRACING TO AVOID FREEZING CONDITIONS FROM OUTDOOR INSTALLATION.

REVISION			
NO.	DATE	BY	APVD
DSGN	DR	CHK	APVD
C SHORES	D BELLARD-BENNETT	M STRONG	

PLANTATION PIPE LINE COMPANY
LEWIS DRIVE RELEASE
BELTON, SOUTH CAROLINA
SITE ID #18693
KINDER MORGAN BELTON PIPELINE RELEASE

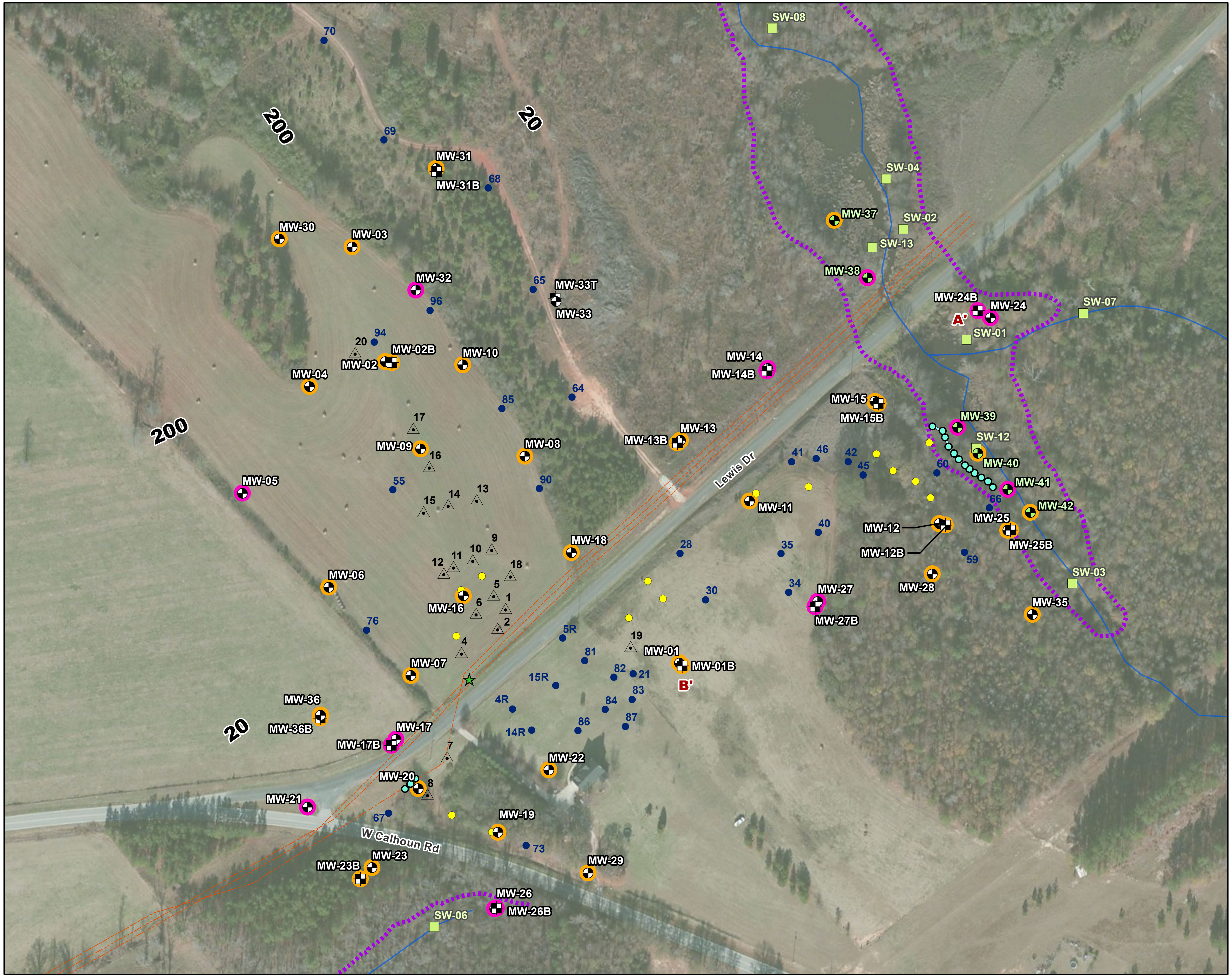
ch2m.

Figure 11. Preliminary Process and Instrumentation Diagram

Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

DATE	MARCH 2016
PROJ	669228
DWG	
SHEET	

(PW: CH2MHILL_DEN001 | 656401 | LEWIS DRIVE | BOD) FILENAME: BOD_P-12_656401.dgn PLOT DATE: 2016\08\29 PLOT TIME: 2:38:10 PM



VICINITY MAP

- ★ Release Point
- ◕ Shallow Monitoring Well (not yet surveyed)
- ◑ Residuum Monitoring Well
- ▦ Bedrock Monitoring Well
- ● Piezometer ("R" indicates Replacement)
- △ Recovery Sump
- ○ Recovery Trench Point
- ● Recovery Well (4" diameter)
- 🟩 Surface Water Sampling Location
- ---- Pipeline
- ≈ Recovery Trench
- ~ Stream (NHD)
- ⋯ Inspection Route for Sheen or Distressed Vegetation
- ● Well to be sampled quarterly for Year 1 and annually thereafter
- ● Well to be sampled quarterly for Year 1 and semiannually thereafter

