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5.0 ANALYSIS OF BROWNFIELD CLEANUP ALTERNATIVES

Based on evaluation of soil, groundwater, and soil gas analytical data collected during the TBA, concentrations of VPH and VOCs in environmental media could pose significant risks to human health under future site redevelopment and future use activities at the Site. Additional response actions will be required to achieve a condition of No Significant Risk and a Permanent Solution under the MCP. Any response actions implemented at the Site will require a site-specific risk assessment to determine if a condition of "No Significant Risk" exists at the Site, and to identify which environmental media must be remediated in order to achieve a condition of No Significant Risk. The risk assessment will evaluate the risks residual contamination at the Site pose to human health, welfare, environment, and public safety. The risk assessment will be performed in accordance with either MCP Method 1 (310 CMR 40.0970) or Method 3 Risk Characterization (310 CMR 40.0990) methods.

The data collected during TBA investigations indicates a significant portion of VPH contamination is located underneath the existing site building. The cleanup alternatives and cost estimates presented below assume that the existing site building is demolished and all demolition debris have been removed from the Site prior to beginning any remediation activities at the Site. Preliminary costs for abatement of asbestos and hazardous materials inside the building are approximately $10,000. Refer to Appendix C for a detailed listing of hazardous materials identified in the existing site building during the TBA investigations. Preliminary cost estimates for demolition of the existing onsite building are approximately $75,000 to $100,000. Those costs include the $10,000 hazardous material abatement and complete demolition and offsite disposal of all building components including foundations and slabs.

The following sections present an analysis of brownfield cleanup alternatives (ABCA) that describe potential remedial alternatives to achieve a condition of No Significant Risk and a Permanent Solution under the MCP (310 CMR 40.1000). The remedial alternatives presented below provide a range of potential cleanup strategies that include complete removal and off-site disposal of contaminated soil, *in situ* (in place) remediation of contaminated soil and groundwater, and monitored natural attenuation whereby contaminants are broken down into harmless by-products through natural processes.

5.1 Excavation and Off-Site Disposal of Contaminated Soil

Based on TBA soil data, VPH has impacted an eastern portion of the Site that encompasses approximately 4,500 square feet (Figure 4-1). VPH-impacted soils were documented from approximately three (3) feet to up to a maximum depth of ten (10) feet bgs. A significant portion of VPH-impacted soils are located beneath the existing Site building. In order for excavation of contaminated soils to be a viable and effective cleanup alternative (i.e. achieve a Condition of No Significant Risk), the existing onsite building will need to be demolished prior to performing excavation activities. Additionally, VPH-impacted soils are located below the water table (approximately six (6) feet bgs during TBA investigations) and dewatering will be required to effectively perform excavation work. Groundwater will need to be pumped to a temporary holding tank and either treated onsite or transported to an offsite disposal facility.

5.2 In Situ Remedial Alternatives

A summary of *in situ* remedial alternatives is presented in the sections that follow. *In situ* remediation is often a cost-effective alternative to excavation and off-site disposal where the volume of contaminated soil is large and/or a significant volume of contaminated soil is located below the water table where dewatering/treatment and excavation "in the wet" will be required to completely remove contaminated material.

5.2.1 Enhanced Aerobic Bioremediation

Aerobic bioremediation is a process by which naturally occurring microorganisms degrade organic contaminants into carbon dioxide and water. For these processes to occur there must be sufficient oxygen, otherwise aerobic function ceases. Under this alternative, aerobic bioremediation is accomplished by introducing oxygen to the subsurface soil and groundwater, typically by injecting oxygen rich solutions like Oxygen Release Compound (ORC®). Solutions like ORC® slowly release oxygen into the surrounding soil and groundwater to boost the aerobic function of naturally occurring microorganisms. ORC®-type solutions are typically applied through the use of direct push drilling and injected at specifically calculated horizontal and vertical locations. Several applications may be required to achieve cleanup goals. Enhanced bioremediation has proven effective in treating most non-chlorinated VOCs, including gasoline-related petroleum hydrocarbons.

