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LETTER REGARDING SCREENING AND SELECTION OF REMEDIAL TECHNOLOGY ALTERNATIVES AT OPERABLE UNIT 4 NTC ORLANDO FL

11/16/1998

HARDING LAWSON ASSOCIATES

November 16, 1998

Commanding Officer
Southern Division
Naval Facilities Engineering Command
2155 Eagle Drive
North Charleston, SC 29406

ATTN: **Ms. Barbara Nwokike, Code 187300**

SUBJECT: **Screening and Selection of Remedial Technologies**
Operable Unit (OU) 4
Naval Training Center (NTC), Orlando, Florida
Contract No. N62467-89-D-0317/CTO 135

Dear Barbara:

At the September Orlando Partnering Team (OPT) meeting in Orlando, Harding Lawson Associates (HLA) presented a preliminary list of potential remedial technologies for OU 4. These technologies have been further evaluated as part of the alternative selection process for the OU 4 feasibility study (FS). This letter is to provide you with the details of the FS process completed to date, including selection of remedial action objectives (RAOs) and screening of the available technologies for development into remedial alternatives. We are currently beginning the detailed analysis of these alternatives.

Contaminants of Concern at OU 4

The primary contaminant of concern (COC) at OU 4 is tetrachloroethene (PCE), a chlorinated solvent that was used extensively in the dry-cleaning operations at Building 1100. PCE is present in groundwater at concentrations that exceed drinking water standards (MCLs). Trichloroethene and cis-dichloroethene are two principal degradation byproducts of PCE, and are both also present in groundwater above MCLs. The contaminant plume has migrated into Lake Druid at concentrations that exceed Florida's Surface Water Standards.

The PCE source area is concentrated in the vicinity of the laundry building (Building 1100), and is believed to be approximately 250 feet long, 50 feet wide, and 40 feet deep.

Antimony is also a COC in OU 4 groundwater. Antimony has been detected above MCLs in the southeastern portion of OU 4. The plume is 200 to 300 feet in diameter, and appears to be stationary.

Some COCs have also been detected in OU 4 surface soil, including PAHs, PCBs, and arsenic. These contaminants have been detected in three discrete areas, and as discussed at the September OPT meeting, contaminated soil will be removed from these areas by the Charleston Shipyard Detachment. Therefore, no remedial technologies for OU 4 surface soil will be evaluated in the FS.

There are two Remedial Action Objectives (RAOs) for OU 4: (1) reduce the potential for human ingestion of groundwater containing COC concentrations that exceed drinking water standards or risk-based acceptable exposure levels, and (2) control migration of VOC concentrations in groundwater that contribute to exceedances of Florida surface water standards in Lake Druid.

Potential Remedial Technologies for OU 4

The following technologies have been selected for detailed evaluation in the OU 4 FS. The rationale for technology selection and/or elimination is included in the attachment:

In-Situ Technologies

- Air Sparging
- Chemical Oxidation (potassium permanganate)
- Natural Attenuation
- Enhanced Biodegradation
- Recirculation Wells
- *In-Situ* Fixation (antimony only)

Ex-Situ Technologies

All of the following technologies assume groundwater extraction via vertical extraction wells:

- Air Stripping
- Chemical Oxidation (UV light with hydrogen peroxide)
- Direct Discharge to the Orlando STP (antimony only)
- Ion Exchange (antimony only)
- Metals Precipitation (antimony only)
- Electrochemical (antimony only)

The two of the last three *ex-situ* antimony technologies are expected to be screened down to one for detailed evaluation.

Two technologies in particular may be conspicuous by their absence. Reactive walls were eliminated from consideration because this technology would not be suited to source area remediation. A reactive wall would be placed downgradient of the source area, and therefore would duplicate the function of the existing recirculation well system. Given the planned transfer of OU 4 to the city of Orlando, technologies that would leave the source in place (also including containment technologies such as slurry walls or sheet piling) are not practical. Leaving the source area untreated would also likely be unacceptable to the regulators.

Phytoremediation has also been eliminated from consideration. Although currently being studied by USEPA and the University of Georgia (UG), phytoremediation is not likely to be practical as a primary remedial technology for OU 4. The collection and treatment trench proposed by USEPA would require considerable site disruption, and would face several regulatory challenges. The USEPA/UG studies are also not likely to be complete within the time frame required for OU 4 remediation. At this time, we believe phytoremediation is best suited as a polishing step for treatment of VOCs that may reach Lake Druid.

