**Sitewide Feasibility Study
Eielson Air Force Base, Alaska**

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EXECUTIVE SUMMARY

INTRODUCTION

The Sitewide Feasibility Study (FS) is required under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the National Contingency Plan (NCP), and the Federal Facility Agreement (FFA) for Eielson Air Force Base (AFB). It is based on findings presented in the Sitewide Remedial Investigation (RI) Report (USAF 1995a), and the Sitewide Baseline Risk Assessment (BLRA) Report (USAF 1995b).

Under the FFA, 64 potential source areas were placed in one of six operable units, based on similar contaminant and environmental characteristics, or were included for evaluation under a Source Evaluation Report (SER). The sitewide RI was directed at contamination that was not confined to an operable unit (OU) or SER source area. The objectives of the sitewide RI were to:

- provide information about site characteristics to support individual OU RI/FS efforts and the sitewide RI/FS, including site hydrogeology and determination of background soil and groundwater characteristics;
- identify and characterize contamination that is not confined or attributable to a specific source area through sitewide monitoring of groundwater and surface water;
- evaluate cumulative risks to human health and the environment from contamination on a sitewide basis; and
- provide a mechanism for continued cohesive sitewide monitoring.

To ensure that offsite communities are not negatively affected by site contamination, several surface water bodies and the North Boundary wells were monitored for contamination. The North Boundary Wells were sampled to monitor groundwater quality downgradient of the developed portion of the base. The surface water bodies investigated included: Garrison Slough, French Creek, Moose Creek, Piledriver Slough, Flightline Pond, and Lily Lake.

Results from the sitewide remedial investigation and baseline risk assessment indicate that polychlorinated biphenyl (PCB) contamination found in Garrison Slough presents an increased risk to human health through the ingestion of contaminated fish. All other areas addressed by the sitewide investigation have been determined to present an acceptable risk to human health and the environment (USAF 1995b). Thus, this FS focuses on the evaluation of technologies and alternatives for remediation of the aquatic sediments and fish populations occupying Garrison Slough.

GARRISON SLOUGH CONTAMINATION

Garrison Slough runs through the developed portion of the base and is adjacent to 16 potential contaminant source areas. It receives most of the surface runoff from the developed portion of the base, and may also receive contaminated groundwater from several source areas.

Fuel-related volatile organics, chlorinated solvents, and pesticides were detected at low concentrations ($<2 \mu\text{g/L}$) in surface water. Pesticides up to $11,000 \mu\text{g/kg}$ of 4,4'-DDD, diesel range

organics (DRO) up to 38 mg/kg, and PCBs up to 55,000 $\mu\text{g/kg}$ were detected in sediments. Concentrations of metals in the surface water and sediment were generally within the ranges of background values for groundwater and soil on the base (PNL 1994a).

Sediment samples collected in 1994 confirmed the presence of PCBs (found in an earlier investigation), with the maximum concentration measured 300 m (328 yd) upstream of Arctic Avenue. PCBs were below detection limits in samples collected further upstream. Approximately 240 m (263 yd) downstream, the PCB concentration dropped by an order of magnitude to 3200 $\mu\text{g/kg}$. Another 470 m (514 yd) further downstream, the PCB concentration dropped another order of magnitude to 130 $\mu\text{g/kg}$. The PCB concentration remained at this same order of magnitude near Transmitter Road. This PCB contamination appears to have originated from a point source just south of the Base Civil Engineering Maintenance Shop (perhaps from surface runoff or a past incidental spill).

Results from the BLRA indicate that ingestion and dermal contact with the sediment presents an acceptable risk. However, PCB concentrations in fish occupying lower Garrison Slough pose an excess cancer risk on the order of 10^{-3} , using a recreational land-use scenario. Thus, this stretch of the slough is being considered for remedial action.

REMEDIAL ACTION OBJECTIVES

Remedial action objectives (RAOs) have been developed for lower Garrison Slough based on the general remediation goals defined by CERCLA, the NCP criteria for acceptable risk, and the applicable or relevant and appropriate regulatory requirements (ARARs). The primary goal of remediation is to reduce the potential risk to human health from the consumption of PCB-contaminated fish. This goal can be achieved by:

- Preventing ingestion of contaminated fish from lower Garrison Slough, and
- Reducing the highest concentrations and mass of PCBs available for uptake by water column organisms, including fish, so that fish tissue concentrations of PCBs will eventually achieve acceptable levels.

No direct relationship can be quantified between sediment PCB concentrations and resultant fish tissue concentrations in lower Garrison Slough. However, fish tissue samples with the highest levels of PCBs were collected from areas in the slough with the highest PCB sediment contamination. Thus, a preliminary remediation goal for sediment was developed based on removing most of the mass of PCBs. This approach assumes that removing or isolating the sediment with the highest PCB concentrations and reducing the overall mass available for uptake by water column organisms would, over time, lead to a reduction in the average PCB fish tissue concentration. The RAOs are shown in Table ES.1.

Alternatives

Potential remedial response actions, remedial technologies, and process options were screened to identify the most reasonable actions for fish and aquatic sediments. Alternatives were developed by combining the selected technologies for individual media into comprehensive cleanup alternatives. The alternatives were screened based on a preliminary evaluation of effectiveness, implementability, and cost. Five basic alternatives were retained for further evaluation. They

Table ES.1. Remedial Action Objectives

Medium	Contaminant of Concern	Exposure Route	Receptor	Preliminary Remediation Goal
Fish	PCBs (Aroclor 1260)	Food Chain	Human	0.69 $\mu\text{g}/\text{kg}^{(a)}$ (wet weight)
Sediment	PCBs (Aroclor 1260)	Food Chain	Human (through fish intake)	Reduce the peak concentrations and a preponderance of the PCB mass
(a) Based on a back calculation for the fish tissue concentration that would produce a total excess cancer risk of less than 10^{-6} (recreational exposure).				

include the No Action alternative, a Limited Action alternative, a containment alternative (In Situ Capping), and two removal alternatives (Dredge and Dispose, and Dredge and Treat). Each of these alternatives is briefly described in the following paragraphs.

