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TECHNICAL MEMORANDUM IN SITU ENHANCED BIOREMEDIATION PILOT STUDY 3 MONTH POST INJECTION ACTIVITIES CENTRAL GROUNDWATER PLUME OPERABLE UNIT 1 (OU 1) MCAS CHERRY POINT NC

1/6/2011

CH2M HILL

In Situ Enhanced Bioremediation Pilot Study, 3-month Post-injection Activities Update, Central Groundwater Plume, Operable Unit 1, MCAS Cherry Point, North Carolina

PREPARED FOR: MCAS Cherry Point Partnering Team

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Introduction

This technical memorandum (TM) presents the 3-month post-injection activities and data for the In Situ Enhanced Bioremediation (ISEB) Pilot Study for Operable Unit (OU) 1 at Marine Corps Air Station (MCAS) Cherry Point, North Carolina (**Figures 1** and **2**); specifically, the portion of OU1 that has been designated as the Central Groundwater Plume. This TM was prepared under the Naval Facilities Engineering Command (NAVFAC)—Mid-Atlantic, Comprehensive Long-term Environmental Action—Navy (CLEAN) 1000 Contract N62470-08-D-1000, Contract Task Order (CTO) 144.

Overview

The Feasibility Study, Operable Unit 1, Central Groundwater Plume, Marine Corps Air Station, Cherry Point, North Carolina (CH2M HILL, 2011a) (2011 Feasibility Study [FS]) evaluated potential remedial alternatives to address site-related constituents of concern (COCs) in groundwater in the Central Groundwater Plume at OU1, primarily trichloroethene (TCE), 1,2-dichloroethene (DCE), and vinyl chloride (VC). In August 2010, the MCAS Cherry Point Partnering Team agreed to conduct a field-scale Pilot Study at OU1 to evaluate the site-specific effectiveness of ISEB in a biobarrier type approach using Slow Release Emulsified Vegetable Oil Substrate (SRS), a common emulsified vegetable oil (EVO) substrate utilized for enhanced reductive dechlorination (ERD) and provided by Terra Systems, Inc. The Pilot Study would also gather data necessary for the optimization of full-scale implementation during the Remedial Design (RD) phase. **Figures 3** and **4** provide the location of the Pilot Study area within OU1 and the Pilot Study area injection and monitoring well network, respectively.

Pilot Study Objectives and Goals

The objectives of the ISEB Pilot Study are to assess the potential effectiveness of the ISEB biobarrier and for potential optimization of full-scale implementation during a future RD of the permanent remedy. The specific goals of the ISEB Pilot Study are as follows:

- Achieve 90 percent reduction of TCE concentrations in the monitoring wells downgradient of the biobarrier
- Achieve 75 percent reduction of overall VOC concentrations in the monitoring wells downgradient of the biobarrier
- Reduce the potential for offsite migration of affected groundwater that would cause unacceptable risks to human or ecological receptors

Since the biobarrier was installed downgradient of the source area due to inaccessibility and access restrictions in the source area, source area contaminant mass is not being treated. Thus, it is possible that over time, contaminant and geochemical parameter concentrations within the Pilot Study area will rebound to baseline levels without additional substrate application.

The new and existing monitoring wells within the Pilot Study area were gauged and sampled prior to initiating the Pilot Study injections. The resulting laboratory and analytical data and field geochemical data provided the baseline conditions for the Pilot Study. The data collected for the 3-month post-injection activities were compared to the baseline conditions to evaluate performance against the ISEB Pilot Study goals.

3-Month Post-injection Activities

The 3-month post-injection activities involved groundwater level gauging and groundwater sampling of the seven Pilot Study monitoring wells. All field activities were conducted in accordance with the protocols and standard operating procedures (SOPs) described in the *Final Master Field Sampling Plan, MCAS Cherry Point, North Carolina* (CH2M HILL, 2004).

The well construction information for the Pilot Study injection and monitoring wells is summarized in **Table 1**.

Groundwater Gauging

Groundwater level gauging was conducted on the five newly installed monitoring wells and two existing monitoring wells prior to purging. Each monitoring well was opened and the air within the well casing was immediately screened for volatile organic compounds (VOCs), carbon monoxide, hydrogen sulfide, and lower explosive limit (LEL) in percent as methane, and recorded in log books. These gases are generated by bacteria in anaerobic environments from an organic substrate, such as ERD substrates (EVO), which are injected into the subsurface. After each well was opened, the groundwater table was given time to equilibrate before the depth to water and total well depth were recorded in log books.

Groundwater Sampling

Groundwater sampling was conducted at the seven Pilot Study monitoring wells and the samples were analyzed for the following constituents:

- Select VOCs: SW-846 USEPA Method 8260B:
  - 1,1,1-TCA
  - 1,1,2,2-PCA
  - 1,1,2-Trichloro-1,2,2-trifluoroethane (Freon-113)
  - 1,1,2-TCA
  - 1,1-DCA
  - 1,1-DCE
  - 1,2-DCA
  - cis-1,2-DCE
  - trans-1,2-DCE
  - Bromodichloromethane
  - Bromoform
  - Chloromethane
  - Dichlorodifluoromethane (Freon-12)
  - Methylene chloride
  - PCE
  - TCE
  - VC
- Field Analyzed Natural Attenuation Indication Parameters (NAIPs):
  - Ferrous Iron (Hach kit – Phenanthroline Method)
  - Nitrate/Nitrite (Hach kit – Cadmium Reduction/Diazotization Method)
  - Dissolved Oxygen (DO) (Chemetrics kit – Rhodazine D Method)
  - Conductivity (In-Site Troll 9500 Water Quality Meter – Methods 2510; USEPA 120.1)
  - pH/Oxidation-Reduction Potential (ORP) (In-Site Troll 9500 Water Quality Meter – Method 2580)
  - Temperature (In-Site Troll 9500 Water Quality Meter – USEPA 170.1)
  - Turbidity (HANNA HI 98703 – USEPA Method 180.1)
- Laboratory Analyzed NAIPs:
  - Methane, ethane, ethene (MEE): RSK-175
  - Total organic carbon (TOC): SW846 USEPA Method 9060A
  - Sulfate: USEPA Method 375.4
  - Sulfide: USEPA Method SM4500S2-E
  - Volatile Fatty Acids (VFAs): Method AM23G
  - Microbial Analysis for *Dehalococcoides* spp. (1) and functional genes qPCR*/DNA-qPCR* (including *Dehalobacter*, *Desulfuromonas*, methane oxidizing bacteria, and the toluene dioxygenase enzyme)

3-Month Post-injection Results

Groundwater Gauging

During well head screening, VOCs and hydrogen sulfide were not measured at concentrations greater than background levels; however, three wells were found to be under pressure and had carbon monoxide readings greater than background levels (52MW79 at 3 parts per million [ppm], 52MW80 at 18 ppm, and 52MW81 at 6 ppm). Additionally, 52MW80 had a percent LEL as methane reading greater than background, at 2.4 percent. This measurable generation of biogas in some monitoring wells during the 3-month sampling event in comparison to the lack of measurable biogas during baseline sampling is strong evidence that considerable post-injection subsurface microbial activity is occurring.

Groundwater level measurements were collected only from monitoring wells during the 3-month post-injection event. Gauging data are included in **Table 1**.

Groundwater Sampling Results

All injection and monitoring wells were sampled for the site-specific VOCs by SW-846 USEPA Method 8260B, as listed above. The baseline and 3-month post-injection groundwater sampling results are presented in **Table 2**, and exceedances of regulatory screening criteria are shown on **Figures 5** and **6**, for both upper or lower surficial aquifer wells, respectively. As defined in the Sampling and Analysis Plan (SAP), concentrations of groundwater contaminants identified in this pilot study were compared to the lowest of the North Carolina Administrative Code Title 15A, Subchapter 2L Groundwater Quality Standards (NC 2L Standards) and Environmental Protection Agency (EPA) maximum contaminant limits (MCLs). For all COCs, the NC 2L Standard is the more conservative criterion, with the exception of 1,1,2-TCA, which does not have a defined NC 2L Standard. However, this analyte was not detected during the baseline or the 3-month sampling activities. **Table 3** presents the Field Parameter results for the baseline and the 3-month sampling events.

Pilot Study Area 3-Month VOC-related Impacts

Upper Surficial Aquifer

In general, constituent concentrations detected in the samples collected from the upper surficial aquifer have decreased when compared to the baseline data collected prior to ERD injections. As shown in **Table 2** and on **Figure 5**, only one exceedance of the NC 2L Standards was observed. Vinyl chloride was detected in the groundwater sample collected from OU1-52MW77 at a concentration of 9 micrograms per liter (μg/L), above the 0.03 μg/L NC 2L Standard.

Table 4 (top half) shows the minimum, maximum, and average VOC concentrations for both baseline and 3-month post-injection sampling events, as well as the overall percent reduction in VOC concentrations in the upper surficial aquifer observed to date. Monitoring 16GW11 was omitted from the analysis because it is an upgradient monitoring well that is sampled to monitor concentrations entering the biobarrier and is not representative of VOC reductions achieved by the biobarrier. As shown in **Table 4**, the initial results are tracking to achieve the ISEB Pilot Study goals, as noted by a reduction in TCE concentrations of greater than 97 percent, which is above the Pilot Study goal of 90 percent. Total VOC concentrations were observed to be reduced by 81 percent, which is greater than the overall Pilot Study goal of 75 percent.

Lower Surficial Aquifer

COC concentrations in the lower surficial aquifer have consistently been observed to be higher than those in the upper surficial aquifer. During the baseline sampling event, 1,1,2,2-PCA, 1,1-DCA, 1,1-DCE, TCE cis-1,2-DCE, trans-1,2-DCE, and VC were site-specific analytes observed in the lower surficial aquifer. The lower surficial aquifer VOC concentrations are presented in **Table 2** and on **Figure 6**.

Table 4 (bottom half) summarizes the results of the 3-month sampling event and calculates the percent reduction of each VOC as well as total VOCs in the lower surficial aquifer. Monitoring MW53 was omitted from the analysis because it is an upgradient monitoring well that is sampled to monitor concentrations entering the biobarrier and is not representative of VOC reductions achieved by the biobarrier. As shown in **Table 4**, the initial results are tracking to achieve the ISEB Pilot Study TCE goal, as noted by a reduction in TCE concentration of 96 percent.

Although the total VOC reduction target objective has yet to be achieved, an overall reduction of VOCs by 41 percent was observed in the 3-month event. This reduction in overall VOCs is coupled with an increase of daughter product concentrations, primarily in well 52GW79. This is strong evidence that reductive dechlorination of site COCs is being accelerated by introducing the ERD substrate and bioaugmentation culture. It is likely that total VOC concentrations will continue to decrease over the next few months.

Pilot Study Area 3-month Groundwater ERD Evaluation

Groundwater samples for the new and existing monitoring wells were analyzed for the entire suite of NAIPs, as listed above, with results summarized in **Tables 2** and **5**. All injection and monitoring wells were field-tested for the NAIPs ferrous iron, nitrate, and nitrite using Hach kits, and DO using a Chemetrics kit (**Table 3)**. These data are also shown on **Figures 7** and **8**, for both upper surficial or lower surficial aquifer wells, respectively. An evaluation of the NAIP data for ERD is summarized in **Table 5** and an additional evaluation for the TOC and VFA data is included in **Table 6**. As was done for the VOC analysis, upgradient monitoring wells 16GW11 and MW53 were omitted from the ERD evaluation. Further discussion of the 3-month post-injection ERD evaluation is broken out between the upper and lower surficial aquifers in the text below.

Upper Surficial Aquifer

As shown in **Tables 2, 3 and 5** and **Figure 7**, 3-month NAIP and field parameter results in the upper surficial aquifer provide many lines of evidence indicating favorable conditions for ERD of chlorinated VOCs in the Pilot Study area. Results for pH, ORP, DO, nitrate, ferrous iron, and sulfate were all within favorable ranges for ERD requirements.

