PUBLIC COMMENT DRAFT
MASSACHUSETTS CONTINGENCY PLAN
REVISED PHASE III REMEDIAL ACTION PLAN

FORMER VARIAN FACILITY SITE
150 SOHIER ROAD
BEVERLY, MASSACHUSETTS 01915

MassDEP Site # 3-0485

Submitted by:

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Project No. 631010764
March 2023

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Acronyms and Abbreviations

1,1-DCA	1,1-dichloroethane
1,1-DCE	1,1-dichloroethene
1,1,1-TCA	1,1,1-trichloroethane
µg/L	micrograms per liter
AST	aboveground storage tank
AUL	Activity and Use Limitation
AS	air sparging
APTIM	Aptim Environmental & Infrastructure, LLC
AOC	areas of concern
bgs	below ground surface
Bomac	Bomac Laboratories Inc.
BWSC	Bureau of Waste Site Cleanup
CA	chloroethane
CAC	colloidal activated carbon
cis-1,2-DCE	cis-1,2-dichloroethene
CSA	comprehensive site assessment
CO2	carbon dioxide
COCs	chemicals of concern
CVOC	chlorinated volatile organic compound
DPE	dual-phase extraction
DPT	direct push technology
DOC	dissolved organic carbon
DNAPL	dense non-aqueous phase liquid
ERD	enhanced reductive dechlorination
ERH	electric resistance heat
ERI	electrical resistance imagery
EVO	emulsified vegetable oil
GAC	granular activated carbon
GHG	greenhouse gas
gpm	gallons per minute
HRC	hydrogen release compound
ISB	In situ bioremediation
ISCO	In situ chemical oxidation
ISCR	In situ chemical reduction
ISTR	In situ thermal remediation
kWh	kilowatt-hour
kW	kilowatt
MassDEP	Massachusetts Department of Environmental Protection
MCP	Massachusetts Contingency Plan
mg/kg	milligrams per kilogram

mg/L	milligrams per liter
MNA	monitored natural attenuation
MPE	multi-phase extraction
OHM	oil and/or hazardous material
O&M	operation and maintenance
P&T	pump and treat
PAZ	permeable adsorptive zone
PCE	tetrachloroethene
PIP	public involvement plan
PRB	permeable reactive barrier
PRZ	permeable reactive zone
PSL	potential source locations
RAP	remedial action plan
RCM	Reactive Core Mat®
RTN	release tracking number
SBGR	subgrade biogeochemical reactor
scfm	standard cubic feet per minute
SEE	steam enhanced extraction
S-mZVI	sulfidated micro zero valent iron
TCE	trichloroethene
THC	thermal conductive heat
TOC	total organic carbon
TPE	two-phase extraction
trans-1,2-DCE	trans-1,2-dichloroethene
TSDF	treatment/storage/disposal facility
VC	vinyl chloride
VOC	volatile organic compound
ZVI	zero valent iron

1.0 INTRODUCTION

APTIM Environmental & Infrastructure, LLC (APTIM) has prepared this Phase III Comprehensive Remedial Action Alternatives Report (Remedial Action Plan [RAP]) for the Massachusetts Department of Environmental Protection (MassDEP) in accordance with the Massachusetts Contingency Plan (MCP; Section 310 CMR 40.0850) for the Former Varian Facility located at 150 Sohier Road, in Beverly, MA (Site). Within this report, the term “Site” is used in accordance with the MCP, as any place or area where OHM from Varian’s former facility have come to be located. The “facility” refers to Varian’s former facility property. The Site location is shown on **Figure 1**. Due to historical operations and releases of oil and/or hazardous material (OHM), the Former Varian Facility is listed as a Disposal Site under the MCP and was assigned Release Tracking Number (RTN) 3-0485.

This Phase III RAP details proposed remedial (treatment) actions, provides an analysis of those remedial alternatives against established criteria, and describes the selected remedial actions to be taken to result in a Permanent Solution at the site. As required by the MCP, this Phase III RAP is being submitted electronically to the MassDEP concurrently with a completed Comprehensive Response Action Transmittal Form (BWSC-108). A copy of the BWSC-108 form is provided as **Appendix A**. The Site is an active Public Involvement Plan (PIP) site under the MCP. Therefore, a copy of this report will also be sent to the Information Repository established for the Former Varian Facility Site and to the Town of Beverly. This report was presented at a public meeting on January 24, 2023, and underwent a 20-day public comment period. This revised Phase III RAP incorporates revisions based on the comments received from MassDEP and the public. The revisions primarily address the bedrock and PSL-10 source areas.

1.1 Regulatory Reporting

In 2000, Varian submitted a Phase II Comprehensive Site Assessment (CSA) for the Site. This report documented the data and results of a comprehensive site assessment conducted from 1995 to 1999 to define the source, nature, and extent of the OHM releases at the property, including the investigation of 19 potential source locations (PSLs).

Based on the 2000 Phase II CSA, a condition of No Significant Risk existed at the Site with the exception of potential future risk associated with hypothetical future use of groundwater as drinking water. Remediation was recommended to address soil and groundwater impacts. Varian submitted a Phase III RAP in August 2021 and a Phase IV Remedy Implementation Plan (RIP) in December 2001. The Phase IV RIP described proposed remedial actions for addressing chlorinated volatile organic compounds (CVOCs) in soil and groundwater at the Site. In situ oxidation of CVOCs in soil and groundwater using permanganate (a common oxidant) was chosen as a suitable remedial alternative for the Site. Initial implementation of the Comprehensive Response Action, including permanganate injection, began in July 2002.

Response actions at the Site continued under the MCP in Remedy Operations Status (ROS) from 2002 through 2022. Semi-annual ROS reports documented the cleanup activities at the Site. Activities included supplementing the cleanup plan with bioremediation, installing multiple treatment wells, and further assessment of source areas. Well installation since the completion of the 2000 Phase II CSA has included approximately 54 remediation wells and 97 monitoring wells.

In 2012, the Phase III RAP and Phase IV RIP were modified to include soil vapor extraction (SVE). Two SVE systems were installed and continue to operate at Building 3 and Building 5 to mitigate potential vapor intrusion into the buildings and to extract CVOCs from the soil above the water table.

In November 2020, the MassDEP began a comprehensive review of response actions at the Site at the request of Beverly public officials and area residents. In December 2020, MassDEP completed an indoor air sampling program at 41 homes in the area of the Site, which determined that there was no evidence that CVOCs from the former Varian facility were impacting the indoor air of any of the homes that were sampled.

In March 2021, Varian began Site implementation of a MassDEP-approved work plan dated January 25, 2021. That plan included the following:

- resampling of indoor air at 21 of the homes selected by MassDEP
- additional well installation, surface water sampling, and sediment sampling activities in response to data gaps identified by MassDEP
- evaluation of potential human health, ecologic, and pet risk posed by CVOCs detected in the streams at the Site

A Vapor Intrusion Assessment Report was submitted on April 29, 2021, which detailed the results of the indoor air sampling. A total of 55 indoor air samples and 33 soil vapor samples were collected at 21 homes in February and March 2021. Additionally, sump water samples were collected at five homes in the study area. The vapor intrusion assessment also considered groundwater sample results from 13 shallow groundwater monitoring wells. Based on a lines-of-evidence evaluation conducted following MassDEP guidelines and using the data collected, a complete vapor intrusion pathway was not identified in any of the homes where testing was conducted.

Results of additional assessment activities outlined in the above-referenced MassDEP-approved work plan were included in the August 4, 2021, Phase V Remedy Operation Status (ROS) Report. This report concluded that:

- The data from vapor intrusion investigations at commercial properties on Tozer Road indicated there is No Significant Risk due to potential indoor air exposure that may be related to contributions from the former Varian facility. At the time, three properties were recommended for additional sampling to exclude potential background sources unrelated to the facility and further assess the vapor intrusion pathway.
- Potential human health exposure for Stream A and the Unnamed Stream posed No Significant Risk to human health.
- Due to the low level and limited potential risk to environmental receptors, ecological risk did not need to be further evaluated.

- The assessment of potential risk to pets (dogs) that may drink surface water demonstrated that the maximum detected concentrations in surface water are well below the screening levels identified for the protection of pets.

In a letter dated February 18, 2022, MassDEP ended the ROS for the Site and requested the completion of a revised Phase II CSA and a revised Phase III RAP for the Site. On October 7, 2022, a revised Phase II CSA was submitted by Varian. The October 2022 Phase II CSA comprehensively assesses current site conditions, including nature and extent of CVOCs, which were determined to be the primary compounds released at the Site, and provides an updated evaluation of risk based on these current site conditions. Regarding the revised Phase II CSA, the following is noted:

- **Shallow Groundwater:** Varian completed the installation of six shallow groundwater wells in the spring of 2021 in the neighborhoods downgradient of 150 Sohier Road under a MassDEP-approved work scope. As outlined in the January 2022 ROS report, four rounds of groundwater sampling at these new wells did not indicate the presence of CVOCs. This confirmed the 2000 Phase II CSA conclusions that shallow CVOC impacts in groundwater posed No Significant Risk in the residential areas west and south of 150 Sohier Road.

- **Seeps:** In 2021, additional surface water sampling was conducted. The risk assessment included in the June 2021 ROS report demonstrated again that VOCs detected in the streams at the Site posed No Significant Risk to human health or the environment.

- **Sediment:** Varian implemented additional sediment sampling activities under a MassDEP-approved work scope in the spring of 2021. The risk assessment included in the June 2021 ROS report demonstrated that CVOCs detected in the streams at the Site posed No Significant Risk to human health or the environment.

- **DNAPL:** Current groundwater concentrations were evaluated to assess the potential presence of DNAPL. That evaluation did identify wells in the Building 3 area where DNAPL is likely present in the vicinity of the wells due to relatively elevated CVOCs concentrations in soil and groundwater. In addition, subsequent sampling of groundwater at the Building 5 area did indicate that there is likely DNAPL in the bedrock near one well, given the relatively elevated CVOC concentrations in groundwater. The results suggest that DNAPL is or was present and has migrated into the deep overburden and potentially into fractured bedrock. Given the age of the release and absence of DNAPL detection in monitoring wells since 1997, DNAPL in the overburden is likely present residually (e.g., in discontinuous droplets) but is not mobile, while any DNAPL that is present in bedrock is likely present in fractures, many of which are small and poorly connected to other fractures, thereby limiting DNAPL mobility.

- **Electrical Resistance Imagery (ER):** To further assess the potential extent of elevated CVOCs beneath and adjacent to the Building 3 complex, an ERI study and confirmation drilling were conducted in the spring and summer of 2022. The results of that assessment work provide a clearer picture of the extent of elevated CVOCs in the Building 3 source area. The data has been used to estimate the area of elevated CVOC impacts that may warrant additional treatment beneath the Building 3 area.

Based on the levels of CVOCs present in the Building 3 source area and the Building 5 source area, additional remediation is warranted to limit the potential downgradient migration of CVOCs in groundwater. These two areas will be the focus of additional remediation at the Site. Based on the data, there is no indication of DNAPL in the open field area to the south of Building 5, referred to as PSL10. While the levels of CVOCs present at the PSL10 area are much lower than those in the Building 3 source area and the Building 5 source area, remediation may also be conducted in that area to limit potential downgradient migration of CVOCs in groundwater. The future remedial activities in these three source areas are the focus of this Phase III RAP.

1.2 Statement of Purpose

As stated in the MCP, the purpose of a Phase III RAP is to describe and document the information, rationale, and results used to identify and evaluate remedial action alternatives in sufficient detail to support the selection of the proposed remedial action alternative. The objective is to select a remedial action alternative that will likely result in a Permanent Solution. The exception being where it is demonstrated that a Permanent Solution is not feasible or that the implementation of a Temporary Solution would be more cost effective and timely than the implementation of a Permanent Solution.

2.0 GENERAL SITE INFORMATION

This section summarizes the Site area and history, including a discussion of potential receptors and affected media. Previous remedial measures, previous proposed remedial options, and treatment areas are also presented.

2.1 Disposal Site Name, Location, and Locus Map

Varian's former facility was located at 150 Sohier Road in Beverly, Essex County, Massachusetts. The property at 150 Sohier Road has the Universal Transverse Mercator coordinates of North 4,715,075 meters and East 345,475 meters, Longitude 70^{o} 52' 57" West: Latitude 42^{o} 34' 28" North. **Figure 2**, the Former Varian Facility Site Map identifies the location of 150 Sohier Road and the surrounding area.

The facility is located on approximately 24 acres of land and contains four large complexes of buildings covering approximately 250,000 square feet. The facility's southern portion includes an open field and a paved parking area. The central portion of the Site consists of a building complex (Buildings 5, 5A, 8, and 10) (referred to as the Building 5 complex). North of the Building 5 complex is a paved parking area and to the northwest is another building complex (Buildings 1, 2, 3, 4, and 6) (referred to as the Building 3 complex). Northeast of the Building 3 complex is a wastewater treatment plant in Building 9. West of the Building 3 complex is former Building 7, which is now operated as Kelly Classics and Restoration.

Presently, Communications & Power Industries, Inc. (CPI) uses Buildings 1 through 6, 8, 9, and 10, and other structures at the 150 Sohier Road property.

2.2 Disposal Site History and Potential Receptors

Bomac Laboratories, Inc. (Bomac) initially developed the facility property in 1950. Bomac sold the operations to Varian in 1959. Varian continued operations at the facility until the sale of the business in 1995 to the current owner and operator, CPI.

Since the facility's construction and during Varian's occupancy from 1959 to 1995, operations at the facility have consisted of researching and manufacturing of electronic equipment. During Varian's ownership, electron tubes were manufactured for radar applications under Standard Industrial Codes 3671 and 3673. The electron tubes were shipped off-site and primarily used by the United States Department of Defense. Manufacturing processes at the facility included electroplating, acid and alkali cleaning, painting, etching, and equipment maintenance.

During Varian's operations, various industrial processes were performed in the production areas of the facility buildings. These areas were locations where chemicals of concern (COCs) were present. Drywells and leaching fields associated with the production areas were reportedly used for waste disposal before the installation of the wastewater treatment system in 1972.

A total of 19 Potential Source Locations (PSLs) were initially identified at the Site, as summarized below. The general area of these locations is illustrated on **Figure 2**. The current status of each of the PSLs is also summarized below. Of these 19 PSLs, 5 PSLs are confirmed or likely source areas. Three of these PSLs beneath the Building 3 complex (PSLs 5, 6, and 11) are referred to as the Building 3 source area.

PSL 7 beneath Building 5 is referred to as the Building 5 source area. PSL 10 is the open field source area south of Building 5.

Potential Source Locations	Site Location	PSL Status in 2022
PSL1 – Former 500-gallon AST	North of Building 4	Not a Source Area (low priority)
PSL2 – Potential Former Dry Well	Southeast Corner of Building 9	Not a Source Area (low priority)
PSL3 – Potential Former Dry Well	Southwest Corner of Building 1	Not a Source Area (low priority)
PSL4 – Former Septic System	Building 1	Not a Source Area (low priority)
PSL5 – Former Septic Tank/Leach Field	Northeast corner of Building 1	Likely Source Area – ongoing investigation & remediation
PSL6 – Former Septic Tank/ Leach Field	Southeast of Building 1 (presently beneath Building 6)	Likely Source Area – ongoing investigation & remediation
PSL7 – Chem Laboratory	Building 5, includes former piping beneath the building	Confirmed Source Area – ongoing investigation & remediation
PSL8 – Building 7 Sumps	West Side of Building 7	Not a Source Area (low priority)
PSL9 – Utility Inspection Pit	Exterior Wall of Chem Lab in Building 3	While the pit itself was not a Source Area, lines in the structure are part of PSL 11
PSL10 – Open Field	South of Building 5	Confirmed Source Area – ongoing investigation & remediation
PSL11 – Laboratory	Northern Portion of Building 3, includes former subgrade piping and former discharge line to unnamed stream	Confirmed Source Area – ongoing investigation & remediation
PSL12 – Potential Former Lime Pit	Northeast corner of Building 1	Not a Source Area (low priority)
PSL13 – Former Beverly Landfill	East of Sohier Road and extending onto facility near Building 5	Not a Source Area (low priority)
PSL14 – Concrete-lined Trenches	Facility buildings	Not a Source Area (low priority)
PSL15 – Sumps	Buildings 2 and 3	Not a Source Area (low priority)
PSL16 – Transformers	Five locations on Site	Not a Source Area (low priority)
PSL17 – Floor Drains	Facility buildings	Not a Source Area (low priority)
PSL18 – Machine Shop Oils	West side of Building 7	Not a Source Area (low priority)
PSL19 – Unnamed Stream	Northeast Corner of Facility	Not a Source Area but ongoing investigation and risk evaluation being conducted

Notes:

(blue shading)	Building 3 Source Area
(red shading)	Building 5 Source Area
(green shading)	PSL10 Source Area

Potential receptors include the following: workers at the 150 Sohier Road facility, workers at properties on Tozer Road, and residents in areas to the west and south of Tozer Road.

2.3 Phase II Findings and Conclusions

Information about historical industrial processes and subsurface analytical data from PSL investigations indicated that the COCs at the Site are chlorinated volatile organic compounds (VOCs). Trichloroethene (TCE), tetrachloroethene (PCE), and 1,1,1-trichloroethane (1,1,1-TCA) were the three primary chlorinated solvents historically used at Varian's former facility. Eight COCs were identified for the Site, including the three parent compounds, TCE, PCE, 1,1,1-TCA; and five common degradation ("daughter") compounds, cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-dichloroethene (trans-1,2-DCE), 1,1-dichloroethene (1,1-DCE), 1,1-dichloroethane (1,1-DCA), and vinyl chloride (VC).

Releases of VOCs at the Building 3 complex appear to have occurred in PSL-5 (former Building 1 septic tank/leach field), PSL-6 (former septic tank/leach field beneath Building 6), and PSL-11 (Building 3 chemical laboratory). As noted previously, these PSLs are collectively referred to as the Building 3 source area. Releases of VOCs at Building 5 appear to have also occurred at PSL-7 (Building 5 chemical laboratory), which is referred to as the Building 5 source area. Additionally, VOC releases seem to have occurred at PSL10 (open field), primarily on the western property line near 32 Tozer Road. This location is referred to as the PSL10 source area.

As discussed above, response actions at the Site were conducted under the MCP in ROS from 2002 through 2022. From 2002 until 2019, over 219,000 gallons of permanganate solution were injected in the Building 3 source area, the Building 5 source area, the PSL 10 source area, and at downgradient locations as part of the cleanup program. In addition, between 2006 and 2020, over 67,000 gallons of bioremediation additive were injected at the Site to clean up VOCs in groundwater. Estimating the amount of VOCs treated through *in situ* remediation requires a number of assumptions, which contribute to uncertainty. With that in mind, it is estimated that over 1,400 pounds of VOCs have been treated by permanganate and bioremediation since 2002. In 2012, the Phase III Remedial Action Plan and Phase IV Plan were modified to include soil vapor extraction (SVE). Two SVE systems were installed and continue to operate at Building 3 and Building 5 to mitigate potential vapor intrusion into the buildings and to extract VOCs from the soil above the water table. More than 2,000 pounds of VOCs have been removed and treated by the two SVE systems. Prior to the start of permanganate treatment at the Site, a groundwater pumping system operated from 1992 until 2002. During its operation, the groundwater pump and treat system removed over 5,000 pounds of VOCs in groundwater.

Available data were presented in the October 2022 Phase II CSA and define the nature and extent of VOCs associated with the former Varian facility at 150 Sohier Road. Existing and potential pathways identified during the assessment include groundwater (flow through overburden and bedrock aquifers), surface water (nearby streams), buried utilities, sediment, soil vapor, and indoor air.

The nature and extent of VOCs in soil at the Site was determined based on the results of field (photoionization detector) screening recorded during drilling activities and laboratory analysis of soil samples collected at the Site. Soil impacts are noted in the three main source areas at 150 Sohier Road. These include the Building 3 source area, the Building 5 source area, and the PSL 10 source area. VOC soil impacts have not been observed in downgradient areas.

The current nature and extent of the COCs in groundwater in the overburden and bedrock aquifers were evaluated in the October 2022 Phase II CSA using data collected from monitoring wells over two years of sampling, May 2020 through May 2022. The highest CVOC concentrations are detected in groundwater on the former Varian facility property. Groundwater sampling results from 2022 indicate:

- Concentrations of TCE range from non-detect to 260 milligrams per liter (mg/L), with the greatest concentration located beneath Building 3 (well AP31-DO).
- Concentrations of PCE range from non-detect to 43 mg/L, with the greatest concentration located beneath Building 5 (well OB35-DO).
- Concentrations of cis-1,2-DCE range from non-detect to 500 mg/L, with the greatest concentration located just east of Building 3 (well AP33-DO).
- Concentrations of 1,1,1-TCA range from non-detect to 41 mg/L, with the greatest concentration located just east of Building 3 (well AP24-DO).

Groundwater occurs at the Site in two distinct aquifers: the overburden aquifer and the bedrock aquifer. Groundwater in the overburden at the Site generally occurs in and flows under water table conditions through the porous space between the soil grains. The overburden aquifer is recharged directly by infiltration of rainwater and surface runoff through unpaved areas. In the bedrock aquifer, groundwater flows through interconnected fractures and faults within the rock itself. The two aquifers are locally in communication, meaning that water flows between the overburden and bedrock aquifers. The majority of Site groundwater in each aquifer generally flows from the facility property to the west/southwest, following the regional groundwater flow pattern, which is south and west toward Shoe Pond and the Bass River. The transmissivity of the bedrock aquifer is substantially lower than that of the overburden aquifer, meaning that less groundwater (and dissolved CVOCs, if present) flows through bedrock relative to the overburden. Additionally, because of retardation effects (e.g., the propensity of CVOCs to adsorb onto the soil matrix), the velocity of the core of the CVOC plume is less than that of groundwater.

Where CVOCs are present at sufficient concentrations in shallow groundwater, there is potential for the volatilization of CVOCs into soil vapor above the groundwater. If this occurs in close proximity to a building, there is a potential that VOCs can pass through cracks and gaps in the foundation or via diffusion through the building slab. Extensive sampling has been conducted to evaluate this potential at the 150 Sohier Road property, at commercial properties on Tozer Road, and in downgradient residential areas. As a result of that sampling, mitigation measures (SVE systems) were installed and are operating to intercept and remove VOCs in soil vapor at Building 3 and Building 5. Sampling has shown that operation of the two SVE systems have resulted in a condition of No Significant Risk. Additional sampling is planned at one property on Tozer Road and one property on Longview Drive. If warranted, mitigation measures may be implemented at those properties. At other Site locations where sampling has been conducted, the results indicate that indoor air is not a significant pathway of concern.

Based on the levels of VOCs present in the Building 3 source area and the Building 5 source area, additional remediation is warranted to limit the potential downgradient migration of CVOCs in groundwater. These two areas will be the focus of additional remediation at the Site. While the levels of CVOCs present at the PSL10 area are much lower than those in the Building 3 source area and the Building 5 source area, remediation will also be conducted in that area to limit potential downgradient migration of CVOCs in groundwater.

As required by the MCP and Site conditions, a Method 3 Risk Assessment was conducted. That assessment evaluated the potential health effect of possible exposure to VOCs associated with the former Varian facility. Receptors, or potentially exposed people, included workers at the 150 Sohier Road facility, workers at properties on Tozer Road, and residents and commercial workers in areas west and south of Tozer Road. The result of that assessment indicated there is no current or future Significant Risk to residents, including children playing in the stream. No Significant Risk was identified to workers on Tozer Road. No Significant Risk was identified to workers in the 150 Sohier Road buildings with the operation of the existing SVE systems. However, a condition of No Significant Risk of harm has not been demonstrated for future construction workers who could potentially be exposed to groundwater in one area at the 150 Sohier Road property. The risk assessment demonstrated that a current condition of No Significant Risk of harm to safety, public welfare and the environment exists at the Site, with operation of the two SVE systems at 150 Sohier Road. A condition of No Significant Risk of harm has not been demonstrated for future construction workers who could potentially be exposed to groundwater in certain areas at the 150 Sohier Road property.

2.4 Remedial Objectives

The goals of this remedial action are:

1. **Source Elimination/Control** –sources of contamination are eliminated, or if they are not eliminated, they are eliminated to the extent feasible and they are controlled

2. **Migration Control** – plumes of dissolved CVOCs in groundwater and vapor-phase CVOCs in the vadose zone are stable or contracting

3. **DNAPL** – DNAPL with micro-scale mobility is removed to the extent feasible based upon consideration of conceptual site model (CSM) principles

4. **Groundwater** –to the extent feasible, reduce CVOC concentrations in groundwater to achieve or approach background conditions

5. **Indoor Air** – reduction of CVOCs to levels below appropriate criteria at 150 Sohier Road (e.g., the commercial/industrial threshold values or MassDEP workplace target)

The reduction in concentrations of COCs will be obtained using one or more remediation technologies appropriate for the site treatment areas. The selection of the remedial technologies will account for the property uses, onsite and nearby environmental conditions, cost, and the safety of persons living and/or working at or near the property.

2.5 Overall Approach to Evaluating Remedial Alternatives

A two-step process was used to evaluate various remedial technologies and alternatives:

- An Initial Screening of remediation technologies was completed to determine the most applicable approaches to address the remedial treatment areas at the site. The Initial Screening of technologies was conducted by considering site-specific conditions such as the types of contaminant(s) present, soil type, groundwater depth and flow, and general technology applicability and availability. The Initial Screening process identifies a short-list of applicable and available technologies that are expected to effectively reduce soil and groundwater concentrations at the Site.

- Several remediation alternatives were assembled using the short-listed technologies selected during the Initial Screening process. The remedial alternatives determined to be most appropriate were retained, further evaluated, and ranked in the Detailed Evaluation process. The Detailed Evaluation process considers criteria such as effectiveness, reliability, ease of implementation, relative cost, risk, green benefits, and time.

- The most applicable remedial alternative was identified based on the Detailed Evaluation criteria and alternative ranking.

Section 3.0 presents the Initial Screening process used to identify applicable remedial alternatives to address the remedial treatment areas at the Site.

Section 4.0 presents the Detailed Evaluation process used to evaluate and select the remedial alternatives to be implemented at the Site.

3.0 INITIAL SCREENING OF REMEDIAL TECHNOLOGIES (310 CMR 40.0856)

As specified in the MCP, an initial screening was conducted to identify remedial action alternatives which are reasonably likely to be feasible, based on the OHM present, impacted media, and site characteristics. A remedial response alternative is deemed feasible if it is reasonably likely to achieve a level of No Significant Risk, is a Permanent or Temporary Solution, and if the individuals with the expertise needed to effectively implement a solution are available.

Based on the Phase II CSA findings and remedial objectives outlined previously, there are five areas of concern (AOCs) considered for treatment for which technologies were evaluated and retained. These AOCs include:

- The Building 3 source area overburden;
- The Building 5 source area overburden;
- Bedrock (including bedrock proximate to Building 5);
- The PSL10 source area; and
- The downgradient plume.

A critical element in controlling groundwater migration is addressing the source areas. Treatment in the downgradient plume area is included to reduce CVOC levels along the groundwater flow pathway that would result in beneficial reductions in the areas west and south of Tozer Road.

An initial screening of applicable remedial technologies was conducted to provide source control and migration control. The initial screening was based upon the following criteria:

- *Technical Feasibility:* This criterion evaluates the applicability and reliability of the alternative to treat the contaminants based on performance on similar sites and contaminants.

- *Available Expertise:* This criterion evaluates whether the individuals with the expertise needed to implement the alternatives are available.