5.2.2 Chemical Oxidation

Using this remedial alternative, direct chemical oxidation of petroleum hydrocarbons is accomplished by introducing an oxidizer (catalyzed hydrogen peroxide, sodium persulfate, or similar) that acts to break down petroleum hydrocarbons. High percentage oxidant solutions (up to 50% is common) are applied to the targeted subsurface area through direct injection distribution system. Following the oxidant solution application, a catalyst (iron, sodium persulfate, or similar depending on the selected oxidant) is applied to the targeted subsurface area creating a reagent solution. Injections of reagent solutions can produce vigorous chemical reactions known to produce gas and steam. Follow-up injection applications and collection of soil and groundwater samples would be required to document achievement of cleanup goals. Several applications of reagent may be required to achieve cleanup goals.

5.3 Monitored Natural Attenuation

Monitored natural attenuation (MNA) involves long-term monitoring of physical, chemical, and biological process that, under favorable conditions, will naturally (i.e. no human involvement) reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil and/or groundwater. However, MNA remedial alternatives have the potential to significantly prolong the period of time required to achieve cleanup goals.

5.4 Evaluation of Remedial Alternatives

The following subsections provide an analysis of cleanup alternatives with preliminary order-of-magnitude cost estimates for each alternative. The evaluation presented below assumes regulatory acceptance of the remedial approach and a MCP Method 1 or Method 3 risk assessment demonstrating that the residual concentrations of contaminants after remediation are protective of human health, the environment, and public welfare. To evaluate a range of potential remedial alternatives, Nobis evaluated the effectiveness, implementability, cleanup time, resiliency to climate change, and overall cost estimates for four (4) potential remedial scenarios. Cost estimates do not include construction costs for redevelopment of the property, only preparation of the property for redevelopment. An initial screening of cleanup alternatives is presented in Table 5-1. Cost estimate details are summarized in Tables 5-2, 5-3, and 5-4.

The following is a tabular summary of the alternatives considered in this TBA Report.

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Alternative Number	Remedial Alternative Type	Estimated Remedial Cost Range
1	Excavation and Off-Site Disposal of Contaminated Soil	$220,000-$285,000
2	Enhanced Aerobic Bioremediation	$195,000-$250,000
3	In Situ Chemical Oxidation	$255,000-$415,000
4	Monitored Natural Attenuation	Eliminated

5.4.1 Alternative 1: Excavation and Offsite Disposal of Contaminated Soils

Remedial Alternative Description

Under this alternative, all soils containing concentrations of VPH greater than Method 1 risk assessment standards for Category S-1 soil would be excavated and transported for off-site disposal. Confirmatory soil sampling would be performed at the completion of excavation actives to document the effectiveness of the remedial alternative. Based on TBA soil data, VPH impacted soils in the eastern portion of the site encompasses approximately 4,500 square feet and extends from approximately three (3) feet to a maximum depth of ten (10) feet bgs, with an average contaminated zone thickness of approximately three and one-half (3.5) feet. Excavation of VPH impacted soils would generate approximately 600 cubic yards of contaminated soil requiring off-site disposal. Based on soil data collected to date, soil could likely be disposed of at an appropriately licensed facility and treated using low temperature thermal desorption.

To effectively excavate VPH impacted soils located in saturated overburden materials, groundwater will likely need to be pumped to a temporary holding tank and either treated onsite or transported to an offsite disposal facility. For conservative cost estimating purposes, Nobis assumes that approximately 1,000 gallons of groundwater will be generated during excavation activities that will require off-site disposal.

Effectiveness

This alternative would be protective of human health and the environment. Contaminant reduction would be accomplished through the physical removal of impacted environmental media, but no treatment of contaminants would occur as contaminated media would be transported for disposal into a licensed landfill. The short-term impacts to the community during implementation would be relatively high (i.e. heavy truck traffic), but could be mitigated through engineering controls. This alternative would be highly effective in the long term since contaminants would be removed from the site with no potential for rebound or degradation into harmful remediation by-products.

Implementability

This remedial alternative is easy to implement from a technical and administrative standpoint and could be completed in a relatively short time frame (approximately one (1) week on site). Excavation and off-site disposal is a well-developed technology that is commonly used to remove impacted material from contaminated sites, and the required resource to implement this technology are readily available from several vendors.