Trends for MEE and microbial analysis have also shown favorable conditions for ERD when the 3-month data are compared to baseline results (**Table 5** and **Figure 7**). Methane concentrations have increased above baseline, indicating that increasingly reducing conditions are present in the Pilot Study area. Additionally, a detection of ethene in the sample collected from 52GW77 also indicates that reductive dechlorination is proceeding to non-harmful end products in this well. These results, coupled with the continued detectable *Dehalococcoides* concentrations in the upper surficial aquifer, are strong lines of evidence that the overall decreasing trend of VOC concentrations observed in the upper surficial aquifer is a result of enhanced microbial activity and not dilution. *Dehalobacter* concentrations were also observed to increase in one monitoring well (52GW80) by nearly three orders of magnitude.

Large increases in methane oxidizing bacteria (MOB) have also been observed in the upper surficial aquifer, likely a response to the production of biogas; that is, methane from the carbon substrate injected in the EISB process. Anaerobic methane oxidation has been widely observed under sulfate-reducing or methanogenic conditions (Kotelnikova, 2002). Furthermore, increases in toluene dioxygenase concentrations over baseline conditions indicate a potential for aerobic cometabolism of chloroethenes. The presence of toluene dioxygenases also indicates the presence of microaerobic zones, although the aquifer appears to be anaerobic overall. The degree of expression of oxygenases under microaerobic conditions is comparable to levels found under aerobic (DO > 4 milligrams per liter [mg/L]) conditions (Ma and Love, 2001). Abundance of microorganisms and oxygenases indicate a good potential for occurrence of aerobic cometabolism of chloroethenes, especially for cis-1,2-DCE and VC, representing an added benefit to ERD.

In addition to the NAIP trends discussed above, TOC and VFA concentrations have also increased overall against baseline concentrations in both upper surficial monitoring wells (**Tables 2, 5,** and **6**). It should also be noted that groundwater samples were collected for TOC analysis immediately after injection, and a large initial spike was noted in upper surficial monitoring well 52GW80, located approximately 12.7 feet from the nearest injection well (**Table 6**). The initial spike was likely related to the lactate portion of the SRS substrate. As the lactate is used up, TOC concentrations are expected to level off and remain relatively constant as the slow-release oil portion of the substrate becomes the primary carbon addition source.

The VFAs butyrate and pyruvate were not detected in any monitoring wells during the baseline sampling event, but were detected in both downgradient upper surficial aquifer monitoring wells, indicating increased biological activity.

Lower Surficial

Tables 2, 3 and 5 and **Figure 8** also provide the NAIP and field parameter data observed in the lower surficial aquifer within the OU1 ISEB Pilot Study area. Results for ORP, DO, nitrate, ferrous iron, and sulfate were all within favorable ranges for ERD requirements, while pH levels are considered to be favorable to unfavorable.

The pH in groundwater samples collected from monitoring wells 52MW78, 52MW79, and 52MW81 have shown a drop in pH below a value of 6.0 since the baseline sampling event. Because pH is a critical parameter for the *Dehalococcoides* population and the success of an ERD strategy, this parameter will continue to be monitored closely. If pH continues to decline, adding a buffering agent could be considered for future injection events. However, data from the 3-month sampling event indicated increases in the *Dehalococcoides* populations in all three downgradient lower surficial monitoring wells; therefore, pH does not appear to be inhibiting growth and reductive dechlorination at this stage in the Pilot Study.

Trends for MEE and microbial analysis are showing largely favorable conditions for ERD when the 3-month data are compared to baseline results (**Table 5** and **Figure 7**). Methane concentrations have increased above baseline, indicating that increasingly reducing conditions are present in the Pilot Study area. Additionally, increases in both ethene and ethane in two of three downgradient monitoring wells indicate that reductive dechlorination is proceeding to non-harmful end products in these wells. These results, coupled with an increase in *Dehalococcoides* concentrations by one to three orders of magnitude in the lower surficial aquifer, are strong lines of evidence that the overall decreasing trend of VOC concentrations that has been observed is a result of enhanced microbial activity and not dilution. *Dehalobacter* have also shown significant increases in concentrations over baseline, doubling in one monitoring well and increasing by one to two orders of magnitude in the other two downgradient lower surficial monitoring wells.

Large increases in MOB and toluene dioxygenase concentrations have also been observed in the lower surficial aquifer. Proliferation of MOB and toluene dioxygenases releasing microbes were likely a response to the biogas generation and biostimulation, and also indicate the possibility of the presence of microaerobic zones in the aquifer, as discussed above.

In addition to the NAIP trends discussed above, TOC and VFA concentrations have also increased overall against baseline concentrations in the lower surficial monitoring wells (**Tables 2, 5,** and **6**), which provides evidence that ERD substrate continues to be available for ERD. It should also be noted that groundwater samples were collected for TOC analysis immediately after injection, and a large initial spike was noted in lower surficial monitoring wells 52GW78 (12.3 feet from nearest injection well) and 52GW81 (11.0 feet from nearest injection well) (**Table 6**). The initial spike was likely related to the lactate portion of the SRS substrate. As the lactate is used up, TOC concentrations are expected to level off and remain relatively constant as the slow-release oil portion of the substrate becomes the primary carbon addition source.

The VFAs butyrate and pyruvate were not detected in any monitoring wells during the baseline sampling event but were detected in all three downgradient lower surficial monitoring wells during the 3-month sampling event, indicating increased biological activity.

Conclusions

In summary, the conclusions for the 3-month post-injection groundwater sampling event are as follows:

- The TCE reduction goal of 90 percent has been exceeded in both the upper and lower surficial aquifers.
- Total VOC concentration reductions in the upper surficial aquifer have exceeded the reduction goal of 75 percent.
- Although the target total VOC reduction of 75 percent has not yet been met for the lower surficial aquifer, a reduction of 41 percent was observed in conjunction with an observed increase of daughter product concentrations. This provides a strong line of evidence that reductive dechlorination of site COCs is being accelerated by introducing the ERD substrate. It is likely that total VOC concentrations will continue to decrease over the next few months.
- NAIPs and microbial data in the upper and lower surficial aquifers provide many lines of evidence indicating favorable conditions for ERD of chlorinated VOCs in the Pilot Study area.

Post-Injection Monitoring

As specified in the OU1 Pilot Study SAP (CH2M HILL, 2011b), groundwater monitoring is to be conducted at intervals of 3, 6, 9, 12, and 24 months following injections. The next *post-injection* sampling event (6 month) was completed during the week of December 12, 2011.

Post-injection groundwater samples will continue to be collected from the seven Pilot Study wells**.** The injection wells will not be included in the post-injection monitoring activities. All sample handling and analysis will be conducted in accordance with the Master Field Sampling Plan (AGVIQ/CH2M HILL, 2004a) and the Master Quality Assurance Plan (AGVIQ/CH2M HILL, 2004b).

As additional data are collected and evaluated, further conclusions regarding substrate distribution will be drawn. The additional data will also be used in comparison to the baseline data to determine effectiveness in achieving Pilot Study goals.

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Tables

TABLE 1

Construction Information and Groundwater Elevation Data

OU1 Biobarrier Pilot Study

Marine Corps Air Station Cherry Point

Cherry Point, North Carolina

Pilot Study	Well ID	Surficial Aquifer Zone	Total Well Depth (ft bgs)	Screen[a,b] Length (ft)	Screen Interval (ft bgs)	Top of Casing Elevation (feet msl)	Ground Surface Elevation (feet msl)	Depth to Water (ft btoc)	Depth to Water (ft msl)
Injection Well Pairs	OU1-52IW01	Upper	36	15	20 - 35	20.39	20.70	NM	NM
	OU1-52IW02	Lower	51	15	35 - 50	20.38	20.46	NM	NM
	OU1-52IW03	Upper	36	15	20 - 35	20.17	20.22	NM	NM
	OU1-52IW04	Lower	51	15	35 - 50	20.11	20.24	NM	NM
	OU1-52IW05	Upper	36	15	20 - 35	19.53	19.84	NM	NM
	OU1-52IW06	Lower	51	15	35 - 50	19.61	19.86	NM	NM
	OU1-52IW07	Upper	36	15	21 - 36	19.44	19.63	NM	NM
	OU1-52IW08	Lower	46	15	30 - 45	19.40	19.59	NM	NM
	OU1-52IW09	Upper	36	15	20 - 35	19.31	19.52	NM	NM
	OU1-52IW10	Lower	48	15	32 - 47	19.32	19.46	NM	NM
	OU1-52IW11	Upper	36	15	20 - 35	18.95	19.16	NM	NM
	OU1-52IW12	Lower	46	15	30 - 45	19.28	19.35	NM	NM
	OU1-52IW13	Upper	36	15	20 - 35	18.60	18.60	NM	NM
	OU1-52IW14	Lower	46	15	30 - 45	19.00	19.04	NM	NM
Newly Installed Monitoring Wells	OU1-52MW77	Upper	33	10	22 - 32	19.66	20.06	11.15	8.51
	OU1-52MW78	Lower	49	10	38 - 48	19.57	19.86	11.91	7.66
	OU1-52MW79	Lower	49	10	38 - 48	19.72	19.86	12.11	7.61
	OU1-52MW80	Upper	33	10	22 - 32	19.64	19.75	10.75	8.89
	OU1-52MW81	Lower	49	10	38 - 48	19.67	19.65	12.00	7.67
Existing Monitoring Wells	16GW11	Upper	27	15	12 - 27	22.64	21.17	13.65	8.99
	MW53	Lower	54	10	44 - 54	22.40	20.54	14.68	7.72

Notes:

[a] 4-inch diameter with 0.020-inch slot Vee-wire Schedule (Sch.) 40 PVC screen for injection wells

[b] 2-inch diameter 0.010-inch machine slot Sch. 40 PVC screen for monitoring wells

