FINAL TECHNICAL MEMORANDUM CH2MHILL

Work Plan for Conducting Bench-Scale Studies at Site 17, NSF-IH, Indian Head, Maryland

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DATE: January 19, 2007

Introduction

This Work Plan presents the proposed approach for conducting chemical oxidation bench-scale studies on saturated soil and groundwater samples collected at Site 17 (Disposed Metal Parts Along Shoreline) at Naval Support Facility, Indian Head (NSF-IH) in Indian Head, Maryland. As agreed upon with the Indian Head Installation Restoration Team (IHIRT) and further discussed below, saturated soil and groundwater samples were collected on an accelerated basis to avoid sampling during the bald eagle nesting season.

Rationale

The Draft Site 17 Groundwater Feasibility Study (FS; Section 5.5; CH2M HILL, 2006) identified uncertainties associated with the effectiveness of selected *in situ* chemical oxidation (ISCO) technologies for treating trichloroethylene (TCE) detected at concentrations suggesting the local presence of pure phase TCE. To evaluate the effectiveness of certain chemical oxidation technologies for treating TCE *in situ*, bench-scale studies were proposed to and approved by the IHIRT on November 29, 2006. This Work Plan documents the scope of work to complete the tasks in support of the objectives outlined below.

Objective

The primary objective of the bench-scale studies is to collect data that will be used to minimize the uncertainties that were identified for ISCO technologies in the FS. The results of the bench-scale studies will be used to design a pilot test and full-scale implementation of the technology at Site 17. The objective will be accomplished through the following: (1) collection of continuous Macro-Core™ sampling from the ground surface to the clay layer identified during the Pre-FS investigation (CH2M HILL, 2002) for subsurface lithological

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information; and (2) collection of saturated soil and groundwater samples for use in the bench-scale studies.

Bench-Scale Studies

The objectives of the bench-scale study are to:

- Determine the effectiveness of select ISCO in treating DNAPL TCE;
- Determine the site-specific demand of reagents; and
- Identify potential side effects of the select technologies that may not be compatible with the current site use.

CH2M HILL's subcontractor, Xpert Design Diagnostics (XDD), will conduct the bench-scale studies with supervision from CH2M HILL. Appendix A provides a detailed description of the bench-scale studies for the ISCO technologies (activated persulfate and permanganate) and the milestones for the study by XDD. XDD's work plan for the bench-scale studies is presented in Appendix A.

Scope of Work

Activities conducted and to be conducted include the following: (1) Macro-Core™, saturated soil, and groundwater sampling; and (2) bench-scale study. A detailed description of each activity is provided below.

Macro-Core™, Saturated Soil, and Groundwater Sampling

On December 4 and 5, 2006, soil borings were advanced using a direct-push technology (DPT) rig with CH2M HILL oversight at Site 17 locations IS17DP64 through IS17DP68 (Figure 1). Parratt-Wolff, Inc., of Hillsborough, North Carolina, provided the drilling services. The DPT locations were selected in the area around previously sampled DPT location IS17DP27, which had exhibited a maximum TCE concentration in groundwater of 870,000 µg/L during the remedial investigation (RI). Sampling was accelerated because noise-inducing activities such as DPT drilling are prohibited for approximately 6 months following the official start of the bald eagle nesting season on December 15, 2006. To avoid a long delay in the project, IHIRT concurred on November 29, 2006, that the samples must be collected before December 15, 2006.

Collection of saturated soil and groundwater samples was conducted in accordance with the NSF-IH Master Plans (Tetra Tech NUS, 2004). A health and safety plan addendum was developed to reflect site-specific health and safety requirements for this task. In addition, munitions and explosives of concern (MEC) avoidance support was also conducted throughout the sampling activities as dictated by the requirements of the explosives safety submission waiver approved by the Naval Ordnance Safety and Security Activity on January 25, 2005.

To better estimate the mass of the oxidant to be used if an ISCO technology were selected for shallow groundwater remediation at Site 17, the thickness of the shallow aquifer is required. The saturated soil thickness and subsurface lithology at Site 17 were not fully characterized during previous investigations (CH2M HILL, 2006). Therefore, continuous 4-

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foot Macro-Core™ samples were collected at location IS17DP65 to obtain information on the subsurface lithology as well as to direct the depths from which saturated soil and groundwater samples were collected.

Saturated soil and groundwater samples were collected from five DPT locations (IS17DP64 through IS17DP68). For the saturated soil sample, approximately 32.4 pounds (lb) of clay soil and 35.5 lb of sand soil were collected. The saturated soil samples were collected using 2-inch inner diameter (ID) Macro-Core™. Each Macro-Core™ sampler was lined with a clear acetate-liner. Approximately 5 liters of groundwater were collected from location IS17DP65. The saturated soil samples (contained in capped 2-foot acetate liners) and groundwater samples (contained in 5-liter amber bottles) were packed in coolers and shipped to XDD under executed chain-of-custody.