Source Data:
Environmental Systems Research Institute (ESRI)
World Imagery Layer, 2015
United States Geological Survey (USGS) National Hydrography
Dataset (NHD)

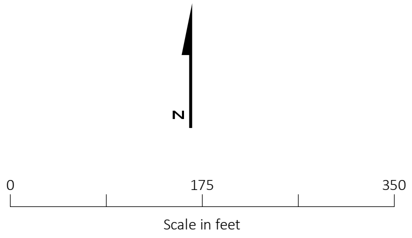
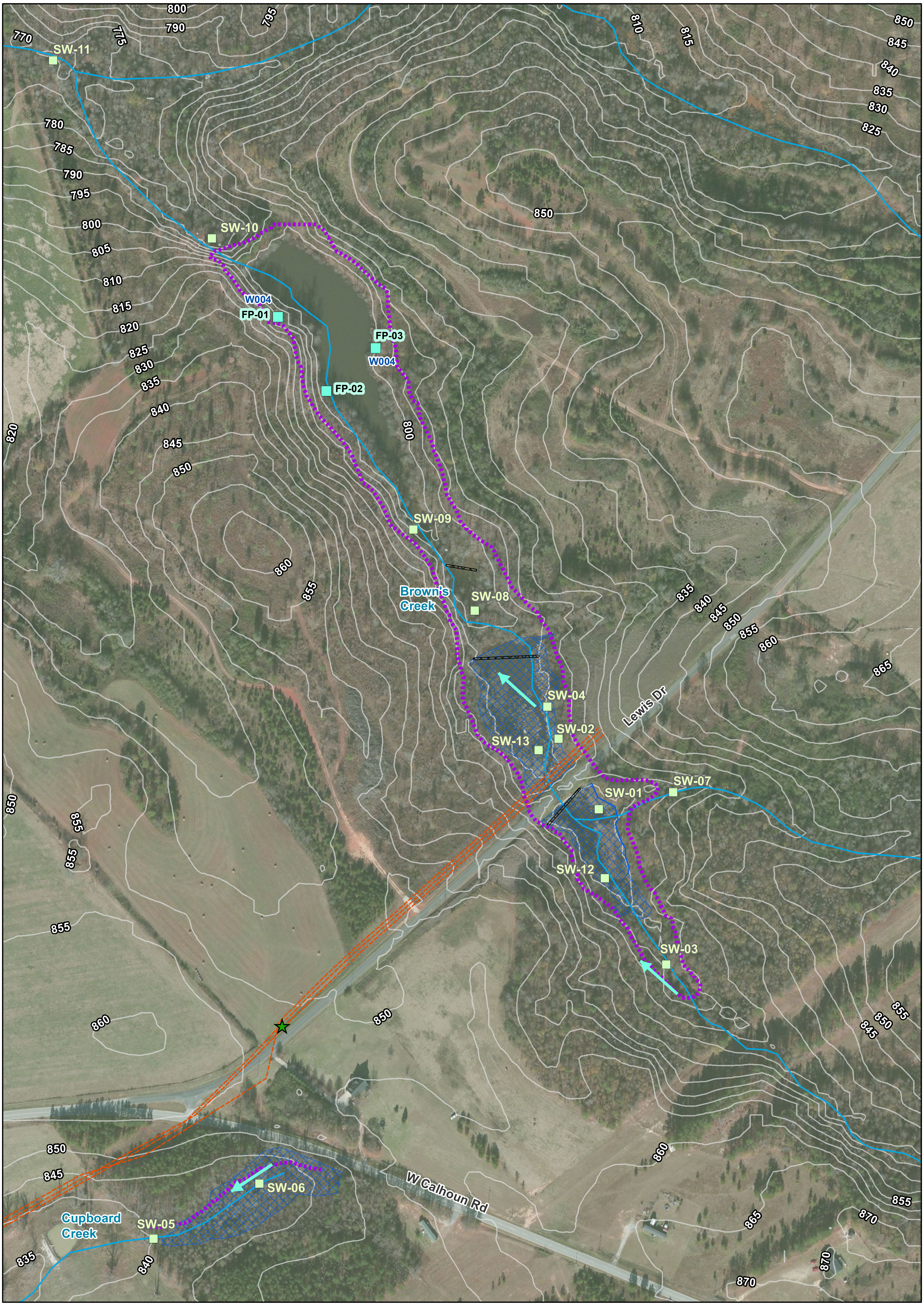


Figure 12. Monitoring Plan
Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

ch2m



LEGEND

- ★ Release Point
- 🟩 Surface Water Sampling Location
- 🟩 Fish Pond Surface Water Sampling Location
- --- Pipeline
- ▪▪▪ Inspection Route for Sheen or Distressed Vegetation
- ➡ Flow Direction of Creek
- ~ Topographic Contour (5-foot Interval)
- ~ National Hydrography Dataset Stream
- ▨ Delineated Wetland
- ▨ Beaver Dam

N

0 250 500

Scale in Feet

Base Map Source:
*Environmental Systems Research Institute (ESRI) ArcMap World Imagery, 2015
*United States Geological Survey (USGS) National Hydrography Dataset (NHD)

Figure 13. Surface Water Sampling Plan

Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693
"Kinder Morgan Belton Pipeline Release"

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Appendix A
Bioscreen Modeling

Appendix A
Bioscreen Modeling

CH2M performed fate and transport modeling using BIOSCREEN (Version 1.4) software (Newell, et al., 1996) to calculate the target groundwater treatment criteria that must be achieved so that benzene concentrations in surface water do not exceed 2.2 micrograms per liter (µg/L) within Brown's Creek and Cupboard Creek at the Lewis Drive Release Site, Belton, South Carolina. A description of the BIOSCREEN model, input parameters, and model results are described below.

