FINAL REPORT

Raytheon Company

Phase III Remedial Action Plan

Former Raytheon Facility
430 BostonPost Road
Wayland, Massachusetts

Tier IB Permit No. 133939

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PHASE III REMEDIAL ACTION PLAN

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Background

On behalf of Raytheon Company (Raytheon), Environmental Resources Management (ERM) has prepared this Phase III– Remedial Action Plan (Phase III) for an approximately 83-acre property located at 430 Boston Post Road in Wayland, Massachusetts (defined as the "Site", Figure 1). The Site, surrounding properties and physical features are shown in Figure 2.

The Phase III describes and documents the information, reasoning and results used to identify and evaluate remedial action alternatives in sufficient detail to support selection of the "preferred" remedial action alternative. The Phase III is used to identify remedial alternatives that are reasonably likely to achieve a level of "No Significant Risk", and where feasible, a Permanent Solution. The Phase III recommends the alternative(s) most likely to reduce the levels of oil and/or hazardous materials (OHM) in the environment to levels that will achieve a Permanent Solution, if feasible.

Target Media & Cleanup Objectives

Previous assessment and remedial response actions identified and abated sources of OHM release to the environment. Residual OHM impacts that require active remedial abatement are limited to polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and heavy metals in wetland soil/sediment and chlorinated hydrocarbons (predominantly trichloroethene (TCE)) in groundwater. Target cleanup goals for wetland soil/sediment and groundwater are based on elimination of a condition of "significant risk" to human health and the environment. An estimated 3,700 cubic yards of wetland soil/sediment over an approximately 1.5-acre area will require abatement to achieve a Permanent Solution. Groundwater will require abatement to Massachusetts Maximum Contaminant Levels for drinking water to achieve a Permanent Solution.

Recommended Remedial Alternatives

Based on a screening of technologies that were deemed to be reasonably feasible in achieving cleanup of wetland soil and groundwater, a series of remedial alternatives were identified including:

Wetland Soil/Sediment

- Alternative #1- Excavation & Off-Site Disposal
- Alternative #2-Excavation, On-Site Stabilization & Off-Site Disposal

Groundwater

- Alternative #1-Bioremediation
- Alternative #2-Chemical Oxidation
- Alternative #3-Air Sparging/Soil Vapor Extraction
- Alternative #4-Treatment Wall
- Alternative #5-Pump & Treat

Based on both detailed and comparative analyses of remedial alternatives using regulatory criteria stipulated in the Massachusetts Contingency Plan (MCP) 310 CMR 40.0000, Alternative #1, Excavation & Off-Site Disposal and Alternative #2, Chemical Oxidation were selected as the preferred remedial action alternatives for abatement of wetland soil/sediment and groundwater, respectively.

1.0 *INTRODUCTION*

1.1 *BACKGROUND*

On behalf of Raytheon Company (Raytheon), Environmental Resources Management (ERM) has prepared this Phase III– Remedial Action Plan (Phase III) for an approximately 83-acre property located at 430 Boston Post Road in Wayland, Massachusetts (defined as the "Site", Figure 1). The Site, surrounding properties and physical features are shown in Figure 2.

The Phase III was prepared to satisfy requirements of the Massachusetts Contingency Plan (MCP), specifically 310 CMR 40.0850 for the Site. The Phase III is the third part of a five-phase process required under the MCP for assessment and remediation of a release(s) of oil and/or hazardous materials (OHM) to the environment. The Phase III is based on the results of the Phase II-Comprehensive Site Assessment (Phase II) completed for the Site.

The Phase III is used to identify remedial alternatives which are reasonably likely to achieve a level of "No Significant Risk", and where feasible, a Permanent Solution. The Phase III recommends that alternative(s) most likely to reduce the levels of OHM in the environment to levels that will achieve a Permanent Solution, if feasible.

1.2 *PURPOSE & SCOPE*

The purpose of the Phase III is to support the selection of the proposed remedial action alternative and documents the information, reasoning and results used to identify and evaluate remedial action alternatives in sufficient detail to support selection of the "preferred" remedial action alternative. In accordance with 310 CMR 40.0850, the Phase III includes three primary activities:

- Identification and initial screening of remedial technologies that are reasonably likely to be feasible and achieve a level of "No Significant Risk".
- Identification and detailed evaluation of remedial action alternatives to ascertain which alternatives will meet the

performance standards and requirements set forth in 310 CMR 40.0850, 40.0900 and 40.1000, and whether these alternatives constitute Permanent or Temporary Solutions.

- Selection of the preferred remedial action alternative(s) most likely to achieve a Permanent Solution.

1.3 REPORT ORGANIZATION

The report is organized to satisfy the requirements of the MCP (310 CMR 40.0850). The report contains the following sections:

Section 1.0 *Introduction*- describes the background, purpose and scope of the Phase III.

Section 2.0 *Summary of the Phase II –Comprehensive Site Assessment*- includes a summary of the Phase II conclusions.

Section 3.0 *Development of Remedial Action Objectives*- includes the identification of regulatory requirements, justification for selection of target cleanup levels and areas of OHM impacted media (i.e., groundwater and wetland soil/sediment) requiring abatement to achieve remedial goals.

Section 4.0 *Identification and Initial Screening of Remedial Technologies*- includes the identification of remedial technologies reasonably likely to achieve remedial goals and form the basis for selection of alternatives for detailed evaluation.

Section 5.0 *Detailed Evaluation of Remedial Alternatives*- includes an evaluation of the degree to which each alternative meets detailed evaluation criteria including; effectiveness, short-term and long-term reliability, technical difficulty, cost, risk, benefit, timeliness and aesthetic value.

Section 6.0 *Comparative Analysis of Alternatives*- includes a comparative analysis of criteria between alternatives including; effectiveness, short-term and long-term reliability, technical difficulty, cost, risk, benefit, timeliness and aesthetic value.

Section 7.0 *Recommended Remedial Action Plan*- includes the rationale for, and selection of, the preferred remedial action alternative(s) and a projected schedule for implementation under Phase IV Remedy Implementation Plan.

Section 8.0 *References*

2.0 SUMMARY OF PHASE II COMPREHENSIVE SITE ASSESSMENT

2.1 PHASE II SUMMARY

The Phase II included a series of field investigations through August 2001 to assess the source(s), nature and extent of impact from historic releases of OHM to the environment. Multiple short-term remedial response actions were completed during Phase I and Phase II to abate suspect sources of release including drywells, sumps, drains, catch basins, storage tanks and one localized fill area.

Phase II field sampling included soil, groundwater and wetland sediment, surface water and biota. The results were utilized to define the nature and extent of OHM in affected media and conduct a Method 3 Risk Characterization, including a Stage II Environmental Risk Characterization. The Phase II presented the following conclusions:

1) All Past Identified Sources of OHM Release Have Been Abated.

Decommissioning of the facility by Raytheon included abatement of residual OHM remaining within former structures (e.g., the stormwater conveyance system, boiler room pit and sump, and manhole W-4. (Refer to Figure 3 for former structures. Additional source abatement was conducted during and post-Phase I (Limited Removal Actions (LRAs) for drywells and the Release Abatement Measure (RAM) at test pit TP-3) and during the Phase II (RAM for the former No. 6 fuel oil tank WAY-02). As a result, all confirmed or probable sources of OHM release at the Site have been abated.

2) The Extent of Site OHM Impact Appears Limited to Soil, Groundwater and Wetland Soil/Sediment.

Residual OHM impacts are largely limited to soil, groundwater and wetland soil/sediment associated with the following former sources:

- Soil impacted by No. 6 fuel oil released from a former 20,000-gallon underground storage tank (WAY-02) located beneath former Building 3 and in the former courtyard between former Building Nos. 3 and 4 (Figure 3). This release (RTN 3-13302) was closed under the filing of a Class A-3 Response Action Outcome (RAO) Statement by the current property owner in October 1998.

- Groundwater is impacted primarily by trichloroethene (TCE) and associated degradation products, associated with a release from former manhole W-4 located adjacent to the north side of former Building 4 (Figure 3 and 4). The manhole was connected to piping located within the former Printed Circuit Board Shop within Building 4. Minor residual TCE impacts to groundwater have also been detected due to OHM releases discovered at TP-3 and drywell DW-05 (see Figures 3). Tetrachloroethene (PCE) has also been detected sporadically in groundwater and may be associated with previous historical uses. The main plume extends southwest from manhole W-4 and appears limited to depths of up to approximately 80 feet by underlying unconsolidated deposits. Extrapolation of the extent of groundwater impact downgradient indicates dilution to levels below detection limits.

- Wetland soil/sediment is impacted by polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and metals associated with historic inadvertent, incidental releases to the stormwater conveyance system and discharge at outfall OF-01 (Figures 3). The extent of impact appears limited to between 250 and 450 feet from OF-01 (Figures 5and 6). No evidence of adverse impact to the Sudbury River has been detected. Stunted vegetation (mainly cattail growth) attributable to Site OHM has been mapped within an approximately one-acre portion of the wetland adjacent to OF-1 (Figure 7). This condition constitutes a condition "readily apparent harm" (ARAH) that will likely require abatement.

3) OHM in Wetland Soil/Sediment and Groundwater Pose a Condition of "Significant Risk."

VOCs in groundwater and PCBs, PAHs and metals in wetland soil/ sediment pose a condition of "significant risk" to human health. This condition is based on the potential for future exposure by hypothetical receptors (residents living on the Site and trespassers, uses that are currently prohibited/restricted). Risks to human health posed by the Site under current land use conditions are considered negligible, since there is currently no complete exposure pathway (i.e., groundwater is not a current source of drinking water and access to impacted areas of the wetland will be restricted by fencing and signage until remedial actions can be completed). PAHs, PCBs and metals in wetland sediment surrounding the ARAH pose a condition of "significant risk" to the environment.

4) The Site Does Not Pose a "Significant Risk" of Harm to Human Safety & Public Welfare.

Site OHM does not pose a condition of "significant risk" to human safety or public welfare.

5) A Phase III-Remedial Alternative Evaluation is Necessary.

Pursuant to 310 CMR 40.0852, a Phase III evaluation shall be conducted for any disposal Site for which a Phase II has been completed and a RAO, in accordance with 310 CMR 40.1000, has not yet been achieved. The Phase III will include the identification of remedial alternatives to abate impacts to groundwater and wetland soil and sediment that pose a condition of "significant risk." The Phase III will conclude what the preferred remedial alternative(s) for the Site will be. Design and implementation of the remedy will be conducted under Phase IV.

3.0 REMEDIAL ACTION OBJECTIVES

3.1 OVERVIEW

The purpose of this section is to establish objectives for remedial action of affected media that will enable achievement of a Permanent Solution, if feasible. Remedial action objectives will be expressed as media-specific target cleanup goals for OHM in groundwater and wetland soil/sediment that if achieved, would restore the Site to a condition of "no significant risk", meet MCP performance standards for the filing of a Response Action Outcome (RAO) Statement and represent a Permanent Solution for the Site. Key MCP Response Action Performance Standards (RAPS) for achievement of a Permanent Solution include:

- Elimination or control of each source of OHM which is resulting, or is likely to result, in an increase in concentrations of OHM in an environmental medium, either as a consequence of a direct discharge, or through inter-media transfer (per 310 CMR 40.1003).
- Reduction in the concentration of OHM in affected media to levels that do not pose a condition of "significant risk" of harm to human health, safety, public welfare and the environment (per 310 CMR 40.1003).
- Reduction in the concentration of OHM in affected media to levels that would exist in the absence of the Site. Such measures shall, to the extent feasible, achieve or approach background levels of OHM in the environment as defined under 310 CMR 40.0006 (per 310 CMR 40.1020).
- Reduction in the overall mass and volume of OHM at the Site to the extent feasible, regardless of whether it is feasible to achieve one or more Temporary or Permanent Solutions, or whether it is feasible to achieve background for the entire Site (per 310 CMR 40.0191).
- Restoration of groundwater, where feasible, to the applicable standards of quality within a reasonable period of time to protect the existing and potential uses of such resources (per 310 CMR 40.0191).

Local, state and federal regulatory requirements applicable to the development of remedial action objectives and achievement of RAPS are discussed in this section by media.

3.2 *REMEDIAL ACTION OBJECTIVES*

3.2.1 *Target Media and OHM*

Based on the results of the Phase II, all past sources of OHM release have been eliminated. Residual OHM impacts are largely limited to TCE (and degradation by-products) and tetrachloroethene (PCE) in groundwater and PAHs, PCBs and metals in wetland soil/sediment. OHM in wetland soil and sediment do not appear to act as a source of impact to groundwater or surface water during periods of inundation, when the wetland is flooded and accessible to potential aquatic receptors. OHM in wetland soil and sediment may be a contributing source of impact to surface water existing as discontinuous pools or puddles under low-flow (worst-case) conditions. However, abatement of wetland soil/sediment is anticipated to result in abatement of impacts to surface water under low-flow conditions that are potentially attributable to wetland soil/sediment. Therefore, remedial action objectives will be developed for TCE, TCE degradation by-products and PCE in groundwater and PAHs, PCBs and metals in wetland sediment.

Remedial action objectives will not be developed for residual OHM in Site soil (exclusive of the wetland) or surface water. Supporting documentation for these conditions is presented in the Phase II Report and summarized below:

- Soil impacted by releases of OHM on-Site have been addressed by a previous RAO filing (a partial Class A-3 RAO was filed for RTN 3-13302 for the WAY-02 petroleum release) by the current property owner on 14 May 1999, or do not pose a condition of "significant risk" requiring abatement.
- Impacts to surface water within the wetland are limited to dissolved aluminum, cadmium, copper and zinc during dry periods when surface water is present as discontinuous pools or puddles not flowing to the river. Under these conditions, impacts to surface water are largely limited to areas where OHM in wetland soil and sediment is targeted for remediation. Therefore, abatement of impacts to surface water in these areas will be achieved through abatement of wetland soil/sediment. During periods of inundation when the wetland is flooded, impacts to surface water are limited to copper. The presence of copper in surface water is attributed to low pH conditions ubiquitous to the

Town of Wayland public water supply. Since the source of copper is considered a "local condition", no remedial abatement of surface water for copper is proposed.

3.2.2 *Target Cleanup Goals for Wetland Soil/Sediment*

Results of the human health and environmental risk characterizations presented in the Phase II indicate that PAHs, PCBs and metals in wetland soil/sediment pose a potential risk of harm to human health and the environment. Development of target cleanup goals for wetland soil and sediment are based on consideration of the estimated potential risk posed by PAHs, PCBs and metals to human health and the environment, applicable state and federal regulations governing wetlands remediation, applicable state and federal regulations governing the management of remediation wastes and consideration of the feasibility of abatement to background.

Based on vegetative mapping of the wetland, an approximately 0.6-acre area of stunted vegetative growth was identified adjacent to the former stormwater outfall (OF-01, based on a measured reduction in the density cattail stem growth, Figure 7). Correlation of OHM concentrations in wetland soil/sediment to OHM concentrations found in cattail roots within the area of stunted growth suggest that the area of stunted growth may represent a phytotoxic effect of OHM on the cattails, resulting in inhibited plant growth. In accordance with 310 CMR 40.0955(3) and 40.0995(3)(b)(1)(b), visual evidence of stressed biota attributable to Site OHM represents a condition of "readily apparent harm" constituting a condition of "significant risk." The area of "readily apparent harm" (ARAH), corresponding to stunted vegetative growth, is displayed in Figures 7 and 8.

In accordance with 310 CMR 40.0995(b)(2) and available MA DEP guidance, the Stage II environmental risk characterization (Stage II) was designed to focus on the evaluation of potential risk to the environment posed by OHM in wetland soil and sediment excluding areas that are deemed to pose a "significant risk" based on readily apparent harm. Therefore the Stage II excluded quantitative evaluation of the ARAH, since the ARAH is by definition deemed to pose a condition of "significant risk" requiring abatement.

Based on the preliminary results of the Stage II, the boundary of the ARAH was expanded to incorporate adjacent sample locations where the concentrations of OHM in wetland soil and sediment were similar to those detected within the mapped ARAH. The resulting Expanded ARAH is displayed in Figure 8. The Expanded ARAH was established based on the following criteria:

1. Concentrations of OHM within the Expanded ARAH correspond to the 95 percent upper confidence limit of the arithmetic mean of OHM concentrations within the ARAH (mapped area of stunted vegetative growth). Based on similarities in OHM distributions within the ARAH to those within the Expanded ARAH, and preliminary estimates of the potential risks to the environment, the Expanded ARAH maintained a reasonable likelihood to pose a condition of "significant risk" to the environment, requiring abatement.