No Action Alternative

The No Action alternative is required under the NCP to provide a baseline against which other alternatives can be compared. Under this alternative, no further remedial action would be taken. However, environmental monitoring of fish and sediment would be conducted to assess the progress of natural attenuation.

Limited Action Alternative

The Limited Action alternative would use institutional controls to limit current and future ingestion of contaminated fish, and engineering controls to inhibit the migration of fish into contaminated reaches of the slough. A fish advisory or Catch-and-Release-only restrictions would be promulgated by the Alaska State Department of Fish and Game. A rock dam would be constructed downstream from Arctic Avenue to prevent fish from migrating into the contaminated portion of the slough. Monitoring and annual maintenance would be performed to ensure the integrity of the rock dam. Fish and sediment concentrations and distributions would be monitored to track performance of this remedial action.

In Situ Capping Alternative

The In Situ Capping alternative would use temporary institutional controls to limit current ingestion of contaminated fish, and would cap a preponderance of the PCB sediment contamination to inhibit its bioaccumulation in the fish population. A temporary fish advisory or Catch-and-Release-only restrictions would be promulgated by the Alaska State Department of Fish and Game. When the PCB concentrations in the fish population have decreased to RAO levels, the fishing advisory/restrictions would be lifted.

A 300-m (1000 ft) long stretch of lower Garrison Slough, immediately upstream of Arctic Avenue, would be lined with a multilayer cap to isolate PCB contaminated sediment from the ecosystem. This portion of the slough contains ~80% of the mass of the PCB contamination found in the entire slough. Capping would be performed in late summer when surface water flows are their lowest,

and the groundwater table is near its deepest. Surface water would be routed around the capping area to reduce the potential for sediment resuspension and transport, and to make installation of the liner less complicated. After minimal preparation of the stream bed (devegetation and contouring), a permeable geotextile liner would be installed, and covered by successive 10-15 cm (4-6 in.) thick layers of pea gravel; 5 cm diam. very coarse pebble (2 in. drain rock), and finally 5 to 15 cm diam. small cobble (2-6 in. rock). The complete liner is estimated to raise the bed of the slough 30 to 45 cm (12 to 18 in.). Periodic maintenance would be required to maintain the integrity of the cap. Monitoring of fish and downstream sediment concentrations would be performed to ensure the performance of the remedial action.

Dredge and Dispose Alternative

The Dredge and Dispose alternative would use temporary institutional controls to limit current ingestion of contaminated fish, remove a preponderance of the PCB contamination, and dispose of the contaminated sediment on base. A temporary fish advisory or Catch-and-Release-only restrictions would be promulgated, as in the In Situ Capping alternative.

A preponderance of PCB contamination in the sediment would be removed by mechanically dredging approximately 300 m (1000 ft) of Garrison Slough immediately upstream of Arctic Avenue. This portion of the slough contains ~80% of the mass of the PCB contamination. Dredging activities would be performed in late summer when surface water flows are their lowest, and the groundwater table is near its deepest. Surface water would be routed around the targeted dredging area to reduce the potential for sediment resuspension and transport, and to reduce the amount of water picked up during the dredging operation. A large backhoe would excavate the sediment to a depth of approximately 0.6 m (2 ft) plus a 10% over dig. This operation would produce an estimated 660 m³ (860 cu yd) of dredged material which would be placed into dump trucks. The dredged sediment would then be hauled to an on-base landfill and disposed directly to an unlined trench, covered with native soils, and revegetated. The use of a hydraulic dredge was also evaluated, but would produce a high water-to-solids ratio, necessitating the treatment of large amounts of water. Monitoring of fish and downstream sediment concentrations would be performed to ensure the performance of the remedial action.

Dredge and Treat Alternative

The Dredge and Treat alternative would use temporary institutional controls to limit current ingestion of contaminated fish, remove a preponderance of the PCB contamination, and treat the contaminated sediment on base. A temporary fish advisory or Catch-and-Release-only restrictions would be promulgated as in previous alternatives.

A preponderance of PCB contamination in the sediment would be removed, as in the Dredge and Dispose alternative. The dredged material would be hauled to an existing on-base land farming facility. The dredge material would be evenly spread over a 15 cm (12 in.) thick bed of soil amendments (straw or sawdust) and inoculated with white rot fungus (*Phanerocheate Chrysosporium*) and nutrients. The sediment, soil amendments, and nutrients would then be tilled and evenly mixed. The addition of soil amendments is estimated to increase the volume of the waste materials by a factor of 2. Land farming would degrade the PCBs to carbon dioxide over several months to years. Following treatment, the clean soil would be left in place. Monitoring of fish and downstream sediment concentrations would be performed to ensure the performance of the remedial action.

EVALUATION

A detailed analysis of the remedial alternatives was conducted to evaluate each potential alternative against the seven NCP criteria. A comparative analysis was also made using the five NCP balancing criteria. A visual presentation of the comparative analysis is shown in Table ES.2. The estimated cost for each alternative is presented in Table ES.3.

The individual analyses indicated the No Action alternative would not achieve the RAOs, at least not for tens of years (via natural attenuation).

The Limited Action alternative would rely on institutional controls to meet the RAO for fish tissue. However, it would not meet the RAO for sediment (except through natural attenuation). The rock dam would essentially eliminate the upper reaches of the slough for spawning and other productive use.

