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FINAL GROUNDWATER TREATABILITY STUDY WORK PLAN IN SITU CHEMICAL
OXIDATION PILOT STUDY FOR OPERABLE UNIT 4 (OU 4) WITH TRANSMITTAL LETTER
NTC ORLANDO FL
12/13/1999
ABB ENVIRONMENTAL

Harding Lawson Associates



02545-033

December 13, 1999

Commanding Officer
Southern Division, Naval Facilities Engineering Command
2155 Eagle Drive
North Charleston, SC 29406

ATTN: Ms. Barbara Nwokike, Code 187300

**SUBJECT: Operable Unit 4, Groundwater Treatability Studies
In-Situ Chemical Oxidation Pilot Study
Naval Training Center, Orlando, Florida
Contract No. N62467-89D-0317/135**

Dear Barbara:

Enclosed please find copies of the Final NTC Orlando OU 4 Treatability Study Work Plan No. 3, Data Collection Plan for Assessing In-Situ Chemical Oxidation Using Potassium Permanganate. This work plan was prepared to present the technical approach for evaluating in-situ chemical oxidation as a potential remedial technology for the source area and groundwater at OU 4.

Comments from the Florida Department of Environmental Protection have been incorporated into this Final document. A copy of the Response to Comments has been added to the work plan as Appendix I. The natural attenuation baseline sampling requested by you and Cliff Casey has also been added to the pilot study scope.

If you have questions or comments regarding this document, please contact me at (781) 245-6606 or John Kaiser at (407) 522-7570.

Very truly yours,

HARDING LAWSON ASSOCIATES

Mark J. Salvetti, P.E.
Task Order Manager

Enclosures

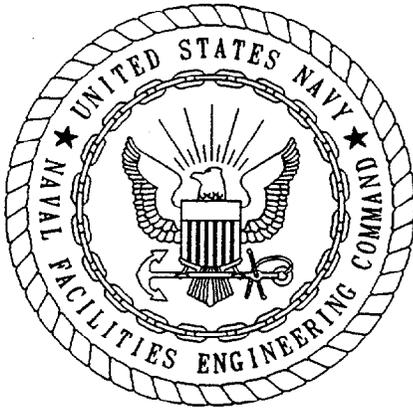
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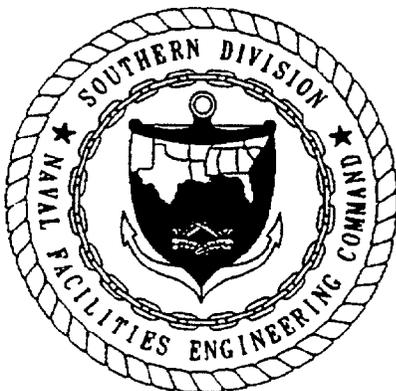


**TREATABILITY STUDY WORK PLAN NO. 3
DATA COLLECTION PLAN FOR ASSESSING
IN-SITU CHEMICAL OXIDATION USING
POTASSIUM PERMANGANATE**

**OPERABLE UNIT 4
AREA C
NAVAL TRAINING CENTER, ORLANDO, FLORIDA**

**UNIT IDENTIFICATION CODE: N65298
CONTRACT NO. N62467-89-D-0317/135**

DECEMBER 1999



**SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORTH CHARLESTON, SOUTH CAROLINA
29419-9010**

TREATABILITY STUDY WORK PLAN NO. 3
DATA COLLECTION PLAN FOR ASSESSING
IN-SITU CHEMICAL OXIDATION USING
POTASSIUM PERMANGANATE

OPERABLE UNIT 4

NAVAL TRAINING CENTER, AREA C
ORLANDO, FLORIDA

Unit Identification Code: N65298

Contract No.: N62467-89-D-0317/135

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December 1999



CERTIFICATION OF TECHNICAL
DATA CONFORMITY (MAY 1987)

The Contractor, Harding Lawson Associates, Inc. (HLA), hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. N62467-89-D-0317/135 are complete and accurate and comply with all requirements of this contract.

DATE: December 13, 1999

NAME AND TITLE OF CERTIFYING OFFICIAL: John Kaiser
Installation Manager

NAME AND TITLE OF CERTIFYING OFFICIAL: Mark Salvetti, P.E.
Project Technical Lead

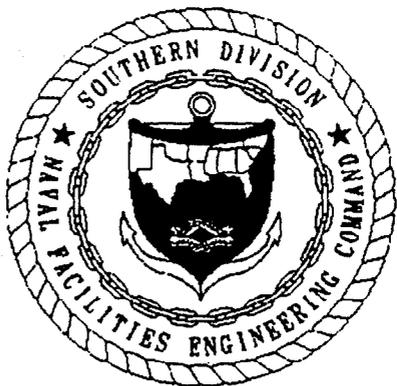
(DFAR 252.227-7036)



This work plan was prepared to present the technical approach for evaluating in-situ chemical oxidation using potassium permanganate as a potential source area and groundwater remedial alternative at Operable Unit 4 at the Naval Training Center, Orlando, Florida. The engineering evaluation and professional opinions rendered in this document were conducted or developed in accordance with commonly accepted procedures consistent with applicable standards of practice.

Willard A. Murray, P.E.

Willard A. Murray 12/14/99
Senior Consulting Engineer
Professional Engineer No. PE039866
Expires February 28, 2001



FOREWORD

To meet its mission objectives, the U.S. Navy performs a variety of operations, some requiring the use, handling, storage, or disposal of hazardous materials. Through accidental spills and leaks and conventional methods of past disposal, hazardous materials may have entered the environment in ways unacceptable by today's standards. With growing knowledge of the long-term effects of hazardous materials on the environment, the Department of Defense (DOD) initiated various programs to investigate and remediate conditions related to suspected past releases of hazardous materials at their facilities. Two of these programs are the Installation Restoration (IR) program and the Base Realignment and Closure (BRAC) program.

The IR program complies with the Base Closure and Realignment Act of 1988 (Public Law 100-526, 102 Statute 2623) and the Defense Base Closure and Realignment Act of 1990 (Public Law 101-510, 104 Statute [1808]), which require the DOD to observe pertinent environmental legal provisions of the Comprehensive Environmental Response, Compensation, and Liability Act, Executive Order 12580, and the statutory provisions of the Defense Environmental Restoration Program, the National Environmental Policy Act, and any other applicable statutes that protect natural and cultural resources.

Originally, the Navy's part of this program was called the Naval Assessment and Control of Installation Pollutants (NACIP) program. Early reports reflect the NACIP process and terminology. The Navy eventually adopted the program structure and terminology of the standard IR program.

The IR program is conducted in several stages as follows:

- Preliminary Assessment (PA),
- A Site Inspection (SI) (formerly the PA and SI steps were called the Initial Assessment Study under the NACIP program),
- Remedial Investigation and Feasibility Study (RI/FS), and
- Remedial Design and Remedial Action.

The goal of the BRAC program is to expedite and improve environmental response actions to facilitate the disposal and reuse of a BRAC installation while protecting human health and the environment.

The Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM), the U.S. Environmental Protection Agency (USEPA), and the Florida Department of Environmental Protection (FDEP) collectively coordinate the cleanup activities through the BRAC cleanup team, called the Orlando Partnering Team (OPT), in Orlando. This team approach is intended to foster partnering, accelerate the environmental cleanup process, and expedite timely, cost-effective, and environmentally responsible disposal and reuse decisions.

Questions regarding the BRAC program at Naval Training Center, Orlando should be addressed to the SOUTHNAVFACENGCOM BRAC Environmental Coordinator, Mr. Wayne Hansel, Code 18B7, at (407) 895-6714 or SOUTHNAVFACENGCOM Engineer-in-Charge, Ms. Barbara Nwokike, Code 1873, at (843) 820-5566.

EXECUTIVE SUMMARY

Operable Unit (OU) 4 is composed of Study Areas 12, 13, and 14 at Area C. Building 1100, located in Study Area 13, was constructed in 1943 and was used as a laundry and dry-cleaning facility, serving the entire military base.

A plume of chlorinated solvent contaminated groundwater originating from the area around Building 1100 and migrating into the adjacent Lake Druid was identified during site investigations conducted at OU 4. Volatile organic compounds (VOCs) detected in groundwater and surface water from Lake Druid included tetrachloroethene (PCE), trichloroethene (TCE), *cis*-1,2-dichloroethene (DCE), *trans*-1,2-DCE, 1,1-DCE, and vinyl chloride (VC). Source areas appear to be multiple and are likely located adjacent to and beneath Building 1100. An Interim Remedial Action (IRA), consisting of two recirculation wells, has been implemented to intercept and treat the majority of the contaminated groundwater before reaching Lake Druid.

At OU 4, an initial technology screening evaluation was conducted to evaluate remedial options for contaminated groundwater and source area treatment. Remedial technologies that were identified for potential treatability study at OU 4 include phytoremediation; air sparging; *in situ* chemical oxidation; and natural attenuation. This work plan was prepared as part of the treatability study process to present the technical approach for evaluating *in situ* chemical oxidation using potassium permanganate (KMnO₄) at OU 4.

In-situ chemical oxidation was selected based on the type of contaminants present in the groundwater (PCE and its degradation products) and the ability of KMnO₄ to readily oxidize these compounds. If successfully piloted, *in-situ* chemical oxidation could be used for source removal and to treat areas with high concentrations of VOCs in groundwater.

This work plan presents the technical scope of work and schedule for conducting fieldwork to determine if *in-situ* chemical oxidation is a feasible technology for OU 4. The pilot study is intended to determine if site-specific conditions may inhibit or prohibit the use of *in situ* chemical oxidation at OU 4, and to establish necessary design and performance criteria for full-scale implementation. These criteria include the ability to create and maintain a groundwater circulation cell, the optimum KMnO₄ aqueous concentration required to oxidize the OU 4 source area VOCs, and the maximum reduction of groundwater VOC concentrations achievable with this technology.

A preliminary evaluation of this technology performed in the Draft Final OU 4 Feasibility Study (FS) (Harding Lawson Associates [HLA], 1999a) suggested KMnO₄ oxidation was an attractive remedial alternative. However, the evaluation was based on performance and cost assumptions derived from case studies. This pilot study will establish design parameters for KMnO₄ oxidation at OU 4, allowing a more accurate re-evaluation of the technology in the Final OU 4 FS.

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GLOSSARY

ABB-ES	ABB Environmental Services, Inc.
bls	below land surface
BRAC	Base Realignment and Closure (Act)
CO ₂	carbon dioxide
DCE	dichloroethene
DOD	Department of Defense
ECD	electron capture detector
F.A.C	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FID	flame ionization detector
FS	Feasibility Study
FSP	field sampling plan
GC	gas chromatograph
GMP	groundwater monitoring point
gpm	gallons per minute
g/l	grams per liter
g/min	grams per minute
HLA	Harding Lawson Associates
ID	inside diameter
IDW	investigation-derived waste
IR	Installation Restoration
IRA	interim remedial action
KMnO ₄	potassium permanganate
l/min	liters per minute
MCL	Maximum Concentration Limits
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
µg/l	micrograms per liter
NACIP	Naval Assessment and Control of Installation Pollutants
NTC	Naval Training Center
OD	outside diameter
OPT	Orlando Partnering Team
OU	Operable Unit
PA	Preliminary Assessment
PCE	tetrachloroethene
POP	Project Operations Plan
ppb	parts per billion
PVC	polyvinyl chloride
RI	remedial investigation
SI	site inspection
SOUTHNAV- FACENGC	Southern Division, Naval Facilities Engineering Command

GLOSSARY (Continued)

TCE	trichloroethene
TOC	total organic carbon
TOC	top of casing
USEPA	U.S. Environmental Protection Agency
USP	United States Pharmacopoeia
VC	vinyl chloride
VOC	volatile organic compounds

1.0 INTRODUCTION

Harding Lawson Associates, Inc. (HLA), under contract to Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM), has prepared this work plan for an in-situ chemical oxidation pilot study at Operable Unit (OU) 4, at the Naval Training Center (NTC), Area C, in Orlando, Florida. This work plan has been prepared under contract number N62467-89-D-0317/135.

Remedial technologies that may be effective in treating groundwater contaminated with volatile organic compounds (VOCs) at OU 4 have been screened for evaluation in the Draft Final OU 4 Feasibility Study (FS) (HLA, 1999a). Technologies that require additional information regarding performance, implementability, and full-scale cost to adequately perform a feasibility assessment have been recommended for further evaluation during treatability studies.

Remedial technologies that were identified for potential treatability studies at OU 4 include phytoremediation; air sparging; *in situ* chemical oxidation; and natural attenuation. Natural attenuation (HLA, 1998a) and air sparging (ABB Environmental Services, Inc. [ABB-ES], 1998a; HLA, 1999a) have already been evaluated. This work plan was prepared as part of the treatability study process to present the technical approach for evaluating in-situ chemical oxidation with potassium permanganate ($KMnO_4$) at OU 4.

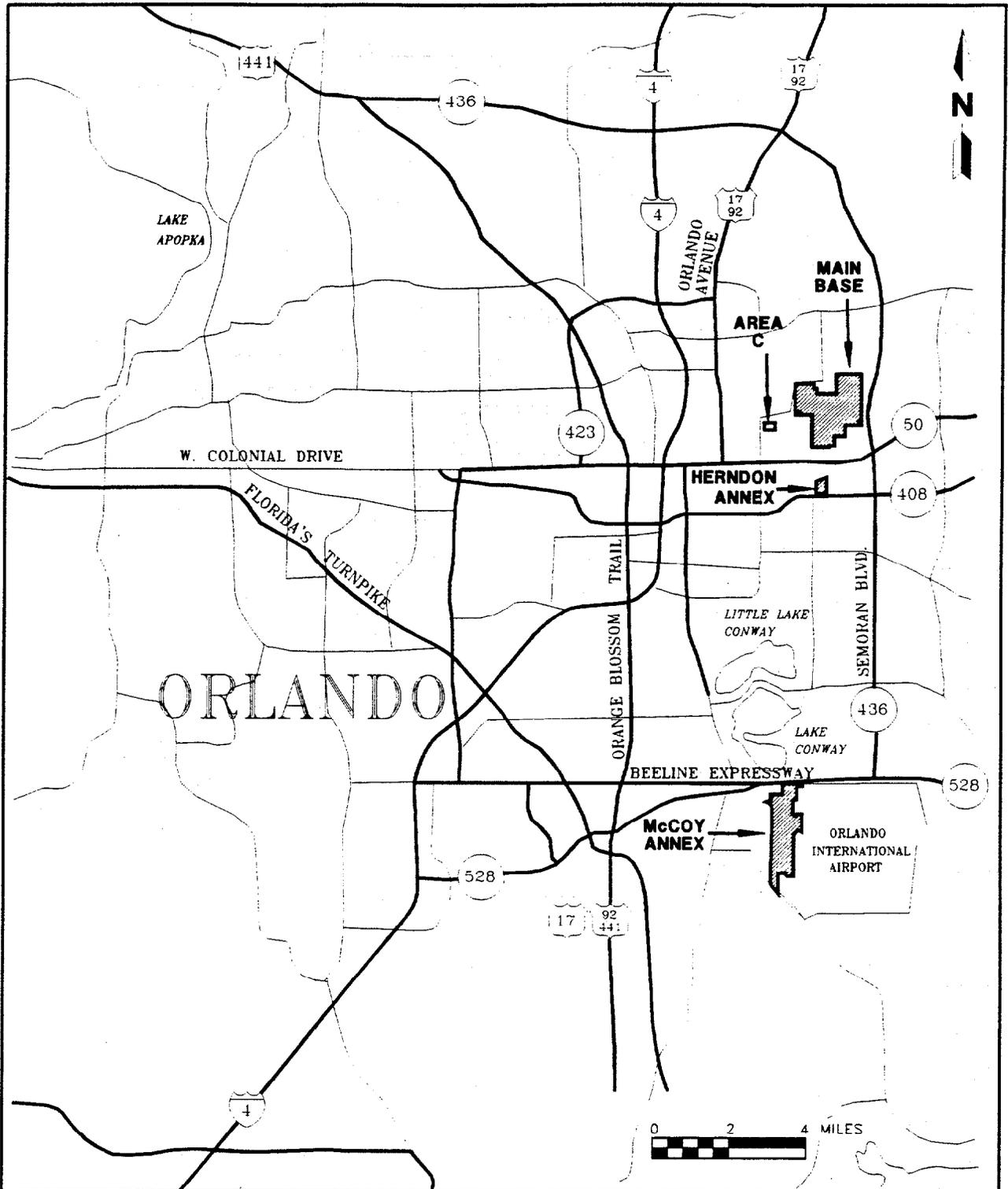
This work plan has incorporated elements of the Project Operations Plan (POP) (ABB-ES, 1997a), which contains the requirements of a Quality Assurance Project Plan, Health and Safety Plan, and elements of a Field Sampling Plan (FSP) related to sampling equipment, procedures, and sample handling and analysis. Other FSP elements specific to this site, including sampling objectives and sample location and frequency, will be addressed in this work plan. A site-specific addendum to the health and safety plan found in the POP is included as an Appendix to this document.

1.1 SITE DESCRIPTION. OU 4 is composed of Study Areas 12, 13, and 14 at Area C (Figure 1-1 and 1-2). Building 1100, located in Study Area 13, was constructed in 1943 and was used as a laundry and dry-cleaning facility, serving the entire military base. Prior to construction of the facility in 1943, the land was undeveloped. The laundry was closed in 1994. Building 1100 (the laundry) was identified as a site where releases of hazardous materials had occurred.

Several investigations have already occurred at OU 4, either under the Base Realignment and Closure (BRAC) Act site screening program or under subsequent efforts to characterize the contamination discovered during the site screening. Results from the investigations conducted at OU 4 to date are summarized in the OU 4 Remedial Investigation (RI) Workplan (ABB-ES, 1997b) and the Draft Final RI Report (HLA, 1998b).

These efforts have identified a plume of chlorinated solvent-contaminated groundwater originating from the area around the former base laundry and migrating into the adjacent Lake Druid. Contour lines illustrating the approximate defined boundary of the 100 parts per billion (ppb) total VOCs are shown on Figure 1-3. VOCs detected in groundwater and surface water from Lake Druid included tetrachloroethene (PCE), trichloroethene (TCE), *cis*-1,2-dichloroethene (DCE), *trans*-1,2-DCE, 1,1-DCE, and vinyl chloride (VC). Source areas appear to be multiple and are likely located adjacent to and beneath the former laundry, Building 1100. The approximate extent of the suspected multiple source areas is also shown on Figure 1-3. No source area associated with the southern portion of the plume has been identified. Because VOC concentrations are several orders of magnitude lower than in the northern plume, the source was likely a small release that has either been depleted or removed.

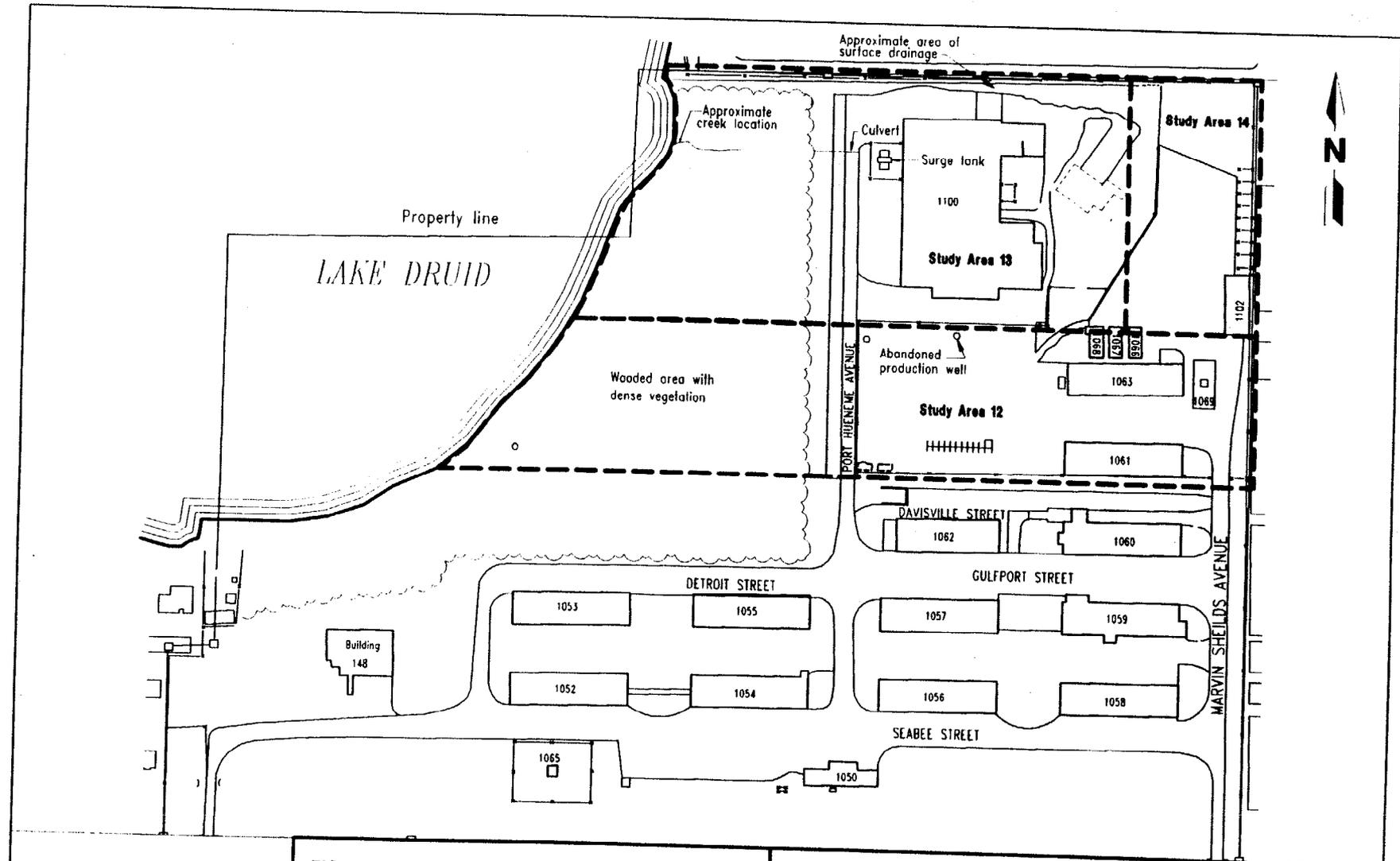
An Interim Remedial Action (IRA), consisting of two recirculation wells (UVB-1 and UVB-2, locations shown on Figure 1-3), has been implemented to intercept and treat the majority of the contaminated groundwater before reaching Lake Druid.



**FIGURE 1-1
SITE LOCATION MAP**



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ORLANDO, FLORIDA**

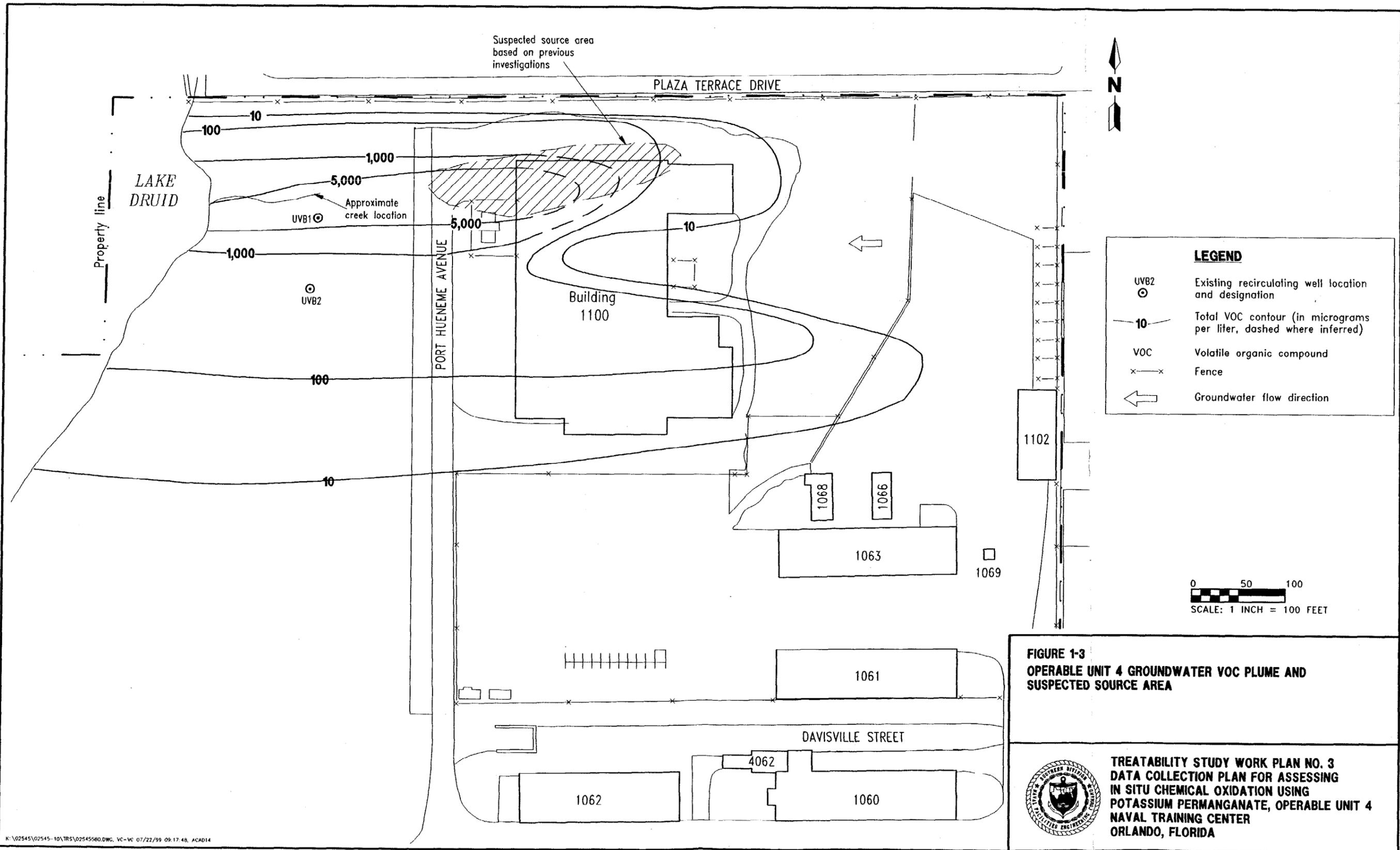


0 125 250
 SCALE: 1 INCH = 250 FEET

**FIGURE 1-2
 MAP OF AREA C**



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 ORLANDO, FLORIDA**



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Although the IRA has required considerable maintenance and has encountered several periods of down time, groundwater data from the edge of Lake Druid has shown considerable reductions in VOCs. The last round of groundwater sampling (January 1999) found groundwater VOC concentrations in two points adjacent to the lake were below Florida Surface Water Standards for the first time. IRA operation has been summarized in four quarterly reports (HLA, 1998c, 1999b, 1999c, 1999d).

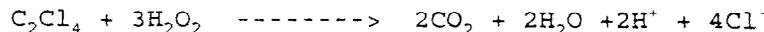
Based on the OU 4 Focused Field Investigation (ABB-ES, 1996a), the source investigation (ABB-ES, 1997c), and the OU 4 RI (HLA, 1998b), the chlorinated solvent groundwater plume ranges from approximately 4 to 45 feet below land surface (bls) with total VOCs in excess of 30 milligrams per liter (mg/l) in the source area(s), and up to approximately 6 mg/l between the laundry and Lake Druid. The depth of the plume in the source area shown on Figure 1-3 is approximately 30 to 35 feet bls. The water table between Lake Druid and the laundry varies seasonally from less than 1 foot to 4 feet bls.

The soil density of the surficial aquifer typically ranges from medium dense to dense, with the exception of a hard layer (very dense) approximately 15 to 20 feet bls, with varying thickness of 2 to 5 feet. However, this hard layer does not act as a hydraulic or chemical confining layer or barrier.

Analysis of pumping test data indicated that the surficial aquifer can be separated into two zones. From the groundwater surface to approximately 20 to 25 feet bls, the horizontal hydraulic conductivity is about 10 ft/day. Below that point to approximately 55 feet bls, the horizontal hydraulic conductivity is about 40 ft/day. In both zones the vertical hydraulic conductivity was determined to be about three times lower than the horizontal hydraulic conductivity.

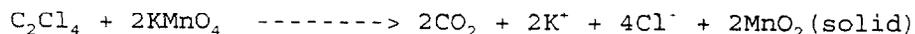
1.2 EVALUATION OF IN SITU CHEMICAL OXIDATION AS A REMEDIAL ALTERNATIVE. In-situ chemical oxidation involves the injection of a chemical oxidant into the source zone. The contaminant is destroyed through contact with the chemical oxidizer. Byproducts include carbon dioxide, water, and chloride (when chlorinated compounds are oxidized). The oxidation is non-specific, and all compounds present that can be oxidized by a given reagent will react. In-situ chemical oxidation holds particular promise when applied to chlorinated solvent sites such as OU 4. Chlorinated solvents can be slow to biodegrade, and in cases where residual source material is present, can require many decades to remediate using conventional technologies such as pump and treat. However, chlorinated compounds (particularly those with double bonds, such as PCE, TCE, DCE, etc) are readily destroyed when contacted with chemical oxidants.

There are two common chemical oxidants typically used for in-situ treatment. One uses hydrogen peroxide through a Fenton's reagent reaction catalyzed by iron. This process typically requires the injection of an acid solution to lower groundwater pH, followed by a ferrous sulfate catalyst and hydrogen peroxide. The oxidation of PCE proceeds as follows:



This reaction is highly exothermic and also produces quantities of oxygen from the decomposition of excess hydrogen peroxide. The reactants are unstable and short-lived. This process has been commercialized and is offered by several firms that specialize in this technology.

KMnO_4 has also been shown to be an effective oxidant for PCE and TCE (Schnarr et al, 1997; Hood et al, 1998; West et al, 1997). An aqueous solution of KMnO_4 is injected or flushed through the source area. The basic stoichiometry for the oxidation of PCE is as follows:



This reaction does not generate excess heat and the reactant is long-lived, allowing it to be flushed through a source area by pumping to maximize contact with the contaminant zone. KMnO_4 has also been shown to be more effective at oxidizing PCE and TCE than the Fenton's process (West et al, 1997).

1.3 PURPOSE OF THE IN-SITU CHEMICAL OXIDATION PILOT TEST. This work plan presents the technical scope of work and schedule for conducting fieldwork to determine if in-situ chemical oxidation with KMnO_4 is a feasible technology to effectively oxidize the OU 4 source area and reduce the concentrations of VOCs in groundwater. A preliminary evaluation of this technology performed in the Draft Final OU 4 FS (HLA, 1999a) suggested KMnO_4 oxidation was an attractive remedial alternative. However, the evaluation was based on performance and cost assumptions derived from literature experience. This pilot study will establish design parameters for KMnO_4 oxidation at OU 4, allowing a more accurate re-evaluation of the technology in the Final OU 4 FS.

1.4 IN-SITU CHEMICAL OXIDATION PILOT TEST OBJECTIVES. The objective of the chemical oxidation pilot test is to provide site-specific data supporting assessment of this alternative in the Final OU 4 FS. Site-specific parameters to be evaluated during the pilot test are as follows:

1. ability to create and maintain groundwater circulation cell
2. optimum KMnO_4 aqueous concentration required to oxidize the OU 4 source area VOCs
3. ability to treat source area VOCs both above and below the layer of dense sand
4. maximum reduction of groundwater VOC concentrations achievable with this technology

1.5 ORGANIZATION OF THE IN-SITU CHEMICAL OXIDATION WORK PLAN. The remainder of this work plan presents the pilot-test design, the test procedure and types of data to be collected, the methodology of the field and analytical programs, and methodology for data analysis and interpretation.

2.0 PILOT TEST IMPLEMENTATION

This chapter will describe conceptual design, the layout, and necessary equipment to perform the KMnO_4 oxidation pilot test. The test layout and well installation will be described followed by the description and arrangement of other necessary equipment. At the conclusion of this chapter, site closure and demobilization activities will be discussed.

2.1 POTASSIUM PERMANGANATE (KMnO_4) BENCH-SCALE EVALUATIONS. Two bench-scale evaluations were performed prior to recommending KMnO_4 as a technology suitable for piloting. Contaminated OU 4 groundwater was dosed with various concentrations of KMnO_4 to observe the rate of PCE and TCE oxidation. Saturated soil samples from the OU 4 source area were also treated with a KMnO_4 solution to establish oxidant demand by naturally occurring organics in site soils.

2.1.1 Bench-Scale Oxidation Rate Evaluation Contaminated groundwater was collected from an OU 4 source area well (OLD-13-07A) and shipped to Carus Chemical, in Peru, Illinois. Carus is the sole domestic producer of KMnO_4 , and maintains a treatability laboratory for evaluation of KMnO_4 applications.

PCE and TCE concentrations were measured prior to KMnO_4 addition, and then one hour and two hours after addition of various concentrations of KMnO_4 . KMnO_4 concentrations ranged from 100 mg/l to 4,000 mg/l. These data were combined with the results of another rate evaluation performed by Carus for a non-Navy PCE site in Florida managed by the HLA office in Tallahassee. These data are all included in Appendix B.

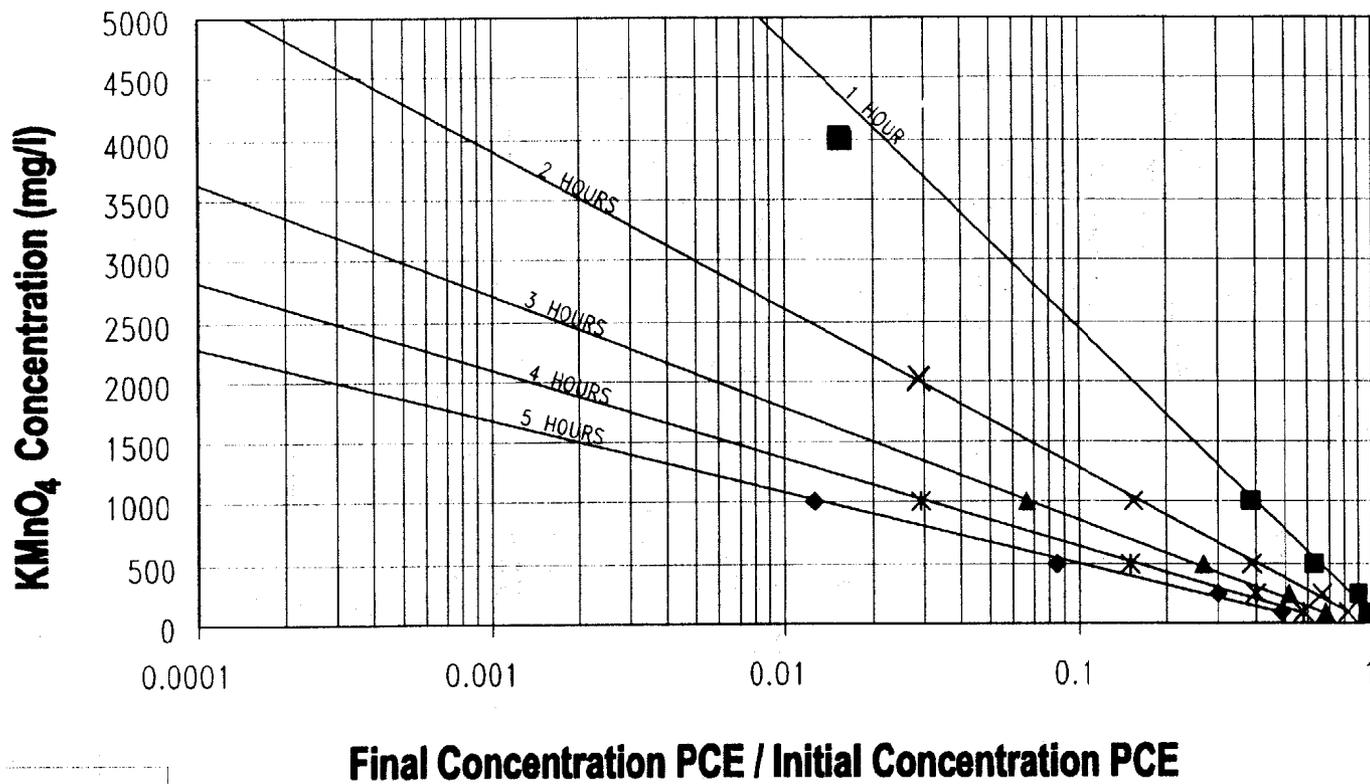
The bench-scale data provided a means to relate the decrease in PCE concentration (expressed as a ratio of PCE concentration over initial PCE concentration) as a function of time and KMnO_4 concentration. The results are presented graphically in Figure 2-1. Only PCE was used in this graph, as the reaction kinetics favor TCE oxidation. The TCE oxidized very quickly after addition of KMnO_4 . The rate of PCE oxidation will be the limiting step.

The pilot test approach calls for extraction of source area groundwater, addition of KMnO_4 , and then reinjection (see below). In this situation, Florida requires that Maximum Concentration Limits (MCLs) be achieved prior to reinjection of the treated groundwater. Figure 2-1 can now be used to determine the rate constant for the reaction of PCE at various KMnO_4 concentrations. The rate constant can then be used to predict treatment system performance prior to reinjection (see subsection 3.2.1).

2.1.2 Bench-Scale Soil KMnO_4 Demand Because the injected KMnO_4 will oxidize most organic material present, the KMnO_4 demand of site soils could consume enough KMnO_4 that this process would not be economical at OU 4. To evaluate this potential, two saturated soil samples (from approximately 10 feet bls) were collected from the area proposed for the pilot study and submitted to Carus for a KMnO_4 demand test. Split samples were also submitted to an analytical laboratory for total organic carbon (TOC) analysis. Results of both analyses are included in Appendix B.