ft - feet

ft bgs - feet below ground surface

TABLE 2

Baseline and 3-Month Post Injection

Groundwater VOC and NAIP Detections

OU1 Biobarrier Pilot Study

Marine Corps Air Station Cherry Point

Cherry Point, North Carolina

Station ID	**Screening Criteria**	16GW11				OU1-MW53			52GW77				
Sample ID		16GW11-052511	OU1-16GW11-060911	OU1-16GW11-092111	OU1-16GW11-092911	MW53-052511	OU1-MW53-060911	OU1-MW53-092011	OU1-52GW77-052511	OU1-52GW77D-052511	OU1-52GW77-061011	OU1-52GW77-092011	OU1-52GW77D-092011
Sample Date		05/25/11	06/09/11	09/21/11	09/29/11	05/25/11	06/09/11	09/20/11	05/25/11	05/25/11	06/10/11	09/20/11	09/20/11
Chemical Name													
Volatile Organic Compounds (UG/L)													
1,1,2,2-Tetrachloroethane	0.2	0.5 U	NA	0.5 U	NA	0.5 U	NA	0.5 U	0.5 U	0.5 U	NA	0.5 U	0.5 U
1,1-Dichloroethane	6	0.5 U	NA	0.5 U	NA	0.5 U	NA	0.5 U	**0.53 J**	**0.29 J**	NA	0.5 U	0.5 U
1,1-Dichloroethene	7	0.5 U	NA	0.5 U	NA	**0.93 J**	NA	**1.6**	**0.43 J**	**0.44 J**	NA	0.5 U	0.5 U
1,2-Dichloroethene (total)	70	**8.4**	NA	**1.8 J**	NA	**510**	NA	**940**	**100**	**110**	NA	**25**	**24**
cis-1,2-Dichloroethene	70	**7.7**	NA	1.8 B	NA	**400**	NA	**610**	**93**	**100**	NA	**24**	**23**
Methylene chloride	5	2.5 U	NA	2.5 U	NA	2.5 U	NA	2.5 U	2.5 U	2.5 U	NA	2.5 U	2.5 U
trans-1,2-Dichloroethene	100	**0.72 J**	NA	0.5 U	NA	**120**	NA	**190**	**7.7**	**8.3**	NA	**1.6**	**1.7**
Trichloroethene	3	1.2 U	NA	0.5 U	NA	**610**	NA	**680**	**29**	**31**	NA	**0.77 J**	1.3 B
Vinyl chloride	0.03	**1.2 J**	NA	1 U	NA	**1.5 J**	NA	**2.8**	**20**	**20**	NA	**8.7**	**9**
Wet Chemistry													
Ethane (ug/l)	--	2 U	NA	2 U	NA	**3.9 J**	NA	**6.1 J**	2 U	NA	NA	2 U	NA
Ethene (ug/l)	--	2 U	NA	2 U	NA	2 U	NA	2 U	**2.5 J**	NA	NA	**1.5 J**	NA
Methane (ug/l)	--	**8.2 J**	NA	**4.2 J**	NA	**52**	NA	**78**	**700**	NA	NA	**7,300**	NA
Sulfate (mg/l)	250	**14**	NA	**16**	NA	**1.3**	NA	**15**	**13**	NA	NA	0.5 U	NA
Sulfide (mg/l)	--	0.75 U	NA	0.75 U	NA	**1**	NA	**0.8 J**	0.75 U	NA	NA	0.75 U	NA
Total organic carbon (TOC) (mg/l)	--	**1.4**	**7.1**	**1.9**	NA	**1.6**	**2.4**	**1.7**	**5.2**	NA	**10**	**130**	NA
Voltile Fatty Acids													
Butyrate (mg/l)	--	0.05 U	NA	0.05 U	NA	0.05 U	NA	0.05 U	0.05 U	NA	NA	**17 D**	NA
Formic acid (mg/l)	--	**0.061 J**	NA	**0.09 J**	NA	**0.066 J**	NA	**0.096 J**	**0.099 J**	NA	NA	**1.6 D**	NA
Lactic Acid (mg/l)	--	**0.12**	NA	**0.27**	NA	**0.15**	NA	**0.21**	**0.25**	NA	NA	**6 D**	NA
Propionic Acid (mg/l)	--	**0.052**	NA	**0.075**	NA	**0.07**	NA	**0.13**	0.05 U	NA	NA	**60 D**	NA
Pyruvate (mg/l)	--	0.15 U	NA	0.15 U	NA	0.15 U	NA	0.15 U	0.15 U	NA	NA	**1.2 D**	NA
General Microbial Analyses (CELLS/ML)													
Desulfuromonas	--	**2.8**	NA	NA	**6.5**	**4,100**	NA	**170**	**20**	NA	NA	**116**	NA
Methane Oxidizing Bacteria	--	**8,500**	NA	NA	**17,800,000**	**2,340**	NA	**559,000**	**62,600**	NA	NA	**92,600,000**	NA
Toluene Deoxygenase	--	**0.50**	NA	NA	**32,800**	0.5 U	NA	0.8 U	0.6 U	NA	NA	**69,200**	NA
Dechlorinating Bacteria (CELLS/ML)													
Dehalobacter	--	**9,330**	NA	NA	**213**	**3,290**	NA	2.4 U	**96,100**	NA	NA	**102,000**	NA
Dehalococcoides	--	**14.2**	NA	NA	**0.6 J**	**196**	NA	**0.9**	**1,780**	NA	NA	**7.2**	NA

Notes:

Exceeds one or more criteria

Bold indicates detections

NA - Not analyzed

B - Analyte not detected above the level reported in blanks

D - Compound identified in an analysis at a secondary dilution factor

J - Analyte present, value may or may not be accurate or precise

U - The material was analyzed for, but not detected

CELLS/ML - Cells per milliliter

MG/L - Milligrams per liter

UG/L - Micrograms per liter

TABLE 2

Baseline and 3-Month Post Injection

Groundwater VOC and NAIP Detections

OU1 Biobarrier Pilot Study

Marine Corps Air Station Cherry Point

Cherry Point, North Carolina

Station ID	**Screening Criteria**	52GW78			52GW79				52GW80			
Sample ID		OU1-52GW78-052511	OU1-52GW78-060911	OU1-52GW78-092011	OU1-52GW79-052511	OU1-52GW79-061011	OU1-52GW79-092111	OU1-52GW79-092911	OU1-52GW80-052511	OU1-52GW80-061011	OU1-52GW80-092111	OU1-52GW80-092911
Sample Date		05/25/11	06/09/11	09/20/11	05/25/11	06/10/11	09/21/11	09/29/11	05/25/11	06/10/11	09/21/11	09/29/11
Chemical Name												
Volatile Organic Compounds (UG/L)												
1,1,2,2-Tetrachloroethane	0.2	0.5 U	NA	0.5 U	0.5 U	NA	2 U	NA	0.5 U	NA	0.5 U	NA
1,1-Dichloroethane	6	**1.3**	NA	**0.85 J**	**1.2**	NA	**2.5 J**	NA	0.5 U	NA	0.5 U	NA
1,1-Dichloroethene	7	**2.5**	NA	**1.1**	**2.3**	NA	**2.3 J**	NA	0.5 U	NA	0.5 U	NA
1,2-Dichloroethene (total)	70	**1,300**	NA	**700**	**1,300**	NA	**2,400**	NA	**31**	NA	**3**	NA
cis-1,2-Dichloroethene	70	**1,200**	NA	**580**	**1,200**	NA	**2,200**	NA	**30**	NA	**3**	NA
Methylene chloride	5	2.5 U	NA	**3.2 J**	2.5 U	NA	10 U	NA	2.5 U	NA	2.5 U	NA
trans-1,2-Dichloroethene	100	**110**	NA	**54**	**80**	NA	**86**	NA	**1.6**	NA	0.5 U	NA
Trichloroethene	3	**720**	NA	**11**	**480**	NA	**46**	NA	**9.6**	NA	0.5 U	NA
Vinyl chloride	0.03	**23**	NA	**59**	**20**	NA	**74**	NA	**3.1**	NA	1 U	NA
Wet Chemistry												
Ethane (ug/l)	--	**4.1 J**	NA	**4.3 J**	**3.2 J**	NA	**5.8 J**	NA	2 U	NA	2 U	NA
Ethene (ug/l)	--	2 U	NA	**4.4 J**	**1.1 J**	NA	**2.9 J**	NA	2 U	NA	2 U	NA
Methane (ug/l)	--	**180**	NA	**1,900**	**130**	NA	**170**	NA	**700**	NA	**6,000**	NA
Sulfate (mg/l)	250	**35**	NA	0.5 U	**28**	NA	**7**	NA	**9.2**	NA	0.5 U	NA
Sulfide (mg/l)	--	0.75 U	NA	**0.95 J**	0.75 U	NA	0.75 U	NA	0.75 U	NA	0.75 U	NA
Total organic carbon (TOC) (mg/l)	--	**2.3**	**3,100**	**190**	**1.7**	**22**	**97**	NA	**3.4**	**1,800**	**450**	NA
Voltile Fatty Acids												
Butyrate (mg/l)	--	0.05 U	NA	**34 D**	0.05 U	NA	**11 D**	NA	0.05 U	NA	**67 D**	NA
Formic acid (mg/l)	--	**0.11**	NA	**2.1 D**	**0.17**	NA	**1.3 D**	NA	**0.094 J**	NA	**13 D**	NA
Lactic Acid (mg/l)	--	**0.28**	NA	**12 D**	**0.16**	NA	**0.64 J**	NA	0.1 U	NA	**10 D**	NA
Propionic Acid (mg/l)	--	0.05 U	NA	**60 D**	**0.064**	NA	**28 D**	NA	**0.08**	NA	**320 D**	NA
Pyruvate (mg/l)	--	0.15 U	NA	**1.9 D**	0.15 U	NA	**0.51**	NA	0.15 U	NA	**8.5**	NA
General Microbial Analyses (CELLS/ML)												
Desulfuromonas	--	**12.2**	NA	**2,650**	**215**	NA	NA	**25.2**	**4.4**	NA	NA	**0.7 J**
Methane Oxidizing Bacteria	--	**805**	NA	**115,000,000**	**58,900**	NA	NA	**824,000,000**	**274,000**	NA	NA	**511,000,000**
Toluene Deoxygenase	--	0.5 U	NA	**2,080,000**	**6,690**	NA	NA	**1,200,000**	**20,200**	NA	NA	**138,000**
Dechlorinating Bacteria (CELLS/ML)												
Dehalobacter	--	**10,500**	NA	**368,000**	**19,300**	NA	NA	**3,360,000**	**561**	NA	NA	**342,000**
Dehalococcoides	--	**39.7**	NA	**10,300**	**861**	NA	NA	**21,600**	**2,200**	NA	NA	**40.3**

Notes:

Exceeds one or more criteria

Bold indicates detections

NA - Not analyzed

B - Analyte not detected above the level reported in blanks

D - Compound identified in an analysis at a secondary dilution factor

J - Analyte present, value may or may not be accurate or precise

U - The material was analyzed for, but not detected

CELLS/ML - Cells per milliliter

MG/L - Milligrams per liter

UG/L - Micrograms per liter

TABLE 2

Baseline and 3-Month Post Injection

Groundwater VOC and NAIP Detections

OU1 Biobarrier Pilot Study

Marine Corps Air Station Cherry Point

Cherry Point, North Carolina

Station ID	**Screening Criteria**	52GW81				OU1-52IW01		OU1-52IW02	OU1-52IW03	OU1-52IW04	OU1-52IW05	OU1-52IW06	OU1-52IW07
Sample ID		OU1-52GW81-052511	OU1-52GW81-061011	OU1-52GW81-092111	OU1-52GW81-092911	OU1-52IW01-052411	OU1-52IW01D-052411	OU1-52IW02-052511	OU1-52IW03-052411	OU1-52IW04-052311	OU1-52IW05-052311	OU1-52IW06-052311	OU1-52IW07-052411
Sample Date		05/25/11	06/10/11	09/21/11	09/29/11	05/24/11	05/24/11	05/25/11	05/24/11	05/23/11	05/23/11	05/23/11	05/24/11
Chemical Name													
Volatile Organic Compounds (UG/L)													
1,1,2,2-Tetrachloroethane	0.2	0.5 U	NA	0.5 U	NA	0.5 U	0.5 U	**0.5**	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethane	6	**1.2**	NA	**0.56 J**	NA	**2.9**	**3.1**	**0.42 J**	**0.75 J**	**1**	0.5 U	**0.24 J**	0.5 U
1,1-Dichloroethene	7	**3.7**	NA	**0.7 J**	NA	**0.67 J**	**0.6 J**	**1.2**	0.5 U	**1.8**	0.5 U	**0.7 J**	0.5 U
1,2-Dichloroethene (total)	70	**1,600**	NA	**260**	NA	**100**	**110**	**620**	**70**	**910**	**44**	**250**	**23**
cis-1,2-Dichloroethene	70	**1,500**	NA	**250**	NA	**96**	**100**	**510**	**64**	**870**	**41**	**240**	**22**
Methylene chloride	5	2.5 U	NA	2.5 U	NA	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
trans-1,2-Dichloroethene	100	**34**	NA	**42**	NA	**7.5**	**7.8**	**110**	**6.2**	**38**	**3.2**	**8.4**	**1.3**
Trichloroethene	3	**440**	NA	**14**	NA	**15**	**14**	**770**	**5.1**	**330**	**5.3**	**130**	**4.4**
Vinyl chloride	0.03	**28**	NA	**13**	NA	**20**	**20**	**3.1**	**12**	**22**	**11**	**16**	**6.1**
Wet Chemistry													
Ethane (ug/l)	--	**3.1 J**	NA	**1.9 J**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethene (ug/l)	--	**2.6 J**	NA	**1.7 J**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methane (ug/l)	--	**610**	NA	**2,600**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate (mg/l)	250	**27**	NA	0.5 U	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfide (mg/l)	--	0.75 U	NA	**1.1**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total organic carbon (TOC) (mg/l)	--	**4.5**	**1,600**	**120**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Voltile Fatty Acids													
Butyrate (mg/l)	--	0.05 U	NA	**8.5 D**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Formic acid (mg/l)	--	**0.19**	NA	**1.2 D**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lactic Acid (mg/l)	--	**0.21**	NA	**1 D**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Propionic Acid (mg/l)	--	**0.06**	NA	**28 D**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyruvate (mg/l)	--	0.15 U	NA	**0.4**	NA	NA	NA	NA	NA	NA	NA	NA	NA
General Microbial Analyses (CELLS/ML)													
Desulfuromonas	--	**65.9**	NA	NA	**3.1**	NA	NA	NA	NA	NA	NA	NA	NA
Methane Oxidizing Bacteria	--	**53,500**	NA	NA	**1,110,000,000**	NA	NA	NA	NA	NA	NA	NA	NA
Toluene Deoxygenase	--	0.5 U	NA	NA	**574,000**	NA	NA	NA	NA	NA	NA	NA	NA
Dechlorinating Bacteria (CELLS/ML)													
Dehalobacter	--	**464,000**	NA	NA	**864,000**	NA	NA	NA	NA	NA	NA	NA	NA
Dehalococcoides	--	**672**	NA	NA	**9,130**	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

