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From:
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Date:
June 29, 2015

ARCADIS Project No.:
00266401.0000.00006

Subject:
Vestal Water Supply Well 1-1 Site
NYSDEC Site 7-04-009A
Source Area Technology Feasibility Evaluation

At the request of the New York State Department of Environmental Conservation (NYSDEC), this Source Area Technology Feasibility Evaluation has been developed to screen and evaluate remedial alternatives for treatment of the onsite source area at the Vestal Water Supply Well 1-1 Site in Vestal, New York. During execution of NYSDEC work assignment #D004443-4, which includes a Remedial System Optimization (RSO) evaluation of the Well 1-1A treatment system, it became apparent that remediation of the onsite source area would have a significant benefit to the environment and human health, and would likely be more cost effective than long-term treatment of the offsite groundwater plume at Well 1-1A. As such, the primary purpose of this technical memorandum is to identify remedial alternatives suitable for source area remediation, to evaluate these alternatives versus typical feasibility study evaluation criteria, and to compare the value of source area remediation versus continued operation of the Well 1-1A treatment system. The evaluation was completed by:

- Identifying remedial technologies suitable for treatment of the source area through a technology screening process.
- Developing remedial alternatives using the technologies retained as part of the screening process.

- Evaluating if achieving alternate standards at the onsite source area has the potential to protect human health and the environment at offsite locations.

- Evaluating the remedial alternatives using standard feasibility study evaluation criteria; and,

- Evaluating and comparing the cost and feasibility of implementing the onsite remedial alternatives relative to:

  - Meeting alternate standards that would be suitable for the protection of human health and the environment and be consistent with the intended use of the property.

  - Meeting the ROD required remedial action objective of returning the site to unrestricted use standards; and,

  - The cost of continuing to operate the offsite groundwater extraction and treatment system at Well 1-1A.

This evaluation herein was conducted in accordance with Department of Environmental Remediation (DER)-10 and the NYSDEC DER program policy for Green Remediation (DER-31).

Finally, while it is understood that the onsite area has multiple release areas and constituents of concern (COCs), this evaluation is focused on the treatment of Trichloroethene (TCE) and 1,1,1-Trichloroethane (TCA) (and/or their daughter compounds) which represent the majority of the onsite contaminant mass and represent the biggest risk to human health and the environment.

Site Background and Basis of Design

A brief description of the site background and basis of design used for the development and evaluation of remedial alternatives is provided below.

Site Background

The source area for the Vestal Water Supply Well 1-1 site (the "site") is located in the Town of Vestal in southwestern Broome County, New York. The site is located approximately 1,180 feet south of the Susquehanna River and is zoned for commercial-light industrial activities. The site is occupied by a 60,000 square foot building that formerly housed a circuit board manufacturing operation. The site is currently used for recycling electronics (Lockheed Martin Information Systems and Global Solutions, 2012).

The site was contaminated with chlorinated solvents (primarily TCE, 1,1,1-TCA and their associated daughter compounds) and petroleum related VOCs through historical site operations. Multiple soil and groundwater investigations have been completed to evaluate the nature and extent of contamination and support the US EPA issued a Record of Decision (ROD). The previous investigations have identified three suspected release areas at the Site. A soil vapor extraction (SVE) system was operated in two of these areas (designated Area 2 and Area 4) to remediate contaminated soil. The SVE system was successful in achieving the ROD required cleanup objective in Area 2 but was not capable of remediating soils to the ROD required cleanup objective in Area 4. Figure 1 shows the site location and general site features, as well as Well 1-1A and the current Town of Vestal water supply wells.

The Town of Vestal currently operates two production wells identified as Wells 1-2A and 1-3 that function as the main source of water for Water District 1 which are located approximately 2,700 feet west of the site. Former supply Well 1-1A, located approximately 1,800 feet northwest of the site, currently operates as a groundwater remedial well which prevents the migration of contamination to the Wells 1-2A and 1-3.

Basis of Design

The basis of design used for the identification and screening of remedial technologies and evaluation/costing of remedial alternatives were generated from the following references:

- Flow and Contaminant Transport Models of 1,1,1-TCA and TCE in Groundwater at the Vestal Water Supply Well 1-1 National Priorities List (NPL) Site (Lockheed Martin Information Systems and Global Solutions, 2014).

- The Preliminary Conceptual Site Model (Lockheed Martin Information Systems and Global Solutions, 2012); and,

- The Vestal Chlorinated Hydrocarbon Source Assessment/Remedy Site (Lockheed Martin Information Systems and Global Solutions, 2007).

A summary of the basis of design elements extracted from these references is provided below. Exceptions and/or modifications to the information provided in the documents are identified, as appropriate.

Geology and Hydrogeology

The hydrostratigraphy of the site area from ground surface to depth includes:

- Fill material consisting of concrete fragments and poorly sorted sands and silt is present from 0 to 5 ft below land surface (bls) at varying thicknesses.

- Modern alluvium consisting of a heterogeneous interbedding of silt, clay and sand lenses with low hydraulic conductivities that range from 0.04 to 1.4 feet per day (ft/day) is present from approximately 5 ft bls to a maximum of 20 ft bls.

- The principal aquifer is composed of glaciofluvial sand and gravel that have high to very high hydraulic conductivities ranging from 100 to 10,000 ft/day. Glaciofluvial deposits are present from approximately 15 to 20 ft bls to 40 ft bls with varying thicknesses throughout the target area.

- Lodgment till consisting of unsorted clays to boulder material is present beneath the glaciofluvial deposits with varying thicknesses. The till has hydraulic conductivities that are generally less than (<) 10 ft/day. And,

- Devonian shale bedrock with hydraulic conductivities < 25 ft/day. Both the bedrock and lodgment till are semi-confining aquitards with low hydraulic conductivities.

The depth to groundwater at the site varies seasonally but is generally encountered between 15 and 20 ft bls. The direction of groundwater flow is generally to the west/northwest toward Well 1-1A within the principal aquifer. The estimated groundwater velocity onsite appears to be faster than at offsite locations and is estimated to range from as high as 6 to 8.5 ft/day onsite and 1 to 2.5 ft/day offsite. The difference in groundwater velocities may be attributed to the thinning of the principal aquifer to as little as 5 feet at monitoring well 4009-23 and to the relative thickness of the principal aquifer downgradient of 4009-23 (e.g., approximately 2 to 4 times thicker than onsite). A cross-section location and the cross-section of the onsite and offsite hydrostratigraphy along the downgradient groundwater flow path are shown on Figures 2 and 3, respectively.

Remedial Target Areas, Estimated Mass, and Cleanup Levels

The Preliminary Conceptual Site Model (Lockheed Martin Information Systems and Global Solutions, 2012) identified three separate release areas and confirmed the likely presence of 1,1,1-TCA and TCE dense non-aqueous phase liquid (DNAPL) using multiple lines of evidence. In addition, it was noted that the majority of the 1,1,1-TCA and TCE mass (> 85 percent) is present within the silts, clays, and sands of the modern alluvium deposits from approximately 15 to 20 ft bls. It should be noted that this interval also represents the approximate groundwater smear zone which is traditionally more difficult to target for remediation than the true saturated zone or vadose zone. The Preliminary Conceptual Site Model estimates that approximately 3,544 pounds (lbs) of 1,1,1-TCA and TCE mass remain in the source areas. ARCADIS believes this value is potentially significantly underestimated because it does not include an assumption for the volume of DNAPL present. For a comparative perspective, it is estimated that Well 1-1 and 1-1A have already removed approximately 6,700 lbs of contaminant mass. In addition, the operation of an SVE system at two locations onsite (Area 2 and Area 4 – see Figure 1) appears to have removed nearly 4,000 lbs of contaminant mass. Combined, it is estimated that greater than 10,000 lbs of contaminant mass have already been removed through previous remedial actions with a minimal decrease in concentrations at offsite Well 1-1A and onsite source area monitoring wells. While there is insufficient data to estimate the true amount of mass (i.e., the volume of DNAPL is unknown), ARCADIS has assumed that there is 20,000 lbs of mass remaining as a conservative assumption for cost estimating purposes.

