Environmental
Resources
Management

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31 January 2003
Reference: 143.78

Massachusetts Department of Environmental Protection
Northeast Regional Office
Bureau of Waste Site Cleanup
205 Lowell Street
Wilmington, MA 01887

Re: Release Abatement Measure Six-Month Status Report
In Situ Chemical Oxidation Pilot Study - Modification #1
Former Raytheon Facility
430 Boston Post Road
Wayland, Massachusetts (the "Site")
RTN 3-13302, Permit No. 133939

Dear Sir or Madam:

On behalf of Raytheon Company (Raytheon), Environmental Resources Management (ERM) is submitting this Release Abatement Measure (RAM) Six-Month Status Report for the above-referenced Site. This RAM Status Report was prepared in accordance with the requirements of 310 CMR 40.0445 of the Massachusetts Contingency Plan (MCP). The original RAM Transmittal Form BWSC-106 is attached and a copy is included as Appendix A. This Six-Month Status Report describes work performed through 10 January 2003.

BACKGROUND

ERM prepared a RAM Plan, dated 11 September 2001, that was submitted to the Department of Environmental Protection (DEP or Department) on 12 September 2001. ERM submitted the most recent RAM Six-Month Status Report, dated 25 July 2002, describing the tasks completed for the original RAM Plan through June 2002.

The RAM Plan presented plans for a pilot study in two areas involving in-situ chemical oxidation (ISCO) of chlorinated hydrocarbons (primarily trichloroethene (TCE)) in groundwater. The purpose of the RAM was to evaluate the ability to reduce the concentrations of chlorinated volatile organic compounds (CVOCs) in groundwater using ISCO. The two pilot study areas were designed to evaluate two delivery methods for

introducing oxidants to the subsurface (i.e., pressurized injection and passive injection) and two permanganate concentrations (2% and 4%).

RAM Plan Modification #1 was submitted to the Department on 22 October 2002 presenting a work plan for an expanded pilot in the MW-43 area. This expanded pilot test was designed to evaluate the ability to reduce the concentration of CVOCs using the hydraulic fracturing and liquid atomized injection (HFLAI) technique, additional oxidant (sodium permanganate) and multiple injection points and injection intervals. The activities included in the RAM Plan Modification #1 were selected to provide additional treatment of the subsurface materials while building upon the results from the previous RAM activities. Figure 1 presents a Site Locus Map, Figure 2 presents a Site plan and Figure 3 presents a detailed Site plan of the pilot study area.

The expanded pilot study consisted of the following tasks:

- Install additional monitoring wells
- Establish baseline hydrogeochemistry
- Apply reagent
- Install confirmatory soil borings
- Post-injection groundwater monitoring

The remainder of this RAM Status Report is formatted consistent with the requirements of Massachusetts Contingency Plan (MCP), 310 CMR 40.0445 (2).

A) STATUS OF RESPONSE OPERATIONS

Install Monitoring Wells

The purpose of this task was to install an adequate monitoring well network to monitor the effects of the ISCO injection. Seven monitoring wells previously existed in the pilot area. Of these wells, five are set at a depth of 20 feet (MW-43S, MW-104, MW-105, MW-106, and MW-212), one well is set at a depth of 30 feet (MW-210) and one well is set at a depth of 55 feet (MW-43D).

On 9 and 12 November 2002, ERM provided oversight for installation of five new monitoring wells at the Site (MW-105M, MW-106M, MW-117, MW-118 and MW-212M). The wells were installed by Geosearch, Inc. (Geosearch) of Sterling, Massachusetts using either Geoprobe™ direct-push drill rig or hand tools (MW-117 and MW-118). Three of these wells (MW-105M, MW-106M and MW-212M) were installed adjacent to existing monitoring wells in the pilot area to provide well couplets screened across the entire overburden aquifer. Wells MW-117 and MW-118 were installed inside the building to monitor conditions downgradient of the pilot area.

Monitoring wells were constructed in all borings using ¾-inch or one-inch inside diameter (ID), Schedule 40, polyvinyl chloride (PVC) riser pipe and well screen, sand filter pack, bentonite seal, concrete surface seal and flush-mounted roadbox. A summary of relevant monitoring well construction data is presented in Table 1. Monitoring well locations are shown on Figure 3. Boring logs and well construction details are presented in Appendix B. The locations and elevations of the indoor monitoring wells were surveyed relative to the existing Site datum by Chas. J. Sells, Inc. Survey of MW-105M, MW-106M and MW-212M will be conducted concurrent with the next groundwater sampling round.

