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CORRECTIVE MEASURES IMPLEMENTATION PLAN SOLID WASTE MANAGEMENT UNIT 55 WITH TRANSMITTAL AND RESPONSE TO COMMENTS NAVAL ACTIVITY PUERTO RICO

6/1/2012

AGVIQ/CH2M HILL

AGVIQ
ENVIRONMENTAL SERVICES
CH2M HILL
JOINT VENTURE

June 15, 2012

U.S. Environmental Protection Agency – Region II
290 Broadway – 22nd Floor
New York, New York 10007-1866

Attn: Mr. Phil Flax

RE: Contract No. N62470-08-D-1006
Task Order No. JM04
Solid Waste Management Unit (SWMU) 55
Naval Activity Puerto Rico – Ceiba, Puerto Rico
Corrective Measures Implementation Plan for SWMU 55

Dear Mr. Flax:

AGVIQ-CH2M HILL Constructors Inc. Joint Venture III (AGVIQ-CH2M HILL), on behalf of the Navy, is pleased to provide one hard copy and one electronic copy provided on CD of the Corrective Measures Implementation Plan for SWMU 55 at Naval Activity Puerto Rico. Additional distribution has been made as indicated below.

If you have any questions regarding this submittal, please contact Mr. Stacin Martin at (757) 322-4080.

Sincerely,

AGVIQ-CH2M HILL Constructors Inc. Joint Venture III

Tom Beisel, P.G.
Project Manager

cc: Ms. Debra Evans-Ripley/BRAC PMO SE (letter only)
Mr. David Criswell/BRAC PMO SE (letter only)
Mr. Tim Gordon/USEPA Region II (2 hard copies and 2 CDs)
Mr. Mark E. Davidson, BRAC PMO SE (1 hard copy and 1 CD)
Mr. Stacin Martin/NAVFAC Atlantic (1 hard copy and 1 CD)
Mr. Pedro Ruiz/NAPR (1 CD)
Mr. Carl Soderberg/USEPA Caribbean Office (1 hard copy and 1 CD)
Ms. Gloria Toro/PR EQB (1 hard copy and 1 CD)
Ms. Wilmarie Rivera/PR EQB (1 CD)
Ms. Connie Crossley/Booz Allen Hamilton (1 hard copy and 1 CD)
Ms. Bonnie Capito/NAVFAC LANTDIV (1 hard copy)
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Responses to Comments Summary	
Regulatory Comments from:	Timothy R. Gordon (EPA Project Coordinator), Cathy Dare (TechLaw, Inc.), Wilmarie Rivera (PREQB Federal Facilities Coordinator)
Document:	*Corrective Measures Implementation Plan*, Naval Activity Puerto Rico (NAPR), EPA ID PR2170027203, Ceiba, Puerto Rico, dated January 2012
Regulatory Letter Date:	Email Dated: February 28, 2012
Response Due Date:	June 18, 2012
Response Submittal Date:	June 18, 2012

The following comments were generated based on a technical review of the Response to EPA Comments dated October 3, 2011 on the *Corrective Measures Implementation Plan for SWMU 55,* dated August 2011. The revised *Corrective Measures Implementation Plan for SWMU 55,* dated January 2012 (CMI) was also evaluated for compliance with the responses. An evaluation of the Responses to Comments (RTCs) is presented first below. Only those comments which were not adequately addressed are included below. After the RTC evaluation, additional general and specific comments on the January 2012 CMI are presented.

EPA GENERAL COMMENTS

Evaluation of the Response to EPA General Comment 3: The response partially addresses the comment; however, the requested supporting basis for the proposed monitoring is not provided as part of the CMI Section 2.0. For understanding, regulatory oversight, and defensibility, the CMI should include a discussion of the basis by which the monitoring program well selection, measured parameters, and frequency were determined. The supporting basis should be included in each of the Section 2.0 sub-sections to explain the decision process in determining the proposed monitoring regime necessary to ensure compliance with the corrective action objectives (CAOs), contaminant plume control, and protection of human health and the environment. Revise the CMI to include supporting basis documentation relative to each element of the monitoring program.

Response:
Section 2.0 of the CMI has been revised to include the requested information.

Evaluation of Response to EPA General Comment 5 and Specific Comment 19: The response partially addresses the comment. The CMS Addendum should specify the type of sampling which needs to be conducted on the remedial wastes generated during the excavation. In addition, the sampling of these wastes is not included in the site-specific Sampling and Analysis Plan (SAP). Revise the CMI and SAP to discuss the appropriate sample(s) to be collected to characterize the excavated soils prior to reuse or disposal.

Response:
Section 1.7.1 of the CMI has been revised to include the sample type.

Evaluation of the Response to EPA General Comment 8: The response partially addresses the comment. The CMI, Section 3.2.2, Groundwater Monitoring and Injection Well Installation, indicates that for each newly constructed well "headspace screening using a photoionization detector (PID)" will be conducted; however the CMI does not discuss why this data will be collected, provide criteria for evaluating the headspace data, or explain how this data will be used. Also, this PID sampling is also not included in the Sampling and Analysis Plan (SAP). Revise the CMI and SAP to discuss the rationale for collecting headspace data, provide sampling criteria to evaluate this data, and explain how the data will be used.

Response:
Section 3.2.2 of the CMI has been revised to remove the collection of headspace data from the well installation description.

Evaluation of the Response to EPA General Comment 13: The response partially addresses the comment. The response and CMI do not consider tidal influence or water table mounding due to precipitation. The gravel and bioreactor may behave like an injection well, so mounding during and after precipitation events is possible. In addition, tidal influence on this structure has not been considered; since gravel will provide less resistance than soil, it is possible that more tidal influence will be observed in the gravel-filled excavation than in nearby wells, resulting in a more significant water table rise in the excavation. The basis for the statement in Section 3.4 that the permanganate will remain below the top of the gravel layer is not provided. Further, the description of the design and construction of the bioreactor is not sufficient to verify that there will be adequate separation of the sodium permanganate ($NaMnO_4$) from the mulch. Section 1.4, Contaminant Migration Potential states there is 0.25 feet of tidal fluctuation. The gravel with mulch should be placed such that the bottom of the mulch is at least 0.25 or 0.5 feet above the highest expected groundwater level, considering both tidal influence and infiltrating precipitation. Otherwise, if it rains and there is tidal fluctuation, permanganate may rise into the mulch and be consumed by the organics in the mulch. As part of the design, a distance should be specified to maintain separation of the $NaMnO_4$ from the mulch (e.g., gravel in the bottom, permanganate injection into gravel, x feet of additional gravel, topped by 8 feet of gravel mixed with mulch). Revise the CMI to provide engineered schematics, construction details, and process steps which be implemented to maintain adequate separation between the $NaMnO_4$ and the mulch.

Response:
A 3-layer, finite element model using the modeling code MicroFEM (http://www.microfem.com/) was run to evaluate the amount of time required for the $NaMnO_4$ solution to infiltrate into groundwater. Assuming an initial 2 feet of head, it is expected that all but about 0.5 foot of the $NaMnO_4$ solution will infiltrate after 1 day. Therefore, potential rise in the water table due to precipitation infiltration will not be a significant issue. The CMI has been revised to include this information.

Groundwater levels were measured at multiple time points on April 29, 2010. The data were collected within 2.5 hours of the morning low tide, during the morning high tide, and within 30 minutes of the afternoon low tide. The maximum change in water elevation of 0.26 feet (about 3 inches) was measured at well 55MW19, located near Ensenada Honda. Therefore, minimal impact to the bioreactor is expected.

Additional groundwater level measurements in the source area were collected at multiple times on June 21, 2011. These measurements were collected within 0.5 hours of the morning low tide and 1.5 hours of the afternoon high tide. The maximum change in elevation of 0.04 foot (about 0.5 inch) was measured at well 55IW01.

The 1,800 gallons of $NaMnO_4$ should only fill about 2 feet of the infiltration gallery. Therefore, ISCO reagent is not expected to come into contact with the mulch as a result of fluctuations in the groundwater level. Mounding of the water table during the ISB phase will help in distribution of organic material as the mounding subsides.

Construction details provided in the CMI are sufficient to complete construction of the system.

EPA SPECIFIC COMMENTS

Evaluation of Response to EPA Specific Comment 2, EPA Specific Comment 20, and EPA Specific Comment 21: The responses partially address the comments. The response indicates that the calculations are included in the CMI Appendix B; however, Appendix B shows only parameters used and assumed calculated values and does not include the actual derivation calculations which can be verified. In addition, the supporting basis indicated in Section 3.5 simply relies on an estimate used for a previous similar project and does not include calculations for residence time and bioreactor size determinations based on actual site specific parameters such as groundwater flow, degradation rate, and maximum concentration of the contaminants present. The determination of the bioreactor design size and residence time should be based on appropriate methodologies presented in EPA or industry guidance such as the Air Force Center for Engineering and the Environment, *Technical Protocol For Enhanced Anaerobic Bioremediation Using Permeable Mulch Biowalls And Bioreactors,* dated May 2008. The CMI should be revised to provide a basis of design for the bioreactor, using industry accepted methodologies which incorporate site-specific parameters to determine treatment needs and design specifications. Methodologies and actual calculations may be documented in the CMI Appendix B. See also the Additional General Comment 1 below for additional discussion concerning the remedy design requirements.

Response:
The calculation sheets have been expanded.

The residence time was not a calculated value. The number is based on collective site data provided in the CMS demonstrating a residence time of 10 to 14 days is required to achieve TCE treatment within the bioreactor.

The bioreactor guidance document referenced, *Technical Protocol For Enhanced Anaerobic Bioremediation Using Permeable Mulch Biowalls And Bioreactors,* was developed, in part, by the AGVIQ-CH2M HILL senior technical consultant on this project, Doug Downey. The document was completed very early in the development of the technology and significantly more data have been collected since the publication of the guidance document than was available prior to its writing, resulting in general industry revisions to the technical approach. Industry accepted methodologies have been used in design of this remedy.

EPA ADDITIONAL GENERAL COMMENTS

1. The CMI does not meet the minimum requirements outlined in the Final RCRA Corrective Action Plan, OSWER 9902.3-2A, dated May 1994 (CA Guidance) relative to the remedy design plans and specifications that are based on the conceptual design. CMI Figures 3-3 and 3-4 may serve as conceptual design; however, the CMI does not discuss the development or schedule for providing the 100% (or intermediate) design point plans and specifications.

   The CA Guidance states the following in Section III: Intermediate Plans and Specifications (30, 50, 60, 90 and/or 95% Design Point):

"The Permittee/Respondent shall prepare draft Plans and Specifications that are based on the Conceptual Design but include additional design detail. A draft Operation and Maintenance Plan and Construction Workplan shall be submitted to the implementing agency simultaneously with the draft Plans and Specifications. The draft design package must include drawings and specifications needed to construct the corrective measure. Depending on the nature of the corrective measure, many different types of drawings and specifications may be needed. Some of the elements that may be required are:
- *General Site Plans*
- *Process Flow Diagrams*
- *Mechanical Drawings*
- *Electrical Drawings*
- *Structural Drawings*
- *Piping and Instrumentation Diagrams*
- *Excavation and Earthwork Drawings*
- *Equipment Lists*
- *Site Preparation and Field Work Standards*
- *Preliminary Specifications for Equipment and Material*

General correlation between drawings and technical specifications is a basic requirement of any set of working construction plans and specifications."

Revise the CMI to include a discussion of the need for the development of design plans and specifications which meet the criteria established in the CA Guidance including a schedule of completion and submittal to regulatory agencies for review. The discussion should identify if intermediate plans and specifications (i.e., 30, 50, 60, 90 and/or 95% Design Point) will be necessary or if only the 100% design will be developed.

Response:
As indicated in the CMI Section 3, Final Plans and Specifications, the final remedy design has been provided in the CMI.

As explained in Section 2 of the CMI, a draft OM&M Plan will be provided after system installation.

The CMI will act as the Construction Work Plan.

Drawing and specifications to construct the corrective measure have been provided in the CMI. These include:

- General site plans
- Site preparation and field work standards.
- Preliminary specifications for material

Because of the simplicity of the system, the following plans are not required:

- Process flow diagram
- Mechanical drawings
- Electrical drawings
- Structural drawings
- Piping and instrumentation diagrams
- Excavation and earthwork drawings
- Equipment lists

No additional design plans or specifications are required to complete the system installation.

2. For clarity and understanding, the CMI should include a matrix table which documents each SWMU 55 well and the proposed sampling during each phase. The table should include the well number, monitoring group (e.g. Pre-ISB, Trichloroethene (TCE) Plume Stability, etc), and the rationale for selection (or exclusion) of the well. For clarity, revise the CMI to include a matrix table that lists each well and the monitoring group(s) to which it is assigned as well as the rationale for including or excluding the well from the sampling program.

   Response:
   Section 2 of the CMI has been revised to include the requested matrix table .

EPA ADDITIONAL SPECIFIC COMMENTS

1. **Section 1.4, Contaminant Migration Potential, Page 1-9:** The explanation in the first bullet at the top of page 1-9 does not take diurnal tidal fluctuations into account. Twice each day, for several hours before and after low tide, groundwater flow should be toward Ensenada Honda. This is not discussed in the text and it is unclear if groundwater measurements have been collected from all site wells within 2 hours of lower low tide to evaluate the groundwater flow direction(s) at low tide. In addition, the potential impact of the Saprolite on groundwater flow is not discussed. Further, this explanation is inconsistent with the discussion of the horizontal hydraulic gradient in the next paragraph. Revise the CMI to discuss the potential impacts due to tidal fluctuations and the Saprolite on groundwater flow. Also, state whether water levels have been collected from all site wells within 2 hours of lower low tide.

   Response:
   The text in Section 1.4 has been revised for clarity.

2. **Section 1.4, Contaminant Migration Potential, Page 1-9:** An upward gradient is not a barrier to dense non-aqueous phase liquid (DNAPL) transport. Since the maximum detected concentration of TCE exceeds 1 percent (%) of the aqueous solubility of TCE, it is likely that a DNAPL is present. Statements that the upward gradient is a full or part-time "barrier ... for downward contaminant migration" should be deleted. Revise this section to acknowledge that upward gradients are not barriers to DNAPL transport and delete instances of the quoted statement.

   Response:
   The text in Section 1.4 has been revised for clarity.

3. **Section 1.5.3, Downgradient Plume Approach, Page 1-14:** This section indicates that "the MNA [monitored natural attenuation] potential and stability of the distal portion of the plume should be evaluated over time." The determination of monitored natural attenuation (MNA) should be conducted as a MNA study in accordance with the US EPA *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (EPA/600/R-98/128) dated September 1998 (MNA Guidance). The CMI does not address the need for a MNA study meeting the standards of the MNA Guidance. The MNA study work plan should be included as part of the CMI or identified as a subsequent separate document. The CMI should also discuss applicable goals and objectives to be addressed by the MNA study work plan. Revise the CMI to discuss inclusion of MNA as a remedy component in accordance with the MNA Guidance and either include a MNA work plan in the CMI Plan or discuss the provisions for conducting the study and subsequent development of an appropriate work plan.

   Response:
   The CMS Addendum and the CMI have been revised to include text addressing the potential need for an MNA study.

4. **Section 1.5.4, Land Use Controls, Page 1-14:** The CMI discussion relative to land use controls (LUCs) should include details describing the specific LUCs, monitoring requirements, contingencies if the conditions are not met, and the requirements and process for removal of the LUCs. The CMI does not provide the detailed information necessary to verify if the LUCs will be effective in the protection of human health and the environment. Revise the CMI to detail the LUC portion of the remedy such that a determination of protectiveness can be made. At a minimum the details should include those items indicated above.

   Response:
   The LUCs are summarized in Section 1.5.4 of the CMI; however, details of the LUCs are provided in the Quitclaim Deed for Parcel 2.

5. **Section 1.5.5, Summary of Major Assumptions, ERD [enhanced reductive dechlorination] and MNA will not be affected by groundwater salinity, Page 1-15:** The CMI does not provide sufficient basis to support the assumption that salinity will not impact enhanced reductive dechlorination (ERD) and MNA. A map that depicts the salinity in each well with superimposed trichloroethylene (TCE) and cis-1,2-dichloroethene (DCE) concentration contours may provide data which can be used to verify this assumption. Revise the CMI to provide a map that depicts the salinity in each well with superimposed TCE and DCE concentration contours.

   Response:
   The requested figure has been provided. There are not sufficient data points to generate contours.

6. **Section 1.5.5, Summary of Major Assumptions, Rate of natural attenuation occurring, Page 1-15:** This section bullet states that the extent of soil contamination will be delineated under this CMI plan, but the list of data gaps does not include delineating the extent of TCE in soil to determine the location and size of the proposed excavation area. Revise the CMI to identify and address this data gap. Additionally, the delineation sampling needs to be included in the SAP; revise the SAP to include this activity.

   Response:
   The CMI does not state the extent of TCE in soil will be determined and no soil sampling will be conducted.

7. **Section 1.7, Waste Management, Page 1-16:** The CMI should address the potential for dust migration during the excavation of contaminated soil, the associated impacts and potential risk to receptors, dust monitoring, and the necessary mitigation measures to protect potential onsite and offsite receptors. The CMI does not include any discussion of the potential for dust migration due to the excavation activities or documentation that demonstrates that dust migration will not impact air quality to potential receptors. Revise the CMI to provide discussion for potential dust migration due to the proposed excavation which includes a determination of risks, monitoring, and appropriate mitigation.