The Flow and Contaminant Transport Models of 1,1,1-TCA and TCE in Groundwater at the Vestal Water Supply Well 1-1 NPL Site (Lockheed Martin Information Systems and Global Solutions, 2014) indicate a ROD defined soil cleanup objectives for 1,1,1-TCA and TCE of 0.17 mg/kg and 0.14 mg/kg respectively. These cleanup criteria are lower, but generally consistent with the NYSDEC Unrestricted Soil Cleanup Objectives (SCOs) of 0.68 mg/kg and 0.47 mg/kg for 1,1,1-TCA and TCE, respectively. However, the transport model further indicates that remediation of the onsite source area to the ROD defined objectives will have no significant benefit to the protection of the offsite supply wells or the Susquehanna River versus alternate standards that are significantly higher than the ROD defined objectives. To evaluate this conclusion, ARCADIS completed a simple attenuation evaluation which estimated the steady-state attenuation factor for concentrations currently detected at onsite source area monitoring wells to the concentrations detected at Well 1-1A. The attenuation factor was then used to estimate a theoretical source concentration that was low enough to achieve maximum contaminant levels (MCLs) at Well 1-1A. ARCADIS concluded that an order of magnitude reduction in mass at the source area would likely be sufficient to achieve the objective of protecting the offsite supply wells and the Susquehanna River. Although simplified in nature, this evaluation is generally consistent with the US EPA model which concluded that remediation of 1,1,1-TCA to a concentration of 60 mg/kg would be equally protective to the restoration of offsite groundwater as remediation to the ROD defined standard.

The site is currently zoned for commercial-light industrial use and it is not anticipated that the zoning will change in the future. Based upon the current and anticipated use of the site and the flow and transport evaluations provided above, the current ROD required cleanup objectives appear to be overly aggressive and are not required to provide protection to human health and the environment. To provide a basis of comparison the ROD required cleanup objectives, ARCADIS has assumed that the remedial target footprint for the basis of design in this technical memorandum is the 100 mg/kg soil iso-concentration contour for TCE and 1,1,1-TCA. The treatment footprint of the 100 mg/kg soil iso-concentration contour is generally consistent with the footprint of the US EPA recommended 60 mg/kg value and is consistent (or lower than) the NYSDEC Commercial SCOs. Figure 4, illustrates the estimated area where 1,1,1-TCA and TCE concentrations exceed the ROD defined standards and are greater than the NYSDEC unrestricted SCOs.

In summary, there is significant mass present at the site with the majority of mass being located approximately 15 to 20 ft bls within the silts, clays, and sands of the modern alluvial deposits. Furthermore, the majority of the mass (>95 percent) is located within the 100 mg/kg iso-concentration contour which has a significantly smaller footprint than the ROD defined cleanup objective of 0.14 mg/kg and is present, primarily, at accessible areas located outside of the onsite building. Finally, ARCADIS and US EPA estimates indicate that remediation of the source to a soil cleanup objective consistent with the current use of the site (e.g., the NYSDEC Commercial standards) will be sufficient for the protection of human health and the environment both onsite and through the offsite migration of groundwater.

Estimated Cleanup Timeframes

The Preliminary Conceptual Site Model (Lockheed Martin Information Systems and Global Solutions, 2012) provides multiple lines of evidence indicating the presence of DNAPL onsite. The majority of contamination (> 80 percent) is within the 15 to 20 ft bls interval, which is primarily modern alluvium consisting of a heterogeneous interbedding of silt, clay and sand lenses. This information supports that without treatment, the source area would provide a continuing source to groundwater contamination above regulatory standards for potentially several decades or longer.

The Flow and Contaminant Transport Models of 1,1,1-TCA and TCE in Groundwater at the Vestal Well 1-1 NPL Site (Lockheed Martin Information Systems and Global Solutions, 2014) evaluated estimated remediation times for offsite groundwater assuming the instantaneous treatment or control of the onsite source area. The model results indicate:

- Well 1-1A would be required to operate for five additional years after source treatment is completed to continue to meet MCLs at the Town of Vestal supply Wells 1-2A and 1-3; and,

- The plume would attenuate sufficiently after 15 to 20 years such that former supply Well 1-1A could be reused as a supply well.

In summary, it is estimated that without treatment, the source area will persist for decades or longer. In addition, it is estimated that the downgradient plume will attenuate relatively rapidly after source area treatment has been accomplished.

Previous and Current Remedial Actions

As mentioned previously, the operation of an SVE system at two onsite locations (Area 2 and Area 4) have removed nearly 4,000 lbs of contaminant mass. The SVE system removed approximately 2,000 lbs of mass from Area 2 and was generally successful at remediating soils to the ROD defined cleanup objectives at this location. The system was subsequently moved to Area 4 where it operated somewhere between the years 2003 and 2007. The SVE system removed approximately 2,000 lbs from Area 4 after which it was shut down due to the perception that the technology had reached its limit of effectiveness and the observation of significant contaminant mass stored within the silts and clays within the SVE influence area. (Well 1-1A has removed approximately 6,700 pounds of contaminant mass.) Combined, it is estimated that greater than 10,000 lbs of contaminant mass have already been removed through previous remedial actions with a minimal decrease in contaminant concentrations at Well 1-1A and onsite source area monitoring wells.

Upon review of the Vestal Chlorinated Hydrocarbon Source Assessment/Remedy Site (Lockheed Martin Information Systems and Global Solutions, 2007), ARCADIS believes that SVE likely reached its limit of technical effectiveness in Area 4 because of the storage of contaminant mass in low permeability deposits and because of the presence of mass in the smear zone, which is not generally not conducive for establishing air flow through traditional SVE alone. However, more aggressive extraction technologies such as multiphase extraction (MPE) would likely be successful at accessing the majority of this mass.

In summary, previous remedial actions for onsite soils indicate that vapor extraction technology is capable of achieving the ROD required remedial objectives if it is implemented in the proper environmental setting. While a significant quantity of contaminant mass has been removed through the operation of existing systems, it is believed that a significant quantity remains due to persistent concentration trends at onsite monitoring wells and Well 1-1A.

Source Area Remedy Objectives

Source area treatment objectives are based on the basis of design elements described previously. This provides a basis of comparison of each remedial alternative against the traditional feasibility study evaluation criteria. It should be noted that the objectives provided below are not necessarily in compliance with the current ROD requirements, but were established to provide achievable objectives for the protection of human health and the environment within the constraints of the site setting, best available technologies, and NYSDEC remediation guidelines. The source area objectives established for the evaluation include:

- The protection of human health by eliminating direct exposure, ingestion, and inhalation risks.
- The protection of human health and the environment through restoring the site to conditions consistent with the intended current and future use of the site (i.e., to NYSDEC Commercial SCOs) and by minimizing offsite migration of contaminant mass (and subsequent discharge to the Susquehanna River).
- The removal of the source area, to the extent practicable, using the best available technology(s).

In addition to the above, the cost and/or ability of each alternative to achieve restoration of the site to pre-release conditions (e.g., the current ROD defined cleanup standards which are consistent with the NYSDEC Unrestricted SCOs for soil) was also evaluated and discussed in the comparative evaluation of alternatives. Finally, while it is unclear if the vapor intrusion pathway is present onsite, the ability of a remedy to address vapor intrusion is discussed, where applicable.

Technology Screening Evaluation

A technology screening evaluation was completed using the basis of design elements described previously to identify technologies suitable for the inclusion in remedial alternatives for onsite source treatment. The technology screening evaluation included a two-step process including an initial screening process to establish a broad range of potentially applicable technologies and a final screening process to narrow the list of technologies and focus on the most appropriate for the site.

Evaluation Criteria

The preliminary screening process used engineering judgment and experience to identify technologies compatible with the site basis of design and to evaluate if the identified technologies were suitable for further evaluation as part of the final screening process. Technologies retained as part of the final screening process were evaluated on the following criteria:

- Effectiveness – Potential effectiveness in achieving the source area remedy objectives reliability of technology; and potential impacts to human health and the environment,
- Implementability – Technical and administrative feasibility of implementing the technology at the site; and,
- Relative cost – Relative cost to implement the technology, including capital cost and cost for operation, maintenance and monitoring (OM&M).

A summary of the technology screening evaluation is provided below.

Preliminary Screening Results

Table 1 presents a summary of the preliminary technology screening process. As shown on Table 1, a total of 23 technology process options were evaluated and a total of 16 technology process options were retained for further consideration as part of the final screening process.