HLA welcomes your input regarding this selection of remedial technologies for OU 4. We will be discussing these choices and the selection of remedial alternatives at the November OPT meeting in Orlando. If you have any questions or comments regarding this letter, please call me at (781) 245 - 6606.

Very Truly Yours,

HARDING LAWSON ASSOCIATES

Mark J. Salvetti

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Task Order Manager

Attachments

cc: W. Hansel (SDIV)
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TABLE A-1
PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES

OU 4 - NAVAL TRAINING CENTER, ORLANDO FLORIDA

General Response Actions[1]	Remedial Technology Types	Preliminary Screening	Comments
No Action	No Action (continue IRA)	Retained	· Provides a baseline for comparison with other remedial actions.
Limited Action	Deed Restrictions with Monitoring	Retained	· Restrictions on use of groundwater for drinking water could be enforced.
	Use Limitations Lake Druid	Eliminated	· Too difficult to enforce
Containment	Hydraulic Barrier	Eliminated	· Source area extraction/treatment (in lieu of groundwater extraction for containment) would be more effective at similar cost.
	Slurry Wall	Eliminated	· Could adversely affect groundwater flow patterns at the site. Effectiveness is questionable due to vertical gradients and high hydraulic conductivity. IRA already provides containment.
	Sheet pile with cap	Eliminated	· Same issues as with slurry wall.
Extraction	Vertical Wells	Retained	· Pumping test at OU 4 reveals that vertical recovery wells can provide good horizontal and vertical connection through the surficial aquifer.
	Horizontal Wells	Eliminated	· Typically more expensive for deep aquifers and more beneficial in low permeable soils. Pumping tests at OU 4 reveal that vertical wells can provide sufficient hydraulic connection in the aquifer.
	Collection Trench	Eliminated	· Compared with vertical wells, trenches would be more costly to install at the OU 4 source area (in Building 1100) for little improved efficiency.
	Surfactant Flushing	Eliminated	· Intended to promote accelerated flushing of saturated soils. Could exacerbate contaminant migration and overtax capabilities of downgradient remedial actions.
Treatment, In-situ[2]	Air Sparging with Vapor Collection	Retained	· OU 4 pilot test revealed that a cemented sand layer 20 feet bls prevented injected air from migrating to the surface. OU 4 is amenable to air sparging, if the cemented sand layer can be penetrated to remove injected air.
	Chemical Oxidation	Retained	· This technology is appropriate given the presence of DNAPL and highly permeable site soils at OU 4. Pilot testing is required to assess the effectiveness.

TABLE A-1
PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES

OU 4 - NAVAL TRAINING CENTER, ORLANDO FLORIDA

Treatment, In-situ[2] (Cont'd)	Natural Attenuation	Retained	· Evidence of naturally occurring biodegradation exists at OU 4. However, concentrations of VOCs in Lake Druid indicate that degradation is neither complete nor rapid enough without implementing additional remedial measures.
	Enhanced Biodegradation	Retained	· Natural biodegradation (reductive dechlorination) is already occurring at OU4 which is indicative that enhanced biodegradation could be potentially effective.
	Phytoremediation	Eliminated	· To date, USGS investigations conclude that phytoremediation cannot stop COCs from migrating to Lake Druid. Construction of a drainage ditch could redirect flow through aquatic plants to remediate some but not all the discharge. Phytoremediation may be applicable as a polishing step at the lake perimeter if used with other technologies. However, a waiver from meeting surface water standards in this remedial zone in Lake Druid would be required. USEPA and the University of Georgia are currently studying phytoremediation at OU 4.
	Steam Stripping	Eliminated	· Not cost effective compared with conventional air sparging because site soils are relatively permeable and contaminants are readily strippable without introduction of heat.
	Recirculation/In-well Stripping	Retained	· This technology has already been implemented at OU 4 as an IRA to control migration of VOCs to Lake Druid.
	Permeable Reactive Wall	Eliminated	· Cannot be used to treat the source area. Would only duplicate the containment action that is already being performed by the existing IRA.
	In-situ Fixation (Inorganic Treatment)	Retained	· Potentially applicable for preventing migration of the antimony plume.
Treatment, Ex-Situ[3]	Air Stripping and Aeration	Retained	· The organic COCs at OU 4 are readily strippable.
	Organic Adsorption	Eliminated	· In comparison with other available technologies, organic adsorption (granular activated carbon) is not cost effective for primary treatment of VOC concentrations present at OU 4.
	Chemical Oxidation (UV/OX with hydrogen peroxide)	Retained	· UV/OX with hydrogen peroxide is applicable for destruction of the organic COCs identified at OU 4.