   Response:
   Section 1.7 of the CMI has been revised.

8. **Section 1.7.1, Solid Waste and Section 3.2.1, Site Preparation, Page 1-16:** The CMI does not discuss the potential impact rain events may have on waste management needs and procedures. Section 1.7.1 discusses the use of a bermed sediment barrier, but it does not include details relative to the berm height and the potential need for

containment to prevent rainfall runoff from the solid waste piles. In addition Section 3.2.1 indicates "A lined soil stockpile area will be established and necessary stormwater management controls installed;" however it does not discuss the controls that may be necessary. The CMI should include calculations using a potential maximum rain event to determine whether the capacity of the berm is sufficient. Also, characterization of the containment water needs to be completed prior to disposal, but this is not discussed in the CMI or SAP. Revise the CMI to discuss potential rain events and associated waste management considerations necessary to prevent contaminated runoff, including sampling accumulated water before it is discharged.

Response:
Section 1.7 of the CMI has been revised.

9. **Section 3.5, Bioreactor Setup, Page 3-9:** This section does not provide adequate provisions for monitoring the presence of $NaMnO_4$. The CMI should specify that the bioreactor operation should not begin until it has been established that $NaMnO_4$ is not present in any site wells. This section only requires that $NaMnO_4$ not be present in the well installed in the middle of the excavation/gravel/bioreactor, but the influence is likely to extend beyond the bioreactor. Also, the first sentence refers to one well; however, Section 3.3, indicates there will be three wells. The text needs to be consistent and all three wells installed within the bioreactor should be monitored for permanganate. Revise the CMI to be consistent and indicate that all three wells in the bioreactor will be monitored for $NaMnO_4$. Also, revise the CMI to specify $NaMnO_4$ should not be present in any wells in the vicinity of the bioreactor when bioreactor operation begins.

   Response:
   The text has been revised to specify bioreactor operations will not begin until $NaMNO_4$ is not present in the vicinity of the bioreactor.

   Only a single monitoring well is located within the bioreactor, and is screened in the gravel portion of the reactor. The other two wells will be screened only in the mulch and used for injection of EVO. These wells are not constructed for monitoring purposes and only the monitoring well will be used as a monitoring point.

10. **Section 3.6, Mid-Plume EVO Injections, Page 3-10 and Section 3.2.2, Groundwater Monitoring and Injection Well Installation, Page 3-1:** The locations of the mid-plume wells are not consistent with previous text and Appendix A of the Corrective Measures Study Addendum, SWMU 55 dated January 2012. In addition the CMI does not include the rationale for the location of the mid-plume wells. The description of the injection wells as "mid-plume" appears to be based on the

configuration of the TCE plume, which appears to be migrating to the southeast, but not the stated groundwater flow direction (i.e., to the south or southwest) and the flow direction depicted on Figures 3-6 and 3-7 in Appendix A of the Corrective Measures Study Addendum, SWMU 55 dated January 2012 (the CMS). This inconsistency needs to be resolved. The well locations do not match the groundwater flow direction and if the plume is stagnant as described in the CMS, injection wells should be installed in a grid that covers the entire plume, rather than a single row under the assumption that the contaminant plume will migrate through and be treated by the injected edible vegetable oil (EVO). Revise the CMI to resolve the inconsistency between the groundwater flow direction and apparent direction of TCE plume migration. Also, include a 100% Design Basis with sufficient details to justify the proposed mid-plume injection well configuration.

Response:
The TCE concentration in groundwater clearly indicates the TCE migration is to the south- southeast, as was stated in the text. The location of the mid-plume wells was based on the configuration of the TCE plume. The text in Section 1.4 of the CMI has been revised for clarity.

11. **Section 3.7.2, Optimization, Table 3-1, Page 3-17:** The CMI should include a decision tree which provides a prioritization for the optimization options identified in Table 3-1. Table 3-1 indicates the same trigger for the first three parameters; however, the optimization options are different. Additional considerations or a decision tree would provide clarification and establish a prioritization of options to be considered for optimization in cases where the same impact trigger occurs. The discussion and Table 3-1 should provide additional direction for the optimization considerations in cases where the impact trigger is the same.

Response:
Additional considerations have been added to Table 3-1.

12. **Section 3.7.2, Optimization, Table 3-1, Page 3-17:** The first three parameters are based on the assumption that TCE will be present in the bioreactor after in-situ chemical oxidation (ISCO) is complete, but it is possible that TCE concentrations in the bioreactor will not have rebounded when EVO injections and recirculation begins. In this potential situation, TCE would still be present in areas that were not treated by ISCO. The optimization criteria should be rewritten to consider this possibility. Revise Table 3-1 to address the situation where TCE concentrations in the bioreactor have not rebounded before bioreactor operations begin.

Response:
Because contaminated groundwater will be extracted from monitoring well 7MW07 and recirculated through the bioreactor for treatment, TCE will be present in the bioreactor. Table 3-1 has not been revised.

13. **Section 3.7.3, Exit Strategy, Page 3-12:** The third bullet indicates that the "downgradient plume concentrations of TCE" are a criterion to stop EVO injections; however "downgradient" has not been defined and given the inconsistency in describing the ground water flow direction, it is not clear what direction the term "downgradient" would be considered for performance measurement. Revise the CMI to clearly define "downgradient" relative to use as a performance measure and specify the wells that are considered downgradient.

    Response:
    The TCE plume geometry clearly indicates the TCE migration is to the south-southeast and the term downgradient applies to the dissolved phase TCE plume located south-southeast of the source area. The CMI has not been revised.

PREQB GENERAL COMMENT

Document approved as final September 14, 2011.

Corrective Measures Implementation Plan
SWMU 55

Naval Activity Puerto Rico
Ceiba, Puerto Rico

Revision 00

Contract No. N62470-08-D-1006
Task Order No. JM04

Submitted to:

NAVFAC
Naval Facilities Engineering Command

U.S. Naval Facilities Engineering Command Southeast

Prepared by:

AGVIQ Environmental Services
CH2M HILL Joint Venture

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June 2012

Corrective Measures Implementation Plan
SWMU 55

Naval Activity Puerto Rico
Ceiba, Puerto Rico

Revision No. 00

Contract No. N62470-08-D-1006
Task Order No. JM04

Submitted to:

U.S. Naval Facilities Engineering Command
Southeast

Prepared by:

CH2MHILL
Constructors, Inc.

June 2012

Prepared/Approved By:

Tom Beisel, Project Manager — June 15, 2012
Date

Approved By:

Michael Halil, Deputy Program Manager — June 15, 2012
Date

Client Acceptance:

U.S. Navy Responsible Authority — June 15, 2012
Date

Certification Page

Corrective Measures Implementation Plan SWMU 55

(Revision No. 00)

I certify under penalty of law that I have examined and am familiar with the information submitted in this document and all appendices, and that this document and its appendices were prepared either by me personally or under my direction or supervision in a manner designed to ensure that qualified and knowledgeable personnel properly gathered and presented the information contained herein. I further certify, based on my personal knowledge or on my inquiry of those individuals immediately responsible for obtaining the information, that the information is true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowingly and willfully submitting a materially false statement.

Signature: ______________________

Name: Mark. E. Davidson

Title: BRAC Environmental Coordinator

Date: June 15, 2012

Contents

Appendices - (Provided on CD)

Tables

Figures

Acronyms and Abbreviations

AGVIQ-CH2M HILL	AGVIQ-CH2M HILL Constructors, Inc. Joint Venture III
Baker	Baker Environmental, Inc.
bgs	below ground surface
CAO	corrective action objective
CMI	corrective measures implementation
CMS	Corrective Measures Study
COC	contaminant of concern
COPC	contaminant of potential concern
CSM	conceptual site model
DCE	cis-1,2-dichloroethene
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
ERD	enhanced reductive dechlorination
EVO	emulsified vegetable oil
g/day	grams per day
g/L	grams per liter
gpm	gallons per minute
GPS	global positioning system
HSA	hollow-stem auger
ISB	in situ bioremediation
ISCO	in situ chemical oxidation
LRA	Puerto Rico Local Redevelopment Authority
LUC	land use control
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
MCL	maximum contaminant level
MEE	methane, ethane, and ethene

MNA	monitored natural attenuation
$NaMnO_4$	sodium permanganate
NAPR	Naval Activity Puerto Rico
NAVFAC SE	Naval Facilities Engineering Command Southeast
NPDES	National Pollutant Discharge Elimination System
NSRR	Naval Station Roosevelt Roads
OM&M	operation and maintenance
ORP	oxidation-reduction potential
PCB	polychlorinated biphenyl
PID	photoionization detector
PREQB	Puerto Rico Environmental Quality Board
PTOD	permanganate total oxidant demand
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
SAP	Sampling and Analysis Plan
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TCE	trichloroethene
TCLP	toxicity characteristic leaching procedure
TOC	total organic carbon
TWFF	Tow Way Fuel Farm
VC	vinyl chloride
VOC	volatile organic compound
yd^3	cubic yards

1.0 Conceptual Design

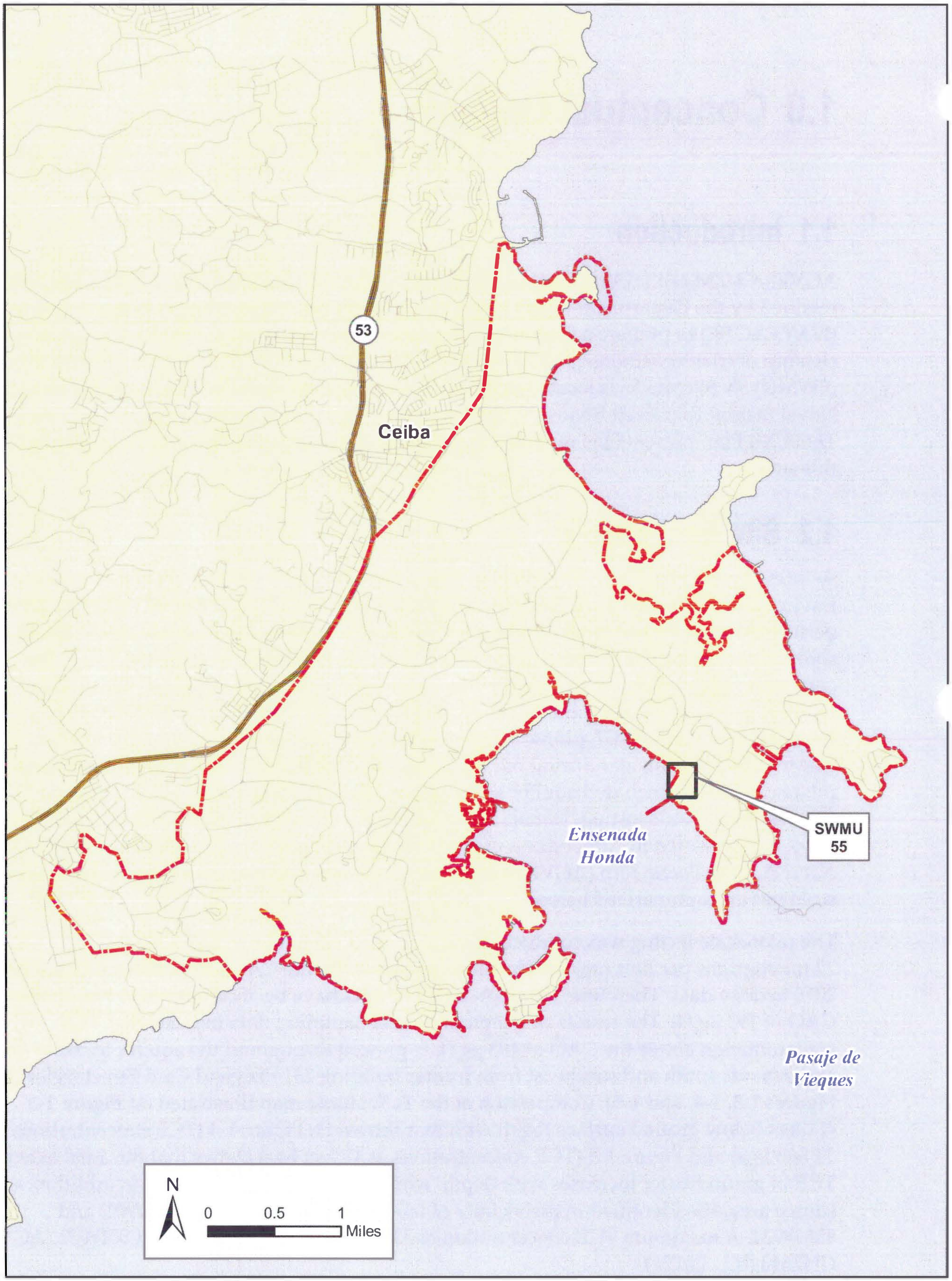
1.1 Introduction

AGVIQ-CH2M HILL Constructors, Inc. Joint Venture III (AGVIQ-CH2M HILL) has been retained by the Department of the Navy, Naval Facilities Engineering Command Southeast (NAVFAC SE) to prepare a Corrective Measures Implementation (CMI) Plan to address the cleanup of trichloroethene (TCE) in groundwater beneath Solid Waste Management Unit (SWMU) 55. SWMU 55 is located at Naval Activity Puerto Rico (NAPR), formerly known as Naval Station Roosevelt Roads (NSRR), in Ceiba, Puerto Rico (refer to Figures 1-1 and 1-2). This CMI Plan presents the remedial approach and technologies that will be implemented at this site.

1.2 Site Background

As prescribed in the *Corrective Measures Study Final Report for SWMUs 54 and 55* (Baker Environmental, Inc. [Baker], 2005) (hereinafter referred to as the CMS), AGVIQ-CH2M HILL performed an in situ chemical oxidation (ISCO) pilot-scale test to evaluate the ability of sodium permanganate ($NaMnO_4$) to reduce TCE concentrations in groundwater to the corrective action objective (CAO). Testing involved the installation of four injection wells (55IW01 through 55IW04) and 25 monitoring wells (55MW01 through 55MW25) to complete the delineation of the TCE plume and monitor the vertical and horizontal distribution of $NaMnO_4$ in groundwater during pilot-scale testing. Additional work completed during the pilot-scale testing included aquifer slug tests and permanganate total oxidant demand (PTOD) bench-scale testing. Details of the additional characterization and pilot-scale test work are presented in Appendix A of the *Corrective Measures Study Addendum, SWMU 55, Naval Activity Puerto Rico* (AGVIQ-CH2M HILL, 2012a). The major findings from the pilot-scale test are summarized below.

The pilot-scale testing was conducted based on the CMS and the 2005 CAO of 22 micrograms per liter (μg/L). However, in May 2012, the CAOs were revised based on 2011 toxicity data. Therefore, the pilot-scale test data have been compared to the revised CAO of 193 μg/L. The results of the groundwater sampling data indicate that TCE contamination above the CAO of 193 μg/L is present throughout the aquifer to the bedrock and extends south and southeast from former Building 2314 beyond Card Street (refer to Figures 1-3, 1-4, and 1-5). Comparison of the TCE plume map illustrated on Figure 1-3 (14 feet below ground surface [bgs]) with that shown on Figure 1-4 (TCE concentrations at 25 feet bgs) and Figure 1-5 (TCE concentrations at 41 feet bgs) shows that the areal extent of TCE in groundwater increases with depth, while concentrations decrease. In addition, a TCE source area was identified in the vicinity of monitoring wells 7MW07, 55IW01, and 55MW24. A maximum TCE concentration of 33,600 μg/L was measured at 55IW01 (AGVIQ-CH2M HILL, 2012a).