Final Screening Results

Table 2 presents a summary of the final technology screening process. As shown on Table 2, a total of 13 technology process options were retained for inclusion into the development of the remedial alternatives. The technology process options included the following:

- No action, to serve as the baseline for all active remedial alternatives.
- Institutional and engineering controls, including deed restriction, access restriction (through the filing of an environmental easement and preparation of a Site Management Plan), and existing site cover material.
- Excavation including the off-site disposal of contaminated soils and on-site reuse of uncontaminated soils that are acceptable as site fill but are excavated to access the deeper contaminated soils.
- MPE and/or SVE for treatment of contamination in the modern alluvium soils combined with aquifer sparging for treatment of soils in the principal aquifer. It should be noted that although SVE only had moderate success at Area 4, ARCADIS believes that its success was limited by the local variation in geologic sequences (e.g., silts/clays) that are acting as mass storage areas combined with the fact that majority of contamination is present within the smear zone or saturated zone (e.g., 15 to 20 ft bls). To that end, ARCADIS believes the use of aggressive pumping through MPE (e.g., application of an extremely high vacuum for total fluids recovery) has a reasonably high likelihood of success within this geology.
- Aquifer sparging (AS) for the treatment of principle aquifer soils and groundwater (to be combined with MPE and/or SVE).
- Thermal treatment using the Electrical Resistance Heating to approximately 20 ft bls (until the glaciofluvial deposits are encountered) and Steam Enchanced Extraction (SEE) for treatment of the glaciofluvial deposits. Thermal treatment represents the most aggressive in-situ technology capable of meeting both the alternate cleanup objectives and the ROD cleanup objectives.
- In-situ stabilization. When combined with a treatment amendment such as zero-valent iron, in-situ stabilization will meet the objective of preventing the offsite migration of contaminated groundwater within accessible locations.
- In-situ chemical reduction. In-situ chemical reduction using zero-valent iron and/or a mixture of zero-valent iron and a labile carbon source to promote enhanced reductive dechlorination may be combined with in-situ stabilization or injected directly through direct-push equipment.

As described previously, each of the retained technology process options was used to generate remedial alternatives. A description of the remedial alternatives evaluated is provided below.

Remedial Alternatives Development

Remedial alternatives were developed using the technologies identified as part of the final screening process. In general, remedial alternatives were sequenced from the most implementable/least aggressive alternative to the most aggressive/least implementable alternative. A description and analysis of each of the remedial alternatives is provided below.

Common Elements

Common elements represent technology process options that are included in each of the active remedial alternatives. The common elements for source area remediation include deed restrictions and access restrictions (through the filing of an environmental easement and preparation of a Site Management Plan), and engineering controls through maintenance of the existing site cover material.

In addition to the above, it is recognized that indoor air/soil vapor monitoring may be required, vapor mitigation may be required (e.g., sub-slab depressurization) and/or long-term groundwater monitoring may be required. However, the costing for these elements have not been provided in the remedial cost estimates.

Remedial Alternatives

The following remedial alternatives were identified for evaluation. As described previously, remedial alternatives are generally sequenced by their overall implementability (highest to lowest) and effectiveness and cost (lowest to highest).

1. *Alternative S1* – No action.
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2. *Alternative S2* – No active remediation. Common elements only.

3. *Alternative S3* – MPE and/or SVE for the remediation of modern alluvium deposits combined with AS for the treatment of glaciofluvial deposits within the primary aquifer.

4. *Alternative S4* – In-situ soil stabilization with chemical reduction; includes,

    a. In-situ treatment using stabilization with chemical reduction. This includes the use of deep soil mixing (DSM) augers with a cement/bentonite/zero-valent iron slurry. DSM would be applied to accessible soils located outside of the building only; and,

    b. Chemical reduction for soils and groundwater inside of the building using direct-push injections.

5. *Alternative S5* – Excavation with off-site disposal with AS/MPE; includes,

    a. Excavation with off-site disposal of contaminated soils and on-site reuse of clean overlying soils for soils outside of the building to approximately 20 ft bls (e.g., until the glaciofluvial deposits are encountered).

    b. AS/MPE for soils located inside of the building.

6. *Alternative S6* - In-situ thermal treatment using Electrical Resistance Heating to approximately 20 ft bls (until the glaciofluvial deposits are encountered) and Steam Enchanced Extraction (SEE) for treatment of the glaciofluvial deposits.

A summary of the remedial alternative comparative analysis is provided below.

Remedial Alternatives Comparative Analysis

The remedial alternatives were compared to the following criteria as part of the comparative analysis:

- Protection of Human Health and the Environment.
- Compliance with Regulatory Requirement.
- Long-Term Effectiveness and Permanence.
- Reduction of Toxicity, Mobility, and Volume with Treatment.
- Short-Term Effectiveness.
- Implementability.
- Cost; and,
- Sustainability.

In addition, each evaluation criterion (with the exception of sustainability) were given a relative screening score for each of the remedial alternatives using a 1 to 5 scaling system where a rating of 1 represents the least favorable outcome relative to the evaluation criteria and a rating of 5 represents the most favorable outcome relative to the evaluation criteria. The individual criteria screening scores were then summed for each alternative to provide an overall screening score for each alternative. The overall screening scores were used as the basis for the comparative evaluation. Finally, remedial costs for Alternatives S3 through

S6 were provided as a range, with the low cost range representing the cost for targeting treatment to the NYSDEC Commercial SCOs and the high cost range for targeting treatment to the ROD required cleanup objectives. It should be clarified that the relative screening score provided is relative to the achievement of the NYSDEC Commercial SCOs. While achievement of the current ROD required cleanup objectives has been evaluated, the evaluation is provided for comparative purposes only. A summary of the remedial alternatives comparative evaluation is provided in Table 3.

A brief description of the comparative advantages and disadvantages of each alternative relative to the evaluation criteria is provided below.

Protection of Human Health and the Environment

Alternatives S3, S5, and S6 each provide for equal protection of human health and the environment by achieving the source area remedy objectives through active treatment and through implementation of the common elements. Alternative 1 provides no protection of human health and the environment. Alternative 2 provides some protection through preventing contact with impacted soil, but does not provide any environmental benefit and leaves human health and environmental risks associated with the potential for vapor intrusion and offsite migration of contaminated groundwater.

It should also be noted that alternatives that incorporate MPE and/or SVE (e.g., Alternatives S3 and S5) could be expanded to include additional capacity for vapor mitigation of the building, if necessary. Alternative S4 does not include a vapor extraction component for remediation and/or vapor intrusion mitigation and was therefore ranked slightly lower than the other active remedial alternatives.

Assuming the common elements are implemented under each remedial alternative, there is no additional protection to human health and the environment by remediating to the ROD required SCOs.

Compliance with Regulatory Requirements

Alternatives S3, S4, S5, and S6 will meet the NYSDEC Commercial SCOs through active treatment and/or containment of the source area. Alternatives S1 and Alternative S2 provide no active remediation and therefore would not be capable of complying with regulatory requirements.

Based on the current property use, it is unlikely that all areas where the concentration of COCs are greater than the ROD required SCOs could be accessed. However, for practical purposes (e.g., without removing the existing building), thermal treatment (Alternative S6) likely provides the only technology capable of achieving the ROD required SCOs site-wide. The implementation of thermal treatment inside the building would still require the temporary relocation of building tenants and a significant disruption to current operations for a period of one to two years.

Long-Term Effectiveness and Permanence

Alternatives S4, S5, and S6 were given the highest rating because they are equally capable of achieving the source area treatment objectives and are equally reliable in the long-term. Alternative has S6 the highest probability of achieving all source area treatment objectives in the long-term. Alternative S3 received a slightly lower screening score due to the requirement to maintain above-grade mechanical equipment for the majority of the treatment area and because of the small uncertainty on the efficacy of MPE.

Alternatives 1 and 2 are not considered effective in the long term as they are not capable of achieving the source area remedy objectives.

Reduction of Toxicity, Mobility, and Volume with Treatment

Alternatives S5 and S6 were given the highest rating because they have the highest probability of removing the most contaminant mass when compared to the other alternatives. Alternative S5 (excavation with AS/MPE) ranked second highest because while anticipated to be effective, it is less aggressive than excavation with offsite disposal and thermal treatment

Alternatives 1 and 2 will not result in a reduction of toxicity, mobility, or volume of contaminant mass.

As stated previously, treatment to the ROD required objective of 0.14 mg/kg will only result in the removal of an additional 2.5 percent of the contaminant mass present at the site when compared to treatment to the 100 mg/kg treatment objective.

