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PHASE III REMEDIAL ACTION PLAN
284 Winter Street
Haverhill, Massachusetts

RTNs 3-32792 and 3-32875

July 2022
File No. 01.0172397.10

PREPARED FOR:
Boston Gas Company d/b/a National Grid
Waltham, Massachusetts

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July 13, 2022
File No. 0172397.10

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

Re: Phase III Remedial Action Plan (RAP)
284 Winter Street
Haverhill, Massachusetts
Release Tracking Numbers (RTNs) 3-32792 and 3-32875

Dear Sir/Madam:

On behalf of Boston Gas Company d/b/a National Grid (National Grid), GZA GeoEnvironmental, Inc. (GZA) is pleased to submit this Phase III Remedial Action Plan (RAP) for the above referenced Site. The Site has been designated by Massachusetts Department of Environmental Protection (MassDEP) as Release Tracking Numbers 3-32792 and 3-32875. This RAP has been prepared by GZA in accordance with Section 310 CMR 40.0861 of the Massachusetts Contingency Plan (MCP) to describe the selection of a Comprehensive Remedial Alternative for this property. A RAP has also been prepared by Anchor QEA for the Little River portion of the Site and is included as Appendix C.

Should you have any questions, please contact Mr. Charles Lindberg, LSP, at 781-278-3830.

Very truly yours,

GZA GEOENVIRONMENTAL, INC.

Justin Ivas
Assistant Project Manager

John A. Colbert
Consultant/Reviewer

Charles A. Lindberg, LSP
Senior Principal

Attachment: Phase III RAP

cc: Jesse Edmands, National Grid

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

On behalf of Boston Gas Company d/b/a National Grid (National Grid), GZA GeoEnvironmental, Inc. (GZA) has prepared this Phase III Remedial Action Plan (RAP) for the Disposal Site located at 284 Winter Street in Haverhill, Massachusetts (the “Site”). The primary Massachusetts Department of Environmental Protection (MassDEP) release tracking number (RTN) for the Site is 3-32792. RTN-3-32875, which was assigned in connection with a notification condition requiring an Immediate Response Action (IRA) also remains active for the Site. A Site Locus Plan is included as Figure 1, and Figure 2 presents the disposal site boundary and other pertinent site features.

The 284 Winter Street property (Property) is currently owned by Haffner Realty Trust (Haffner) and is occupied by a gasoline service station and car wash facility. In March 2015, Haffner filed a Release Notification Form (RNF) notifying the MassDEP that concentrations of certain Oil and/or Hazardous Materials (OHM) in soil samples exceeded the Reportable Concentrations (RCs) established by the Massachusetts Contingency Plan (MCP, 310 CMR 40.0000). MassDEP issued a Notice of Responsibility (NOR) to Haffner in April 2015, and assigned RTN 3-32792 to this 120-day reporting condition. Subsequently, in May 2015, MassDEP assigned RTN 3-32875 to a 2-hour reporting condition associated with a petroleum sheen on the surface water of the Little River adjacent to the Property[1].

Between 2015 and 2019, response actions associated with both RTNs were conducted by Ramboll US Corporation, formerly known as Ramboll Environ, of Westford, Massachusetts (Ramboll) on behalf of Haffner. As required by the MCP, Ramboll submitted a Phase I Initial Site Investigation (ISI) and Tier Classification in April 2016, based on which the Site was classified as a Tier I Site. The Phase I ISI documented that the Site had been the location of a former Manufactured Gas Plant (MGP) operated by Haverhill Gas Works.

In November 2016, MassDEP issued an NOR to National Grid, a successor company to a former owner of the Property, noting that the liability was joint and several between Haffner and National Grid. In November 2019, following Haffner’s signing of a settlement agreement between the two potentially responsible parties (PRPs), National Grid assumed the role of Responsible Party for the two RTNs via a Tier Classification Transfer. GZA submitted a Phase II Comprehensive Site Assessment (Phase II) report on behalf of National Grid in April 2022.

The RAP has been organized as follows:

- Section 2.0 summarizes the Site history and describes conditions requiring remediation;
- Section 3.0 summarizes remedial objectives and outlines the goals of the Phase III RAP;
- Section 4.0 contains a discussion of general classes of remedial technologies that are typically applicable at similar sites, and presents a preliminary screening of technologies to address the Site conditions, as appropriate;
- Section 5.0 identifies potential Remedial Action Alternatives (RAAs) comprised of one or more technologies retained during the initial screening and evaluates the RAAs using criteria established by the MCP and presents the Remedial Action Plan, i.e. a description of the selected RAA(s) and a discussion of how they will be implemented.

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[1] A third RTN (3-34906) was assigned to the property in May 2018, when an elevated headspace reading was detected in a soil sample during the removal of an underground storage tank (UST).

- Section 6.0 provides the supporting information required by the MCP, including feasibility evaluation(s); the Phase III Completion Statement; and documentation of public notifications; and
- Section 7.0 summarizes the conclusions of the Phase III RAP.

This submittal is subject to the limitations in Appendix A. In accordance with MassDEP policy, the report and transmittal form BWSC-108 were submitted electronically via eDEP. A copy of the transmittal form is included in Appendix B.

2.0 BACKGROUND

The Disposal Site consists of the property located at 284 Winter Street in Haverhill, Massachusetts, which is currently occupied by a gasoline service station and car wash, along with surrounding areas to the southeast, southwest, west and northwest. An adjacent vacant property to the southeast of the 284 Winter Street parcel, a portion of the Little River which flows along the Property's western boundary, and a portion of the Winter Street right-of-way to the north of the Property all lie within the Disposal Site boundary. The Site occupies 1.6 acres of land with a relatively level upland area separated from the Little River (at an elevation approximately 15 feet below that of the upland area) by a masonry retaining wall.

The Site lies within a commercial/industrial area in the downtown portion of Haverhill. No water supplies are located in the vicinity of the Site and other environmentally sensitive areas other than the Little River have not been identified in the Site area. The Little River has been channelized in the Site area and it enters a concrete flood conduit at the downstream edge of the Disposal Site; this conduit flows beneath downtown Haverhill and discharges to the Merrimack River.

An MGP operated at the 284 Winter Street property between approximately 1853 and 1970, with various manufactured gas production processes utilized over this period. The Property has been used as a gasoline service station, fuel oil distribution facility and a car wash since 1977.

During a site assessment for a planned real estate transaction in November 2014, certain constituents were reported in soil and groundwater samples at concentrations exceeding the MCP RCs. The owner of the property (Haffner) notified the MassDEP regarding this finding in March 2015 and RTN 3-32792 was assigned. During assessment of this RTN in May 2015, Haffner's consultant (Ramboll) noted a sheen on the Little River that appeared to be emanating from the Property. An additional notification to MassDEP was made and an additional RTN (3-32875) was assigned. IRA activities were initiated in May 2015 in response to this finding and included gauging and recovery of NAPL in Site monitoring wells and installation of absorbent booms in the Little River. A semi-permanent boom system was installed within the River in November 2016 and has been maintained through the present under the IRA.

Ramboll completed a Phase I ISI on behalf of Haffner in April 2016 for RTNs 3-32792 and 3-32875 and continued IRA activities through October 2019. The Phase II work required under the MCP was not completed by the specified deadline and MassDEP issued a Notice of Noncompliance (NON). National Grid assumed responsibility for the MCP response actions for the two RTNs in November 2019 with the filing of a Tier Classification transfer. National Grid and MassDEP signed an Administrative Consent Order (ACO) in October 2020 which established a deadline of April 6, 2022 for submittal of the Phase II report.

The Site is underlain by an historic fill layer of varying thickness and composition which overlies a fine-grained deposit consisting of silt or silty sand. The fill underlying the 284 Winter Street property is typical of an historic urban fill, composed of reworked natural soils with significant quantities of debris, including concrete, asphalt, brick, wood, coal, and glass. Remnants of former structures were encountered at a number of locations during subsurface explorations at the Site. Geologic cross-sections of the Site are depicted on Figures 3A and 3B.

Groundwater flow at the Site is generally toward the west/southwest, with the Little River as the main discharge point. A "perched" groundwater condition exists within the footprint of the historical manufactured gas relief holder in the central portion of the Site, with groundwater elevations typically 7 to 8 feet higher than elsewhere within the property and within 4 feet of ground surface. Total groundwater flow through the Site is estimated to be approximately 1 gallon per minute (gpm), with flow rates restricted by the relatively low permeability of Site soils. The estimated transport velocity for groundwater at the Site is approximately 0.1 feet/day (37 feet/year).

Petroleum and MGP-related constituents including naphthalene, other polycyclic aromatic hydrocarbons (PAHs), extractable petroleum hydrocarbon (EPH) and volatile petroleum hydrocarbon (VPH) fractions and aromatic volatile organic compounds (VOCs) are present in soils throughout the Property, with the most significant impacts found at the 5- to 20-foot depth range below ground surface. While constituent of concern (COC) concentrations in soil exceeded the MCP Method 1 cleanup standards at a number of locations, they were generally below upper concentration limits (UCLs).

The primary COCs detected in groundwater samples at levels above the Method 1 standards included naphthalene, C9-C10 aromatics and benzene, with the highest concentrations reported in the central, western and southern portions of the Property. Significant impacts to groundwater extend from the eastern portion of the Property to the Little River; wells installed on the western side of the river to the southwest of the 284 Winter Street property did not indicate detectable levels of the primary Site COCs.

Concentrations of constituents detected in soil gas at the Site appear to be primarily related to incidental emissions and spills associated with the active gasoline and diesel storage and dispensing operations. GZA's evaluation concluded that the reported concentrations do not indicate significant potential for vapor intrusion into occupied structures at the Site.

Non-aqueous Phase Liquid (NAPL) has been observed at several locations across the western, central, and southern portions of the Site, but significant accumulations of separate-phase materials have only been observed at two locations in the upland area, one of which is within the historical relief gas holder. Evaluations of NAPL mobility and recoverability completed under MassDEP guidance concluded that these materials are not feasible to recover. NAPL has historically migrated to the Little River and has been periodically observed seeping from the retaining wall at the edge of the Property under certain conditions.

Significant impacts were observed to the sediments beneath the Little River adjacent to the Property, including elevated concentrations of Site COCs and the presence of visible oil and/or tar (VOT) over a substantial area. Anchor QEA LLC of Amesbury, Massachusetts (Anchor) completed an evaluation of the Little River portion of the Site under contract to National Grid; that assessment was documented in the April 2022 Phase II report. Anchor has also completed a separate Phase III RAP for the Little River portion of the Site which is included as Appendix C of this submittal.

The Phase II Report identified the need for additional response actions in the following areas of the Site:

- A Method 3 Risk Characterization has indicated that quantitative human health risk estimates were above the relevant MCP criteria for one receptor group/exposure scenario: construction/utility workers excavating below the water table within the former holder area. The risk estimate for this scenario was driven by benzene and naphthalene concentrations in the perched groundwater within the former holder, where an active electrical line (believed to be powering an exterior light pole) is apparently present.

- Sediment conditions within the Little River adjacent to the Site pose a risk of environmental harm and represent a condition of Readily Apparent Harm (RAH) to environmental receptors due to the widespread VOT.

With the exception of these issues, the Phase II study concluded that conditions within the Disposal Site did not pose a significant risk to human health or public welfare assuming the filing of an Activity and Use Limitation (AUL) that would restrict certain future Site uses (e.g., residential use). Accordingly, this Phase III evaluation focuses on the two items above (sediment conditions evaluated in Appendix C).

3.0 REMEDIAL OBJECTIVES

In accordance with the MCP, a Phase III evaluation must be conducted if a Permanent Solution is not achieved following the completion of a Phase II investigation. The goal of the Phase III evaluation is to identify and evaluate RAAs which:

1. are likely to achieve a condition of No Significant Risk (NSR) at the Site;
2. eliminate Substantial Hazards; and
3. result in a Permanent or Temporary Solution, where a Permanent Solution includes measures that reduce, to the extent feasible, the concentrations of oil and/or hazardous materials to levels that achieve or approach background.

3.1 SITE CLOSURE CATEGORIES

Section 310 CMR 40.1000 of the MCP establishes two types of closure documentation for disposal sites – Permanent Solutions and Temporary Solutions. Permanent Solutions are further subdivided based on the need for conditions. This section describes each of the closure categories that may be applicable at the Site. The MCP requires that a Phase III evaluation result in the selection of a RAA that is likely to result in a Permanent Solution, except where it is demonstrated to be infeasible and the implementation of a Temporary Solution is more cost effective and timely.

3.1.1 Permanent Solution

As described previously, the MCP requires that remedial actions be evaluated based on their ability to reach a Permanent Solution, if feasible. The achievement of a Permanent Solution requires the elimination to the extent feasible, or control of all sources of OHM and control of the subsurface migration of OHM such that plumes of dissolved OHM in groundwater and vapor-phase OHM in the vadose zone are stable or contracting. Assessment of the nature, extent and mobility of any NAPL that is present at the Site and completion of non-stable NAPL and NAPL with micro-scale mobility removal, to the extent feasible, are also required for Permanent Solutions. Permanent Solutions apply to sites where:

- a level of No Significant Risk (in accordance with 310 CMR 40.0900) exists or has been achieved;
- all source of OHM have been eliminated or controlled;
- control of plumes of dissolved OHM in groundwater and vapor-phase OHM in the vadose zone has been achieved;

- NAPL, if present, has been addressed as specified in 310 CMR 40.1003(6)(a);
- all threats of release have been eliminated; and
- the level of OHM concentrations in the environment have been reduced, as close to background concentrations as feasible.

Permanent Solutions with Conditions is the closure category that applies to sites that meet the criteria above and the NSR finding relies on an AUL or other assumed limitation on current or future activities. These other assumed limitations include:

- the recommendation of Best Management Practices for non-commercial gardening in a residential setting to minimize and control potential risk;
- concentrations of OHM at the disposal site are consistent with Anthropogenic Background levels;
- the location of residual contamination within a public way or within a rail right-of-way; or
- the absence of an occupied building or structure in an area in which the groundwater would otherwise be classified as GW-2 and where the residual concentrations of OHM in the groundwater exceed the GW-2 standards.

In the absence of these assumed limitations on site activities, Permanent Solutions are considered "Permanent Solutions with No Conditions".

Permanent Solutions do not apply to disposal sites where average groundwater and/or soil concentrations exceed UCLs unless the impacted soil has been permanently immobilized or fixated as part of a remedial action, is located at a depth greater than 15 feet below ground surface (bgs) or is located beneath an Engineered Barrier. Additionally, a Permanent Solution cannot be achieved if groundwater concentrations exceed an applicable standard where groundwater is categorized as GW-1.

3.1.2 Temporary Solution

A Temporary Solution is an acceptable remedy under the MCP if a Permanent Solution is shown to be infeasible or if a Temporary Solution is shown to be more cost effective and timely than a Permanent Solution, as long as enterprising steps are taken towards achieving a Permanent Solution. A Temporary Solution is defined in the MCP as (310 CMR 40.0006) follows:

…any measure or combination of measures which will, when implemented, eliminate any substantial hazard which is presented by a disposal site or by any oil and/or hazardous material at or from such site in the environment until a Permanent Solution is achieved.

Under a Temporary Solution, OHM concentrations may exceed UCLs; also, OHM concentrations may exceed applicable or suitably analogous standards as long as such concentrations do not pose a Substantial Hazard.

In addition to eliminating Substantial Hazards, a Temporary Solution must, to the extent feasible, eliminate, control or mitigate all sources of OHM, control or mitigate subsurface OHM migration and address non-stable NAPL. The MCP requires periodic evaluation and definitive and enterprising steps towards achieving a Permanent Solution if a Temporary Solution is implemented.

3.2 IDENTIFICATION OF REMEDIAL OBJECTIVES

This section identifies remedial objectives for the upland portion of the Site, based on the potential risks described above and in the Phase II CSA, and the applicable closure criteria. Remedial objectives encompass those related to risk, including addressing both Substantial Hazards and Significant Risks, and the other criteria for demonstrating a Permanent or Temporary Solution, including:

- Elimination or control of sources of OHM;
- Control of the subsurface migration of OHM; and
- Addressing NAPL.

While specific residual sources of OHM have not been identified on the upland portion of the Site, the historical relief holder was observed to contain NAPL and dissolved concentrations of certain COCs in groundwater higher than those found elsewhere at the Site. However, the former relief holder area is presently mostly covered by asphalt pavement or the car wash building and GZA's review of groundwater quality data indicates that concentrations are not increasing over time. Accordingly, it is GZA's opinion that this possible residual source of OHM has been controlled under current Site conditions. Concentrations of Site COCs in groundwater appear to be stable or decreasing over time and there is no indication that plumes of dissolved OHM are expanding at the Site. Accordingly, control of the subsurface migration of OHM is not a specific remedial objective. Nonstable NAPL has not been observed in the upland portion of the Site and the NAPL with micro-scale mobility (as that term is defined under the MCP) detected in several monitoring wells has been deemed infeasible to recover in accordance with MassDEP guidance. Accordingly, addressing NAPL in the upland area is not a specific remedial goal for this Phase III evaluation.

The exceedance of the MCP risk criteria for construction/utility workers excavating below the water table within the former holder area may also constitute a Substantial Hazard since it could theoretically pose short-term risk over the next several years. Accordingly, that condition would need to be addressed to achieve a Temporary Solution for the upland portion of the Site. As described above, a condition of NSR cannot be demonstrated for the relief holder area due primarily to benzene and naphthalene concentrations in the perched groundwater in this portion of the Site. Therefore, remedial actions are required to address this condition.

4.0 INITIAL SCREENING OF REMEDIAL TECHNOLOGIES (310 CMR 40.0861(2)(a))

As required by Section 310 CMR 40.0856 of the MCP, GZA performed an initial screening of available remedial technologies to assist in identifying those technologies suitable for inclusion as RAAs. Depending on the nature of OHM and Site media, RAAs may be comprised of one or more technologies that are implemented concurrently or sequentially to attain remedial goals. Technologies were retained for possible inclusion as RAAs if they were deemed reasonably likely to be feasible based on the OHM present, impacted media, and Site characteristics. Per 310 CMR 40.0856, RAAs (which may comprise one or more technologies) are reasonably likely to be feasible if the following is true:

- The technologies to be employed by the alternative are reasonably likely to achieve a Permanent Solution or Temporary Solution; and
- Individuals with the expertise needed to effectively implement available solutions would be available, regardless of arrangements for securing their services.

The initial screening for this Phase III focused on technologies that could address the COCs in soil and groundwater within the former relief holder area. These technology categories included:

- No Further Action;
- Institutional Controls;
- Natural attenuation;
- Containment;
- NAPL Recovery
- In-situ treatment; and
- Ex-situ treatment.

Table 1 provides a summary of the preliminary screening, which was based on state and federal guidance for evaluation of remedial technologies; a discussion of the results is provided below. Within each section, the description of the remedial technology is followed by a conclusion that presents the viability of the screened technology relative to upland Site conditions and identifies those technologies retained for further evaluation as part of a RAA.

For this RAP, GZA judged a remedial technology to be potentially feasible if: (1) it was likely to reduce risks to levels that would permit the achievement of a Permanent Solution; and (2) the technology appeared to be technically and economically implementable at the Site. It was recognized that a remedial approach involving a combination of technologies would likely be necessary to attain remedial goals across the upland portion of the Property.

4.1 NO FURTHER ACTION

The "no further action" alternative assumes no additional efforts are made to reduce the mass and concentration of OHM at the Site. This alternative does not reduce Site risks associated with OHM currently present, and provides no additional protection to safety, public welfare or the environment. However, it does provide a basis for assessing the effects of performing remedial actions, and a baseline against which other remedial technologies can be compared.

No further action is not applicable at the Site because the calculated non-cancer risk estimate for construction workers working within the former relief holder area exceeds the MCP non-cancer risk limit of 1. Therefore, it was not retained for further consideration in this Phase III RAP.

4.2 INSTITUTIONAL CONTROLS

Institutional controls are mechanisms to limit access to impacted media, and include alternatives such as site fencing and AULs (i.e., deed restrictions). The primary purpose of institutional controls is to limit future site activities and uses and, as a result, potential human exposures to site OHM. While institutional controls do not eliminate contamination, they can provide an effective, reasonable approach for reducing human health exposure potential, and thus risk, if properly maintained and enforced.

Institutional controls, such as the use of AULs to restrict future use, would be a key component of any remedy designed to achieve a Permanent Solution at this Site, based on GZA's evaluation. Therefore, this technology was retained for further evaluation.

4.3 NATURAL ATTENUATION

Natural attenuation relies on naturally occurring processes such as volatilization, adsorption, dilution, oxidation, reduction, and biodegradation to reduce the mass, concentration, and/or toxicity of contaminants.

Volatilization, and thus off-gassing, of COCs from groundwater into vadose zone soil, reduces the concentrations of those compounds in the groundwater. Chemicals with vapor pressures greater than 10 millimeters of mercury (mm Hg), such as the C_5-C_8 aliphatic hydrocarbons, are generally considered to be volatile, whereas the PAHs and heavier EPH-range compounds have low to intermediate vapor pressure and are considered non-volatile. As another measure of volatility, compounds with dimensionless Henry's Law constants of greater than 1, such as benzene, the C_5-C_8 and C_9-C_{12} aliphatic fractions in the VPH range and the C_9-C_{18} aliphatic fraction in the EPH range, are more likely to partition into air than remain in groundwater, whereas the C_9-C_{10} aromatic hydrocarbons, C_{11}-C_{22} aromatic hydrocarbons and naphthalene present at the Site tend to remain in the groundwater. Volatilization may be a significant attenuation mechanism for benzene in groundwater within the relief holder but would not be a factor for certain other COCs at this property.

The likelihood of a compound adsorbing to soil versus leaching into groundwater, where concentrations might be reduced via dilution, can be predicted based on its organic carbon partitioning coefficient (Koc). Koc values of less than 100 ml/g (e.g., benzene) indicate that a chemical has a high potential to leach into groundwater. Conversely, compounds with Koc values greater than 1,000 ml/g have a higher affinity (partitioning) for solids and are less mobile in the groundwater environment. Within the VPH/EPH ranges, the Koc increases from 1.7×10^3 ml/g for the C_9-C_{10} aromatic hydrocarbons to 6.8×10^5 ml/g for the C_9-C_{18} aliphatic hydrocarbons, indicating that hydrocarbons are in general more likely to sorb to soil than leach into groundwater, and that their tendency to leach into groundwater decreases as their molecular weight increases. The adsorptive nature of the COCs at this property means that dilution is unlikely to be a significant attenuation mechanism.

Biodegradation is the transformation of organic compounds via metabolism by microorganisms. Biodegradation of hydrocarbons occurs naturally in the environment and results from the aerobic metabolism of compounds by heterotrophic microorganisms (primarily bacteria). The ultimate end products of biodegradation are carbon dioxide and water. Microbial species capable of degrading hydrocarbons are usually found in some capacity as indigenous populations in soils and groundwater in the environment. The rate of biodegradation is governed by several factors related to the availability of required constituents (e.g., carbon and oxygen, in the case of aerobic biodegradation processes), nutrients (e.g., nitrogen and phosphorus), and organic growth factors necessary for the growth of the microbial population. With the exception of naphthalene, PAH compounds are not readily biodegraded and are considered persistent compounds in the environment.

Natural attenuation, which may occur via any or all of the processes described above, is considered a passive remedial technology in that no active remediation is performed. Often, the rate and progress of natural attenuation is assessed via routine soil and/or groundwater monitoring (i.e., monitored natural attenuation [MNA]) to assess the natural reduction in contaminant concentrations and to monitor potential migration; such monitoring may include the assessment of surrogate indicators of attenuation processes.

Based on the concentrations of benzene and other COCs observed in groundwater within the relief holder more than 50 years after MGP operations ceased, it does not appear that these constituents are amenable to natural attenuation via volatilization, dilution, or biodegradation. This approach has been eliminated as a primary remedial technology. Biodegradation of some compounds in groundwater is likely to occur, resulting in lowered dissolved concentrations over time; however, the rate of such degradation is unlikely to result in a condition of NSR within the foreseeable future.

Therefore, although natural attenuation is likely to be a de facto component of any remedial alternative, it was not retained for further evaluation.

4.4 CONTAINMENT TECHNOLOGIES

Containment technologies can be used to limit exposure via dermal contact with, ingestion of, and/or inhalation of impacted media, and/or to limit leaching of OHM from soils by reducing water infiltration into, or flow through, the impacted soil medium. These technologies can consist of horizontal or vertical barriers as described further below. In addition, groundwater extraction, which is an effective hydrodynamic means of limiting groundwater migration, is also discussed in this section. Note that the residual OHM present within the former relief holder appears to be partially contained by the former structure in its current state; these conditions impact the utility of some of the technologies described below.

4.4.1 Horizontal Barriers

Horizontal barriers such as soil caps or engineered barriers are the most commonly used horizontal containment technologies. Soil capping, in its most basic form, consists of the placement of clean soil material over a demarcation layer, with long term maintenance of this cap. Use of low-permeability material (a layer of asphalt pavement, concrete, polymeric membrane or natural low permeability material such as clay) within the cap can mitigate infiltration of surface water into the subsurface and thus limit the potential for OHM migration; however, the existing groundwater flow patterns and potential need for stormwater management must then be taken into consideration. Implementation of a cap must also take into account the likely future activities in the area, and the potential need for additional institutional controls such as fencing or signage.

An engineered barrier, as defined in 310 CMR 40.0996, is a cap specifically designed to support a Permanent Solution that:

- Prevents direct contact with contaminated media;
- Controls vapors or dust emanating from contaminated media;
- Prevents erosion and infiltration of precipitation or run-off that could jeopardize the integrity of the barrier or result in the potential mobilization and migration of contaminants;
- Is comprised of materials that are resistant to degradation;
- Is consistent with the technical standards of RCRA Subpart N, 40 CFR 264.300, 310 CMR 30.600 or equivalent standards;
- Includes a demarcation layer that visually identifies the beginning of the barrier; and
- Is appropriately monitored and maintained to ensure its long-term integrity and performance in accordance with a monitoring and maintenance plan submitted to MassDEP, with one or more financial assurance mechanism(s) to provide for ongoing future monitoring, maintenance and (if necessary) replacement of the barrier.

Horizontal barriers do not result in source removal nor do they remediate the environmental medium. Once installed, they must be indefinitely maintained; therefore, an AUL requiring barrier inspection and long-term maintenance must be implemented in conjunction with any barriers that are relied upon to maintain a condition of NSR or No Substantial Hazard.

The Phase II report concluded that average soil concentrations at the Site did not exceed UCLs; accordingly, an engineered barrier is not required or appropriate for this Site. While capping may serve to limit potential exposures for facility workers to residual OHM in shallow soils, it would not address the potential construction/utility exposures associated with the existing electrical line. Therefore, horizontal barriers were eliminated as a primary technology.

4.4.2 Vertical Barriers

Vertical barriers consist of low-permeability material installed to impede the flow of groundwater and limit the lateral migration of OHM within the subsurface. Such barriers must be designed to account for potential groundwater mounding. Cutoff walls have been used for decades as vertical barriers to provide long-term solutions for controlling the horizontal transport of groundwater. Examples of these subsurface barriers consist of driven sheet piling, concrete walls and vertical "slurry-trenches" excavated under slurry head and subsequently filled with a low permeability backfill. In the case of "slurry-trenches", the slurry hydraulically supports the trench excavation during construction to prevent collapse, and in some cases can be used in a mixture with the native soil to form the low permeability "backfill" that inhibits groundwater flow.

A vertical low-permeability barrier would not be appropriate for the former relief holder area as the existing holder walls appear to be performing this function and restricting groundwater outflow. Therefore, this alternative was not retained for further evaluation.

4.4.3 Groundwater Extraction

In addition to horizontal and vertical barriers, another technology included in the "containment" category is groundwater extraction, which is best suited to providing plume containment and/or capture, rather than remediating dissolved constituents. The technology utilizes groundwater depression pumps, typically set in extraction wells or sumps below the groundwater table, that depress the groundwater table providing containment of the impacted groundwater. Following treatment, the groundwater may be discharged back into the aquifer using injection wells or recharge galleries, discharged to surface water, discharged to a sanitary sewer system or transported off-site for treatment/disposal.

Groundwater depression is most effective in homogeneous saturated soils with moderate to high hydraulic conductivity. The impacted groundwater addressed by this Phase III is within the former relief holder which was filled with miscellaneous fill exhibiting highly variable hydraulic conductivities. Additionally, groundwater extraction alone would be unlikely to reduce COC concentrations to below risk-based criteria due to the presence of impacted fill within the relief holder. Therefore, groundwater extraction was not retained as a stand-alone technology for further evaluation. However, it should be noted that groundwater extraction may be an element of RAAs that use other technologies, e.g., temporary groundwater dewatering may be required in conjunction with alternatives such as excavation.

4.5 NAPL RECOVERY

NAPL recovery can consist of either passive or active removal of separate phase materials from the subsurface, where active removal systems are differentiated from passive systems by the addition of continuous groundwater extraction to enhance the gradients used to induce the NAPL to flow toward the removal location.

Active NAPL removal systems are designed to control the migration of NAPL (typically only effective for Light NAPL or LNAPL) by imposing an additional groundwater gradient toward one or more collection locations. This process results in the capture of LNAPL within the resulting groundwater "drawdown cone" which extends some distance from the removal location. An advantage of active removal technologies, as opposed to the passive technologies described above, is that the mass of contaminants in the subsurface is also reduced via the removal, collection, and/or treatment of impacted groundwater. However, although LNAPL product recovery technologies have been used extensively for light fuel oils, and their successes are well documented, active NAPL removal is generally considered difficult, if not infeasible, at MGP sites. This is because MGP NAPLs are not easily induced to flow through the subsurface along groundwater gradients due to their typical viscous, tar-like consistency. In addition, groundwater extraction is generally ineffective at inducing Dense NAPL (DNAPL) flow towards collection points, and in fact, can cause unintended DNAPL migration to points deeper into the subsurface. Therefore, active NAPL removal was not retained for further evaluation at this Site.

Examples of passive NAPL removal technologies include the use of adsorbent materials within recovery wells, systems that skim LNAPL from the water surface within a well, total fluid pumps specifically positioned to extract DNAPL (and collaterally, often some limited groundwater) from the bottom of a well, and manual bailing or pumping of LNAPL and/or DNAPL from wells. While such technologies may be effective for the NAPL at the Site and are being implemented as part of the ongoing IRA, the Phase II concluded that continued NAPL recovery is not feasible under MassDEP's guidance. Therefore, NAPL recovery has been eliminated as a primary remedial technology.

4.6 IN SITU TREATMENT TECHNOLOGIES

In situ treatment destroys, neutralizes, or reduces the toxicity of contaminants while leaving the environmental medium in place. In situ technologies result in limited site disturbance with limited need for excavation, treatment and/or handling of contaminated media. This limits risks to remedial construction workers, on-site employees, and site abutters that can occur during more intrusive removal activities. The following in situ treatment technologies were included in the initial screening.

4.6.1 Soil Vapor Extraction (SVE) and/or Air Sparging (AS)

Soil vapor extraction (SVE) is an in situ physical treatment technology that is fully developed and widely utilized. An SVE system applies a vacuum to the unsaturated zone to induce a controlled flow of air to remove VOCs and some semi-volatile organic compounds (SVOCs) from soil. In the case of petroleum-based OHM, an added benefit of SVE is that it generally increases the level of oxygen in the subsurface, and, therefore, the rate of aerobic biodegradation. The extracted soil gas may be treated using activated carbon or catalytic or thermal oxidation to remove organic contaminants from the system discharge.

SVE is applicable only in the unsaturated zone, but can be supplemented by the addition of air sparging (AS) to remediate volatile compounds in saturated zone soil and groundwater. AS requires the installation of air injection wells extending below the water table to inject air into the saturated zone, following which SVE wells screened in the unsaturated zone are used to capture the resulting vapors. As in the case of SVE, volatile compounds liberated from the saturated zone are typically treated prior to atmospheric discharge using activated carbon or catalytic or thermal oxidation. In addition to removing constituents via volatilization, an AS system can also promote biodegradation (i.e., "bioventing") by stimulating indigenous bacterial growth and associated aerobic biodegradation through the introduction of oxygen into the formation.

Due to their low volatility and slow rate of aerobic biodegradation, the SVOCs and NAPL at the Site would likely not be remediated sufficiently to consider AS/SVE an effective technology. In addition, the heterogeneous nature of the fill within the former relief holder and the presence of obstructions would significantly limit the effectiveness of AS/SVE. Further, the presence of buried MGP infrastructure and the associated potential for short-circuiting may result in preferential air flow pathways that could result in incomplete capture of VOCs by the SVE system and allow impacted vapors to migrate away from the treatment area. Therefore, AS/SVE was not deemed a suitable technology and was not retained for further evaluation.

4.6.2 Soil Flushing

Soil flushing is a method of in situ chemical treatment in which solvents or surfactants are added to the soil matrix to desorb contaminants. According to the Federal Remediation Technologies Roundtable web site, soil flushing is most effective at remediating VOCs and inorganic compounds, and is only moderately effective at desorbing SVOCs and heavier hydrocarbons from soils. In the target remedial area at the Site, the presence of fill and buried infrastructure in the vadose zone, the limited effectiveness of the technology in remediating the primary COCs, and the presence of DNAPL make this an unsuitable technology. Therefore, soil flushing is not retained for use at the Site.

4.6.3 Chemical Oxidation

Chemical oxidation is an in situ chemical treatment technology that involves the injection of an oxidizing agent, such as permanganate, hydrogen peroxide, persulfate, or ozone, to break down OHM through a series of oxidation reactions. The oxidizing agents are typically injected in liquid or gaseous form into soils and groundwater. Factors that limit the effectiveness of this technology include distribution of oxidant into the subsurface and incomplete oxidation, which can occur depending on the contaminants and oxidizing agents used. The persistence and migration of the oxidant in the subsurface must also be evaluated under site-specific conditions.

Although in situ chemical oxidation can be successfully used to treat a wide range of contaminants, including halogenated VOCs and SVOCs, it is generally less effective on heavier-end petroleum compounds and NAPL (or NAPL-saturated soils). Its effectiveness would also be limited by similar considerations to those stated above, i.e., the nature of the fill material and the presence of buried MGP infrastructure beneath the Site. Therefore, chemical oxidation is not retained for evaluation in this Phase III RAP for the Site.

4.6.4 In Situ Solidification/Stabilization

Solidification and/or stabilization reduces the mobility of OHM in the environment through chemical or physical means. Chemical stabilization alters contaminants by converting them into less bioavailable, less mobile, or less toxic forms; e.g., it can be used to reduce the solubility of metals through the control of pH and alkalinity. Physical immobilization involves the addition of binders such as Portland cement, furnace slag, fly ash, bentonite, and/or limestone to encapsulate contaminated soil or sediments within a solid and stable matrix. The process, which can be performed either ex situ or in situ, results in blocks of material with high structural integrity that are resistant to weathering and aqueous leaching. Selection of this technology must take into account the effects of the resultant low-permeability monolith on groundwater flow at a Site.

In situ solidification/stabilization (ISS) uses auger/caisson systems and injector head systems to add polymer-, clay- and/or cement-based binders to the impacted soil without excavation, leaving the resultant stabilized material in place. Alternatively, the binder material can be mixed in with an excavator bucket where the OHM is present at shallower depths; this method is generally more cost effective as it is typically faster than an auger/caisson system approach and can also penetrate and excavate out potential subsurface obstructions.

