APPENDIX K

Detailed Technology Evaluation

Table K-1. Review of candidate removal action technologies for the T-117 NTCRA

		Effectiveness			Implementability					
Process Option	Brief Description	Contaminants of Concern Typically Treated	Advantages	Disadvantages	Site Conditions	Advantages	Disadvantages	Unit Cost Range	Screening Decision	Citation
***In Situ* Treatment**										
Biological										
Aerobic biodegradation	Degradation of organic contaminants in the soil using microbes in the presence of oxygen. Enhanced bioremediation includes the injection of nutrients, oxygen or other amendments.	Effective principally to PAHs, other non-halogenated SVOCs, and BTEX. Biodegradation of PCBs not feasible.	Biodegradation is a demonstrated and proven remedial technology for volatiles and SVOCs. Treating of residuals is typically unnecessary.	Biodegradation of PCBs has not yet been demonstrated to consistently meet treatment goals; groundwater may require treatment; cleanup goals may not be attained if the soil matrix prohibits contaminant-microorganism contact; preferential flow paths may severely decrease contact between injected nutrients and oxygen.	Not applicable to PCB impacted soil on site.	Readily implemented with minimal construction requirements; minimal impact on current or future industrial uses; may be used in conjunction with other technologies in a combined alternative; no heating or expensive inputs required.	Typically used in conjunction with other alternatives (e.g. anaerobic biodegradation); pilot-scale testing necessary. May require long-term commitment to monitoring, additional actions, or permanent institutional controls.	$20 – $80/cy)	Not applicable due to site COCs, PCBs, site hydrologic characteristics, and time constraints.	FRTR Screening Matrix Section 4.2 (FRTR 2002)
Anaerobic biodegradation	Anaerobic degradation *in situ* with the injection of a methanogenic culture, anaerobic mineral medium and routine supplements of glucose to maintain methanogenic activity. Nutrients and pH are controlled to enhance degradation.	Effective principally on chlorinated volatile organic chemicals (VOCs). Biodegradation of PCBs is not proven.	Anaerobic biodegradation is a demonstrated and proven remedial technology for chlorinated VOCs and SVOCs. Treating of residuals is typically unnecessary.	In situ anaerobic remediation of PCBs is currently unproven as a standalone technology. Cleanup goals may not be attained if the soil matrix prohibits contaminant-microorganism contact, preferential flow paths may severely decrease contact between injected nutrients.	Not applicable to PCB impacted soil on site.	Readily implemented with minimal construction requirements; Minimal impact on current or future industrial uses; May be used in conjunction with other technologies in a combined alternative; No heating or expensive inputs required.	Typically used in conjunction with other alternatives (e.g. aerobic biodegradation); pilot-scale testing necessary. May require long-term commitment to monitoring, additional actions, or permanent institutional controls.	$20 – $80/cy	Not applicable due to site COCs, PCBs, site hydrologic characteristics and time constraints.	Battelle (2002); FRTR Screening Matrix Section 4.2 (FRTR 2002)
Phyto-remediation	Phytoremediation is a process that uses plants to remove, transfer, stabilize, and destroy contaminants in soil.	Phytoremediation can be used to clean up metals, pesticides, solvents, explosives, crude oil, PAHs, and landfill leachate. Effective at up-taking PCBs in shallow soils (surface to 3 ft below grade) and low concen-trations, but not proven to meet action levels for higher levels of PCBs.	Passive technique, solar energy driven, effective shallow soils.	Typically used for low-level contaminants, process/technology is not proven to reduce site PCB concentrations in soil to less than 1mg/kg. Treats shallow soils.	Applicable to shallow soils with low PCB concentrations. Not applicable to deep soil layers or high PCB concentrated areas of site.	Aesthetically pleasing, readily implemented with minimal construction requirements; minimal impact on current or future industrial and shipping uses of waterway; may be used in conjunction with other technologies in a combined alternative.	May require long-term commitment to monitoring with the potential for additional actions if alternative fails to meet site cleanup goals; may require permanent institutional controls (e.g., deed restrictions) that may affect future site development and uses.	$110 – $1,800/ cy depending on site conditions	Not applicable: not proven to clean up PCBs to screening levels, unable to remediate to necessary depth.	FRTR Screening Matrix Section 4.3 (FRTR 2002)

Table K-1. Review of candidate removal action technologies for the T-117 NTCRA (cont.)