2. Concentrations of total PCBs within the Expanded ARAH exceeded thresholds stipulated under the federal Toxic Substance Control Act (TSCA) that would require removal to meet federal regulations for the management of PCB remediation waste (i.e., total PCBs exceeding 50 parts per million (ppm)).

Based on the above criteria, the Expanded ARAH was identified as an area that would likely require remedial abatement. The Expanded ARAH is estimated to comprise a cumulative area of 1.5 acres, with OHM impacts limited largely to the upper 18 inches of wetland soil/sediment. As a result, quantitative assessment of the potential risks posed by OHM in wetland soil/sediment focused on the area of the wetland outside of the boundary of the Expanded ARAH (i.e. the surrounding area representing the remainder of the wetland). This approach enabled the quantitative risk assessments to focus on surrounding area of the wetland where the need for remedial abatement was not readily apparent, thereby maximizing the usability of the quantitative risk estimates in developing risk-based remedial action objectives.

Results of the human health risk characterization indicate that OHM in areas of the wetland outside of the Expanded ARAH do not pose a condition of "significant risk" to human health. Therefore, abatement of the Expanded ARAH would meet MA DEP risk management criteria for protection of human health for "reasonably foreseeable" future uses of the wetland.

As indicated in the human health risk characterization, this approach assumes that residential use of the wetland is not a "reasonably foreseeable" future use. This assumption is based on the existence of State and federal regulations prohibiting future development of the wetland for residential use including: the Federal Wetlands Protection Act

(33 CFR 320-330), the Massachusetts Wetland Protection Act (310 CMR 10.00), federal regulations (FEMA) prohibiting development of the floodplain and inclusion of the reach of the Sudbury River adjacent to the Site on the national list of Wild and Scenic Rivers. Therefore, limiting abatement of OHM in wetland soil/sediment to the Expanded ARAH assumes that future residential use of the wetland would be prohibited by the current deed restriction, and that the deed restriction would be amended to include portions of the wetland not currently included.

Similarly, results of the Stage II indicate that OHM, in areas of the wetland outside of the Expanded ARAH, do not pose a condition of "significant risk" to the environment. Therefore, abatement of the Expanded ARAH would meet MA DEP risk management criteria for protection of the environment.

In accordance with 310 CMR 40.1020, the feasibility of abatement of OHM in wetland soil/sediment to background was considered in the development of remedial action objectives. However, abatement of wetland soil/sediment to background is excluded in the development of target cleanup goals based on requirements of the Massachusetts Wetlands Protection Act 310 CMR 10.00. Specifically, 310 CMR 10.53, General Provisions, Subpart (3), regarding considerations by authorities issuing an Order of Conditions for work within a wetland resource area, part (q) indicates, "Assessment, monitoring, containment, mitigation, and remediation of, or other response to, a release or threat of release of oil and/or hazardous materials in accordance with the provisions of 310 CMR 40.0000 and the following general condition (although no such measure may be permitted which is designed in accordance with the provisions of 310 CMR 40.1020 solely to reduce contamination to a level lower than that which is needed to achieve a condition of "No Significant Risk" as defined in 310 CMR 40.0006(10)).

Risk-based, contaminant-specific target cleanup goals for wetland soil/sediment necessary to satisfy MCP RAPS for achievement of a Permanent Solution are summarized in the table below. These target cleanup goals represent the average residual concentration of OHM in wetland soil/sediment following abatement of the Expanded ARAH.

Wetland Soil/Sediment Target Cleanup Goals

Compound	*Target Cleanup Goals (ppm)*
Total PCBs	2
Total PAHs	9
Chromium (trivalent)	350
Copper	370
Lead	220
Silver	15

Since abatement of wetland soil/sediment includes the management of PCB remediation waste, it will be necessary to obtain US EPA approval of remediation plans pursuant to TSCA regulations 40 CFR 761.61 prior to implementation of remedial actions. Therefore, an application for risk-based disposal approval under 40 CFR 761.3(2)(c) will be filed with US EPA Region I. Therefore, final target cleanup goals for total PCBs in wetland soil/sediment will be subject to US EPA approval. The areas targeted for abatement are displayed in Figure 8.

3.2.3 *Target Cleanup Goals for Groundwater*

Since the Site is located within a Current Drinking Water Source Area (a Zone II aquifer protection district for the Baldwin Pond Wellfield), abatement measures must reduce the concentrations of VOCs in groundwater to applicable Massachusetts Maximum Contaminant Levels (MMCLs) in order to achieve a Permanent Solution. A reduction in VOC concentrations to MMCLs would achieve a condition of "no significant" risk to human health under future conditions (i.e., groundwater is not currently used as a source of drinking water within the defined or projected extent of the plume). Based on exposure point concentrations (EPCs) utilized in the risk assessment, VOCs exceeding applicable MMCLs are summarized in the table below.

VOCs in Groundwater with EPCs Greater than MMCLs

Compound	Exposure Point Concentration (EPC) (ug/l) @ Well Location	Massachusetts Maximum Contaminant Level (ug/l)
Trichloroethene (TCE)	323 ug/l @ MW-43S	5 ug/l
Tetrachloroethene (PCE)	28 ug/l @ HA-104	5 ug/l
Vinyl Chloride (VC)	4.5 ug/l @ MW-13	2 ug/l

Notes: EPCs for TCE and PCE represent the average concentration over time at the monitoring well exhibiting the highest concentration in groundwater. The EPC for VC represents the maximum concentration detected at well MW-13 (destroyed) since this is the most recent monitoring result.

Quantitative estimates of the potential risk posed by TCE, PCE and VC in groundwater to a future residential receptor consuming impacted groundwater indicate that each of the above VOCs exceed the Excess Lifetime Cancer Risk (ELCR) threshold of 1E-05 set by MA DEP, driving a condition of "significant risk" in groundwater. In addition, the estimated ELCR for 1,1-dichloroethene (DCE), a degradation by-product of TCE, also exceeds the MA DEP threshold of 1E-05 at an EPC of 5.7 ug/l, but is below the MMCL of 7 ug/l. Since the occurrence of DCE in groundwater is coincident with that of TCE, abatement of TCE is likely to reduce DCE below levels triggering an ELCR of 1E-05.

The level and extent of TCE, PCE or VC in groundwater is not anticipated to adversely impact down-gradient surface water quality or potential environmental receptors. A reduction in the concentrations of VOC to MMCLs would meet RAPS for achievement of a condition of "no significant risk." Therefore, MMCLs are adopted as initial target cleanup goals for VOCs in groundwater. The extent of TCE impact in groundwater is mapped in Figure 4.

To achieve a Permanent Solution, RAPS also requires consideration of abatement to background levels, if feasible. Available MA DEP guidance indicates that "achievement" of background is considered "generically infeasible" for chlorinated hydrocarbons in groundwater, but indicates that a reduction in contaminant concentrations should "approach" background, if feasible. Therefore, as a secondary target cleanup goal, abatement of TCE, PCE and VC in groundwater will attempt to "approach" background, if feasible. The feasibility of abatement of VOCs in groundwater to "approach" background will be evaluated based on the success of remedial measures at reducing VOC concentrations in groundwater to MMCLs.

4.0 IDENTIFICATION AND INITIAL SCREENING OF REMEDIAL TECHNOLOGIES

4.1 OVERVIEW

This section presents a review of remedial technologies that were evaluated based on their ability to achieve abatement of OHM in wetland soil/sediment and groundwater. Selected technologies were screened using the specific criteria outlined in the following section. In accordance with 310 CMR 40.0856 summary of the screening process for the remedial technologies is provided in Table 1. Technologies that passed the screening were incorporated into a series of media-specific remedial actions alternatives; proposed remedial management options consisting of both engineered controls and risk management strategies (e.g., institutional controls and/or monitoring plans). Section 5.0 includes the identification and detailed evaluation of remedial alternatives.

4.2 SCREENING CRITERIA

The screening process is intended to identify those remedial technologies that maintain a potential to reduce OHM concentrations in wetland soil/sediment and groundwater to target cleanup goals. The screening includes an evaluation of the ability of promising remedial technologies to meet the following criteria:

- Effectiveness – the ability of the technology to achieve a permanent or temporary solution; i.e., meeting remedial action objectives.
- Implementability – the availability of personnel to implement the technology.

4.3 TECHNOLOGY SCREENING

4.3.1 Wetland Soil/Sediment

Natural Attenuation

Natural attenuation is the process by which the concentrations of OHM in the environment are reduced by natural biological, chemical or physical processes rather than by implementation of engineered processes. Natural attenuation would not be a suitable technology for abatement of wetland soil/sediments since a condition of "readily apparent harm" would remain, prohibiting achievement of either a Temporary or Permanent Solution. Therefore, natural attenuation is not considered to be an effective technology and is eliminated from further consideration.

Containment

Containment of wetland soil/sediment within an engineered landfill may be effective technology to achieve a Temporary Solution, but is unlikely to be implementable due to regulatory restrictions. Therefore, containment technologies are eliminated from further consideration.

Removal by Excavation

Removal by excavation is a common technology used to remediate soils/sediment within a wetland. Excavation would require extensive permitting, on- or off-Site treatment and disposal of remediation wastes generated, replication of wetland habitat in disturbed areas and monitoring/ maintenance of habitat recovery. Based on the size (1.5 acres), depth (up to 18 inches) and location of the area targeted for abatement, excavation would require construction of flood controls and temporary roads to facilitate access and removal by heavy equipment. In addition, staging areas would need to be constructed on Site for dewatering or treatment and transportation for off-Site disposal.

Removal by excavation would enable achievement of a Permanent Solution and is therefore an effective technology. Excavation is implementable, since Site physical conditions are adequate to enable excavation and the equipment and persons are available. Therefore excavation is carried forward as a technology suitable for development of remedial alternatives and detailed analysis.

On-Site /Off-Site Treatment

Reasonably feasible treatment technologies that could be implemented on- or off-Site for abatement of OHM in wetland soil/sediment include:

- Stabilization/ Solidification: an ex-situ process that immobilizes OHM contaminated soil/sediment into building materials or structural fill. The stabilized/solidified mixture would immobilize the contaminants, including PCBs, PAHs and metals. This treatment technology is potentially effective in achieving a Permanent or Temporary Solution, is implementable, and is therefore carried forward.
- Thermal Treatment: a variety of high (e.g., incineration) and low temperature (desorption) thermal treatment technologies are available to treat organic contaminants in wetland soil/sediment, but would not be effective in abate of metals. Therefore, thermal treatment technologies are excluded from further consideration since they would not be effective in achievement of a Permanent or Temporary Solution.
- Soil Washing: an ex-situ process that reduces the volume of contaminated material by physical and chemical separation methods to remove organics and metals. The smaller volume of residual waste would require additional treatment and/or disposal. However, this method is not generally effective in treating fine grain sediments containing high organic carbon content like those in the wetland. Therefore this technology is eliminated from further consideration based on its low rate of success in remediation of wastes with characteristics similar to that on-Site.
- Phytoremediation: an in situ treatment process that utilizes plants to extract, degrade or volatilize OHM such as metals and PAHs; however, has not been proven successful in the abatement of PCBs. Therefore, phytoremediation is unlikely to be effective in achieving a Temporary or Permanent Solution and is eliminated from further consideration.

Off-Site Transportation &Disposal

Dewatered wetland soil and sediment could be transported to a permitted RCRA or TSCA disposal facility. Off-Site disposal would be effective in achieving a Permanent Solution and is commonly implemented. Therefore off-Site disposal is retained as an effective and implementable technology.

Remedial Alternatives for Wetland Soil/Sediment

Based on the technology screening, the following remedial alternatives are identified as candidates for the abatement of wetland soil/sediment and are carried forward for detailed evaluation:

- Alternative #1 – Excavation & Off-Site Disposal
- Alternative #2 – Excavation, On-Site Stabilization & Off-Site Disposal

4.3.2 Groundwater

Bioremediation

Bioremediation involves intrinsic biodegradation of OHM in groundwater by addition of bio-stimulating compounds. Bioremediation would involve the injection of one or more of the following: electron donors (i.e. carbon substrate), nutrients, electron acceptors or exogenous microbes to promote degradation of the contaminants. Typically, an anaerobic environment is required for degradation of chlorinated VOCs. Bioremediation also requires that extensive groundwater sampling and modeling be performed to evaluate the effectiveness of the technology.

Bioremediation is an effective technology to reduce concentrations of chlorinated VOCs in groundwater. Bioremediation has previously been implemented at Sites with groundwater impacts in overburden. This technology is compatible with Site conditions and could be effective at achieving a Permanent Solution; therefore it is carried forward for detailed analysis.

In-Situ Chemical Oxidation

In-situ chemical oxidation involves the injection of a chemical oxidant, to chemically degrade the contaminants into non-toxic by-products. However, there are often competing reactions with naturally occurring reduced or oxidizable species such as metals or natural organic material. The total non-contaminant related oxidant demand is referred to as the soil oxidant demand. The type and quantity of oxidant is dependent on the combined natural oxidant demand of aquifer and the demand of the contaminants present in groundwater.

A variety of chemical oxidants exist, including hydrogen peroxide, permanganate, persulfate and ozone. All of these oxidants have been proven effective at destroying TCE. The use of permanganate or persulfate for the Site has been considered. Persulfate is less susceptible to soil oxidant demand than permanganate. Therefore, the final oxidant selection will be based on data obtained from the proposed bench-scale soil oxidant demand test (i.e., persulfate will likely be used if soil oxidant demand is high and permanganate will likely be used if soil oxidant demand is low).

Successful implementation of in-situ chemical oxidation would be dependent on the effectiveness of delivering oxidants to the impacted groundwater. Transport of the oxidants within the aquifer may be conducted under either natural or forced hydraulic gradients.

In-situ chemical oxidation is an implementable technology that has historically been effective in reducing the concentrations of chlorinated ethenes in groundwater. This technology could be effective at achieving a Permanent Solution and is therefore carried forward for detailed analysis.

Air Sparging/Soil Vapor Extraction

Air Sparging (AS) involves the injection of air into groundwater to promote partitioning of VOCs into a vapor phase by volatilization. Soil Vapor Extraction (SVE) involves the removal of VOCs from the vadose zone using a vacuum extraction system. The combination of these technologies (AS/SVE) can be effective at reducing the mass of VOCs in groundwater.

The technology is readily implementable, potentially compatible with Site subsurface conditions and maintains the potential to achieve a Permanent Solution. Therefore, this alternative is carried forward for detailed evaluation.

Treatment Wall

Treatment walls involve the emplacement of permeable reactive media, such as zero-valent iron, into the subsurface to treat contaminated groundwater as it passes through the wall under natural hydraulic gradients. Zero-valent iron is a strong chemical reductant that has been shown to reductively dechlorinate a variety of chlorinated solvents.

Treatment walls can be installed by trenching or by pressure injection of nanometer-sized iron colloids into the aquifer. Groundwater can be directed to the treatment wall using an impermeable barrier wall (i.e., funnel and gate). Treatment walls are primarily used for migration control and do not decrease the mass of chlorinated solvents upgradient of the wall. Therefore, long-term monitoring must be completed to evaluate the efficacy of the wall over time. Biofouling can occur within the treatment wall, resulting in decreased hydraulic conductivity and reactivity of the wall. If this occurs, then the wall would require cleaning or replacement.

This technology is implementable and may be effective at achieving a Permanent Solution at the Site. Therefore this technology is carried forward for detailed evaluation.

Pump and Treat

Pump and treat is a technology that includes a variety of process options. The three basic components of pump and treat are extraction, treatment, and discharge. A series of extraction wells screened in the overburden could be used to intercept the contaminant plume. The extracted groundwater could be treated by a number of processes, such as air stripping, activated carbon or chemical/ultraviolet oxidation. The treated groundwater would then be reinjected at the Site, or discharged to the stormwater system.

Pump and treat technology is commonly used to prevent contaminant migration. With proper well placement, pump and treat can be effective at minimizing contaminant migration. Therefore, this alternative is carried forward for detailed evaluation.

Remedial Alternatives for Groundwater

Based on the technology screening, the following remedial alternatives are identified as candidates for the abatement of groundwater and are carried forward for detailed evaluation:

- Alternative #1 - Bioremediation
- Alternative #2 - Chemical Oxidation
- Alternative #3 – Air Sparging/Soil Vapor Extraction (AS/SVE)
- Alternative #4 - Treatment Wall
- Alternative #5 – Pump and Treat

5.0 DETAILED EVALUATION OF ALTERNATIVES

5.1 OVERVIEW

Pursuant to 310 CMR 40.0857, this section includes a detailed evaluation of remedial alternatives identified in the initial screening of remedial technologies presented in the previous section. Proposed remedial alternatives for each media are listed below and consist of both engineered controls and risk management strategies.