Geology in the pilot area generally consists of interbedded fine- to coarse-grained sand and silt layers. Based on historical data, a grey silt unit exists beneath the pilot area. The silt unit appears to be semi-confining in the pilot area, preventing migration of CVOCs to the underlying sand unit. Therefore, the expanded pilot study was focused on the upper sand layer and upper portion of the silt layer.

Establish Baseline Hydrogeochemistry

This task was conducted to establish baseline conditions for groundwater flow and quality within the pilot test area prior to conducting the oxidant injections. The baseline monitoring program consisted of the following field measurements and laboratory analyses:

Analysis	Method of Analysis	Rationale	Frequency
Groundwater Elevation	Field Probe	Evaluate groundwater table elevation	Note 1
PH	Field Flow-Through Cell	Evaluate aquifer conditions	Note 1
Electrical Conductivity	Field Flow-Through Cell	Evaluate aquifer conditions and oxidant	Note 1
Temperature	Field Flow-Through Cell	Evaluate aquifer conditions	Note 1
Eh	Field Flow-Through Cell	Indicator of oxidant	Note 1
Dissolved Oxygen	Field Flow-Through Cell	Evaluate aquifer conditions	Note 1
Color	Field Visual Assessment	Indicator of permanganate	Note 1
Permanganate	Field Colorimetry	Quantify concentration of permanganate in groundwater	Note 1
VOCs	Lab - EPA Method 8021C	Contaminant concentrations	Note 2
Chloride	Lab - EPA Method 300.0	Degradation by-product	Note 2
Sodium	Lab - EPA Method 200.7	Evaluate aquifer conditions and potential tracer	Note 2
Manganese	Lab - EPA Method 200.7	Degradation product of MnO_4	Note 2
Chromium (Note 3)	Lab - EPA Method 200.7	Oxidation can convert Cr^3 to Cr^6	Note 2

Notes:
1. These parameters will be monitored daily during oxidant addition and weekly thereafter until unreacted permanganate is no longer present or stabilizes
2. These parameters will be monitored during the baseline round and after unreacted permanganate is no longer present or stabilizes. VOCs will be monitored at a minimum of quarterly.
3. Hexavalent chromium was not analyzed during the baseline sampling but will be analyzed during future sampling events.

Groundwater samples collected in the field were preserved on ice and documented consistent with chain-of-custody protocols. One trip blank for CVOC analysis was submitted to the laboratory with the baseline groundwater samples.

Monitoring was conducted in the following wells:

Location	Rationale
MW-43S, MW-43D, MW-104, MW-105, MW-105M, MW-106, MW-106M, MW-210, MW-212, MW-212M	Wells within the pilot area (10)
MW-44S, MW-44M, MW-44D	Wells up-gradient of the pilot area (3)
MW-101, MW-102, MW-103, MW-107, MW-108, MW-213, MW-214, MW-117, MW-118	Wells down-gradient of the pilot area (9)
MW-209, MW-211	Wells cross-gradient of the pilot area (2)

The baseline groundwater sampling event was conducted 11 and 12 November 2002. The two indoor wells (MW-117 and MW-118) were sampled on 3 December 2002 due to insufficient water in the wells in November 2002. Prior to sample collection, all monitoring wells were gauged using an electronic water level indicator to determine groundwater elevations. Groundwater samples were collected using low flow sampling techniques. Geochemical field parameters were measured during sample collection to record conditions and document stabilization prior to sample collection. Groundwater sampling equipment (i.e. tubing) was dedicated to prevent cross-contamination between monitoring points.