Table ES.2. Comparison of Remedial Action Alternatives Using the Five Balancing Criteria

Criterion	No Action	Limited Action	In Situ Capping	Dredge and Dispose	Dredge and Treat
Long-Term Effectiveness and Permanency	○	○	⊙	◐	●
Reduction of Toxicity, Mobility, and Volume Through Treatment	○	○	○	○	◐
Short-Term Effectiveness	○	⊙	◐	●	●
Implementability	NA	●	⊙	●	◐
Cost	●	◐	○	⊙	⊙
Legend: best = ● good = ◐ poor = ⊙ worst = ○ NA = Not Applicable					

Table ES.3. Summary of Estimated Costs

Alternative	Capital Cost	Present Worth of Annual Operations and Maintenance Cost ^(a)	Present Worth of Annual Monitoring Cost ^(a)	Total Present Worth Cost ^(a)
NO ACTION	\$0	\$0	\$98,000	\$98,000
LIMITED ACTION	\$11,000	\$31,000	\$98,000	\$140,000
IN SITU CAPPING	\$182,000	\$33,000	\$75,000	\$290,000
DREDGE AND DISPOSE	\$164,000	\$0	\$27,000	\$191,000
DREDGE AND TREAT	\$139,000	\$51,000	\$27,000	\$217,000
(a) Present worth, assuming 30 years at 5 percent.				

In Situ Capping would effectively meet the RAOs over the short term by isolating the contaminants in situ, and inhibiting the mobility of the PCBs into the food chain. However, it would require continual monitoring and annual maintenance. Thus, its long-term effectiveness is uncertain and relative costs are high. In addition, it would destroy the existing stream bed and local ecosystem and raise the base level of the stream.

Both removal alternatives, Dredge and Dispose and Dredge and Treat, would effectively meet the RAOs by removing ~80% of the PCB contamination from the slough. Dredging would have a short-term adverse affect on the stream bed and the local ecosystem. Only the Dredge and Treat alternative would permanently reduce the volume and toxicity of the PCBs (via biological dechlorination).

LIST OF ACRONYMS

AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
AFB	Air Force Base
ARAR	Applicable or relevant and appropriate requirements
AWQC	Ambient water quality criteria
BTEX	benzene, toluene, ethylbenzene, and xylene
BLRA	Baseline Risk Assessment
C	Centigrade
CE	Civil Engineers
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DCE	Dichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DRO	diesel range organics
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
FFA	Federal Facility Agreement
FNSB	Fairbanks North Star Borough
FS	Feasibility Study
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
KEPG	potassium polyethylene glycol
MCL	maximum contaminant level
NCP	National Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
O&M	Operations and Maintenance
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
OUUU	Ozone, Ultraviolet, Ultrasonic Water process
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyl
PEL	permissible exposure limits
PNL	Pacific Northwest Laboratory
PRG	Preliminary Remediation Goal
RAO	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
SARA	Superfund Amendments and Reauthorization Act
SER	Source Evaluation Report
SQC	Sediment Quality Criteria
TBC	To Be Considered
TCE	Trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TSCA	Toxic Substances Control Act
USAF	United States Air Force
VOC	Volatile Organic Compound

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1.0 INTRODUCTION

The Sitewide Feasibility Study (FS) is required under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the National Contingency Plan (NCP), and the Federal Facility Agreement (FFA) for Eielson Air Force Base (AFB).

The remedial investigation/feasibility study (RI/FS) process provides an opportunity for early selection of final remedies for specific source areas. The sitewide RI/FS is a streamlined set of documents prepared in response to the request from the U.S. Air Force (USAF), U.S. Environmental Protection Agency (EPA), and Alaska Department of Environmental Conservation (ADEC) Remedial Project Managers for a narrowly focused evaluation of contamination that is not confined or attributed to a specific operable unit or other source area evaluation group.

The sitewide FS is based on the findings presented in the following documents:

- Surface Water and Sediment Investigation Draft Report (USAF 1994d)
- Screening Baseline Risk Assessment (USAF 1994a)
- Biological Risk Assessment (USAF 1995d)
- Technical Memo: "Preliminary Assessment of PCB Sediment Contamination in Garrison Slough"^(a)
- Sitewide Remedial Investigation (RI) Report (USAF 1995a)
- Sitewide Baseline Risk Assessment (BLRA) Report (USAF 1995b)

1.1 SITEWIDE BACKGROUND AND HISTORY

Eielson AFB encompasses approximately 8000 hectares (19,770 acres) in interior Alaska, 160 km (99 mi) south of the Arctic Circle (Figure 1.1). In carrying out its defense mission, contamination of the soils and groundwater at the base has resulted from the storage and handling of fuels, oils, and solvents, plus the operation of landfills. Initially this contamination was evaluated under the U.S. Air Force Installation Restoration Program (IRP). In 1982, the IRP was initiated with a record search to identify past disposal sites containing contaminants that may pose a hazard to human health or the environment.

Under the IRP, the U.S. Air Force identified 64 potential areas of contamination at Eielson AFB. These potential source areas include old landfills, storage and disposal areas, fueling system leaks, and spill areas.

(a) Technical Memo. "Preliminary Assessment of PCB Sediment Contamination in Garrison Slough, Eielson Air Force Base, Alaska." Prepared by the Pacific Northwest Laboratory, Richland, Washington, for the U.S. Air Force Environmental Restoration Program, Eielson Air Force Base, Alaska. Pacific Northwest Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

Figure 1.1. Regional Location Map

Eielson AFB was listed on the National Priorities List (NPL) (54 Fed. Reg. 48184) on November 21, 1989 by the EPA. This listing designated the facility as a federal Superfund site subject to the remedial response requirements of CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA).

In May 1991, the U.S. Air Force, the State of Alaska, and the EPA entered into an FFA (EPA et al. 1991) that established the procedural framework and schedule for developing, implementing, and monitoring CERCLA response actions. Under the FFA, the 64 potential source areas were placed in one of six operable units (OUs), based on similar contaminant and environmental characteristics, or were included for evaluation under a Source Evaluation Report (SER).