TABLE A-1
PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES

OU 4 - NAVAL TRAINING CENTER, ORLANDO FLORIDA

Treatment, Ex-Situ[3] (Cont'd)	Biological	Eliminated	· In comparison with other available technologies, an on-site system would not be cost effective for primary treatment of the VOC concentrations present at OU 4. Discharge to Orlando's STP (considered a suspended growth biological process) is not permitted because sanitary sewer discharge limits are lower than detected groundwater concentrations.
	POTW (Inorganic Treatment)	Retained	· Retained for treatment of inorganics only. Inorganic COCs (antimony) in groundwater at OU 4 are below the STP industrial user's permit limit concentrations. This treatment option will require payment of discharge fees.
	Ion Exchange (Inorganic Treatment)	Retained	· Retained for further evaluation of antimony treatment.
	Metals Precipitation (Inorganic Treatment)	Retained	· Retained for further evaluation of antimony treatment.
	Electrochemical (Inorganic Treatment)	Retained	· Retained for further evaluation of antimony treatment.
Discharge	POTW (Orlando STP)	Retained	· Potential technology for discharge of treated groundwater. This discharge option will require long-term payment of discharge fees as opposed to treatment O&M costs.
	Surface Water (Lake Druid)	Retained	· Potential technology for discharge of treated groundwater. This discharge option will potentially require filing a NPDES permit and may require inorganic treatment in addition to organic treatment to meet surface water standards.
	Groundwater Reinjection	Retained	· Potential technology for discharge of treated groundwater. This discharge option will require installation of injection wells and Underground Injection Control permitting.

TABLE A-1
PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES

OU 4 - NAVAL TRAINING CENTER, ORLANDO FLORIDA

[1] General response actions describe general medium-specific measures that may be employed to address the remedial action objectives (RAOs). The RAOs for OU 4 are as follows:

RAO 1: Reduce the potential for human ingestion of groundwater containing COC concentrations that exceed drinking water regulatory requirements or risk-based acceptable exposure levels.

RAO 2: Control migration of VOC concentrations in groundwater that contribute to exceedances of FDEP surface water standards in Lake Druid.

Note: All general response actions (including No Action) include continuation of the existing IRA (recirculation well operation)

[2] Refer to Attachment A for further discussion regarding the advantages and limitations of each *in-situ* treatment.

[3] Refer to Attachment A for further discussion regarding the advantages and limitations of each *ex-situ* treatment.

Acronyms:

bls	below land surface
COC	contaminant of concern
DNAPL	dense nonaqueous-phase liquid
FDEP	Florida Department of Environmental Protection
IRA	Interim Remedial Action
NPDES	National Pollutant Discharge Elimination System
POTW	publicly-owned treatment works
RAOs	Remedial Action Objectives
STP	sewage treatment plant
SVE	soil vapor extraction
USGS	U.S. Geological Survey
UV/OX	ultraviolet oxidation
VOC	volatile organic compounds

ATTACHMENT A
PRELIMINARY SCREENING OF GROUNDWATER TREATMENT TECHNOLOGIES

OU 4
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

PRELIMINARY SCREENING OF GROUNDWATER TREATMENT TECHNOLOGIES
NTC, ORLANDO OU4

Treatment technologies screened in this attachment are categorized into two general response actions: *in-situ* and *ex-situ* treatment. *In-situ* technologies are processes that are capable of removing compounds from groundwater without extracting groundwater. In contrast to groundwater extraction and *ex-situ* treatment, *in-situ* treatment does not generate water requiring discharge. Additionally, only the target contaminants of concern are treated, as opposed to treating nontarget constituents to achieve discharge limitations for extracted groundwater. However, *ex-situ* treatment technologies can usually be controlled and monitored more readily. *In-situ* treatment technologies identified for OU 4 that are preliminarily screened in this attachment include:

- Air Sparging with Vapor Collection
- Chemical Oxidation
- Enhanced Biodegradation / Natural Attenuation
- Phytoremediation
- Steam Stripping
- Recirculation/In-Well Stripping
- Permeable Reactive Wall
- *In-Situ* Fixation (inorganics only)

Ex-situ treatment technologies preliminarily screened in this attachment include:

- Air Stripping and Aeration
- Organic Adsorption
- Oxidation
- Biological
- Publicly-Owned Treatment Works (POTW) Treatment
- Ion Exchange (inorganics only)
- Metals Precipitation (inorganics only)
- Electrochemical (inorganics only)

IN-SITU TREATMENT TECHNOLOGIES

Air Sparging with Soil Vapor Extraction

Description:

- Air is injected into the saturated zone to create turbulence to volatilize organic compounds in the groundwater. As air moves up through the aquifer, contaminants partition into the gas phase and are then collected as organic vapors from the vadose zone.
- Typically used in combination with soil vapor extraction (SVE) to control off-gas generated by organic compound volatilization. SVE uses negative pressure to collect extracted vapors. Vapor extraction wells or trenches are installed above the water table in a configuration to capture vapors generated from air sparging.