Process Option	Brief Description	Effectiveness: Contaminants of Concern Typically Treated	Effectiveness: Advantages	Effectiveness: Disadvantages	Implementability: Site Conditions	Implementability: Advantages	Implementability: Disadvantages	Unit Cost Range	Screening Decision	Citation
Chemical										
Chemical oxidation	Delivery of oxidizers into soils using injection wells in contaminated soils. Oxidation of organics using oxidizing agents such as ozone, peroxide, permanganate, or Fenton's reagent.	It is used to treat VOCs including dichloroethene, trichloroethene, tetrachloroethene, and BTEX. Oxidation is less efficient with SVOCs including pesticides, PAHs, and PCBs.	Destruction by chemical oxidation can have fast reaction rates and high treatment efficiencies.	Low permeability or heterogeneous soils are difficult to treat; reactions may produce unwanted byproducts; potential of spreading contamination.	Injection at depth is applicable to all areas of the site. May have unwanted consequences in near-bank soils and sediments, not typically used for PCBs.	Readily implemented under site constraints and construction requirements; May be used in conjunction with other technologies in a combined alternative.	Requires the storage and handling of large quantities of hazardous oxidizing chemicals. Oxidation may occur outside the intended treatment area. May require additional technologies to meet cleanup goals.	$150 – $500/cy	Not applicable for site chemicals of concern, for site soil characteristics and additional site risks.	FRTR Screening Matrix Section 4.16 (FRTR 2002)
Physical-Extractive Processes										
Soil vapor extraction	Vacuum is applied to the vadose zone soil to induce the controlled flow of air and remove volatile and some semivolatile contaminants.	Effective at extracting VOCs with a Henry's law constant greater than 0.01 or a vapor pressure greater than 0.02 inches Hg in permeable soil. Not effective at extracting PCBs.	Proven and effective technology for removing VOCs in permeable soil.	Not effective at removing PCBs.	Applicable to in the upland in the vadose zone. Not applicable in the saturated zone or to site COCs.	Proven and established technology.	Treatment of exhaust air may be required.	$300 – $1,100/ cy depending on size of site and site conditions	Not applicable due to inability to address site COCs.	FRTR (2002)
Fracturing	Cracks are developed by fracturing beneath the surface in low permeability soils to open new passageways that increase the effectiveness of many in-situ processes and enhance extraction efficiencies.	Can be used on a variety of COCs, depending on the in-situ process it is used in conjunction with.	Increases the effectiveness of in-situ technologies and enhances extraction efficiencies.	The potential exists to open new pathways for unwanted spread of contamination. The technology only as good as the associated in-situ process.	Not applicable to high permeability fill soils predominant found at T-117	Can aid soil vapor extraction or other in-situ technologies.	Requires other in-situ technologies.	$150 – $270/ton)	Not applicable due high permeability of site soils.	FRTR Screening Matrix Section 4.6 (FRTR 2002)
Soil flushing	Water or water containing an additive to enhance contaminant solubility is applied to the soil or injected into the groundwater to raise the water table into the contaminated soil zone. Contaminants are leached into the groundwater, which is extracted and treated.	The technology can be used to treat VOCs, SVOCs, fuels, and pesticides. Technology unproven to treat PCBs to 1 mg/kg.	Ability to mobilize a wide range of organic contaminants from coarse-grained soils.	Low permeability or heterogeneous soils are difficult to treat; surfactants can adhere to soil and reduce effective soil porosity; reactions of flushing fluids with soil can reduce contaminant mobility; potential of washing the contaminant beyond the capture zone; above ground separation and treatment needed.	Applicable to vadose and saturated zones of soil by raising the water table. May not be effective to the bank area due to potential discharge into the surface water. Less applicable to heterogeneous soils.	Technically readily implemented within the site constraints; does not interfere with current site uses.	Requires infrastructure, monitoring, and treatability studies. May require additional actions if alternative fails to meet site cleanup goals.	$20 – $50/cy	Not applicable due to unproven technology, possible contaminant migration to surface waters and heterogeneous fill soils.	FRTR Screening Matrix, Section 4.7 (FRTR 2002)

Table K-1. Review of candidate removal action technologies for the T-117 NTCRA (cont.)