The KMnO_4 demand was determined by adding site soil to a solution of KMnO_4 with a known concentration. After 30 minutes, the concentration of KMnO_4 in solution was remeasured. The before and after difference in KMnO_4 concentrations is the KMnO_4 demand of the soil.

The KMnO_4 demand of the two soil samples collected from OU 4 was 588 mg/l and 359 mg/l, and the associated TOC concentrations were 3,000 milligrams per kilogram (mg/kg) and 1,200 mg/kg, respectively. These values contrast to the 8,400 mg/l KMnO_4 demand for soil from the Tallahassee site mentioned in Subsection 2.1.1. The comparably low KMnO_4 demand for OU 4 soil suggests most of the injected KMnO_4 will remain available to oxidize VOCs.



LEGEND

- ◆ 5 Hours
- ✱ 4 Hours
- ▲ 3 Hours
- ✕ 2 Hours
- 1 Hour

mg/l Milligrams per liter
 KMnO₄ Potassium permanganate
 PCE Tetrachloroethene

**FIGURE 2-1
 PCE OXIDATION RATES**



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 DATA COLLECTION PLAN FOR ASSESSING
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 POTASSIUM PERMANGANATE, OPERABLE UNIT 4
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2.2 IN-SITU CHEMICAL OXIDATION CONCEPTUAL DESIGN. Development of the pilot study required selection of a pilot study location, hydraulic modeling to determine the number and location of extraction and injection wells, design of the groundwater extraction and KMnO_4 feed system, and the design of a groundwater monitoring plan to evaluate the in-situ oxidation performance.

2.2.1 Pilot Study Location The OU 4 groundwater VOC plume and suspected source area are shown on Figure 1-3. The majority of the source area is believed to be located beneath Building 1100. However, the source area does extend beneath a paved area off the northwest corner of Building 1100, north of the surge tank. PCE has been detected in groundwater in this area at concentrations exceeding 25,000 micrograms per liter ($\mu\text{g}/\ell$). Several groundwater monitoring points (GMPs) from the unsuccessful air sparging pilot study (HLA, 1999a) are also located in this area, and can be used to monitor VOC and KMnO_4 concentrations during the pilot study.

Because of the accessibility of this area, the high VOC concentrations, and the presence of several suitable monitoring points, the KMnO_4 pilot study will occur at this location.

2.2.2 Hydraulic Modeling The hydrogeology of the pilot test location was modeled using Visual MODFLOW. Aquifer parameters were those developed by the United States Geological Survey (USGS, 1998) from the OU 4 IRA Pumping Test (ABB-ES, 1996b). A two-layer model was used, consistent with the USGS findings - a shallow zone (0 to 20 feet bls) with a horizontal hydraulic conductivity of 10 feet per day (ft/day), and a deeper zone (20 to 60 feet bls) with a horizontal hydraulic conductivity of 40 ft/day. Modeling details are included in Appendix C.

Various extraction and injection well scenarios were evaluated to determine the number of wells and the extracted/injected groundwater flowrate necessary to establish a recirculation cell across the accessible source area. Particle tracking was also used to estimate KMnO_4 travel times for the shallow and deep layers.

The modeling determined that three extraction and three injection wells were necessary to optimize the chemical oxidation recirculation cell (Figure 2-2). The extraction wells are located on the downgradient end of the recirculation cell, on Port Hueneme Avenue. The wells are oriented north-south on 10-foot centers. The injection wells are located 65 feet upgradient (east) of the extraction wells, and are also set on 10-foot centers. The extraction wells will consist of 4-inch inside diameter (ID) polyvinyl chloride (PVC) riser with a 20 foot screen, set to a depth of 30 feet bls. The injection wells will be identical, with the exception of 25 foot screens to help ensure complete distribution of the KMnO_4 solution. A suitably sized recirculation cell can be established by extracting and injecting approximately 5 gallons per minute (gpm) total, distributed equally among each of the three extraction/injection well pairs.

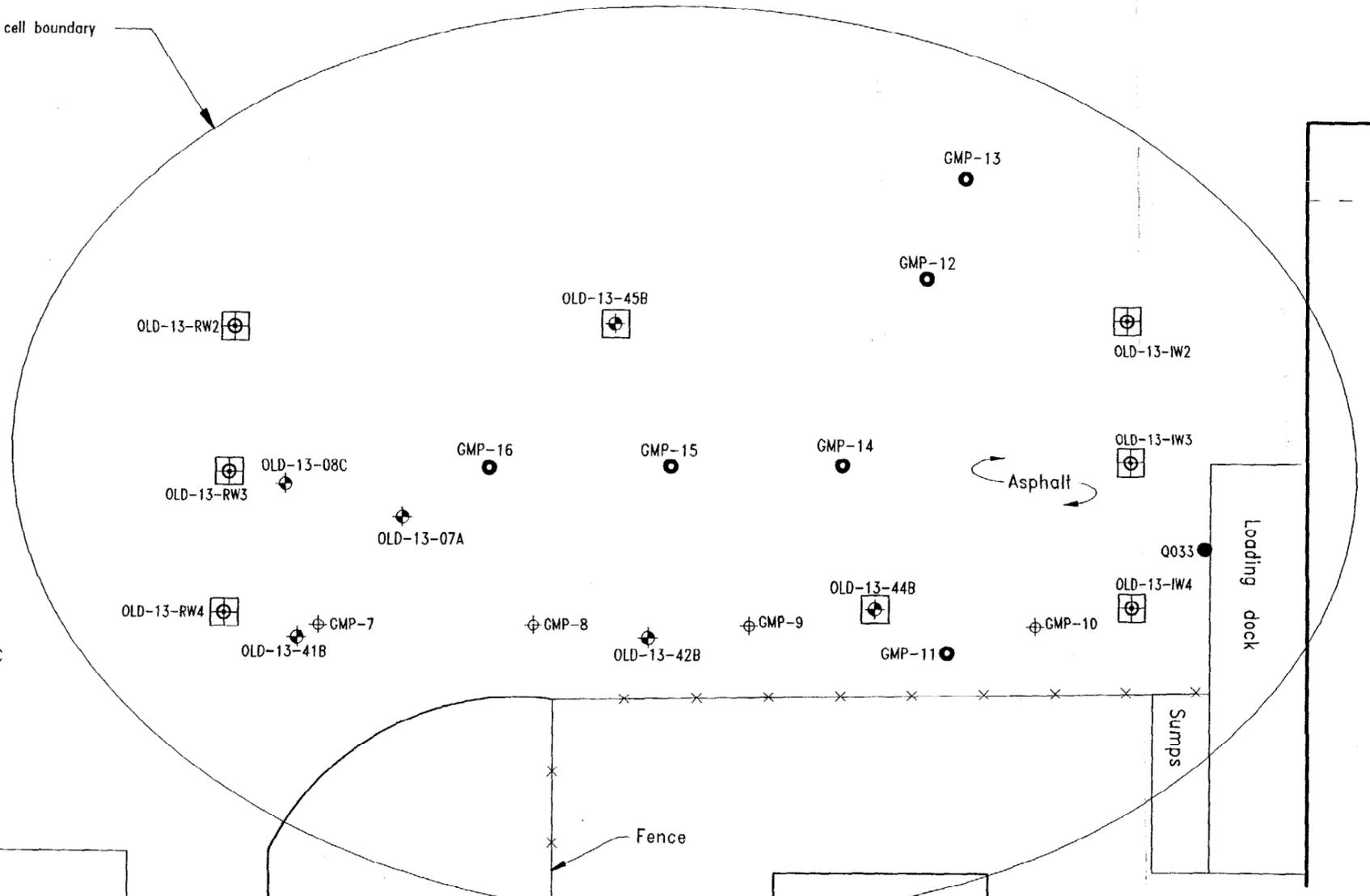
At this flow rate, the travel time between the middle extraction/injection well pair will be approximately 160 days in the shallow aquifer, and 40 days in the deep aquifer. Varying pumping rates and the number of extraction/injection wells did not significantly reduce the necessary travel time.

2.2.3 KMnO_4 Physical Properties KMnO_4 is a manufactured product, consisting of dark purple or bronze-like rhombic crystals. Carus Chemical Company in Peru, Illinois is the only domestic producer of KMnO_4 . KMnO_4 has a long history of use in the drinking water, wastewater, and chemical manufacturing industries. In potable water applications, KMnO_4 oxidizes iron, manganese, and hydrogen sulfide. It controls taste and odor problems, and is a pre-oxidant for trihalomethane control.

Carus manufactures KMnO_4 in several different grades. For the OU 4 pilot study, KMnO_4 will be purchased in 330 pound drums in either a free-flow or United States Pharmacopoeia (USP) grade. The powdered KMnO_4 will be mixed with extracted



Circulation cell boundary



Roof overhang

Wall

Building 1100

Asphalt

Loading dock

Sumps

Fence

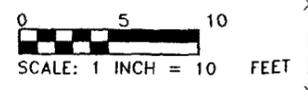
Surge tank

PORT HUENEME AVENUE

Grass

LEGEND

- ⊕ OLD-13-43C Monitoring well location and designation
- ⊕ OLD-13-46B Proposed monitoring well location and designation
- ⊕ GMP-4 Microwell location and designation
- GMP-16 Proposed microwell location and designation
- Q033 Temporary direct-push technology well location and designation
- ⊕ OLD-13-RW4 Proposed recovery or injection well location and designation
- GMP Groundwater monitoring point
- IW Injection well
- RW Recovery well



**FIGURE 2-2
PILOT TEST MONITORING POINT LAYOUT**



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groundwater prior to reinjection into the source area. The aqueous solubility of KMnO_4 is approximately 60 grams per liter (g/l) at 20C, but the concentrations used for the pilot study will be considerably less (see Subsection 3.2.1). Additional KMnO_4 physical property data can be found in Appendix B, and storage and handling requirements are included in the health and safety plan addendum in Appendix A.

2.2.4 KMnO_4 Injection Approval In addition to potassium and manganese, KMnO_4 solutions will also contain various other inorganics that were present in the raw manganese ore after mining. In some cases, concentrations of these metals in the KMnO_4 solution will exceed Florida secondary drinking water quality standards as set forth in Rules 62-550.310 and 62-550.320, Florida Administrative Code (F.A.C.). This can present an obstacle with respect to reinjection into the aquifer at OU 4, which is classified as a Florida Class G-II aquifer.

Rule 62-522.300(1), F.A.C. provides that:

No installation shall directly or indirectly discharge into groundwater any contaminant that causes a violation in the water quality standards and criteria for the receiving groundwater as established in Chapter 62-520 except within a zone of discharge established by permit or rule pursuant to this chapter.

Furthermore, Rule 62-522.300(2) (a), F.A.C. provides that:

(2) No zone of discharge shall be allowed under any of the following circumstances: (a) Discharges through wells or sink holes that allow direct contact with Class G-I or Class G-II groundwater, except projects designed to recharge aquifers with surface water of comparable quality, or projects designed to transfer water across or between aquifers of comparable quality for the purpose of storage or conservation.

On June 7, 1999, HLA petitioned the Florida Department of Environmental Protection (FDEP) Office of General Counsel for a variance from Rule 62-522.300(2)(a) to allow injection of KMnO_4 for the OU 4 pilot study. On September 3, 1999, the variance was granted by the department under Rule 62-520.500, F.A.C., allowing a maximum KMnO_4 concentration of 7.6 g/l for the Free-Flow solution, and 11.6 g/l for the USP solution. The variance information and the KMnO_4 inorganic compositions for the various grades are included in Appendix D.

2.2.5 Pilot Study Feed System A schematic of the KMnO_4 feed system is shown on Figure 2-3. A single centrifugal pump will be used at the surface to extract groundwater from all three extraction wells. The three extraction wells will be piped in parallel to the extraction pump. Flow meters and valves on each extraction well will be provided to equalize the flow from each well.

The extraction pump will pump groundwater to the KMnO_4 feed system. The feed system will consist of two Merrick Industries Omega DrumInvert Series 82-50 drum inverters fitted with Model 25-07 Helix Feeders and polyethylene washdown dissolvers (see Appendix E) or equivalent. The two drum inverters will be piped in series, and wired so that the second feeder begins operating once the first KMnO_4 drum is empty. This arrangement will reduce the frequency of KMnO_4 drum changeouts and help ensure the system never runs out of KMnO_4 . The control system will be designed to shut down the entire system should both drums of KMnO_4 be depleted.

After addition of the KMnO_4 , the groundwater will be pumped to two 1,600-gallon mixing tanks piped in series. Each open-top tank will be fitted with an electric mixer to ensure complete dissolution of the KMnO_4 , although only the mixer in the first tank is expected to be necessary. The mixing tanks will also provide the necessary residence time to ensure the VOCs in the extracted groundwater have been oxidized to concentrations below the Florida MCL. At the expected flowrate of 5 gpm, the two tanks will provide an average total residence time of 10 hours before the treated groundwater is reinjected. A further discussion of mixing tank operation and reaction kinetics can be found in subsection 3.2.1.

The KMnO_4 oxidation reaction produces insoluble particulates of MnO_2 . Other insoluble inorganic oxides may also be produced from the oxidation of inorganics (such as iron) that are present in the groundwater. The inorganic particulates will be filtered out of the treated groundwater prior to reinjection. The filtration will be accomplished with two cartridge filters installed in parallel after the reinjection pump. Each filter housing will contain 14 cleanable filter cartridges.

Calculations (see Appendix F) have estimated that the VOCs and inorganics in extracted groundwater will consume the KMnO_4 at a rate of only 0.1 g/l. The initial KMnO_4 dosage will be much higher (see Subsection 3.2.1), leaving the majority of the added KMnO_4 available for the in-situ oxidation.

Groundwater will be reinjected using a variable speed, positive displacement pump located between the cartridge filters and the last mixing tank. The positive displacement pump will ensure the reinjection rate will remain constant, even as the discharge pressure on the pump increases due to filter clogging. Reinjection rates to each reinjection well will be balanced using flowmeters and valving.

The mixing tanks will be fitted with appropriate level controls to prevent overflow and maintain a constant reinjection of treated groundwater. This will likely be accomplished by temporarily shutting off the groundwater extraction pump based on a high level signal from the second mixing tank.

Drums of KMnO_4 will be stored in Building 1100. The City of Orlando Fire Department has inspected the building and is expected to grant a permit for storage. The drum inverters and Helix Feeders will also be located within the building. It is expected that the pumps, mix tanks, and filter will be located outdoors, although it may be possible to mount the entire feed system on a trailer located within Building 1100. An 8-foot high chain link fence will be erected to surround the GMPs and any components of the treatment system located outdoors.

2.3 PILOT STUDY MONITORING PLAN. Groundwater and KMnO_4 feed system monitoring will be necessary to track the progress of the source area remediation, and to confirm that organic and inorganic regulatory limits in the reinjected groundwater are not exceeded. Because travel times in the shallow and deep portions of the surficial aquifer are different, a separate monitoring program will be required for each zone.

2.3.1 Shallow Zone Groundwater Monitoring The Visual MODFLOW particle tracks were used to establish GMP locations and sampling frequency (Figure 2-4). Arrows indicate flow direction, and are located at 20 day intervals along the particle tracks. The estimated number of days before the injected KMnO_4 reaches each monitoring point are also shown.

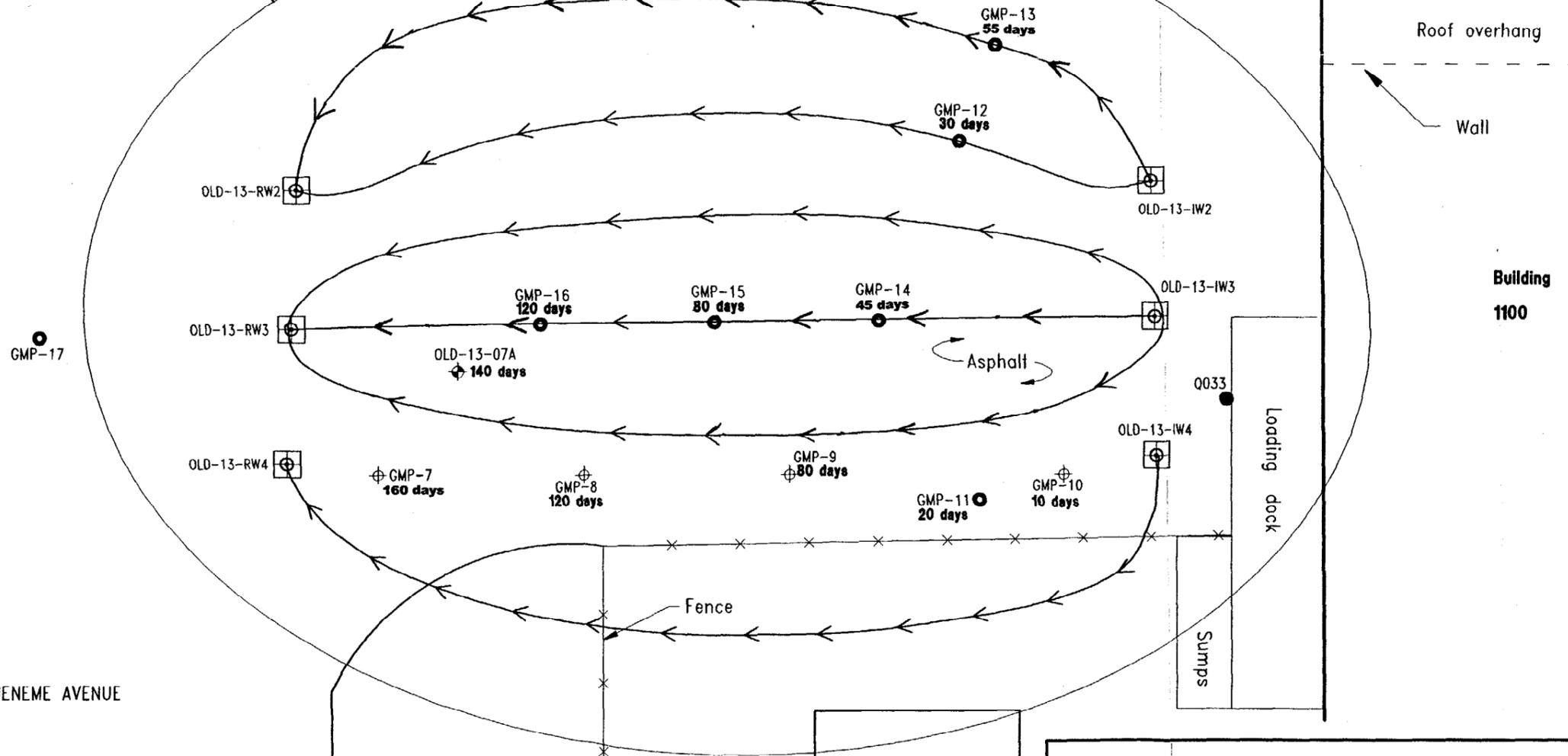
The monitoring plan utilizes several existing GMPs that were previously installed in this area (GMP-7 through GMP-10). These consist of 0.5-inch-ID PVC risers with 3-foot 0.010 slot screens prepacked with 20/40 silica sand, installed via direct-push (TerraProbeSM) to approximately 18 feet bls (Figure 2-4). Monitoring well OLD-13-07A is also part of the monitoring plan. This well is constructed of 2-inch-ID PVC riser with 15 feet of machine slotted screen, and a total depth of 18 feet.

Several additional monitoring points (GMP-11 through GMP-16) will be installed at the proposed locations shown on Figure 2-4. The proposed locations were selected to provide monitoring points at additional elapsed time intervals than are available using only the existing points. Two of the new locations (GMP-12 and GMP-13) are also located perpendicular to groundwater flow paths to monitor the distribution of KMnO_4 across the width (north-south) of the treatment cell. One monitoring point (GMP-17) will also be installed downgradient of the treatment cell to confirm containment of the KMnO_4 . These new monitoring points will be identical to the existing GMPs, with the exception of 9-foot screens



Circulation cell boundary

Particle tracks (arrow every 20 days)



LEGEND	
⊕	OLD-13-07A Monitoring well location and designation
⊕	GMP-4 Microwell location and designation
●	Q033 Temporary direct-push technology well location and designation
⊕	OLD-13-RW4 Proposed recovery or injection well location and designation
●	GMP-17 Proposed microwell location and designation
●	GMP Groundwater monitoring point
⊕	IW Injection well
⊕	RW Recovery well

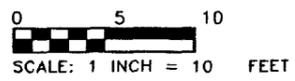


FIGURE 2-4
UPPER TREATMENT ZONE
PARTICLE TRACKS AND GROUNDWATER MONITORING POINTS

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instead of 3-foot screens (Figure 2-5). Total depth will be 18 feet. No permanent surface completion will be used in order to simplify future abandonment procedures.

The majority of the monitoring points are located through the center of the treatment cell, as groundwater travel times are shortest and so the effectiveness of the $KMnO_4$ injection will be more easily observed. A contaminant cross-section through several of the existing monitoring points (using previously collected data) is shown on Figure 2-6.

2.3.2 Deep Zone Groundwater Monitoring The monitoring point locations for the deep portion of the surficial aquifer are also based on Visual MODFLOW particle tracks (Figure 2-7). Travel times in this zone are much shorter than in the shallow zone because of the higher hydraulic conductivity. One pore volume can be flushed through the center of the treatment cell in approximately 40 days.

Existing monitoring wells OLD-13-42B and OLD-13-41B are expected to intercept the injected $KMnO_4$ 25 days and 50 days after injection, respectively. These wells are constructed of 2-inch-ID PVC riser and 5 feet of machine-slotted PVC screen, and are set 28 feet bls.

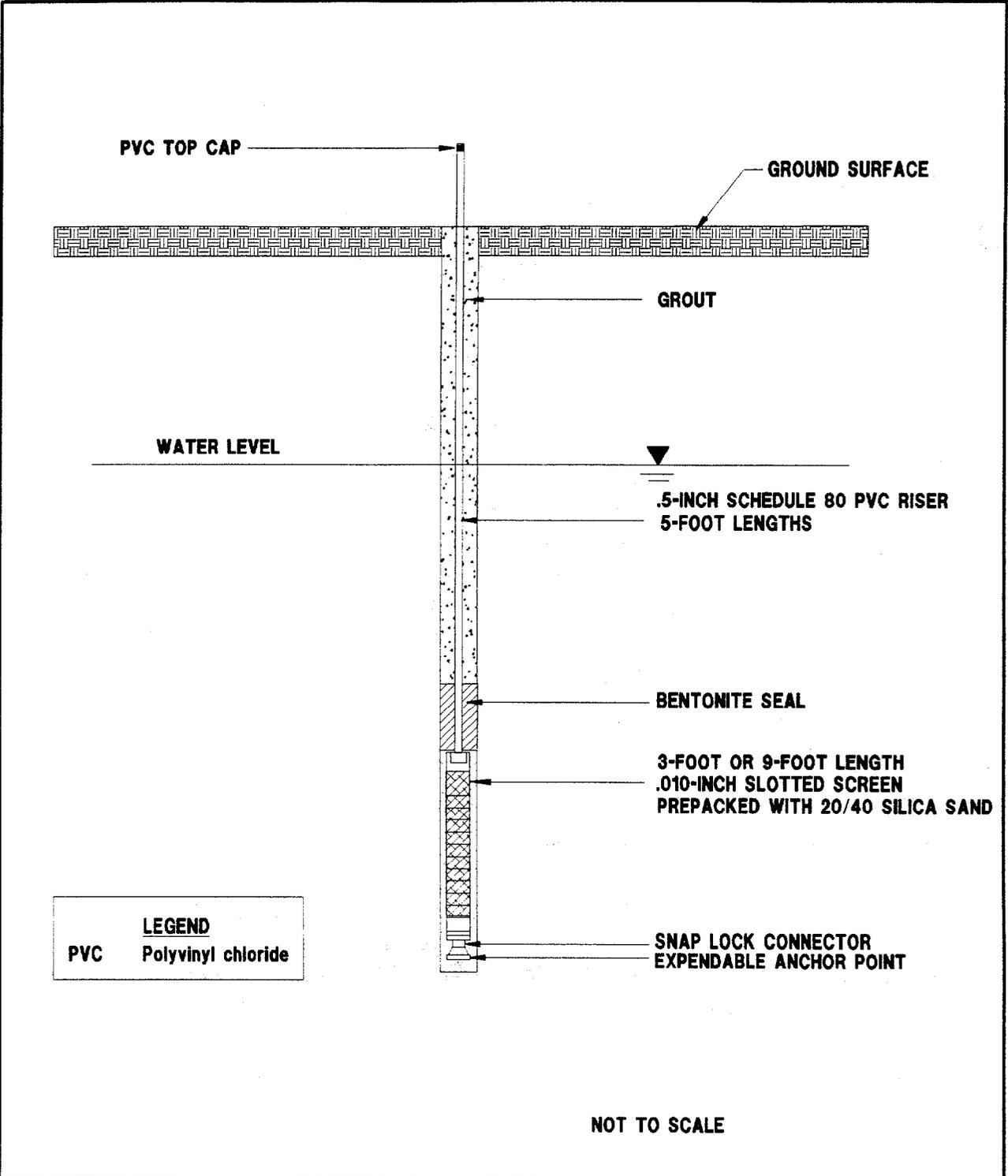
Three additional monitoring wells will be installed at the proposed locations shown on Figure 2-7. Monitoring wells OLD-13-44B and OLD-13-45B will be installed to intercept the $KMnO_4$ 10 days and 20 days after injection, respectively. Monitoring well OLD-13-46B will be paired with GMP-17 to confirm containment of the $KMnO_4$ in the lower zone. These three wells will be constructed of 2-inch-ID PVC riser with 10 feet of machine-slotted screen, and set to a depth of 30 feet bls.

Existing deep monitoring wells OLD-13-08C (screened from 57 to 62 feet bls) and OLD-13-43C (screened from 45 to 50 feet bls) will be monitored for $KMnO_4$ beginning approximately 30 days after startup. This monitoring is intended to locate $KMnO_4$ that may have unexpectedly migrated downward beneath the intended circulation cell.

2.3.3 Well Installation and Development The GMPs will be installed using a direct-push technology via HLA's TerraProbeSM. Development of the GMPs will be accomplished using a peristaltic pump. Pump tubing shall be lowered to the bottom of the well so that fines are agitated and removed from the well in the development water. Development shall continue until a minimum of 10 well casing volumes of water are removed from the well and the pH, temperature, specific conductivity, and redox potential of the groundwater have stabilized. Well development investigation-derived waste (IDW) will be collected and stored. Refer to the NTC, Orlando POP for further details about development procedures and IDW management (ABB-ES, 1997a).

The extraction/reinjection well pairs will be installed by RotosonicSM (preferred) or hollow-stem auger drilling. The six extraction/reinjection wells will be constructed using 4-inch-ID PVC flush-threaded, Schedule 40 PVC riser with 20 feet (extraction) or 25 feet (reinjection) of 0.030 slot PVC well screen. The bottom of the well screen shall be set 30 feet bls. A five foot sump shall be placed at the bottom of the screen for capturing sediment that may enter the wells during operation. The filter pack will be placed in the annular space around the well screen from the bottom of the borehole to at least 2 feet above the screen using the tremie method. The filter pack material shall be 6/20 grade clean silica sand. Screen slot size and filter pack grade are based on grain size analyses of soils previously collected at OU 4 (Appendix G).

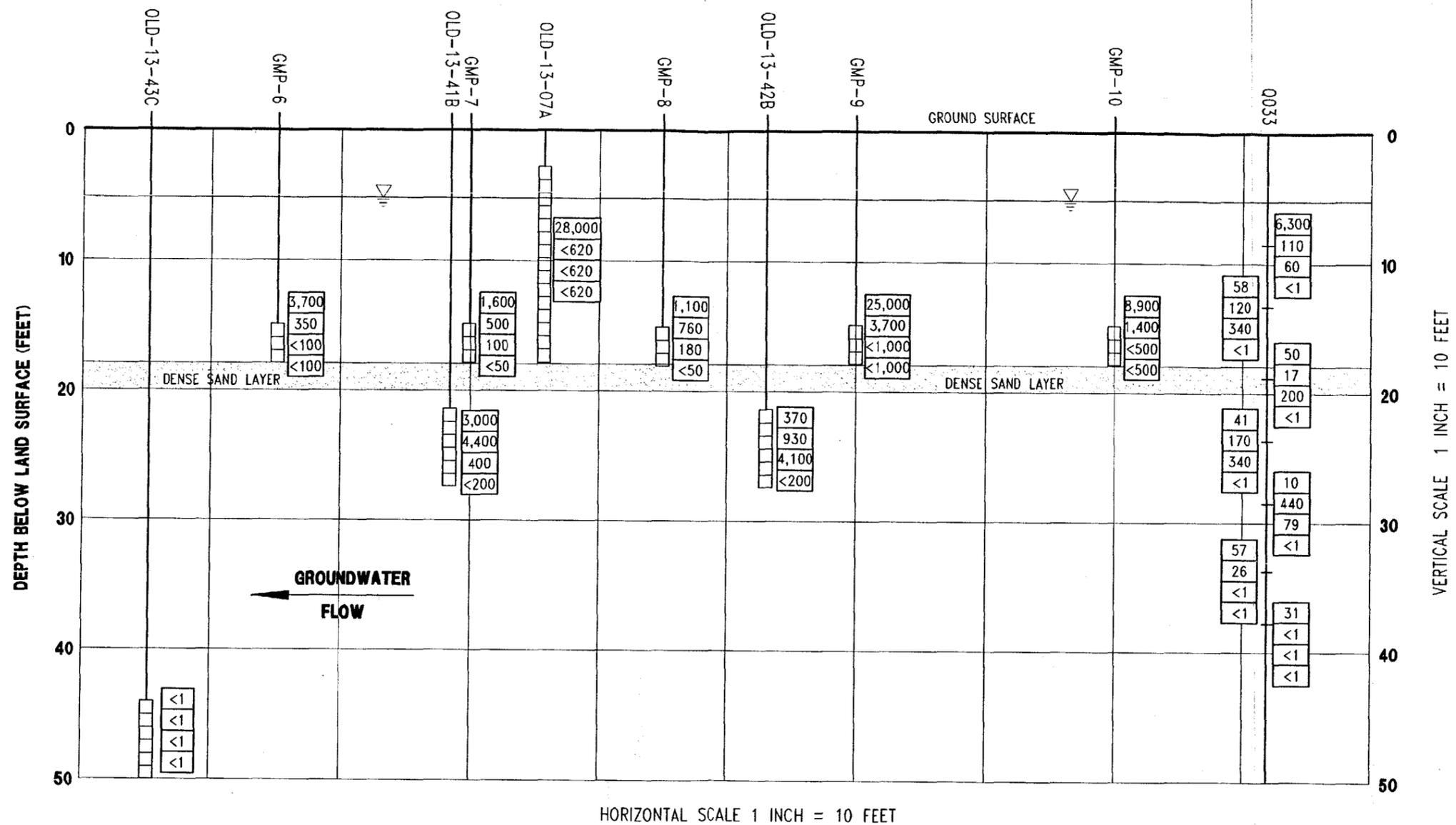
A 2-foot thick bentonite seal will be installed above the filter pack and will be allowed sufficient hydration time. A fine sand "cap" (30/65 standard sand) will be placed at least 1 foot above the bentonite seal to provide a buffer support for the uncured grout column. A grout mixture of neat cement and 2 to 4 percent bentonite powder will be placed by tremie method from the top of the fine sand cap to within 2 feet of ground surface. Each extraction/reinjection



**FIGURE 2-5
GROUNDWATER MONITORING POINT
MICROWELL CONSTRUCTION DIAGRAM**



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LEGEND

<1	Tetrachloroethene	 Monitoring well with screen
<1	Trichloroethene	
<1	cis-Dichloroethene	
<1	Vinyl chloride	
GMP	Groundwater monitoring point	 Water table
<	Less than	

NOTE: All concentrations are in microgram per liter.

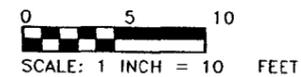


FIGURE 2-6
PILOT TEST CROSS-SECTION



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Circulation cell boundary

Particle tracks (arrow every 20 days)

Roof overhang

Wall

OLD-13-RW2

OLD-13-45B
25 days

OLD-13-IW2

OLD-13-46B

Asphalt

OLD-13-IW3

OLD-13-RW3

OLD-13-08C

0033

Loading dock

Building
1100

OLD-13-RW4

OLD-13-41B
50 days

OLD-13-42B
25 days

OLD-13-44B
10 days

OLD-13-IW4

Sumps

PORT HUENEME AVENUE

Fence

Surge tank

Grass

LEGEND

- ⊕ OLD-13-42B Monitoring well location and designation
- ⊕ OLD-13-46B Proposed monitoring well location and designation
- Q033 Temporary direct-push technology well location and designation
- ⊕ OLD-13-RW4 Proposed recovery or injection well location and designation
- IW Injection well
- RW Recovery well

0 5 10
SCALE: 1 INCH = 10 FEET

**FIGURE 2-7
LOWER TREATMENT ZONE
PARTICLE TRACKS AND GROUNDWATER MONITORING POINTS**



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POTASSIUM PERMANGANATE, OPERABLE UNIT 4
NAVAL TRAINING CENTER
ORLANDO, FLORIDA**

well will be completed using a flush mounted protective steel casing set in a 3 foot by 4 foot by 6 inch thick concrete pad. Further well installation details can be found in the NTC, Orlando POP (ABB-ES, 1997a).

Thorough development of the extraction/reinjection wells will be critical to ensure adequate performance. Development of these wells will follow a performance-based approach. Each well will be surged with a surge block, and then pumped while measuring specific capacity. These steps will be repeated until the specific capacity stops changing, and the pumped water is clear. The wells will then be surged and pumped harder. These cycles will be repeated until the specific capacity has stabilized and the extracted water is clear. Well development IDW will be collected and stored. Refer to the NTC, Orlando POP for further details about development procedures and IDW management (ABB-ES, 1997a).

The three new monitoring wells will be installed using the same method as the extraction/reinjection wells. These monitoring wells will be constructed using 2-inch-ID, PVC flush-threaded, Schedule 40 PVC riser with 0.020 slot PVC well screens. The bottom of the well screens will be set at 30 feet bls. The filter pack material shall be a 20/30 clean silica sand. No sump will be required in these wells, but otherwise the construction and completion details will be identical to the extraction/reinjection wells.

Development of the monitoring wells will be based on stabilization of well parameters and total volume purged. Well development IDW will be collected and stored. Refer to the NTC, Orlando POP for further details about development procedures and IDW management (ABB-ES, 1997a).

2.3.4 Groundwater Elevation Survey The horizontal and vertical coordinates of the GMPs and monitoring wells associated with the pilot study will be surveyed by a Florida-licensed surveyor. The elevation of groundwater shall be determined by subtracting the depth of water below top of casing (TOC) from the elevation at the TOC. At least one round of water-level measurements will be taken from all wells associated with the pilot study prior to startup.

After startup, water levels will be measured weekly in shallow and deep monitoring points near the extraction and injection wells, within the treatment cell itself, and in downgradient monitoring points GMP-17 and OLD-13-46B. Background water levels will be measured in monitoring wells OLD-13-01A and OLD-13-40B, located on the north side of Building 1100, approximately 200 feet northeast of the pilot study. These two wells are outside the area to be influenced by the pilot study, and will provide data to define regional water level trends. Water levels within and near the circulation cell will be used to compare actual with expected hydraulic performance. The Orlando Partnering Team (OPT) will discuss and approve any required operational changes suggested by the water level data.

2.3.5 Performance Monitoring Program A monitoring program has been developed to measure changes in source area VOC concentrations, to monitor the migration and in-situ consumption of the KMnO_4 solution, to evaluate changes to groundwater inorganic concentrations due to the KMnO_4 injection, and to ensure VOCs have been oxidized adequately in the mix tanks and the terms of the underground injection variance are met.

If the KMnO_4 successfully oxidizes OU 4 source area VOCs, the pilot study will operate for up to 120 days. This duration will ensure that oxidation system parameters can be optimized for full-scale implementation, and most (if not all) of the VOCs in the pilot study treatment zone will be oxidized. If necessary, the treatment duration can be extended.

The groundwater monitoring schedule for the 120 day (16 week) pilot study duration is shown on Table 2-1. An initial round of baseline data will be collected prior to pilot system startup. The baseline data will also include collection of natural attenuation parameters. Groundwater samples will be shipped to an offsite laboratory for analysis of VOCs by U.S. Environmental Protection Agency (USEPA) Method 8021, inorganics by USEPA Methods 6000/7000,

**Table 2-1
Groundwater Monitoring Schedule**

Treatability Study Work Plan No. 3
Data Collection Plan for Assessing In Situ Chemical Oxidation Using Potassium Permanganate
Operable Unit 4
Naval Training Center, Area C
Orlando, Florida

Pore Volume Travel Time (Days)	10		20		25		30		45		50		55		80		120		140		Extraction Wells	Injection Wells	Downgradient Wells		KMnO ₄ System		Total Weekly Samples																					
	Monitoring Well	GMP-10	OLD-13-44B	GMP-11	OLD-13-45B	OLD-13-42B	GMP-12	GMP-14	OLD-13-41B	GMP-13	GMP-15	GMP-9	GMP-16	GMP-8	OLD-13-07A	GMP-17	OLD-13-46B	Influent	Effluent																													
Sample Frequency																																																
Baseline	⊗	⊗	X	X	⊗	⊗	X	⊗	⊗	⊗	X	X	X	XXX	XXX	○	○	⊗	⊗							22/12																						
Week 1	⊗	⊗																								4/2																						
Week 2	⊗	⊗	X																							5/4																						
Week 3	X	X	X	X	X																					7/0																						
Week 4	X	X	X	X	⊗	⊗																				8/4																						
Week 5	X	X	X	X	X	X	X																			9/0																						
Week 6	X	X	X	X	X	X	X	⊗																		10/4																						
Week 7	X	X	X	X	X	X	X	X																		10/0																						
Week 8	X	X	X	X	X	X	X	X	⊗				X	X	X											14/3																						
Week 9						X			X																	4/0																						
Week 10	X	X	X			X	⊗		X																	8/3																						
Week 11						X	X	X	X	X	X															8/0																						
Week 12				X	X			○	X	⊗	⊗															7/5																						
Week 13							X			X	X															5/0																						
Week 14	X	X	X			X				X	X															8/2																						
Week 15																										2/0																						
Week 16	⊗	⊗	X	X	⊗	⊗	X	⊗	⊗	⊗	⊗	X	X	X	XXX	XXX	○	○	⊗	⊗						22/12																						
Week 20																																																
TOTAL																																																153/51

Notes: X = VOCs, conductivity, pH, temp, turbidity, oxidation/reduction potential, KMnO₄.
 ⊗ = VOCs, conductivity, pH, temp, turbidity, oxidation/reduction potential, KMnO₄, inorganics, chloride, TOC, alkalinity.
 ○ = TOC and full-suite metals analyses; natural attenuation parameters (Baseline and Week 16 only).
 18/11 = X/O totals.
 Shaded columns indicate Upper Zone monitoring well.
 Travel time of one pore volume within Upper Zone = 160 days.