Results of the baseline groundwater monitoring round indicated the presence of chromium in groundwater in well MW-104 at a concentration of 0.56 milligrams per liter (mg/L), which exceeds the applicable Reportable Concentration (RCGW-1 of 0.1 mg/L). A groundwater sample from this well was previously analyzed for chromium in August 2001, prior to the initial injection of permanganate in the MW-43 pilot study, and no chromium was detected. Chromium solubility is affected by oxidation-reduction conditions in the aquifer, with chromium being more soluble under more oxidizing conditions. Therefore, it is likely that the presence of chromium at concentrations above the RCGW-1 standard is attributable to the initial permanganate pilot study. Once groundwater conditions return to ambient following the ongoing pilot study, it is likely that chromium will precipitate from groundwater reducing concentrations to below applicable drinking water standards. Raytheon intends to submit a Release Notification Form (RNF) to the Department to document this new release condition within the 120-day notification period.

Results of the baseline groundwater monitoring round are presented in Tables 2 and 3. Laboratory analytical reports are presented in Appendix C.

Groundwater Elevation Data

Groundwater elevations were consistent with historical data for the Site. Historical groundwater elevation data are presented in the Six-Month RAM Status Report, dated 25 July 2002.

Field Observations and Field Parameter Data

The data indicated that residual permanganate was not present in the wells in the MW-43 test area prior to application of additional permanganate. Based on these data, it appears that permanganate previously added in this area had fully reacted prior to completion of the Modification #1 addition. The ORP data in this area further confirmed that the permanganate injected during the 2001 pilot test was completely consumed prior to implementation of the current pilot test.

CVOC Concentrations

Trichloroethene (TCE), tetrachloroethene (PCE), cis, 1-2 dichloroethene (cis-DCE) and vinyl chloride (VC) were detected in the groundwater samples collected from wells in the immediate vicinity of the pilot test area. TCE was detected at the highest concentrations, with a maximum of 190 µg/L in MW-210. VC was only detected in MW-212M in the immediate vicinity of the pilot test area at a concentration of 2.6 µg/L. The VOC concentrations in this area were within the range of concentrations detected prior to the initial pilot study conducted in this area in October 2001.

Apply Reagent

The oxidant injection was conducted in the MW-43 pilot area on 13 and 14 November 2002. ERM provided oversight of Redox-Tech, LLC, who conducted the HFLAI injection of sodium permanganate at the Site. Sodium permanganate was delivered to the Site as a pre-mixed and pre-diluted 23% solution in two 5,000-gallon stainless steel tanker trucks.

Injections were conducted by pumping oxidant directly from the containers using air-driven positive displacement pumps. The oxidant

was pumped directly into temporary well points driven and retracted by a truck-mounted Geoprobe™ rig. Injected fluids were conveyed into the formation using a specialized injection tool provided by Redox-Tech. This tool uses air in conjunction with the injected fluid to create a high pressure mist (i.e. atomization) emplaced at each injection interval.

Approximately 9,000 gallons of 23% sodium permanganate were injected into five temporary injection points. A sixth injection point (INJ-5) was proposed but not utilized due to its close proximity to the building.

Injection of the sodium permanganate was initially accomplished using HFLAI in injection point, INJ-1. The use of HFLAI was suspended following measurement of ground heave at the edge of the pilot area. Subsequent injections were accomplished by hydrofracturing/ pressurized fluid injection (HFPI), with the exception of INJ-5.

ERM attempted to passively apply permanganate to the area of INJ-5 using MW-106M. Due to extremely low recharge into this well, only a minimal amount of permanganate was applied during the pilot test. Field observations indicated that injection of permanganate into MW-106M had affected MW-106, as well. Therefore, permanganate was not applied to MW-106. Refer to Figure 3.

Each injection location was vacuum-excavated to a depth of eight feet prior to the pilot test to minimize the potential to damage subsurface utilities during advancement of the injection points. A two-foot long injection tip was advanced to the bottom of the target treatment zone in each injection location. A portion of the permanganate was injected under high pressure into that interval through a small, circular opening in the injection tip. The injection tip was then withdrawn approximately two feet to the next interval and oxidant was injected at this depth. These sequential injections were repeated from maximum depths of between 27 and 23 feet, to depths of 16 to 19 feet at each location. The injection was not conducted in shallower intervals to minimize injection into unsaturated vadose zone soils and prevent the potential for vertical short-circuiting through the eight-foot deep, vacuum-excavated boreholes.