ISS has been successfully implemented at several MGP sites to physically immobilize residual coal tar and can be an effective remedial technology. However, observations of the fill within the former relief holder footprint indicate the presence of large pieces of concrete and other obstructions within a heterogeneous fill mixture containing wood, glass, brick, and other debris. Additionally, there is limited area available within the Site to accommodate the large footprint of an ISS operation. These subsurface conditions and space constraints would limit the effectiveness of ISS and complicate implementation of this technology. Based on this evaluation, solidification/stabilization approaches (including ISS) were eliminated from consideration.

4.6.5 Bioremediation

Bioremediation is a managed process in which microbiological activity results in the transformation of chemical constituents in soil and/or groundwater to other compounds. The microorganisms, which may be either naturally occurring or injected as part of a managed bioremediation process, require carbon sources and nutrients to provide energy for growth and survival. Degradation of natural substances in soil, and carbon from the COCs, provide food for the development of microbial populations in these media. Under aerobic conditions, bioremediation results in the conversion of many organic COCs to carbon dioxide, water, and microbial cell mass; under anaerobic conditions, the by-products of bioremediation include methane and carbon dioxide. For the purposes of this RAP, biological natural attenuation processes are considered different than bioremediation in that bioremediation relies on intentional initiation and management of the biological treatment processes.

In situ bioremediation of soil or groundwater typically involves the addition of water containing dissolved oxygen, nutrients, electron acceptors and/or specific contaminant degrading microorganisms to the subsurface. Bioventing, i.e., the addition of oxygen to the subsurface, can also be performed to enhance naturally occurring biodegradation. VOCs and light hydrocarbons are readily degraded under aerobic conditions, but MGP-related DNAPL and high molecular weight PAHs, such as those present at this property, are extremely slow to biodegrade and are generally deemed persistent in the environment. In addition, the multi-ring high molecular weight PAHs that are some of the risk drivers at MGP sites often degrade only partially, with the resulting intermediate compounds posing equal or greater risk than the original COCs. Therefore, in situ bioremediation was not retained for further evaluation.

4.6.6 Thermal Treatment

Thermal treatment involves the application of steam or hot air injection, or the use of electrical resistance, conductive, electromagnetic, or radio frequency heating. This technology can be used to enhance SVE by increasing the rate of volatilization of VOCs and SVOCs (and thereby increasing vapor extraction rates). Thermal treatment may also be used to heat NAPL into a less viscous state where it can be recovered via active extraction wells or trenches. Thermal treatment above the boiling point of water would decrease the viscosity of coal tar NAPL, potentially resulting in its effective removal through active extraction. Due to the limitations associated with SVE and active extraction, as described above, and the safety considerations associated with implementing such technology in close proximity to active gasoline dispensing operations, and occupied structures, thermal treatment was not deemed appropriate at this Site and was eliminated from further consideration.

4.7 EX SITU TREATMENT TECHNOLOGIES (REMOVAL, MANAGEMENT, AND DISPOSAL)

Ex situ treatment technologies apply to the treatment of environmental media following removal from the subsurface. The approach can be used for both soil (excavation), and groundwater (extraction).

Excavation has been successfully used at many MGP sites to remove soil with localized elevated OHM concentrations, typically from relatively shallow depths (<15 feet bgs). Complicating factors in areas of the Site include the presence of subsurface utilities, historical MGP infrastructure, building foundations, and/or DNAPL. Each of these factors can be addressed, but add significantly to the technical complexity of this option. Excavation has been retained for additional evaluation, and issues related to the handling and management of materials that may be removed from the Site are discussed in the following sections.

Due to the odor issues associated with MGP constituents, primarily naphthalene but also reduced sulfur compounds, air monitoring and odor management would need to be an integral part of an excavation operation. Air monitoring parameters and action levels would be established prior to the initiation of excavation, and ambient air in the work zone and at the perimeter would be monitored for some or all of the following parameters: carbon monoxide, percent oxygen, lower explosive limit, hydrogen sulfide, hydrogen cyanide gas, dust, and/or VOCs. The use of odor- and VOC-suppressing foam may be required to limit olfactory impacts on facility workers, customers and other potential human receptors. It is anticipated that standard dust control techniques, such as watering down unpaved surfaces in areas of heavy equipment traffic or watering uncovered dry soils, would also be implemented.

Once the soil has been removed from the subsurface, thermal treatment is a generally accepted means of treatment for coal tar-impacted soil. The physical destruction of the coal tar through thermal treatment allows the soils to be reused as fill after treatment, which is a more sustainable approach for the remediation of these materials. The Clean Earth – ESMI (ESMI) thermal treatment facility in Loudon, New Hampshire is within reasonable trucking distance to the Site and would typically be the preferred destination for any soil that is excavated. However, past experience has indicated that certain soils excavated from within the former holder may not meet ESMI's acceptance criteria and could also have hazardous waste characteristics requiring additional consideration for off-site disposal. Therefore, alternatives such as transportation of the soil to a landfill facility such as the Waste Management Turnkey landfill in Rochester, New Hampshire or an out-of-state hazardous waste receiving facility must also be considered as a potential option.

In the case of excavation below groundwater, dewatering and groundwater management would be required. It is likely that standard techniques for control of groundwater (e.g., excavation sumps) could be employed. Extracted groundwater could be collected for off-site treatment/disposal, although costs could be prohibitive if large quantities of liquids are generated. Dewatering effluent could also be treated to remove Site COCs and then discharged to the ground, the Little River, or the sanitary sewer system. Discharge to the ground surface would be regulated under 310 CMR 40.0045 and would likely be impractical at this Site given the high water table within the former holder and the logistical constraints. Surface water discharges would require permitting under the successor program to the USEPA's National Pollutant Discharge Elimination System (NPDES) Remediation General Permit (RGP). As an alternate approach, treated effluent could be discharged to the sanitary sewer system[2] at the Site under an appropriate permit.

5.0 SELECTION AND JUSTIFICATION OF A COMPREHENSIVE REMEDIAL ALTERNATIVE (310 CMR 40.0861(2)(b))

As noted above, potential risks to construction/utility workers within the footprint of the former relief holder area estimated using conservative exposure assumptions exceeded the MCP risk criteria. These risk estimates were driven primarily by benzene and naphthalene concentrations in groundwater within the former structure. Due to the presence of an active utility (electric line) within the holder footprint, exposures to workers without the benefit of typical health and safety procedures has to be assumed. NAPL observed in one location within the structure was deemed to be infeasible to recover and soil and groundwater concentrations in this area were below UCLs. However, the observed groundwater concentrations at well MW-1, the presence of separate phase product at B107, and the perched groundwater conditions

[2] Note that discharge of groundwater to sanitary sewer systems is prohibited within the Massachusetts Water Resource Authority (MWRA) jurisdiction but Haverhill has its own treatment system which allows such discharges.

(representing a mechanism for radial flow outward from the former holder structure) could be indicative of a residual source of OHM under conservative assumptions. Remedial action alternatives were developed to address these two items – potential risks to utility/construction workers and the possibility of conditions within the former holder constituting a residual OHM source.

Section 5.1 describes each of the evaluation criteria to provide context for the Phase III evaluation process, and Section 5.2 describes how these criteria were used to evaluate RAAs that were developed to address conditions at the Site. In general, the technologies retained following the initial screening were combined to develop RAAs to achieve a Permanent Solution. The RAAs were then evaluated in terms of the MCP-established criteria, as documented in Table 2.

5.1 EVALUATION CRITERIA

Section 310 CMR 40.0858 of the MCP lists the following specific criteria that must be evaluated to evaluate the potential feasibility of RAAs at a site. Descriptions of each of the criteria are presented below:

Effectiveness: the effectiveness of achieving a Permanent or Temporary Solution; reusing, recycling, detoxifying or treating OHM; and reducing OHM levels at the Site to concentrations that achieve or approach background levels.

Reliability: the degree of certainty of successfully attaining remedial goals, as well as the effectiveness of associated measures required to manage residues or remaining wastes, or to control emissions or discharges to the environment.

Difficulty of implementation: technical complexity in terms of integration with existing facility operations or other current/potential remedial actions; any necessary monitoring, operating and maintenance or Site access requirements or limitations; the availability of materials, services, equipment or specialists; the availability of off-site treatment storage or disposal facilities; and whether the alternative meets regulatory requirements.

Relative cost: costs of implementation, the costs of environmental restoration and potential damages to natural resources, and the relative consumption of energy resources in the operation of the alternative.

Risks: short-term on-site and off-site risks posed during implementation/operation and during the period of attaining applicable standards, and the potential risks of harm to health, safety, public welfare or the environment at the Site after completion of the remedial action.

Benefits: comparative benefits, including restoration of natural resources, providing for the productive reuse of the Site, avoided costs of relocating people and businesses, and increased value of the Site; also, the relative effect of each alternative on non-pecuniary interests, such as aesthetic values.

Timeliness: the length of time required to achieve a level of No Significant Risk.

5.2 DEVELOPMENT AND EVALUATION OF REMEDIAL ACTION ALTERNATIVES

This section outlines the two potential remedial alternatives developed for the upland portion of the 284 Winter Street property:

1. Relocation of Utility Line within the Holder Footprint (**RAA-1**)

2. Focused Excavation of Impacted Soil/Fill within the Holder with Dewatering (**RAA-2**).

Note that full-scale excavation of the material within the holder footprint was considered but deemed to be infeasible due the substantial disruption to property operations that would occur and the costs involved. Note that the former holder extends beneath the southwestern portion of the existing car wash building; significant demolition and reconstruction and business disruption including temporary closure would be required for that alternative.

Development, screening, and evaluation of remedial alternatives for the Little River portion of the Site is documented in Appendix C.

RAA-1: Relocation of Utility Line

Based on geophysical studies and Site observations, an active subsurface electrical line runs roughly north-south through the eastern/central portion of the former holder, just west of the car wash building (See Figure 4). Under this alternative, the existing line within the holder would be abandoned and rerouted below grade outside of the structure's footprint. This would eliminate the potential exposure pathway that resulted in the risk limit exceedances. Potential exposures to future construction workers would be controlled via the filing of an AUL requiring appropriate health and safety and soil management procedures for excavations in this area. The AUL would also prohibit installation of new subsurface utilities within the footprint of the former holder.

This RAA would also include an evaluation of the potential for other subsurface utility lines within the holder footprint, incorporating both surface geophysical methods and vacuum excavation probes. Supplemental assessment of subsurface conditions within the holder would also be part of this remedial option; up to four additional explorations would be advanced within the limits of the holder (as determined from historical plans and geophysical work) to observe and document soil and groundwater conditions for consistency with existing data. If the supplemental assessment work confirms that conditions within the holder are not indicative of a continuing source of OHM that would warrant supplemental remedial action, rerouting of the electrical line would proceed. If conditions in other portions of the holder footprint are observed to vary significantly from existing data, a supplemental Phase III evaluation may be required. The line would be routed from the light pole just south of the car wash building to the southeast corner of the structure within a shallow trench (Figure 4). Excavated soils would be reused as backfill to the extent feasible and the surface cover would be restored. Excess soils would be transported off-site for appropriate treatment/disposal, preferably for thermal treatment and recycling. We anticipate that the volume of soils requiring off-site treatment/recycling under this alternative would be negligible (less than 10 cubic yards).

RAA-2: Focused Excavation of Impacted Soil/Fill within the Holder with Dewatering

This approach would involve focused excavation of impacted fill within the holder which exhibits evidence of the potential presence of "residual source" material. Soils within the 10 to 14 foot bgs range at exploration B107 (outside and west of the car wash building) which indicated coal tar saturation would be the primary target of this excavation program; the excavation may be expanded based on the results of supplemental assessment activities[3]. Excavated soils would be placed in lined and covered roll-off containers pending off-site treatment/disposal. We estimate that up to 100 to 200 cubic yards of soil/fill would be excavated under this option. Dewatering would be required to support the excavation activities and lower the perched groundwater level (approximately 3 feet bgs) within this portion of the holder. Groundwater would be pumped from sumps within the excavation to a fractionation (frac) tank staged within the Site. Depending upon the quality of the extracted groundwater, it would either be transported off-site directly for treatment/disposal via tanker

[3] The supplemental assessment program for the former relief holder outlined under RAA-1 above would be completed for RAA-2 also.

trucks or pre-treated on-site with a mobile system and then trucked off-site for disposal. We estimate that 20,000 gallons of groundwater will be generated for treatment/disposal as part of this remedial option.

During the focused excavation, a portion of the northern wall of the former holder will be excavated and observed. Under the assumption that the holder wall is sustaining the perched groundwater condition, the portion of the wall exposed in the excavation will be removed or breached to a depth of approximately 6 feet bgs. This would limit any future mounding of groundwater following the excavation/dewatering work, eliminate the shallow groundwater condition driving the emergency utility worker risk exceedance and further eliminate/control any residual source conditions by reducing COC concentrations in this portion of the Site. The excavation would then be backfilled with any suitable materials segregated during excavation supplemented by off-site borrow. Following backfilling, the pavement surface will be restored and any obvious cracks or holes in the asphalt pavement or concrete overlying the former holder footprint will be sealed to limit future infiltration. An AUL restricting future residential usage of the Site (along with certain other activities and usage) and requiring appropriate health and safety and soil management procedures for excavations would also be filed for the property under this alternative.

A comparative evaluation of both RAAs using the criteria established by the MCP is summarized in Table 2 and discussed below.

5.2.1 Effectiveness

Both RAA-1 and RAA-2 would lead to a Permanent Solution with Conditions for the upland portion of the Site. Under RAA-1, the only exposure pathway that could pose a significant risk (construction/utility workers exposure to COCs in air within a trench originating from shallow groundwater) would be addressed, resulting in a condition of No Significant Risk. An AUL would also be required to prohibit installation of new utilities within the former holder footprint, restrict residential use and require appropriate health and safety procedures for excavations. Under RAA-2, the focused soil removal, dewatering and modifications to the former holder wall would eliminate the shallow groundwater condition driving the risk exceedance and reduce COC concentrations in groundwater. An AUL restricting future residential usage of the Site and requiring appropriate health and safety procedures for excavations would also be required under this option.

Based on available data on Site soils, it is assumed that material excavated under either alternative would be transported to ESMI or a similar facility for off-Site treatment by thermal desorption and/or recycling. Under RAA-2, it is likely that some portion of the excavated soil will not be accepted for thermal treatment and recycling at ESMI; instead, landfill disposal may be required for these materials based on prior experience at similar sites. Accordingly, OHM would be destroyed or recycled under RAA-2 but not all OHM generated under RAA-2 would be destroyed/recycled. Neither RAA would achieve or approach background in the near future.

5.2.2 Reliability

Both RAA-1 and RAA-2 represent reliable approaches to achieving a condition of No Significant Risk. RAA-1 would eliminate the emergency utility repair exposure scenario that could pose a significant risk but would rely on an AUL to properly manage future excavation in this area. RAA-2 would also rely on an AUL to limit exposures via future excavations across the Site, although estimated risk limits were not exceeded outside of the holder area. RAA-2 would include excavation of only a small fraction of the material within the former holder; the reliability of this approach in eliminating/controlling a potential OHM source would be limited. This option would also include handling and removal of significantly higher volumes of waste (soil, groundwater, and debris) with accompanying generation of emissions; in contrast, RAA-1 will generate a negligible volume of soil with no significant potential for air emissions. The wastes and emissions generated under either RAA can be managed under the MCP and in accordance with standard practice at MGP sites.

5.2.3 Comparative Difficulty

RAA-2 would be a technically and logistically complex operation involving excavation and dewatering near existing gasoline station and car wash operations and infrastructure on a relatively small property in an urban setting. It would be substantially more complex than RAA-1, because it would require deep excavations, associated dewatering and water treatment or disposal, and management of larger volumes of impacted remediation waste. Both RAAs would have some impact on facility operations, but the adverse impact of RAA-2 would be significantly greater because it would likely require that facility operations be suspended during implementation. Air monitoring and odor control would be required during both RAAs, but would be much more extensive under RAA-2 because of the greater volumes of excavation involved and the higher COC concentrations in the excavated material. Experienced personnel and equipment are anticipated to be readily available to implement either RAA, and arrangements exist between National Grid and disposal facilities for the treatment or recycling of remediation waste. For either alternative, the work would be conducted on property that is not owned or occupied by National Grid, so access arrangements would be required with the current property owner.

5.2.4 Comparative Costs

RAA-2 is estimated to be substantially more costly than RAA-1, with an estimated cost of approximately $228,000[4] compared to an estimated cost of approximately $61,000 for RAA-1. Cost estimates for each option are summarized on Table 3. The RAA-2 costs are higher due to a larger volume of material required to be excavated and disposed of (10 CY for RAA-1 versus 200 CY for RAA-2), the requirement for dewatering and water treatment or disposal , additional duration of the remedial work, and additional odor control required for RAA-2.

5.2.5 Comparative Risks

There would be short-term risks associated with both RAAs, including soil management and odor control, and transportation of remediation wastes, but these would be minimal under RAA-1 due to the shallow excavation depths and small quantity of soil for excavation. RAA-2 has additional short-term risks that RAA-1 does not, including risks associated with groundwater management, additional truck traffic for transportation of larger volumes of remediation waste, and higher potential for exposure to MGP-impacted soils. Based on experience at other sites, these short-term risks can be managed using best management practices and established protocols. More significantly, however, under RAA-2 there would be moderately high risk associated with deeper excavations near existing infrastructure, along with the risk of interruption of the car wash operations.

The known longer-term risks associated with residual OHM would be higher under RAA-1, under which residual OHM concentrations in the holder area would not be addressed. However, there is moderate risk of mobilizing NAPL in the subsurface under RAA-2 while excavating and dismantling a portion of the holder wall.

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[4] Note that this estimate does not include business disruption costs for the car wash.

5.2.6 Comparative Benefits, including Non-Pecuniary Benefits

Both RAAs would allow for productive continued use of the property. RAA-1 has the benefit of limiting disruption of current facility operations, while RAA-2 has lower potential lost value associated with restrictions on possible future property usage. Restoration of natural resources is not an applicable criterion in this heavily developed location, and neither RAA would offer significant non-pecuniary or aesthetic benefits. Note, however, that RAA-2 would generate a significantly larger volume of remediation waste, and higher emissions of greenhouse gases associated with the transportation of impacted soils and groundwater from the Site to treatment/disposal facilities, and would therefore have a substantially higher carbon footprint.

5.2.7 Comparative Timeliness

In the short-term, RAA-2 would take longer to complete than RAA-1 due to the larger volume of excavation and dewatering and associated water treatment/disposal. The design phase for RAA-2 would also be considerably longer than that of RAA-1. However, we anticipate that either option could be completed within 1 year.

5.2.8 Summary of Detailed Evaluation

Both RAA-1 and RAA-2 represent effective and reliable approaches to achieving a condition of No Significant Risk in the upland portion of the property. The two alternatives are comparable in terms of benefits. However, RAA-2 is substantially more complex, both logistically and technically, due to the deeper excavation and dewatering required, which also results in significant additional short-term risks during remediation compared to RAA-1. RAA-2 would have higher greenhouse gas emissions associated with the additional transportation of remedial waste and is estimated to be significantly more costly than RAA-1. RAA-2 will also take longer to complete than RAA-1 due to design requirements and the larger and more complex scope. Therefore, based on the criteria of comparative difficulty, cost, risks, and green benefits, RAA-1 was selected as the preferred remedial alternative for the 284 Winter Street upland area.

5.3 LITTLE RIVER REMEDIAL EVALUATION

A Phase III evaluation conducted by Anchor for the impacted portion of the Little River and the retaining wall separating the river from the upland portion of the 284 Winter Street property is included as Appendix C of this submittal. Anchor selected partial dredging and capping of sediments within the Little River and sealing of any preferential migration pathways in the retaining wall as the preferred remedial alternative for this area.

5.4 SELECTED COMPREHENSIVE REMEDIAL ALTERNATIVE

The selected CRA for the 284 Winter Street Site includes the following RAAs:

- Relocation of the electrical line that presently runs through the former relief holder;
- Implementation of an AUL that prohibits installation of new underground utility lines within the footprint of the relief holder and restricts residential and certain other future uses of the Site;
- Sealing/removal of historical piping and penetrations in the retaining wall that separates the upland portion of the Site from the Little River; and
- Focused dredging and capping of the sediments within the Little River adjacent to the Site.

5.5 GREEN REMEDIATION EVALUATION

The June 2014 MCP revisions included requirements to include assessment of "green" remediation approaches when evaluating and selecting remedial alternatives under the MCP. MassDEP issued guidance for implementing this requirement in October 2014 ("Greener Cleanup Guidance, WSC#14-150). This guidance references the USEPA definition of "green" remediation as "the practice of considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprints of cleanup actions". As indicated in the guidance, the principal regulatory authority relevant to green remediation is part of the Response Action Performance Standards (RAPS) of the MCP (310 CMR 40.0191(3)(e)). The RAPS citation follows:

(3) The application of RAPS shall be protective of health, safety, public welfare, and the environment and shall include, without limitation, in the context of meeting the requirements of this Contingency Plan, consideration of the following:

(e) eliminating or reducing, to the extent practicable and consistent with response action requirements and objectives, total energy use, air pollutant emissions, greenhouse gases, water use, materials consumption, and ecosystem and water resources impacts, resulting from the performance of response actions through energy efficiency, renewable energy use, materials management, waste reduction, land management, and ecosystem protection.

The green remediation requirements are also incorporated into the detailed evaluation of remedial alternatives under the comparative cost criteria (310 CMR 40.0858(4)).

MassDEP's guidance is directed at supporting environmental professionals in the consideration and use of approaches that eliminate or reduce the environmental footprint of cleanup activities to the extent possible. Five core elements to be addressed by such approaches are identified within the guidance:

- Minimizing total energy use while maximizing the use of renewable energy;
- Minimizing emissions of greenhouse gases and other air pollutants;
- Minimizing water use and impacts to water resources;
- Reducing, reusing, and recycling materials and waste; and
- Avoiding or reducing adverse impacts to ecosystems and land resources.

RAAs that limit the volume of soil or groundwater removed from the Site result in smaller volumes of remediation waste. This in turn results in significantly fewer truckloads of material to be transported from the Site and backfill material imported to the Site, resulting in a lower carbon footprint associated with such transportation. These objectives will be achieved by the selection of RAAs that are targeted to Site-specific conditions in each area of the property; these include the relocation of the electrical line rather than excavating a portion of the former holder area and a focused sediment dredging and capping approach in place of full-scale sediment removal. The combination of these efforts will limit the volume of waste generation, greenhouse gas emissions, and water and energy use while still addressing the appropriate MGP-impacted media and resulting in a condition of No Significant Risk at the Site.

To manage the limited but unavoidable effects of the selected CRA implementation, rigorous controls will be implemented to limit air and dust emissions, runoff and noise throughout the remedial process. Construction vehicle idling and emissions will be limited to the extent feasible. The project schedule will be arranged to combine tasks, where appropriate, and limit trips to the Site.

It is GZA's opinion that the proposed remedial plan addresses the relevant requirements of 310 CMR 40.0191(3)(e). Details regarding the implementation of the selected CRA will be provided in an upcoming Phase IV Remedy Implementation Plan (RIP) to be submitted to MassDEP.

6.0 ADDITIONAL PHASE III RAP REQUIREMENTS

Following the selection of a CRA, the MCP prescribes certain evaluations that must be documented in a Phase III RAP. The requirements listed under Sections 310 CMR 40.0861(2)(d), (f) and (h) are only required in cases where the selected CRA will result in a Temporary Solution and hence do not apply to the upland remediation documented in this report. The following sections address the remaining requirements of Section 310 CMR 40.0861. These requirements are addressed in Section 7.2 of Anchor's Phase III report in Appendix C for the selected RAA for the Little River portion of the Site.

6.1 DISCUSSION OF PERMANENT SOLUTION (310 CMR 40.0861(2)(E))

Section 310 CMR 40.0861(2)(e) requires that, if a Permanent Solution is selected as the Comprehensive Remedial Alternative, the Phase III RAP include a discussion of (i) how the alternative is likely to achieve a level of No Significant Risk and (ii) the projected timeframe, based on available information, for meeting the requirements for a Permanent Solution.

RAA-1 can be implemented expeditiously to achieve a Condition of No Significant Risk (assuming the filing of an AUL prior to the PSS). Specifically, the electrical line can be relocated in a timely fashion to eliminate the potential exposure to emergency utility workers at the Site. It is anticipated this RAA can be implemented within the next 12 to 18 months.

6.2 FEASIBILITY OF ACHIEVING/APPROACHING BACKGROUND (310 CMR 40.0861(2)(G))

Under Section 310 CMR 40.0861(2)(g), if a Permanent Solution is selected, the RAP must include the results of the evaluation under 310 CMR 40.0860 of the feasibility of reducing the concentrations of OHM material in the environment at the disposal site to levels that achieve or approach background, unless it includes a demonstration that the selected alternative is designed to achieve background.

In the upland portion of 284 Winter Street, approaching background would require that soil across the property, including soil beneath the car wash building, be excavated to a depth of 10 to 20 feet bgs and replaced with clean fill material. The costs for demolition and restoration of the building, and excavation of an approximately 45,000 square foot area to a depth of 15 feet with associated retaining wall reconstruction, groundwater management and soil disposal costs, and temporary business closure are estimated to exceed $10,000,000. In contrast, the cost for the selected CRA is estimated at $68,000. MassDEP policy has established that the incremental costs of remediation to achieve or approach background may be deemed substantial and disproportionate (i.e., economically infeasible) if they exceed 20 percent of the cost to remediate to a condition of NSR; accordingly, achieving background is deemed infeasible at the Site.

6.3 PROJECTED SCHEDULE FOR IMPLEMENTATION OF PHASE IV ACTIVITIES (310 CMR 40.0861(2)(I))

Design and permitting efforts for the Little River portion of the remedy will govern the remedial schedule for the Site. It is anticipated that a package of plans and specifications will be developed over the next eleven months, and will be presented to MassDEP with a Phase IV Remedy Implementation Plan (RIP) in June 2023 in accordance with the Administrative Consent Order. Initiation of Little River remedy implementation will be largely dependent on the permitting process and property owner access negotiations and approvals. Upland remediation may be completed in advance of the Little River work.

Following completion of remedy implementation, a Phase IV completion statement will be filed. It is anticipated that some level of inspection and monitoring may be required under the MCP following submittal of the Phase IV completion statement.

6.4 PHASE III COMPLETION STATEMENT (310 CMR 40.0862)

In accordance with Section 310 CMR 40.0862 of the MCP, GZA hereby provides this LSP Opinion that:

- the selected Comprehensive Remedial Alternative is likely to achieve a Permanent Solution for both the upland and Little River portions of the Site, and
- the Phase III conforms with applicable Phase III performance standards and requirements.

The certification required by 310 CMR 40.0009 is provided on the accompanying BWSC-108 form (copy in Appendix B).

6.5 PUBLIC NOTIFICATION (310 CMR 40.0863)

In keeping with the public notification requirements established by Section 310 CMR 40.1403(3)(e) of the MCP, the Chief Municipal Officer and Board of Health for the City of Haverhill have been notified of the availability of this Phase III Remedial Action Plan. Copies of the notification letters, which included the conclusions from this evaluation, are included in Appendix D.

7.0 CONCLUSIONS

This Phase III Remedial Action Plan (RAP) selects the following Remedial Action Alternatives for the 284 Winter Street Site (RTN 3-32792):

- Relocation of the electrical line that presently runs through the former relief holder;
- Implementation of an AUL that prohibits installation of new underground utility lines within the footprint of the relief holder and restricts residential and certain other future uses of the Site;
- Sealing/removal of historical piping and penetrations in the retaining wall that separates the upland portion of the Site from the Little River; and
- Focused dredging and capping of the sediments within the Little River adjacent to the Property.

The design of the relevant components of these RAAs will be documented in a Phase IV Remedy Implementation Plan.

Tables

TABLE 1
INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
284 WINTER STREET SITE
HAVERHILL, MASSACHUSETTS
MASSDEP RTN 3-32792

Technology	Description	Feasibility and Effectiveness of Technology	Conclusion
No Further Action	No additional efforts made to mitigate or monitor contamination beyond that which may have already been performed.	Not applicable in areas with uncontrolled sources, substantial hazard, or condition of significant risk to current receptors. Due to the presence of a risk exceedance (construction/utility workers), this would not result in a Permanent Solution at the Site.	Not retained for further consideration.
Institutional Controls	Fence or otherwise isolate impacted areas; implement Activity and Use Limitation (AUL) to minimize or manage potential human exposure to impacted area.	AULs are considered appropriate for this Site and it is anticipated that one or more AULs will be implemented as part of the Permanent Solution.	Retained for further consideration as part of a Permanent Solution for the Site.
Natural Attenuation	Relies on naturally occurring processes such as volatilization, adsorption, dilution, oxidation, reduction, and biodegradation to reduce the mass, concentration, and/or toxicity of contaminants.	Natural attenuation has apparently not been effective at reducing concentrations within the former holder over the last 50 years; therefore, it was not deemed feasible for remediation.	Not retained for further consideration.
Containment			
• Cap/Engineered Barrier	Construct and maintain an engineered barrier as defined in 310 CMR 40.0996, or place a clean soil cap over impacted soils.	Capping reduces human or environmental to oil and/or hazardous material (OHM), but would not eliminate the potential risks to emergency utility workers.	Capping is not retained for further consideration.
• Vertical Barrier	Construct low permeability barriers to impede migration of groundwater (e.g., via adsorptive organo-clay).	Not an appropriate technology given that groundwater migration is not posing a significant risk.	Not retained for further evaluation.
• Groundwater Extraction	Pump groundwater from subsurface and either treat at surface and re-inject, discharge under a NPDES permit or dispose of at an off-Site facility.	Groundwater extraction is not an effective means for removing source materials but is effective as a support technology for deeper excavations.	Retained as a support technology for excavation.
NAPL Recovery			
• NAPL Recovery	Recovery of Dense or Light Non-aqueous Liquids using passive approaches	Effective in some scenarios, but NAPL has been deemed infeasible to recover at this Site	Not retained for further evaluation.
In-Situ Treatment			
• Soil Vapor Extraction (SVE) and/or Air Sparging (AS)	SVE: Extract and treat soil vapors from unsaturated zone. SVE/AS: Inject air below the water table to promote removal of volatile organic compounds (VOCs) from groundwater via volatilization and enhanced aerobic degradation, and capture sparge air in the unsaturated zone for treatment, if necessary.	Best suited to light hydrocarbons (e.g., gasoline); less effective for treatment of heavier hydrocarbons. The presence of heterogeneous fill material, as well as higher molecular weight manufactured gas plant (MGP) residuals, would limit the effectiveness of AS/SVE.	Not retained for further evaluation.
• Soil Flushing/Surfactants	Add surfactants to the soil matrix to desorb and capture constituents of concern (COCs)	Most effective at remediating VOCs and inorganic compounds; only moderately effective at desorbing Semi-VOCs from soils. The heterogeneity of the vadose zone/fill materials and the limited effectiveness in remediating the primary COCs make this an unsuitable technology. Therefore, soil flushing/surfactant addition is not retained for further evaluation.	Not retained for further evaluation.

TABLE 1
INITIAL SCREENING OF REMEDIAL TECHNOLOGIES
284 WINTER STREET SITE
HAVERHILL, MASSACHUSETTS
MASSDEP RTN 3-32792

Technology	Description	Feasibility and Effectiveness of Technology	Conclusion
In-Situ Treatment Cont'd			
• Chemical Oxidation	Inject chemical oxidizers such as ozone, hydrogen peroxide, permanganate, or persulfate into unsaturated soil or groundwater. Oxidation chemically converts hazardous compounds to less toxic compounds that are more stable, less mobile, and/or inert.	Oxidation would be difficult to implement due to heterogeneous fill and is less effective on heavier-end compounds. Because of its limited effectiveness at treating Site COCs, its inability to address source materials, and its primary use as a saturated zone technology, chemical oxidation was not retained for further evaluation.	Not retained for further evaluation.
• Solidification/ Stabilization	Add binders to the soil to encapsulate COCs in place and prevent migration.	Difficult to implement due to heterogeneous conditions, space constraints and the presence of numerous obstructions in the subsurface at the Site.	Not retained for further evaluation.
• In-situ Biotreatment	For unsaturated zone soil treatment, a vacuum blower draws air from trenches or wells screened in the unsaturated zone, enhancing aerobic biodegradation. For soil or groundwater treatment, water and nutrients can be added as needed to enhance biological degradation.	Less effective at degrading heavier hydrocarbons which are generally persistent in the environment. Less effective at remediating isolated pockets of COCs and source material within the soils.	Not retained for further evaluation.
• In-Situ Thermal Treatment	Introduce heat into the subsurface to volatilize contaminants and decrease nonaqueous phase liquid (NAPL) viscosity.	Thermal treatment is incompatible with current site usage as a gasoline service station.	Not retained for further evaluation.
Ex-Situ Treatment			
• Excavation	Excavate impacted soils and fill. Dewatering with treatment may be required.	Effective for addressing most OHM and reducing residual sources by removal of impacted materials. Typically most favorable at depths of less than 20 feet below grade, and in areas with limited subsurface utilities/buried infrastructure.	Retained for further consideration.
• On-Site Treatment following Removal	Excavated soil and sediment can be treated on-Site via biological, physical, chemical or thermal means, following which it can be re-used as backfill.	Installation and operation of an on-site soil or treatment process was deemed logistically infeasible given the limited size and active use of the potential work areas.	Not retained for further evaluation.
• Off-Site Disposal following Removal	Soil and sediment can be transported off -Site for disposal or recycling via a variety of processes, including thermal desorption, incineration, asphalt batch treatment, or landfilling.	Facilities for off-Site disposal or recycling are readily available, and arrangements are in place for remedial waste from National Grid sites to be transported to these facilities.	Retained for further consideration.
• Solidification/ Stabilization	Add binders to the soil to encapsulate COCs in place and prevent migration.	Difficult to implement due to heterogeneous conditions, space constraints and the presence of numerous obstructions in the subsurface at the Site.	Not retained for further evaluation.
• In-situ Biotreatment	For unsaturated zone soil treatment, a vacuum blower draws air from trenches or wells screened in the unsaturated zone, enhancing aerobic biodegradation. For soil or groundwater treatment, water and nutrients can be added as needed to enhance biological degradation.	Less effective at degrading heavier hydrocarbons which are generally persistent in the environment. Less effective at remediating isolated pockets of COCs and source material within the soils.	Not retained for further evaluation.
• In-Situ Thermal Treatment	Introduce heat into the subsurface to volatilize contaminants and decrease nonaqueous phase liquid (NAPL) viscosity.	Thermal treatment is incompatible with current site usage as a gasoline service station.	Not retained for further evaluation.