Non-shaded columns indicate Lower Zone monitoring well.
 Travel time of one pore volume within Lower Zone = 40 days.

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methane/ethane/ethylene, total organic carbon, total dissolved solids, and color. Field methods will be used to collect conductivity, oxidation/reduction potential, temperature, pH, alkalinity, hardness, dissolved oxygen, chloride, sulfate, nitrate, total and ferrous iron, carbon dioxide, and turbidity data. VOC analysis will be performed at each of the proposed 16 monitoring points. The inorganic and natural attenuation analyses are only proposed at sufficient locations to establish a baseline for groundwater within the cell.

Prior to startup, KMnO_4 samples will be collected from the drums of KMnO_4 purchased from Carus. An initial solution will be prepared for each chemical batch number represented by the delivered drums. Each solution will be analyzed for inorganics by an offsite laboratory to confirm inorganic concentrations will be within the limits specified in the underground injection variance application (Appendix D).

During startup, a mobile laboratory will be onsite to provide rapid VOC analyses. The mobile lab will be used to provide PCE oxidation rate data after the initial addition of KMnO_4 to the extracted groundwater. Water samples will be collected frequently from the mix tanks in order to confirm the bench-scale data on Figure 2-1. The treatment system will be operated in a batch mode (i.e. no reinjection) until the mobile lab data confirms VOC concentrations have been reduced to below the Florida MCL. The treatment system will also be designed to allow KMnO_4 -treated groundwater to be recycled back to the KMnO_4 feed system should additional chemical be required to achieve MCLs. Initial KMnO_4 dosages and expected oxidation times are discussed in Chapter 3.0.

After startup, the groundwater sample locations and frequency are dependent on the predicted KMnO_4 travel times, as shown on Table 2-1.

3.0 TEST PROCEDURE AND DATA COLLECTION

Test procedures for the pilot study are provided in this chapter. Portions of these procedures will entail laboratory or field analyses of groundwater samples and KMnO_4 solutions.

3.1 PRE-STARTUP ACTIVITIES. The following procedures will be used to estimate baseline conditions for the chemical oxidation pilot test:

- Measure and record the initial water level in OLD-13-07A, OLD-13-41B, OLD-13-42B, OLD-13-44B, OLD-13-45B, OLD-13-46B, OLD-13-RW2, -RW3, -RW4, OLD-13-IW2, -IW3, -IW4, and GMPs 7 through 17.
- Collect baseline groundwater samples in accordance with Field Sampling and Analysis Procedures (Chapter 4.0) from OLD-13-07A, OLD-13-41B, OLD-13-42B, OLD-13-44B, OLD-13-45B, OLD-13-46B, OLD-13-RW2, -RW3, -RW4, OLD-13-IW2, -IW3, -IW4, and GMPs 7 through 17. Analyses will be as specified in Table 2-1.
- Prepare 10 g/l aqueous solutions from each lot or batch of KMnO_4 delivered from Carus Chemical. Solutions will be analyzed by an offsite laboratory for total inorganics to confirm compliance with the underground injection variance.

3.2 ESTABLISH INITIAL OPERATING PARAMETERS. The initial operation of the pilot study will confirm the ability of the KMnO_4 to oxidize VOCs in extracted groundwater prior to reinjection. This initial operation will also allow extraction well flowrates to be set.

3.2.1 System Startup Based on the MODFLOW simulations, a total extracted groundwater flow of approximately 5 gpm (19 liters per minute [ℓ/min]) will be necessary to establish a recirculation cell of the required size. The extraction pump will be started and the flow from each of the three extraction wells will be set at approximately 1.7 gpm (6.4 ℓ/min). The KMnO_4 feeders will be set to deliver KMnO_4 at a rate of approximately 75 grams per minute (g/min) to achieve the 4 g/l KMnO_4 solution planned for initial startup. The extracted groundwater will be pumped to the KMnO_4 feed system and then into the first mix tank. Once the first mix tank has filled (in approximately 5 hours), the groundwater will flow to the second mix tank by gravity. The reinjection pump will not be operated until VOC concentrations in the second mix tank are below Florida MCLs.

Groundwater samples will be collected at the extraction pump discharge, from the KMnO_4 feed system discharge, and from each mix tank at one hour intervals until primary standards are met. Each sample will be analyzed for VOCs using the onsite mobile laboratory and for KMnO_4 using field instrumentation. Methods and special considerations are included in Chapter 4.0.

The system will be operated with the agitator in the first mix tank operating, and the second mix tank unstirred. Thus the first tank will function as a continuous stirred-tank reactor (CSTR) and the second tank as a plug flow reactor. The mixing in the first tank will ensure complete dissolution of the KMnO_4 , and the plug flow in the second tank will maximize conversion of the PCE to meet MCLs.

Based on previous estimates (HLA, 1999a), the concentration of PCE in extracted groundwater is anticipated to be on the order of 5,000 $\mu\text{g}/\ell$. To achieve the Florida MCL of 3 $\mu\text{g}/\ell$ requires a reduction of $3/5,000 = 0.0006$. Referring to Figure 2-1, this reduction should occur in slightly over 2 hours at a KMnO_4 concentration of 4 g/l in a batch mode. However, the pilot study will operate continuously. Using Figure 2-1 to derive a reaction rate constant for 4 g/l KMnO_4 , and using the appropriate equations for CSTR and plug flow reactors, the PCE concentration leaving the first mix tank is expected to be approximately

245 µg/l, and below detection leaving the second mix tank. Calculations are presented in Appendix H.

VOC reaction rate data collected during the initial operation will be compared to predicted values derived from bench-scale data and Figure 2-1. As the startup period progresses, the validity of the predicted PCE oxidation rates will be evident. If field data suggests that the available 10 hour residence time will be inadequate to achieve MCLs, the concentration of KMnO_4 can be increased by shutting off the extraction pump and recycling treated water out of the mixing tanks and through the KMnO_4 feed system by using the reinjection pump (Figure 2-3).

Once the field data has demonstrated that the Florida MCLs can be achieved with 4 g/l KMnO_4 , the reinjection pump can be started. Treated groundwater will be pumped through the filtration system and into each reinjection well. The reinjection rate to each well will be set at approximately 1.7 gpm.

Once the reinjection pump has been started, the system will be balanced and allowed to operate unattended. Adequate controls will be in place to prevent mixing tank overflow and to shutdown the entire pilot should all the KMnO_4 in the feed system be depleted.

HLA personnel will service the system with a frequency dictated by the KMnO_4 feed rate and overall system operability. It is anticipated that daily visits will initially be necessary, reducing to once every other day if operations allow.

3.2.1 System Operation The system is expected to operate as discussed above. However, the KMnO_4 dosage may be increased up to the maximum concentrations allowed by the underground injection variance. Increases in KMnO_4 dosage will be based on the ability to oxidize VOCs in extracted groundwater within the 10 hour residence time, and also by the measured KMnO_4 and VOC concentrations in the GMPs.

If groundwater monitoring data indicates total consumption of KMnO_4 in-situ, or little reduction in VOC concentrations, then KMnO_4 concentrations in the reinjected water will be increased, potentially up to the limits set by the underground injection variance. The decision to increase KMnO_4 dosages will be discussed with the Navy and the OPT prior to implementation.

The rate of KMnO_4 addition will also be adjusted to account for KMnO_4 that may be recycled through the system after the first flush of the treatment cell. The MODFLOW simulation predicted that one lower zone pore volume could be flushed through the center of the treatment cell in approximately 40 days. At this time some injected KMnO_4 that has not been consumed could begin to appear in the extraction wells, and therefore in the groundwater fed to the KMnO_4 treatment system. KMnO_4 concentrations in the extracted groundwater will be monitored, and if necessary the rate of fresh KMnO_4 addition can be reduced to maintain the desired concentrations in the reinjected groundwater.

Water levels in the reinjection wells will also be monitored during each site visit to ensure the reinjection wells are not fouling and will not overflow.

In accordance with the requirements of the underground injection variance (Appendix D), downgradient monitoring wells OLD-13-46B and GMP-17 will be monitoring quarterly for one year after completion of the pilot study. Analytical parameters will include inorganics, total dissolved solids, color, chloride, and pH.

4.0 FIELD SAMPLING AND ANALYSIS PROCEDURES

This chapter describes techniques to be used for the analysis of VOCs, inorganics, and KMnO_4 concentrations during the pilot study.

4.1 SAMPLE COLLECTION AND PREPARATION. Groundwater samples will be collected from various monitoring wells and GMPs in accordance with the approach outlined in section 2.3.5. Water samples will also be drawn from sample ports located at various locations in the feed system piping. At a minimum, sample ports will be located before and after the KMnO_4 feed system, and before and after the filter. Samples can also be collected from the open-top mixing tanks using a bailer or peristaltic pump.

4.1.1 Monitoring Well and GMP Sampling All monitoring wells and GMPs will be purged and sampled using low-flow techniques. The purpose of using low-flow purging is to ensure that the sample taken is from the targeted aquifer zone.

Prior to purging, the breathing zone and the mouth of each well will be monitored for VOCs with a flame-ionization detector. Each well shall then be purged prior to sampling to clear the well of stagnant water, which is not representative of aquifer conditions. New 1/4-inch outside diameter (OD) Teflon™ tubing will be lowered into each well and connected to an ISCO peristaltic pump for purging. During purging temperature, pH, conductivity, dissolved oxygen, and turbidity will be measured regularly. When all parameters have stabilized, a sample will be taken.

Groundwater for VOC and dissolved oxygen analyses shall be collected as a grab sample by slowly purging a sample through the Teflon™ tubing. The tubing is removed from the well, and the groundwater sample is drained by gravity out of the Teflon™ tubing that had been in the well and into 40-ml vials or into the ampule used for dissolved oxygen analysis.

For all other groundwater monitoring well sampling, a new 2.5-liter amber bottle will be used to create a vacuum collection assembly. A rubber stopper, #5 size, is wrapped in a Teflon™ swatch and placed in the bottle mouth with two 1/4-inch-OD Teflon™ tubing sections inserted through two holes in the stopper. One piece of tubing will run up from the well, and the other will run to the peristaltic pump. A vacuum shall be created in the bottle, and the groundwater sample will slowly be drawn in. The 2.5-liter amber bottle is filled, and the contents are poured into the containers appropriate for each parameter and will be sent to the laboratory for analysis. The inlet of the tubing will be set at the midpoint of the screened interval in each monitoring well. Filtered inorganic samples will be collected by connecting a 0.45-micron filter in line between the well and the 2.5-liter bottle. Additional sampling and sampling preparation procedures can be referenced in the NTC, Orlando POP (ABB-ES, 1997a).

4.1.2 Feed System Sampling All of the sampling taps located on the feed system are expected to be located in portions of the system that are under pressure. Water samples can therefore be expected to flow directly out of each tap and into the sample container. A peristaltic pump will be used to draw out a sample in situations when necessary, such as when sample filtration is required.

4.2 SAMPLE ANALYSIS. The following section describes the field and laboratory methods for sample analysis.

4.2.1 Volatile Analyses All aqueous samples intended for VOC analysis will be submitted to an offsite Florida-certified laboratory for analysis of halogenated volatile organics using USEPA Method 8021. Because residual dissolved KMnO_4 present in groundwater would continue to oxidize VOCs after sample collection, the oxidation reaction must be quenched if the sample is to represent current site conditions. The quenching will be accomplished by adding several crystals

of sodium thiosulfate to each sample vial used for analysis of aqueous samples containing KMnO_4 .

Note: When KMnO_4 is mixed with hydrochloric acid, toxic chlorine gas is liberated. Caution must be observed to ensure HCl does not come into contact with any KMnO_4 during sampling!

4.2.1.1 Field Laboratory A field laboratory will be used during initial startup to help establish baseline conditions and also confirm the rate of VOC oxidation prior to reinjection of treated groundwater. Target analytes shall include PCE, TCE, DCE, and VC. Quantitation levels of $1 \mu\text{g}/\ell$ will be maintained to confirm treated water achieves Florida primary standards for VOCs. Analysis methodology will be based on standard USEPA methods SW-846 (USEPA, 1992a): 5030 (purge and trap preparation), 8000A (gas chromatograph [GC] calibration), and 8021 (halogenated volatile organics) with modifications for field analysis.

The instrumentation used will be a Hewlett-Packard 5890 Series II gas chromatograph equipped with a DB-624, 0.53 millimeter diameter capillary column or equivalent. It will be fitted with a tekmar purge and trap concentrator and an electron capture detector (ECD) for chlorinated hydrocarbons. The ECD is very selective for halogenated compounds and should achieve sufficiently low quantitation limits for this study. Quantitation will be accomplished by means of Hewlett-Packard Chemstation Chromatography software package provided with the GC.

4.2.2 Inorganic Analyses All aqueous samples intended for inorganic analysis will be submitted to an offsite Florida-certified laboratory for analysis of target analyte list inorganics using USEPA 6000/7000 methods. As discussed in section 2.2.5, the KMnO_4 oxidation reaction produces insoluble precipitates. These particulates will be filtered from the extracted groundwater prior to reinjection.

To assure that inorganic analysis of groundwater or process water is consistent with the injected composition, all aqueous samples (including baseline groundwater samples) will be filtered prior to analysis.

4.2.2 Dissolved KMnO_4 Analysis The KMnO_4 concentration in an aqueous solution is best measured using standard spectrophotometric methods. A calibration curve will be developed by measuring the absorbance of various KMnO_4 standard solutions at a wavelength of 525 nanometers. This procedure is outlined in Appendix B. Standard solutions will be prepared at concentrations of $1 \text{ g}/\ell$, $4 \text{ g}/\ell$, $6 \text{ g}/\ell$, and $10 \text{ g}/\ell$.

Once the spectrophotometer calibration curve is established, aqueous samples collected from the feed system, monitoring wells, and GMPs will be inserted in the spectrophotometer for determination of KMnO_4 concentration. All aqueous samples must be filtered to remove turbidity prior to spectrophotometric analysis.

5.0 DATA ANALYSIS AND INTERPRETATION

Data collected from this pilot study will be reviewed, processed, and presented to aid in determining the suitability of in-situ chemical oxidation as a source removal technology for OU 4. These results will be used to update the assumptions used to evaluate this technology in the draft OU 4 FS (HLA, 1999a).

When evaluating the pilot data, the focus will be as follows:

- determine whether site-specific factors would inhibit or prohibit the technology's use,
- establish the required concentration of KMnO_4 to achieve in-situ oxidation of VOCs in the source area, and
- establish the maximum achievable reduction of source area VOCs.

5.1 SITE-SPECIFIC FACTORS. Various factors may inhibit or prohibit the use of KMnO_4 at OU 4. By monitoring groundwater in the upper and lower zones of the treatment cell, the ability to deliver KMnO_4 above, below, and through the hard layer can be established. Although bench-scale data suggested that KMnO_4 demand unrelated to the VOCs will be minimal, other unforeseen aquifer conditions could lead to excessive in-situ consumption of KMnO_4 , leaving little to oxidize the VOCs and requiring uneconomical KMnO_4 feed rates.

Operational difficulties associated with filtration of the suspended particulates or extraction/reinjection well clogging could also affect the ability to apply this technology full-scale at OU 4.

All of these issues will be carefully evaluated during the operation of the pilot study.

5.2 REQUIRED KMnO_4 CONCENTRATION. The pilot study approach is intended to allow the determination of the necessary concentration of KMnO_4 required to oxidize VOCs in the source area.

5.3 VOLATILE ORGANIC COMPOUND (VOC) REDUCTION. Source area remediation followed by natural attenuation monitoring has been identified as an attractive alternative for remediation of OU 4 groundwater (HLA, 1999a). Based on the degradation rate in the plume between the source area and Lake Druid, groundwater VOC concentrations in the source area need to be reduced to approximately 100 $\mu\text{g}/\ell$ to achieve Florida Surface Water Standards at the lake (HLA, 1998a). The goal of the KMnO_4 injection is to reduce VOC concentrations within the treatment cell down to this level. The groundwater monitoring plan outlined in this work plan is expected to be adequate to establish the in-situ effectiveness of the KMnO_4 injection.

Analysis of natural attenuation parameters both before and after treatment with KMnO_4 will also aid in evaluating natural attenuation as a remedial alternative. The data will be used to determine the effect of KMnO_4 oxidation on natural attenuation conditions, and also can be used to evaluate the potential effectiveness of enhancing natural attenuation with injected amendments.

6.0 SCHEDULE

It is expected that this in-situ chemical oxidation work plan will be presented to the OPT and FDEP's reviewing engineer in September 1999. Procurement of equipment, well installations, system assembly, operation, and data collection could be completed within 30 days of work plan approval.

Although MODFLOW simulations suggest over 160 days will be required to flush one pore volume through the center of the treatment cell in the shallow zone, the effectiveness of the KMnO_4 injection and the optimum feed concentrations are expected to be established within the first 8 weeks of operation. A summary of the pilot study results will be issued after the 8 weeks (or sooner if the pilot is unsuccessful), to provide adequate data to finalize the FS. If the pilot is successful, operation will continue for the full 120 days to remediate as much of the treatment cell as possible. A final report will be issued at the completion of the pilot study.

REFERENCES

- ABB Environmental Services, Inc. (ABB-ES), 1996a. *Interim Remedial Action Focused Field Investigation Report, Operable Unit 4, Naval Training Center, Orlando, Florida*. Prepared for SOUTHNAVFACENGCOC, North Charleston, South Carolina (November).
- ABB-ES, 1996b. *Operable Unit 4, Interim Remedial Action Study: Pumping Test Implementation and Results, Naval Training Center, Orlando, Florida*: prepared for Southern Division, Naval Facilities Engineering Command, North Charleston, South Carolina, October.
- ABB-ES, 1997a. *Project Operations Plan for Site Investigations and Remedial Investigations, Naval Training Center, Orlando, Florida*. Prepared for Southern Division, Naval Facilities Engineering Command, North Charleston, South Carolina (August).
- ABB-ES, 1997b. *Remedial Investigation and Feasibility Study Workplan, Operable Unit 4, Study Areas 12, 13, and 14 - Area C, Naval Training Center, Orlando, Florida*. Prepared for SOUTHNAVFACENGCOC, North Charleston, South Carolina (October).
- ABB-ES, 1997c. *Technical Memorandum, Interim Remedial Action, Focused Investigation/Source Confirmation, Building 1100 Surge Tank, Naval Training Center, Orlando, Florida*. Prepared for SOUTHNAVFACENGCOC, North Charleston, South Carolina (May).
- ABB-ES, 1998a. *Treatability Study Work Plan No. 2, Data Collection Plan for Assessing Air Sparging, Operable Unit 4, Naval Training Center, Orlando, Florida*. Prepared for SOUTHNAVFACENGCOC, North Charleston, South Carolina (April).
- Harding Lawson Associates, 1998a. *Draft Treatability Study, Technical Memorandum No. 1, Natural Attenuation Assessment, Operable Unit 4, Naval Training Center, Orlando, Florida*. Prepared for SOUTHNAVFACENGCOC, North Charleston, South Carolina (July).
- HLA, 1998b. *Remedial Investigation, Operable Unit 4, Study Areas 12, 13, and 14 (Area C), Naval Training Center, Orlando, Florida*. Prepared for SOUTHNAVFACENGCOC, North Charleston, South Carolina (September).
- HLA, 1998c. *Quarterly Report No. 1, Interim Remedial Action, Performance Monitoring and Sampling Plan, Operable Unit 4, Naval Training Center, Orlando, Florida*. Prepared for SOUTHNAVFACENGCOC, North Charleston, South Carolina (April 16).
- HLA, 1999a. *Feasibility Study, Operable Unit 4, Naval Training Center, Orlando, Florida*. Prepared for SOUTHNAVFACENGCOC, North Charleston, South Carolina (January).
- HLA, 1999b. *Quarterly Report No. 2, Interim Remedial Action, Performance Monitoring and Sampling Plan, Operable Unit 4, Naval Training Center, Orlando, Florida*. Prepared for SOUTHNAVFACENGCOC, North Charleston, South Carolina (March 12).
- HLA, 1999c. *Quarterly Report No. 3, Interim Remedial Action, Performance Monitoring and Sampling Plan, Operable Unit 4, Naval Training Center, Orlando, Florida*. Prepared for SOUTHNAVFACENGCOC, North Charleston, South Carolina (May 28).
- HLA, 1999d. *Quarterly Report No. 4, Interim Remedial Action, Performance Monitoring and Sampling Plan, Operable Unit 4, Naval Training Center, Orlando, Florida*. Prepared for SOUTHNAVFACENGCOC, North Charleston, South Carolina (September 15).

REFERENCES

- Hood, E.D., N.R. Thomson, and G.J. Farquhar, 1998. *In Situ Oxidation: An Innovative Treatment Strategy to Remedial Trichlorethylene and Perchloroethylene DNAPLs in Porous Media*. Presented at The 6th Symposium on Groundwater and Soil Remediation, Montreal, Quebec, (March).
- Schnarr, M., C. Truax, G. Farquhar, E. Hood, T. Gonullu, and B. Stickney. 1996. *Laboratory and Controlled Field Experiments Using Potassium Permanganate to Remediate Trichloroethylene and Perchloroethylene DNAPLs in Porous Media*. *Journal of Contaminant Hydrology*, (December).
- U.S. Environmental Protection Agency (USEPA), 1992a. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846*, 3rd ed. Washington, D.C.
- U.S. Geological Survey, 1998. *Assessment of the Potential Effects of Phytoremediation on Groundwater Flow Around Area C at Orlando Naval Training Center, Florida*. Water-Resources Investigations Report 98-4110.
- West, O.R., S.R. Cline, W.L. Holden, F.G. Gardner, B.M. Schlosser, J.E. Thate, D.A. Pickering. *A Full-Scale Demonstration on In Situ Chemical Oxidation Through Recirculation at the X-701B Site, Field Operations and TCE Degradation*. Prepared for the U.S. Department of Energy. Oak Ridge National Laboratory, Environmental Sciences Division, Publication No. 4727 (December).

APPENDIX A
HASP ADDENDUM

Preface

The following pages constitute the Health and Safety Plan (HASP) addendum for the Naval Training Center (NTC), Orlando Project Operations Plan for Site Investigations and Remedial Investigations. This addendum must be used in conjunction with the existing generic HASP for NTC, Orlando. The pages in this addendum should be inserted, where indicated, in the generic HASP. The generic HASP, with these pages correctly inserted, completes the update of the NTC, Orlando HASP for the in-situ chemical oxidation pilot study at Operable Unit (OU) 4.

2.3 SCOPE OF WORK (WORK PLAN). The in-situ chemical oxidation pilot study will consist of the injection of a $KMnO_4$ solution into the subsurface. The contaminants found in the source area are expected to oxidize in-situ. The pilot study performance will be monitored by sampling groundwater within the treatment zone.

Objective: Install appropriate equipment to allow the pilot testing and monitoring of an in-situ chemical oxidation system.

Methods:

- microwell installation by TerraProbe™
- installation of monitoring wells and extraction/reinjection wells via Rotasonic drilling
- installation of appropriate equipment to extract groundwater, dose with $KMnO_4$, and reinject

Objective: Establish if in-situ chemical oxidation is a viable remediation technology for OU 4. Establish optimum $KMnO_4$ dosage, the ability to treat source area VOCs both above and below the layer of dense sand, and the maximum reduction of groundwater VOC concentrations achievable with this technology.

Methods:

- groundwater sampling
- feed system monitoring
- feed system operation and maintenance

2.4.5 Monitoring The work environment will be monitored to ensure that "Immediately Dangerous to Life and Health" or other dangerous conditions are identified. At a minimum, monitoring will include evaluations for combustible atmospheres, oxygen-deficient environments, and hazardous concentrations of airborne contaminants. The combustible gas meter, set to alarm at 10 percent of the lower explosive limit (LEL), will be continuously used.

2.4.6 Air Sampling To the extent feasible, the presence of airborne contaminants will be evaluated through the use of direct reading instrumentation. Information gathered will be used to ensure the adequacy of the levels of protection being used at the site and may be used as the basis for upgrading or downgrading the levels of protection in conformance with action levels provided in this HASP and at the direction of the site health and safety officer. Contaminants expected to be a concern at OU 4 are shown in Table 2-2.

The following sampling equipment will be used at the site:

1. PORTA-FID organic vapor analyzer (OVA), and
2. LEL/oxygen meter.

Refer to Appendix F for information on the calibration and maintenance of the equipment.

If the OVA reads steadily above background in the breathing zone, continue working in modified Level D until the OVA reads 8 ppm above background in the breathing zone, at which time upgrade to Level C. If the OVA reads 116 ppm (or greater) above background, upgrade to Level B.

If the LEL meter reads 10 percent of the LEL or greater, use nonsparking tools. IF the LEL meter reads 20 percent of the LEL or greater, stop work and evacuate the site.

The above action limits are summarized below.

**Table 2-2
Contaminants of Concern at Operable Unit 4**

Treatability Study Work Plan No. 3
Data Collection Plan for Assessing In Situ Chemical Oxidation Using Potassium Permanganate
Operable Unit 4
Naval Training Center, Area C
Orlando, Florida

Chemical	Approximate Odor Threshold (ppm)	Permissible Exposure Limits (ppm)	Threshold Limit Value (ppm)	Physical Characteristics	Dermal Toxicity	Remarks
1,2-Dichloroethene	500	200	200	Colorless liquid, sweet odor.	Moderate skin irritant.	Nausea, vomiting, weakness, tremor, cramps, CNS depression.
Tetrachloroethene	47	25	25	Colorless liquid with an odor like chloroform.	Moderate skin irritant.	Inhalation may irritate eyes and nose and cause CNS damage.
Trichloroethene	82	50	50	Colorless liquid, sweet odor.	Can cause dermatitis.	Eye and nose irritation, blurred vision, nausea, CNS damage.
Potassium permanganate	Odorless	5 mg/m ³	0.2 mg/m ³	Dark purple solid	Moderate skin irritant.	Strong oxidizer. Produces chlorine gas when mixed with HCl. Inhalation may irritate respiratory tract and eyes.
Sodium Thiosulfate	Odorless	None Established	None Established	Monoclinic, colorless crystals	Moderate skin irritant.	May cause irritation to skin, eyes, and respiratory tract.

Notes: RI/FS = Remedial Investigation and Feasibility Study.
ppm = parts per million.
CNS = central nervous system.
A1 = Known Human Carcinogen.
HCl = hydrochloric acid.

Sources: American Industrial Hygienists Association, 1989.
U.S. Department of Transportation and U.S. Coast Guard, 1991.
National Institute of Occupational Safety and Health, 1990.
American Conference of Governmental and Industrial Hygienists.
Occupational Safety and Health Administration, 1989.

Level B PPE required if:

- OVA greater than or equal to 116 ppm,

Level C PPE required if:

- OVA greater than or equal to 8 ppm but less than 116 ppm.

Level D PPE required if:

- OVA less than 8 ppm.

Wherever feasible, engineering controls will be used to avoid the need to upgrade from Level D. An example is the use of industrial-sized fans to blow hazardous vapors from the breathing zone.

If air monitoring instrumentation indicates the need to upgrade to Level B along the northern property line, all work will be suspended to avoid the possibility of creating a dangerous condition outside Navy property.

2.4.7 KMnO₄ Handling Operation of the KMnO₄ feed system will require frequent change-out of empty drums of KMnO₄. All handling of KMnO₄ will be performed in Level C with either a full-face respirator or a half-face respirator with a face shield. Personnel shall work in pairs. An eyewash station will be available at the KMnO₄ handling area. Further precautions are outlined in the material safety data sheet.

2.4.8 Sodium Thiosulfate Handling Sodium thiosulfate will be used to quench the KMnO₄ oxidation reaction in groundwater sampled for VOC analysis. Only small quantities will be handled (several crystals per 40 milliliter vial); gloves and safety glasses must be worn to prevent contact with skin and eyes. Avoid producing dust. Further precautions are outlined in the material safety data sheet.

MATERIAL SAFETY DATA SHEET

CAIROX Potassium Permanganate

Section 1 Chemical Product and Company Identification

PRODUCT NAME: CAIROX Potassium Permanganate, KMnO_4 **TRADE NAME:** CAIROX® Potassium Permanganate
SYNONYMS: Permanganic acid potassium salt
Chameleon mineral
Condy's crystals
Permanganate of potash

MANUFACTURER'S NAME: CARUS CHEMICAL COMPANY **TELEPHONE NUMBER FOR INFORMATION:** 815\223-1500

MANUFACTURER'S ADDRESS: Carus Chemical Company
1500 Eighth Street
P. O. Box 1500
LaSalle, IL 61301 **EMERGENCY TELEPHONE NO.:** 800\435-6856

CHEMTREC TELEPHONE NO.: 800\424-9300

Section 2 Composition/Information on Ingredients

Material or component	CAS No.*	%	Hazard Data
Potassium Permanganate	7722-64-7	97% min. KMnO_4	PEL**C*** 5 mgMn per cubic meter of air (5mgMn per cubic meter of air is equivalent to 0.0046 ounces per 1000 cubic feet of air) TLV-TWA**** 0.2 mg Mn per cubic meter of air

- * Chemical Abstract Service Number.
- ** OSHA Permissible Exposure Limit, manganese compounds (expressed as Mn) 29CFR1910.1000 Table Z1.
- *** Ceiling Exposure Limit or maximum exposure concentration not to be exceeded under any circumstances.
- **** American Conference of Governmental Industrial Hygienists 1998, for manganese dust and compounds, expressed as Mn. TLV-TWA = The time weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

Section 3 Hazards Identification

- Eye Contact**
Potassium permanganate is damaging to eye tissue on contact. It may cause severe burns that result in damage to the eye.
- Skin Contact**
Prolonged contact of solutions at room temperature may be irritating to the skin, leaving brown stains. Concentrated solutions at elevated temperature and crystals are damaging to the skin.
- Inhalation**
Acute inhalation toxicity data are not available. However, airborne concentrations of potassium permanganate in the form of dust or mist may cause damage to the respiratory tract.
- Ingestion**
Potassium permanganate, if swallowed, may cause severe burns to mucous membranes of the mouth, throat, esophagus, and stomach.

Section 4

First Aid Measures

1. Eyes

Immediately flush eyes with large amounts of water for at least 15 minutes holding lids apart to ensure flushing of the entire surface. Do not attempt to neutralize chemically. Seek medical attention immediately. Note to physician: Decomposition products are alkaline.

2. Skin

Immediately wash contaminated areas with water. Remove contaminated clothing and footwear. Wash clothing and decontaminate footwear before reuse. Seek medical attention immediately if irritation is severe and persistent.

3. Inhalation

Remove person from contaminated area to fresh air. If breathing has stopped, resuscitate and administer oxygen if readily available. Seek medical attention immediately.

4. Ingestion

Never give anything by mouth to an unconscious or convulsing person. If person is conscious, give large quantities of water. Seek medical attention immediately.

Section 5

Fire Fighting Measures

NFPA* HAZARD SIGNAL

Health Hazard (less than 1 hour exposure)	1 = Materials which under fire conditions would give off irritating combustion products. Materials which on the skin could cause irritation.
Flammability Hazard	0 = Materials that will not burn.
Reactivity Hazard	0 = Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.
Special Hazard	OX = Oxidizer

*National Fire Protection Association 704

FIRST RESPONDERS:

Wear protective gloves, boots, goggles, and respirator. In case of fire, wear positive pressure breathing apparatus. Approach incident with caution. Use Emergency Response Guide NAERG 96 (RSPA P5800.7). Guide No. 140.

FLASHPOINT

None

FLAMMABLE OR EXPLOSIVE LIMITS

Lower: Nonflammable

Upper: Nonflammable

EXTINGUISHING MEDIA

Use large quantities of water. Water will turn pink to purple if in contact with potassium permanganate. Dike to contain. Do not use dry chemicals, CO₂, Halon® or foams.

SPECIAL FIREFIGHTING PROCEDURES

If material is involved in fire, flood with water. Cool all affected containers with large quantities of water. Apply water from as far a distance as possible. Wear self-contained breathing apparatus and full protective clothing.

UNUSUAL FIRE AND EXPLOSION HAZARDS

Powerful oxidizing material. May decompose spontaneously if exposed to intense heat (150°C/302°F). May be explosive in contact with certain other chemicals (Section 10). May react violently with finely divided and readily oxidizable substances. Increases burning rate of combustible material.



Section 6 **Accidental Release Measures**

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED

Clean up spills immediately by sweeping or shoveling up the material. Do not return spilled material to the original container. Transfer to a clean metal drum. EPA banned the land disposal of D001 ignitable waste oxidizers. These wastes must be deactivated by reduction. To clean floors, flush with abundant quantities of water into sewer, if permitted by Federal, State, and Local regulations. If not permitted, collect water and treat chemically (Section 13).

PERSONAL PRECAUTIONS

Personnel should wear protective clothing suitable for the task. Remove all ignition sources and incompatible materials before attempting clean-up.

Section 7 **Handling and Storage**

Work/Hygienic Practices

Wash hands thoroughly with soap and water after handling potassium permanganate, and before eating or smoking. Wear proper protective equipment. Remove contaminated clothing.

Ventilation Requirements

Provide sufficient mechanical and/or local exhaust to maintain exposure below the Permissible Exposure Limit (PEL).

Conditions for Safe Storage

Store in accordance with NFPA 430 requirements for Class II oxidizers. Protect containers from physical damage. Store in a cool, dry area in closed containers. Segregate from acids, peroxides, formaldehyde, and all combustible, organic or easily oxidizable materials including anti-freeze and hydraulic fluid.

Section 8 **Exposure Controls/Personal Protection**

Respiratory Protection

In the case where overexposure may exist, the use of an approved NIOSH-MSHA dust/mist respirator or an air supplied respirator is advised. Engineering or administrative controls should be implemented to control dust.

Eye

Faceshield, goggles, or safety glasses with side shields should be worn. Provide eye wash in working area.

Gloves

Rubber or plastic gloves should be worn.

Other Protective Equipment

Normal work clothing covering arms and legs, and rubber, or plastic apron should be worn.



Section 9 Physical and Chemical Properties

APPEARANCE AND ODOR Dark purple solid with a metallic luster, odorless

BOILING POINT, 760 mm Hg Not applicable **SPECIFIC GRAVITY** 2.7 @ 20°C (68°F)

VAPOR PRESSURE (mm Hg) Not applicable **VAPOR DENSITY (AIR=1)** Not applicable

SOLUBILITY IN WATER % BY SOLUTION 6.0% at 20°C (68°F); and 20% at 65°C (149°F)

PERCENT VOLATILE BY VOLUME Not volatile

EVAPORATION RATE (BUTYL ACETATE=1) Not applicable

MELTING POINT Starts to decompose with evolution of oxygen (O₂) at temperatures above 150°C (302°F)

OXIDIZING PROPERTIES Strong oxidizer

Section 10 Stability and Reactivity

STABILITY Under normal conditions, the material is stable.

CONDITIONS TO AVOID Contact with incompatible materials or heat (>150°C/302°F)

INCOMPATIBLE MATERIALS Acids, peroxides, formaldehyde, antifreeze, hydraulic fluids, and all combustible organic or readily oxidizable inorganic materials including metal powders. With hydrochloric acid, toxic chlorine gas is liberated.

HAZARDOUS DECOMPOSITION PRODUCTS When involved in a fire, potassium permanganate may form corrosive fumes.

CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION Material is not known to polymerize.

Section 11 Toxicological Information

Potassium Permanganate: Acute oral LD₅₀(rat) = 780 mg/kg Male (14 days) 525 mg/kg Female (14 days)
The fatal adult human dose by ingestion is estimated to be 10 grams or 0.35 ounces.
(Ref. Handbook of Poisoning: Prevention, Diagnosis & Treatment, Twelfth Edition)

EFFECTS OF OVEREXPOSURE

1. Acute Overexposure

Irritating to body tissue with which it comes into contact.

2. Chronic Overexposure

No known cases of chronic poisoning due to potassium permanganate have been reported. Prolonged exposure, usually over many years, to heavy concentration of manganese oxides in the form of dust and fumes, may lead to chronic manganese poisoning, chiefly involving the central nervous system.

3. Carcinogenicity

Potassium permanganate has not been classified as a carcinogen by OSHA, NTP, IARC.

4. Medical Conditions Generally Aggravated by Exposure

Potassium permanganate will cause further irritation of tissue, open wounds, burns or mucous membranes.

Registry of Toxic Effects of Chemical Substances
RTECS #SD6476000



Section 15 Regulatory Information (cont.)