Exceeds one or more criteria

Bold indicates detections

NA - Not analyzed

B - Analyte not detected above the level reported in blanks

D - Compound identified in an analysis at a secondary dilution factor

J - Analyte present, value may or may not be accurate or precise

U - The material was analyzed for, but not detected

CELLS/ML - Cells per milliliter

MG/L - Milligrams per liter

UG/L - Micrograms per liter

TABLE 2

Baseline and 3-Month Post Injection

Groundwater VOC and NAIP Detections

OU1 Biobarrier Pilot Study

Marine Corps Air Station Cherry Point

Cherry Point, North Carolina

Station ID	**Screening Criteria**	OU1-52IW08	OU1-52IW09	OU1-52IW10	OU1-52IW11	OU1-52IW12	OU1-52IW13	OU1-52IW14
Sample ID		OU1-52IW08-052311	OU1-52IW09-052411	OU1-52IW10-052311	OU1-52IW11-052411	OU1-52IW12-052211	OU1-52IW13-052411	OU1-52IW14-052211
Sample Date		05/23/11	05/24/11	05/23/11	05/24/11	05/22/11	05/24/11	05/22/11
Chemical Name								
Volatile Organic Compounds (UG/L)								
1,1,2,2-Tetrachloroethane	0.2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethane	6	**0.7 J**	0.5 U	**2.1**	0.5 U	**0.32 J**	0.5 U	**0.96 J**
1,1-Dichloroethene	7	**1.3**	0.5 U	0.5 U	0.5 U	**0.93 J**	0.5 U	**2.2**
1,2-Dichloroethene (total)	70	**420**	**8.5**	**3,600**	**25**	**480**	**160**	**760**
cis-1,2-Dichloroethene	70	**400**	**8.2**	**3,500**	**25**	**480**	**150**	**750**
Methylene chloride	5	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
trans-1,2-Dichloroethene	100	**11**	**0.29 J**	**56**	**0.83 J**	**6.6**	**5.4**	**9.5 J**
Trichloroethene	3	**62**	**0.94 J**	**540**	**5.4**	**140**	**12**	**100**
Vinyl chloride	0.03	**24**	**1.7 J**	**110**	**3**	**8.4**	**59**	**64**
Wet Chemistry								
Ethane (ug/l)	--	NA	NA	NA	NA	NA	NA	NA
Ethene (ug/l)	--	NA	NA	NA	NA	NA	NA	NA
Methane (ug/l)	--	NA	NA	NA	NA	NA	NA	NA
Sulfate (mg/l)	250	NA	NA	NA	NA	NA	NA	NA
Sulfide (mg/l)	--	NA	NA	NA	NA	NA	NA	NA
Total organic carbon (TOC) (mg/l)	--	NA	NA	NA	NA	NA	NA	NA
Voltile Fatty Acids								
Butyrate (mg/l)	--	NA	NA	NA	NA	NA	NA	NA
Formic acid (mg/l)	--	NA	NA	NA	NA	NA	NA	NA
Lactic Acid (mg/l)	--	NA	NA	NA	NA	NA	NA	NA
Propionic Acid (mg/l)	--	NA	NA	NA	NA	NA	NA	NA
Pyruvate (mg/l)	--	NA	NA	NA	NA	NA	NA	NA
General Microbial Analyses (CELLS/ML)								
Desulfuromonas	--	NA	NA	NA	NA	NA	NA	NA
Methane Oxidizing Bacteria	--	NA	NA	NA	NA	NA	NA	NA
Toluene Deoxygenase	--	NA	NA	NA	NA	NA	NA	NA
Dechlorinating Bacteria (CELLS/ML)								
Dehalobacter	--	NA	NA	NA	NA	NA	NA	NA
Dehalococcoides	--	NA	NA	NA	NA	NA	NA	NA

Notes:

Exceeds one or more criteria

Bold indicates detections

NA - Not analyzed

B - Analyte not detected above the level reported in blanks

D - Compound identified in an analysis at a secondary dilution factor

J - Analyte present, value may or may not be accurate or precise

U - The material was analyzed for, but not detected

CELLS/ML - Cells per milliliter

MG/L - Milligrams per liter

UG/L - Micrograms per liter

TABLE 3

Baseline and 3-Month Field Analyzed

Natural Attenuation Indication Parameters

OU1 Biobarrier Pilot Study

Marine Corps Air Station Cherry Point

Cherry Point, North Carolina

Pilot Study Well Type	Well ID	Surficial Aquifer Zone	Temperature (°C) June 2011	Temperature (°C) September 2011	Conductivity (mS/cm) June 2011	Conductivity (mS/cm) September 2011	pH June 2011	pH September 2011	Turbidity (NTUs) June 2011	Turbidity (NTUs) September 2011
Newly Installed Monitoring Wells	OU1-52MW77	Upper	20.07	22.47	2.378	0.930	6.38	6.56	17.6	1.08
	OU1-52MW78	Lower	23.53	22.09	2.410	0.380	6.46	5.18	24.0	50.0
	OU1-52MW79	Lower	21.80	22.60	0.415	0.218	6.65	5.37	13.5	80.2
	OU1-52MW80	Upper	19.86	22.45	3.876	1.276	6.29	6.14	8.97	14.3
	OU1-52MW81	Lower	22.98	22.69	0.568	0.413	6.62	5.88	24.0	40.1
Existing Monitoring	16GW11	Upper	20.96	24.22	0.281	0.338	6.43	6.41	36.0	4.84
	MW53	Lower	22.46	23.42	0.464	0.463	6.99	7.05	21.8	6.87

Notes:
ft bgs - feet below ground surfa
°C - degrees Celcius
mS/cm - milliSiemens per centimeter
mg/L - milligrams per liter
SU - scientfic units
mV - milliVolts
NTUs - nephelometric turbidity units
Ferrous Iron - Hach kit - Phenanthroline Method
Nitrate/Nitrite - Hach kit - Cadmium Reduction/Diazotization Method
Dissolved Oxygen - Chemetrics kit - Rhodazine D™ Method

TABLE 3

Baseline and 3-Month Field Analyzed

Natural Attenuation Indication Parameters

OU1 Biobarrier Pilot Study

Marine Corps Air Station Cherry Point

Cherry Point, North Carolina

Pilot Study Well Type	Well ID	Surficial Aquifer Zone	ORP (mV) June 2011	ORP (mV) September 2011	DO (mg/L) June 2011	DO (mg/L) September 2011	Ferous Iron (mg/L) June 2011	Ferous Iron (mg/L) September 2011	Nitrate (mg/L) June 2011	Nitrate (mg/L) September 2011	Nitrite (mg/L) June 2011	Nitrite (mg/L) September 2011
Newly Installed Monitoring Wells	OU1-52MW77	Upper	-57	-128	<0.025	<0.025	3.2	5.0	<1	<1	0.23	0.17
	OU1-52MW78	Lower	-13	-214	<0.025	0.20	2.6	4.0	13.2	<1	0.10	0.07
	OU1-52MW79	Lower	-71	-81	<0.025	<0.025	1.5	3.0	<1	13.2	<0.01	<0.01
	OU1-52MW80	Upper	-40	-121	<0.025	<0.025	2.8	5.0	<1	<1	0.23	0.23
	OU1-52MW81	Lower	4.0	-277	0.05	<0.025	3.0	2.2	<1	<1	<0.01	<0.01
Existing Monitoring	16GW11	Upper	47	-69	5.02	1.00	0.1	<0.2	<1	<1	<0.01	<0.01
	MW53	Lower	-95	-86	0.20	0.10	2.0	2.0	<1	17.6	<0.01	<0.01

Notes:
ft bgs - feet below ground surfa
°C - degrees Celcius
mS/cm - milliSiemens per centimeter
mg/L - milligrams per liter
SU - scientfic units
mV - milliVolts
NTUs - nephelometric turbidity units
Ferrous Iron - Hach kit - Phenanthroline Meth
Nitrate/Nitrite - Hach kit - Cadmium Reductio
Dissolved Oxygen - Chemetrics kit - Rhodazine

TABLE 4

VOC Data Evaluation - 3-Month Sample Summary

Marine Corps Air Station Cherry Point

Cherry Point, North Carolina

Upper Surficial Aquifer												
		May 2011					**September 2011**					
VOCs	**Screening Criteria**	**Minimum Value**	**Minimum Value Location**	**Maximum Value**	**Maximum Value Location**	**Average VOCs**	**Minimum Value**	**Minimum Value Location**	**Maximum Value**	**Maximum Value Location**	**Average VOCs**	**Percent VOC Reduction**
1,1,2,2-Tetrachloroethane	0.2	0.5 U	2 of 2 Locations	0.5 U	--	0.5 U	0.5 U	2 of 2 Locations	0.5 U	--	0.5 U	--
1,1-Dichloroethane	6	0.5 U	2 of 2 Locations	0.53	OU1-52MW77	0.27	0.5 U	2 of 2 Locations	0.5 U	--	0.5 U	100.0%
1,1-Dichloroethene	7	0.5 U	OU1-52MW80	0.44	OU1-52MW77	0.22	0.5 U	2 of 2 Locations	0.5 U	--	0.5 U	100.0%
cis-1,2-Dichloroethene	70	30	OU1-52MW80	100	OU1-52MW77	65.0	3.0 B	OU1-52MW80	24	OU1-52MW77	13.5	79.2%
Methylene chloride	5	2.5 U	2 of 2 Locations	2.5 U	--	2.5 U	2.5 U	2 of 2 Locations	2.5 U	--	2.5 U	--
trans-1,2-Dichloroethene	100	1.6	OU1-52MW80	8.3	OU1-52MW77	5.0	0.5 U	OU1-52MW80	1.7	OU1-52MW77	0.85	82.8%
Trichloroethene	3	9.6	OU1-52MW80	31	OU1-52MW77	**20.3**	0.5 U	OU1-52MW80	1.3 B	OU1-52MW77	0.65	96.8%
Vinyl Chloride	0.03	3.1	OU1-52MW80	20	OU1-52MW77	**11.6**	1.0 U	OU1-52MW80	9.0	OU1-52MW77	**4.5**	61.0%
Total VOCs						102.3					19.5	**80.9%**
Lower Surficial Aquifer												
		May 2011					**September 2011**					
VOCs	**Screening Criteria**	**Minimum Value**	**Minimum Value Location**	**Maximum Value**	**Maximum Value Location**	**Average VOCs (ug/L)**	**Minimum Value**	**Minimum Value Location**	**Maximum Value**	**Maximum Value Location**	**Average VOCs (ug/L)**	**Percent VOC Reduction**
1,1,2,2-Tetrachloroethane	0.2	0.5 U	3 of 3 Locations	0.5 U	--	0.5 U	0.5 U	3 of 3 Locations	0.5 U	--	0.5 U	--
1,1-Dichloroethane	6	1.2	2 of 3 Locations	1.3	OU1-52MW78	1.2	0.56 J	OU1-52MW81	2.5 J	OU1-52MW79	1.3	-5.7%
1,1-Dichloroethene	7	2.3	OU1-52MW79	3.7	OU1-52MW81	2.8	0.7 J	OU1-52MW81	2.3 J	OU1-52MW79	1.4	51.8%
cis-1,2-Dichloroethene	70	1,200	2 of 3 Locations	1,500	OU1-52MW81	**1,300**	250	OU1-52MW81	2,200	OU1-52MW79	**1,010**	22.3%
Methylene chloride	5	2.5 U	3 of 3 Locations	2.5 U	--	2.5 U	2.5 U	2 of 3 Locations	3.2 J	OU1-52MW78	1.1	-1066.7%
trans-1,2-Dichloroethene	100	34	OU1-52MW81	110	OU1-52MW78	74.7	42	OU1-52MW81	86	OU1-52MW79	60.7	18.8%
Trichloroethene	3	440	OU1-52MW81	720	OU1-52MW78	**546.7**	11	OU1-52MW78	46	OU1-52MW79	**23.7**	95.7%
Vinyl Chloride	0.03	20	OU1-52MW79	28	OU1-52MW81	**23.7**	13	OU1-52MW81	74	OU1-52MW79	**48.7**	-105.6%
Total VOCs						1,949					1,147	**41.2%**