Each DPT borehole was abandoned with clean sand from the bottom of the hole to approximately 2 feet from the top of the borehole. The top 2 feet were filled with bentonite slurry to ground surface. This method was designed to minimize the subsurface heterogeneity that may cause hindrance in the groundwater flow, and subsequently non-uniform distribution of oxidant or reductant reagent, if any *in situ* injection technology were to be selected for the full-scale remediation. The abandonment method was similar to the one for Site 47[1]. Detailed descriptions of the field activities and the lithology information collected during the field event in December 2006 will be presented in a technical memorandum.

Reporting

CH2M HILL will provide updates on the results of the bench-scale studies to the IHIRT at partnering meetings and via teleconference calls. The final results and recommended path forward for a remediation approach will be presented in a technical memorandum and submitted to the IHIRT.

References

CH2M HILL. 2002. *Pre-Feasibility Study Field Activities and Results, Site 17, Indian Head Division – Naval Surface Warfare Center*, Indian Head, Maryland.

CH2M HILL, 2006. *Draft Feasibility Study for Site 17, Disposed Metal Parts along the Shoreline, Naval Support Facility Indian Head*, Indian Head, Maryland.

Tetra Tech NUS, 2004. Master Plans for Installation Restoration Program Environmental Investigations at Naval District Washington, Indian Head, Indian Head, Maryland.

[1] Abandonment method for Site 47 was discussed with, and concurred by, IHIRT members on November 15, 2005.

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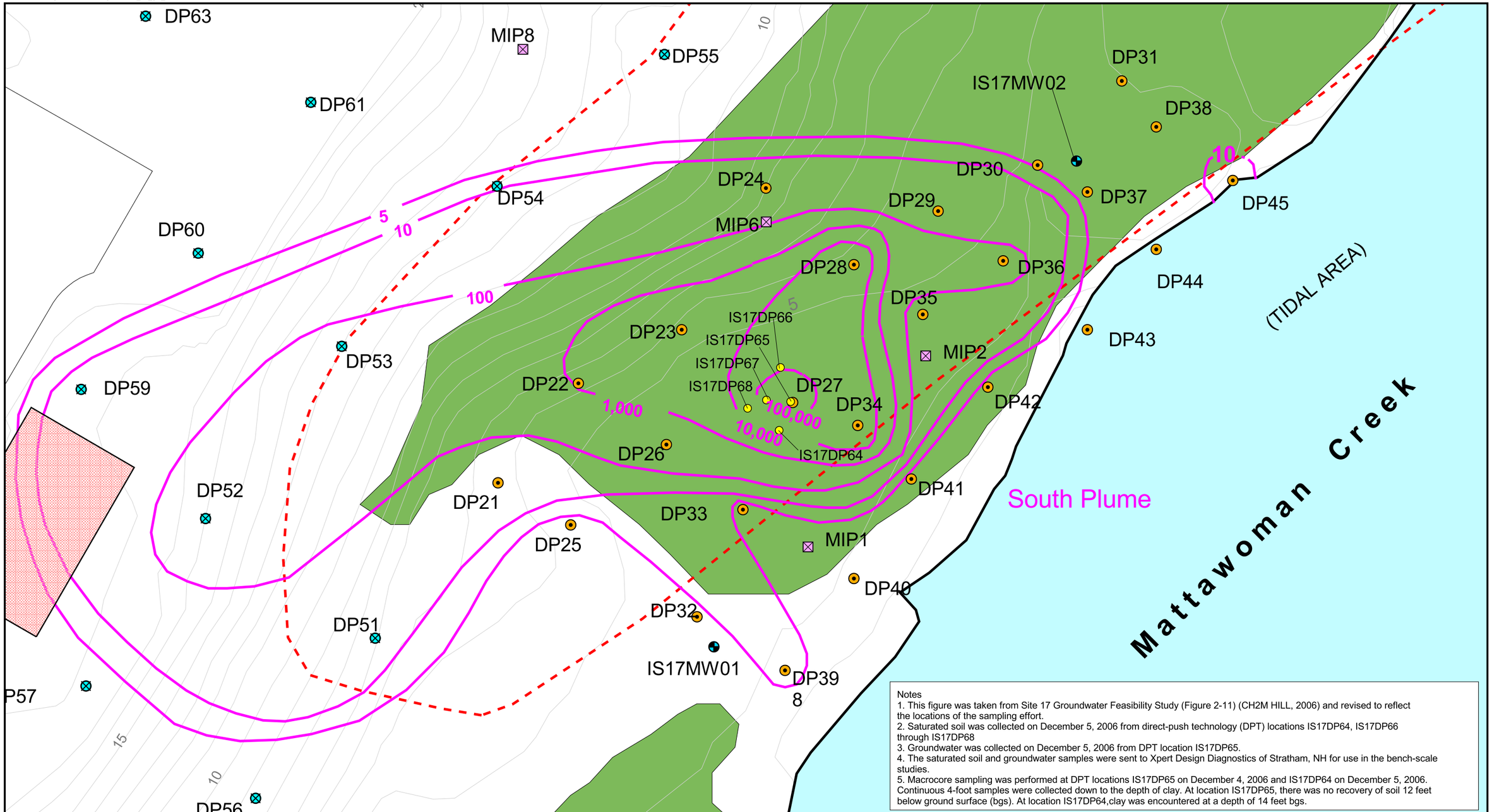