TABLE 2
DETAILED EVALUATION OF REMEDIAL ACTION ALTERNATIVES
284 WINTER STREET SITE
HAVERHILL, MASSACHUSETTS
MASSDEP RTN 3-32792

Evaluation Criterion	Remedial Action Alternative 1 Relocate Utility Lines and Implement Activity and Use Limitation	Remedial Action Alternative 2 Focused Soil Excavation with Dewatering and Implement Activity and Use Limitation
1. Comparative Effectiveness		
a) Ability to achieve a Permanent or Temporary Solution	Would lead to a Permanent Solution.	Would lead to a Permanent Solution.
(b) Ability to reuse, recycle, destroy, detoxify, or treat oil and/or hazardous materials (OHM)	OHM would not be removed, destroyed or treated.	Some OHM, including potential residual source material would be removed and destroyed/treated off site. Most impacted soils and groundwater would be left in place.
(c) Ability to reduce OHM levels to concentrations that achieve or approach background.	Would not achieve or approach background in the near future; natural attenuation would result in decreased concentrations over time.	Not likely to achieve or approach background; natural attenuation would result in decreased concentrations over time.
2. Comparative Reliability		
(a) The degree of certainty that the alternative will be successful	Strong degree of certainty that exposure pathway that could lead to significant risk would be eliminated.	The alternative should eliminate the key exposure pathway and effectively control risk but may not be effective in eliminating/controlling the potential residual OHM source.
(b) Residue/waste/emissions/discharge control or management	The limited excavation required would generate a small quantity of soil for management with accompanying dust and odor monitoring and control requirements.	Soil management, dust and odor monitoring and control, and groundwater management required.
3. Comparative Difficulty		
(a) Technical complexity	Low technical complexity. Shallow excavation and conventional electrical line installation protocols.	Moderate technical complexity due to the high water table, the need for dewatering and the proximity of existing site infrastructure. Additionally, modifying the holder wall to eliminate groundwater monitoring may be a complex undertaking.
(b) Integration with existing operations and other remedial actions	Would have to be coordinated with property owner, as an electrical outage may be required and the work is being done in access road to the car wash.	Would have to be coordinated with property owner, as work is being done in the parking lot of an active facility. Due to the need for excavated soil and extracted groundwater storage, the footprint of the work area would be expanded.
(c) Monitoring, operations, maintenance or site access requirements or limitations	Only limited air monitoring and odor control required. Potential property access issues are described above.	Air monitoring and odor control required. Potential property access issues are described above. Long-term monitoring or maintenance not required.
(d) Availability of necessary services, materials, equipment, or specialists	Equipment, materials, and personnel readily available.	Equipment, materials, and personnel readily available.
(e) Availability, capacity and location of off-site treatment, storage and disposal facilities	Remediation waste can be readily disposed of under existing arrangements between National Grid and off-site facilities.	Remediation waste can be readily disposed of under existing arrangements between National Grid and off-site facilities.
(f) Likelihood of alternative being permitted/approved by regulatory agencies	Work is within the 100-foot buffer zone for the Little River so a filing with Haverhill Conservation Commission would be required. Approval is likely based on previous experience.	Work is within the 100-foot buffer zone for the Little River so a filing with Haverhill Conservation Commission would be required. Approval is likely based on previous experience.
4. Comparative Costs	$68,000	$210,000

TABLE 2
DETAILED EVALUATION OF REMEDIAL ACTION ALTERNATIVES
284 WINTER STREET SITE
HAVERHILL, MASSACHUSETTS
MASSDEP RTN 3-32792

Evaluation Criterion	Remedial Action Alternative 1 Relocate Utility Lines and Implement Activity and Use Limitation	Remedial Action Alternative 2 Focused Soil Excavation with Dewatering and Implement Activity and Use Limitation
5. Comparative Risks		
(a) Short-term risks associated with implementation	The limited potential risks including soil management, odor control, and transportation of remediation wastes, can be readily managed based on experience at other sites.	The limited potential risks including soil management, odor control, water management, traffic issues, and transportation of remediation wastes, can be readily managed based on experience at other sites.
(b) Long-term risks associated with implementation	None anticipated.	None anticipated
(c) Potential risk of harm to health, safety, public welfare or the environment by residual OHM	Risks associated with residual OHM (e.g. via violation of the AUL) would remain.	OHM concentrations would be reduced, as would the potential for exposure, but residual OHM would remain in soil and groundwater.
6. Comparative Benefits		
(a) Benefit of restoring natural resources	The upland portion of the property has limited value as a natural resource due to current and historical usage.	Removal of soils and possible residual source material would provide some benefit but upland portion of property has limited value as a natural resource..
(b) Providing for the productive reuse of the site	No change in the current productive use of the area is anticipated.	No change in the current productive use of the area is anticipated.
(d) Avoided lost value of the site.	No lost value and no change in use of property.	No change in use of property.
7. Comparative Timeliness	Can be performed in a timely manner.	Can be performed in a timely manner but time frame would be longer that RAA-1.
8. Effect on Non-pecuniary Interests	No effects on non-pecuniary interests were identified for this property.	No effects on non-pecuniary interests were identified for this property.

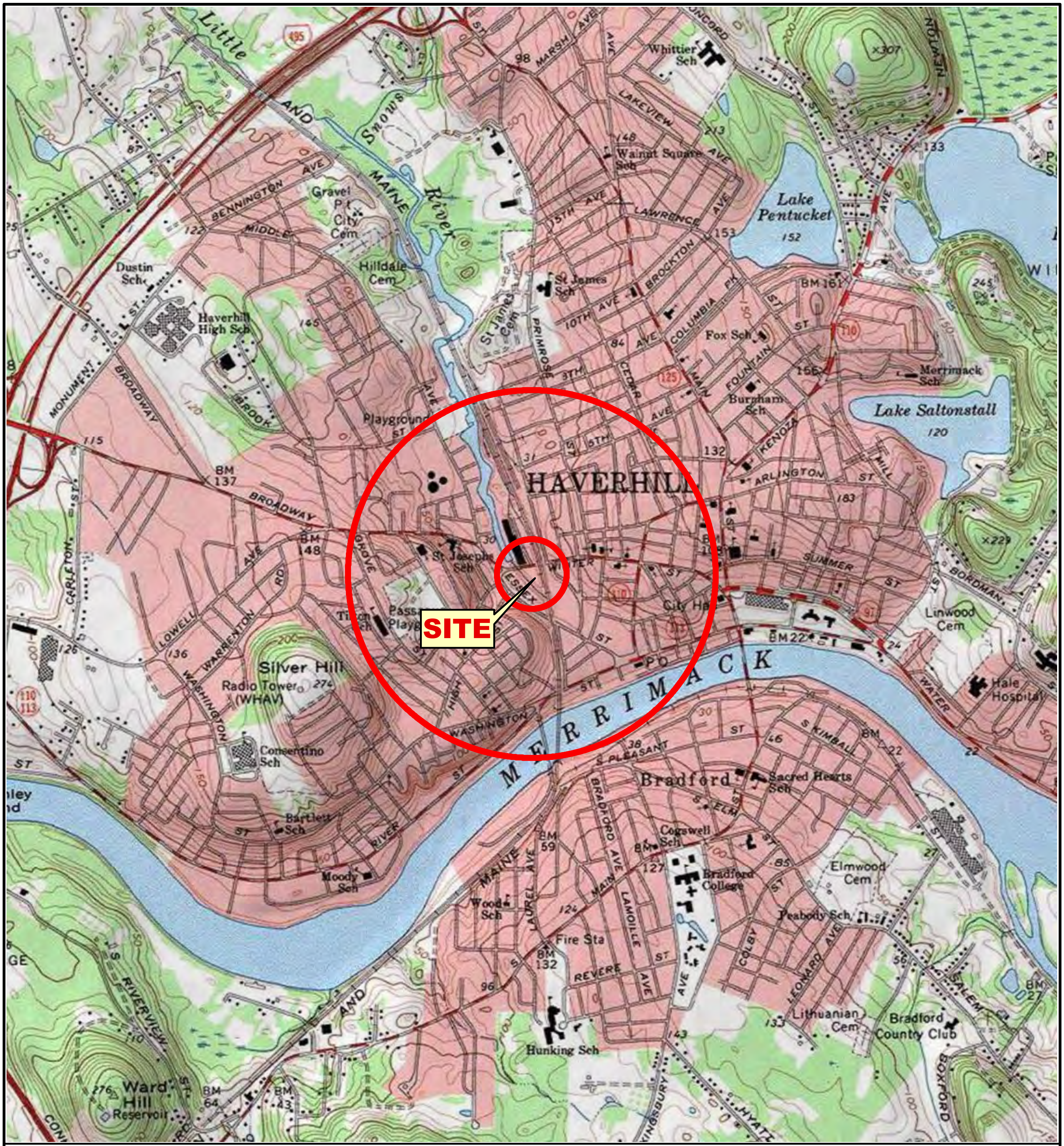
TABLE 3
COST ESTIMATE SUMMARY
284 WINTER STREET
HAVERHILL, MASSACHUSETTS

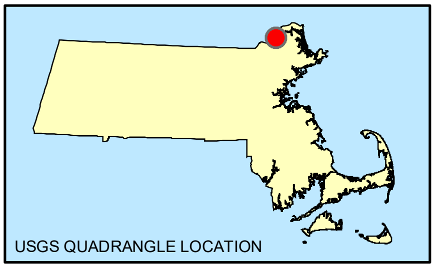
Item	RAA-1	RAA-2
Permitting, Engineering & Procurement	$8,000	$30,000
Supplemental Assessment	$15,000	$15,000
Mobilization/Site Preparation	$2,000	$10,000
Soil Excavation and Disposal	$5,000	$60,000
Groundwater Treatment/Disposal	$0	$50,000
Electrical Line Rerouting	$5,000	$0
Site Restoration	$2,000	$10,000
Activity and Use Limitation	$10,000	$10,000
Partial Permanent Solution Statement	$10,000	$10,000
Contingency - 25% (Construction Costs)	$4,000	$33,000
Total	$61,000	$228,000

Notes:

1. RAA-1 involves relocating the electrical line that passes through the former holder. RAA-2 includes a focused excavation and dewatering program to address soils near B107 (200 cubic yards).
2. This estimate of probable costs is based on a conceptual level design and should be considered preliminary and subject to future revision based on design refinement. Estimate is not to be considered for construction purposes.
3. The estimate presented is developed using current and generally accepted engineering cost estimation methods. Note that these estimates are based on assumptions concerning future events and actual costs may be affected by known and unknown risks. Actual costs may vary from these estimates and such variations may be material.
4. Costs are rounded as appropriate.
5. Soil excavation and disposal costs include the excavation, dewatering and treatment of extracted water, off-Site soil disposal, field oversight staffing, and equipment, analysis, and staffing required for environmental monitoring.
6. Permitting, engineering and procurement costs include design development, bid specification document preparation and procurement support, project management and the preparation of the Phase IV Remedy Implementation Plan.
7. A streamlined procurement effort was assumed for both options.

Figures





SOURCE : THIS MAP CONTAINS THE ESRI ARCGIS ONLINE USA TOPOGRAPHIC MAP SERVICE, PUBLISHED JUNE 19, 2019 BY ESRI ARCIMS SERVICES AND UPDATED AS NEEDED. THIS SERVICE USES UNIFORM NATIONALLY RECOGNIZED DATUM AND CARTOGRAPHY STANDARDS AND A VARIETY OF AVAILABLE SOURCES FROM SEVERAL DATA PROVIDERS.

Data Supplied by : esri

0 1,000 2,000 4,000 6,000

SCALE IN FEET

N W E S

PROJ. MGR.: KFM DESIGNED BY: KFM REVIEWED BY: CAL OPERATOR: SMW/EMD DATE: 06-22-2022	LOCUS PLAN SHOWING 500 FOOT & 1/2 MILE RADII	JOB NO. 01.0172397.10
	PHASE III REMEDIAL ACTION PLAN 284 WINTER STREET HAVERHILL, MASSACHUSETTS	FIGURE NO. 1

LEGEND

- AQSS-04 — APPROXIMATE SEDIMENT CORE LOCATION (ANCHOR QEA - 2021)
- VE-1 — VACUUM EXCAVATION PROBE PERFORMED BY GEOSEARCH AUGUST 11, 2021
- GZ-1 — MONITORING WELL INSTALLED BY GEOSEARCH AUGUST 31 - SEPTEMBER 1, 2020
- 1A — SEDIMENT SAMPLE COLLECTED BY GZA ON JUNE 8-10, 2020
- P1 — PIPE OR SEEP LOCATION
- SG-1 — SOIL GAS POINT PERFORMED BY GZA ON FEBRUARY 5, 2020
- B102 — MONITORING WELL INSTALLED BY GEOSEARCH JANUARY 21-23, 2020 AND OBSERVED BY GZA
- B101 — SOIL BORING PERFORMED BY GEOSEARCH (2020) AND OBSERVED BY GZA
- NFNP-01 — NAPL SAMPLE COLLECTED BY GZA PERSONNEL NOVEMBER 1, 2016
- NFSB-01 (MW) — MONITORING WELL INSTALLED BY TECHNICAL DRILLING SERVICES OCTOBER 20-25, 2016 AND OBSERVED BY GZA
- NFSB-05 — SOIL BORING PERFORMED BY TECHNICAL DRILLING SERVICES OCTOBER 20-25, 2016 AND OBSERVED BY GZA
- NFAA-01 — AMBIENT AIR SAMPLE COLLECTED BY GZA PERSONNEL OCTOBER 19, 2016
- NFSV-01 — SOIL VAPOR SAMPLE COLLECTED BY GZA PERSONNEL OCTOBER 18-19, 2016
- NFCB-01 — CATCH BASIN SEDIMENT SAMPLE COLLECTED BY GZA PERSONNEL OCTOBER 18-19, 2016
- ENV-1MW — MONITORING WELL INSTALLED BY RAMBOLL ENVIRON APRIL 27-28, 2015
- ENV-2B(A) — SOIL BORING COMPLETED BY RAMBOLL ENVIRON APRIL 27-28, 2015
- MW-1 — MONITORING WELL INSTALLED BY LESSARD ENVIRONMENTAL
- DISPOSAL SITE BOUNDARY
- 284 WINTER STREET PROPERTY BOUNDARY AS RECORDED ON ALTA/ACSM LAND TITLE SURVEY PLAN PERFORMED BY MHF DESIGN CONSULTANTS (STAMPED FEBRUARY 12, 2015) NOTE: THIS BOUNDARY DIFFERS FROM THE MASSGIS ASSESSORS PARCEL DATA.
- ASSESSORS PARCEL DATA PROVIDED BY MASSGIS ON SEPTEMBER 1, 2020

SOURCE

1) THIS MAP CONTAINS THE ESRI ArcGIS ONLINE BING MAPS AERIAL LAYER PACKAGE, PUBLISHED APRIL 13, 2020 BY ESRI ARCIMS SERVICES AND UPDATED MONTHLY. THIS SERVICE USES UNIFORM NATIONALLY RECOGNIZED DATUM AND CARTOGRAPHY STANDARDS AND A VARIETY OF AVAILABLE SOURCES FROM SEVERAL DATA PROVIDERS.
2) THE LOCATIONS OF THE MONITORING WELLS INSTALLED BY GEOSEARCH AUGUST 31 - SEPTEMBER 1, 2020 WERE LOCATED FROM A SURVEY PERFORMED BY THE MORIN-CAMERON GROUP, INC. ON SEPTEMBER 29, 2020. THE LOCATIONS OF THE SEDIMENT SAMPLES COLLECTED BY GZA IN JUNE 2020 AND THE PIPE LOCATIONS WERE APPROXIMATELY DETERMINED USING A TRIMBLE GEO-7X HAND-HELD GPS ON 06-10-2020. THE LOCATIONS OF THE MONITORING WELLS AND SOIL BORINGS PERFORMED BY GEOSEARCH IN JANUARY 2020 WERE APPROXIMATELY DETERMINED USING A TRIMBLE GEO-7X HAND-HELD GPS ON 05-07-2020. THE LOCATIONS OF THE NF SERIES OF EXPLORATIONS AND SAMPLING LOCATIONS WERE APPROXIMATELY DETERMINED USING A TRIMBLE GEO-XH HAND-HELD GPS ON 10-18-2016. THE LOCATIONS OF THE SOIL GAS POINTS INSTALLED BY GZA IN FEBRUARY 2020, SOIL BORING INSTALLED BY GEOSEARCH AUGUST 31, 2021 (GZA-2A), AND THE VACUUM EXCAVATION PROBES PERFORMED BY GEOSEARCH AUGUST 11, 2021 WERE APPROXIMATELY DETERMINED BY LINE OF SIGHT FROM EXISTING TOPOGRAPHIC AND MAN-MADE FEATURES. THESE DATA SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
3) THE LOCATIONS OF THE SOIL BORINGS AND MONITORING WELLS PERFORMED BY RAMBOLL AND THE MONITORING WELLS PERFORMED BY LESSARD WERE APPROXIMATELY DETERMINED FROM A PLAN PREPARED BY RAMBOLL ENTITLED: "SITE LAYOUT", FIGURE 2, DATED: 02-10-2017, PROJECT.: 1690005598.
4) THE LOCATIONS OF THE APPROXIMATE SEDIMENT CORE LOCATIONS PERFORMED BY ANCHOR QEA IN 2021 WERE DETERMINED FROM A GEODATABASE FILE PROVIDED BY ANCHOR QEA ON MARCH 29, 2022, FILE: AQ SAMPLE LOCATIONS 20220329.GDB.
5) THE HISTORIC RELIEF GAS HOLDER WAS APPROXIMATELY LOCATED FROM AN "UNDATED HISTORICAL PLAN" IN THE RAMBOLL ENVIRON PHASE I INITIAL SITE INVESTIGATION REPORT, DATED APRIL 2016.

0 25 50 100
SCALE IN FEET

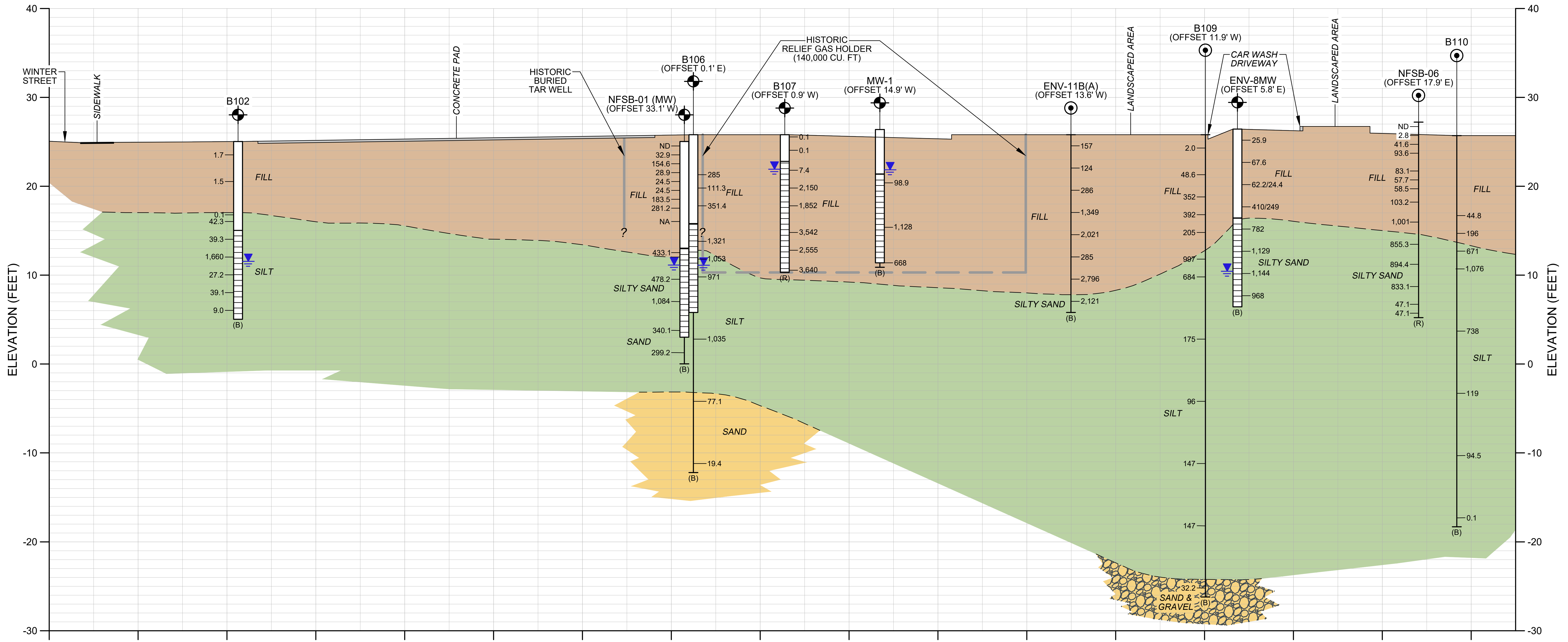
PHASE III REMEDIAL ACTION PLAN
284 WINTER STREET
HAVERHILL, MASSACHUSETTS

EXPLORATION LOCATION PLAN

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com

PREPARED FOR: nationalgrid

PROJ MGR: KFM	REVIEWED BY: CAL	CHECKED BY: KFM	FIGURE
DESIGNED BY: KFM	DRAWN BY: SMW/EMD	SCALE: 1 " = 50 FEET	2
DATE: 06/22/2022	PROJECT NO. 01.0172397.10	REVISION NO.	



GEOLOGIC CROSS-SECTION A-A'

LEGEND

B106 (OFFSET 0.1' E) — MONITORING WELL DESIGNATION; OFFSET DIRECTION & DISTANCE
GROUND SURFACE
WELL CASING
285 — PID RESULT (PPMV)
WELL SCREEN
GROUNDWATER ELEVATION IN FEET (SEPTEMBER 15, 2020 GAUGING)
APPROXIMATE STRATUM CHANGE
(B) — BOTTOM OF BORING

(R) - REFUSAL OF BORING
PID - PHOTOIONIZATION DETECTOR
PPMV - PARTS PER MILLION BY VOLUME
ND - INDICATES NOT DETECTED ABOVE INSTRUMENT DETECTION LIMIT (<0.1 PPMV)
NA - INDICATES NOT ANALYZED

STRATUM KEY

- FILL
- SILTY SAND / SILT
- SAND
- SAND & GRAVEL

NOTES:

1. THE STRATIFICATION LINES ARE APPROXIMATE, BASED UPON DATA FROM A LIMITED NUMBER OF WIDELY SPACED EXPLORATIONS AND THUS REPRESENT APPROXIMATE BOUNDARIES BETWEEN STRATUM TYPES. THE ACTUAL TRANSITIONS ARE EXPECTED TO BE MORE GRADUAL AND VARY FROM THOSE SHOWN.

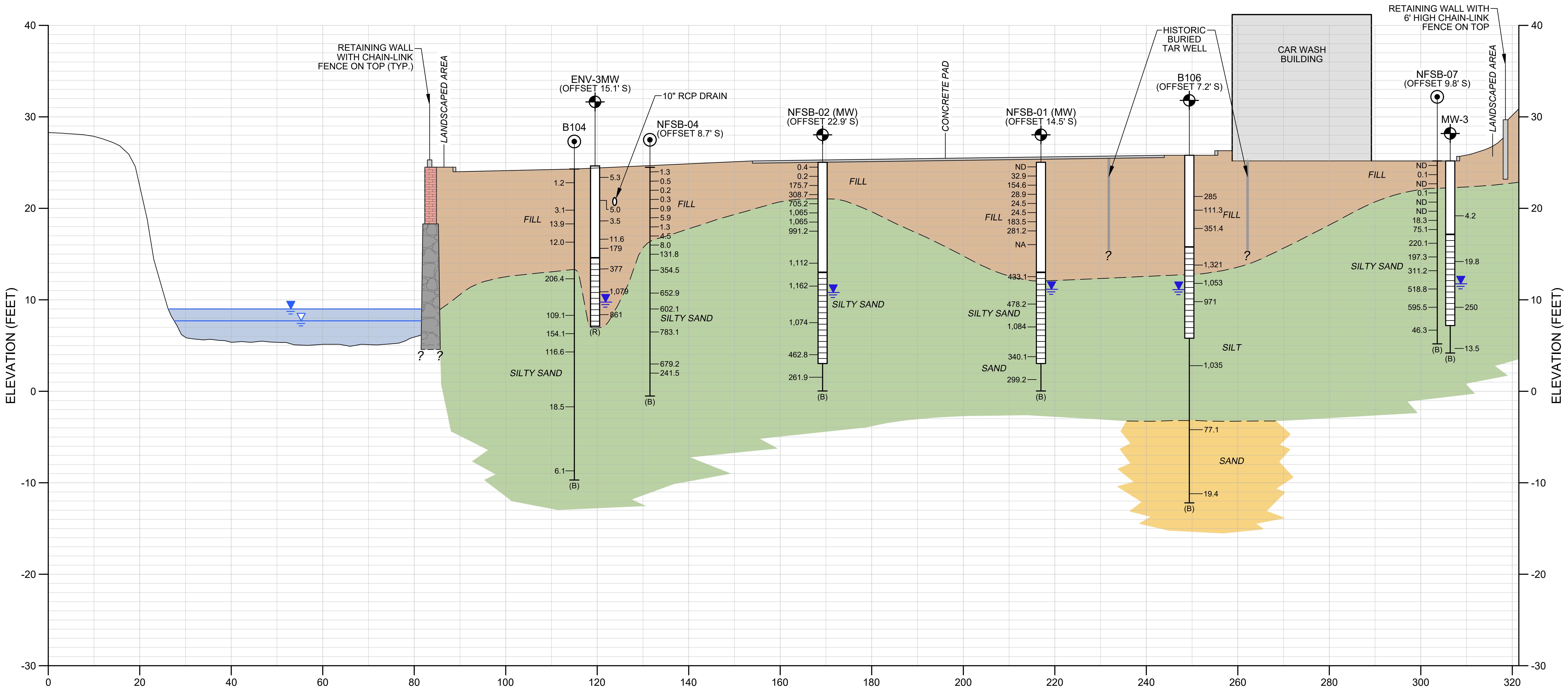
VERTICAL SCALE IN FEET: 0, 5', 10', 20'
HORIZONTAL SCALE IN FEET: 0, 10', 20', 40'

PHASE III REMEDIAL ACTION PLAN
284 WINTER STREET
HAVERHILL, MASSACHUSETTS

GEOLOGIC CROSS-SECTION A-A'

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com	PREPARED FOR: nationalgrid

PROJ MGR: KFM	REVIEWED BY: CAL	CHECKED BY: KFM	FIGURE
DESIGNED BY: KFM	DRAWN BY: EMD	SCALE: AS NOTED	3A
DATE: 06-22-2022	PROJECT NO. 01.0172397.10	REVISION NO.	



GEOLOGIC CROSS-SECTION B-B'

LEGEND

B106 — MONITORING WELL DESIGNATION
(OFFSET 7.2' S) — OFFSET DIRECTION & DISTANCE
GROUND SURFACE
WELL CASING
285 — PID RESULT (PPMV)
WELL SCREEN
GROUNDWATER ELEVATION IN FEET (SEPTEMBER 15, 2020 GAUGING)
APPROXIMATE STRATUM CHANGE
(B) — BOTTOM OF BORING

(R) - REFUSAL OF BORING
PID - PHOTOIONIZATION DETECTOR
PPMV - PARTS PER MILLION BY VOLUME
ND - INDICATES NOT DETECTED ABOVE INSTRUMENT DETECTION LIMIT (<0.1 PPMV)
NA - INDICATES NOT ANALYZED

STRATUM KEY

FILL
SILTY SAND / SILT
SAND

NOTES:

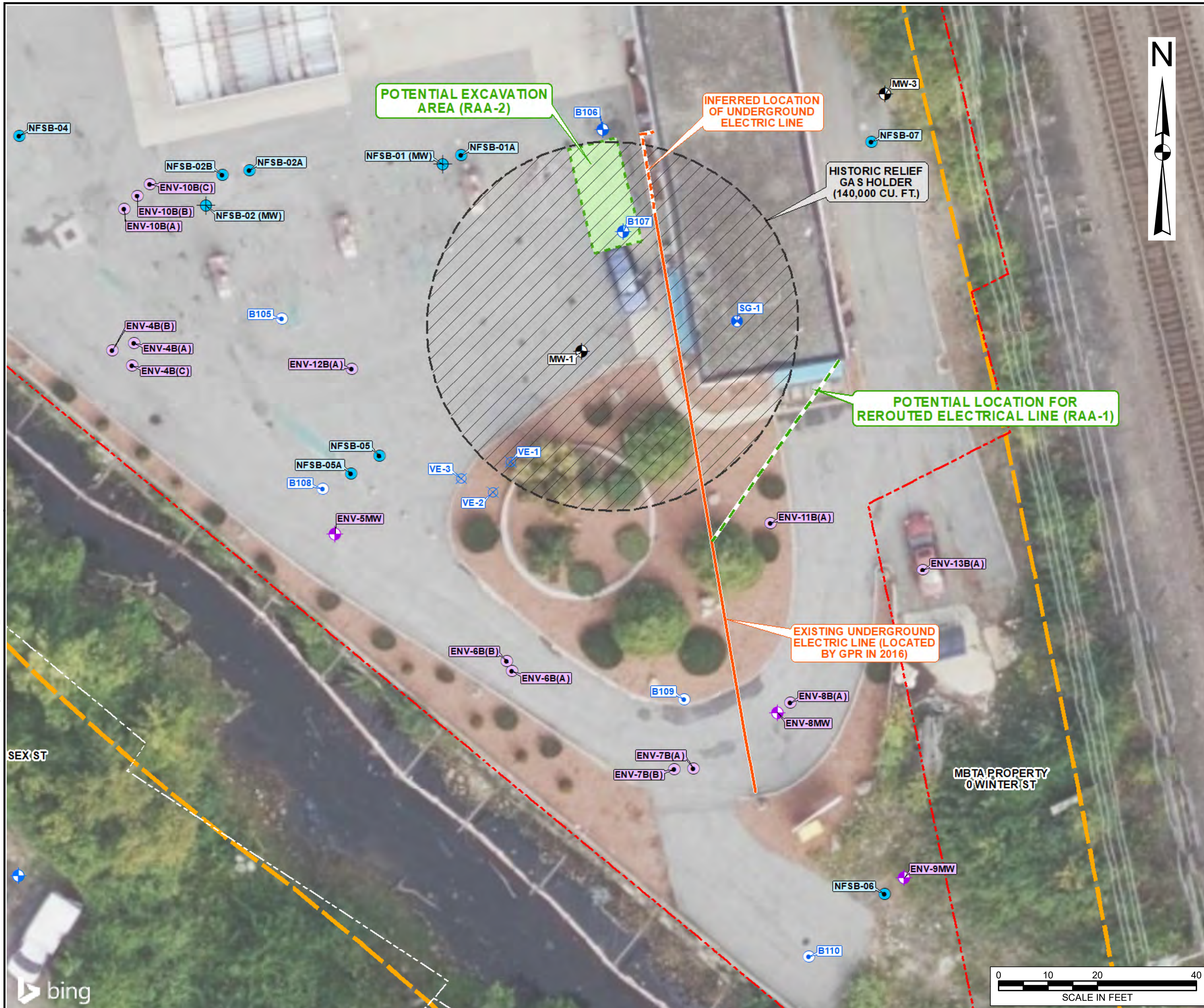
1. THE STRATIFICATION LINES ARE APPROXIMATE, BASED UPON DATA FROM A LIMITED NUMBER OF WIDELY SPACED EXPLORATIONS AND THUS REPRESENT APPROXIMATE BOUNDARIES BETWEEN STRATUM TYPES. THE ACTUAL TRANSITIONS ARE EXPECTED TO BE MORE GRADUAL AND VARY FROM THOSE SHOWN.

VERTICAL SCALE IN FEET
0 5' 10' 20'
0 10' 20' 40'
HORIZONTAL SCALE IN FEET

PHASE III REMEDIAL ACTION PLAN
284 WINTER STREET
HAVERHILL, MASSACHUSETTS

GEOLOGIC CROSS-SECTION B-B'

PREPARED BY:		PREPARED FOR:	
GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com		nationalgrid	
PROJ MGR: KFM	REVIEWED BY: CAL	CHECKED BY: KFM	FIGURE 3B
DESIGNED BY: KFM	DRAWN BY: EMD	SCALE: AS NOTED	
DATE: 06-22-2022	PROJECT NO. 01.0172397.10	REVISION NO.	



LEGEND

- VE-1 — VACUUM EXCAVATION PROBE PERFORMED BY GEOSEARCH AUGUST 11, 2021
- GZ-1 — MONITORING WELL INSTALLED BY GEOSEARCH AUGUST 31 - SEPTEMBER 1, 2020
- SG-1 — SOIL GAS POINT PERFORMED BY GZA ON FEBRUARY 5, 2020
- B102 — MONITORING WELL INSTALLED BY GEOSEARCH JANUARY 21-23, 2020 AND OBSERVED BY GZA
- B101 — SOIL BORING PERFORMED BY GEOSEARCH (2020) AND OBSERVED BY GZA
- NFSB-01 (MW) — MONITORING WELL INSTALLED BY TECHNICAL DRILLING SERVICES OCTOBER 20-25, 2016 AND OBSERVED BY GZA
- NFSB-05 — SOIL BORING PERFORMED BY TECHNICAL DRILLING SERVICES OCTOBER 20-25, 2016 AND OBSERVED BY GZA
- ENV-1MW — MONITORING WELL INSTALLED BY RAMBOLL ENVIRON APRIL 27-28, 2015
- ENV-2B(A) — SOIL BORING COMPLETED BY RAMBOLL ENVIRON APRIL 27-28, 2015
- MW-1 — MONITORING WELL INSTALLED BY LESSARD ENVIRONMENTAL
- DISPOSAL SITE BOUNDARY
- 284 WINTER STREET PROPERTY BOUNDARY ON AS RECORDED ALTA/ACSM LAND TITLE SURVEY PLAN PERFORMED BY MHF DESIGN CONSULTANTS (STAMPED FEBRUARY 12, 2015) NOTE: THIS BOUNDARY DIFFERS FROM THE MASSGIS ASSESSORS PARCEL DATA.
- ASSESSORS PARCEL DATA PROVIDED BY MASSGIS ON SEPTEMBER 1, 2020

SOURCE

1) THIS MAP CONTAINS THE ESRI ArcGIS ONLINE BING MAPS AERIAL LAYER PACKAGE, PUBLISHED APRIL 13, 2020 BY ESRI ARCIMS SERVICES AND UPDATED MONTHLY. THIS SERVICE USES UNIFORM NATIONALLY RECOGNIZED DATUM AND CARTOGRAPHY STANDARDS AND A VARIETY OF AVAILABLE SOURCES FROM SEVERAL DATA PROVIDERS.
2) THE LOCATIONS OF THE MONITORING WELLS INSTALLED BY GEOSEARCH AUGUST 31 - SEPTEMBER 1, 2020 WERE LOCATED FROM A SURVEY PERFORMED BY THE MORIN-CAMERON GROUP, INC. ON SEPTEMBER 29, 2020. THE LOCATIONS OF THE MONITORING WELLS AND SOIL BORINGS PERFORMED BY GEOSEARCH IN JANUARY 2020 WERE APPROXIMATELY DETERMINED USING A TRIMBLE GEO-7X HAND-HELD GPS ON 05-07-2020. THE LOCATIONS OF THE NF SERIES OF EXPLORATIONS AND SAMPLING LOCATIONS WERE APPROXIMATELY DETERMINED USING A TRIMBLE GEO-XH HAND-HELD GPS ON 10-18-2016. THE LOCATIONS OF THE SOIL GAS POINTS INSTALLED BY GZA IN FEBRUARY 2020, SOIL BORING INSTALLED BY GEOSEARCH AUGUST 31, 2021 (GZA-2A), AND THE VACUUM EXCAVATION PROBES PERFORMED BY GEOSEARCH AUGUST 11, 2021 WERE APPROXIMATELY DETERMINED BY LINE OF SIGHT FROM EXISTING TOPOGRAPHIC AND MAN-MADE FEATURES. THESE DATA SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
3) THE LOCATIONS OF THE SOIL BORINGS AND MONITORING WELLS PERFORMED BY RAMBOLL AND THE MONITORING WELLS PERFORMED BY LESSARD WERE APPROXIMATELY DETERMINED FROM A PLAN PREPARED BY RAMBOLL ENTITLED: "SITE LAYOUT", FIGURE 2, DATED: 02-10-2017, PROJECT.: 1690005598.
4) THE HISTORIC RELIEF GAS HOLDER WAS APPROXIMATELY LOCATED FROM AN "UNDATED HISTORICAL PLAN" IN THE RAMBOLL ENVIRON PHASE I INITIAL SITE INVESTIGATION REPORT, DATED APRIL 2016.