A variety of remediation technologies are available to address CVOCs in soil and groundwater, as either a stand-alone technology or as part of an integrated remedial strategy. The following list contains a summary of general response actions, remedial technologies, and process options for discussion in the initial screening:

- Institutional Actions
  - Activity Use Limitations (AUL)
  - Monitoring (Groundwater/Vapor)
- Containment
  - Capping
  - Immobilization
  - In-Situ Treatment Zones (ITZ)
  - Vertical Barriers
- Removal
  - Groundwater Pump & Treat (P&T)

    - Soil Excavation
- In-Situ Treatment
    - Physical
        - Air Sparging (AS)
        - Colloidal Activated Carbon (CAC)
        - Groundwater Circulation Well (GCW)
        - Multi-Phase Extraction (MPE)
        - Soil Vapor Extraction (SVE)
    - Biological
        - Engineered Wetlands/Phytoremediation
        - In-Situ Bioremediation (ISB)
        - Monitored Natural Attenuation (MNA)
        - Subgrade Biogeochemical Reactor (SBGR)
    - Chemical
        - In-Situ Chemical Oxidation (ISCO)
        - In Situ Chemical Reduction (ISCR)
    - Thermal Remediation
        - Electric Resistance Heat (ERH)
        - Steam Enhanced Extraction (SEE)
        - Thermal Conductive Heat (TCH)
- Ex-Situ Treatment
    - Physical
        - Air-Stripping
        - Liquid Phase Granular Activated Carbon (GAC)
        - Vapor Phase GAC
    - Chemical (UV Oxidation)
- Disposal
    - Groundwater (Surface Water/Wastewater Treatment Facility [WWTF])
    - Soil (Treatment/Storage/Disposal)

These initial screening alternatives, along with relative advantages and disadvantages, are presented in the following sections.

3.1 Technology Screening Overview

Table 1 summarizes the technology screening for the Site including:

- A description of the technology;
- The feasibility that the technology could be incorporated as part of a Permanent or Temporary Solution;
- The availability of experts to implement the technology;
- The media (soil, groundwater, vapor, surface water) addressed by the technology;
- The need for ex-situ treatment (groundwater, soil, or vapor) associated with the technology;
- The AOCs for which the technology has been retained (Building 3 Overburden, Building 5 Overburden, Bedrock, PSL10, Downgradient Plume); and
- The basis for retaining or eliminating the technology.

Of the technologies identified above, the following were eliminated during the technology screening (refer to Table 1 for rationale):

- Containment
    - Capping
    - Immobilization
    - Vertical Barriers
- Removal
    - Soil Excavation[1]
- In-Situ Treatment
    - Physical
        - Air Sparging
        - Groundwater Circulation Wells
    - Biological
        - Engineered Wetland/Phytoremediation
        - Subgrade Biogeochemical Reactor
- Ex-Situ Treatment
    - Air Stripping
    - UV Oxidation
- Disposal
    - Wastewater Treatment Facility

3.2 Initial Screening Summary

The initial screening of applicable remedial technologies has been performed for CVOCs in groundwater and soil at the Site. The initial screening was performed to identify remedial technologies that are likely to be successful in addressing Site COCs. Of the technologies identified above, the following were retained during the technology screening (refer to **Table 1** for rationale). These technologies are also summarized in **Table 2**, including the AOC for which the technologies have been retained.

- Institutional Actions
    - Activity Use Limitations (AUL)
    - Monitoring (Groundwater/Vapor)
- Containment
    - In-Situ Treatment Zones (ITZ)
- Removal
    - Groundwater Pump & Treat (P&T)
    - Soil Excavation[1]
- In-Situ Treatment
    - Physical
        - Activated Carbon (AC)
        - Multi-Phase Extraction (MPE)
        - Soil Vapor Extraction (SVE)
    - Biological
        - In-Situ Bioremediation (ISB)
        - Monitored Natural Attenuation (MNA)
    - Chemical
        - In-Situ Chemical Oxidation (ISCO)

[1] Some excavation may be conducted in the PSL-10 source area if warranted by pre-design investigation findings at PSL10. Refer to Section 4.1.2.2.4 for additional discussion.

        - In Situ Chemical Reduction (ISCR)
    - Thermal Remediation
        - Electric Resistance Heat (ERH)
        - Steam Enhanced Extraction (SEE)
        - Thermal Conductive Heat (TCH)
- Ex-Situ Treatment
    - Physical
        - Liquid Phase Granular Activated Carbon (GAC)
        - Vapor Phase GAC
- Disposal
    - Groundwater (Surface Water)

As noted previously, there are five areas being considered for treatment. Because these areas are dissimilar, each with several applicable technologies, a single remedial action alternative that meets the requirements of 310 CMR 40.0857(2) was not identified.

Generally, a detailed evaluation is not required after identifying a remedial action during the initial screening when the following conditions are met:

a) The remedial action is proven to be effective in remediating the types of OHM present at the disposal site, based upon experience gained at other disposal sites with similar site and contaminant conditions

b) The remedial action results in the reuse, recycling, destruction, detoxification, treatment, or any combination thereof of the OHM present at the disposal site

c) The remedial action can be implemented in a manner that will not pose a significant risk of harm to health, safety, public welfare, or the environment, as described in 310 CMR 40.0900

d) The remedial action is likely to result in the reduction and/or control of OHM at the disposal site to a degree and in a manner such that the requirements of a Permanent Solution as set forth in 310 CMR 40.1000 will be met

Since these conditions are not met, a detailed evaluation was required to further evaluate the retained alternatives, as presented in **Section 4.0.**

4.0 DETAILED EVALUATION OF REMEDIAL ACTION ALTERNATIVES (310 CMR 40.0858)

The following sections present a detailed evaluation of remedial action alternatives in accordance with 310 CMR 40.0858, including a Feasibility Evaluation in accordance with 310 CMR 40.0860. The methodology used for conducting the detailed evaluations is described below.

4.1 Remedial Alternative Evaluation Methodology

Detailed evaluations of remedial alternatives are conducted in three steps:

- Step 1. Review short-listed remedial technologies from initial screening and assemble remedial action alternatives;
- Step 2. Evaluate and score retained alternatives using a detailed evaluation process; and
- Step 3. Rank and select a remedial alternative using an evaluation scoring matrix.

4.1.1 Assemble Remedial Action Alternatives

Based on the retained remedial technologies in **Section 3.2**, remedial action alternatives (RAAs) were assembled for each treatment area. The concentration of the COCs, as well as the subsurface hydrogeology, dictate the most effective treatment technologies. From high concentrations to low concentrations, the most effective in-situ technologies range in general from in-situ thermal remediation (ISTR) to in-situ chemical oxidation (ISCO) to in-situ chemical reduction (ISCR) to in-situ bioremediation (ISB) to monitored natural attenuation (MNA). In general, assembled alternatives are listed according to the above technology prioritization, not according to likelihood of implementation.

In the rest of this discussion, the term “chloroethenes” (CE) is used to refer to the combined concentration or mass of the following CVOCs: PCE, TCE, cis-1,2-DCE, and VC. This should not be confused with the term “chloroethene,” which is occasionally used in the literature as an alternate name for VC

4.1.1.1 Building 3 Overburden

The treatment zone associated with this AOC is presented in **Figure 3**. It is approximately 13,000 square feet (ft^2) and 45 ft deep. Based on an approximate average soil concentration of 100 milligrams per kilogram (mg/kg) and an approximate average groundwater concentration of 100 milligrams per liter (mg/L), it is estimated that this area has 6,500 lbs of total chloroethenes (5,500 lbs adsorbed[2] and 1,000 lbs dissolved[3]). As such, this AOC has the highest CVOC mass. Therefore, the RAAs focus on ISTR and ISCO. The RAA also evaluates the effect of having unrestricted interior “building access”, which would require temporarily relocating the existing building operations (e.g., plating operation) before conducting remediation. In all cases, an ISB polish was included to further reduce concentrations after implementation of the primary treatment, as well as continued operation of the existing soil vapor extraction (SVE) system to remove vapor-phase CVOC mass and protect indoor air.

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[2] 13,000 ft^2 soil * 45 ft soil * 1 m^3 soil/35.3147 ft^3 soil * 1,500 kg soil /m^3 soil = 24,848,000 kg soil * 100 mg CE/kg soil * 1 lb CE/453,592 mg CE= 5,478 lbs (approximately 5,500 lbs)

[3] 13,000 ft^2 soil * 45 ft soil x 0.28 ft^3 water/ft^3 soil * 28.3168 L water/ft^3 water = 4,638,000 L * 100 mg CE/L water * 1 lb CE/453,592 mg CE = 1,020 lbs (approximately 1,000 lbs)

Remedial Action Alternatives for Building 3 Overburden
RAA #1 – ISTR w/o Building Access, ISB Polish & Continued SVE System Operation
RAA #2 – ISTR w/ Building Access, ISB Polish & Continued SVE System Operation
RAA #3 – ISCO w/o Building Access ISB Polish & Continued SVE System Operation

4.1.1.2 Building 5 Overburden

The treatment zone associated with this AOC s area is presented in **Figure 4**. It is approximately 7,000 ft^2 and 55 ft deep. Based on an approximate average soil concentration of 20 mg/kg and an approximate average groundwater concentration of 40 mg/L, it is estimated that this area has 1,000 lbs of total chloroethenes (700 lbs adsorbed[4] and 300 lbs dissolved[5]). The estimated CVOC mass is substantially lower than for Building 3 and covers a smaller area. While ISTR was included as an RAA, the other two RAA represent treatment technologies which have been used to a limited extent in Building 5, namely ISCO and ISB, are also suitable for this type of CVOCs and range of concentrations. All alternatives include continued operation of the SVE system to remove vapor-phase CVOC mass and protect indoor air.

Remedial Action Alternatives for Building 5 Overburden
RAA #1 – ISTR w/o Building Access & Continued SVE System Operation
RAA #2 – ISCO w/o Building Access & Continued SVE System Operation
RAA #3 – ISB w/o Building Access & Continued SVE System Operation

4.1.1.3 Bedrock

The treatment zone of this AOC is proximate to Building 5 and is defined by OB-54-BR and OB-45-BR to the east and OB-52-BR to the west. It is approximately 40,000 ft^2 and represents the upper 50 ft of the bedrock aquifer. Because groundwater is only present in bedrock fractures, estimating contaminant mass is less accurate. Based on an approximate average groundwater concentration of 100 mg/L total chloroethenes, the estimated contaminant mass ranges from 125 to 1,250 pounds[6]. In bedrock, adsorbed contamination is not anticipated to be a significant consideration for treatment since the rock formation does not readily adsorb CVOCs. Based on the groundwater concentrations in bedrock, the three intermediate technologies (ISCO, ISCR and ISB) are likely the most appropriate. The concentrations detected in groundwater in this area are also too high to consider MNA. As ISTR has been evaluated for both Building 3 and Building 5, and because of the potential presence of DNAPL, it will

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[4] 7,000 ft^2 soil x 55 ft soil * 1 m^3 soil/35.3147 ft^3 soil * 1,500 kg soil /m^3 soil = 16,353,000 kg soil * 20 mg CE/kg soil * 1 lb CE/453,592 mg CE= 720 lbs (approximate 700 lbs)

[5] 7,000 ft^2 soil x 55 ft soil x 0.28 ft^3 water/ft^3 soil x 28.3168 L water/ft^3 water = 3,053,000 L * 40 mg CE/L water * 1 lb CE/453,592 mg CE = 270 lbs (approximate 300 lbs)

[6] 40,000 ft^2 bedrock * 50 ft bedrock * (0.01 – 0.1 [range]) ft^3 water/ft^3 bedrock * 28.3168 L water/ft^3 water = (566,000 – 5,663,000 L) * 100 mg CE/L water * 1 lb CE/453,592 mg CE = 125 – 1,250 lbs (depending on porosity)

also be considered as a fourth RAA for this AOC.

Remedial Action Alternatives for Bedrock
RAA #1 – ISCO
RAA #2 – ISCR (using Sulfidated Microscale Zero Valent Iron [S-mZVI])
RAA #3 – ISB
RAA #4 - ISTR

4.1.1.4 PSL10 Area

The treatment area of this AOC is defined by CL10-S/CL10-DO/MW2_32-Tozer and the ISCO injection wells AP-19, AP-20, AP-21, and AP-22. It is approximately 7,200 ft^2. Based on an approximate average soil concentration of 4 mg/kg and an approximate average groundwater concentration of 4 mg/L, it is estimated that the overburden has 100 lbs of total chloroethenes (85 lbs adsorbed[7] and 15 lbs dissolved[8]). The concentrations in shallower wells CL10-S and AP-22 exhibit seasonal fluctuations in CVOC concentrations that seem to indicate the presence of vadose soil contamination that is mobilized and transported vertically to groundwater during seasonal groundwater table fluctuations or surficial recharge.

This treatment area has low levels of contamination (< 10 mg/L chloroethene[8]) relative to other source areas, and there is no indication of potential DNAPL in this area. Therefore, ISTR is not an appropriate technology for the PSL10 area. ISCO has been used successfully in this area previously; however, delivery of a sufficient volume of the ISCO solution has been limited by the low permeability of the glacial till formation. The levels are low enough relative to other source areas to evaluate MNA. In addition, colloidal activated carbon (CAC) is included as a third RAA. For the purpose of this evaluation and in the rest of this report, the use of CAC is assumed; however, based on additional pre-design investigations, an alternative approach may be used, such as ISCR (e.g., ZVI) or a combination of ISCR and CAC.

Remedial Action Alternatives for PSL10
RAA #1 – ISCO
RAA #2 – CAC Permeable Adsorptive Zone (PAZ)
RAA #3 – MNA

4.1.1.5 Downgradient Plume

The treatment area for this AOC is assumed to be along Tozer Road from OB-4-DO (south of Route 128)

[7] 7,200 ft^2 soil x 30 ft soil * 1 m^3 soil/35.3147 ft^3 soil * 1,500 kg soil /m^3 soil = 9,170,000 kg soil * 4 mg CE/kg soil * 1 lb CE/453,592 mg CE= 85 lbs

[8] 7,200 ft^2 soil x 30 ft soil x 0.28 ft^3 water/ft^3 soil x 28.3168 L water/ft^3 water = 1,713,000 L * 4 mg CE/L water * 1 lb CE/453,592 mg CE = 15 lbs

[8] The maximum total chloroethene concentration in the past 3 years was 7.2 mg/L at AP-20.

to near CL04-DO (south of 30 Tozer Road), about 1,000 feet. The depth to bedrock ranges from 90 feet at CL03-DO to 30 feet at CL04-DO. This AOC has relatively low levels of contamination (maximum of 5 mg/L total chloroethenes); therefore, neither ISTR nor ISCO are warranted. Permeable reactive zones (PRZ [S-mZVI or CAC]) are evaluated, along with MNA. The primary focus of the cleanup plan at the Site is source area treatment. In this AOC, in-situ treatment near Tozer Road is proposed to reduce CVOC levels along the groundwater flow pathway that would result in beneficial reductions in the areas west and south of Tozer Road. Another benefit of this treatment would be the capture of CVOC mass that could potentially remobilize during source area treatment occurring upgradient (e.g., Building 3 Overburden). For both non-MNA alternatives, treatment of the downgradient bank seeps observed at Stream A has also been included using a permeable adsorptive zone (PAZ) using granular activated carbon. Varian is planning to implement a limited treatment in the area of the seep to provide mitigation in this area.

Remedial Action Alternatives for Downgradient Plume
RAA #1 – S-mZVI Permeable Reactive Zone (PRZ) w/GAC PAZ Seep Treatment
RAA #2 –CAC Permeable Adsorptive Zone (PAZ) w/GAC PAZ Seep Treatment
RAA #3 – MNA

4.1.2 Evaluate Remedial Action Alternatives

4.1.2.1 Evaluation Criteria

The MCP requires the evaluation of specific criteria for remedial alternatives at 310 CMR 40.0858. These criteria include effectiveness, reliability, difficulty, cost, risks, and comparative cleanup time.

4.1.2.1.1 Effectiveness

To rank the alternatives in terms of effectiveness (E), a score of 1 (least effective) to 5 (most effective) was assigned to each alternative under consideration. A score of 5 was assigned to only those alternatives that have been demonstrated to be a successful remediation tool at sites with similar COCs and geologic characteristics. To receive a rating of 5, the alternatives should reuse, recycle, destroy, detoxify, or treat the OHM and have a high probability of achieving a Permanent or Temporary Solution. Decreasing scores were assigned to alternatives which: (1) are less proven or not as readily available; (2) do not reduce levels of untreated OHM to concentrations that achieve or approach background; or (3) do not properly control residues or wastes or discharges to the environment.

4.1.2.1.2 Reliability

The comparative short-term and long-term reliability (R1) of the alternatives was evaluated. A score of 1 (least reliable) to 3 (most reliable) was assigned to each alternative under consideration. Those alternatives which provided a higher degree of certainty of being successful were given a higher score. In addition, a higher score indicates greater effectiveness in managing wastes and controlling emissions or discharges to the environment.

4.1.2.1.3 Difficulty

To rank alternatives in terms of difficulty (D) of implementation or technical complexity, a score of 1 (most difficult) to 3 (least difficult) was assigned to each alternative under consideration. A score of 3 was assigned to those alternatives that are anticipated to have the least delay due to permitting and equipment procurement, and for which the materials and resources are readily available for implementation. A score of 3 also indicates that the technology has a low technical complexity. Decreasing scores were assigned to alternatives that are anticipated to have difficulties with permitting, access agreements, interruption to present operations (e.g., relocation of manufacturing activities at Building 3), availability of necessary off-site treatment, storage and disposal facilities, and increased complexity requiring a higher level of training for operators.

4.1.2.1.4 Cost

The alternatives were further ranked from 1 to 3 according to relative cost (C). Alternatives with the lowest relative costs were assigned a score of 3. The scores decrease to a minimum of 1 as relative cost increases. The estimates present the initial construction costs, estimated annual operations, and maintenance costs.

Costs were estimated for each of the Remedial Action Alternatives using the following information and criteria:

- Estimated treatment area and depth of impacted material as indicated from soil and groundwater data.
- Estimated quantities of reagent or augmentation material based on the volume of soil and groundwater to be treated and the characteristics of the various treatment methods.
- Estimates of the time for various labor categories to prepare the necessary documentation to design, permit, install, and operate each alternative method-based history with similar projects.
- Typical installation techniques including wells, treatment fluid pumping for injection, or alternative injection methods.
- Material and equipment costs based on history of similar projects.
- Typical performance of similar systems in the remediation of similar sites.

Cost estimates are included in **Appendix B**; relative costs are provided below:

Treatment Technology	Estimated Treatment Cost ($/lb contaminant)			
	Areas of Concern			
	Building 3	Building 5	Bedrock	PSL10
ISTR	$2,600	$9,900	$14,000-$140,000	NA
ISCO	$1,700	$6,400	$4,000 - $40,000	$15,000
ISCR	NA	NA	$2,600 - $26,000	NA
ISB	NA	$3,900	$1,500 - $15,000	NA

4.1.2.1.5 Risk

The alternatives were ranked from 1 to 3 based on the potential relative short- and long-term risk (R2) of harm to human health, safety, public welfare, or the environment associated with their implementation.

The implementation risks should also consider on- and off-site risks associated with excavation, transport, disposal, containment, construction, operation or maintenance activities, or discharges to the environment. A score of 3 was assigned to alternatives that expect to incur low-level risks. Decreasing scores were assigned as risk associated with implementation increased.

4.1.2.1.6 Green Benefit

Each alternative was ranked on a scale of 1 to 4 based on the green benefits (B) related to that alternative. Alternatives that are expected to limit energy use or use renewable energy and resources, limit air pollution or greenhouse gas emissions, reduce, reuse, and recycle waste, protect land and ecosystems, and limit adverse visual and aesthetic impacts would receive a score of 4. Alternatives that will not meet these objectives were assigned a lower score.

4.1.2.1.7 Timeliness

Each alternative was ranked on a scale of 1 to 3 based on the estimated time (T) required to achieve the desired remediation goal. Alternatives that will achieve the goal the quickest were assigned a value of 3. Alternatives that will take longer but result in an acceptable treatment time were assigned a value of 2. Alternatives with treatment times longer than desired were assigned a value of 1.

A detailed evaluation was performed on the short-listed remedial alternatives for each AOC. The following factors were used in this evaluation: effectiveness, short-term and long-term reliability, difficulty in implementation, comparative cost, relative risk associated with implementation, green benefits, and timeliness.

The following equation was used to calculate the overall score of each alternative:

$$\text{Score} = E+R1+D+C+R2+B+T$$

where:

E = effectiveness
R1 = reliability
D = difficulty score
C = estimated relative cost score
R2 = risk associated with implementation score
B = green benefits score, and
T = timeliness score

The scores may range from 7 to 24. The alternative evaluation indices were developed based upon the above-described matrix system, literature review, professional judgement, and APTIM's remediation experience. The selected remedial action alternative was based on the results of the scoring matrix unless otherwise stated.

4.1.2.2 Detailed Evaluation of Remedial Action Alternatives

The detailed evaluation of RAAs assembled in **Section 4.1.1** are presented in **Table 3** (Building 3 Overburden), **Table 5** (Building 5 Overburden), **Table 7** (Bedrock), **Table 9** (PSL10 Area) and **Table 11** (Downgradient Plume), respectively.

4.1.2.2.1 Building 3 Overburden

Based on the risk assessment, TCE groundwater concentration must be reduced to approximately 0.56 mg/L TCE in the shallow groundwater (assuming no protections for future construction workers in an excavation scenario). However, potential future construction worker exposure in the hot spot areas will likely be addressed by protective measures specified in an Activity and Use Limitation (AUL). The treatment goal will therefore be to reduce levels in the source areas to a concentration that eliminates the potential for DNAPL to act as a continuing source of CVOC migration in groundwater. To that end, a reduction of concentrations in groundwater to 50% of the 1% solubility limit is proposed. The solubility limit for TCE is 1,100 mg/L; 1% of that is 11 mg/L. Therefore, the treatment goal for TCE would be 5 mg/L in groundwater. APTIM used the EPA's Soil-Water Partition Equation ("Soil Screening Guidance: Technical Background Document, EPA/540/R95/128, May 1996) to estimate the mass reduction required:

$$C_t = C_{gw} * \left(K_{oc} * f_{oc} + \frac{\theta_w + \theta_a * H}{\rho_b}\right)$$

where:

C_t = Overall equilibrium concentration (mg/kg)
C_{gw} = Equilibrium groundwater concentration (mg/L)
f_{oc} = Organic carbon content of soil (kg/kg [assumed 0.002 [default])
K_{oc} = Soil organic carbon-water partition coefficient (L/kg [assumed 166 {TCE}])
θ_w = Water-filled soil porosity (L_{water}/L_{soil} [assumed 0.28])
θ_a = Air-filled soil porosity (L_{air}/L_{soil} [assumed 0 for saturated soils])
H = Henry's law constant (dimensionless [0.4 {TCE}])
ρ_b = Dry soil bulk density (Kg/L [assumed 1.5])

When the constant values are inserted, the equation reduces to:

$$C_t[mg/kg] = 0.52 * C_{gw}\ [mg/L]$$

The following equation provides the total contaminant mass in pounds (M_c [assuming DNAPL has been removed to the extent possible]):

$$M_c = \frac{C_t * (M_s + M_{gw})}{453{,}592}$$

$$M_c = \frac{0.52 * C_{gw} * (M_s + M_{gw})}{453{,}592}$$

where:

M_c = Total contaminant mass (lbs)
M_s = Soil mass (24,848,000 kg) (assuming treatment zone dimensions and dry soil bulk density referenced in Section 4.1.1.1)
M_{gw} = Groundwater mass (4,638,000 L * 1 kg/L = 4,638,000 kg) (assuming treatment zone dimensions and water-filled porosity density referenced in **Section 4.1.1.1**)
Note: 453,592 is conversion factor from milligrams to pounds

If the post-treatment TCE groundwater concentration goal (C_{gw}) is 5 mg/L, then the total contaminant mass must be reduced to approximately 200 lbs, which means an overall 97% reduction is required.

The detailed evaluation for the Building 3 overburden focuses on the primary remedial technology (ISTR vs. ISCO). Because this is the area with the highest CVOC mass, ISB polish has been included to either take advantage of the elevated temperatures following ISTR (which would enhance biological activity), or simply to take advantage of improved access offered by ISCO wells.

Alternatives 1 and 3 involve accessing the subsurface contamination by angled drilling, which is more expensive to implement than vertical drilling and potentially less effective. However, the vertical drilling associated with Alternative 2 requires the temporary relocation of certain Building 3 operations (e.g., plating operation), which is also potentially cost prohibitive.

The cost estimates for Alternatives 1 and 2 are based on a proposal provided by a vendor that proposes to utilize a combination of thermal conductance heating (TCH) and steam-enhanced extraction (SEE). The costs are not primarily driven by the level of contamination, but the amount of energy needed to raise the subsurface temperature to 212 ^{o}F. For the purposes of developing cost estimates, the Alternative 3 cost (as well as ISCO-based RAA in other AOCs) is based on using sodium permanganate. Since it is a design element, a final determination of the oxidant that will be used in the treatment area will be made in the Phase IV Plan. The cost of ISCO is not primarily driven by the level of contamination, but by the amount of oxidant needed to overcome the natural soil oxidant demand (SOD [conservatively assumed to be 3 g/kg]).

It is assumed that primary treatment (ISTR or ISCO) with Alternatives 1, 2, and 3 will result in 90%, 95%, and 80% CVOC mass reduction, respectively. It is anticipated that Alternative 2 will not require a period of natural attenuation to reach the final groundwater concentration, but a short period of natural attenuation will achieve the 97% reduction for Alternative 1. With an estimated 80% CVOC mass reduction for Alternative 3, it is assumed that five years of natural attenuation will be needed following treatment. The remedial timeframes for the Alternatives were estimated as follows:

Alternative 1		Alternative 2		Alternative 3	
ISTR	18 mo	Plating Operations Relocation	18 mo	Well Installation	4 mo
1st ISB Injection	1 mo	ISTR	12 mo	1st ISCO Injection	3 mo
Time Between Injections	18 mo	1st ISB Injection	1 mo	Time Between Injections	6 mo
2nd ISB Injection	1 mo	Time to Evaluate Need for Additional Injection	24 mo	2nd ISCO Injection	3 mo
Time to Evaluate Need for Additional Injection	18 mo			Time Between Injections	6 mo
Natural Attenuation	24 mo			3rd ISCO Injection	3 mo
				Time Between Injections	6 mo
				1st ISB Injection	1 mo
				Time Between Injections	18 mo
				2nd ISB Injection	1 mo
				Time to Evaluate Need for Additional Injection	18 mo
				Natural Attenuation	60 mo
Total	**80 mo**	**Total**	**55 mo**	**Total**	**129 mo**

4.1.2.2.2 Building 5 Overburden

APTIM performed similar required contaminant mass reduction calculations to those discussed in Section 4.1.2.2.1 for the Building 3 overburden. It is estimated that 90% contaminant mass reduction is needed to ensure that the equilibrium groundwater concentration is reduced to 5 mg/L.

All three alternatives are based on accessing the subsurface contamination by angled drilling. As with Building 3, the cost of the first two alternatives is based on a combination of thermal conductance heating (TCH) and steam enhanced extraction (SEE) (Alternative 1) or on the use of sodium permanganate (Alternative 2). Due to lower CVOCs mass than for Building 3, ISB polishing is not included. The third alternative is based on the injection of emulsified vegetable oil (EVO) and SDC-9 bioaugmentation culture to enhance reductive dechlorination. High pressure fracturing and/or pulsed injection with be utilized to the extent possible to improve delivery of bioremediation amendments.