Notes
1. This figure was taken from Site 17 Groundwater Feasibility Study (Figure 2-11) (CH2M HILL, 2006) and revised to reflect the locations of the sampling effort.
2. Saturated soil was collected on December 5, 2006 from direct-push technology (DPT) locations IS17DP64, IS17DP66 through IS17DP68
3. Groundwater was collected on December 5, 2006 from DPT location IS17DP65.
4. The saturated soil and groundwater samples were sent to Xpert Design Diagnostics of Stratham, NH for use in the bench-scale studies.
5. Macrocore sampling was performed at DPT locations IS17DP65 on December 4, 2006 and IS17DP64 on December 5, 2006. Continuous 4-foot samples were collected down to the depth of clay. At location IS17DP65, there was no recovery of soil 12 feet below ground surface (bgs). At location IS17DP64,clay was encountered at a depth of 14 feet bgs.

LEGEND

- Monitoring Wells with TCE Results
- July 2002 MIP/DPT Locations with TCE Results
- December 2004 MIP/DPT and March 2005 DPT Locations with TCE Results
- August 2005 MIP/DPT Locations with TCE Results
- December 2006 DPT Locations
- Approximate IR Site Boundary
- Buildings
- Demolished Buildings
- Wooded Area
- Road
- Topographic Elevation Contours (feet msl)
- Base Boundary
- Isoconcentration Contour

N

0 30 60 Feet

1" = 30'

Figure 1
Saturated Soil/Groundwater Sample and Macrocore Sample Locations
Site 17 Bench-Scale Study
NSF-IH, Indian Head, Maryland

CH2MHILL

Appendix A
Bench Scale Technology Evaluation Workplan

STRATEGIC. ENVIRONMENTAL. SOLUTIONS.

Transmitted via email

January 2, 2007

Gunarti Coghlan
CH2M HILL
13921 Park Center Road Suite 600
Herndon, VA 20171

RE: **Indian Head Bench Scale Technology Evaluation Workplan**
Site 17, Indian Head, Maryland

Dear Ms. Coghlan,

Xpert Design and Diagnostics, LLC (XDD) is pleased to present the attached bench scale evaluation workplan for your use. This work was conducted under XDD project No. 06010.

If you have any questions regarding the information in this work plan, please do not hesitate to call me at (603) 778-1100 ext. 227.

Sincerely,
XPERT DESIGN AND DIAGNOSTICS, LLC

Annette Lee
Project Manager

cc: Michael Marley (XDD)
Brant Smith, P.E., Ph.D. (XDD)

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INDIAN HEAD BENCH SCALE TECHNOLOGY EVALUATION WORK PLAN

Site 17
Naval Support Facility, Indian Head
Indian Head, Maryland

Prepared For:

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Prepared By:

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December 19, 2006

TABLE OF CONTENTS

1.0 INTRODUCTION 1
1.1 Background Information 1
1.2 Bench Scale Evaluation Objectives 2
2.0 BENCH SCALE EVALUATION APPROACH 2
2.1 Baseline Assessment and Preliminary Tests 3
2.2 Activated Persulfate 4
2.3 Permanganate 6
3.0 REPORTING 7
4.0 MATERIALS 7
5.0 SCHEDULE 7
6.0 PROJECT TEAM 8

TABLES

Table 1 Bench Scale Technology Evaluation Milestones
Table 2 Baseline Assessment and Preliminary Tests
Table 3 Persulfate Evaluation Structure
Table 4 Permanganate Evaluation Structure

FIGURES

Figure 1 Conceptual Design of Persulfate and Permanganate Bench Scale Tests

1.0 INTRODUCTION

XDD, LLC (XDD) was retained by CH2M HILL to conduct a bench scale evaluation to assess the effectiveness of chemical oxidation technologies on subsurface contamination at Site 17 in Indian Head, Maryland (Site 17). CH2M HILL is performing this work for the United States Navy (Navy) under Contract N62470-02-D-3052 Task Order 0053.

1.1 BACKGROUND INFORMATION

The Indian Head Division of the Naval Surface Warfare Center (Indian Head) occupies a 3,500-acre peninsula between the Potomac River and Mattawoman Creek, and is located in the town of Indian Head, Maryland, about 30 miles south of Washington, DC. Indian Head was first used by the Navy in 1890 for the testing of naval guns. It has since evolved into a state of the art facility specializing in naval munitions and includes the National Center for Energetics.

The presence of a presumably small and isolated area of dense non-aqueous phase liquid (DNAPL) was indicated by a trichloroethylene (TCE) concentration of 870,000 µg/L from one direct push technology (DPT) sample IS17-DP27 collected within the center of the South plume at Site 17. The value represents 80% of the pure-phase solubility of TCE (1.1×10^6 µg/L) suggesting the presence of DNAPL in close proximity to the groundwater sample[1].