Model Description

BIOSCREEN is based on the Domenico analytical solution to groundwater transport that considers chemical advection, dispersion, adsorption, biodegradation, and saturated zone source area mass. BIOSCREEN is a screening-level model that is meant to be used only as a tool in the decision-making process. Further, the model is not designed to account for complexities such as multiple releases and previously implemented remedial actions. Therefore, results of the model evaluation should only be used as estimates when evaluating remedial technologies and not as actual future concentrations.

Model Input Parameters

The BIOSCREEN model inputs are summarized in Table A-1. Benzene was chosen as the model solute because of its lower target concentration of 2.2 µg/L at the points of compliance: Brown's Creek to the north and northeast of the site, and Cupboard Creek to the south (South Carolina Department of Health and Environmental Control [SCDHEC] 2012).

Table A-1. BIOSCREEN Model Inputs
Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

Parameter	Unit	Northeast to Brown's Creek	North through Hayfield to Brown's Creek	South to Cupboard Creek	Source
Hydraulic conductivity	cm/s	0.023	0.037	0.088	Slug test results[1] for MW-15, MW-02, and MW-23, respectively
Hydraulic gradient	ft/ft	0.03	0.01	0.007	Gradient[1] from MW-16 to MW-15, from MW-16 to MW-03, and from MW-17 to MW-23, respectively
Porosity	unitless	0.2	0.2	0.2	Piedmont residuum, conservatively
Estimated plume length	ft	980	875	315	Lateral distribution of benzene analytical results[1]
Soil bulk density	lb/cf	129.3	129.3	118.4	Geotechnical test results[1] at MW-24, MW-24, and MW-23, respectively
Soil bulk density	kg/L	2.07	2.07	1.90	Calculation
Fraction of organic carbon	unitless	0.0018	0.0019	0.0010	Organic carbon analytical results[1] for MW-24, MW-10, and MW-23, respectively
Model solute	—	Benzene	Benzene	Benzene	Chosen for its low target concentration

Table A-1. BIOSCREEN Model Inputs
Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

Parameter	Unit	Northeast to Brown's Creek	North through Hayfield to Brown's Creek	South to Cupboard Creek	Source
Target concentration at surface water boundary	µg/L	2.2	2.2	2.2	South Carolina Department of Health and Environmental Control R.61-68, *Water Classifications and Standards*, Human Health for consumption of water and organism, Benzene, June 22, 2012
Solute partition coefficient	L/kg	83	83	83	LaGrega et al., 1994
Solute half-life in groundwater	days	28	28	28	Babeu and Vaishnav, 1987
Solute half-life in groundwater	years	0.08	0.08	0.08	Calculation
Modeled area width	ft	245	175	385	Lateral distribution of benzene analytical results^2
Source thickness in saturated zone	ft	39	56	17	Cross-section^2 takeoffs, conservatively
Distance from release point to surface water	ft	950	2,000	375	Site plan^2 takeoffs

Notes:
1. *Comprehensive Site Assessment Report, Lewis Drive Release Site*, Belton, South Carolina, CH2M, July 2016.
µg/L = micrograms per liter
cm/s = centimeters per second
ft = feet
ft/ft = feet per foot
kg/L = kilograms per liter
L/kg = liters per kilogram
lb/cf = pounds per cubic foot

Model Results

Because groundwater flow radiates in three directions from the release point, benzene concentration profiles were modeled using the following migration pathways:

1. Northeastward from the release point to Brown's Creek
2. Northward from the release point through the hayfield to Brown's Creek
3. Southward from the release point to Cupboard Creek*

Model results are presented in Attachment 1 and summarized below in Table A-2.

Model Summary

Along the 950-foot path length from the release point northeastward to Brown's Creek, a benzene concentration of 420 µg/L at the release point is calculated to naturally attenuate to the surface water standard of 2.2 µg/L at the interface with Brown's Creek. A benzene concentration of 20 µg/L is calculated to require a horizontal distance of approximately 400 feet from Brown's Creek in order to naturally attenuate to the surface water standard of 2.2 µg/L at the creek.

Along the 2,000-foot path length from the release point northward through the hayfield, benzene concentrations exceeding 200,000 µg/L at the release point are calculated to naturally attenuate below the surface water standard of 2.2 µg/L at the interface with Brown's Creek. This high concentration indicates that the long northward pathway is not the driver among the three pathways.

Table A-2. BIOSCREEN Model Outputs
Corrective Action Plan
Lewis Drive Release, Belton, South Carolina
Site ID #18693 "Kinder Morgan Belton Pipeline Release"

Parameter	**Unit**	**Northeast to Brown's Creek**	**North through Hayfield to Brown's Creek**	**South to Cupboard Creek**
Allowable concentration of benzene at the point of release	µg/L	420	>200,000	12*
Allowable distance to creek for natural attenuation of 20 µg/L benzene	ft	400	225	480*

Notes:
µg/L = micrograms per liter
ft = feet
* The calculated target concentration at the release point may be lower than that necessary to be protective of Cupboard Creek because current evidence indicates that the southern portion of the plume may not be hydraulically connected to Cupboard Creek.