It is assumed that primary treatment (ISTR or ISCO) with Alternatives 1, 2, and 3 will result in 90%, 80% and 70% CVOC mass reduction, respectively. It is assumed that Alternatives 2 and 3 will need 1.5-3 years of natural attenuation to reach the required reduction. The remedial timeframes for the alternatives were estimated as follows:

Alternative 1		Alternative 2		Alternative 3	
ISTR	12 mo	Well Installation	3 mo	Well Installation	3 mo
		1st ISCO Injection	2 mo	1st ISB Injection	2 mo
		Time Between Injections	6 mo	Time Between Injections	18 mo
		2nd ISCO Injection	2 mo	2nd ISB Injection	2 mo
		Time Between Injections	6 mo	Time to Evaluate Need for Additional Injection	18 mo
		3rd ISCO Injection	2 mo	Natural Attenuation	36 mo
		Time to Evaluate Need for Additional Injection	6 mo		
		Natural Attenuation	18 mo		
Total	**12 mo**	**Total**	**45 mo**	**Total**	**79 mo**

4.1.2.2.3 Bedrock

The cost of the three non-thermal alternatives is based on the injection of sodium permanganate for the ISCO alternative (SOD of 0.5 g/kg), sulfidated-micro zero valent iron (S-mZVI) for the ISCR alternative, or EVO/SDC-9 for the ISB alternative. In each case, 30 injection wells would be installed into the top 50 foot of the bedrock aquifer. The remedial timeframes for the Alternatives were estimated as follows:

Alternative 1		Alternative 2		Alternative 3	
Well Installation	6 mo	Well Installation	6 mo	Well Installation	6 mo
1st ISCO Injection	3 mo	1st ISCR Injection	2 mo	1st ISB Injection	2 mo
Time Between Injections	6 mo	Time Between Injections	18 mo	Time Between Injections	18 mo
2nd ISCO Injection	3 mo	2nd ISCR Injection	2 mo	2nd ISB Injection	2 mo
Time Between Injections	6 mo	Time to Evaluate Need for Additional Injection	24 mo	Time Between Injections	18 mo
3rd ISCO Injection	3 mo			3rd ISB Injection	2 mo
Time to Evaluate Need for Additional Injection	24 mo			Time to Evaluate Need for Additional Injection	24 mo
Total	**51 mo**	**Total**	**52 mo**	**Total**	**72 mo**

As with the Building 3 and Building 5 source areas, the thermal alternative is based on a combination of thermal conductance heating (TCH) and steam enhanced extraction (SEE).

Alternative 4	
ISTR	12 mo
Total	**12 mo**

4.1.2.2.4 PSL10

Treatment in this area is not needed to address significant risk or to contain the potential migration of CVOCs from potential DNAPL. In addition, there is no indication of potential DNAPL in this area. Treatment is included in this area to provide reduction in CVOC levels along the groundwater flow pathway that would result in beneficial reductions in the areas downgradient to the west. Alternative 1 (ISCO) involves adding sodium permanganate through 10 injection wells (an increase from the current four injection wells) throughout the treatment zone and pneumatic fracturing to improve reagent delivery. Alternative 2 (CAC) involves injecting colloidal activated carbon (e.g., PlumeStop®) into a permeable adsorptive zone (PAZ or “treatment wall”). Alternative 3 is MNA.

The remedial timeframes for the Alternatives were estimated as follows:

Alternative 1		Alternative 2		Alternative 3	
Well Installation	1 mo	1st CAC Injection	1 mo	Natural Attenuation	240 mo
1st ISCO Injection	2 mo	Time Between Injections	6 mo		
Time Between Injections	6 mo	2nd CAC Injection	1 mo		
2nd ISCO Injection	2 mo	Time to Evaluate Need for Additional Injection	6 mo		
Time to Evaluate Need for Additional Injection	6 mo	Natural Attenuation	24 mo		
Natural Attenuation	48 mo				
Total	**65 mo**	**Total**	**38 mo**	**Total**	**240 mo**

Since DNAPL is not present in this area, a remedial goal of the Method 1 GW-2 standards (0.05 mg/L and 0.005 mg/L for PCE and TCE, respectively) will be used for groundwater that is within both 30 feet of the 32 Tozer Road building and 15 feet of ground surface. The only existing monitoring well within these distance criteria is MW-2_32-TOZER. Other groundwater in the PSL10 area would be subject to the GW-3 standards (30 mg/L and 5 mg/L for PCE and TCE, respectively). In December 2022, the PCE/TCE concentrations were 0.75/0.13 mg/L at MW-2_32-TOZER, compared to the GW-2 standards of 0.05/0.005 mg/L. The required reduction from the current levels to the GW-2 standards represents approximately 5 half-lives (a half-life corresponds to the time needed to reduce concentration by one half). It is noted that 90% of ISCO injections (as measured by injection volume) at PSL10 occurred before or during 2011. If the concentrations at AP-19, AP-20, AP-21, AP-22, CL10-S, CL10-DO, and MW-2_32-TOZER are averaged for each sampling round since Spring 2011 to obtain an overall PSL10 plume concentration, the maximum PCE/TCE concentrations occurred in Fall 2012 with 2.6 mg/L PCE and 0.68 mg/L of TCE. When the subsequent 10 years of sampling are analyzed, the 90th percentile PCE/TCE half-lives are 5/10 years, respectively. Five (5) half-lives of 10 years would represent a remediation time of 50 years for Alternative 3. This extended timeframe is a demonstration of the impact of the vadose zone contamination mentioned in **Section 4.1.1.4**.

For both Alternative 2 and Alternative 3, a pre-bid design soil gas survey will be conducted to delineate vadose zone contamination, with additional investigation conducted to characterize remaining source areas in the saturated zone (e.g., soil and groundwater sampling). Depending on the results, a vadose zone remediation component, such as shallow soil excavation if appropriate, may be added to the RAA. If the CAC PAZ is installed across the plume near MW-2_32-TOZER, the impacts of solubilizing vadose zone contamination will be mitigated by a PAZ in the saturated zone downgradient of the PAZ source. Assuming limited back-diffusion from the soil matrix, downgradient groundwater subject to GW-2 standards may be remediated fairly quickly (i.e., an MNA period of 2 years was included to ensure containment by the PAZ). The MNA period for ISCO was assumed to be double (4 years) due to the impact of the vadose zone contamination.

4.1.2.2.5 Downgradient Plume

Treatment in this area is not needed to address significant risk or to contain the potential migration of CVOCs from the source material. Treatment is included in this area to provide reduction in CVOC levels along the groundwater flow pathway that would result in beneficial reductions in the areas west and south of Tozer Road. Again, the primary focus the cleanup plan at the Site is source area treatment. As noted, treatment in this AOC is proposed to reduce CVOC levels along the groundwater flow pathway. Another benefit of this treatment is the capture of CVOC mass that may be remobilized during source area treatment occurring upgradient (e.g., Building 3 Overburden). Alternatives 1 and 2 involve the installation of a “treatment wall,” either with S-mZVI or CAC to either abiotically dechlorinate or adsorb groundwater contamination. Also, as noted in **Section 4.1.1.5**, Alternatives 1 and 2 will include an option for seep treatment of two areas near Stream A. This treatment is assumed to be a permeable adsorptive zones (PAZ) Reactive Core Mat® (RCM) with GAC anchored to the west bank of the stream.

4.1.3 Selection of Remedial Action Alternatives

The RAA detailed evaluations presented in Section 4.1.2.2 are summarized in **Table 4** (Building 3 Overburden), **Table 6** (Building 5 Overburden), **Table 8** (Bedrock), **Table 10** (PSL10 Area), and **Table 12** (Downgradient Plume), respectively.

4.1.3.1 Building 3 Overburden

The cost of temporarily moving Building 3 operations would make Alternative 2 cost-prohibitive, so the evaluation comes down to Alternatives 1 and 3 (Table 4). While the cost of ISTR alternative is approximately 40% higher than ISCO alternative ($2,400/lb vs. $1,700/lb contaminant removed), the technology is likely more effective, reliable, and timely; therefore, it is recommended that ISTR with primarily angled drilling be implemented for Building 3 overburden, followed by ISB polishing. The current SVE system will continue operation until remedial objectives are attained. It should be noted that the warehouse area of Building 3 is proposed to be relocated to allow inside access for angled and vertical drilling. So Alternative 2 does include a hybrid approach, with some portions of Building 3 being relocated. A full move of all operations in the Building 3 area would require the construction of an addition or a standalone building of approximately 7,500 square feet. Further evaluation of a full move option in early 2022, based on a rough order of magnitude estimate, indicated that it would add between $18 and 24 million to the response costs. Moreover, the need for design, permitting, and construction of a new space would delay implementation of thermal treatment by at least one year.

4.1.3.2 Building 5 Overburden

Alternative 3 (ISB) has the highest score for the Building 5 Overburden source area. As noted previously, given the lower CVOC concentrations at Building 5 relative to Building 3, it is estimated that Building 5 requires a 90% reduction (i.e., 1,000 to 100 lbs) in CVOC mass to eliminate DNAPL to the extent possible, compared to the 97% reduction (i.e., 6,500 to 200 lbs) in CVOC mass in the Building 3 source area. As noted in **Section 4.1.2.1.4**, the unit costs ($/lb of contaminant) for implementing ISTR/ISCO in Building 5 are four times as high as the cost to implement these technologies at Building 3. This is primarily because the contaminant mass at Building 5 is one-sixth the contaminant mass at Building 3 (i.e., significantly less evidence of DNAPL). While the additional cost of ISTR was justifiable for Building 3 due to increased effectiveness, reliability, and timeliness compared to ISCO, those same advantages would not apply at Building 5. ISB has proven effective in Building 5 and increasing remedial costs by 65-150% is not justifiable. Therefore, it is recommended that ISB with angled drilling be implemented for Building 5 overburden. The current SVE system will continue operation until remedial objectives are attained (i.e., reduction of CVOC in indoor air below appropriate criteria).

4.1.3.3 Bedrock

From a total scoring standpoint, Alternative 1 (ISCO) scores highest (Table 8) for the bedrock source area. It is not likely that ISB (Alternative 3) can be used successfully at the initial groundwater concentrations (100 mg/L). Although Alternative 1 is 50% more expensive than Alternative 2 (see **Section 4.1.2.1.4**), ISCR likely would not effectively address the potential DNAPL present. Although ISTR has the potential to treat DNAPL the most effectively, the cost is three times that of ISCO. There is also risk of mobilizing DNAPL and/or dissolved phase VOCs to downgradient bedrock locations using ISTR, because maintaining hydraulic containment in bedrock can be very difficult. Therefore, it is recommended that ISCO be implemented for Building 5 bedrock. Additional bedrock evaluation will be conducted before full-scale implementation to optimize the delivery method to ensure that oxidant reaches the most contaminated fractures.

4.1.3.4 PSL10 Area

From a total scoring standpoint, Alternative 2 (CAC PAZ) scores highest (Table 10) for the PSL10 Area; however, the score for ISCO is very similar. While MNA (Alternative 3) is less expensive, the anticipated timeframe (50 years) for this area is not acceptable. As indicated in **Section 4.1.2.2.4**, a pre-design soil gas survey and additional pre-design investigations will be conducted to delineate vadose zone contamination that may extend the timeframe of the remediation of this area. If a vadose zone component is required, the costs and timeliness of ISCO and CAC PAZ will be re-evaluated.

4.1.3.5 Downgradient Plume

From a total scoring standpoint, Alternative 1 (S-mZVI PRZ [Tozer Road] and GAC PAZ [seep]) scores highest (Table 12). Although significantly more expensive than Alternative 3 (MNA), it will provide beneficial reductions in CVOC concentration sooner in downgradient areas and eliminate discharges to Stream A from the seeps. Based on preliminary cost estimates, the S-mZVI PRZ is more cost-effective than a CAC PAZ. In one study by Regenesis (manufacturer of both products), CAC PAZ provided longer time to breakthrough than S-mZVI PRZ. In this same study, combined CAC/S-mZVI provided a significantly longer time to breakthrough than either product separately. The final product selection (including possibly a combination) will be completed as part of the final design process.

4.2 Selected Remedial Alternative [310 CMR 40.0861 (2)(c)]

The Selected Remedial Alternative for the treatment of CVOCs in groundwater and soil at the Site is:

Selected Remedial Action Alternative
Building 3 Overburden – ISTR w/o Building Access, ISB Polish & Continued SVE System Operation *Building 5 Overburden – ISB w/o Building Access & Continued SVE System Operation* *Bedrock – ISCO* *PSL10 Area – Colloidal Activated Carbon Permeable Adsorptive Zone (CAC PAZ) or ISCO* *Downgradient Plume – Sulfidated Micro Zero Valent Iron Permeable Reactive Zone (S-mZVI PRZ) for Tozer Road and Granular Activated Carbon Permeable Adsorptive Zone (GAC PAZ) for the Seep Areas*

5.0 FEASIBILITY EVALUATIONS (310 CMR 40.0860)

The MCP (310 CMR 40.0861[2]) requires the following feasibility evaluations and discussions to be documented in a Remedial Action Plan:

1. If a Temporary Solution is selected as the remedial action alternative, perform an evaluation of the feasibility of implementing a Permanent Solution;
2. If a Permanent Solution is selected as the remedial action alternative, include a discussion of how the alternative is likely to achieve a level of No Significant Risk;
3. If a Temporary Solution is selected as the remedial action alternative, include a discussion of how the alternative is likely to eliminate any substantial hazards posed by the disposal site until a Permanent Solution is implemented;
4. If a Permanent Solution is selected, include the results of an evaluation of the feasibility of reducing the concentrations of OHM in the environment at the disposal site to levels that achieve or approach background; and
5. If the selected remedial action alternative is a Temporary Solution, include a detailed description of definitive and enterprising steps to identify and develop an alternative that will likely result in a Permanent Solution and a schedule for the implementation of such steps.

The selected alternatives described in this report will achieve a Temporary Solution. The above items are discussed in separate sections below.

5.1 Feasibility of Implementing a Permanent Solution

The selected alternatives for each area of the Site are summarized in Section 4.2. The selected remedial alternatives are reasonably likely to achieve a Permanent Solution at the Site. However, it is not expected that a Permanent Solution will be achieved by the February 18, 2024 deadline set by MassDEP in their letter dated February 18, 2022. These alternatives are expected to achieve a Temporary Solution by February 18, 2024, as required by the MassDEP. A Temporary Solution was selected because there are no feasible alternatives that could attain a permanent solution within the timeframe specified by MassDEP. For example, the shortest projected cleanup timeframe for Building 3 is 49 months (**Section 4.1.2.2.1**). This conclusion is based on the following:

- The complexity of designing a thermal treatment approach beneath an active manufacturing building that is not owned or operated by the potentially responsible party (for the Building 3 source area)
- The planning and coordination of potentially relocating active manufacturing activities at the facility (for the Building 3 source area)
- The presence of dense, low permeability soils in the overburden in the treatment areas (for both the Building 3 source area and the Building 5 source area)
- The need to treat potential DNAPL in fractured bedrock located 60 to 90 feet below grade (for the bedrock)
- The long travel times associated with groundwater flow at the Site, and up to two years of natural attenuation monitoring are anticipated for some treatment approaches.

The implementation of this remedy will result in a significant reduction in CVOC mass. It will also significantly reduce the potential for CVOC migration in downgradient areas to human and ecological receptors (for which a condition of no significant risk has already been determined).

5.2 Discussion of How the Remedial Approach Will Eliminate Substantial Hazards

The risk assessment provided in the October 2022 Phase II did not identify the presence of a Substantial Hazard at the Site.

5.3 Definitive and Enterprising Steps to Reach a Permanent Solution

Although the selected remedial approaches are expected to lead to a Permanent Solution, a Temporary Solution will first be completed to meet the regulatory timeframe. The following definitive and enterprising steps will be conducted to ensure that the RAA will achieve a Permanent Solution:

- Developing an operation and maintenance plan that will enhance the performance of the remedial action and identify areas for improvement
- Updating the routine monitoring program to confirm the progress of treatment in the treatment areas and observing CVOC trends in downgradient areas
- Developing innovative ways to reduce the costs and time associated with implementing the remedial plan
- Completing regular six-month reporting of operation and maintenance and monitoring results with recommendations for remedy modification as appropriate.

5.4 Feasibility of Concentrations Achieving or Approaching Background

An evaluation of achieving or approaching background is required in a Phase III evaluation where a Permanent Solution is selected. As stated, this Phase III Temporary has been selected for this Site.

5.5 Schedule for Implementation of Remedial Activities

The approximate schedule for implementation of the comprehensive response actions at the Site is outlined below:

- December 7, 2022, submit Phase III
- January 24, 2023, Phase III public meeting
- March 17, 2023, Submit Revised Phase III
- March 17, 2023, Submit Partial Phase IV, Part 1 (thermal treatment, Tozer Road barrier, and Stream A barrier)
- May 2, 2023, Public meeting to present Revised Phase III and Partial Phase IV, Part 1
- Q3 2023, Submit Partial Phase IV, Part 2 (Building 5 treatment, bedrock treatment and PSL-10 treatment)
- Q2 or Q3 2023, implementation of treatment at seep
- Q2 to Q3 2023, finalize access, procurement and design of ISTR
- Q3 to Q4 2023, construction of ISTR
- Q3 to Q4 2023, implementation of downgradient plume treatment

- Q1 2024, begin thermal treatment
- Implement treatment at Building 5, bedrock and PSL-10, 2024

6.0 PUBLIC INVOLVEMENT (310 CMR 40.0863)

In accordance with the MCP, the following public involvement activities will be completed relevant to Phase III including:

- The Chief Municipal Officer and Board of Health will be notified of the availability of this revised Phase III report, including information about how local officials may obtain a copy of the report.
- Copies of the Phase III Report will be sent to the Information Repositories established in the Public Involvement Plan (PIP) for the Former Varian Facility Site and to the Town of Beverly.

Copies of the Public Involvement notices are included in **Appendix C**.

7.0 OUTCOME (310 CMR 40.0864)

The selected remedial action alternatives presented in this Phase III Remedial Action Plan are:

Building 3 Area:

In situ thermal remediation, followed by in-situ bioremediation polish, and continued soil vapor extraction operation

Building 5 Area:

In situ bioremediation and continued soil vapor extraction operation

Bedrock:

In situ chemical oxidation

PSL10 Area:

ISCO or colloidal activated carbon permeable adsorptive zone (CAC PAZ)

Downgradient Plume:

Sulfidated Micro Zero Valent Iron Permeable Reactive Zone (S mZVI PRZ) for Tozer Road and Granular Activated Carbon Permeable Adsorptive Zone (GAC PAZ) for the seep areas

A Phase III Completion Statement (BWSC-108 form) is included in **Appendix A**.

8.0 LIMITATIONS ON WORK PRODUCT

The information contained in this report, including its conclusions, is based upon the information that was made available to APTIM Environmental and Infrastructure, LLC. (APTIM) during the investigation and obtained from the services described, which were performed within time and budgetary restraints.

APTIM makes no representation concerning the legal significance of its findings or of the value of the property investigated. APTIM has no contractual liability to any third parties for the information or opinions contained in this report.

Unless and until the parties agree otherwise in writing, the use of this report or any information contained therein by any third party shall be at such third party's sole risk.

TABLES

Table 1
INITIAL SCREENING OF GENERAL RESPONSE ACTIONS AND TECHNOLOGY PROCESS OPTIONS

Former Varian Facility Site
Beverly, MA

General Response Action	Remedial Technology	Process Options	Description	Feasibility of Achieving a Permanent or Temporary Solution (Y/N)	Available Expertise to Implement (Y/N)	Media					Ex-Situ Treatment			Retained					Comments
						Soil	Groundwater	DNAPL	Vapor	Surface Water	Groundwater	Soil	Vapor	Building 3 Area Overburden	Building 5 Area Overburden	Bedrock	PSL 10 Area	Downgradient Plume	
Institutional Controls	Restrictions	Activity Use Limitation (AUL)	An AUL can be placed on a property, or a portion of a property, to limit exposures when there is a potential risk for unrestricted use of a property (such as in a residential scenario). An AUL establishes permanent limitations on future site uses and activities. An AUL can be implemented at any time during the clean-up process and can be a component strategy for achieving a Temporary or Permanent Solution.	Y	Y	X	X		X					X	X		X		**Retained:** AUL may be needed for construction workers potentially exposed to groundwater or the continued operation of the SVE system.
	Monitoring	Groundwater Monitoring	Long-term monitoring of groundwater concentrations to ensure remedial goals are maintained.	Y	Y		X	X										X	**Retained:** To demonstrate that the downgradient CVOC plume is stable or contracting or otherwise controlled or mitigated to the extent feasible, long-term groundwater monitoring is likely needed.
		Vapor Monitoring	Long-term monitoring of indoor air to ensure remedial goals are maintained.	Y	Y				X					X	X			X	**Retained:** To demonstrate that the vapor phase CVOCs in indoor air in buildings or residences is stable or contracting or otherwise controlled or mitigated to the extent feasible, long-term vapor monitoring is likely needed.
Containment	*General*	*NA*	*Containment is a physical barrier that prevents human contact with the impacted groundwater and soil. Containment is also a strategy to limit contaminant migration via soil, water, or air. Containment can be implemented when the source material remains on the property.*	*NA*	*NA*														*NA*
	Capping	Asphalt Clay Concrete Geosynthetic Membrane	A capping system involves the physical covering of an area containing buried waste, contaminated soil, or contaminated groundwater. Capping prevents the release of contaminants to the ambient atmosphere and greatly reduces surface water infiltration.	N	Y	X													**Eliminated:** The areas of highest contamination are already covered by buildings. Per 310 CMR 40.0414(7), a cap or engineered barrier will not be considered a Permanent Solution if other alternatives are feasible.
	Immobilization	Solidification/Stabilization (S/S)	S/S treatment is designed to immobilize CVOCs within impacted soil. Solidification refers to a process that uses a binding agent to encapsulate the CVOCs. The binding agent decreases the soil's permeability and increases its compressive strength. Stabilization involves a chemical reaction that reduces the CVOC's leachability and/or reduces their solubility.	N	Y	X	X	X											**Eliminated:** The soil concentrations in the vadose zone are not a concern at this site and much of the source area are situated below buildings and inaccessible to S/S.
	In-Situ Treatment Zone (ITZ)	Permeable Adsorptive Barrier (PAB) Permeable Reactive Barrier (PRB)	A ITZ is a zone created below ground to clean up impacted groundwater as the groundwater flows through the zone. Depending on the media, CVOCs are removed through various processes: sorption, reaction (oxidation or reduction) or biodegradation. Two types of ITZ are used: (1) continuous; and, (2) funnel and gate, which include low-permeability barriers that intercept the groundwater flow and direct it through a smaller treatment zone.	Y	Y		X										X	X	**Retained:** An ITZ may be an effective strategy to prevent further downgradient migration from the property and/or migration into surface water. It could use activated carbon (granular or colloidal) (permeable adsorptive barrier [PAB]) or zero valent iron (ZVI) (permeable reactive barrier [PRB]). It could be emplaced in a trench, injected or installed as Reactive Core Mat (RCM)®.
	Vertical Barriers	Sheet Pile Slurry Walls	A low permeability, vertical subsurface barrier (generally sheet pile or slurry wall) that can be installed below ground to contain or redirect groundwater flow in the vicinity of a Site.	Y	Y		X												**Eliminated:** The most likely application of a vertical subsurface barrier is the downgradient plume. However, the depth to bedrock on Tozer Road precludes the use of vertical barriers.
Removal	Groundwater	Pump & Treat (P&T)	P&T involves withdrawing impacted groundwater from the subsurface via wells or trenches. Dissolved constituents are typically removed in an aboveground treatment system (refer to ex-situ treatment technologies) and treated water discharged (refer to disposal technologies). P&T can be used to achieve hydraulic control, prevent migration of a plume, or groundwater recirculation to flush water through residual source areas or enhance the distribution of in situ treatment amendments in the subsurface. It is not effective for contaminant mass reduction (requires many pore volume flushes to removed sorbed contaminants). Other disadvantages of P&T include long-term operation and associated high capital and operating costs.	Y	Y		X				X			X	X	X	X		**Retained:** A P&T system was operated for 10 years with diminishing returns; therefore, another technology is needed to treat the sources of CVOC under Buildings 3 and 5. However, a P&T system could be incorporated to circulate amendments through a given source areas.
	Soil	Excavation	Excavation involves the physical removal and on-site treatment/off-site disposal, of impacted soils. Disadvantages of this method may include the need for impacted areas to be fully accessible (that is, no utilities or buildings in the target excavation area), difficulty excavating soils at depth, the potential need for subsurface dewatering, particularly when dealing with saturated zone soils, and the high cost of soil handling. In the case of off-site treatment/disposal, the high cost of transportation is also a drawback. Advantages of excavation include the relative short term for implementation and the significant reduction in contaminant mass through source removal.	Y	Y	X						X							**Eliminated:** Although impractical for use in Building 3 or Building 5 areas due to building and utility presence and depth of impacts, limited excavation may be implementable in the PSL10 area. However, there are no current soil data which would identify an area where excavation would be warranted.

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						Soil	Groundwater	DNAPL	Vapor	Surface Water	Groundwater	Soil	Vapor	Building 3 Area Overburden	Building 5 Area Overburden	Bedrock	PSL 10 Area	Downgradient Plume	
In-Situ Treatment	Physical	Soil Vapor Extraction (SVE)	SVE is an in-situ remediation technique designed to remove and treat CVOCs from the soil in the vadose zone. A vacuum is applied to contaminant-impacted soils to extract vapors, which are conveyed to an ex-situ treatment system. SVE can be used to remediate soils beneath buildings and other areas inaccessible to other methods of remediation.	Y	Y	X			X				X	X	X				**Retained:** Although diminishing mass recovery has been observed, the Building 3 and Building 5 SVE systems will remain in operation to mitigate the vapor intrusion to indoor air pathway.
		Activated Carbon (AC)	Activated carbon (AC) can be introduced into the subsurface either in granular (GAC) or colloidal (CAC) form. GAC can be emplaced in a trench or as part of Reactive Core Mat® (RCM). The GAC contaminant removal process is similiar to that described for liquid phase carbon (LPC) under "Ex-Situ Treatment". CAC involves two contaminant removal processes: adsorption by AC and degradation by reactive amendments. Amendments may include zero valent iron (BOS 100®) to stimulate abiotic dechlorination, calcium peroxide/sodium persulfate (GOGAC®) to stimulate chemical oxidation, or hydrogen release compound (HRC) (PlumeStop®) to stimulate biodegradation. Adsorption can significantly retard CVOC migration and allow longer residence times with the reactive amendments. Generally most applicable to areas with lower groundwater concentrations.	Y	Y		X										X	X	**Retained:** AC products can be provided for sorption, chemical oxidation, biodegradation or abiotic dechlorination and may be an effective treatment of downgradient portions of the plume.
		Air Sparging (AS)	Air sparging uses the injection of compressed air into impacted groundwater to enhance the partitioning of contaminants into the air, effectively "stripping" the CVOCs. Injected air also causes volatilization of CVOCs from saturated soils, and to a lesser extent, from soils in the vadose zone. The contaminant vapors migrate upward toward the vadose zone, where they are captured by a soil vapor extraction (SVE) system and treated by an ex-situ system..	N	Y		X						X						**Eliminated:** Air sparging is generally not recommended for sites where DNAPL is present in the area to be remediated.
		Groundwater Circulation Well (GCW)	Groundwater circulation wells remove dissolved CVOCs from groundwater by stripping the CVOCs to the vapor phase within the well, without bringing groundwater to the ground surface. In-well stripping creates a groundwater circulation cell by injecting air into a double-screened well, lifting the water in the well and forcing it out the upper screen while additional water is drawn in the lower screen. Once in the well, some of the CVOCs are transferred from the dissolved phase to the vapor phase by air stripping. The contaminated air rises in the well to the water surface where vapors are drawn off and treated by a SVE system. Alternatively, GCW could be used to distribute injectates.	Y	Y		X						X						**Eliminated:** Groundwater recirculation wells could be used in place of a PRB to prevent plume migration downgradient of the source areas. GCW could also be used to introduce remedial additives to the subsurface; however, its use for the downgradient plume would require both power and space for treatment train, which may not readily be available. For the purposes of the remedial action alternative evaluation, additives are assumed to be introduced through injection wells.
		Multi-Phase Extraction (MPE)	MPE is a technique that utilizes a high vacuum to recover vapors and liquids simultaneously from extraction wells. MPE can recover groundwater and vapors from saturated and unsaturated zones. MPE functionally increases the hydraulic and pneumatic gradient toward the extraction wells and provides enhanced liquid recovery rates. Groundwater extracted from the subsurface is then treated in the same way as with traditional groundwater P&T system. Extracted vapors are treated in the same way as with traditional SVE systems.	Y	Y		X		X		X		X	X	X				**Retained:** MPE is most often associated with residual DNAPL remediation in the unsaturated and shallow saturated zone. The potential DNAPL at this site is at the deep overburden-bedrock interface; therefore, it would not be effective as a stand alone technology. However, MPE may be used as part of in situ thermal remedial alternatives.