Soil underlying the site consists of fill material in the upper 10 to 12 feet of the subsurface. The fill is characterized by greenish clay with silt containing wood fragments. The fill is underlain by interbedded and interconnected fine to medium sand with some clay lenses.

The contamination at Site 17 to be addressed in this bench scale evaluation is in the surficial aquifer (2 feet to 14 feet below ground surface, bgs). Groundwater has been encountered from a range of 2 to 5 feet bgs. A low permeability layer was encountered from the depth of 14 feet bgs. The organic contaminant of concern (COC) in this area is TCE and is the primary COC to be

[1] Source for aqueous solubility: EPA. 2004. *In Situ Thermal Treatment of Chlorinated Solvents – Fundamentals and Field Applications*. EPA 542-R-04-010.

reviewed as part of this evaluation. The contamination is thought to be sorbed onto soils, dissolved into the groundwater, and present as DNAPL.

1.2 BENCH SCALE EVALUATION OBJECTIVES

The general objectives for the bench scale tests as stated in CH2M HILL's Scope of Work provided to the Navy include:

- To determine the relative distribution of COC mass (associated with depth and soil type in saturated zone)
- To determine the effectiveness of chemical oxidation technologies in treating TCE residual DNAPL;
- To estimate the site-specific demand of reagents; and
- To identify potential side-effects of the select technologies, such as incompatibility with the current site use, mobilizing other regulated contaminants, and creating undesired by-products.

2.0 BENCH SCALE EVALUATION APPROACH

The bench scale technology evaluation will be conducted to evaluate the following technologies for the treatment of TCE contamination at Site 17:

- Activated persulfate (either by alkaline or iron activation); and
- Permanganate.

CH2M HILL, Inc. will collect saturated soil and groundwater from the area that is likely to have the highest concentration of TCE near IS17DP27 and that represent different lithologies of the shallow aquifer. Once the Site 17 soil and groundwater are received by XDD, the soils will undergo a baseline assessment and preliminary tests, including the mass profiling, SOD measurements and activation testing (for persulfate only). The results of this baseline assessment will be used to finalize the specific test approach details including:

- The need to supplement the soils with the COCs. The initial concentration of TCE in the site soil to be used in the testing will be modified or spiked to represent approximately 20 to 50% greater than the maximum soil concentrations measured during the baseline soil sampling (Section 2.1). Additionally, the theoretical soil concentration will be estimated based on the groundwater concentrations observed at IS17-DP27 (assuming equilibrium

partitioning and no DNAPL) to support the baseline soil sample results and proposed spiking amount;

- The number of oxidant applications theoretically required to treat the contaminated groundwater and soil and residual DNAPL; and
- The number of soil and/or groundwater sampling events that will be required during the various evaluations.

The milestones provided in Table 1 assume a period of time between dosing and sampling, which will be adjusted following a review of the baseline assessment and preliminary test results. This assumed time period was 10 days for both persulfate and the permanganate systems.

Laboratory analyses will be performed by Resource Laboratory in Portsmouth, New Hampshire. It is estimated that up to 124 samples will be sent for analysis (a combination of metals and VOCs in soil and groundwater, and TCLP analyses).

2.1 BASELINE ASSESSMENT AND PRELIMINARY TESTS

The bench scale evaluation will begin with a series of baseline assessments and preliminary tests, which will include: contaminant mass distribution profiling, baseline VOC analysis of soil and groundwater, soil oxidant demand measuring, buffer capacity testing and preliminary activation test (for persulfate only) as shown in Table 2.

The contaminant mass distribution profiling will be performed to gain better understanding of the relative TCE distribution in soil due to depth, lithology, and the location of potential DNAPL residual. The soil will be classified by soil type using visual observation, and screened for VOCs using a photoionization detector (PID). Based on the screening results, soil sampling intervals will be selected to represent the concentration profile of each core. The soil samples will be submitted for laboratory analysis. This data will determine the soil spiking concentrations for the remaining tests.

Baseline analysis will be performed on unspiked, composited samples once mass distribution profiling is completed. Soil (clay and sand) and groundwater samples will be sent to the laboratory for grain size analysis (soil only), VOCs and metals.

The soil oxidant demand (SOD) testing will be performed on both sand and clay samples to determine the concentrations of oxidant for both activated persulfate and permanganate systems. The buffering capacity for the activated persulfate system will be evaluated to estimate the quantity of base required to raise the subsurface conditions to the target pH, typically greater than pH 10.5, in the event that proposed activator is alkaline. If the results indicate a high buffering capacity, activation using iron may be required.