Along the 375-foot path length from the release point southward to Cupboard Creek, a benzene concentration of 12 µg/L at the release point is calculated to naturally attenuate to the surface water standard of 2.2 µg/L at the creek. However, the calculated target concentration at the release point may be lower than that necessary to be protective of Cupboard Creek because current evidence indicates that the southern portion of the plume may not be hydraulically connected to Cupboard Creek. Even though product has been measured in wells just 200 feet north of the creek, there have been no petroleum hydrocarbon detections in surface water samples collected in Cupboard Creek.

References

Babeu, L. & Vaishnav, D.D. 1987. Journal of Industrial Microbiology. 2: 107. doi:10.1007/BF01569509.

CH2M. 2016. *Comprehensive Site Assessment Report, Lewis Drive Release Site, Belton, South Carolina*. July.

LaGrega, Buckingham, and Evan. 1994. Hazardous Waste Management, Appendix A.

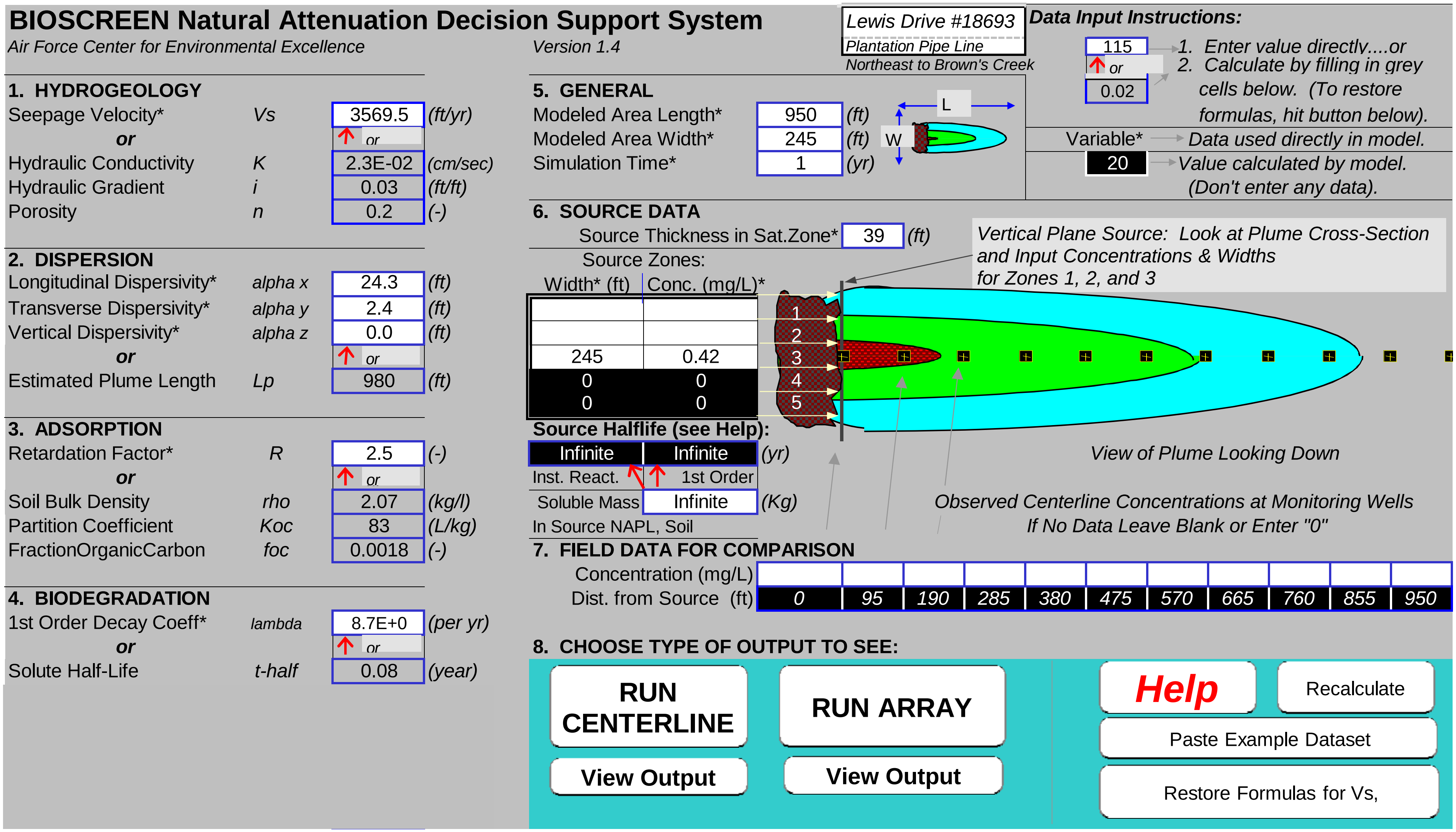
Newell, C. J., R. K. McLeod, and J. R. Gonzales. 1996. *BIOSCREEN Natural Attenuation Decision Support System*, Version 1.4. Air Force Center for Environmental Excellence, Brooks AFB, San Antonio, Texas

South Carolina Department of Health and Environmental Control (SCDHEC). 2012. R.61-68 *Water Classifications and Standards, Human Health for consumption of water and organism*. June 22.