		Effectiveness			Implementability					
Process Option	Brief Description	Contaminants of Concern Typically Treated	Advantages	Disadvantages	Site Conditions	Advantages	Disadvantages	Unit Cost Range	Screening Decision	Citation
Thermal treatment	Steam injection, hot air injection, electrical resistance heating, electromagnetic heating, fiber optic heating, or radio frequency heating is used to increase the volatilization rate of SVOCs and facilitate extraction.	Applicable primarily to VOCs, also used for SVOCs, pesticides and fuels. Less effective for PCBs.	Proven and effective technology for removing VOCs in soil.	Performance in extracting PCBs can be poor; soil with highly variable permeabilities may result in uneven delivery of gas flow to the impacted areas; air emissions will require treatment; hot air injection has limitations due to the low heat capacity of air.	Not applicable to PCB contaminated soils at the site.	Technically readily implemented within the site constraints; does not interfere with current site uses; quick cleanup times.	Requires infrastructure, monitoring, and treatability studies. May require additional actions if alternative fails to meet site cleanup goals. Costly.	$40 – $170/cy (EPA); $30 – $60/ cy (frtr.gov)	Not applicable due to site properties such as debris (thermal conductivity), or ineffectiveness to site COCs (steam injection, radio frequency heating), lack of full scale demonstration (conductive heating).	FRTR Screening Matrix Section 4.10 (FRTR 2002); EPA (EPA 2006b)
Electro kinetic separation	Removes metals and polar organic contaminants from low permeability soil, mud, sludge, and marine dredging through the application of a low intensity direct current between ceramic electrodes that are divided into a cathode array and an anode array.	Typically used for heavy metals, anions, and polar organics. Limited applicability to PCBs.	Applicable in low permeability soils with high moisture content.	Effectiveness is sharply reduced for wastes with a moisture content of less than 10%; oxidation/reduction reactions can form undesirable products; most effective in clays because of the negative surface charge; limited full scale implementation.	Soils are limited for PCBs. High permeability soils and buried metallic material may inhibit process.	Effective an efficient in saturated soils with low permeability contaminated with metals and polar organics.	Infrastructure may interfere with future site uses; limited full scale applications. Can form undesirable products.	$90/cy	Not applicable due to site conditions: high permeability soils and buried debris, and site COCs: PCBs, TPH.	FRTR Screening Matrix Section 4.5 (FRTR 2002).
Physical Immobilization										
Soil solidification	Traps or immobilizes hazardous substances using physical or chemical means.	Generally used for inorganics, solidification for organics is not a proven technology.	Capable of reducing mobility of contaminated waste by greater than 95% for inorganic compounds.	The long term effect of weathering cannot be predicted from laboratory experiments, highly depended on the physical properties of the soil, effectiveness for SVOCs such as PCBs is ongoing.	Applicable primarily for inorganics; limited effectiveness for organics including TPH and PCBs.	Processes well demonstrated, require conventional materials handling equipment, and are available from a number of vendors.	Processes may increase volumes, processing below the water table may require dewatering, reagent delivery and effective mixing are more difficult than for ex situ applications.	$40 – $250/cy depending on depth and soil conditions	Not applicable due to inability to address site COCs and site conditions (chemical concentrations below the water table, hetero-geneous soils, and leaching potential of solidified soils).	

Table K-1. Review of candidate removal action technologies for the T-117 NTCRA (cont.)