The final portion of the baseline assessment will be a preliminary test to evaluate the effectiveness of two types of persulfate activation: iron and alkaline. To confirm the ability of either activator to degrade TCE, a single application of the activators will be applied to a mixture of Site 17 groundwater and soil (one system for each soil type). The reactors, along with control reactors, which will not be dosed with activators, will be allowed to equilibrate for approximately 10 days. It is anticipated that up to 8 single reactor systems will be evaluated for VOC analysis. These, including the baseline results, will be evaluated to confirm the activator's ability to degrade TCE.

Results of the baseline assessment and preliminary tests will be compiled and submitted to CH2M HILL for review and discussion with XDD prior to initiation of the injection simulation tests (Sections 2.2 and 2.3).

2.2 ACTIVATED PERSULFATE

Following selection of the activator, XDD will initiate a more comprehensive bench scale evaluation that will estimate the following:

- The relative effectiveness of two different concentrations of persulfate;
- The mass of oxidant required to degrade the approximate mass of VOC contamination; and

- The metals mobilization potential.

The primary bench test (Injection Simulation), outlined in Table 3, will consist of up to three separate applications of oxidant and activator to simulate three injection events in both clay and sand reactors. The exact number of oxidant applications will depend upon the distribution of TCE (amount sorbed versus. amount in solution and amount present as residual DNAPL). Two different concentrations of oxidant (to be determined based on the baseline and SOD results) and a control will be evaluated. COCs in duplicate reactors for each system will be evaluated after the first application of oxidant to establish the degradation ratio. Additional duplicate reactors will be evaluated after the third application of oxidant, if necessary, to determine the treatment's overall effectiveness and ability to reach remedial goals.

The assessment of potential metals mobilization will be accomplished through analyses of groundwater samples for total and dissolved metals prior to and after the addition of activated persulfate, as outlined in Table 3. The oxidant loading for the metals mobilization portion of the testing will be based on the injection simulation results to mimic a probable field design. The post-oxidation sample will be collected during a period of highly oxidizing conditions to represent the worst case metals mobilization potential. A set of control reactors will also be evaluated.

It is anticipated that up to 14 duplicate reactor systems (i.e., each test condition presented in Table 3 will be represented by 2 reactors; therefore, 28 reactors total will be analyzed by the laboratory) will be evaluated for VOCs and up to 4 duplicate reactor systems will be assessed for dissolved metals (2 for groundwater within the clay reactors and 2 for groundwater within the sand reactors), as shown in Table 3, during the bench scale evaluation. The number of samples submitted for analysis will be determined based on the results of the initial baseline sampling and is anticipated to be between 17 and 34 for VOCs and 8 for metals (4 for total metals and 4 for dissolved metals). The exact number of VOC analyses performed will depend upon the number of reactor systems assess for soil and groundwater and whether or not a multiple application strategy is employed, as discussed above.

2.3 PERMANGANATE

To evaluate the appropriateness of permanganate at Site 17, XDD will perform the following bench scale evaluation to estimate the following:

- The relative effectiveness of two different concentrations of permanganate;
- The mass of oxidant required to degrade the approximate mass of VOC contamination; and
- The metals mobilization potential.

The oxidant demand of the soil and the stability of permanganate will be evaluated prior to the primary bench test (Injection Simulation). Similar to activated persulfate, the injection simulation will consist of up to three applications of permanganate to simulate three injection events, as outlined in Table 4. The number of applications will be based on the amount of oxidant required to degrade the COC observed in the baseline analysis. Duplicate samples and controls will be sent to the laboratory after the first and third application (if necessary).

The assessment of potential metals mobilization will be accomplished through analyses of groundwater samples for total and dissolved metals prior to and after the addition of permanganate, as outlined in Table 4. The oxidant loading for the metals mobilization portion of the testing will be based on the injection simulation results to mimic a probable field design. The post-oxidation sample will be collected during a period of highly oxidizing conditions to represent the worst case metals mobilization potential. A set of control reactors will also be evaluated.

In addition to the 2 shared baseline reactors described in Section 2.2, it is anticipated that up to 12 duplicate reactor systems (i.e., each test condition presented in Table 3 will be represented by 2 reactors; therefore, 24 reactors total will be analyzed by the laboratory) will be evaluated for VOCs and up to 4 duplicate reactor systems will be assessed for metals (2 for groundwater within the clay reactors and 2 for groundwater within the sand reactors) during the Injection Simulation test. The number of samples submitted for analysis will be determined based on the results of the mutual baseline sampling, and is anticipated to be between 15 to 30 for VOCs and

8 for metals (4 for total metals and 4 for dissolved metals). The exact number of VOC analyses will be based on the number of reactor systems where both groundwater and soil are analyzed for VOCs and if multiple applications are used, as discussed above.

3.0 REPORTING

XDD will provide CH2M HILL with a three- to five-page report (excluding appendices) that will contain:

- The results of the bench scale evaluation;
- A brief analysis of the data;
- Photograph documentation of the bench scale test procedures;
- A recommendation on which technology is best suited for the site based on the bench scale results; and
- A conceptual pilot scale testing and full-scale implementation approaches.

The report will be submitted to CH2M HILL for review and comment, and XDD will provide a revised version of the report incorporating review comments.