The sitewide remedial investigation (RI) of Eielson AFB investigated contamination that was not confined to an OU or SER source area. Sitewide issues will be addressed in a Sitewide Record of Decision. The objectives of the sitewide RI were to:

- provide information about site characteristics to support individual OU RI/FS efforts and the sitewide RI/FS, including site hydrogeology and determination of background soil and groundwater characteristics;
- identify and characterize contamination that is not confined or attributable to a specific source area through sitewide monitoring of groundwater and surface water;
- evaluate cumulative risks to human health and the environment from contamination on a sitewide basis; and
- provide a mechanism for continued cohesive sitewide monitoring.

The main base is located in the Tanana River Valley, about 5 km (3 mi) east of the river. Tributaries flowing through Eielson AFB include: Piledriver Slough to the west, Moose Creek to the east, French Creek to the northeast and Garrison Slough, which flows through the developed portion of the base (Figure 1.2).

To ensure that offsite communities are not negatively affected by site contamination, several surface water bodies and the North Boundary wells have been monitored for contamination. The North Boundary Wells are sampled annually to monitor groundwater quality downgradient of the developed portion of the base. The surface water bodies included in this assessment are:

- Garrison Slough
- French Creek
- Moose Creek
- Piledriver Slough
- Flightline Pond
- Lily Lake

Figure 1.2. Surface Drainage Map

1.2 NATURE AND EXTENT OF CONTAMINATION

The sitewide RI investigated contamination in groundwater, surface water, sediment, and aquatic biota. Contamination in excess of natural background levels was not identified in groundwater at the downgradient (north) edge of the base (USAF 1992; USAF 1994c; USAF 1995c).

Surface water bodies at or in the vicinity of Eielson AFB cross OU boundaries and may have been affected by contaminants from past base activities. Garrison Slough is the most likely surface water body to have been affected by contamination because it is near 16 potential contaminant source areas, and because it receives most of the surface runoff from the developed portion of the base. Garrison Slough may also receive contaminated groundwater from several source areas.

Consequently, past investigations of surface water and sediment quality have focused on Garrison Slough. Few water samples were collected from French Creek, Piledriver Slough, or other surface water bodies during the 1988 through 1990 IRP investigations. Surface water and sediment at selected locations have been sampled by the U.S. Air Force's Bioenvironmental Engineering Services at Eielson AFB since April, 1992. Additional information about the surface water and sediment quality was collected in 1993 (USAF 1994d) and 1994^(a) (USAF 1995a) to assess the risk to human health and the environment. That investigation was performed in conjunction with the biological risk assessment (USAF 1994e), and included Garrison Slough, French Creek, Moose Creek, Piledriver Slough, Flightline Pond, and Lily Lake (USAF 1994d).

Results from these investigations indicate that Garrison Slough has been the most affected by base activities. The other surface water bodies show only traces of contamination. Concentrations of metals in water and sediment samples were within the ranges of background values for groundwater and soil at Eielson AFB. A brief description of the nature and extent of contamination found in surface water bodies at or in the vicinity of Eielson AFB is presented in following paragraphs.

1.2.1 Garrison Slough

Garrison Slough shows the greatest impact from base activities. Fuel-related volatile organics, chlorinated solvents, and pesticides were detected in surface water. Pesticides, diesel range organics (DRO), and polychlorinated biphenyls (PCBs) were detected in sediments. Concentrations of metals in water and sediment were generally within the ranges of background values for groundwater and soil on the base (USAF 1994d).

Fuel-Related Compounds. Fuel-related compounds (benzene and ethylbenzene) were detected at low concentrations (less than or equal to 2.6 $\mu\text{g/L}$) in surface water samples from the entire length of Garrison Slough. The most likely source of these compounds is contaminated groundwater discharging to the slough from one or more adjacent source areas (e.g., LF03/FT09, ST48) (USAF 1994a).

(a) Technical Memo. "Preliminary Assessment of PCB Sediment Contamination in Garrison Slough, Eielson Air Force Base, Alaska." Prepared by the Pacific Northwest Laboratory, Richland, Washington for the U.S. Air Force Environmental Restoration Program, Eielson Air Force Base, Alaska.

Chlorinated Solvents. Trichloroethylene (TCE) was detected in all water samples from Garrison Slough, except at sampling station GS00 (Figure 1.3). The maximum concentration ($0.8 \mu\text{g/L}$) was detected at station GS06, near the fire training area, in 1992. Cis-1,2-DCE was detected at all stations except GS04 and GS06, with the maximum concentration ($2.2 \mu\text{g/L}$) detected at GS05. Possible sources of these compounds are contaminated groundwater discharging to the slough from source areas LF03, ST18, and ST48.

Diesel Range Organics. DROs were detected in sediment samples with concentrations ranging from 14 mg/kg to 38 mg/kg at four of seven sampling stations. Potential sources for DRO include surface runoff from roads, the runway, and adjacent source areas.

Pesticides. Low concentrations of pesticides (4,4'-DDD, 4,4'-DDE, and delta-BHC) were detected in surface water from Garrison Slough at a maximum concentration of $0.052 \mu\text{g/L}$. The pesticides 4,4'-DDT, 4,4'-DDD, 4,4'-DDE, endosulfan sulfate, and delta-BHC were detected in sediment samples at a maximum concentration of $170 \mu\text{g/kg}$. Fish tissue samples also contained detectable concentrations of pesticides, including DDT isomers, its metabolites, hexachlorobenzene, and dieldrin. The pesticides were probably introduced by the routine application of pesticides at the base.