STATELISTS	Michigan Critical Materials Register:	Not listed
	California Proposition 65:	Not listed
	Massachusetts Substance List:	5 F8
	Pennsylvania Hazard Substance List:	E
FOREIGNLISTS	Canadian Domestic Substances List (DSL)	Listed
	Canadian Ingredient Disclosure List	Listed
	European Inventory of Existing Chemical Substances (EINECS)	Listed

Section 16 Other Information

NIOSH	National Institute for Occupational Safety and Health
MSHA	Mine Safety and Health Administration
OSHA	Occupational Safety and Health Administration
NTP	National Toxicology Program
IARC	International Agency for Research on Cancer

Kenneth Krogulski

February 1999



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Section 12

Ecological Information

Entry to the Environment

Potassium Permanganate has a low estimated lifetime in the environment, being readily converted by oxidizable materials to insoluble MnO_2 .

Bioconcentration Potential

In non-reducing and non-acidic environments MnO_2 is insoluble and has a very low bioaccumulative potential.

Aquatic Toxicity

Rainbow trout, 96 hour LC_{50} : 1.80 mg/l

Blugill sunfish, 96 hour LC_{50} : 2.3 mg/l

Section 13

Disposal Consideration

DEACTIVATION OF D001 IGNITABLE WASTE OXIDIZERS BY CHEMICAL REDUCTION

Reduce potassium permanganate in aqueous solutions with sodium thiosulfate (Hypo), a sodium bisulfite or ferrous salt solution. The biosulfite or ferrous salt may require some dilute sulfuric acid to promote rapid reduction. If acid was used, neutralize with sodium bicarbonate to neutral pH. Decant or filter, and mix the sludge with sodium carbonate and deposit in an approved landfill. Where permitted, the sludge can be drained into sewer with large quantities of water. Use caution when reacting chemicals. Contact Carus Chemical for additional recommendations.

Section 14

Transport Information

DEPARTMENT OF TRANSPORTATION INFORMATION:

Proper Shipping Name: 49 CFR172.101.....Potassium Permanganate
ID Number: 49 CFR172.101.....UN 1490
Hazard Class: 49 CFR172.101.....Oxidizer
Division: 49 CFR172.101.....5.1
Packing Group: 49 CFR172.101.....II

Section 15

Regulatory Information

TSCA Listed in the TSCA Chemical Substance Inventory

CERCLA Hazardous Substance

Reportable Quantity: 40 CFR116.4; 40 CFR302.4.....RO-100 lb.

RCRA Oxidizers such as potassium permanganate meet the criteria of ignitable waste. 40 CFR 261.21

SARA TITLE III Information

Section 302 Extremely hazardous substance: Not listed

Section 311/312 Hazard categories: Fire, acute and chronic toxicity

Section 313 Carox Potassium Permanganate contains 33-35% manganese as part of the chemical infrastructure (manganese compounds CAS Reg. No. N/A) and is subject to the reporting requirements of Section 313 of Title III, Superfund Amendments and Reauthorization Act of 1966 and 40 CFR 372.



Section 15 Regulatory Information (cont.)

STATELISTS	Michigan Critical Materials Register:	Not listed
	California Proposition 65:	Not listed
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Rev. 2/99 Form # CX 1026

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Please reduce your browser font size for better viewing and printing.

MSDS**Material Safety Data Sheet**

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865

MALLINCKRODT

24 Hour Emergency Telephone: 908-859-2151
CHEMTREC: 1-800-424-9300

National Response in Canada
CANUTEC: 613-996-6686

Outside U.S. and Canada
Chemtec: 202-483-7616

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

All non-emergency questions should be directed to Customer Service (1-800-562-2537) for assistance.

SODIUM THIOSULFATE ANHYDROUS

MSDS Number: S5234 — Effective Date: 12/08/96

1. Product Identification

Synonyms: Thiosulfuric acid, disodium salt; disodium thiosulfate; sodium hyposulfite
CAS No.: 7772-98-7
Molecular Weight: 158.11
Chemical Formula: Na₂S₂O₃
Product Codes: J.T. Baker: 3954 Mallinckrodt: 8096

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Sodium Thiosulfate	7772-98-7	100%	Yes

3. Hazards Identification

Emergency Overview

CAUTION! MAY BE HARMFUL IF SWALLOWED OR INHALED. MAY CAUSE IRRITATION TO SKIN, EYES, AND RESPIRATORY TRACT.

J.T. Baker SAF-T-DATA^(tm) Ratings (Provided here for your convenience)

Health Rating: 0 - None
Flammability Rating: 0 - None
Reactivity Rating: 1 - Slight
Contact Rating: 1 - Slight

Lab Protective Equip: GOGGLES; LAB COAT
Storage Color Code: Orange (General Storage)

Potential Health Effects

Inhalation:

May cause irritation to the respiratory tract. Symptoms may include coughing and shortness of breath.

Ingestion:

Low level of toxicity by ingestion. Diarrhea may occur by ingestion of large quantities.

Skin Contact:

Irritation may occur from prolonged skin contact.

Eye Contact:

Contact may cause mechanical irritation.

Chronic Exposure:

Chronic exposure may cause skin effects.

Aggravation of Pre-existing Conditions:

No information found.

4. First Aid Measures

Inhalation:

Remove to fresh air. Get medical attention for any breathing difficulty.

Ingestion:

Induce vomiting immediately as directed by medical personnel. Never give anything by mouth to an unconscious person. Get medical attention.

Skin Contact:

Wash exposed area with soap and water. Get medical advice if irritation develops.

Eye Contact:

Wash thoroughly with running water. Get medical advice if irritation develops.

5. Fire Fighting Measures

Fire:

Not considered to be a fire hazard.

Explosion:

Not considered to be an explosion hazard.

Fire Extinguishing Media:

Use any means suitable for extinguishing surrounding fire.

Special Information:

Use protective clothing and breathing equipment appropriate for the surrounding fire.

6. Accidental Release Measures

Ventilate area of leak or spill. Wear appropriate personal protective equipment as specified in Section 8. Spills: Sweep up and containerize for reclamation or disposal. Vacuuming or wet sweeping may be used to avoid dust dispersal.

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area. Protect against physical damage. Isolate from incompatible substances. Containers of this material may be hazardous when empty since they retain product residues (dust, solids); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:

None established.

Ventilation System:

In general, dilution ventilation is a satisfactory health hazard control for this substance. However, if conditions of use create discomfort to the worker, a local exhaust system should be considered.

Personal Respirators (NIOSH Approved):

For conditions of use where exposure to the dust or mist is apparent, a half-face dust/mist respirator may be worn. For emergencies or instances where the exposure levels are not known, use a full-face positive-pressure, air-supplied respirator. **WARNING:** Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.

Skin Protection:

Wear protective gloves and clean body-covering clothing.

Eye Protection:

Safety glasses. Maintain eye wash fountain and quick-drench facilities in work area.

9. Physical and Chemical Properties

Appearance:

Monoclinic, colorless crystals.

Odor:

Odorless.

Solubility:

50 g/100 g cold water

Density:
1.69

pH:
No information found.

% Volatiles by volume @ 21C (70F):
0

Boiling Point:
Not applicable.

Melting Point:
> 100C (> 212F)

Vapor Density (Air=1):
No information found.

Vapor Pressure (mm Hg):
No information found.

Evaporation Rate (BuAc=1):
No information found.

10. Stability and Reactivity

Stability:
Stable under ordinary conditions of use and storage.

Hazardous Decomposition Products:
Burning may produce sulfur oxides.

Hazardous Polymerization:
Will not occur.

Incompatibilities:
Metal nitrates, sodium nitrite, iodine, acids, lead, mercury, and silver salts.

Conditions to Avoid:
Incompatibles.

11. Toxicological Information

No LD50/LC50 information found relating to normal routes of occupational exposure.

Ingredient	---NTP Carcinogen---		IARC Category
	Known	Anticipated	
-----\Cancer Lists\-----			

Sodium Thiosulfate (7772-98-7)

No

No

None

12. Ecological Information

Environmental Fate:

No information found.

Environmental Toxicity:

No information found.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.

15. Regulatory Information

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-----\Chemical Inventory Status - Part 1\-----
Ingredient                                     TSCA  EC   Japan  Australia
-----
Sodium Thiosulfate (7772-98-7)                Yes  Yes   Yes    Yes

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-----\Chemical Inventory Status - Part 2\-----
Ingredient                                     Korea  DSL   NDSL  Phil.
-----
Sodium Thiosulfate (7772-98-7)                Yes   Yes   No    Yes

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-----\Federal, State & International Regulations - Part 1\-----
Ingredient                                     -SARA 302-  -SARA 313-
RQ  TPQ  List  Chemical Catg.
-----
Sodium Thiosulfate (7772-98-7)                No   No    No    No

```