Advantages Over Other *In-situ* Alternatives:

- proven technology for removal of volatile organics (VOCs) from groundwater
- relatively simple process using readily available equipment and contractors
- potentially effective even with the presence of dense nonaqueous-phase liquid (DNAPL).
- methane can be added to enhance cometabolism of chlorinated organics
- can be readily installed within the source area at OU 4 through the floor slab of the building

Limitations:

- contaminants are not destroyed but are transferred to another media (air)
- must be combined with a vapor collection system to prevent gas migration
- air flow through the saturated zone may not be uniform resulting in uncontrolled movement of vapors
- depths of contaminants and specific geology must be considered
- soil heterogeneity may cause some zones to be relatively untreated

Applicability to OU 4: Retained. An air sparging pilot test performed at OU 4 revealed that a hard layer of cemented sand located approximately 20 feet below land surface (bls) prevented the injected air from migrating to the surface. However, the test results suggested that OU 4 would be amenable to air sparging, if some means of penetrating the cemented sand layer is provided to remove the generated vapors.

In Situ Chemical Oxidation

Description: There are two principal versions of this technology:

- A chemical reagent is injected into the contaminated portion of the aquifer. The reaction chemistry is related to the Fenton's Reaction, and basically uses a catalyst along with hydrogen peroxide to breakdown organic chemical bonds into end products of carbon dioxide and water.
- Potassium permanganate ($KMnO_4$) generates a reaction similar to Fenton's reagent, except the permanganate ion (MnO_4^-), rather than hydrogen peroxide, acts as the oxidant. May be better suited to source area remediation than Fenton's.

Advantages Over Other *In-Situ* Alternatives:

- process is not adversely affected by the presence of DNAPL.
- organic contaminants of concern (COCs) are destroyed and not transferred to another media
- treatment can be readily performed within the source area at OU 4 through the floor slab of the building
- can potentially achieve more that 99 percent VOC destruction efficiency

Limitations:

- a bench- and pilot-scale test would be necessary prior to implementing at OU 4.
- Fenton's requires vendors with technology expertise for effective dosing
- high pH, total organic carbon and inorganic (iron, manganese, magnesium, and calcium) concentrations can adversely effect the process
- considerable amounts of reagent (high cost) may be required to reduce highly contaminated (DNAPL) areas
- $KMnO_4$ process requires groundwater extraction, chemical addition, and reinjection
- successful Fenton's bench-scale test results can generally be reproduced at a high percentage; however successful field pilot studies are not as reproducible principally due to difficulty in delivery of the reagent into the groundwater.

Applicability to OU 4: Retained. The highly permeable site soils and groundwater chemistry are favorable for this technology to remediate the source area.

Natural Attenuation

Description:

- naturally-occurring processes that act without human intervention to reduce the mass, toxicity, mobility, volume or concentration of contamination.
- works through nondestructive mechanisms such as dispersion, adsorption, dilution, volatilization, and/or chemical and biological stabilization of contaminants and destruction mechanisms such as biodegradation.

Advantages Over Other *In-Situ* Alternatives:

- organic contaminants are destroyed (through biodegradation)
- less generation or transfer of remediation waste
- less intrusive as less structures are required
- may be applied to all or part of a site depending on site conditions and objectives
- may be used inexpensively in conjunction with, or as a follow-up to other remedial methods
- no active remedial action required for implementation (thereby lower cost); only long-term groundwater monitoring is required to assess process progression

Limitations:

- attenuation processes are adversely affected by the presence of DNAPL; not suitable for source remediation
- longer time frames may be required to achieve remediation objectives, compared with active remediation
- long-term monitoring and associated costs
- more extensive outreach efforts may be required in order to gain public acceptance
- significant data used as input parameters for modeling need to be collected as evidence that the processes will effectively reduce contaminant concentrations

Applicability to OU 4: Retained. Based on RI work, natural biodegradation (reductive dechlorination) is occurring at OU4. As the tetrachloroethene (PCE) plume moves down (due to the downward groundwater potential) and west towards the lake, the PCE biologically degrades to trichloroethene (TCE) and TCE degrades to *cis*-1,2-dichlorethene (DCE). Relatively little PCE is present as the plume completes its migration west and discharges upward into Lake Druid. However, concentrations of VOCs in Lake Druid indicate that this degradation is neither complete nor rapid enough to meet regulatory standards without implementation of additional remedial measures.