4.0 MATERIALS

The testing described above will require approximately 20 kilograms of impacted soils (10 kilograms clay and 10 kilograms sand) and 10 liters of impacted groundwater, to be provided by CH2M HILL. It is expected that these soils will be representative of the target remediation area at Site 17. Following the bench scale testing, disposal of any remaining soil and groundwater will be coordinated by XDD using a manifest that is signed by an authorized representative of Site 17.

5.0 SCHEDULE

Bench tests will be initiated upon receipt of the required materials. Based on the timing presented in the milestones on Table 1, approximately 26 weeks may be required to conduct the bench scale evaluation and submit the draft report. This is a conservative estimate; the timing will be dependent on the results of the baseline samples.

6.0 PROJECT TEAM

Key members of the XDD Project Team that will be working on this bench-scale evaluation are:

- Michael Marley, XDD President. Mr. Marley is the Principal in-charge of this project.
- Annette Lee, Project Manager. Ms. Lee is a Project Manager in XDD's New Hampshire office and will be overseeing these bench scale evaluations.
- Brant Smith, P.E., Ph.D., Senior Engineer. Dr. Smith will be responsible for technical oversight of the bench scale studies.

Appendix A Tables

TABLE 1
Bench Scale Technology Evaluation Milestones
Site 17 Bench-Scale Studies
NSF-IH, Indian Head, Maryland
XDD Project 06010

Milestone	Week
Conduct Contaminant Mass Distribution Profiling	0
Perform Soil Oxidant Demand and Persulfate Buffer Capacity Tests	1-2
Receive Mass Distribution Profiling Results	2
Submit Baseline Analysis Samples	2-3
Receive Baseline Analysis Results	4-5
Begin Preliminary Alkaline and Iron Activated Persulfate Test	5
Submit Preliminary Persulfate Activation Test Samples	7
Receive Preliminary Persulfate Activation Test Results	9
Discuss Results with CH2M Hill to Confirm Approach for Remainder of Evaluation	10-11
Begin Persulfate and Permanganate Injection Simulation Tests	13
Complete Persulfate and Permanganate Injection Simulation Test	19
Begin and Complete Dissolved Metals Tests	20-23
Draft Report to CH2M HILL	24-26

TABLE 2
Baseline Assessment and Preliminary Tests
Site 17 Bench-Scale Studies
NSF-IH, Indian Head, Maryland
XDD Project 06010

Mass Distribution Profiling		# Samples	Sample Type	Analysis	TAT (Turnaround Time)
Assume (4) 10- to 15-foot cores (boreholes); up to 5 samples per core => 20 samples					
	Sand	up to 10	soil	VOCs (CLP OLM04.3)	STD 14 days
	Clay	up to 10	soil	VOCs (CLP OLM04.3)	STD 14 days
# Laboratory Analyses =>		up to 20			

Baseline Analysis		# Samples	Sample Type	Analysis	TAT (Turnaround Time)
Grain Size	Sand	1	soil	Grain Size (ASTM D422)	STD 14 days
	Clay	1	soil	Grain Size (ASTM D422)	STD 14 days
# Laboratory Analyses =>		2			
VOCs (unspiked, composited)	Sand	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Clay	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Groundwater	2	water	VOCs (CLP OLM04.3)	STD 14 days
# Laboratory Analyses =>		6			
Metals (composited)	Sand	2	soil	Total Metals (CLP ILM05.3)	STD 14 days
	Clay	2	soil	Total Metals (CLP ILM05.3)	STD 14 days
	Groundwater	2	water	Total Metals (CLP ILM05.3)	STD 14 days
	Groundwater	2	water	Dissolved Metals (CLP ILM05.3)	STD 14 days
# Laboratory Analyses =>		8			

Preliminary Persulfate Activation Test

Sand		Reactors	Sample Type	Analysis	TAT (Turnaround Time)
Alkaline Activation	Control	1	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 1	1	soil	VOCs (CLP OLM04.3)	STD 14 days
Iron Activation	Control	1	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 1	1	soil	VOCs (CLP OLM04.3)	STD 14 days
# Laboratory Analyses =>		4			

Clay		Reactors	Sample Type	Analysis	TAT (Turnaround Time)
Alkaline Activation	Control	1	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 1	1	soil	VOCs (CLP OLM04.3)	STD 14 days
Iron Activation	Control	1	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 1	1	soil	VOCs (CLP OLM04.3)	STD 14 days
# Laboratory Analyses =>		4			

Notes:
EPA Method 8260B may substitute the CLM OLM04.3 method for VOCs analyses.