Wetland Soil/Sediment

- Alternative #1 – Excavation & Off-Site Disposal
  - Institutional controls
  - Permitting
  - Excavation and on site management of OHM impacted soil/sediment (3,700 cubic yards)
  - Off-site transportation, treatment and/or disposal
  - Wetland restoration and monitoring
- Alternative #2 – Excavation, On-Site Stabilization & Off-Site Disposal
  - Institutional controls
  - Permitting
  - Excavation and on site management of OHM impacted soil/sediment (3,700 cubic yards)
  - On-site stabilization
  - Off-site transportation and disposal
  - Wetland restoration and monitoring

Groundwater

- Alternative #1 - Bioremediation
  - Biogeochemical groundwater monitoring
  - Microcosm studies
  - Pilot study
  - System design and installation
  - Groundwater monitoring
- Alternative #2 - Chemical Oxidation
  - Bench-scale study

    - Pilot Study
    - System design and implementation
    - Groundwater monitoring
- Alternative #3 – Air Sparging/Soil Vapor Extraction (AS/SVE)
    - Pilot study
    - System design and installation
    - Operations and maintenance
    - Groundwater monitoring
- Alternative #4 - Treatment Wall
    - System design and installation
    - Operations and maintenance
    - Groundwater monitoring
- Alternative #5 – Pump and Treat
    - System design and installation
    - Operations and maintenance
    - Groundwater monitoring

Pursuant to 310 CMR 40.0858, the detailed evaluation must consider seven criteria for each alternative, which are defined in Section 5.2. Each wetland alternative is evaluated relative to these criteria in Section 5.3. Each groundwater alternative is evaluated relative to these criteria in Section 5.4. A comparative analysis of the alternatives relative to each screening criteria is presented by media in Section 6.0.

5.2 SCREENING CRITERIA

A detailed evaluation of the alternatives includes a brief description of the site-specific aspects of each alternative. This is followed by an evaluation of each alternative using the following criteria:

Effectiveness — This criterion identifies whether the alternative will achieve a Permanent or a Temporary Solution. It also addresses how contaminant concentrations will be reduced and the likelihood that residual concentrations will approach or achieve "background."

Reliability — This criterion addresses the likelihood that the alternative will be successful and the effectiveness of any measures required to manage waste streams generated by the alternative.

Implementability	This criterion addresses the technical complexity of the alternative and its compatibility with site constraints. It also addresses whether the remedial alternative has successfully been used at other sites in similar situations.
Cost	This criterion addresses the short-term and long-term costs associated with implementing the alternative. A 30-year operation and maintenance period was assumed using a seven percent discount rate for each alternative. The costs presented are intended for use in the comparative analysis in Section 6.0.
Risks	This criterion addresses the expected short-term and long-term risk associated with the alternative.
Benefits	This criterion addresses the expected benefits associated with the alternative.
Timeliness	This criterion compares the timeliness of each alternative in terms of achieving a level of no significant risk. A 30-year evaluation period was selected for the purposes of the evaluation.

Note: The cost estimates presented in this section are not intended for budgeting or contracting purposes, but were prepared for comparison of the alternatives. Actual costs could vary. Supplemental investigation activities and detailed-design phases would provide the specific information needed to increase the accuracy of the cost estimates.

5.3 WETLAND SOIL/SEDIMENT

5.3.1 Alternative #1-Excavation & Off-Site Disposal

The primary engineering and management components of Alternative #1 include institutional controls, permitting, excavation and segregation, dewatering, off-site disposal and wetland restoration. Each of these components is described briefly below:

- *Implementation of Institutional Controls* – includes modification of the existing AUL on the property.
- *Permitting* – obtain approval from permitting authorities, including DEP, EPA, Wayland Conservation Commission and the U.S. Army Corps of Engineers.
- *Excavation and Segregation* – excavation and segregation of remediation waste into stockpiles specific to waste characteristics and disposal facility receiving requirements (e.g., as a non-RCRA, RCRA or TSCA remediation waste).
- *Dewatering*- decrease the water content of the remediation waste and treat the water either on or off-site.
- *Transportation & Disposal* –transport remediation waste to licensed disposal facilities based on waste characterization and receiving facility requirements.
- *Wetland Restoration* – restoration of disturbed wetland habitats including replacement of substrates, replication of wetland plants species and monitoring of habitat recovery.

Effectiveness

Excavation and off-site disposal would reduce OHM to levels that would not pose a condition of "significant risk" to human health or the environment and enable achievement of a Permanent Solution. This alternative would not destroy or detoxify OHM and would not reduce the residual levels of OHM in the environment to background, since reduction to background is prohibited under regulations of the Wetland Protection Act. Residual levels of OHM in the wetland would require modification of the existing AUL to include areas not currently restricted (i.e., the Hamlen Parcel).

Reliability

Excavation and off-site disposal is a reliable remedial method that has been used for decades to abate OHM in wetland environments. Therefore, this alternative carries a high degree of certainty in its ability to meet target cleanup goals necessary to achieve a Permanent Solution. Institutional controls would be an effective, reliable means of managing potential risks posed by residual OHM concentrations remaining following remediation.

Implementability

Removal by excavation is a common technology used to remediate soils/sediment within a wetland. Excavation would require extensive permitting, on- or off-site treatment and disposal of remediation wastes generated, replication of wetland habitat in disturbed areas and monitoring/ maintenance of habitat recovery. Based on the size (1.5 acres), depth (up to 18 inches) and location of the area targeted for abatement, excavation would require construction of flood controls and temporary roads to facilitate access and removal by heavy equipment. The total volume of remediation waste generated by this alternative is estimated at 3,700 cubic yards. In addition, staging areas would need to be constructed on Site for dewatering or treatment and transportation for off-Site disposal. Therefore, excavation and off-site disposal is deemed to be implementable.

Cost

The cost estimate for the off-site treatment/disposal alternative is summarized in Table 2. For budgeting purposes, it has been assumed that the wetland soil and sediment would be disposed of off-site at a licensed TSCA disposal facility. The estimated cost for this alternative is $4,070,000. On-going operation and maintenance would include monitoring restoration of the replicated wetland, estimated at approximately $35,000 annually for the first five years following completion of wetlands restoration. Therefore, the total present worth cost of this alternative is estimated at $4,224,000.

Risks

Excavation and off-site disposal would provide a long-term risk reduction, but a short-term loss of habitat functions. Effective management of remedial actions and remediation waste would ensure protection of human health (use of personal protective equipment) and the environment (engineering controls) during implementation, anticipated to require from three to four months to complete. Restoration of habitat is projected to take years.

Benefits

Excavation and off-site disposal would result in a short-term loss of habitat value, but be beneficial to the long-term restoration of natural resources by replicating currently stressed vegetative wetlands. Restoration would also avoid any future loss in value of the site.

Timeliness

Excavation and off-site disposal would expedite achievement of a condition of "no significant risk" to human health and the environment by eliminating the potential for OHM exposure. This criterion is weighted most heavily in the detailed evaluation of the alternatives for abatement of wetland soil/sediment, since stressed wetlands vegetation has triggered an Imminent Hazard, pursuant to 310 CMR 40.0955 (3), requiring timely implementation of response actions.

5.3.2 Alternative #2- Excavation, On-Site Stabilization & Off-Site Disposal

The primary engineering and management components of Alternative #2 are identical to Alternative #1, with one exception; remediation wastes would be treated on site through stabilization/solidification prior to disposal off-site. Therefore, the primary criteria that require consideration in a detailed analysis are cost and timeliness, since effectiveness, reliability, implementability, risks, benefits and timeliness would be generally similar to Alternative #1.

Cost

The cost estimate for the Excavation, On-Site Stabilization & Off-Site Disposal is summarized in Table 3. For budgetary purposes it is assumed that thermal treatment would be used. The estimated cost for this alternative is $4,660,000. On-going operation and maintenance would include monitoring restoration of the replicated wetland, estimated at approximately $35,000 annually for the first five years following completion of wetlands restoration. Therefore, the total present worth cost of this alternative is estimated at $4,814,000.

Timeliness

It is estimated that this alternative would require approximately four to six months (i.e., requiring from 25 to 50 percent more time than Alternative #1).

5.4 GROUNDWATER

5.4.1 Alternative #1 - Bioremediation

Biological remediation is a method that relies on microbes to degrade contaminants in-situ. TCE, PCE and DCE can be naturally degraded in a reducing (sulfidic or methanogenic) environment through the process of reductive dehalogenation. The more chlorinated the compound the more susceptible it is to reductive dehalogenation. For example, PCE is more rapidly dehalogenated than DCE. Reductive dehalogenation is inhibited in aerobic environments.

In addition to a reducing environment, the dehalogenation process requires four essential elements: microbes, nutrients, a carbon source (i.e. substrate), and electron donors. Bioremediation involves maintaining the right balance of these elements in the subsurface to maximize the long-term degradation rate. Each element is described below.

- Dehalogenating microbes are likely present in the aquifer. However, indigenous microbes may not be capable of complete reductive dehalogenation. In many cases, the process only proceeds to the production of DCE and complete degradation to ethene does not occur. It may be beneficial to inject exogenous microbes that are known to be effective at degrading chlorinated solvents.
- Nutrients are required to optimize microbial activity. Nitrogen and phosphorous are the most common nutrient supplements that are used to enhance the natural degradation process. The amount of nutrients that are added is contingent upon site-specific characteristics. In some cases, naturally occurring nutrients in the subsurface are sufficient to promote bioremediation.
- Natural carbon sources are sometimes sufficient to maintain a healthy microbe population and optimize the rate of VOC degradation, but a carbon source (i.e., substrate) can also be added.
- Electron donors are necessary for the dehalogenation process to proceed. Chlorinated solvents, such as TCE, serve as electron acceptors; therefore, an electron donor must be present in the aquifer. If there are not sufficient electron donors in the subsurface, then compounds such as hydrogen, glucose or methanol must be added. Some of these compounds may also serve as a carbon source.

The primary components of Alternative #1 include biogeochemical monitoring, microcosm studies, pilot study, system design and installation and groundwater monitoring. Each of these components is described briefly below:

- *Biogeochemical monitoring* –collection of groundwater data to evaluate oxidation-reduction conditions, organic carbon concentrations, presence of electron acceptors, nutrient concentrations and the presence of biological activity.
- *Microcosm studies* –laboratory studies involving various combinations

of substrates, nutrients and exogenous microbes (i.e., bioaugmentation).

- *Pilot study* – field implementation of a small-scale system designed based on results of the microcosm study to evaluate if results of the most successful laboratory microcosm can be repeated at the Site.
- *System design and implementation* – design and construction of a full-scale system based on results of the microcosm and pilot studies.
- *Groundwater monitoring* – conduct long-term groundwater monitoring to evaluate the efficacy of the system and modify system parameters over time, if necessary.

Effectiveness

There is limited evidence at the site of biologically-mediated TCE degradation (i.e. limited evidence of daughter products such as DCE and VC). Historic groundwater monitoring data indicate that the aquifer is aerobic. Aerobic conditions would require injection of a significant amount of substrate using an extensive injection well network over a relatively long period of time to create anoxic conditions. Bench-scale and pilot-scale studies would have to be completed to determine quantities and type of substrate to be added. Bioremediation is a technology that has the potential to be effective in achieving a Permanent Solution and/or background conditions within the foreseeable future.

Reliability

The variability associated with creating a reducing environment in a currently oxidized subsurface could affect the reliability of bioremediation at the site. Bench-scale and pilot-scale studies would need to be performed to better evaluate the reliability of bioremediation at this site.

Implementability

This alternative would be feasible to implement. The plume is accessible from the property parking lot where additional wells or injection systems could be installed. There are existing monitoring wells that could also be utilized during the pilot scale study. Bioremediation has been successfully implemented at several sites to remediate TCE impacts to groundwater.

Cost

It is generally cost prohibitive to create methanogenic over large areas when initial aquifer conditions are oxygenated. The costs associated with the bioremediation alternative are summarized in Table 4. Initial capital costs are estimated at $375,875. The annual operation and maintenance cost is estimated to be $216,000. The present worth of this alternative is estimated at $2,800,000.

Risks

The short-term risk associated with this alternative is the potential for worker exposure to site contaminants. Precautions would need to be taken during the drilling to minimize this possibility. Potential worker exposure to site contaminants would be minimized since personnel trained in hazardous waste operations would be installing the wells and appropriate precautions would be taken to prevent exposure.

There are no long-term risks associated with this technology. However, if bioremediation were only partially successful, it would continue to allow impacted groundwater to migrate. Long-term groundwater monitoring would need to be performed. The operation and maintenance of a bioremediation system is not expected to pose any long-term risks.

Benefits

The benefit of bioremediation is that an enhanced natural process could be used to achieve the remedial action objectives with minimal disturbance of site operations and without the generation of remediation wastes requiring treatment or disposal. Bioremediation would likely be beneficial in restoring groundwater quality to achieve a Permanent Solution and minimize the potential for future degradation of property value.

Timeliness

Even if effective, bioremediation would require time for microbial populations to acclimate to site conditions and could take a few years to achieve the groundwater remedial action objectives. Due to the variability of natural degradation processes and site conditions, it is difficult to predict the time frame for this alternative.

5.4.2 *Alternative #2 – In Situ Chemical Oxidation*

This alternative involves the injection of an oxidant (i.e., permanganate or persulfate) to chemically transform chlorinated ethenes to innocuous by-products (e.g., carbon dioxide, water and chloride). Permanganate and persulfate are non-selective oxidants. This means that in addition to chlorinated ethenes the oxidant will oxidize other reduced soil and groundwater constituents, such as natural organic carbons (i.e., humic and fulvic acids) and reduced minerals. The soil oxidant demand will be determined using bench-scale laboratory tests. The concentration and volume of oxidant to be injected will be calculated using the soil oxidant demand and the observed concentrations of chlorinated ethenes at the Site.

The primary components of Alternative #2 include soil oxidant demand bench-scale testing, pilot study, system design and implementation and groundwater monitoring. Each of these components is described briefly below:

- *Soil oxidant demand bench-scale testing* –laboratory study that evaluates the naturally-occurring soil oxidant demand at the Site.
- *Pilot study* – field implementation of a small-scale system designed based on results of the soil oxidant demand test to evaluate if in situ chemical oxidation can be effectively implemented given Site hydrogeologic conditions.
- *System design and implementation* – design and construction of a full-scale system based on results of the bench-scale and pilot studies.
- *Groundwater monitoring* – conduct long-term groundwater monitoring to evaluate the efficacy of the system and modify system parameters over time, if necessary.

Effectiveness

Chemical oxidation is an effective technology to destroy a wide range of chemicals, including chlorinated ethenes. The actual effectiveness of this technology at the site could be determined by the performance of bench-scale and/or pilot-scale studies. Based on ERM's experience in utilizing chemical oxidation at sites with similar contaminants and hydrogeologic characteristics, this alternative maintains the potential to be effective in achieving a Permanent Solution.

Reliability

Chemical oxidation is a well established technology with a history of success at mitigating chlorinated ethene impacts in groundwater. Based on our experience implementing this technology at similar sites, there is a high degree of certainty that it could be effectively implemented at this Site to achieve a Permanent Solution. The reliability of the technology is affected by the oxidant demand of the aquifer and the ability to distribute oxidant to the impacted media. The results of the bench scale and pilot scale studies will be better indicators of the reliability of the technology at the site.

Implementability

This alternative is feasible to implement. Chemical oxidation has been successfully implemented at several sites with similar subsurface impacts and hydrogeologic conditions. The plume is accessible from the parking lot, except for the area under building, where natural or forced gradients may be used to transport oxidants. Existing monitoring wells can be utilized during the pilot study.

Cost

The costs associated with chemical oxidation are summarized in Table 5. Initial capital costs are estimated at $802,125. Annual Operating costs are estimated at $31,200. The present worth of this alternative is estimated at $900,000.

Risks

Short-term risks associated with this alternative include the potential to mobilize contamination and the potential for worker exposure to site contaminants and oxidants. Precautions would need to be taken during the installation of delivery wells to minimize this possibility. Worker exposure to site contaminants would be minimized since personnel trained in hazardous waste operations would be installing the wells and appropriate precautions would be taken to prevent exposure.

Benefits

A benefit of chemical oxidation is that it can be implemented with minimal disturbance to the site and without waste generation. If successful, chemical oxidation will reduce the impact of chlorinated VOCs to the aquifer to achieve a Permanent Solution and minimize the potential for future degradation of property value.

Timeliness

When effective, chemical oxidation can reduce concentrations of chlorinated ethenes in groundwater significantly over a relatively short period of time. The timeliness of this technology can be better predicted following the bench scale and pilot scale studies.