Attachment

BIOSCREEN Model Runs

Attachment
BIOSCREEN Model Runs



BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence

Version 1.4

Lewis Drive #18693
Plantation Pipe Line
Northeast to Brown's Creek

Data Input Instructions:

115 → *1. Enter value directly....or*
or *2. Calculate by filling in grey*
0.02 *cells below. (To restore formulas, hit button below).*

Variable* → *Data used directly in model.*
20 → *Value calculated by model. (Don't enter any data).*

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	3569.5	*(ft/yr)*
or		*or*	
Hydraulic Conductivity	*K*	2.3E-02	*(cm/sec)*
Hydraulic Gradient	*i*	0.03	*(ft/ft)*
Porosity	*n*	0.2	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	24.3	*(ft)*
Transverse Dispersivity*	*alpha y*	2.4	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		*or*	
Estimated Plume Length	*Lp*	980	*(ft)*

3. ADSORPTION

Retardation Factor*	*R*	2.5	*(-)*
or		*or*	
Soil Bulk Density	*rho*	2.07	*(kg/l)*
Partition Coefficient	*Koc*	83	*(L/kg)*
FractionOrganicCarbon	*foc*	0.0018	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	8.7E+0	*(per yr)*
or		*or*	
Solute Half-Life	*t-half*	0.08	*(year)*

5. GENERAL

Modeled Area Length*	950	*(ft)*
Modeled Area Width*	245	*(ft)*
Simulation Time*	1	*(yr)*

6. SOURCE DATA

Source Thickness in Sat.Zone* 39 *(ft)*

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3

Source Zones:

Width* (ft)	Conc. (mg/L)*	
		1
		2
245	0.42	3
0	0	4
0	0	5

Source Halflife (see Help):

Infinite	Infinite	*(yr)*
Inst. React.	1st Order	
Soluble Mass	Infinite	*(Kg)*

In Source NAPL, Soil

View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

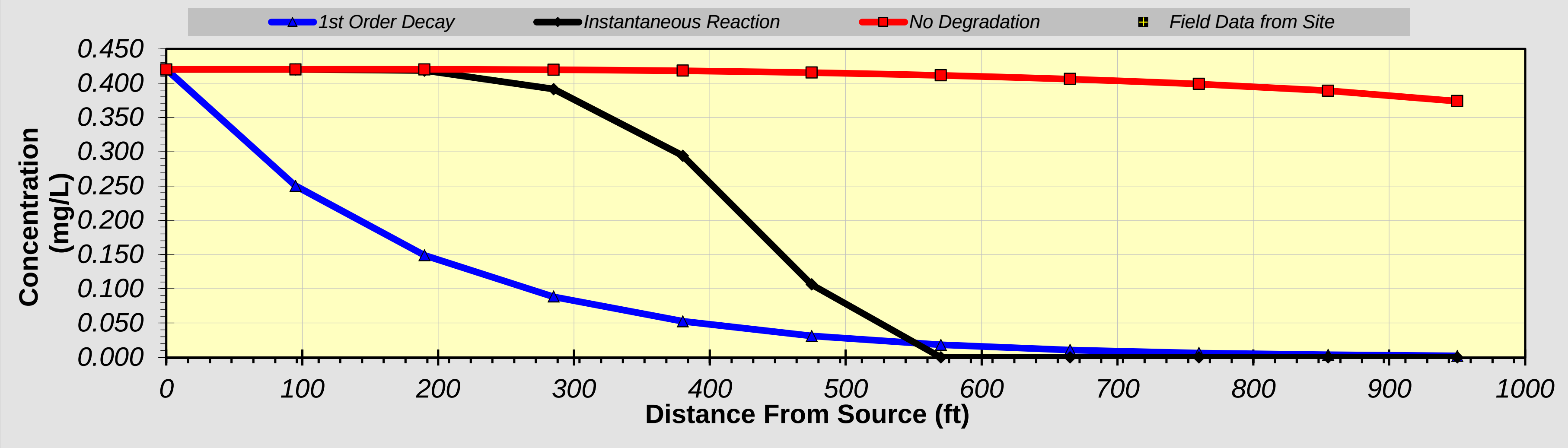
Concentration (mg/L)											
Dist. from Source (ft)	*0*	*95*	*190*	*285*	*380*	*475*	*570*	*665*	*760*	*855*	*950*

8. CHOOSE TYPE OF OUTPUT TO SEE:

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Lewis Drive #18693
Plantation Pipe Line
Northeast to Brown's Creek

	Distance from Source (ft)										
TYPE OF MODEL	0	95	190	285	380	475	570	665	760	855	950
No Degradation	0.420	0.420	0.420	0.420	0.418	0.415	0.411	0.406	0.399	0.389	0.374
1st Order Decay	0.420	0.250	0.149	0.089	0.053	0.031	0.018	0.011	0.006	0.004	0.0022
Field Data from Site											