Road

Expressway

Naval Activity Puerto Rico Boundary

FIGURE 1-1
SWMU 55 Location
SWMU 55
Naval Activity Puerto Rico

Monitoring Well Screened Primarily Less than 25 ft bgs

Injection Well Screened Primarily Less than 25 ft bgs

Monitoring Well Screened Primarily Greater than 25 ft bgs

Injection Well Screened Primarily Greater than 25 ft bgs

Monitoring Well

SWWU 55 Boundary

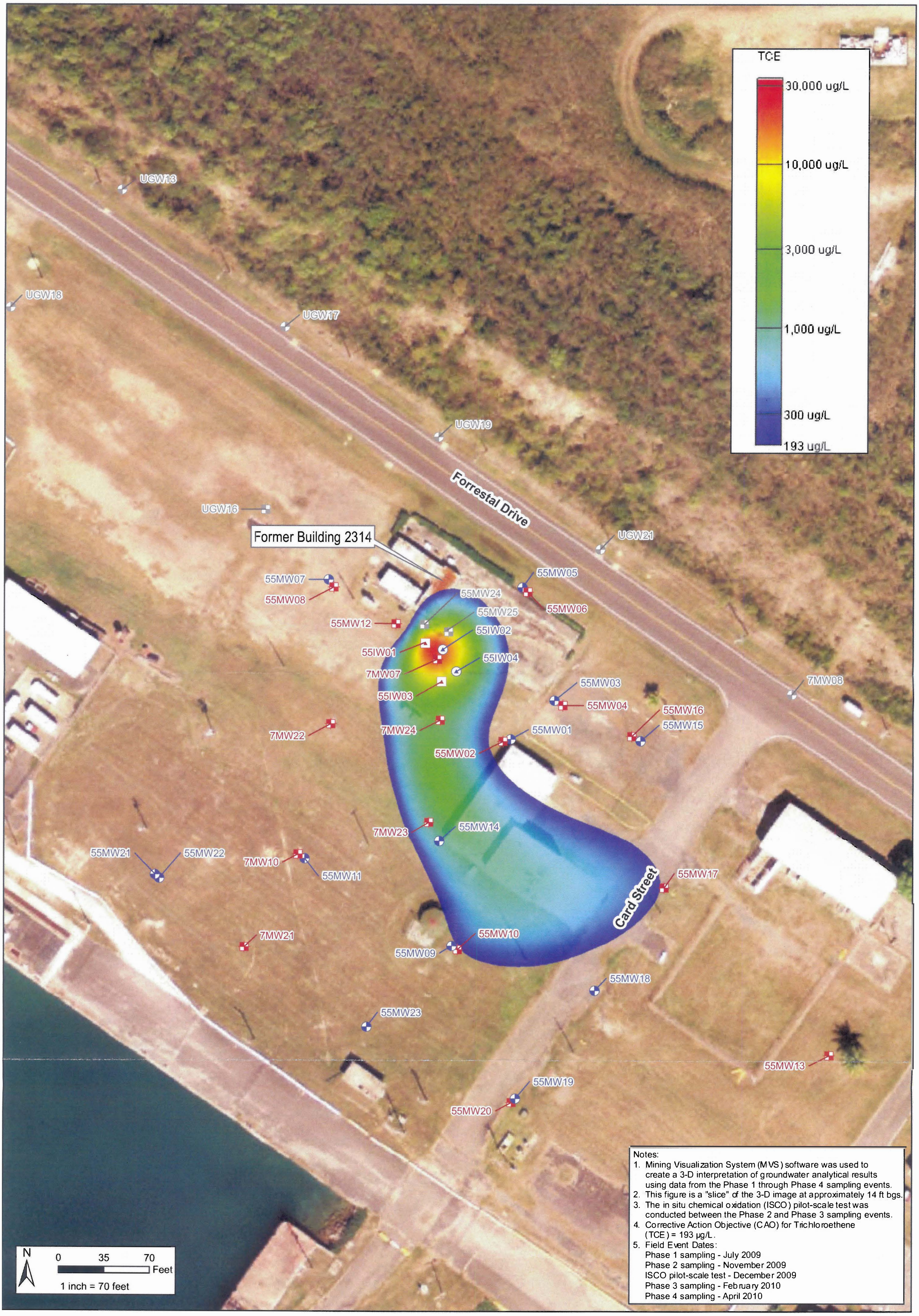
N 0 60 120 Feet

1 inch = 120 feet

FIGURE 1-2
Site Layout
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MANAGED.LOCAL\CRITIGEN\PROJECTS\USNAVYPUERTORICO20000317\MAPFILES\SWMU55\2011\CMIREPORT\FIG_1-2_SWMU55_SITELAYOUT.MXD JCARR 5/16/2012 2:13:40 PM

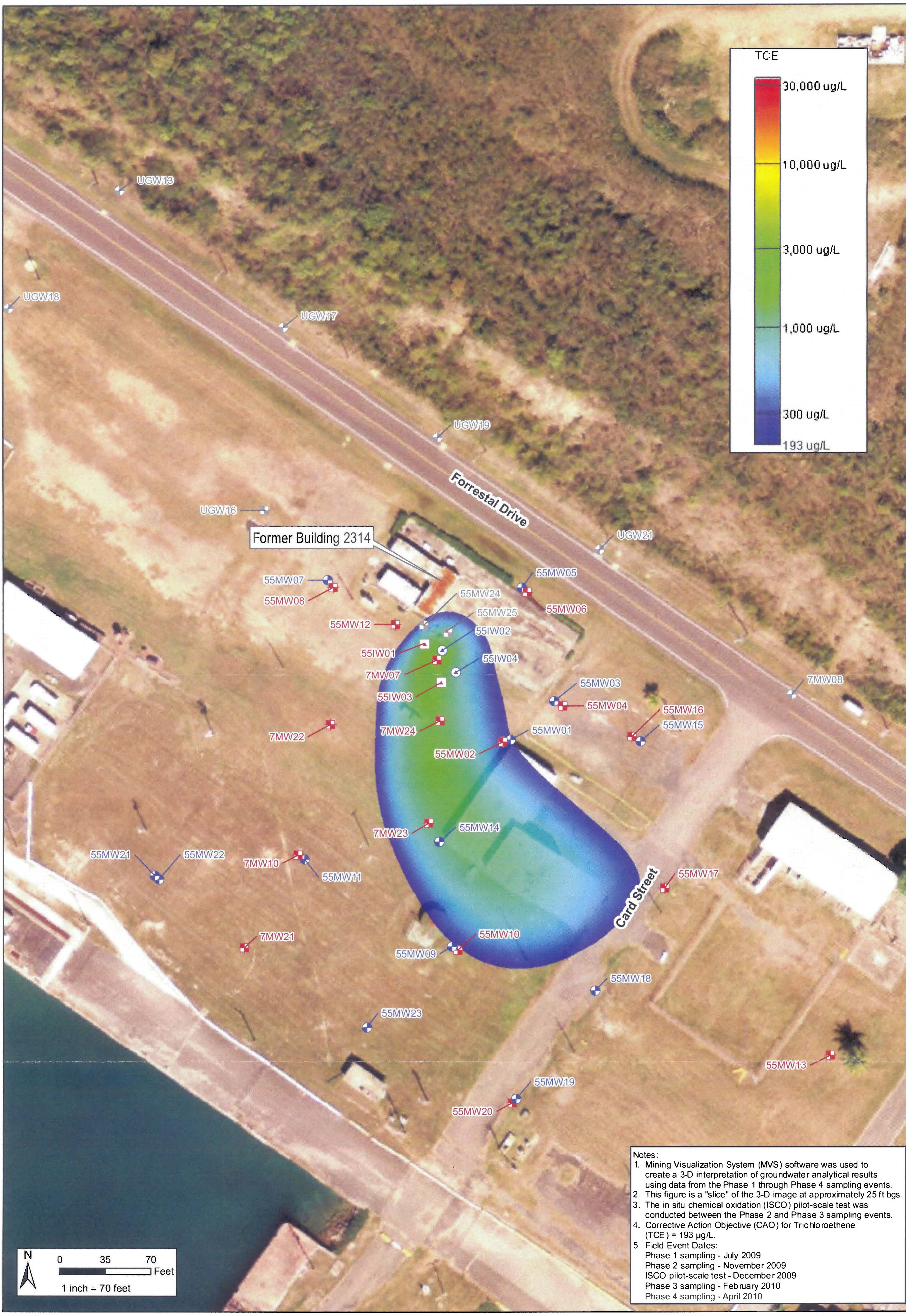


- Monitoring Well Screened Primarily Less than 25 ft bgs
- Injection Well Screened Primarily Less than 25 ft bgs
- Monitoring Well Screened Primarily Greater than 25 ft bgs
- Injection Well Screened Primarily Greater than 25 ft bgs
- Existing monitoring wells not used to develop 3-D interpretation.

FIGURE 1-3
Shallow Aquifer Zone TCE Concentrations – Baseline
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MNUSTRICTGFS01\PROJECTS\USNAVYPUERTORICO20000317\MAPFILES\SWMU55\2011\CMIREPORT\FIG_1-3_BASELINE_SHALLOW.MXD JCARR 6/6/2012 3:55:49 PM

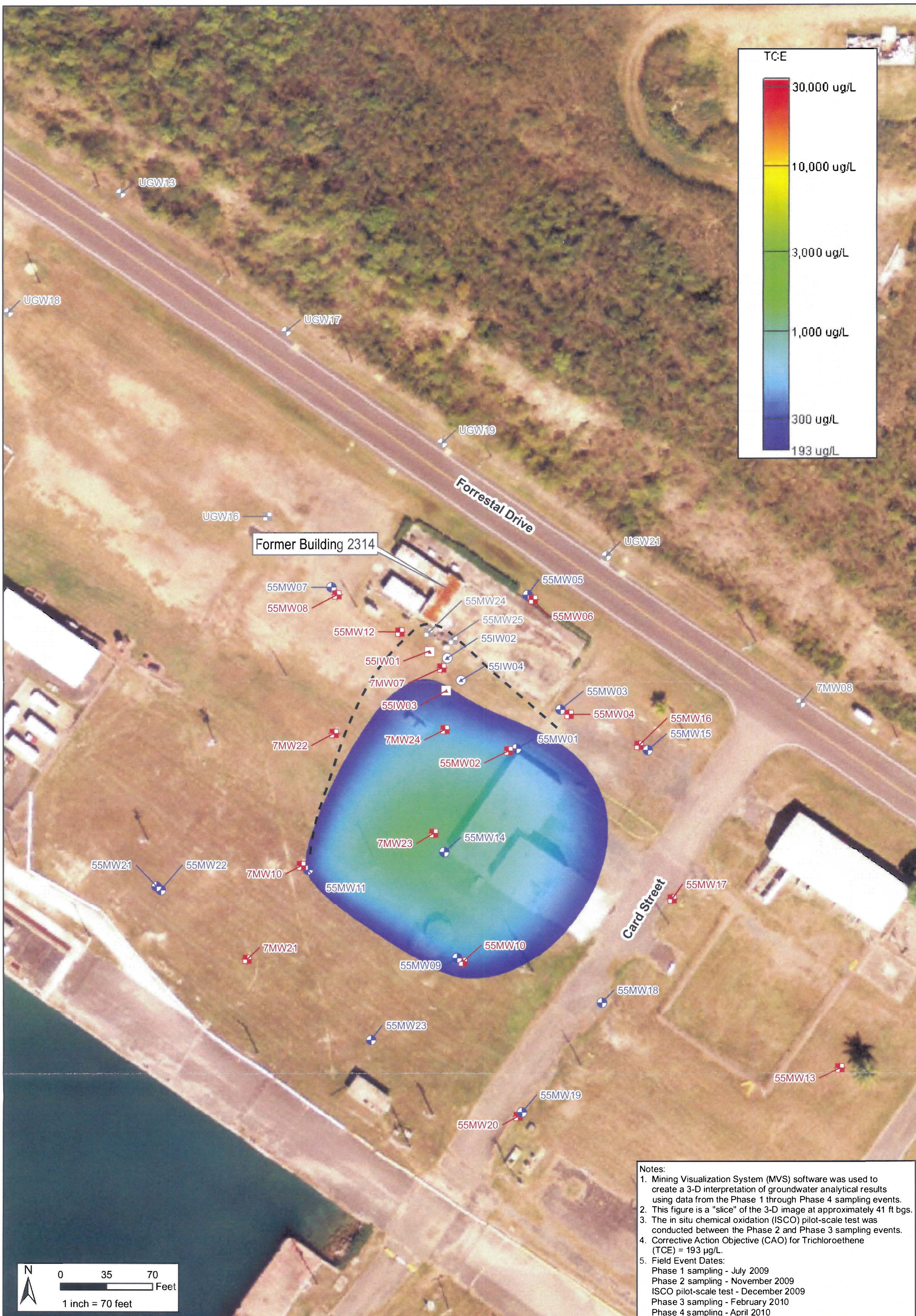


Monitoring Well Screened Primarily Less than 25 ft bgs
Injection Well Screened Primarily Less than 25 ft bgs
Monitoring Well Screened Primarily Greater than 25 ft bgs
Injection Well Screened Primarily Greater than 25 ft bgs
Existing monitoring wells not used to develop 3-D interpretation.

FIGURE 1-4
Mid-Aquifer Zone TCE Concentrations – Baseline
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MNUSTRICTGFS01\PROJECTS\USNAVYPUERTORICO2 0000317\MAPFILES\SWMU55\2011\CMIREPORT\FIG_1-4_BASELINE_MID.MXD JCARR 6/1/2012 10:17:00 AM



Notes:
1. Mining Visualization System (MVS) software was used to create a 3-D interpretation of groundwater analytical results using data from the Phase 1 through Phase 4 sampling events.
2. This figure is a "slice" of the 3-D image at approximately 41 ft bgs.
3. The in situ chemical oxidation (ISCO) pilot-scale test was conducted between the Phase 2 and Phase 3 sampling events.
4. Corrective Action Objective (CAO) for Trichloroethene (TCE) = 193 µg/L.
5. Field Event Dates:
   - Phase 1 sampling - July 2009
   - Phase 2 sampling - November 2009
   - ISCO pilot-scale test - December 2009
   - Phase 3 sampling - February 2010
   - Phase 4 sampling - April 2010

Monitoring Well Screened Primarily Less than 25 ft bgs
Injection Well Screened Primarily Less than 25 ft bgs
Monitoring Well Screened Primarily Greater than 25 ft bgs
Injection Well Screened Primarily Greater than 25 ft bgs
Existing monitoring wells not used to develop 3-D interpretation.
Estimated extent of TCE in excess of 193 µg/L

FIGURE 1-5
Deep Aquifer Zone TCE Concentrations – Baseline
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MNUSTRICTGFS01\PROJECTS\USNAVYPUERTORICO20000317\MAPFILES\SWMU55\2011\CMSREPORT\FIG_1-5_BASELINE_DEEP.MXD JCARR 6/6/2012 12:06:44 PM

The ISCO pilot-scale test was conducted between December 3 and 17, 2009. During this time, 10,000 gallons of a 1.6 percent $NaMnO_4$ solution was injected at four injection wells (55IW01 through 55IW04). Each injection well received 2,500 gallons of injection solution, and a total of approximately 1,300 pounds of $NaMnO_4$ were injected at SWMU 55. Test results showed an injection radius of approximately 25 feet was achieved during active injection, although the distribution was not uniform. Initially, significant decreases in TCE concentrations were observed in the test area; however, within 3 months, permanganate concentrations had decreased substantially and significant TCE rebound was observed.

AGVIQ-CH2M HILL determined that because the formation was found to have a low oxidant demand during PTOD bench-scale testing, the rapid depletion of $NaMnO_4$ was a result of oxidant migration along zones of higher permeability within the fill, rather than degradation of the oxidant alone.

The rapid dissipation of oxidant during pilot-scale testing indicates multiple injections would be required to attain sufficient permanganate residence time to oxidize the TCE and achieve the CAO. Additionally, because the interconnectivity of the higher permeability zones is unknown, the possibility exists that the injection of large volumes of oxidant over the entire plume may result in the unintentional discharge of $NaMnO_4$ into Ensenada Honda. The lack of $NaMnO_4$ persistence in the TCE source area, combined with rapid rebound, indicates that full-scale ISCO would not be a cost-effective remedy for the SWMU 55 TCE plume. Therefore, an alternative treatment approach was recommended, including excavation with an ISCO application in the bottom of the excavation to aggressively reduce TCE in source area soils, followed by in situ bioremediation (ISB) to establish longer term treatment in the source zone and to enhance monitored natural attenuation (MNA) of the remaining TCE plume.

This alternative treatment approach is described in Section 1.5 and the CMS Addendum.

1.3 Corrective Measures Objectives

Based on discussions with the U.S. Environmental Protection Agency (EPA) Region 2, the initial step of quantitative risk assessment was omitted for SWMU 55 since it was presumed that the levels of contamination warranted evaluation of corrective measures, and the next step of developing CAOs was performed as part of the CMS (see Section 2.4.1 of the CMS [Baker, 2005]).The CAOs for SWMU 55 were based on land use and potential receptor exposure assumptions, selection of contaminants of potential concern (COPCs), exposure assessment and methodology, and a toxicity evaluation performed for NAPR in accordance with EPA guidance (see Section 6.0 of the CMS for EPA guidance references [Baker,2005]).

As discussed in the SWMU 55 CMS Addendum, the CAOs for both soil and groundwater were developed in the CMS (Baker, 2005), which was conditionally approved by the EPA in October, 2005. Also, the groundwater CAOs were developed based on an industrial use of the site as was originally proposed in the 2004 Reuse Plan submitted to the Puerto Rico Local Reuse Authority (NAVFAC, 2004). Since groundwater CAOs developed in the CMS were risk-based for industrial use, land use controls (LUCs) to prevent use of the groundwater is included as part of the remedy (during cleanup and after reaching the CAOs) in order to be protective of human health. The LUCs will be included in any lease or transfer deed. In addition, any lease or transfer deed associated with SWMU 54 or 55 will state that vapor intrusion shall be considered by the new owner during the design/

construction of any future structures on the parcel. If development other than industrial use (i.e., residential, or per the April 2010 amended reuse plan [NAVFAC, 2010]) is proposed, the new owner must work with the Puerto Rico Environmental Quality Board (PREQB) and EPA to establish any additional investigation/risk assessment/cleanup activities. If the property owner wishes to remove the LUC on the groundwater from the deed in the future, it will be the responsibility of the property owner to demonstrate the groundwater meets all state and federal maximum contaminant levels (MCLs), and to obtain approval from the Navy, EPA, and PREQB prior to LUC removal.

The CAO for TCE was used to delineate the TCE plume and design the corrective action. The CAO development is summarized in greater detail in the CMS Addendum and is described in the Final CMS (Baker, 2005).