Polychlorinated Biphenyls. PCBs with a maximum concentration of $7650 \mu\text{g/kg}$ were detected in 6 of 11 sediment samples collected near Arctic Avenue in 1990 (HLA 1991). Sediment samples collected in 1994 confirmed the presence of PCBs, with a maximum concentration of $55,000 \mu\text{g/kg}$ measured at sampling station GS12 near Building 2350 (Figure 1.3)^(a). PCBs were not detected upstream of station GS12. Approximately 240 m (260 yd) downstream, the PCB concentration dropped by an order of magnitude to $3200 \mu\text{g/kg}$ (at GS07). At GS09, approximately 470 m (503 yd) further downstream, the PCB concentration dropped another order of magnitude to $130 \mu\text{g/kg}$. The PCB concentration was on the same order of magnitude ($230 \mu\text{g/kg}$) at Transmitter Road (GS06). This PCB contamination appears to originate (perhaps from surface runoff or an incidental spill) from a point source just south of Building 2350, which houses a vehicle maintenance shop. Aroclor 1260 was above detection limits in fish tissue samples collected from throughout Garrison Slough, with the highest concentrations ($3000 \mu\text{g/kg}$ wet weight) collected from lower Garrison Slough. Aroclor 1260 was also detected in invertebrates collected from lower Garrison Slough.

1.2.2 French Creek

Surface water samples from French Creek showed traces of pesticides (4,4'-DDD, 4,4'-DDE, and dieldrin). Methylene chloride was detected at a concentration of less than $1 \mu\text{g/L}$ in one sample; its presence is probably due to laboratory contamination. DRO were detected at a concentration of 11 mg/kg in the sediment sample collected adjacent to source area LF02.

One of four fish tissue samples collected from French Creek near Quarry Road, and two of four samples from lower French Creek contained detectable levels of PCB (Aroclor 1260). The respective maximum concentrations were 28.9 and $24.6 \mu\text{g/kg}$ wet weight. Aroclor 1260 was the

(a) Technical Memo. "Preliminary Assessment of PCB Sediment Contamination in Garrison Slough, Eielson Air Force Base, Alaska". Prepared by the Pacific Northwest Laboratory, Richland, Washington, for the U.S. Air Force Environmental Restoration Program, Eielson Air Force Base, Alaska.

principal contributor to the total cancer risk for the locations 4E-05 and 5E-05 (USAF 1995b). DDT isomers and its metabolites were also detected in fish tissue samples from French Creek.

1.2.3 Moose Creek and Piledriver Slough

Moose Creek and Piledriver Slough appear to be almost free of contamination. No contaminants were detected in surface water from Moose Creek (collected downstream of its confluence with French Creek). Only a trace of tetrachloroethylene ($0.071 \mu\text{g/L}$) was detected in surface water from Piledriver Slough (sampling station PS01). The tetrachloroethylene may have derived from source area LF01, although it was not detected in groundwater collected from a monitoring well located between LF01 and the slough.

DRO and diethylphthalate were detected in the Moose Creek sediment sample at concentrations of 12mg/kg and $460 \mu\text{g/kg}$, respectively. The source of DRO may be upstream sediment or the adjacent roadway. The diethylphthalate is probably a laboratory contaminant; phthalate esters are used as plasticizers and are common laboratory contaminants.

One of four fish tissue samples collected from Piledriver Slough contained detectable levels of PCBs (Aroclor 1260); $17.6 \mu\text{g/kg}$ wet weight. This sample was the principal contributor to the total cancer risk of $3\text{E}-05$ (USAF 1995b). The source of PCBs in the one fish tissue sample from Piledriver Slough has not been identified.

DDT isomers, its metabolites, and hexachlorobenzene were also detected in fish tissue samples from Piledriver Slough, as well as from upper Moose Creek (excluding hexachlorobenzene).

1.2.4 Flightline Pond and Lily Lake

The only contaminant detected in the water sample from Flightline Pond was a trace of the pesticide delta-BHC. The sediment from Flightline Pond contained DRO at a concentration of 41 mg/kg and 10 PAHs at a maximum concentration of $2600 \mu\text{g/kg}$ (pyrene). The hydrocarbons probably originated from jet exhaust from the runway south of the pond. No contaminants were detected in the water sample from Lily Lake (USAF 1995a). The sediment sample contained 11 mg/kg DRO and 5 PAHs at a maximum concentration of $1400 \mu\text{g/kg}$ (pyrene) (USAF 1995a).

1.3 SITE CHARACTERISTICS AND SPECIAL CONSIDERATIONS

Eielson AFB is located within the Fairbanks North Star Borough (FNSB) approximately 40 km (25 mi) southeast of Fairbanks and 26 km (16 mi) southeast of the city of North Pole, Alaska, along the Richardson Highway (Figure 1.1). Approximately 1477 hectares (3650 acres) of the base are improved or partially improved with the remaining land encompassing forest, wetlands, lakes, and ponds. The base is bounded on the east and south by Fort Wainwright, a U.S. Army installation, and on the west and north by private and public land. The base is isolated from major urban areas with the adjacent public and private land zoned for general use. The approximate population of the FNSB, Fairbanks, and North Pole is 82,000, 32,000, and 1600, respectively. Other communities near Eielson AFB include Moose Creek, which abuts the northern border of the base, and the Salcha area, which abuts the southern border of the base.

Figure 1.3. Surface Water and Sediment Sampling Locations (1994)

The main base is located in the Tanana River Valley, about 5 km (3 mi) east of the river. Regional drainage is northwestward into the Tanana River, which flows into the Yukon River. Tributaries flowing through Eielson AFB include: Piledriver Slough to the west, Moose Creek to the east, and French Creek to the northeast. Garrison Slough flows from the south to north through the developed portion of the base (Figure 1.3).

The climate is characterized by large diurnal and seasonal temperature variations, low precipitation, and low humidity. Average summer temperatures range between 7 and 16° Centigrade (C) (44.6 and 60.8°F).