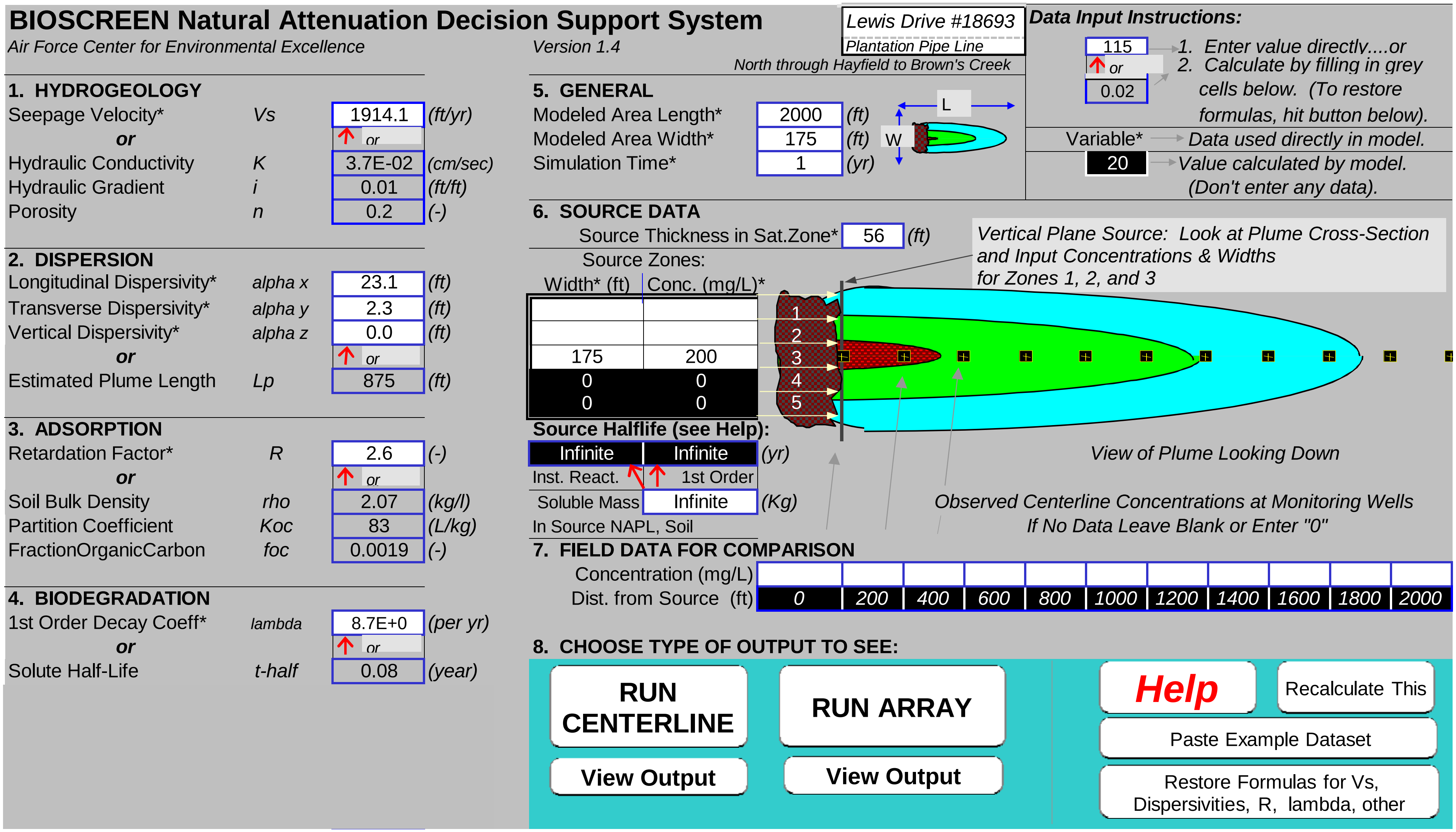


Calculate Animation

Time:
1 Years

Return to

Recalculate This



BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence

Version 1.4

Lewis Drive #18693

Plantation Pipe Line

North through Hayfield to Brown's Creek

Data Input Instructions:

115 → *1. Enter value directly....or*

or *2. Calculate by filling in grey cells below. (To restore formulas, hit button below).*

0.02

Variable* → *Data used directly in model.*

20 → *Value calculated by model. (Don't enter any data).*

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	1914.1	*(ft/yr)*
or		or	
Hydraulic Conductivity	*K*	3.7E-02	*(cm/sec)*
Hydraulic Gradient	*i*	0.01	*(ft/ft)*
Porosity	*n*	0.2	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	23.1	*(ft)*
Transverse Dispersivity*	*alpha y*	2.3	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		or	
Estimated Plume Length	*Lp*	875	*(ft)*

3. ADSORPTION

Retardation Factor*	*R*	2.6	*(-)*
or		or	
Soil Bulk Density	*rho*	2.07	*(kg/l)*
Partition Coefficient	*Koc*	83	*(L/kg)*
FractionOrganicCarbon	*foc*	0.0019	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	8.7E+0	*(per yr)*
or		or	
Solute Half-Life	*t-half*	0.08	*(year)*

5. GENERAL

Modeled Area Length*	2000	*(ft)*
Modeled Area Width*	175	*(ft)*
Simulation Time*	1	*(yr)*

6. SOURCE DATA

Source Thickness in Sat.Zone* 56 *(ft)*

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3

Source Zones:

Width* (ft)	Conc. (mg/L)*	Zone
		1
		2
175	200	3
0	0	4
0	0	5

Source Halflife (see Help):