1.4 Contaminant Migration Potential

Groundwater samples collected from the SWMU 55 area in April 1998 as part of the CMS for the Tow Way Fuel Farm (TWFF) indicated TCE contamination in groundwater resulting from an unknown source. Based on interviews with Base personnel, a building destroyed during Hurricane Hugo in 1989 was formerly located immediately northeast of well 7MW07 (former Building 2314). This building was used for the storage and maintenance of small watercraft, and cleaning and degreasing operations at this building may have released TCE to soil and groundwater. Soil samples collected during the CMS (Baker, 2005) measured a maximum TCE concentration in soil of 110 μg/kg at the soil boring 7TCESB05. In the corresponding groundwater sample, TCE was measured at 2,000 μg/L, which was later detected at 28,000 μg/L. The results suggest that a significant continuing soil source does not exist.

SWMU 55 is situated above saprolite, weathered bedrock and bedrock that, near the bayshore, abuts sandy marine sediments artificially filled in to level and raise the wharf areas. To the south-southwest of 55MW23 (on the right in the section) is a retaining wall (seawall) that reportedly extends below the fill and is anchored in original materials (saprolite or possibly bedrock) at least 40 feet bgs. This retaining wall extends northwest far beyond 55MW21 and southeast far beyond 55MW13. The proximity of SWMU 55 to Ensenada Honda and the presence of the retaining wall greatly influence groundwater flow and the migration of the TCE plume. In particular, the proximity to the bay causes tidal effects on water levels measured in inland wells (see Appendix A of the CMS Addendum). Likewise, the presence of the saltwater-freshwater interface may affect water levels and groundwater chemistry in wells near the bay. The retaining wall locally blocks freshwater discharge directly to the bay. Near the inland side of the wall, fresh groundwater is forced to flow either to the northwest or southeast to find a point of connection (discharge) to the bay.

Eleven nested well sets were installed during the site investigation to determine horizontal and vertical gradients across SWMU 55. Water levels were measured on April 29, 2010 and August 17, 2010, and vertical gradients were calculated using the online EPA Vertical Gradient Calculator (EPA, 2011), as shown in Table 1-5. Nested well pairs 55MW05/55MW06, 55MW07/55MW08, 7MW10/55MW11, and 55MW21/55MW22 had upward vertical gradients for both gauging events, while nested well pairs 55MW01/55MW02, 55MW03/55MW04, 55MW15/55MW16, and 7MW23/55MW14 had downward vertical gradients for both gauging events. Gradients at nested well pairs 55MW09/55MW10 (upward/downward) and 55MW19/55MW20 (downward/upward) varied during the gauging events. These results suggest that a tidal influence to head measurements must be considered in order to interpret the potentiometric surface of the aquifer properly.

Based on potentiometric levels in wells near Forrestal Drive, the direction of groundwater flow in the shallow and deeper portions of the aquifer appears to be south or southwest toward Ensenada Honda. The water table aquifer has an estimated average hydraulic conductivity of 13.5 feet/day and an approximate hydraulic gradient of 0.006. Combining hydraulic conductivity, gradient and an estimated porosity range from 0.2 to 0.4; the groundwater velocity at SWMU 55 ranges between 74 and 148 feet per year. Estimating conservatively, the last TCE release may have occurred in 1989. Because TCE has a low retardation factor (that is, it moves readily with groundwater), it is expected that the TCE plume would have reached Ensenada Honda in the 21 years between the estimated last release and the last sampling event, and as a result, groundwater monitoring wells near Ensenada Honda should have measurable levels of TCE. However, TCE was not measured above the detection limit of 5 μg/L near Ensenada Honda during the 2009 - 2010 investigation in monitoring wells 55MW19, 55MW20, 55MW21, 55MW22, and 55MW23, or historically at monitoring well 7MW07. The potential reasons for the lack of measurable levels of TCE in groundwater close to Ensenada Honda may include:

- The TCE plume is diluted by infiltration as it migrates toward the bay.
- Natural degradation processes are reducing TCE levels in the plume.
- The direction of plume migration is not directly toward Ensenada Honda.

Separate from using groundwater gradients to infer direction of plume migration, measurements of the TCE concentrations in groundwater provide direct evidence of the location and direction of plume migration. As indicated in the CMS Addendum, fresh groundwater and the TCE contamination are migrating to the south and southeast. There is little to no TCE near the seawall because groundwater flow is parallel to the wall toward the southeast. Available groundwater-level data suggest that the saltwater-freshwater interface near the retaining wall is less than 40 feet bgs, and deepens inland. The deeper TCE plume naturally migrates toward the bay, but encounters the interface and is forced to rise up into the shallower parts of the aquifer. The retaining wall is deep enough that the presence of the interface prevents the plume from migrating under the wall. Overall, the conceptual site model (CSM) indicates the TCE plume will continue to migrate to the south-southeast until the fresh groundwater can pass around (or through) the retaining wall and discharge to the bay.

The potential for groundwater to release TCE to Ensenada Honda surface water was evaluated previously by sampling the storm sewers within and contiguous to the TWFF and associated stormwater outfalls (Baker, 2005). The mass of TCE reaching Ensenada Honda was previously estimated at 98.2 grams per day (g/day) using a maximum flow velocity of site groundwater of 113 feet/day and assuming a linear flow from the source area toward Ensenada Honda. These calculations conservatively estimated the possible TCE concentration in Ensenada Honda surface water to not exceed 61.9 μg/L, and compared these values against the ecological protection-based CAO of 200 μg/L (Baker, 2005). In addition, cumulative discharge-based concentrations in Ensenada Honda were estimated, indicating that it would take 118.5 years for the site contamination discharge to surpass TCE concentrations of 200 μg/L. However, this model does not take into account the dilution, degradation, and other loss mechanisms that are characteristic of TCE, and the calculations are based on TCE migration directly from SWMU 55 to the bay. The current CSM indicates the plume will travel much further to the southeast before finding a gap in the retaining wall, and discharging to the bay.

TABLE 1-1
Summary of Groundwater Vertical Gradients within the SWMU 55 Site
SWMU 55
Naval Activity Puerto Rico

Well Identification	Interval	Top of Casing (TOC) Elevation (feet NGVD29)	Depth to Top of Well Screen (feet BTOC)	Screen Length (feet)	Depth to Water (feet BTOC)	Bottom of Screen to Top of Screen (L:H) (feet/ feet)	Bottom of Screen to Top of Screen (L:H) (up/ down)	Top of Screen to Top of Screen (H:H) (feet/ feet)	Top of Screen to Top of Screen (H:H) (up/ down)	Mid-point of Screen to Mid-point of Screen (M:M) (feet/ feet)	Mid-point of Screen to Mid-point of Screen (M:M) (up/ down)	Bottom of Screen to Bottom of Screen (L:L) (feet/ feet)	Bottom of Screen to Bottom of Screen (L:L) (up/ down)	Top of Screen to Bottom of Screen (H:L) (feet/ feet)	Top of Screen to Bottom of Screen (H:L) (up/ down)
						April 29, 2010									
55MW-01D	Deep	14.89	27.50	15.0	12.69	0.008	Down	0.016	Down	0.016	Down	0.016	Down	0.558	Down
55MW-02S	Shallow	14.82	12.00	15.0	12.38										
55MW-03D	Deep	16.66	27.10	15.0	14.39	0.002	Down	0.005	Down	0.045	Down	0.044	Down	0.044	Up
55MW-04S	Shallow	16.40	13.20	15.0	14.07										
55MW-05D	Deep	13.81	28.30	15.0	11.12	0.002	Up	0.003	Up	0.003	Up	0.003	Up	0.192	Up
55MW-06S	Shallow	13.87	13.10	15.0	11.23										
55MW-07D	Deep	14.59	27.80	15.0	12.43	0.006	Up	0.013	Up	0.013	Up	0.013	Up	3.167	Up
55MW-08S	Shallow	14.55	12.70	15.0	12.58										
55MW-09D	Deep	10.16	27.80	15.0	8.91	0.001	Up	0.001	Up	0.001	Up	0.001	Up	0.010	Up
55MW-10S	Shallow	10.16	10.80	15.0	8.93										
55MW-11D	Deep	10.49	27.30	15.0	9.24	0.008	Up	0.015	Up	0.012	Up	0.010	Up	0.023	Up
7MW-10S	Shallow	7.03	1.90	10.0	6.05										
55MW-14D	Deep	12.69	27.80	15.0	11.18	0.002	Down	0.004	Down	0.004	Down	0.003	Down	0.012	Down
7MW-23S	Shallow	9.06	8.30	10.0	7.48										
55MW-15D	Deep	14.29	43.10	15.0	11.73	0.001	Down	0.002	Down	0.002	Down	0.002	Down	0.005	Down
55MW-16S	Shallow	14.36	18.00	15.0	11.75										
55MW-17S	Shallow	9.62	7.10	15.0	8.13	0.011	Down	0.014	Down	0.015	Down	0.015	Down	0.021	Down
55MW-18D	Deep	8.87	48.80	10.0	7.96										
55MW-19D	Deep	8.08	49.10	10.0	6.65	0.004	Down	0.005	Down	0.006	Down	0.006	Down	0.010	Down
55MW-20S	Shallow	8.18	14.20	15.0	6.56										
55MW-21I	Intermediate	10.03	28.00	15.0	9.27	0.002	Up	0.003	Up	0.003	Up	0.003	Up	0.007	Up
55MW-22D	Deep	10.03	55.30	15.0	9.18										

TABLE 1-1
Summary of Groundwater Vertical Gradients within the SWMU 55 Site
SWMU 55
Naval Activity Puerto Rico

Well Identification	Interval	Top of Casing (TOC) Elevation (feet NGVD29)	Depth to Top of Well Screen (feet BTOC)	Screen Length (feet)	Depth to Water (feet BTOC)	Bottom of Screen to Top of Screen (L:H) (feet/ feet)	(up/ down)	Top of Screen to Top of Screen (H:H) (feet/ feet)	(up/ down)	Mid-point of Screen to Mid-point of Screen (M:M) (feet/ feet)	(up/ down)	Bottom of Screen to Bottom of Screen (L:L) (feet/ feet)	(up/ down)	Top of Screen to Bottom of Screen (H:L) (feet/ feet)	(up/ down)
						August 17, 2010									
55MW-01D 55MW-02S	Deep Shallow	14.89 14.82	27.50 12.00	15.0 15.0	10.90 10.63	0.007	Down	0.013	Down	0.013	Down	0.013	Down	0.465	Down
55MW-03D 55MW-04S	Deep Shallow	16.66 16.40	27.10 13.20	15.0 15.0	12.60 12.25	0.003	Down	0.007	Down	0.007	Down	0.007	Down	0.066	Up
55MW-05D 55MW-06S	Deep Shallow	13.81 13.87	28.30 13.10	15.0 15.0	8.91 9.00	0.001	Up	0.002	Up	0.002	Up	0.002	Up	0.115	Up
55MW-07D 55MW-08S	Deep Shallow	14.59 14.55	27.80 12.70	15.0 15.0	11.04 11.03	0.001	Up	0.002	Up	0.002	Up	0.002	Up	0.500	Up
55MW-09D 55MW-10S	Deep Shallow	10.16 10.16	27.80 10.80	15.0 15.0	8.50 8.46	0.001	Down	0.002	Down	0.002	Down	0.002	Down	0.020	Down
55MW-11D 7MW-10S	Deep Shallow	10.49 7.03	27.30 1.90	15.0 10.0	8.87 5.45	0.00	Up	0.00	Up	0.00	Up	0.00	Up	0.00	Up
55MW-14D 7MW-23S	Deep Shallow	12.69 9.06	27.80 8.30	15.0 10.0	10.53 6.69	0.01	Down	0.01	Down	0.01	Down	0.01	Down	0.04	Down
55MW-15D 55MW-16S	Deep Shallow	14.29 14.36	43.10 18.00	15.0 15.0	9.55 9.60	0.00	Down	0.01	Down	0.01	Down	0.01	Down	0.00	Down
55MW-17S 55MW-18D	Shallow Deep	9.62 8.87	7.10 48.80	15.0 10.0	7.34 6.53	0.00	Up	0.00	Up	0.00	Up	0.00	Up	0.00	Up
55MW-19D 55MW-20S	Deep Shallow	8.08 8.18	49.10 14.20	10.0 15.0	6.11 6.53	0.01	Up	0.01	Up	0.01	Up	0.01	Up	0.02	Up
55MW-21I 55MW-22D	Intermediate Deep	10.03 10.03	28.00 55.30	15.0 15.0	9.10 9.00	0.00	Up	0.00	Up	0.00	Up	0.00	Up	0.01	Up

Notes:
BTOC = below top-of-casing
NGVD29 = National Geodetic Vertical Datum of 1929
Source:
Vertical gradients calculated using the EPA on-line tools for site assessment calculation: Vertical Gradients with Well Screen Effects.
At URL: http://www.epa.gov/athens/learn2model/part-two/onsite/vgradient02.htm

According to the CMS (Baker, 2005), the only outfall that can discharge surface runoff originating from the TWFF is Outfall 010 (a National Pollution Discharge Elimination System [NPDES]-permitted outfall). As such, the Outfall 010 storm sewer system represents the only potential transport pathway for chemicals in surface soil to migrate with surface runoff to Ensenada Honda. This outfall was sampled and there were no measurable levels of TCE in the surface water sample. Because levels of TCE in soil at SWMU55 are low, the potential for offsite migration of TCE in surface water is negligible.

1.5 Description of Corrective Measures

1.5.1 Additional Characterization

To complete the horizontal delineation of the source area and potentially improve the siting of the bioreactor, one shallow well will be installed about 20 feet north of 55MW24. This well will be sampled during the pre-corrective action monitoring event outlined in Section 3.1.

1.5.2 Source Area Approach

The CMS was amended (AGVIQ-CH2M HILL, 2012a) to recommend implementation of a combined treatment approach, including excavation, ISCO, and ISB to address the source area, defined as groundwater exceeding 10,000 µg/L TCE. First, high-level TCE contamination will be removed from the source area through excavation, followed by construction of an infiltration gallery/bioreactor in the excavation. The gravel-filled infiltration gallery will first be used to distribute $NaMnO_4$ in the aquifer to rapidly oxidize residual TCE in the soils directly beneath the excavation. This aggressive mass removal should reduce the amount of time required to complete the ISB treatment. When permanganate is no longer detected in site groundwater (estimated to take approximately 4 months) the infiltration gallery will be converted into the bioreactor by injecting emulsified vegetable oil (EVO) into the gravel/mulch portion of the bioreactor and recirculating groundwater through the bioreactor. The ISCO technology is described in the CMS (Baker, 2005), and the bioreactor technology is described in the CMS Addendum (AGVIQ-CH2MHILL, 2012a).

Because uniform distribution of $NaMnO_4$ was not achieved during the pilot-scale testing, an infiltration gallery was recommended for the distribution of $NaMnO_4$, rather than injection wells, to mimic the migration paths followed by the original TCE spill into the subsurface. Additionally, an infiltration gallery maximizes the $NaMnO_4$ mass that can be introduced to the source area while minimizing displacement of TCE. This remedial approach will aggressively remove TCE contamination from the source area and lead to TCE concentration reductions in the downgradient plume over time. After the immediate reduction in TCE mass through excavation and oxidation, the bioreactor will be established to address residual TCE contamination in the soil and groundwater of the source area. The bioreactor will provide a longer-term source area treatment system. The recirculation of downgradient groundwater through the bioreactor system will also extend the anaerobic treatment zone downgradient to further reduce downgradient plume concentrations.

- Monitoring Well Screened Primarily Less than 25 ft bgs
- Injection Well Screened Primarily Less than 25 ft bgs
- Monitoring Well Screened Primarily Greater than 25 ft bgs
- Injection Well Screened Primarily Greater than 25 ft bgs
- Proposed Injection Well
- Proposed Monitoring Well
- Monitoring Well

FIGURE 1-6
Proposed Monitoring and Injection Well Locations
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

Other than the excavation and initial EVO injection, the bioreactor will operate automatically using a solar-powered pump to recirculate groundwater. After 2 years, the bioreactor treatment area will be expanded to include all of the 1,000 µg/L TCE plume area. During this phase, an additional downgradient extraction well may be incorporated into the bioreactor.

1.5.3 Downgradient Plume Approach

The remainder of the TCE plume will be treated over an extended timeframe using a combination of enhanced reductive dechlorination (ERD), implemented through limited injections of EVO, and MNA. To reduce the remediation timeframe, the plume downgradient of the bioreactor will be treated using a line of EVO injection wells across the middle of the plume. Because the full extent of this TCE plume was only recently defined, the MNA potential and stability of the distal portion of the plume should be evaluated over time and the need for an MNA study will be determined. Annual plume monitoring will be used to determine rates of TCE removal via enhanced MNA and evaluate the downgradient plume stability.

1.5.4 Land Use Controls

Current LUCs will be maintained until the CAOs are achieved in both the source area and downgradient plume. The LUCs are detailed in the CDR Parcel 2 (SWMU 55) Deed and include:

- No permanent residences may be installed on the property.
- No groundwater extraction wells may be installed by the deed grantee.
- Potential for vapor intrusion must be considered by the developer and addressed by the developer, as needed.
- The grantee may not interfere with any existing or future groundwater remedial systems.
- The grantee must complete annual inspections of the property to ensure all LUCs are being complied with and provide written certification of the inspection.
- The grantee must comply with the RCRA Administrative Order on Consent for this property (provided to the Puerto Rico Local Redevelopment Authority [LRA] by the U.S. Navy).
- Release of environmental conditions and grantee covenants can be considered only with EPA concurrence.
- In order to develop, improve, use, or maintain the property in a manner inconsistent with the LUCs, the grantee must submit a written request seeking approval to the Director at the NAVFAC BRAC Program Management Office Southeast.