Enhanced Biodegradation

Description:

- A process of enhancing natural bacterial degradation of organic contaminants by introducing nutrients or other compounds (i.e., hydrogen release or oxygen release compounds) to stimulate bacterial growth and the speed of biodegradation of organic contaminants.
- Can be applied using aerobic (oxygen-rich) conditions or anaerobic (oxygen-poor) conditions.
- PCE, TCE and cis-DCE have been shown to biodegrade under anaerobic conditions, but PCE is resistant to degradation under aerobic conditions. Less chlorinated compounds such as TCE and cis-DCE can be degraded under either anaerobic conditions or under aerobic conditions. Aerobic biodegradation of TCE and cis-DCE can be accomplished by a type of aerobic bacteria known as methanotrophs or methane-utilizing bacteria.

Advantages Over Other *In-Situ* Alternatives:

- innovative technology
- organic contaminants are destroyed (through biodegradation)
- less generation or transfer of remediation waste
- favorable public acceptance

Limitations:

- laboratory-scale biodegradation testing and pilot-scale test may be required to evaluate the microbial conditions present in site groundwater, establish suitable amendment concentrations, identify factors that may inhibit microbial growth, and to demonstrate the technology effectiveness
- high COC concentrations (i.e., DNAPL) can inhibit microbial activity; not suitable for source remediation
- hydraulic control of the contaminated portion of the aquifer may be required

Applicability to OU 4: Retained. Based on RI work, natural biodegradation (reductive dechlorination) is already occurring at OU4 making enhanced biodegradation a potentially favorable technology. May be particularly suited to the southern VOC plume, where there does not appear to be a source area of residual NAPL.

Phytoremediation

Description:

- Processes that use naturally-occurring and/or genetically-engineered vegetation to clean up or contain contaminated groundwater.
- Although shown to be very effective in specific situations, the processes are not well understood and they have been applied (in full-scale) to a relatively small, but growing, number of contaminated sites.

Advantages Over Other *In-Situ* Alternatives:

- innovative technology
- low-impact
- high public acceptance
- generally very cost competitive with other alternatives (10-20% of the cost of mechanical alternatives)
- plants can generally tolerate higher contaminant concentrations than microorganisms.
- effective in series with other technologies (polishing step)
- waste disposal volumes (thereby costs) eliminated or significantly reduced
- applicable to a range of contaminants (organics and metals)
- double-duty effect of hydraulic control of contaminated plume migration along with uptake (trees)

Limitations:

- optimum effectiveness in settings where depth to groundwater is less than ten feet below the surface.
- may require extended time to achieve cleanup goals (i.e., multiple growing seasons)
- may not be able to achieve required reductions in chemical concentrations
- unfamiliar technology and will likely require more studies and testing prior to regulatory approval
- effectiveness of the technology may be governed by physical conditions (weather conditions, animal and insect damage, blights/funguses) that are difficult to control.
- high concentrations of chemicals can be toxic to plants

Applicability to OU 4: Eliminated. U.S. Geological Survey (USGS, 1998) investigations conclude that under existing conditions, phytoremediation alone at OU 4 cannot hydraulically prevent the discharge of contaminants into Lake Druid because the overall estimated evapotranspirative losses would be small relative to the groundwater discharge to Lake Druid. USGS suggests that the installation of a drainage ditch could redirect flow through the rooting zone of aquatic plants which could remediate the groundwater discharge. The drainage ditch would intercept flow from 0 to approximately 40 feet below the water table but would still allow water in the lower 20 feet of the surficial aquifer system to continue to discharge to Lake Druid. As a result, it may not be used alone to effectively stop groundwater discharge to Lake Druid. Used in conjunction with other technologies, phytoremediation may be applicable as a final polishing step at the lake perimeter, but would likely require a waiver from the Florida Department of Environmental Protection (FDEP) from meeting surface water standards in this remedial zone. USEPA and the University of Georgia are currently studying phytoremediation at OU 4.