Average winter temperatures range between -26 and -13°C (-14.8 and -8.6°F). The extreme temperatures recorded since 1944 are a high of 33°C (91.4°F) in June and -53°C (-63.4°F) in January. The average annual precipitation is 36 cm (14.2 in.), which includes 180 cm (70.9 in.) of snow. Average monthly precipitation ranges from 1.3 cm (0.5 in.) to 6.4 cm (2.5 in.). The greatest rainfall usually occurs in July and August.

The developed portion of the base, which has been constructed on fill material, is underlain by a shallow, unconfined aquifer comprised of 60 to 90 m (65.6 to 98.4 yd) of loose alluvial sands and gravel overlying relatively low-permeability bedrock. The aquifer is characterized by high transmissivities and relatively flat groundwater gradients. Depth to the top of the unconfined aquifer ranges between 1.5 and 4.5 m (1.6 to 4.9 yd). The groundwater generally flows to the north-northwest with the direction of flow locally influenced by Garrison Slough and groundwater extraction from the base supply wells. Garrison Slough is believed to be lower than the water table throughout the year over most of the slough's length, acting as a drain for the shallow aquifer (PNL 1993b).

Groundwater is the only source of potable water at the base and in the nearby communities. The water contains high background concentrations of metals, including arsenic (<5 to 10 µg/l), iron (<20 to 9,000 µg/l), magnesium (4,000 to 20,000 µg/l), and manganese (<10 to 4,000 µg/l) (USAF 1992). Potable water in the main base water distribution system is treated to remove iron and sulfide. Groundwater is also the principal water source for various other industrial, domestic, agricultural, and firefighting uses.

Eielson AFB facilities are actively used by the Alaskan Air Command in support of the strategic defense mission of the USAF. Site contamination is largely the result of past fuel spills and leaks from fuel loading, unloading, storage, and distribution activities. These fuel handling activities remain vital to the ongoing mission of the base and will actively continue as part of future base operations. Remediation in active areas will be coordinated, to the extent feasible, with ongoing base activities, including maintenance and construction.

It is also extremely important that fuel handling activities do not continue to serve as a source of release to the environment. Any active leaks need to be identified and corrected before beginning remediation of contaminated soils, floating fuel, or groundwater. For the purpose of preparation of the sitewide FS, it has been assumed that active fuel handling and storage activities will be conducted in accordance with applicable requirements.

1.4 SCOPE OF THE SITEWIDE FEASIBILITY STUDY

The sitewide FS is a streamlined feasibility study that focuses on the evaluation of technologies that provide the most viable alternatives for remediation of aquatic sediments and fish populations in

lower Garrison Slough. The alternatives proposed in this FS are designed to address PCB contaminated sediments and fish populations as described in Section 1.2.

All other areas addressed by the sitewide remedial investigation have been determined to present an acceptable risk to human health and the environment (USAF 1995b).

2.0 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

This section presents the development of RAOs for the contaminated portions of Garrison Slough. The RAOs have been developed using the general remediation goals defined by CERCLA, the findings presented in the Surface Water and Sediment Investigation Draft Report (USAF 1994d), the Preliminary Assessment of PCB Sediment Contamination in Garrison Slough^(a), the Sitewide RI Report (USAF 1995a), the Screening Baseline Risk Assessment (USAF 1994a), the Biological Risk Assessment (USAF 1995d), the Baseline Risk Assessment (USAF 1995b), and applicable or relevant and appropriate regulatory requirements (ARARs).

2.1 CERCLA GOALS

General remediation goals for cleanup of releases of hazardous substances have been defined by CERCLA and are implemented through the requirements of the NCP. The NCP establishes an evaluation process for selection of remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste. Remedial actions, where hazardous substances remain on site, must also attain the requirements promulgated under federal or state statutes that are applicable or relevant and appropriate. The ARARs may apply to remediation of a specific media (soils, surface water, or groundwater) or may apply to a specific action. CERCLA Section 121(d) states that a remedial action will attain the standard of control established under the Safe Drinking Water Act. EPA has included the expectation that contaminated groundwaters will be returned to their beneficial uses wherever practicable, within a time frame that is reasonable for the circumstances of the site. If groundwater can be used for drinking water, CERCLA remedies should, where practicable, restore the groundwater to attain drinking water standards.

The objectives for the remedial action are developed early in the remedy selection process. The RAOs specify the contaminants and media of concern, the potential exposure pathways, and the preliminary remediation goals. The preliminary remediation goals (PRGs) identify acceptable exposure levels that will be protective of human health and the environment. The goals are developed through consideration of potential health and environmental risk and the identified ARARs.

The purpose of the remedy selection process is to implement remedies that eliminate, reduce, or control risks to human health and the environment [40 CFR 300.430(a)(1)]. The NCP identifies the following as acceptable risk to human populations:

- For noncarcinogens, an acceptable exposure is one to which human populations, including sensitive subgroups such as children and pregnant women, may be exposed without adverse effects during a lifetime or a part of a lifetime, incorporating an adequate margin of safety.

(a) Technical Memo. "Preliminary Assessment of PCB Contamination in Garrison Slough, Eielson Air Force Base, Alaska." Prepared for the U.S. Air Force Environmental Restoration Program, by the Pacific Northwest Laboratory, Richland, Washington.

- For carcinogens, EPA has set a remedial goal for total risk that represents an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} .

2.2 FINDINGS OF THE BASELINE RISK ASSESSMENT

The Sitewide Screening Baseline Risk Assessment (USAF 1994a) and the Sitewide Baseline Risk Assessment (USAF 1995b) provide an evaluation of the potential current and future risks from contaminants in surface water bodies at or in the vicinity of Eielson AFB.

Risk estimates were calculated using a recreational land-use scenario that was developed for the OU 3, 4, and 5 BLRA (USAF 1994b). This conservative scenario considers a sensitive subgroup (children) wading, playing, and fishing in surface water bodies and along their banks. Assuming these recreational activities for the land use, the following exposure pathways were considered:

- Ingestion of surface water
- Dermal contact with surface water
- Incidental ingestion of sediments
- Dermal contact with sediments
- Ingestion of fish.