Process Option	Brief Description	Effectiveness: Contaminants of Concern Typically Treated	Effectiveness: Advantages	Effectiveness: Disadvantages	Implementability: Site Conditions	Implementability: Advantages	Implementability: Disadvantages	Unit Cost Range	Screening Decision	Citation
Vitrification	Uses an electric current *in situ* to melt sediment or other earthen materials at extremely high temperatures (2,900-3,650 °F). Inorganic compounds are incorporated into the vitrified glass and crystalline mass and organic pollutants are destroyed.	Applicable to inorganic and organic chemicals. Has been tested on PCBs, but not at a full scale and at action levels of 1 mg/kg.	The vitrification process can destroy, remove, or immobilize site COCs in the impacted soil; the process has been tested on the site COCs.	Long-term reaction to weathering uncertain; treatment of off gas necessary; treatment of organics still under development.	May have reduced applicability for PCB contaminated soils and heterogeneous soils and soils with debris.	Implementable at site and destroy COCs; short remedial time frame; should not require long term management or sampling at the site.	The solidified material may hinder future site use; treatability studies may be required; depth of contaminants may limit some types of application processes; treatment below the water table may require dewatering.	$380 – $430/cy	Not applicable; full scale remediation of PCB contaminated soils to 1 ppm is unproven. Additional chal-lenges include heterogeneous file soils, buried debris, and dewatering of saturated soils. Risks include possibility of dioxins and furans as by-products due to high temperatures.	FRTR Screening Matrix Section 4.10 (FRTR 2002); EPA (2006b)
Ex Situ Treatment										
Biological										
Land farming/ composting	Soil is mixed with amendments and placed on a treatment area that typically includes leachate collection. The soil and amendments are mixed using conventional tilling equipment or other means to provide aeration. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation. Other organic amendments such as wood chips, potato waste, or alfalfa are added to composting systems.	Not applicable to PCBs. Contaminants that have been successfully treated using land farming include diesel fuel, No. 2 and No. 6 fuel oils, JP-5, oily sludge, wood-preserving wastes (pentachlorophenol and creosote), coke wastes, and certain pesticides.	Uses natural, biological processes to remediate soil.	Large space necessary, conditions must be controlled, volatile constituents may need to be pre-treated, long treatment times, ineffective for many metals and persistent organics such as PCBs.	Less applicable to PCB contaminated soils or soils with metals.	Excavation implementable at site; use of natural processes to aid in remediation	Large space necessary, importance of controlling conditions, erosion, moisture, dust, gas emissions, laboratory and pilot tests necessary..	$480 – $580/cy	Not applicable due to COCs on site (PCBs metals), long processing time and large processing area.	FRTR Screening Matrix Section 4.12 (FRTR 2002); Battelle (Battelle 2002)
Biopiles	Excavated soils are mixed with amendments and placed in aerated aboveground enclosures. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation.	Not applicable to PCBs. Biopile treatment has been applied to treatment of non-halogenated VOCs and fuel hydrocarbons.	Works quickly for applicable COCs; uses biological processes to remediate soil.	Ability of microbes to degrade PCBs currently limited and under development. Volatiles must be treated.	Less applicable to PCB contaminated soils or soils with metals.	Excavation implementable at site; use of natural processes to aid in remediation	Extensive space and required for treatment facilities; requires excavation of contaminated soils and management of volatiles.	$30 – $60/cy plus operation and maintenance	Not applicable; currently not proven to be effective to site COCs (PCBs).	FRTR Screening Matrix Section 4.11(FRTR 2002); Battelle (2002)

Table K-1. Review of candidate removal action technologies for the T-117 NTCRA (cont.)

		Effectiveness			Implementability					
Process Option	Brief Description	Contaminants of Concern Typically Treated	Advantages	Disadvantages	Site Conditions	Advantages	Disadvantages	Unit Cost Range	Screening Decision	Citation
Fungal biodegradation	Fungal biodegradation refers to the degradation of a wide variety of organic pollutants by using fungal lignin-degrading or wood-rotting enzyme systems (example: white rot fungus).	Bench scale studies indicate a destruction of PCBs between 29 and 70%. Limited full scale application data.	Low cost destruction of COCs.	Requires excavation of contaminated soils; technology may not degrade COCs to achieve clean up criteria; Treatment time may exceed 12 months.	Less applicable to PCB contaminated soils.	Excavation implementable at site; inexpensive strategy using natural processes.	Requires excavation of contaminated soils; Soil must be transported off-site and treatment facilities, management of volatiles. Treatment time may exceed 12 months.	na	Not applicable due to limited full scale experience and limited applicability to PCBs.	Ruiz-Aguilar et al. (2002)
Slurry-phase biological treatment	An aqueous slurry is created by combining soil with water and other additives. The slurry is mixed to keep solids suspended and microorganisms in contact with the contaminants. Upon completion of the process, the slurry is dewatered and the treated soil is removed for disposal. Sequential anaerobic/aerobic slurry-phase bioreactors are used to treat PCBs.	Bioremediation techniques have been successfully used to remediate soils, sludges, and sediments contaminated by explosives, petroleum hydrocarbons, petrochemicals, solvents, pesticides, wood preservatives, and other organic chemicals. Effective on PCBs when a sequential anaerobic/aerobic slurry-phase bioreactor is used, but limited in full scale demonstrations.	Destroys site COCs; higher efficiency compared to other biological treatments; biological variables more easily controlled.	Ability of microbes to degrade PCBs is still in development; disposing of wastewaters is necessary.	Applicable to all site soils	Excavation implementable at site; mobile treatment units are available	Requires excavation of contaminated soils, treatment facility must be constructed, treatability study must be conducted, over a 13 day residence time necessary; throughput of available equipment is slow.	\$130 – \$160/ cy	Not applicable: technology for remediation of PCBs is still developing, and low throughput of available equipment.	FRTR Screening Matrix Section 4.14 (FRTR 2002)
Chemical										
Reduction/ oxidation	Reduction/oxidation chemically converts hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are hypochlorites, chlorine, and chlorine dioxide.	Reduction/ oxidation is effective for inorganics and is less effective for SVOCs such as PCBs or soils with high levels of oil and grease; not applicable to the site chemicals of concern.	Proven effectiveness with metals	Less effective for SVOCs or soils with high levels of oil and grease; not applicable to the site chemicals of concern.	Not applicable to PCB and TPH impacted soil on site.	Full scale, well established technology.	Pilot studies are necessary due to sensitivity of the effectiveness of the technology to site conditions (such as organic content).	\$150 – \$500/cy	Not applicable to PCB and TPH concentrations in site soils.	FRTR Screening Matrix Section 4.16 (FRTR 2002)
Dehalogenation	Contaminated soils and the reagent (typically potassium polyethylene glycol) are mixed and heated in a treatment vessel. The reaction causes the polyethylene glycol to replace halogen molecules and render the compound nonhazardous or less toxic.	Applicable to treating PCBs.	The technology can be used as a standalone technology or in combination with another technology; has been shown to reduce PCB concentration to clean up goals.	High clay and moisture content in soil will increase treatment costs; Technology is generally not cost effective for large waste volumes; concentrations of chlorinated organics >5% require large volumes of reagent; waste stream created by process needs disposal.	Applicable to all excavated site soils.	Technology has been shown to reduce site COCs to clean up goals; excavation implementable at site.	Requires excavation of contaminated soils; Soil must be transported off-site and treatment facilities constructed at another property; Storage of large quantities of reagent and process waste will be required.	\$200 – \$500/ton	Not applicable due to infrastructure requirements and reagent and process wastes	FRTR Screening Matrix Section 4.17 (FRTR 2002); Davila et al. (1993)