5.4.3 Alternative #3 - Air Sparging/Soil Vapor Extraction (AS/SVE)

Air sparging (AS) is a remedial method designed to partition VOCs in groundwater from dissolved phase to vapor phase. Air bubbled through the aquifer acts as a stripper, volatilizing chlorinated ethenes into the air stream, which transports the vapor phase into the vadose zone. Soil vapor extraction (SVE) technology is utilized to remove VOCs from the vadose zone by inducing a vacuum to promote air movement through the soil. The extracted air stream is then treated and released to the atmosphere.

For purposes of this feasibility study, a continuous wall of injection and extraction points could be installed at the site boundary (approximately 1,500 feet long) to prevent migration of impacted groundwater off the former Raytheon property. Injection points would be placed every forty feet. Connectivity analysis would be performed to determine exact spacing. Extraction points will be installed within a twenty-foot radius of the injection points, in two rows, on both sides of the injection points.

The AS system would consist of an air compressor, blower, and pipe manifold to deliver air stream to the aquifer. The SVE system would consist of a vacuum blower, moisture separator and vapor phase activated carbon vessels.

Limiting factors are:

- Air flow through the vadose zone may not be uniform. Soil heterogeneity may cause some zones to be relatively unaffected. Large screened intervals are required in extraction wells for soil with highly variable permeabilities or stratification, which may result in uneven delivery of gas flow from the contaminated regions.

- Depth of contaminants and specific site geology must be considered. Air injection wells must be designed for site-specific conditions.

- Soil that has a high percentage of fines and a high degree of saturation will require higher vacuums (increasing costs) and/or hindering the operation of the in situ SVE system.

- Soil that has high organic content or is extremely dry has a high sorption capacity for VOCs, which results in reduced removal rates.

- SVE is not effective in the saturated zone; however, lowering the water table can expose more media to SVE.

- Injection pressures may cause groundwater table mounding.

The primary components of Alternative #3 include a pilot study, system design and installation, operations and maintenance, and groundwater monitoring. Each of these components is described briefly below:

- *Pilot study* – field implementation of a small-scale system to evaluate if AS/SVE can be effectively implemented given Site hydrogeologic conditions.
- *System design and installation* – design and construction of a full-scale system based on results of the pilot study. System construction includes AS injection and SVE extraction well installation, trenching, piping and construction of the ex situ treatment system.
- *Operations and maintenance* – long-term operation and maintenance of the full-scale system.
- *Groundwater monitoring* – conduct long-term groundwater monitoring to evaluate the efficacy of the system and modify system parameters over time, if necessary.

Effectiveness

Historically AS/SVE is a proven technology for the remediation of VOCs in various environments. However, the effectiveness of AS/SVE can be limited by the heterogeneity of the overburden. Injection and extraction of air in heterogeneous overburden can result in channelization of the air stream, which may limit VOC removal. Given the large plume area and heterogeneous overburden an AS/SVE system may not be as effective as other technologies at this site. A pilot study would be required to collect more specific design and implementation data.

Reliability

AS/SVE is typically a reliable remedial alternative. The system has a limited amount of equipment (blowers) that would require maintenance. If a high percentage of fines are located in the overburden there could be an issue with clogged screens. In addition, the vapor extraction points may not completely capture the volatilized air stream due to the nature of the heterogeneous overburden.

Treating the extracted air stream is anticipated to be very reliable. The air stream will be pumped through activated carbon, which adsorbs volatiles in the air prior to discharge to the atmosphere. If the activated carbon is changed out or regenerated at appropriate intervals, the system would meet emissions objectives.

Implementability

This alternative would be feasible to implement. The plume is accessible from the facility parking lot where injection/extraction wells could be installed. The construction of the air systems and piping network is technically feasible. Selection of injection and extraction point locations would be dependent on pilot study results. There are existing monitoring wells that could also be utilized during a pilot scale study.

Operations and maintenance would need to be performed to ensure continuous operation of the system. The system would be inspected weekly to check for proper air flows and blower/vacuum operation. The treated air stream would need to satisfy emissions standards and potential permitting.

AS/SVE is a common technology and has been effectively implemented at numerous sites with groundwater impact to mitigate off-site migration.

Cost

The costs associated with the AS/SVE alternative are summarized in Table 6. Initial capital costs are estimated at $480,888. The annual operation and maintenance expense is estimated to be $159,600. The present worth of this alternative is estimated at $1,700,000.

Risks

There would be no significant short-term risks since the groundwater would likely remain in the subsurface and there would not be any excavation, transport, containment, or construction activities in the subsurface. There would be a short-term risk associated with the installation of injection and extraction points, and the extracted air stream, prior to treatment. Worker exposure would be minimized since site personnel would be trained in hazardous waste operations.

There are no long-term risks associated with this technology. However, if AS/SVE were only partially successful, it would continue to allow impacted groundwater to migrate off the former Raytheon property. Long-term groundwater monitoring would need to be performed. The operation and maintenance of an AS/SVE system is not expected to pose any long-term risks.

Benefits

Benefits of AS/SVE include minimal disturbance to Site operations and minimal waste generation. If effective, extraction wells could capture a significant portion of the volatized air stream. The volume of impacted groundwater in the deep aquifer would be reduced. Potential impacts to downgradient properties would be minimized.

Timeliness

Even if effective, AS/SVE would take a few years to achieve the management of migration/reduction of groundwater impacts to below GW-1 remedial action objectives. Due to the variability of extraction/injection processes and site conditions, it is difficult to predict the time frame for this alternative. Because it doesn't treat groundwater across the entire Site, operation of the system would likely occur over a relatively long period of time.

5.4.4 *Alternative #4 – Treatment Wall*

Treatment walls are a passive technology that involve the installation of a permeable granular iron wall across the path a groundwater containing chlorinated VOCs. As impacted groundwater flows through the permeable zone, chlorinated ethenes react with the granular iron. TCE degrades spontaneously in the presence of iron without additives or energy. The dechlorination reaction is also accompanied by the hydrolysis of water to form hydrogen gas.

Since treatment walls are a passive technology, there is a substantial cost saving over a technology such as pump and treat because there is little or no operations and maintenance. In-situ granular iron may need to be replaced or maintained to sustain reaction rates and permeability. The reaction chemistry induces a change in pH, which may cause the precipitation of inorganics including the iron. This can be corrected by flushing the interface between the treatment wall and the downgradient native material or by replacement of the wall.

Factors that influence the design of a treatment wall include:

- Site Geology
- Plume dimensions
- Upgradient VOC concentrations
- Groundwater velocity

The above parameters influence the depth and thickness of the reactive zone, to allow for sufficient residence time for the reaction. The treatment wall is installed via pressure injection or by driving sheet piling and excavation of native material and replacing it with granular iron. Groundwater can be directed through the wall using a funnel and gate system, where an impermeable wall is used to direct impacted groundwater toward the reactive wall.

The primary components of Alternative #4 include system design, treatment wall construction/installation, operations and maintenance, and groundwater monitoring. Each of these components is described briefly below:

- *System design* – design of a full-scale system based on existing hydrogeochemical data for the Site.
- *Treatment wall construction/installation* – construction or injection of a treatment wall using zero-valent iron.
- *Operations and maintenance* – long-term operation and maintenance of the treatment wall.
- *Groundwater monitoring* – conduct long-term groundwater monitoring to evaluate the efficacy of the system over time.

Effectiveness

Treatment walls are an effective technology to degrade chlorinated ethenes to non-toxic by-products. The actual effectiveness of this technology at the site will be determined by the ability to direct the impacted groundwater toward the reactive wall. Observed chlorinated VOCs in groundwater indicate a wide plume of impacted groundwater requiring a long treatment (i.e., up to 1000 feet). A treatment wall can be an effective technology and has the potential to achieve a permanent solution.

Reliability

Full-scale installations of treatment walls began in 1994. If the reactive wall is installed to intercept a groundwater plume in either a funnel and gate system or as a continuous wall, then it is a reliable technology. Problems occur when the wall is fouled by the build-up of inorganics that can clog the permeable zone or when impacted groundwater bypasses the wall.

Implementability

A treatment wall may be difficult to implement at this site. Raytheon is not the property owner and therefore must obtain approval from the owner to perform major construction. The dimensions of a reactive wall at this location would be substantial and could increase the cost of implementing this technology considerably. The location of the treatment wall will make it difficult to monitor downgradient concentrations. Therefore a treatment wall may me difficult to implement at this site.

Cost

The costs associated with installing a treatment wall on site are summarized in Table 7. Initial capital costs are estimated at $548,313. Annual operating costs are estimated at $61,200. The present worth of this alternative is estimated at $1,000,000.

Risks

Short-term risks associated with this alternative include worker exposure to site contaminants. Precautions would need to be taken during the installation of the treatment wall to minimize this possibility. Worker exposure to site contaminants would be minimized since personnel trained in hazardous waste operations would be installing the wells and appropriate precautions would be taken to prevent exposure.

There are no long-term risks associated with this technology. However, if a treatment wall were only partially successful, it would continue to allow impacted groundwater to migrate. Long-term groundwater monitoring would need to be performed. The operation and maintenance of a treatment wall is not expected to pose any long-term risks.

Benefits

A treatment wall will disturb site activities during installation, but during operation site disturbance will be minimal. A benefit of treatment wall technology is that it does not generate waste during operation, but in most cases the wall will have to be removed following the completion of the remediation. If successful, a treatment wall will reduce the impact of chlorinated VOCs to the aquifer.

Timeliness

Treatment walls can be installed over a short period of time but require operation over longer periods. The time the treatment wall is in operation is dependent on groundwater velocities and the mass of VOCs located upgradient of the wall. The timeliness of this technology can be better predicted following the design studies.

5.4.5 *Alternative #5 – Pump and Treat*

This alternative would involve pumping groundwater from the subsurface to a treatment system, which could discharge to surface water, the stormwater system, of groundwater. Groundwater monitoring would also be performed. For the purpose of estimating the approximate cost of the pump and treat alternative, the following treatment sequence was assumed:

- Groundwater extraction via extraction wells installed along the southern edge of the property
- Treatment
  - Equalization/settling tank
  - Particle filter
  - Air stripper (up to 50 gallons per minute)
  - Liquid-phase carbon for groundwater
  - Vapor-phase carbon for air stripper off-gas
- Discharge of treated groundwater

As discussed in Section 4, the exact configuration of the treatment system would be decided during the design phase. Alternatives to air stripping, such as chemical/UV oxidation, could be considered along with alternatives to vapor-phase carbon, such as thermal oxidation. The exact configuration of the treatment system would be decided based on design factors, derived from the results of pilot-scale studies, and performance factors, such as effectiveness, reliability, and operation and maintenance costs.

The primary components of Alternative #5 include system design, system installation, operations and maintenance, and groundwater monitoring. Each of these components is described briefly below:

- *System design* – design of a full-scale system based on existing hydrogeochemical data for the Site.

- *System installation* – install a full-scale system, including extraction well installation, trenching, piping and construction of the ex situ treatment system.
- *Operations and maintenance* – long-term operation and maintenance of the full-scale system.
- *Groundwater monitoring* – conduct long-term groundwater monitoring to evaluate the efficacy of the system and modify system parameters over time, if necessary.

Effectiveness

The effectiveness of the pump and treat alternative is primarily related to the ability of the extraction well(s) to create a zone of capture. Due to the nature of contaminant migration in heterogeneous overburden, effective capture of the plume could be difficult. Extraction in heterogeneous aquifers typically result in channelization of groundwater flow; therefore removal of VOCs would be limited by diffusion rates. Low yield wells would require a large well field, and numerous extraction points. Data regarding the site geology, groundwater flow patterns, and contaminant trends would be used to identify the optimum well locations and configurations.

Air stripping is considered to be effective at treating organic compounds that have Henry's Law constants greater than 0.01. As shown in the following table, the primary constituents of concern at the site are amenable to treatment using air stripping:

Henry's Law Constants for VOCs

Compound	*Henry's Law Constant (dimensionless)*
Vinyl Chloride	1.12
Methylene Chloride	0.09
1,2-DCE	0.29
1,2-DCA	0.04
TCE	0.41
PCE	0.74

Notes: Compounds with Henry's Law Constant greater than 0.01 are considered amenable to air stripping.

Liquid-phase carbon would be effective as a polishing step to further reduce the concentration of residual VOCs and inorganics.

Reliability

Pump and treat is generally a reliable treatment alternative. However, the mechanical pumping and treatment equipment is subject to malfunctions. Fouling of inorganics or biological growth as well as fluctuations in contaminant concentrations can affect system performance. In addition, the groundwater extraction wells may not be able to fully capture the impacted groundwater due to the nature of the heterogeneous overburden.

The processes for managing the waste streams generated by the treatment process are expected to be very reliable. The groundwater would be treated on-site and discharged. With proper operation and maintenance, the treatment system would be expected to consistently meet the treatment objectives.

Implementability

Construction and operation of a pump and treat system is technically feasible. Once the groundwater has been extracted, treatment would be relatively easy to implement. The treatment system would need to be inspected at least weekly to ensure proper operation. Continuous maintenance activities would need to be performed to ensure proper operation. The treated water discharge and off-gas emissions would need to satisfy applicable standards and permitting requirements.

Pump and treat is a commonly used technology for preventing the migration of contamination and is used to control dissolved phase contamination.

Cost

The costs associated with the pump and treat alternative are summarized in Table 8. Initial capital costs are estimated at $804,450. Additional annual operation and maintenance expenses are estimated to be $161,040. The present worth of the total projected cost for this alternative is estimated at $2,900,000.

Risks

The short-term risk associated with this alternative is worker exposure to site contaminants. Precautions would need to be taken during the drilling to minimize this possibility. Worker exposure to site contaminants would be minimized since personnel trained in hazardous waste operations would be installing the wells and appropriate precautions would be taken to prevent exposure. Long-term groundwater monitoring would need to be performed to monitor this situation.

Benefits

The pump and treat alternative would permanently reduce the mass of contaminants in the aquifer. The extraction wells could capture a large portion of contamination migrating from the source area through the aquifer. Potential impacts to abutting properties would be minimized.

Timeliness

A pump and treat system would require long-term operation. Historically, pump and treat is not a highly efficient technology. Mass removal is limited to system capture zone and diffusion rates. The unpredictability of the rate of mass removal makes it difficult to determine the timeframe of treatment.

6.0 COMPARATIVE EVALUATION OF ALTERNATIVES

6.1 OVERVIEW

This section presents a comparative evaluation of the remedial alternatives discussed in Section 5.0 for each impacted media. This evaluation compares the remedial alternatives for each screening criterion and determines which alternative(s) is (are) most likely to satisfy the requirements of that criterion. The purpose of the comparative analysis is to assist in selecting the remedial alternative that appears most likely to achieve the remedial goals for the Site (i.e., the alternative that best satisfies the majority of screening criteria).

To assist in this analysis, a numerical scoring system was adopted to calculate a cumulative score for each alternative based on; 1) the relative importance of each of the seven criteria in meeting response action objectives for that media (i.e., a weighting factor for each criteria by media); and 2) the degree to which the alternative meets each of the seven detailed evaluation criteria listed under 310 CMR 40.0858 (i.e., effectiveness, reliability, implementability, cost, risk, benefits and timeliness). This scoring process is summarized below.

Each of the evaluation criteria were first assigned a relative weighting factor based on judging the *relative* importance of the criteria in meeting remedial action objectives:

- A weighting factor of "3" was assigned if the criteria was judged to be of *highest importance* in meeting the remedial action objectives.

- A weighting factor of "2" was assigned if the criteria was judged to be of *moderate importance* in meeting the remedial action objectives.

- A weighting factor of "1" was assigned if the criteria was judged to be of *least importance* in meeting the remedial action objectives.

Each of the remedial alternatives was then assigned a numerical evaluation score based on the degree to which the alternative was judged, on a relative basis, to meet the each of the seven evaluation criteria. Evaluation scores were assigned as follows:

- A numerical score of "3" was assigned if the alternative was judged to be *more favorable than other alternativ*es in meeting the evaluation criteria.

- A numerical score of "2" was assigned if the alternative was judged to be *relatively similar to other alternatives* in meeting the evaluation criteria.

- A numerical score of "1" was assigned if the alternative was judged to be *less favorable than other alternatives* in meeting the evaluation criteria.

Criterion-specific scores for each remedial alternative were calculated as the product of the weighting factor and the evaluation score. The total score for each remedial alternative was calculated by summing the criterion-specific scores. The comparative evaluation scores for each alternative are summarized in Table 9 for wetland soil/sediment and Table 10 for groundwater and described in the following sections.