Short-Term Effectiveness

Alternative S5 removes a significant quantity of mass in the short-term, but poses less of a short-term health and safety risk to site workers during implementation when compared to Alternative S6. Alternatives S6 was ranked slightly lower because installation and operation of the thermal treatment infrastructure poses a higher health and safety risk to both the system operators and site workers during implementation when compared to the other treatment options. Alternatives S3 and S4 ranked equally as both technologies are capable of achieving a moderate reduction in mass in the short-term. It should be noted that the implementation of chemical reduction (Alternative S4) could result in the generation of methane which could require engineering controls (e.g., vapor mitigation) within the onsite building.

Alternatives 1 and 2 are not considered effective in the short term as they are not capable of achieving the source area remedy objectives.

Implementability

Alternatives S1 and S2 ranked highest because they require no active remedial action for implementation. Of the active remedial alternatives, Alternative S3 ranked the highest because it will result in the lowest site disruption during implementation. Further, SVE has already been demonstrated to be implementable at the site. Alternatives S4 and S5 will result in moderate site disturbance outside of the building and will require careful planning to minimize disruption to site activities and protect site workers. Alternative S6 received the lowest score because thermal treatment will require the installation of significant treatment infrastructure and a robust treatment system. Furthermore, site workers may need to be temporarily relocated due to the potential hazards associated with implementation of the technology.

Treatment to the ROD required SCOs would require a significant expansion of the targeted treatment footprint. As stated previously, the only technology that is potentially implementable and capable of achieving the ROD required SCOs is thermal treatment. However, thermal treatment would also require the temporary relocation of site occupants during implementation due to the health and safety risks associated with implementation. In summary, it seems unlikely that treatment to the ROD required SCOs is implementable at the site.

Cost

A summary of the opinion of probably costs for each alternative is provided on Table 4. Alternatives S1 and S2 are the least cost options because they require no active remedial components and minimal long-term operation and maintenance. Of the remedial alternatives, Alternative S3 (AS with MPE/SVE) represents the lowest estimated cost at $1.74MM while Alternative S6 represents the highest estimated cost at $2.92MM. All active remedial options are significantly lower in cost when compared to the 30 years present value to continue operation of offsite remedial Well 1-1A of approximately $3.5 to 4.0MM.

Treatment to the ROD required SCOs increases the opinion of probable cost by a factor of 1.8 to greater than 6 depending on the remedial alternative and would only result in the removal of approximately 2.5 percent more contaminant mass. Of the active remedial alternatives, Alternative S3 (AS with MPE/SVE) has the least cost sensitivity relative to an increase in the volume treated.

Sustainability

All alternatives evaluated have advantages and disadvantages relative to sustainability and green remediation practices. Non-remedial Alternatives S1 and S2 do not produce a remediation based carbon footprint and produce a minimal waste stream; however, they are not capable of restoring groundwater to a useable resource. Of the remedial alternatives, Alternative S4 would rank highest in sustainability because it produces the lowest remediation based carbon footprint, produces minimal waste, and is capable of restoring groundwater to a useable resource while Alternative S6 would rank lowest in sustainability because it will produce a significant carbon based footprint because of the energy demand associated with thermal treatment.

Conclusions

The following conclusions are generated from the feasibility evaluation:

- It is technically feasible to implement a source area remedial technology that is protective of human health and the environment.

- The establishment of an alternate cleanup standard for soil is warranted based upon:

    - Remediation to the ROD required SCOs provides no further protection of human health and the environment both onsite (soil and groundwater) and offsite (groundwater) when institutional controls are implemented in conjunction with an active source treatment alternative.

    - Remediation to the ROD required SCOs is not consistent with the current and/or future use of the site.

    - Remediation to the ROD required SCOs is likely technically impracticable because of the site constraints.

    - Remediation to the ROD required SCOs would only result in the removal of an additional 2.5 percent of the contaminant mass at the site but would result in a significantly larger remediation based carbon footprint and waste stream, and a cost increase of 1.8 to greater than 6 times greater when compared to alternate cleanup standards that are still capable of protecting human health and the environment.

- Based upon the groundwater velocity in the primary aquifer, cleanup downgradient would likely be achieved quickly, with discontinuation of pumping at Well 1-1A likely feasible within less than five years.

- Of the remedial alternatives, Alternative S5 (excavation with AS/MPE) had the overall highest ranking score because it provides the highest degree of mass removal (along with Alternative S6) and could likely be implemented with the proper engineering controls and construction sequencing (e.g., to maintain existing site operations and minimize the risk to health and safety). However, the feasibility of implementation would need to be confirmed with the current site operations and/or property owners.

- Alternative S3 (AS/MPE/SVE) represents the most implementable, lowest cost, remedial option likely capable of achieving protection of human health and the environment. Furthermore, Alternative S3 has the least cost sensitivity relative to treatment area and could be expanded to treat a larger treatment footprint with comparatively minimal cost (e.g., compared to the other remedial alternatives).

- The cost to remediate the site to the ROD required SCOs is significantly higher than the achievement of alternate standards (e.g., the NYSDEC Commercial SCOs) and provides minimal additional benefit to human health and the environment and minimal additional mass removal (e.g., an additional 2.5 percent removal of the total mass). Furthermore, unless the existing building can be partially demolished, or, a significant portion of the existing property can be temporarily vacated for a period of one to two years, it is technically infeasible (not implementable) to achieve the ROD required SCOs at the Site.

- The cost to implement source treatment is significantly lower than the cost to continue operating Well 1-1A for the next 30 years.

LEGEND

4009-7	Monitoring Well & Identifier
	SVE Area Boundary
Well 1-3	Former or Current Water Supply Wells

0 350 700

APPROXIMATE SCALE IN FEET

ARCADIS

Figure 1

Site Location

Vestal Water Supply Site

Vestal, NY

NYSDEC Site #7-04-009

G:\PROJECT\00266401.0000\Site Location

LEGEND

4009-7 MONITORING WELL & IDENTIFIER

0 350 700

APPROXIMATE SCALE IN FEET

ARCADIS

Figure 2

Stratigraphic Cross-Section Location

Vestal Water Supply Site

Vestal, NY

NYSDEC Site #7-04-009

G:\PROJECT\00266401.0000\Feb 2014 Plume X-Sect.pptx

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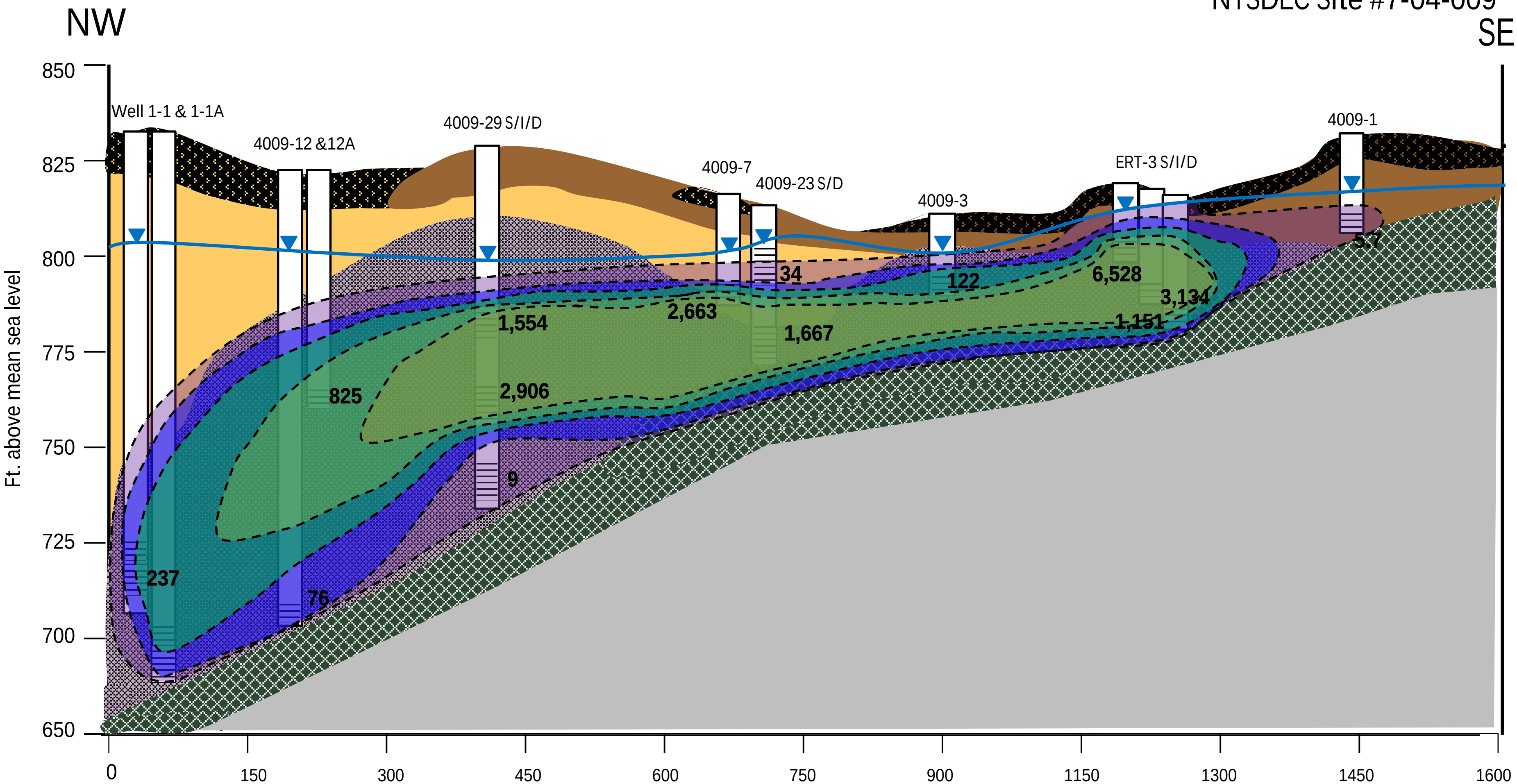
Figure 3