Notes:
All concentrations in micrograms per liter
16GW11 or MW53 not included in data evaluation
mg/L - micrograms per liter
U - Compound analyzed for but not detected
J - Reported value is estimated
B - Analyte not detected above the level reported in blanks
VOCs - Volatile organic compounds

TABLE 5

ERD Data Evaluation - 3-Month Sample Summary

Marine Corps Air Station Cherry Point

Cherry Point, North Carolina

Natural Attenuation Indicator Parameter	Lines of Evidence for Enhanced Reductive Dechlorination	Minimum Value	Minimum Value Location	Maximum Value	Maximum Value Location	Favorable/Unfavorable
Upper Surficial Aquifer						
pH	Greater than 5; Less than 9	6.14	OU1-52MW80	6.56	OU1-52MW77	Favorable
ORP (mV)	Less than +50 mV (favorable) Less than -100 mV (ideal)	-128	OU1-52MW77	-121	OU1-52MW80	Favorable
DO (mg/L)	Less than 1.0 mg/L	<0.025	2 of 2 Locations	--	--	Favorable
Nitrate (mg/L)	Less than 1.0 mg/L	<1.0	2 of 2 Locations	--	--	Favorable
Ferrous Iron (Fe^{2+}) (mg/L)	Measurable Levels	--	--	5.0	2 of 2 Locations	Favorable
Sulfate (mg/L)	Concentrations decrease below background over	<0.5	2 of 2 Locations	--	--	Favorable; concentrations decreased below background levels
Methane (mg/L)	Concentrations increase above background over time	6,000	OU1-52MW80	7,300	OU1-52MW77	Favorable; concentrations increased above background levels
Ethane (mg/L)		< 2.0	2 of 2 Locations	--	--	Unfavorable; concentrations were not detected above baseline
Ethene (mg/L)		< 2.0	OU1-52MW80	1.5 J	OU1-52MW77	Unfavorable to favorable; detected levels in one well
TOC (mg/L)	Increase above baseline	130	OU1-52MW77	450	OU1-52MW80	Favorable
VFAs (sum of all VFAs; mg/L)	Initial increase above baseline then decrease over time as substrate is utilized by microbes	85.8 D	OU1-52MW77	418.5 D	OU1-52GW80	Favorable; initial increase over baseline concentrations
Dehalococcoides Population (cells per mL)	Increase above baseline over time as ERD substrate and VOCs are utilized; cells per mL	7.2	OU1-52MW77	40.3	OU1-52MW80	Unfavorable to favorable; while *Dehalococcoides* concentrations have decreased slightly over baseline levels, there is still a detectable population
Lower Surficial Aquifer						
Natural Attenuation Indicator Parameter	**Lines of Evidence for Enhanced Reductive Dechlorination**	**Minimum Value**	**Minimum Value Location**	**Maximum Value**	**Maximum Value Location**	**Favorable/Unfavorable**
pH	Greater than 5; Less than 9	5.18	OU1-52MW78	5.88	OU1-52MW81	Favorable
ORP (mV)	Less than +50 mV (favorable) Less than -100 mV (ideal)	-277	OU1-52MW81	-81	OU1-52MW79	Favorable to Ideal
DO (mg/L)	Less than 1.0 mg/L	<0.025	2 of 3 Locations	0.2	OU1-52MW78	Favorable; 2 of 3 locations with detected DO show decreasing concentrations over baseline levels
Nitrate (mg/L)	Less than 1.0 mg/L	<1.0	2 of 3 Locations	13.2	OU1-52MW79	Favorable; 2 of 3 locations with decreasing concentrations over baseline levels
Ferrous Iron (Fe^{2+}) (mg/L)	Measurable Levels	2.2	OU1-52MW81	4.0	OU1-52MW78	Favorable
Sulfate (mg/L)	Concentrations decrease below background over time	<0.5	2 of 3 locations	7.0	OU1-52MW79	Favorable; concentrations decreased below background levels (baseline) in 3 of 3 locations
Methane (mg/L)	Concentrations increase above background over time	170	OU1-52MW79	2,600	OU1-52MW81	Favorable; concentrations increased above background levels (baseline) in 4 of 4 locations
Ethane (mg/L)		1.9 J	OU1-52GW81	5.8 J	OU1-52MW79	Favorable; concentrations increased slightly above background levels (baseline) in 2 of 3 locations
Ethene (mg/L)		1.7 J	OU1-52GW81	4.4 J	OU1-52GW78	Favorable; concentrations increased slightly above background levels (baseline) in 2 of 3 locations
TOC (mg/L)	Increase above baseline	98	OU1-52MW79	190	OU1-52GW78	Favorable; concentrations increased above background levels (baseline) in 3 of 3 locations
VFAs (sum of all VFAs; mg/L)	Initial increase above baseline then decrease over time as substrate is utilized by microbes	39.1 D	OU1-52GW81	110 D	OU1-52GW78	Favorable; initial increase over baseline concentrations in 3 of 3 locations
Dehalococcoides Population (cells per mL)	Increase above baseline over time as ERD substrate and VOCs are utilized; cells per mL	10,300	OU1-52MW78	21,600	OU1-52GW79	Favorable; *Dehalococcoides* concentrations have increased by 2 to 3 orders of magnitude over background levels (baseline) in 3 of 3 locations

Notes:
16GW11 or MW53 not included in data evaluation

mg/L - micrograms per liter
mg/L - milligrams per liter
mL - milliliters
mV - milliVolts

ND - Not detected
NTUs - nephelometric turbidity units
SU - scientfic units
VFAs - volatile fatty acids

TABLE 6

TOC and VFA Data Evaluation

Marine Corps Air Station Cherry Point

Cherry Point, North Carolina

Pilot Study Well Type	Well ID	Surficial Aquifer Zone	Screen Interval (ft bgs)	Closest Injection Well*	Distance to Closest Injection Well (ft)	Baseline TOC (mg/L)	Post Injection TOC (mg/L)	3-Month Post Injection TOC (mg/L)	Baseline VFAs (mg/L)	3-Month Post Injection VFAs (mg/L)
Newly Installed Monitoring Wells	OU1-52MW77	Upper	22 - 32	OU1-52IW05	18.4	5.2	10	130	0.349	85.8
	OU1-52MW78	Lower	38 - 48	OU1-52IW08	12.3	2.3	**3,100**	**190**	0.390	**110**
	OU1-52MW79	Lower	38 - 48	OU1-52IW10	15.5	1.7	22	98	0.394	41.5
	OU1-52MW80	Upper	22 - 32	OU1-52IW09	12.7	3.4	**1,800**	**450**	0.174	**418.5**
	OU1-52MW81	Lower	38 - 48	OU1-52IW12	11.0	4.5	**1,600**	**120**	0.460	**39.1**
Existing Monitoring Wells	16GW11	Upper	12 - 27	OU1-52IW03	11.4	1.4	7.1	1.9	0.233	0.435
	MW53	Lower	44 - 54	OU1-52IW04	10.5	1.6	2.4	1.7	0.286	0.436

Notes:
*Closest injection well screened in same aquifer as monitoring well
ft - feet
bgs - below ground surface
mg/L - milligrams per liter

Figures

Legend

- Cities
- Rivers and Streams
- Military Installation
- County Boundary

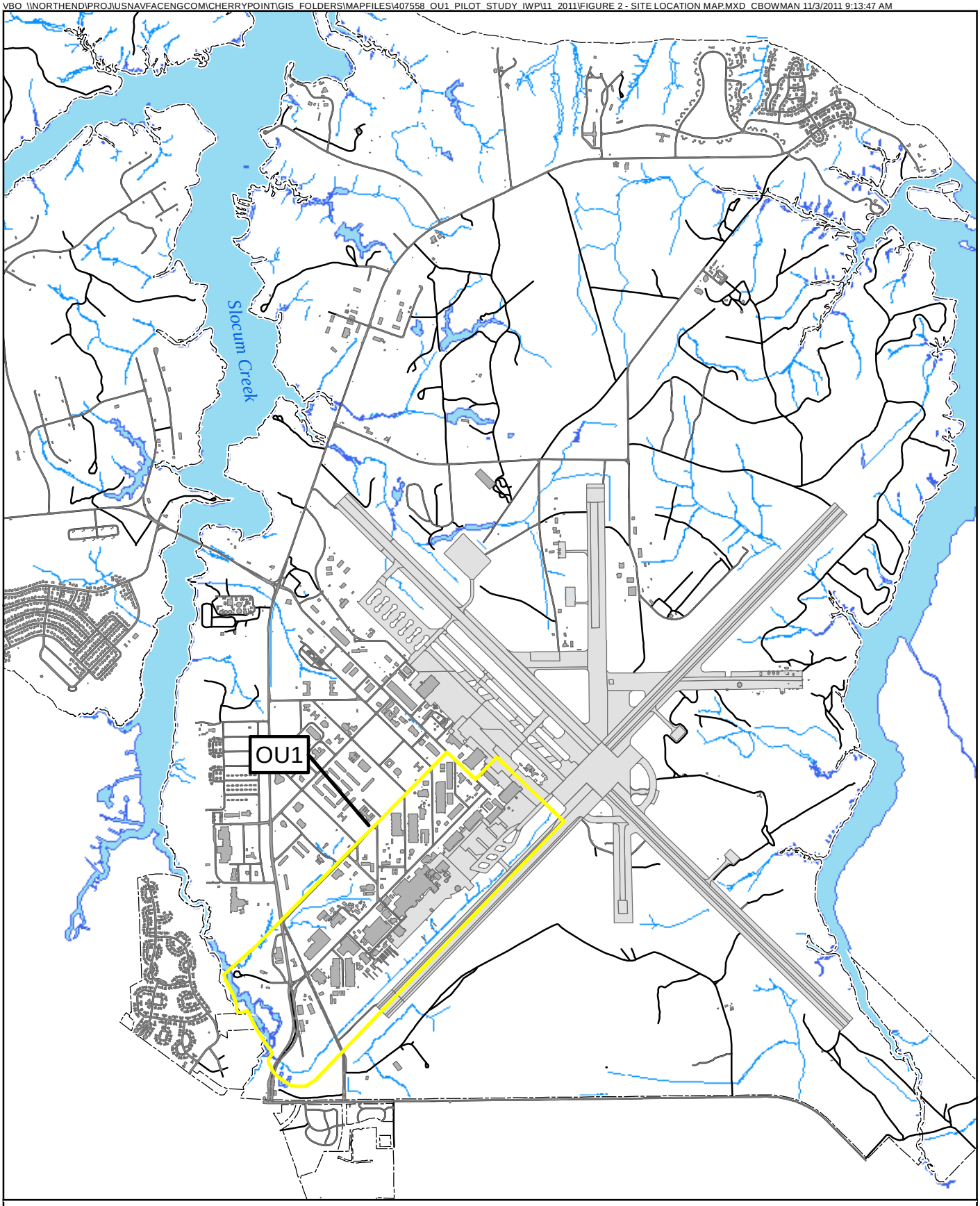
N
W E
S

0 20,000 40,000
Feet

Figure 1
Base Location Map
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL.