The injections were conducted on the perimeter of the pilot area first to minimize potential displacement of CVOC-impacted groundwater from the treatment area. Injections were initially conducted in INJ-1, INJ-6 and INJ-4, then moved inward to points INJ-3 and INJ-2. The injections

were conducted at pressures generally ranging from 160 to 80 pounds per square inch (psi). Injection volumes are summarized below:

- INJ-1 1,500 gallons
- INJ-2 4,050 gallons
- INJ-3 1,000 gallons
- INJ-4 925 gallons
- INJ-6 1,500 gallons

INJ-2 was the final injection location used, therefore, the excess permanganate was injected into this well at the end of the pilot testing.

Install Confirmatory Soil Borings

The purpose of this task was to evaluate the efficacy of the injection techniques at distributing permanganate within the treatment area. On 23 November 2002, 10 days after the permanganate injection, four soil borings were advanced within the MW-43 pilot study area. The borings were advanced by Geosearch using a direct-push technique. Boring locations were selected to evaluate the vertical and horizontal distribution of permanganate within the pilot area. The locations of the borings are shown on Figure 3 (B-1, B-2, B-3 and B-4). Each soil boring was continuously logged beginning at a depth of eight feet to the bottom of the boring, between 28 and 30 feet. Soil samples were collected continuously and were screened for total VOCs using a photoionization detector (PID) and visually inspected and photographed for the presence of permanganate (i.e. identified by characteristic purple color). Photographs are included in Appendix D.

No color was noted in boring B-2, located approximately 24 to 32 feet from the injection wells. However, permanganate testing indicated a minor amount of permanganate (5 parts per million) at a depth of 22 to 25 feet.

As expected, the greatest evidence of permanganate presence was identified in B-4. This boring is located within the expected radial influence of INJ-1, INJ-2 and INJ-3. Soil samples revealed the presence of permanganate from a depth of approximately 17 feet (top of the water table) to the bottom of the boring at a depth of 30 feet. Some fingering of permanganate was observed between depths of approximately 22 to 28

feet. Permanganate testing indicated that the highest concentration of permanganate was detected in the soil sample collected from 20 to 24 feet.

The presence of permanganate was less consistent in samples collected from B-1 and B-3. Fingers of permanganate were observed in these borings at depths ranging from 10 to 28 feet. Permanganate testing indicated permanganate concentrations in these borings were lower than those measured in soil samples collected from B-4. The fingering effects and lower concentration in these borings are likely due to geologic heterogeneity and a greater distance from the injection points.

In summary, it appears that using pressurized injection of permanganate resulted in a lateral distribution of permanganate of between 15 and 30 feet and a vertical distribution of between 13 and 18 feet (injection zone was approximately 10 feet thick). This distribution is generally consistent with the proposed work plan to provide treatment within the targeted area.

One soil sample from each boring was submitted for laboratory analysis of VOCs by EPA Method 8260/5035. The sample chosen for analysis was the sample exhibiting the highest PID reading or the sample located just above the water table if no PID readings were noted. The analytical results are summarized in Table 4 and the laboratory results are included in Appendix E. The soil samples were also tested for permanganate concentration. These results are included in Appendix F.

The analytical results indicated VOC concentrations below the respective Reportable Concentrations.

Post-Injection Groundwater Monitoring

The purpose of this task was to monitor the progress of the ISCO pilot study over time. Five post-injection field parameter monitoring rounds were conducted over the period from 21 November 2002 through 2 January 2003 (Table 2). These monitoring rounds included measurements of groundwater elevations and field parameters (including permanganate concentration). Field colorimetry results are included in Appendix F. Post-injection sampling of groundwater for VOC analysis has not yet been conducted due to the widespread presence of the permanganate. The RAM Plan stated that groundwater

analysis of VOCs will take place after the permanganate has been consumed or on a quarterly basis.

Groundwater Elevation Data

Groundwater elevations in the immediate area of the permanganate injection were not measured due to the presence of permanganate in the wells. Groundwater elevations in wells outside of the area of injection indicated a generally increasing trend. Due to the distance of these wells from the injection area, this is likely due to precipitation events during the period of monitoring and not due to the pilot injection. Wells MW-117 and MW-118 were dry during monitoring.