Stratigraphic Cross-Section
Vestal Water Supply Site
Vestal, NY
NYSDEC Site #7-04-009



LEGEND

Well Location

4009-23 S/D

Stratigraphic Units

- Fill Material
- Silt & Clay
- Sand and Silt
- Gravel and Sand
- Till
- Bedrock (Shale)

Approximate Scale in feet: 1" = 130 ft.
Vertical Exaggeration approximately 1.5X

Note:
Stratigraphic contacts estimated based on available boring data. Posted concentrations in ug/kg total VOCs.

90 0 90 Feet

Approximate Scale

LEGEND:

TCE: trichloroethene

TCA: 1,1,1-trichloroethane

TCA & TCE Concentration (mg/kg)

- <0.14
- 0.14 - 1
- 1 - 10
- 10-100
- > 100
- SVE Area Boundary

N

Notes:
Maximum Measured Concentration = 23,600 mg/kg
Clean-up level = 0.14 mg/kg
Cleanup level is based upon the ROD defined cleanup level for TCE
Average Depth = 16.5 ft.

Source: *EPA Lockheed Martin Conceptual Site Model Report*, February 6, 2012

ARCADIS Infrastructure · Water · Environment · Buildings	Vestal Water Supply NYSDEC Site #7-04-009 Vestal, New York	**Concentrations of TCE and TCA in Overburden Deposits**	**March 2015** **Figure 4**

G:\PROJECT\00266401.0000\Vestal TCA TCE Maps

Table 1
Summary of Preliminary Source Area Remedial Technology Screening Evaluation

Vestal Water Supply
(NYSDEC HW ID 704009A)
Vestal, Broome County, New York

Response Actions	Remedial Technologies	Process Options	Description	Retained: Yes or No	Decision Rationale
No Action	No action	No Action	Not applicable	Yes	Use as a baseline for comparison to other alternatives or guidance values
Environmental Easement	Instutional Controls	Deed Restrictions	Deed restrictions to limit the property use and implementation of a Site Management Plan and a Soil Management Plan.	Yes	Minimize potential for exposure to residual concentrations. May be combined with other process options.
	Engineering Controls	Access Restrictions	Place access restrictions along the property boundary (i.e., fencing and signage).	Yes	Minimize potential for exposure to residual concentrations. May be combined with other process options.
Containment	Capping	Soil, Asphalt and/or Concrete Cover	Prevent direct contact through the use of cover.	Yes	Most areas with soil concentrations greater than applicable soil cleanup objectives are covered by asphalt or concrete. May be combined with other process options.
	Barriers (Horizontal or Vertical)	Grout Injection	Pressure Inject grout at depth to provide a low permeability confining unit and prevent migration	No	Potentially applicable although there are more effective options for soil remediation.
Removal	Excavation	Excavation	Remove soil through mechanical methods.	Yes	Applicable in areas where soil concentrations greater than cleanup levels are accessible.
	Extraction	SVE	Apply a vacuum to extraction wells to enhance the VOC volatilization. Recover and treat vapor.	Yes	An SVE system was installed and operated at the source area but has reached its limit of effectiveness under its current configuration. May be combined with other technologies (e.g., air sparging, thermal treatment, MPE).
		MPE	Application of a high vacuum (typically >10 in. of hg) to extraction wells to enhance total fluids recovery. Treat and dispose of extracted fluids.	Yes	Applicable, more aggressive/effective remedial technology than SVE alone within fine-grained matrix and when there are non-aqueous phase liquids. May also be combined with other technologies such as thermal remediation.
Disposal	Disposal/Reuse	On-site	Disposal or reuse of soil on-site that is below regulatory criteria.	Yes	Applicable for soils that are excavated but below cleanup criteria.
		Off-site	Disposal of soil or remediation process residuals off-site.	Yes	Applicable for soils that are above cleanup criteria. Dispoal location and treatment dependant on waste profiling and current waste disposal facility capacity.
In-Situ Treatment	Physical	Cosolvent/Surfactant Flushing	Flush soil with a cosolvent or surfactant solution to promote the desorption and solubilization of hydrophobic contaminants.	No	Minimal effectiveness because of the need to have direct contact with the contaminant mass and large area with soil greater than cleanup levels.
		Aquifer Sparging	Strip VOCs using air injection wells.	Yes	Effective at treating saturated zone soil and groundwater containing chlorinated ethenes in higher permeability soils. May not be implementable where low permeability soils exist that would prevent contact with air or the collection of vapors through SVE and/or MPE.
		Thermal Treatment	Heat the subsurface to promote the volatilization and/or direct destruction of contaminants in-situ. Requires treatment of extracted water vapor and soil gas.	Yes	Effective for chlorinated VOCs and many other recalcitrant compounds. Requires collection and treatment of volatilized VOCs
	Chemical	Oxidation	Mixing of an oxidizing agent to oxidize contaminants.	Yes	Effective, but implementation in the vadose zone requires in-situ mixing with augers or other mechanical equipment. May be combined with stabilization/solidification. Generally considered less effective for sites with DNAPL when compared to enhanced bioremediation.
		Chemical Reduction	Mixing of a treatment reagent (typically zero-velent iron plus a labile carbon source) to promote both abiotic reductive dechlorination.	Yes	Effective, but implementation in the vadose zone requires in-situ mixing with augers or other mechanical equipment. May be combined with stabilization/solidification and/or in-situ enhanced bioremediation.
		Stabilization/ Solidification	Treatment/Fixation of soil and contaminants by mixing.	Yes	Not effective alone for VOCs, but effective for VOCs when mixed with a treatment reagent such as zero-valent iron or an oxidant.
	Biological	In-Situ Enhanced Bioremediation	Mixing of a treatment reagent (typically a carbon source) to promote biotic reductive dechlorination.	No	Effective in the saturated zone, but difficult to distribute carbon source effectively in the vadose zone to maintain the anaerobic conditions required for reductive dechlorination.
		Bio-venting	Add oxygen to vadose zone to stimulate aerobic microorganisms for the catabolization of contaminants.	No	Some chlorinated ethenes (e.g., PCE, TCE, 1,1,1-TCA) do not have a viable aerobic pathway to ethane and ethene.
Ex-Situ Treatment	Physical	Soil Washing	Move high quantities of liquids through soil to desorb contaminants.	No	Typically retained for contaminants such as PCBs and metals that adhere to find grained matrix. Likely not cost or technically effective for VOCs.
		Low-Temperature Thermal Treatment	Heat soil using a conveyor and burner system to promote the volatilization of VOCs and some SVOCs. Heat of hydration (e.g., quicklime) can also promote volatilization.	Yes	Effective at treating many compounds. Requires excavation of contaminated soil and collection and treatment of VOCs.
		On-site Incineration	Heat soil using a conveyor and burner system to thermally oxidize VOCs.	No	Although effective for on-site soil treatment for VOCs, the cost per unit volume of treated soil would make incineration infeasible.
	Chemical	Oxidation	Oxidize contaminants in ex-situ soil piles using a variety of commercially available oxidation processes.	Yes	Effective at treating chlorinated ethenes. Requires on-site above grade mixing and treatment.
	Biological	Land Farming	Stockpile and till soils to promote aerobic biodegradation.	No	Not effective for contaminants that degrade under anaerobic conditions (e.g., chlorinated solvents) or metals.