PHASE III REMEDIAL ACTION PLAN
284 WINTER STREET
HAVERHILL, MASSACHUSETTS

REMEDIAL ALTERNATIVES

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com

PREPARED FOR: nationalgrid

PROJ MGR: KFM	REVIEWED BY: CAL	CHECKED BY: KFM	FIGURE 4
DESIGNED BY: KFM	DRAWN BY: SMW/EMD	SCALE: 1 " = 20 FEET	
DATE: 06/23/2022	PROJECT NO. 01.0172397.10	REVISION NO.	

Appendix A

Limitations

LIMITATIONS

1. This revised Phase III Remedial Action Plan has been prepared on behalf of and for the exclusive use of Boston Gas Company d/b/a National Grid (National Grid) , solely for use in summarizing recent remedial evaluations completed at the 284 Winter Street property located in Haverhill, Massachusetts (Release Tracking Number 3-32792) under the Massachusetts Contingency Plan (MCP - 310 CMR 40.0000). This report and the findings contained herein shall not, in whole or in part, be disseminated or conveyed to any other party, nor used by any other party in whole or in part, without the prior written consent of GZA or National Grid. However, GZA acknowledges and agrees that the report may be conveyed to the Massachusetts Department of Environmental Protection (MassDEP).

2. GZA's work was performed in accordance with generally accepted practices of other consultants undertaking similar studies at the same time and in the same geographical area, and GZA observed that degree of care and skill generally exercised by other consultants under similar circumstances and conditions. GZA's findings and conclusions must be considered not as scientific certainties, but rather as our professional opinion concerning the significance of the limited data gathered during the course of the study. No other warranty, express or implied is made. Specifically, GZA does not and cannot represent that the Site contains no hazardous material, oil, or other latent condition beyond that observed by GZA during completion of Phase IV remedial work.

3. The observations described in this report were made under the conditions stated therein. The conclusions presented in the report were based upon services performed and observations made by GZA.

4. In the event that National Grid or others authorized to use this report obtain information on environmental or hazardous waste issues at the Site not contained in this report, such information shall be brought to GZA's attention forthwith. GZA will evaluate such information and, on the basis of this evaluation, may modify the conclusions stated in this report.

5. The conclusions and recommendations contained in this report are based in part upon the data obtained from environmental samples obtained from relatively widely spread subsurface explorations. The nature and extent of variations between these explorations may not become evident until further exploration. If variations or other latent conditions then appear evident, it will be necessary to reevaluate the conclusions and recommendations of this report.

6. The generalized soil profile described in the text is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized and have been developed by interpretations of widely spaced explorations and samples; actual soil transitions are probably more gradual. For specific information, refer to the boring logs.

7. In the event this work included the collection of water level data, these readings have been made in the test pits, borings and/or observation wells at times and under conditions stated on the exploration logs. These data have been reviewed and interpretations have been made in the text of this report. However, it must be noted that fluctuations in the level of the groundwater may occur due to variations in rainfall and other factors different from those prevailing at the time measurements were made.

8. The conclusions contained in this report are based in part upon various types of chemical data and are contingent upon their validity. These data have been reviewed and interpretations made in the report. Moreover, it should be noted that variations in the types and concentrations of contaminants and variations in their flow paths may occur due to seasonal water table fluctuations, past disposal practices, the passage of time, and other factors. Should additional chemical data become available in the future, these data should be reviewed by GZA and the conclusions and recommendations presented herein modified accordingly.

9. In the event this work included the performance of a risk evaluation, GZA's risk evaluation was performed in accordance with generally accepted practices of the Massachusetts Contingency Plan and other consultants undertaking similar studies. The findings of the risk evaluation are dependent on numerous assumptions and uncertainties inherent in the risk assessment process. Sources of uncertainty may include the description of Site conditions and the nature and extent of chemical distribution and the use of toxicity information. Consequently, the findings of the risk assessment are not an absolute characterization of actual risks, but rather serve to highlight potential sources of risk at the Site. Although the range of uncertainties has not been quantified, the use of conservative assumptions and parameters throughout the assessment would be expected to err on the side of protection of human health and the environment.

10. This report contains approximate cost estimates for purposes of evaluating alternative remedial programs. These estimates involve approximate quantity evaluations. A preliminary estimate of this nature is likely to vary substantially from Contractors' Bid Prices and is not to be considered the equivalent of nor as reliable as Contractors' Bid Prices. Prices for similar work undertaken in the future will be subject to general and sometimes erratic price increases

Appendix B

Transmittal Form BWSC108

Massachusetts Department of Environmental Protection
Bureau of Waste Site Cleanup

COMPREHENSIVE RESPONSE ACTION TRANSMITTAL FORM & PHASE I COMPLETION STATEMENT
Pursuant to 310 CMR 40.0484 (Subpart D) and 40.0800 (Subpart H)

BWSC 108

Release Tracking Number
3 - 32792

A. SITE LOCATION:

1. Site Name: HAFFNER'S
2. Street Address: 284 WINTER STREET
3. City/Town: HAVERHILL
4. ZIP Code: 018300000

☑ 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#: 6891

2. First Name: CHARLES A
3. Last Name: LINDBERG

4. Telephone: 7812783830
5. Ext.:
6. Email: charles.lindberg@gza.com

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: BOSTON GAS CO D/B/A NATIONAL GRID

3. Contact First Name: JESSE 4. Last Name: EDMANDS

5. Street: 40 SYLVAN RD 6. Title: PROGRAM MANAGER

7. City/Town: WALTHAM 8. State: MA 9. ZIP Code: 024511120

10. Telephone: 7819073682 11. Ext: 12. Email: jesse.edmands@nationalgrid.com

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: OTHER PRPS

☐ 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: ______________________________ 3. Title: PROGRAM MANAGER
Signature

4. For: BOSTON GAS CO D/B/A NATIONAL GRID 5. Date: ______________
(Name of person or entity recorded in Section D) (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: ______________

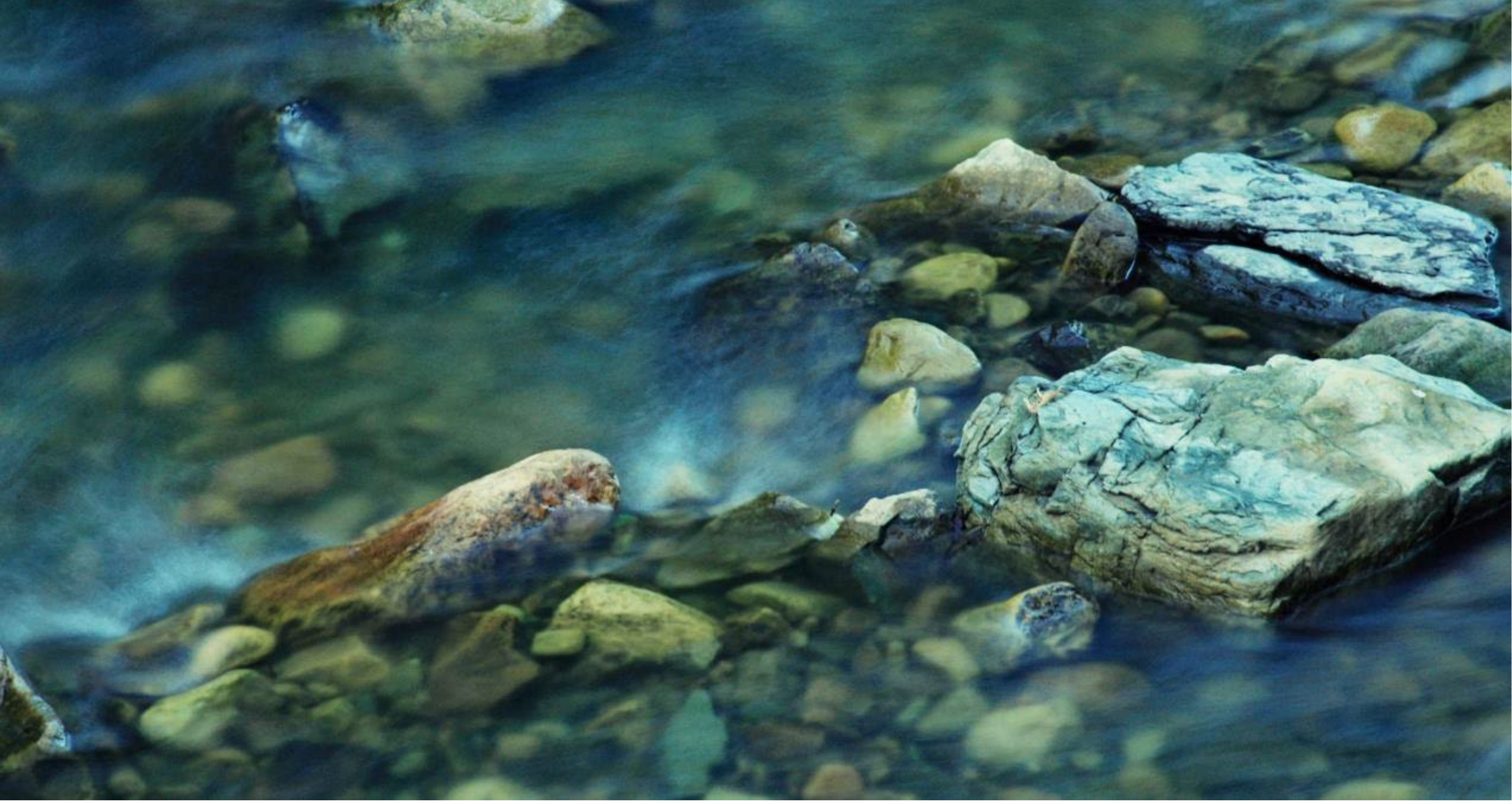
11. Telephone: ______________ 12. Ext.: ________ 13. Email: ______________

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 C

Anchor Phase III RAP – Little River



July 2022
Former Haverhill MGP Site – 284 Winter Street, Haverhill, Massachusetts

Phase III Remedial Action Plan – Little River

Prepared for Boston Gas Company d/b/a National Grid

July 2022
Former Haverhill MGP Site – 284 Winter Street, Haverhill, Massachusetts

Phase III Remedial Action Plan – Little River

Prepared for
National Grid
40 Sylvan Road
Waltham, Massachusetts 02451

Prepared by
Anchor QEA, LLC
9 Water Street, First Floor
Amesbury, Massachusetts 01913

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ABBREVIATIONS

AUL	activity and use limitation
bml	below mudline
BMP	best management practice
City	City of Haverhill, Massachusetts
CSA	comprehensive site assessment
cy	cubic yard
EPH	extractable petroleum hydrocarbons
ERC	environmental risk characterization
GAC	granular activated carbon
GZA	GZA GeoEnvironmental, Inc.
Haffner	Haffner Realty Trust
kg	kilogram
LSP	Licensed Site Professional
MassDEP	Massachusetts Department of Environmental Protection
MBTA	Massachusetts Bay Transportation Authority
MCP	*Massachusetts Contingency Plan*
mg	milligram
MGL	Massachusetts General Law
MGP	manufactured gas plant
NAPL	nonaqueous phase liquid
National Grid	Boston Gas Company d/b/a National Grid
OHM	oil and/or hazardous materials
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEC	probable effects concentration
Phase II CSA Report	*Phase II Comprehensive Site Assessment Report*
RAA	Remedial Action Alternative
RAH	readily apparent harm
RAP	Remedial Action Plan
RCM	reactive core mat
RIP	Remedy Implementation Plan
RTN	release tracking number
sf	square foot
Site	284 Winter Street, Haverhill, Massachusetts
TPAH	total polycyclic aromatic hydrocarbons
USACE	U.S. Army Corps of Engineers
VOT	visible oil and/or tar

1 Introduction

This Phase III Remedial Action Plan (RAP) for the Little River portion of the former Haverhill manufactured gas plant (MGP) site was prepared by Anchor QEA, LLC, on behalf of Boston Gas Company, d/b/a National Grid (National Grid), in accordance with the *Massachusetts Contingency Plan* (MCP; MassDEP 2020) requirements for a Phase III RAP. The former MGP was located at 284 Winter Street in Haverhill, Massachusetts (Site; Figure 1), on property that abuts the Little River to the east and is currently owned by Haffner Realty Trust (Haffner). The Site comprises an upland component and an in-river component and has been assigned release tracking number (RTN) 3-32792 by the Massachusetts Department of Environmental Protection (MassDEP). Anchor QEA of Amesbury, Massachusetts, is conducting the in-river investigation, and GZA GeoEnvironmental, Inc. (GZA), of Norwood, Massachusetts, is conducting the upland investigation.

This report applies primarily to the Little River portion of the Site and is intended to be an appendix to the Phase III RAP being prepared by GZA (GZA 2022a) on behalf of National Grid. Phase III information about the upland portion of the Site will be provided in GZA's Phase III RAP unless otherwise noted.

1.1 Objectives

The objective of this RAP is to identify, evaluate, and recommend a selected Remedial Action Alternative (RAA) for oil and/or hazardous materials (OHM)-impacted sediment within the Site (Figure 1). A Phase III RAP is being prepared by GZA for areas within the upland portion of the Site.

Additional information pertaining to the work conducted in the Little River is provided in Section 2.

1.2 Licensed Site Professional and Person Undertaking Response Action

National Grid is undertaking, and intends to continue to undertake, the actions required by MassDEP under Massachusetts General Law (MGL) Chapter 21E and the MCP with respect to MGP waste at the Site. The contact information for National Grid was provided in the MassDEP Phase III RAP Transmittal Form (BWSC-108) that accompanies GZA's Phase III RAP (GZA 2022a).

Charles Lindberg of GZA is the Licensed Site Professional (LSP) of Record for the Site (License Number 6891). His contact information, which is also provided in BWSC-108, is as follows:

Charles Lindberg, LSP
GZA GeoEnvironmental, Inc.
249 Vanderbilt Avenue
Norwood, Massachusetts 02062

1.3 Site Location and Description

The approximately 1.2-acre property at 284 Winter Street in downtown Haverhill is currently occupied by a Haffner's gasoline service station and car wash. The property is nearly covered by pavement or structures, and commercial and industrial properties surround the property. The Site is abutted to the north by Winter Street, and across the street is a vacant industrial mill complex. The Site is abutted to the south and west by the Little River; an approximately 15-foot-high masonry retaining wall separates the Site from the river to the west. Beyond the river are commercial and residential buildings. The Site is abutted to the east by an active Massachusetts Bay Transportation Authority (MBTA) railroad right-of-way, beyond which is a residential apartment complex (Figure 1).

The Site was formerly the location of an MGP operated by the Haverhill Gas Works, which manufactured coal gas from approximately 1853 to 1970. On-site infrastructure associated with the coal gas manufacturing process included two holders, retorts, condensers, and purifiers, as well as auxiliary sheds and other support structures. The manufactured gas was stored in holders on the Site until 1893, when storage was moved to holders on Hilldale Avenue. Historical research documented in an earlier report (Ramboll 2016) determined the MGP facility was converted to carbureted gas manufacturing sometime between 1910 and 1912. The MGP produced oil gas from 1951 until 1960.

Sometime between 1970 and 1976, most of the aboveground portions of the former MGP structures were removed or demolished. An aerial photograph from 1971 shows all that remained aboveground were the former coal bins adjacent to the railroad along the east side of the Site, an office and stock room on the northwest portion of the Site, and one aboveground oil tank. Haffner has been continuously operating a retail gasoline station, car wash, and fuel oil distribution facility at the Site since approximately 1976 or 1977 (Ramboll 2016; GZA 2022b).

1.3.1 In-River Component of the Site

The in-river component of the Site includes the portion of the Little River adjacent to the upland property where the former MGP stood (Figure 1). There, the river ranges from approximately 20 to 50 feet wide. During periods of low water, portions of the riverbed are exposed, but water several feet deep remains in a meandering channel. The sediment surface is a combination of sand, gravel, and cobbles; vegetation (e.g., grass, weeds) is present in the channel at several locations.

The Little River is approximately 12.9 miles long and rises in Kingston, New Hampshire. South of the Site, the Little River is directed underground where it flows through a conduit beneath various properties in Haverhill until it discharges into the Merrimack River approximately one-quarter mile south of the Site.

The Merrimack River is tidally influenced for 22 miles from the ocean to Haverhill. The Little River may be tidally influenced up to the Little River dam, which is just upstream of the Site. After evaluating the impact of tidal conditions in the Little River for the Little River dam removal feasibility study, Fuss and O'Neill concluded most of the Little River within the conduit just downstream of the Site was influenced daily by tides (Fuss and O'Neill 2021a). However, only extreme high tides or coastal storm surges appear to have an impact on the Little River upstream of the conduit due to the relatively elevated channel bottom elevations (including the reach adjacent to the Site).

The in-river portion of the Site is constrained by several structures. Approximately 70 feet upstream of the Site is the Little River dam, a stone masonry structure built in the 1800s. The dam and the adjacent mill building likely predate the former MGP. Immediately downstream of the dam and upstream of the in-river portion of the Site is the Winter Street bridge. Approximately 500 feet south of the Winter Street bridge and downstream of the in-river portion of the Site is the headwall for the Little River conduit, which was constructed from 1937 to 1938 as part of the U.S. Army Corps of Engineers' (USACE's) Haverhill Local Protection Project. The conduit is operated and maintained by the City of Haverhill (the City). A vertical retaining wall 15 to 20 feet tall runs along most of the eastern side of the Little River. The river's western bank and the southern portion of the eastern bank are heavily overgrown, steep, and may include remnants of former structures such as retaining walls. Photographs of the Winter Street bridge, the Little River dam, and the river's eastern and western banks are included in Appendix A of the *Phase II Comprehensive Site Assessment Report* (Phase II CSA Report) for the Little River portion of the Site (GZA 2022b). It should be noted that the City is currently in the design phase of a project to remove the Little River dam. Remedial activities conducted within the in-river portion of the Site would need to be coordinated with the dam removal project, to the extent required. National Grid is participating in ongoing discussions and coordination with the City's representatives involved with the dam removal project.

1.4 Scope of Phase III Remedial Action Plan

This Phase III RAP was developed to comply with the requirements of the MCP. In accordance with the MCP (at Section 310 CMR 40.0850), the Phase III RAP objectives are as follows:

- Identify and evaluate RAAs that are reasonably likely to achieve a level of No Significant Risk considering the OHM present, contaminated media, and Site characteristics.
- Recommend an RAA that will lead to a Temporary or Permanent Solution, where a Permanent Solution includes measures that reduce, to the extent feasible, the concentrations of OHM in the environment to levels that achieve or approach background.
- Describe and document the information, reasoning, and results to identify and evaluate RAAs in sufficient detail to support the selection of the proposed RAA.

2 Site and Regulatory History

A detailed description of the general Site and the regulatory history associated with the Site is presented in GZA's Phase III RAP (GZA 2022a).

3 Nature and Extent of OHM

OHM that originated at the Site may have been discharged directly into the Little River when the MGP was in operation, or it may have been released to upland soil and groundwater and subsequently migrated through the subsurface into the river. During investigations conducted through 2021, samples of soil, sediment, groundwater, and surface water were collected from the upland and in-river portions of the Site to assess the potential for OHM from the former MGP to have migrated, or to migrate in the future, to other areas of the Little River. Local conditions were also evaluated to assess other potential OHM sources.

The potential for OHM to migrate from the MGP to the Little River was assessed by comparing visual observations of impacted sediment and the results of laboratory analyses of sediment and surface water from the in-water portion of the Site to visual observations from borings and the results of laboratory analyses of soil and groundwater samples from the Site's upland portion. Additional factors related to OHM migration, including visual observations of Site conditions (i.e., hardened tar deposits on portions of the retaining wall and deposits within pipes exiting through the retaining wall), general groundwater and surface water hydraulics, sediment transport, and local conditions, were considered in this assessment.

The nature and extent of OHM impacts at the Site have been characterized based on the results of analyzing sediment samples. The findings of these investigations are described in the Phase II CSA Report submitted to MassDEP (GZA 2022b). The Phase II CSA findings are summarized below to provide a framework for the evaluation of RAAs presented in Sections 6 and 7 of this Phase III RAP.

3.1 Historical Releases and Sources

The upland portion of the Site was previously occupied by an MGP facility that manufactured coal gas from approximately 1853 to 1970. Site history research performed for the Phase II CSA found no documented releases or discharges to the waterway that would be consistent with the presence of visible oil and/or tar (VOT) and elevated levels of 16 total polycyclic aromatic hydrocarbons (TPAH16) in shallow sediment within the Site. But based on the nature and extent of MGP residuals in the upland portions of the Site, the primary source for VOT and polycyclic aromatic hydrocarbons (PAHs) found in the Site shallow sediment is likely historical release(s) from the former MGP to the surface water with subsequent deposition in sediment. Some of these releases may have been via upland subsurface pipes that extend through the retaining wall (GZA 2022b). In addition, sediments within the Site were also likely affected by other historical non-MGP point and nonpoint discharges in the Little River. Potential non-MGP sources of VOT and PAHs include current gas station operations, historical spills, surface water drainage from Winter Street and other nearby paved areas, and combined sewer outfalls.

3.2 Visible Oil and/or Tar in Sediment

VOT, defined as the presence of nonaqueous phase liquid (NAPL) or tar within sediment, was observed in 25 of the 36 vibracore and hand auger samples collected from the in-river portion of the Site (GZA 2022b). The VOT observed in sediment ranged from trace droplets to saturated sediment. Sediment saturated with VOT was present in most cores as a very dark brown to black tar-like material with no apparent free-flowing NAPL based on field observations. A strong coal-tar-like odor was generally associated with intervals containing VOT. Sheens and staining were also observed in sediment samples. An area containing VOT within the upper 12 inches of sediment over an area greater than 1,000 square feet (sf) was identified, which represents a condition of readily apparent harm (RAH) as defined in 310 CMR 40.0995 (3)(b)1(c).

Because the VOT was observed at various depths in the sediment cores and observations were not limited to a specific stratigraphic unit or along a stratigraphic interface, the VOT does not appear to have migrated at depth along pathways from the upland portion of the Site into the Little River sediment. No cores appeared to contain evidence of upward migration of VOT, and the results of the NAPL mobility testing conducted as part of the Phase II CSA activities indicated that NAPL migration is not occurring via advection (GZA 2022b). The variable deposition of VOT in the sediment, the lack of an apparent migration pathway, the presence of tar-like material in at least one pipe in the retaining wall, and the observations of hardened tar on the retaining wall blocks indicate that the deposition of VOT may have been caused by one or more releases into the Little River from the former MGP.

Section 310 CMR 40.1003(7)(a)-(b) states that a Permanent or Temporary Solution cannot be achieved unless NAPL with micro-scale mobility has been removed to the extent feasible (for a Permanent Solution) or removed and/or controlled to the extent feasible (for a Temporary Solution). NAPL with micro-scale mobility is defined in 310 CMR 40.006 as "NAPL with a footprint that is not expanding, but which is visibly present in the subsurface in sufficient quantities to migrate or potentially migrate as a separate phase over a short distance and visibly impact an excavation, boring or monitoring well."

NAPL is visually present within the subsurface of the in-river portion of the Site within a footprint that does not appear to be expanding but does not appear to be in sufficient quantities to migrate as a separate phase based on visual observations of the tar-like material (just discussed) and the results of NAPL mobility tests. Therefore, NAPL within the in-river portion of the Site does not appear to have micro-scale mobility.

Ten samples from two visually heavily impacted sediment cores from locations AQSS-12 and AQSS-13 were submitted for laboratory measurement of percent NAPL saturation and NAPL mobility testing (GZA 2022b). The measured percent NAPL saturation ranged from 2.9% to 28.3%, and there was no change in percent NAPL saturation prior to or after centrifuging the samples. No NAPL was observed in the water that was released during the tests. This indicates the NAPL within the samples is not mobile. In combination with the minimal visible free product observed in the sediment cores, the percent NAPL saturation results support the conclusion that NAPL within the in-river portion of the Site does not appear to have micro-scale mobility.

3.3 Chemical Characteristics

Bulk sediment analytical data were collected as part of the Phase II CSA investigations. Field investigations were conducted in 2016, 2020, and 2021 to evaluate the nature and extent of the OHM in Little River sediment and to support the Conceptual Site Model; details of the field investigations are summarized in the Phase II CSA Report (GZA 2022b). Based on the Method 3 Risk Characterization conducted as part of the Phase II CSA, a risk of environmental harm in sediments was identified (hereafter referenced as environmental risk characterization [ERC]-based risk) in another area in addition to the RAH area. The other area is limited and located adjacent to the RAH area (see Figure 2). The risk of environmental harm is due to OHM concentrations in sediment that exceeded the screening criteria. Concentrations of PAHs, select metals, polychlorinated biphenyls (PCBs), and extractable petroleum hydrocarbon (EPH) fractions in surface sediment exceeded screening levels and, therefore, have the potential to pose a risk to aquatic receptors.

In addition to the risk posed by OHM concentrations in bulk sediment, there is the potential for risk to ecological receptors based on OHM concentrations in porewater. Groundwater from the upland portion of the Site can migrate via subsurface pathways into the pore space of shallow sediment in the in-river portion of the Site, where it is then referred to as sediment porewater (USEPA 2001). Groundwater migrates into the river with both horizontal and vertical velocity components, eventually discharging to the surface water. The migration of OHM-impacted groundwater through the sediment column may therefore result in elevated concentrations of OHM in the pore space of shallow sediment where biological activity occurs (i.e., the bioturbation zone, which is generally the top 6 inches of sediment) and has the potential to create a future porewater-based risk to benthic organisms. This potential applies even if shallow sediment is remediated because the porewater in shallow sediment that remains after remediation could potentially be impacted by the migration of deeper residual OHM to the shallow porewater.

3.3.1 Concentrations above Local Conditions

As part of the Phase II CSA, Anchor QEA conducted a Method 3 Stage I Environmental Screening in accordance with the requirements of 310 CMR 40.0995(3). The need for a site-specific risk assessment is dependent upon the comparison of site-related contaminant levels to the concentrations prevalent in the site vicinity; therefore, a comparison of OHM concentrations to background levels should be conducted prior to initiating the site-specific risk assessment

(MassDEP 1995). However, as is typical in many Massachusetts waterways where there was a strong historical industrial presence, background conditions as defined in Section 9.4.1 of the MassDEP guidance may not exist in the vicinity of the Site.

MassDEP 1995 states that "[surface water and sediment] concentrations may be compared to contaminant levels that represent 'local conditions.' If concentrations at the site are consistent with background and/or local conditions, it may be possible to eliminate the need for further assessment."

The guidance continues to define local conditions as "concentrations of OHM that are higher than background levels but nevertheless ubiquitous throughout the vicinity of the Study Area and are attributable to sources other than the site in question."

Local conditions around the Site are associated with levels of OHM present in Little River sediment and surface waters that are attributable to other industrial sources, permitted discharges, and nonpoint sources. Evaluating local sediment OHM concentrations requires detailed knowledge of the OHM source locations, the variability in OHM releases over time, and the migration and deposition of the OHM released from those sources based on hydraulic flows and sedimentation rates. Local conditions in the vicinity of the Study Area were assessed by Anchor QEA in the Phase II CSA Report (GZA 2022b).

As discussed in the Phase II CSA Report, attempts to collect sediment from the Winter Street bridge to the Little River dam to potentially represent local conditions were unsuccessful. Multiple attempts were made to collect a sediment sample using a ponar grab sampler from the Winter Street bridge, but no sample was recovered due to the grab sampler encountering cobbles/rocks. Therefore, samples collected by Fuss and O'Neill in 2020 and 2021 upstream of the Little River dam were used to represent local conditions (Fuss and O'Neill 2021a [Table 9], 2021b [Table 4]). The following summarizes the local conditions evaluation in the Phase II CSA Report (GZA 2022b):

- The concentrations of TPAH16 from the 0.0- to 0.5-foot interval in sediment samples from outside the Substantial Hazard areas but within the Site boundary exceeded the average TPAH16 concentration of 29.9 milligrams per kilogram (mg/kg) measured in the presumed local conditions samples (Fuss and O'Neill 2021a, 2021b).
- In general, the concentrations of metals in the surface sediments within the Site boundary are comparable to the metals concentrations in the sediment in the presumed local conditions samples.
- Only PCB Aroclors 1254 and 1260 were detected in the samples representing local conditions collected upstream of the dam. But a different source contributed to the PCBs detected in the vicinity of the Site because an additional Aroclor (Aroclor 1242) was detected.

Based on these comparisons, TPAH16 and PCB Aroclor 1242 in Site sediment exceed local conditions concentrations. The relatively elevated TPAH16 concentration in Site sediment samples is consistent with historical releases from Site operations and with Site sediment sample analyses results. There is insufficient information to attribute the presence of PCB Aroclor 1242 to a specific source. The remainder of the report will reference background conditions, which are assumed to be consistent with local conditions as just discussed.

3.4 Summary of Environmental Conditions

This summary describes the OHM impacts to sediment in the in-river portion of the Site and the resulting environmental conditions requiring remedial action under the MCP.

3.4.1 Substantial Hazard

The Phase II CSA concluded that a condition of RAH—defined in 310 CMR 40.0995 (3)(b)1(c) as the "visible presence of oil, tar, or other nonaqueous phase hazardous material in soil within three feet of the ground surface over an area equal to or greater than two acres, or over an area equal to or greater than 1,000 SF in sediment within one foot of the sediment surface"—is present in a portion of the Little River. Per 310 CMR 40.0956(2)(b), RAH represents a Substantial Hazard. A condition of RAH was identified in the area surrounding sample location 5A and the extent of the channel starting from AQSS-07 downstream to the headwall of the Little River conduit, for a total area of approximately 16,900 sf or 0.4 acre. (Figure 2). RAH being present to the headwall of the Little River conduit is a conservative assumption because no sediment cores could be collected during the September 2022 field investigation south of AQSS-20 due to Site conditions including heavy vegetation along the shoreline that blocked the crane operator's line of sight, the presence of cobbles and small boulders along the riverbed that inhibited penetration by the vibratory coring equipment, and maintaining a safe working distance from the railroad tracks and electrical power lines. These areas are considered the Substantial Hazard areas.

3.4.2 Environmental Risk Characterization-Based Risk Summary

The Phase II CSA concluded that concentrations of PAHs, select metals, PCBs, and EPH in surface sediment exceeded screening levels and, therefore, have the potential to pose a risk to aquatic receptors. There is also the potential for risk to ecological receptors based on OHM concentrations in porewater. In addition to a comparison to screening criteria, concentrations of OHM in sediment were compared to presumed local conditions concentrations (Section 3.3.1).

Fuss and O'Neill concluded that the concentrations of metals, PAHs, and petroleum hydrocarbons in sediment behind or upstream of the dam (i.e., the location where samples were collected that were used to represent local conditions for the Phase II CSA Report [GZA 2022b]) "are broadly consistent with urban background conditions and do not pose a unique ecological risk to the receiving waterways." Therefore, remedial alternatives will address sediment with the following concentrations:

- TPAH16 equal to or greater than the average local conditions concentration of 29.9 mg/kg
- Chromium equal to or greater than the probable effects concentration (PEC) of 111 mg/kg
- PCBs equal to or greater than the PEC of 0.676 mg/kg

In addition, due to relatively elevated concentrations of benzene in bulk sediment within the Substantial Hazard areas and in upland groundwater samples at the Site, screening criteria will be developed for benzene and used to screen bulk sediment and porewater samples to support the remedial design; conservatively, concentrations of ethylbenzene, toluene, and xylene will also be evaluated. These compounds were not previously identified as part of the ERC because the samples were located within the Substantial Hazard area.

4 Remedial Objectives and Response Action Outcome Requirements

This section describes how a Permanent or Temporary Solution may be achieved for the in-river portion of the Site under the MCP. It also summarizes the findings and conclusions of the Phase II CSA Report (GZA 2022b) as they pertain to the need for remediation to achieve a Permanent or Temporary Solution, identifies remedial objectives for the in-river portion of the Site, and describes site-specific issues that influence the selection of remedial alternatives.

4.1 General Requirements for Achieving Permanent and Temporary Solutions

Section 310 CMR 40.1000 establishes requirements and procedures to meet a Permanent or Temporary Solution. Per 310 CMR 40.0852(2), the MCP requires a Phase III evaluation to result in the selection of an RAA that is likely to result in a Permanent Solution, except where it is demonstrated to be infeasible or the implementation of a Temporary Solution is more cost effective and timely. The following sections describe solutions that may be applicable to the in-river portion of the Site.

4.1.1 Permanent Solution

As described previously, the MCP requires remedial actions to be evaluated based on their ability to reach a Permanent Solution, if feasible. As defined in 310 CMR 40.1040(1), a Permanent Solution applies to sites where remedial activities have done the following:

- Achieved a level of No Significant Risk (in accordance with 310 CMR 40.0900)
- Eliminated or controlled any source of OHM
- Controlled plumes of dissolved-phase OHM in groundwater and vapor-phase OHM in the vadose zone
- Addressed NAPL, if present
- Eliminated all threats of release
- Reduced the level of OHM in the environment as close to background levels as feasible

4.1.2 Temporary Solution

A Temporary Solution is an acceptable remedy under the MCP if a Permanent Solution is shown to be infeasible or a Temporary Solution is shown to be more cost effective and timely so long as enterprising steps toward achieving a Permanent Solution are taken. According to 310 CMR 40.1050(1), a Temporary Solution applies when the following occurs:

- A condition of No Substantial Hazard exists and has been documented pursuant to 310 CMR 40.0956

- All sources of OHM have been identified, characterized, and, to the extent feasible, eliminated or controlled
- Plumes of dissolved-phase OHM in groundwater and vapor-phase OHM in the vadose zone have been controlled
- NAPL, if present, has been addressed
- A Phase III evaluation has been completed and one of the following has been concluded:
  - Response actions to achieve a Permanent Solution are not currently feasible
  - Response actions to achieve a Permanent Solution are feasible and shall be continued toward a Permanent Solution

Section 310 CMR 40.1050(4) requires periodic reviews of Temporary Solutions where achievement of a Permanent Solution is not feasible. The reviews are to be conducted every fifth year after the date of filing a Temporary Solution Statement and are to continue until a Permanent Solution statement is submitted.