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						Soil	Groundwater	DNAPL	Vapor	Surface Water	Groundwater	Soil	Vapor	Building 3 Area Overburder	Building 5 Area Overburder	Bedrock	PSL 10 Area	Downgradient Plume	
In Situ Treatment (Continued)	Biological	Engineered Wetland/Phytoremediation	Engineered wetlands are manmade wetlands used to promote the action of natural, physical, geochemical, and biological processes to mineralize organic contaminants, immobilize inorganic contaminants, and remove suspended particulates.	Y	Y					X									**Eliminated:** An engineered wetland could be used to address downgradient seeps. However, at this point, an alternative approach to seep treatment is proposed (i.e., Reactive Core Mat); therefore, the technology is tabled presently.
		In-Situ Bioremediation (ISB)	Bioremediation occurs when microorganisms (microbes) degrade contaminants in the soil and/or groundwater. The contaminants serve two purposes: (1) provide a source of carbon; and, (2) provide electrons. Microbes gain energy by catalyzing reactions that break chemical bonds and transfer electrons from the contaminant (electron donor) to an electron acceptor. Aerobic microbes use oxygen as the electron acceptor; however, PCE/TCE are degraded anaerobically (absence of oxygen). In-situ bioremediation (ISB) involves making the subsurface conditions favorable for microbial growth. Several factors may affect the ability of a microorganism to degrade constituents including susceptibility of the compound to biodegradation, bioavailability of the contaminant, contaminant concentration, electron acceptor supply, pH, temperature, and nutrient supply (such as nitrogen and phosphorus).	Y	Y	X	X							X	X	X			**Retained:** ISB has been used successfully in the shallow overburden area near the unnamed stream east of Building 9, the deep and shallow overburden adjacent and beneath Building 3, and in the shallow overburden beneath Building 5. It may be needed as a polishing step to the more aggressive thermal or chemical treatment of the source areas.
		Monitored Natural Attenuation (MNA)	MNA depends on the natural processes of biodegradation, sorption, dilution, evaporation, and chemical reaction to attenuate concentrations of contaminants in soil and groundwater.	Y	Y	X	X							X	X	X	X	X	**Retained:** MNA may demonstrate that the downgradient CVOC plumes are stable or contracting or otherwise controlled or mitigated to the extent feasible..
		Subgrade Biogeochemical Reactor (SBGR)	SBGR technology typically consists of removal of contaminated soil and backfill of the soil void with gravel and treatment amendments. SBGRs may include infiltration piping and a low-flow pumping system to recirculate contaminated groundwater through the SBGR for treatment.	Y	Y	X	X												**Eliminated:** The installation of an SGBR may be applicable in the low concentrations in soil and groundwater in the PSL10 and downgradient areas, although elevated concentrations at PSL10 may be too deep to make backfill feasible. However, for the purpose of simplifying remedial action alternatives, SBGR will be shelved in favor of the more general "in-situ bioremediation".
	Chemical	In Situ Chemical Oxidation (ISCO)	ISCO involves the injection of powerful electron acceptors into the subsurface, including Fenton's-catalyzed hydrogen peroxide, ozone, permanganate, and persulfate. The oxidant is injected into the subsurface through a network of injection wells. Each oxidant has advantages and disadvantages, although all have been used successfully with PCE/TCE. Effectiveness dependent on adequate distribution of oxidant and presence of competing electron donors.	Y	Y	X	X	X						X	X	X	X		**Retained:** Sodium permanganate oxidation has been used at the Site for significant mass destruction of CVOCs. However, rebound in CVOC concentrations has been observed in Building 3 wells, likely from the limited ability to apply the oxidant under the building.
		In Situ Chemical Reduction (ISCR)	ISCR involves the transferring of electrons to contaminants from reductants. Zero valent iron (ZVI) is widely implemented for abiotic degradation of PCE/TCE. Abiotic reduction avoids the production of intermediates (cis-1,2-DCE or VC), which are typical daughter products of biotic reductive dechlorination. ZVI can be placed into the subsurface by several methods: excavation and backfill, trenching, soil mixing, direct push technology injection, and hydraulic/gravity feed delivery to conventional injection wells.	Y	Y	X	X	X								X	X	X	**Retained:** ZVI may have applications in the bedrock, PSL10 and the PRB for the downgradient plume.

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Beverly, MA

General Response Action	Remedial Technology	Process Options	Description	Feasibility of Achieving a Permanent or Temporary Solution (Y/N)	Available Expertise to Implement (Y/N)	Media					Ex-Situ Treatment			Retained					Comments
						Soil	Groundwater	DNAPL	Vapor	Surface Water	Groundwater	Soil	Vapor	Building 3 Area Overburden	Building 5 Area Overburden	Bedrock	PSL 10 Area	Downgradient Plume	
In Situ Treatment (Continued)	Thermal	*General*	*In situ thermal remediation (ISTR) applies heat to the subsurface to change the properties of DNAPL, sorbed, and dissolved phase CVOCs to allow easier extraction via MPE system. The primary changes include the following: increased solubility (decreased surface/interfacial tension), decreased viscosity, increased vapor pressure and potential volatilization, and decreased density.*	*NA*	*NA*														*NA*
		Electrical Resistance Heating (ERH)	The ERH process involves the placement of multiple electrode groups in the subsurface and the application of polyphase electrical current. Voltage is applied to the electrodes, resulting in an electrical current that flows through the subsurface materials from high to low potential. The electrical resistance presented by the soil generates heat, which is transferred by conduction to heat the formation up to and including the local boiling point of water. The heat mobilizes the COCs, which are collected by vapor extraction wells. Ex-situ treatment of recovered media is required.	Y	Y	X	X	X			X		X	X	X				**Retained:** This technology has been retained for further evaluation.
		Steam Enhanced Extraction (SEE)	The SEE process uses live steam injection to heat subsurface materials and sweep contamination from the subsurface. Steam used for subsurface heating is typically generated onsite through the combustion of fuel oil or gas in conjunction with a portable boiler system. Subsurface heating occurs initially through the transfer of latent heat to the subsurface during steam condensation in the vicinity of steam injection wells. As subsurface temperatures increase around the injection point, the condensation front increases radially outward. With continued steam injection, the condensation front eventually intersects system extraction wells where vapor, groundwater, and displaced fluids containing the COCs are recovered. Ex-situ treatment of recovered media is required.	Y	Y	X	X	X			X		X	X	X				**Retained:** This technology has been retained for further evaluation.
		Thermal Conduction Heating (TCH)	The TCH process involves the transfer of thermal energy into the subsurface by direct conduction from specially designed heater wells. A heater well is comprised of a sealed, carbon steel casing installed in heat resistant cementitious grout. Methods applied within the annular space of the heater casing vary by technology supplier; however, the overall process is similar and results in the heating of subsurface soil by direct thermal conduction processes. The soil around the heater is dried and COCs present in the target treatment interval are volatilized. The vapors are recovered by dedicated vapor extraction wells which may be independent points or co-located with heating equipment. Ex-situ treatment of recovered media is required.	Y	Y	X	X	X			X		X	X	X				**Retained:** This technology has been retained for further evaluation.
Ex-Situ Treatment	Physical	Air Stripping	Air stripping is an ex situ technology that removes CVOCs from pumped groundwater by passing the water over a media having a large surface area while exposing the contaminated water to uncontaminated air flow. The CVOCs are transferred (i.e., volatilized) from the groundwater to the vapor phase in the countercurrent air stream, where the vapor is either directly discharged or routed to an off-gas treatment.	N	Y		X						X						**Eliminated:** Air stripping is a common remedial technology for treatment of contaminated groundwater. However, at this site, ISTR will remove nearly 90% of the contaminant in the vapor phase rather than the liquid phase and the ISTR companies have proposed LPC for treatment of the liquid phase; therefore, air stripping is eliminated.
		Liquid Phase Granular Activated Carbon (LPC)	Adsorption is the adhesion of CVOCs to adsorption media (e.g., GAC). Treatment is performed by passing a water stream through vessels containing activated carbon, which removes contaminants by physisorption until available active sites are occupied. Once a CVOC breaks through a GAC unit above a pre-determined level, it is considered "spent," and must either be regenerated for reuse or replaced.	Y	Y		X							X	X				**Retained:** LPC is a common adsorbent used to treat water generated at remediation sites.
		Vapor Phase Granular Activated Carbon (VPC)	Adsorption is the adhesion of CVOCs to adsorption media (e.g., GAC). Treatment is performed by passing a vapor stream through vessels containing activated carbon, which removes contaminants by physisorption until available active sites are occupied. Once a CVOC breaks through a GAC unit above a pre-determined level, it is considered "spent," and must either be regenerated for reuse or replaced.	Y	Y				X					X	X				**Retained:** VPC is a common adsorbent used to treat vapor generated at remediation sites.
	Chemical	UV Oxidation	Ultraviolet (UV) oxidation involves the destruction of extracted CVOCs in groundwater by the addition of strong oxidizers and irradiation with UV light.	N	Y		X												**Eliminated:** A more common treatment technology is liquid phase granular activated carbon.
Disposal	Groundwater	Surface Water Discharge	Treated groundwater is directed to a surface water body either directly or through a storm sewer.	Y	Y		X							X	X				**Retained:** Properly treated groundwater should be able to be discharged to surface water directly or through storm drain.
		Wastewater Treatment Facility (WWTF)	Treated groundwater is directed to a sanitary sewer leading to a WWTF.	N	Y		X												**Eliminated:** Town of Beverly precludes the discharge of groundwater to the sanitary sewer.
	Soil	Treatment/Storage/Disposal Facility (TDSF)	Excavated, impacted soil is transported off-site to a permitted off-site TDSF.	Y	Y	X											X		**Eliminated:** As excavation was eliminated as a remedial technology, disposal of excavated soil will not be needed.

Table 2
INITIAL TECHNOLOGY SCREENING SUMMARY

Former Varian Facility Site
Beverly, MA

General Response Action	Remedial Technology	Process Options	Building 3 Area Overburden	Building 5 Area Overburden	Bedrock	PSL 10 Area	Downgradient Plume
Institutional Controls	Restrictions	Activity Use Limitation (AUL)	X	X		X	
	Monitoring	Groundwater Monitoring					X
		Vapor Monitoring	X	X			X
Containment	In-Situ Treatment Zone	Permeable Adsorptive Barrier (PAB) Permeable Reactive Barrier (PRB)				X	X
Removal	Groundwater	Pump & Treat (P&T)	X	X	X	X	
In-Situ Treatment	Physical	Soil Vapor Extraction (SVE)	X	X			
		Activated Carbon (AC)				X	X
		Multi-Phase Extraction (MPE)	X	X			
	Biological	In-Situ Bioremediation (ISB)	X	X	X		
		Monitored Natural Attenuation (MNA)	X	X	X	X	X
	Chemical	In Situ Chemical Oxidation (ISCO)	X	X	X	X	
		In Situ Chemical Reduction (ISCR)			X	X	X
	Thermal	Electrical Resistance Heating (ERH)	X	X			
		Steam Enhanced Extraction (SEE)	X	X			
		Thermal Conduction Heating (TCH)	X	X			
Ex-Situ Treatment	Physical	Liquid Phase Granular Activated Carbon (LPC)	X	X			
		Vapor Phase Granular Activated Carbon (VPC)	X	X			
Disposal	Groundwater	Surface Water Discharge	X	X			

Table 3
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
Building 3 Overburden

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 In-Situ Thermal Remediation (ISTR) w/o Building Access w/In-Situ Bioremediation (ISB) Polish and Continued SVE Operation	Alternative 2 In-Situ Thermal Remediation (ISTR) w/Building Access w/In-Situ Bioremediation (ISB) Polish and Continued SVE Operation	Alternative 3 In-Situ Chemical Oxidation (ISCO) w/o Building Access w/In-Situ Bioremediation (ISB) Polish and Continued SVE Operation
1. Effectiveness (E)			
a) Ability to Achieve a Permanent or Temporary Solution	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.
i. No Significant Risk (NSR)/No Substantial Hazard (NSH)	• A condition of NSH already exists (Temporary Solution). The reduction in soil-groundwater concentrations beneath the building will likely result in a level of NSR (Permanent Solution), as risk to future construction workers will be eliminated and SVE system can be shutdown with no impact to indoor air	• A condition of NSH already exists (Temporary Solution). The reduction in soil-groundwater concentrations beneath the building will likely result in a level of NSR (Permanent Solution), as risk to future construction workers will be eliminated and SVE system can be shutdown with no impact to indoor air	• A condition of NSH already exists (Temporary Solution). The reduction in soil-groundwater concentrations beneath the building will likely result in a level of NSR (Permanent Solution), as risk to future construction workers will be eliminated and SVE system can be shutdown with no impact to indoor air
ii. Source Eliminated/Controlled	• The source of OHM contamination (high soil-groundwater concentrations) will be controlled to the extent feasible (Temporary Solution), rather than eliminated (Permanent Solution). ISTR more effective and get closer to Permanent Solution than ISCO.	• The source of OHM contamination (high soil-groundwater concentrations) will be eliminated and controlled (Permanent Solution).	• The source of OHM contamination (high soil-groundwater concentrations) will be controlled to the extent feasible (Temporary Solution), rather than eliminated (Permanent Solution).
iii. Groundwater Plumes Managed	• The control of source areas will eventually lead to a stable or contracting groundwater plume (Permanent/Temporary Solution).	• The control of source areas will eventually lead to contracting groundwater plume (Permanent/Temporary Solution).	• The control of source areas will eventually lead to contracting groundwater plume (Permanent/Temporary Solution).
iv. DNAPL Removed/Controlled	• All non-stable DNAPL and DNAPL with micro-scale mobility will be removed to the extent feasible (Permanent Solution).	• All non-stable DNAPL and DNAPL with micro-scale mobility will be removed to the extent feasible (Permanent Solution).	• All non-stable DNAPL and DNAPL with micro-scale mobility will be removed to the extent feasible (Permanent Solution).
v. Release Threats Eliminated	• No threats of release exist (Permanent/Temporary Solution)	• No threats of release exist (Permanent/Temporary Solution)	• No threats of release exist (Permanent/Temporary Solution)
vi. Background Levels Achieved/Approached	• Background concentrations will not be achieved or approached (see 1c below). (Temporary Solution)	• Background concentrations will not be achieved or approached (see 1c below). (Temporary Solution)	• Background concentrations will not be achieved or approached (see 1c below). (Temporary Solution)
b) Ability to Reuse, Recycle, Destroy, Detoxify, or Treating OHM On-Site	• OHM in the subsurface will be transferred from the subsurface to liquid phase and vapor phase carbon and destroyed off-site during carbon regeneration.	• OHM in the subsurface will be transferred from the subsurface to liquid phase and vapor phase carbon and destroyed off-site during carbon regeneration.	• OHM in the subsurface will be destroyed (oxidized) insitu.
c) Ability to Achieve or Approach Background Conditions	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. It is unlikely that TCE/PCE concentrations will be reduced to non-detectable levels, therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard. The GW2 standard for TCE is 5 ppb. It is not likely that the groundwater concentration will be reduced to 2.5 ppb in shallow groundwater beneath the Building 3 complex and background will not be approached. GW2 would be the applicable standard as CVOCs could volatilize into indoor air.	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. It is unlikely that TCE/PCE concentrations will be reduced to non-detectable levels, therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard. The GW2 standard for TCE is 5 ppb. It is not likely that the groundwater concentration will be reduced to 2.5 ppb in shallow groundwater beneath the Building 3 complex and background will not be approached. GW2 would be the applicable standard as CVOCs could volatilize into indoor air.	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. It is unlikely that TCE/PCE concentrations will be reduced to non-detectable levels, therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard. The GW2 standard for TCE is 5 ppb. It is not likely that the groundwater concentration will be reduced to 2.5 ppb in shallow groundwater beneath the Building 3 complex and background will not be approached. GW2 would be the applicable standard as CVOCs could volatilize into indoor air.
Effectiveness Rating	4	5	2
2. Reliability (R1)			
a) Certainty of Success	• Less certainty of success without building access and the need to use angled drilling. • ISTR has greater certainty of success in source area than ISCO.	• Greater certainty of success with building access and the ability to use vertical drilling. • Greater certainty of success with ISTR in source area than ISCO.	• Less certainty of success without building access and the need to use angled drilling. • Lower certainty of success with ISCO in source area than ISTR.
b) Effectiveness of Measures to Manage Residues	• No residues to be managed.	• No residues to be managed.	• No residues to be managed.
c) Effectiveness of Measures to Control Emissions or Discharges	• Emissions or discharges controlled by extraction and liquid/vapor phase carbon.	• Emissions or discharges controlled by extraction and liquid/vapor phase carbon.	• No emissions anticipated. Injection rate control and monitoring required to protect against oxidant daylighting.
Reliability Rating	2	3	1

Table 3
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
Building 3 Overburden

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 In-Situ Thermal Remediation (ISTR) w/o Building Access w/In-Situ Bioremediation (ISB) Polish and Continued SVE Operation	Alternative 2 In-Situ Thermal Remediation (ISTR) w/Building Access w/In-Situ Bioremediation (ISB) Polish and Continued SVE Operation	Alternative 3 In-Situ Chemical Oxidation (ISCO) w/o Building Access w/In-Situ Bioremediation (ISB) Polish and Continued SVE Operation
3. Difficulty (D)			
a) Technical Complexity	• ISTR more technically complex than ISCO. • Accessing the contaminated zone without building access more technically complex than accessing with building access.	• ISTR more technically complex than ISCO. • Accessing the contaminated zone with building access less technically complex than accessing without building access.	• ISCO less technically complex than ISTR. • Accessing the contaminated zone without building access more technically complex than accessing with building access.
b) Difficulty of Integration with Existing Facility Operations	• Difficult to integrate with existing facility operations.	• Very difficult to integrate as current operations in Building 3 must be relocated.	• Difficult to integrate with existing facility operations.
c) Operation, Maintenance & Monitoring (OM&M) or Site Access Requirements/Limitations	• This alternative likely to result in the higher soil-groundwater concentrations than Alternative 2 and relatively longer period for groundwater monitoring.	• This alternative likely to result in the lowest soil-groundwater concentrations and the shortest period of time for groundwater monitoring.	• This alternative likely to result in the higher soil-groundwater concentrations than Alternative 2 and relatively longer period for groundwater monitoring.
d) Availability of Services, Materials, Equipment or Specialists	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.
e) Availability, Capacity and Location of Off-Site Treatment, Storage, Disposal Facilities (TSDFs)	• Facilities are readily available for off-site regeneration of spent carbon (LPC/VPC).	• Facilities are readily available for off-site regeneration of spent carbon (LPC/VPC).	• No TSDF required.
f) Permits	• Discharge permits may be needed for treated groundwater and off-gas.	• Discharge permits may be needed for treated groundwater and off-gas.	• No special permits are anticipated to be required. Injection wells are authorized by rule under undeground injection control (UIC) rule.
Implementability Rating	**2**	**1**	**2**
4. Cost (C)			
a) Estimated Cost of Implementation	• $16,165,000 (ISTR) (including energy consumption) • $644,400 (ISB Polish) • $160,000 (SVE) • $16,969,400 (Total [Table B-1])	• $11,577,000 (ISTR) (including energy consumption) • $325,000 (ISB Polish) • $110,000 (SVE) • $12,012,000 (Remediation Subtotal [Table B-2) • $10,000,000-$15,000,000 (Temporary Building) • $22,012,000-$27,012,000 (Total)	• $10,150,000 (ISCO) • $644,400 (ISB Polish) • $258,000 (SVE) • $11,052,400 (Total [Table B-3])
b) Cost of Environmental Restoration & Potential Damages to Natural Resources	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.
c) Cost of Energy Consumption	• $2,660,000 (Table B-1) • 7,000,000 KWH (electricity) and 200,000 therms (natural gas)	• $2,550,000 (Table B-2) • 6,000,000 KWH (electricity) & 300,000 therms (natural gas)	• Energy consumption not significant
Cost Rating	**2**	**1**	**3**
5. Risk (R2)			
a) Relative Risk During Implementation	• Moderate risk associated with installation activities.	• Moderate risk associated with installation activities.	• Moderate risk associated with installation activities.
b) Relative Risk During Operations	• Risk of vapor migration should be effectively controlled by extraction system.	• Risk of vapor migration should be effectively controlled by extraction system.	• Low risk associated with daylighting and handling of oxidants • Lower overall risk than associated with ISTR.
c) Relative Risk Associated with Remaining OHM	• Risk associated with remaining OHM is dependent on the ability of angled drilling to gain access to the source areas.	• Lowest risk associated with remaining OHM.	• Risk associated with remaining OHM is dependent on the ability of angled drilling to gain access to the source areas.
Risk Rating	**2**	**2**	**3**

Table 3
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
Building 3 Overburden

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 In-Situ Thermal Remediation (ISTR) w/o Building Access w/In-Situ Bioremediation (ISB) Polish and Continued SVE Operation	Alternative 2 In-Situ Thermal Remediation (ISTR) w/Building Access w/In-Situ Bioremediation (ISB) Polish and Continued SVE Operation	Alternative 3 In-Situ Chemical Oxidation (ISCO) w/o Building Access w/In-Situ Bioremediation (ISB) Polish and Continued SVE Operation
6. Green Benefits (B)			
a) Minimizes Energy Use or Uses Renewable Energy and Resources	• Significantly higher energy usage than ISCO.	• Significantly higher energy usage than ISCO.	• Significantly lower energy usage than ISTR.
b) Minimizes Air Pollution or Greenhouse Gas (GHG) Emissions	• Ex-situ treatment systems should minimize air pollution. However, the remediation will generate GHG (1,100 mtCO2e [Scope 1] and 2,300 mtCO2e [Scope2]).	• Ex-situ treatment systems should minimize air pollution. However, the remediation will generate GHG (1,600 mtCO2e [Scope 1] and 1,900 mtCO2e [Scope 2]).	• Minimal air pollution or greenhouse gas emissions (Scope 2 [electricity for injection equipment]).
c) Reduce, Reuse & Recycle Waste	• CVOCs are transferred to LPC/VPC, which require off-site carbon regeneration.	• CVOCs are transferred to LPC/VPC, which require off-site carbon regeneration.	• CVOCs are destroyed insitu.
d) Minimizes Adverse Aesthetic Impacts on Receptors Outside of the Property	• No adverse aesthetic impacts to off-site receptors.	• No adverse aesthetic impacts to off-site receptors.	• No adverse aesthetic impacts to off-site receptors.
Green Benefits Rating	**1**	**1**	**2**
7. Timeliness (T)			
a) Time to Achieve Remedial Objective	• ISTR - 1.5 year • 2 ISB injection - 3 years • MNA - 2 year • Total - 6.5 years	• Plating operations relocation - 1.5 year • ISTR - 1 year • 1 ISB injection: 2 years • Total - 4.5 years	• 3 ISCO injections - 2.5 year • 2 ISB injections - 3 year • MNA - 5 year • Total - 10.5 years
Timeliness Rating	**2**	**2**	**1**

Notes:

E Effectiveness
- 1 = Not widely used and probably not effective
- 2 = Widely used but probably not effective, or not widely used and may not be effective
- 3 = Widely used but may not be effective, or not widely used but probably effective
- 4 = Widely used and probably effective, or not widely used but proven and effective
- 5 = Widely used, proven, and effective

R1 Reliability
- 1 = Low reliability and/or high maintenance
- 2 = Average reliability and/or average maintenance
- 3 = High reliability and/or low maintenance

D Difficulty
- 1 = Most difficult to implement
- 2 = Moderate difficulty to implement
- 3 = Easiest to implement

C Cost
- 1 = Highest relative cost compared to other alternatives
- 3 = Lowest relative cost compared to other alternatives

R2 Risk
- 1 = Highest risks associated with implementation
- 2 = Moderate risk associated with implementation
- 3 = Lowest risk associated with implementation

GB Green Benefits
- 1 = Low benefits
- 2 = Low to moderate benefits
- 3 = Moderate to high benefits
- 4 = High benefits

T Time
- 1 = Extended treatment time
- 2 = Acceptable treatment time
- 3 = Rapid treatment

Score = E + R1 + D + C + R2 + GB + T; Possible scores are 7 to 24

Table 4
REMEDIAL ALTERNATIVE EVALUATION SUMMARY
Building 3 Overburden

Former Varian Facility Site
Beverly, MA

Alternative #	Alternative Description	Effectiveness	Reliability	Difficulty	Cost	Risk	Green Benefits	Timeliness	Score	Overall Ranking
1	In-Situ Thermal Remediation (ISTR) w/o Building Access w/ISB Polish and Continued SVE Operation	4	2	2	2	2	1	2	15	1
2	In-Situ Thermal Remediation (ISTR) w/ Building Access w/ISB Polish and Continued SVE Operation	5	3	1	1	2	1	2	15	1
3	In-Situ Chemical Oxidation (ISCO) w/o Building Access w/ISB Polish and Continued SVE Operation	2	1	2	3	3	2	1	14	3

Notes:

E Effectiveness
- 1 = Not widely used and probably not effective
- 2 = Widely used but probably not effective, or not widely used and may not be effective
- 3 = Widely used but may not be effective, or not widely used but probably effective
- 4 = Widely used and probably effective, or not widely used but proven and effective
- 5 = Widely used, proven, and effective

R1 Reliability
- 1 = Low reliability and/or high maintenance
- 2 = Average reliability and/or average maintenance
- 3 = High reliability and/or low maintenance

D Difficulty
- 1 = Most difficult to implement
- 2 = Moderate difficulty to implement
- 3 = Easiest to implement

C Cost
- 1 = Highest relative cost compared to other alternatives
- 3 = Lowest relative cost compared to other alternatives

R2 Risk
- 1 = Highest risks associated with implementation
- 2 = Moderate risk associated with implementation
- 3 = Lowest risk associated with implementation

GB Green Benefits
- 1 = Low benefits
- 2 = Low to moderate benefits
- 3 = Moderate to high benefits
- 4 = High benefits

T Time
- 1 = Extended treatment time
- 2 = Acceptable treatment time
- 3 = Rapid treatment

Score = E + R1 + D + C + R2 + GB + T; Possible scores are 7 to 24

Table 5
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
Building 5 Overburden