```

-----\Federal, State & International Regulations - Part 2\-----
Ingredient                                     CERCLA  -RCRA-  -TSCA-
                                           261.33  8(d)
-----
Sodium Thiosulfate (7772-98-7)                No      No      No

```

Chemical Weapons Convention: No TSCA 12(b): No CDTA: No

SARA 311/312: Acute: Yes Chronic: No Fire: No Pressure: No
Reactivity: No (Pure / Solid)

Australian Hazchem Code: No information found.
Poison Schedule: No information found.

WHMIS:

This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

16. Other Information

NFPA Ratings: Health: 1 Flammability: 0 Reactivity: 0

Label Hazard Warning:

CAUTION! MAY BE HARMFUL IF SWALLOWED OR INHALED. MAY CAUSE IRRITATION TO SKIN, EYES, AND RESPIRATORY TRACT.

Label Precautions:

Avoid contact with eyes, skin and clothing. Wash thoroughly after handling. Avoid breathing dust. Keep container closed. Use with adequate ventilation.

Label First Aid:

If inhaled, remove to fresh air. Get medical attention for any breathing difficulty. In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes. Get medical attention if irritation develops or persists. If swallowed, induce vomiting immediately as directed by medical personnel. Never give anything by mouth to an unconscious person.

Product Use:

Laboratory Reagent.

Revision Information:

Pure. New 16 section MSDS format, all sections have been revised.

Disclaimer:

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Prepared by: Strategic Services Division
Phone Number: (314) 539-1600 (U.S.A.)

3.0 CHEMICAL HAZARDS RESPONSE INFORMATION SYSTEM (CHRIS) DATA SHEETS

TETRACHLOROETHYLENE

<p>Common Synonyms</p> <p>Tetraco Percloro Perchloroethylene Perk</p>		<p>Watery liquid</p>	<p>Colorless</p>	<p>Sweet odor</p>
<p>Sinks in water, irritating vapor is produced.</p>				
<p>Shut discharge if possible. Avoid contact with liquid and vapor. Isolate and remove discharged material. Notify local health and pollution control agencies.</p>				
<p>Fire</p>		<p>Not flammable. Poisonous gases are produced when heated.</p>		
<p>Exposure</p>		<p>CALL FOR MEDICAL AID.</p> <p>VAPOR Irritating to eyes, nose and throat. If inhaled, will cause difficult breathing, or loss of consciousness. Move to fresh air. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen.</p> <p>LIQUID Irritating to skin and eyes. Harmful if swallowed. Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk.</p>		
<p>Water Pollution</p>		<p>Effect of low concentrations on aquatic life is unknown. May be dangerous if it enters water courses. Notify local health and waste officials. Notify operators of nearby water intakes.</p>		
<p>1. RESPONSE TO DISCHARGE (See Response Methods Handbook) Should be removed Chemical and physical treatment</p>		<p>2. LABEL</p> <p>2.1 Category: None 2.2 Class: Not pertinent</p>		
<p>1. CHEMICAL DESIGNATIONS</p> <p>3.1 CG Compatibility Class: Not listed 3.2 Formula: C₂Cl₄ 3.3 IMO/IUM Designation: 9.0/1807 3.4 DOT ID No.: 1887 3.5 CAS Registry No.: 127-18-4</p>		<p>4. OBSERVABLE CHARACTERISTICS</p> <p>4.1 Physical State (as shipped): Liquid 4.2 Color: Colorless 4.3 Odor: Ethereal like chloroform, milky sweet</p>		
<p>5. HEALTH HAZARDS</p> <p>5.1 Personal Protective Equipment: For high vapor concentrations use approved canister or air-supplied mask; chemical goggles or face shield; plastic gloves.</p> <p>5.2 Symptoms Following Exposure: Vapor can affect central nervous system and cause numbness. Liquid may irritate skin after prolonged contact. May irritate eyes but causes no injury.</p> <p>5.3 Treatment of Exposure: INHALATION: If illness occurs, remove patient to fresh air, keep him warm and quiet, and get medical attention. INGESTION: induce vomiting only on physician's recommendation. EYES AND SKIN: flush with plenty of water and get medical attention if irritation or injury occurs.</p> <p>5.4 Threshold Limit Value: 50 ppm 5.5 Short Term Inhalation Limit: 100 ppm for 60 min. 5.6 Toxicity by Ingestion: Grade 2; LD₅₀ = 0.5 to 5 g/kg 5.7 Lethal Toxicity: None 5.8 Vapor (Gas) Irritant Characteristics: Vapors cause a slight smarting of the eyes or throat if present in high concentrations. The effect is temporary. 5.9 Liquid or Solid Irritant Characteristics: Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin. 5.10 Ocular Threshold: 5 ppm 5.11 IDLH Value: 500 ppm</p>				

<p>6. FIRE HAZARDS</p> <p>6.1 Flash Point: Not flammable 6.2 Flammable Limits in Air: Not flammable 6.3 Fire Extinguishing Agents: Not pertinent 6.4 Fire Extinguishing Agents Not to be Used: Not pertinent 6.5 Special Hazards of Combustion: Products: Toxic, irritating gases may be generated in fire. 6.6 Behavior in Fire: Not pertinent 6.7 Ignition Temperature: Not flammable 6.8 Electrical Hazard: Not pertinent 6.9 Burning Rate: Not flammable 6.10 Adiabatic Flame Temperature: Data not available 6.11 Self-Heating Air to Fuel Ratio: Data not available 6.12 Flame Temperature: Data not available</p>		<p>10. HAZARD ASSESSMENT CODE (See Hazard Assessment Handbook) A-X</p>																													
<p>7. CHEMICAL REACTIVITY</p> <p>7.1 Reactivity With Water: No reaction 7.2 Reactivity With Common Materials: No reaction 7.3 Stability During Transport: Stable 7.4 Neutralizing Agents for Acids and Caustics: Not pertinent 7.5 Polymerization: Not pertinent 7.6 Inhibitor of Polymerization: Not pertinent 7.7 Molar Ratio (Reactant to Product): Data not available 7.8 Reactivity Group: Data not available</p>		<p>11. HAZARD CLASSIFICATIONS</p> <p>11.1 Code of Federal Regulations: OSHA 11.2 NAS Hazard Rating for Bulk Water Transportation:</p> <table border="1"> <thead> <tr> <th>Category</th> <th>Rating</th> </tr> </thead> <tbody> <tr> <td>Fire</td> <td>0</td> </tr> <tr> <td>Health</td> <td></td> </tr> <tr> <td>Vapor Irritant</td> <td>1</td> </tr> <tr> <td>Liquid or Solid Irritant</td> <td>1</td> </tr> <tr> <td>Poison</td> <td>2</td> </tr> <tr> <td>Water Pollution</td> <td></td> </tr> <tr> <td>Human Toxicity</td> <td>1</td> </tr> <tr> <td>Aquatic Toxicity</td> <td>3</td> </tr> <tr> <td>Aesthetic Effect</td> <td>2</td> </tr> <tr> <td>Reactivity</td> <td></td> </tr> <tr> <td>Other Chemicals</td> <td>1</td> </tr> <tr> <td>Water</td> <td>0</td> </tr> <tr> <td>Salt Reaction</td> <td>1</td> </tr> </tbody> </table> <p>11.3 NFPA Hazard Classifications: Not listed</p>		Category	Rating	Fire	0	Health		Vapor Irritant	1	Liquid or Solid Irritant	1	Poison	2	Water Pollution		Human Toxicity	1	Aquatic Toxicity	3	Aesthetic Effect	2	Reactivity		Other Chemicals	1	Water	0	Salt Reaction	1
Category	Rating																														
Fire	0																														
Health																															
Vapor Irritant	1																														
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Reactivity																															
Other Chemicals	1																														
Water	0																														
Salt Reaction	1																														
<p>8. WATER POLLUTION</p> <p>8.1 Aquatic Toxicity: Data not available 8.2 Waterfowl Toxicity: Data not available 8.3 Biological Oxygen Demand (BOD): None 8.4 Food Chain Concentration Potential: None</p>		<p>12. PHYSICAL AND CHEMICAL PROPERTIES</p> <p>12.1 Physical State at 15°C and 1 atm: Liquid 12.2 Molecular Weight: 185.83 12.3 Boiling Point at 1 atm: 230°F = 121°C = 394°K 12.4 Freezing Point: -8.3°F = -22.4°C = 250.8°K 12.5 Critical Temperature: 637°F = 347°C = 620°K 12.6 Critical Pressure: Not pertinent 12.7 Specific Gravity: 1.83 at 20°C (liquid) 12.8 Liquid Surface Tension: 31.3 dynes/cm = 0.0313 N/m at 20° 12.9 Liquid Water Interfacial Tension: 44.4 dynes/cm = 0.0444 N/m at 25° 12.10 Vapor (Gas) Specific Gravity: Not pertinent 12.11 Ratio of Specific Heats of Vapor (Gas): 1.118 12.12 Latent Heat of Vaporization: 90.2 Btu/lb = 50.1 cal/g = 2.10 X 10⁴ J/kg 12.13 Heat of Combustion: Not pertinent 12.14 Heat of Decomposition: Not pertinent 12.15 Heat of Solution: Not pertinent 12.16 Heat of Polymerization: Not pertinent 12.17 Heat of Fusion: Data not available 12.18 Limiting Value: Data not available 12.19 Vapour Pressure: Data not available</p>																													
<p>9. SHIPPING INFORMATION</p> <p>9.1 Grades of Purity: Dry cleaning and industrial grades: 95- % 9.2 Storage Temperature: Ambient 9.3 Inert Atmospheric: No requirement 9.4 Venting: Pressure-vacuum</p>		<p>NOTES</p>																													

TTE

TETRACHLOROETHYLENE

12.17 SATURATED LIQUID DENSITY		12.18 LIQUID HEAT CAPACITY		12.19 LIQUID THERMAL CONDUCTIVITY		12.20 LIQUID VISCOSITY	
Temperature (degrees F)	Pounds per cubic foot	Temperature (degrees F)	British thermal unit per pound-F	Temperature (degrees F)	British thermal unit-inch per hour- square foot-F	Temperature (degrees F)	Centipoise
35	103.400	0	.198		N O T P E R T I N E N T	55	.958
40	103.099	10	.200			60	.929
45	102.900	20	.201			65	.900
50	102.599	30	.202			70	.873
55	102.299	40	.203			75	.848
60	102.000	50	.204			80	.823
65	101.700	60	.205			85	.800
70	101.400	70	.206			90	.777
75	101.099	80	.207			95	.756
80	100.799	90	.208			100	.736
85	100.500	100	.210			105	.716
90	100.200	110	.211			110	.698
95	99.910	120	.212			115	.680
100	99.610	130	.213			120	.663
105	99.320	140	.214			125	.647
110	99.020	150	.215			130	.631
115	98.730	160	.216		135	.616	
120	98.429	170	.217		140	.601	
125	98.139	180	.218		145	.588	
130	97.839	190	.220		150	.574	
135	97.549	200	.221		155	.561	
140	97.250	210	.222		160	.549	
145	96.959				165	.537	
150	96.669				170	.526	
155	96.370				175	.515	
160	96.080						

12.21 SOLUBILITY IN WATER		12.22 SATURATED VAPOR PRESSURE		12.23 SATURATED VAPOR DENSITY		12.24 IDEAL GAS HEAT CAPACITY	
Temperature (degrees F)	Pounds per 100 pounds of water	Temperature (degrees F)	Pounds per square inch	Temperature (degrees F)	Pounds per cubic foot	Temperature (degrees F)	British thermal unit per pound-F
68.02	.016	60	.236	60	.00702	0	.108
		70	.318	70	.00929	25	.110
		80	.425	80	.01216	50	.113
		90	.561	90	.01575	75	.116
		100	.732	100	.02022	100	.118
		110	.948	110	.02571	125	.120
		120	1.217	120	.03242	150	.122
		130	1.548	130	.04055	175	.125
		140	1.953	140	.05032	200	.127
		150	2.446	150	.06199	225	.129
		160	3.042	160	.07583	250	.131
		170	3.756	170	.09215	275	.132
		180	4.607	180	.11130	300	.134
		190	5.616	190	.13360	325	.136
		200	6.805	200	.15940	350	.138
		210	8.199	210	.18910	375	.139
		220	9.824	220	.22330	400	.141
		230	11.710	230	.26230	425	.142
		240	13.890	240	.30660	450	.143
		250	16.390	250	.35680	475	.144
		260	19.260	260	.41330	500	.146
		270	22.520	270	.47680	525	.147
		280	26.230	280	.54790	550	.148
						575	.148
						600	.149

TRICHLOROETHYLENE

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<p>Common Synonyms Trichloroethylene Trielene; Aeglyon Chazylen Germaglene Triethylene Trichloron; Trielene</p>		<p>Watery liquid</p>	<p>Colorless</p>	<p>Slight odor</p>
<p>Sinks in water. Irritating vapor is produced.</p>				
<p>Stop discharge if possible. Keep people away. Avoid contact with liquid and vapor. Call fire department. Facilitate and remove discharged material. Notify local health and pollution control agencies.</p>				
<p>Fire</p>	<p>Combustible. POISONOUS GASES ARE PRODUCED IN FIRE. Wear goggles and self-contained breathing apparatus. Extinguish with dry chemical, carbon dioxide, or foam.</p>			
<p>Exposure</p>	<p>CALL FOR MEDICAL AID. VAPOR Irritating to eyes, nose and throat. If inhaled, will cause nausea, vomiting, difficult breathing, or loss of consciousness. Move to fresh air. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen. LIQUID Irritating to skin and eyes. If swallowed, will cause nausea, vomiting, difficult breathing, or loss of consciousness. Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk and have victim induce vomiting. IF SWALLOWED and victim is UNCONSCIOUS OR HAVING CONVULSIONS, do nothing except keep victim warm.</p>			
<p>Water Pollution</p>	<p>Effect of low concentrations on aquatic life is unknown. May be dangerous if it enters water intakes. Notify local health and waste officials. Notify operators of nearby water intakes.</p>			
<p>1. RESPONSE TO DISCHARGE (See Response Methods Handbook) Should be removed Chemical and physical treatment</p>		<p>2. LABEL 2.1 Category: None 2.2 Class: Not pertinent</p>		
<p>3. CHEMICAL DESIGNATIONS 3.1 CG Compatibility Class: Halogenated hydrocarbon 3.2 Formula: $CH_2=CCl_2$ 3.3 IMO/JUN Designator: 9.0/1710 3.4 DOT ID No.: 1710 3.5 CAS Registry No.: 79-01-4</p>		<p>4. OBSERVABLE CHARACTERISTICS 4.1 Physical State (as shipped): Liquid 4.2 Color: Colorless 4.3 Odor: Chloroform-like; ethereal</p>		
<p>5. HEALTH HAZARDS</p> <p>5.1 Personal Protective Equipment: Organic vapor-air gas canister; self-contained breathing apparatus for emergency; neoprene or vinyl gloves; chemical safety goggles; face shield; neoprene safety shoes; neoprene suit or apron for splash protection.</p> <p>5.2 Symptoms Following Exposure: INHALATION: symptoms range from irritation of the nose and throat to nausea, an attitude of irresponsibility, blurred vision, and finally disturbance of central nervous system resulting in cardiac failure. Chronic exposure may cause organic injury. INGESTION: symptoms similar to inhalation. SKIN: irritating action can cause dermatitis. EYES: slightly irritating sensation and lachrymation.</p> <p>5.3 Treatment of Exposure: Do NOT administer adrenalin or epinephrine; get medical attention for all cases of overexposure. INHALATION: remove victim to fresh air; if necessary, apply artificial respiration and/or administer oxygen. INGESTION: have victim drink water and induce vomiting; repeat three times; then give 1 tablespoon spoon salts in water. EYES: flush thoroughly with water. SKIN: wash thoroughly with soap and warm water.</p> <p>5.4 Threshold Limit Value: 50 ppm 5.5 Short Term Inhalation Limit: 200 ppm for 30 min. 5.6 Toxicity by Ingestion: Grade 3; LD₅₀ = 50 to 500 mg/kg 5.7 Late Toxicity: Data not available 5.8 Vapor (Gas) Irritant Characteristics: Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary. 5.9 Liquid or Solid Irritant Characteristics: Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin. 5.10 Odor Threshold: 50 ppm 5.11 IDLH Value: 1,000 ppm</p>				

<p>6. FIRE HAZARDS</p> <p>6.1 Flash Point: 90°F C.C.; practically nonflammable 6.2 Flammable Limits in Air: 8.0%-10.5% 6.3 Fire Extinguishing Agents: Water fog 6.4 Fire Extinguishing Agents Not to be Used: Not pertinent 6.5 Special Hazards of Combustion: Products: Toxic and irritating gases are produced in fire situations. 6.6 Behavior in Fire: Not pertinent 6.7 Ignition Temperature: 770°F 6.8 Electrical Hazard: Not pertinent 6.9 Burning Rate: Not pertinent 6.10 Autotank Flame Temperature: Data not available 6.11 Self-Heating Air to Fuel Ratio: Data not available 6.12 Flame Temperature: Data not available</p>		<p>10. HAZARD ASSESSMENT CODE (See Hazard Assessment Handbook) A-X-Y</p>
<p>7. CHEMICAL REACTIVITY</p> <p>7.1 Reactivity With Water: No reaction 7.2 Reactivity With Common Materials: No reaction 7.3 Stability During Transport: Stable 7.4 Neutralizing Agents for Acids and Bases: Not pertinent 7.5 Polymerization: Not pertinent 7.6 Inhibitor of Polymerization: Not pertinent 7.7 Metal Ratio (Reactant 99): Product: Data not available 7.8 Reactivity Group: 08</p>		<p>11. HAZARD CLASSIFICATIONS</p> <p>11.1 Code of Federal Regulations: OSHA 11.2 NIOSH Hazard Rating for Bulk Water Transportation: Category _____ Rating _____ Fire: _____ 1 Health: _____ 1 Vapor Irritant: _____ 1 Liquid or Solid Irritant: _____ 1 Poison: _____ 2 Water Pollution: _____ 1 Human Toxicity: _____ 1 Acute Toxicity: _____ 2 Asesthetic Effect: _____ 2 Reactivity: _____ 1 Other Chemical: _____ 1 Wear: _____ 0 Self Reaction: _____ 1</p> <p>11.3 NFPA Hazard Classification: Category _____ Classification _____ Health Hazard (Blue): _____ 2 Flammability (Red): _____ 1 Reactivity (Yellow): _____ 0</p>
<p>2. WATER POLLUTION</p> <p>2.1 Acute Toxicity: 800 mg/l/40 hr/droplet/ml/fresh water 2.2 Waterfowl Toxicity: Data not available 2.3 Biological Oxygen Demand (BOD): Data not available 2.4 Feed Chain Concentration Potential: None</p>		<p>12. PHYSICAL AND CHEMICAL PROPERTIES</p> <p>12.1 Physical State at 15°C and 1 atm: Liquid 12.2 Molecular Weight: 131.04 12.3 Boiling Point at 1 atm: 187°F = 87°C = 360°K 12.4 Freezing Point: -123.5°F = -86.4°C = 186.8°K 12.5 Critical Temperature: Not pertinent 12.6 Critical Pressure: Not pertinent 12.7 Specific Gravity: 1.48 at 20°C (liquid) 12.8 Liquid Surface Tension: 29.3 dynes/cm = 0.0293 N/m at 20°C 12.9 Liquid Water Interfacial Tension: 34.5 dynes/cm = 0.0345 N/m at 24°C 12.10 Vapor (Gas) Specific Gravity: 4.5 12.11 Ratio of Specific Heats of Vapor (Gas): 1.114 12.12 Latent Heat of Vaporization: 103 Btu/lb = 57.2 cal/g = 2.4 x 10⁴ J/kg 12.13 Heat of Combustion: Not pertinent 12.14 Heat of Decomposition: Not pertinent 12.15 Heat of Solution: Not pertinent 12.16 Heat of Polymerization: Not pertinent 12.25 Heat of Fusion: Data not available 12.26 Limiting Value: Data not available 12.27 Reid Vapor Pressure: 2.5 psia</p>
<p>3. SHIPPING INFORMATION</p> <p>3.1 Grade of Purity: Technical dry clearing; degreasing; extraction 3.2 Storage Temperature: Ambient 3.3 Inert Atmosphere: No requirement 3.4 Venting: Pressure-vacuum</p>		<p>NOTES</p>

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TRICHLOROETHYLENE

12.17 SATURATED LIQUID DENSITY		12.18 LIQUID HEAT CAPACITY		12.19 LIQUID THERMAL CONDUCTIVITY		12.20 LIQUID VISCOSITY	
Temperature (degrees F)	Pounds per cubic foot	Temperature (degrees F)	British thermal unit per pound-F	Temperature (degrees F)	British thermal unit-inch per hour- square foot-F	Temperature (degrees F)	Centipoise
0	94.669	0	.220		N O T P E R T I N E N T	15	.800
5	94.410	10	.221			20	.775
10	94.150	20	.223			25	.750
15	93.889	30	.225			30	.727
20	93.629	40	.226			35	.705
25	93.370	50	.228			40	.684
30	93.110	60	.230			45	.664
35	92.849	70	.231			50	.645
40	92.589	80	.233			55	.627
45	92.330	90	.235			60	.610
50	92.070	100	.236			65	.593
55	91.809	110	.238			70	.577
60	91.549	120	.240		75	.562	
65	91.290	130	.241		80	.548	
70	91.030	140	.243		85	.534	
75	90.770	150	.245		90	.521	
80	90.509	160	.246		95	.508	
85	90.250	170	.248		100	.496	
90	89.990				105	.485	
95	89.730				110	.474	
100	89.469				115	.463	
105	89.209				120	.453	
110	88.950						
115	88.690						
120	88.429						
125	88.169						

12.21 SOLUBILITY IN WATER		12.22 SATURATED VAPOR PRESSURE		12.23 SATURATED VAPOR DENSITY		12.24 IDEAL GAS HEAT CAPACITY	
Temperature (degrees F)	Pounds per 100 pounds of water	Temperature (degrees F)	Pounds per square inch	Temperature (degrees F)	Pounds per cubic foot	Temperature (degrees F)	British thermal unit per pound-F
77.02	.110	40	.508	40	.01245	0	.136
		50	.678	50	.01628	25	.139
		60	.894	60	.02105	50	.143
		70	1.166	70	.02695	75	.146
		80	1.507	80	.03418	100	.149
		90	1.929	90	.04296	125	.152
		100	2.448	100	.05354	150	.155
		110	3.081	110	.06619	175	.157
		120	3.846	120	.08120	200	.160
		130	4.765	130	.09891	225	.162
		140	5.862	140	.11960	250	.165
		150	7.163	150	.14380	275	.167
		160	8.695	160	.17180	300	.169
		170	10.490	170	.20390	325	.172
		180	12.580	180	.24080	350	.174
		190	15.010	190	.28280	375	.176
		200	17.810	200	.33040	400	.177
		210	21.020	210	.38420	425	.179
						450	.181
						475	.182
						500	.184
						525	.185
						550	.186
						575	.187
						600	.188

<p>Common Synonyms Acetylene dichloride sym-dichloroethylene Diform cis-1, 2-dichloroethylene trans-1, 2-dichloroethylene</p>	<p>Liquid Colorless Sweet pleasant odor</p>	<p>Sinks in water. Flammable, irritating vapor is produced.</p>
<p>Wear goggles and self-contained breathing apparatus. Shut off ignition sources. Call fire department. Stop discharge if possible. Keep people away. Isolate and remove discharged material. Notify local health and pollution control agencies.</p>		
<p>Fire</p>	<p>FLAMMABLE POISONOUS GASES MAY BE PRODUCED IN FIRE. Containers may explode in fire. Flashback along vapor trail may occur. Vapor may explode if ignited in an enclosed area. Extinguish with dry chemicals, foam or carbon dioxide. Water may be ineffective on fire. Cool exposed containers with water.</p>	
<p>Exposure</p>	<p>CALL FOR MEDICAL AID. VAPOR If inhaled will cause dizziness, nausea, vomiting, or difficult breathing. Move victim to fresh air. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen. LIQUID Irritant if swallowed. If SWALLOWED and victim is CONSCIOUS, have victim drink water or milk.</p>	
<p>Water Pollution</p>	<p>Effect of low concentrations on aquatic life is unknown. May be dangerous if it enters water intakes. Notify local health and waste officials. Notify operators of nearby water intakes.</p>	
<p>1. RESPONSE TO DISCHARGE (See Response Methods Handbook) Issue warning-high flammability Restrict access Evacuate area Should be removed Chemical and physical treatment</p>	<p>2. LABEL 2.1 Category: Flammable liquid 2.2 Class: 3</p>	
<p>1. CHEMICAL DESIGNATIONS 3.1 CG Compatibility Class: Not listed 3.2 Formula: C₂H₂Cl₂ 3.3 IMO/UN Designation: 3.2/1150 3.4 DOT ID No.: 1150 3.5 CAS Registry No.: 540-59-0</p>	<p>4. OBSERVABLE CHARACTERISTICS 4.1 Physical State (as shipped): Liquid 4.2 Color: Colorless 4.3 Odor: Ethereal, slightly acrid, pleasant, chloroform-like</p>	
<p>5. HEALTH HAZARDS</p>		
<p>5.1 Personal Protective Equipment: Rubber gloves; safety goggles; air supply mask or self-contained breathing apparatus. 5.2 Symptoms Following Exposure: Inhalation causes nausea, vomiting, weakness, tremor, epigastric cramps, cerebral nervous depression. Contact with liquid causes irritation of eyes and (on prolonged contact) sun. Ingestion causes slight depression to deep narcosis. 5.3 Treatment of Exposure: INHALATION: remove from further exposure; if breathing is difficult, give oxygen; if victim is not breathing, give artificial respiration, preferably mouth-to-mouth; give oxygen when breathing is resumed; call a physician. EYES: flush with water for at least 15 min. SKIN: wash well with soap and water. INGESTION: give gastric lavage and cathartics. 5.4 Threshold Limit Value: 200 ppm 5.5 Short Term Inhalation Limits: Data not available 5.6 Toxicity by Ingestion: Grade 2; oral LD₅₀ = 770 mg/kg (rat) 5.7 Late Toxicity: Produces liver and kidney injury in experimental animals 5.8 Vapor (Gas) Irritant Characteristics: Data not available 5.9 Liquid or Solid Irritant Characteristics: Data not available 5.10 Odor Threshold: Data not available 5.11 IDLH Value: 4,000 ppm</p>		

<p>6. FIRE HAZARDS</p> <p>6.1 Flash Point: 377° C.C. 6.2 Flammable Limits in Air: 9.7%-12.8% 6.3 Fire Extinguishing Agents: Dry chemical, foam, carbon dioxide 6.4 Fire Extinguishing Agents Not to be Used: Water may be ineffective. 6.5 Special Hazards of Combustion Products: Phosgene and hydrogen chloride fumes may form in fire. 6.6 Behavior in Fire: Vapor is heavier than air and may travel a considerable distance to a source of ignition and flash back. 6.7 Ignition Temperature: 880°F 6.8 Electrical Hazards: Data not available 6.9 Burning Rate: 2.6 mm/min. 6.10 Adiabatic Flame Temperature: Data not available</p> <p style="text-align: right;"><i>(Continued)</i></p>	<p>10. HAZARD ASSESSMENT CODE (See Hazard Assessment Handbook) A-X-Y</p>
<p>7. CHEMICAL REACTIVITY</p> <p>7.1 Reactivity With Water: No reaction 7.2 Reactivity with Common Materials: No reaction 7.3 Stability During Transport: Stable 7.4 Neutralizing Agents for Acids and Caustics: Not pertinent 7.5 Polymerizability: Will not occur under ordinary conditions of shipment. The reaction is not vigorous. 7.6 Inhibitor of Polymerization: None used 7.7 Motor Rotor (Reactor to Product): Data not available 7.8 Reactivity Group: Data not available</p>	<p>11. HAZARD CLASSIFICATIONS</p> <p>11.1 Code of Federal Regulations: Flammable liquid 11.2 HAS Hazard Rating for Bulk Water Transportation: Not listed 11.3 HPPA Hazard Classification: Category Classification Health Hazard (Blue) 2 Flammability (Red) 3 Reactivity (Yellow) 2</p>
<p>8. WATER POLLUTION</p> <p>8.1 Aquatic Toxicity: Data not available 8.2 Waterway Toxicity: Data not available 8.3 Biological Oxygen Demand (BOD): Data not available 8.4 Feed Chain Concentration Potential: None</p>	<p>12. PHYSICAL AND CHEMICAL PROPERTIES</p> <p>12.1 Physical State at 15°C and 1 atm: Liquid 12.2 Molecular Weight: 97.0 12.3 Boiling Point at 1 atm: °C: 140°F = 60°C = 333°K °F: 118°F = 48°C = 321°K 12.4 Freezing Point: °C: -114°F = -81°C = 182°K °F: -58°F = -50°C = 223°K 12.5 Critical Temperature: Not pertinent 12.6 Critical Pressure: Not pertinent 12.7 Specific Gravity: 1.27 at 25°C (liquid) 12.8 Liquid Surface Tension: 24 dynes/cm = 0.024 N/m at 20°C 12.9 Liquid Water Interfacial Tension (est.): 30 dynes/cm = 0.030 N/m at 20°C 12.10 Vapor (Gas) Specific Gravity: 3.34 12.11 Ratio of Specific Heats of Vapor (Gas): 1.1468 12.12 Latent Heat of Vaporization: 130 Btu/lb = 72 cal/g = 3.0 x 10⁴ J/kg 12.13 Heat of Combustion: -4,647.2 Btu/lb = -2,892.9 cal/g = -112.67 x 10⁴ J/mole 12.14 Heat of Decomposition: Not pertinent 12.15 Heat of Solution: Not pertinent 12.16 Heat of Polymerization: Not pertinent 12.25 Heat of Fusion: Data not available 12.29 Limiting Value: Data not available 12.27 Reid Vapor Pressure: Data not available</p>
<p>6. FIRE HAZARDS (Continued)</p>	
<p>6.11 Stoichiometric Air to Fuel Ratio: Data not available 6.12 Flame Temperature: Data not available</p>	

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1,2-DICHLOROETHYLENE

12.17 SATURATED LIQUID DENSITY		12.18 LIQUID HEAT CAPACITY		12.19 LIQUID THERMAL CONDUCTIVITY		12.20 LIQUID VISCOSITY	
Temperature (degrees F)	Pounds per cubic foot	Temperature (degrees F)	British thermal unit per pound-F	Temperature (degrees F)	British thermal unit-inch per hour- square foot-F	Temperature (degrees F)	Centipoise
35	81.020	35	.193	65	.907	40	.478
40	80.820	40	.196	70	.894	50	.454
45	80.610	45	.198	75	.882	60	.432
50	80.400	50	.200	80	.869	70	.411
55	80.190	55	.202	85	.857	80	.393
60	79.980	60	.204	90	.844	90	.376
65	79.780	65	.207	95	.832	100	.360
70	79.570	70	.209	100	.819	110	.345
75	79.360	75	.211	105	.807	120	.331
80	79.150	80	.213	110	.794	130	.319
85	78.940	85	.216	115	.782	140	.307
90	78.740	90	.218	120	.769	150	.296
95	78.530	95	.220	125	.757	160	.286
100	78.320	100	.222	130	.744	170	.276
105	78.110	105	.224			180	.267
110	77.900	110	.227			190	.259
115	77.690	115	.229			200	.251
120	77.490	120	.231			210	.244
125	77.280	125	.233				
130	77.070	130	.236				
135	76.860	135	.238				
140	76.650	140	.240				

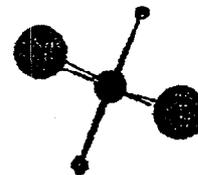
12.21 SOLUBILITY IN WATER		12.22 SATURATED VAPOR PRESSURE		12.23 SATURATED VAPOR DENSITY		12.24 IDEAL GAS HEAT CAPACITY	
Temperature (degrees F)	Pounds per 100 pounds of water	Temperature (degrees F)	Pounds per square inch	Temperature (degrees F)	Pounds per cubic foot	Temperature (degrees F)	British thermal unit per pound-F
68	.630	55	3.009	55	.05284	0	.150
		60	3.396	60	.05906	20	.153
		65	3.824	65	.06587	40	.156
		70	4.297	70	.07330	60	.159
		75	4.817	75	.08141	80	.162
		80	5.389	80	.09023	100	.165
		85	6.016	85	.09980	120	.167
		90	6.702	90	.11020	140	.170
		95	7.453	95	.12140	160	.173
		100	8.272	100	.13360	180	.176
		105	9.164	105	.14660	200	.179
		110	10.130	110	.16070	220	.182
		115	11.190	115	.17590	240	.185
		120	12.330	120	.19220	260	.188
		125	13.560	125	.20960	280	.191
		130	14.900	130	.22830	300	.194
		135	16.340	135	.24820	320	.197
		140	17.890	140	.26960	340	.200
						360	.203
						380	.205
						400	.208
						420	.211
						440	.214

APPENDIX B

POTASSIUM PERMANGANATE INFORMATION

CAIROX® Potassium Permanganate

Potassium permanganate is one of the most vigorous and versatile commonly used inorganic oxidants available. It has been used for over a century as an oxidizing agent employed in a wide variety of organic and inorganic oxidation reactions conducted in acidic, alkaline and neutral environments. Permanganate oxidation reactions of inorganic compounds typically exhibit rapid rates while those oxidation reactions involving organic substances exhibit a high degree of stereoselectivity.



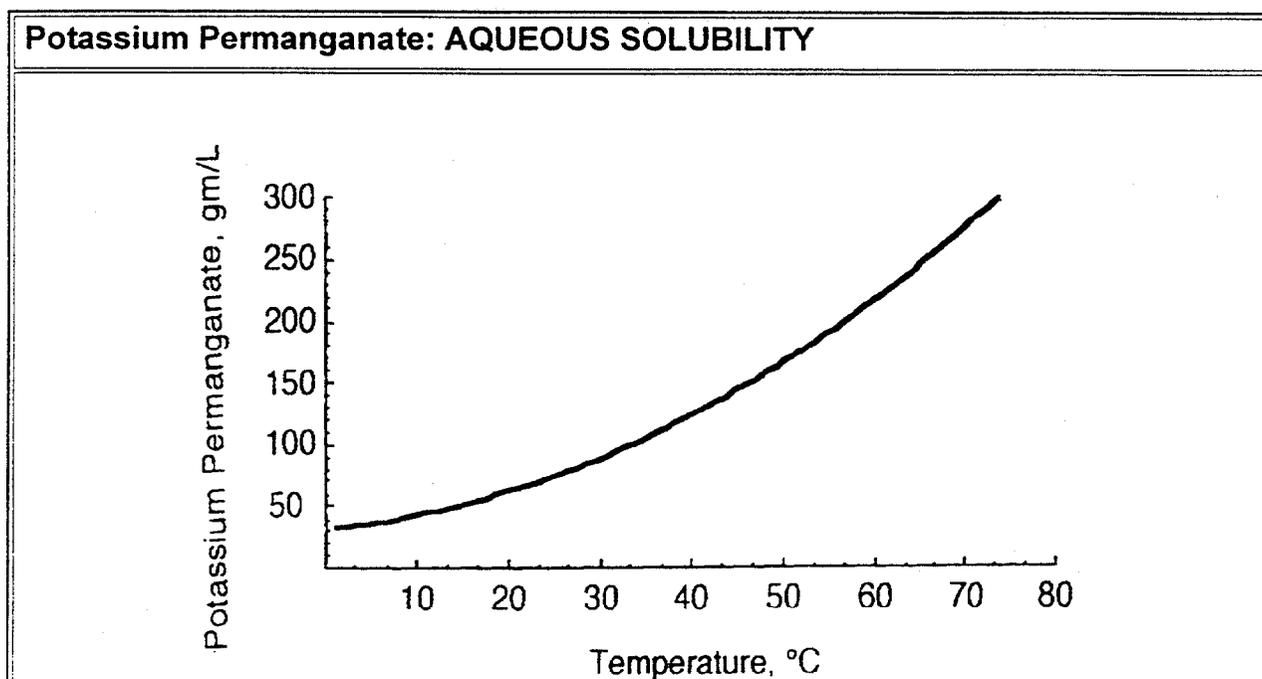
CAIROX® potassium permanganate is a strong oxidant with a long history of safe use in drinking water, wastewater, and chemical manufacturing industries. In potable water applications, CAIROX® oxidizes iron, manganese, and hydrogen sulfide. It controls taste and odor problems, zebra mussels, and is a pre-oxidant for THM (trihalomethane) control. In the wastewater field, it is used to oxidize hydrogen sulfide and other odors, prevent corrosion, destroy phenol and other toxic pollutants, control and remove grease, and for sludge odor control as well as improved sludge dewaterability and biodegradability.

CAIROX® finds extensive applications in the chemical manufacturing industry as an oxidant as well as for metal surface treatment and equipment cleaning.

PERMANGANATE COMPOUNDS		
	Compound	CAS Registry Number
Permanganic acid	HMnO_4	13465-41-3
Potassium Permanganate	KMnO_4	7722-64-7
Sodium Permanganate	NaMnO_4	10101-50-5
Permanganate ion	MnO_4^-	1433-13-2

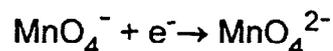
Potassium Permanganate: CHEMICAL PROPERTIES	
Density	2.703 grams/cm ³ at 20°C