6.2 *WETLAND SOIL/SEDIMENTS*

The two alternatives identified for abatement of wetland soil/sediment and the calculated comparative evaluation scores for each alternative are summarized below:

- *Alternative #1 – Excavation & Off-Site Disposal*
  Comparative Evaluation Score = **37**
- *Alternative #2 - Excavation, On-Site Stabilization & Off-Site Disposal*
  Comparative Evaluation Score = **23**

Based on the comparative evaluation scores calculated for abatement of wetland soil/sediment, Alternative #1- Excavation & Off-Site Disposal scores highest in comparative evaluation. Key factors that resulted in a higher score for Alternative #1 include:

- <u>Reliability</u>- Alternative #1 is judged to be more reliable than Alternative #2 since implementation of stabilization technologies at similar sites with similar contaminants and conditions have not consistently achieved remedial action objectives (case in point, results of a pilot study for treatment of sediments from New Bedford Harbor indicated higher concentration of total PCBs in the stabilized waste than the untreated waste).

- <u>Cost</u>- Alternative #1 is slightly more cost-effective than Alternative

#2.

- Timeliness- Alternative #1 is likely to be accomplished in 25 to 50 percent less time than Alternative #2. This criteria was weighed to be of highest importance in the selection of alternatives for abatement of wetland soil/sediments since the observed conditions of "readily apparent harm" warrant selection of the remedial alternative that is most timely.

6.3 GROUNDWATER

The five alternatives identified for abatement of groundwater and the calculated comparative evaluation scores for each alternative are summarized below:

- *Alternative #1 – Bioremediation*
  Comparative Evaluation Score = **31**
- *Alternative #2 – Chemical Oxidation*
  Comparative Evaluation Score = **40**
- *Alternative #3 – Air Sparging & Soil Vapor Extraction (AS/SVE)*
  Comparative Evaluation Score = **21**
- *Alternative #4 – Treatment Wall*
  Comparative Evaluation Score = **31**
- *Alternative #5 – Pump & Treat*
  Comparative Evaluation Score = **23**

Based on the comparative evaluation scores calculated for abatement of groundwater, Alternative #2- Chemical Oxidation scores highest in comparative evaluation. Key factors that resulted in a higher score for Alternative #2 are:

- Effectiveness- Chemical oxidation is effective in reducing the concentrations of chlorinated ethenes in groundwater to achieve a Permanent Solution.

- Reliability- Performance of this technology at sites with similar contaminants and subsurface conditions has shown this to be a reliable alternative. This technology does not generate remediation waste requiring additional management and generally results in destruction of OHM in groundwater.

- Implementability- There are no significant obstacles to implementation of this alternative at the Site.

- Cost- This was the most cost-effective alternative for groundwater abatement.

- Benefits- This alternative would likely restore the natural resource (i.e., the aquifer) and avoid future loss in value of the Site.

- Timeliness- This alternative would likely achieve remedial action objectives for groundwater faster than other alternatives.

7.0 RECOMMENDED REMEDIAL ALTERNATIVES

7.1 SELECTION OF REMEDIAL ACTION ALTERNATIVES

Wetland Soil/Sediment

Based on the results of the comparative analysis, Alternative #1 Excavation & Off-Site Disposal is selected as the preferred remedy for abatement of wetland soil/sediment since it would be effective, feasible to implement, poses minimal risk and would achieve the remedial objectives in a timely manner at a lower cost. This alternative would also cause less disruption to current uses of the Site than Alternative #2.

Groundwater

Based on the results of the comparative analysis, Alternative #2 Chemical Oxidation is the preferred remedy for abatement of groundwater since it would be effective, reliable, feasible to implement, is cost-effective, poses minimal risk, and could achieve the remedial objectives in a timely manner.

The effectiveness of chemical oxidation will be reevaluated following the completion of bench-scale and pilot studies. If chemical oxidation is judged to not be effective based on Site-specific pilot studies, than another remedial alternative will be considered.

7.2 FEASIBILITY OF ACHIEVING BACKGROUND

The MCP (310 CMR 40.0860(6)(a)) states that achieving background should be considered feasible unless "the incremental cost of conducting the remedial alternative is substantial and disproportionate to the incremental benefit of risk reduction, environmental restoration, and monetary and non-pecuniary values." Using a benchmark comparison approach, ERM evaluated the cost of additional remediation to approach or achieve background to the cost of achieving a condition of “no significant risk” at the Site.

Wetland Soil/Sediment

Based on the results of the detailed cost evaluation in Section 5, the cost to complete Alternative #1 is estimated at $4.2MM to achieve a condition of "no significant risk." The volume of soil/sediment requiring removal and disposal is estimated at 3,700 cyds. Abatement of wetland soil/sediment to background would require removal of soil/sediment at all sample locations where the concentration of total PCBs are greater than 1.8 ppm (i.e., the maximum background concentration detected). Using a target cleanup goal of 2 ppm total PCBs to "achieve or approach" background, the volume of remediation waste is estimated to increase from 3,700 cyds to approximately 12,000 cyds. This represents an approximately 330 percent increase in volume and cost.

Available MA DEP guidance regarding the use of benchmark comparisons in determining the feasibility of abatement to background indicates that, if the additional costs to remediate beyond a condition of "no significant risk" to levels that approach background exceed 20 percent of the cost to remediate to a condition of "no significant risk" then remediation to approach background should be considered infeasible. Therefore, based on the above benchmark comparison remediation of wetland soil/sediment to approach or achieve background is considered infeasible.

In addition, as indicated in Section 3.2.3, the Massachusetts Wetland Protection Act, 310 CMR 10.53, prohibits approval of remedial measures that would abate OHM in a wetland below a level necessary to achieve a condition of "no significant risk." Therefore, abatement to background would not be possible under current state regulations.

Groundwater

In the case of impacts to groundwater, the remedial technology chosen may be able to approach background. As stated in Section 3.2.2, DEP guidance indicates that the "achievement" of background concentrations is considered infeasible for chlorinated ethenes in groundwater. The implementation of Alternative #2 Chemical Oxidation for groundwater abatement will attempt to "approach" background concentrations, as a secondary remedial objective. The feasibility of approaching background will be evaluated based on the success of the alternative in meeting target cleanup goals.

7.3 IMPLEMENTATION SCHEDULE

Raytheon is scheduled to submit the Phase IV Remedy Implementation Plan (RIP), as described in 310 CMR 40.0874, to DEP by May 2002. A tentative schedule for Phase IV activities is provided below:

Implementation Schedule for Phase IV

Date	*Event*
May 2002	Complete Phase IV RIP
2002	Implement RIP
2003	As-Built Construction Report
2003	Final Inspection Report

8.0 REFERENCES

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Tables

Table 1

Summary of Remedial Technology Screening

Phase III Remedial Action Plan
Former Raytheon Facility, Wayland, MA

Response Action	*Remedial Technology*	*Description*	*Implementablity*	*Effectiveness*	*Cost*	*Status*
Wetlands	Excavation and Off-Site Disposal	Excavate impacted; dewater excavated material, transport and treat/dispose of off-site. Restore wetlands and monitor functionality.	Compatible with site conditions. Moderately difficult to implement. Work in wetlands require special equipment and preparation	Effective at removing impacted soils and treating off-site. Restoration if successful is effective. Ability to achieve a permanent solution.	High	Carried Forward for Detailed Analysis
	Excavation, On-Site Solidification and Disposal,	Excavate impacted media; dewater excavated material, treat and prepare soil for disposal on-site. Restore wetlands and monitor functionality	Difficult to implement,. Incompatible with site conditions. Site not appropriate for on site disposal	Effective at removing impacted soil. Not feasible to dispose of treated soil on site. Does not have ability to achieve a permanent solution	High	Eliminated
	Excavation, On-Site Solidification, and Off-Site Disposal	Excavate impacted; dewater excavated material, treat and prepare soil for transportation and disposal off-site. Restore wetlands and monitor functionality.	Compatible with site conditions. Space available for on-site treatment, excavation moderately difficult to implement.	Effective at removing impacted soils and treating off-site. Restoration if successful is effective. Ability to achieve a permanent solution.	High	Carried Forward for Detailed Analysis
	Phytoremediation	The use of plants to remediate selected contaminants in impacted soil. Plants remediate impacted soils through degradation, uptake, metabolism, immobilization or volatilization.	Compatible with site conditions. Moderately difficult to implement. Plant species selection is critical to match with site conditions and targeted contaminants.	Site currently under phytotoxic conditions in some areas. Would need to be combined with excavation in order to be effective. Not proven effective for PCBs.	Moderate	Eliminated
Groundwater	Bioremediation	Injection of nutrients, chemical energy, and other materials necessary to promote microbial degradation of the contaminants.	Passive technology could be easily implemented. Compatible with site conditions. Limited evidence of biodegradation on site, sue to oxidized conditions.	Effective at remediating chlorinated solvents in anaerobic environment. Bench-scale and pilot-scale testing would be needed to confirm effectiveness at the site. Ability to achieve a permanent solution	High	Carried Forward for Detailed Analysis
	In-Situ Chemical Oxidation	The injection of permanganate, hydrogen peroxide or other oxidizing agent to chemically breakdown chlorinated VOCs to water, carbon dioxide, and chlorides.	Compatible with site conditions. Moderately difficult to implement. Site groundwater is naturally oxidized. Passive technology, oxidant delivered via injection wells.	Innovative technology that has been shown to remediate chlorinated solvents. Bench-scale and pilot-scale testing would be needed to confirm effectiveness at the site. Ability to achieve a permanent solution	Moderate	Carried Forward for Detailed Analysis
	Air Sparging/Soil Vapor Extraction	The injection of air or steam into groundwater promotes the degradation/volatilization of dissolved phase contaminants. Extraction wells are installed to recover the volatilized or dissolved contaminants.	Incompatible with site conditions. Volatilized contaminants could effect indoor air quality in manufacturing buildings. Low hydraulic conductivity would require extensive well network.	Silt layer identified across site may cause channelization of air stream. Removal of VOCs below silt layer will be limited by diffusion rates. Does not have bility to achieve a permanent solution	Moderate	Carried Forward for Detailed Analysis
	Treatment Wall	Passive treatment using permeable wall consisting of reactive material such as zero valent iron. Slurry wall could be used to direct groundwater through the treatment wall (funnel and gate system).	Compatible with site conditions. Would require installation at property boundary. Would not mitigate migration off-site of VOCs that are currently past this point.	Passive technology would not disturb site after installation. Effective technology to removing VOCs in groundwater. Ability to achieve a permanent solution	Moderate	Carried Forward for Detailed Analysis
	Pump and Treat	Groundwater extracted via pumping wells, collection trench or other means would be treated using a representative technology such as chemical/UV, liquid phase carbon. Treated groundwater would be discharged to surface water or reinjected.	Compatible with site conditions. Moderately difficult to implement. Low sustainable yields at site, ranges from 0.3 to 1.5 gpm. Several pumping wells would be required, upto depths of sixty-feet.	Pump and Treat Systems installed in heterogeneous aquifers typically result in channelization of groundwater flow to the pumping well; limiting influence on subsurface. Ability to achieve a temporary solution	High	Carried Forward for Detailed Analysis

Table 2
Cost Estimate for Wetland Soil/Sediment
Alternative #1- Excavation & Off-Site Disposal
Phase III – Remedial Action Plan
Former Raytheon Facility
Wayland, MA

Remedial Cost Item	No. of Units	Units	Unit Cost ($)	Notes	Cost ($)
A. Construction Activities					
AUL Implementation	1	Lump Sum	$50,000		$50,000
Site Preparation					
Mobilization	1	Lump Sum	$20,000		$20,000
Excavation, staging, transportation	3,630	cubic yard	$15		$54,453
Soil characterization	1	Lump Sum	$25,000		$25,000
Dewatering/Treatment System	1	Lump Sum	$50,000		$50,000
Water treatment system - Operate	3	months	$12,000		$36,000
Off-Site Disposal					
Transportation by rail	318	load	$100		$31,763
Off-Site Disposal	6,353	ton	$350	(a)	$2,223,375
Wetland Restoration					
Soil topography	3,630	cubic yard	$25		$90,750
Plant replication	1.5	acre	$250,000		$375,000
Closure/Verification Sampling					
Sampling	1	Lump Sum	$25,000		$25,000
Analysis	60	sample	$500		$30,000
Regrading	1.5	acre	$10,000		$15,000
			Subtotal		$3,026,340
Design/Construction Oversight - 15%					$453,951
Contingency - 20%					$605,268
			Estimated Construction Cost		**$4,090,000**
B. Annual O&M Cost					
Annual Monitoring	1	annually	$750	(a)	$25,000
Data compilation and review	2	Lump Sum	$2,500		$5,000
			Subtotal		$30,000
			Contingency (20%)		$5,000
			Estimated Annual O&M Cost		**$35,000**
C. Present Worth					
Present Worth of Construction Costs					$4,090,000
Present Worth of O&M	5	Years			$154,000
			Estimated Present Worth (rounded)	(b)	**$4,244,000**

Notes:
(a) Assumes 1.75 tons/cubic yard conversion factor
(b) The above cost estimate is intended for comparison of the alternatives, not for budgeting or contracting purposes. Actual costs will vary. Supplemental investigation activities and detailed-design phases would provide the specific information needed to increase the accuracy of the cost estimates.

Table 3
Cost Estimate for Wetland Soil/Sediment
Alternative #2- Excavation, On-Site Stabilization & Off-Site Disposal
Phase III – Remedial Action Plan
Former Raytheon Facility
Wayland, MA

Remedial Cost Item	No. of Units	Units	Unit Cost ($)	Notes	Cost ($)
A. Construction Activities					
AUL Implementation	1	Lump Sum	$50,000		$50,000
Site preparation					
Mobilization	1	Lump Sum	$20,000		$20,000
Excavation, staging, transportation	3,630	cubic yard	$15		$54,453
Soil characterization	1	Lump Sum	$25,000		$25,000
Dewatering/Treatment System	1	Lump Sum	$50,000		$50,000
Water treatment system - Operate	3	months	$12,000		$36,000
On-Site Stabilization					
On-Site Stabilization	6,353	ton	$200	(a)	$1,270,558
Transportation by rail	338	load	$100		$33,750
Off-site Treatment/Disposal	8,449	ton	$165	(a)	$1,394,120
Wetland Restoration					
Soil topography	3,630	cubic yard	$25		$90,750
Plant replication	1.5	acre	$250,000		$375,000
Closure/Verification Sampling					
Sampling	1	Lump Sum	$25,000		$25,000
Analysis	60	sample	$500		$30,000
Regrading	1.5	acre	$10,000		$15,000
			Subtotal		$3,469,631
Design/Construction Oversight - 15%					$520,445
Contingency - 20%					$693,926
		Estimated Construction Cost			**$4,680,000**
B. Annual O&M Cost					
Annual Monitoring	1	annually	$750	(a)	$25,000
Data compilation and review	2	Lump Sum	$2,500		$5,000
			Subtotal		$30,000
			Contingency (20%)		$5,000
		Estimated Annual O&M Cost			**$35,000**
C. Present Worth					
Present Worth of Construction Costs					$4,680,000
Present Worth of O&M	5	Years			$154,000
		Estimated Present Worth (rounded)		(b)	**$4,834,000**

Notes:
(a) Assumes 1.75 tons/cubic yard conversion factor for dewatered soil and 1/3 ratio of stabilizing agent to sediment
(b) The above cost estimate is intended for comparison of the alternatives, not for budgeting or contracting purposes. Actual costs will vary. Supplemental investigation activities and detailed-design phases would provide the specific information needed to increase the accuracy of the cost estimates.

Table 4
Cost Estimate for Groundwater
Alternative #1- Bioremediation
Phase III – Remedial Action Plan
Former Raytheon Facility
Wayland, MA

Remedial Cost Item	No. of Units	Units	Unit Cost ($)	Notes	Cost ($)
A. Construction Activities					
Pump	3	Each	$5,000		$15,000
Pump Controls	3	Each	$2,500		$7,500
Piping, Fittings	1	Lump Sum	$35,000		$35,000
Holding Tank	1	Lump Sum	$20,000		$20,000
Tank Pad	1	Lump Sum	$5,000		$5,000
Treatment System Shed	1	Lump Sum	$20,000		$20,000
Equipment installation	1	Lump Sum	$75,000		$75,000
Control Panel	1	Lump Sum	$30,000		$30,000
Utilities (electrical, water)	1	Lump Sum	$35,000		$35,000
			Subtotal		$242,500
Design - 15%					$36,375
Construction Oversight - 20%					$48,500
Contingency - 20%					$48,500
			Estimated Construction Cost	(c)	**$375,875**
B. Annual O&M Cost					
Sample wells	20	well	$750	(a)	$15,000
Data compilation and review	2	Lump Sum	$2,500		$5,000
Microorganisms	1	1000lb bag	$18,000		$18,000
Nutrients	360	drum	$250		$90,000
O&M Labor	52	week	$1,000		$52,000
			Subtotal		$180,000
Contingency (20%)					$36,000
			Estimated Annual O&M Cost		**$216,000**
C. Present Worth					
Present Worth of Construction Costs					$375,875
Present Worth of O&M	20	Years			$2,448,000
			Estimated Present Worth (rounded)	(b)	**$2,800,000**

Notes:
(a) Sampling costs based on sampling 10 wells semi-annually for VOCs by Method 8260. Labor is included.
(b) The above cost estimate is intended for comparison of the alternatives, not for budgeting or contracting purposes. Actual costs will vary. Supplemental investigation activities and detailed-design phases would provide the specific information needed to increase the accuracy of the cost estimates.
(c) Assumes use of existing monitoring wells and proposed recharge wells. Costs for new wells are not included.