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 In-Situ Thermal Remediation (ISTR) w/Continued SVE Operation	Alternative 2 In-Situ Chemical Oxidation (ISCO) w/Continued SVE Operation	Alternative 3 In-Situ Bioremediation (ISB) w/Continued SVE Operation
1. Effectiveness (E)			
a) Ability to Achieve a Permanent or Temporary Solution	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.
i. No Significant Risk (NSR)/No Substantial Hazard (NSH)	• A condition of NSH already exists (Temporary Solution). The reduction in soil-groundwater concentrations beneath the building will likely result in a level of NSR (Permanent Solution), as risk to future construction workers will be eliminated and SVE system can be shutdown with no impact to indoor air.	• A condition of NSH already exists (Temporary Solution). The reduction in soil-groundwater concentrations beneath the building will likely result in a level of NSR (Permanent Solution), as risk to future construction workers will be eliminated and SVE system can be shutdown with no impact to indoor air.	• A condition of NSH already exists (Temporary Solution). The reduction in soil-groundwater concentrations beneath the building will likely result in a level of NSR (Permanent Solution), as risk to future construction workers will be eliminated and SVE system can be shutdown with no impact to indoor air.
ii. Source Eliminated/Controlled	• The source of OHM contamination (high soil-groundwater concentrations) will be eliminated or controlled to the extent feasible (Temporary Solution), rather than eliminated to the extent feasible and controlled (Permanent Solution).	• The source of OHM contamination (high soil-groundwater concentrations) will be eliminated or controlled to the extent feasible (Temporary Solution), rather than eliminated to the extent feasible and controlled (Permanent Solution).	• The source of OHM contamination (high soil-groundwater concentrations) will be controlled to the extent feasible (Temporary Solution), rather than eliminated (Permanent Solution).
iii. Groundwater Plumes Managed	• The control of source areas will eventually lead to a stable or contracting groundwater plume (Permanent/Temporary Solution).	• The control of source areas will eventually lead to contracting groundwater plume (Permanent/Temporary Solution).	• The control of source areas will eventually lead to contracting groundwater plume (Permanent/Temporary Solution).
iv. DNAPL Removed/Controlled	• All non-stable DNAPL and DNAPL with micro-scale mobility will be removed to the extent feasible (Permanent Solution).	• All non-stable DNAPL and DNAPL with micro-scale mobility will be removed to the extent feasible (Permanent Solution).	• All non-stable DNAPL and DNAPL with micro-scale mobility will be removed to the extent feasible (Permanent Solution).
v. Release Threats Eliminated	• No threats of release exist (Permanent Solution or Temporary Solution)	• No threats of release exist (Permanent Solution or Temporary Solution)	• No threats of release exist (Permanent Solution or Temporary Solution)
vi. Background Levels Achieved/Approached	• Background concentrations will not be achieved or approached (see 1c below). (Temporary Solution)	• Background concentrations will not be achieved or approached (see 1c below). (Temporary Solution)	• Background concentrations will not be achieved or approached (see 1c below). (Temporary Solution)
b) Ability to Reuse, Recycle, Destroy, Detoxify, or Treating OHM On-Site	• OHM in the subsurface will be transferred from the subsurface to liquid phase and vapor phase carbon and destroyed off-site during carbon regeneration.	• OHM in the subsurface will be destroyed (oxidized) insitu.	• OHM in the subsurface will be destroyed (biotic reductive dechlorination) insitu.
c) Ability to Achieve or Approach Background Conditions	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. It is unlikely that TCE/PCE concentrations will be reduced to non-detectable levels, therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard. The GW2 standard for TCE is 5 ppb. It is not likely that the groundwater concentration will be reduced to 2.5 ppb in shallow groundwater beneath the Building 5 and background will not be approached. GW2 would be the applicable standard as CVOCs could volatilize into indoor air.	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. It is unlikely that TCE/PCE concentrations will be reduced to non-detectable levels, therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard. The GW2 standard for TCE is 5 ppb. It is not likely that the groundwater concentration will be reduced to 2.5 ppb in shallow groundwater beneath the Building 3 complex and background will not be approached. GW2 would be the applicable standard as CVOCs could volatilize into indoor air.	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. It is unlikely that TCE/PCE concentrations will be reduced to non-detectable levels, therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard. The GW2 standard for TCE is 5 ppb. It is not likely that the groundwater concentration will be reduced to 2.5 ppb in shallow groundwater beneath the Building 3 complex and background will not be approached. GW2 would be the applicable standard as CVOCs could volatilize into indoor air.
Effectiveness Rating	**4**	**3**	**3**
2. Reliability (R1)			
a) Certainty of Success	• ISTR has greater certainty of success in source area than ISCO or ISB.	• ISCO has less certainty of success than ISTR.	• ISB has proved successful in Building 5.
b) Effectiveness of Measures to Manage Residues	• No residues to be managed.	• No residues to be managed.	• No residues to be managed.
c) Effectiveness of Measures to Control Emissions or Discharges	• Emissions or discharges controlled by extraction and liquid/vapor phase carbon.	• No emissions anticipated. Injection rate control and monitoring required to protect against oxidant daylighting.	• No emissions anticipated. Injection rate control and monitoring required to protect against substrate daylighting.
Reliability Rating	**3**	**2**	**2**

Table 5
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
Building 5 Overburden

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 In-Situ Thermal Remediation (ISTR) w/Continued SVE Operation	Alternative 2 In-Situ Chemical Oxidation (ISCO) w/Continued SVE Operation	Alternative 3 In-Situ Bioremediation (ISB) w/Continued SVE Operation
3. Difficulty (D)			
a) Technical Complexity	• ISTR more technically complex than ISCO or ISB.	• ISCO less technically complex than ISTR. • The technical complexity of ISCO is similar to that of ISB.	• ISB less technically complex than ISTR. • The technical complexity of ISB is similar to that of ISCO.
b) Difficulty of Integration with Existing Facility Operations	• Moderately difficult to integrate with current operations in Building 5.	• Moderately difficult to integrate with current operations in Building 5.	• Moderately difficult to integrate with current operations in Building 5.
c) OM&M or Site Access Requirements/Limitations	• This alternative likely to result in the lowest soil-groundwater concentrations and the shortest period of time for groundwater monitoring.	• This alternative likely to result in the higher soil-groundwater concentrations than Alternative 1 and relatively longer groundwater monitoring.	• This alternative likely to result in the higher soil-groundwater concentrations than Alternative 1 and relatively longer groundwater monitoring.
d) Availability of Services, Materials, Equipment or Specialists	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.
e) Availability, Capacity and Location of Off-Site TSDFs	• Facilities are readily available for off-site regeneration of spent carbon (LPC/VPC).	• No TSDF required.	• No TSDF required.
f) Permits	• Discharge permit may be needed for treated groundwater and off-gas.	• No special permits are anticipated to be required. Injection wells are authorized by rule under UIC rule.	• No special permits are anticipated to be required. Injection wells are authorized by rule under UIC rule.
Implementability Rating	**1**	**3**	**3**
4. Cost (C)			
a) Estimated Cost of Implementation	• $9.839,000 (ISTR) (including energy consumption) • <u>$24,000 (SVE)</u> • $9,863,000 (Total) (Table B-4)	• $6,290,000 (ISCO) • <u>$90,000 (SVE)</u> • $6,380,000 (Total) (Table B-5)	• $3,766,000 (ISB) • <u>$158,000 (SVE)</u> • $3,924,000 (Total) (Table B-6)
b) Cost of Environmental Restoration & Potential Damages to Natural Resources	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.
c) Cost of Energy Consumption	• $1,820,000 (Table B-4) • 4,900,000 KWH (electricity) and 14,000 MMBTU (natural gas)	• Energy consumption not significant compared to ISTR.	• Energy consumption not significant compared to ISTR.
Cost Rating	**1**	**2**	**3**
5. Risk (R2)			
a) Relative Risk During Implementation	• Moderate risk associated with installation activities.	• Moderate risk associated with installation activities.	• Moderate risk associated with installation activities.
b) Relative Risk During Operations	• Risk of vapor migration should be effectively controlled by extraction system.	• Moderate risk associated with daylighting and handling of oxidants • Overall lower risk than ISTR.	• Low risk associated with ISB additive daylighting. • Overall lower risk than ISTR.
c) Relative Risk Associated with Remaining OHM	• Risk associated with remaining OHM is dependent on the ability of angled drilling to gain access to the source areas.	• Risk associated with remaining OHM is dependent on the ability of angled drilling to gain access to the source areas.	• Risk associated with remaining OHM is dependent on the ability of angled drilling to gain access to the source areas.
Risk Rating	**2**	**3**	**3**

Table 5
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
Building 5 Overburden

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 In-Situ Thermal Remediation (ISTR) w/Continued SVE Operation	Alternative 2 In-Situ Chemical Oxidation (ISCO) w/Continued SVE Operation	Alternative 3 In-Situ Bioremediation (ISB) w/Continued SVE Operation
6. Green Benefits (GB)			
a) Minimizes Energy Use or Uses Renewable Energy and Resources	• Significantly higher energy than ISCO and ISB.	• Significantly less energy usage than ISTR. • Energy usage of ISCO and ISB both minimal.	• Significantly less energy usage than ISTR. • Energy usage of ISCO and ISB both minimal.
b) Minimizes Air Pollution or Greenhouse Gas Emissions	• Ex-situ treatment systems should minimize air pollution. However, the remediation will generate GHG (750 mtCO2e [Scope 1] and 1,600 mtCO2e [Scope2]).	• Minimal air pollution or greenhouse gas emissions.	• Minimal air pollution or greenhouse gas emissions.
c) Reduce, Reuse & Recycle Waste	• CVOCs are transferred to LPC/VPC, which require off-site carbon regeneration.	• CVOCs are destroyed.	• CVOCs are biotically reduced to ethene.
d) Minimizes Adverse Aesthetic Impacts on Receptors Outside of the Property	• No adverse aesthetic impacts to off-site receptors.	• No adverse aesthetic impacts to off-site receptors.	• No adverse aesthetic impacts to off-site receptors.
Green Benefits Rating	**1**	**2**	**2**
7. Timeliness (T)			
a) Time to Achieve Remedial Objective	• 1 year	• 3 ISCO injection - 2.5 years • MNA - 1.5 year • Total - 4 years	•2 ISB injection - 3.5 years • MNA - 3 year • Total - 6.5 years
Timeliness Rating	**3**	**2**	**2**

Notes:

E Effectiveness
1 = Not widely used and probably not effective
2 = Widely used but probably not effective, or not widely used and may not be effective
3 = Widely used but may not be effective, or not widely used but probably effective
4 = Widely used and probably effective, or not widely used but proven and effective
5 = Widely used, proven, and effective

R1 Reliability
1 = Low reliability and/or high maintenance
2 = Average reliability and/or average maintenance
3 = High reliability and/or low maintenance

D Difficulty
1 = Most difficult to implement
2 = Moderate difficulty to implement
3 = Easiest to implement

C Cost
1 = Highest relative cost compared to other alternatives
3 = Lowest relative cost compared to other alternatives

R2 Risk
1 = Highest risks associated with implementation
2 = Moderate risk associated with implementation
3 = Lowest risk associated with implementation

GB Green Benefits
1 = Low benefits
2 = Low to moderate benefits
3 = Moderate to high benefits
4 = High benefits

T Time
1 = Extended treatment time
2 = Acceptable treatment time
3 = Rapid treatment

Score = E + R1 + D + C + R2 + GB + T; Possible scores are 7 to 24

Table 6
REMEDIAL ALTERNATIVE EVALUATION SUMMARY
Building 5 Overburden

Former Varian Facility Site
Beverly, MA

Alternative #	Alternative Description	Effectiveness	Reliability	Difficulty	Cost	Risk	Green Benefits	Timeliness	Score	Overall Ranking
1	In-Situ Thermal Remediation (ISTR) w/Continued SVE Operation	4	3	1	1	2	1	3	15	3
2	In-Situ Chemical Oxidation (ISCO) w/Continued SVE Operation	3	2	3	2	3	2	2	17	2
3	In-Situ Bioremediation (ISB) w/Continued SVE Operation	3	2	3	3	3	2	2	18	1

Notes:

E Effectiveness
- 1 = Not widely used and probably not effective
- 2 = Widely used but probably not effective, or not widely used and may not be effective
- 3 = Widely used but may not be effective, or not widely used but probably effective
- 4 = Widely used and probably effective, or not widely used but proven and effective
- 5 = Widely used, proven, and effective

R1 Reliability
- 1 = Low reliability and/or high maintenance
- 2 = Average reliability and/or average maintenance
- 3 = High reliability and/or low maintenance

D Difficulty
- 1 = Most difficult to implement
- 2 = Moderate difficulty to implement
- 3 = Easiest to implement

C Cost
- 1 = Highest relative cost compared to other alternatives
- 3 = Lowest relative cost compared to other alternatives

R2 Risk
- 1 = Highest risks associated with implementation
- 2 = Moderate risk associated with implementation
- 3 = Lowest risk associated with implementation

GB Green Benefits
- 1 = Low benefits
- 2 = Low to moderate benefits
- 3 = Moderate to high benefits
- 4 = High benefits

T Time
- 1 = Extended treatment time
- 2 = Acceptable treatment time
- 3 = Rapid treatment

Score = E + R1 + D + C + R2 + GB + T; Possible scores are 7 to 24

Table 7
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
Bedrock

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 In-Situ Chemical Oxidation (ISCO)	Alternative 2 In-Situ Chemical Reduction (ISCR)	Alternative 3 In-Situ Bioremediation (ISB)	Alternative 4 In-Situ Thermal Remediation (ISTR)
1. Effectiveness (E)				
a) Ability to Achieve a Permanent or Temporary Solution	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution would not be achieved.	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution would not be achieved.	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.
i. No Significant Risk (NSR)/No Substantial Hazard (NSH)	• A condition of No Significant Risk already exists for bedrock groundwater (Permanent Solution).	• A condition of No Significant Risk already exists for bedrock groundwater (Permanent Solution).	• A condition of No Significant Risk already exists for bedrock groundwater (Permanent Solution).	• A condition of No Significant Risk already exists for bedrock groundwater (Permanent Solution).
ii. Source Eliminated/Controlled	• The source of OHM contamination (high groundwater concentrations) will be eliminated, to the extent feasible, and, if not eliminated, controlled (Permanent Solution) or eliminated or controlled to the extent feasible (Temporary	• The source of OHM contamination (high groundwater concentrations) will be eliminated, to the extent feasible, and, if not eliminated, controlled (Permanent Solution) or controlled to the extent feasible (Temporary Solution).	• The source of OHM contamination (high groundwater concentrations) will be eliminated, to the extent feasible, and, if not eliminated, controlled (Permanent Solution) or controlled to the extent feasible (Temporary Solution).	• The source of OHM contamination (high groundwater concentrations) will be eliminated, to the extent feasible, and, if not eliminated, controlled (Permanent Solution) or controlled to the extent feasible (Temporary Solution).
iii. Groundwater Plumes Managed	• The control of source areas will eventually lead to stable or contracting groundwater plume (Permanent/Temporary Solution).	• The control of source areas will eventually lead to stable or contracting groundwater plume (Permanent/Temporary Solution).	• The control of source areas will eventually lead to stable or contracting groundwater plume (Permanent/Temporary Solution).	• The control of source areas will eventually lead to stable or contracting groundwater plume (Permanent/Temporary Solution).
iv. DNAPL Removed/Controlled	• All non-stable DNAPL and DNAPL with micro-scale mobility will be removed to the extent feasible (Permanent Solution). DNAPL can form MnO2 crust around when in contact with permanganate, which limits further degradation.	• ISCR unlikely to address DNAPL, precluding a Temporary Solution.	• ISB unlikely to address DNAPL, precluding a Temporary Solution.	• All non-stable DNAPL and DNAPL with micro-scale mobility will be removed to the extent feasible (Permanent Solution).
v. Release Threats Eliminated	• No threats of release exist (Permanent Solution)	• No threats of release exist (Permanent Solution)	• No threats of release exist (Permanent Solution)	• No threats of release exist (Permanent Solution)
vi. Background Levels Achieved/Approached	• Background concentrations will be approached (see 1c below). (Permanent Solution)	• Background concentrations will be approached (see 1c below). (Permanent Solution)	• Background concentrations will be approached (see 1c below). (Permanent Solution)	• Background concentrations will be approached (see 1c below). (Permanent Solution)
b) Ability to Reuse, Recycle, Destroy, Detoxify, or Treating OHM On-Site	• OHM in the subsurface will be destroyed (oxidized) insitu.	• OHM in the subsurface will be converted to non-toxic acetylene and ethene (abiotic-dechlorination) insitu; ISCR can also promote reducing conditions amenable to biotic degradation of CVOCs.	• OHM in the subsurface will be converted to ethene (biotic reductive dechlorination) insitu, although toxic intermediate daughter products such as cis-1,2-DCE and VC can accumulate if conditions are not ideal.	• OHM in the subsurface will be transferred from the subsurface to liquid phase and vapor phase carbon and destroyed off-site during carbon regeneration.
c) Ability to Achieve or Approach Background Conditions	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. It is unlikely that TCE/PCE concentrations will be reduced to non-detectable levels, therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard, which for bedrock groundwater is GW3. The GW3 standard for TCE is 5,000 ppb. It is likely that the groundwater concentration will be reduced to less than 2,500 ppb and background will be approached. The GW3 standard would apply as groundwater can migrate to surface water.	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. It is unlikely that TCE/PCE concentrations will be reduced to non-detectable levels, therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard, which for bedrock groundwater is GW3. The GW3 standard for TCE is 5,000 ppb. It is likely that the groundwater concentration will be reduced to less than 2,500 ppb and background will be approached. The GW3 standard would apply as groundwater can migrate to surface water.	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. It is unlikely that TCE/PCE concentrations will be reduced to non-detectable levels, therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard, which for bedrock groundwater is GW3. The GW3 standard for TCE is 5,000 ppb. It is likely that the groundwater concentration will be reduced to less than 2,500 ppb and background will be approached. The GW3 standard would apply as groundwater can migrate to surface water.	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. It is unlikely that TCE/PCE concentrations will be reduced to non-detectable levels, therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard, which for bedrock groundwater is GW3. The GW3 standard for TCE is 5,000 ppb. It is likely that the groundwater concentration will be reduced to less than 2,500 ppb and background will be approached. The GW3 standard would apply as groundwater can migrate to surface water.
Effectiveness Rating	**3**	**2**	**1**	**3**

Table 7
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
Bedrock

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 In-Situ Chemical Oxidation (ISCO)	Alternative 2 In-Situ Chemical Reduction (ISCR)	Alternative 3 In-Situ Bioremediation (ISB)	Alternative 4 In-Situ Thermal Remediation (ISTR)
2. Reliability (R1)				
a) Certainty of Success	• Success of remediation in bedrock is not certain given inherent uncertainties with bedrock fracture distribution and characteristics • ISCO has a greater certainty of success than ISCR or ISB because it is better at treating residual DNAPL that may be present in bedrock.	• Success of remediation in bedrock is not certain given inherent uncertainties with bedrock fracture distribution and characteristics • ISCR has a greater certainty of success than ISB, but less certainty of success than ISCO.	• Success of remediation in bedrock is not certain given inherent uncertainties with bedrock fracture distribution and characteristics • ISB has a less certainty of success than ISCO or ISCR because of high CVOC concentrations and potential presence of DNAPL.	• Success of remediation in bedrock is not certain given inherent uncertainties with bedrock fracture distribution and characteristics • ISTR has a greater certainty of success than ISCR or ISB because it is better at treating residual DNAPL that may be present in bedrock.
b) Effectiveness of Measures to Manage Residues	• No residues to be managed.	• No residues to be managed.	• No residues to be managed.	• No residues to be managed.
c) Effectiveness of Measures to Control Emissions or Discharges	• No emissions anticipated. Injection rate control and monitoring required to protect against oxidant daylighting.	• No emissions anticipated. Injection rate control and monitoring required to protect against reductant daylighting.	• No emissions anticipated. Injection rate control and monitoring required to protect against bioamendment daylighting.	• Emissions or discharges controlled by extraction and liquid/vapor phase carbon.
Reliability Rating	**3**	**2**	**1**	**2**
3. Difficulty (D)				
a) Technical Complexity	• Accessing the contamination in the bedrock is moderately complex regardless of the amendment being added.	• Accessing the contamination in the bedrock is moderately complex regardless of the amendment being added.	• Accessing the contamination in the bedrock is moderately complex regardless of the amendment being added.	• ISTR more technically complex than ISCO, ISCR or ISB.
b) Difficulty of Integration with Existing Facility Operations	• Not difficult to integrate with existing facility operations.	• Not difficult to integrate with existing facility operations.	• Not difficult to integrate with existing facility operations.	• Not difficult to integrate with existing facility operations.
c) OM&M or Site Access Requirements/Limitations	• This alternative likely to result in groundwater concentrations and groundwater monitoring periods between Alternative 4 and Alternative 3.	• This alternative likely to result in groundwater concentrations and groundwater monitoring periods between Alternative 4 and Alternative 3.	• This alternative likely to result in the highest groundwater concentrations and the longest period of time for groundwater monitoring.	• This alternative likely to result in the lowest groundwater concentrations and the shortest period of time for groundwater monitoring.
d) Availability of Services, Materials, Equipment or Specialists	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.
e) Availability, Capacity and Location of Off-Site TSDFs	• No TSDF required.	• No TSDF required.	• No TSDF required.	• Facilities are readily available for off-site regeneration of spent carbon (LPC/VPC).
f) Permits	• No special permits are anticipated to be required. Injection wells are authorized by rule under UIC rule.	• No special permits are anticipated to be required. Injection wells are authorized by rule under UIC rule.	• No special permits are anticipated to be required. Injection wells are authorized by rule under UIC rule.	• Discharge permit may be needed for treated groundwater and off-gas.
Implementability Rating	**2**	**2**	**2**	**2**
4. Cost (C)				
a) Estimated Cost of Implementation	• $5,245,000 (Table B-7)	• $3,175,000 (Table B-8)	• $1,833,500 (Table B-9)	• $16,656,500 (Table B-10) (including energy consumption)
b) Cost of Environmental Restoration & Potential Damages to Natural Resources	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.
c) Cost of Energy Consumption	• Energy consumption of this alternative is not significant	• Energy consumption of this alternative is not significant	• Energy consumption of this alternative is not significant	• $5,746,000 (Table B-10) • 14,820,000 KWH (electricity) and 520,000 MMBTU (natural gas)
Cost Rating	**2**	**2**	**3**	**1**
5. Risk (R2)				
a) Relative Risk During Implementation	• Moderate risk associated with installation activities.	• Moderate risk associated with installation activities.	• Moderate risk associated with installation activities.	• Moderate risk associated with installation activities.
b) Relative Risk During Operations	• Moderate risk associated with daylighting and handling of oxidants	• Low risk associated with daylighting and handling of additives	• Low risk associated with daylighting and handling of additives	• Risk of vapor migration should be effectively controlled by extraction system. However, there is risk of mobilizing DNAPL or dissolved phase VOCs to downgradient locations.
c) Relative Risk Associated with Remaining OHM	• As indicated under "Effectiveness", a condition of No Significant Risk already exists for bedrock groundwater.	• As indicated under "Effectiveness", a condition of No Significant Risk already exists for bedrock groundwater.	• As indicated under "Effectiveness", a condition of No Significant Risk already exists for bedrock groundwater.	• As indicated under "Effectiveness", a condition of No Significant Risk already exists for bedrock groundwater.
Risk Rating	**2**	**2**	**2**	**1**

Table 7
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
Bedrock

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 In-Situ Chemical Oxidation (ISCO)	Alternative 2 In-Situ Chemical Reduction (ISCR)	Alternative 3 In-Situ Bioremediation (ISB)	Alternative 4 In-Situ Thermal Remediation (ISTR)
6. Green Benefits (GB)				
a) Minimizes Energy Use or Uses Renewable Energy and Resources	• Energy consumption of this alternative is not significant	• Energy consumption of this alternative is not significant	• Energy consumption of this alternative is not significant	• Significantly higher energy than ISCO, ISCR and ISB.
b) Minimizes Air Pollution or Greenhouse Gas Emissions	• Minimal air pollution or greenhouse gas emissions.	• Minimal air pollution or greenhouse gas emissions.	• Minimal air pollution or greenhouse gas emissions.	• Ex-situ treatment systems should minimize air pollution. However, the remediation will generate GHG (2,800 mtCO2e [Scope 1] and 4,700 mtCO2e [Scope2]).
c) Reduce, Reuse & Recycle Waste	• CVOCs are destroyed (oxidized) insitu.	• CVOCs are converted to acetylene and ethene (abiotic dechlorination) insitu.	• CVOCs are converted to ethene (biotic reductive dechlorination) insitu.	• CVOCs are transferred to LPC/VPC, which require off-site carbon regeneration.
d) Minimizes Adverse Aesthetic Impacts on Receptors Outside of the Property	• No adverse aesthetic impacts to off-site receptors.	• No adverse aesthetic impacts to off-site receptors.	• No adverse aesthetic impacts to off-site receptors.	• No adverse aesthetic impacts to off-site receptors.
Green Benefits Rating	**2**	**2**	**2**	**1**
7. Timeliness (T)				
a) Time to Achieve Remedial Objective	• 3 ISCO injections - 4.5 years	• 2 ISCR injections - 4.5 years	•3 ISB injections - 6 years	•1 year
Timeliness Rating	**2**	**2**	**2**	**3**

Notes:

E Effectiveness
- 1 = Not widely used and probably not effective
- 2 = Widely used but probably not effective, or not widely used and may not be effective
- 3 = Widely used but may not be effective, or not widely used but probably effective
- 4 = Widely used and probably effective, or not widely used but proven and effective
- 5 = Widely used, proven, and effective

R1 Reliability
- 1 = Low reliability and/or high maintenance
- 2 = Average reliability and/or average maintenance
- 3 = High reliability and/or low maintenance

D Difficulty
- 1 = Most difficult to implement
- 2 = Moderate difficulty to implement
- 3 = Easiest to implement

C Cost
- 1 = Highest relative cost compared to other alternatives
- 3 = Lowest relative cost compared to other alternatives

R2 Risk
- 1 = Highest risks associated with implementation
- 2 = Moderate risk associated with implementation
- 3 = Lowest risk associated with implementation

GB Green Benefits
- 1 = Low benefits
- 2 = Low to moderate benefits
- 3 = Moderate to high benefits
- 4 = High benefits

T Time
- 1 = Extended treatment time
- 2 = Acceptable treatment time
- 3 = Rapid treatment

Score = E + R1 + D + C + R2 + GB + T; Possible scores are 7 to 24

Table 8
REMEDIAL ALTERNATIVE EVALUATION SUMMARY
Bedrock

Former Varian Facility Site
Beverly, MA

Alternative #	Alternative Description	Effectiveness	Reliability	Difficulty	Cost	Risk	Green Benefits	Timeliness	Score	Overall Ranking
1	In-Situ Chemical Oxidation (ISCO)	3	3	2	2	2	2	2	16	1
2	In-Situ Chemical Reduction (ISCR)	2	2	2	2	2	2	2	14	2
3	In-Situ Bioremediation (ISB)	1	1	2	3	2	2	2	13	3
4	In-Situ Thermal Remediation (ISTR)	3	2	2	1	1	1	3	13	3

Notes:

E Effectiveness
- 1 = Not widely used and probably not effective
- 2 = Widely used but probably not effective, or not widely used and may not be effective
- 3 = Widely used but may not be effective, or not widely used but probably effective
- 4 = Widely used and probably effective, or not widely used but proven and effective
- 5 = Widely used, proven, and effective

R1 Reliability
- 1 = Low reliability and/or high maintenance
- 2 = Average reliability and/or average maintenance
- 3 = High reliability and/or low maintenance

D Difficulty
- 1 = Most difficult to implement
- 2 = Moderate difficulty to implement
- 3 = Easiest to implement

C Cost
- 1 = Highest relative cost compared to other alternatives
- 3 = Lowest relative cost compared to other alternatives

R2 Risk
- 1 = Highest risks associated with implementation
- 2 = Moderate risk associated with implementation
- 3 = Lowest risk associated with implementation

GB Green Benefits
- 1 = Low benefits
- 2 = Low to moderate benefits
- 3 = Moderate to high benefits
- 4 = High benefits

T Time
- 1 = Extended treatment time
- 2 = Acceptable treatment time
- 3 = Rapid treatment