4.2 Current and Future Risks and Ongoing Sources

Current and future risks, as well as the potential for ongoing sources of OHM in the river sediment, were evaluated to determine whether a Permanent or a Temporary Solution could be achieved for the in-river portion of the Site. The ERC (GZA 2022b) found the following at the Site:

- A Substantial Hazard is present within the in-river portion of the Site due to the area of RAH. VOT was observed in the upper 1.0 foot of sediment in an area of approximately 16,900 sf.
- Potential sources of OHM are not controlled. This includes the potential source of sheens observed on surface water which could be originating from VOT within the sediment or from NAPL potentially exiting pipes in the retaining wall or seeping through the lower portions of the retaining wall at or above the interface with the sediment surface.
- A condition of No Significant Risk has not been achieved for the in-river portion of the Site. Ecological risk exists for approximately 5,300 sf outside the Substantial Hazard area, defined by the presence of OHM concentrations in bulk sediment exceeding screening criteria established in the ERC (GZA 2022b) and in comparison to local conditions (see Section 3.4.2).
- Based on concentrations of benzene in bulk sediment and upland groundwater samples, the potential for benzene, ethylbenzene, toluene, and xylene to represent risk to ecological receptors will be evaluated as part of remedial design (see Section 3.4.2).
- An area of approximately 22,200 sf within the Little River and material to a maximum depth of approximately 5.5 feet below mudline (bml) exceed OHM concentrations in bulk sediment representative of background conditions.

4.3 Identification of Remedial Objectives

The following remedial objectives could achieve a Temporary or Permanent Solution when implemented through an RAA:

- **Address Condition of Substantial Hazard and eliminate, control, or mitigate source material to the extent feasible.** A Substantial Hazard exists in approximately 16,900 sf of the in-river portion of the Site. In addition, VOT in shallow sediments and behind the base of the retaining wall to the east of the Little River has been identified as a potential source of ongoing impacts (i.e., sheen) to surface water. The pipes extending through the retaining wall represent a potential migration pathway for source material. To achieve a Temporary Solution, the Substantial Hazard must be eliminated and the source material must be eliminated, controlled, or mitigated to the extent feasible.
- **Achieve a condition of No Significant Risk.** Approximately 5,300 sf of sediment determined to pose a Significant Risk to the environment based on the ERC needs to be remediated to reduce PAH concentrations to below local conditions concentrations, and there is the potential for risk to ecological receptors based on OHM concentrations in porewater in the Substantial Hazard area. Bulk sediment and porewater concentrations above ERC-based criteria need to be addressed to achieve a Permanent Solution.
- **Reduce the level of OHM in the environment to background concentrations to the extent possible**. Approximately 22,200 sf of sediment within the Little River to a maximum depth of approximately 5.5 feet bml exceed OHM concentrations in bulk sediment representative of background conditions. To achieve a Permanent Solution, the level of OHM in the environment must be reduced to background conditions to the extent possible.

4.4 Site-Specific Factors Affecting the Selection of a Remedial Alternative

The following characteristics of the Site were considered in the selection of a feasible and implementable remedial alternative:

- Direct access to Site sediments is significantly limited by the retaining wall on the east side of the Little River; the steep, heavily vegetated slope on the west side; the Winter Street bridge and Little River dam upstream; and the Little River conduit, which limits access downstream.
- Room for a staging and sediment processing area is significantly limited. An active gas station and car wash is present on the upland portion of the Site to the east of the Little River. Active commercial properties owned by multiple entities are located on the west side.
- The in-river portion of the Site is associated with multiple upland properties that are controlled and owned by different entities.
- No information about the construction of the retaining wall was located in a records search. Based on historical photographs, at least part of the wall appears to have been constructed as

part of the development of the Site. The wall appears to be constructed from granite blocks, concrete, and bricks, so subsequent renovations may have occurred after the initial construction. The full removal of impacted sediment is not feasible currently due to the depth of impacts along the retaining wall and the wall's poor condition.

5 Initial Screening of Remedial Technologies

This section presents the results of the remedial technology screening conducted in accordance with 310 CMR 40.0856. The remedial technologies were initially screened to identify technologies suitable for inclusion in RAAs based on past project experience, knowledge of established remedial technologies for sediment and associated OHM, knowledge of Site conditions, and engineering judgment. Results of the initial screening are summarized in Table 1.

During the initial screening, remedial technologies were considered as components of RAAs; they did not have to satisfy the initial screening criteria on their own, but rather as a part of an RAA.

A remedial technology was retained for further evaluation if it was likely to reduce risks to levels that would permit the achievement of a Permanent or Temporary Solution and if it appeared to be technically and economically implementable at the Site. Remedial technologies were retained for possible inclusion in RAAs if they were deemed reasonably likely to be feasible based on the OHM present, the media contaminated, and the Site characteristics based on other sites with OHM, environmental media containing OHM, and settings and characteristics similar to those of the in-river portion of the Site. For the purposes of 310 CMR 40.0856, RAAs are reasonably likely to be feasible if they meet both of the following criteria:

- The technologies to be employed by the RAA are reasonably likely to achieve a Permanent Solution by doing the following:
  - Achieving a level of No Significant Risk, as specified in 310 CMR 40.1000
  - Eliminating or controlling potential OHM sources, as specified in 310 CMR 40.1003(5)
- Individuals with the expertise needed to effectively implement available solutions are available, regardless of arrangements for securing their services.

Retained technologies that could achieve the remedial objectives alone or in combination with other remedial technologies were considered for inclusion in RAAs. They include Deed Restrictions/Activity and Use Limitations (AULs), sediment removal, and sediment capping. The 21 technologies shown in Table 1 were retained.

6 Detailed Evaluation of Remedial Action Alternatives

RAAs for the in-river portion of the Site were developed by combining remedial technologies retained during the initial screening process outlined in Section 5 (Table 2). RAAs development also considered Site conditions, OHM, affected media, and the way the individual technologies fit together to formulate a remedial action that would meet remedial objectives.

This section presents the RAAs developed for the in-river portion of the Site and provides the detailed evaluation of remedial action alternatives required by the MCP.

6.1 Description of Remedial Action Alternatives

6.1.1 RAA-1: No Action

An RAA of no action is not a viable alternative for the Site due to the presence of RAH and OHM sources. However, RAA-1 is included in the suite of alternatives as a baseline to which all other alternatives are compared.

6.1.2 RAA-2: Modified Boom System

RAA-2 consists of modifying the existing semipermanent boom system installed in November 2016 to make it a more robust system to continue managing the appearance of sheen on surface water in the Little River. Long-term maintenance and monitoring of the system, including periodic replacement of absorbent and hard booms and maintenance of the steel structure, would be required. A semipermanent boom system would meet the requirements under 310 CMR 40.0956(2) to "mitigate" the RAH and under 310 CMR 40.1003(5)(c) to "control" sources, and it would achieve a Temporary Solution.

RAA-2 represents a minimalistic approach to addressing Site impacts within the Little River with limited effectiveness because it would only be mitigating and controlling the appearance of the sheen on surface water and not eliminating the source of the sheens. Long-term reliability would depend on the continual monitoring and maintenance of the system and would only control the sheens, not eliminate Site impacts; temporary failures of the system may occur during high-flow events and due to debris travelling downstream with the flow of the river. Compared to more invasive alternatives that include dredging or capping, modifying the existing boom system could occur more quickly, at a lower cost, and potentially with limited permitting. Risks to the environment and workers during construction would likely be lower due to the shorter duration to implement the work and more limited and less invasive Site activities. Impacts to the existing Site operations (i.e., active gas station and car wash) would also be less than other alternatives due to the shorter work duration and potentially smaller work area. RAA-2 would not improve nonpecuniary interests such as aesthetics; a portion of the semipermanent boom system would remain visible adjacent to the retaining wall from the Winter Street bridge and limited debris removal within the Little River would be required. From the upland portion of the Site, occasional sheens would be visible on the surface of the water in the Little River. If the property owners on the western shoreline cleared vegetation, the semipermanent boom system and occasional sheen on surface water would be visible from their properties.

Although RAA-2 mitigates the RAH and controls the OHM source through addressing the appearance of sheen on surface water, it is possible that regulatory approval may not be received for the alternative due to the minimalistic approach. Continuing to maintain a semipermanent boom system may interfere with the proposed upstream dam removal activities and may limit ecological benefits downstream of the dam. Therefore, modifying the boom system is currently not considered a viable remedial alternative and is not discussed in the evaluation of alternatives.

If the selected remedial alternative (see Section 7.1) is deemed infeasible to implement based on future design work, property owner interactions, or interpretation of data collected as part of the anticipated pre-design investigation(s), RAA-2 will be revisited as a remedial alternative designed to mitigate and control Site impacts within the Little River.

6.1.3 RAA-3: Cap Only

RAA-3 consists of a permeable active cap placed on-grade (i.e., no dredging or sediment removal prior to placement). An active cap is a cap that includes amendments such as granular activated carbon to sorb contaminants. Placement of a permeable active cap on-grade was considered as a baseline effort to achieve closure in the in-river portion of the Site. A permeable active cap can be designed to address the Substantial Hazard, mitigate the generation of sheens from VOT in sediments or behind the base of the retaining wall that ultimately migrate to the surface water within the Little River, and the sediment and porewater with OHM concentrations that present risk to ecological receptors. Although a permeable active cap could feasibly be designed to address these conditions, the placement of a cap on-grade within the Little River is not considered implementable. Placement of a cap on-grade within the river would increase the mudline elevation and the flood potential within that section of the river. Therefore, the placement of a permeable active cap on-grade was not considered a viable remedial alternative and is not discussed in the evaluation of alternatives.

6.1.4 RAA-4: Combined Dredge and Backfill/Cap

RAA-4 comprises mechanical dredging, dredged material stabilization and dewatering, and off-site disposal of dredged material at an approved disposal facility; and placement of a permeable active cap to mitigate the generation of sheens from VOT in sediments or behind the base of the retaining wall to the surface water. Mechanical dredging can be combined with permeable active capping in three different scenarios (RAA-4a, RAA-4b, and RAA-4c) with two different footprints to change the level of protectiveness of the RAA.

RAA-4a is the baseline effort (not considering RAA-2) required to achieve closure in the in-river portion of the Site by addressing the Substantial Hazard and controlling OHM sources to mitigate the generations of sheens on surface water to achieve a Temporary Solution. RAA-4b and RAA-4c build upon RAA-4a as follows:

- RAA-4b includes deeper dredging within the same remedial footprint as RAA-4a to accommodate a permeable active cap that addresses OHM concentrations in porewater
- RAA-4c includes a larger remedial footprint to address OHM concentration in sediment and porewater that represent risk to ecological receptors and also deeper dredging than RAA-4a to accommodate a permeable active cap that addresses OHM concentrations in porewater

RAA-4c requires the greatest effort, but it also eliminates the Substantial Hazard and addresses OHM concentrations in bulk sediment and porewater to achieve a condition of No Significant Risk. The feasibility of achieving or approaching background conditions as part of a Permanent Solution is discussed further in Section 6.1.5. Sections 6.1.4.1 through 6.1.4.3 describe the three combined dredge-and-cap scenarios in more detail. A plan view showing the footprints for the three scenarios is shown in Figures 2 and 3.

6.1.4.1 RAA-4a

Alternative RAA-4a includes dredging within a 16,900 sf footprint to eliminate the Substantial Hazard and placement of permeable active cap within the same footprint to mitigate the generation of sheens on surface water. Pipes extending through the retaining wall will be capped or sealed to eliminate a potential migration pathway. RAA-4a is expected to achieve a Temporary Solution by eliminating the Substantial Hazard and controlling potential OHM sources (i.e., the source of sheen on the surface water). This alternative does not address risk posed to ecological receptors by OHM bulk sediment or in porewater and, therefore, will not meet the criteria for a Permanent Solution. The conceptual design for RAA-4a has the following major elements:

- **Mechanical Dredging:** Approximately 1,400 cubic yards (cy) of sediment over a 16,900 sf area would be removed to eliminate the Substantial Hazard. (That volume estimate includes the USACE-recommended 1.5 volume increase factor to account for future detailed design of stable dredge cut side slopes and provides overdredge allowance [Palermo et al. 2008].) The assumed design dredge depth is 1.5 feet to remove the sediment containing VOT that results in RAH and to accommodate adding cap material to mitigate future sheen generation from residual VOT in sediment. It is assumed that dredging would employ mechanical methods working within the footprint of the Little River. Methods to bypass or limit submerged conditions within the in-river portion of the Site during sediment removal will be evaluated as part of design. Working within the footprint of the Little River in "dry" conditions provides better control over VOT and sheen releases during dredging and enables the equipment operator to have more accuracy and control over the equipment than they might have working from the top of the wall.

- **Sediment and Water Management:** Dredged sediment would be transported by a crane in containers to a sediment processing area. For the purposes of this report, it is assumed the sediment processing area would be located in the upland portion of the Site. An evaluation of the potential location of the sediment processing area, including the upland portion of the Site and adjacent properties to the west, will be conducted as part of design; property owner negotiations will be included in the evaluation. For the purposes of this report, it has also been assumed that dredged sediment may require processing through a combination of passive dewatering (i.e., gravity settling and drainage) and solidification/stabilization (e.g., the addition of Portland cement) to pass paint filter testing or other facility-required analyses for acceptable moisture content prior to being transported off site for disposal. Impacted water generated during remedial activities would be collected in the staging area and pumped into storage tanks to await subsequent transport to an off-site treatment and disposal facility. Water generated during sediment processing, including stormwater within the processing area, would be containerized and transported off site for treatment and disposal at an approved facility.
- **Permeable Active Cap Placement:** Potential generation and releases of sheen from sediment and from the base of the retaining wall would be addressed by placing a permeable active cap composed of a layer of reactive core mat (RCM) containing organoclay and erosion-protection aggregate layer. The organoclay will be lapped up against the base of the retaining wall to control potential sheen releases generated through the base of the wall. The RCM will be anchored by an overlying erosion-protection aggregate layer similar in grain size to the existing riverbed material and designed to withstand erosional forces (Appendix A). After dredging, approximately 1,400 cy of cap material would be placed in the dredge footprint. The erosion-protection aggregate material would consist of a 0.5-foot filter layer and a 1.0-foot gravel/cobble layer and would be placed to the existing grade. Although placement of alternative materials, such as bulk organoclay rather than the RCM, will be evaluated as part of the design, a layer of RCM is assumed for this Phase III evaluation.
- **Additional Sheen Generation Management:** Future pre-design investigations in the early stages of development for a Phase IV Remedy Implementation Plan (RIP) would evaluate sheen migration through the wall (via pipes and masonry joints) as a source. If these migration mechanisms are confirmed, pipes that exit through the retaining wall would be sealed and retaining wall masonry joints would be addressed, to the extent feasible, to mitigate transport of NAPL through the retaining wall. In addition, a supplemental exploration program would be implemented as part of pre-design investigations to further evaluate the

potential for preferential NAPL migration pathways from the upland portion of the Site to the Little River.

- **Long-Term Cap Monitoring:** Long-term cap monitoring and maintenance is included in this RAA. It is assumed that monitoring would be conducted over a 30-year period.

6.1.4.2 RAA-4b

Like RAA-4a, alternative RAA-4b includes dredging within a 16,900 sf footprint to eliminate the Substantial Hazard and placement of a permeable active cap. In addition to an organoclay layer to address the generation of sheens on the surface water, RAA-4b includes placement of a chemical containment layer to address risk to ecological receptors posed by dissolved-phase porewater OHM within the RAA-4b footprint. This alternative is also expected to achieve a Temporary Solution by eliminating the Substantial Hazard and controlling potential OHM sources and by addressing a portion of the bulk sediment and porewater that presents risk to ecological receptors. The conceptual design for RAA-4b has the following major elements:

- **Mechanical Dredging:** Approximately 2,350 cy of sediment over a 16,900 sf area would be removed to eliminate the Substantial Hazard. (The removed volume estimate includes the USACE-recommended 1.5 volume increase factor to account for future detailed design of stable dredge cut side slopes and to provide an overdredge allowance.) The assumed design dredge depth is 2.5 feet to address the Substantial Hazard, mitigate sheen generation, and address dissolved-phase OHM. Dredging would occur within the same footprint as RAA-4a but to a deeper depth to accommodate the chemical containment layer within the permeable active cap. Although RAA-4b removes more sediment than RAA-4a, impacted sediment would remain at depth within the river. Dredging is assumed to use the same means and methods as RAA-4a.
- **Sediment and Water Management:** Dredged sediment and water would be managed in a manner similar to the techniques used in RAA-4a.
- **Permeable Active Cap Placement:** A permeable active cap would be placed over the approximately 16,900 sf of the in-river portion of the Site that would also be dredged. The objective of the cap is two-fold: mitigate the generation of sheens and sequester dissolved-phase organic compounds in porewater after dredging. The conceptual cap cross section contains a layer of RCM (or equivalent) to mitigate the generate of sheens, a layer of sorbent material (granular activated carbon [GAC] or the like) mixed with sand to sequester contaminants (Appendix B), a granular filter layer (consisting of gravel-sized material), and an armor layer (consisting of stone up to approximately 6 inches in diameter) to resist erosive forces (Appendix A). The estimated cap thickness is 2.5 feet.
- **Additional Sheen Generation Management:** Additional sheen generation management would be handled similar to RAA-4a.

- **Long-Term Cap Monitoring:** Long-term cap monitoring and maintenance is included in this RAA; it is assumed that monitoring would be conducted over a 30-year period.

6.1.4.3 RAA-4c

Alternative RAA-4c combines mechanical dredging and capping to address sediment with OHM concentrations that represent a condition of Significant Risk. This alternative includes dredging within an approximately 22,200 sf footprint to eliminate the Substantial Hazard and address sediments representing Significant Risk. Like RAA-4b, RAA-4c includes placement of a post-dredge cap to address the risk to ecological receptors posed by dissolved-phase OHM, but it addresses this risk within the in-river Site boundary footprint, not just the Substantial Hazard area. And like RAA-4b, RAA-4c includes placement of a permeable active cap to both mitigate generation of sheen and address dissolved-phase OHM. But unlike RAA-4a and RAA-4b, this alternative is expected to achieve a Permanent Solution by eliminating the Substantial Hazard, controlling potential OHM sources, and achieving a condition of No Significant Risk. The conceptual design for RAA-4c includes the following major elements:

- **Mechanical Dredging:** Approximately 3,100 cy of sediment over an approximately 22,200 sf area would be removed to eliminate the Substantial Hazard and to address OHM that represents ecological risk. (The removed volume includes the USACE-recommended 1.5 volume increase factor to account for future detailed design of stable dredge cut side slopes and to provide an overdredge allowance.) This alternative is more robust than RAA-4b because it addresses OHM over a larger area. The assumed design dredge depth is 2.5 feet to address the Substantial Hazard and accommodate material to mitigate sheen generation and address dissolved-phase OHM. Although RAA-4c removes more sediment over a larger area than RAA-4b, impacted sediment would remain at depth within the river. Dredging is assumed to use the same means and methods as RAA-4a.
- **Sediment and Water Management:** Dredged sediment and water would be managed as they would be under RAA-4a.
- **Cap Placement:** A permeable active cap would be constructed to meet the same objectives as RAA-4b.
- **Additional Sheen Generation Management:** Additional sheen generation management would be handled similar to RAA-4a.
- **Long-Term Cap Monitoring:** Long-term cap monitoring and maintenance is included in this RAA. It is assumed that monitoring would be conducted over a 30-year period.

6.1.5 RAA-5: Dredge Only

RAA-5 consists of removing visually impacted sediment to achieve a Permanent Solution for the in-river portion of the Site. Based on the field investigation conducted to support the Phase II CSA, sediment with no visual observations of VOT and with concentrations of OHM that do not pose ecological risk was identified at the base of 4 of the 36 vibracore and hand auger locations within the Little River. This information was used to evaluate potential dredge depths that would address all identified impacted sediment, with the potential for additional dredging to be identified during construction based on field observations. Expected dredge depths range from 4 to 6 feet bml to remove visually impacted sediment and OHM concentrations that pose risk to ecological receptors. In addition, the potential for NAPL to migrate through the lower portion of the retaining wall would need to be addressed by placing sorbent material, installing a cutoff wall, or by other means.

Full removal of the impacted sediment with the retaining wall in its current condition is not feasible due to the depth of impacts along the wall (e.g., 4 to 6 feet bml) and the uncertain structural condition of the wall. Based on the lack of information on the construction of the retaining wall and engineering judgment, dredging adjacent to the retaining wall should be limited to 2 feet or less, which would limit the amount of impacted material that can be removed. A preliminary evaluation of replacing the wall conducted in 2017 concluded that repair or replacement was not economically feasible, with costs comparable to or higher than the sediment remediation costs. Due to the combined depth of impacted material and the condition of the retaining wall, RAA-5 is not considered a feasible alternative and is not discussed in the evaluation of alternatives.

In the Phase III process, it is necessary to evaluate the feasibility of reducing OHM in the environment at the Site to levels that achieve or approach background conditions. Reducing OHM in the environment to background or near background conditions is a criterion for achieving a Permanent Solution unless it can be shown that reaching background levels is infeasible. Section 310 CMR 40.0860(7)(a) does not quantify when an incremental cost of conducting a remedial action is "substantial and disproportionate" to the incremental benefit; however, the *Conducting Feasibility Evaluations Under the MCP* (MassDEP 2004) policy provides guidance for evaluating the feasibility of approaching or attaining background conditions. Section 9.3.3.4 of the guidance states that "it shall be considered feasible to conduct remedial actions to achieve background conditions if the additional costs to remediate beyond a NSR [No Significant Risk] condition are equal to or less than 20 percent of the cost to remediate to NSR."

Even without the additional dredging and dredged material disposal costs associated with RAA-5, the potential range of preliminary costs associated with replacing the retaining wall to facilitate dredging to the full vertical extent of OHM impacts is greater than the estimated cost to remediate to No Significant Risk (i.e., RAA-4c). The cost for approaching background conditions is, therefore, much greater than an additional 20% of the cost to remediate to No Significant Risk.

Based on the preceding guidance and the anticipated cost of remediating to background, it is not feasible to approach or achieve background conditions. In contrast, RAA-4c can achieve a Permanent Solution for the in-river portion of the Site.

6.2 Detailed Evaluation of RAAs

This section presents detailed evaluation criteria and compares the three RAA-4 scenarios with respect to those criteria. Section 310 CMR 40.0858 requires the following detailed evaluation criteria:

- Effectiveness
- Short- and long-term reliability
- Implementation
- Comparable cost
- Risk
- Benefits
- Timeliness
- Nonpecuniary interest

The RAAs in the detailed evaluation (RAA-4a through RAA-4c) have many similar elements, address similar areas, and are composed of similar technologies; however, they build upon each other and increase the extent of active remediation from RAA-4a to RAA-4c. The three alternatives were evaluated in accordance with 310 CMR 40.0858.

6.2.1 Effectiveness

In accordance with 310 CMR 40.0858(1), the effectiveness of each alternative was assessed in terms of the following: 1) achieving a Permanent or Temporary Solution under 310 CMR 40.1000; 2) reusing, recycling, destroying, detoxifying, or treating OHM at the disposal site; and 3) reducing levels of untreated OHM at the Site to concentrations that achieve or approach background.

Each identified RAA is effective in achieving either a Temporary or Permanent Solution. All three would address potential risks by removing OHM-impacted sediment from the in-river portion of the Site and managing OHM by transporting the sediment off site for disposal. In addition, RAA-4b and RAA-4c address the potential risk associated with dissolved-phase OHM.

RAA-4a would achieve a Temporary Solution for the in-river portion of the Site and represents the baseline effort required to achieve closure (not considering RAA-2). The Substantial Hazard would be removed, but sediment outside the RAA-4a footprint that poses a risk based on OHM comparison to screening levels and the risk from OHM in bulk sediment and porewater would not be addressed. RAA-4a would remove the smallest volume of OHM-impacted sediment of the evaluated alternatives; therefore, RAA-4a is considered less effective than RAA-4b or RAA-4c for overall risk reduction, but comparable in terms of achieving Site closure.

RAA-4b would achieve a Temporary Solution and would be more effective than RAA-4a because it would remove more OHM-impacted sediment, destroy a greater mass of OHM through off-site thermal desorption, and contain OHM concentrations in porewater within the Substantial Hazard area.

RAA-4c would achieve a Permanent Solution and be the most effective of the three alternatives because it would remove the most OHM-impacted sediment and subsequently destroy the most OHM through off-site thermal desorption. It would also be the most effective for risk reduction because it would address OHM-impacted sediment and OHM concentrations in porewater over the largest area.

Although RAA-4a through RAA-4c would reduce the OHM in the surface sediments, none of the identified RAAs would reduce sediment OHM to levels that achieve or approach background conditions in the sediments at depth. As discussed in Section 6.1.5, removal of OHM-impacted sediment sufficient to achieve or approach background levels within the in-river portion of the Site is not feasible.

6.2.2 Short-Term and Long-Term Reliability

Under 310 CMR 40.0858(2), short- and long-term reliability criteria address the degree of certainty that the alternative will be successful and the effectiveness of any measures required to manage residues or remaining wastes or to control emissions or discharges to the environment. All three RAAs would have similar short-term reliability because they all contain dredging elements; however, RAA-4b and RAA-4c would be more reliable in the short term because they immediately address porewater OHM through capping.

The three RAAs involve mechanical dredging of sediment OHM. Mechanical dredging, coupled with dredged material stabilization and off-site disposal via thermal desorption at an approved facility, has been successfully implemented at numerous sites with similar characteristics and OHM, including other sites in Massachusetts remediated by National Grid that include MGP-related OHM in sediment. Dredging would remove sediment that contains OHM and, therefore, would provide confidence that RAAs would be successful in achieving remedial objectives. Thermal desorption of sediments containing PAHs and NAPL is a proven technology, and the Clean Earth facility in Loudon, New Hampshire, has been identified as one capable of accepting the material and has successfully processed sediment containing MGP-related OHM from other sites. Subsequent design development may identify other approved facilities, but the estimated costs include the assumption that dredged sediment will be disposed of at the Clean Earth thermal desorption facility as nonhazardous waste.

Dredging conducted under all three RAAs would require use of best management practices (BMPs) and engineering controls to protect the aquatic environment (i.e., manage sediment resuspension and sheen generation during dredging and to limit subsequent post-dredge residuals) and the surrounding area (i.e., air quality controls and traffic plans for addressing risk associated with increased construction vehicle traffic over public roads). Environmental controls are expected to be used in the short term during construction to manage potential discharges to the environment. National Grid has developed BMPs that have successfully protected and limited impacts to the aquatic environment and surrounding area for similar remedial operations. Even with the use of BMPs and engineering controls, there is the potential for short- and long-term impacts associated with dredged residuals and potential releases.

RAA-4b and RAA-4c would address ERC-based risk in bulk sediment and porewater to a greater extent than RAA-4a through the use of a permeable active cap and, therefore, have better short-term reliability. BMPs, engineering, and environmental controls would be expected to be required during cap placement in RAA-4b and RAA-4c as well.

RAA-4b and RAA-4c would have better long-term reliability compared to RAA-4a because they would remove a greater volume of sediment OHM from the in-river portion of the Site than RAA-4a would. RAA-4c would have better long-term reliability than RAA-4b because it would include installation of a cap over a larger footprint, which would address both the area of Substantial Hazard and achieve a condition of No Significant Risk.

6.2.3 Implementability

Under 310 CMR 40.0858(3), the comparative difficulty of implementing each RAA identified by an initial screening shall be evaluated in terms of the following:

- The technical complexity of the alternative
- Where applicable, the integration of the alternative with existing facility operations and other current or potential remedial actions
- Any necessary monitoring, operations, maintenance, or site access requirements or limitations
- The availability of necessary services, materials, equipment, or specialists
- The availability, capacity, and location of necessary off-site treatment, storage, and disposal facilities
- Whether the alternative meets regulatory requirements for any likely approvals, permits or licenses required by the Department [MassDEP] or other state, federal, or local agencies

6.2.3.1 Technical Complexity

The three RAAs include mechanical dredging within a portion of the Little River. Mechanical dredging has been conducted successfully at numerous sites around the country with similar characteristics and OHM. Dredging is a complex operation that relies heavily on both engineering and environmental controls. Further technical complexity is added to this dredging project by the following:

- The river environment
  - The water levels and flow in this portion of the Little River increase after storms. There are no upstream means of managing the flow within the river, so in-river work will need to adapt to water conditions or establish engineering controls to manage water levels. These environmental challenges will be important when considering construction means and methods.
- Site features
  - The geometry of the Site includes the retaining wall on the eastern shoreline and the steep, heavily vegetated slope on the western shoreline. Both features make accessing the river extremely challenging. Working from the upland adjacent to the retaining wall would require an offset from the top of the wall and the use of equipment that can extend far enough to reach the required dredge depths in the river. If access were desired from the western shoreline, access agreements would need to be established with property owners, the shoreline would need to be modified to allow access down to the river, and pre- and post-sampling of the property would likely be required to confirm contamination of the property did not occur during construction.
  - The upland Site footprint is relatively small and is currently used as an active gas station with a car wash. Use of the upland as a staging area may require limiting access to portions of the upland site, which would impact commercial activities. Limiting the size of the staging area would likely limit the production rates and extend the duration of the remediation activities.
  - Engineering controls would be required to eliminate potential impacts to the Little River conduit located immediately downstream of the Site and protect the aquatic environment and surrounding areas. In addition, MBTA railroad tracks and electrical power lines run parallel to the headwall of the conduit. Site activities would be designed to maintain safe distances from both features.
- OHM distribution in the Little River
  - Field observations suggest that the occurrence of VOT-impacted sediment and OHM concentrations representing Significant Risk have been observed and identified in an approximately 22,200 sf area and in selected areas up to 5.5 feet bml. During remediation, dredging in heavily impacted areas would likely produce heavy sheen and would require environmental controls and monitoring.

The dredging activities of the three RAAs are of approximately equal technical complexity. Given the challenges of working in a riverine environment and the Site characteristics, mechanical dredging is expected to be complex. Placement of the RCM would likely add complexity; prior to placement, debris would need to be removed and a "levelling" layer would likely need to be added to provide a smooth surface on which to place the RCM. If the RCM is placed on an uneven surface, damage to the RCM and point loading of NAPL may occur, with both processes potentially causing failure of the RCM. Although dredging is expected to be complex, the technology is well developed, and many projects have been implemented successfully at sites with similar characteristics.

RAA-4b and RAA-4c also have capping components. The conceptual cap design consists of three layers of bulk material that would be challenging to place. The challenges posed by the riverine environment and the complexity of placing a cap in actively flowing and submerged conditions may affect cap placement precision. Temporary flow controls may be required during remediation to accommodate dredging and cap placement. Because RAA-4b and RAA-4c include more robust capping than RAA-4a, RAA-4b and RAA-4c are considered more technically complex.

6.2.3.2 Integration of Alternatives with Other Operations and Remedial Actions

The Site requires both upland and in-water RAAs. In-water RAAs need to be integrated into the upland remedial plans for the Site and the operations that are currently underway there (i.e., active gas station and car wash). In-water RAAs also need to accommodate future projects that may occur in the Little River, including the removal of the Little River dam by the City, as described in Section 6.2.3.3.

6.2.3.3 Integration with Other Current or Planned Activities

The City is currently in the design phase for removal of the Little River dam immediately upstream of the in-river portion of the Site. It is estimated the dam removal work will commence in fall 2024. Although an estimated 5,000 cy of sediment that has deposited behind the dam would be dredged and transported off site for disposal prior to dam removal by the City, it is anticipated that most of the material that has deposited behind the dam would be transported downstream by the natural flow of the river until a new steady-state condition is achieved (Fuss and O'Neill 2021). The sediment has the potential to partially deposit within the in-river portion of the Site. Based on hydrodynamic analyses, the water velocities downstream of the dam and within the boundary of the in-river portion of the Site are predicted to be similar before and after dam removal (Appendix A).

6.2.3.4 Monitoring or Site Access Requirements

Conducting work in the Little River would require consent from the MBTA and five other property owners (assuming property rights extend to the midpoint of the river) and from the City, which maintains an access corridor adjacent to the Winter Street bridge. Multiple access agreements would need to be negotiated to work in these portions of the Little River. Work in the vicinity of the conduit may need to be coordinated with the City, which is assumed to manage and maintain the conduit. National Grid does not own any of the Site.

All three RAAs would include a post-remediation monitoring and maintenance program that would require additional work beyond the planned construction, and property access would be required following initial remedial activities. If a need for maintenance activities is indicated by the monitoring results, additional cap construction would be required.

6.2.3.5 Availability of Services, Materials, Equipment, or Specialists

Necessary services, equipment, and specialized operators are available in the general New England/New York area to perform the required mechanical dredging and permeable active capping called for by the RAAs. Similar projects have been completed successfully in the area in the past, and qualified contractors and equipment are available to conduct the work. Materials required for the cap included in RAA-4b and RAA-4c are also readily available with sufficient lead time.

Granular materials would be selected from local quarries, and sorbent cap material, including RCM, would come from vendors on the East Coast or in the Midwest. The cap would be placed as layers of bulk material. The RCM and bulk material would be installed using conventional earth-moving equipment. Operators are available for this type of work.

6.2.3.6 Availability, Capacity, and Location of Off-Site Treatment, Storage, and Disposal Facilities

The upland portion of the Site has been tentatively identified as a staging and sediment processing area for dredged material stabilization and stockpiling prior to transportation to an off-site facility for disposal. The parcel is owned by Haffner.

Although space on the property is limited, locating the necessary sediment management operations is feasible in the space that is presumed available. An evaluation of a potential alternative area, including an adjacent property to the west of the Little River, will be evaluated as part of design. Selecting a staging and sediment processing area to support the remediation work within the Little River will require negotiations with the property owner(s). Stabilized dredge material would be transported off site for treatment and recycling. As previously noted, the Clean Earth thermal desorption facility in Loudon, New Hampshire, has been identified as the location for treatment and recycling. Previous projects with similar OHM have used that facility.

All three alternatives are similar in regard to availability, capacity, and location of off-site disposal facilities. RAA-4a would remove and dispose of less material, but there are no constraints currently on the amount of material within the range of the three alternatives that can be processed and disposed of off site.

6.2.3.7 Meets Regulatory Requirements for Permits and Licenses

Working in the riverine environment requires several local, state, and federal permits. Based on previous project experience, it is likely that each identified RAA would meet regulatory requirements for likely approvals, permits, or licenses and can be equally permitted and implemented. Table 3 summarizes the permits required to complete the in-river work.

6.2.4 Comparable Cost

The comparable cost of the alternatives under 310 CMR 40.0858(4) is presented in terms of the following:

- Costs of implementing the alternative, including without limitation: design, construction, equipment, site preparation, labor, permits, disposal, operation, maintenance, and monitoring costs
- Costs of environmental restoration, potential damages to natural resources, including consideration of impacts to surface waters, wetlands, wildlife, fish, and shellfish habitat
- The relative consumption of energy resources in the operation of the alternatives and externalities associated with the use of those resources

The estimate of probable cost for RAA-4a through RAA-4c is presented in Table 4. Estimated costs are based on feasibility study level of design and include construction, materials, and labor costs; long-term monitoring costs; engineering costs; and a +50%/-30% contingency. Estimates of probable costs for the three alternatives range from approximately $2.6 million (RAA-4a -30% contingency) to $6.3 million (RAA-4c +50% contingency) and increase from alternative RAA-4a to RAA-4c.

6.2.5 Evaluation of Risks

Under 310 CMR 40.0858(5), this detailed evaluation considers the risks posed by each alternative in three different time frames: the short term during remedial construction, the period required for the alternative to attain applicable remedial standards; and the longer term following remedial activity (i.e., the future risks).