TABLE 3
Activated Persulfate Evaluation Structure
Site 17 Bench-Scale Studies
NSF-IH, Indian Head, Maryland
XDD Project 06010

CLAY

Injection Simulation		Reactors	Sample Type	Analysis	TAT (Turnaround Time)
	Baseline of Spiked Soil	2	soil	VOCs (CLP OLM04.3)	72 hours
Control	Application 1	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 2 or Application 3[2]	2 1	soil water	VOCs (CLP OLM04.3) VOCs (CLP OLM04.3)	STD 14 days STD 14 days
High Oxidant Concentration[1]	Application 1	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 2 or Application 3[2]	2 1	soil water	VOCs (CLP OLM04.3) VOCs (CLP OLM04.3)	STD 14 days STD 14 days
Low Oxidant Concentration[1]	Application 1	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 2 or Application 3[2]	2 1	soil water	VOCs (CLP OLM04.3) VOCs (CLP OLM04.3)	STD 14 days STD 14 days
# Laboratory Analyses =>		17			

Metals Test		Reactors	Sample Type	Analysis	TAT (Turnaround Time)
High Oxidant Concentration[2,3]	Control	2	water	Total/Dissolved Metals (CLP ILM05.3)	STD 14 days
	Application 1	2	water	Total/Dissolved Metals (CLP ILM05.3)	STD 14 days
# Laboratory Analyses =>		8	(equivalent to 8 analyses: 4 total, 4 dissolved)		

SAND

Injection Simulation		Reactors	Sample Type	Analysis	TAT (Turnaround Time)
	Baseline of Spiked Soil	2	soil	VOCs (CLP OLM04.3)	72 hours
Control	Application 1	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 2 or Application 3[2]	2 1	soil water	VOCs (CLP OLM04.3) VOCs (CLP OLM04.3)	STD 14 days STD 14 days
High Oxidant Concentration[1]	Application 1	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 2 or Application 3[2]	2 1	soil water	VOCs (CLP OLM04.3) VOCs (CLP OLM04.3)	STD 14 days STD 14 days
Low Oxidant Concentration[1]	Application 1	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 2 or Application 3[2]	2 1	soil water	VOCs (CLP OLM04.3) VOCs (CLP OLM04.3)	STD 14 days STD 14 days
# Laboratory Analyses =>		17			

Metals Test		Reactors	Sample Type	Analysis	TAT (Turnaround Time)
High Oxidant Concentration[2,3]	Control	2	water	Total/Dissolved Metals (CLP ILM05.3)	STD 14 days
	Application 1	2	water	Total/Dissolved Metals (CLP ILM05.3)	STD 14 days
# Laboratory Analyses =>		8	(equivalent to 8 analyses: 4 total, 4 dissolved)		

Notes:

1. High and Low oxidant loading concentrations will be determined following receipt of the baseline soils data
2. *As necessary: Results from Application 1 will be evaluated to determine if the final samples are submitted for laboratory analysis following either the 2nd or 3rd application.*
3. High was selected to create most extreme case scenario
4. EPA Method 8260B may substitute the CLM OLM04.3 method for VOCs analyses.

TABLE 4
Permanganate Evaluation Structure
Site 17 Bench-Scale Studies
NSF-IH, Indian Head, Maryland
XDD Project 06010

CLAY

Injection Simulation		Reactors	Sample Type	Analysis	TAT (Turnaround Time)
	Baseline of Spiked Soil	shared[1]	soil	VOCs (CLP OLM04.3)	72 hours
Control	Application 1	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 2 or Application 3[3]	2 1	soil water	VOCs (CLP OLM04.3) VOCs (CLP OLM04.3)	STD 14 days STD 14 days
High Oxidant Concentration[2]	Application 1	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 2 or Application 3[3]	2 1	soil water	VOCs (CLP OLM04.3) VOCs (CLP OLM04.3)	STD 14 days STD 14 days
Low Oxidant Concentration[2]	Application 1	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 2 or Application 3[3]	2 1	soil water	VOCs (CLP OLM04.3) VOCs (CLP OLM04.3)	STD 14 days STD 14 days
# Laboratory Analyses =>		15			

Metals Test		Reactors	Sample Type	Analysis	TAT (Turnaround Time)
High Oxidant Concentration[2,4]	Control	2	water	Total/Dissolved Metals (CLP ILM05.3)	STD 14 days
	Application 1	2	water	Total/Dissolved Metals (CLP ILM05.3)	STD 14 days
# Laboratory Analyses =>		8	(equivalent to 8 analyses: 4 total, 4 dissolved)		

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Injection Simulation		Reactors	Sample Type	Analysis	TAT (Turnaround Time)
	Baseline of Spiked Soil	shared[1]	soil	VOCs (CLP OLM04.3)	72 hours
Control	Application 1	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 2 or Application 3[3]	2 1	soil water	VOCs (CLP OLM04.3) VOCs (CLP OLM04.3)	STD 14 days STD 14 days
High Oxidant Concentration[2]	Application 1	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 2 or Application 3[3]	2 1	soil water	VOCs (CLP OLM04.3) VOCs (CLP OLM04.3)	STD 14 days STD 14 days
Low Oxidant Concentration[2]	Application 1	2	soil	VOCs (CLP OLM04.3)	STD 14 days
	Application 2 or Application 3[3]	2 1	soil water	VOCs (CLP OLM04.3) VOCs (CLP OLM04.3)	STD 14 days STD 14 days
# Laboratory Analyses =>		15			