VBO \\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\407558_OU1_PILOT_STUDY_IWP\11_2011\FIGURE 2 - SITE LOCATION MAP.MXD CBOWMAN 11/3/2011 9:13:47 AM



Legend

- OU Boundary
- Base Boundary
- Buildings
- Runway
- Road
- Surface Water

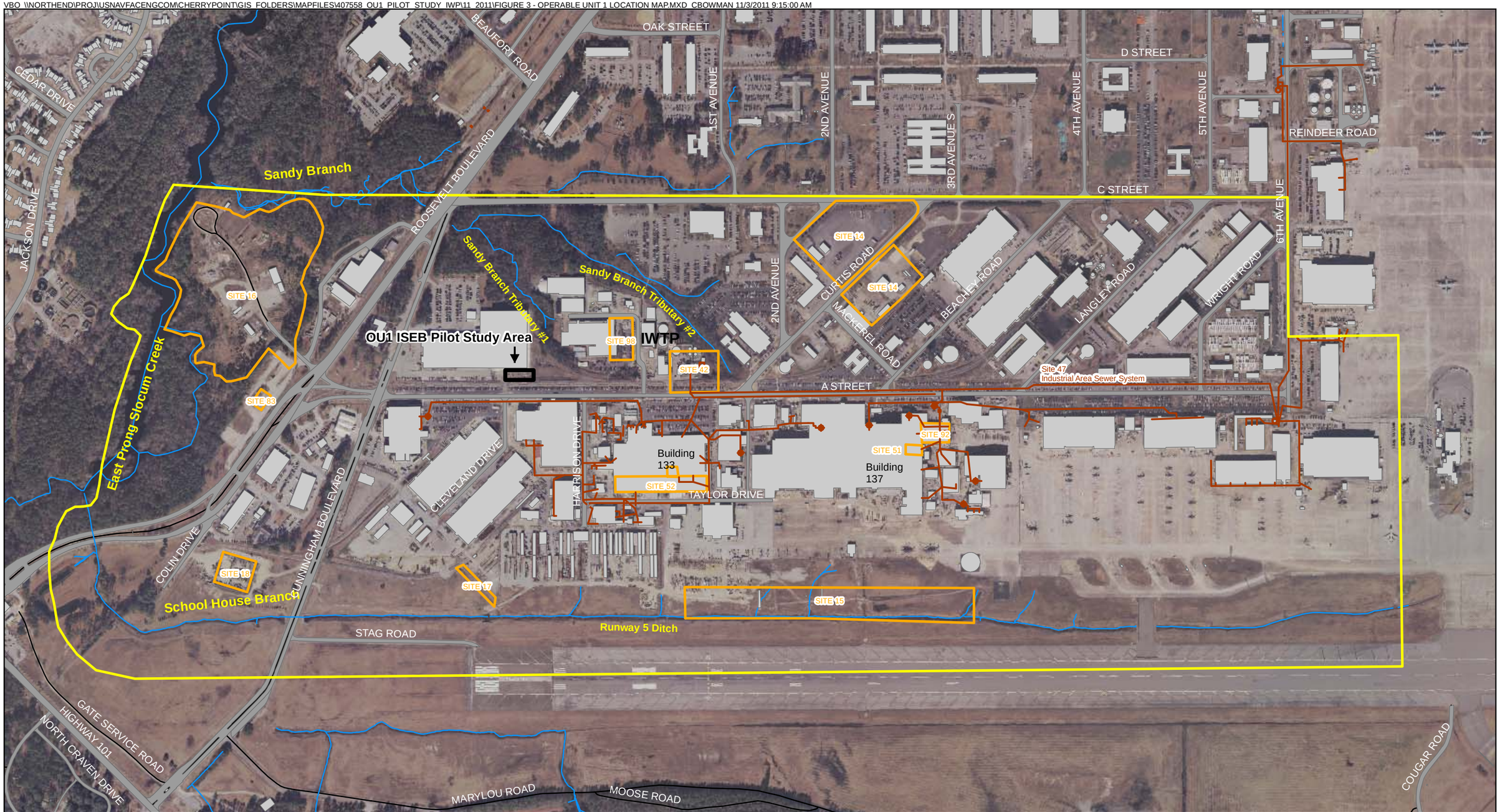
N
W E
S

0 1,500 3,000
Feet

Figure 2
OU1 Location Map
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL.

VBO \\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\407558_OU1_PILOT_STUDY_IWP\11_2011\FIGURE 3 - OPERABLE UNIT 1 LOCATION MAP.MXD CBOWMAN 11/3/2011 9:15:00 AM



Legend

- Surface Water
- Industrial Area Sewer System
- In-Situ Enhanced Bioremediation Pilot Study Area
- Site Boundary
- OU1 Boundary
- Existing Buildings

IWTP - Industrial Wastewater Treatment Plant

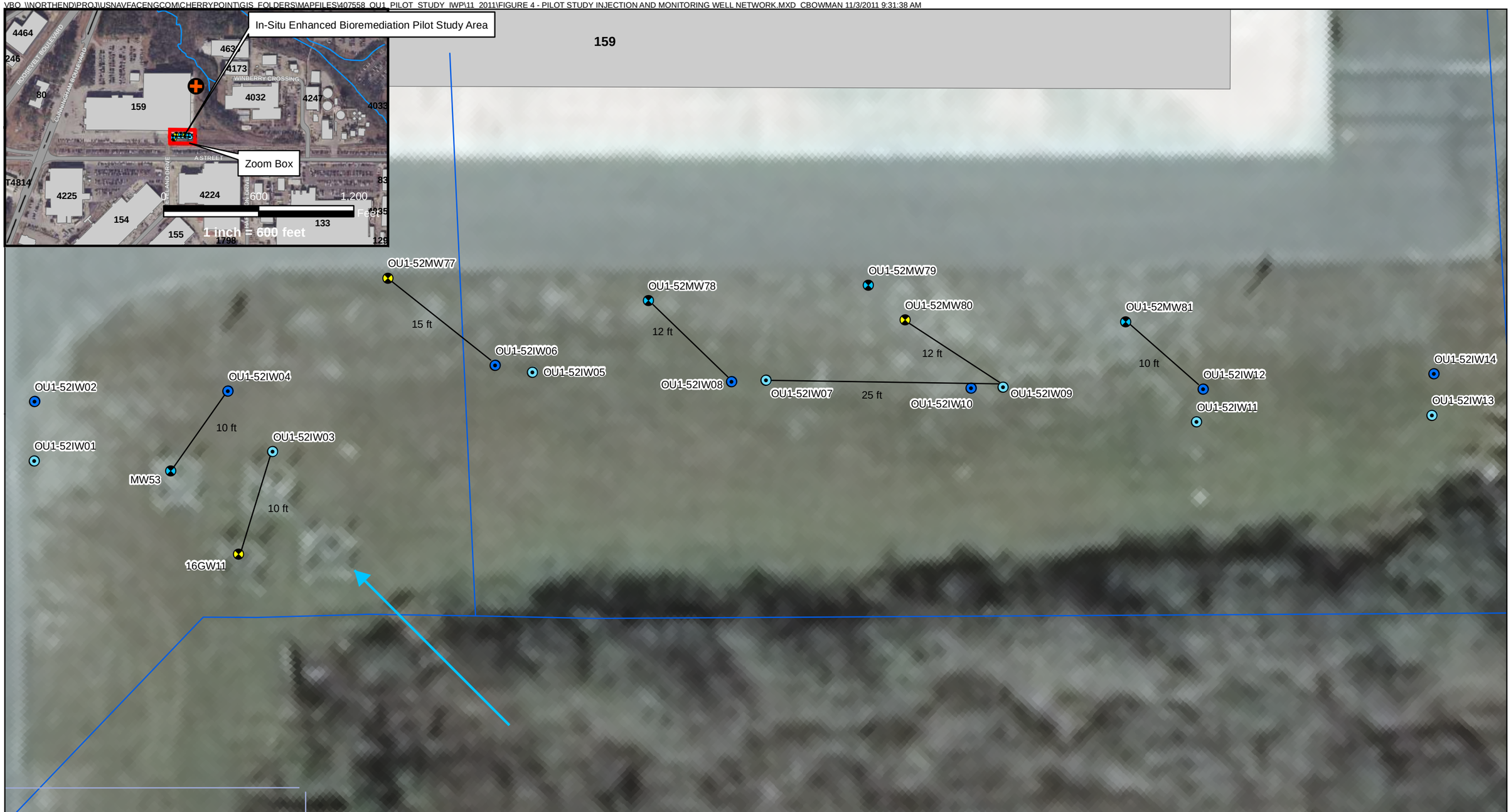
N W E S

0 600 1,200 Feet

Figure 3
Sites Within OU1
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL.

VBO \\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\407558_OU1_PILOT_STUDY_IWP\11_2011\FIGURE 4 - PILOT STUDY INJECTION AND MONITORING WELL NETWORK.MXD CBOWMAN 11/3/2011 9:31:38 AM



Legend

- Monitoring Well - Lower Surficial Aquifer
- Monitoring Well - Upper Surficial Aquifer
- Pilot Study Injection Well - Lower Surficial Aquifer
- Pilot Study Injection Well - Upper Surficial Aquifer
- Fire Hydrant
- Electrical Cable Line
- Industrial Waste Line
- Storm Sewer Line
- Water Line
- Groundwater Flow Direction
- Existing Buildings