Steam Stripping

Description:

- Steam is forced into the contaminated aquifer through injection wells to vaporize volatile and semivolatile (SVOC) contaminants.
- Vaporized components rise to the vadose zone where they are removed by vacuum extraction

Advantages Over Other *In-Situ* Alternatives:

- innovative technology
- can remove large portions of waste accumulations and retard downward and lateral migration of organic contaminants
- typically effective within a short to medium duration (a few weeks to several months)

Limitations:

- more cost effective at treating SVOCs and fuels than VOCs in comparison with other technologies
- soil type, contaminant concentration, geology, and hydrogeology can significantly impact process effectiveness
- only demonstrated mostly at the pilot-scale

Applicability to OU 4: Eliminated. Not cost effective compared with conventional air sparging because site soils are relatively permeable and contaminants are readily strippable without introduction of heat.

Recirculation/In-Well Stripping

Description:

- A double screened well is used to create a circulation sphere within the affected portion of the aquifer. Typically, groundwater enters through a screen in the lower part of the recirculation well, travels up through the well, and returns to the aquifer through a screen near the top, thus creating a spherical capture zone. Groundwater treatment occurs by air stripping within the well prior to returning to the aquifer.
- Several different proprietary designs of this technology are available.

Advantages Over Other Alternatives:

- innovative technology
- groundwater in the treatment cell can undergo several stripping cycles, allowing low treatment levels to be achieved within and downgradient of the recirculation cell
- returns groundwater to the aquifer without extraction eliminating the need to consider water disposal options
- no drawdown occurs eliminating the possibility of wetland dewatering
- vertical component of the recirculating water can flush areas where contaminants may be concentrated, accelerating cleanups compared to conventional groundwater extraction, and reducing the likelihood of concentration rebound after system shutdown
- modifications to the basic in-well stripping process can involve additives to enhance biodegradation
- has already been implemented at OU 4 as an IRA

Limitations:

- biological and iron fouling of the system may occur
- vertical circulation more effective than radial flow, but process still limited by slow dissolution of residual NAPL into groundwater
- installation may cause smearing of contaminants in DNAPL areas
- not as effective at sites that have lenses of low-conductivity deposits

Applicability to OU 4: Retained. The recirculation well technology has already been implemented at OU 4 as an IRA to control migration of VOCs that contribute to the exceedances of FDEP surface water standards in Lake Druid.

Permeable Reactive Wall

Description:

- A permeable reaction wall that is installed across the flow path of a contaminant plume, allowing the passage of water while prohibiting the movement of contaminants by employing various agents (i.e., zero valent iron, sorbents, or microbes).
- As contaminated groundwater passes through the wall under natural groundwater flow conditions, the contaminants are removed through chemical and physical processes.

Advantages Over Other *In-Situ* Alternatives:

- passive process; relatively low impact to the environment and property use
- low O&M costs consisting of periodic wall maintenance and sampling and analysis of observation wells.
- waste disposal volumes (therefore costs) eliminated or significantly reduced.
- particularly effective in tight soils

- potentially operable for long periods of time
- innovative technology
- use of zero valent iron as a media destroys chlorinated solvents by reductive dechlorination mechanisms

Limitations:

- technology using zero valent iron is patented and currently available through only one vendor (the University of Waterloo of Ontario, Canada).
- not practical for deep plume remediation; depth of reactive wall typically limited by installation method (e.g. backhoe reach).
- reactive barrier materials (e.g. elemental iron polymer resins) can be relatively expensive, so continuous walls can be cost prohibitive; at some sites this can be overcome by incorporating funnel and gate design to reduce the required size of the reactive wall (gate)
- removal or replacement of the barrier may be difficult and/or costly;
- long-term effectiveness of the wall has not been field-verified (laboratory tests have been conducted to simulate over 20 years of use, but first full-scale implementation of this technology has been in place for only 4 years)
- precipitates or films may form on the reactive materials limiting the hydraulic and reactive lifetime of the wall (thereby requiring intensive operation and maintenance such as flushing).
- bench-scale studies would have to be performed
- hydraulic modeling would be required to verify if any adverse effects would occur as a result of the wall installation; modeling would be complex because confining unit is approximately 60 feet bls.

Applicability to OU 4: Eliminated. The technology can not be used to treat the source area but can only be used to provide containment of the plume near the source area. Installation of the reactive wall would only duplicated action already being performed by the existing IRA.

In-Situ **Fixation (Inorganic Treatment)**

Description:

- Oxygen (in the form of hydrogen peroxide) is delivered into the aquifer. By creating an oxidizing environment, soluble inorganic fractions will be more strongly adsorbed to the soil particles or will copreciate and be effectively removed from solution.