Resiliency to Climate Change

Because the post-remediation site grades and the permeability of site materials would be the same as the current conditions, this alternative would be resilient to climate change factors such as rising seas levels and changing flood zones. In fact, post-remediation site lines and grades could be modified to increase flood storage capacity or manage stormwater, if warranted to support redevelopment. Complete removal of contaminated soil would mitigate potential impacts from a higher groundwater table such as increase leaching of contaminants to groundwater. The location of this site, within 1,000 feet from the coast line, makes it susceptible to these changes, which creates a risk of contaminant migration to sensitive areas. Removal of contaminated soils would mitigate this potential concern.

Cost Estimate

The estimated cost range to execute Remedial Alternative 1 would be approximately $220,000 to $285,000. A summary of estimated costs are included in Table 5-2.

5.4.2 Alternative 2: Enhanced Aerobic Bioremediation

Remedial Alternative Description

Under this alternative, a solution like ORC® would be applied through the use of direct push drilling and injected at specifically calculated horizontal and vertical locations. Based on the negative oxidation reduction potential (ORP) values (generally ranging from -50 to -100 millivolts) and the low dissolved oxygen values (generally less than 0.5 mg/l) observed during low flow sampling, reducing conditions may be present at the site. Additional site-specific soil and groundwater data would need to be collected and used to determine the amount of ORC® required to achieve favorable geochemical conditions that would lead to aerobic bioremediation. Several applications may be required to achieve cleanup goals. Confirmatory soil and groundwater sampling would need to be performed to evaluate the effectiveness of this alternative. Additional long-term groundwater monitoring may be required to monitor for contaminant rebound following completion of the remedial alternative.

Effectiveness

This alternative would be protective of human health and the environment. Contaminant reduction would be accomplished through treatment of soil and groundwater, resulting in reduction of the toxicity, mobility, and volume of contamination. Short-term impacts to the community would be low, as there would be no excavation of soils or transportation of contaminated soils over public roadways. The long-term effectiveness would be moderate to high, depending upon subsurface conditions, with the possibility of persistent contamination or contaminant rebound if site conditions are not optimal for the delivery of the treatment reagent.

Implementability

This alternative would be easily implementable from a technical and administrative standpoint, however there would be some barriers to implementation including geochemical conditions in the subsurface that might limit the effectiveness of the chemical/biological reactions necessary to achieve contaminant degradation, and the need for additional site-specific soil and groundwater data in order to develop an injection plan. Several applications of treatment reagent may be required to achieve cleanup goals, therefore the time frame for remediation is estimated to be six (6) months to one (1) year. The oxygen enhancement technology has been proven effective at reducing petroleum contaminant mass at sites similar in nature to this site, and the required resources are available from a limited number of vendors.

Resiliency to Climate Change

As above, the treatment of contamination would be accomplished without modifying the site grades or infiltration capacity of site soils, therefore this alternative would provide resiliency against rising sea levels, changing flood zones, and higher groundwater tables. However, since no excavation or site work would be performed, there is less opportunity to include flood storage or stormwater controls into the remedial plan.

The treatment of contaminants would prevent the migration of contaminants. The location of this site, within 1,000 feet from the coast line, makes it susceptible to these changes, which creates a risk of contaminant migration to sensitive areas. Treatment of contaminated soils would mitigate this potential concern.

Cost Estimate

The estimate cost range for Alternative 2 would be $195,000 to $250,000. A summary of estimated remedial costs for Alternative 2 are presented in Table 5-3.

5.4.3 Alternative 3: In Situ Chemical Oxidation

Remedial Alternative Description

Under this alternative, a chemical oxidant would be injected into subsurface soil and groundwater in the approximately 4,500 square foot area. This alternative would require the construction of approximately ten (10) to 15 temporary injection wells to apply the selected oxidant. Similar to Alternative 2, site specific data collected during TBA investigations suggest that reducing conditions may be present at the Site. Additional site-specific soil and groundwater data would need to be collected and used to develop bench scale tests to determine the oxidant demand of Site soils. The oxidant demand of soils determines the amount of oxidant that will need to be applied to achieve cleanup goals. Therefore, higher levels of oxidant demand lead to increase remediation costs.