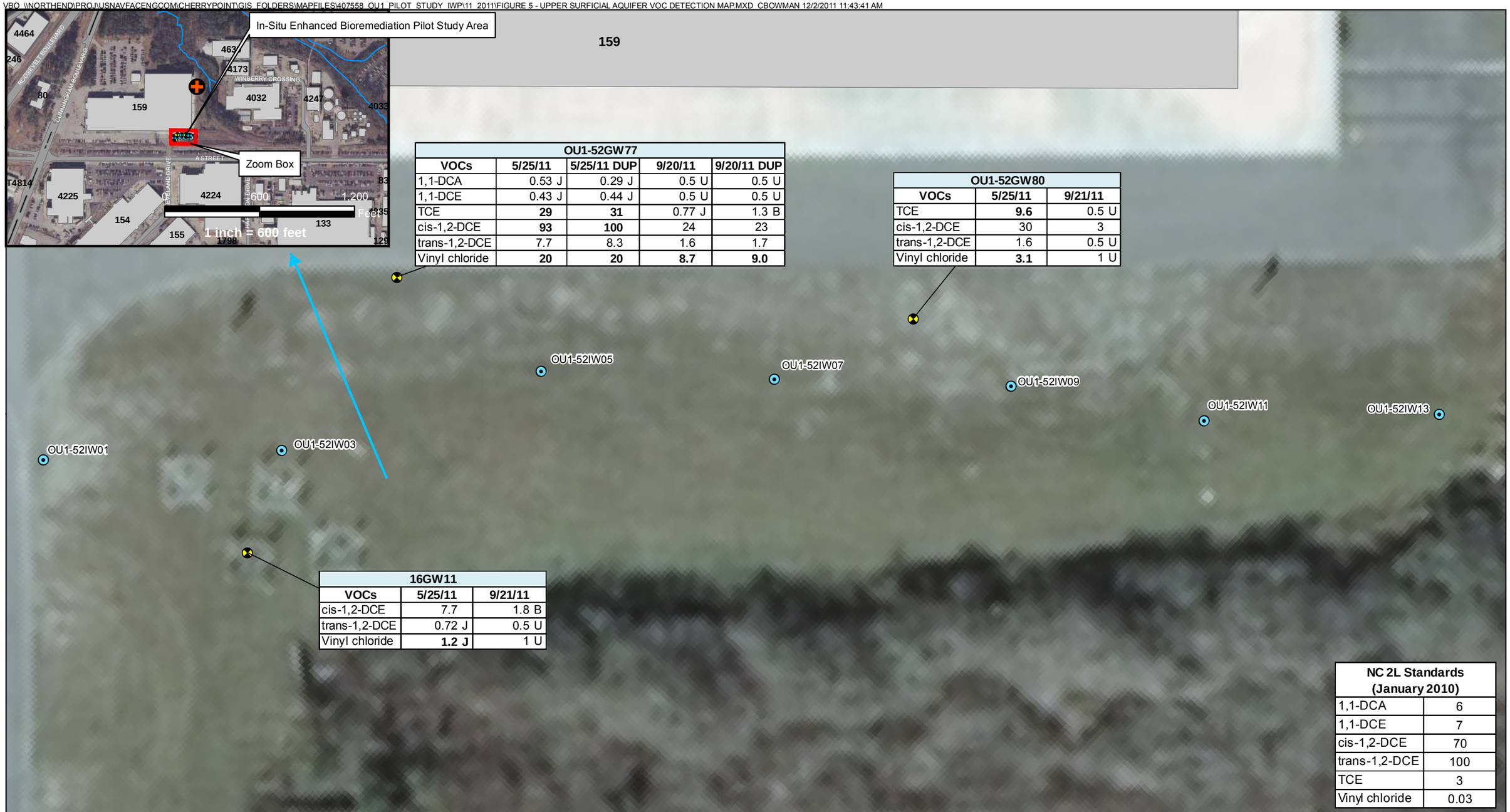
N W E S

0 10 20 Feet

1 inch = 10 feet

Figure 4
OU1 ISEB Pilot Study Injection and Monitoring Well Network
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL.



OU1-52GW77				
VOCs	5/25/11	5/25/11 DUP	9/20/11	9/20/11 DUP
1,1-DCA	0.53 J	0.29 J	0.5 U	0.5 U
1,1-DCE	0.43 J	0.44 J	0.5 U	0.5 U
TCE	**29**	**31**	0.77 J	1.3 B
cis-1,2-DCE	**93**	**100**	24	23
trans-1,2-DCE	7.7	8.3	1.6	1.7
Vinyl chloride	**20**	**20**	**8.7**	**9.0**

OU1-52GW80		
VOCs	5/25/11	9/21/11
TCE	**9.6**	0.5 U
cis-1,2-DCE	30	3
trans-1,2-DCE	1.6	0.5 U
Vinyl chloride	**3.1**	1 U

16GW11		
VOCs	5/25/11	9/21/11
cis-1,2-DCE	7.7	1.8 B
trans-1,2-DCE	0.72 J	0.5 U
Vinyl chloride	**1.2 J**	1 U

NC 2L Standards (January 2010)	
1,1-DCA	6
1,1-DCE	7
cis-1,2-DCE	70
trans-1,2-DCE	100
TCE	3
Vinyl chloride	0.03

Legend
- Monitoring Well - Upper Surficial Aquifer
- Pilot Study Injection Well - Upper Surficial Aquifer
- Fire Hydrant
- Groundwater Flow Direction
- Existing Buildings

Notes:
All VOC concentrations given in micrograms per liter (µg/L)
All VOC exceedances of NC 2L Standards are in **bold** text
1,1-DCA - 1,1-Dichloroethane
1,1-DCE - 1,1-Dichloroethene
cis-1,2-DCE - cis-1,2-Dichloroethene
trans-1,2-DCE - trans-1,2-Dichloroethene
TCE - Trichloroethene

B - Analyte not detected above the level reported in blanks
D - Compound identified in an analysis at a secondary dilution factor.
J - Analyte present. Value may or may not be accurate or precise
U - The material was analyzed for, but not detected

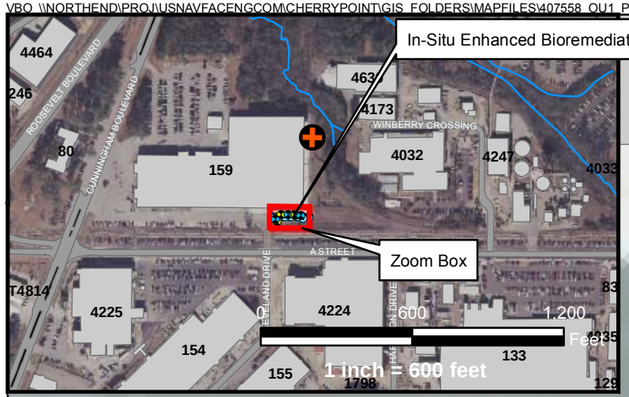
Figure 5
Upper Surficial Aquifer VOC Detections Map
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

N W E S

1 inch = 10 feet
0 10 20 Feet

CH2MHILL.

VBO \\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\407558_OU1_PILOT_STUDY_IWP\11_2011\FIGURE 6 - LOWER SURFICIAL AQUIFER VOC DETECTIONS MAP.MXD CBOWMAN 12/1/2011 4:25:52 PM



159

OU1-52GW78		
VOCs	5/25/11	9/20/11
1,1-DCA	1.3	0.85 J
1,1-DCE	2.5	1.1
TCE	**720**	**11**
cis-1,2-DCE	**1,200**	**580**
trans-1,2-DCE	**110**	54
Vinyl chloride	**23**	**59**

OU1-52GW79		
VOCs	5/25/11	9/20/11
1,1-DCA	1.2	2.5 J
1,1-DCE	2.3	2.3 J
TCE	**480**	**46**
cis-1,2-DCE	**1,200**	**2,200**
trans-1,2-DCE	80	86
Vinyl chloride	**20**	**74**

OU1-52GW81		
VOCs	5/25/11	9/21/11
1,1-DCA	1.2	0.56 J
1,1-DCE	3.7	0.7 J
TCE	**440**	**14**
cis-1,2-DCE	**1,500**	**250**
trans-1,2-DCE	34	42
Vinyl chloride	**28**	**13**

OU1-52IW02
OU1-52IW04
OU1-52IW06
OU1-52IW08
OU1-52IW10
OU1-52IW12
OU1-52IW14

MW53		
VOCs	5/25/11	9/20/11
1,1-DCE	0.93 J	1.6
TCE	**610**	**680**
cis-1,2-DCE	**400**	**610**
trans-1,2-DCE	**120**	**190**
Vinyl chloride	**1.5 J**	**2.8**

NC 2L Standards (January 2010)	
1,1-DCA	6
1,1-DCE	7
cis-1,2-DCE	70
trans-1,2-DCE	100
TCE	3
Vinyl chloride	0.03

Legend
- Monitoring Well - Lower Surficial Aquifer
- Pilot Study Injection Well - Lower Surficial Aquifer
- Fire Hydrant
- Groundwater Flow Direction
- Existing Buildings

Notes:
All VOC concentrations given in micrograms per liter (µg/L)
All VOC exceedances of NC 2L Standards are in **bold** text
1,1-DCA - 1,1-Dichloroethane
1,1-DCE - 1,1-Dichloroethene
cis-1,2-DCE - cis-1,2-Dichloroethene
trans-1,2-DCE - trans-1,2-Dichloroethene
TCE - Trichloroethene

B - Analyte not detected above the level reported in blanks
D - Compound identified in an analysis at a secondary dilution factor.
J - Analyte present. Value may or may not be accurate or precise
U - The material was analyzed for, but not detected

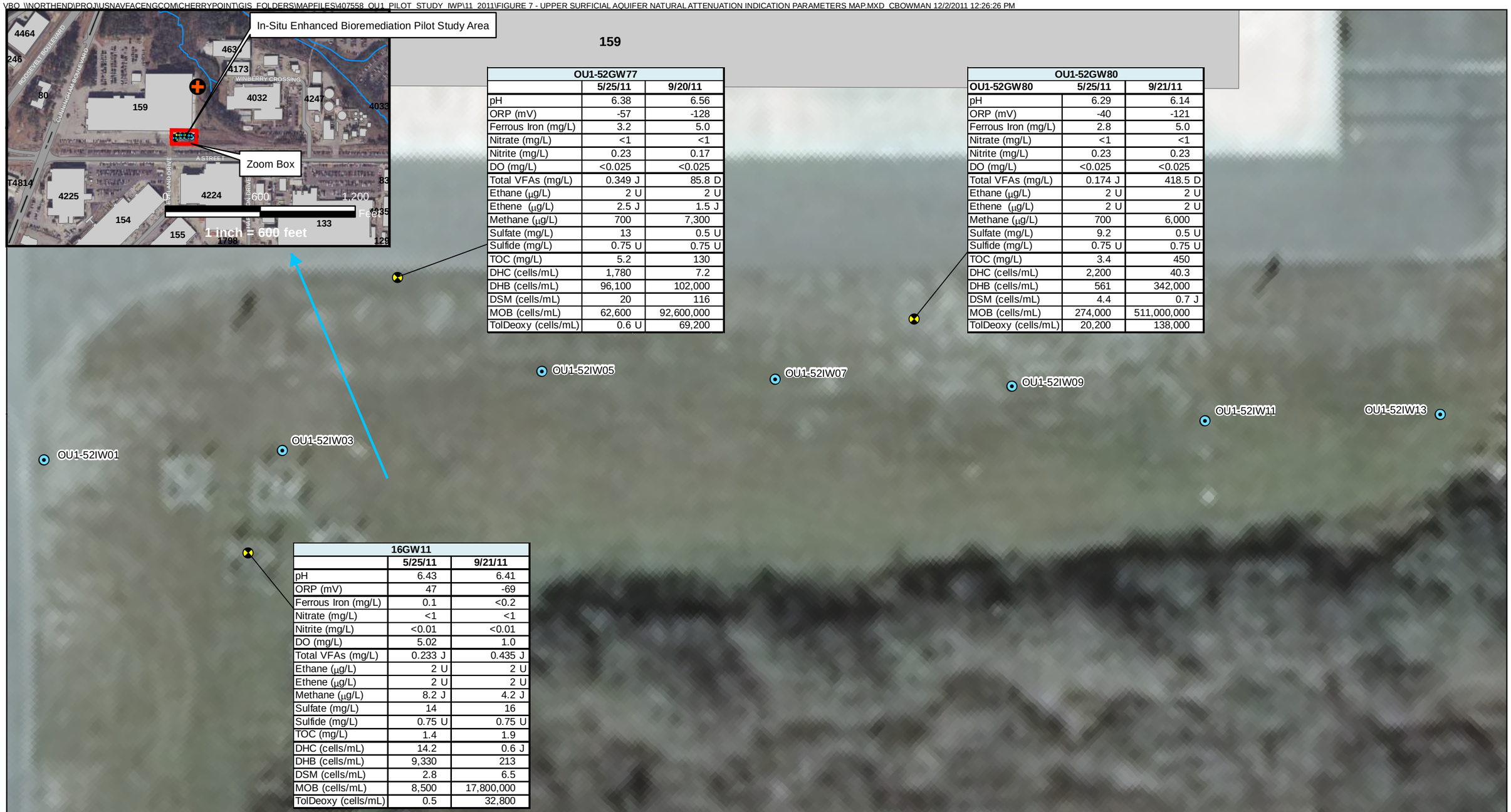
1 inch = 10 feet

0 10 20 Feet

Figure 6
Lower Surficial Aquifer VOC Detections Map
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL.