1.5.5 Summary of Major Assumptions

A summary of major assumptions used in development of this technical approach are outlined below:

- **$NaMnO_4$ will persist in the aquifer for approximately 4 months.** This assumption is based on results of the ISCO pilot testing described in the Pilot Test Report (Appendix A of the CMS Addendum, AGVIQ-CH2M HILL, 2012a). During pilot testing, $NaMnO_4$ was observed to persist for less than 4 months in the subsurface. The bioreactor will not be established until $NaMnO_4$ is no longer detected in the source area.
- **Complete dechlorination of TCE can be achieved at SWMU 55.** According to groundwater data collected in August 2010, cis-1,2-dichloroethene (DCE) was detected at several monitoring wells at SWMU 55, indicating ERD is already naturally occurring. Methane has also been detected in the source area, indicating anaerobic conditions favoring ERD are present. The August 2010 data are presented in the Pilot Test Report.
- **ERD in the source zone can be easily reestablished after ISCO.** The aquifer volume that will be impacted by the ISCO application is small and ERD will be immediately established within the bioreactor and then reestablished in the surrounding source area groundwater within a few months of startup. According to groundwater data collected in August 2010, DCE was detected within the pilot test area known to be impacted by permanganate during the pilot test injection, indicating ERD is occurring in this area after ISCO. Methane has also been detected in the source area, indicating anaerobic conditions favoring ERD are present. The August 2010 data are presented in the Pilot Test Report.
- **ERD and MNA will not be affected by groundwater salinity.** Based on conductivity data collected during well purging at SWMU 55, elevated salinity was generally only encountered in wells closer to Ensenada Honda and should not impact the bioreactor operations in the source zone more than 250 feet upgradient or the EVO mid-plume injection zone 150 feet northeast of the bay (Figure 1-7). Additionally, in August 2010, DCE and methane were detected at monitoring wells that appear to have high salinity (for example, 55MW09 and 55MW10), indicating favorable conditions for ERD exist and degradation of TCE is already occurring at the site.
- **Excavation area is approximately 20 feet by 20 feet.** Based on data collected during the source area characterization, a significant portion of the TCE-contaminated soil and shallow groundwater can be removed during excavation for the bioreactor construction. The location and size of the excavation will be finalized based on additional characterization conducted under this CMI Plan.
- **Source area treatment will require about 5 years to achieve the CAO.** Based on CH2M HILL experience with bioreactor effectiveness at other bioreactor installations, 95 to 99 percent reductions in TCE are expected in the source area within 3 to 4 years. Additional time may be required to achieve CAOs in the downgradient areas.

Monitoring Well Screened Primarily Less than 25 ft bgs
Injection Well Screened Primarily Less than 25 ft bgs
Monitoring Well Screened Primarily Greater than 25 ft bgs
Injection Well Screened Primarily Greater than 25 ft bgs

Monitoring Well
SWWU 55 Boundary

Note: Data collected in August 2010.

N 0 60 120 Feet
1 inch = 120 feet

FIGURE 1-7
Salinity and VOC Data
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MANAGED.LOCAL\CRITIGEN\PROJECTS\USNAVYPUERTORICO20000317\MAPFILES\SWMU55_SALINITYVOC.MXD JCARR 3/22/2012 1:51:06 PM

Data gaps that will be addressed during the corrective action are summarized below:

- **Complete delineation of the TCE plume.** Although not necessary to implement the source area treatment, one additional monitoring well will be installed to complete delineation of the TCE source area (see Figure 1-6). The well (55MW26) may be used to improve siting of the bioreactor. Future vertical delineation will be completed after source area TCE concentrations have been reduced to 500 μg/L or less.

- **Rate of natural attenuation occurring.** Because the extent of the TCE plume has only recently been defined, the rate at which the plume is naturally attenuating has not been established. Groundwater data collected under this CMI Plan will be evaluated to assess the rates of MNA.

- **Plume stability.** Because the extent of the TCE plume has only recently been defined, the stability of the plume has not been determined. However, since no additional release of TCE has occurred since at least 1998, it is assumed the plume is well established and fairly stable. Groundwater data collected over time will be evaluated to determine if the plume geometry is changing, possibly as a result of the corrective action.

1.6 Design Criteria

The performance criteria for the three major phases of treatment at SWMU 55 (excavation, ISCO, and ISB) are summarized below:

- **Excavation.** The exact location of the excavation will be established based on analytical data from 7MW07, 55IW01, 55MW12, 55MW24, 55MW25, and a new well installed approximately 20 feet north of 55MW24 (55MW26) prior to the excavation. The purpose of the excavation is to remove as much TCE mass as possible during construction of the bioreactor. Therefore, the size and the location of the bioreactor may be adjusted slightly based on the results of the new source area monitoring well, but there are no other additional design criteria.

- **ISCO.** The ISCO phase is considered a short-term, aggressive means of removing as much high-level TCE contamination directly below the excavation, as possible. Removal of this additional TCE mass through chemical oxidation will facilitate the bioreactor effectiveness, reduce the operating time of the bioreactor, and further eliminate TCE mass from migrating into the downgradient plume. The permanganate will be added as an 84 grams per liter (g/L) solution into the gravel layer of the infiltration gallery during construction. This will be a one-time ISCO application. No additional permanganate applications are planned.

- **ISB.** The ISB phase is a long-term treatment of the source area using the in situ bioreactor and mid-plume EVO injections to reduce the TCE concentrations in the source area and downgradient plume. The bioreactor will be designed and operated to attain sufficient residence time for recirculated groundwater to completely degrade TCE.

1.7 Waste Management

1.7.1 Solid Waste

Soil cuttings generated from well installation will be containerized in 20-cubic yard (yd^3) roll off boxes at a Base-approved temporary storage location pending waste characterization and offsite disposal.

Based on soil disposal conducted during the pilot-scale testing (AGVIQ-CH2MHILL, 2012a), soil removed from the excavation is expected to be non-hazardous. This soil will be placed in two stockpiles inside a lined, bermed area near the excavation and segregated as follows:

- Soil removed from 0 to 2 feet bgs will be stockpiled and then used as backfill.
- Soil removed from 2 to 12 feet bgs will be stockpiled pending waste characterization and offsite disposal.

Preparation of the temporary waste management area will include grading the stockpile area to drain pooling water that will not come into contact with stockpiled soils. In addition, triangular swales approximately 15 to 20 feet wide and approximately 1 foot deep will be installed around the perimeter of the stockpile area. The swales will be used to route potential stormwater away from the stockpiles while still allowing equipment access to the area. The stockpile area will be lined with 10-millimeter plastic and the swales will be lined with 6-millimeter plastic. The outside wall of the swales will be lined with geotechnical fabric to minimize erosion. Haybales will be placed in the downgradient cut of the swales to minimize stormwater flow rates and potential for erosion. The soil stockpile will remain uncovered unless there is a potential for a rain event; in that case, the stockpile will be covered with 10-millimeter plastic and secured with rope and sand bags. This approach minimizes potential for stormwater to contact stockpiled soil resulting in a waste stream, concern about underestimating a rain event and required berm sizing, and the labor and soil needed to build a berm. Soils removed to create the swales will be used during site grading to balance the stockpile area.

The soil from 0 to 2 feet bgs will be staged in a separate area from the remaining excavated soils. Soils from 0 to 2 ft bgs within the excavation and the trench soils will be stockpiled separately and sampled for TCE. The analytical results will be compared to the EPA Regional Screening Level and soils that exceed this level will be properly disposed. Soils that do not exceed the screening level will be used as backfill for the trench and the upper two feet of the bioreactor. One sample will be collected from the excavation soils 0 to 2 feet bgs and one sample will be collected from the trench soils.

The bioreactor excavation and backfill process is normally accomplished within 4 days. If weather conditions indicate potential for a rain event, the stockpiles will be covered securely with plastic sheeting or tarps and straw waddles (or equivalent) to prevent contaminating underlying materials and causing water runoff. An air monitoring plan will be in place to protect onsite workers from potential valorization exposure when uncovering the stockpile as well as during excavation activities.

Any accumulated water in the stockpile area will be contained for disposal or pumped into the bioreactor for treatment.

One soil sample will be collected for waste characterization from each rolloff box, and the 2 to 12 feet bgs stockpile. The soil samples will be analyzed for toxicity characteristic leaching procedure (TCLP) volatile organic compounds (VOCs) (SW1311/8260C), TCLP semivolatile organic compounds (SVOCs) (SW1311/8270D), TCLP metals (SW1311/6010C/7470A), TCLP pesticides (SW1311/8081B), TCLP herbicides (SW1311/8151A), polychlorinated biphenyls (PCBs) (SW8082), corrosivity (SW9045), and ignitability (SW1010).

The samples will be composite samples, other than VOCs, which will be a single grab sample.

Dust migration will be monitored using a MiniRAM Aerosol detector, or similar device. If the action level of 1 milligram per cubic meter (mg/m^3) is exceeded, dust mitigation measures such as wetting the source of the dust or ceasing work until particulates are below 1 mg/m^3, will be implemented.

1.7.2 Liquid Waste

Liquids from decontamination, well development, and purge water will be placed in 600-gallon poly tanks within secondary containment at Base-approved temporary storage locations pending waste characterization and offsite disposal. One liquid sample will be collected per a year and analyzed for Resource Conservation and Recovery Act (RCRA) VOCs (SW8260C), RCRA SVOCs (SW8270D), RCRA metals (SW6010C/7470A), RCRA pesticides (SW8081B), PCBs (SW8082A), herbicides (SW8151A), corrosivity (SW9045), and ignitability (SW 1010).

1.8 Required Permits

According to the NAPR, no dig permit will be required for this project. The PREQB has indicated the permanganate injection notification for pilot-scale testing that was provided should be amended to include the corrective action permanganate and EVO applications and source area groundwater recirculation.

2.0 Operation, Maintenance, and Monitoring Plan

An Operation, Maintenance, and Monitoring (OM&M) Plan will be developed based on the final system installation and operating conditions. Because of the dynamic nature of in situ systems, it is not possible to identify optimal operating conditions prior to construction; therefore, it is most efficient to generate an OM&M Plan after system fabrication and construction. The OM&M Plan will detail the monitoring requirements for the post-ISCO performance monitoring, pre-ISB monitoring, bioreactor system operations, and TCE plume stability monitoring.

The OM&M Plan will contain the following elements:

1.0 Introduction
- Purpose and Scope
- System Description

2.0 Operation and Maintenance Procedures
- Bioreactor System Startup
- Bioreactor Operations
- Summary of Normal Operating Conditions
- Operations Troubleshooting

3.0 System Monitoring
- Post-ISCO Performance Monitoring
- Pre-ISB Monitoring
- Bioreactor and Mid-Plume ISB Performance Monitoring
- TCE Plume Stability Monitoring

4.0 Waste Management

5.0 OM&M Contingency Procedures

6.0 References

2.1 Post-ISCO Performance Monitoring

Monthly sampling events will be conducted beginning 30 days after the completion of the permanganate placement in the infiltration gallery. Groundwater samples will be collected from the internal bioreactor monitoring well, injection wells 55IW02 and 55IW04, and monitoring wells 7MW07, 7MW10, 7MW23, 7MW24, 55MW01, 55MW02, 55MW12, 55MW14, 55MW25, and 55MW26 during monthly monitoring and analyzed for $NaMnO_4$ using a field colorimeter. Additional wells may be sampled, if required, to fully characterize the permanganate distribution. Field parameters, including dissolved oxygen (DO), turbidity, conductivity, pH, salinity, temperature, and oxidation-reduction potential (ORP), will be recorded during well purging, unless permanganate is present.

The sample locations, other than the bioreactor well, are shown on Figure 2-1.

The monitoring locations were selected based on the pilot test results, which demonstrated the maximum downgradient distribution of about 50 feet. Wells located further downgradient will also be monitored to ensure permanganate does not reach the bay (Table 2-1). The analysis will only include $NaMnO_4$ because the monitoring is being conducted only to determine NaMnO4 persistence. The sampling frequency selected was based on pilot test results that demonstrated $NaMnO_4$ persisted in the subsurface for 4 months.

All sampling and analyses will be conducted in accordance with the Sampling and Analysis Plan (SAP) (AGVIQ-CH2MHILL, 2012b). Purge water will be contained pending proper disposal, in accordance with Section 1.7.

TABLE 2-1
Monitoring Well Matrix
SWMU 55
Naval Activity Puerto Rico

Well ID	Monitoring Group	Rationale
7MW07	Post-ISCO, Pre-ISB, Bioreactor	This well is in the area expected to be impacted by the ISCO and ISB applications.
7MW10	Post-ISCO, Pre-ISB, TCE Plume	This well is outside the area expected to be directly impacted by the ISCO and ISB applications, but can characterize the TCE plume.
7MW21	None	TCE has not been detected at this well historically.
7MW22	Pre-ISB, TCE Plume	This well is outside the area expected to be directly impacted by the ISCO and ISB applications, but can characterize the TCE plume.
7MW23	Post-ISCO, Pre-ISB, Mid-Plume	This well is downgradient of the ISCO application and will likely help define total extent of the $NaMnO_4$ distribution. This well is directly downgradient of a mid-plume injection well.
7MW24	Post-ISCO, Pre-ISB, Bioreactor	This well is downgradient of the ISCO application and will likely help define total extent of the NaMnO4 distribution. This will is downgradient of the bioreactor and may help define the total extent of the bioreactor impact.
55BW01	Post-ISCO, Pre-ISB, Bioreactor	This well is in the middle of the bioreactor and will detect presence of permanganate and characterize ISB conditions within the bioreactor.
55IW01	None	This well will be abandoned prior to bioreactor construction.
55IW02	Post-ISCO, Pre-ISB	This well will help determine if $NaMnO_4$ is still present in the aquifer.
55IW03	None	This is an injection well.
55IW04	Post-ISCO, Pre-ISB	This well will help determine if $NaMnO_4$ is still present in the aquifer.
55MW01	Post-ISCO, Pre-ISB, Mid-Plume	This well is downgradient of the ISCO application and will likely help define total extent of the $NaMnO_4$ distribution. This well is directly downgradient of a mid-plume injection well.
55MW02	Post-ISCO, Pre-ISB, Mid-Plume	This well is downgradient of the ISCO application and will likely help define total extent of the $NaMnO_4$ distribution. This well is directly downgradient of a mid-plume injection well.

TABLE 2-1
Monitoring Well Matrix
SWMU 55
Naval Activity Puerto Rico

Well ID	Monitoring Group	Rationale
55MW03	None	This well is not expected to be directly impacted by the ISCO or ISB applications.
55MW04	None	This well is not expected to be directly impacted by the ISCO or ISB applications.
55MW05	Pre-ISB, TCE Plume	This well is outside the area expected to be directly impacted by the ISCO and ISB applications, but can characterize the TCE plume.
55MW06	Pre-ISB, TCE Plume	This well is outside the area expected to be directly impacted by the ISCO and ISB applications, but can characterize the TCE plume.
55MW07	None	This well is not expected to be directly impacted by the ISCO or ISB applications.
55MW08	None	This well is not expected to be directly impacted by the ISCO or ISB applications.
55MW09	Pre-ISB, TCE Plume	This well is outside the area expected to be directly impacted by the ISCO and ISB applications, but can characterize the TCE plume.
55MW10	Pre-ISB, TCE Plume	This well is outside the area expected to be directly impacted by the ISCO and ISB applications, but can characterize the TCE plume.
55MW11	Pre-ISB, TCE Plume	This well is outside the area expected to be directly impacted by the ISCO and ISB applications, but can characterize the TCE plume.
55MW12	Post-ISCO, Pre-ISB, Bioreactor	This well is side gradient of the ISCO application and will likely help define total extent of the $NaMnO_4$ distribution. This will is side gradient of the bioreactor and may help define the total extent of the bioreactor impact.
55MW13	None	TCE has not been detected at this well historically.
55MW14	Post-ISCO, Pre-ISB, Mid-Plume	This well is downgradient of the ISCO application and will likely help define total extent of the $NaMnO_4$ distribution. This well is directly downgradient of a mid-plume injection well.
55MW15	Pre-ISB, TCE Plume	This well is outside the area expected to be directly impacted by the ISCO and ISB applications, but can characterize the TCE plume.
55MW16	Pre-ISB, TCE Plume	This well is outside the area expected to be directly impacted by the ISCO and ISB applications, but can characterize the TCE plume.
55MW17	Pre-ISB, TCE Plume	This well is outside the area expected to be directly impacted by the ISCO and ISB applications, but can characterize the TCE plume.
55MW18	Pre-ISB, TCE Plume	This well is outside the area expected to be directly impacted by the ISCO and ISB applications, but can characterize the TCE plume.
55MW19	None	TCE has not been above 5 µg/L at this well historically.

TABLE 2-1
Monitoring Well Matrix
SWMU 55
Naval Activity Puerto Rico

Well ID	Monitoring Group	Rationale
55MW20	None	TCE has not been above 5 µg/L at this well historically.
55MW21	None	TCE has not been detected at this well historically.
55MW22	None	TCE has not been detected at this well historically.
55MW23	None	TCE has not been detected at this well historically.
55MW24	None	This well will be abandoned prior to bioreactor construction.
55MW25	Post-ISCO, Pre-ISB, Bioreactor	This well is in the area expected to be impacted by the ISCO and ISB applications.
55MW26	Post-ISCO, Pre-ISB, Bioreactor	This well is in the area expected to be impacted by the ISCO and ISB applications.