Metals Test		Reactors	Sample Type	Analysis	TAT (Turnaround Time)
High Oxidant Concentration[2,4]	Control	2	water	Total/Dissolved Metals (CLP ILM05.3)	STD 14 days
	Application 1	2	water	Total/Dissolved Metals (CLP ILM05.3)	STD 14 days
# Laboratory Analyses =>		8	(equivalent to 8 analyses: 4 total, 4 dissolved)		

Notes:

1. Baseline results will be the shared between the persulfate and permanganate tests
2. High and Low oxidant loadig concentrations will be determined following receipt of the baseline soils data
3. *As necessary: Results from Application 1 will be evaluated to determine if the final samples are submitted for laboratory analysis following either the 2nd or 3rd application.*
4. High was selected to create most extreme case scenario
5. EPA Method 8260B may substitute the CLM OLM04.3 method for VOCs analyses.

Appendix A Figure
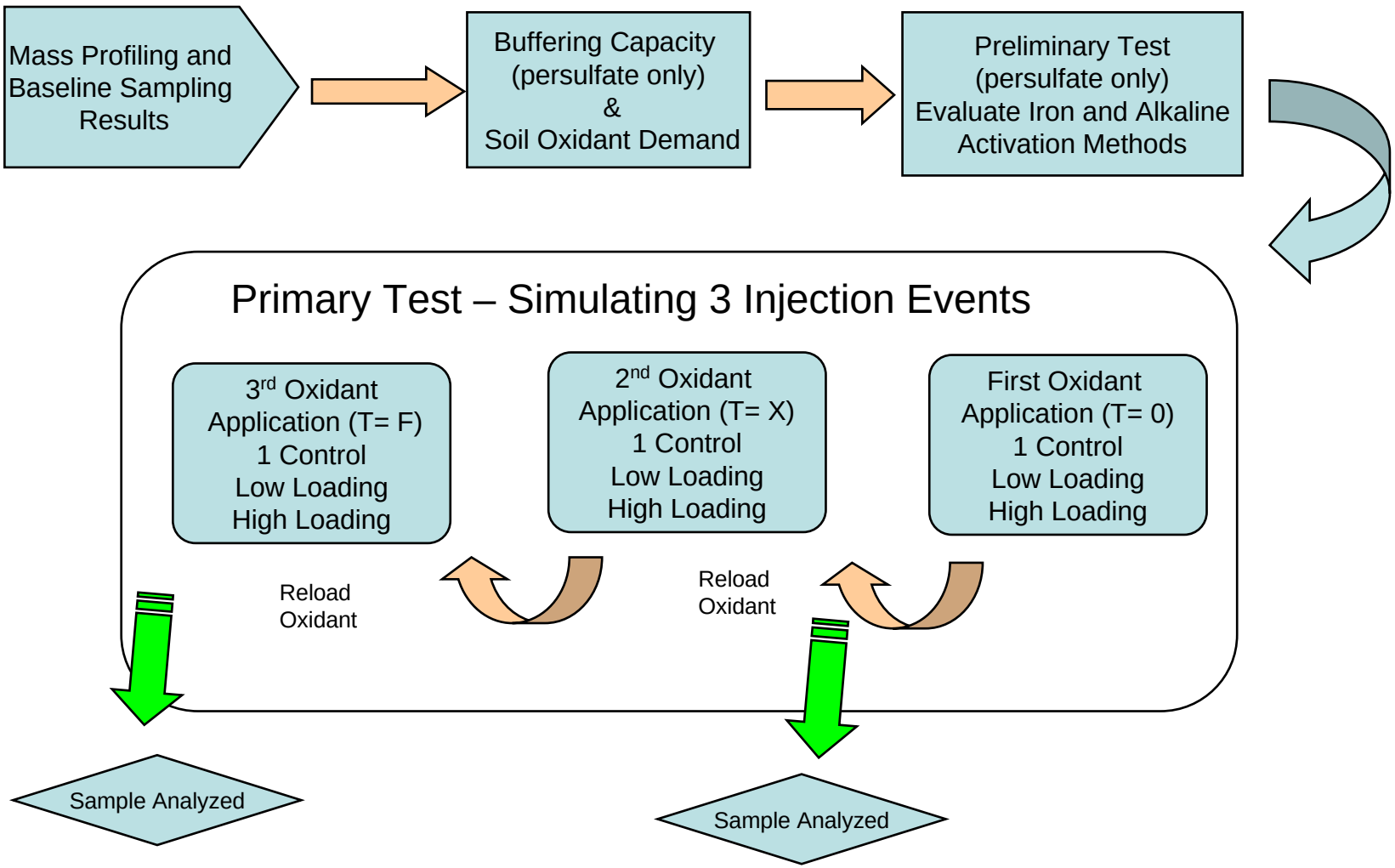
FIGURE 1
Conceptual Design of Persulfate And Permanganate Bench Scale Tests