6.2.5.1 Short-Term Risks during Construction

The three alternatives include dredging in the Little River and, therefore, pose potential short-term risks from possible discharges into the environment during in-water activities and when transporting dredged material off site for disposal. The potential risk is proportional to the amount of material dredged (i.e., the greater volume of material dredged, the greater the potential risk for discharges to the environment during dredging and transport). Based on the estimated volume of material to be dredged, RAA-4a represents the least short-term risk during construction, and RAA-4c represents the most short-term risk. RAA-4c removes approximately 1,700 cy more sediment than RAA-4a and approximately 750 cy more than RAA-4b.

Although effective in removing OHM-impacted sediment, mechanical dredging poses short-term risks due to releases via resuspension and release to the water column and air, including the potential discharge of OHM to surface water and air that must be managed. Even the most state-of-the-art dredging and excavation equipment methods have technical limitations that often result in contaminant release and residuals left behind that require further management to achieve the desired risk reductions (Bridges et al. 2008). A water quality monitoring program would be employed during construction to monitor the potential effects of dredging on the environment, as needed. Environmental controls, including turbidity curtains, absorbent booms, and other BMPs, can be used in conjunction with water quality monitoring to protect surface water. However, the effectiveness of BMPs such as turbidity control devices is often limited by site conditions and/or the technical limitations of the technology or BMP. For instance, silt curtains have been demonstrated to be generally ineffective in reducing the downstream release of dissolved contaminants. If monitoring indicates that dredging is adversely affecting water quality, dredging operations would be modified using engineering controls, for example by having a cleanup crew ready in the event of a discharge. Working in "dry" conditions limits the potential for releases of OHM to surface water.

Emissions of volatile OHM, particulates, and odors into the air due to dredging activities conducted in the "dry" as well as during on-site sediment handling, stabilization, and stockpiling also represent a potential short-term risk. Air quality monitoring would be conducted in both the work area and along the perimeter of the Site. If monitoring indicates that OHM, particulate matter, or odors are being emitted and might affect the health of workers and receptors, engineering controls would be employed to mitigate those emissions. On-site dust control measures and odor/volatile-controlling foam would be applied where necessary.

The short-term risk of transporting material off site for disposal is greatest for RAA-4c, which requires the disposal of the largest volume of material; the short-term risk is the least for RAA-4a due to the smaller volume of material requiring disposal. It is assumed that material would be loaded onto trucks and transported to the Clean Earth facility in Loudon, New Hampshire. Specifications would restrict truck loading to avoid overloading. Dredged material placed in trucks would have been stabilized with the appropriate dosing of stabilization agent so the dredged material passes the paint filter test prior to transport. Upon leaving the Site, truck tires would be cleaned or brushed to limit material tracked off the Site. A traffic control plan would manage traffic at the Site and would identify the best routes from the stabilization area to the disposal facility while avoiding busy traffic areas.

There are potential short-term risks associated with water management from dewatering dredged material and collecting surface water runoff in the sediment processing area. Risks include the potential for a release of water if pipes are damaged or become disconnected. In colder months, it is possible that water will freeze within frac tanks. If there is a significant rain event and sufficient water capacity is not considered, there is the possibility that there will be insufficient capacity within the frac tank(s) and water will overflow the system.

In addition to short-term risks associated with dredged material and dredged material transport, there are short-term risks associated with working in the vicinity of the retaining wall. Vehicle movement at the top of the wall and dredging activities at the base have the potential to affect the stability of the wall. Specifications would restrict the work zones in the upland portion of the Site and limit dredged depths along the base of the retaining wall to minimize short-term risks.

There are also short-term risks associated with fully or partially bypassing water in the Little River and with working in the vicinity of the Little River conduit headwall, the MBTA railroad tracks, and electrical power lines. Risks associated with these Site features would be managed through BMPs, engineering controls, and Site and work limitations that will be documented in the Specifications and coordinated with the contractor.

6.2.5.2 Risks While Achieving Applicable Remedial Standards

Potential on-site and off-site risks during the time period for the alternative to achieve an applicable remedial standard are associated with the permeable active cap, specifically the NAPL sorbent layer and the chemical containment layer in alternatives RAA-4b and RAA-4c.

The NAPL sorbent layer is intended to control the migration of NAPL through ebullition-facilitated transport and eliminate sheens on the surface of the Little River. There is a potential for the NAPL sorbent layer to fail if NAPL migrates around the NAPL sorbent layer, additional areas of sheen generation are identified, or rates of ebullition-facilitated NAPL transport are higher than estimated based on site observations. Long-term monitoring would be implemented with each alternative to monitor potential sheen in the Little River and to conduct maintenance, if needed.

The cap layer that would address dissolved-phase OHM in porewater would sequester OHM contained in the porewater as the porewater migrates through the cap layer and before it enters the biologically active zone in the top 6 inches of sediment and eventually discharges into the surface water. RAA-4b and RAA-4c would address potential future porewater-based risk. RAA-4a may mitigate some OHM from the porewater, but additional material (e.g., GAC) would not be included in the backfill to aid in OHM sequestration.

There is a potential risk of cap failure. The cap may fail due to migration of OHM into the shallow portions of the cap that are biologically active or by erosion or other damage to the cap. These scenarios are not likely due to predictive OHM transport modeling that incorporates conservative assumptions during cap design development, adding an armor layer to the cap to limit potential erosion, and imposing AULs to limit Site activities and the associated potential for cap damage.

Based on previous experience, the potential risk of failure for caps that contain dissolved OHM is not significant.

Because the permeable active cap for RAA-4b and RAA-4c also addresses risk presented by dissolved-phase OHM, the ability of these two alternatives to reduce potential risk during the time required to achieve a remedial objective is considered better than that of RAA-4a. And of the alternatives, RAA-4c has the ability to provide the largest reduction due to the larger footprint of its cap.

6.2.5.3 Long-Term Risks

Of the three alternatives, RAA-4c is expected to best manage potential long-term risk. RAA-4c removes both the Substantial Hazard and the ecological risk; RAA-4a and RAA-4b only address the Substantial Hazard area.

6.2.6 Benefits

Under 310 CMR 40.0858(6), the evaluation of benefits includes the following: 1) the benefit of restoring natural resources; 2) the productive reuse of the site; 3) the avoided costs of relocating people or businesses and of providing alternative water supplies; and 4) the avoided lost value of the site.

Dredging is expected to produce a short-term disruption to natural resources as part of all three alternatives; however, after removal of OHM, there is the potential for long-term restoration of improved habitat and the development of a more active biological community. RAA-4a and RAA-4b disturb comparatively smaller areas of habitat in the short term by only removing the Substantial Hazard area. RAA-4c removes both the Substantial Hazard and sediment posing a risk, ultimately allowing for a more productive aquatic community in the future.

Material placement is expected to alter benthic habitat in the short term for all three alternatives. RAA-4c has the potential to cause the most habitat alteration because it would cap the largest area. A comparatively smaller area is backfilled or capped in RAA-4a and RAA-4b than in RAA-4c; therefore, the habitat alteration is expected to be proportionally less. Armor material placed over the cap would be similar to the existing bed material and therefore would reproduce a similar benthic habitat.

The Site use is not expected to change significantly in the foreseeable future, nor is the implementation of any of the three RAAs expected to change the use of the Site. The cap placed as part of all three RAAs would likely require multiple AULs to protect the integrity of the cap. Alternative RAA-4a removes slightly less sediment, which may result in a shorter construction period.

6.2.7 Timeliness

Under 310 CMR 40.0858(7), timeliness refers to the length of time required for each alternative to eliminate any uncontrolled OHM sources and achieve a level of No Significant Risk. RAA-4a and RAA-4b score relatively poorly with respect to timeliness because they would remove only the Substantial Hazard area and would not achieve a level of No Significant Risk. They would require additional dredging and cap placement to achieve a level of No Significant Risk.

RAA-4c provides the greatest timeliness to achieve a condition of No Significant Risk because it would eliminate the combined Substantial Hazard and ecological risk area and the dissolved-phase OHM concentrations by capping.

6.2.8 Nonpecuniary Interests

Under 310 CMR 40.0858(8), the relative effect of the alternatives on nonpecuniary interests, such as aesthetic values, is evaluated. All three alternatives would remove sediment containing VOT from the in-river portion of the Site. VOT in sediment has been reported as a source of sheen. Sheen has been observed in the in-river portion of the Site over time, and a semipermanent boom system was installed in November 2016 to address the appearance of sheens on surface water. Removing a portion of the VOT from the in-river portion of the Site and placing a NAPL-sorption layer are expected to reduce the occurrence of sheens and improve the aesthetic appearance of the river surface.

The three alternatives would also remove the debris (e.g., tires, shopping cart, logs, and concrete) from the in-river portion of the Site, increasing the aesthetic appearance of the river.

All three alternatives are expected to have a considerable carbon footprint, based on expected fuel consumption for dredging, dredged material transport, and dredged material treatment. The consumption of fuel is expected to increase from RAA-4a to RAA-4c based on the increasing need for dredging, dredged and capping materials transport, and treatment (e.g., by thermal desorption). The carbon footprint can be partially mitigated by developing efficient work practices, using biofuel, and selecting efficient equipment.

The potential effect on nonpecuniary interests is similar for RAA-4a and RAA-4b because they have a similar footprint within which debris removal, dredging, and capping would occur. Although some aesthetic improvements might occur outside the dredge/cap footprint to transition the design into the surrounding area, it is likely that RAA-4c would have the greatest potential effect on nonpecuniary interests due to the larger remedial footprint.

7 Selection of the Remedial Action Alternative

7.1 Description of the Selected Remedial Action Alternative

Based on the detailed analysis of RAAs presented in this Phase III RAP, RAA-4c is recommended as the selected alternative for further refinement and implementation in the in-river portion of the Site. RAA-4c is designed to provide a Permanent Solution. It achieves a condition of No Significant Risk by removing OHM-impacted sediment from approximately 22,200 sf of the Little River and placing a cap that will address both OHM source material and dissolved-phase OHM. Substantial Hazard and OHM that posed ecological risks identified in the Phase II CSA Report will be removed during dredging (GZA 2022b).

The feasibility evaluations required by 310 CMR 40.0860 are presented in the following section.

7.2 Feasibility Evaluations

As part of the Phase III evaluation process, 310 CMR 40.0860 requires that feasibility evaluations be conducted as follows.

7.2.1 Feasibility Assessment – Permanent Solution

A Permanent Solution is feasible for the in-river portion of the Site if AULs can be applied to all applicable properties where a cap would be installed. RAA-4c would qualify the in-river portion of the Site for a Permanent Solution by eliminating the Substantial Hazard, controlling sources of OHM to the Little River (i.e., appearance of sheens on surface water), and achieving a level of No Significant Risk.

7.2.2 Feasibility Assessment – Background Conditions

As discussed in Section 6.1.5, removal of sediment impacted with visible NAPL and concentrations of OHM above background concentrations is not feasible due to the uncertain structural condition of the retaining wall, associated recommended limitations on dredge depths adjacent to the retaining wall, and the high estimated cost of replacing the retaining wall to accommodate the extent of dredging needed to approach or achieve background conditions. Therefore, it is not feasible to reduce concentrations of OHM at depth to background or near background conditions. The placement of a permeable active cap following mechanical dredging would contain the remaining OHM and mitigate the potential migration of NAPL and dissolved-phase PAHs to the surface sediments.

7.2.3 Feasibility Assessment – Upper Concentration Limits

There are no upper concentration limit conditions in the in-river portion of the Site; therefore, this assessment is not applicable.

7.2.4 Feasibility Assessment – Critical Exposure Pathways

This feasibility assessment is not applicable. There are no Critical Exposure Pathways in the in-river portion of the Site.

7.2.5 Feasibility Assessment – Oil and Hazardous Material

7.2.5.1 Source Elimination or Control

OHM concentrations in the in-river portion of the Site represent material deposited via a historical source. As discussed in prior sections, potential ongoing sources of sheen to surface water include NAPL within the sediment being transported via ebullition and the potential migration of NAPL from behind the base of the retaining wall. Future pre-design investigations in the early stages of development of a Phase IV RIP would evaluate sheen migration through the wall as a potential OHM source. In addition, a supplemental exploration program would be implemented to further evaluate the potential for preferential NAPL migration pathways from the upland portion of the Site to the Little River. If needed, the remedial design would include measures to address OHM migration through the wall. All three RAAs would eliminate the release of OHM (i.e., sheen observed on surface water) and control sources of OHM to the extent feasible. In addition, all three RAAs include the capping or sealing of pipes that extend through the retaining wall to eliminate potential migration pathways.

7.2.5.2 Migration Control

The Little River represents a discharge point for groundwater, and no vadose zone is present within the Little River. Therefore, this feasibility assessment is not applicable.

7.2.5.3 Nonaqueous Phase Liquid

The nature, extent, and mobility of NAPL observed in the in-river portion of the Site was evaluated as part of the Phase II CSA Report (GZA 2022b). Based on that evaluation, NAPL present in the in-river portion of the Site was identified as stable under advective forces and potentially mobile due to ebullition-facilitated transport; an area of RAH was also identified. NAPL in the in-river portion of the Site does not appear to have micro-scale mobility (see Section 3.2). All three RAAs would adequately contain and control the identified NAPL to address potential NAPL migration via ebullition and to remove NAPL that represents RAH. The application of an organoclay RCM in all three RAAs would control potential NAPL migration through the base of the retaining wall.

8 Completion Statement, Public Involvement, and Report Limitations

The Completion Statement and Public Notification are discussed and presented in GZA's Phase III RAP (GZA 2022a).

9 References

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Tables

Table 1
Initial Screening of Remedial Technologies

Category	General Response Actions	Remedial Technology Type	Remedial Technology	Process Options	Description	Reasonably likely to Achieve a Permanent or Temporary Solution as Part of a Remedial Action Alternative	Technically Feasible	Retained for Consideration for Remedial Action Alternative Development	Screening Comments
No Action/Institutional Controls	No action	Natural attenuation	Natural attenuation	N/A	No active remedy.	No	No	Yes	Retained. Although this remedial technology type does not effectively achieve objectives, it is retained for comparison purposes.
	Institutional controls	Deed restrictions	Deed restrictions	N/A	AUL applied to property deed.	No	Yes	Yes	Retained. Will be considered in combination with another remedial technology.
Aquatic Containment	In situ containment	Permeable cap	Permeable cap	Active cap	Use of highly sorptive material (e.g., organoclay or activated carbon) to sequester contaminants. Cap is permeable to water and gas. Contaminants are sorbed by active material.	Yes	Yes	Yes	Retained. May not be feasible if cap thickness exceeds water depth or sufficient dredge depths cannot be achieved to accommodate a cap.
				Isolation cap	Use of earthen materials to provide a barrier between contamination and receptors. Cap is permeable to water and gas.	Yes	Yes	Yes	Retained. May not be feasible if cap thickness exceeds water depth or sufficient dredge depths cannot be achieved to accommodate a cap.
		Low-permeability cap	Low-permeability cap	Engineered cap	Use of impermeable or low-permeability materials to contain contamination.	Yes	Yes	No	Not retained. Potential for gas generation and groundwater discharge are problematic, and other capping technologies are available and implementable given site conditions.
In Situ Treatment	Biological	Biological treatment	Biological treatment	Enhanced bioremediation	Addition of carbon source to encourage microbial activity.	No	Yes	No	Not retained. The nature of the contamination in the river is such that it does not support in situ biological treatment. NAPL is present at the site and can inhibit the growth of the organisms selected for bioremediation. Previous experience does not favor this alternative.
	Physiochemical	In situ amendment	In situ amendment	Carbon addition	Introducing carbon (i.e., sorptive sites) into sediment either by physically mixing or by pellet form to be mixed via bioturbation.	No	Yes	No	Not retained. Separate phase NAPL will overwhelm sorptive sites made available by addition of carbon.
		Immobilization	In Situ Solidification/ Stabilization	Solidification/ Stabilization	Addition and mixing of materials (e.g., Portland cement) into sediments containing MGP-related constituents to limit the mobility of the MGP-related constituents in sediment. Involves treating sediment to produce a stable relatively immobile material with low leachability that physically and chemically binds MGP-related constituents in the solidified/stabilized matrix.	Yes	No	No	Not retained. The presence of cobbles/debris larger than 6 inches may interfere with auger mixing process.

Table 1
Initial Screening of Remedial Technologies

Category	General Response Actions	Remedial Technology Type	Remedial Technology	Process Options	Description	Reasonably likely to Achieve a Permanent or Temporary Solution as Part of a Remedial Action Alternative	Technically Feasible	Retained for Consideration for Remedial Action Alternative Development	Screening Comments
Sediment Removal, Management, and Disposal	Sediment removal	Dredging	Mechanical dredging	Mechanical excavator or crane	Excavator or crane equipped with controls and special buckets for excavating close to the retaining wall. This remedial technology may also require bracing along the retaining wall.	Yes	Yes	Yes	Retained. Mechanical dredging is frequently conducted at sites with similar settings and contaminant characteristics. Necessary equipment and operators are readily available in the region. Sediment removed by this remedial technology will be at nearly the same solids content as in-situ conditions leading to less water generation and water treatment needed during dredging operations than with hydraulic dredging. This process option is anticipated for the majority of sediment removal. Mechamical dredging can also occur "in the dry" if water levels are reduced.
			Hydraulic dredging	Cutterhead or pure suction dredge	A rotating cutterhead loosens sediment and a centrifugal pump draws the sediment and water slurry through a pipeline. Pure suction dredge is a hydraulically dredges with minimal agitation of sediment.	Yes	Yes	No	Not retained. Hydraulic dredging is not feasible at the site due to sediment conditions (presence of cobbles and debris) and the volume of water containing OHM that requires treatment. Generally, this technology entrains more water than mechanical dredging, but accuracy is greater. The accuracy required at this site can be achieved by mechanical dredging, and the added expense due to water generation and treatment is not warranted. The upland space required for a water treatment train necessary to treat the amount of water generated by hydraulic dredging is limited.
			Specialty dredging	Pneumatic	Air-operated submersible pump with pipeline transport.	Yes	No	No	Not retained. Technology is likely implementable, but unproven for similar projects. Also, availability in the Northeast is limited.
				Vacuum	Vacuum removal trucks.	Yes	Yes	No	Not retained. Sediment conditions (presence of cobbles and debris) are not amenable to vacuum truck removal due to the potential for clogging the equipment.

Table 1
Initial Screening of Remedial Technologies

Category	General Response Actions	Remedial Technology Type	Remedial Technology	Process Options	Description	Reasonably likely to Achieve a Permanent or Temporary Solution as Part of a Remedial Action Alternative	Technically Feasible	Retained for Consideration for Remedial Action Alternative Development	Screening Comments
Sediment Removal, Management, and Disposal	Sediment transport and management	Transport of dredged materials (on site and off site)	Transport of dredged materials (on site and off site)	Pipeline	Pump slurry from dredge area to processing area.	Yes	Yes	No	Not retained. Additional water may need to be added to allow for pumping and pipeline transport to on-site processing area. Use of technology is unlikely due to the volume of water that would need to be managed.
				Conveyor	Convey dredged material from barge to processing area.	Yes	No	No	Not retained. Water is not deep enough to allow barge and conveyor transport of dredged materials.
				Barge	Dredged material placed in barges or scows, which are transported to processing area by tugs or work boats. Material offloaded from barge to processing area using earthmoving equipment, crane, or conveyor.	Yes	No	No	Not retained. Water is not deep enough to allow barge or scow transport.
				Container	Dredged material placed in water-tight containers, which are transported to processing area by a crane or excavator. Dredged material can be managed in the container or removed from the container and unloaded into a processing area using earthmoving equipment or crane.	Yes	Yes	Yes	Retained. Container transport is retained for transport of dredged material from the river to an upland processing area.
				Truck	Off-site transport to disposal facility or on-site transport to processing area.	Yes	Yes	Yes	Retained. Truck transport is retained for transport to off-site disposal facility.
		Dewatering	Dewatering	Gravity Settling and Drainage	Allowing stockpiled sediment to passively dewater.	Yes	Yes	Yes	Retained. Technology has been successful on other sites to reduce moisture content necessary for off-site disposal. May be combined with additional dewatering technologies, particularly for finer grained material (i.e., silt and clay).
		Dewatering	Solidification /Stabilization	Admixtures/additives (e.g., cement based or other)	Portland cement, kiln dust, fly ash, lime, clay minerals, and other absorbent materials.	No	Yes	Yes	Retained. Technology has been successful on other sites and will likely be combined with additional dewatering technologies. However, technology may not be necessary to implement if sediment samples pass the paint filter test and do not contain reactive sulfide.

Table 1
Initial Screening of Remedial Technologies

Category	General Response Actions	Remedial Technology Type	Remedial Technology	Process Options	Description	Reasonably likely to Achieve a Permanent or Temporary Solution as Part of a Remedial Action Alternative	Technically Feasible	Retained for Consideration for Remedial Action Alternative Development	Screening Comments
Sediment Removal, Management, and Disposal	Sediment transport and management	Dewatering	Dewatering	Geotextile bag	Dredged or rehandled materials are pumped into geotextile bags, and excess water flows through the pores in the geotextiles, resulting in effective dewatering and volume reduction of the dredged materials. Solids remain in the geotextile bag and water discharges from bag. Water must be treated.	Yes	Yes	No	Not retained. This process is typically applicable to hydraulically dredged material and hydraulic dredging was not retained. The geotextile bag influent would require pumping from a scow or a stockpile, and the material pumped would need to be of a pumpable water content. Entraining additional water into dredged material for the purpose of dewatering is not efficient. The effluent water from the geotextile bag dewatering process must also be treated.
	Sediment transport and management	Dewatering	Mechanical dewatering	Belt filter press	Sediment slurry drops onto a perforated belt where gravity drainage takes place. Thickened solids are pressed between a series of rollers to further dewater solids.	No	Yes	No	Not retained. This process is typically applicable to hydraulically dredged material and hydraulic dredging was not retained. Process cannot typically achieve required solids content. Also, limited upland space is available for staging equipment.
				Plate and frame filter press	Sediment slurry is pumped into cavities formed by a series of plates covered by a filter cloth. Liquids are forced through the filter cloth and dewatered solids are collected in the filter cavities.	Yes	Yes	No	
				Hydrocyclones	Sediment slurry is fed tangentially into a funnel-shaped unit to facilitate centrifugal forces necessary to separate solids from liquids. Dewatered solids are collected, and overflow liquid is discharged.	No	Yes	No	

Table 1
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Category	General Response Actions	Remedial Technology Type	Remedial Technology	Process Options	Description	Reasonably likely to Achieve a Permanent or Temporary Solution as Part of a Remedial Action Alternative	Technically Feasible	Retained for Consideration for Remedial Action Alternative Development	Screening Comments
Sediment Removal, Management, and Disposal	Sediment transport and management	Liquids management	On-site water treatment	Oil/water separation	Process where oil-based products are separated from suspended solids in dredged sediment and are skimmed away. Technology considered in combination with other on-site water treatment options. Treated water would be released into river.	Yes	Yes	No	Not retained. Retained sediment removal technologies are limited to mechanical dredging, which is not anticipated to generate the significant water volumes associated with hydraulic dredging, suction dredging, or vacuum truck removal. Remedial technology is technically feasible but likely not economical due to the anticipated limited water generation compared to hydraic and specialty dredging methods.
				Filtration	Process where contaminants are filtered out through various media (e.g., sand) from the liquid stream. Technology considered in combination with other on-site water treatment options. Treated water would be released into river.	Yes	Yes	No	
				Chemically assisted clarification	Process where chemicals (i.e., polymers) are added to the liquid stream to assist in clarification. Technology considered in combination with other on-site water treatment options. Treated water would be released into river.	Yes	Yes	No	
				Carbon adsorption	Process where granular activated carbon is used to remove contaminants from the aqueous phase. Technology considered in combination with other on-site water treatment options. Treated water would be released into river.	Yes	Yes	No	
			Off-site water treatment	City of Haverhill WWTP	Water would require extensive treatment before introducing into WWTP.	Yes	No	No	Not retained. Water would require extensive pre-treatment before introduction into a WWTP.
				Other disposal facility	Collecting water and containerizing on site. Transporting off site for disposal.	Yes	Yes	Yes	Retained. The expected quantity of water anticipated is most cost-effectively treated off site. Frac tanks will be used to temporarily store liquid waste on site before off site treatment.

Table 1
Initial Screening of Remedial Technologies

Category	General Response Actions	Remedial Technology Type	Remedial Technology	Process Options	Description	Reasonably likely to Achieve a Permanent or Temporary Solution as Part of a Remedial Action Alternative	Technically Feasible	Retained for Consideration for Remedial Action Alternative Development	Screening Comments
Sediment Removal, Management, and Disposal	Sediment transport and management	Aquatic environmental controls	Containment barriers	Permeable curtain/barrier	Permeable temporary barrier constructed of geotextile. Water flows through, but sediment particles that are larger than the apparent opening size of the geotextile are contained.	Yes	Yes	Yes	Retained. Reactive permeable geosynthetics (e.g., CETCo mats) can be used to address water column NAPL and dissolved organics, if necessary.
				Air bubble walls	Introduces air into water column to direct and contain sediment particles.	Yes	Yes	No	Not retained. Technology is less effective compared to other technologies.
				Impermeable curtain/barrier	Impervious temporary barrier that redirects flow around the dredge area.	Yes	No	No	Not retained. Water flow in the river limits the use of an impermeable curtain/barrier.
				Sheet pile walls	Install sheeting to contain particulate matter.	Yes	Yes	No	Not retained. Rocky shoreline on the western bank and retaining wall on the eastern bank prevent access for equipment needed for sheet pile wall installation.
				Containment/absorbent boom and skimmers	Booms made of sorptive material that sorb NAPL from water surface.	Yes	Yes	Yes	Retained.
			Water quality monitoring	Near-field and far-field monitoring during dredging	Monitoring water quality in the near field around the dredge area as well as at upstream and downstream far field locations.	Yes	Yes	Yes	Retained. Water quality monitoring will be required by permits for in-water work that disturbs sediment.
		Airborne environmental controls	Organic vapor, dust, and odor control	Sprung structure	A temporary structure that contains potential airborne releases for upland sediment processing and stockpiling of dredged sediment.	Yes	Yes	Yes	Retained. Will be used as needed if required by monitoring.
				Plastic liner	Place plastic liner over upland stockpiles of dredged sediment when not being activley managed.	Yes	Yes	Yes	Retained. Will be used as needed if required by monitoring.
				Foam	Foam suppresses odors and vapors emanating from upland stockpiled of dredged sediment.	Yes	Yes	Yes	Retained. Will be used as needed if required by monitoring.
			Air monitoring	Monitoring work area and surrounding areas	Monitoring background upwind and downwind conditions (i.e., organic vapor and dust) with periodic laboratory analysis, as needed.	Yes	Yes	Yes	Retained. Air quality monitoring is retained for ensuring the safety of workers and receptors.
		Ex situ solids treatment	Soil washing	Soil washing	Sediment is put in contact with an aqueous solution to remove contaminants from the soil particles.	No	Yes	No	Not retained. Not compatible with MGP sediment.

Table 1
Initial Screening of Remedial Technologies

Category	General Response Actions	Remedial Technology Type	Remedial Technology	Process Options	Description	Reasonably likely to Achieve a Permanent or Temporary Solution as Part of a Remedial Action Alternative	Technically Feasible	Retained for Consideration for Remedial Action Alternative Development	Screening Comments
Sediment Removal, Management, and Disposal	Sediment transport and management	Ex situ solids treatment	Stabilization/ Solidification	Asphalt-batching (on site)	Mixing excavated sediment with asphalt emulsion to immobilize contaminants.	No	Yes	No	Not retained. On-site upland space is not available for asphalt batching.
				Asphalt-batching (off site)		No	Yes	Yes	Retained.
			Thermal treatment	Vitrification	High-temperature heating to destroy contaminants.	No	Yes	No	Not retained. Would require permitting and because sediment/OHM are nonhazardous, incineration is not necessary. Not a cost-effective technology for site conditions.
				Incineration (off site)	Sediments are incinerated off site for high-temperature thermal destruction.	Yes	Yes	No	Not retained. Incineration is not necessary due to the contaminants of concern identified at the site and the concentrations of the contaminants.
				Thermal desorption (on site)	Heating of excavated sediment in a rotary dryer to volatilize hydrocarbons, which are collected and destroyed in a thermal oxidizing unit.	Yes	No	No	Not retained. On-site upland space is not available.
				Thermal desorption (off site)		Yes	Yes	Yes	Retained. Thermal desorption has been used effectively for similar materials from other sites.
		On site disposal	Nearshore CDF	Earthen berms or structural walls	Construction of a containment vessel on site that contains some material in situ and acts as disposal for sediment removed from outside of the CDF footprint.	Yes	No	No	Not retained. On-site space is not available for development of or disposal into a CDF.
		Off-site disposal	Off-site CDF	Earthen berms and structure walls	Placement of material in an engineered containment cell located off site.	Yes	Yes	No	Not retained. Off-site CDF is not available.
		Off-site disposal	CAD	Natural or artificial bathymetric depression	Placement of material in a bathymetric depression or created depression in open water. Cap with clean material.	Yes	Yes	No	Not retained. Location not available for a CAD cell at or near the site.
	Solids disposal	Off-site disposal	Off-site disposal	Upland hazardous landfill	Disposal of sediments/debris with MGP-related impacts in an existing permitted hazardous landfill.	Yes	Yes	No	Not retained. Sediment and OHM are not hazardous.
				Upland nonhazardous landfill	Disposal of sediment in an existing permitted nonhazardous landfill.	Yes	Yes	Yes	Retained. Retained based on success on previous projects.
				MSW landfill	Disposal of sediment/debris in a municipal solid waste landfill.	Yes	Yes	No	Not retained. OHM concentrations are too high for local municipal solid waste landfill disposal.

Table 1
Initial Screening of Remedial Technologies

Notes:

1. Each remedial technology is evaluated based on the following criteria as required by 310 CMR 40.0856(1): 1) Is the technology reasonably likely to achieve a Permanent or Temporary solution; and 2) Are individuals with the expertise needed to effectively implement the technology available regardless of arrangements required for securing their services. Technologies that meet both these criteria are generally retained for inclusion into RAAs; however, some technologies that meet the criteria are not retained due to specific site conditions that render the technology ineffective for this Site.
2. The remedial technologies presented in the table above are components of remedial action alternatives and are not being evaluated as individual entities. The potential for a remedial technology to achieve a permanent or temporary solution is based on the inclusion of the technology into an RAA.

AUL: acitvity and use limitation
CAD: confined aquatic disposal
CDF: confined disposal facility
MGP: manufactured gas plant
MSW: municipal solid waste
N/A: not applicable
NAPL: nonaqueous phase liquid
OHM: oil and/or hazardous material
PAH: polycyclic aromatic hydrocarbon
RAA: remedial action alternative
VOT: visible oil and tar
WWTP: wastewater treatment plant

Table 2
Summary of Remedial Action Alternatives

Alternative	Predicted Outcome	Major Design Elements
RAA-1: No Action	Does not achieve a temporary or permanent solution for the in-river portion of the site	N/A
RAA-2: Modified Boom System	Temporary solution	• Mitigates Substantial Hazard and controls in-water sources – Modify existing semi-permanent boom system – Plug pipes extending through retaining wall • Long-term semi-permanent boom system monitoring and maintenance
RAA-3: Install Cap on Grade	N/A. Not an implementable alternative for the in-river portion of the site	• Eliminates Substantial Hazard and ERC-based risk area and contains in-water sources – Install permeable active cap consisting of NAPL-sorbent material, dissolved phase chemical containment layer, and clean backfill within Substantial Hazard area on existing sediments (e.g., on grade) – Place NAPL-sorbent material at the base of the retaining wall; plug pipes extending through retaining wall • Long-term cap monitoring and maintenance
RAA-4a: Eliminate Substantial Hazard via dredging, contain potential ongoing sources	Temporary solution	• Eliminates Substantial Hazard and contains in-water sources – Dredge sediment to remove Substantial Hazard – Transport dredged sediment to upland portion of the site for stabilization/dewatering with Portland cement (or equivalent) – Transport stabilized sediment off site for disposal at thermal desorption facility – Install permeable active cap consisting of NAPL-sorbent material and clean backfill within Substantial Hazard area – Place NAPL-sorbent material at the base of the retaining wall; plug pipes extending through retaining wall • Long-term cap monitoring and maintenance • Activity and Use Limitation required on properties where the cap is installed to protect the integrity of the cap from potential in-river activities
RAA-4b: Eliminate Substantial Hazard via dredging, address partial ERC-based risk area via capping, contain potential ongoing sources	Temporary solution	• Eliminates Substantial Hazard and in-water sources and addresses ERC-based risk area within Substantial Hazard footprint – Dredge sediment to remove Substantial Hazard – Transport dredged sediment to upland portion of the site for stabilization/dewatering with Portland cement (or equivalent) – Transport stabilized sediment off site for disposal at thermal desorption facility – Install permeable active cap consisting of NAPL-sorbent material, dissolved phase chemical containment layer, and clean backfill within Substantial Hazard area – Place NAPL-sorbent material at the base of the retaining wall; plug pipes extending through retaining wall • Long-term cap monitoring and maintenance • Activity and Use Limitation required on properties where the cap is installed to protect the integrity of the cap from potential in-river activities
RAA-4c: Eliminate Substantial Hazard via dredging, address ERC-based risk area via dredging and capping, contain potential ongoing sources	Permanent solution	• Eliminates Substantial Hazard and in-water sources and addresses ERC-based risk area – Dredge sediment to remove Substantial Hazard; dredge sediment to accomodate a cap in ERC-based risk footprint – Transport dredged sediment to upland portion of the site for stabilization/dewatering with Portland cement (or equivalent) – Transport stabilized sediment off site for disposal at thermal desorption facility – Install permeable active cap consisting of NAPL-sorbent material, dissolved phase chemical containment layer, and clean backfill within ERC-based risk footprint – Place NAPL-sorbent material at the base of the retaining wall; plug pipes extending through retaining wall • Long-term cap monitoring and maintenance • Activity and Use Limitation required on properties where the cap is installed to protect the integrity of the cap from potential in-river activities

Table 2
Summary of Remedial Action Alternatives

Alternative	Predicted Outcome	Major Design Elements
RAA-5: Approach Background Conditions via dredging, contain potential ongoing sources	N/A. Not an implementable alternative for the in-river portion of the site	• Eliminates Substantial Hazard and ERC-based risk area and eliminates or contains in-water sources – Dredge sediment to approach Background Conditions – Transport dredged material to upland portion of the site for stabilization/dewatering with Portland cement (or equivalent) – Transport stabilized dredged material off site for disposal at thermal desorption facility – Place NAPL sorbent-material at the base of the retaining wall; plug pipes extending through retaining wall • Long-term monitoring and maintenance

Notes:
ERC: environmental risk characterization
N/A: not applicable
RAA: remedial action alternative
NAPL: nonaqueous phase liquid

Table 3
Summary of Environmental Permits

Application/License or Permit	Regulatory Agency	Regulations
Federal		
Department of the Army General Permit Commonwealth of Massachusetts	U.S. Army Corps of Engineers, New England District	• Rivers and Harbors Act of 1899 (Section 10) • Clean Water Act (Section 404) • Massachusetts Programmatic General Permit
State		
Environmental Notification Form	Massachusetts Office of Energy and Environmental Affairs	• MEPA 301 CMR 11.00
Chapter 91 Waterways Permit/License	Massachusetts Department of Environmental Protection	• Massachusetts Public Waterfront Act ("Chapter 91")
Massachusetts Coastal Zone Management	Office of Coastal Zone Management	• Massachusetts Coastal Zone Management Act
401 Water Quality Certification - BRP WW 08 - Minor Dredging Project Certification	Massachusetts Department of Environmental Protection	• Clean Water Act
Local		
Notice of Intent/Order of Conditions	City of Haverhill Conservation Commission/Massachusetts Department of Environmental Protection	• Massachusetts Wetlands Protection Act

Notes:

Final list of required environmental permits will be developed following a pre-application meeting with applicable regulatory agencies.