2.2 Pre-ISB Monitoring

A pre-ISB monitoring event will be completed prior to initiating the ISB phase of work. The pre-ISB baseline will be used to ensure permanganate is no longer present in the system and to determine aquifer conditions prior to initiating the ISB phase of work.

Groundwater samples will be collected from the internal bioreactor monitoring well, injection wells 55IW02 and 55IW04, and 20 monitoring wells, and will be analyzed for VOCs (TCE, DCE, and vinyl chloride [VC]) and MNA parameters (alkalinity, chloride, ferrous iron, nitrate, nitrite, sulfate, sulfide, total organic carbon [TOC], and methane, ethane, and ethene [MEE]). Field parameters including DO, turbidity, conductivity, pH, salinity, temperature, and ORP will be recorded during well purging. Other than the bioreactor monitoring well, the sample locations are shown on Figure 2-1.

The monitoring locations were selected to characterize the portion of the plume expected to be most impacted by the ISB application in the bioreactor and the mid-plume wells. The analyses to be conducted were selected to evaluate the impact of the remedy on VOC concentrations and geochemical parameters. This is a single sampling event.

All sampling and analyses will be conducted in accordance with the SAP (AGVIQ-CH2M HILL, 2011b). Purge water will be contained pending proper disposal, in accordance with Section 1.7.

2.3 Bioreactor and Mid-Plume ISB Monitoring

Trained local technicians will inspect the bioreactor for proper flow rates/pressures and equipment operations on a monthly basis. Because the bioreactor is a very simple system utilizing only solar powered pumps for mechanical equipment, little maintenance is expected. Additionally, other bioreactor systems have operated for over 4 years before pump replacement was required. No fouling of the lines or bioreactor recirculation manifolds have been observed to date. These systems typically have less than 2 percent downtime.

Monitoring Well Screened Primarily Less than 25 ft bgs
Injection Well Screened Primarily Less than 25 ft bgs
Monitoring Well Screened Primarily Greater than 25 ft bgs
Injection Well Screened Primarily Greater than 25 ft bgs
Proposed Injection Well
Proposed Monitoring Well
Monitoring Well
Proposed Bioreactor Monitoring Well

Note:
1. Wells with a Black Halo Represent Post-ISCO and Pre-ISB Monitoring Locations.
2. Wells with a Green Halo Represent Pre-ISB Only Monitoring Locations.

FIGURE 2-1
Post-ISCO and Pre-ISB Monitoring Locations
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MNUSTRICTGFS01\PROJECTS\USNAVYPUERTORICO20000317\MAPFILES\SWMU55\2011\CMIREPORT\FIG_2-1_ISCO_ISB_MONITORING_LOCATIONS.MXD JCARR 6/8/2012 10:52:48 AM

Both bioreactor and mid-plume injection monitoring will occur semi-annually for the first year of operation and annually thereafter, and will be used to evaluate bioreactor and mid-plume injection performance. Samples of the bioreactor influent will be collected from the extraction well (7MW07) and samples of the bioreactor effluent will be collected from the internal bioreactor monitoring well to evaluate bioreactor performance. In addition, groundwater samples will be collected from monitoring wells 7MW24, 55MW12, 55MW25, and 55MW26 to evaluate bioreactor influence on the surrounding aquifer. Groundwater samples will be collected from monitoring wells 7MW23, 55MW01, 55MW02, and 55MW14 to evaluate mid-plume EVO injection performance.

Bioreactor influent, bioreactor effluent, and groundwater samples will be analyzed for VOCs (TCE, DCE, and VC) and MNA parameters (alkalinity, chloride, ferrous iron, nitrate, nitrite, sulfate, sulfide, TOC, and MEE). Field parameters including DO, turbidity, conductivity, pH, salinity, temperature, and ORP will be recorded during well purging. The sample locations are shown on Figure 2-2. All sampling and analyses will be conducted in accordance with the SAP (AGVIQ-CH2M HILL, 2012b). Purge water will be contained pending proper disposal, in accordance with Section 1.7.

The monitoring locations were selected to characterize the portion of the plume expected to be most impacted by the ISB application in the bioreactor and the mid-plume wells. The analyses to be conducted were selected to evaluate the impact of the remedy on VOC concentrations and geochemical parameters. The sampling frequency is based on experience successfully operating other bioreactor systems, as summarized in the CMS Addendum (AGVIQ-CH2M HILL, 2012a).

The system data will be evaluated by engineers and microbiologists to ensure favorable conditions for ERD are maintained within the bioreactor. The data will also be analyzed to evaluate TCE destruction efficiency inside and outside the bioreactor.

2.4 TCE Plume Stability Monitoring

TCE plume monitoring will occur semi-annually for the first year of bioreactor operation and annually thereafter, and will be used to ensure the TCE plume is not expanding and to evaluate MNA of the downgradient plume.

Groundwater samples will be collected from 11 monitoring wells and will be analyzed for VOCs (TCE, DCE, and VC) and MNA parameters (alkalinity, chloride, ferrous iron, nitrate, nitrite, sulfate, sulfide, TOC, and MEE). This list of analytes may be revised after the first year to provide only the most relevant data for MNA evaluation. Field parameters including DO, turbidity, conductivity, pH, salinity, temperature, and ORP will be recorded during well purging. All sampling and analyses will be conducted in accordance with the SAP (AGVIQ-CH2M HILL, 2011b). Purge water will be contained pending proper disposal, in accordance with Section 1.7.

The monitoring locations were selected to characterize the TCE plume stability. The TCE concentration in these wells is expected to remain constant early on in the remedy and then decrease with time. The analyses to be conducted were selected to evaluate the impact of the remedy on VOC concentrations and geochemical parameters. To maintain efficiency in site operations, the sample collection will coincide with the bioreactor and mid-plume ISB monitoring.

- Monitoring Well Screened Primarily Less than 25 ft bgs
- Injection Well Screened Primarily Less than 25 ft bgs
- Monitoring Well Screened Primarily Greater than 25 ft bgs
- Injection Well Screened Primarily Greater than 25 ft bgs
- Proposed Injection Well
- Proposed Monitoring Well
- Proposed Bioreactor Monitoring Well
- Monitoring Well

Note:
1. Wells with a Purple Halo Represent Bioreactor Monitoring Locations.
2. Wells with a Green Halo Represent Mid-Plume Injection Monitoring Locations.
3. Wells with an Orange Halo Represent TCE Plume Monitoring Locations.

FIGURE 2-2
Bioreactor, Mid-Plume Injection, and TCE Plume Monitoring Locations
SWMU55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MNUSTRICTGFS01\PROJECTS\USNAVYPUERTORICO20000317\MAPFILES\SWMU55\2011\CMIREPORT\FIG_2-2_MONITORING_POINTS.MXD JCARR 6/8/2012 11:32:09 AM

2.5 Reporting

A summary of the SWMU 55 activities described in this CMI Plan and the progress of each activity will be presented in annual reports. Additionally, one progress update will be provided 6 months after the bioreactor startup. Additional updates may be issued after major changes to the system. The outline of the reports is as follows:

Executive Summary

1.0 Introduction

- Purpose and Scope
- Background Information

2.0 Summary of Field Activities

- ISB Injection Procedures
- Well Gauging and Sampling Procedures
- Community or Government Contact

3.0 Discussion of Results

- ISB Injection Rates and Injection Volumes
- Groundwater Flow
- Groundwater Test Results

4.0 Conclusions and Recommendations

- System Effectiveness
- Problems and Resolution
- Work Projected for Next Reporting Period

5.0 References

3.0 Final Plans and Specifications

The bioreactor concept is relatively new for groundwater remediation purposes, and limited literature and guidance are available for design purposes. This design is based on CH2M HILL's experience at other successfully operating bioreactor installations as summarized in the CMS Addendum (AGVIQ-CH2M HILL, 2012a). These bioreactors have been installed in a variety of soil conditions using the procedure outlined below. The majority were installed in low permeability aquifers or formations with high and low permeability layers. Because the bioreactor begins with an excavation in the suspected source area, the downward flow of organic rich water from the bioreactor will often follow the same permeable layers or fractures that the original spill of TCE followed. This is a distinct advantage of bioreactors when compared to injection well screens that may hit-or-miss small permeable zones that carry TCE contamination away from the source.

3.1 Pre-Corrective Action Monitoring

A baseline monitoring event will be completed prior to initiating the corrective action. The baseline will be used to establish the plume geometry prior to implementing corrective action and to evaluate plume stability and MNA.

Groundwater samples will be collected from 36 monitoring wells and will be analyzed for VOCs (TCE, DCE, and VC). In addition, select monitoring wells will be analyzed for MNA parameters (alkalinity, chloride, ferrous iron, nitrate, nitrite, sulfate, sulfide, TOC, and MEE). Field parameters including DO, turbidity, conductivity, pH, salinity, temperature, and ORP will be recorded during well purging. The sample locations are shown on Figure 3-1. All sampling and analyses will be conducted in accordance with the SAP (AGVIQ-CH2M HILL, 2011b). Purge water will be contained pending proper disposal, in accordance with Section 1.7.

3.2 Source Area Excavation

3.2.1 Site Preparation

The location of the bioreactor will be staked by AGVIQ-CH2M HILL using global positioning system (GPS) coordinates. A lined soil stockpile area will be established and necessary stormwater management controls installed. A utility clearance will be conducted in the excavation area. If necessary, the work area and the stockpile area will be fenced to maintain security.

3.2.2 Groundwater Monitoring and Injection Well Installation

Prior to implementation of the corrective action, one monitoring well (55MW26) will be installed to complete the horizontal delineation of the TCE source area. In addition, six EVO injection wells will be installed as shown on Figure 1-6.

- Monitoring Well Screened Primarily Less than 25 ft bgs
- Injection Well Screened Primarily Less than 25 ft bgs
- Monitoring Well Screened Primarily Greater than 25 ft bgs
- Injection Well Screened Primarily Greater than 25 ft bgs
- Proposed Injection Well
- Proposed Monitoring Well
- Monitoring Well
- Proposed Bioreactor Monitoring Well

Note:
1. Wells with a Black Halo Represent Volatile Organic Compounds (VOCs) Monitoring Locations.
2. Wells with a Green Halo Represent Volatile Organic Compounds (VOCs) and Monitored Natural Attenuation (MNA) Monitoring Locations.

FIGURE 3-1
Pre-Corrective Action Monitoring Locations
SWMU 55
Naval Activity Puerto Rico

CH2MHILL.

DVR \\MNUSTRICTGFS01\PROJECTS\USNAVYPUERTORICO20000317\MAPFILES\SWMU55\2011\CMIREPORT\FIG_3-1_PRE-CORRECTIVE_ACTION_MONITORING_LOCATIONS.MXD JCARR 6/8/2012 11:35:25 AM

The well will be installed using hollow-stem auger (HSA) drilling techniques. As the boring is advanced, soil samples will be collected every 5 feet for lithologic description.

The well will be constructed using 2-inch inner diameter polyvinyl chloride (PVC) casing. The monitoring well screen will be placed between 10 and 25 feet bgs and constructed of 0.020-inch slot screen. The injection wells will be screened 3 feet below the water table to the bedrock surface and constructed of 0.020-inch slot screen. The wells will be finished with a threaded 2-inch PVC riser to reach ground surface. Sand filter pack and bentonite seal material will be installed, and the annular space will be grouted to the ground surface with Portland cement grout. Each well will be completed with a 3-foot by 3-foot cement pad with locking cover. Additionally, four bollards painted yellow will be installed at each corner of the well pad. Actual depth of the wells may be changed in accordance with observations made by the field personnel during well installation activities.

The wells will be developed after the annular space grout has been allowed to cure for a minimum of 24 hours. The development procedures will comply with the SOPs provided in Appendix A.

The coordinate locations and elevations of the installed wells will be surveyed by a land surveyor registered in Puerto Rico. The wells will be surveyed relative to a previously established benchmark. The horizontal location will be surveyed to an accuracy of 0.1 foot, and the ground surface and top of casing elevations will be surveyed to an accuracy of 0.01 foot.

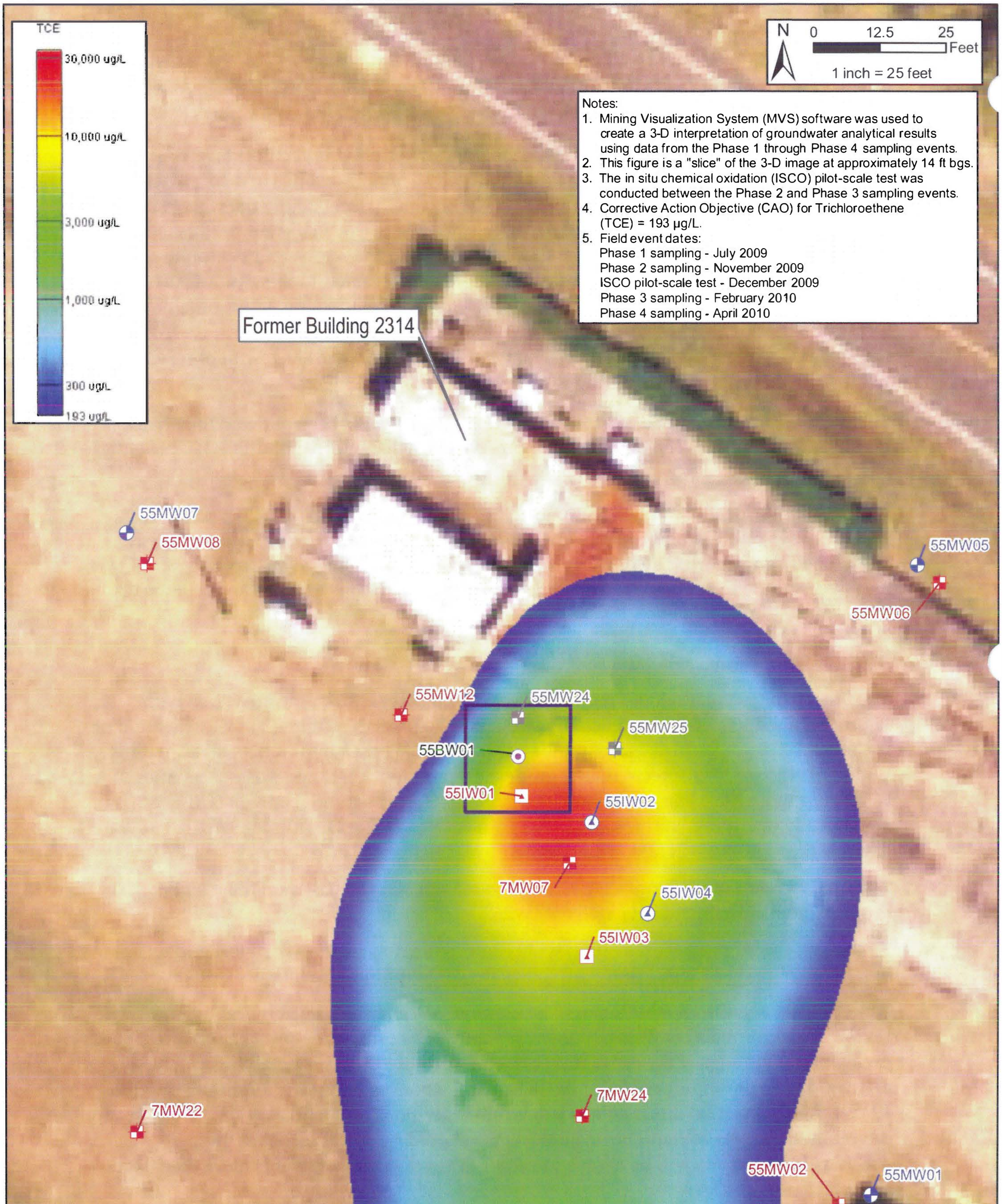
3.2.3 Excavation

The bioreactor excavation will remove an estimated 180 yd^3 from the area shown on Figure 3-2. The size of the bioreactor is based on two primary criteria: 1) the excavation of the most contaminated TCE soils at the site and 2) achieving a hydraulic residence time within the bioreactor for recirculated groundwater of about 14 days. Residence times of 12 days or more have been used to achieve at least 90 percent reduction of TCE in other successfully operating bioreactors at sites with similar TCE concentrations in groundwater as SWMU 55 (AGVIQ-CH2M HILL, 2012a).

The final location of the bioreactor excavation may be refined based on the results of groundwater sampling at new well 55MW26.

At the top, the bioreactor excavation will be approximately 20 feet by 20 feet and will extend to a depth of up to 12 feet. Figure 3-2 shows the extent of the excavation.

Based on site conditions, shoring may be required. A qualified geotechnical engineer will review and approve a contingency shoring plan for the excavation prior to initiating excavation. The sides of the excavation can be sloped, if needed, for stability as long as the excavation is a minimum of 15 feet by 15 feet at the bottom and has a minimum depth of 12 feet. AGVIQ-CH2M HILL will measure the dimensions of the excavation for verification of volumes. The vertical and horizontal extents should be within 1 foot of these specifications. No one will be allowed to enter the excavation when it is more than 4 feet deep.