Advantages Over Other *In-Situ* Alternatives:

- innovative technology
- proven effective at treating inorganics at mining and hazardous waste sites which have achieved closure from the USEPA

Limitations:

- a bench- and pilot-scale test would be necessary prior to implementing; may not be effective with antimony
- requires vendors with chemical expertise for effective dosing
- high pH, total organic carbon and inorganic (iron, manganese, magnesium, and calcium) concentrations can adversely effect the process
- ineffective delivery of the peroxide solution may cause the antimony to migrate

Applicability to OU 4: Retained for more detailed screening.

EX-SITU TREATMENT TECHNOLOGIES

Air Stripping and Aeration

Description:

- VOCs are transferred from groundwater to the vapor phase by contacting the water with a continuous supply of clean air
- Many vendor-specific air stripping and aeration units exist and can generally be grouped into the four categories: packed towers, diffused aeration, cascade towers, and tray towers

Advantages Over Other *Ex-Situ* Alternatives:

- well demonstrated technology that can easily achieve a variety of treatment levels
- bench- and pilot-scale tests are not necessary because removal efficiencies for PCE, TCE and DCE are fairly well documented
- systems can be readily enlarged to increase removal efficiency

Limitations:

- presence of inorganic compounds can potentially foul air strippers (iron greater than 5 ppm and hardness greater than 800 ppm). Frequent cleaning, adjustment, or replacement of packing may be required to maintain effective removal efficiencies
- process energy costs can be high

Applicability to OU 4: Retained. PCE and its chlorinated degradation products are applicable for this technology.

Organic Adsorption

Description:

- Groundwater is pumped through one or more vessels containing activated carbon to which dissolved organic (VOCs and SVOCs) contaminants adsorb.
- When concentrations of contaminants in the effluent from the vessels exceeds a certain level, the carbon can be regenerated in place, regenerated off-site, or removed and disposed.

Advantages to Organic Adsorption Over Other Alternatives:

- well demonstrated technology with high removal efficiencies
- because removal efficiencies for PCE, TCE and DCE are fairly well documented, bench- and pilot-scale tests are not necessary
- particularly effective for polishing water discharges from other remedial technologies to attain regulatory compliance
- can be deployed rapidly

Limitations:

- presence of multiple contaminants can impact process performance
- when compared to air stripping, aeration, and oxidation, organic adsorption is not as cost effective for the removal of VOCs (more cost effective for removal of SVOCs).
- costs are high if used as the primary treatment on groundwater with high contaminant concentration levels
- contaminants are only adsorbed to another media which requires regeneration or disposal

Applicability to OU 4: Eliminated. Not cost effective as primary treatment of VOCs at concentrations present at OU 4 in comparison with other available technologies.

Oxidation

Description:

- *ex-situ* process that destroys VOCs in groundwater by changing the oxidation state of target contaminants.
- common general categories of oxidation include: ultraviolet light, ozone, hydrogen peroxide (H_2O_2), chlorinated compounds (hypochlorous acid [HOCl], chloramines and chlorine dioxide), and potassium permanganate.

Advantages Over Other *Ex-Situ* Alternatives:

- typically can achieve more than 99 percent destruction efficiency of organic compounds.
- attractive for use at contaminated sites, as the systems have very low, if any, air emissions.
- organic contaminants are destroyed rather than transferred to another media.

Limitations:

- pretreatment for removal of naturally occurring inorganics (e.g., iron, lead, or manganese) may be required to prevent fouling of UV/OX systems.
- treatability studies are required to determine optimum operating parameters such as pH and chemical dosage and if inorganic treatment is required.
- more complex process using specialized equipment and suppliers
- free radical scavengers can inhibit contaminant destruction efficiency. Excessive dosages of chemical oxidizers can act as a scavenger

Applicability to OU 4: Retained for further evaluation.

Biological

Description:

- Degrade contaminants in water with microorganisms through biological systems; biological systems may be either attached (i.e., trickling filters or rotating biological contactors) or suspended (i.e., activated sludge, fluidized bed, or sequencing batch reactors) systems
- Common method of reducing the concentration of organic compounds in wastewater; the same techniques typically applied in wastewater treatment can be applied to groundwater treatment. Bioreactors with cometabolites may be used to treat halogenated VOCs.