Table 5
Cost Estimate for Groundwater
Alternative #2- Chemical Oxidation
Phase III – Remedial Action Plan
Former Raytheon Facility
Wayland, MA

Remedial Cost Item	No. of Units	Units	Unit Cost ($)	Notes	Cost ($)
A. Construction Activities					
Mobilization	1	Lump Sum	$20,000		$20,000
Geoprobe Points (170 points, 3 a day)	56	Day	$2,000		$112,000
Geoprobe Points (50 points, 2nd round)	17	Day	$2,000		$34,000
Geoprobe Points (20 points, 2nd round)	7	Day	$2,000		$14,000
Oxidant	3	Per Injection	$35,000		$105,000
Piping, Fittings	1	Lump Sum	$2,500		$2,500
Piping Installation	1	Lump Sum	$20,000		$20,000
Additional Sampling	3	Lump Sum	$15,000		$45,000
Utilities (elect., telephone, water)	1	Lump Sum	$5,000		$5,000
Oversight	80	day	$2,000		$160,000
			Subtotal		$517,500
Design - 15%					$77,625
Construction Oversight - 20%					$103,500
Contingency - 20%					$103,500
			Estimated Construction Cost		**$802,125**
B. Annual O&M Cost					
Sample wells	20	well	$800	(a)	$16,000
Data compellation and review	2	Lump Sum	$5,000		$10,000
			Subtotal		$26,000
Contingency (20%)					$5,200
			Estimated Annual O&M Cost		**$31,200**
C. Present Worth					
Present Worth of Construction Costs					$802,125
Present Worth of O&M	5	Years			$137,000
			Estimated Present Worth (rounded)	(b)	**$900,000**

Notes:
(a) Sampling costs based on sampling 10 wells semi-annually for VOCs by Method 8260. Labor is included.
(b) The above cost estimate is intended for comparison of the alternatives, not for budgeting or contracting purposes. Actual costs will vary. Supplemental investigation activities and detailed-design phases would provide the specific information needed to increase the accuracy of the cost estimates.

Table 6
Cost Estimate for Groundwater
Alternative #3- Air Sparging/Soil Vapor Extraction
Phase III – Remedial Action Plan
Former Raytheon Facility
Wayland, MA

Remedial Cost Item	No. of Units	Units	Unit Cost ($)	Notes	Cost ($)
A. Construction Activities					
Mobilization	1	Lump Sum	$20,000		$20,000
Installation of Injection Points	40	point	$1,500	(a)	$60,000
Installation of Extraction Points	120	point	$1,500		$180,000
SVE Unit	1	Lump Sum	$20,000		$20,000
Air Sparging Unit	1	Lump Sum	$12,500		$12,500
Carbon Vessels	2	unit	$2,000		$4,000
Activated Carbon	1,000	pounds	$1.50		$1,500
Startup Samples	5	sample	$450		$2,250
Permitting	1	Lump Sum	$10,000		$10,000
Labor	60	day	$2,000		$120,000
			Subtotal		$310,250
Design - 15%					$46,538
Construction Oversight - 20%					$62,050
Contingency - 20%					$62,050
		Estimated Construction Cost			**$480,888**
B. Annual O&M Cost					
Sample wells	40	well	$800	(b)	$32,000
Maintenance (Labor)	52	weekly	$1,000		$52,000
Maintenance (Parts)	1	Lump Sum	$5,000		$5,000
Activated Carbon	26	bi-weekly	$1,500.00		$39,000
Data compilation and review	2	Lump Sum	$2,500		$5,000
			Subtotal		$133,000
Contingency (20%)					$26,600
		Estimated Annual O&M Cost			**$159,600**
C. Present Worth					
Present Worth of Construction Costs					$480,888
Present Worth of O&M	10	Years			$1,199,000
		Estimated Present Worth (rounded)		(c)	**$1,700,000**

Notes:
(a) Estimate assumes 1,500 ft long wall, 20 foot spacings
(b) Sampling costs based on sampling 10 wells semi-annually for VOCs by Method 8260. Labor is included.
(c) The above cost estimate is intended for comparison of the alternatives, not for budgeting or contracting purposes. Actual costs will vary. Supplemental investigation activities and detailed-design phases would provide the specific information needed to increase the accuracy of the cost estimates.

Table 7
Cost Estimate for Groundwater
Alternative #4- Treatment Wall
Phase III – Remedial Action Plan
Former Raytheon Facility
Wayland, MA

Remedial Cost Item	No. of Units	Units	Unit Cost ($)	Notes	Cost ($)
A. Construction Activities					
Mobilization	1	Lump Sum	$20,000		$20,000
Pressure Injection of Granular Iron	275	ton	$850	(a)	$233,750
Monitoring Well Installation	5	Well	$15,000		$75,000
Startup Samples	1	Lump Sum	$15,000		$15,000
Permitting	1	Lump Sum	$10,000		$10,000
Labor	60	day	$2,000		$120,000
			Subtotal		$353,750
Design - 15%					$53,063
Construction Oversight - 20%					$70,750
Contingency - 20%					$70,750
			Estimated Construction Cost		**$548,313**
B. Annual O&M Cost					
Sample wells	20	well	$800	(b)	$16,000
Flushing Fouled Wall	1	event	$30,000		$30,000
Data compilation and review	2	Lump Sum	$2,500		$5,000
			Subtotal		$51,000
Contingency (20%)					$10,200
			Estimated Annual O&M Cost		**$61,200**
C. Present Worth					
Present Worth of Construction Costs					$548,313
Present Worth of O&M	10	Years			$460,000
			Estimated Present Worth (rounded)	(c)	**$1,000,000**

Notes:
(a) Estimate assumes 1,500 ft long wall, 3 ft. wide and 70 ft. deep
(b) Sampling costs based on sampling 10 wells semi-annually for VOCs by Method 8260. Labor is included.
(c) The above cost estimate is intended for comparison of the alternatives, not for budgeting or contracting purposes. Actual costs will vary. Supplemental investigation activities and detailed-design phases would provide the specific information needed to increase the accuracy of the cost estimates.

Table 8
Cost Estimate for Groundwater
Alternative #5- Pump & Treat
Phase III – Remedial Action Plan
Former Raytheon Facility
Wayland, MA

Remedial Cost Item	No. of Units	Units	Unit Cost ($)	Notes	Cost ($)
A. Construction Activities					
Mobilization	1	Lump Sum	$20,000		$20,000
Deep Extraction Wells	4	Per Well	$15,000		$60,000
Extraction Pumps	2	each	$5,000		$10,000
Pump Controls	2	each	$2,500		$5,000
Piping	1	Lump Sum	$25,000		$25,000
Treatment System Building	1	Lump Sum	$50,000		$50,000
Heater	1	Lump Sum	$5,000		$5,000
1,500 gal. Equalization Tank	1	each	$5,000		$5,000
Particle Filter	1	Lump Sum	$3,000		$3,000
Air Stripper w/ Blower	1	each	$40,000		$40,000
Vapor Phase Carbon w/ Regeneration	1	Lump Sum	$100,000		$100,000
Liquid Phase Carbon	1	Lump Sum	$50,000		$50,000
Transfer Pumps	5	each	$1,000		$5,000
Compressor	1	each	$5,000		$5,000
Effluent Piping	1	Lump Sum	$10,000		$10,000
Equipment Installation	1	Lump Sum	$100,000		$100,000
Control Panel	1	Lump Sum	$10,000		$10,000
Utilities (elect., telephone, water)	1	Lump Sum	$5,000		$5,000
Startup Samples	1	Lump Sum	$5,000		$5,000
Permitting	1	Lump Sum	$6,000		$6,000
			Subtotal		$519,000
Design - 15%					$77,850
Construction Oversight - 20%					$103,800
Contingency - 20%					$103,800
		Estimated Construction Cost			**$804,450**
B. Annual O&M Cost					
Sample wells	20	well	$800	(a)	$16,000
Regeneration Liquid Disposal	12	drums	$350		$4,200
Utilities	1	year	$5,000		$5,000
Data compilation and review	2	Lump Sum	$2,500		$5,000
O&M Labor	52	week	$2,000		$104,000
			Subtotal		$134,200
Contingency (20%)					$26,840
		Estimated Annual O&M Cost			**$161,040**
C. Present Worth					
Present Worth of Construction Costs					$804,450
Present Worth of O&M	30	Years			$2,138,000
		Estimated Present Worth (rounded)		(b)	**$2,900,000**

Notes:
(a) Sampling costs based on sampling 10 wells semi-annually for VOCs by Method 8260. Labor is included.
(b) The above cost estimate is intended for comparison of the alternatives, not for budgeting or contracting purposes. Actual costs will vary. Supplemental investigation activities and detailed-design phases would provide the specific information needed to increase the accuracy of the cost estimates.
(c) Does not include costs for bench and pilot studies

Table 9 *DRAFT*

Comparative Analysis of Remedial Alternatives- Wetland Soil/Sediment

Phase III Remedial Action Plan

Former Raytheon Facility, Wayland, MA

Remedial Alternative	*Description*	*Effectiveness*		*Reliability*		*Implementablity*		*Cost*		*Risk*		*Benefits*		*Timeliness*		*Total*
		Weight	*Score*	*Weight*	*Score*	*Weight*	*Score*	*Weight*	*Score*	*Weight*	*Score*	*Weight*	*Score*	*Weight*	*Score*	*Score*
#1 Excavation & Off-Site Disposal	Excavate impacted; dewater excavated material, transport and treat/dispose of off-site. Restore wetlands and monitor functionality.	3	2	2	3	2	3	2	2	2	2	1	2	3	3	**37**
#2 Excavation, On-Site Solidification, and Off-Site Disposal	Excavate impacted; dewater excavated material, treat and prepare soil for transportation and disposal off-site. Restore wetlands and monitor functionality.	3	2	2	1	2	1	2	2	2	2	1	2	3	1	**23**

Notes:

Weighting factors are assigned based on the relative importance of each criterion in meeting remedial action objectives:

High Importance - 3 points
Medium Importance - 2 points
Low Importance - 1 point

Evaluation Scores (Escores) are assigned to each remedial alternative based on the relative favorability of alternatives in meeting the evaluation criterion:

Highly Favorable - 3 points
Moderately Favorable - 2 points
Slightly Favorable - 1 point

The total score is determined by multiplying the weighting factor by the EScore and summing the criteria-specific scores for each alternative.
The highest score represents that alternative deemed most favorable for abatement of that media.

Table 10 *DRAFT*

Comparative Analysis of Remedial Alternatives- Groundwater

Phase III Remedial Action Plan

Former Raytheon Facility, Wayland, MA

Remedial Alternative	*Description*	*Effectiveness*		*Reliability*		*Implementablity*		*Cost*		*Risk*		*Benefits*		*Timeliness*		*Total*
		Weight	*Score*	*Weight*	*Score*	*Weight*	*Score*	*Weight*	*Score*	*Weight*	*Score*	*Weight*	*Score*	*Weight*	*Score*	*Score*
#1 Bioremediation	Injection of nutrients, chemical energy, and other materials necessary to promote microbial degradation of the contaminants.	3	3	2	2	3	1	1	1	2	3	2	3	1	2	**31**
#2 In-Situ Chemical Oxidation	The injection of permanganate, hydrogen peroxide or other oxidizing agent to chemically breakdown chlorinated VOCs to water, carbon dioxide, and chlorides.	3	3	2	3	3	3	1	3	2	2	2	3	1	3	**40**
#3 Air Sparging/Soil Vapor Extraction	The injection of air or steam into groundwater promotes the degradation/volatilization of dissolved phase contaminants. Extraction wells are installed to recover the volatilized or dissolved contaminants.	3	1	2	3	3	1	1	2	2	2	2	1	1	1	**21**
#4 Treatment Wall	Passive treatment using permeable wall consisting of reactive material such as zero valent iron. Slurry wall could be used to direct groundwater through the treatment wall (funnel and gate system).	3	3	2	2	3	2	1	3	2	1	2	3	1	1	**31**
#5 Pump and Treat	Groundwater extracted via pumping wells, collection trench or other means would be treated using a representative technology such as chemical/UV, liquid phase carbon. Treated groundwater would be discharged to surface water or reinjected.	3	1	2	3	3	2	1	1	2	2	2	1	1	1	**23**

Notes:

Weighting factors are assigned based on the relative importance of each criterion in meeting remedial action objectives:

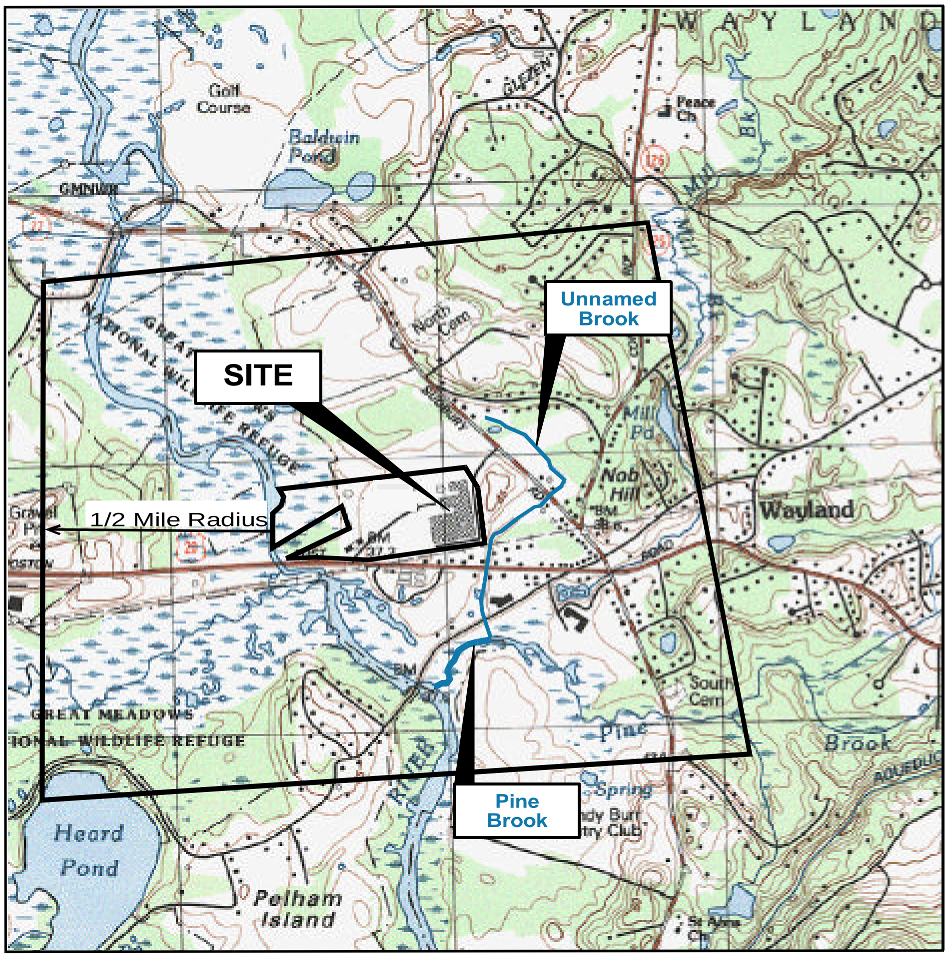
High Importance - 3 points
Medium Importance - 2 points
Low Importance - 1 point

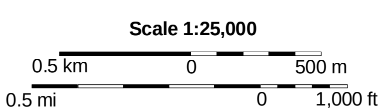
Evaluation Scores (Escores) are assigned to each remedial alternative based on the relative favorability of alternatives in meeting the evaluation criterion:

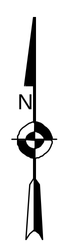
Highly Favorable - 3 points
Moderately Favorable - 2 points
Slightly Favorable - 1 point

The total score is determined by multiplying the weighting factor by the EScore and summing the criteria-specific scores for each alternative.
The highest score represents that alternative deemed most favorable for abatement of that media.