Table K-1. Review of candidate removal action technologies for the T-117 NTCRA (cont.)

Process Option	Brief Description	Effectiveness			Implementability			Unit Cost Range	Screening Decision	Citation
		Contaminants of Concern Typically Treated	Advantages	Disadvantages	Site Conditions	Advantages	Disadvantages			
Solvent extraction	Contaminated soil and solvent extractant are mixed in an extractor, dissolving the contaminants. The extracted solution is then placed in a separator, where the contaminants and extractant are separated for treatment and further use (example: B.E.S.T.™ and propane extraction process).	Effective in treating soils containing primarily organic contaminants such as PCBs, petroleum wastes, and VOCs.	Proven technology for removal of site COCs; can be used in conjunction with other remedial technologies.	Higher clay content may reduce extraction efficiency; traces of solvent may remain in the treated soils.	Applicable to all soils at the site.	Excavation implementable at site; Local experienced contractors for excavation.	Cost prohibitive; Requires excavation; Soil must be transported off-site and treatment facilities constructed at another property. Increased traffic in community.	$270 – $1,300 / cy depending on quantity (source: frtr.gov)	Not applicable due to necessary infrastructure, and fate of solvents in soil.	FRTR Screening Matrix Section 4.15 (FRTR 2002)
Soil washing (biogenesis)	Multi-step process of preprocessing, aeration, sediment washing, cavitation and oxidation and liquid/solid separation.	Applicable to treating PCBs, but unproven at full scale to meet cleanup goals.	Can be used on a large variety of COCs.	Still in research and development phase, fate of PCBs unknown,	Applicable to the sediments of the site, off site property will need to be used for infrastructure.	Emerging technology, potential reuse of waste soils, chemicals used are safe and biodegradable.	The use of waste soils in question, regulatory approval is time-consuming, BioGenesis is proprietary, takes up a large amount of land area and infrastructure, unit costs not verifiable, the costs are not comparative to the benefits.	$60 – $300/ cy depending on site conditions ($300/cy for sites similar to T-117) (Source: BioGenesis.com and RETEC, June 28, 2005)	Not applicable due to the unproven technology, time for permitting, and necessary infrastructure.	Davila et al. (1993); RETEC(2005b) FRTR (2002);
Physical										
Separation	Contaminated fractions of solids are concentrated through gravity, magnetic or sieving separation processes.	Applicable to SVOCs, fuels, inorganics, and selected VOCs and pesticides. Only applicable to adsorptive COCs that would adhere to the fine-grained soil.	Established technology at full scale applications.	Does not destroy COCs; separation dependent upon soil and contaminant characteristics.	Applicable to all soils at the site.	Will reduce the quantity hazardous waste (PCBs>50 mg/kg) needed for disposal; Easily implemented on-site.	Infrastructure for soil storage, separation and sampling; slow throughput rates with available equipment; requires treatability studies.	$100 – $160/cy (source: frtr.org)	Not applicable: does not destroy contaminants; must be used in conjunction with other technologies; slow through put; and extensive infrastructure necessary.	FRTR Screening Matrix Section 4.18 (FRTR 2002)
Solar detoxification	Ultraviolet energy in sunlight destroys contaminants through photochemical and thermal reactions.	Limited information on destruction efficiency of PCBs at previous site applications.	Is applicable to PCBs, VOCs and SVOCs.	Limited site data for full scale application, only effective during the daytime with normal intensity of sunlight.	Applicable to all soils at the site.	Destroys site COCs; Site soils may be used for backfill; passive technique using the natural energy of the sun.	Requires excavation of contaminated soils; Soil must be transported off-site and treatment facilities constructed, large infrastructure required for treatment.	$150 – $500/cy (source: frtr.org)	Not applicable: unproven technology in large scale application.	FRTR Screening Matrix, Section 4.20 (FRTR 2002)