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Effectiveness

This alternative would be protective of human health and the environment. Contaminant reduction would be accomplished through treatment of soil and groundwater, resulting in reduction of the toxicity, mobility, and volume of contamination. Short-term impacts to the community would be low, as there would be no excavation of soils or transportation of contaminated soils over public roadways. The long-term effectiveness would be moderate to high, depending upon subsurface conditions, with the possibility of persistent contamination or contaminant rebound if site conditions are not optimal for the delivery of the treatment reagent or amenable to the chemical reactions that form the basis of this technology.

Implementability

This alternative would be easily implementable from a technical and administrative standpoint, however there would be some barriers to implementation including geochemical conditions in the subsurface that might limit the effectiveness of the chemical reactions necessary to achieve contaminant degradation, and the need for additional site-specific soil and groundwater data in order to develop an injection plan. Several applications of treatment reagent may be required to achieve cleanup goals, therefore the time frame for remediation is estimated to be six (6) months to one (1) year. This technology has been proven effective at reducing petroleum contaminant mass at sites similar in nature to this site, and the required resources are available from several vendors.

Resiliency to Climate Change

As above, the treatment of contamination would be accomplished without modifying the site grades or infiltration capacity of site soils, therefore this alternative would provide resiliency against rising sea levels, changing flood zones, and higher groundwater tables. However, since no excavation or site work would be performed, there is less opportunity to include flood storage or stormwater controls into the remedial plan.

The treatment of contaminants would prevent the migration of contaminants. The location of this site, within 1,000 feet from the coast line, makes it susceptible to these changes, which creates a risk of contaminant migration to sensitive areas. Treatment of contaminated soils would mitigate this potential concern.

Cost Estimate

The estimated cost range of Alternative 3 would be $255,000 to $415,000. A summary of estimated remedial costs for Alternative 3 are presented in Table 5-4.

5.4.4 Alternative 4: Monitored Natural Attenuation

Remedial Alternative Description

Overall, concentrations of VPH in Site soil and groundwater have generally declined since environmental investigations began in the mid-1980s, suggesting that some natural attenuation of VPH is occurring at the Site. Long-term monitoring of physical chemical, and biological process will be required until cleanup goals are achieved.

Effectiveness

This alternative would not be protective of human health because it is not likely to reduce risk in the short term, and has the potential to significantly prolong the period of time required (possibly decades) to achieve cleanup goals. There would be minimal short-term impacts to the community since only limited action would be taken to reduce contaminant levels. The long-term effectiveness of this alternative would be dependent upon the rate at which natural degradation of contaminants occurs.

Implementability

This alternative is technically and administratively feasible. However, the time frame for remediation is likely to be extremely long, therefore this remedial alternative may limit site redevelopment options.

Resiliency to Climate Change

This alternative would be the least resilient to climate change factors, since there would be less reduction of contaminant levels and no opportunity for improvements in flood storage or stormwater management.

Cost Estimate

The costs for Alternative 4 are typically less than Alternatives 1, 2, and 3. However, based on the results of the effectiveness, implementability, and resiliency to climate change analysis, this alternative has been eliminated from consideration as a stand-alone remedial alternative. However, Alternative 4 may be economical as a complement to an active treatment alternative if further contaminant reduction is required after treatment or removal of source material.

5.5 Remedial Alternative Recommendation

Nobis recommends implementation of Remedial Alternative 1 – Excavation and Offsite Disposal of Contaminated Soils. This recommendation is based on the following factors:

- Remedial Alternative 1 will be protective of human health and the environment;
- Remedial Alternative 1 is easily implementable and will be the most reliable alternative to reduce the contaminant mass in soil and groundwater;
- Remedial Alternative 1 is relies on well-established technologies that are readily available from several vendors;
- Remedial Alternative 1 can be completed in a short time frame;
- Remedial Alternative 1 includes earthwork and site restoration that will provide the opportunity to incorporate increased flood storage and stormwater control as warranted to support the site redevelopment;
- Remedial Alternative 1 requires the least amount of long-term operation and monitoring costs;
- Remedial Alternative 1 can be completed at a reasonable cost; and
- Remedial Alternative 1 provides the best potential for future site reuse and redevelopment.