Notes:

MPE	Multi-Phase Extraction
VOCs	Volatile Organic Compounds
SVOCs	Semi-Volatile Organic Compounds
SVE	Soil Vapor Extraction

Table 2
Summary of Detailed Remedial Technology Screening Evaluation For Source Area

Vestal Water Supply (NYSDEC HW ID 704009A) Vestal, Broome County, New York

Remedial Technologies	Process Options	Effectiveness Evaluation		Implementability Evaluation		Relative Cost Evaluation		Retained?	
No Action	No Action	Low	No effect on soil concentrations. Effectiveness is limited to the naturally occurring processes.	High	Easily implemented.	Low	No additional costs.	Yes	Use as a baseline for comparison to other alternatives.
Institutional Controls	Deed Restrictions	Moderate	No effect on soil concentrations. Maintaining the Site Management Plan will reduce potential exposure to residual concentrations.	High	Easily implemented.	Low	Negligible costs.	Yes	Will be used for the management of residual contamination under all scenarios.
Engineering Controls	Access Restrictions	Moderate	Limiting site access and maintaining the Site Management Plan will reduce potential for exposure to residual concentrations.	High	Easily implemented.	Low	Negligible costs.	Yes	Considered in conjunction with other process options
Capping	Soil, Asphalt and/or Concrete Cover	Low	Prevents direct exposure and stormwater infiltration but does not result in a reduction in mass.	High	Easily implemented.	Low	Relatively low capital cost and O&M cost. Most of the soil contamination is already beneath existing cover material.	Yes	Considered in conjunction with other process options. Will provide protection from direct exposure for residual contamination and/or in areas that are not accessible.
Removal	Excavation	High	Effective for mass removal in areas where soil is contributing to groundwater concentrations.	Moderate	Could be implemented in the parking areas but not inside the building due to the current occupancy/site operations. Would require trench boxes and structure shoring to be implemented safely and in parallel with existing site operations.	Moderate to High	Typically a higher capital cost then comparable removal or in-situ process options.	Yes	Highly effective at the removal of mass through physical excavation/removal and disposal offsite. Considered in conjunction with other process options.
	SVE	Low	Demonstrated not to be effective at treating the source area alone through operation of existing system. However, is effective at mass removal where the geology is conducive for treatment through SVE	High	SVE system already nstalled.	Moderate	Moderate cost for installation of SVE wells, conveyance piping and blower(s). Moderate O&M cost.	Yes	May be used in conjunction with other process options such as MPE and/or aquifer sparging for groundwater
	MPE	Moderate to High	Existing geology appears conducive for MPE within the shallow and intermediate silty sand sequences. Effectiveness would need to be refined through pilot testing.	Moderate to High	Similar infrastructure as SVE technology which has already been implemented at the site.	Moderate	Low to moderate capital cost to install MPE wells. Moderate O&M cost.	Yes	Potentially effective for source treatment alone and/or as a supplement to another process option such as aquifer sparging for groundwater.
Disposal	Disposal Off-Site	High	Proven effective for the management of excavated soils containing VOCs at thousands of remediation sites across the United States.	Moderate to High	Used in conjunction with excavation. Requires coordination and acceptance of material at an off-site location.	Moderate to High	Cost dependent on the classification of the soil for disposal.	Yes	To be used as the soil management methodology for excavated soils above applicable reuse standards.
	Reuse On-Site	High	Applicable soil will be below applicable regulatory criteria and will be suitable for reuse as fill material.	High	Used in conjunction with excavation. Requires confirmation sampling to confirm soil quality meets the reuse criteria.	Low	No treatment required. Soil will meet applicable reuse criteria.	Yes	To be used as the soil management methodology for excavated soils below applicable reuse standards.
In-Situ Physical Treatment	Aquifer Sparging	Moderate	Effectiveness dependant on achieving contact of air with VOCs. Effective at treating VOCs in permeable soils. Would be effective within the sand and gravel layers at the site but not within silts. Capable of enhancing DNAPL treatment through volatilization.	Moderate to High	Generally implementable within the permeable layers at the site. Can be installed within the existing building with specialized/small drill rigs.	Moderate	Moderate capital cost for installation of aquifer sparge and SVE wells and treatment equipment. Moderate O&M costs.	Yes	Technology would be implementable within the sand and gravel layers at the site within the source area. Would require pilot testing.
	Thermal Treatment	High	Effective at treating DNAPL and VOC source areas in similar geologies.	Moderate	Implementation would require the installation of electrodes or heater wells. Could be implemented in the parking areas but not inside the building due to the current occupancy/site operations.	High	High capital cost for installation of infrastructure and off-gas treatment.	Yes	Retained for comparison to more cost effective technologies. Highly effective for the treatment of VOCs, however, would likely not be implementable beneath the exisitng building due to site occupancy. Significant capital cost when compared to other technologies.
In-Situ Chemical Treatment	Oxidation	Moderate	Effective at oxidizing chlorinated solvents and other VOCs. Effectiveness is limited by the ability to achieve full contact with the VOCs.	Moderate	Implementable, but would require the use of deep soil mixing to effectively distribute reagents and provide sufficient contact with VOCs. Would not be implementable inside the building due to the current occupancy/site operations.	High	High chemical costs. Would likely require multiple applications of oxidant to be effective at source treatment.	No	Would not be implementable beneath the exisitng building. Less effective for DNAPL source areas when compared to other technologies that require deep soil mixing such as chemical reduction with stabilization.
	Chemical Reduction	Moderate to High	Effective at degrading chlorinated solvents through reductive dechlorination. Effectiveness is limited by the ability to achieve full contact with the VOCs.	Moderate	Implementable, but would require the use of deep soil mixing to effectively distribute reagents in vadose zone to provide sufficient contact with VOCs. Would require installation via direct-push injection equipment for saturated zone soils inside the building.	Moderate to High	High capital cost for in-situ mixing and initial chemical dosing. However, a single application would likely be sufficient if used in conjunction with stabilization/solidification.	Yes	Would be effective for the treatment of VOCs if combined with stabilization/solidiification and deep soil mixing. Would have moderate effectiveness for treatment of saturated zone soils within the building through direct-push injection.
	Stabilization/Solidification	Moderate	Not effective alone for the treatment of VOCs; however, effective when combined with a treatment amendment such as zero-valent iron.	Moderate	Implementable, but would require the use of deep soil mixing to effectively distribute reagents and provide sufficient contact with VOCs. Would not be implementable inside the building due to the current occupancy/site operations.	Moderate	Moderate capital cost for in-situ mixing of reagents. Cost increases to moderate to high if additional chemicals are added to provide treatment of the VOCs.	Yes	Would be effective for the treatment of VOCs if amended with a treatment reagent such as zero-valent iron.
Ex-Situ Physical Treatment	Low-Temperature Thermal Treatment	High	Effective at treating VOCs.	Low	Requires significant space for the handling and treatment of excavated soils which is not available on-site due to the active operating facility.	Moderate	Moderate capital cost for mobilization and installation of treatment infrastructure and off-gas treatment.	No	Not implementable in a safe manner due to the existing site operations.
Ex-Situ Chemical Treatment	Oxidation	Moderate to High	Effective at oxidizing chlorinated solvents and other VOCs. Effectiveness is limited by the ability to achieve full contact with the VOCs.	Low	Requires significant space for the handling and treatment of excavated soils which is not available on-site due to the active operating facility.	Moderate	High capital cost for soil excavation, treatment, and backfill. Not all of the material would be used as backfill and disposal would be required.	No	Not implementable in a safe manner due to the existing site operations.