Table K-1. Review of candidate removal action technologies for the T-117 NTCRA (cont.)

		Effectiveness			Implementability					
Process Option	**Brief Description**	**Contaminants of Concern Typically Treated**	**Advantages**	**Disadvantages**	**Site Conditions**	**Advantages**	**Disadvantages**	**Unit Cost Range**	**Screening Decision**	**Citation**
Solidification/ vitrification	The mobility of constituents in a solid medium is reduced through addition of immobilization additives. Various additives and processes are available for different COCs.	Primarily used for inorganics; vitrification is effective for organics. Not proven to meet action levels at full scale implementation of PCBs.	Technology has been well developed for use with inorganics.	Uses with organics such as PCBs are limited. Leaching behavior can be unpredictable over long time periods.	Limited applicability to PCB impacted soils; could be used primarily on PCB concentrations > 50 mg/kg.	Excavation implementable at site; excavated soil may be used for backfill. Can be used alone or in conjunction with other remedial technologies.	Requires excavation of contaminated soils; soil must be transported off-site and treatment facilities constructed at another property; treatability studies necessary; slow throughput with available equipment; may significantly increase soil volume; high contaminant concentration and/or high water content results in higher project costs.	\$90 – \$190/cy (source: frtr.org)	Not applicable due to slow throughput of available equipment, unpredictable leaching characteristics of solidified PCB contaminate soils.	FRTR Screening Matrix Section 4.20 (FRTR 2002); Davila et al. (1993)
Thermal										
Onsite incineration	Temperatures greater than 1,400 °F are used to volatilize and combust organic chemicals. Commercial incinerator designs are rotary kilns equipped with an afterburner, a quench, and an air pollution control system.	Applicable to site COCs where concentrations exceed the hazardous waste designation; principally PCBs > 50 mg/kg. Would also be effective at destruction of petroleum waste	Complete and permanent destruction of site COCs; effective across wide range of soil characteristics.	Fine-grained soil may be difficult to treat; dewatering may be required prior to treatment; potential for creation of dioxins and furans during incineration; off-gas treatment necessary.	Applicable to all areas of the site.	Destroys site COCs; site soils may be used for backfill; will not affect future site uses.	PSCAA (Puget Sound Clean Air Agency) new source permits are expensive and time intensive. Slow throughput and high energy costs for available equipment.	\$700 – \$1,100/cy	Not applicable due to expense and time of PSCAA new source permits.	FRTR Screening Matrix Section 4.20(FRTR 2002); Davila et al. (1993).
High-temperature thermal desorption (HTTD) then destruction	Temperatures in the range of 600 to 1,200 °F are used to volatilize organic chemicals. These thermal units are typically equipped with an afterburner and baghouse for destruction of air emissions.	Applicable to SVOCs, PAHs, PCBs, pesticides, volatile metals, VOCs. Limited full scale demonstrability for PCBs. The process is applicable for the separation of organics from refinery wastes, coal tar wastes, wood-treating wastes, creosote-contaminated soils, hydrocarbon-contaminated soils, mixed (radioactive and hazardous) wastes, synthetic rubber processing waste, pesticides and paint wastes.	Thermal desorption and combustion is effective with a range of SVOCs.	Thermal desorption is a separation method and not a destruction method; destruction of organic compounds occurs within an off-gas chamber or unit that is integrated into the thermal desorption system; fine-grained soil and/or high moisture content will increase retention times.	Applicable to all soil at the site.	Destroys site COCs; Site soils may be used for backfill; Will not affect future site uses.	Requires excavation of contaminated soils; Soil must be transported off-site and treatment facilities constructed; treatability tests necessary, slow throughput of available equipment.	\$40 – \$230/cy depending on site size and difficulty	Not applicable: does not destroy contaminants; must be used in conjunction with other technologies; slow throughput; and extensive infrastructure necessary.	FRTR Screening Matrix Section 4.25 (FRTR 2002);

Table K-1. Review of candidate removal action technologies for the T-117 NTCRA (cont.)