Recreational land-use has been divided into two exposure scenarios - current and future. The current recreational child is assumed to be on-base for three years, which is consistent with movement of dependents. The future recreational child is assumed to play on-base for 12 years.

The recreational scenario provides for 60 days per year of exposure at surface water bodies. This assumes that a child spends 30 days fishing and 30 days playing in sediments. The figure of 30 days per year is used to represent children spending about 20 percent of their available summertime days at the slough. On the days spent fishing, fish are caught, taken home, and eaten by the child (300 grams per day). While at the surface water body, the child drinks 0.5 L of the surface water per day. It was assumed that children will be exposed to surface water sediments on their hands, arms, feet, and lower legs, representing surface areas averaging 2756 m² for 6-year-old children and 4800 m² for 12-year-old children.

The excess cancer risk and the Hazard Index for each surface water body are presented in Table 2.1. This table presents the values for both the current and future recreational land-use exposure scenarios. In addition, this table indicates the percentage of the risk due to the PCB concentrations in fish tissue. This table indicates that the highest excess cancer risk and hazard index values are associated with Garrison Slough, primarily lower Garrison Slough. A large percentage of these risk values (on the order of 80 to 90%) is due to the concentration of PCBs in fish tissue samples. Table 2.2 summarizes the cancer risk and hazard index for lower Garrison Slough and indicates the primary exposure pathway is through the ingestion of fish.

Thus, the sitewide FS is focused towards remediating the source of PCBs found in lower Garrison Slough (USAF 1995a), and towards reducing/removing the primary exposure pathway (ingestion of fish).

Table 2.1. Summary of Baseline Risk Assessment Results (USAF 1995b)

Site	Current Recreational Land Use		Future Recreational Land Use		PCB Contribution	
	Total Hazard Index	Total Cancer Risk	Total Hazard Index	Total Cancer Risk	Cancer	Hazard Index
Background						
Chatanika River	<1E-07	<1E-02	<1E-07	<1E-02	0%	0%
Upper French Creek	1E-06	2E-02	3E-06	1E-02	0%	0%
Offsite Monitoring						
Piledriver Slough	9E-06	1E+00	3E-05	90E-01	85%	99%
Grayling Lake	2E-07	<1E-02	6E-07	<1E-02	0%	0%
Hidden Lake	3E-07	<1E-02	1E-06	<1E-02	0%	0%
28 Mile Pit	<1E-07	<1E-02	2E-07	<1E-02	0%	0%
Garrison Slough						
Upper	6E-05	7E+00	2E-04	6E+00	81%	98%
Middle	5E-05	3E+00	2E-04	2E+00	31%	90%
Lower	1E-03	2E+02	4E-03	2E+02	98%	100%
Transmitter Road	4E-07	1E-02	3E-07	1E-02	0%	0%
Moose Creek Confluence	9E-05	1E+01	3E-04	1E+01	94%	99%
French Creek						
Quarry Road	1E-05	2E+00	4E-05	1E+00	91%	99%
FC02	1E-04	4E+00	5E-07	<1E-02	0%	0%
Lower	2E-05	2E+00	5E-05	2E+00	73%	86%
Other On-Site Surface Water						
Flightline Pond	3E-07	<1E-02	1E-06	<1E-02	0%	0%
Lily Lake	<1E-07	<1E-02	1E-06	<1E-02	0%	0%
Upper Moose Creek	2E-06	1E-01	8E-06	8E-02	0%	0%
Groundwater						
North Boundary Wells	<1E-07	<1E-02	<1E-07	<1E-02	0%	0%
Note: The contributions from the site background metals are subtracted from these totals.						

Table 2.2. Cancer Risk and Hazard Index at Lower Garrison Slough (USAF 1995b)

Exposure Pathway	Land Use Scenario					
	Current Recreational		Future Recreational		Future Residential	
	Cancer Risk	Hazard Index	Cancer Risk	Hazard Index	Cancer Risk	Hazard Index
Ingestion of fish	1E-03	2E+02	4E-03	2E+02	NC	NC
Ingestion of surface water	<1E-07	<1E-02	<1E-07	<1E-02	NC	NC
Dermal contact with surface water	<1E-07	<1E-02	<1E-07	<1E-02	NC	NC
Ingestion of sediments	1E-05	2E+00	3E-05	1E+00	NC	NC
Dermal contact with sediments	4E-06	6E-01	1E-05	5E-01	NC	NC
Ingestion of groundwater	NA	NA	NA	NA	NA	NA
Dermal contact with groundwater	NA	NA	NA	NA	NA	NA
Summation for all exposure pathways	1E-03	2E+02	4E-03	2E+02	NA	NA
Summation - site background metals	1E-03	2E+02	4E-03	2E+02	NA	NA
Note: The reasonable maximum exposure case is used for future residential land use scenario. NC: Not analyzed because the pathway was not considered complete under this land use scenario. NA: Chemical data for this medium was not available.						

2.3 CHEMICALS OF CONCERN

Site contamination at Eielson AFB is due to past base activities that dictate, in turn, the potential contaminants of concern. The principal contaminants of concern are:

- Benzene, toluene, ethylbenzene, and xylene (BTEX) and lead, which are components of fuels that have been leaked or spilled
- Chlorinated solvents that have been leaked, spilled, or discarded
- PAHs that have resulted from the incomplete combustion of hydrocarbons
- Pesticides that have been applied at the base
- PCBs that have been used and stored at the base.

Elevated levels of inorganic chemicals (such as, arsenic, manganese) have been noted in the soils and waters of the base. The OU 2 BLRA (USAF 1993) presents evidence indicating these elevated levels are not due to base activities. Thus, they have not been considered in this FS.