Monitoring Well Screened Primarily Less than 25 ft bgs

Proposed Bioreactor Monitoring Well

Injection Well Screened Primarily Less than 25 ft bgs

Monitoring Well Screened Primarily Greater than 25 ft bgs

Injection Well Screened Primarily Greater than 25 ft bgs

Existing monitoring wells not used to develop 3-D interpretation.

Excavation Area

FIGURE 3-2
Extent of Excavation and Bioreactor Location
SWMU 55
Naval Activity Puerto Rico

CH2MHILL

The soil removed from the excavation will be placed on 10-mil plastic sheeting and bermed with a sediment barrier. If weather conditions indicate the potential for a rain event, the stockpiles will be covered securely with plastic sheeting or tarps and straw waddles (or equivalent) to prevent contaminating underlying materials and water run-off. Soil waste management procedures are discussed in Section 1.7. Monitoring and engineering controls will be used to protect the workers from potential exposure to volatilized TCE.

The final excavation configuration will be presented to stakeholders in the 6-month progress report and the annual reports.

3.3 Infiltration Gallery/Bioreactor Construction

Prior to backfilling, three 2-inch-diameter wells will be lowered into the excavation. One well will be placed in the center of the bioreactor as a monitoring point and two wells will be placed off-center as injection points. The monitoring well will be screened in the gravel zone of the bioreactor, while the two injection wells will be screened in the mulch/gravel layer. The monitoring well will consist of about 12 feet of upper casing and 3 feet of 0.01-inch slot screen at the bottom. The bottom of the excavation will be backfilled with 4 feet of gravel (to cover the well screen). Permanganate will then be placed in the infiltration gallery, as outlined in Section 3.4.

The EVO injection points, consisting of 8 feet of upper casing and 3 feet of 0.02-inch slot screen at the bottom, will then be placed and a mixture of 70 percent mulch and 30 percent gravel (by volume) will be added to the excavation to within 1 foot of the original ground surface. This mulch to gravel ratio was selected to bolster the amount of organic carbon in the bioreactor. Since the site is not expected to be developed before the source area treatment is completed, more typical bioreactor construction, which requires a higher gravel content to avoid potential for settling after construction is complete, is not required. During construction, the mulch to gravel ratio will be verified on a weight basis as the mixture is installed in the bioreactor. A schematic of the bioreactor construction is provided on Figure 3-3.

The mulch/gravel ratio will be verified by weighing a 1-cubic-foot sample of each material to determine bulk density. During mixing and backfill, four samples of the mixed material will be collected and evaluated for bulk density. The samples will be collected at the beginning of mixing, after approximately one-quarter of the material has been placed, after approximately one-half the material has been placed, and after approximately three-quarters of the material has been placed.

The gravel will be washed rock or river gravel 0.5 to 1.25 inch. The mulch will be composted organic mulch material containing leaves and small wood chips with a 3-inch maximum dimension. It should not contain fresh mulch or over 10 percent pine tree mulch; however, it may be up to 15 percent grass or leaves.

Drip irrigation piping will be assembled as a large square and placed flat on top of the bioreactor mulch/gravel backfill. The drip irrigation piping will consist of two separate (primary and secondary) distribution racks constructed of 1/2-inch-diameter PVC pipe with 1/8-inch-diameter holes approximately every 4 feet along the pipe (see Figure 3-4). When the gravel/mulch backfill is approximately 2 feet from the original ground surface, the secondary distribution rack will be placed in the excavation. One foot of the gravel/mulch will be placed on top the secondary distribution rack, and the primary distribution rack will be placed on top of that layer of gravel and mulch. Initially, only the primary distribution rack will be plumbed to 7MW07.

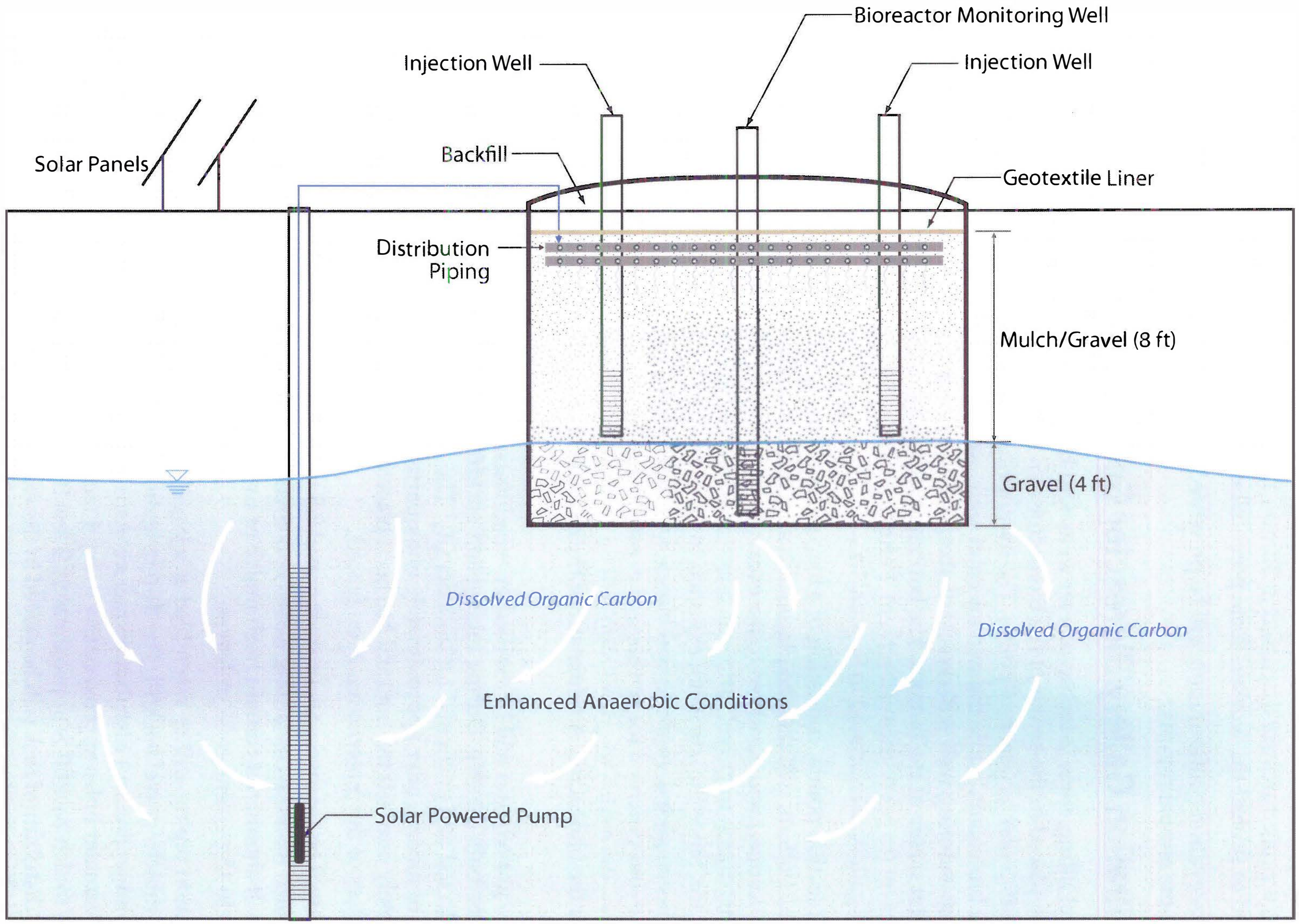


FIGURE 3-3
In Situ Bioreactor Cross Section
SWMU 55
Naval Activity, Puerto Rico

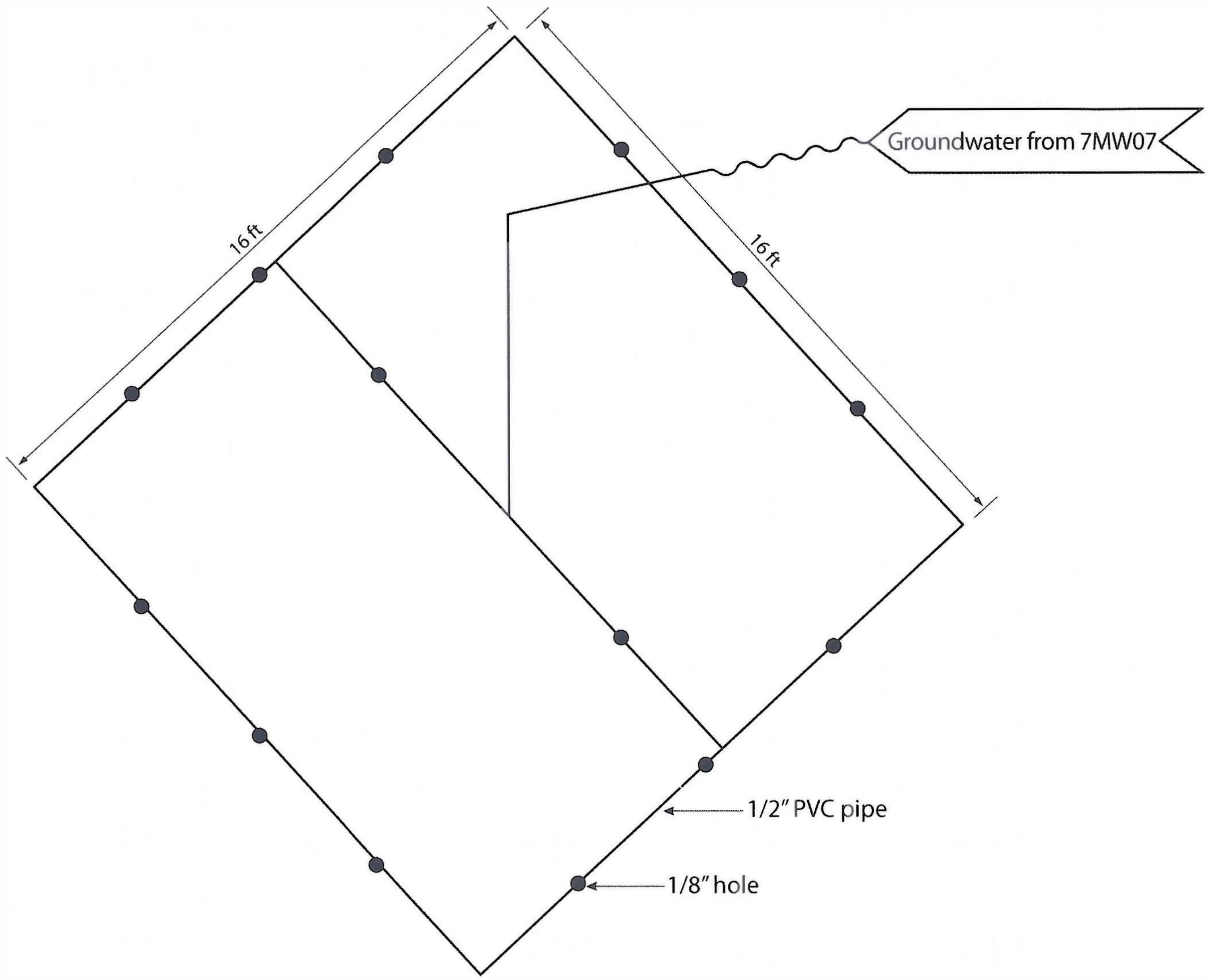


FIGURE 3-4
Distribution Rack Schematic
SWMU 55
Naval Activity Puerto Rico

The secondary distribution rack will be reserved for possible future use, either if the primary rack gets clogged, or if additional distribution capacity is required to bring more extraction wells online during possible future expansion of the treatment zone.

Geotextile fabric will be placed over the top of the piping system and bioreactor to protect the infiltration system from fines in the backfill soil. The soil backfill will be completed to grade and mounded approximately 12 inches to account for settling and to promote drainage.

3.3.1 Bioreactor Vault and Groundwater Conveyance

The extracted water from well 7MW07 will be transferred to the top of the bioreactor through a 0.75-inch Schedule 40 PVC pipe that is buried approximately 18 inches below the surface to prevent damage from surface grading. The groundwater conveyance trenches will be approximately 1 foot wide by 18 inches deep with a total of approximately 100 feet requiring trenching. The trench will be backfilled with 12 inches of sand and the rest with trench spoils, and compacted with the excavator. The pipe and control wire will have 4 inches of sand below. Marking tape will be installed at the top of the sand (8 inches above the pipe).

A plastic valve box will be installed in the groundwater conveyance trench between the 7MW07 wellhead and the bioreactor. The vault will be at least 24 inches long, 18 inches wide, and 18 inches deep. The connections to the two sets of infiltration piping will be made inside this vault. The vault will also include the flow totalizer and pressure gauge to track infiltration system pressure. PVC unions will be installed on the risers of the infiltration piping and the groundwater conveyance.

3.3.2 Solar Pump Installation

A Grunfos™ SQFlex (11SQF-2), 4-inch centrifugal, solar-powered pumping system will be installed to recirculate 1 to 1.5 gallons per minute (gpm) of contaminated groundwater through the bioreactor for treatment. Adjacent monitoring well 7MW07, screened from 12.5 to 27.5 feet bgs with a screen slot size of 0.01 inch, will be used as the extraction well. Another extraction well (new or existing) could later be equipped with a solar-powered pump to expand the zone of recirculation downgradient of the bioreactor. A flow totalizer will be installed to track the volume of groundwater recirculated through the bioreactor.

Five 50-watt, 17.4-volt solar panels will be mounted adjacent to the electrical pull box for the control panel. The solar panels will be mounted at an angle of 40 degrees facing south-southeast. An IO100 control switch will be mounted on the solar panels to turn the pump on and off.

3.3.3 Site Restoration

The remaining open excavation will be backfilled using soil from the 0 to 2 feet bgs excavation stockpile. The soil will be compacted to the satisfaction of the AGVIQ-CH2M HILL site manager by using the excavator bucket to lightly compact the soil (no compaction testing). A 12-inch-tall mound of soil will be placed over the bioreactor. The mound will be rough graded to drain away from the center of the excavation. Any ruts or depressions will be repaired in order to prevent ponding of water. All site areas disturbed during this work will be seeded using a common grass seed mix. Best management practices will be used to prevent erosion and establish grass cover.

3.4 ISCO Application

The ISCO application will involve the introduction of approximately 1,800 gallons of an 84-g/L $NaMnO_4$ solution (approximately 1,300 pounds of $NaMnO_4$) into the infiltration gallery after the gravel has been placed in the excavation. This is the same amount of $NaMnO_4$ mass that was injected in the aquifer during the pilot-scale testing (see Appendix A of the CMS Addendum), which was estimated to have migrated 100 feet or less downgradient of the injection zone before either being consumed or becoming very dispersed. The primary discharge concern is Ensenada Honda, which is more than 350 feet downgradient. To minimize the potential for mobilizing TCE from the source area, the $NaMnO_4$ solution volume will be limited to one pore space of the gravel zone of the infiltration gallery. The $NaMnO_4$ solution volume and concentration calculations are provided in Appendix B.

The $NaMnO_4$ will be staged onsite as a 40 percent solution in a 300-gallon tote. The $NaMnO_4$ solution will be mixed onsite in 500-gallon batches using the NAPR mobile mix system constructed during the pilot-scale testing. The 40 percent $NaMnO_4$ solution will be diluted using a ratio of 5.5 gallons of water per gallon of 40 percent $NaMnO_4$ to achieve the 84-g/L solution for placement in the infiltration gallery. The $NaMnO_4$ concentration of the solution mixed for placement will be measured after each tank is completely mixed to determine the average $NaMnO_4$ concentration.

The $NaMnO_4$ solution will be added to the gravel portion of the infiltration gallery prior to completing the remaining bioreactor construction. The 1,800 gallons of $NaMnO_4$ solution is expected to fill the bottom 2 feet of the infiltration gallery and the amount of solution in the infiltration gallery will remain well below the top of the gravel layer. A 3-layer, finite element model using the modeling code MicroFEM (http://www.microfem.com/) was run to evaluate the time required for the $NaMnO_4$ to infiltrate into groundwater. Assuming an initial 2 feet of head, there is expected to be about 0.5 foot of $NaMnO_4$ solution in the infiltration gallery after 1 day. The modeling information summary is provided in Appendix B. Post-ISCO performance monitoring will be conducted as outlined in Section 2.1.

Gauging data collected in June 2011 indicates there is little tidal influence in the source area and the $NaMnO_4$ level in the infiltration gallery should not be significantly affected by tidal fluctuations.

All chemical handling activities will be conducted in accordance with the Health and Safety Plan (AGVIQ-CH2M HILL, 2009).

3.5 Bioreactor Setup

When permanganate is no longer detected in the vicinity of the bioreactor, the oxidation phase of the source removal will be complete. Since the ISCO phase is strictly a chemical oxidation treatment (not biological), the absence of permanganate will be a sufficient indication of when it is appropriate to begin ERD. At this point, reductive conditions will be established in the aquifer by injecting approximately 4,750 pounds of a 60 percent (weight) EVO into the infiltration gallery. The EVO will be injected as a 19 percent (weight) solution, requiring approximately 1,800 gallons of solution to be injected into the bioreactor injection wells.

The EVO will be staged onsite as a 60 percent solution in 300-gallon totes. The injectant will be mixed onsite in 500-gallon batches using the NAPR mobile mix system constructed during the pilot-scale testing. The 60 percent EVO solution will be diluted using a ratio of 2 gallons of water per gallon of 60 percent EVO to achieve the 19 percent solution for injection.