Score = E + R1 + D + C + R2 + GB + T; Possible scores are 7 to 24

Table 9
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
PSL10 Area

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 In-Situ Chemical Oxidation (ISCO)	Alternative 2 Colloidal Activated Carbon (CAC) Permeable Adorptive Zone (PAZ)	Alternative 3 Monitored Natural Attenuation (MNA)
1. Effectiveness (E)			
a) Ability to Achieve a Permanent or Temporary Solution	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.
i. No Significant Risk (NSR)/No Substantial Hazard (NSH)	• A condition of No Significant Risk already exists in the PSL10 groundwater (Permanent Solution).	• A condition of No Significant Risk already exists in the PSL10 groundwater (Permanent Solution).	• A condition of No Significant Risk already exists in the PSL10 groundwater (Permanent Solution).
ii. Source Eliminated/Controlled	• The source of OHM contamination will be controlled to the extent feasible (Temporary Solution), rather than eliminated (Permanent Solution). Supplemental treatment (e.g., soil excavation) may be conducted based on additional assessment.	• The source of OHM contamination will be controlled to the extent feasible (Temporary Solution), rather than eliminated (Permanent Solution). Supplemental treatment (e.g., soil excavation) may be conducted based on additional assessment.	• The source of OHM contamination may not be controlled to the extent feasible (Temporary Solution), rather than eliminated (Permanent Solution).
iii. Groundwater Plumes Managed	• The control of source areas will eventually lead to stable or contracting groundwater plume (Permanent/Temporary Solution).	• The control of source areas will eventually lead to stable or contracting groundwater plume (Permanent/Temporary Solution).	• The control of source areas will eventually lead to stable or contracting groundwater plume (Permanent/Temporary Solution).
iv. DNAPL Removed/Controlled	• DNAPL not present in this area.	• DNAPL not present in this area.	• DNAPL not present in this area.
v. Release Threats Eliminated	• No threats of release exist (Permanent Solution)	• No threats of release exist (Permanent Solution)	• No threats of release exist (Permanent Solution)
vi. Background Levels Achieved/Approached	• Background will be approached (see 1c below) (Permanent Solution)	• Background will be approached (see 1c below) (Permanent Solution)	• Background will be approached (see 1c below) (Permanent Solution)
b) Ability to Reuse, Recycle, Destroy, Detoxify, or Treating OHM On-Site	• OHM in the subsurface will be destroyed (oxidized) insitu.	• OHM in the subsurface will be adsorbed and possibly converted to ethene (biotic reductive dechlorination).	• OHM in the subsurface will be attenuated through a combination of natural processes (biodegradation, sorption, dilution, evaporation, and chemical reaction).
c) Ability to Achieve or Approach Background Conditions	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. Therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard. The GW2 standard for PCE and TCE are 50 ppb and 5 ppb, respectively. The most recent PCE/TCE concentrations at MW2_32-TOZER are 750/130 ppb. It is likely that concentrations will be reduced to 25/2.5 ppb and background will be approached. GW2 would be the applicable standard as CVOCs could volatilize into indoor air.	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. Therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard. The GW2 standard for PCE and TCE are 50 ppb and 5 ppb, respectively. The most recent PCE/TCE concentrations at MW2_32-TOZER are 750/130 ppb. It is likely that concentrations will be reduced to 25/2.5 and background will be approached. GW2 would be the applicable standard as CVOCs could volatilize into indoor air.	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. Therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard. The GW2 standard for PCE and TCE are 50 ppb and 5 ppb, respectively. The most recent PCE/TCE concentrations at MW2_32-TOZER are 750/130 ppb. It is likely that concentrations will be reduced to 25/2.5 and background will be approached. GW2 would be the applicable standard as CVOCs could volatilize into indoor air.
Effectiveness Rating	**5**	**5**	**3**
2. Reliability (R1)			
a) Certainty of Success	As a condition of No Significant Risk already exists, certainty of success is not an issue	As a condition of No Significant Risk already exists, certainty of success is not an issue	As a condition of No Significant Risk already exists, certainty of success is not an issue
b) Effectiveness of Measures to Manage Residues	• No residues to be managed.	• No residues to be managed.	• No residues to be managed.
c) Effectiveness of Measures to Control Emissions or Discharges	• No emissions anticipated. Injection rate control and monitoring required to protect against oxidant daylighting.	• No emissions anticipated. Injection rate control and monitoring required to protect against additive daylighting.	• No emissions or discharges.
Reliability Rating	**3**	**3**	**2**

Table 9
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
PSL10 Area

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 In-Situ Chemical Oxidation (ISCO)	Alternative 2 Colloidal Activated Carbon (CAC) Permeable Adorptive Zone (PAZ)	Alternative 3 Monitored Natural Attenuation (MNA)
3. Difficulty (D)			
a) Technical Complexity	• ISCO and CAC permeable adsorptive zone more technically complex than MNA	• ISCO and CAC permeable adsorptive zone more technically complex than MNA	• Not technically complex.
b) Difficulty of Integration with Existing Facility Operations	• Not difficult to integrate with existing facility operations.	• Not difficult to integrate with existing facility operations.	• Not difficult to integrate with existing facility operations.
c) OM&M or Site Access Requirements/Limitations	• ISCO and CAC PAZ will require less time for groundwater monitoring than MNA.	• ISCO and CAC PAZ will require less time for groundwater monitoring than MNA.	• This alternative will require the longest OM&M period.
d) Availability of Services, Materials, Equipment or Specialists	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.
e) Availability, Capacity and Location of Off-Site TSDFs	• No TSDF required.	• No TSDF required.	• No TSDF required.
f) Permits	• No special permits are anticipated to be required.	• No special permits are anticipated to be required.	• No special permits are anticipated to be required.
Implementability Rating	**2**	**2**	**3**
4. Cost (C)			
a) Estimated Cost of Implementation	• $1,434,000 (Table B-11)	• $1,577,000 (Table B-12)	• $675,000 (Table B-13)
b) Cost of Environmental Restoration & Potential Damages to Natural Resources	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.
c) Cost of Energy Consumption	• Energy consumption of this alternative is not significant	• Energy consumption of this alternative is not significant	• Energy consumption of this alternative is not significant
Cost Rating	**1**	**1**	**3**
5. Risk (R2)			
a) Relative Risk During Implementation	• Moderate risk associated with installation activities.	• Moderate risk associated with installation activities.	• No risk during implementation.
b) Relative Risk During Operations	• Moderate risk associated with daylighting and handling of oxidants	• Low risk associated with daylighting and handling of additives.	• Little to no risk during operations.
c) Relative Risk Associated with Remaining OHM	• As indicated under "Effectiveness", a condition of No Significant Risk already exists in the PSL10 groundwater.	• As indicated under "Effectiveness", a condition of No Significant Risk already exists in the PSL10 groundwater.	• As indicated under "Effectiveness", a condition of No Significant Risk already exists in the PSL10 groundwater.
Risk Rating	**2**	**2**	**3**

Table 9
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
PSL10 Area

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 In-Situ Chemical Oxidation (ISCO)	Alternative 2 Colloidal Activated Carbon (CAC) Permeable Adorptive Zone (PAZ)	Alternative 3 Monitored Natural Attenuation (MNA)
6. Green Benefits (GB)			
a) Minimizes Energy Use or Uses Renewable Energy and Resources	• Energy consumption of this alternative is not significant	• Energy consumption of this alternative is not significant	• Energy consumption of this alternative is not significant
b) Minimizes Air Pollution or Greenhouse Gas Emissions	• Minimal air pollution or greenhouse gas emissions.	• Minimal air pollution or greenhouse gas emissions.	• No air pollution or greenhouse gas emissions.
c) Reduce, Reuse & Recycle Waste	• CVOCs are destroyed (oxidized) insitu.	• CVOCs are adsorbed insitu and possibly converted to ethene biotically.	• CVOCs are attenuated insitu.
d) Minimizes Adverse Aesthetic Impacts on Receptors Outside of the Property	• No adverse aesthetic impacts to off-site receptors.	• No adverse aesthetic impacts to off-site receptors.	• No adverse aesthetic impacts to off-site receptors.
Green Benefits Rating	**3**	**3**	**2**
7. Timeliness (T)			
a) Time to Achieve Remedial Objective	• 2 ISCO Injections: 1.5 years • MNA: 4 years • 5.5 years	• 2 CAC Injections: 1 year • MNA: 2 year • 3 years	• MNA: 50 years
Timeliness Rating	**3**	**3**	**1**

Notes:

E Effectiveness
- 1 = Not widely used and probably not effective
- 2 = Widely used but probably not effective, or not widely used and may not be effective
- 3 = Widely used but may not be effective, or not widely used but probably effective
- 4 = Widely used and probably effective, or not widely used but proven and effective
- 5 = Widely used, proven, and effective

R1 Reliability
- 1 = Low reliability and/or high maintenance
- 2 = Average reliability and/or average maintenance
- 3 = High reliability and/or low maintenance

D Difficulty
- 1 = Most difficult to implement
- 2 = Moderate difficulty to implement
- 3 = Easiest to implement

C Cost
- 1 = Highest relative cost compared to other alternatives
- 3 = Lowest relative cost compared to other alternatives

R2 Risk
- 1 = Highest risks associated with implementation
- 2 = Moderate risk associated with implementation
- 3 = Lowest risk associated with implementation

GB Green Benefits
- 1 = Low benefits
- 2 = Low to moderate benefits
- 3 = Moderate to high benefits
- 4 = High benefits

T Time
- 1 = Extended treatment time
- 2 = Acceptable treatment time
- 3 = Rapid treatment

Score = E + R1 + D + C + R2 + GB + T; Possible scores are 7 to 24

Table 10
REMEDIAL ALTERNATIVE EVALUATION SUMMARY
PSL10 Area

Former Varian Facility Site
Beverly, MA

Alternative #	Alternative Description	Effectiveness	Reliability	Difficulty	Cost	Risk	Green Benefits	Timeliness	Score	Overall Ranking
1	In-Situ Chemical Oxidation (ISCO)	5	3	2	1	2	3	3	19	1
2	Colloidal Activated Carbon (CAC) Permeable Adsorptive Zone (PAZ)	5	3	2	1	2	3	3	19	1
3	Monitored Natural Attenuation (MNA)	3	2	3	3	3	2	1	17	3

Notes:

E Effectiveness
1 = Not widely used and probably not effective
2 = Widely used but probably not effective, or not widely used and may not be effective
3 = Widely used but may not be effective, or not widely used but probably effective
4 = Widely used and probably effective, or not widely used but proven and effective
5 = Widely used, proven, and effective

R1 Reliability
1 = Low reliability and/or high maintenance
2 = Average reliability and/or average maintenance
3 = High reliability and/or low maintenance

D Difficulty
1 = Most difficult to implement
2 = Moderate difficulty to implement
3 = Easiest to implement

C Cost
1 = Highest relative cost compared to other alternatives
3 = Lowest relative cost compared to other alternatives

R2 Risk
1 = Highest risks associated with implementation
2 = Moderate risk associated with implementation
3 = Lowest risk associated with implementation

GB Green Benefits
1 = Low benefits
2 = Low to moderate benefits
3 = Moderate to high benefits
4 = High benefits

T Time
1 = Extended treatment time
2 = Acceptable treatment time
3 = Rapid treatment

Score = E + R1 + D + C + R2 + GB + T; Possible scores are 7 to 24

Table 11
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
Downgradient Plume

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 Zero Valent Iron (ZVI) Permeable Reactive Zone (PRZ) and Seep Treatment	Alternative 2 Colloidal Activated Carbon (CAC) Permeable Adsorptive Zone (PAZ) and Seep Treatment	Alternative 3 Monitored Natural Attenuation (MNA)
1. Effectiveness (E)			
a) Ability to Achieve a Permanent or Temporary Solution	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.	• Based on evaluation of risk/hazard, sources, plumes, DNAPL, release threats, and achieving background concentrations, a Temporary Solution will be achieved.
i. No Significant Risk (NSR)/No Substantial Hazard (NSH)	• A condition of No Significant Risk already exists in the downgradient groundwater (Permanent Solution).	• A condition of No Significant Risk already exists in the downgradient groundwater (Permanent Solution).	• A condition of No Significant Risk already exists in the downgradient groundwater (Permanent Solution).
ii. Source Eliminated/Controlled	• No OHM source to be controlled or eliminated.	• No OHM source to be controlled or eliminated.	• No OHM source to be controlled or eliminated.
iii. Groundwater Plumes Managed	• The PRZ will prevent migration of plume from source areas to downgradient areas and result in stable or contracting downgradient plume.	• The PAZ will prevent migration of plume from source areas to downgradient areas and result in stable or contracting downgradient plume.	• This alternative may not provide protection against plume migration.
iv. DNAPL Removed/Controlled	• No DNAPL in this area to be removed/controlled.	• No DNAPL in this area to be removed/controlled.	• No DNAPL in this area to be removed/controlled.
v. Release Threats Eliminated	• No threats of release exist (Permanent Solution)	• No threats of release exist (Permanent Solution)	• No threats of release exist (Permanent Solution)
vi. Background Levels Achieved/Approached	• Background has already been approached (see 1c below) (Permanent Solution)	• Background has already been approached (see 1c below) (Permanent Solution)	• Background concentrations will not be achieved or approached (Permanent Solution).
b) Ability to Reuse, Recycle, Destroy, Detoxify, or Treating OHM On-Site	• OHM in the subsurface will be converted insitu to acetylene and ethene (abiotic dechlorination).	• OHM in the subsurface will be adsorbed insitu and potentially converted to ethene (biotic reductive dechlorination).	• OHM in the subsurface will be attenuated through a combination of natural processes (biodegradation, sorption, dilution, evaporation, and chemical reaction).
c) Ability to Achieve or Approach Background Conditions	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. Therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard. The GW3 standard for TCE is 5,000 ppb. Groundwater concentrations are already well below 2,500 ppb. GW3 standard is applicable as groundwater can discharge to surface water.	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. Therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard. The GW3 standard for TCE is 5,000 ppb. Groundwater concentrations are already well below 2,500 ppb. GW3 standard is applicable as groundwater can discharge to surface water.	• **Achieve Background:** TCE/PCE cannot be attributed to: (1) geologic or ecologic conditions or atmospheric deposition of industrial process or engine emissions; (2) coal or wood ash associated with fill materials; (3) releases to groundwater from a public water supply system; or, (4) petroleum residues that are incidental to the normal operation of motor vehicles. Therefore, background will not be achieved. • **Approach Background:** For persistent compounds like TCE/PCE, "approach background" in groundwater requires that the concentration at each exposure point is at or below 1/2 of applicable Method 1 standard. The GW3 standard for TCE is 5,000 ppb. Groundwater concentrations are already well below 2,500 ppb. GW3 standard is applicable as groundwater can discharge to surface water.
Effectiveness Rating	**5**	**5**	**3**
2. Reliability (R1)			
a) Certainty of Success	• Greater certainty of success with PRB/PAB than MNA. • CVOCs discharging to the stream will be adsorbed insitu.	• Greater certainty of success with PRB/PAB than MNA. • CVOCs discharging to the stream will be adsorbed insitu.	• MNA has lower certainty of success than PRB/PAB.
b) Effectiveness of Measures to Manage Residues	• No residues to be managed.	• No residues to be managed.	• No residues to be managed.
c) Effectiveness of Measures to Control Emissions or Discharges	• No emissions anticipated. Injection rate control and monitoring required to protect against additive daylighting.	• No emissions anticipated. Injection rate control and monitoring required to protect against additive daylighting.	• No emissions or discharges.
Reliability Rating	**3**	**3**	**1**

Table 11
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
Downgradient Plume

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 Zero Valent Iron (ZVI) Permeable Reactive Zone (PRZ) and Seep Treatment	Alternative 2 Colloidal Activated Carbon (CAC) Permeable Adsorptive Zone (PAZ) and Seep Treatment	Alternative 3 Monitored Natural Attenuation (MNA)
3. Difficulty (D)			
a) Technical Complexity	• PRB/PAB and seep treatment more technically complex than MNA	• PRB/PAB and seep treatment more technically complex than MNA	• Not technically complex.
b) Difficulty of Integration with Existing Facility Operations	• Not difficult to integrate with existing facility operations.	• Not difficult to integrate with existing facility operations.	• Not difficult to integrate with existing facility operations.
c) OM&M or Site Access Requirements/Limitations	• Groundwater monitoring associated with PRZ will be significantly shorter than that associated with MNA. • Access to seep/stream location will need to be negogiated.	• Groundwater monitoring associated with PAZ will be significantly shorter than that associated with MNA. • Access to seep/stream location will need to be negogiated.	• This alternative will require the longest OM&M period.
d) Availability of Services, Materials, Equipment or Specialists	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.	• The services, materials, equipment, and specialists needed are readily available.
e) Availability, Capacity and Location of Off-Site TSDFs	• No TSDF required.	• No TSDF required.	• No TSDF required.
f) Permits	• Wetlands permit will be required for seep treatment.	• Wetlands permit will be required for seep treatment.	• No special permits are anticipated to be required.
Implementability Rating	**2**	**2**	**3**
4. Cost (C)			
a) Estimated Cost of Implementation	• $1,730,000 (Table B-13)	• $3,010,000 (Table B-14)	• $185,000 (Table B-15)
b) Cost of Environmental Restoration & Potential Damages to Natural Resources	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.	• No further environmental restoration is anticipated to be necessary.
c) Cost of Energy Consumption	• Energy consumption not significant	• Energy consumption not significant	• Energy consumption not significant
Cost Rating	**2**	**1**	**3**
5. Risk (R2)			
a) Relative Risk During Implementation	• Moderate risk associated with installation activities.	• Moderate risk associated with installation activities.	• No risk associated with installation activities.
b) Relative Risk During Operations	• Little to no risk during operations.	• Little to no risk during operations.	• Little to no risk during operations.
c) Relative Risk Associated with Remaining OHM	• As indicated under "Effectiveness", a condition of No Significant Risk already exists in the downgradient groundwater. PRZ will protect potential downgradient receptors from plume migration from source areas.	• As indicated under "Effectiveness", a condition of No Significant Risk already exists in the downgradient groundwater. PAZ will protect potential downgradient receptors from plume migration from source areas.	• As indicated under "Effectiveness", a condition of No Significant Risk already exists in the downgradient groundwater. However, it does not protect potential downgradient receptors from plume migration from source areas to the same extent as PRZ or PAZ.
Risk Rating	**2**	**2**	**2**

Table 11
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
Downgradient Plume

Former Varian Facility Site
Beverly, MA

Evaluation Criteria	Alternative 1 Zero Valent Iron (ZVI) Permeable Reactive Zone (PRZ) and Seep Treatment	Alternative 2 Colloidal Activated Carbon (CAC) Permeable Adsorptive Zone (PAZ) and Seep Treatment	Alternative 3 Monitored Natural Attenuation (MNA)
6. Green Benefits (GB)			
a) Minimizes Energy Use or Uses Renewable Energy and Resources	• Energy consumption of this alternative is not significant	• Energy consumption of this alternative is not significant	• Energy consumption of this alternative is not significant
b) Minimizes Air Pollution or Greenhouse Gas Emissions	• Minimal air pollution or greenhouse gas emissions.	• Minimal air pollution or greenhouse gas emissions.	• Minimal air pollution or greenhouse gas emissions.
c) Reduce, Reuse & Recycle Waste	• CVOCs are converted to acetylene ethene abiotically insitu.	• CVOCs are adsorbed insitu and possibly converted to ethene biotically.	• CVOCs are attenuated insitu.
d) Minimizes Adverse Aesthetic Impacts on Receptors Outside of the Property	• No adverse aesthetic impacts to off-site receptors.	• No adverse aesthetic impacts to off-site receptors.	• No adverse aesthetic impacts to off-site receptors.
Green Benefits Rating	**2**	**2**	**3**
7. Timeliness (T)			
a) Time to Achieve Remedial Objective	• 1 year.	• 1 year.	• 10+ years.
Timeliness Rating	**3**	**3**	**1**

Notes:

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1 = Not widely used and probably not effective
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3 = Widely used but may not be effective, or not widely used but probably effective
4 = Widely used and probably effective, or not widely used but proven and effective
5 = Widely used, proven, and effective

R1 Reliability
1 = Low reliability and/or high maintenance
2 = Average reliability and/or average maintenance
3 = High reliability and/or low maintenance

D Difficulty
1 = Most difficult to implement
2 = Moderate difficulty to implement
3 = Easiest to implement

C Cost
1 = Highest relative cost compared to other alternatives
3 = Lowest relative cost compared to other alternatives

R2 Risk
1 = Highest risks associated with implementation
2 = Moderate risk associated with implementation
3 = Lowest risk associated with implementation

GB Green Benefits
1 = Low benefits
2 = Low to moderate benefits
3 = Moderate to high benefits
4 = High benefits

T Time
1 = Extended treatment time
2 = Acceptable treatment time
3 = Rapid treatment

Score = E + R1 + D + C + R2 + GB + T; Possible scores are 7 to 24

Table 12
REMEDIAL ALTERNATIVE EVALUATION SUMMARY
Downgradient Plume

Former Varian Facility Site
Beverly, MA

Alternative #	Alternative Description	Effectiveness	Reliability	Difficulty	Cost	Risk	Green Benefits	Timeliness	Score	Overall Ranking
1	Zero Valent Iron (ZVI) Permeable Reactive Barrier (PRB) & Seep Treatment	5	3	2	2	2	2	3	19	1
2	Colloidal Activated Carbon (CAC) Permeable Adsorptive Barrier(PAB) & Seep Treatment	5	3	2	1	2	2	3	18	2
3	Monitored Natural Attenuation (MNA)	3	1	3	3	2	3	1	16	3

Notes:

E Effectiveness
- 1 = Not widely used and probably not effective
- 2 = Widely used but probably not effective, or not widely used and may not be effective
- 3 = Widely used but may not be effective, or not widely used but probably effective
- 4 = Widely used and probably effective, or not widely used but proven and effective
- 5 = Widely used, proven, and effective

R1 Reliability
- 1 = Low reliability and/or high maintenance
- 2 = Average reliability and/or average maintenance
- 3 = High reliability and/or low maintenance

D Difficulty
- 1 = Most difficult to implement
- 2 = Moderate difficulty to implement
- 3 = Easiest to implement

C Cost
- 1 = Highest relative cost compared to other alternatives
- 3 = Lowest relative cost compared to other alternatives

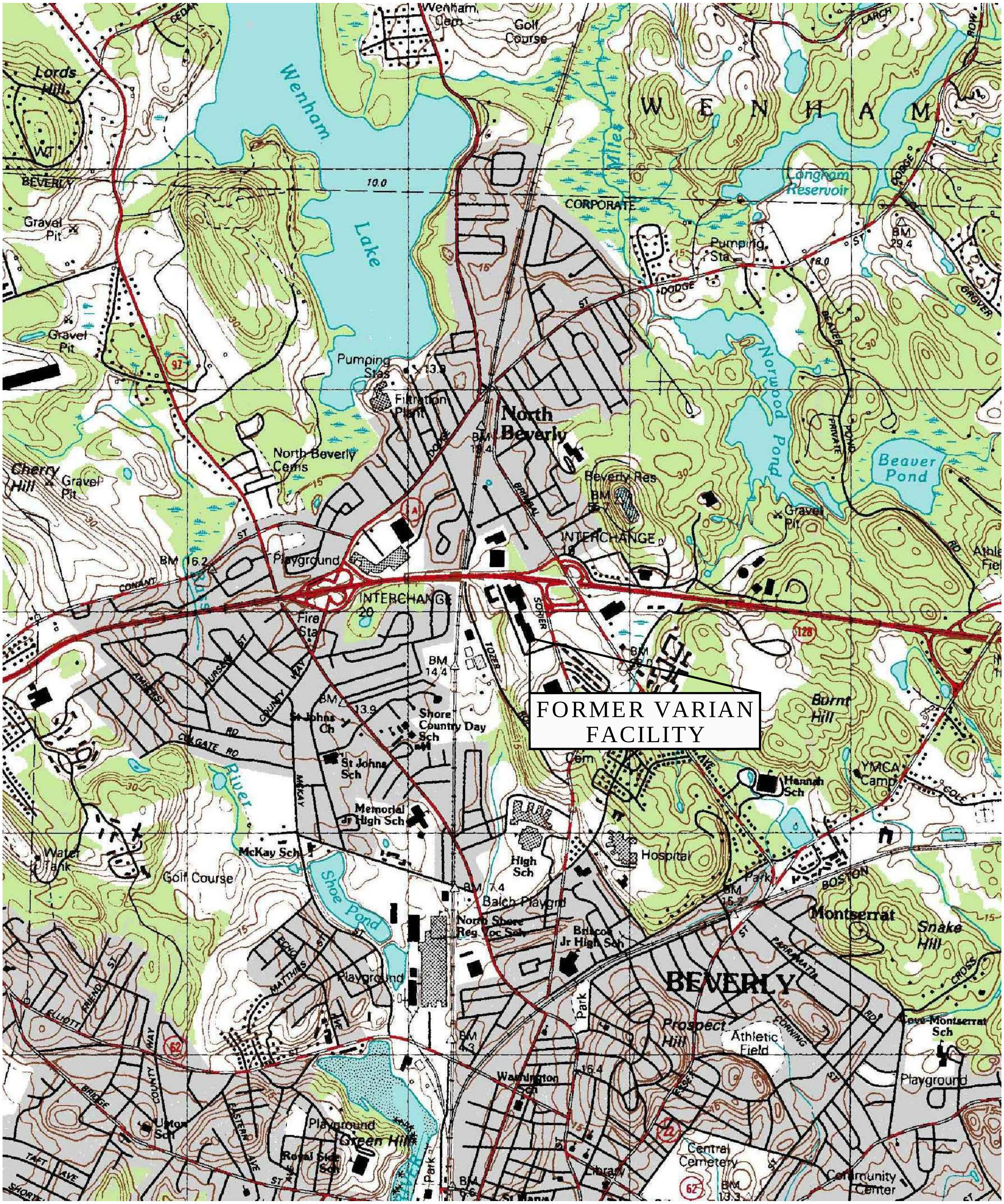
R2 Risk
- 1 = Highest risks associated with implementation
- 2 = Moderate risk associated with implementation
- 3 = Lowest risk associated with implementation

GB Green Benefits
- 1 = Low benefits
- 2 = Low to moderate benefits
- 3 = Moderate to high benefits
- 4 = High benefits

T Time
- 1 = Extended treatment time
- 2 = Acceptable treatment time
- 3 = Rapid treatment

Score = E + R1 + D + C + R2 + GB + T; Possible scores are 7 to 24

FIGURES



OFFICE	DRAWN BY	CHECKED BY	APPROVED BY	DRAWING NUMBER
CANTON, MA	CD 09/22/17	RC 09/22/17	-- --	139340-01SITELOC

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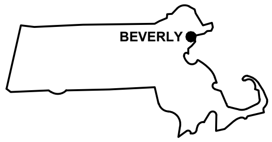
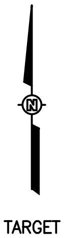


MASSACHUSETTS



SOURCE:
USGS 7.5 MIN. SERIES SALEM MA, TARGET QUAD, 1985
SCALE: 1:25,000
X = 250750 m
Y = 925017 m
MA STATE PLANE GRID (meters)

APTIM

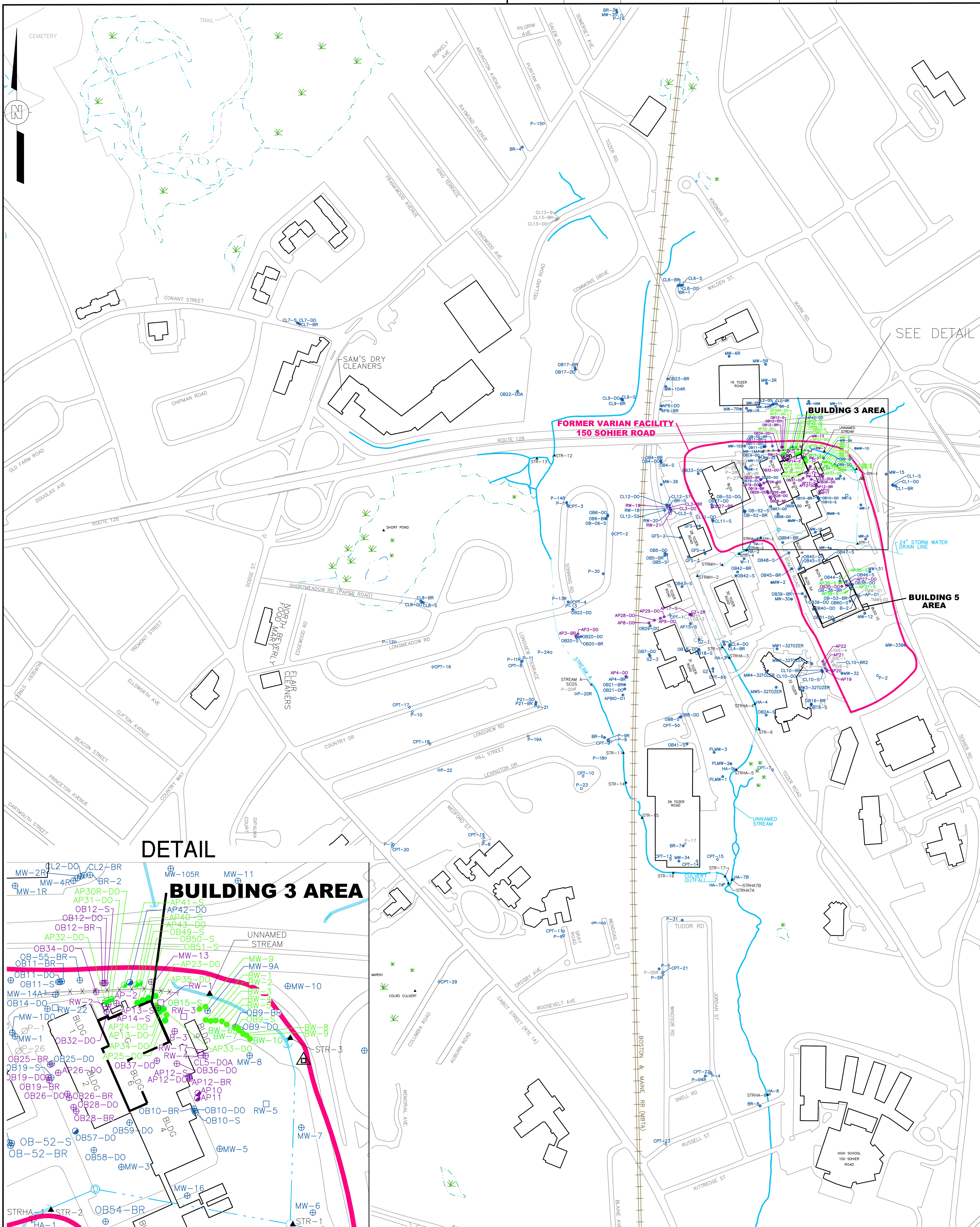
APTIM ENVIRONMENTAL & INFRASTRUCTURE, INC.
150 ROYALL STREET
CANTON, MASSACHUSETTS
(617) 589-5111

FIGURE 1
SITE LOCATION MAP

FORMER VARIAN FACILITY
150 SOHIER ROAD
BEVERLY, MASSACHUSETTS

XREF Files: IMAGE Files:
File: O:\PROJECT\ray varian\631010764-D211.dwg Layout: Layout1 User: Greg.Jones Sep 30, 2022 - 1:52pm

DRAWN BY	ELS	CHECKED BY	RC	--	DRAWING NAME	631010764-D211
	9/13/22	APPROVED BY	RC	--		



LEGEND:

- TEMPORARY PERMANGANATE INJECTION POINT
- ABANDONED OR DESTROYED WELL
- PIEZOMETER (P)
- BENCHMARK LOCATION (MSL)
- RECOVERY WELL (RW)
- MONITORING WELL (MW)
- ANGLED WELL
- BIOREMEDIATION INJECTION WELL
- SURFACE WATER STREAM (STR) SAMPLE LOCATION
- CONE PENETROMETER TESTPOINT (CPT)
- HAND AUGER SAMPLE LOCATION (HA) ADJACENT TO A STREAM (STRHA)
- STRMH — MANHOLE ACCESS TO THE STREAM LOCATED WITHIN A CULVERT
- APPROXIMATE BUILDING LOCATION
- APPROXIMATE DRAIN MANHOLE LOCATION
- APPROXIMATE LOCATION OF STREAM IN CULVERT
- APPROXIMATE STREAM LOCATION
- WATER AND MARSH AREA

CL4-BR — WELL IDENTIFICATION
MONITORING WELLS SHOWN IN BLUE
PAST AND CURRENT PERMANGANATE INJECTION WELLS SHOWN IN PURPLE
BIOREMEDIATION INJECTION WELLS SHOWN IN GREEN

CL-9	CLUSTER WELL NUMBER S=SHALLOW DO=DEEP OVERBURDEN BR=BEDROCK
STR-6	STREAM SAMPLE LOCATION NUMBER
STRHA-1	STREAM/SURFACE WATER SAMPLE
HA-1	HAND AUGER WELL LOCATION NUMBER
STRMH-1	STREAM/MANHOLE LOCATION NUMBER
MW-5	MONITORING WELL NUMBER
GZ-1	MONITORING WELL NUMBER
PLMW-1	MONITORING WELL NUMBER
BR-1	BEDROCK WELL NUMBER

BEDROCK WELLS BR-1 THROUGH BR-8 AND CL9-BR HAVE MULTILEVEL GROUNDWATER MONITORING SYSTEMS PRESENT WITHIN THE BEDROCK. ZONE 1 REFERS TO THE DEEPEST SAMPLING ZONE, ZONE 2 REFERS IS THE MIDDLE SAMPLING INTERVAL, AND ZONE 3 CLOSEST TO THE GROUND SURFACE.