CMR: Code of Massachusetts Regulations

MEPA: Massachusetts Environmental Policy Act

Table 4
Cost Estimate Summary

Item No.	Item	Alternative RAA-4a	Alternative RAA-4b	Alternative RAA-4c
1.0	Submittals	$ 125,000	$ 125,000	$ 125,000
2.0	Health and Safety and Security	$ 50,000	$ 68,000	$ 82,000
3.0	Temporary Facilities and Mobilization/Demobilization	$ 769,000	$ 871,000	$ 945,000
4.0	Surveys	$ 54,000	$ 67,500	$ 67,500
5.0	Resuspension Controls	$ 100,000	$ 100,000	$ 100,000
6.0	Debris Removal and Disposal	$ 35,000	$ 46,000	$ 54,000
7.0	Mechanical Dredging and On-Site Transport	$ 168,000	$ 282,000	$ 372,000
8.0	Cap Materials and Placement	$ 192,000	$ 432,000	$ 564,000
9.0	Sediment Stabilization and Disposal	$ 322,000	$ 541,000	$ 713,000
10.0	Water Management and Disposal	$ 27,000	$ 45,000	$ 60,000
11.0	Solid Waste Disposal	$ 33,000	$ 33,000	$ 33,000
12.0	Retaining Wall and Pipe Sealant	$ 8,200	$ 8,200	$ 8,200
13.0	Engineering Costs	$ 865,400	$ 1,031,600	$ 1,156,600
14.0	Long-Term Monitoring	$ 448,000	$ 492,000	$ 513,000
	Construction Total	**$ 1,880,000**	**$ 2,620,000**	**$ 3,120,000**
	Total Costs (without Contingency)	**$ 3,193,400**	**$ 4,143,600**	**$ 4,789,600**
	Construction Contingency (+50%)	$ 940,000	$ 1,310,000	$ 1,560,000
	Construction Contingency (-30%)	$ 564,000	$ 786,000	$ 936,000
	Total (+50% Construction Contingency)	**$ 4,133,400**	**$ 5,453,600**	**$ 6,349,600**
	Total (-30% Construction Contingency)	**$ 2,629,400**	**$ 3,357,600**	**$ 3,853,600**

Notes:
1. This estimate of probable costs is based on a conceptual-level design and should be considered preliminary and subject to future revision based on design refinement. Estimate is not to be considered for construction purposes.
2. The estimate presented is developed using current and generally accepted engineering cost estimation methods. Note that these estimates are based on assumptions concerning future events, and actual costs may be affected by known and unknown risks including, but not limited to, changes in general economic and business conditions, site conditions that were unknown to Anchor QEA, LLC, at the time the estimates were performed, future changes in Site conditions, regulatory or enforcement policy changes, and delays in performance. Actual costs may vary from these estimates, and such variations may be material.
3. Costs are rounded as appropriate.
4. Construction costs include sediment removal, sediment and water management and disposal, and capping.
5. Construction costs include costs for materials, equipment, and labor (Item No. 1.0 through 12.0).
6. Total Costs (without Contingency) include Construction, Engineering, and Long-term Monitoring costs.
7. Cap maintenance and monitoring costs are presented as present value.
8. A +50%/-30% contingency is applied to construction costs.
9. Engineering costs include costs associated with permitting, predesign data collection, design development, bidding support, construction oversight, environmental monitoring, and final reporting.
RAA: remedial action alternative

Figures

LEGEND:

Project Location

Tax Parcel

NOTES:
1. Horizontal datum is Massachusetts State Plane, North American Datum of 1983, U.S. Feet.
2. Aerial image is acquired from MassGIS at https://www.mass.gov/info-details/massgis-data-layers. Image date is 2019.
3. Tax parcels acquired from MassGIS at https://massgis.maps.arcgis.com on August 27, 2019.

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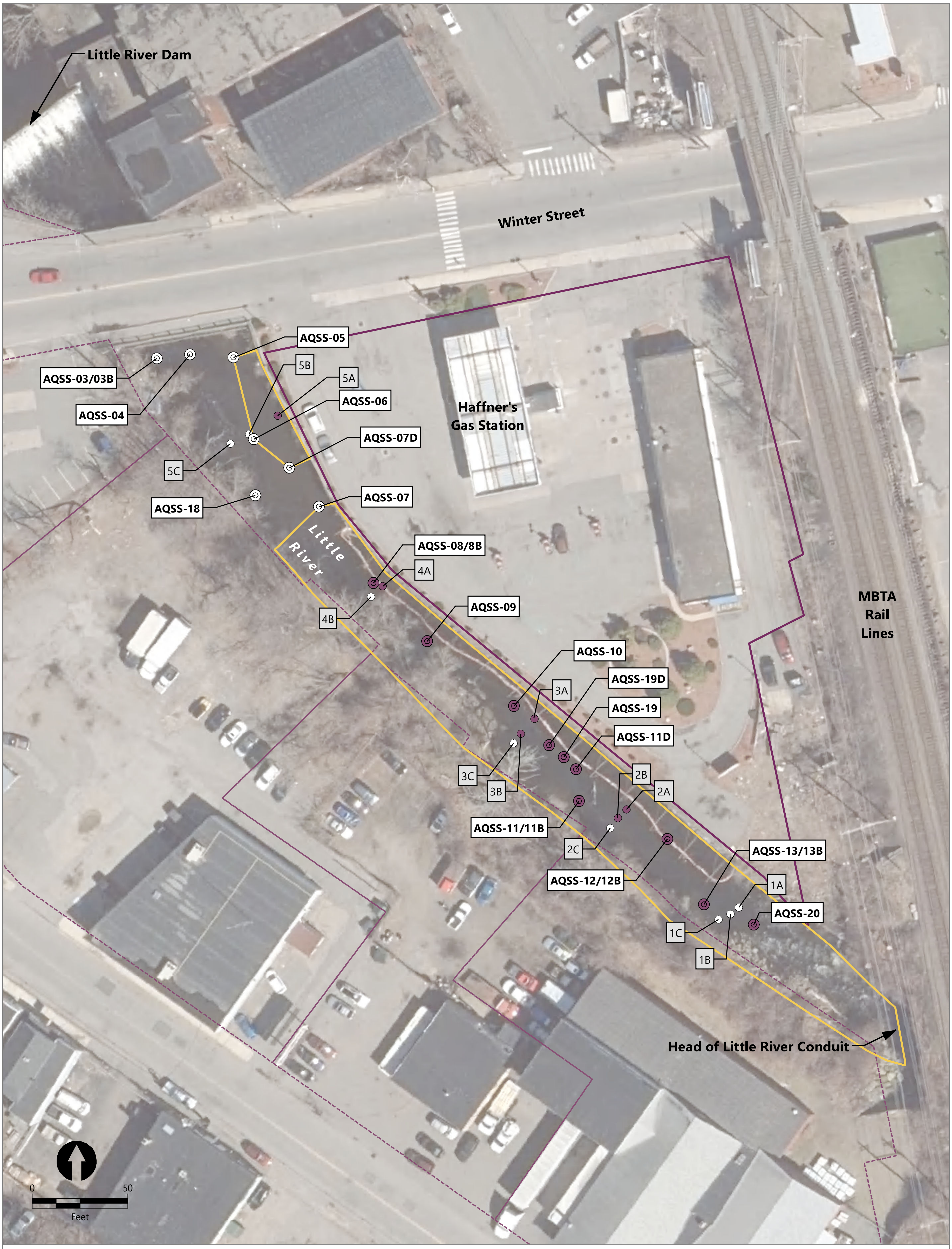
Figure 1
Site Location Map
Phase III Remedial Action Plan – Little River
Former Haverhill MGP Site



LEGEND:

- Tax Parcel
- Property Boundary
- Approximate Sediment Core Location (Anchor QEA 2021)
- Sediment Sample Location (GZA 2020)
- Visible Oil and/or Tar Present 0.0' – 1.0' below mudline
- Approximate RAA-4a and RAA-4b Remedial Footprint Delineated by Substantial Hazard Areas

NOTES:

1. Horizontal datum is Massachusetts State Plane, North American Datum of 1983, U.S. Feet.
2. Aerial image is acquired from MassGIS at https://www.mass.gov/info-details/massgis-data-layers. Image date is 2019.
3. Tax parcels acquired from MassGIS at https://massgis.maps.arcgis.com on August 27, 2019.
4. Property boundary as recorded on ALTA/ACSM Land Title Survey plan performed by MHF Design Consultants (stamped February 12, 2015)

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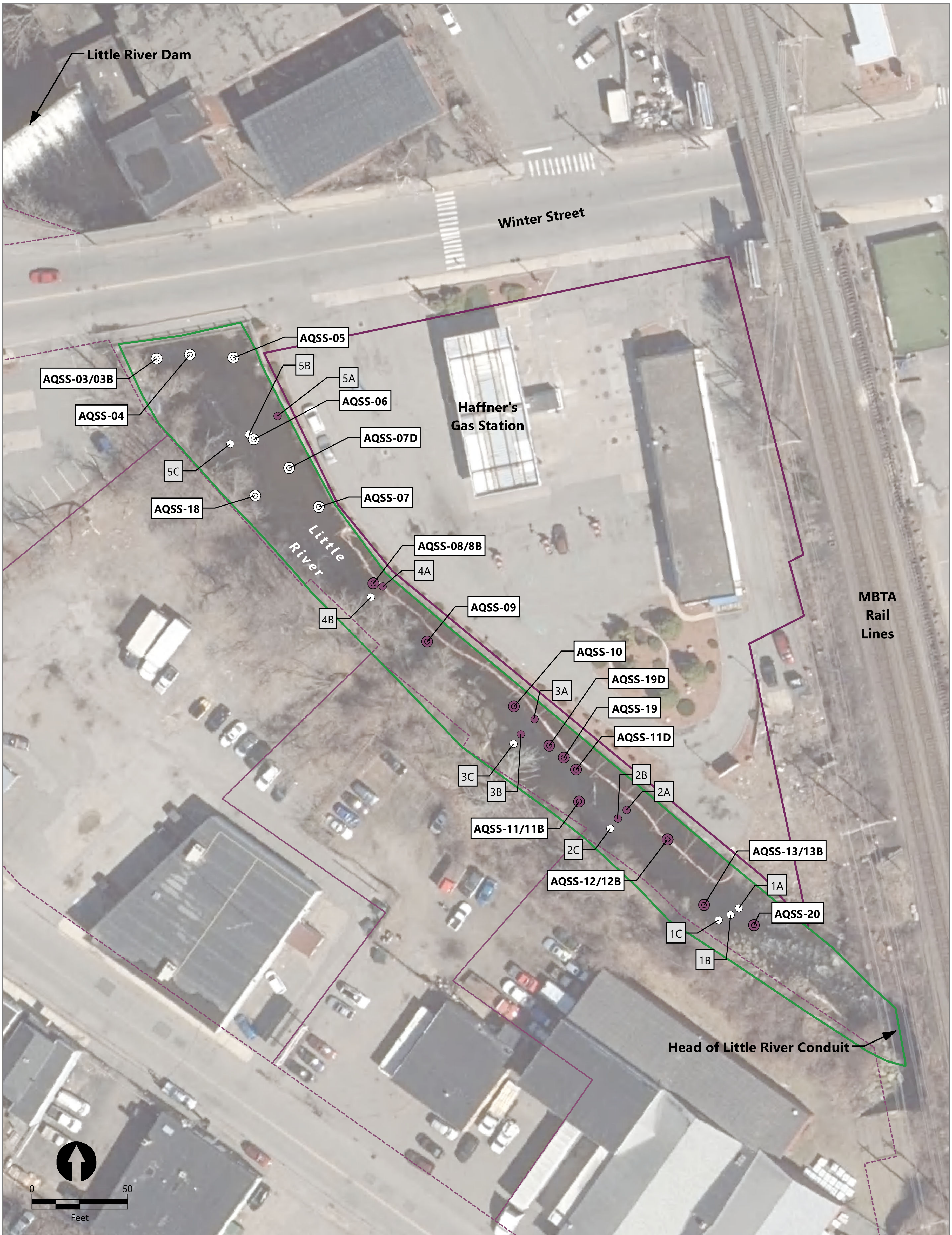
Figure 2
RAA-4a and RAA-4b Footprint
Phase III Remedial Action Plan – Little River
Former Haverhill MGP Site



LEGEND:

- Tax Parcel
- Property Boundary
- Approximate Sediment Core Location (Anchor QEA 2021)
- Sediment Sample Location (GZA 2020)
- Visible Oil and/or Tar Present 0.0' – 1.0' below mudline
- Approximate RAA-4c Remedial Footprint Delineated by In-River Site Boundary

NOTES:

1. Horizontal datum is Massachusetts State Plane, North American Datum of 1983, U.S. Feet.
2. Aerial image is acquired from MassGIS at https://www.mass.gov/info-details/massgis-data-layers. Image date is 2019.
3. Tax parcels acquired from MassGIS at https://massgis.maps.arcgis.com on August 27, 2019.
4. Property boundary as recorded on ALTA/ACSM Land Title Survey plan performed by MHF Design Consultants (stamped February 12, 2015)

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Figure 3
RAA-4c Footprint
Phase III Remedial Action Plan – Little River
Former Haverhill MGP Site

Appendix A
Erosion-Protection Evaluation

July 2022
Former Haverhill MGP Site – 284 Winter Street, Haverhill, Massachusetts

Appendix A:
Erosion-Protection Evaluation

Prepared for Boston Gas Company d/b/a National Grid

July 2022
Former Haverhill MGP Site – 284 Winter Street, Haverhill, Massachusetts

Appendix A:
Erosion-Protection Evaluation

Prepared for
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40 Sylvan Road
Waltham, Massachusetts 02451

Prepared by
Anchor QEA, LLC
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Amesbury, Massachusetts 01913

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ABBREVIATIONS

cfs	cubic feet per second
D_{50}	median diameter
D_{100}	maximum diameter
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
HEC-RAS	Hydrologic Engineering Center River Analysis System
NAVD88	North American Vertical Datum of 1988
Phase III RAP	*Phase III Remedial Action Plan*
Site	284 Winter Street, Haverhill, Massachusetts
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USCS	Unified Soil Classification System

1 Introduction

This appendix presents the erosion-protection evaluation performed for the in-river (i.e., Little River) portion of the former Haverhill manufactured gas plant site at 284 Winter Street in Haverhill, Massachusetts (Site), as part of the *Phase III Remedial Action Plan* (Phase III RAP) for the Site (Anchor QEA 2022). As discussed in the Phase III RAP, the remedial design may include the placement of either a single-layer physical cover or a multiple-layer engineered cap (including a chemical isolation component) to mitigate exposure to the constituents of concern. Both the physical cover layer and the engineered cap would require particle sizes able to withstand potential erosive forces (i.e., an erosion-protection layer).

The evaluation to identify potential erosive forces and stable particle sizes was performed in accordance with the U.S. Environmental Protection Agency's (USEPA's) and the U.S. Army Corps of Engineers' (USACE's) *Assessment and Remediation of Contaminated Sediments (ARCS) Program: Guidance for In-Situ Subaqueous Capping of Contaminated Sediments* (Palermo et al. 1998) and other technical guidance documents referenced where appropriate.

Hydrodynamic flows (i.e., current velocities) resulting from extreme flow events are the primary potential erosive forces that may affect the stability of the erosion-protection layer. There is no motorized vessel access to the Site; therefore, vessel-related impacts including vessel-generated waves, propeller wash, and anchor drag were not considered. Wind-generated waves are not expected to affect the stability of a cap erosion-protection layer at the Site. Ice was assumed to not affect the stability of a cap erosion-protection layer for this evaluation. Potential ice impacts will be further evaluated during subsequent design phases of the project.

The results of previous hydraulic analyses were used to estimate the stable particle sizes required to resist potential erosive forces from various flow events. This appendix summarizes the key hydrodynamic flow characteristics and the evaluation of median stable particle sizes.

2 Design and Performance Criteria

Setting performance standards is a necessary first step in developing the design requirements for the erosion-protection layer. The following description of the functions of a cap erosion-protection layer is found in Palermo et al. (1998):

> The cap component for stabilization/erosion protection has a dual function. On the one hand, this component of the cap is intended to stabilize the contaminated sediments being capped, and prevent them from being resuspended and transported offsite. The other function of this component is to make the cap itself resistant to erosion. These functions may be accomplished by a single component, or may require two separate components in an in-situ cap.

Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (USEPA 2005) provides the following guidance about cap design:

> [T]he design of the erosion-protection features of an in-situ cap (i.e., armor layers) should be based on the magnitude and probability of occurrence of relatively extreme erosive forces estimated at the capping site. Generally, in-situ caps should be designed to withstand forces with a probability of 0.01 per year, for example, the 100-year storm.

The erosion-protection layer was evaluated using methods published by USEPA and USACE specifically for in-situ caps, including *Appendix A: Design of Armor Layers* (Maynord 1998). Consistent with USEPA guidance and based on project requirements, the design and performance criteria for the erosion-protection layer include being physically stable under the conditions predicted to occur during a 100-year flood flow event.

3 Hydraulic Analysis

As flow moves through a channel, hydraulic characteristics such as water surface elevation and current velocity are affected by the geometry of the channel cross section. Hydrodynamic flows, particularly during high-flow events, can result in elevated current velocities and corresponding bed shear stresses.

The erosion-protection evaluation used the results from a hydraulic analysis performed by Fuss and O'Neill for the Little River as part of the Little Dam Removal Feasibility Study (Fuss and O'Neill 2021). The analysis presented in Fuss and O'Neill (2021) assessed the hydraulic characteristics during various return-interval flow events, including predicted flow velocities and water surface elevations, and compared pre- and post-dam-removal conditions. Flow events evaluated ranged from base flow conditions up to the 500-year return-interval event including the 100-year event.

The hydraulic analysis presented in Fuss and O'Neill (2021) was performed using the USACE Hydrologic Engineering Center River Analysis System (HEC-RAS) model. HEC-RAS is a public-domain, general-purpose model designed to assess 1D flow in natural streams and channels.

3.1 Site Hydraulic Characteristics

The Little River is approximately 12.9 miles long. It rises in Kingston, New Hampshire, and discharges into the Merrimack River approximately 0.3 mile downstream of the Site. The Site is an approximately 500-foot-long reach of the Little River between the Winter Street bridge and the Little River Conduit, which discharges into the Merrimack River in the city of Haverhill, Massachusetts.

The Site is constrained by several structures. Approximately 70 feet upstream of the Site is the Little River Dam. The dam is a run-of-river structure and does not control flows at the Site. The upstream boundary of the Site is at the Winter Street bridge. The downstream boundary of the Site is the headwall and inlet for the Little River Conduit. A vertical retaining wall 15 to 20 feet tall runs along most of the eastern side of the Little River at the Site. The river's western bank and the southern portion of the eastern bank are heavily overgrown, steep, and may include remnants of former structures such as retaining walls.

The Merrimack River is tidally influenced for 22 miles from the ocean to Haverhill. The Little River may be tidally influenced up to the Little River Dam, which is just upstream of the Site. As described in Fuss and O'Neill (2021), most of the Little River within the conduit just downstream of the Site experienced daily impacts from tides, but due to the channel bottom elevations only extremely high tides or coastal storm surges appear to affect the Little River upstream of the conduit at the Site.

The *Flood Insurance Study* (FIS) for Essex County, Massachusetts, developed by the Federal Emergency Management Agency (FEMA; FEMA 2018), estimated return-interval flow rates for the

Little River near the Site, including the 10-, 50-, 100-, and 500-year return-interval flow events. The FEMA FIS shows that the extents of the 100-year floodplain are limited along the Little River near the Site, which results in higher flows being conveyed in the channel (FEMA 2018). Therefore, current velocities at the Site are expected to increase during extreme flow events due to the limited extents of the floodplain. Fuss and O'Neill (2021) estimated lower-flow-condition discharges near the Site, including a base flow during the seasonal low period in August and September and fish passage flows during passage season from March 1 to June 30. Table A-1 shows the range of flow values at the Site estimated by Fuss and O'Neill (2021) and FEMA (2018).

Table A-1
Model Simulation Flow Conditions

Flow Event	Discharge (cfs)
Base flow	9.8[a]
95% exceedance flow	13.3[b]
50% exceedance flow	56.3[b]
5% exceedance flow	201.7[b]
FEMA 10-year event	1,160[c]
FEMA 50-year event	1,920[c]
FEMA 100-year event	2,330[c]
FEMA 500-year event	3,520[c]

Notes:

a. Value, from Fuss and O'Neill (2021), represents estimated base flow during seasonal low-flow period in August and September.
b. Values, from Fuss and O'Neill (2021), represent estimated fish passage flows during passage season from March 1 to June 30.
c. Extreme event discharge data obtained from FEMA (2018).

3.2 Hydraulic Modeling

The hydraulic analysis described in Fuss and O'Neill (2021) was performed using HEC-RAS version 5.0.7 for all model simulations.

FEMA developed a HEC-2 (predecessor to HEC-RAS) model for the Little River as part of the FIS for Essex County, Massachusetts (FEMA 2018). Fuss and O'Neill obtained the completed HEC-2 model developed by FEMA and used that information to develop the HEC-RAS model for the hydraulic analysis for the Little River, including the portion of the river at the Site (Fuss and O'Neill 2021). The upstream boundary of the HEC-RAS model was approximately 120 feet upstream of the Rosemont Avenue bridge crossing. The downstream boundary was the confluence of the Little River and the Merrimack River. The HEC-RAS results were compared to the FEMA FIS water surface elevations for the 100-year flow event to confirm the model performance was acceptable (Fuss and O'Neill 2021).

The HEC-RAS model was updated to incorporate Site-specific bathymetric data collected from select portions of the model extents. Additional transects, including two at the Site, were added to the model to increase its resolution (Fuss and O'Neill 2021).

Model simulations were run for the range of flow events listed in Table A-1 under existing (i.e., pre-dam-removal) conditions and proposed (i.e., post-dam-removal) conditions. The results of the pre- and post-dam-removal simulations were compared to evaluate changes in hydraulic characteristics such as water surface elevations and flow velocities throughout the model extents, including the portion of the Little River at the Site (Fuss and O'Neill 2021).

3.2.1 Model Results

The model results showed minimal differences in water surface elevations and flow velocities between the pre- and post-dam-removal simulations for the FEMA 10-year, 50-year, 100-year, and 500-year flow events. Flow velocities near the Site ranged from approximately 2.9 to 6.3 feet per second for the return-interval flow events, with the highest flow velocity resulting from the 100-year flow event near the upstream end of the Site. Maximum water depth for the 100-year flow event ranged from approximately 13.1 to 14.6 feet at each transect near the Site (Fuss and O'Neill 2021).

The flow velocities for the base flow condition were less than approximately 2.5 feet per second near the Site, and the maximum water depth at each transect near the Site ranged from less than approximately 0.5 to 2 feet. The flow velocities for the range of fish passage flows were less than approximately 4.1 feet per second near the Site, and maximum water depth at each transect near the Site ranged from less than approximately 0.5 to 3.5 feet (Fuss and O'Neill 2021).

Table A-2 summarizes the maximum predicted flow velocities and corresponding water surface elevations from Fuss and O'Neill (2021) at the Site for each flow event evaluated.

Table A-2
Maximum Flow Velocities and Water Surface Elevations at the Site

Flow Event	Maximum Predicted Flow Velocity at the Site (fps)[1]	Water Surface Elevation (feet NAVD88)[2]
Base flow	2.5	7.2
95% exceedance flow	2.6	7.2
50% exceedance flow	3.9	7.5
5% exceedance flow	4.1	8.7
FEMA 10-year event	5.1	15.0
FEMA 50-year event	5.9	18.5
FEMA 100-year event	6.3	20.1
FEMA 500-year event	5.4	26.1

Notes:

1. Values shown are from Fuss and O'Neill (2021).
2. Value from Fuss and O'Neill (2021) corresponding to case with maximum flow velocity at the Site.

fps: feet per second

As shown in Table A-2, both the predicted current velocity and the water surface elevation at the Site increase as the discharge increases, which is to be expected because the limited extents of the Little River floodplain near the Site cause higher flows to be conveyed in the channel.

4 Stable Particle Size Evaluation

As discussed previously, the design of an erosion-protection layer must consider potential erosive forces that may act on the river bottom so an appropriate, stable particle size that will adequately resist erosive forces can be selected. Hydrodynamic forces are considered the most significant potential erosive force that may affect the stability of the erosion-protection layer at the Site because wind- or vessel-generated waves, vessel-induced propeller wash, anchor drag, and ice are not expected to affect the erosion-protection layer. Potential ice impacts will be evaluated further during subsequent design phases of the project.

4.1 Hydrodynamic Flows

Equation A-1 was used to estimate the median diameter (D_{50}) stable particle size required to resist erosive forces from the maximum predicted flow velocities and corresponding bed shear stresses for the cases simulated as described in Section 3.2.1. The methodology, outlined in Maynord (1998), is based on USACE's *Hydraulic Design of Flood Control Channels* (USACE 1994).

Equation A-1

$$D_{50} = S_f C_s C_v C_T C_G d \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{\frac{1}{2}} \frac{V}{\sqrt{K_1 g d}} \right]^{2.5} \text{ where:}$$

D_{50}	=	median particle size in feet
Sf	=	safety factor = 1.5 (minimum 1.1)
Cs	=	stability coefficient for incipient failure = 0.30 for angular rock
C_V	=	velocity distribution coefficient = 1.0 for straight channels or inside of bends
C_T	=	blanket thickness coefficient = 1.0 for flood flows
C_G	=	gradation coefficient = $(D85/D15)^{1/3}$
D_{85}/D_{15}	=	gradation uniformity coefficient = 3.5 (typical range = 1.8 to 3.5)
d	=	water depth in feet
γ_s	=	unit weight of stone = 165 pounds per cubic foot
γ_w	=	unit weight of water = 62.4 pounds per cubic foot
V	=	depth-averaged velocity in feet per second (used maximum 100-year flow velocity near the Site)
K_1	=	side slope correction factor = 0.90 (conservative value used to represent a slope over the cap area of approximately 2 feet horizontal to 1 foot vertical)
g	=	acceleration due to gravity = 32.2 feet per second squared

For the maximum 100-year flow velocity of 6.3 feet per second and the corresponding maximum water depth of approximately 14 feet, the computed median stable particle size (D_{50}) was approximately 3.4 inches. A D_{50} of 3.4 inches corresponds to cobble-sized material according to the Unified Soil Classification System (USCS). A shallower water depth of 7 feet was evaluated with a flow velocity of 6.3 feet per second, and the computed stable D_{50} particle size was approximately 4 inches, also a USCS cobble-sized material. A flow velocity of 4.1 feet per second—the maximum velocity under a lower flow condition (i.e., non-return-interval event)—was evaluated with a water depth of 0.5 foot; the computed D_{50} particle size was approximately 2.7 inches, a USCS coarse gravel-sized material.

Based on the computed D_{50} values, a D_{50} of 4 inches is required to resist the potential erosive forces from the 100-year return-interval flow event for a cap erosion-protection (i.e., armor) layer.

Figure A-1 shows the existing conditions and riverbed substrate near the upstream portion of the Site containing sand, gravel, and cobble-sized materials. As can be seen here, the computed stable cobble material for the cap erosion-protection layer is consistent with the existing riverbed substrate.

Figure A-1
Existing Conditions in the Upstream Portion of the Site

Note:
Photograph of upstream portion of Site near the Winter Street bridge taken on June 22, 2022, by Anchor QEA

4.2 Erosion-Protection Layer Thickness

Maynord (1998) recommends that the thickness of the erosion-protection layer be twice the median particle diameter ($2 \times D_{50}$) or 1.5 times the maximum particle diameter ($1.5 \times D_{100}$), whichever is greater. With a D_{50} of approximately 4 inches, the D_{100} was estimated to be approximately 6 inches based on guidance in USACE (1992). Therefore, the estimated minimum erosion-protection layer thickness is approximately 9 inches, which is 1.5 times the D_{100} of 6 inches.

4.3 Filter Layer Considerations

A filter layer provides an interface between the erosion-protection layer and the protected material and is an essential element for protecting contaminated sediments (Maynord 1998). As described in the USACE engineering manual *Design of Coastal Revetments, Seawalls, and Bulkheads* (USACE 1995), a filter is a transitional layer of gravel, small stone, or fabric placed between the underlying soil and the structure. The filter prevents migration of one granular material through another (often referred to as "piping"), distributes the weight of the armor units to provide more uniform settlement, and permits relief of hydrostatic pressures within the soils. For areas above the waterline, filters also prevent surface water from causing erosion (gullies) beneath the armor stone.

A filter layer is often required when using larger diameter material for the erosion-protection layer of an engineered cap. The same armor-to-filter relationships are used to assess the potential for piping between the filter layer and the chemical isolation layer and may be used to evaluate the gradations for the chemical isolation material as well. For an erosion-protection layer of cobble-sized material, it is expected that a filter layer consisting of gravel-sized material will likely be required as part of the cap design. As shown in Figure A-1, a gravel-sized material is consistent with the existing riverbed substrate. The gradation of the filter layer will be evaluated and designed for compatibility with the armor layer and with the underlying chemical isolation layer of the engineered cap as part of subsequent design phases.

5 References

Anchor QEA (Anchor QEA, LLC), 2022. *Phase III Remedial Action Plan – Little River*. Former Haverhill Manufactured Gas Plant Site. Prepared for Boston Gas Company d/b/a National Grid. July 2022.

FEMA (Federal Emergency Management Agency), 2018. *Flood Insurance Study, Essex County, Massachusetts (All Jurisdictions).* Flood Insurance Study Number 25009CV001C. July 19, 2018.

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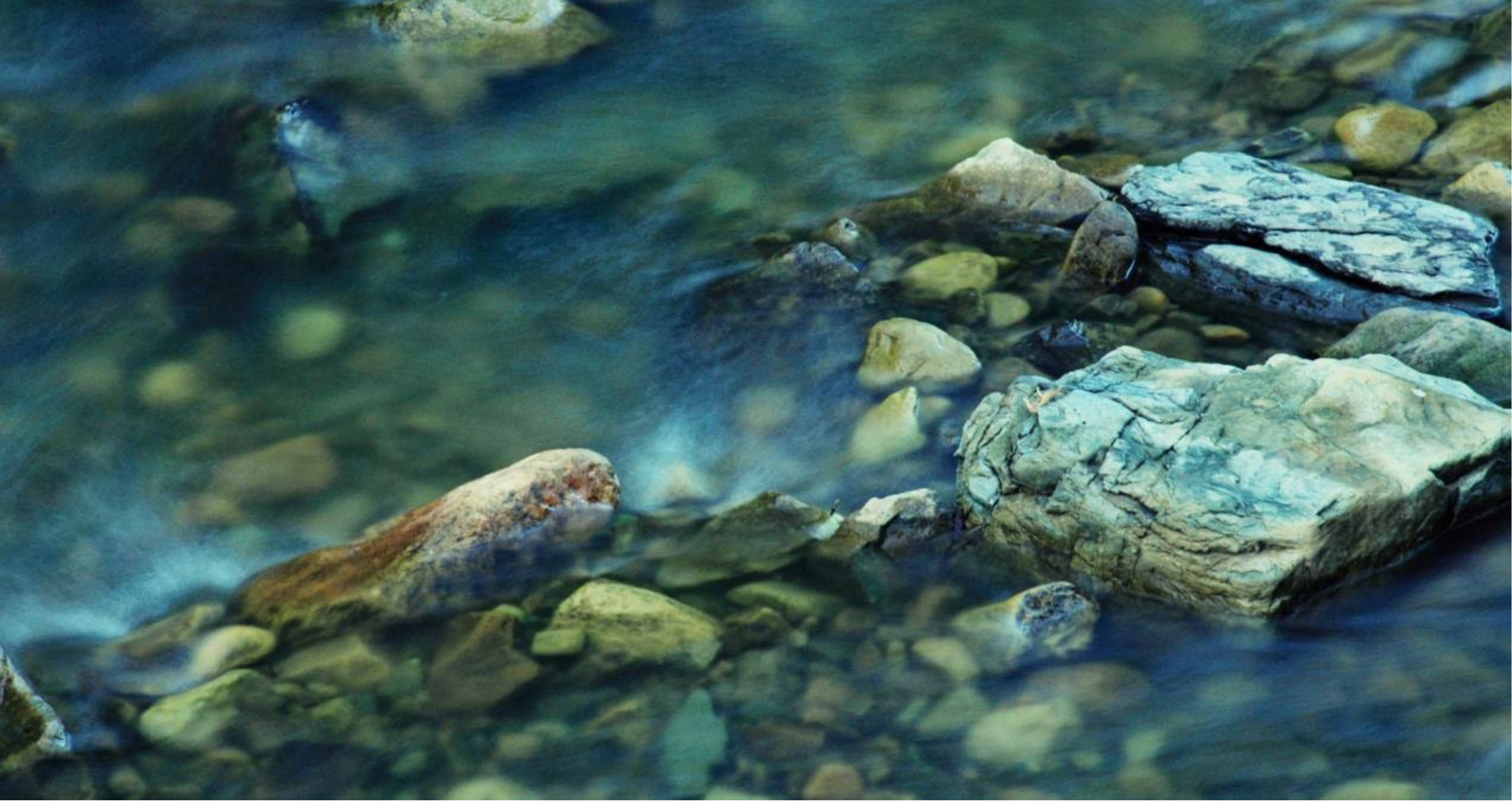
Appendix B
Preliminary Chemical Isolation Layer Design Analysis



July 2022
Former Haverhill MGP Site – 284 Winter Street, Haverhill, Massachusetts

Appendix B:
Preliminary Chemical Isolation Layer Design Analysis

Boston Gas Company d/b/a National Grid

July 2022
Former Haverhill MGP Site – 284 Winter Street, Haverhill, Massachusetts

Appendix B: Preliminary Chemical Isolation Layer Design Analysis

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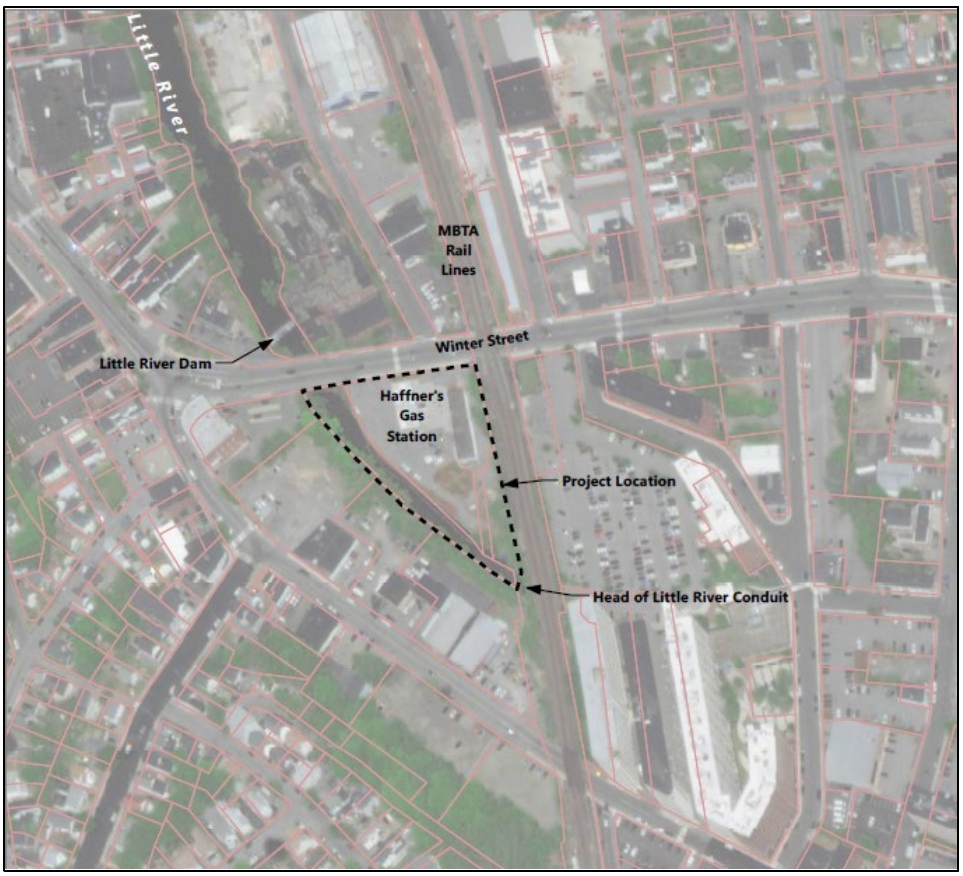
ABBREVIATIONS

µg/L	micrograms per liter
BTEX	benzene, toluene, ethylbenzene, and xylene
cm	centimeter
cm/day	centimeters per day
cm/hr	centimeters per hour
cm/yr	centimeters per year
cm^2/s	centimeters squared per second
cm^2/yr	centimeters squared per year
USEPA	U.S. Environmental Protection Agency
f_{OC}	fraction organic carbon
g/cm^3	grams per cubic centimeter
hr	hour
K_d	equilibrium partition coefficient
K_{OC}	organic carbon partition coefficient
L/kg	liters per kilogram
mg/kg	milligrams per kilogram
PAH	polycyclic aromatic hydrocarbon
Site	284 Winter Street in Haverhill, Massachusetts
TOC	total organic carbon
yr^{-1}	per year

1 Introduction

This appendix to the *Phase III Remedial Action Plan* (Phase III RAP) describes preliminary evaluations of the cap chemical isolation layer design for the former manufactured gas plant (MGP) at 284 Winter Street in Haverhill, Massachusetts (the Site). The former MGP was located on property that abuts the Little River to the east and is currently owned by Haffner Realty Trust (see Figure B-1). The Site includes an upland portion and an in-river portion; this appendix applies primarily to the in-river portion (hereinafter "Site" refers to the in-river portion, unless otherwise stated).