The bioreactor phase of treatment will begin by initiating recirculation of groundwater extracted from monitoring well 7MW07 into the top of the bioreactor. After initiating recirculation of the EVO laden groundwater, monitoring will be conducted to evaluate system performance and need for optimization (see Section 2.0). Based on previous bioreactor operations experience, effective recirculation of organic-rich water and an anaerobic treatment zone can best be established with an extraction well within 15 feet of the bioreactor. Using an extraction well downgradient of the source ensures that the most contaminated groundwater at the site is recirculated through the bioreactor for treatment. The extraction well is expected to produce from 1 to 1.5 gpm during full sun and should average about 770 gallons per day recirculated through the bioreactor. This value is based on a 14-day residence time and 10 hours of pump operation per day, similar to the bioreactor installation at Travis AFB (AGVIQ-CH2M HILL, 2012a). Because the NAPR and Travis AFB have similar solar potential, daily pump operation duration at the NAPR is expected to be similar to that achieved at Travis AFB.

Treatment of elevated TCE in the source area is expected to take 2 to 3 years to reduce TCE levels by 95 percent. At that point, a new extraction well that is 40 to 50 feet downgradient of the source could be used to extract additional TCE from the aquifer and treat it in the bioreactor. It is possible that most of the groundwater within a 50-foot radius of the bioreactor could reach the CAO of 22 µg/L within 5 years. The bioreactor is not expected to treat the TCE outside of a 50-foot radius of the bioreactor. However, 95 percent or greater reductions in source area TCE concentrations will greatly reduce the flux of TCE from the source area and will decrease downgradient TCE concentrations.

All chemical handling activities will be conducted in accordance with the Health and Safety Plan (AGVIQ-CH2M HILL, 2012c).

3.6 Mid-Plume EVO Injections

The downgradient attenuation of the plume will be enhanced through injection of EVO at a line of mid-plume wells. Approximately 430 pounds of a 60 percent (weight) EVO solution will be injected at each well. The EVO will be injected as a 1.5 percent (weight) solution and approximately 4,600 gallons of solution will be injected at each of the six wells. A 1.5 percent EVO solution was injected during the SWMU 54 pilot testing where TCE concentrations are similar to the SWMU 55 mid-plume concentrations and complete degradation of TCE was achieved (AGVIQ-CH2M HILL, 2012d).

The EVO will be staged onsite as a 60 percent solution in 300-gallon totes. The injectant will be mixed onsite in 500-gallon batches using the NAPR mobile mix system constructed during the pilot-scale testing. The 60 percent EVO solution will be diluted using a ratio of 64 gallons of water per gallon of 60 percent EVO to achieve the 1.5 percent solution for injection.

3.7 Bioreactor Operations Optimization and Exit Strategy

3.7.1 Operations

The bioreactor should operate using solar power with minimal maintenance requirements. Minimal groundwater mounding is expected as a result of the bioreactor operations. As described in Section 2.0, system monitoring will be conducted on a monthly basis to ensure the system is operating properly.

3.7.2 Optimization

An observational approach to optimization will be used for the bioreactor. Following the pre-ISB monitoring event, a baseline sampling event prior to EVO injection, data will be collected during semiannual monitoring events for the first year and then annually thereafter (see Section 2.0) to evaluate system performance. Within the first year of operation, TCE degradation within the bioreactor is expected to achieve a 90 percent reduction in TCE concentrations in groundwater exiting the bioreactor. If the TCE mass reduction is less than 70 percent, optimization of the system will be evaluated. Also, if accumulation in the concentrations of TCE degradation daughter products (DCE and VC) is observed, optimization of the system will be evaluated. Table 3-1 summarizes the operational parameters that can be optimized and the expected impact of optimization.

TABLE 3-1
Optimization Guidance
SWMU 55
Naval Activity Puerto Rico

Parameter	Design	Impact
Flow Rate	1 to 1.5 gpm	Increased flow rate would expand treatment zone (limited by carbon released by bioreactor). Higher recirculation rate could shorten the effective life of the mulch. The performance trigger for flow rate adjustment is the biodegradation of TCE in the bioreactor. The flow rate will be set at 1.5 gpm initially and decreased if a 90 percent TCE removal cannot be sustained in the bioreactor.
Vegetable Oil Injection	Once	Reinjection would stimulate dechlorination if first injection and mulch are not providing adequate dissolved organic carbon. Additional injections will be considered if a 90 percent TCE removal rate cannot be sustained in the bioreactor and the TOC measured in the bioreactor is below 20 mg/L.
Bioaugmentation and Micronutrients	None	The addition of a commercial dehalococcoides bacteria culture with micronutrients could be useful in increasing the rate and completeness of dechlorination. The performance trigger for bioaugmentation and micronutrients would be failure of the bioreactor to achieve 90 percent TCE removal or the buildup of DCE or VC in the bioreactor indicating incomplete reduction. Bioaugmentation or addition of micronutrients will be considered only after optimizations of the flow rate and vegetable oil injection have been implemented.
pH Adjustment	6-9 pH	Some pH drop is normal in bioreactor systems due to the ongoing production of fatty acid breakdown products from mulch and vegetable oil. pH values below 6.0 can inhibit biological activity. If pH drops below 6.0 in the internal bioreactor well, a solution of calcium carbonate (lime) or calcium sulfate will be added to increase pH above 6.0.

TABLE 3-1
Optimization Guidance
SWMU 55
Naval Activity Puerto Rico

Parameter	Design	Impact
TCE ERD byproduct concentrations in groundwater	ERD degradation to completion	Additional EVO injection or addition of micronutrients would stimulate biodegradation to completion. The performance trigger for bioreactor optimization is accumulation of TCE degradation products (DCE and VC) over time.
Monitoring Frequency	Semiannual	Limited semiannual monitoring could allow for better system optimization and decrease costs. Not all wells require semiannual monitoring.

3.7.3 Exit Strategy

Annual site monitoring will be completed throughout the plume to determine if the plume geometry is stable and if TCE concentrations in groundwater are generally decreasing over time. This data will be used to evaluate the plume stability and model the expected timeframe required to achieve CAOs for the site.

The bioreactor will be operated until one of the following conditions is met:

- Source area concentrations of TCE have been reduced by at least 95 percent.
- Additional mass removal is determined to be technically or economically infeasible. Groundwater and bioreactor data will be used to evaluate changes in the groundwater TCE concentrations over time. If no changes are observed over multiple monitoring events and the bioreactor operations cannot be revised to achieve complete ERD of TCE, an alternative technology will be considered.

The system will enter a rebound period (6 months to 1 year). Following a rebound assessment, a recommendation will be made for either continued operation and further optimization or closure of the bioreactor. Groundwater monitoring will continue during this time and the rebound assessment will include evaluation of groundwater concentrations after the bioreactor is no longer operating to determine if TCE concentrations increase.

EVO injections will be conducted at the mid-plume injection wells every 2 to 3 years until one of the following conditions is met:

- Downgradient plume concentrations of TCE have been reduced by at least 95 percent or below the CAO of 22 µg/L.
- Impact to groundwater is determined to be negligible.

Groundwater data will be used to evaluate changes in the groundwater TCE concentrations over time. If no changes are observed over multiple monitoring events and the EVO injections cannot be revised to achieve complete ERD of TCE, an alternative technology will be considered.

To minimize the chance of dragging TCE contamination from the upper 40 feet of the aquifer down to depth with drilling tooling, the Navy proposes delaying further characterization until the TCE concentrations in the upper 40 feet have been reduced below 500 µg/L. This reduction is expected to take place over the next 3 years through bioreactor operation and the mid-plume injection of emulsified vegetable oil to enhance biodegradation. At this time, the downgradient zone of the plume has been fully defined to depth where TCE in monitoring wells 55MW21 (screened 25 – 40 feet bgs), 55MW22 (screened 52 to 67 feet bgs), 55MW23 (screened 28 to 43 feet bgs), 55MW19 (screened 49 to 59 feet bgs), and 55MW18 (screened 49 to 59 feet bgs) was measured below 22 µg/L. Therefore, the plume is not migrating offsite in the deep zone.

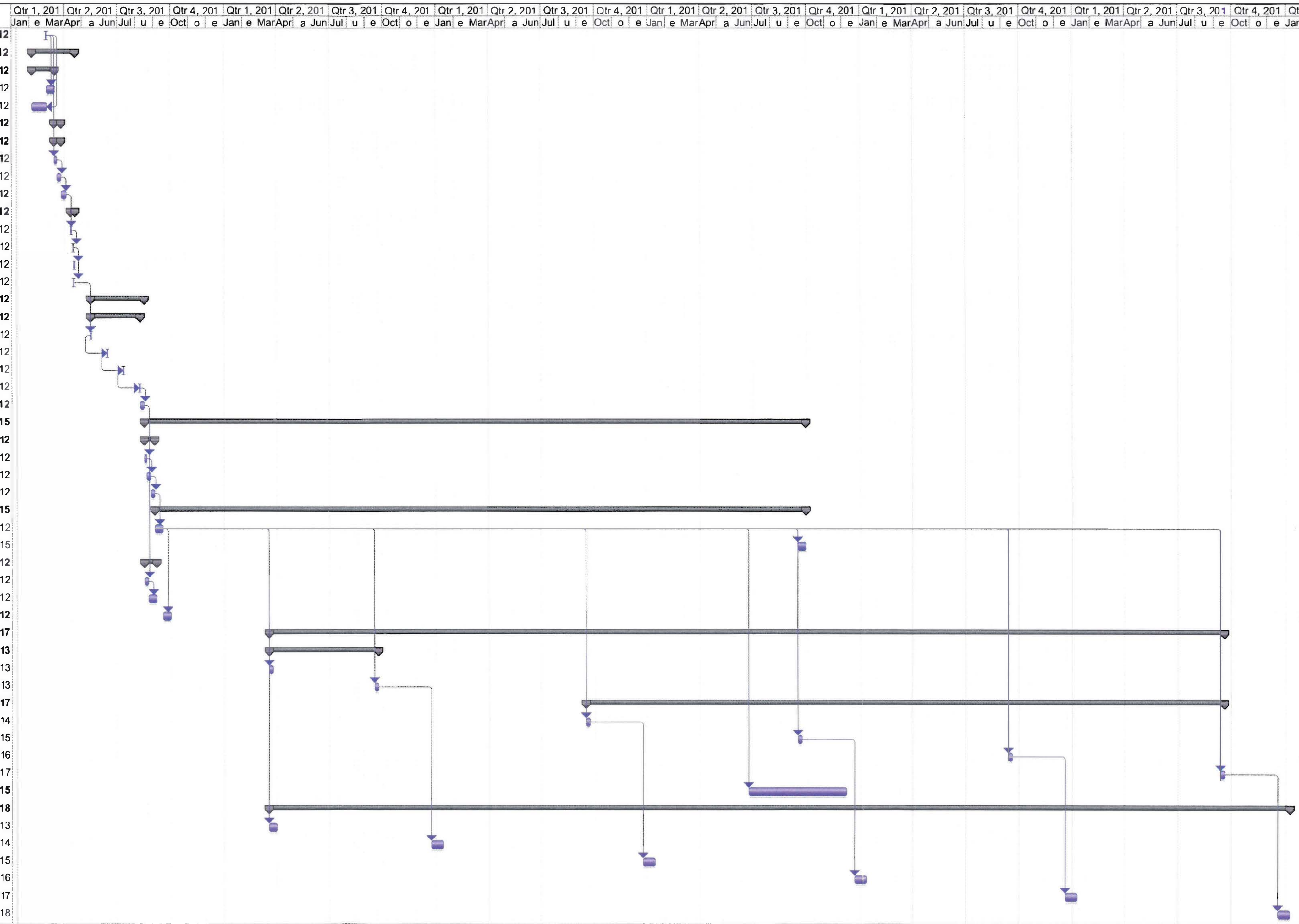
After the TCE concentration as been reduced to 500 µg/L or less, deep zone monitoring wells will be considered for installation in the source zone and the vicinity of 55MW01, 55MW09, 55MW11, and 55MW14.

3.8 Implementation Schedule

An implementation schedule is presented on Figure 3-5. This schedule outlines the project activities for the expected duration of the source area treatment, estimated as 5 years. The MNA of the downgradient plume will likely extend beyond 5 years, but is not included in this schedule.

Bioreactor Implementation Schedule
SWMU 55

ID	Task Name	Duration	Start	Finish
1	**Notice to Proceed**	**1 day**	**Thu 3/1/12**	**Thu 3/1/12**
2	**Bioreactor Installation**	**54 days**	**Mon 2/6/12**	**Thu 4/19/12**
3	**Pre-Mobilization**	**29 days**	**Mon 2/6/12**	**Thu 3/15/12**
4	Procurement	10 days	Fri 3/2/12	Thu 3/15/12
5	Injection Notification	20 days	Mon 2/6/12	Fri 3/2/12
6	**Field Implementation**	**8 days**	**Thu 3/15/12**	**Mon 3/26/12**
7	**Well Installation**	**8 days**	**Thu 3/15/12**	**Mon 3/26/12**
8	Monitoring Well	3 days	Thu 3/15/12	Mon 3/19/12
9	Mid-Plume Injection Well	5 days	Tue 3/20/12	Mon 3/26/12
10	**Baseline Monitoring**	**7 days**	**Tue 3/27/12**	**Wed 4/4/12**
11	**Infiltration Gallery Construction and ISCO**	**6 days**	**Thu 4/12/12**	**Thu 4/19/12**
12	Site Prep	2 days	Thu 4/12/12	Fri 4/13/12
13	Excavation	1 day	Mon 4/16/12	Mon 4/16/12
14	Construction	3 days	Tue 4/17/12	Thu 4/19/12
15	ISCO Application	1 day	Tue 4/17/12	Tue 4/17/12
16	**Monitoring**	**67 days**	**Wed 5/16/12**	**Thu 8/16/12**
17	**Performance Monitoring - ISCO**	**62 days**	**Wed 5/16/12**	**Thu 8/9/12**
18	30-Day Monitoring	2 days	Wed 5/16/12	Thu 5/17/12
19	60-Day Monitoring	2 days	Wed 6/13/12	Thu 6/14/12
20	90-Day Monitoring	2 days	Wed 7/11/12	Thu 7/12/12
21	120-Day Monitoring	2 days	Wed 8/8/12	Thu 8/9/12
22	**Pre-ISB Monitoring**	**5 days**	**Fri 8/10/12**	**Thu 8/16/12**
23	**Bioreactor Installation and Operations**	**812 days**	**Fri 8/17/12**	**Mon 9/28/15**
24	**Field Effort**	**12 days**	**Fri 8/17/12**	**Mon 9/3/12**
25	Site Prep	2 days	Fri 8/17/12	Mon 8/20/12
26	Equipment Installation	5 days	Tue 8/21/12	Mon 8/27/12
27	Shakedown Testing	5 days	Tue 8/28/12	Mon 9/3/12
28	**Bioreactor EVO Injection**	**800 days**	**Tue 9/4/12**	**Mon 9/28/15**
29	Intial Injection	10 days	Tue 9/4/12	Mon 9/17/12
30	Reinjection	10 days	Tue 9/15/15	Mon 9/28/15
31	**O&M Plan**	**15 days**	**Fri 8/17/12**	**Thu 9/6/12**
32	O&M Plan Generation	5 days	Fri 8/17/12	Thu 8/23/12
33	Navy Review	10 days	Fri 8/24/12	Thu 9/6/12
34	**Mid Plume EVO Injection**	**10 days**	**Tue 9/18/12**	**Mon 10/1/12**
35	**Monitoring**	**1175 days**	**Tue 3/19/13**	**Mon 9/18/17**
36	**Semi-Annual Monitoring**	**135 days**	**Tue 3/19/13**	**Mon 9/23/13**
37	6-Month	5 days	Tue 3/19/13	Mon 3/25/13
38	Year 1	5 days	Tue 9/17/13	Mon 9/23/13
39	**Annual Monitoring**	**785 days**	**Tue 9/16/14**	**Mon 9/18/17**
40	Year 2	5 days	Tue 9/16/14	Mon 9/22/14
41	Year 3	5 days	Tue 9/15/15	Mon 9/21/15
42	Year 4	5 days	Tue 9/13/16	Mon 9/19/16
43	Year 5	5 days	Tue 9/12/17	Mon 9/18/17
44	**Deep Zone Characterization**	**120 days**	**Tue 6/23/15**	**Mon 12/7/15**
45	**Reporting**	**1255 days**	**Tue 3/19/13**	**Mon 1/8/18**
46	Progress Report	10 days	Tue 3/19/13	Mon 4/1/13
47	Annual Report for Year 1	15 days	Tue 12/24/13	Mon 1/13/14
48	Annual Report for Year 2	15 days	Tue 12/23/14	Mon 1/12/15
49	Annual Reportfor Year 3	15 days	Tue 12/22/15	Mon 1/11/16
50	Annual Report for Year 4	15 days	Tue 12/20/16	Mon 1/9/17
51	Annual Report for Year 5	15 days	Tue 12/19/17	Mon 1/8/18



Project: Worksheet 16
Date: Mon 1/9/12

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

Figure 3-5
Project Schedule
SWMU 55 Naval Activity Puerto Rico

4.0 References

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