THIS MAP HAS BEEN COMPILED FROM SURVEY DATA COLLECTED IN JULY 1994, MARCH 1995, OCTOBER 1995, SEPTEMBER 1996, MARCH 1997, DECEMBER 1997, SEPTEMBER 1998, JANUARY 2000, FEBRUARY 2001, JUNE 2002, SEPTEMBER 2002, JULY 2003, FEBRUARY 2004, OCTOBER 2004; 2005, JULY 2012, MAY 2014, AUGUST 2018 FROM VARIOUS EXISTING PLANS, AND OBSERVATIONS MADE IN THE FIELD BY CB&I ENVIRONMENTAL & INFRASTRUCTURE, INC., AND APTIM ENVIRONMENTAL & INFRASTRUCTURE, INC.

SCALE: 0 — 250 — 500 — 750 FEET

FIGURE 2
EXPANDED SITE PLAN
FORMER VARIAN FACILITY SITE - BEVERLY, MA.

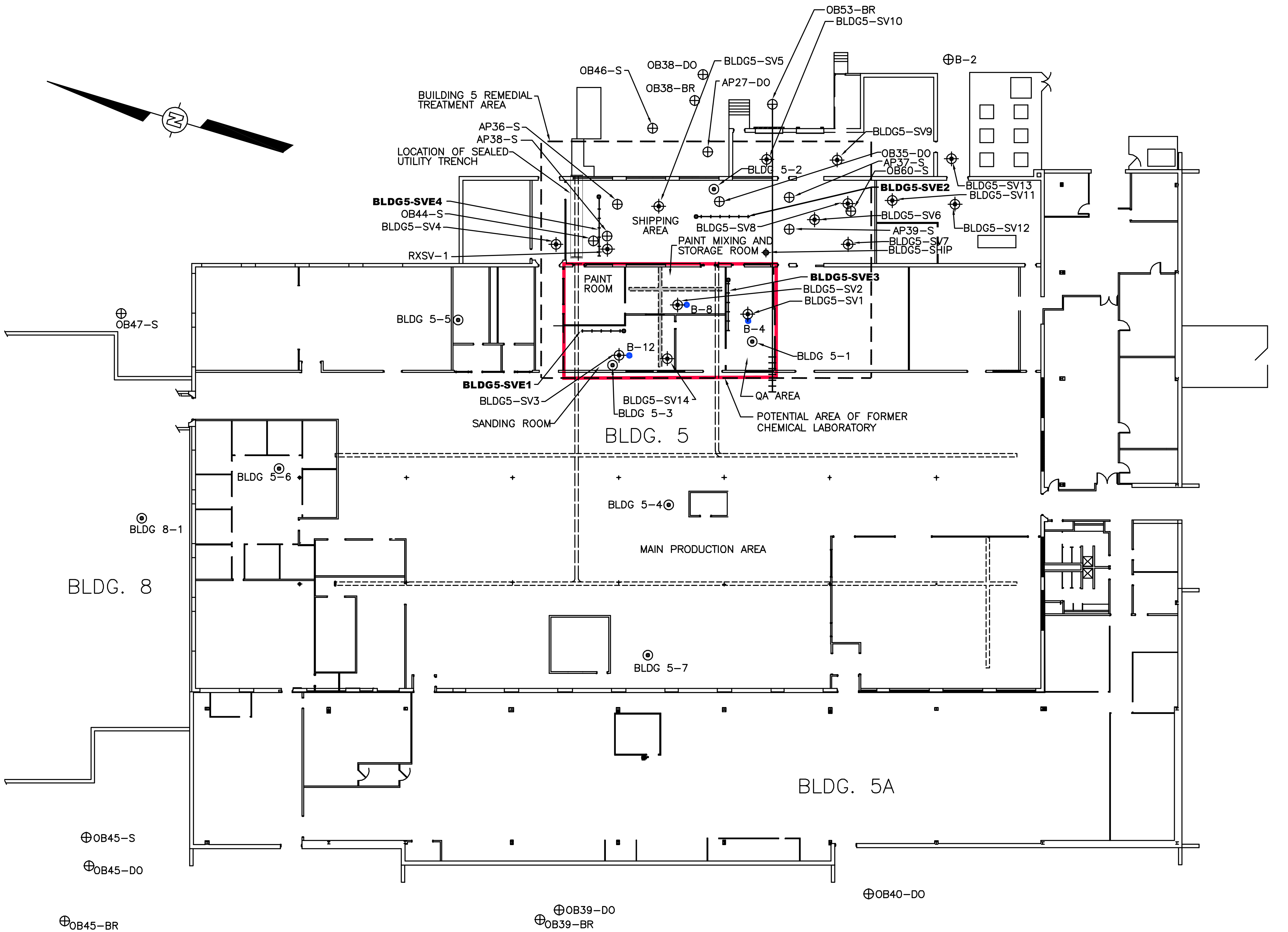
PREPARED FOR: VARIAN MEDICAL SYSTEMS, INC. PALO ALTO, CALIFORNIA

SCALE: 1" = 250'	DRAFTED BY: ELS
DATE: 9-13-2022	PROJECT NO.: 631010764

PREPARED BY:

APTIM ENVIRONMENTAL & INFRASTRUCTURE, INC.

BUILDING 3
BASEMENT AREA
ESTIMATED TREATMENT AREA (APPROXIMATELY 10 TO 40 FEET BELOW SURFACE GRADE) BASED ON SOIL RESISTIVITY >1,000 OHM-M IN APRIL 2022 ELECTRICAL RESISTANCE IMAGERY
BUILDING 2
BASEMENT AREA
N
SCALE
0 15 30 45 FEET
APTIM
150 Royall Street
Canton, Massachusetts
DESIGNED BY: --
DRAWN BY: --
CHECKED BY: --
APPROVED BY: --
VARIAN MEDICAL SYSTEMS, INC.
PALO ALTO, CALIFORNIA
FIGURE 3
ESTIMATED BUILDING 3 TREATMENT AREA
FORMER VARIAN FACILITY SITE - BEVERLY, MA
DATE: -/-/--
SCALE: AS SHOWN
DRAWING NO. 631010764-D203
SHEET NO. --
OFFICE Pittsburgh, PA
DRAWING NUMBER 631010764-D203
VERIFY SCALE 0 1"
Xref :
Image :
File: C:\roy building\631010764-D203.dwg
Plot Date/Time: Sep. 12, 2022 - 6:32am
Plotted By: Greg.Jones



LEGEND

- SUB-SLAB SOIL VAPOR SAMPLE LOCATION (2011-2014)
- INDOOR AIR SAMPLE LOCATION (2011-2014)
- SUB-SLAB SOIL VAPOR SAMPLE LOCATION (1995)
- MONITORING WELL
- SOIL BORING
- FORMER UTILITY TRENCH FILLED WITH CONCRETE
- UTILITY TRENCH
- SVE TRENCH WELL
- ANGLED WELL AND SCREEN

INDOOR AIR SAMPLE ID RTN 3-0485	ROOM
BLDG 5-1	QA AREA
BLDG 5-2	SHIPPING AREA
BLDG 5-3	SANDING ROOM
BLDG 5-4	PRODUCTION AREA
BLDG 5-5	CATHODE SPRAY ROOM
BLDG 5-6	COMMON OFFICE AREA
BLDG 5-7	DEGREASER AREA
BLDG 8-1	HIGH POWER TESTING BUILDING 8 BASEMENT

SCALE
0 30 60 FEET

REFERENCE:

PLAN DERIVED FROM COMMUNICATIONS & POWER INDUSTRIES MAP, DATED 07/11/03, CLEAN HARBORS ENVIRONMENTAL SERVICES, INC. MAP TITLED "1962-BUILDING 5", CB&I ENVIRONMENTAL & INFRASTRUCTURE, INC., AND APTIM ENVIRONMENTAL & INFRASTRUCTURE, INC. FIELD RECONNAISSANCE, JULY 2012, APRIL 2014 AND AUGUST 2018.

APTIM
APTIM ENVIRONMENTAL & INFRASTRUCTURE, INC.
150 ROYALL STREET
CANTON, MASSACHUSETTS

FIGURE 4
BUILDING 5 REMEDIAL TREATMENT AREA
FORMER VARIAN FACILITY
150 SOHIER ROAD
BEVERLY, MASSACHUSETTS

DRAWING NUMBER	APPROVED BY	CHECKED BY	DRAWN BY	OFFICE
146898-SITE PLAN	-- / --	RC 9/16/22	CD/ES 9/16/22	CANTON, MA

XREF Files: IMAGE Files:
File: O:\Shaw Offices - CAD Files\Stoughton, MA\631323790 6\Phase 4\BUILDING 5 SYSTEM\146898-SITE PLAN.dwg
Plot Date/Time: Feb 09, 2023 - 1:51pm
Plotted By: Greg.Jones

APPENDIX A

COMPREHENSIVE RESPONSE ACTION TRANSMITTAL FORM BWSC-108

Massachusetts Department of Environmental Protection
Bureau of Waste Site Cleanup

BWSC 108

COMPREHENSIVE RESPONSE ACTION TRANSMITTAL FORM & PHASE I COMPLETION STATEMENT

Pursuant to 310 CMR 40.0484 (Subpart D) and 40.0800 (Subpart H)

Release Tracking Number: 3 - 485

A. SITE LOCATION:

1. Site Name: VARIAN-MICROWAVE DIV

2. Street Address: 150 SOHIER RD

3. City/Town: BEVERLY

4. ZIP Code: 019150000

☐ 5. Check here if the disposal site that is the source of the release is Tier Classified. Check the current Tier Classification Category:

☐ a. Tier I ☐ b. Tier ID ☐ c. Tier II

B. THIS FORM IS BEING USED TO: (check all that apply)

☐ 1. Submit a **Phase I Completion Statement,** pursuant to 310 CMR 40.0484.

☐ 2. Submit a **Revised Phase I Completion Statement,** pursuant to 310 CMR 40.0484.

☐ 3. Submit a **Phase II Scope of Work,** pursuant to 310 CMR 40.0834.

☐ 4. Submit an **interim Phase II Report.** This report does not satisfy the response action deadline requirements in 310 CMR 40.0500.

☐ 5. Submit a **final Phase II Report and Completion Statement,** pursuant to 310 CMR 40.0836.

☐ 6. Submit a **Revised Phase II Report and Completion Statement,** pursuant to 310 CMR 40.0836.

☐ 7. Submit a **Phase III Remedial Action Plan and Completion Statement,** pursuant to 310 CMR 40.0862.

☑ 8. Submit a **Revised Phase III Remedial Action Plan and Completion Statement,** pursuant to 310 CMR 40.0862.

☐ 9. Submit a **Phase IV Remedy Implementation Plan,** pursuant to 310 CMR 40.0874.

☐ 10. Submit a **Modified Phase IV Remedy Implementation Plan,** pursuant to 310 CMR 40.0874.

☐ 11. Submit an **As-Built Construction Report,** pursuant to 310 CMR 40.0875.

☐ 12. Submit a **Phase IV Status Report,** pursuant to 310 CMR 40.0877.

☐ 13. Submit a **Phase IV Completion Statement,** pursuant to 310 CMR 40.0878 and 40.0879.

Specify the outcome of Phase IV activities: (check one)

☐ a. Phase V Operation, Maintenance or Monitoring of the Comprehensive Remedial Action is necessary to achieve a Permanent or Temporary Solution.

☐ b. The requirements of a Permanent Solution have been met. A completed Permanent Solution Statement and Report (BWSC104) will be submitted to DEP.

☐ c. The requirements of a Temporary Solution have been met. A completed Temporary Solution Statement and Report (BWSC104) will be submitted to DEP.

B. THIS FORM IS BEING USED TO (cont.): (check all that apply)

☐ 14. Submit a **Revised Phase IV Completion Statement,** pursuant to 310 CMR 40.0878 and 40.0879.

☐ 15. Submit a **Phase V Status Report,** pursuant to 310 CMR 40.0892.

☐ 16. Submit a **Remedial Monitoring Report.** (This report can only be submitted through eDEP.)

a. Type of Report: (check one) ☐ i. Initial Report ☐ ii. Interim Report ☐ iii. Final Report

b. Frequency of Submittal: (check all that apply)

☐ i. A Remedial Monitoring Report(s) submitted monthly to address an Imminent Hazard.

☐ ii. A Remedial Monitoring Report(s) submitted monthly to address a Condition of Substantial Release Migration.

☐ iii. A Remedial Monitoring Report(s) submitted every six months, concurrent with a Status Report.

☐ iv. A Remedial Monitoring Report(s) submitted annually, concurrent with a Status Report.

c. Status of Site: (check one) ☐ i. Phase IV ☐ ii. Phase V ☐ iii. Remedy Operation Status ☐ iv. Temporary Solution

d. Number of Remedial Systems and/or Monitoring Programs: ____________________

A separate BWSC108A, CRA Remedial Monitoring Report, must be filled out for each Remedial System and/or Monitoring Program addressed by this transmittal form.

☐ 17. Submit a **Remedy Operation Status,** pursuant to 310 CMR 40.0893.

☐ 18. Submit a **Status Report to maintain a Remedy Operation Status,** pursuant to 310 CMR 40.0893(2).

☐ 19. Submit a **Transfer and/or a Modification of Persons Maintaining a Remedy Operation Status (ROS),** pursuant to 310 CMR 40.0893(5) (check one, or both, if applicable).

☐ a. Submit a Transfer of Persons Maintaining an ROS (the transferee should be the person listed in Section D, "Person Undertaking Response Actions").

☐ b. Submit a Modification of Persons Maintaining an ROS (the primary representative should be the person listed in Section D, "Person Undertaking Response Actions").

c. Number of Persons Maintaining an ROS not including the primary representative: ____________________

☐ 20. Submit a **Termination of a Remedy Operation Status,** pursuant to 310 CMR 40.0893(6).(check one)

☐ a. Submit a notice indicating ROS performance standards have not been met. A plan and timetable pursuant to 310 CMR 40.0893(6)(b) for resuming the ROS are attached.

☐ b. Submit a notice of Termination of ROS.

☐ 21. Submit a **Phase V Completion Statement,** pursuant to 310 CMR 40.0894.

Specify the outcome of Phase V activities: (check one)

☐ a. The requirements of a Permanent Solution have been met. A completed Permanent Solution Statement and Report (BWSC104) will be submitted to DEP.

☐ b. The requirements for a Temporary Solution have been met. A completed Temporary Solution Statement and Report (BWSC104) will be submitted to DEP.

☐ 22. Submit a **Revised Phase V Completion Statement,** pursuant to 310 CMR 40.0894.

☐ 23. Submit a **Temporary Solution Status Report,** pursuant to 310 CMR 40.0898.

☐ 24. Submit a **Plan for the Application of Remedial Additives** near a sensitive receptor, pursuant to 310 CMR 40.0046(3).

a. Status of Site: (check one)

☐ i. Phase IV ☐ ii. Phase V ☐ iii. Remedy Operation Status ☐ iv. Temporary Solution

C. LSP SIGNATURE AND STAMP:

I attest under the pains and penalties of perjury that I have personally examined and am familiar with this transmittal form, including any and all documents accompanying this submittal. In my professional opinion and judgment based upon application of (i) the standard of care in 309 CMR 4.02(1), (ii) the applicable provisions of 309 CMR 4.02(2) and (3), and 309 CMR 4.03(2), and (iii) the provisions of 309 CMR 4.03(3), to the best of my knowledge, information and belief,

> *if Section B indicates that a* ***Phase I, Phase II, Phase III, Phase IV or Phase V Completion Statement*** *and/or a* ***Termination of a Remedy Operation Status*** *is being submitted*, the response action(s) that is (are) the subject of this submittal (i) has (have) been developed and implemented in accordance with the applicable provisions of M.G.L. c. 21E and 310 CMR 40.0000, (ii) is (are) appropriate and reasonable to accomplish the purposes of such response action(s) as set forth in the applicable provisions of M.G.L. c. 21E and 310 CMR 40.0000, and (iii) comply(ies) with the identified provisions of all orders, permits, and approvals identified in this submittal;

> *if Section B indicates that a* ***Phase II Scope of Work*** *or a* ***Phase IV Remedy Implementation Plan*** *is being submitted,* the response action(s) that is (are) the subject of this submittal (i) has (have) been developed in accordance with the applicable provisions of M.G.L. c. 21E and 310 CMR 40.0000, (ii) is (are) appropriate and reasonable to accomplish the purposes of such response action(s) as set forth in the applicable provisions of M.G.L. c. 21E and 310 CMR 40.0000, and (iii) comply(ies) with the identified provisions of all orders, permits, and approvals identified in this submittal;

> *if Section B indicates that an* ***As-Built Construction Report,*** *a* ***Remedy Operation Status,*** *a* ***Phase IV, Phase V or Temporary Solution Status Report,*** *a* ***Status Report to Maintain a Remedy Operation Status,*** *a* ***Transfer or Modification of Persons Maintaining a Remedy Operation Status*** *and/or a* ***Remedial Monitoring Report*** *is being submitted,* the response action(s) that is (are) the subject of this submittal (i) is (are) being implemented in accordance with the applicable provisions of M.G.L. c. 21E and 310 CMR 40.0000, (ii) is (are) appropriate and reasonable to accomplish the purposes of such response action(s) as set forth in the applicable provisions of M.G.L. c. 21E and 310 CMR 40.0000, and (iii) comply(ies) with the identified provisions of all orders, permits, and approvals identified in this submittal.

I am aware that significant penalties may result, including, but not limited to, possible fines and imprisonment, if I submit information which I know to be false, inaccurate or materially incomplete.

1. LSP#: 4689

2. First Name: BRIAN J 3. Last Name: COTE

4. Telephone: 6175896175 5. Ext.: ____ 6. Email: ____

7. Signature: ____

8. Date: ____ (mm/dd/yyyy) 9. LSP Stamp:

D. PERSON UNDERTAKING RESPONSE ACTIONS:

1. Check all that apply: ☐ a. change in contact name ☐ b. change of address ☐ c. change in the person undertaking response actions

2. Name of Organization: VARIAN MEDICAL SYSTEMS INC

3. Contact First Name: MATTHEW 4. Last Name: GILLIS

5. Street: 525 9TH STREET 6. Title:

7. City/Town: WASHINGTON 8. State: DC 9. ZIP Code: 200040000

10. Telephone: 11. Ext: 12. Email:

E. RELATIONSHIP TO SITE OF PERSON UNDERTAKING RESPONSE ACTIONS: ☐ Check here to change relationship

☑ 1. RP or PRP ☐ a. Owner ☐ b. Operator ☐ c. Generator ☐ d. Transporter

☑ e. Other RP or PRP Specify: NON-SPECIFIED PRP

☐ 2. Fiduciary, Secured Lender or Municipality with Exempt Status (as defined by M.G.L. c. 21E, s. 2)

☐ 3. Agency or Public Utility on a Right of Way (as defined by M.G.L. c. 21E, s. 5(j))

☐ 4. Any Other Person Undertaking Response Actions Specify Relationship:

F. REQUIRED ATTACHMENT AND SUBMITTALS:

☑ 1. Check here if the Response Action(s) on which this opinion is based, if any, are (were) subject to any order(s), permit(s) and/or approval(s) issued by DEP or EPA. If the box is checked, you MUST attach a statement identifying the applicable provisions thereof.

☐ 2. Check here to certify that the Chief Municipal Officer and the Local Board of Health have been notified of the submittal of any Phase Reports to DEP.

☑ 3. Check here to certify that the Chief Municipal Officer and the Local Board of Health have been notified of the availability of a Phase III Remedial Action Plan.

☐ 4. Check here to certify that the Chief Municipal Officer and the Local Board of Health have been notified of the availability of a Phase IV Remedy Implementation Plan.

☐ 5. Check here to certify that the Chief Municipal Officer and the Local Board of Health have been notified of any field work involving the implementation of a Phase IV Remedial Action.

☐ 6. If submitting a Transfer of a Remedy Operation Status (as per 310 CMR 40.0893(5)), check here to certify that a statement detailing the compliance history for the person making this submittal (transferee) is attached.

☐ 7. If submitting a Modification of a Remedy Operation Status (as per 310 CMR 40.0893(5)), check here to certify that a statement detailing the compliance history for each new person making this submittal is attached.

☐ 8. Check here if any non-updatable information provided on this form is incorrect, e.g. Release Address/Location Aid. Send corrections to: BWSC.eDEP@state.ma.us.

☑ 9. Check here to certify that the LSP Opinion containing the material facts, data, and other information is attached.

G. CERTIFICATION OF PERSON UNDERTAKING RESPONSE ACTIONS:

1. I, ____________________, attest under the pains and penalties of perjury (i) that I have personally examined and am familiar with the information contained in this submittal, including any and all documents accompanying this transmittal form, (ii) that, based on my inquiry of those individuals immediately responsible for obtaining the information, the material information contained in this submittal is, to the best of my knowledge and belief, true, accurate and complete, and (iii) that I am fully authorized to make this attestation on behalf of the entity legally responsible for this submittal. I/the person or entity on whose behalf this submittal is made am/is aware that there are significant penalties, including, but not limited to, possible fines and imprisonment, for willfully submitting false, inaccurate, or incomplete information.

>*if Section B indicates that this is a* **Modification of a Remedy Operation Status (ROS),** I attest under the pains and penalties of perjury that I am fully authorized to act on behalf of all persons performing response actions under the ROS as stated in 310 CMR 40.0893(5)(d) to receive oral and written correspondence from MassDEP with respect to performance of response actions under the ROS, and to receive a statement of fee amount as per 4.03(3).

I understand that any material received by the Primary Representative from MassDEP shall be deemed received by all the persons performing response actions under the ROS, and I am aware that there are significant penalties, including, but not limited to, possible fines and imprisonment, for willfully submitting false, inaccurate or incomplete information.

2. By: ____________________ (Signature)   3. Title: ____________________

4. For: VARIAN MEDICAL SYSTEMS INC (Name of person or entity recorded in Section D)   5. Date: __________ (mm/dd/yyyy)

☐ 6. Check here if the address of the person providing certification is different from address recorded in Section D.

7. Street: ____________________

8. City/Town: __________   9. State: __________   10. ZIP Code: __________

11. Telephone: __________   12. Ext.: __________   13. Email: __________

YOU ARE SUBJECT TO AN ANNUAL COMPLIANCE ASSURANCE FEE OF UP TO $10,000 PER BILLABLE YEAR FOR THIS DISPOSAL SITE. YOU MUST LEGIBLY COMPLETE ALL RELEVANT SECTIONS OF THIS FORM OR DEP MAY RETURN THE DOCUMENT AS INCOMPLETE. IF YOU SUBMIT AN INCOMPLETE FORM, YOU MAY BE PENALIZED FOR MISSING A REQUIRED DEADLINE.