Figures







ENVIRONMENTAL RESOURCES MANAGEMENT

399 Boylston Street, Boston, Massachusetts 02116 (617) 267-8377

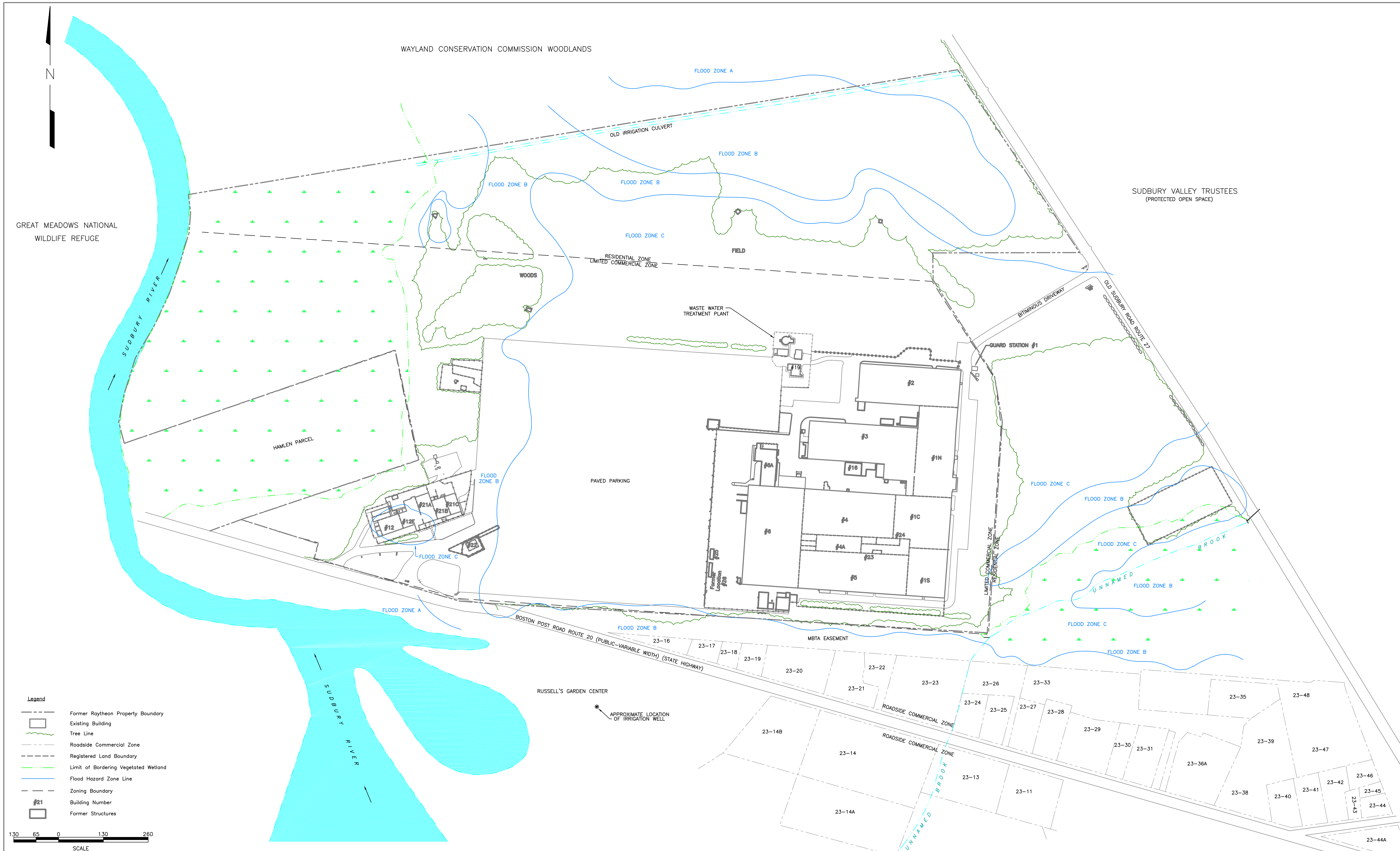
CLIENT NAME: Raytheon	*DRAWN BY:* RBL	*DATE:* 7/5/01
FILE NAME: Locus Map	*SCALE:* 1:25,000	*PROJ:* 143.57

Raytheon Company
430 Boston Post Road Wayland, Massachusetts

SITE LOCUS MAP

FIGURE NO.: 1

PRINCIPAL-IN-CHARGE: JD *PROJECT MANAGER:* JMcT



NO.	DATE	APPR.	REVISION	NO.	DATE	APPR.	REVISION

Former Raytheon Facility
430 Boston Post Road
Wayland Massachusetts

Environmental Resources Management
Boston, Massachusetts 02116 (617) 267-8377
ERM

CHECKED: John Drobinski	DATE		
DESIGN ENGINEER			
PROJECT ENGINEER: Rachel Leary			
PROJECT MANAGER: John McTique			
APPROVED			
APPROVED			

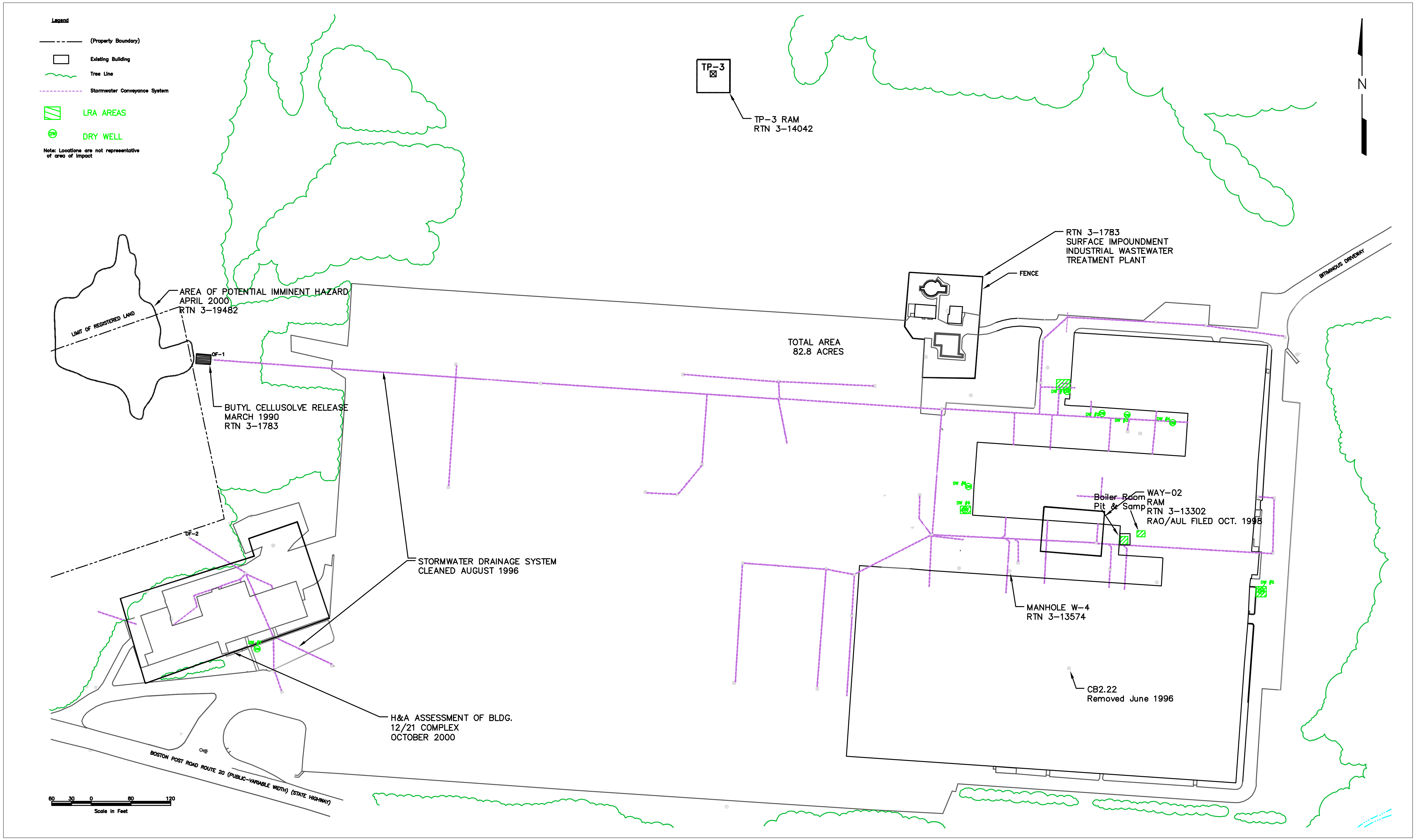
Site and Surrounding Features Map

FIGURE NO. 2

REV. NO.

DRAWN	DATE	CLIENT APPROVAL	
C.POMAMTE/CMP	02.19.01/03.12.01		
SCALE: 1"=260'	W.O. No. 143.53	ISSUED FOR	DATE

SHEET OF



ERM 399 BOYLSTON STREET-BOSTON, MA 02116 (617) 267-8377	Raytheon Company 430 Boston Post Road Wayland, Massachusetts	Designed by:	Sources & Interim Remedial Response Action Map
		Drawn by: CMP	
		Checked by: RJF	
		Reviewed by: JMcT	Scale: 1" = 60' / Date: 3/12/01
		Submitted by:	Drawing No. / Figure No. 3 / Contract No. 143.50

Revisions

Symbol	Description	Date	Approved
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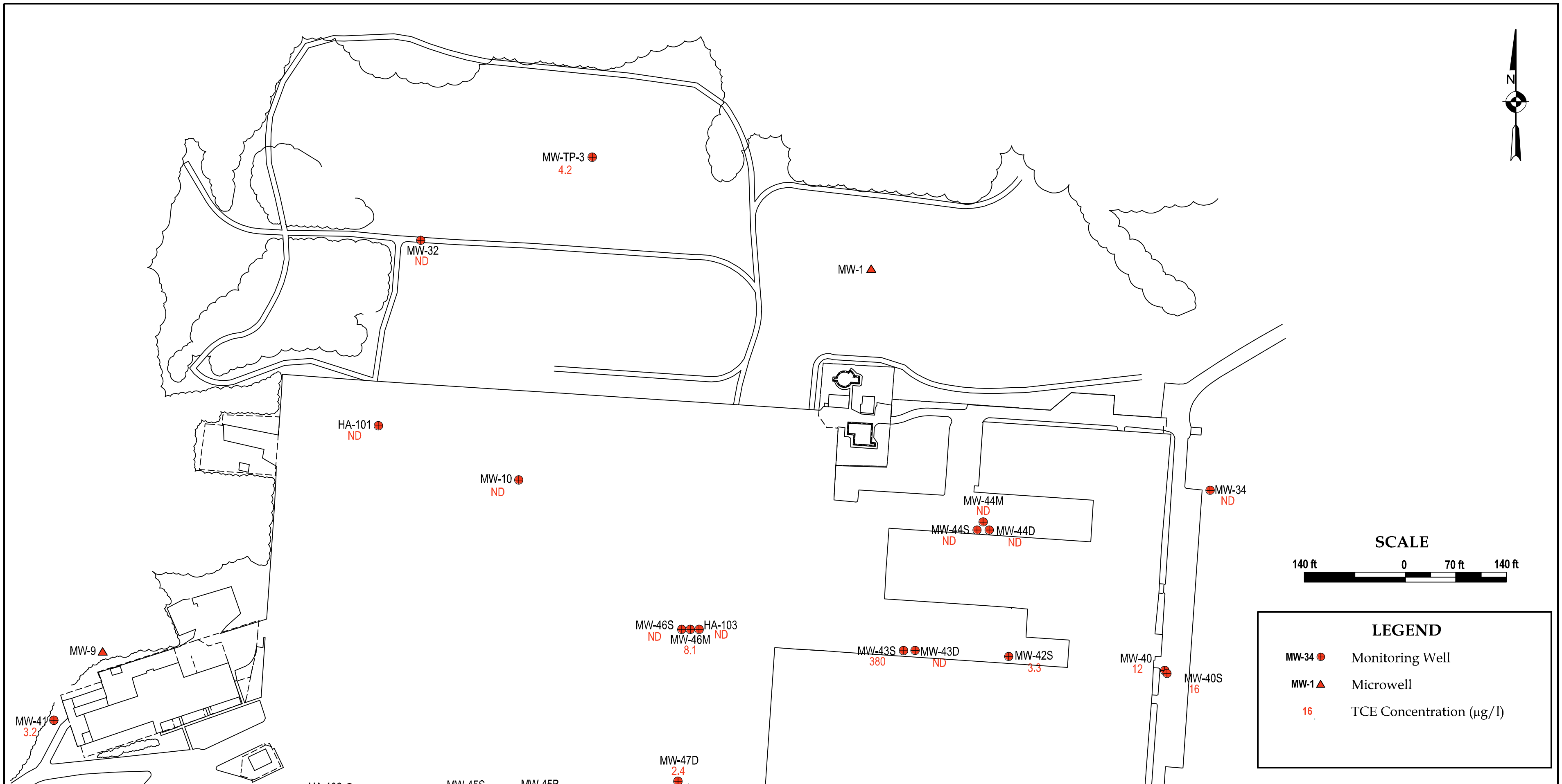
	Report Figures\Final Figures\Fig 5 Ph I Update		



ENVIRONMENTAL RESOURCES MANAGEMENT

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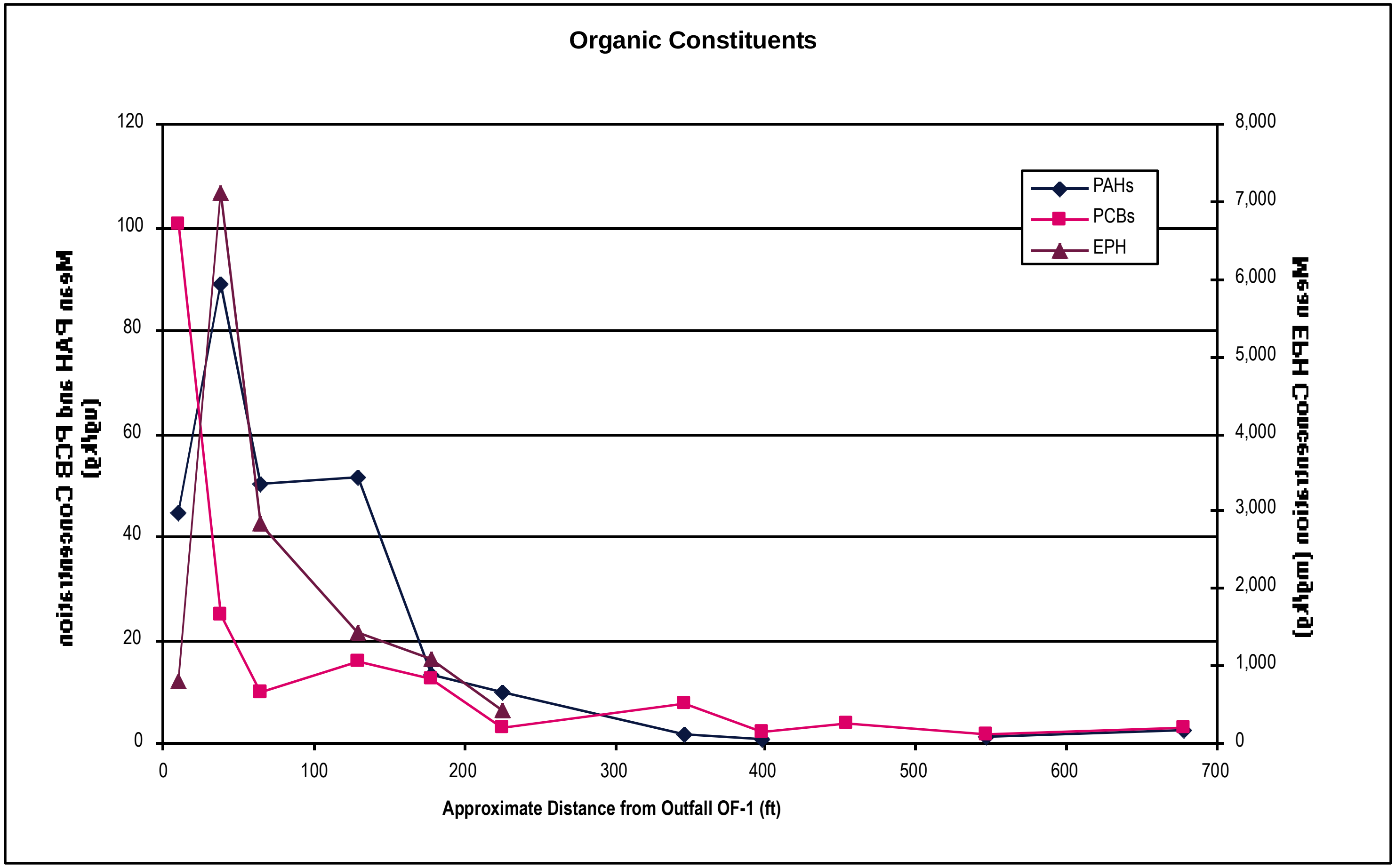
CLIENT NAME:	Raytheon	DRAWN BY:	RJF	DATE:	7/5/01		
FILE NAME:	TCE Conc Apr 00	SCALE:	1″ = 140′	PROJ:	143.57		