Aqueous Stability	<p>MnO_4^- is not the thermodynamically stable form of manganese in water, thus, permanganate tends to (very slowly) oxidize water with the evolution of oxygen:</p> $4 \text{MnO}_4^- + 4 \text{H}^+ \rightarrow 4 \text{MnO}_2 + 2 \text{H}_2\text{O} + \text{O}_2\uparrow$
Solubility	The aqueous solubility of alkali metal permanganates - measured

Solubility	at room temperature decreases as the atomic number increases. 900 g/L for NaMnO_4 60 g/L for KMnO_4 2.5 g/L for CsMnO_4
Aqueous Solubility	Aqueous solubility KMnO_4 , gram/liter = $30.55 + 0.796 (T, ^\circ\text{C}) + 0.0392 (T, ^\circ\text{C})^2$ Where: T = Solution Temperature, Centigrade
Melting Point	Decomposes at 200 - 300 $^\circ\text{C}$.
Thermal Decomposition	$10 \text{KMnO}_4 \xrightarrow{250-300^\circ\text{C}} 2.65\text{K}_2\text{MnO}_4 + [2.35 \text{K}_2\text{O} \cdot 7.35 \text{MnO}_{2.05}] + 6\text{O}_2$
Crystal Structure	orthorhombic space group Pnma and four molecules per unit cell $a=9.105\text{\AA}$, $b=5.720\text{\AA}$, and $c=7.425\text{\AA}$.
Bonding	The manganese atom is surrounded by four oxygen atoms located at the corners of a regular tetrahedron. The average Mn-O bond distance in the permanganate ion is $1.629 \pm 0.008 \text{\AA}$ The average O-Mn-O bond angle is $109.4 \pm 0.7^\circ$
Bulk Density	approximately 100 pounds / cubic foot
Specific Gravity	$1.0000 + 0.007 [\text{KMnO}_4, \% (w/w)]$
Color	The permanganate ion (MnO_4^-) is purple.

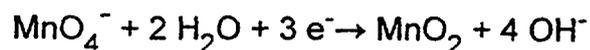


Potassium Permanganate: REDOX REACTIONS

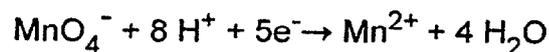
- Alkaline conditions (pH >12), $E_0 = 0.56$



- Neutral conditions (pH range of 3.5 to 12), $E_0 = 1.69$

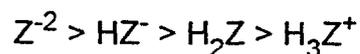


- Acidic conditions (pH <3.5), $E_0 = 1.51$

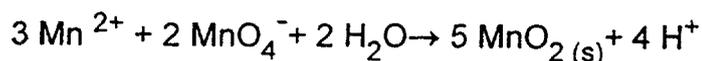


Redox potential is a function of oxidant concentration and solution pH.

Potassium permanganate, as a general rule will oxidize anions more readily than neutral molecules which are oxidized more readily than cations.

**Potassium Permanganate: OXIDATION EXAMPLES**

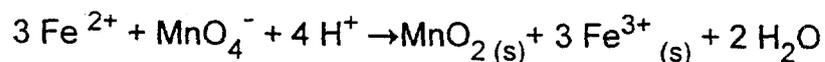
- Divalent Manganese: Mn^{2+}



1 part Mn^{2+} requires 1.92 parts KMnO_4

1 part KMnO_4 will oxidize 0.52 parts Mn^{2+}

- Divalent Iron: Fe^{2+}

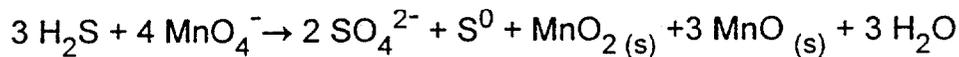


1 part Fe^{2+} requires 0.94 parts KMnO_4

1 part KMnO_4 will oxidize 1.06 parts Fe^{2+}

- Hydrogen Sulfide: H_2S

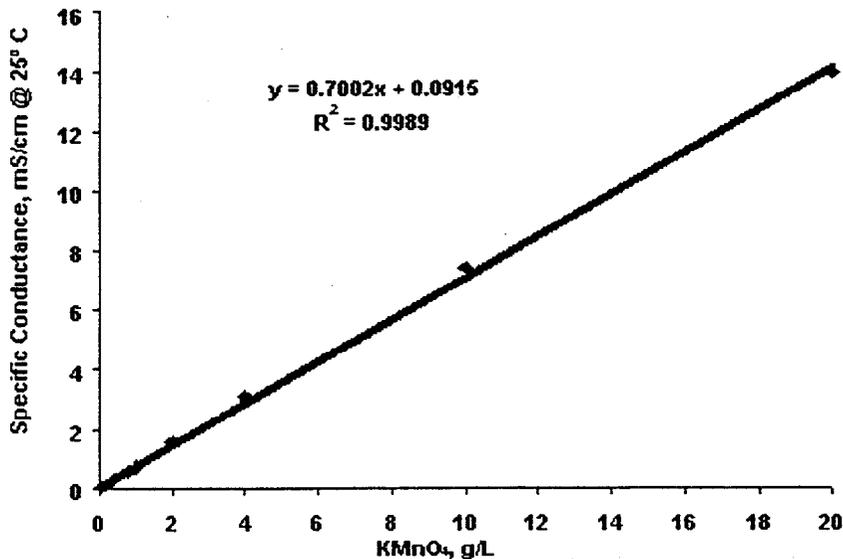
Reaction shown under neutral conditions:



1 part H₂S requires 6.2 parts KMnO₄

1 part KMnO₄ will oxidize 0.16 parts H₂S

Specific Conductance vs KMnO₄ Concentration in Water



KMnO ₄ Concentration, %	Specific Conductance, mS/cm @ 25°C
0.08	0.0508
0.20	0.1303
0.40	0.298
0.80	0.596
1.0	0.745
2.0	1.576
4.0	3.07
10	7.39
20	13.91

CAIROX® Potassium Permanganate: SAFETY AND HANDLING

Packaging and Storage

Most grades of CAIROX® are available in 25 kg pails, 50 kg kegs, 150 kg drums, 1500 kg cycle-bins, and bulk up to 48,000 lb. Special packages will be considered upon request.

Under normal conditions, CAIROX® is stable. It will keep indefinitely if stored in a cool, dry area in a closed container. Avoid contact with acids, peroxides, and all combustible organic or readily oxidizable materials including metal powders. With

	hydrochloric acid, chlorine gas is liberated. It may decompose if exposed to heat (>150°C/302°F).
Handling and Protective Equipment	<p>Where exposure to air-borne CAIROX® may exist, a user should wear goggles, rubber or plastic gloves, and an approved NIOSH-MSHA dust and mist respirator. Normal clothing that covers arms and legs and a rubber or plastic apron are suitable attire. Always provide ventilation in the work area.</p> <p>CAIROX® potassium permanganate is often fed as a solution, generally at concentrations ranging from 1 to 4%. Wear the same type of personal protective equipment when working with a permanganate solution.</p> <p>Following exposure to CAIROX® potassium permanganate, brown stains of manganese dioxide often form as a natural decomposition product. These stains are harmless and can be removed using a solution composed of 3 parts 3% USP hydrogen peroxide, 4 parts 5% food grade white vinegar, and 3 parts tap water. If used to remove the stain from skin, wash off excess when the stain is gone. Do not use if skin becomes red or irritated, or on sensitive tissue such as eyes, mucous membranes, open wounds, or burns.</p>
First Aid	<p>First aid treatment for eye contact involves water flushing for at least 15 minutes, holding lids apart to insure that the entire surface is flushed. Never attempt to neutralize chemically.</p> <p>Contaminated areas of skin should be water washed immediately, and contaminated clothing and footwear should be removed.</p> <p>For an inhalation problem, move the person out of the contaminated area to fresh air. Administer oxygen if required.</p> <p>In the case of accidental ingestion, give large quantities of water if the person is conscious.</p> <p>Seek medical attention immediately for all forms of contact if the situation warrants.</p>
Fire	<p>Fires involving CAIROX® may be controlled and extinguished by using large quantities of water. Do not use dry chemical, CO₂, or Halon extinguishers. If fumes are present, wear a positive breathing apparatus and full protective clothing.</p>

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 Last Updated: 9/23/97

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E-Mail: salesmkt@caruschem.com



MATERIAL SAFETY DATA SHEET

CAIROX Potassium Permanganate

Section 1 Chemical Product and Company Identification

PRODUCT NAME: CAIROX Potassium Permanganate, KMnO_4 **TRADE-NAME:** CAIROX® Potassium Permanganate
SYNONYMS: Permanganic acid potassium salt
Chameleon mineral
Condy's crystals
Permanganate of potash

MANUFACTURER'S NAME: CARUS CHEMICAL COMPANY **TELEPHONE NUMBER FOR INFORMATION:** 815/223-1500

MANUFACTURER'S ADDRESS: Carus Chemical Company
1500 Eighth Street
P. O. Box 1500
LaSalle, IL 61301
EMERGENCY TELEPHONE NO.: 800/435-6856
CHEMTREC TELEPHONE NO.: 800/424-9300

Section 2 Composition/Information on Ingredients

Material or component	CAS No.*	%	Hazard Data
Potassium Permanganate	7722-64-7	97% min. KMnO_4	PEL**C*** 5 mgMn per cubic meter of air (5mgMn per cubic meter of air is equivalent to 0.0046 ounces per 1000 cubic feet of air) TLV-TWA**** 0.2 mg Mn per cubic meter of air

- * Chemical Abstract Service Number
- ** OSHA Permissible Exposure Limit, manganese compounds (expressed as Mn) 29CFR1910.1000 Table Z1
- *** Ceiling Exposure Limit or maximum exposure concentration not to be exceeded under any circumstances.
- **** American Conference of Governmental Industrial Hygienists 1998, for manganese dust and compounds, expressed as Mn. TLV-TWA = The time weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

Section 3 Hazards Identification

- Eye Contact**
Potassium permanganate is damaging to eye tissue on contact. It may cause severe burns that result in damage to the eye.
- Skin Contact**
Prolonged contact of solutions at room temperature may be irritating to the skin, leaving brown stains. Concentrated solutions at elevated temperature and crystals are damaging to the skin.
- Inhalation**
Acute inhalation toxicity data are not available. However, airborne concentrations of potassium permanganate in the form of dust or mist may cause damage to the respiratory tract.
- Ingestion**
Potassium permanganate, if swallowed, may cause severe burns to mucous membranes of the mouth, throat, esophagus, and stomach.



Section 4

First Aid Measures

1. Eyes

Immediately flush eyes with large amounts of water for at least 15 minutes holding lids apart to ensure flushing of the entire surface. Do not attempt to neutralize chemically. Seek medical attention immediately. Note to physician: Decomposition products are alkaline.

2. Skin

Immediately wash contaminated areas with water. Remove contaminated clothing and footwear. Wash clothing and decontaminate footwear before reuse. Seek medical attention immediately if irritation is severe and persistent.

3. Inhalation

Remove person from contaminated area to fresh air. If breathing has stopped, resuscitate and administer oxygen if readily available. Seek medical attention immediately.

4. Ingestion

Never give anything by mouth to an unconscious or convulsing person. If person is conscious, give large quantities of water. Seek medical attention immediately.

Section 5

Fire Fighting Measures

NFPA* HAZARD SIGNAL

Health Hazard (less than 1 hour exposure)	1 = Materials which under fire conditions would give off irritating combustion products. Materials which on the skin could cause irritation.
Flammability Hazard	0 = Materials that will not burn.
Reactivity Hazard	0 = Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.
Special Hazard	OX = Oxidizer

*National Fire Protection Association 704

FIRST RESPONDERS:

Wear protective gloves, boots, goggles, and respirator. In case of fire, wear positive pressure breathing apparatus. Approach incident with caution. Use Emergency Response Guide NAERG 96 (RSPA P5800.7). Guide No. 140.

FLASHPOINT None

FLAMMABLE OR EXPLOSIVE LIMITS Lower: Nonflammable Upper: Nonflammable

EXTINGUISHING MEDIA Use large quantities of water. Water will turn pink to purple if in contact with potassium permanganate. Dike to contain. Do not use dry chemicals, CO₂, Halon® or foams.

SPECIAL FIREFIGHTING PROCEDURES If material is involved in fire, flood with water. Cool all affected containers with large quantities of water. Apply water from as far a distance as possible. Wear self-contained breathing apparatus and full protective clothing.

UNUSUAL FIRE AND EXPLOSION HAZARDS Powerful oxidizing material. May decompose spontaneously if exposed to intense heat (150°C/302°F). May be explosive in contact with certain other chemicals (Section 10). May react violently with finely divided and readily oxidizable substances. Increases burning rate of combustible material.



Section 6 **Accidental Release Measures**

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED

Clean up spills immediately by sweeping or shoveling up the material. Do not return spilled material to the original container. Transfer to a clean metal drum. EPA banned the land disposal of D001 ignitable waste oxidizers. These wastes must be deactivated by reduction. To clean floors, flush with abundant quantities of water into sewer, if permitted by Federal, State, and Local regulations. If not permitted, collect water and treat chemically (Section 13).

PERSONAL PRECAUTIONS

Personnel should wear protective clothing suitable for the task. Remove all ignition sources and incompatible materials before attempting clean-up.

Section 7 **Handling and Storage**

Work/Hygienic Practices

Wash hands thoroughly with soap and water after handling potassium permanganate, and before eating or smoking. Wear proper protective equipment. Remove contaminated clothing.

Ventilation Requirements

Provide sufficient mechanical and/or local exhaust to maintain exposure below the Permissible Exposure Limit (PEL).

Conditions for Safe Storage

Store in accordance with NFPA 430 requirements for Class II oxidizers. Protect containers from physical damage. Store in a cool, dry area in closed containers. Segregate from acids, peroxides, formaldehyde, and all combustible, organic or easily oxidizable materials including anti-freeze and hydraulic fluid.

Section 8 **Exposure Controls/Personal Protection**

Respiratory Protection

In the case where overexposure may exist, the use of an approved NIOSH-MSHA dust/mist respirator or an air supplied respirator is advised. Engineering or administrative controls should be implemented to control dust.

Eye

Faceshield, goggles, or safety glasses with side shields should be worn. Provide eye wash in working area.

Gloves

Rubber or plastic gloves should be worn.

Other Protective Equipment

Normal work clothing covering arms and legs, and rubber, or plastic apron should be worn.



Section 9 Physical and Chemical Properties

APPEARANCE AND ODOR Dark purple solid with a metallic luster, odorless

BOILING POINT, 760 mm Hg	Not applicable	SPECIFIC GRAVITY	2.7 @ 20°C (68°F)
VAPOR PRESSURE (mm Hg)	Not applicable	VAPOR DENSITY (AIR=1)	Not applicable
SOLUBILITY IN WATER % BY SOLUTION	6.0% at 20°C (68°F); and 20% at 65°C (149°F)		
PERCENT VOLATILE BY VOLUME	Not volatile		
EVAPORATION RATE (BUTYL ACETATE=1)	Not applicable		
MELTING POINT	Starts to decompose with evolution of oxygen (O ₂) at temperatures above 150°C (302°F)		
OXIDIZING PROPERTIES	Strong oxidizer		

Section 10 Stability and Reactivity

STABILITY Under normal conditions, the material is stable.

CONDITIONS TO AVOID Contact with incompatible materials or heat (>150°C/302°F)

INCOMPATIBLE MATERIALS Acids, peroxides, formaldehyde, antifreeze, hydraulic fluids, and all combustible organic or readily oxidizable inorganic materials including metal powders. With hydrochloric acid, toxic chlorine gas is liberated.

HAZARDOUS DECOMPOSITION PRODUCTS When involved in a fire, potassium permanganate may form corrosive fumes.

CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION Material is not known to polymerize.

Section 11 Toxicological Information

Potassium Permanganate: Acute oral LD₅₀(rat) = 780 mg/kg Male (14 days) 525 mg/kg Female (14 days)
The fatal adult human dose by ingestion is estimated to be 10 grams or 0.35 ounces.
(Ref. Handbook of Poisoning: Prevention, Diagnosis & Treatment, Twelfth Edition)

EFFECTS OF OVEREXPOSURE

- Acute Overexposure**
Irritating to body tissue with which it comes into contact.
- Chronic Overexposure**
No known cases of chronic poisoning due to potassium permanganate have been reported. Prolonged exposure, usually over many years, to heavy concentration of manganese oxides in the form of dust and fumes, may lead to chronic manganese poisoning, chiefly involving the central nervous system.
- Carcinogenicity**
Potassium permanganate has not been classified as a carcinogen by OSHA, NTP, IARC.
- Medical Conditions Generally Aggravated by Exposure**
Potassium permanganate will cause further irritation of tissue, open wounds, burns or mucous membranes.

Registry of Toxic Effects of Chemical Substances
RTECS #SD6476000



Section 12 Ecological Information

Entry to the Environment

Potassium Permanganate has a low estimated lifetime in the environment, being readily converted by oxidizable materials to insoluble MnO_2 .

Bioconcentration Potential

In non-reducing and non-acidic environments MnO_2 is insoluble and has a very low bioaccumulative potential.

Aquatic Toxicity

Rainbow trout, 96 hour LC_{50} : 1.80 mg/l

Blugill sunfish, 96 hour LC_{50} : 2.3 mg/l

Section 13 Disposal Consideration

DEACTIVATION OF D001 IGNITABLE WASTE OXIDIZERS BY CHEMICAL REDUCTION

Reduce potassium permanganate in aqueous solutions with sodium thiosulfate (Hypo), a sodium bisulfite or ferrous salt solution. The bisulfite or ferrous salt may require some dilute sulfuric acid to promote rapid reduction. If acid was used, neutralize with sodium bicarbonate to neutral pH. Decant or filter, and mix the sludge with sodium carbonate and deposit in an approved landfill. Where permitted, the sludge can be drained into sewer with large quantities of water. Use caution when reacting chemicals. Contact Carus Chemical for additional recommendations.

Section 14 Transport Information

DEPARTMENT OF TRANSPORTATION INFORMATION:

Proper Shipping Name: 49 CFR172.101.....Potassium Permanganate
ID Number: 49 CFR172.101.....UN 1490
Hazard Class: 49 CFR172.101.....Oxidizer
Division: 49 CFR172.101.....5.1
Packing Group: 49 CFR172.101.....II

Section 15 Regulatory Information

TSCA Listed in the TSCA Chemical Substance Inventory

CERCLA Hazardous Substance

Reportable Quantity: 40 CFR116.4; 40 CFR302.4.....RQ-100 lb.

RCRA Oxidizers such as potassium permanganate meet the criteria of ignitable waste. 40 CFR 261.21

SARA TITLE III Information

Section 302 Extremely hazardous substance: Not listed

Section 311/312 Hazard categories: Fire, acute and chronic toxicity

Section 313 Cairox Potassium Permanganate contains 33-35% manganese as part of the chemical infrastructure (manganese compounds CAS Reg. No. N/A) and is subject to the reporting requirements of Section 313 of Title III, Superfund Amendments and Reauthorization Act of 1966 and 40 CFR 372.



Section 15 Regulatory Information (cont.)

STATE LISTS	Michigan Critical Materials Register:	Not listed
	California Proposition 65:	Not listed
	Massachusetts Substance List:	5 F8
	Pennsylvania Hazard Substance List:	E
FOREIGN LISTS	Canadian Domestic Substances List (DSL)	Listed
	Canadian Ingredient Disclosure List	Listed
	European Inventory of Existing Chemical Substances (EINECS)	Listed

Section 16 Other Information

NIOSH	National Institute for Occupational Safety and Health
MSHA	Mine Safety and Health Administration
OSHA	Occupational Safety and Health Administration
NTP	National Toxicology Program
IARC	International Agency for Research on Cancer

Kenneth Krogulski

February 1999



The information contained is accurate to the best of our knowledge. However, data, safety standards and government regulations are subject to change; and the conditions of handling, use or misuse of the product are beyond our control. Carus Chemical Company makes no warranty, either express or implied including any warranties of merchantability and fitness for a particular purpose. Carus also disclaims all liability for reliance on the completeness or confirming accuracy of any information included herein. Users should satisfy themselves that they are aware of all current data relevant to their particular uses.

Rev. 2/99 Form # CX 1026

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CARUS

To: Mr. Mark Salvetti
Harding Lawson & Associates
From: Ms. Jessie Nickerson
Carus Chemical Company
Date: 2 November, 1998
fax #: (781) 246-5060
No. Pages: four (4)

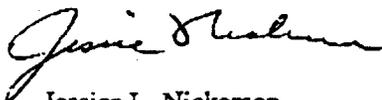
Re: CAIROX® Potassium Permanganate Test Results

Dear Mr. Salvetti:

Attached for your review are the results of our laboratory testing for the treatment of TCE and PCE contaminated water sample. As you can see by the data, CAIROX potassium permanganate was very effective at the TCE removal and, with enough dosing and time, effective on the oxidation of PCE as well.

If we can answer any additional questions for you please feel free to call me at (815)224-6501. Meanwhile, we look forward to working with you on this project. Please call me if you would like to discuss price and delivery of our product or if you also would like to discuss permanganate feed equipment (rental and/or purchase) for this project. Thanks and I look forward to hearing from you.

Best regards,



Jessica L. Nickerson
Industrial Sales & Marketing Manager

cc: Dave Amarante
Phil Vella

Carus Chemical Company
315 Fifth Street
P.O. Box 599
Peru, IL 61354-0599
Tel (815) 223 1500
Fax (815) 224 6697

CARUS CHEMICAL COMPANY
Technology and Quality

Industrial Report

29 October 1998

Customer: Harding Lawson and Associates
Orlando, FL
TECH 7148

cc: D. Amarante
K. Pisarczyk
P. Vella

Attention: I. Nickerson

Author: B. Veronda

Subject: KMnO_4 for the Oxidation of Trichloroethylene (TCE) and
Perchloroethylene (PCE) in Water

Groundwater samples were received from Harding Lawson and Associates on 10 September 1998. The samples were collected 9 September 1998 from a site contaminated with TCE and PCE. A CAIROX[®] treatability study was requested to determine the effects of potassium permanganate (KMnO_4) on TCE and PCE.

From information provided the reaction time was limited to between 1 and 2 hours. Treatment of the samples with potassium permanganate was conducted at those two times, and the results are given in Tables 1 and 2. Figures 1 and 2 show the removal of PCE with respect to KMnO_4 concentration. Because the TCE levels were effectively removed at the first permanganate dose, those results are not shown graphically.

From the data it is evident that TCE and PCE levels can be lowered to $< 20 \mu\text{g/L}$ with CAIROX[®] potassium permanganate. Removal is a function of both reaction time and initial KMnO_4 concentration. Because of the rapid and complete oxidation of TCE and PCE, CAIROX[®] potassium permanganate can be used in a pump and treat system with the treated water (if allowed by regulations) discharged back into the ground.

Table 1. TCE/PCE Removal: 1 Hour Reaction Time

KMnO4 Concentration (mg/L)	TCE Concentration (mg/L)	PCE Concentration** (mg/L)
0	0.055	3.170
100	0.010	3.037
250	*ND	2.126
500	*ND	1.977
1000	*ND	1.225
2000	*ND	0.453
4000	*ND	0.0521

$C_{A_0} = 3.17$

$k_d = 0.016A$

*ND Not Detected

** All results are corrected for dilution.

Figure 1. PCE Removal Using CAIROX® Potassium Permanganate: 1 Hour Reaction Time

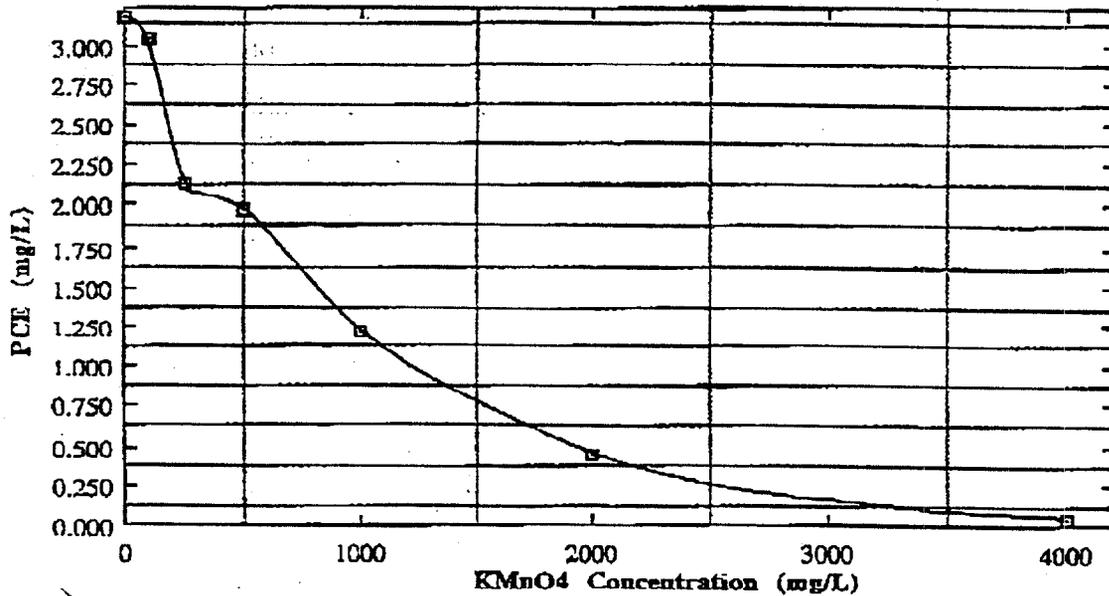


Table 2. TCE/PCE Removal: 2 Hour Reaction Time

KMnO ₄ Concentration (mg/L)	TCE Concentration (mg/L)	PCE Concentration** (mg/L)
0	0.055	3.147
100	†BDL	2.540
250	*ND	2.098
500	*ND	1.222
1000	*ND	0.486
2000	*ND	0.092
4000	*ND	†BDL

$C_{A_0} = 3.15$

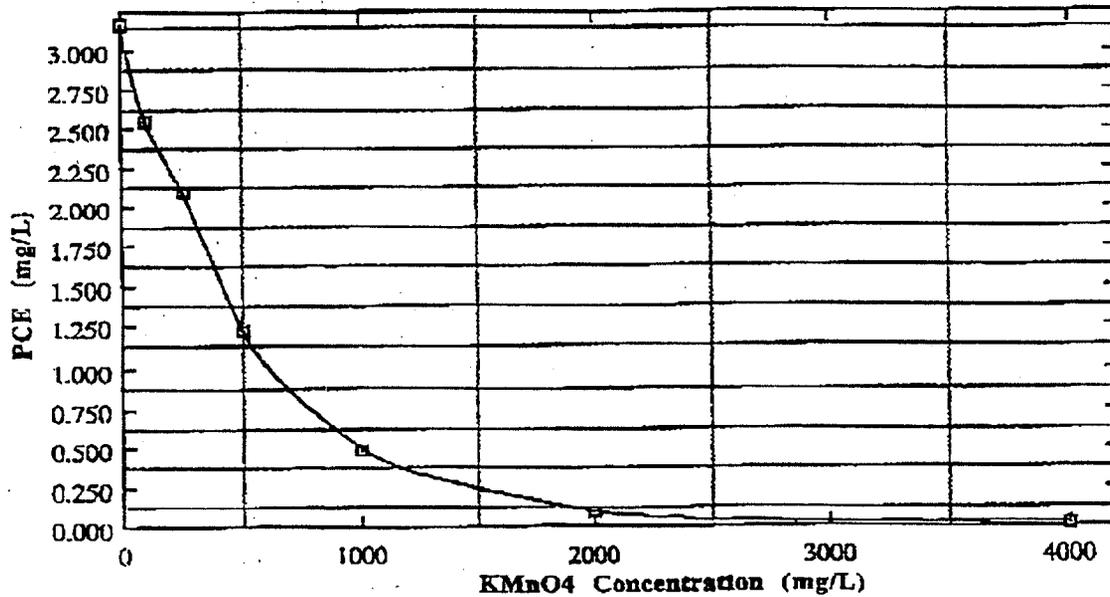
$C/C_0 = 0.029$

†BDL Below Detection Level of <0.010 mg/L

*ND Not Detected

** All results are corrected for dilution

Figure 2. PCE Removal Using CAIROX® Potassium Permanganate: 2 Hour Reaction Time



C


CARUS

To: Mr. Scott Bostian
Harding Lawson & Associates
From: Ms. Jessie Nickerson
Carus Chemical Company
Date: 2 November, 1998
fax #: (850) 656-3386
No. Pages: four (4)

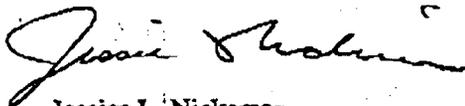
Re: CAIROX® Potassium Permanganate Test Results

Dear Scott:

Attached for your review are the results of our laboratory testing for the treatment of TCE and PCE contaminated water and soil samples. As you can see by the data, CAIROX potassium permanganate was very effective at the TCE removal and, with enough dosing and time, effective on the oxidation of PCE as well. Also, you'll note that the permanganate did not have any adverse reactions (ie, heat generation, etc.).

If we can answer any additional questions for you please feel free to call me at (815)224-6501. Meanwhile, we look forward to working with you on this project. Please call me when you get an idea as to the amount of permanganate you think you will require and also an hourly dosing rate and I'll be able to answer your questions on pricing, including on the rental of the appropriate feed equipment for this project. Thanks and I look forward to hearing from you.

Best regards,



Jessica L. Nickerson
Industrial Sales & Marketing Manager

cc: Dave Amarante
Phil Vella

Carus Chemical Company
315 Fifth Street
P.O. Box 1999
Peru, IL 61354-0599
Tel (815) 223 1500
Fax (815) 224 6697

CARUS CHEMICAL COMPANY
Technology and Quality

Industrial Report

29 October 1998

Customer: Harding Lawson and Associates
Tallahassee, FL
TECH 7127

cc: D. Amante
K. Pisarczyk
P. Vella

Attention: J. Nickerson

Author: B. Veronda

Subject: $KMnO_4$ for the Oxidation of Trichloroethylene (TCE) and
Perchloroethylene (PCE) in Water and Soil

Groundwater and soil samples were received from Harding Lawson and Associates on 27 August 1998. The samples were collected 25 August 1998 from a site contaminated with TCE and PCE. A CAIROX[®] treatability study was requested to determine the effects of potassium permanganate ($KMnO_4$) on TCE and PCE.

Water Sample

The results of the treatability study performed at low $KMnO_4$ concentrations are presented in Table 1. Based on these results, higher permanganate dosages and two separate reaction times were evaluated. The results of those studies are presented in Table 2.

From the data it is evident that TCE and PCE levels can be lowered to < 20 $\mu g/L$ (0.020 mg/L) with CAIROX[®] potassium permanganate. Removal is a function of both reaction time and initial $KMnO_4$ concentration.

Table 1. Effect of $KMnO_4$ on TCE and PCE: Low $KMnO_4$ Dose

Sample	$KMnO_4$ Dose (mg/L.)	Reaction Time (Hours)	TCE (mg/L)	PCE (mg/L)	TCE Removed (%)	PCE Removal (%)
HLA #1	0	24	1.56	5.44	0	0
HLA #2	10	24	1.41	5.19	14.6%	4.9%
HLA #3	25	24	0.45	5.09	27.0%	6.6%
HLA #4	50	24	<0.01	3.70	>99%	32.1%
HLA #5	75	24	<0.01	2.46	>99%	54.9%
HLA #6	100	24	<0.01	1.69	>99%	69.0%

Table 2. Effect of $KMnO_4$ on TCE and PCE: High $KMnO_4$ Dose

Sample	$KMnO_4$ Dose (mg/L)	Reaction Time (hours)	TCE (mg/L)	PCE (mg/L)	% Removal TCE	% Removal PCE
T#1	0	0	1.82	7.06		
T#2	100*	5	<0.01	3.40	>99%	46.6
T#3	250*	5	<0.01	2.13	>99%	66.6
T#4	500*	5	<0.01	0.59	>99%	90.8
T#5	750*	5	<0.01	0.22	>99%	96.6
T#6	1000*	5	<0.01	0.09	>99%	98.6
T#2a	100*	24	<0.01	1.82	>99%	74.2
T#3a	250*	24	<0.01	0.110	>99%	98.4
T#4a	500*	24	<0.01	0.042	>99%	99.4
T#5a	750*	24	<0.01	0.014	>99%	99.8
T#6a	1000*	24	<0.01	0.014	>99%	99.8

* Residual $KMnO_4$ was observed in these samples

Soil Sample

Testing of the soil sample proved to be difficult. Obtaining reproducible results based on the treatment method was the largest problem. This may be due to poor extraction of the soil with hexane, formation of an emulsion after oxidation with potassium permanganate, or the low levels of organics detected. The samples were mixed by hand, reacted for 1 or 2 hours, then extracted with hexane for 1 hour before analysis.

The 30 minute potassium permanganate demand of the soil was approximately 8400 mg/L. The results of the 1 hour test are given in Table 3. The data for the 2 hour reaction time (not shown) indicated no residual TCE in the soil and PCE concentrations below 0.010 mg/L. No adverse interaction was observed between $KMnO_4$ and the soil (e.g. gas or heat evolution, no reaction with carbonate, no pH adjustment needed, etc.) as would be the case if Fenton's System (H_2O_2) was used. From the data generated, CAIROX[®] potassium permanganate will be able to lower both the TCE and PCE concentrations in the soil to levels less than 0.010 mg/L (10 µg/L).

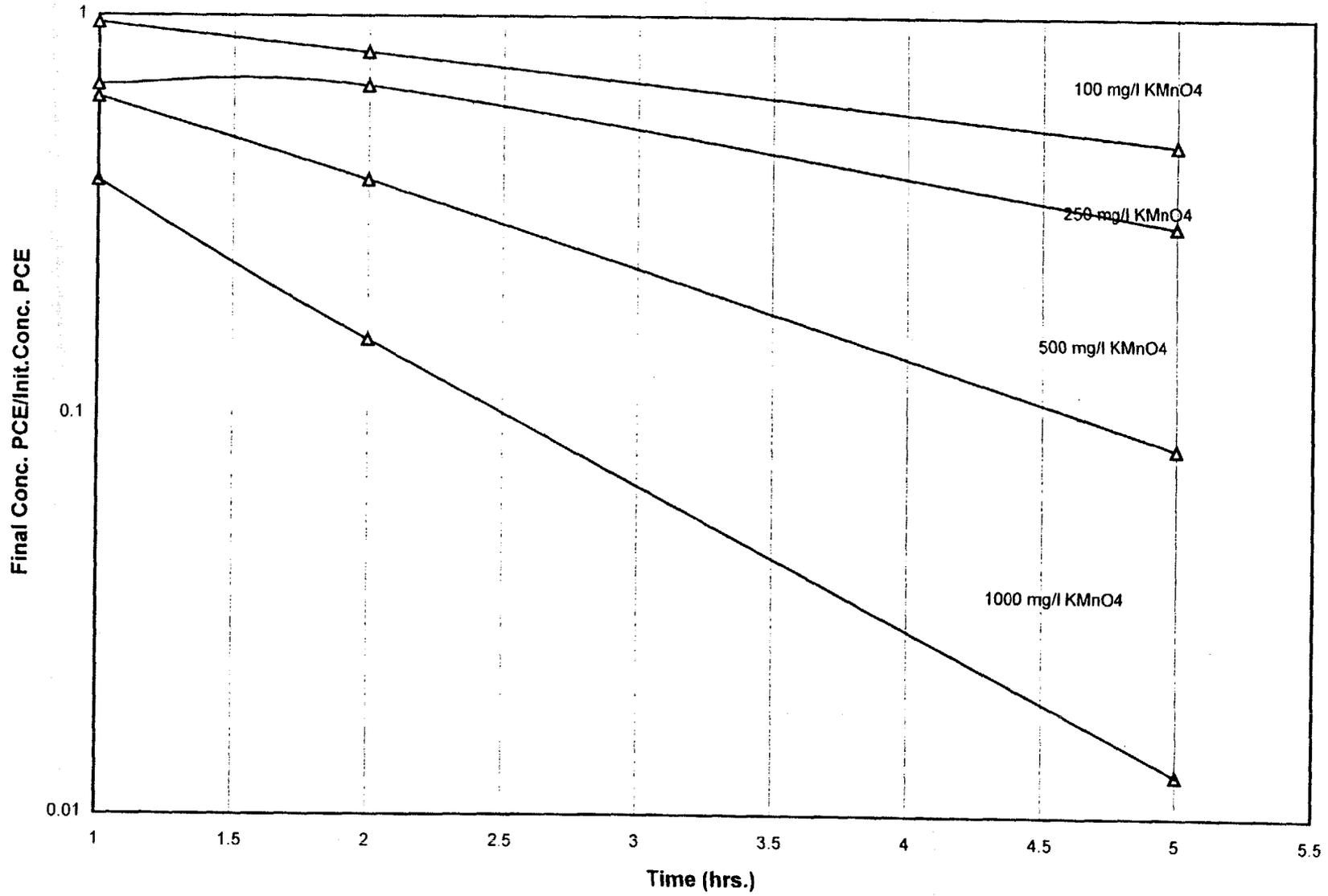
Table 3. TCE/PCE Removal: 1 Hour Reaction Time

KMnO4 Concentration (mg/L)	TCE Concentration (mg/L)	PCE Concentration (mg/L)
0 (First)	**BDL	0.0165
2,500	0.012	0.0297
5,000	*ND	0.0297
7,500	*ND	0.0180
10,000	*ND	0.0122
15,000	*ND	**BDL
20,000	*ND	**BDL
0 (Last)	**BDL	0.0275

*ND Not Detected

** Below Detectable Levels of <0.010 mg/L

Effects of KMnO4 on PCE





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Peru, IL 61354-0599
Tel (815) 223-1500
Fax (815) 224-6697

TO: Mark Salvetti / Harding Lawson & Associates
FAX #: (781) 246-5060
FROM: Dave Amarante
DATE: December 18, 1998
PAGES (including cover): 2

Subject: KMnO₄ Demand Study Results

Mark:

Here are the test results of the KMnO₄ demand study performed by our laboratory. The 30 minute demand test showed that soil samples V4S12071 and V4S12072 consumed 588 mg/L and 359 mg/L of potassium permanganate respectively. This of course could vary during a full-scale field application.

If you have any further questions or need additional information, please contact us at (800) 435-6856. Thank you for interest in Cairox® and have a happy holiday.

Best regards,

David Amarante

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CARUS CHEMICAL COMPANY
Technology and QualityIndustrial Report

15 December 1998

Customer: Harding Lawson and Associates
Orlando, FL
TECH 7259

cc: D. Amarante
J. Nickerson
K. Pisarczyk
P. Vella

Attention: Mark Salvetti

Author: B. Veronda

Subject: KMnO_4 Demand of PCE/TCE Contaminated Soil

Two soil samples were received from Harding Lawson and Associates on 8 December 1998. The samples were collected 7 December 1998 from opposite ends of the site where a pilot study for TCE/PCE oxidation with potassium permanganate is to take place. A CAIROX[®] potassium permanganate demand was requested to determine the demand of the soil surrounding the contaminated area.

The potassium permanganate demand is the amount of permanganate consumed in a given amount of time. For this testing, the time was 30 minutes. It can be assumed that the soil will have a slightly higher consumption rate as the contact time is increased. The results are presented in Table 1.

Table 1. Potassium Permanganate Demands of Soil Samples from Harding Lawson and Associates

Sample ID	30 Minute KMnO_4 Demand (mg/L)
V4S12071	588
V4S12072	359



Date: 01/25/99
Time: 11:35:22
(Mountain Time)

From: Debbie Hula
Quanterra Inc.
4101 Shuffel Drive NW
North Canton, OH 44720

To: Mark Todaro
Harding Lawson
407-8966150

voice: 330-497-9396
fax: 330-497-0772

Number of Pages
Including Cover Sheet: 02

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Quote Number: 025880
Project Number:
Project Name/Site: NTC ORLANDO OU4

QUANTERRA INCORPORATED

PRELIMINARY DATA SUMMARY

 The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8L160185 Harding Lawson NTC ORLANDO 004 Date Reported: 1/25/99 PAGE 1

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD
-----------	--------	-----------------	-------	-------------------

Client Sample ID: U4S12071

Sample #: 001 Date Sampled: 12/15/98 11:15 Date Received: 12/16/98 Matrix: SOLID

Inorganic Analysis				Reviewed
Total Organic Carbon	3000	130	mg/kg	SMCA WALKLEY-BLAC
Total Residue as	79.5	0.10	%	MCAWW 160.3 MOD
Percent Solids				

Results and reporting limits have been adjusted for dry weight.

Client Sample ID: U4S12072

Sample #: 002 Date Sampled: 12/15/98 11:45 Date Received: 12/16/98 Matrix: SOLID