VBO \\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\407558_OU1_PILOT_STUDY_IWP\11_2011\FIGURE 7 - UPPER SURFICIAL AQUIFER NATURAL ATTENUATION INDICATION PARAMETERS MAP.MXD CBOWMAN 12/2/2011 12:26:26 PM



OU1-52GW77		
	5/25/11	9/20/11
pH	6.38	6.56
ORP (mV)	-57	-128
Ferrous Iron (mg/L)	3.2	5.0
Nitrate (mg/L)	<1	<1
Nitrite (mg/L)	0.23	0.17
DO (mg/L)	<0.025	<0.025
Total VFAs (mg/L)	0.349 J	85.8 D
Ethane (μg/L)	2 U	2 U
Ethene (μg/L)	2.5 J	1.5 J
Methane (μg/L)	700	7,300
Sulfate (mg/L)	13	0.5 U
Sulfide (mg/L)	0.75 U	0.75 U
TOC (mg/L)	5.2	130
DHC (cells/mL)	1,780	7.2
DHB (cells/mL)	96,100	102,000
DSM (cells/mL)	20	116
MOB (cells/mL)	62,600	92,600,000
TolDeoxy (cells/mL)	0.6 U	69,200

OU1-52GW80		
OU1-52GW80	5/25/11	9/21/11
pH	6.29	6.14
ORP (mV)	-40	-121
Ferrous Iron (mg/L)	2.8	5.0
Nitrate (mg/L)	<1	<1
Nitrite (mg/L)	0.23	0.23
DO (mg/L)	<0.025	<0.025
Total VFAs (mg/L)	0.174 J	418.5 D
Ethane (μg/L)	2 U	2 U
Ethene (μg/L)	2 U	2 U
Methane (μg/L)	700	6,000
Sulfate (mg/L)	9.2	0.5 U
Sulfide (mg/L)	0.75 U	0.75 U
TOC (mg/L)	3.4	450
DHC (cells/mL)	2,200	40.3
DHB (cells/mL)	561	342,000
DSM (cells/mL)	4.4	0.7 J
MOB (cells/mL)	274,000	511,000,000
TolDeoxy (cells/mL)	20,200	138,000

16GW11		
	5/25/11	9/21/11
pH	6.43	6.41
ORP (mV)	47	-69
Ferrous Iron (mg/L)	0.1	<0.2
Nitrate (mg/L)	<1	<1
Nitrite (mg/L)	<0.01	<0.01
DO (mg/L)	5.02	1.0
Total VFAs (mg/L)	0.233 J	0.435 J
Ethane (μg/L)	2 U	2 U
Ethene (μg/L)	2 U	2 U
Methane (μg/L)	8.2 J	4.2 J
Sulfate (mg/L)	14	16
Sulfide (mg/L)	0.75 U	0.75 U
TOC (mg/L)	1.4	1.9
DHC (cells/mL)	14.2	0.6 J
DHB (cells/mL)	9,330	213
DSM (cells/mL)	2.8	6.5
MOB (cells/mL)	8,500	17,800,000
TolDeoxy (cells/mL)	0.5	32,800

Legend

- Monitoring Well - Upper Surficial Aquifer
- Pilot Study Injection Well - Upper Surficial Aquifer
- Fire Hydrant
- Groundwater Flow Direction
- Existing Buildings

Notes:
μg/L - micrograms per liter
mg/L - milligrams per liter
mL - milliliters
mV - milliVolts
SU - scientfic units
VFAs - volatile fatty acids

J - Analyte present. Value may or may not be accurate or precise
U - The material was analyzed for, but not detected
DHB - *Dehalobacter*
DHC - *Dehalococcoides*
DSM - *Desulfuromonas*
MOB - Methane Oxidizing Bacteria
TolDeoxy - Toluene Deoxygenase

N
W
E
S

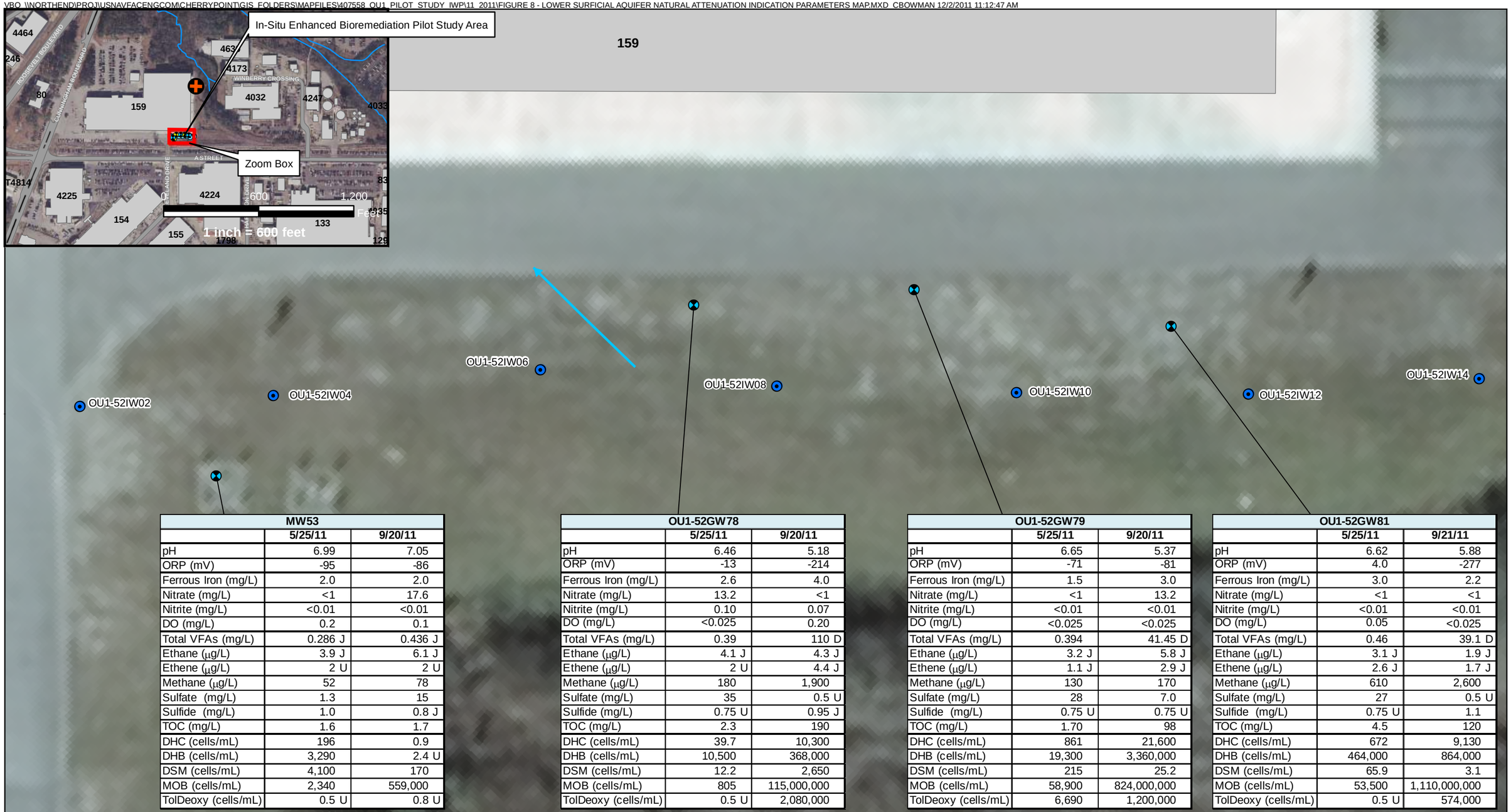
0 10 20 Feet

1 inch = 10 feet

Figure 7
Upper Surficial Aquifer Natural Attenuation Indication Parameters Map
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL.

VBO \\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\407558_OU1_PILOT_STUDY_IWP\11_2011\FIGURE 8 - LOWER SURFICIAL AQUIFER NATURAL ATTENUATION INDICATION PARAMETERS MAP.MXD CBOWMAN 12/2/2011 11:12:47 AM



MW53		
	5/25/11	9/20/11
pH	6.99	7.05
ORP (mV)	-95	-86
Ferrous Iron (mg/L)	2.0	2.0
Nitrate (mg/L)	<1	17.6
Nitrite (mg/L)	<0.01	<0.01
DO (mg/L)	0.2	0.1
Total VFAs (mg/L)	0.286 J	0.436 J
Ethane (µg/L)	3.9 J	6.1 J
Ethene (µg/L)	2 U	2 U
Methane (µg/L)	52	78
Sulfate (mg/L)	1.3	15
Sulfide (mg/L)	1.0	0.8 J
TOC (mg/L)	1.6	1.7
DHC (cells/mL)	196	0.9
DHB (cells/mL)	3,290	2.4 U
DSM (cells/mL)	4,100	170
MOB (cells/mL)	2,340	559,000
TolDeoxy (cells/mL)	0.5 U	0.8 U

OU1-52GW78		
	5/25/11	9/20/11
pH	6.46	5.18
ORP (mV)	-13	-214
Ferrous Iron (mg/L)	2.6	4.0
Nitrate (mg/L)	13.2	<1
Nitrite (mg/L)	0.10	0.07
DO (mg/L)	<0.025	0.20
Total VFAs (mg/L)	0.39	110 D
Ethane (µg/L)	4.1 J	4.3 J
Ethene (µg/L)	2 U	4.4 J
Methane (µg/L)	180	1,900
Sulfate (mg/L)	35	0.5 U
Sulfide (mg/L)	0.75 U	0.95 J
TOC (mg/L)	2.3	190
DHC (cells/mL)	39.7	10,300
DHB (cells/mL)	10,500	368,000
DSM (cells/mL)	12.2	2,650
MOB (cells/mL)	805	115,000,000
TolDeoxy (cells/mL)	0.5 U	2,080,000

OU1-52GW79		
	5/25/11	9/20/11
pH	6.65	5.37
ORP (mV)	-71	-81
Ferrous Iron (mg/L)	1.5	3.0
Nitrate (mg/L)	<1	13.2
Nitrite (mg/L)	<0.01	<0.01
DO (mg/L)	<0.025	<0.025
Total VFAs (mg/L)	0.394	41.45 D
Ethane (µg/L)	3.2 J	5.8 J
Ethene (µg/L)	1.1 J	2.9 J
Methane (µg/L)	130	170
Sulfate (mg/L)	28	7.0
Sulfide (mg/L)	0.75 U	0.75 U
TOC (mg/L)	1.70	98
DHC (cells/mL)	861	21,600
DHB (cells/mL)	19,300	3,360,000
DSM (cells/mL)	215	25.2
MOB (cells/mL)	58,900	824,000,000
TolDeoxy (cells/mL)	6,690	1,200,000

OU1-52GW81		
	5/25/11	9/21/11
pH	6.62	5.88
ORP (mV)	4.0	-277
Ferrous Iron (mg/L)	3.0	2.2
Nitrate (mg/L)	<1	<1
Nitrite (mg/L)	<0.01	<0.01
DO (mg/L)	0.05	<0.025
Total VFAs (mg/L)	0.46	39.1 D
Ethane (µg/L)	3.1 J	1.9 J
Ethene (µg/L)	2.6 J	1.7 J
Methane (µg/L)	610	2,600
Sulfate (mg/L)	27	0.5 U
Sulfide (mg/L)	0.75 U	1.1
TOC (mg/L)	4.5	120
DHC (cells/mL)	672	9,130
DHB (cells/mL)	464,000	864,000
DSM (cells/mL)	65.9	3.1
MOB (cells/mL)	53,500	1,110,000,000
TolDeoxy (cells/mL)	0.5 U	574,000

Legend

- Monitoring Well - Lower Surficial Aquifer
- Pilot Study Injection Well - Lower Surficial Aquifer
- Fire Hydrant
- Groundwater Flow Direction
- Existing Buildings

Notes:
µg/L - micrograms per liter
mg/L - milligrams per liter
mL - milliliters
mV - milliVolts
SU - scientfic units
VFAs - volatile fatty acids

J - Analyte present. Value may or may not be accurate or precise
U - The material was analyzed for, but not detected
DHB - *Dehalobacter*
DHC - *Dehalococcoides*
DSM - *Desulfuromonas*
MOB - Methane Oxidizing Bacteria
TolDeoxy - Toluene Deoxygenase

N S E W

0 10 20 Feet

1 inch = 10 feet

Figure 8
Lower Surficial Aquifer Natural Attenuation Indication Parameters Map
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

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