Advantages Over Other *Ex-Situ* Alternatives:

- innovative technology
- high public acceptance
- waste disposal volumes (thereby costs) eliminated or significantly reduced
- organic contaminants are destroyed rather than transferred to another media

Limitations:

- PCE and TCE degrade under anaerobic conditions, while cis-DCE and lesser-chlorinated compounds degrade faster under aerobic conditions (i.e., both aerobic and anaerobic conditions are often required for treatment)
- treatability studies are required to determine optimum operating parameters such as pH and nutrient requirements
- very high contaminant concentrations may be toxic to microorganisms and require special design approaches
- residuals from sludge processes require treatment or disposal
- discharge of treated effluents may still be regulated
- susceptible to toxic shocks; considerable O&M required to maintain an effective biomass (suspended systems)
- frequent cleaning, stimulation, and distribution of the biomass along the surface of the medium are required to maintain effective treatment (attached systems)

Applicability to OU 4: Eliminated. In comparison with other available technologies, an on-site biological treatment system would not be cost effective as primary treatment of VOCs at concentrations present at OU 4. If biological treatment of extracted groundwater is desired, the most appropriate biological method that would achieve treatment levels would be the City of Orlando's STP, which is considered a suspended growth biological process. However, the Orlando STP has placed local limits on the influent water to its plant. These local limits are lower than anticipated groundwater concentrations.

POTW Treatment

Description:

- Discharge groundwater containing COCs that meet pretreatment discharge limits to the City of Orlando's STP.

Advantages Over Other Treatment Alternatives:

- uses existing infrastructure and treatment facilities capable of handling anticipated groundwater constituents; only a groundwater extraction system and sanitary sewer connection is required
- easily implemented

Limitations:

- monthly fees charged by the STP can be significant for long-term treatment
- public perception and municipal acceptance
- organic influent limits for the Orlando STP are lower than organic concentrations in OU 4 groundwater

Applicability to OU 4: Retained for treatment of inorganics only. The Orlando STP has placed local limits on the influent water to its plant. These local limits are lower than anticipated groundwater concentrations for organic compounds, requiring on-site pretreatment. Inorganic COCs (antimony) in groundwater at OU 4 are below the STP industrial user's permit limit concentrations. As a result extracted groundwater from the antimony plume could be discharged directly to the STP, providing PCE (detected in adjacent downgradient monitoring wells) is not drawn to the extraction area.

Ion Exchange (Inorganics Only)

Description:

- Removes ions from the aqueous phase by the exchange of cations or anions between the contaminant and the exchange medium.
- Ion exchange materials may consist of resins made from synthetic organic, inorganic, or natural polymeric materials.
- After the resin capacity has been exhausted, the resins are regenerated for reuse.

Advantages Over Other *Ex-Situ* Alternatives:

- modular waste treatment units can be used for cost effective deployment
- use of multiple units provides flexibility in varying processing rates
- has been successfully used for treatment of concentrated wastestreams

Limitations:

- oil and grease in the groundwater can clog the exchange resin
- suspended solids content greater than 10 ppm may cause resin binding
- more complex process using specialized equipment and suppliers
- wastewater is generated during the regeneration step and will require additional treatment and disposal

Applicability to OU 4: Retained for further evaluation.

Metals Precipitation (Inorganics Only)

Description:

- Involves conversion of soluble heavy metal salts to insoluble salts that will precipitate. The precipitate is then removed from the treated water by physical methods such as clarification (settling) and/or filtration.
- Has long been the primary method of treating metal-laden industrial wastewaters.

Advantages Over Other *Ex-Situ* Alternatives:

- commonly used process using readily available equipment and contractors
- can be used for pretreatment for other technologies (such as air stripping) where the presence of metals would interfere with the other treatment processes

Limitations:

- process may be incapable of achieving the OU 4 remedial goal of 6 ug/L for antimony; treatability testing would be required
- presence of multiple metal species may lead to removal difficulties
- sludge generated must pass Toxicity Characteristic Leachate Procedure (TCLP) prior to land disposal
- system efficiency relies on adequate solids separation techniques (e.g. clarification, flocculation, and/or filtration)
- process can be costly depending upon reagents used, required system controls, and required operator involvement in system operation

Applicability to OU 4: Retained for further evaluation.

Electrochemical (Inorganics Only)

Description:

- Similar to metals precipitation but uses iron dissolved from the anode of an electrochemical cell and hydrogen peroxide to precipitate the antimony rather than adding other coagulants

Advantages Over Other *Ex-Situ* Alternatives:

- can be used for pretreatment for other technologies (such as air stripping) where the presence of metals would interfere with the other treatment processes

Limitations:

- process may be incapable of achieving the OU 4 remedial goal of 6 ug/L for antimony; bench-and pilot-scale treatability testing would be required to verify applicability of this technology
- presence of multiple metal species may lead to removal difficulties
- sludge generated must pass TCLP prior to land disposal
- hydroxide sludge that is generated is difficult to dewater
- electrodes need to be replaced because the anode is dissolved in the process

Applicability to OU 4: Retained for further evaluation.