Inorganic Analysis				Reviewed
Total Organic Carbon	1200	100	mg/kg	SMCA WALKLEY-BLAC
Total Residue as	98.9	0.10	%	MCAWW 160.3 MOD
Percent Solids				

Results and reporting limits have been adjusted for dry weight.

CAIROX®**Potassium Permanganate**

CAS Registry No. 7722-64-7*

**Materials
Compatibility
Chart****FACT SHEET**

The following two tables, "Metals Compatibility" and "Plastics and Other Non-Metals Compatibility" show materials of construction and whether or not they may be used with solutions of potassium permanganate. In using the information provided in this chart, it should be understood that some of the data was gathered from in-plant and field experiences of engineers and plant operators using permanganate solutions. Over half of the data is from laboratory experiments only. The manufacturers literature was also consulted in the preparation of the charts. In each case, the results are specific to the conditions under which the permanganate was being applied. Use these tables as a guide, but not as a guarantee.

METALS

Potassium permanganate compatibility with metal products will depend upon the solution pH, and for some metals, on the solution temperature.

When adjusting the solution pH, always be certain that the metal is also compatible with the acid or alkali being used.

	SOLUTION pH				SOLUTION pH		
	Acidic	Neutral	Basic		Acidic	Neutral	Basic
Ferrous Metals				Metal Alloys			
Carbon Steel	NO	YES	YES	Brass	NO	YES	YES
Black Iron	NO	YES	YES	Bronze	NO	YES	YES
Galvanized Steel	NO	NO	NO	Hastalloy			
Stainless Steel ¹				B & D	NO	NO	NO
304	YES	YES	YES	C	*	YES	YES
316	YES ²	YES	YES	Incoloy			
420	YES ²	YES	YES	800	*	YES	YES
12% Cr	*	YES ³	YES ³	825	*	YES	YES
17% Cr	*	YES ³	YES ³	840	*	YES	YES ⁸
Carpenter 20	YES	YES	YES	Monel ⁷			
Non-Ferrous Metals				400	*	YES	YES
Aluminum	NO	YES ⁴	NO ⁵				
Copper	NO	YES ⁴	NO ⁵				
Lead	NO	YES ⁴	NO ⁵				
Nickel	YES	YES	YES				
Tantalum	*	*	*				
Tin ⁶	YES	YES	YES				
Titanium	*	YES	YES				
Zinc	NO	NO	NO				
Zirconium ⁹	YES	YES	YES				

*Information not available

SPECIAL NOTES FOR METALS COMPATIBILITY

1. Stainless Steels have a high corrosion rate when chlorides are present in the permanganate solution. They are not compatible with hydrochloric acid (HCl).
2. An accelerated corrosion rate was found when nitric acid is used to acidify permanganate solutions.
3. Compatible at room temperature only.
4. Only "FAIR" or "MODERATE" life when used with permanganate solutions. Short-term use would be acceptable.
5. Unsuitable with alkali, such as sodium hydroxide or potassium hydroxide. Should not be used with alkaline permanganate solutions.
6. "FAIR" with permanganate solutions.
7. "MODERATE" life below 100°F.
8. Incoloy 840 failed when used as the "sheath" material for an immersion heater in a 2% to 4% permanganate solution.
9. Tested at pH 3, 7, and 9.

PLASTICS AND OTHER NON-METALS

Potassium permanganate solutions can affect the strength, flexibility, surface appearance, or color of plastics. The chemical attack that could cause these changes might include: (1) oxidation of the polymer chain, (2) oxidation of the functional groups in or on the chain, or (3) depolymerization.

Fibers

Acetates	YES
Acrylics	YES
Cotton	NO
Nylon (polyamides)	NO
Orlon	NO
Paper	NO
Polyesters	YES ¹
Silk	NO
Wool	NO

Tank, Tank Linings, Pump, and other Equipment Construction Materials

ABS Plastic	YES
Asphaltic Resin	NO
Ceramic	YES
Epoxy Resin	YES ¹
Furan Resin	YES ¹
Glass	YES
Lucite (acrylic resin)	YES
Phenol-Formaldehyde Resin	NO
Phenolic Resin	YES ¹
Styrene Copolymers	YES ¹
Polyallomer	YES
Polybutylene	YES
Polycarbonate	NO
Polyethylene	YES ²
Polypropylene	YES ³
Polystyrene	NO
Polysulfone	YES
Polyurethane	YES
Polyvinyl Chloride I	YES ⁴
Polyvinyl Chloride II	NO

Hose, Tubing, Pipe, and Gasket Materials

Asbestos	NO
Chlorinated Polyvinyl Chloride (CPVC)	YES ³
Ethylene Propylene Rubber (EPR)	NO
Ethylene Propylene Terpolymers (EPT)	YES ⁵
Hycar	NO
Hypalon	YES
Natural Rubber	NO
Nitrile Butadiene Rubber (NBR)	NO ⁶
Neoprene	NO
Norprene	YES
Penton	YES
Polyphenylene Oxides (PPO)	YES
Polyvinylidene Chloride (Tygon)	YES
Polyvinylidene Fluoride (PVDF)	YES ⁷
Styrene Butadiene Rubber (SBR)	
Buna N	NO
Buna S	NO
Teflon FEP	YES ⁷
Teflon TFE	YES
Viton	YES ⁵

Oils, Greases, and Lubricants

All oils, greases, and lubricants must be tested for compatibility with potassium permanganate.

When unknown, assume that potassium permanganate will react with these compounds resulting in fire and/or explosion.

SPECIAL NOTES FOR PLASTICS AND OTHER NON-METALS

1. Temperatures up to 200° F
2. Discolored at 140° F
3. Temperatures of 68° – 176° F
4. Temperatures up to 140° F
5. Temperatures of 68° – 140° F
6. Temperatures to 68° F
7. Temperatures of 68° – 248° F

The information contained herein is accurate to the best of our knowledge. However, data, safety standards and governmental regulations are subject to change, and, therefore, holders and users should satisfy themselves that they are aware of all current data and regulations relevant to their particular use of product. CARUS CHEMICAL COMPANY DISCLAIMS ALL LIABILITY FOR RELIANCE ON THE COMPLETENESS OR ACCURACY OF THE INFORMATION INCLUDED HEREIN. CARUS CHEMICAL COMPANY MAKES NO WARRANTY, EITHER EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR USE OR PURPOSE OF THE PRODUCT DESCRIBED HEREIN. All conditions relating to storage, handling, and use of the product are beyond the control of Carus Chemical Company, and shall be the sole responsibility of the holder or user of the product.

carus CHEMICAL COMPANY

Division of Carus Corporation
315 Fifth Street
P.O. Box 599
Peoria, IL 61354-0599

Telephone: 800 435-8856
815 223-1500
Fax: 815 224-6697

Determination of CAIROX[®] Potassium Permanganate Residual for Wastewater Applications

(Proposed Carus Analytical Method 105: Spectrophotometric)

Objective: This method can be used to determine the residual CAIROX[®] potassium permanganate in water using standard spectrophotometric methods.

Procedure:

1. Prepare a standard CAIROX[®] potassium permanganate solution by measuring 1.015 g KMnO_4 into a 1 liter volumetric and diluting to the mark with distilled water. This will result in a 1000 mg/L stock solution.
2. From this stock solution, prepare KMnO_4 standards in the range of 0 to 50 mg/L. For improved accuracy, a minimum of three (3) standards should be used to generate a calibration curve.
3. Generate an Absorbance vs Concentration calibration curve for the standards prepared (Figure 1). The Absorbance is measured at 525 nm and the resulting curve should be a straight line.
4. Obtain a sample of unknown concentration and filter through a 0.45 μm oxidant resistant filter. This is to remove any turbidity and MnO_2 that may be in the water. Addition of alum or a coagulant before filtering may also be used to improve turbidity and MnO_2 removal.
5. Use an untreated, filtered water sample to zero the spectrophotometer. Measure the Absorbance of the filtered KMnO_4 sample. Using the Calibration Curve, the concentration of the CAIROX[®] potassium permanganate can now be determined. (From the absorbance reading draw a line across (parallel to the Concentration axis). At the point it intersects the Calibration Curve, draw a line down to determine the concentration). As an alternative, if the Calibration Curve was generated by computer, the equation of the line may be available. If so, the absorbance may be used to calculate the concentration value.

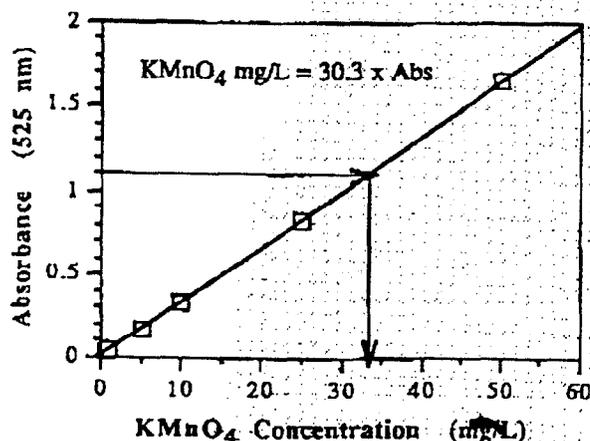


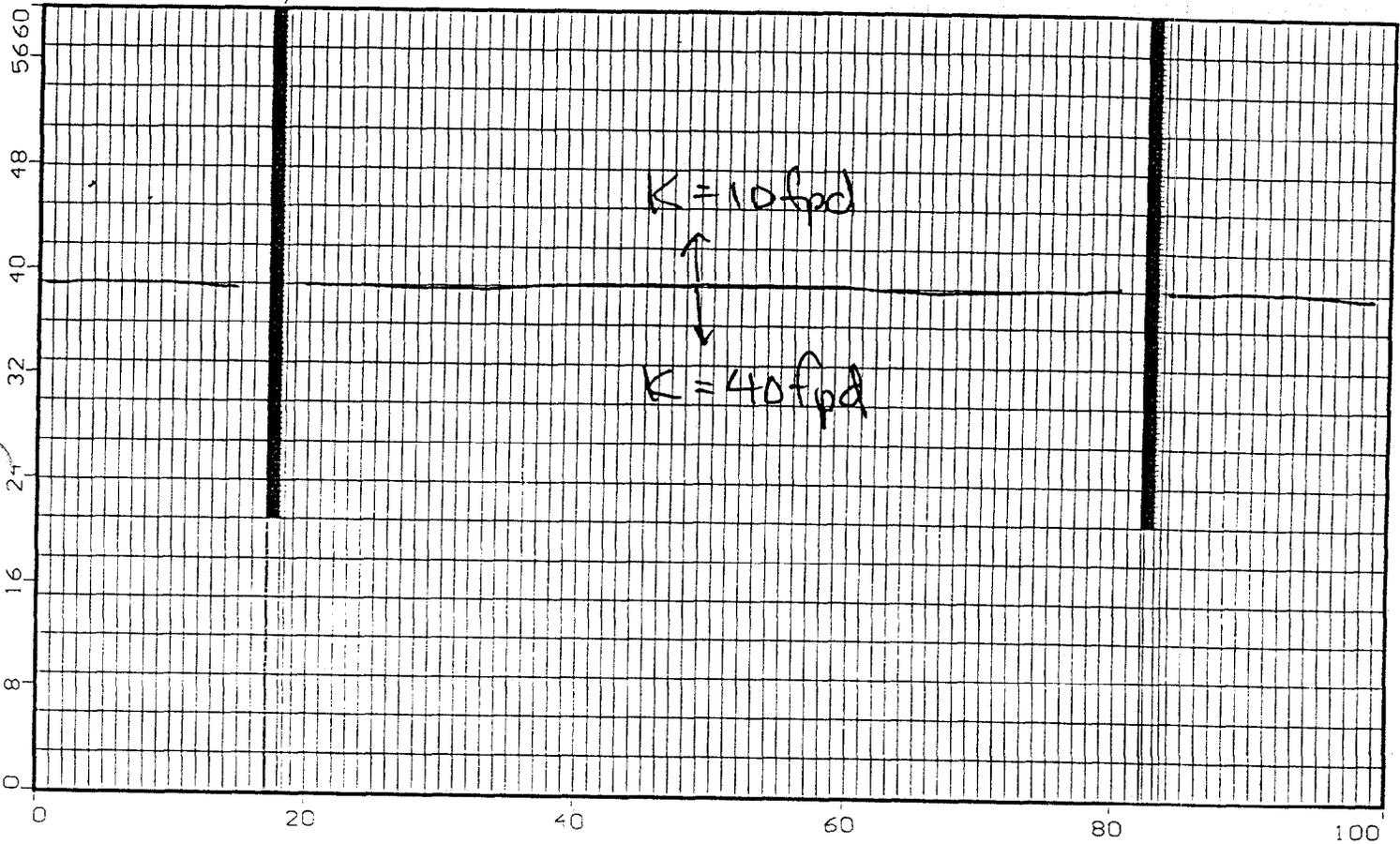
Figure 1. KMnO_4 Calibration Curve
(2.5 cm Cells, Hach DR/2000)

KMnO_4 (mg/L)	Absorbance at 525 nm
0.5	0.018
1.0	0.034
5.0	0.169
10.0	0.339
25.0	0.831
50.0	1.652

Example: If the Absorbance is 1.10, the KMnO_4 concentration will be 33 mg/L.

APPENDIX C
HYDRAULIC MODELING

well screen positions

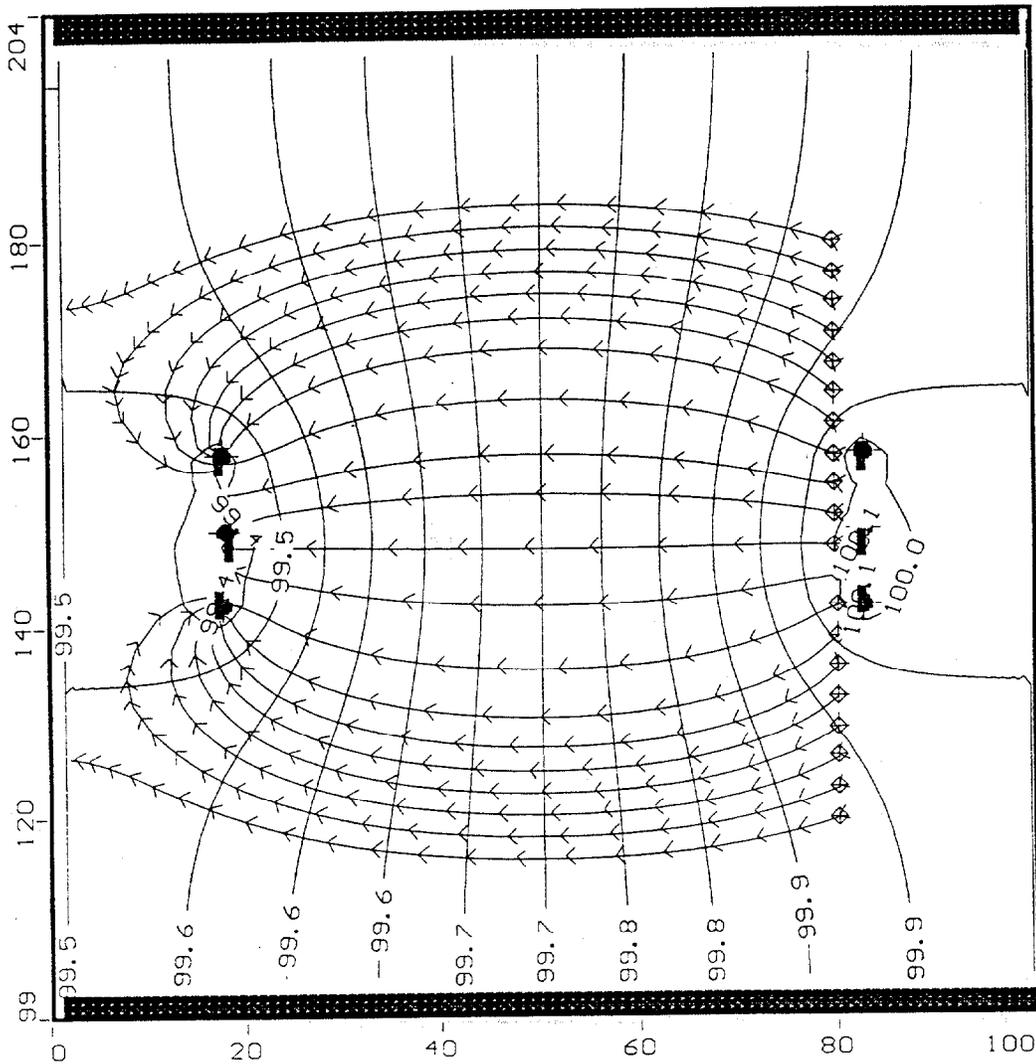


$K_H/K_V = 3$ in both upper & lower zones

Harding Lawson Associates
Project: Orlando OU4 Chem. Ox.
Description: Q = 5 m³/d, y=151.5, 20d
Modeller: W Murray
6 Apr 99

Visual MODFLOW v.2.7.1, (C) 1995-1997
Waterloo Hydrogeologic, Inc.
NC: 100 NR: 100 NL: 20
Current Row: 48

Upper zone
These are exactly $1'' = 20'$

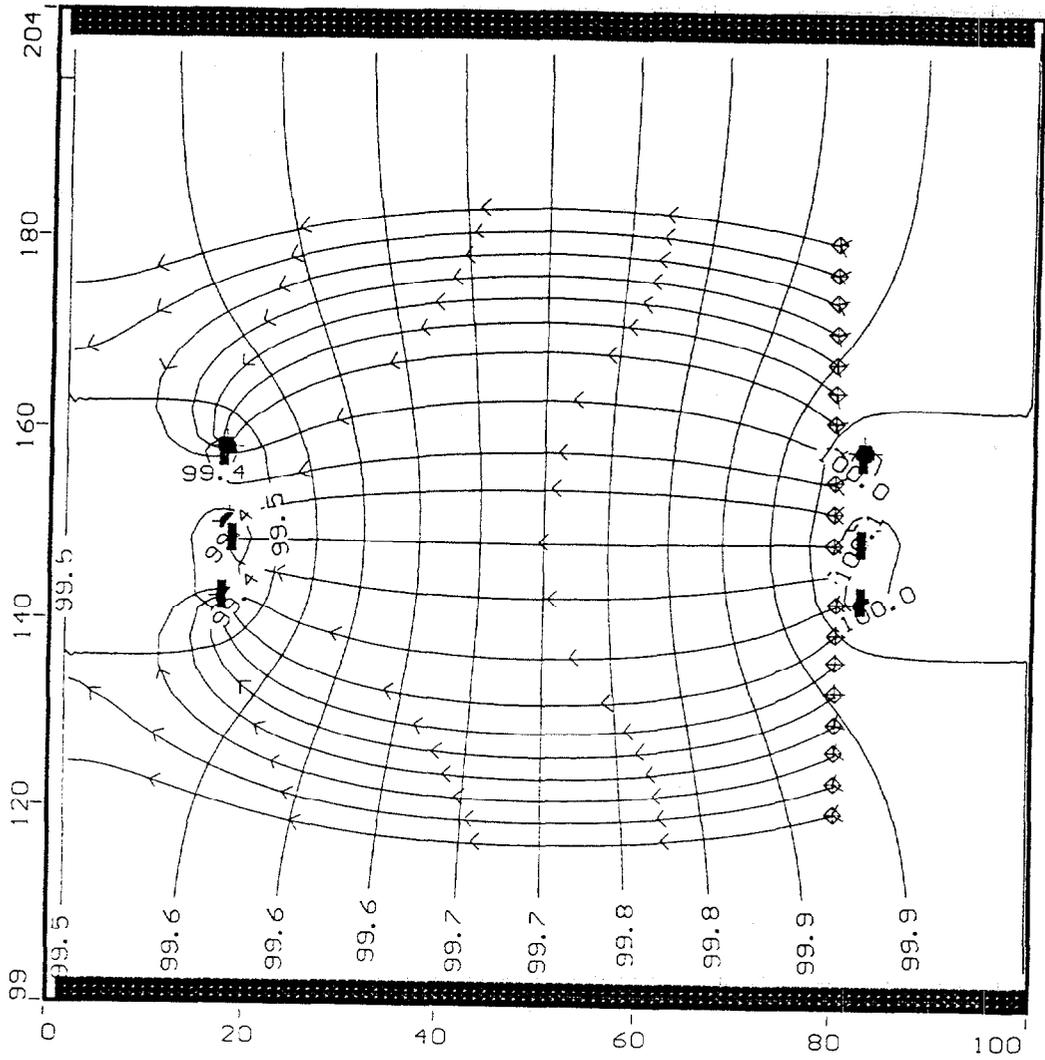


20 day hic marks

Harding Lawson Associates
Project: Orlando OU4 Chem. Ox.
Description: Q = 0.92 gpm ea., z=49.5
Modeller: W Murray
7 Apr 99

Visual MODFLOW v.2.7.1, (C) 1995-1997
Waterloo Hydrogeologic, Inc.
NC: 100 NR: 100 NL: 20
Current Layer: 4

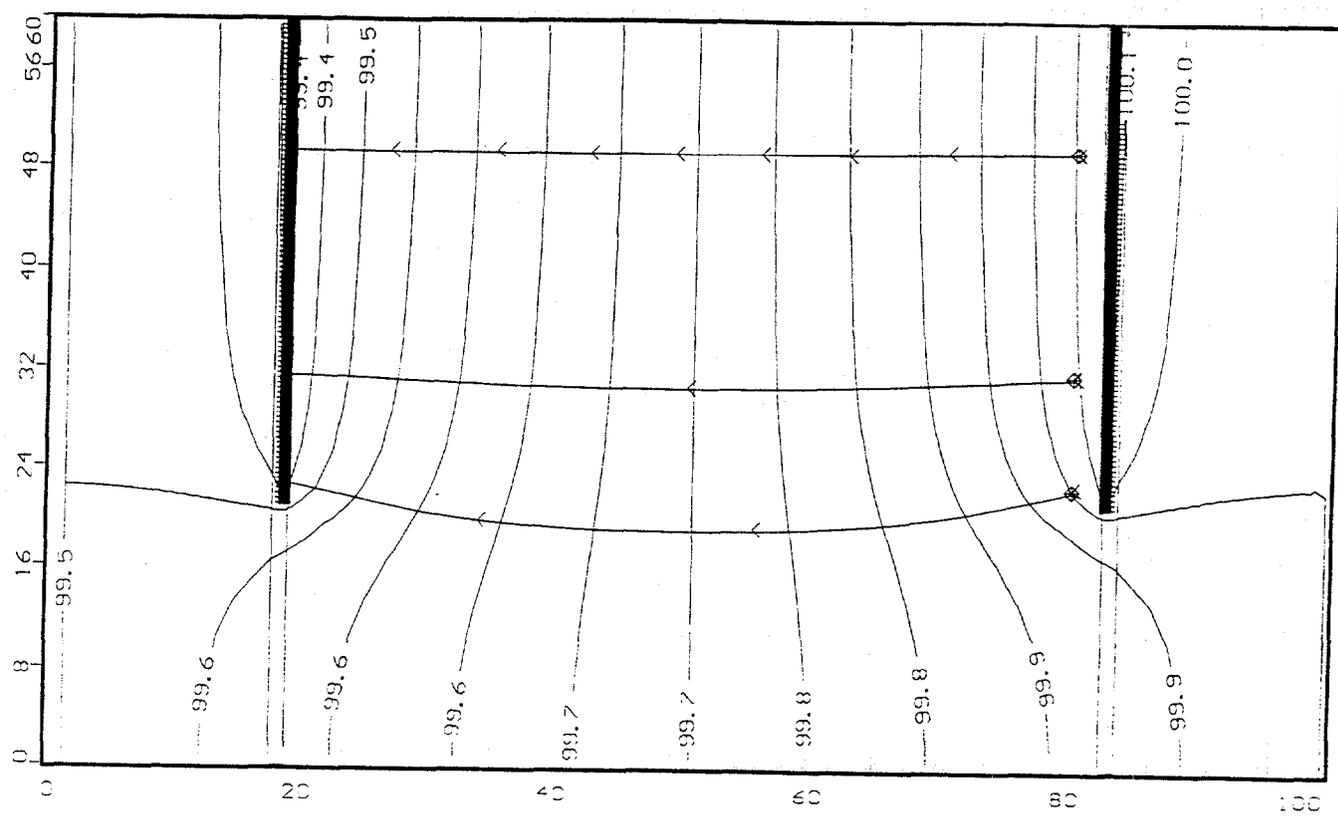
Lower Zone
 $V = 40$.



20 day tic marks

Harding Lawson Associates
Project: Orlando OU4 Chem. Ox.
Description: Q = 0.92 gpm ea., z=31.5
Modeller: W Murray
7 Apr 99

Visual MODFLOW v.2.7.1, (C) 1995-1997
Waterloo Hydrogeologic, Inc.
NC: 100 NR: 100 NL: 20
Current Layer: 10



20 day tic marks

Harding Lawson Associates
 Project: Orlando OU4 Chem. Ox.
 Description: Q = 0.92 gpm ea.
 Modeller: W Murray
 7 Apr 99

Visual MODFLOW v.2.7.1. (C) 1995-1997
 Waterloo Hydrogeologic, Inc.
 NC: 100 NR: 100 NL: 20
 Current Row: 51

APPENDIX D

UNDERGROUND INJECTION VARIANCE

BEFORE THE STATE OF FLORIDA
DEPARTMENT OF ENVIRONMENTAL PROTECTION

In re: Harding Lawson Associates
Petition for Variance

OGC File No. 99-0943

FINAL ORDER GRANTING PETITION FOR
VARIANCE FROM RULE 62-522.300(2)(a)

On June 8, 1999, Harding Lawson Associates (HLA), filed a petition for variance from requirements in rule 62-522.300(2)(a) of the Florida Administrative Code, under section 120.542 of the Florida Statutes and rule 28-104.002 of the Florida Administrative Code. The petition was for a variance from rule 62-522.300(2)(a), which prohibits a zone of discharge for discharges through wells, in order to use a product for in-situ remediation of sites contaminated with certain compounds susceptible to oxidation by potassium permanganate. This process involves the use of wells or borings which is considered installation of one or more temporary Class V underground injection control wells at the site of contamination. A notice of receipt of the petition was published in the Florida Administrative Weekly on July 9, 1999.

1. Petitioner is located at 1080 Woodcock Road, Suite 100, Orlando, Florida 32803.

2. HLA wants to perform in-situ chemical oxidation using potassium permanganate at sites with contaminated soils and ground water.

3. Under rule 62-520.420 of the Florida Administrative Code, the standards for Class G-II ground waters include the primary and secondary drinking water standards of rules 62-550.310 and 62-550.320 of the Florida Administrative Code.

4. Concentrations of potassium permanganate at 7.6 grams per liter (Free Flow grade) or 11.6 grams per liter (Pharmaceutical Grade) will be injected through wells or borings into soil and ground water. When the potassium permanganate solution contacts the contaminant molecules, the molecular bonds are broken (oxidized). The by-products of this reaction are potassium, carbon dioxide, chloride ions, and manganese dioxide. Laboratory and field tests of in-situ chemical oxidation with potassium permanganate have demonstrated the compound's effectiveness for reducing contaminant concentrations.

5. When potassium permanganate is added to the ground water, the secondary drinking water standard for color (15 color units) may temporarily be exceeded. It is also possible that the secondary drinking water standards for total dissolved solids (500 mg/L), aluminum (0.2 mg/L), manganese (0.05 mg/L), silver (0.1 mg/L), and chloride (250 mg/L) could be temporarily exceeded. None of these parameters will be exceeded beyond a 100-foot radius from each point of injection, and any exceedance will not occur for more than 365 days.

6. The injection of this product through temporary wells or borings is considered a type of underground injection control well, Class V, Group 4, "injection wells associated with an aquifer remediation project," as described in rule 62-

528.300(1)(e)4 of the Florida Administrative Code. Under rule 62-528.630(2)(c), "Class V wells associated with aquifer remediation projects shall be authorized under the provisions of a remedial action plan . . . provided the construction, operation, and monitoring of this Chapter are met."

7. Rule 62-522.300(2)(a) from which this petition seeks a variance, prohibits the Department from granting a zone of discharge for a discharge through an injection well to Class G-II ground water. Strict adherence to this rule would preclude the Department from granting approval for the use of the in-situ chemical oxidation with potassium permanganate for remediation of contaminated ground water.

8. The applicable rules state in pertinent part:

62-522.300(1) . . . [N]o installation shall directly or indirectly discharge into any ground water any contaminant that causes a violation in the ground water quality standards and criteria for the receiving ground water as established in Chapter 62-520, F.A.C., except within a zone of discharge established by permit or rule pursuant to this chapter.

62-522.300(2) No zone of discharge shall be allowed under any of the following circumstances:

(a) Discharges through wells or sinkholes that allow direct contact with Class G-I and Class G-II ground water

9. HLA has stated in its petition that to apply the zone of discharge prohibition to its use of this remediation process at contaminated sites would create a substantial hardship. The petition also states that other methods of remediation not using chemical oxidation are not as effective, are more costly, and take longer. Remediation would improve the water quality, and to

prohibit any exceedance of the specified drinking water standards in such a small area of already contaminated ground water and for such short duration would cause a substantial hardship. This small and temporary exceedance is not the usual occurrence, nor are most dischargers involved in the remediation of contaminated ground water. By allowing the use of the in-situ potassium permanganate, the clean up of the contaminated ground water and soils will be accelerated and returned to a usable condition. In addition, the use of the in-situ potassium permanganate has been tentatively approved by the Department's Division of Waste Management as being a sound environmental solution to the contamination, so long as HLA is able to obtain a variance.

10. Zones of discharge for the use of the in-situ potassium permanganate are necessary because of the temporary (not to exceed 365 days) exceedance of the color, total dissolved solids, aluminum, manganese, silver, and chloride standards in the ground water immediately surrounding the injection. Because this ground water is already contaminated and does not meet all applicable standards, allowing a zone of discharge as part of a ground water cleanup for remediation of organic contaminants meets the purpose of the underlying statute, which is to improve the quality of the waters of the state for beneficial uses. Such contaminated ground water is not presently used for drinking purposes, nor is it ever reasonably expected to be so used, thus posing no threat to human health.

11. The Department received no comments about the petition for variance.

12. For the foregoing reasons, HLA has demonstrated that it is entitled to a variance from the prohibition of zones of discharge in rule 62-522.300(2)(a) for its remedial product, with the conditions below.

a. Use of the in-situ potassium permanganate at contaminated sites must be through a Department-approved remediation plan, or other Department-enforceable document.

b. The discharge to the ground water must be through a Class V, Group 4 underground injection control well which meets all of the applicable construction, operating, and monitoring requirements of chapter 62-528 of the Florida Administrative Code.

c. The extent of the zone of discharge for color, total dissolved solids, manganese, aluminum, silver, and chloride shall be a 100-foot radius from the point of injection and the duration of the zone of discharge shall be 365 days from the time of injection. This will allow ample time for the temporarily exceeded parameters to return to their secondary drinking water standards set forth in chapter 62-550 of the Florida Administrative Code, or their naturally occurring background levels at the site, whichever is less stringent.

d. The injection of the product shall be at such a rate and volume that no undesirable migration occurs of either the product, its by-products, or the contaminants already present in the aquifer.

e. The Department-approved remediation plan shall address appropriate ground water monitoring requirements associated with

the use of the in-situ potassium permanganate for remediation based on site-specific hydrogeology and conditions. These shall include the sampling of ground water at monitoring wells located outside the contamination plume, before use of the in-situ potassium permanganate, to determine the naturally occurring background levels of color, total dissolved solids, manganese, aluminum, silver, and chloride which are the parameters pertinent to this variance, as well as pH to be sure that it is not exceeded. They should also include monitoring of these parameters in ground water downgradient from the injection points for at least one year after active remediation.

This order will become final unless a timely petition for an administrative hearing is filed under sections 120.569 and 120.57 of the Florida Statutes before the deadline for a filing a petition. The procedures for petitioning for a hearing are set forth below.

A person whose substantial interests are affected by the Department's action may file for an administrative proceeding (hearing) under sections 120.569 and 120.57 of the Florida Statutes. The petition must contain the information set forth below and must be filed (received) in the Office of General Counsel of the Department at 3900 Commonwealth Boulevard, Mail Station 35, Tallahassee, Florida 32399-3000.

Petitions filed by HLA or any of the parties listed below must be filed within 21 days of receipt of this written notice. Petitions filed by any other persons other than those entitled to written notice under section 120.60(3) of the Florida Statutes

must be filed within 21 days of publication of the public notice receipt of the written notice, whichever occurs first. Under section 120.60(3), however, any person who asked the Department for notice of agency action may file a petition within 21 days of receipt of such notice, regardless of the date of publication. The petitioner shall mail a copy of the petition to Harding Lawson Associates, 1080 Woodcock Road, Suite 100, Orlando, Florida 32803 at the time of filing. The failure of any person to file a petition within the appropriate time period shall constitute a waiver of that person's right to request an administrative determination (hearing) under sections 120.569 and 120.57 of the Florida Statutes, or to intervene in this proceeding and participate as a party to it. Any subsequent intervention (in a proceeding initiated by another party) will be only at the discretion of the presiding officer upon the filing of a motion in compliance with rule 28-106.205 of the Florida Administrative Code.

A petition that disputes the material facts on which the Department's action is based must contain the following information:

- (a) The name, address, and telephone number of each petitioner; the Department case identification number and the county in which the subject matter or activity is located;
- (b) A statement of how and when each petitioner received notice of the Department action;
- (c) A statement of how each petitioner's substantial interests are affected by the Department action;

(d) A statement of the material facts disputed by the petitioner, if any;

(e) A statement of facts that the petitioner contends warrant reversal or modification of the Department action;

(f) A statement of which rules or statutes the petitioner contends require reversal or modification of the Department action; and

(g) A statement of the relief sought by the petitioner, stating precisely the action that the petitioner wants the Department to take.

A petition that does not dispute the material facts on which the Department's action is based shall state that no such facts are in dispute and otherwise shall contain the same information as set forth above, as required by rule 28-106.301.

Because the administrative hearing process is designed to formulate final agency action, the filing of a petition means that the Department's final action may be different from the position taken by it in this notice. Persons whose substantial interests will be affected by any such final decision of the Department have the right to petition to become a party to the proceeding, in accordance with the requirements set forth above.

Mediation under section 120.573 of the Florida Statutes is not available for this proceeding.

This action is final and effective on the date filed with the Clerk of the Department unless a petition is filed in accordance with the above.

Any party to this order has the right to seek judicial review of it under section 120.68 of the Florida Statutes, by filing a notice of appeal under rule 9.110 of the Florida Rules of Appellate Procedure with the clerk of the Department in the Office of General Counsel, Mail Station 35, 3900 Commonwealth Boulevard, Tallahassee, Florida 32399-3000, and by filing a copy of the notice of appeal accompanied by the applicable filing fees with the appropriate district court of appeal. The notice must be filed within thirty days after this order is filed with the clerk of the Department.

DONE AND ORDERED this 3 day of September 1999 in Tallahassee, Florida.

Mimi Drew

Mimi A. Drew
Director,
Division of Water Resource
Management

2600 Blair Stone Road
Mail Station 3500
Tallahassee, Florida 32399-2400
Telephone: (850) 487-1855

FILING AND ACKNOWLEDGMENT FILED, on this date, pursuant to s. 120.52, Florida Statutes, with the designated Department Clerk, receipt of which is hereby acknowledged.

Shirley Shields
Clerk

Sept 3, 1999
Date

Copies furnished to:
George Heuler, UIC Section Rick Ruscito, Petroleum Cleanup
Bill Neimes, Bur. Waste Cleanup Cynthia Christen, OGC
Brent Hartsfield, Bur. Waste Cleanup

CERTIFICATE OF SERVICE

I certify that a copy of the foregoing Final Order has been furnished to Mark J. Salvetti, P.E., by facsimile at 781/246-5060, and by U.S. Mail at Harding Lawson Associates, 107 Audubon Road, Suite 25, Wakefield, MA 01880, on this 3rd day of September 1999.


Cynthia K. Christen
Sr. Assistant General Counsel

Department of
Environmental Protection
3900 Commonwealth Blvd.
MS 35
Tallahassee, FL 32399-3000
Telephone 850/921-9610

Harding Lawson Associates



June 7, 1999

02545.027

Kathy Carter, Agency Clerk
Florida Department of Environmental Protection
Office of General Counsel
Mail Station 35
3900 Commonwealth Blvd.
Tallahassee, FL 32399-3000

Subject: Petition for Variance

Dear Ms. Carter:

Enclosed you will find a petition for Variance from Rule 52-522.300(2)(a), Florida Administrative Code. Harding Lawson Associates requests this variance for the use of In-Situ Chemical Oxidation with Potassium Permanganate in an aquifer remediation design document. By granting this petition, many remediation projects throughout Florida will benefit through the use of this promising technology.

Please feel free to contact me at (781)245-6606 should you have any questions regarding this technology or this petition.

Sincerely,

Harding Lawson Associates

A handwritten signature in cursive script that reads 'Mark J. Salvetti'.

Mark J. Salvetti, P.E.
Project Manager

cc: D. Grabka, Waste Cleanup
W. Neimes, Waste Cleanup
G. Brown, Waste Cleanup

q:\n5\orlando\ou4\treat\chemox\petitionvariancelet.doc



BEFORE THE STATE OF FLORIDA
DEPARTMENT OF ENVIRONMENTAL PROTECTION

IN RE: HARDING LAWSON ASSOCIATES
PETITION FOR VARIANCE

PETITION FOR VARIANCE
FROM RULE 62-522.300(2)(a), FLORIDA ADMINISTRATIVE CODE

Petitioner, Harding Lawson Associates, pursuant to Section 120.542, Florida Statutes, and Rule 28-104, Florida Administrative Code, hereby petitions for a variance from Rule 62-522.300(2)(a), Florida Administrative Code, because the strict application of this rule will create a substantial hardship and will violate principles of fairness. In support thereof Petitioner states:

Background Facts

1. Petitioner is Harding Lawson Associates, (HLA) located at 1080 Woodcock Road, Suite 100, Orlando, Florida 32803, telephone (407) 895-8845, facsimile (407) 896-6150.
2. Research conducted by the University of Waterloo, Canada, and Oak Ridge National Laboratory, has led to the finding that In-Situ Chemical Oxidation using Potassium Permanganate can be an effective remediation technology at sites contaminated with compounds susceptible to oxidation by Potassium Permanganate, including chlorinated solvents. When the Potassium Permanganate solution contacts the contaminant molecules, the molecular bonds are broken (i.e., the contaminant is oxidized). The by-products of this reaction are potassium, carbon dioxide, manganese dioxide, and chloride ions.
3. Laboratory and field tests of In-Situ Chemical Oxidation with Potassium Permanganate have demonstrated remarkable success in quickly reducing contaminant concentrations.
4. When Potassium Permanganate is added to groundwater, the secondary groundwater standard for color may be temporarily exceeded. It is also possible that the secondary standards for Total Dissolved Solids, aluminum, manganese, silver, and perhaps chloride (when high concentrations of chlorinated compounds are oxidized) could be temporarily exceeded. Injection of Potassium Permanganate violates no primary groundwater standards.

The Rule

5. Rule 62-522.300(1) provides that:
No installation shall directly or indirectly discharge into groundwater any contaminant that causes a violation in the water quality standards and criteria for the receiving groundwater as established in Chapter 62-520 except within a zone of discharge established by permit or rule pursuant to this chapter.
6. Furthermore, Rule 62-522.300(2)(a) provides that:
(2) No zone of discharge shall be allowed under any of the following circumstances:

- (a) Discharges through wells or sink holes that allow direct contact with Class G-I or Class G-II groundwater, except projects designed to recharge aquifers with surface water of comparable quality, or projects designed to transfer water across or between aquifers of comparable quality for the purpose of storage or conservation.
7. Pursuant to Rule 62-520.420, the water quality standards for Class G-I and G-II groundwater are the primary and secondary drinking water quality standards as set forth in Rules 62-550.310 and 320, and the minimum criteria provided in Rule 62-520.400, F.A.C.
 8. The relevant water quality standards as provided in Rules 62-550.320 and 62-520.400 are:

Parameter	Standard
pH	6.5 to 8.5
Color	15 color units
Total Dissolved Solids	500 mg/l
Aluminum	200 µg/l
Manganese	50 µg/l
Molybdenum	35 µg/l (Rule 62-520.400)
Silver	100 µg/l
Chloride	250 mg/l

9. Rule 62-522.300(2)(a) implements Sections 403.021, 403.061, and 403.088, Florida Statutes, and has as its specific authority in Section 403.061, Florida Statutes.

Type of Action Requested

10. HLA is requesting a variance from the restrictions imposed by Rule 62-522(2)(a) that would prohibit the Department from granting a zone of discharge in conjunction with the approval of Remedial Action Plans proposing the use of In-Situ Chemical Oxidation with Potassium Permanganate.

Specific Facts Which Demonstrate a Substantial Hardship
Or Violation of Principles of Fairness

11. The concentration of Potassium Permanganate in the injected fluid is a maximum 7.6 g/l (Free Flow grade) or 11.6 g/l (Pharmaceutical Grade), based on the concentration of inorganics with primary standards in the Potassium Permanganate solution. The actual grade and concentration used will be dependent on the effectiveness of the oxidation reaction observed in the field. The compositions of the potential Potassium Permanganate solutions are shown in Attachment A.

These concentrations exceed the secondary standard for Total Dissolved Solids. During the reaction, Manganese Dioxide is generated. In unfiltered samples, this precipitate has the potential to exceed the secondary standard for Manganese. Dissolved concentrations of aluminum (Free Flow grade) or aluminum and silver (Pharmaceutical Grade) may also exceed secondary standards. Depending on the contaminant oxidized, there is also the potential to generate acids and/or bases which may temporarily alter the pH of the groundwater. The buffering capacity of Florida's aquifers will quickly neutralize this condition. Upon injection of the Potassium Permanganate into the contaminant plume, it is expected that the color of the groundwater will turn purple. As the oxidation process proceeds, the groundwater will turn pink

and then clear again depending on the site stratigraphy, contaminant distribution, and the injection scenario. It is expected that through oxidation, dilution, diffusion, and advection, the groundwater color will be reduced to less than 15 color units or to background levels.