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Process Option	Brief Description	Contaminants of Concern Typically Treated	Advantages	Disadvantages	Site Conditions	Advantages	Disadvantages	Unit Cost Range	Screening Decision	Citation
Low-temperature thermal desorption	Temperatures in the range of 200 to 600 °F are used to volatilize and combust organic chemicals. These thermal units are typically equipped with an afterburner and baghouse for treatment of air emissions.	Non-halogenated VOCs and fuels. The technology can be used to treat SVOCs at reduced effectiveness.	Lower operating temperatures reduce the risk of creating dioxins and furans; technology successfully used for full scale remediation of petroleum hydrocarbons, decontaminated soil retains its properties.	Limited effectiveness for PCBs. Thermal desorption is a separation method and not a destruction method; destruction of organic compounds occurs within an off-gas chamber or unit that is integrated into the thermal desorption system.	Limited applicability with PCB contaminated soil.	Site soils may be used for backfill; additional technologies needed to achieve site cleanup goals.	Requires excavation of contaminated soils, Soil must be transported off-site and treatment facilities constructed at another property.	$40 – $230/cy depending on site size and difficulty	Not applicable to PCB contaminated soils.	FRTR Screening Matrix Section 4.25 (FRTR 2002)
Pyrolysis	Chemical decomposition is induced in organic materials by heat in the absence of oxygen. Organic materials are transformed into gaseous components and a solid residue (coke) containing fixed carbon and ash.	The target contaminant groups for pyrolysis are SVOCs and pesticides	Chemical contaminants for which treatment data exist include PCBs, dioxins, PAHs, and many other organics.	Pyrolysis is not effective in destroying or physically separating inorganics from the contaminated medium; treated media containing heavy metals may require stabilization.	Applicable to all soils of the site.	Destroys most site COCs; some site soils may be used as backfill.	Requires drying of the soil to achieve a low soil moisture content (<1%); High moisture content increases treatment costs; Needs specific feed size and materials handling requirements; Limited full scale site data. Requires excavation; Soil must be transported off-site and treatment facilities constructed.	$450/cy	Not applicable due to requiring specific feed size and materials handling requirements, and dewatering of soil. Does not destroy metals.	FRTR Screening Matrix Section 4.24 (FRTR 2002)
Off-Site Commercial Disposal										
Containment										
Subtitle D landfill	Off-site disposal at a licensed commercial landfill facility that can accept nonhazardous soil (PCB < 50 mg/kg).	Applicable to site COCs below hazardous waste designations (PCB<50 mg/kg).	Subtitle D landfills are effective for long term, permanent containment of contaminated materials.	COCs contained, but not permanently destroyed.	Applicable to PCB impacted soils < 50 mg/kg PCB.	Excavation implementable at site; local experienced contractors for excavation. Commercially permitted disposers in region: Chemical Waste Management of the Northwest, US Ecology Idaho, U.S. Ecology, Inc. (NV), Chemical Waste Management (CA), Clean Harbors Grassy Mountains (UT) (Source: epa.gov)	Depends on analytical data from excavated soil. Dewatering may be required to reduce water content for transportation. Increased community traffic and noise.	$55/ton (source: Waste Management quote)	Applicable for soils with PCB concentrations < 50 mg/kg.	Boone (2008)
Subtitle C landfill	Off-site disposal at a licensed commercial landfill facility that can accept hazardous soil removed by excavation (PCB>50mg/kg).	Applicable to site COCs exceeding hazardous waste designations (PCB > 50 mg/kg).	Subtitle C landfills are federally-regulated facilities and are highly effective for long-term, permanent containment of highly contaminated materials.	COCs contained, but not permanently destroyed.	Applicable to PCB impacted soils > 50 mg/kg PCB.	Excavation implementable at site; Local experienced contractors for excavation. Commercially permitted disposers in region: Chemical Waste Management of the Northwest, US Ecology Idaho, U.S. Ecology, Inc. (NV), Chemical Waste Management (CA), Clean Harbors Grassy Mountains (UT) (Source: epa.gov)	Depends on analytical data from excavated soil. Dewatering may be required to reduce water content for transportation. Increased community traffic and noise. Expensive.	$210/ton (source: Waste Management quote)	Applicable for soils with PCB concentrations > 50 mg/kg.	Beck (2008)

Table K-1. Review of candidate removal action technologies for the T-117 NTCRA (cont.)