Figure B-1
Site Map



Capping Little River sediments is one remedial option being considered to address nonaqueous phase liquid (NAPL) and dissolved-phase flux of Site constituents of concern (COCs) from NAPL-impacted sediment. The potential for NAPL migration into the cap and overlying surface water and the need for a NAPL-absorption component are discussed in the Phase III RAP. This appendix describes chemical transport modeling conducted to evaluate the feasibility of capping to address flux of dissolved-phase PAHs. The Phase II risk assessment identified PAHs as having the potential to pose a risk to aquatic receptors at the Site (see Section 7 of Appendix C of *Phase II Comprehensive Site Assessment – 284 Winter Street Haverhill, Massachusetts RTNs 3-32792 and 3-32875* [GZA 2022]). An evaluation of the sediment data indicates that volatile organic compounds (VOCs)—particularly benzene—are present in the sediment at concentrations that may also be of concern. Due to the limited detection data available for benzene, however, only PAHs were simulated in this preliminary cap design modeling. Nevertheless, due to its relatively high mobility and potential for elevated concentrations in Site porewater (based on a limited number of sediment samples with detected benzene), benzene has the potential to significantly influence the cap design (see Section 5 for further discussion of benzene).

The modeling analyses described herein were performed in accordance with guidance on cap design set forth by the U.S. Environmental Protection Agency (USEPA) and the U.S. Army Corps of Engineers (Palermo et al. 1998), and the Interstate Technology and Regulatory Council (ITRC 2014). The primary goal of this modeling was to evaluate the feasibility of capping by simulating the transport of dissolved-phase PAHs within an engineered cap to identify a chemical isolation layer configuration (i.e., thickness and composition) that would provide long-term effectiveness in limiting concentrations at the cap surface to which benthic organisms can be exposed.

2 Approach

The primary goal of this cap design modeling was to simulate the transport of 16 PAHs within the engineered cap to identify a chemical isolation layer configuration (i.e., thickness and composition) that would provide long-term effectiveness by limiting the transport of PAHs to the top of the cap, where benthic organisms can be exposed to the PAHs.

2.1 Model Framework

A widely used 1D model of chemical transport within sediment caps, CapSim (version 3.8; Reible 2021), was used for this evaluation. This model simulates the time variable fate and transport of chemicals (dissolved and sorbed phases, including partitioning between these phases) under the processes of advection, diffusion/dispersion, biodegradation, bioturbation/bioirrigation, and exchange with the overlying surface water within a sediment cap (Lampert and Reible 2009; Go et al. 2009; Shen et al. 2018).

CapSim 3.8 and its predecessors have been used to support the evaluation and design of sediment caps at numerous domestic and international sites, including Gloucester Harbor in Massachusetts (Anchor QEA and GZA 2015). Details on the model structure and underlying theory and equations are provided in Lampert and Reible (2009), Go et al. (2009), and Shen et al. (2018).

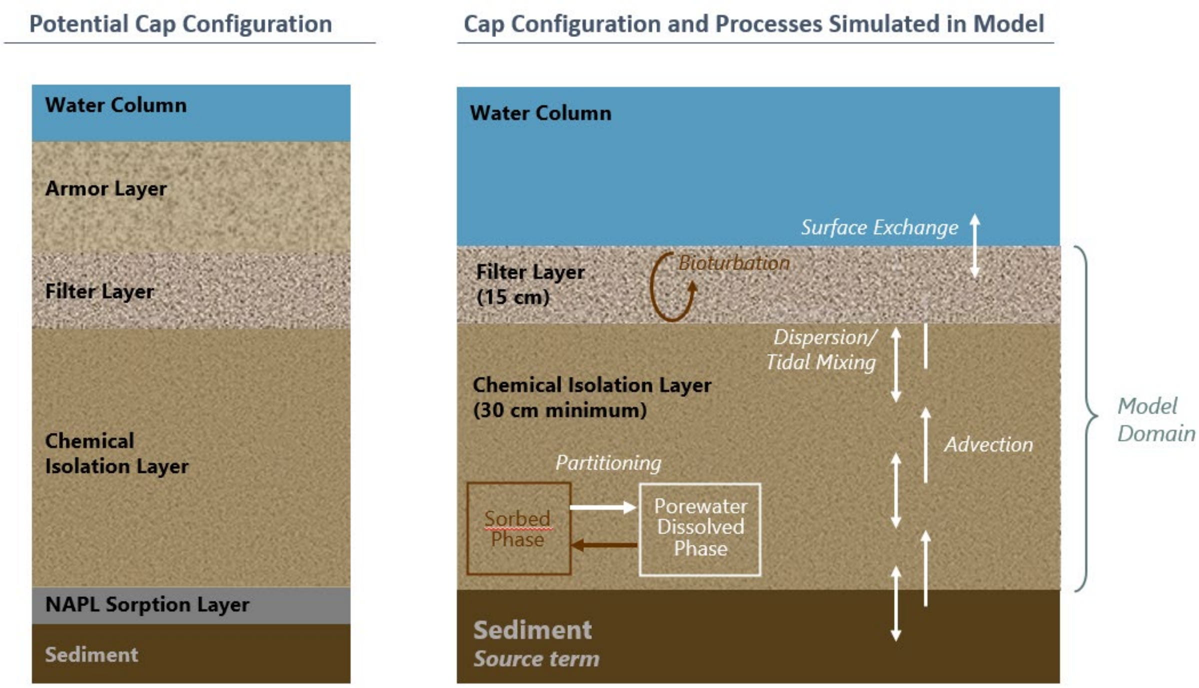
2.2 Model Domain and Layers

The model was configured to represent the presence of a multilayer cap placed atop the sediment surface. The cap design consisted of four basic layers: 1) an armor layer to resist erosion forces; 2) a filter layer to prevent intermixing of the armor and chemical isolation layers; 3) a chemical isolation layer to address dissolved-phase contaminant transport; and 4) a NAPL-absorption layer. The design evaluations for the armor and filter layers are presented in Appendix A of the Phase III RAP.

Figure B-2 is a schematic showing the cap layers represented in the model and the processes simulated by the model. The NAPL-absorption layer and a portion of the armor and filter layers were excluded from the model domain for the following reasons:

1. The NAPL-absorption layer is allocated to the function of addressing the potential for transport of NAPL, so the potential benefits of dissolved-phase sorption that it could provide in the absence of any NAPL transport were conservatively excluded from the model evaluation.
2. The minimum erosion protection layer thickness is 38 centimeters (cm; 15 inches) based on the preliminary design evaluation in Appendix A of the Phase III RAP; the minimum armor and filter layer thicknesses are 23 cm (9 inches) and 15 cm (6 inches), respectively. The relatively large stone size of the armor layer is expected to provide minimal sorptive/attenuative capacity, so conservatively the armor layer was ignored.

Figure B-2
Cap Configurations and Processes Simulated



2.3 Design Target Concentration and Compliance Depth

Target concentrations were selected as points of comparison for the model-predicted concentrations at the cap surface over time. At this Site, compliance was evaluated in the top 15 cm (6 inches) of the cap to maintain consistency with the sediment depth evaluated for the Phase II risk assessment (Section 7 of Appendix C of *Phase II Comprehensive Site Assessment* [GZA 2022]). The probable effects concentration (PEC) for Total PAH 16 (TPAH16) of 22.8 mg/kg is a consensus-based sediment-quality guideline for freshwater sediments (MacDonald et al. 2000) that has been used at other sites as the point of comparison to evaluate the long-term effectiveness of an engineered cap. However, it is anticipated that the dam just upstream of this Site will be removed after the in-river remedy is implemented (Fuss and O'Neill 2021). Removing the dam will release sediments that have built up behind the dam, and some of those sediments are expected to deposit atop the constructed cap. Average background sediment concentrations upstream of the dam are 29 mg/kg TPAH16 (see Section 5.2.1 of Appendix C; GZA 2022), which is higher than the TPAH16 PEC (22.8 mg/kg). Therefore, for the purposes of this evaluation, long-term cap effectiveness was based on maintaining model-predicted concentrations in the top 15 cm of the cap below the background-based TPAH16 concentration of 29 mg/kg for a 100-year simulation period.

3 Model Inputs

The model uses several input parameters that describe chemical-specific properties, cap material properties, and chemical mass transfer rates. These parameters are based on Site-specific data, information from the literature, and experience with cap design at similar sites. The model input parameters, the values used for this modeling assessment, and the source(s) from which they were derived are provided in Table B-1. More details describing certain key model inputs are provided in Sections 3.1 through 3.3.

Table B-1
Input Parameter Values for the Chemical Isolation Cap Model

Model Input Parameter	Value	Data Source
Chemical-Specific Properties		
PAH porewater concentrations (µg/L)	See Table B-3	Calculated from Site sediment data and equilibrium partitioning coefficients. See Section 3.1 for more details.
Log K_{OC} for partitioning in cap materials (log L/kg)	See Table B-2	Due to a lack of Site-specific data, partition coefficients were set to the literature-based K_{OC} values from USEPA (2003).
Molecular diffusivity (cm^2/s)	5.0×10^{-6} to 8.6×10^{-6}	Calculated based on the molecular weight of the PAH compound using the correlation identified from Schwarzenbach et al. (1993). The model calculates an effective diffusion coefficient using the chemical-specific input value for the molecular diffusivity multiplied by a tortuosity factor that is a function of the material porosity.
Chemical biodegradation rate (yr^{-1})	0	Assumed no degradation, which is conservative for PAHs given they have been shown to degrade in sediments under certain conditions.
Chemical Isolation Layer Properties		
Thickness (cm)	Variable	Design parameter; started with a chemical isolation layer thickness of 30 cm and increased as necessary to achieve target concentration.
Dry bulk density (g/cm^3)	1.6	Calculated based on typical particle density of 2.6 g/cm^3 and porosity of 0.4 (see next row).
Total porosity	0.4	Typical value for sand (e.g., Domenico and Schwartz 1990).
Fraction organic carbon (f_{OC}; %)	Variable	Design parameter; started with nominal value (0.1%) based on typical f_{OC} of sand materials and refined as necessary to achieve target concentration; f_{OC} above the nominal value represents the addition of a sorptive amendment.
Filter Layer		
Thickness (cm)	15	Conservatively simulated only 15 cm of granular material to represent a portion of the armor layer, filter layer, and deposited sediment that will infill the interstices.
Dry bulk density (g/cm^3)	1.7	Calculated based on typical particle density of 2.6 g/cm^3 and porosity of 0.35 (see next row).
Total porosity	0.35	Typical value for gravel (e.g., Domenico and Schwartz 1990).

Model Input Parameter	Value	Data Source
f_{OC} (%)	1.0	A value of 1% in the bioturbation zone was selected based on experience from other sites and the assumption that over time, the f_{OC} in the bioturbation zone will increase toward levels expected to deposit on the cap after dam removal.
Mass Transport Properties		
Boundary layer mass transfer coefficient (cm/hr)	0.3	Midpoint of range of values compiled from laboratory and field Site measurements reported in the literature (e.g., Thibodeaux et al. 2001) and values calibrated as part of models of sediment/water exchange at other sites (e.g., USEPA 2006).
Groundwater seepage rate (cm/yr)	365	Calculated based on hydraulic gradients estimated from available hydrogeological information in the river and the adjacent uplands (see Section 3.3). This value is uncertain and will be reassessed during design through additional data collection, should capping be brought forward as the remedy for the Site.
Tortuosity factor for molecular diffusion	Varies with porosity	Model uses an empirical relationship with porosity to calculate a tortuosity factor that is multiplied by the chemical-specific molecular diffusion coefficient to result in an effective diffusion coefficient associated with porous media flow. The Millington and Quirk (1961) relationship was used, because this is applicable to granular (sand and gravel) material.
Net sedimentation rate (cm/yr)	0	Although it is likely that deposition from sediment released will occur when the upstream dam is removed, conservatively no net sedimentation was assumed in the model.
Dispersion length (cm)	1	Dispersion length was calculated from the relationship developed by Neuman (1990), which relates dispersion to model domain length.
Bioturbation depth (cm)	10	Recommended value for cap design in freshwater systems based on literature (e.g., Clarke et al. 2001; USEPA 2015).
Porewater biodiffusion coefficient (cm^2/yr)	100	Parameter represents bioturbation rate applied to dissolved phase; typical value for freshwater systems (e.g., Thibodeaux and Mackay 2011).
Particle biodiffusion coefficient (cm^2/yr)	1	Parameter represents bioturbation rate applies to particulate phase; typical value for freshwater systems (e.g., Thibodeaux and Mackay 2011).
Consolidation thickness (cm) and time (years) to reach 90% consolidation for underlying sediment	None	For the purpose of this Phase III RAP, the effects of consolidation, which can result in an additional upward flux of porewater, were excluded. In future stages of design, this parameter will be reassessed.

3.1 Partition Coefficients

Partitioning of chemicals between the dissolved and sorbed phases (i.e., between porewater and cap material) is described in the model by the chemical-specific equilibrium partition coefficient (K_d). The partition coefficient is calculated in the model based on the customary $K_d = f_{OC}*K_{OC}$ approach (e.g., Karickhoff 1984), where K_{OC} is the compound's organic carbon partition coefficient and f_{OC} is the organic carbon fraction of the solid phase (e.g., cap material). Due to a lack of Site-specific data, partition coefficients were set to the literature-based K_{OC} values from USEPA (2003; see Table B-2).

Table B-2
PAH Partition Coefficients Used in the Model

Chemical Name	Log KOC (log L/kg)
Acenaphthene	3.9
Acenaphthylene	3.2
Anthracene	4.5
Benzo(a)anthracene	5.6
Benzo(a)pyrene	6.0
Benzo(b)fluoranthene	6.2
Benzo(k)fluoranthene	6.2
Benzo(g,h,i)perylene	6.4
Dibenzo(a,h)anthracene	6.6
Indeno(1,2,3-c,d)pyrene	6.6
Chrysene	5.6
Fluoranthene	5.0
Fluorene	4.1
Naphthalene	3.3
Phenanthrene	4.5
Pyrene	4.8

3.2 Porewater Concentrations

The PAH concentrations of the porewater in the sediment beneath the cap define the source term in the cap model. Due to the presence of NAPL in the sediments, the modeling was conducted with the assumption that the river sediment beneath the cap would represent an infinite source of chemical, so the underlying sediment porewater concentrations specified in the model input were held constant over the duration of the long-term simulations.

Porewater was not sampled at the Site, so the porewater concentrations used in the model were calculated from equilibrium partitioning theory based on Site sediment data and the K_{OC} values in

Table B-2. NAPL was observed in many of the sediment samples, which can influence concentrations of chemicals in porewater and therefore must be considered carefully when performing partition calculations with bulk sediment measurements. Equilibrium porewater concentrations calculated using sediment samples that contain NAPL can be overestimated because the equilibrium partition coefficients used in those calculations do not explicitly account for the presence of NAPL. Therefore, the data were evaluated to avoid overestimating dissolved-phase porewater concentrations due to the presence of NAPL in the sediment samples.

Each sediment sample was evaluated for possible NAPL influences by calculating the percent of effective solubility for the calculated porewater concentrations. In accordance with USEPA guidance (Kueper and Davies 2009) and consistent with Raoult's Law, the cumulative mole fraction (i.e., the effective solubility, represented by the parameter α) of a given sample is the sum of the predicted porewater concentration of each detected chemical divided by its single-component subcooled liquid solubility. The equilibrium solubility in water of any component of multicomponent NAPL is referred to as the component's effective solubility. In general, the various chemical components of a multicomponent NAPL suppress the aqueous solubility of the other components, so the effective solubilities of mixed NAPL components are lower than their respective pure-phase solubilities.

If all NAPL chemical components are analyzed for and detected in porewater, then α is equivalent to the percent of effective solubility of the detected NAPL components in the porewater sample, expressed as a decimal. For example, an α value of 0.01 indicates that the NAPL components were detected at 1% of their effective solubility, and an α value of 1 indicates that the NAPL components were detected at 100% of their effective solubility. But if only a portion of the chemical mass in NAPL is quantified on a compound-by-compound basis in the porewater sample, then the value of α that corresponds to 100% of the effective solubility limit is less than 1.

Typically, an α value greater than 10% to 20%, depending on the NAPL source, can suggest a sample may contain NAPL. For example, an evaluation of porewater PAH data from six coal tar samples in Brown et al.(2005) resulted in an average α value of 10%. Because porewater concentrations calculated for some Site sediment samples had elevated α values, which represent the possible influence of NAPL, porewater concentrations from samples with α values greater than 10% were not used to develop the model inputs. Of the samples with α values less than 10%, sample 3C 0-6, which had the highest TPAH16 porewater concentration, was used to define the porewater source term in the model. The calculated porewater concentrations from this sample are listed in Table B-3.

Table B-3
Porewater Concentrations Used in the Model

Chemical Name	Calculated Porewater Concentrations from Sample 3C 0-6 (μg/L)
Acenaphthene	220
Acenaphthylene	220
Anthracene	18
Benzo(a)anthracene	0.87
Benzo(a)pyrene	0.23
Benzo(b)fluoranthene	0.088
Benzo(g,h,i)perylene	0.038
Benzo(k)fluoranthene	0.090
Chrysene	0.69
Dibenzo(a,h)anthracene	0.0086
Fluoranthene	6.3
Fluorene	79
Indeno(1,2,3-c,d)pyrene	0.026
Naphthalene	6,200
Phenanthrene	53
Pyrene	11
TPAH16	6,800

Given that these concentrations are uncertain because they were calculated based on partition coefficients from the literature and were screened based on NAPL effective solubility theory, collecting Site-specific porewater PAH concentrations during design is recommended if the remedy selected for the Site includes capping.

3.3 Groundwater Seepage Rates

Groundwater seepage rates at the Site have not been measured directly. Therefore, groundwater seepage rates were estimated using available hydrogeological information from the river and the adjacent upland. This information included stratigraphic cross sections, boring logs from monitoring wells, field hydraulic conductivity (slug) tests, and groundwater elevation measurements (see Section 6.3.2 of *Phase II Comprehensive Site Assessment* [GZA 2022]).

For this Phase III RAP, the rate of groundwater discharge to the river was assumed to equal the discharge of upland groundwater within the shallow silty sand unit toward the river. In GZA (2022), the total groundwater discharge through the shallow overburden soils in the Site uplands was calculated using Darcy's Law and Site-specific hydraulic properties. Equation B-1 is the Darcy's Law equation for the volumetric flow (discharge) rate through a porous medium:

Equation B-1

$$Q = K \cdot i \cdot A$$

where:

Q	=	discharge rate (ft^3/day)
K	=	aquifer hydraulic conductivity (ft/day)
i	=	hydraulic gradient (ft/ft)
A	=	aquifer total cross-sectional area through which flow occurs (ft^2)

This calculation was performed using a hydraulic conductivity of 1 foot per day, based on slug test results measured at monitoring wells in the Site uplands, and a hydraulic gradient of 0.03 foot per foot, based on groundwater elevations measured at Site monitoring wells. To calculate the cross-sectional area through which shallow groundwater would flow, a saturated thickness of 20 feet for the shallow silty sand unit and an estimated flow path width of 350 feet (based on the width of the Site perpendicular to the direction of groundwater flow) were assumed. These values yield an estimated groundwater discharge of 210 cubic feet per day for shallow groundwater flow through the Site area toward the river.

To estimate the groundwater seepage rate, the groundwater beneath the Site was assumed to discharge to the eastern half of the riverbed, which has a width of approximately 20 feet perpendicular to the riverbank. The seepage rate (q) is equal to the Darcy flux (or specific discharge) and can be calculated as shown in Equation B-2:

Equation B-2

$$q = \frac{Q}{W \cdot L}$$

where:

q	=	seepage rate (ft/day)
Q	=	discharge rate (ft^3/day)
W	=	estimated width of seepage discharge zone (20 ft)
L	=	length of seepage discharge zone (350 ft)

Based on these data and the discharge rate (Q) of 210 cubic feet per day, the seepage rate in the eastern half of the riverbed is estimated at 0.03 foot per day, which is equal to 0.9 centimeter per day (cm/day).

The groundwater seepage rates in the Little River will also be influenced by groundwater discharge from the west side of the river. GZA installed monitoring wells in the uplands west of the river and obtained groundwater elevation measurements but did not perform slug tests at those wells. The boring logs indicated sand, gravel, or both with little or no fine material within the screened intervals of the wells. Drawdown and pumping rate data collected during low-flow sampling at those wells suggest that the hydraulic conductivity of the shallow porous media west of the river may be greater than that of the shallow porous media east of the river. Groundwater elevations measured at those wells also indicate a greater hydraulic gradient toward the Little River from the west side of the creek than from the east. These data indicate the groundwater seepage rate to the river could be significantly greater than the groundwater seepage rate estimated from the hydrogeological information on the east side. However, due to the uncertainty around this value, a groundwater seepage rate of 1 cm/day was used for this preliminary cap model evaluation. It is recommended that Site-specific groundwater seepage rates be collected during the pre-remedial design investigation (see Section 5) so that this model input can be refined during design should capping be brought forward as the selected remedy.

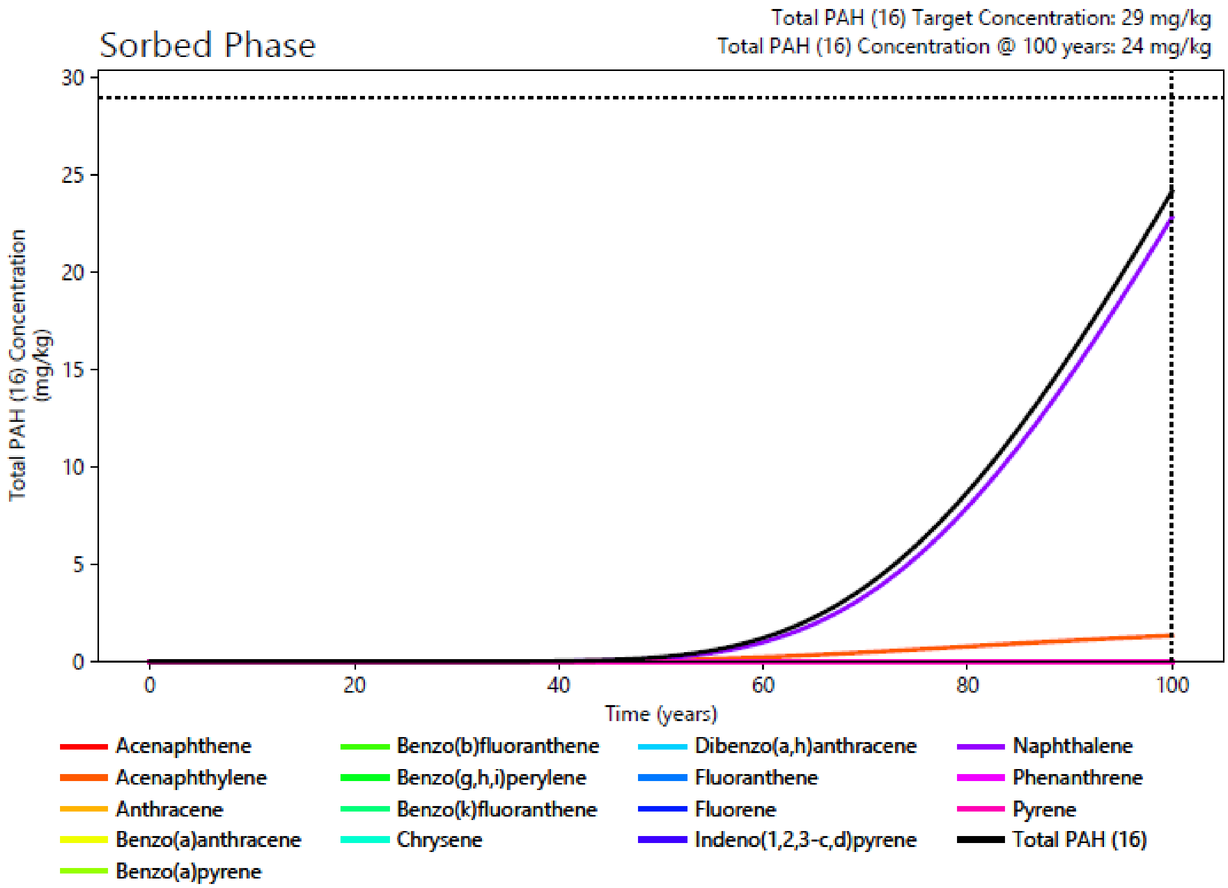
4 Model Results

The model was used to simulate the transport of PAH compounds within the cap layers discussed in Section 2.2. Due to differences in chemical properties (i.e., mobility), the individual PAH compounds that comprise TPAH16 were simulated separately and the TPAH16 concentration was calculated based on the sum of the model results of the individual compounds. Model simulations were conducted to assess the performance of the cap over a 100-year period, as discussed in Section 2.3. Model performance was evaluated by comparing model-predicted solid phase TPAH16 concentrations from the top 15 cm of the cap (expressed as a vertical average) to the target background-based TPAH16 concentration of 29 mg/kg (see Section 2.3).

Simulations started with a 12-inch chemical isolation layer thickness and a nominal total organic carbon (TOC) content of 0.1%. Model results indicated that 12 inches of sand alone was insufficient to maintain concentrations less than the target for more than 100 years. The model was then run iteratively to identify the sorptive amendment content needed to meet the target (i.e., to maintain model-predicted concentrations in the top 15 cm of the cap below the target concentration throughout the 100-year simulation). The TOC content was increased in 5% increments during these iterative simulations.

As shown in Figure B-3, the iterative model evaluations indicated that a 30-cm chemical isolation layer with 50% TOC (or equivalent) will be needed to meet the design target. The use of TOC to represent the sorptive amendment in the model allows for flexibility in the selection of a sorptive amendment during later stages of design if capping is part of the Site remedy. In general, the TOC content for the chemical isolation material could be achieved through multiple commonly used cap amendments, such as organoclay or granular activated carbon (GAC). GAC has been shown to be at least 10 to 100 times more sorbent than TOC for PAHs (e.g., Jonker and Koelmans 2002; Hale and Werner 2010); so, for example, 5.0% by weight GAC could provide similar sorption as 50% TOC.

Figure B-3
Model-Predicted TPAH16 Concentrations within the Top 15 cm of a Cap with a 30-cm Chemical Isolation Layer with 50% TOC



Note: The vertical dotted line at 100 years represents the length of time that protectiveness of the cap was evaluated. The horizontal dotted line at 29 mg/kg represents the target concentration.

5 Data Gaps

Two data gaps identified during this preliminary cap evaluation have the potential to significantly impact the chemical isolation layer design: porewater sampling and groundwater seepage measurement. They are discussed in the remainder of this section.

As discussed in Section 3.2, the porewater PAH concentrations used in the cap model simulations are uncertain because they were calculated based on literature partition coefficients and screened based on NAPL effective solubility theory. Thus, collection of Site-specific porewater PAH concentrations is recommended during design if capping is included in the remedy selected for the Site.

Furthermore, an evaluation of Site sediment data indicated that benzene could be present at concentrations greater than the screening criteria. However, due to the limited number of sediment samples analyzed for benzene and the variability in the available data, benzene was not included in these preliminary model evaluations. The Phase II risk assessment identified PAHs as having the potential to pose a risk to aquatic receptors at the Site (Section 7 of Appendix C of *Phase II Comprehensive Site Assessment* [GZA 2022]), but an evaluation of the limited detections of benzene in Site sediment data indicated that benzene concentrations in porewater could be elevated relative to the screening criteria and should therefore be included in future cap design evaluations. Benzene is a mobile chemical and has a Log Koc of 2.2 log L/kg (EPA 2018), which is more than an order of magnitude lower that the Log Koc of 3.3 log L/kg for naphthalene, which is the PAH that was predicted to drive the cap design (see Figure B-3). Therefore, elevated concentrations of benzene, combined with its relatively low Log Koc, have the potential to drive the design of the chemical isolation layer. In fact, preliminary evaluations suggest that if porewater measurements of benzene are high enough, capping may not be able to meet design targets for the 100-year evaluation period. Therefore, porewater samples should be collected and analyzed for VOCs (i.e., benzene, toluene, ethylbenzene, and xylene [BTEX]) in addition to PAHs if capping is brought forward into the design.

As discussed in Section 3.3, the groundwater seepage rate at the Site is also uncertain. A value of 1 cm/day was selected for use in the preliminary cap evaluations based on information from the east side of the river and is a typical rate for freshwater streams. However, an evaluation of hydrogeological data collected in the uplands to the west of the river indicates the rate could be much higher. A significantly higher seepage rate would result in more robust chemical isolation layer requirements (i.e., greater thickness or amendment content). Thus, groundwater seepage rates in the Little River adjacent to the Site should be measured during the pre-design investigations if capping is part of the Site remedy.

6 Summary

Numerical modeling was conducted to assess the feasibility of capping to address dissolved-phase PAH flux from Site sediment by evaluating the long-term performance of a cap's chemical isolation layer. Preliminary cap modeling indicates that a 30-cm chemical isolation layer with 50% TOC would be needed to maintain cap surface TPAH16 concentrations below the background-based TPAH16 concentration target for more than 100 years. However, there is considerable uncertainty in this conclusion due to the data gaps identified in Section 5. If capping is carried forward as part of the Site remedy, Site-specific groundwater seepage rates and porewater PAH and BTEX concentrations should be measured, and the corresponding model input parameters should be refined based on those data to re-evaluate the chemical isolation layer thickness and amendment needs. Depending on the results of the pre-design investigation sampling, a significantly more robust chemical isolation layer (i.e., thicker or with greater sorptive amendment content) could be needed to address dissolved-phase COC flux at the Site.

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Appendix D

Public Notices

GZA

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July 13, 2022
GZA File No. 01.0172397.10

The Honorable James J. Fiorentini
Mayor of Haverhill
Haverhill City Hall
4 Summer Street, Room 100
Haverhill, MA 01830

Peter Carbone, Chairperson
Haverhill Board of Health
4 Summer Street, Room 210
Haverhill, MA 01830

Re: Phase III Remedial Action Plan
284 Winter Street, Haverhill, Massachusetts
Release Tracking Number (RTN) 3-32792

To Whom It May Concern:

On behalf of Boston Gas Company d/b/a National Grid, GZA GeoEnvironmental, Inc. (GZA) is providing notification in accordance with 310 CMR 40.1403(3)(e) of the Massachusetts Contingency Plan (MCP) that a Phase III Remedial Action Plan (RAP) for the above-referenced Site is being submitted to the Massachusetts Department of Environmental Protection (MassDEP). As required by the MCP, a copy of the Phase III RAP conclusions is attached.

A copy of the Phase III RAP submittal can be viewed under RTN 3-32792 at the MassDEP website: http://eeaonline.eea.state.ma.us/DEP/wsc_viewer/main.aspx after July __, 2022. Copies of the report can also be obtained by contacting Jesse Edmands of National Grid at (781) 907-3682 / jesse.edmands@nationalgrid.com or the undersigned at 781-278-3700 or Charles.lindberg@gza.com.

Very truly yours,

GZA GEOENVIRONMENTAL, INC.

Charles A. Lindberg

Charles Lindberg, LSP
Senior Principal

cc: Jesse Edmands, National Grid
MassDEP, NERO (via eDEP)

Attachments: Phase III RAP Conclusions

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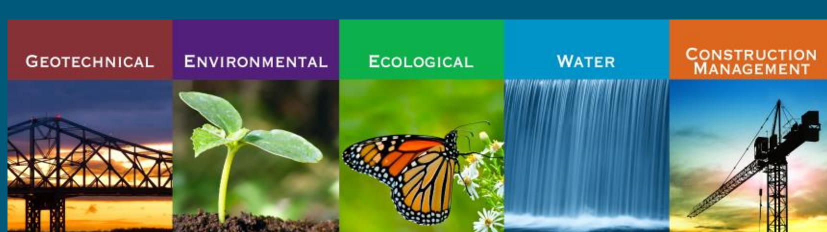
CONCLUSIONS

This Phase III Remedial Action Plan (RAP) selects the following Remedial Action Alternatives for the 284 Winter Street Site (RTN 3-32792):

- Relocation of the electrical line that presently runs through the former relief holder;
- Implementation of an AUL that prohibits installation of new underground utility lines within the footprint of the relief holder and restricts residential and certain other future uses of the Site;
- Sealing/removal of historical piping and penetrations in the retaining wall that separates the upland portion of the Site from the Little River; and
- Focused dredging and capping of the sediments within the Little River adjacent to the Property.

The design of the relevant components of these RAAs will be documented in a Phase IV Remedy Implementation Plan.



GZA GeoEnvironmental, Inc.