The above exceedances are possible in an area extending up to 100 feet from the point of injection. Conditions in the aquifer are expected to return to background within 365 days. Active remedial measures can be implemented if secondary standards continue to be exceeded beyond this period.

12. Pursuant to Rule 62-528.300(1)(e)4, the type of injection well to be utilized in the Potassium Permanganate In Situ Oxidation Process is a Class V, Group 4 well – "injection wells associated with an aquifer remediation project shall be authorized under the provision of a remedial action plan...provided the construction, operation, and monitoring requirements of the Chapter are met." There is no dispute that the subject injection wells will meet the construction, operation, and monitoring requirements of Chapter 62-528.
13. The staff of the Department's Bureau of Waste Cleanup and Bureau of Petroleum Storage Systems are familiar with In-Situ Chemical Oxidation with Potassium Permanganate and are prepared to approve its use at sites contaminated with petroleum compounds and chlorinated solvents. However, the provisions of Rule 62-522.300(1) would appear to prohibit the injection of Potassium Permanganate except within a Zone of Discharge. Rule 62-522.300(2)(a) prohibits the Department from granting a zone of discharge through an injection well to Class G-I and G-II groundwater.
14. Strict adherence to the prohibition of Rule 62-522.300(2)(a) would preclude the Department from granting approval for the use of In-Situ Chemical Oxidation with Potassium Permanganate.
15. Rule 62-522.300 is designed to protect the underground sources of drinking water of clean aquifers. However, the prohibition of a zone of discharge for an injection well to Class G-I and G-II groundwater is a hindrance to a reasonable, common sense remediation process that may cause only a temporary exceedence of a secondary drinking water standard in what is already a highly contaminated aquifer.
16. In-Situ Chemical Oxidation can accomplish the remediation of contaminated aquifers more effectively, more quickly, and potentially, at much lower cost than traditional remediation technologies. Therefore, a strict adherence to the zone of discharge prohibition will prevent the use of a safe, effective, and cost efficient remediation technology.

The Requested Variance Will Serve the Purposes of the Underlying Statute

17. As set forth in Section 403.021(2), Florida Statutes:
It is declared to be the public policy of this state to conserve the waters of the state and to protect, maintain, and improve the quality thereof for public water supplies, for the propagation of wildlife and fish and other aquatic life, and for the domestic, agricultural, industrial, recreational, and other beneficial uses and to provide that no wastes be discharged into any waters of the state without first being given the degree of treatment necessary to protect the beneficial uses of such waters.
18. There are no adverse impacts on human health or the environment that result from colored water. Temporary exceedance of the secondary standards for chloride, aluminum, manganese, silver, and total dissolved solids are also not expected to present any adverse impacts. The buffering capacity of Florida's aquifers is expected to prevent violations of the secondary standard for pH. The temporary exceedence of the secondary drinking water standards in connection with the

remediation of contaminated groundwater will not only allow for the protection and conservation of public water supplies, but will have the net effect of improving those public water supplies. Granting the variance will allow for the more effective cleanup of contaminated public water supplies. Therefore, the variance requested herein will serve the purpose of the underlying statute.

Conclusion

19. Rule 62-522.300(2)(a) precludes the Department from approving the use of an innovative site remediation technology that can more quickly and effectively clean up groundwater at sites contaminated with petroleum compounds and chlorinated solvents. The use of this technology will not cause any adverse impacts to the potential underground drinking water sources, but, in fact, will contribute significantly to improving the quality of those sources.

WHEREFORE, HLA requests that the Department grant a variance from Rule 62-522.300(2)(a) and allow the Department to approve a temporary zone of discharge for any Pilot Study Plan, Remedial Action Plan, or any other plan proposing the use of In-Situ Chemical Oxidation utilizing Potassium Permanganate with the condition that no Site Rehabilitation Completion Order will be granted unless the site meets all applicable, or approved cleanup target levels including color, aluminum, silver, manganese, chloride, total dissolved solids, and pH or their respective site-specific background concentration, whichever is less stringent. The approval document generated by the Department shall detail the physical limits of the permitted zone of discharge.

Respectfully submitted this 7th day of June, 1999.



Mark J. Salvetti, P.E.
Senior Engineer
Harding Lawson Associates

ATTACHMENT A

KMnO4 INORGANIC CONSTITUENTS		
Analyte (µg/l)	Free Flow Solution Concentrations at Maximum 7.6 g/l	Pharmaceutical Grade Concentrations at Maximum 11.6 g/l
Aluminum	600	660
Antimony	0.8	0.8
Arsenic	41	9.7
Barium	23	315
Beryllium	<0.5	<0.8
Boron	35	62
Cadmium	<2.5	<3.9
Chloride	<0.1	73
Calcium	646	27
Chromium	99	96
Cobalt	27	44
Copper	127	12
Iron	176	23
Lead	<0.5	3.1
Magnesium	34	39
Manganese	2,640,100	4,029,600
Mercury	0.30	1.1
Molybdenum	70	<21
Nickel	<5.0	<7.7
Potassium	1,880,300	2,869,900
Selenium	0.38	1.5
Silica	11,080	205
Silver	18	160
Sodium	3,740	1,140
Sulfate	0.1	615
Strontium	8	<0.4
Thallium	<0.5	<0.8
Zinc	37	16
pH	8.5 to 9.5	8.5 to 9.5

APPENDIX E

FEED SYSTEM INFORMATION

MERRICK

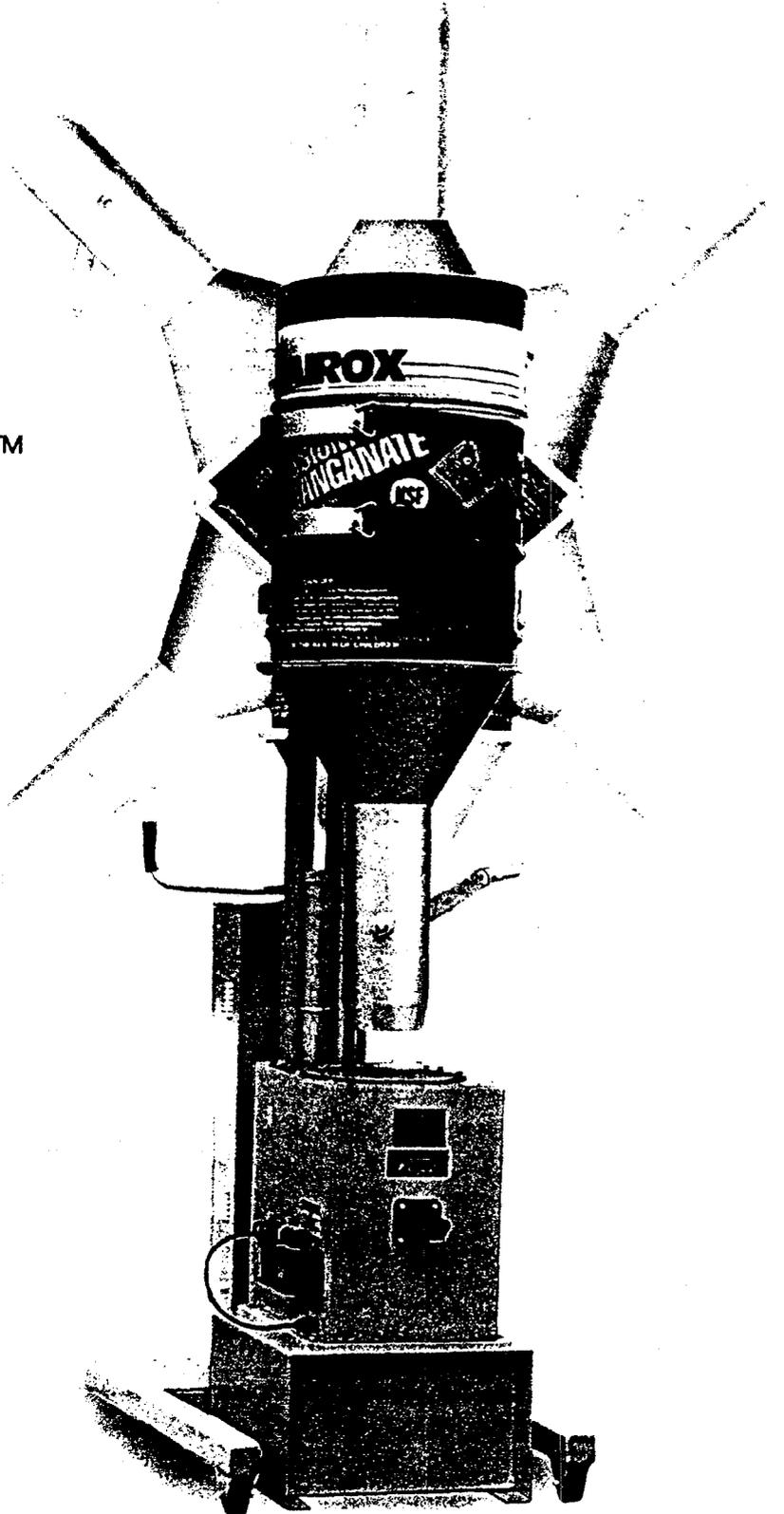
QMEGA®

DrumInvert™
Series 82-50

DrumInvert

Features

- Fully Self-Contained Modular Construction
- Automated Operation Aids in the elimination of Lifting Injuries
- Virtually Dustless Transfer of Chemicals to Feeder Reduces Dangerous Exposure to Personnel
- Portable Battery Operated with Built-in Charger
- Operates with all DOT 30 Gallon Chemical Drums. Ideal for:
 - Potassium Permanganate
 - Calcium Hypochlorite
- Automatically Increases Feeder Hopper Capacity
- Adapts to Most Volumetric Feeders, and Hopper Systems



STANDARD FEATURES

DRUM INVERTER

- Painted Mild Steel Construction with Non-Combustion Promoting Hydraulic Fluid
- 4" x 1.5" Poly Swivel Rear Casters
- 3" x 1.33" Poly Fixed Front Casters

FEEDER ADAPTER

- Carbon Steel Acrylic Enamel Coated with Urethane Dust Seal and Support

TRANSITION HOPPER

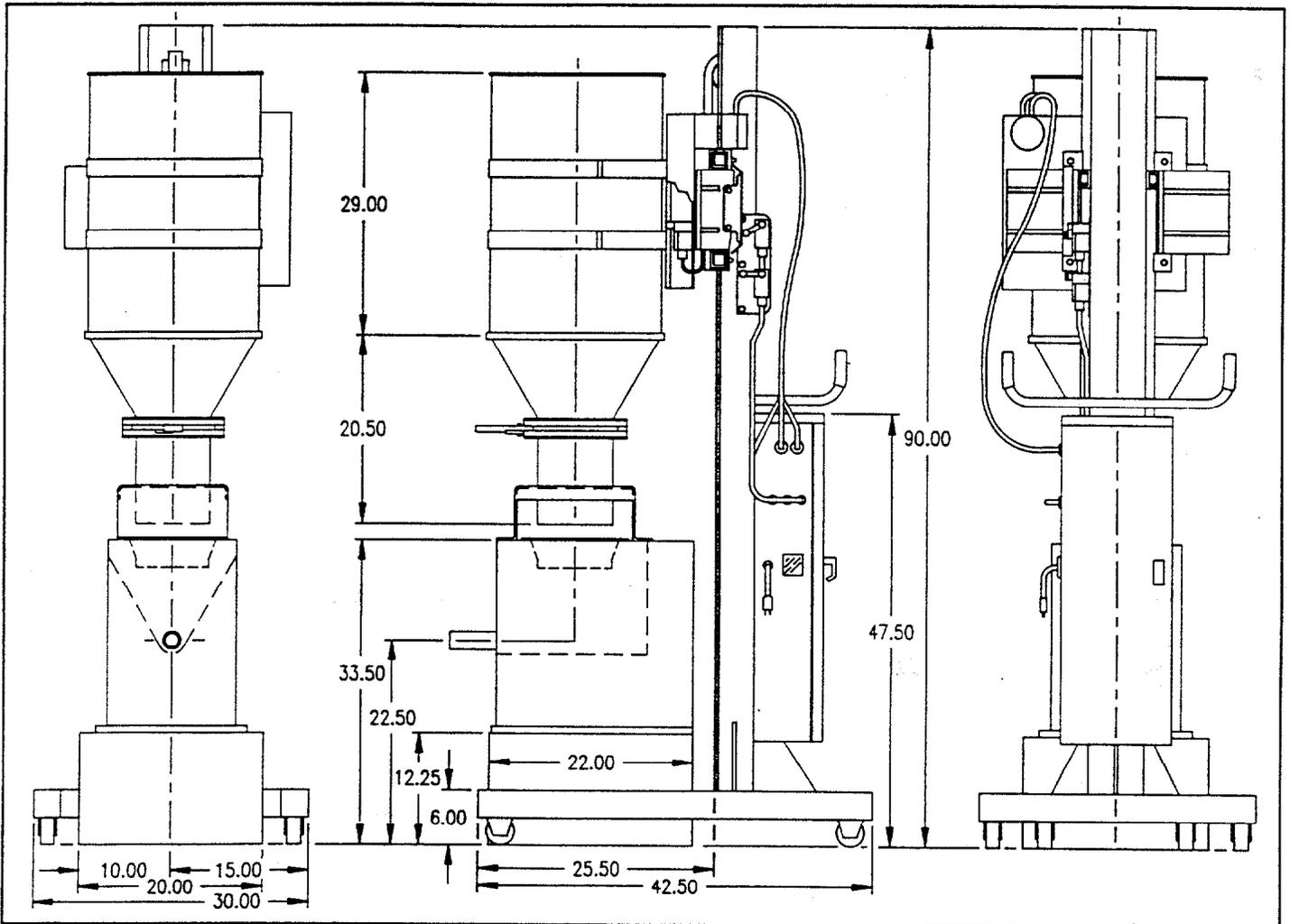
- 316SS with Iris Type Flow Control and Shut-Off Valve

POWER REQUIREMENTS

- 12 Volt Deep Cycle Rechargeable Battery (Not Included)
- 115V Battery Recharger, Plugs into Standard Grounded Outlet

SPECIFICATIONS

The DrumInvert™ is a self-contained chemical drum-lifting, inversion and hopping system. The DrumInvert allows for the virtually dustless transfer of a chemical to a feed system with limiting exposure to operations personnel. The Drum arms secure the chemical drum while operators replace the drum lid with a feeder transition shut-off valve assembly. Once secured, the entire assembly is lifted, inverted 180° and lowered into the feeder adapter seal. The valve is opened allowing the chemical to flow into the feeder hopper for metering to your point of application. Limit switches prevent inadvertent drum movement while in operation. The inverted drum may become an extension hopper until it is empty, or by closing the transition valve, the drum may be removed. The DrumInvert has (2) fixed wheels and (2) swivel wheels which allow for easy mobility.



MERRICK
MERRICK INDUSTRIES, INC.

Merrick Industries, Inc.

10 Arthur Drive
Lynn Haven, FL 32444
Phone: (904)265-3611
FAX: (904)265-9768

Merrick de Mexico

Parral 78, BIS SEXTO PISO Deleg. Cuauhtemoc
Col. Condesa 06140 MEXICO, D.F.
Phone: (525)286-3544
FAX: (525)553-4063

(850)265-3611

APPENDIX F

POTASSIUM PERMANGANATE CONSUMPTION CALCULATIONS

PROJECT UTC Orlando OUA
SUBJECT KMnO₄ Material BalanceSHEET 1 OF 2
JOB NO. 02545.50
DATE Aug 18 1999
COMPUTED BY MJS
CHECKED BY _____

Objective: Calculate rate of precipitate formation in extracted GW dosed with KMnO₄.
Calculate total mass of KMnO₄ necessary to oxidize the source area.

$$\text{KMnO}_4: \text{MW} = 39.1 + 54.9 + 4(16) = 158$$

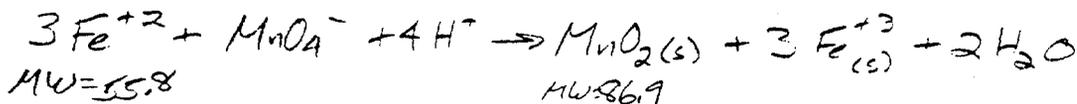
$$\text{PCE: (C}_2\text{Cl}_4\text{)}: \text{MW} = 2(2.0) + 4(35.5) = 165.8$$

IRA Iron Data: ~1200 µg/l

IRA Mn Data: ~1000 µg/l

Mn Data: Not Analyzed

Data from MW's in the vicinity of the pilot study show much lower Mn concentrations, and generally much less (<100 µg/l) iron. Manganese was ND.

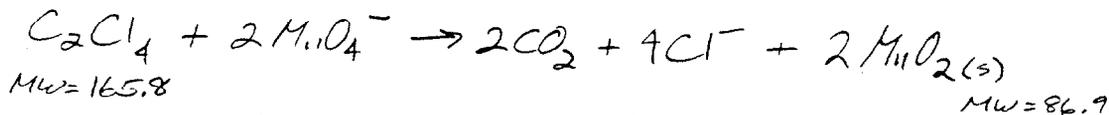


3 moles Fe⁺² requires 1 mole KMnO₄
(3)(55.8) = 167.4 requires 158g

1 part Fe⁺² requires $\frac{158}{167.4} = 0.94$ parts KMnO₄

1 part Fe⁺² produces $\frac{86.9}{167.4} = 0.52$ parts MnO₂

1 part Fe⁺² produces 1 part Fe⁺³



One mole C₂Cl₄ requires 2 moles KMnO₄.

1 part C₂Cl₄ requires $\frac{(2)(158)}{165.8} = 1.9$ parts KMnO₄

1 part C₂Cl₄ produces $\frac{(2)(86.9)}{165.8} = 1.0$ parts MnO₂



PROJECT NTC Orlando OVA

SUBJECT KMnO4 Material Balance

Daily Sludge Production

$$\text{Flow} = \left(\frac{5 \text{ gal}}{\text{min}} \right) \left(\frac{3.785 \text{ l}}{\text{gal}} \right) \left(\frac{60 \text{ min}}{\text{hr}} \right) \left(\frac{24 \text{ hr}}{\text{day}} \right) = 27,252 \text{ l/day}$$

$\underbrace{\hspace{10em}}_{18.9 \text{ l/min}}$

$$\text{Iron} = (27,252 \text{ l/day}) \left(\frac{1200 \text{ g Fe}}{10^6 \text{ l}} \right) = 32.7 \text{ g/day Fe}$$

Assume 5000 mg/l PCE in GW

$$\text{PCE} = (27,252 \text{ l/day}) \left(\frac{5000 \text{ g PCE}}{10^6 \text{ l}} \right) = 136.3 \text{ g/day PCE}$$

$$\begin{aligned} \text{KMnO}_4 \text{ Consumption} &= (32.7 \text{ g/day})(0.94) + (136.3)(1.9) \\ &= 289 \text{ g/day KMnO}_4 \\ &= 0.2 \text{ g/min} \\ \left(\frac{0.2 \text{ g/min}}{18.9 \text{ l/min}} \right) &= 0.01 \text{ g/l} \\ &\text{(Feeding dg/l)} \end{aligned}$$

$$\begin{aligned} \text{Sludge Produced} &= \left(\overset{\text{Fe}^{+2}}{\downarrow} 32.7 \text{ g/day} \right) (0.52) + \overset{\text{PCE}}{\downarrow} 32.7 + (136.3 \text{ g/day})(1.0) \\ &= 186 \text{ g/day} \quad (186 - 32.7 = 153 \text{ g/day MnO}_2) \\ &= 0.4 \text{ lb/day} \quad \text{or } 82\% \end{aligned}$$

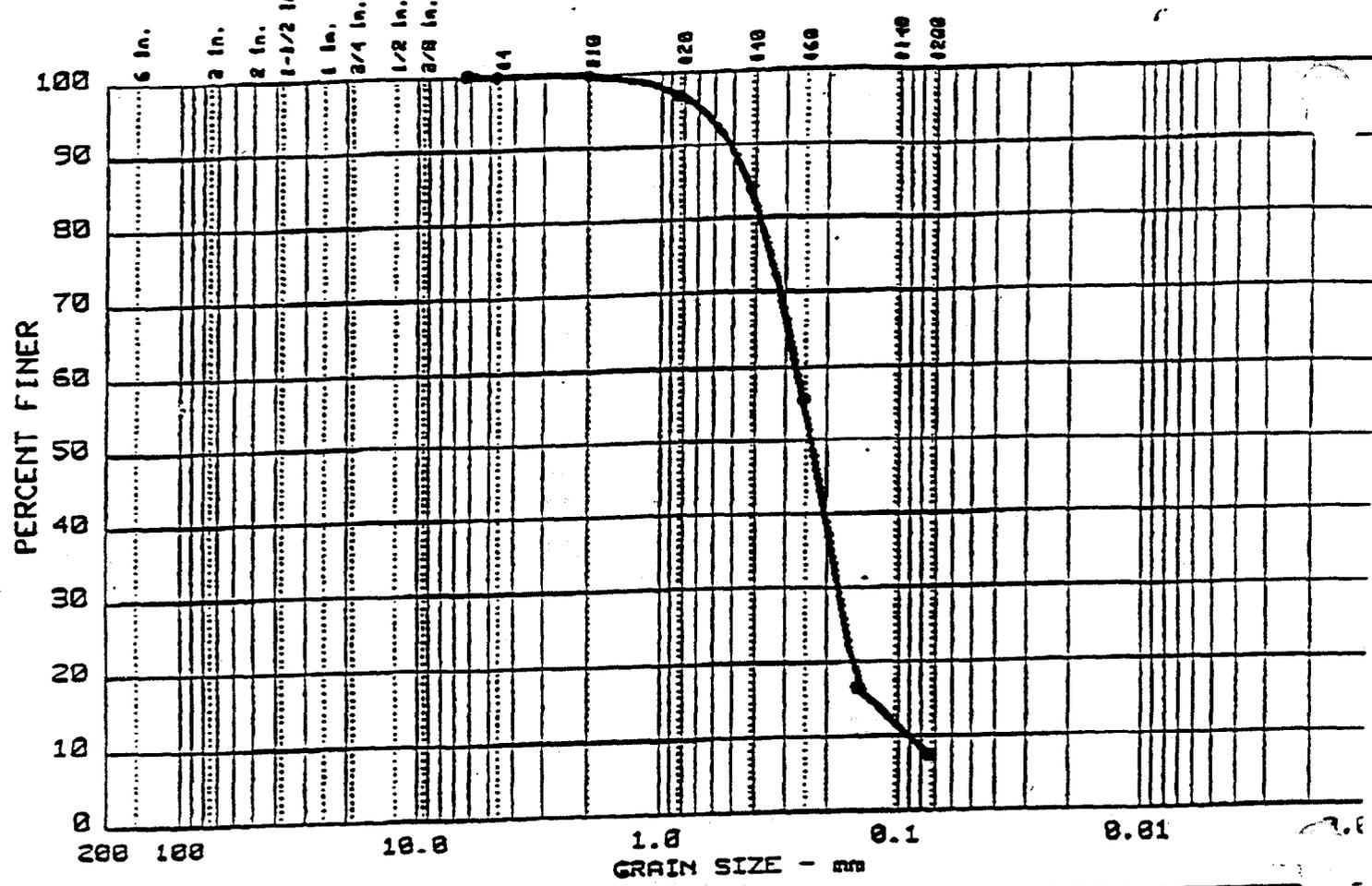
Sludge Loading

$$\begin{aligned} \frac{186 \text{ g/day}}{27,252 \text{ l/day}} &= 0.0068 \text{ g/l} = 6.8 \text{ mg/l} \\ &= \frac{0.0068 \text{ g}}{1000 \text{ g}} \times 100 = 0.0007\% \text{ by wt} \end{aligned}$$

APPENDIX G

FORMATION GRAIN SIZE ANALYSES AND FILTER SIZING

PARTICLE SIZE DISTRIBUTION TEST REPORT



% +3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
0.0	0.1	92.4	7.5		SP-SM		

SIEVE Inches size	PERCENT FINER	
	●	
0.25	100.0	
GRAIN SIZE		
D ₆₀	0.27	
D ₃₀	0.18	
D ₁₀	0.088	
COEFFICIENTS		
C _c	1.33	
C _u	3.0	

SIEVE number size	PERCENT FINER	
	●	
4	99.9	
10	99.7	
20	96.7	
40	84.1	
60	55.5	
100	16.4	
200	7.4	

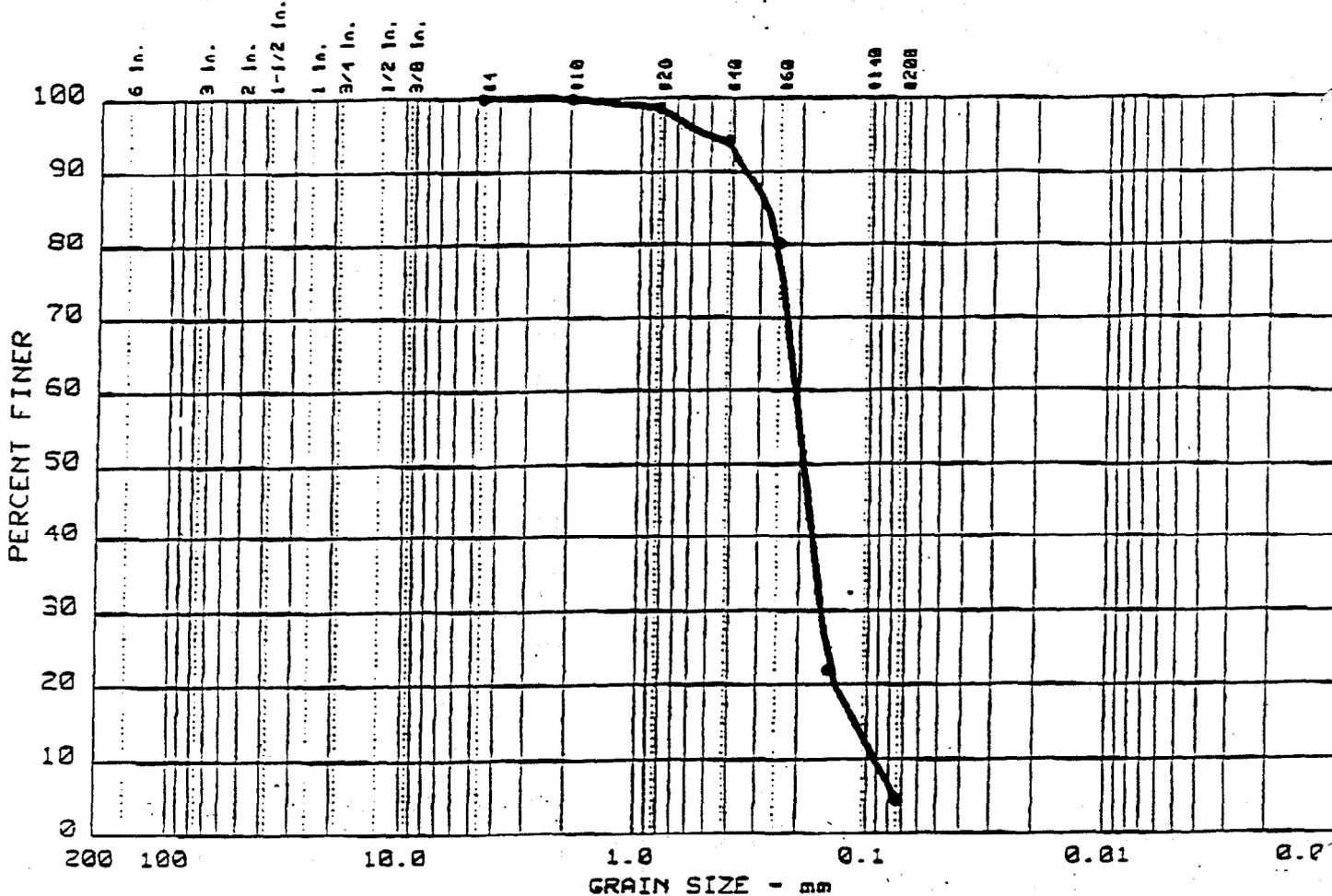
Sample information:
 ● U4SGS02
 F SAND; Ltll M Sa;
 Tr Sl, C Sa, and F Gvl

Remarks:
 SIEVE ONLY

ABB Environmental Services, Inc.

Project No.: 8519.70
 Project: ORLANDO
 Date: 06/12/96
 Data Sheet No. 5

PARTICLE SIZE DISTRIBUTION TEST REPORT



% +3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
0.0	0.0	95.5	4.5		SP		

SIEVE inches size	PERCENT FINER		SIEVE number size	PERCENT FINER		Sample information: • U4SGS04 F SAND; Tr Si, and M and C Sa. Remarks: SIEVE ANALYSIS
			4	100.0		
			10	99.8		
			20	98.7		
			40	94.1		
			60	80.1		
			100	21.9		
			200	4.5		
X GRAIN SIZE						
D ₆₀	0.21					
D ₃₀	0.16					
D ₁₀	0.09					
X COEFFICIENTS						
C _c	1.33					
C _u	2.3					



PARTICLE-SIZE ANALYSIS

ASTM D422

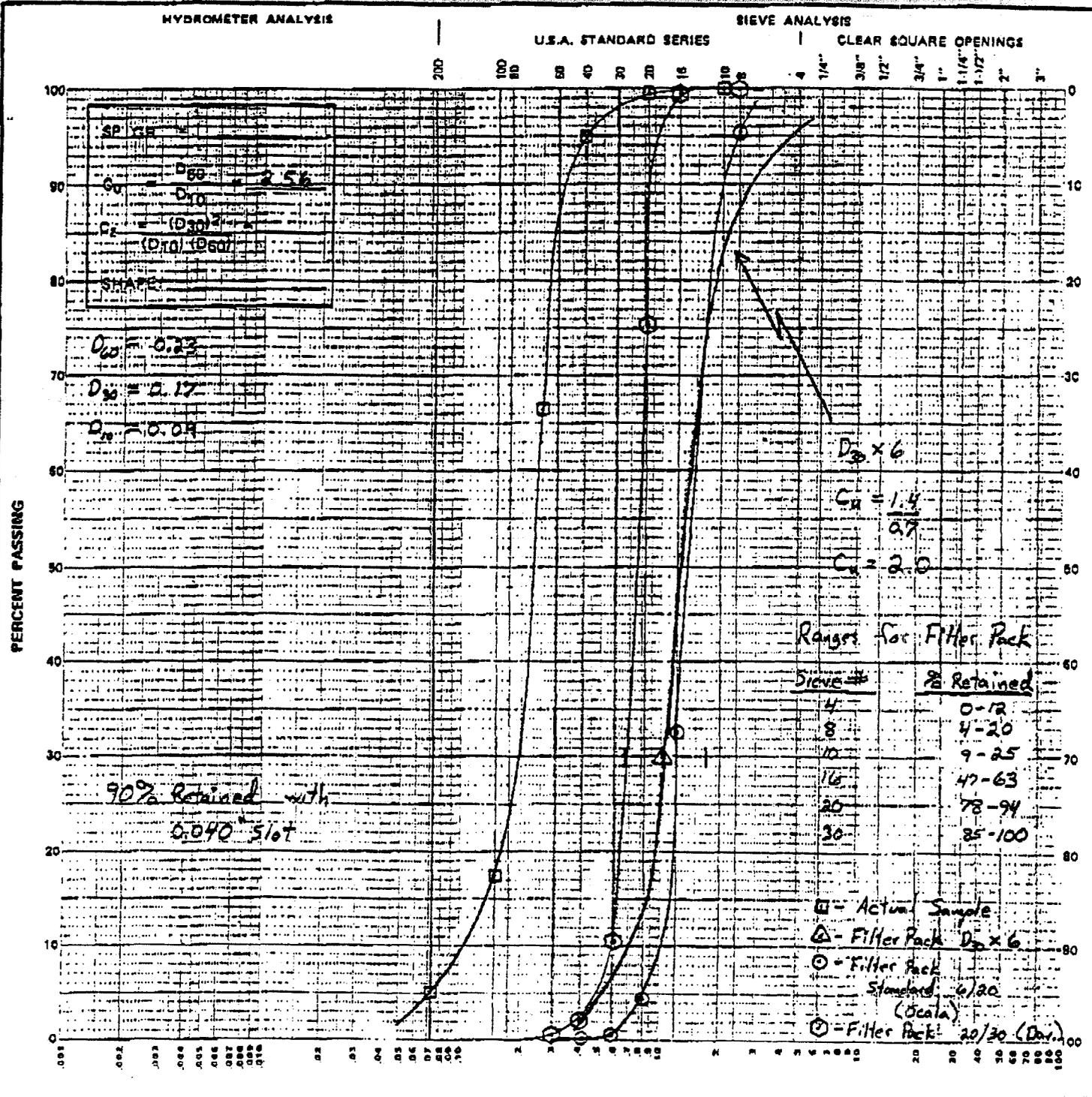
PROJECT DESCRIPTION: OU 4 IRA

MATERIALS LABORATORY:

SAMPLE LOCATION: Area C

SAMPLE NO. V456581

TYPE OF SAMPLE: SAND trace silt



COLLOIDS	CLAY SIZE	SILT SIZE	SAND			COBBLE
			FINE	MEDIUM	COARSE	

SAMPLE CLASSIFICATION

TESTED BY: DATE: COMPUTED BY: J. Nash DATE: 7/9/96 CHECKED BY: DATE:



PARTICLE-SIZE ANALYSIS

ASTM D42

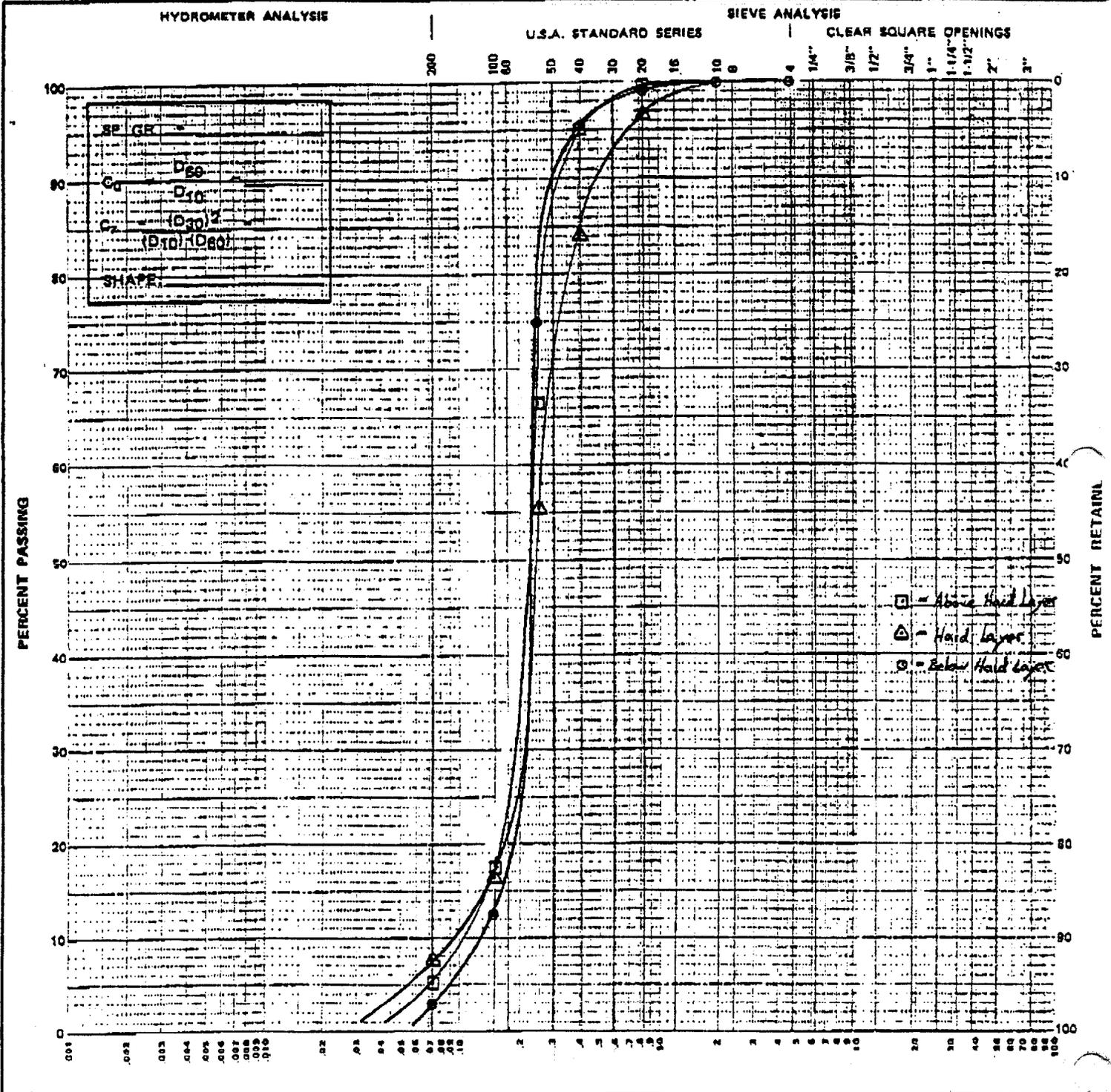
PROJECT DESCRIPTION: 014 IRA

MATERIALS LABORATORY:

SAMPLE LOCATION: Area C

SAMPLE NO. U456501/02/4

TYPE OF SAMPLE: SAND, trace silt



COL-LOIDS	CLAY SIZE	SILT SIZE	SAND			COBBLE
			FINE	MEDIUM	COARSE	
SAMPLE CLASSIFICATION						
TESTED BY:	DATE:	COMPUTED BY:	DATE:	CHECKED BY:	DATE:	
		J. Nash	7/9/96			

Post-It™ brand fax transmittal memo 7671 # of pages 1

To: Roy From: ROB

Subject: GROUNDWATER CO. STD SAND

Dept. Phone #

Fax # 407 426 7586 Fax # 813 422 8610



Serving Florida and the Caribbean Since 1965

PRODUCT INFORMATION

GRADE	8/20	8/30	8/40	20/30	20/40	20/60	20/80	30/40	30/60	30/80	30/100	30/150	40/70	40/100	40/150	40/200	40/300	40/400	40/600
PLANT	OCALA	DAY	LAKE WALES	DAY	LAKE WALES	OCALA	PLANT	DAY	LAKE WALES	LAKE WALES	DAY	BARBER GREEN	OCALA	LAKE WALES	DAY	PLANT	BARBER GREEN	PLANT	PLANT
% RETAINED ON U.S.	45	3	0	0															
#6	4.7	2	1.2	0	0	0		0											
#12	21.4	4.7	7.2																
#16	67.2	44.4	36.5	2	3	9	.1	.1	0	0	0	.1	0	0	0	0	0	0	0
#18	87.3	84.4	66.2																
#20	85.7	86.2	88.0	24.7	26.5	24.9	6.3	.8	.4	.2	.3	1.1	.1	0	.1	0	0	0	0
#25	98.5	98.6	95.5	84.4	83.9	88.8		3.1	1.2	1.0	1.0		2		.2				
#30	99.2	99.2	98.2	89.9	84.5	83.0	45.5	22.3	10.0	4.0	8.8	10.6	1.8	.3	.7	.4	.1	.1	.1
#35				87.0	87.4	85.5		84.6	44.4	28.5	31.8		13.0		4.6				
#40	99.7	99.5	99.4	98.0	98.8	97.5	88.7	83.2	63.2	38.5	47.9	44.9	24.7	2.7	12.5	7.9	2.8	2.5	.1
#45								83.0	80.3										
#50	99.9	99.9	99.9	99.4	99.9	99.0	97.6	87.6	83.2	79.6	72.0	73.8	53.2	45.8	40.2	36.9*	34.9*	11.0	.4
#60							98.9		87.5	88.8	84.0	83.9	68.6	67.6	61.7	60.4	47.2	20.1	1.8
#70									98.1	94.3	81.6	82.2	78.6	80.8	75.4	64.8*	65.2*	37.7	8.7
#100							89.9		99.9	98.5	98.7	98.2	96.1	95.7	94.6	91.2	92.5	71.6	43.9
#140												99.9		99.7		99.1	99.5	98.4	86.9
#200																		99.7	85.2
EFFECTIVE SIZE:	.84	.99	.82	.58	.55	.64	.41	.37	.31	.25	.22	.22	.17	.17	.16	.15	.15	.12	.09
UNIFORMITY COEFFICIENT:	1.88	1.35	1.43	1.35	1.40	1.45	1.86	1.48	1.65	1.7	2.10	2.00	2.10	1.8	1.82	1.9	1.9	1.80	1.87
U.S. GRAIN LIMITS:	10	10	11	19	18	20	25	30	34	39	35	39	48	50	51	56	56	71	93

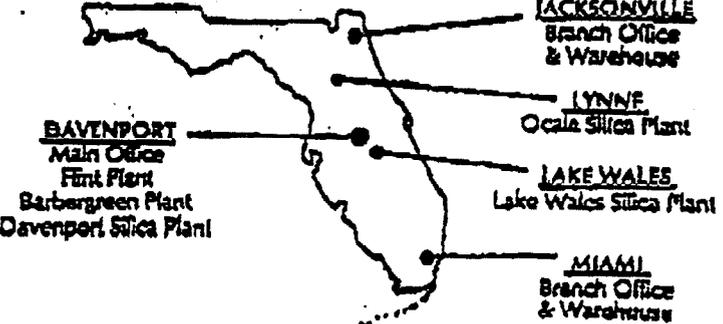
* Standard Sand does not test on this screen. This number was derived mathematically, assuming a curvilinear relationship.

TYPICAL CHEMICAL ANALYSIS
% by difference

Iron oxide (Fe ₂ O ₃)	99.58%
Titanium oxide (TiO ₂)	0.03%
Aluminum oxide (Al ₂ O ₃)	0.38%
Hydrogen oxide (H ₂ O)	0.0024%
Chlorine oxide (Cl ₂ O)	0.0081%
Magnesium oxide (MgO)	0.0058%
Potassium oxide (K ₂ O)	0.017%
Sodium oxide (Na ₂ O)	0.010%
Calcium oxide (CaO)	0.0011%
Loss on Ignition (LOI)	< 5%
Moisture content	< 1%
Specific gravity	2.64

Specialty Grades can generally be achieved by blending various amounts of two or more gradations at the individual plant sites.

FACILITY LOCATIONS



MAIN OFFICE
P.O. Box 35
Highway 17-92 North
Davenport, FL 33837
(813) 422-1171
Fax (813) 422-8610

BRANCH OFFICE
600 East 8th Street
Jacksonville, FL 32208
(904) 855-0516
Fax (904) 365-2022

BRANCH OFFICE
4101 N.W. 70th Ave.
Miami, FL 33166
(305) 593-1431 (Dade)
(305) 524-5322 (Broward)
Fax (305) 583-9781

WARNING - THIS PRODUCT CONTAINS CRYSTALLINE SILICA. AVOID BREATHING DUST FROM THIS PRODUCT AS PROLONGED & REPEATED BREATHING CAN CAUSE A DANGEROUS LUNG DISEASE CALLED SILICOSIS. THE INTERNATIONAL AGENCY FOR RESEARCH ON CANCER REPORTS THERE IS LIMITED EVIDENCE THAT CRYSTALLINE SILICA CAUSE CANCER IN HUMANS. FOLLOW OSHA, MSHA & NIOSH HEALTH STANDARDS FOR SILICA DUST. FOR MORE DETAILED INFORMATION, SEE THE MATERIAL SAFETY DATA SHEET BEFORE USING OR HANDLING THIS PRODUCT.

APPENDIX H

REACTION KINETICS CALCULATIONS



PROJECT NTC Orlando OU4
SUBJECT CSTR Reactions

Objective: Look at $KMnO_4$ / PCE reaction rates and calculate CSTR performance.

Calculate Reaction Rate Constants

Literature indicates reaction is First Order:

$$-\ln \frac{C_A}{C_{A0}} = kt$$

For 1000 mg/L $KMnO_4$ (Data from bench-scale tests)

$T = 1 \text{ hr}$; $-\ln \frac{C_A}{C_{A0}} = -\ln \left(\frac{1.225}{3.170} \right) = 0.951$

$$0.951 = k(1 \text{ hr})$$

$$k = 0.951 \text{ hr}^{-1}$$

$T = 2 \text{ hr}$ (Data From App. B)

$$\left(\ln \frac{0.886}{3.147} \right) = 1.868$$

$$1.868 = k(2 \text{ hr})$$

$$k = 0.934 \text{ hr}^{-1}$$

$T = 3 \text{ hr}$ (Data From Fig 2-1)

$$-\ln(0.067) = 2.70$$

$$2.70 = 3k$$

$$k = 0.90 \text{ hr}^{-1}$$

$T = 4 \text{ hr}$ (Data From Fig 2-1)

$$-\ln(0.029) = 4k$$

$$k = 0.89 \text{ hr}^{-1}$$

$T = 5$ (Data From App. B)

$$-\ln(0.0127) = 5k$$

$$k = 0.873 \text{ hr}^{-1}$$

Ave = 0.91



PROJECT UTC Orlando OVA
SUBJECT CSTR Reactions

For 2000 mg/l (Pull data off Figure 2-1)

$$T = 1 \text{ hr}; \quad C/C_0 = 0.161$$

$$-\ln(0.161) = k$$

$$k = 1.83$$

$$T = 2 \text{ hr}$$

$$-\ln 0.029 = 2k$$

$$k = 1.77$$

$$\text{Ave} = 1.74$$

$$T = 5 \text{ hr}$$

$$-\ln(0.0003) = 5k$$

$$k = 1.62$$

For 3000 mg/l (Pull Data off Fig 2-1)

$$T = 1 \text{ hr}$$

$$-\ln(0.058) = k$$

$$k = 2.85$$

$$T = 3 \text{ hr}$$

$$-\ln(0.00048) = 3k$$

$$k = 2.55$$

$$\text{Ave} = 2.70$$

For 4000 mg/l (Pull Data off Fig 2-1)

$$T = 1 \text{ hr}$$

$$-\ln(0.0225) = k$$

$$k = 3.79$$

$$T = 2 \text{ hr}$$

$$-\ln(0.00087) = 2k$$

$$k = 3.53$$

$$k = 3.66$$



PROJECT NTC Orlando OU4
SUBJECT CSTR Reactions

For 5000 mg/l (Pull Data off Fig 2-1)

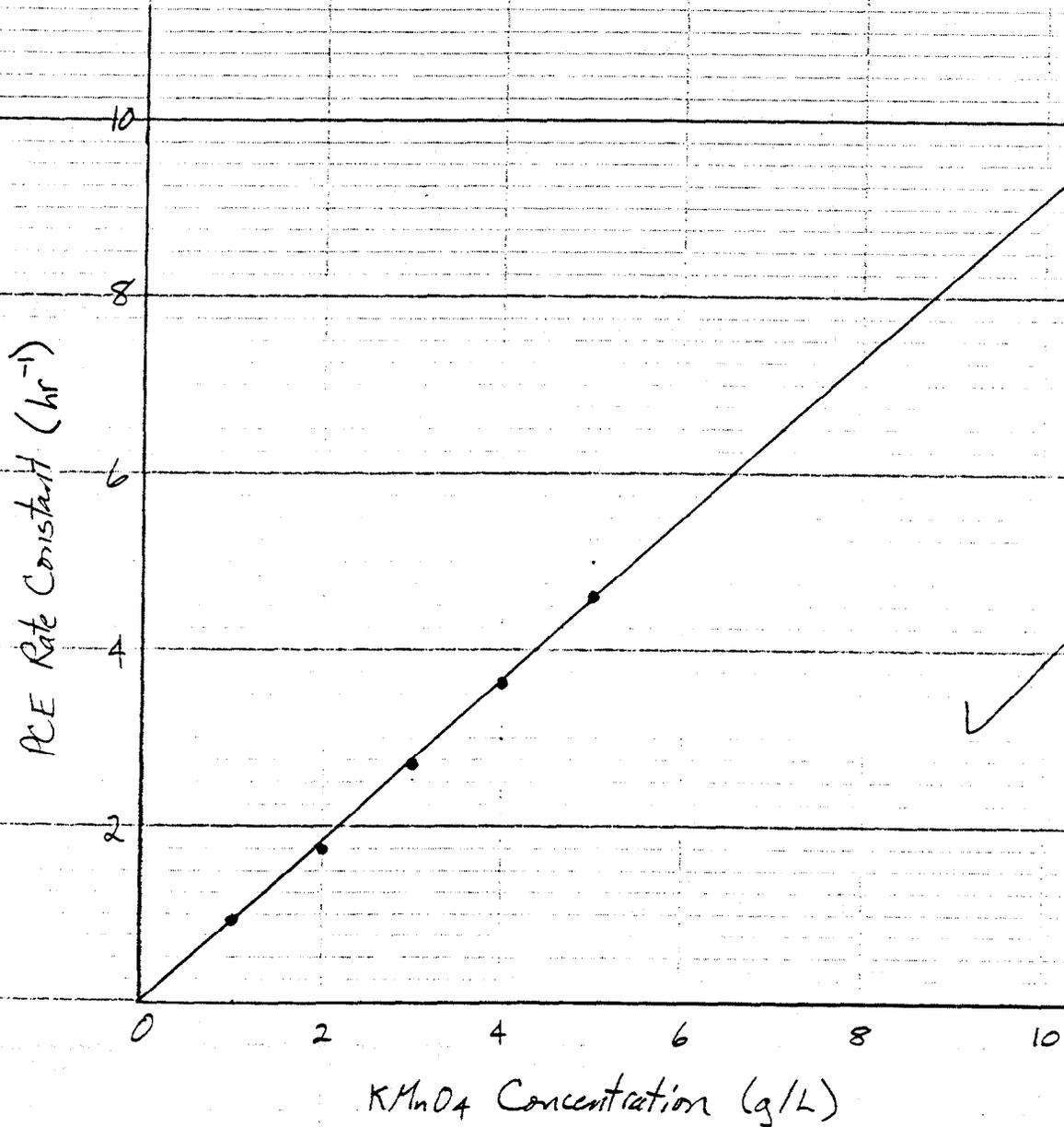
$T = 1 \text{ hr}$
 $-\ln(0.0085) = k$

$k = 4.77$

$T = 2 \text{ hr}$
 $-\ln(0.0015) = 2k$

$k = 4.39$

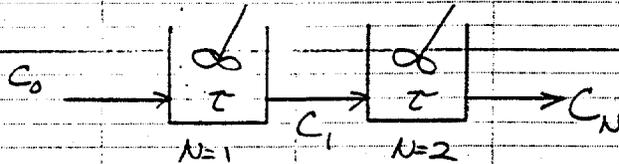
Ave = 4.58 ✓





PROJECT NTC Orlando OUA
SUBJECT CSTR Reactions

For two equal-size mixed reactors in series:



$$\tau = 5.33 \text{ hrs (1600 gal @ 5GPH)}$$

$$\frac{C_0}{C_N} = (1 + k\tau)^N$$

$$C_N = \frac{C_0}{(1 + k\tau)^N}$$

Assume $C_0 = 5000 \mu\text{g/L}$

At 4 g/L KMnO_4 , $k = 3.66$

$$C_N = \frac{5000}{[1 + (3.66)(5.33)]^2} = 12 \mu\text{g/L}$$

Assuming $5000 \mu\text{g/L}$ PCE influent, would not achieve $3 \mu\text{g/L}$ in effluent at 4 g/L KMnO_4 and while stirring both reactors. However, if influent is $< 1260 \mu\text{g/L}$, would expect to achieve $3 \mu\text{g/L}$ effluent.

At 5 g/L KMnO_4 , $k = 4.58$

$$C_N = \frac{5000}{[1 + (4.58)(5.33)]^2} = 8 \mu\text{g/L}$$

At 8 g/L KMnO_4 , $k = 7.3$ (From graph on previous page)

$$C_N = \frac{5000}{[1 + (7.3)(5.33)]^2} = 3 \mu\text{g/L}$$

If $C_0 = 5,000 \mu\text{g/L}$ + both reactors are stirred, need 8 g/L KMnO_4

PROJECT NTC Orlando OVA
SUBJECT CSTR Reactions

Now assume agitator in second tank is not used. This gives a system with a CSTR followed by a plug flow reactor. This will improve the conversion of PCE. Agitating the first tank will help ensure the complete dissolution of $KMnO_4$, and not using the mixer in the second tank may also help settle out solids.

$$\text{For the single CSTR, } \frac{C_0}{C_N} = 1 + k\tau$$

$$\text{For the plug flow tank, } \tau = \frac{1}{k} \ln \frac{C_0}{C}$$

$$k\tau = \ln \frac{C_0}{C}$$

$$e^{k\tau} = \frac{C_0}{C}$$

$$C = C_0 e^{-k\tau}$$

Assume $C_0 = 5,000 \mu\text{g/L}$, $4 \text{g/L } KMnO_4$ ($k=3.66$), $\tau=5.33$

For the first tank,

$$C_N = \frac{C_0}{1+k\tau} = \frac{5000}{[1+(3.66)(5.33)]} = 244 \mu\text{g/L} \checkmark$$

This is now the inlet concentration (C_0) to the plug flow tank:

$$C = (244) e^{-(3.66)(5.33)}$$

$$C = 8 \times 10^{-7} \mu\text{g/L}$$

Clearly, this approach should easily achieve $3 \mu\text{g/L}$ in the effluent using only $4 \text{g/L } KMnO_4$. \checkmark

APPENDIX I

**RESPONSE TO FLORIDA DEPARTMENT OF
ENVIRONMENTAL PROTECTION COMMENTS**

PROJECT REVIEW COMMENTS

**Draft Treatability Study Work Plan No. 3
Data Collection Plan for Assessing In-Situ Chemical Oxidation
Using Potassium Permanganate
Operable Unit 4
Naval Training Center
Orlando, Florida**

Florida Department of Environmental Protection – David Grabka

1. **The Work Plan states that groundwater elevation measurements will be taken prior to the pilot test startup. Groundwater elevation measurements should be collected during each sampling event from wells associated with the pilot study and in the vicinity of the pilot study. This information will be important in validating the groundwater flow model used to predict the treatment flow cell, determining induced hydraulic gradients from the injection and extraction wells in order to calculate groundwater flow velocities, and in determining whether expected flow conditions develop that may require modifying the monitoring plan or installing more monitoring wells.**

Agreed. Water levels will be measured weekly in shallow and deep monitoring points near the extraction and injection wells, within the treatment cell itself, and in downgradient monitoring points GMP-17 and OLD-13-46B. Background water levels will be measured in monitoring wells OLD-13-01A and OLD-13-40B, located approximately 200 feet northeast of the pilot study on the north side of Building 1100. These two wells are outside of the area to be influenced by the pilot study, and will provide data to define regional water level trends. Water levels within and near the circulation cell will be used to compare actual with expected hydraulic performance. The Orlando Partnering Team (OPT) will discuss and approve any required operational changes suggested by the water level data.

Florida Department of Environmental Protection – Bill Neimes

1. **Reactor Kinetics. My comment on the treatment system concerns the interpretation of data taken from the batch treatment studies performed by Carus for use in this treatment system. Figure 2-1 of this work plan provides information for all of the batch testing performed by Carus for groundwater from this site and another site. This figure neatly shows a logarithmic reduction in contaminant concentrations at different time periods. Using the data provided in this graph, the work plan demonstrates that for an initial concentration of 5000 ug/l PCE, a minimum detention time of approximately 2 hours is required for a reduction to 3 ug/l PCE. Since the detention time for the proposed treatment system is over 10 hours, the work plan notes that there will be enough of a safety factor in this design is that all of the treatability PCE. My concern with this design is that all of the treatability studies were performed on batch runs, however, the actual design of this system will be two mixed reactors in series. With the information provided I have done some work calculating the order of reaction and the reaction coefficient for the different batch studies. Although there are not enough data points to accurately calculate a reaction rate for the 4000 mg/l KMnO₄ concentration, there were five data points for the 1000 mg/l KMnO₄ concentration. I plotted the reduction over time for the 1000 mg/l KMnO₄ concentration and came up with a first order reaction and a reaction rate of 0.92^{-hr}. This data is shown on Attachment 1. Since the reaction order is first order, I then plotted the available data for**

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the KMnO_4 concentration of 4000 mg/l and derived a reaction rate of $4.1^{-\text{hr}}$. There were only two data points available for plotting the KMnO_4 concentration of 4000 mg/l so the reliability of this reaction rate coefficient is questionable. However, this is the only information available for calculating a reaction rate at 4000 mg/l KMnO_4 .

Using this reaction rate value of $4.1^{-\text{hr}}$ and plugging this into the first order stir tank reactor of two tanks in series, each with a detention time of 5.33 hours, the final PCE concentration calculates to a value of 35.5 ug/l.

Equation for 1st order stir tank reactor with n tanks:

$$C_f = C_o (1 + kT/n)^n$$

Where:
Cf – final concentration, ug/l
Co – initial concentration (assume 5000 ug/l)
k – $4.1^{-\text{hr}}$
T – detention time – 5.33 hours
n – number of tanks – 2

From this information, it appears that the design in this Treatability Study Work Plan will not meet the required treatment efficiency for eventual reinjection. Based on this, I would recommend that the type of treatment unit be reconsidered. A stir tank reactor is not as efficient as a plug flow reactor and I would suggest that the designers consider changing one of the tanks to a plug flow reactor. Although a plug flow reactor is much more efficient than a stir tank reactor, a plug flow reactor is more dependent upon a consistent influent concentration and is prone to variations in the influent flow. On this basis, I would consider including a combination, stir tank reactor – plug flow reactor in series. In this type of treatment, the stir tank reactor would provide a buffering capacity for any influent flow variations and the subsequent plug flow reactor would provide an efficient means of treating the PCE to injection standards of less than 3 ug/l.

My calculations show that a plug flow reactor with a detention time of 5.33 hours can treat an influent concentration of 5000 ug/l PCE to an effluent concentration of 2×10^{-6} ug/l.

Agreed. If the two tanks are stirred and the influent PCE concentration is 5,000 ug/l, it does not appear that the reinjection standard of 3 ug/l can be met with 4 g/l KMnO_4 . The influent PCE concentration must be less than approximately 1,250 ug/l, or the concentration of KMnO_4 must be increased (up to 8 g/l for a 5,000 ug/l PCE influent concentration).

The work plan will be revised to indicate that the system will be operated with the mixer in the first tank operating and the second tank unstirred, at least until actual PCE concentrations and reaction rates can be established. This approach should ensure complete KMnO_4 dissolution in the first tank, and may also allow solid particles produced during the reaction to

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settle in the second tank, reducing the frequency of filter cleaning required. Calculations for the two different reactor arrangements will be added to Appendix F.

The actual influent PCE concentration to the KMnO_4 feed system will be unknown until the pilot is begun. It is possible that the concentration will be low enough to meet the reinjection standard while stirring both tanks, if desired. An onsite laboratory will be used during startup to evaluate actual PCE concentrations and the extent of the PCE reaction prior to reinjection of any treated groundwater.

- 2. Deep Well. There is sufficient monitoring planned for both the upper zone and deeper zone during this pilot test and I would not recommend any more monitoring in these zones. However, there are no monitoring wells that can monitor groundwater below the injection wells. How can we determine if the injection fluid will not migrate vertically downward? With this, I would recommend that a deep monitoring well be installed at a depth between 40 to 50 feet bls and located somewhere by the three injection wells so that groundwater below the injection wells could be monitored.**

It is unlikely that downward migration of KMnO_4 will occur after injection. The natural groundwater gradient is west towards the lake, the vertical hydraulic conductivity has been found to be 4 times less than the horizontal by USGS modeling, and lateral flow will be induced by the extraction wells. Further, the injection wells will be slotted screen, so the injected KMnO_4 will enter the aquifer with a lateral motion and no downward component.

A cross-section MODFLOW particle track will be added to work plan Appendix C (Hydraulic Modeling). The cross-section shows almost no downward flow between the extraction and injection wells. This was modeled with an anisotropy ratio of three, which is conservative when compared to the USGS estimate of four.

Rather than installing a new deep well, two existing deep wells will be monitored for KMnO_4 . Monitoring well OLD-13-08C is adjacent to shallow well OLD-13-07A (See work plan Figure 2-2. OLD-13-08C will be added to the final figure.), and is screened from 57 to 62 feet bls. The second deep well is just west of the predicted treatment cell (OLD-13-43C), screened from 45 to 50 feet bls. In the highly unlikely event significant downward migration of KMnO_4 occurs, the KMnO_4 should appear in either or both of these wells approximately 1 to 2 months after injection.

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3. **Groundwater Monitoring Schedule.** I agree with the groundwater monitoring schedule set forth on Table 2-1 and believe that this schedule should be adhered to during the treatability study. However, if during the beginning of the treatability study the monitoring data indicate either faster or slower movement of the injected fluids, then the schedule should be adjusted accordingly.

Agreed. The work plan will be revised to note that the monitoring schedule may be adjusted based on observed results, and with the concurrence of the OPT.