Notes:

MNA	Monitored Natural Attenuation
MPE	Multi-Phase Extraction
VOCs	Volatile Organic Compounds
SVE	Soil Vapor Extraction
O&M	Operations & Maintenance
SSDS	Sub-Slab Depressurization System

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Table 3. Detailed and Comparative Evaluation of Remedial Alternatives for Source Area Remediation, Vestal Water Supply Site, Vestal, New York. (1)

Remedial Alternative	Protection of Human Health and the Environment	Compliance with Regulatory Requirements	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility and Volume	Short-Term Effectiveness	Implementability	Cost	Sustainability/Green Remediation Practices
	Threshold Criteria		Balancing Criteria					
Alternative S1 – No Action								
No action. Baseline alternative for comparison to other alternatives.	Does not provide protection of human health and the environment. Inhalation and ingestion risks remain through vapor intrusion, direct contact with impacted soil, and the consumption of contaminated groundwater. Contamination will continue to migrate offsite and will eventually contaminate public supply wells and the Susquehanna River.	Does not achieve regulatory limits in groundwater and soil.	Does not achieve regulatory limits for soil or groundwater over the long-term; however, remedy is easily maintained since no action is required.	No reduction in toxicity, mobility, and volume of soil or groundwater contamination.	Does not achieve regulatory limits or a reduction of mass for soil or groundwater within a reasonable timeframe. Not protective of human health, the environment, and workers in the short-term.	Easily implemented, no action required.	No cost.	Will not generate a remediation based carbon footprint or waste stream. Does not restore groundwater to a useable resource.
Screening Score: 16 (Overall)	Screening Score: 1 (Low)	Screening Score: 1 (Low)	Screening Score: 2 (Low to Moderate)	Screening Score: 1 (Low)	Screening Score: 1 (Low to Moderate)	Screening Score: 5 (High)	Screening Score: 5 (High)	Not included in screening score
Alternative S2 – No Active Remediation								
Implementation of common elements only including deed restrictions and access restrictions (through the filing of an environmental easement and preparation of a Site Management Plan), and engineering controls through maintenance of the existing site cover material.	Provides for some protection of human health through implementation of the common elements which prevent direct contact with contamination and provide a mechanism to enforce long-term maintenance of protective systems; however, vapor intrusion risk remains as well as offsite migration of groundwater contamination. Does not provide additional protection of the environment.	Does not achieve regulatory limits in groundwater and soil.	Does not achieve regulatory limits for soil or groundwater over the long-term. Provides some protection of human health in the long-term but would require continued operation of the offsite groundwater containment system. Not protective of the environment. Remedy is reliable and easily maintained.	No reduction in toxicity, mobility, and volume of soil or groundwater contamination.	Does not achieve regulatory limits or a reduction of mass for soil or groundwater within a reasonable timeframe. Provides for some protection of human health through implementation of the common elements which prevent direct contact with contamination and provide a mechanism to enforce long-term maintenance of protective systems; however, vapor intrusion risk remains as well as offsite migration of groundwater contamination.	Easily implemented, monitoring is currently being conducted and administrative tools (e.g., institutional and engineering controls) are generally implementable.	Minimal cost associated with implementation of the institutional and engineering controls. Requires long-term implementation of the SMP. Second lowest cost of all alternatives = $270,000.	Will not generate a remediation based carbon footprint or waste stream. Does not restore groundwater to a useable resource.
Screening Score: 18 (Overall)	Screening Score: 2 (Moderate)	Screening Score: 1 (Low)	Screening Score: 3 (Moderate)	Screening Score: 1 (Low)	Screening Score: 2 (Low to Moderate)	Screening Score: 5 (High)	Screening Score: 4 (Moderate to High)	Not included in screening score

Notes:

1. Common elements to all alternatives include deed restrictions and access restrictions (through the filing of an environmental easement and preparation of a Site Management Plan), and engineering controls through maintenance of the existing site cover material.

2. Screening scores based on a 1 to 5 numerical scoring system where 1 represents the least favorable outcome and 5 represents the most favorable outcome for the referenced evaluation criteria.

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Table 3. Detailed and Comparative Evaluation of Remedial Alternatives for Source Area Remediation, Vestal Water Supply Site, Vestal, New York. (1)

Remedial Alternative	Protection of Human Health and the Environment	Compliance with Regulatory Requirements	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility and Volume	Short-Term Effectiveness	Implementability	Cost	Sustainability/Green Remediation Practices
	Threshold Criteria		Balancing Criteria					
Alternative S3 – Multi-Phase Extraction (MPE) and/or Soil Vapor Extraction (SVE) Combined with Aquifer Sparging (AS)								
MPE and/or SVE for the remediation of modern alluvium deposits combined with AS for the treatment of glaciofluvial deposits within the primary aquifer, plus implementation of the common elements (see note 1).	Provides soil remediation of the modern alluvium deposits through MPE and/or SVE. Provides saturated zone treatment of glaciofluvial deposits through AS. Prevents offsite migration of contaminated groundwater. Will provide some mitigation of the vapor intrusion pathway through MPE/SVE. Common elements prevent direct contact with contamination and provide a mechanism to enforce long-term operation of systems.	Likely capable of achieving NYSDEC Commercial Use SCOs but not the current ROD required soil standards. Any residual risks and/or mass are controlled by common elements. Furthermore, achievement of the NYSDEC Commercial Use SCOs in soil should result in acceptable groundwater concentrations at offsite supply wells.	Likely capable of achieving NYSDEC Commercial Use SCOs but not the current ROD required soil standards. Protective of human health and the environment in the long-term. Remedy is reliable and easily maintained but requires more operation and maintenance when compared to the other remedial alternatives.	Moderate reduction in toxicity, mobility, and volume of mass. Effectiveness and percent reduction dependent on ability of MPE and/or SVE to access mass within the alluvium deposits.	Capable of achieving a moderate reduction of mass in the short-term. High likelihood that NYSDEC Commercial Use SCOs can be reached in the short-term but not the ROD required standards. Protective of site workers through the partial elimination of the vapor intrusion pathway and implementation of the common elements. Effectiveness of MPE and SVE would require confirmation through pilot testing.	AS, MPE/SVE, and the common elements are easily implemented when targeting the NYSDEC Commercial Use SCOs. Targeting the footprint of the ROD required soil standards would require the installation of significant infrastructure within the existing building and building access would have to be negotiated. The effectiveness of MPE would require confirmation through pilot testing.	Total present worth opinion of probable cost range = $1,740,000 (100 mg/kg) to $3,100,000 (0.14 mg/kg). Third lowest cost when compared to the other alternatives and the lowest cost of the active remedial alternatives.	Continuous operation of the AS/MPE treatment system will generate a remediation based carbon footprint Capable of restoring groundwater to a useable resource. Generation of a continuous waste stream required for the management of off-gas treatment media (assuming treatment with activated carbon).
Screening Score: 24 (Overall)	Screening Score: 4 (Moderate to High)	Screening Score: 4 (Moderate to High)	Screening Score: 3 (Moderate)	Screening Score: 3 (Moderate)	Screening Score: 3 (Moderate)	Screening Score: 4 (Moderate to High)	Screening Score: 3 (Moderate)	Not included in screening score
Alternative S4 – In-Situ Soil Stabilization with Chemical Reduction								
In-situ treatment using stabilization with chemical reduction through deep soil mixing for accessible soils located outside of the building and chemical reduction for soils located inside of the building using direct-push injections, plus implementation of common elements (see note 1).	Will provide some level of vapor intrusion mitigation through treatment but may generate methane resulting in a separate vapor intrusion risk. Provides long-term soil remediation through chemical reduction. Prevents offsite migration of contaminated groundwater through stabilization and chemical reduction. Common elements prevent direct contact with contamination.	Likely capable of achieving NYSDEC Commercial Use SCOs inside of building but not the current ROD required soil standards. Likely capable of achieving ROD required soil standards outside of building over the long-term. Would eventually result in acceptable concentrations at offsite supply wells.	Likely capable of achieving NYSDEC Commercial Use SCOs inside of building but not the current ROD required soil standards. Likely capable of achieving ROD required soil standards outside of building in the long-term. Protective of human health and the environment in the long-term. Remedy is reliable and requires minimal maintenance.	Significant reduction in mobility of mass and moderate to high reduction in toxicity and volume through chemical reduction. mobility, and volume of mass. Will be more effective at areas located outside of the building; however, these areas represent the highest percentage of contaminant mass.	Capable of achieving a significant reduction in the mobility of mass in the short-term. See previous discussion on achievement of regulatory limits. Will generate dissolved methane which may require vapor mitigation beneath existing building for the protection of workers.	Will result in moderate site disturbance during the implementation of stabilization with chemical reduction. Targeting the ROD required soil standards would require a significant quantity of direct-push injection points inside of the existing building and building access would have to be negotiated.	Total present worth opinion of probable cost range = $1,930,500 (100 mg/kg) to $6,600,000 (0.14 mg/kg). Fourth lowest cost when compared to the other alternatives and the second lowest cost of the active remedial alternatives.	Some waste generation during construction (bulking of mixed soil and construction debris) Capable of restoring groundwater to a useable resource. Moderate short-term fuel and energy consumption during construction. Minimal long-term waste generation.
Screening Score: 23 (Overall)	Screening Score: 3 (Moderate)	Screening Score: 4 (Moderate to High)	Screening Score: 4 (Moderate to High)	Screening Score: 3 (Moderate)	Screening Score: 3 (Moderate)	Screening Score: 3 (Moderate)	Screening Score: 3 (Moderate)	Not included in screening score

Notes:

1. Common elements to all alternatives include deed restrictions and access restrictions (through the filing of an environmental easement and preparation of a Site Management Plan), and engineering controls through maintenance of the existing site cover material.