Infinite	Infinite	*(yr)*
Inst. React.	1st Order	
Soluble Mass	Infinite	*(Kg)*

In Source NAPL, Soil

View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells

If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

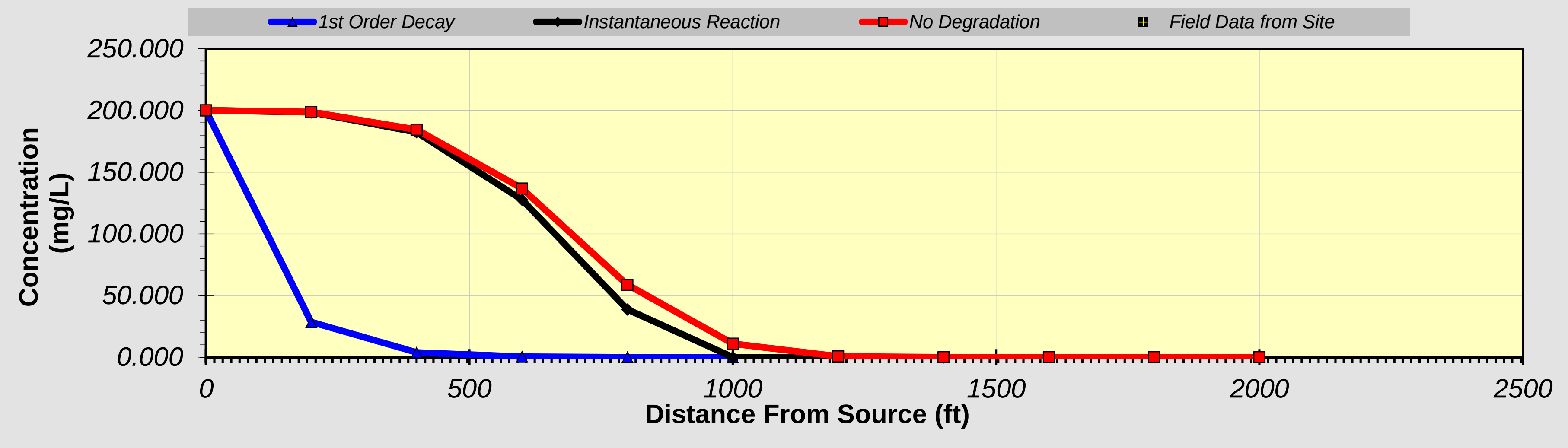
Concentration (mg/L)											
Dist. from Source (ft)	0	200	400	600	800	1000	1200	1400	1600	1800	2000

8. CHOOSE TYPE OF OUTPUT TO SEE:

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Lewis Drive #18693
Plantation Pipe Line
North through Hayfield to Brown's Creek

TYPE OF MODEL	***Distance from Source (ft)*** 0	200	400	600	800	1000	1200	1400	1600	1800	2000
No Degradation	200.000	198.793	184.483	136.574	58.743	10.974	0.755	0.018	0.000	0.000	0.000
1st Order Decay	200.000	28.482	3.917	0.525	0.065	0.006	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



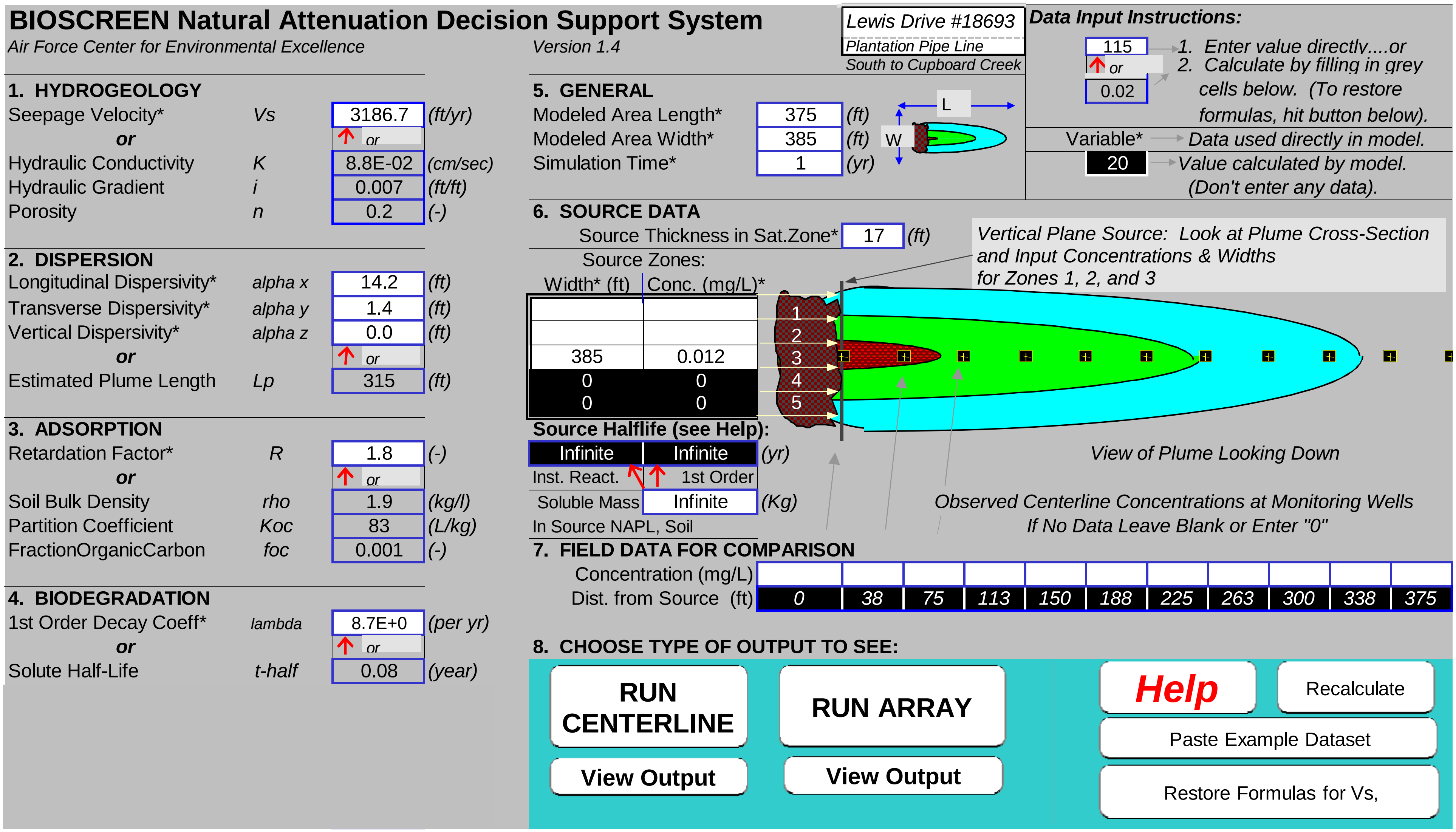
Calculate Animation

Time:

1 Years

Return to

Recalculate This



BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence

Version 1.4

Lewis Drive #18693
Plantation Pipe Line
South to Cupboard Creek

Data Input Instructions:

115 → *1. Enter value directly....or*
or
0.02 → *2. Calculate by filling in grey cells below. (To restore formulas, hit button below).*

Variable* → *Data used directly in model.*
20 → *Value calculated by model. (Don't enter any data).*

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	3186.7	*(ft/yr)*
or		or	
Hydraulic Conductivity	*K*	8.8E-02	*(cm/sec)*
Hydraulic Gradient	*i*	0.007	*(ft/ft)*
Porosity	*n*	0.2	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	14.2	*(ft)*
Transverse Dispersivity*	*alpha y*	1.4	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		or	
Estimated Plume Length	*Lp*	315	*(ft)*

3. ADSORPTION

Retardation Factor*	*R*	1.8	*(-)*
or		or	
Soil Bulk Density	*rho*	1.9	*(kg/l)*
Partition Coefficient	*Koc*	83	*(L/kg)*
FractionOrganicCarbon	*foc*	0.001	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	8.7E+0	*(per yr)*
or		or	
Solute Half-Life	*t-half*	0.08	*(year)*

5. GENERAL

Modeled Area Length*	375	*(ft)*
Modeled Area Width*	385	*(ft)*
Simulation Time*	1	*(yr)*

6. SOURCE DATA

Source Thickness in Sat.Zone* 17 *(ft)*

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3

Source Zones:

Width* (ft)	Conc. (mg/L)*	
		1
		2
385	0.012	3
0	0	4
0	0	5

Source Halflife (see Help):

Infinite	Infinite	*(yr)*
Inst. React.	1st Order	
Soluble Mass	Infinite	*(Kg)*
In Source NAPL, Soil		

View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

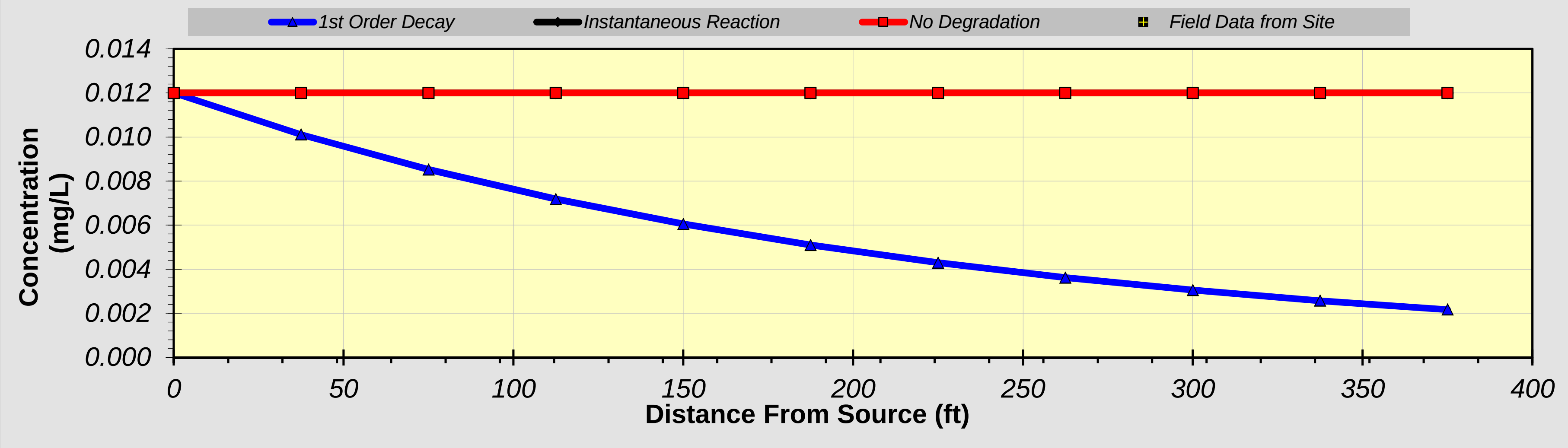
Concentration (mg/L)											
Dist. from Source (ft)	0	38	75	113	150	188	225	263	300	338	375

8. CHOOSE TYPE OF OUTPUT TO SEE:

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Lewis Drive #18693
Plantation Pipe Line
South to Cupboard Creek

	Distance from Source (ft)										
TYPE OF MODEL	0	38	75	113	150	188	225	263	300	338	375
No Degradation	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
1st Order Decay	0.012	0.010	0.009	0.007	0.006	0.005	0.004	0.004	0.003	0.003	0.0022
Field Data from Site											



Calculate Animation

Time: *1 Years*

Return to

Recalculate This