Field Observations and Field Parameter Data

One week following the permanganate injections, evidence of the permanganate solution was detected in most wells monitored in the vicinity of the injection wells (e.g. purple color and/or detectable permanganate concentration in groundwater). The wells that did not exhibit the presence of permanganate were MW-43D (this well is screened approximately 25 feet below the depth of the permanganate injection) and MW-209 (located approximately 20 feet cross-gradient from nearest injection location). Through the end of this reporting period (2 January 2003), permanganate was not observed outside of the immediate vicinity of the injection wells.

ORP readings in the first seven weeks of post-injection monitoring did not reveal increases in wells outside of the immediate vicinity of the permanganate injection.

Continued monitoring will allow evaluation of the permanganate consumption and downgradient effects from the oxidation of CVOCs. Monitoring during this reporting period confirmed the extent of permanganate influence from the injection points at between 15 and 30 feet.

Summary

1. Sodium permanganate was injected into the subsurface in the MW-43 pilot area under pressure. Based on the results of confirmatory soil borings and groundwater monitoring, the injections resulted in a horizontal distribution of between 15 and 30 feet. This is a

significantly larger distribution than that resulting from the gravity addition (5 to 10 feet) conducted earlier in the MW-43 area (reported in the 31 January 2002 Six-Month RAM Status Report).

2. The permanganate injections were conducted sequentially at each location from maximum depths of between 27 and 23 feet, to depths of 16 to 19 feet using two-foot injection spacing. Based on the results of confirmatory soil borings and groundwater monitoring data, the vertical distribution of permanganate was observed to be between 13 and 18 feet (injection zone at each location was approximately 10 feet thick). Some fingering of the permanganate was observed in the soil borings. This is likely a result of geologic heterogeneity.

3. Permanganate persisted in the immediate vicinity of the injection throughout the monitoring period. Continued monitoring will be conducted to evaluate the permanganate consumption rate.

4. Post-injection monitoring of VOC concentrations in groundwater will be conducted in February 2003.

B) NEW SITE INFORMATION

New Site information obtained as part of the ISCO pilot study is discussed above in Section A.

C) MANAGEMENT OF REMEDIATION WASTE, REMEDIAL WASTEWATER AND/OR REMEDIAL ADDITIVES

No Remediation Waste or Remediation Wastewater was generated as part of these RAM activities that required off-site disposal. The application of sodium permanganate as a Remedial Additive was discussed above in Section A and was conducted in compliance with 310 CMR 40.0046. At the end of the pilot test, residual permanganate from the pilot study was transported off-site by the shipper, Synder Trucking.

Personal protective equipment (PPE) was decontaminated as needed and disposed off-site as solid waste. No drill cuttings were generated as the wells were installed using the direct-push technique. Groundwater purged from the wells prior to collection of groundwater samples was returned to the wells following sample collection.

D) REMEDIAL SYSTEM MONITORING DATA

Data associated with monitoring the ISCO pilot studies are discussed above in Section A. The data are also presented in the attached tables.

E) OTHER INFORMATION

Further performance groundwater monitoring and sampling will be conducted to further monitor the effectiveness of the technology.

F) LSP OPINION

The LSP opinion is provided in Section J of BWSC-106 (Appendix A).

If the Department requires additional information or clarification, please contact either of the undersigned at (617) 267-8377.

Sincerely,

for John C. Drobinski, P.G., LSP
Principal-in-Charge

R. Joseph Fiacco, Jr., P.G.
Project Manager

Enclosures:

Tables:	Table 1	Monitoring Well Construction Summary
	Table 2	Groundwater Field Parameter Data
	Table 3	Groundwater Quality Data
	Table 4	Confirmatory Soil Boring Analytical Results
Figures:	Figure 1	Site Locus Map
	Figure 2	Site Plan
	Figure 3	Site Plan Showing Pilot Study Locations

Appendices: Appendix A: RAM Transmittal Form BWSC-106
Appendix B: Boring Logs
Appendix C: Laboratory Analytical Reports - Groundwater
Appendix D: Photographs of Confirmatory Soil Borings
Appendix E: Laboratory Analytical Report - Soil Samples
Appendix F: Field Colorimetry Results

cc: Mr. Edwin Madera, Environmental Restoration Program, Raytheon Company, 528 Boston Post Rd., MS-1880, Sudbury, MA 01776

Public Repository (Primary Location), Wayland Public Library, Louise Brown, 5 Concord Road, Wayland, MA 01778

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