		Effectiveness			Implementability					
Process Option	Brief Description	Contaminants of Concern Typically Treated	Advantages	Disadvantages	Site Conditions	Advantages	Disadvantages	Unit Cost Range	Screening Decision	Citation
Physical										
Separation	Contaminated fractions of solids are concentrated through gravity, magnetic or sieving separation processes.	Applicable to SVOCs, fuels, inorganics, and selected VOCs and pesticides. Only applicable to adsorptive COCs that would adhere to the fine-grained soil.	Full scale, well established technology.	High sampling and analysis costs.	Applicable to all soils at the site.	Will reduce the quantity hazardous waste (PCBs > 50 mg/kg) needed for disposal. Commercially permitted disposers in region or permitted for all EPA regions for physical separation: Terra-Kleen Response Group, Inc. (CA), General electric (NY), Environmental Technology Unlimited Corporation (NC) (Source: epa.gov)	Requires an area at the site for soil storage during separation and sampling; Additional labor for soil pile covering/storage; Additional sampling may be required. Increased traffic in community.	\$100 – \$160/cy	Not applicable: commercial permitted disposers not available in the region.	EPA (2008)
Thermal										
Alternate thermal destruction or incineration	Offsite incineration and disposal at a licensed commercial facility that can accept hazardous soil removed by exca-vation (PCB > 50 mg/kg). Depends on analytical data from excavated soil. Dewatering may be required to reduce water content for transportation.	Applicable to site COCs where concentrations exceed the hazardous waste designation; principally PCBs > 50 mg/kg. Would also be effective at destruction of petroleum waste.	Complete and permanent destruction of site COCs; effective across wide range of soil characteristics.	Fine-grained soil may be difficult to treat; Dewatering may be required prior to treatment; Potential for creation of dioxins and furans during incineration; Off gas treatment necessary.	Applicable to all areas of the site.	Site soils may be used for backfill; Will not affect future site uses. Commercially permitted disposers in region for alternate thermal destruction, incineration: Geosafe Corporation (WA), Clean Harbors Aragonite, LLC (UT) (Source: epa.gov)	Requires excavation of contaminated soils; Soil must be transported off-site and treatment facilities constructed at another property; additional backfill may be necessary due to reduced volume of excavated soil.	\$700 – \$1,100/cy	Applicable for Toxic Substances Control Act (TSCA; PCB >50 mg/kg) material.	EPA (2008)
Chemical										
Dehalogenation	Contaminated soils and the reagent (typically potassium polyethylene glycol) are mixed and heated in a treatment vessel. The reaction causes the polyethylene glycol to replace halogen molecules and render the compound nonhazardous or less toxic.	Applicable to treating the site COCs.	The technology can be used as a standalone technology or in combination with another technology; has been shown to reduce PCB concentration to clean up goals.	High clay and moisture content in soil will increase treatment costs; technology is generally not cost effective for large waste volumes; concentrations of chlorinated organics >5% require large volumes of reagent; waste stream created by process needs disposal.	Applicable to all areas of the site.	Excavation implementable at site; Local experienced contractors for excavation. Technology has been shown to reduce site COCs to clean up goals. Commercially permitted disposers in western US or accepting wastes from all EPA regions for chemical dechlorination: Environmental Protection Services, Inc. (WV), Clean Harbors (PPM), LLC (KS) (Source: epa.gov)	Commercially permitted disposers located prohibitively far away.	\$300 – \$750/ton	Not applicable: commercial permitted disposers not available in the region.	EPA (2008)

BTEX – benzene, toluene, ethylbenzene, and xylene
COC – contaminant of concern
cy - cubic yards
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PSCAA – Puget Sound Clean Air Agency
SVOC – semivolatile organic compound
T-117 – Terminal 117
TPH – total petroleum hydrocarbon
TSCA – Toxic Substances Control Act
FRTR – Federal Remediation Technologies Roundtable
VOC – volatile organic compound

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Table K-1. Review of candidate removal action technologies for the T-117 NTCRA (cont.)

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