Date Stamp (DEP USE ONLY:)

APPENDIX B

DETAILED COST ESTIMATES

Table B-1
REMEDIAL ALTERNATIVE EVALUATION COSTS
Building 3 Overburden
Alternative 1 - ISTR (w/o Building Access),
ISB Polish and Continued SVE Operation

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
ISTR CAPITAL						
Engineering	Detailed Design & Permitting					$ 330,000
	Procurement					$ 50,000
Pre-Operation Site Activities	Mobilization & Site Setup					$ 300,000
	Power Drop/Transformer					$ 150,000
	Vertical Drilling & Well Installation	5,200	ft	$ 300	/ft	$ 1,560,000
	Angle Drilling & Well Installation	5,200	ft	$ 800	/ft	$ 4,160,000
	Vapor Cover Installation					$ 300,000
	Wellfield Piping					$ 300,000
	ISTD Power Equipment Installation					$ 200,000
	Steam Generation System Installation					$ 100,000
	Treatment System Installation					$ 400,000
	Electrical Installation					$ 150,000
	Instrument & Monitoring System Installation					$ 100,000
	Pre-Startup & Shakedown					$ 350,000
Demobilization	Decommissioning					$ 250,000
	Remove Heaters/Wells/Cover					$ 600,000
	Site Clearance & Demobilization					$ 150,000
Indirect Costs	Field Support					$ 250,000
	Home Office Support					$ 400,000
	ISTD Licensing Fees					$ 300,000
				Subtotal ISTR Capital Costs		***$ 10,400,000***
ISTR OPERATION, MAINTENANCE & MONITORING						
Equipment Rental	ISTD Power Equipment	12	months	$ 60,000	/month	$ 720,000
	Steam Generation Equipment	12	months	$ 30,000	/month	$ 360,000
	Treatment System Equipment	12	months	$ 40,000	/month	$ 480,000
Maintenance	Repairs	12	months	$ 3,000	/month	$ 36,000
Site Visits	Labor and Expenses	360	days	$ 2,500	/day	$ 900,000
Vapor Phase Carbon	Transport, Disposal, and Replacement	87,000	lbs	$ 7.00	/lbs	$ 609,000
Utilities	Electricity	7,200,000	kw-hr	$ 0.30	/kw-hr	$ 2,160,000
	Natural Gas	200,000	therm	$ 2.50	/therm	$ 500,000
				Subtotal ISTR OM&M		***$ 5,765,000***
ISB POLISH OPERATION, MAINTENANCE & MONITORING						
Injection Subcontractor	Labor and Expenses	60	days	$ 6,000	/day	$ 360,000
Chemicals	Carbon Source (EVO)	110,000	lbs	$ 2	/lb	$ 220,000
	Bacteria (SDC-9)	920	lbs	$ 70	/L	$ 64,400
				Subtotal ISB OM&M		***$ 644,400***
SVE OPERATION, MAINTENANCE & MONITORING						
SVE System	All Expenses	80	months	$ 2,000	/month	$ 160,000
				Subtotal SVE OM&M		***$ 160,000***
				Subtotal OM&M		***$ 6,569,400***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 16,969,400**

Table B-2
REMEDIAL ALTERNATIVE EVALUATION COSTS
Building 3 Overburden
Alternative 2 - ISTR (w/Building Access),
ISB Polish and Continued SVE Operation

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
			ISTR CAPITAL			
Engineering	Detailed Design & Permitting					$ 300,000
	Procurement					$ 50,000
Pre-Operation Site Activities	Mobilization & Site Setup					$ 200,000
	Power Drop/Transformer					$ 150,000
	Drilling & Well Installation	10,400	ft	$ 300	/ft	$ 3,120,000
	Vapor Cover Installation					$ 100,000
	Wellfield Piping					$ 200,000
	ISTD Power Equipment Installation					$ 200,000
	Steam Generation System Installation					$ 100,000
	Treatment System Installation					$ 400,000
	Electrical Installation					$ 150,000
	Instrument & Monitoring System Installation					$ 100,000
	Pre-Startup & Shakedown					$ 250,000
Demobilization	Decommissioning					$ 200,000
	Remove Heaters/Wells/Cover					$ 600,000
	Site Clearance & Demobilization					$ 100,000
Indirect Costs	Field Support					$ 250,000
	Home Office Support					$ 400,000
	ISTD Licensing Fees					$ 300,000
				Subtotal ISTR Capital Costs		***$ 7,170,000***
			ISTR OPERATION, MAINTENANCE & MONITORING			
Equipment Rental	ISTD Power Equipment	6	months	$ 60,000	/month	$ 360,000
	Steam Generation Equipment	6	months	$ 30,000	/month	$ 180,000
	Treatment System Equipment	6	months	$ 40,000	/month	$ 240,000
Maintenance	Repairs	6	months	$ 3,000	/month	$ 18,000
Site Visits	Labor and Expenses	180	days	$ 2,500	/day	$ 450,000
Vapor Phase Carbon	Transport, Disposal, and Replacement	87,000	lbs	$ 7.00	/lbs	$ 609,000
Utilities	Electricity	6,000,000	kw-hr	$ 0.30	/kw-hr	$ 1,800,000
	Natural Gas	300,000	therm	$ 2.50	/therm	$ 750,000
				Subtotal ISTR OM&M		***$ 4,407,000***
			ISB POLISH OPERATION, MAINTENANCE & MONITORING			
Injection Subcontractor	Labor and Expenses	30	days	$ 6,000	/day	$ 180,000
Chemicals	Carbon Source (EVO)	55,000	lbs	$ 2	/lb	$ 110,000
	Bacteria (SDC-9)	500	lbs	$ 70	/lb	$ 35,000
				Subtotal ISB OM&M		***$ 325,000***
			SVE OPERATION, MAINTENANCE & MONITORING			
SVE System	All Expenses	55	months	$ 2,000	/month	$ 110,000
				Subtotal SVE OM&M		***$ 110,000***
				Subtotal OM&M		***$ 4,842,000***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 12,012,000**

Table B-3
REMEDIAL ALTERNATIVE EVALUATION COSTS
Building 3 Overburden
Alternative 3 - ISCO (w/o Building Access),
ISB Polish and Continued SVE Operation

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
ISCO CAPITAL						
Engineering	Detailed Design & Permitting					$ 250,000
Pre-Operation Site	Vertical Drilling & Well Installation	5,200	ft	$ 300	/ft	$ 1,560,000
Activities	Angle Drilling & Well Installation	5,200	ft	$ 600	/ft	$ 3,120,000
				Subtotal ISTR Capital Costs		***$ 4,930,000***
ISCO OPERATION, MAINTENANCE & MONITORING						
Injection Subcontractor	Labor and Expenses	270	days	$ 6,000	/day	$ 1,620,000
Chemicals	Sodium Permanganate	1,200,000	lbs	$ 3	/lb	$ 3,600,000
				Subtotal ISTR OM&M		***$ 5,220,000***
ISB POLISH OPERATION, MAINTENANCE & MONITORING						
Injection Subcontractor	Labor and Expenses	60	days	$ 6,000	/day	$ 360,000
Chemicals	Carbon Source (EVO)	110,000	lbs	$ 2	/lb	$ 220,000
	Bacteria (SDC-9)	920	liter	$ 70	/liter	$ 64,400
				Subtotal ISB OM&M		***$ 644,400***
SVE OPERATION, MAINTENANCE & MONITORING						
SVE System	All Expenses	129	months	$ 2,000	/month	$ 258,000
				Subtotal SVE OM&M		***$ 258,000***
				Subtotal OM&M		***$ 6,122,400***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 11,052,400**

Table B-4
REMEDIAL ALTERNATIVE EVALUATION COSTS
Building 5 Overburden
Alternative 1 - ISTR (w/o Building Access)
and Continued SVE Operation

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
			ISTR CAPITAL			
Engineering	Detailed Design & Permitting					$ 260,000
	Procurement					$ 40,000
Pre-Operation Site Activities	Mobilization & Site Setup					$ 230,000
	Power Drop/Transformer					$ 120,000
	Vertical Drilling & Well Installation	1,900	ft	$ 300	/ft	$ 570,000
	Angle Drilling & Well Installation	3,400	ft	$ 800	/ft	$ 2,720,000
	Vapor Cover Installation					$ 230,000
	Wellfield Piping					$ 230,000
	ISTD Power Equipment Installation					$ 160,000
	Steam Generation System Installation					$ 80,000
	Treatment System Installation					$ 310,000
	Electrical Installation					$ 120,000
	Instrument & Monitoring System Installation					$ 80,000
	Pre-Startup & Shakedown					$ 270,000
Demobilization	Decommissioning					$ 190,000
	Remove Heaters/Wells/Cover					$ 470,000
	Site Clearance & Demobilization					$ 120,000
Indirect Costs	Field Support					$ 190,000
	Home Office Support					$ 310,000
	ISTD Licensing Fees					$ 230,000
				Subtotal ISTR Capital Costs		***$ 6,930,000***
			ISTR OPERATION, MAINTENANCE & MONITORING			
Equipment Rental	ISTD Power Equipment	6	months	$ 50,000	/month	$ 300,000
	Steam Generation Equipment	6	months	$ 20,000	/month	$ 120,000
	Treatment System Equipment	6	months	$ 30,000	/month	$ 180,000
Maintenance	Repairs	6	months	$ 2,000	/month	$ 12,000
Site Visits	Labor and Expenses	180	days	$ 2,500	/day	$ 450,000
Vapor Phase Carbon	Transport, Disposal, and Replacement	16,000	lbs	$ 7	/lbs	$ 112,000
Utilities	Electricity	4,700,000	kw-hr	$ 0.30	/kw-hr	$ 1,410,000
	Natural Gas	130,000	therm	$ 2.50	/therm	$ 325,000
				Subtotal ISTR OM&M		***$ 2,909,000***
			SVE OPERATION, MAINTENANCE & MONITORING			
SVE System	All Expenses	12	months	$ 2,000	/month	$ 24,000
				Subtotal SVE OM&M		***$ 24,000***
				Subtotal OM&M		***$ 2,933,000***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 9,863,000**

Table B-5
REMEDIAL ALTERNATIVE EVALUATION COSTS
Building 5 Overburden
Alternative 2 - ISCO (w/o Building Access)
and Continued SVE Operation

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
		ISCO CAPITAL				
Engineering	Detailed Design & Permitting					$ 200,000
Pre-Operation Site Activities	Vertical Drilling & Well Installation	1,900	ft	$ 300	/ft	$ 570,000
	Angle Drilling & Well Installation	3,400	ft	$ 600	/ft	$ 2,040,000
					Subtotal ISCO Capital Costs	***$ 2,810,000***
		ISCO OPERATION, MAINTENANCE & MONITORING				
Injection Subcontractor	Labor and Expenses	180	days	$ 6,000	/days	$ 1,080,000
Chemicals	Sodium Permanganate	800,000	lbs	$ 3	/lb	$ 2,400,000
					Subtotal ISCO OM&M	***$ 3,480,000***
		SVE OPERATION, MAINTENANCE & MONITORING				
SVE System	All Expenses	45	months	$ 2,000	/month	$ 90,000
					Subtotal SVE OM&M	***$ 90,000***
					Subtotal OM&M	***$ 3,570,000***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 6,380,000**

Table B-6
REMEDIAL ALTERNATIVE EVALUATION COSTS
Building 5 Overburden
Alternative 3 - ISB (w/o Building Access)
and Continued SVE Operation

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
ISB CAPITAL						
Engineering	Detailed Design & Permitting					$ 250,000
Pre-Operation Site Activities	Vertical Drilling & Well Installation	1,900	ft	$ 300	/ft	$ 570,000
	Angle Drilling & Well Installation	3,400	ft	$ 600	/ft	$ 2,040,000
					Subtotal ISB Capital Costs	***$ 2,860,000***
ISB OPERATION, MAINTENANCE & MONITORING						
Injection Subcontractor	Labor and Expenses	120	days	$ 6,000	/day	$ 720,000
Chemicals	Carbon Source (EVO)	72,000	lbs	$ 2	/lb	$ 144,000
	Bacteria (SDC-9)	600	liter	$ 70	/liter	$ 42,000
					Subtotal ISB OM&M	***$ 906,000***
SVE OPERATION, MAINTENANCE & MONITORING						
SVE System	All Expenses	79	months	$ 2,000	/month	$ 158,000
					Subtotal SVE OM&M	***$ 158,000***
					Subtotal OM&M	***$ 1,064,000***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 3,924,000**

Table B-7
REMEDIAL ALTERNATIVE EVALUATION COSTS
Bedrock
Alternative 1 - ISCO

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
		ISCO CAPITAL				
Engineering	Detailed Design & Permitting					$ 100,000
Pre-Operation Site Activities	Overburden Drilling & Well Installation	1,400	ft	$ 75	/ft	$ 105,000
	Bedrock Drilling & Well Installation	1,600	ft	$ 150	/ft	$ 240,000
				Subtotal ISCO Capital Costs		***$ 445,000***
		ISCO OPERATION, MAINTENANCE & MONITORING				
Injection Subcontractor	Labor and Expenses	240	days	$ 5,000	/day	$ 1,200,000
Chemicals	Sodium Permanganate	1,200,000	lbs	$ 3	/lb	$ 3,600,000
				Subtotal ISCO OM&M		***$ 4,800,000***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 5,245,000**

Table B-8
REMEDIAL ALTERNATIVE EVALUATION COSTS
Bedrock
Alternative 2 - ISCR (S-MicroZVI)

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
			ISCR CAPITAL			
Engineering	Detailed Design & Permitting					$ 100,000
Pre-Operation Site Activities	Overburden Drilling & Well Installation	1,400	ft	$ 75	/ft	$ 105,000
	Bedrock Drilling & Well Installation	1,600	ft	$ 150	/ft	$ 240,000
				Subtotal ISCR Capital Costs		***$ 445,000***
			ISCR OPERATION, MAINTENANCE & MONITORING			
Injection Subcontractor	Labor and Expenses	100	days	$ 2,500	/day	$ 250,000
Chemicals	Sulfidated Micro-Zero Valent Iron	12,400	gal	$ 200	/gal	$ 2,480,000
				Subtotal ISCR OM&M		***$ 2,730,000***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 3,175,000**

Table B-9
REMEDIAL ALTERNATIVE EVALUATION COSTS
Bedrock
Alternative 3 - ISB

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
		ISB CAPITAL				
Engineering	Detailed Design & Permitting					$ 100,000
Pre-Operation Site Activities	Overburden Drilling & Well Installation	1,400	ft	$ 75	/ft	$ 105,000
	Bedrock Drilling & Well Installation	1,600	ft	$ 150	/ft	$ 240,000
				Subtotal ISCB Capital Costs		***$ 445,000***
		ISB OPERATION, MAINTENANCE & MONITORING				
Injection Subcontractor	Labor and Expenses	210	days	$ 5,000	/day	$ 1,050,000
Chemicals	Carbon Source (EVO)	150,000	lbs	$ 2	/lb	$ 300,000
	Bacteria (SDC-9)	550	liter	$ 70	/liter	$ 38,500
				Subtotal ISCB OM&M		***$ 1,388,500***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 1,833,500**

Table B-10
REMEDIAL ALTERNATIVE EVALUATION COSTS
Bedrock
Alternative 4 - ISTR

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
	ISTR CAPITAL					
Engineering	Detailed Design & Permitting					$ 300,000
	Procurement					$ 50,000
Pre-Operation Site Activities	Mobilization & Site Setup					$ 480,000
	Power Drop/Transformer					$ 240,000
	Overburden Drilling & Well Installation	2,745	ft	$ 300	/ft	$ 823,500
	Bedrock Drilling & Well Installation	3,050	ft	$ 500	/ft	$ 1,525,000
	Vapor Cover Installation					$ -
	Wellfield Piping					$ 480,000
	ISTD Power Equipment Installation					$ 320,000
	Steam Generation System Installation					$ 160,000
	Treatment System Installation					$ 630,000
	Electrical Installation					$ 240,000
	Instrument & Monitoring System Installation					$ 160,000
	Pre-Startup & Shakedown					$ 550,000
Demobilization	Decommissioning					$ 400,000
	Remove Heaters/Wells/Cover					$ 950,000
	Site Clearance & Demobilization					$ 240,000
Indirect Costs	Field Support					$ 400,000
	Home Office Support					$ 630,000
	ISTD Licensing Fees					$ 480,000
				Subtotal ISTR Capital Costs		***$ 9,058,500***
	ISTR OPERATION, MAINTENANCE & MONITORING					
Equipment Rental	ISTD Power Equipment	6	months	$ 100,000	/month	$ 600,000
	Steam Generation Equipment	6	months	$ 50,000	/month	$ 300,000
	Treatment System Equipment	6	months	$ 60,000	/month	$ 360,000
Maintenance	Repairs	6	months	$ 5,000	/month	$ 30,000
Site Visits	Labor and Expenses	180	days	$ 2,500	/day	$ 450,000
Vapor Phase Carbon	Transport, Disposal, and Replacement	16,000	lbs	$ 7	/lbs	$ 112,000
Utilities	Electricity	14,820,000	kw-hr	$ 0.30	/kw-hr	$ 4,446,000
	Natural Gas	520,000	therm	$ 2.50	/therm	$ 1,300,000
				Subtotal ISTR OM&M		***$ 7,598,000***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 16,656,500**

Table B-11
REMEDIAL ALTERNATIVE EVALUATION COSTS
PSL10
Alternative 1 - ISCO

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
			ISCO CAPITAL			
Engineering	Detailed Design & Permitting					$ 50,000
	Soil Gas Survey					$ 15,000
Well Installation	Overburden Drilling	400	ft	$ 75	/ft	$ 30,000
				Subtotal ISCO Capital Costs		***$ 95,000***
			ISCO OPERATION, MAINTENANCE & MONITORING			
Injection Subcontractor	Labor and Expenses	80	days	$ 5,000	/day	$ 400,000
Chemicals	Sodium Permanganate	300,000	lbs	$ 3	/lb	$ 900,000
MNA Sampling	Laboratory, Labor & Expenses	4	yrs	$ 13,500	/yr	$ 54,000
				Subtotal ISCO OM&M		***$ 1,354,000***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 1,449,000**

Table B-12
REMEDIAL ALTERNATIVE EVALUATION COSTS
PSL10
Alternative 2 - Colloidal Activated Carbon (CAC) Permeable Reactive Zone

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
CAC PAZ CAPITAL						
Engineering	Detailed Design & Permitting					$ 50,000
	Soil Gas Survey					$ 15,000
Injection	CAC & Injection Subcontractor	150,000	gal	$ 10	/gal	$ 1,500,000
				Subtotal CAC PAZ Capital Costs		***$ 1,565,000***
CAC PAZ OPERATION, MAINTENANCE & MONITORING						
MNA Sampling	Laboratory, Labor & Expenses	2	yrs	$ 13,500	/yr	$ 27,000
				Subtotal CAC PAZ OM&M		***$ 27,000***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 1,592,000**

Table B-13
REMEDIAL ALTERNATIVE EVALUATION COSTS
PSL10
Alternative 3 - Monitored Natural Attenuation

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost			Estimated Cost	
			MNA O&M					
Sample Collection	Labor & Expenses	200	days	$	1,000	/day	$	200,000
Report Preparation	Labor & Expenses	100	days	$	750	/day	$	75,000
Sample Analysis	Laboratory	50	years	$	8,000	/yr	$	400,000
TOTAL REMEDIAL ALTERNATIVE COST							**$**	**675,000**

Table B-14
REMEDIAL ALTERNATIVE EVALUATION COSTS
Downgradient Plume
Alternative 1 - ISCR (S-MicroZVI) PRZ

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
S-mZVI PRB CAPITAL						
Engineering	Detailed Design & Permitting					$ 100,000
Well Installation	Overburden Drilling	6,000	ft	$ 75	/ft	$ 450,000
				Subtotal S-mZVI PRB Capital Costs		***$ 550,000***
REACTIVE CORE MAT CAPITAL (SEEP TREATMENT)						
Engineering	Detailed Design					$ 50,000
	Wetlands Permitting					$ 10,000
Reactive Core Mat	Materials & Installation	60	ft	$ 2,500	/ft	$ 150,000
				Subtotal RCM Capital Costs		***$ 210,000***
S-mZVI OPERATION, MAINTENANCE & MONITORING						
Injection Subcontractor	Labor and Expenses	40	days	$ 2,500	/day	$ 100,000
Chemicals	Sulfidated Micro-Zero Valent Iron	5,400	gal	$ 200	/gal	$ 1,080,000
				Subtotal S-mZVI OM&M		***$ 1,180,000***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 1,730,000**

Table B-15
REMEDIAL ALTERNATIVE EVALUATION COSTS
Downgradient Plume
Alternative 2 - Colloidal Activated Carbon PAZ

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
			CAC PRZ CAPITAL			
Engineering	Detailed Design & Permitting					$ 100,000
Injection	CAC & Injection Subcontractor	270,000	gal	$ 10	/gal	$ 2,700,000
				CAC PRZ Capital Costs		$ 2,800,000
			REACTIVE CORE MAT CAPITAL (SEEP TREATMENT)			
Engineering	Detailed Design					$ 50,000
	Wetlands Permitting					$ 10,000
Reactive Core Mat	Materials & Installation	60	ft	$ 2,500	/ft	$ 150,000
				Subtotal RCM Capital Costs		***$ 210,000***
TOTAL REMEDIAL ALTERNATIVE COST						**$ 3,010,000**

Table B-16
REMEDIAL ALTERNATIVE EVALUATION COSTS
Downgradient Plume
Alternative 3 - Monitored Natural Attenuation

Former Varian Facility Site
Beverly, MA

Task	Description	Estimated Quantity	Units	Unit Cost		Estimated Cost
MNA O&M						
Sample Collection	Labor & Expenses	40	days	$ 1,000	/day	$ 40,000
Report Preparation	Labor & Expenses	20	days	$ 750	/day	$ 15,000
Sample Analysis	Laboratory	10	years	$ 13,000	/yr	$ 130,000
TOTAL REMEDIAL ALTERNATIVE COST						**$ 185,000**

APPENDIX C

PUBLIC INVOLVEMENT NOTICES

NOTICE OF AVAILABILITY

PUBLIC COMMENT DRAFT REVISED PHASE III REMEDIAL ACTION PLAN

FORMER VARIAN FACILITY SITE
150 SOHIER ROAD, BEVERLY, MASSACHUSETTS
MADEP SITE #3-0485

On March 17, 2023, a Public Comment Draft Revised Phase III Remedial Action Plan (Revised Phase III RAP) was provided to the Massachusetts Department of Environmental Protection (MassDEP) for the former Varian Facility Site in Beverly, Massachusetts. This Revised Phase III RAP presents the selected remedial alternatives that will lead to a Permanent Solution at the Former Varian Facility Site. It replaces a Public Comment Draft Phase III RAP that was previously submitted to MassDEP on December 7, 2022. The changes are detailed in the response to MassDEP's comments found at the following link March 16, 2023 Response to Phase III Comments (starting at document page 2).

The Revised Phase III RAP will be presented at a public meeting on May 2, 2023, in Beverly. Additional information about this meeting will be provided in a separate notice, and a public comment period on the document will begin the following day.

A copy of the Revised Phase III RAP is on file and available for review at the Beverly Board of Health (90 Colon Street), the Beverly Conservation Commission (Beverly Town Hall), and the local information repository established for this Site at the Beverly Public Library:

Beverly Public Library – Reference Desk
32 Essex Street
Beverly, MA 01915
978.921.6062
HOURS: Monday-Thursday: 9:00 am-9:00 pm
Friday and Saturday: 9:00 am-5:00 pm
Sunday: 1:00 pm-5:00 pm

A copy of this report is also available at the MassDEP website at the following link:

INSERT LINKXXXXX

Copy: PIP Mailing List

PUBLIC DRAFT REVISED PHASE III REMEDIAL ACTION PLAN
Former Varian Facility Site in Beverly, Massachusetts,
Executive Summary

This public draft Revised Phase III Remedial Action Plan (Revised Phase III RAP) dated March 17, 2023, was prepared for the former Varian Facility Site in Beverly, Massachusetts, in compliance with the Massachusetts Department of Environmental Protection (MassDEP) requirements. Conducted in accordance with 310 CMR 40.0858, the Revised Phase III RAP details potential treatment (remedial) actions, provides an analysis of those remedial alternatives against established criteria, and describes the selected remedial actions to be taken to result in a Permanent Solution at the site.

In a letter dated February 18, 2022, MassDEP requested the completion of a revised Phase II Comprehensive Site Assessment (CSA) and a revised Phase III RAP for the Site. The revised Phase II CSA was submitted for public comment on October 7, 2022, and finalized on March 10, 2023. This report provided an assessment of current site conditions, including the nature and extent of chlorinated volatile organic compounds (CVOCs) at the site, as well as an updated evaluation of risk based on current site conditions. CVOCs were determined to be the primary compounds driving additional treatment (remedial) actions at the Site. Based on the levels of CVOCs present in the Building 3 source area, Building 5 source area, bedrock near Building 5, and potential source location (PSL-10), it was concluded that additional treatment was warranted in those areas to limit the potential downgradient migration of CVOCs in groundwater.

The Revised Phase III RAP describes treatment options for these four source areas. Treatment is also proposed in two downgradient areas to reduce CVOC levels along the groundwater flow pathway to help reduce groundwater concentrations in the areas west and south of Tozer Road. The Revised Phase III RAP provides a detailed evaluation of remedial action alternatives for each treatment area. The process included an initial screening of more than 20 technologies, resulting in a short-list of remedial alternatives for each treatment area. These remedial alternatives were evaluated and scored using specific criteria established under the Massachusetts Contingency Plan (MCP). Those criteria are: effectiveness, reliability, difficulty of implementation, cost, risk, green benefits, and time. The MCP evaluation criteria are not weighted; instead, all remedies are scored against all of the criteria to provide a total score for comparison.

The selected remedial action alternatives presented in the Revised Phase III Remedial Action Plan are:

- **Building 3 Source Area:** In situ thermal remediation, followed by in-situ bioremediation polish, and continued soil vapor extraction (SVE) operation.
    - In situ thermal remediation uses heat in place underground to remove CVOCs.
    - In situ bioremediation involves using microbes in place that consume CVOCs as a source of food or energy.
    - The SVE system, which is already in place, uses a vacuum to remove CVOC vapors from the soil above the water table to prevent CVOC migration into the overlying building.

- **Building 5 Source Area:** In situ bioremediation and continued SVE operation.
    - In situ bioremediation treatment will be expanded with new application methods (e.g., high-pressure and/or pulsed injections).
    - Additional pre-design investigations will be conducted to support treatment expansion.
    - The SVE system will continue to operate to remove CVOCs and prevent their migration into the overlying building.

- **Bedrock (near Building 5):** In situ chemical oxidation (ISCO).
    - ISCO uses chemicals called “oxidants” (such as permanganate) that, when added to contaminated soil and groundwater in place, destroy CVOCs by chemical reaction.
    - Additional pre-design investigations will be conducted to support ISCO implementation

- **PSL-10 Area:** ISCO or installation of a Colloidal Activated Carbon Permeable Adsorptive Zone (Permeable Adsorptive Zone)
  - An active remedy will be implemented in this area. Based on similar final scores, this remedy may be ISCO or a permeable treatment zone.
  - The permeable treatment zone considered is a permeable adsorptive zone, which involves creating an underground area of granular activated carbon to which CVOCs stick (similar to a water filter). Alternatively, a permeable reactive zone may be implemented, which would include reactive material such as iron.
  - Pre-design investigations to be conducted in the PSL-10 area will help confirm the final treatment approach implemented.

- **Downgradient Plume:** Sulfidated Micro Zero Valent Iron Permeable Reactive Zone for Tozer Road and Granular Activated Carbon Permeable Adsorptive Zone for the seep area at Stream A
  - Tozer Road Barrier – A permeable reactive zone is an underground "wall" of reactive material such as iron. Groundwater containing CVOCs flows through the wall. The CVOCs react chemically with the iron, and treated groundwater flows out the other side.
  - Stream A Seep Barrier – A permeable adsorptive zone involves creating an underground area of granular activated carbon to which contaminants stick, similar to a water filter.

The selected remedial alternatives are expected to achieve a Permanent Solution at the Site. The next steps include the preparation of a Phase IV Remedy Implementation Plan for the above treatments. A Phase IV report, Part 1 for the thermal treatment in the Building 3 source area, Tozer Road barrier, and Stream A seep barrier is being issued along with this Revised Phase III RAP in a separate, stand-alone document. A Phase IV report, Part 2 for the Building 5, bedrock, and PSL-10 source areas will be submitted during the third quarter of 2023 (summer 2023).

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More information about these treatment technologies can be found in the U.S. Environmental Protection Agency (EPA) community guides at the following links:

- In-Situ Thermal Remediation: https://semspub.epa.gov/work/HQ/401607.pdf
- In-Situ Bioremediation: https://semspub.epa.gov/work/HQ/401583.pdf
- Soil Vapor Extraction: https://semspub.epa.gov/work/HQ/401619.pdf
- In-Situ Chemical Oxidation: https://semspub.epa.gov/work/HQ/401601.pdf
- Permeable Reactive Barrier: https://semspub.epa.gov/work/HQ/401613.pdf
- Granular Activated Carbon Permeable Adsorptive Zone: https://semspub.epa.gov/work/HQ/401599.pdf