2. Screening scores based on a 1 to 5 numerical scoring system where 1 represents the least favorable outcome and 5 represents the most favorable outcome for the referenced evaluation criteria.

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Table 3. Detailed and Comparative Evaluation of Remedial Alternatives for Source Area Remediation, Vestal Water Supply Site, Vestal, New York. (1)

Remedial Alternative	Protection of Human Health and the Environment	Compliance with Regulatory Requirements	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility and Volume	Short-Term Effectiveness	Implementability	Cost	Sustainability/Green Remediation Practices
	Threshold Criteria		**Balancing Criteria**					
Alternative S5 – Excavation with Off-Site Disposal with AS and MPE								
Excavation with off-site disposal for soils located outside of the building to approximately 20 ft bls (e.g., until the glaciofluvial deposits are encountered) and AS/MPE for soils and inside of the building, plus implementation of the common elements (see note 1).	Provides soil remediation of the building interior through AS/MPE. Provides soil treatment through removal for locations outside of the building. Will provide some mitigation of the vapor intrusion pathway through MPE. Prevents offsite migration of contaminated groundwater. Common elements prevent direct contact with residual contamination and provide a mechanism to enforce long-term operation of systems.	Likely capable of achieving NYSDEC Commercial Use SCOs inside of building but not the current ROD required soil standards. Capable of achieving ROD required soil standards outside of building within the targeted footprint. Would eventually result in acceptable concentrations at offsite supply wells.	Likely capable of achieving NYSDEC Commercial Use SCOs inside of building but not the ROD required soil standards. Capable of achieving ROD required soil standards outside of the building within the targeted footprint. Protective of human health and the environment in the long-term. Remedy is reliable and easily maintained but requires annual maintenance.	Significant reduction in toxicity, mobility, and volume of mass through physical removal. Will be more effective at areas located outside of the building; however, these areas represent the highest percentage of contaminant mass.	Capable of achieving a significant reduction in the toxicity, mobility, and volume of mass in the short-term. See previous discussion on achievement of regulatory limits. Protective of site workers through the partial elimination of the vapor intrusion pathway and implementation of the common elements.	Will result in moderate site disturbance during the implementation of the excavation work. Targeting the footprint of the ROD required soil standards would require the installation of significant infrastructure within the existing building and building access would have to be negotiated. The effectiveness of MPE would require confirmation through pilot testing.	Total present worth opinion of probable cost range = $2,227,000 (100 mg/kg) to $5,900,000 (0.14 mg/kg). Fifth lowest cost when compared to the other alternatives and the second highest cost of the active remedial alternatives.	Continuous operation of the AS/MPE treatment system will generate a remediation based carbon footprint. Significant waste generation during construction (offsite disposal of soil). Capable of restoring groundwater to a useable resource. Moderate short-term fuel and energy consumption during construction.
Screening Score: 26 (Overall)	Screening Score: 4 (Moderate to High)	Screening Score: 4 (Moderate to High)	Screening Score: 4 (Moderate to High)	Screening Score: 4 (Moderate to High)	Screening Score: 5 (High)	Screening Score: 3 (Moderate)	Screening Score: 2 (Low to Moderate)	Not included in screening score
Alternative S6 – Thermal Treatment								
In-situ thermal treatment using Electrical Resistance Heating to approximately 20 ft bls (until the glaciofluvial deposits are encountered) for soils located outside of the building and AS/MPE for soils inside of the building plus implementation of the common elements (see note 1).	Provides soil remediation of the modern alluvium soils through electrical resistance heating and remediation of the glaciofluvial deposits through SEE. Prevents offsite migration of contaminated groundwater. Provides some mitigation of vapor intrusion through soil treatment. Common elements prevent direct contact with contamination.	Capable of achieving ROD required soil standards inside and outside of building within the targeted footprint. Would eventually result in acceptable concentrations at offsite supply wells.	Capable of achieving ROD required soil standards inside and outside of building within the targeted footprint. Protective of human health and the environment in the long-term. Remedy is reliable and requires minimal long-term maintenance.	Significant reduction in toxicity, mobility, and volume of mass through treatment. Equally effective at areas located inside the building and outside of the building.	Capable of achieving a significant reduction of mass in the short-term. High likelihood that regulatory limits can be reached in the short-term. Protective of site workers through the partial elimination of the vapor intrusion pathway and implementation of the common elements.	Will result in significant site disturbance during the implementation of the work. Interior building work will require temporary relocation of operations to maintain the H&S of site workers therefore building access would have to be negotiated. Will require significant infrastructure and temporary treatment systems.	Total present worth opinion of probable cost range = $2,921,000 (100 mg/kg) to $7,000,000 (0.14 mg/kg). Sixth lowest cost when compared to the other alternatives and the highest cost of the active remedial alternatives.	Significant energy demand during operation compared to other technologies. Off-gas treatment will produce hazardous waste (activated carbon) or will generate a significant carbon footprint (thermal oxidation). Capable of restoring groundwater to a useable resource.
Screening Score: 24 (Overall)	Screening Score: 4 (Moderate to High)	Screening Score: 4 (Moderate to High)	Screening Score: 4 (Moderate to High)	Screening Score: 4 (Moderate to High)	Screening Score: 5 (High)	Screening Score: 2 (Low to Moderate)	Screening Score: 1 (Low)	Not included in screening score

Notes:

1. Common elements to all alternatives include deed restrictions and access restrictions (through the filing of an environmental easement and preparation of a Site Management Plan), and engineering controls through maintenance of the existing site cover material.

2. Screening scores based on a 1 to 5 numerical scoring system where 1 represents the least favorable outcome and 5 represents the most favorable outcome for the referenced evaluation criteria.

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Table 4. Summary of Remedial Alternative Costs for Source Area Treatment, Vestal Water Supply Site, Vestal, New York.

Remedial Alternative	Capital Cost ($)	Year 1 Annual O&M Cost ($)	Present Worth O&M Cost ($)	Assumed Duration of Active Treatment (Years)	Cost to Reach ~100 mg/kg	Cost to reach ~0.14 mg/kg
S2	$114,000	$9,000	$156,000	30	$270,000	$270,000
S3	$910,000	$153,000	$830,000	5	$1,740,000	$3,100,000
S4	$1,500,000	$16,000	$430,500	1	$1,930,500	$6,600,000
S5	$1,700,000	$66,000	$527,000	2	$2,227,000	$5,900,000
S6	$2,400,000	$251,000	$521,000	2	$2,921,000	$7,000,000

Estimated Cost for Continued Operation of Well 1-1A (30 Years Present Worth) = $3,500,000 to $4,000,000

Alternative Descriptions

- S2 Implementation of the common elements only (e.g., institutional/engineering controls and site management activities).
- S3 Aquifer sparging with multiphase extraction and/or soil vapor extraction.
- S4 In-situ stabilization with chemical reduction outside the building and chemical reduction via direct-push inside the building.
- S5 Excavation with offsite disposal outside of the building and aquifer sparging with multiphase extraction inside the building.
- S6 Thermal treatment using electrical resistance heating and steam enhanced extraction (steam enhanced extraction required for 0.14 mg/kg costing only).

Notes:

1. Costs are estimated to treatment of the 100 mg/kg iso-concentration line for either TCE or 1,1,1-TCA.
2. Year 1 annual O&M cost for Alternatives S3 through S6 excludes common elements.
3. Present worth O&M costs assume a discount factor of 5 percent and include the cost for the common elements.
4. Assumed duration of active treatment is the estimated time to achieve the alternate cleanup objective of 100 mg/kg.
5. Total cost includes the remedial capital and present worth O&M costs plus the common elements for treatment to the alternative cleanup objective of 100 mg/kg.
6. Total cost to 0.14 mg/kg includes the estimated capital and present worth O&M cost to achieved the ROD SCO or 0.14 mg/kg.
7. Estimated cost for continued operation of Well 1-1A from the Draft Focused Feasibility Study for Groundwater (ARCADIS 2015) and shown for comparative purposes only.