Raytheon Company
430 Boston Post Road Wayland, Massachusetts

Approximate Horizontal Extent of TCE in Groundwater-April 2000

FIGURE NO.: 4

PRINCIPAL-IN-CHARGE: JD PROJECT MANAGER: JMcT



ENVIRONMENTAL RESOURCES MANAGEMENT

399 Boylston Street, Boston, Massachusetts 02116 (617) 267-8377

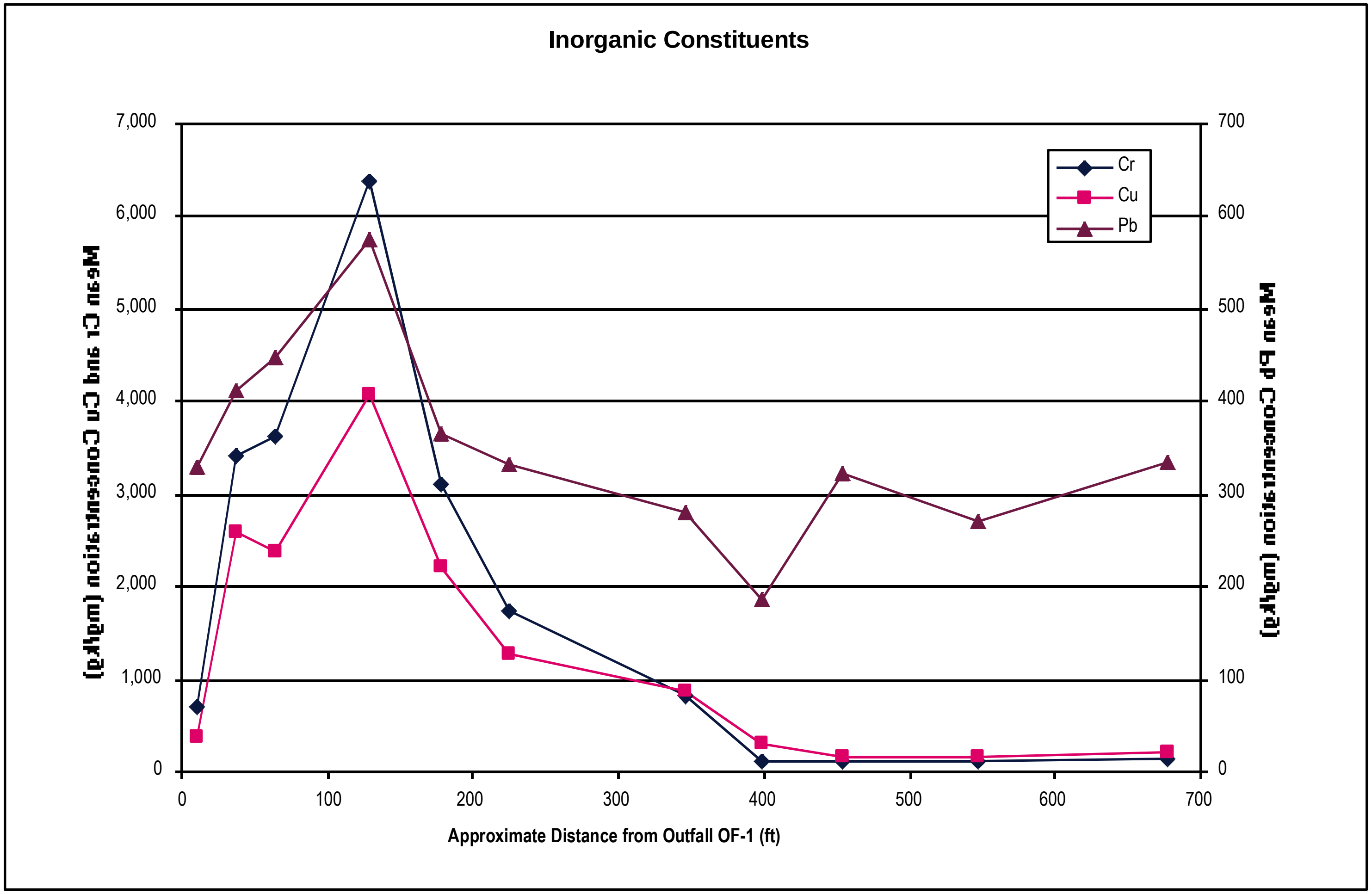
CLIENT NAME: Raytheon	DRAWN BY: LA	DATE: 10/4/01
FILE NAME: Sed Conc-Organic	SCALE:	PROJ: 143.57

Raytheon Company
430 Boston Post Road Wayland, Massachusetts

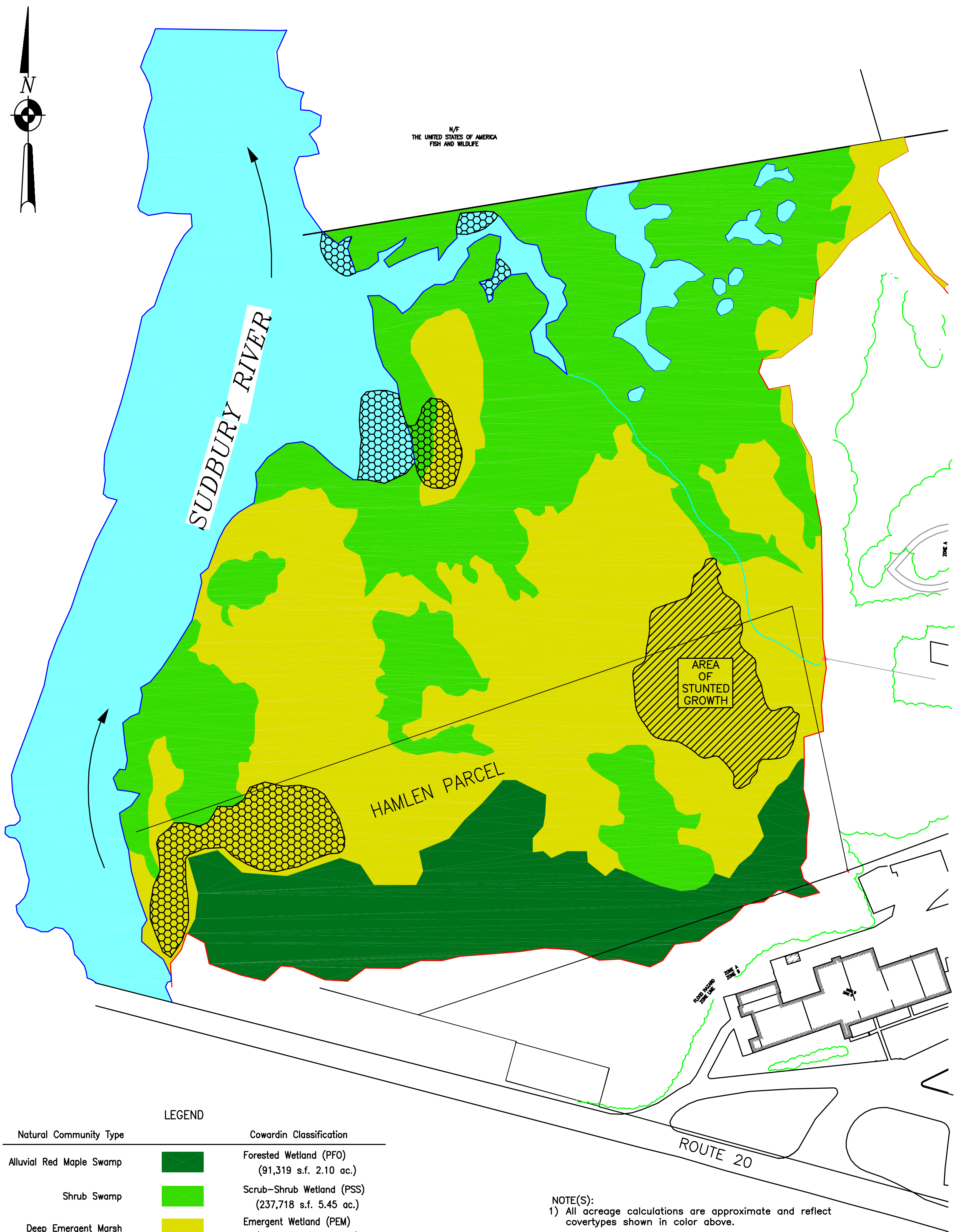
MEAN SOIL/SEDIMENT CONCENTRATION AS A FUNCTION OF DISTANCE FROM OUTFALL OF-1

FIGURE NO.: 5

PRINCIPAL-IN-CHARGE: JD	PROJECT MANAGER: JMcT



ENVIRONMENTAL RESOURCES MANAGEMENT		
399 Boylston Street, Boston, Massachusetts 02116 (617) 267-8377		
CLIENT NAME: Raytheon	*DRAWN BY:* LA	*DATE:* 10/4/01
FILE NAME: Sed Conc-Inorganic	*SCALE:*	*PROJ:* 143.57
Raytheon Company 430 Boston Post Road Wayland, Massachusetts		
MEAN SOIL/SEDIMENT CONCENTRATION AS A FUNCTION OF DISTANCE FROM OUTFALL OF-1		*FIGURE NO.:* 6
PRINCIPAL-IN-CHARGE: JD	*PROJECT MANAGER:* JMcT	



LEGEND

Natural Community Type		Cowardin Classification
Alluvial Red Maple Swamp		Forested Wetland (PFO) (91,319 s.f. 2.10 ac.)
Shrub Swamp		Scrub-Shrub Wetland (PSS) (237,718 s.f. 5.45 ac.)
Deep Emergent Marsh		Emergent Wetland (PEM) (295,670 s.f. 6.79 ac.)
Open Water		(RUB) / (PUB)
		Delineated Wetland Boundary/Project Boundary (location provided by ERM)
River Bulrush		

NOTE(S):

1) All acreage calculations are approximate and reflect covertypes shown in color above.

2) River location and natural community boundaries are approximate, and based on aerial photo interpretation and onsite observations. Aerial photo from MassGIS 1995.

3) Base map information including road locations, buildings, wetland boundary, and swale location based on a plan dated 9/13/99 called "Proposed Sample Collection Grid" produced by ERM.

4) Taken from the Woodlot Alternatives report "Raytheon Project Area, Ecological Characterization," dated December 2000.

SCALE (FEET)

60 0 30 60 120 240

ERM
399 BOYLSTON STREET–BOSTON, MA 02116
(617) 267–8377

Raytheon Company
430 Boston Post Road
Wayland, Massachusetts

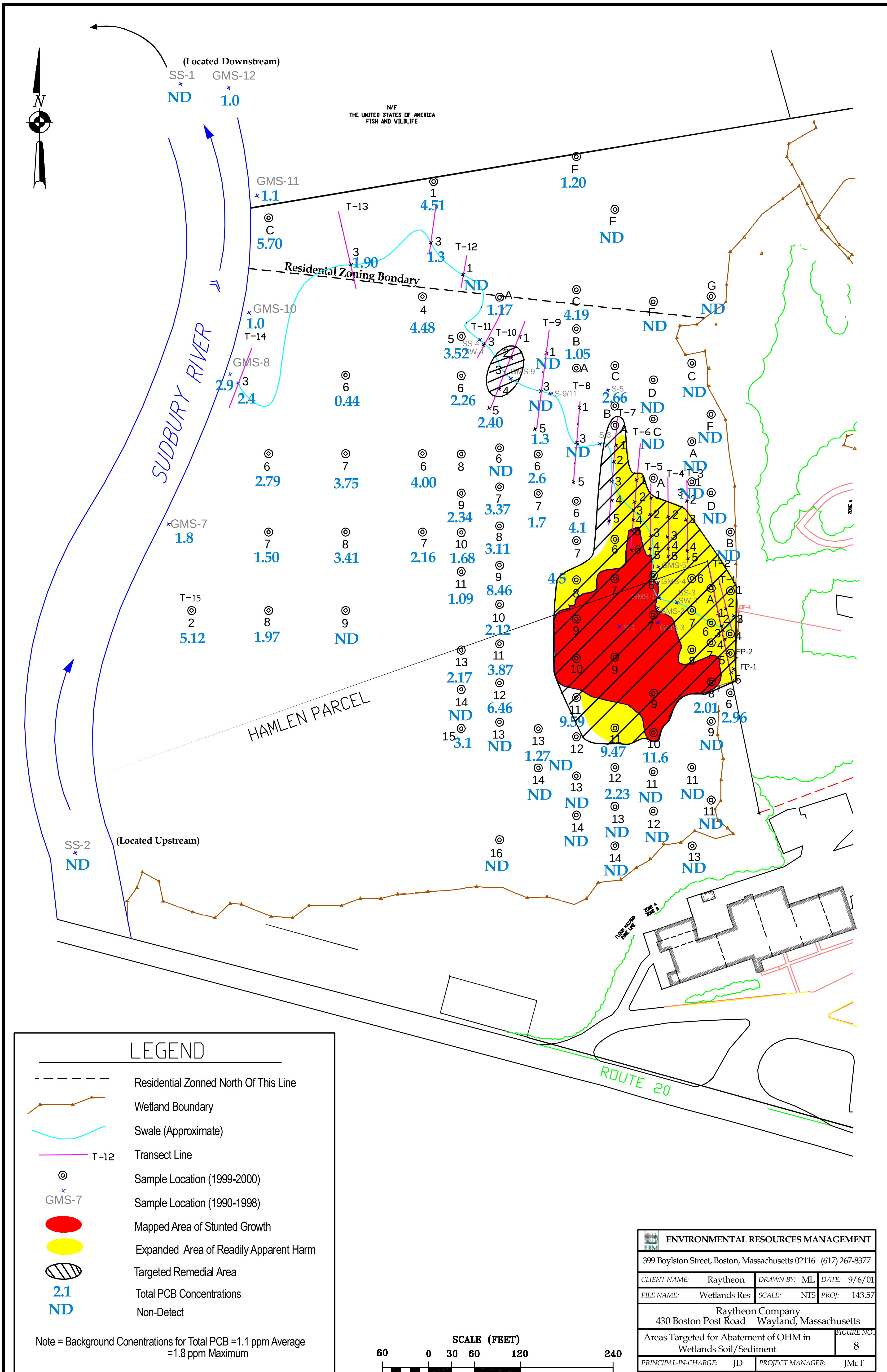
Revisions

Symbol	Description	Date	Approved
	G:\143.50\Job File\Phase II\Report Figures \Final Figures\Fig 14– Wetland Communities Map		

Designed by:
Drawn by: RL
Checked by: RJF
Reviewed by: JMcT
Submitted by: _

Wetland Communities Map

Scale: 1"=120'
Date: 2/19/01
Drawing No.
Figure No. 7
Contract No. 143.50



N
(Located Downstream)
SS-1
ND
GMS-12
1.0
N/F
THE UNITED STATES OF AMERICA
FISH AND WILDLIFE
GMS-11
1.1
Residental Zoning Bondary
SUDBURY RIVER
GMS-10
1.0
GMS-8
2.9
2.4
GMS-7
1.8
HAMLEN PARCEL
(Located Upstream)
SS-2
ND
ROUTE 20
LEGEND
Residential Zonned North Of This Line
Wetland Boundary
Swale (Approximate)
T-12
Transect Line
Sample Location (1999-2000)
GMS-7
Sample Location (1990-1998)
Mapped Area of Stunted Growth
Expanded Area of Readily Apparent Harm
Targeted Remedial Area
2.1
Total PCB Concentrations
ND
Non-Detect
Note = Background Conentrations for Total PCB =1.1 ppm Average
=1.8 ppm Maximum
SCALE (FEET)
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ENVIRONMENTAL RESOURCES MANAGEMENT
399 Boylston Street, Boston, Massachusetts 02116 (617) 267-8377
CLIENT NAME: Raytheon
DRAWN BY: ML
DATE: 9/6/01
FILE NAME: Wetlands Res
SCALE: NTS
PROJ: 143.57
Raytheon Company
430 Boston Post Road Wayland, Massachusetts
Areas Targeted for Abatement of OHM in Wetlands Soil/Sediment
FIGURE NO.
8
PRINCIPAL-IN-CHARGE: JD
PROJECT MANAGER: JMcT