The chemicals of concern for the Garrison Slough area based on recent findings. Those chemicals presented in the Surface Water and Sediment Investigation Draft Report (USAF 1994d), the RI (USAF 1995a), the Screening Baseline Risk Assessment - (USAF 1994a), and the Biological Risk Assessment (USAF 1995d) are summarized in Table 2.3. However, based on the Baseline Risk Assessment (USAF 1995b) PCBs in sediment and fish are the real risk drivers and, thus, are the only target contaminants to be further evaluated for remediation.

2.4 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

SARA requires that remedial actions at Superfund sites achieve a cleanup level that protects human health and the environment. In addition, cleanups must attain legally the ARARs, which are promulgated under federal or state law, unless a waiver is warranted.

Nonpromulgated advisories or guidance are referred to as to-be-considered criteria (TBCs) that may also be incorporated into the evaluation of potential remedies. Superfund remedies are not required to meet TBCs, but they may be used in the selection of remedies in the absence of applicable or sufficiently protective ARARs.

There are three general types of ARARs: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs are usually health- or risk-based concentration limits for specific hazardous substances in various environmental media (such as, water and soils). Location-specific ARARs impose restrictions on certain types of activities, based on site characteristics. Action-specific ARARs are requirements triggered by the type of remedial activities under consideration. Federal and state environmental laws often do not neatly fall into a single category.

The sitewide RI has identified contaminants in surface water, sediment, and aquatic biota at Eielson AFB. The nature and magnitude of the risks to human health and the environment from the contaminants are evaluated in the sitewide biological and human health BLRAs.

Potential chemical, location, and action-specific ARARs for remedial actions considered in this FS are discussed as follows.

Table 2.3. Chemicals of Concern for Garrison Slough

Sediment	Surface Water	Fish
PCBs	Pesticides	PCBs
Pesticides		Pesticides
		PAHs

2.4.1 Chemical-Specific Requirements

Chemical-specific ARARs for groundwater, surface water, and petroleum-contaminated soils identified for Eielson AFB are described in the following paragraphs.

Groundwater. At Eielson AFB, the aquifer system is used as a drinking water supply. Drinking water standards apply to the point of use and not to the aquifer. However, the federal (40 CFR 141) and state (18 ACC 80) drinking water standards may be considered relevant and appropriate to the aquifer. Drinking water standards are listed in Table 2.4. The only MCLs that are typically exceeded by groundwater at Eielson AFB are those for manganese and iron. High manganese, arsenic, and iron concentrations are typical of background conditions for Eielson AFB and the Fairbanks area (USAF 1995a).

Groundwater is protected in accordance with the Alaska Water Quality Standard (18 ACC 70). Groundwater is protected for Class (1)(A), water supply. Standards for toxic and deleterious substances, petroleum hydrocarbons, and oil and grease are identified in Table 2.5.

Surface Water. Section 304 of the Clean Water Act required EPA to establish criteria for water quality that will lead to the protection of human health and aquatic life. These criteria were derived from the evaluation of the latest scientific knowledge on the kind and extent of all identifiable effects of a contaminant in water, including effects on invertebrates, fish, wildlife, plants, and humans.

The EPA ambient water quality criteria (AWQC) for contaminants identified in surface water during the sitewide RI are listed in Table 2.4. Table 2.4 also includes the highest surface water concentrations measured at Eielson AFB in 1993 and 1994. Arsenic and manganese exceeded the human health criteria at all locations except Piledriver Slough and Flightline Pond, and iron exceeded the freshwater chronic AWQC and human health criteria everywhere except at Piledriver Slough and Flightline Pond. As noted previously, iron, manganese, and arsenic concentrations are typical of background conditions at Eielson AFB. The detection limits for some metals (antimony, cadmium, and silver) exceeded some of the AWQC.

Benzene slightly exceeded the value for the protection of human health (consumption of water and organisms) at one location (GS01) in one year (1993). Other Volatile Organic Compounds (VOCs) were below AWQC. Where detected, the pesticides 4,4'-DDD and 4,4'-DDE exceeded the human health AWQC. The pesticide 4,4'-DDD was detected at six Garrison Slough and two French Creek stations, and 4,4'-DDE was detected at four Garrison Slough stations (USAF 1995a). Dieldrin exceeded the freshwater chronic AWQC and the human health criteria at FC02 in 1993. Dieldrin was not detected at this site in 1994 (detection limit [DL] = 0.1 µg/L).

The State of Alaska has promulgated water quality criteria for specific classes of protected water use, and has adopted a nondegradation policy for waters of higher quality than the criteria (18 AAC 70). The Alaska water quality standards that pertain to the contaminants of concern identified in surface water at Eielson AFB are listed in Table 2.5. Surface waters at Eielson AFB are protected for Classes (1)(A) Water Supply, (1)(B) Water Recreation, and (1)(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife. For most classes of water use, concentrations of toxic and deleterious substances may not exceed Alaska drinking water standards, or where those standards do not exist, EPA water quality criteria (Table 2.4). Surface waters at Eielson AFB do not exceed drinking water standards, with the exception of arsenic, iron, and manganese (secondary standards). EPA human health water quality criteria are exceeded for

Table 2.4. EPA Ambient Water Quality Criteria for Contaminants Identified in Surface Water at Eielson AFB

Contaminant	Maximum Concentration (µg/L)	Location, Year	Concentration (µg/L)				Drinking Water Standard (MCL) ^(b)
			Freshwater Aquatic Life Criteria ^(a)		Human Health, 10 ⁻⁶ Risk for Carcinogens ^(a)		
			Acute	Chronic	National Toxics Rule		
					Water and Organisms	Organisms Only	
Antimony	<69.4	NA	NA ^(d)	NA	14	4300	6
Arsenic	17	GS02, 1993	360 (As III)	190 (As III)	0.018	0.14	50
Barium	210	GS00, 1993	NA	NA	2000 (MCL)	NA	2000
Beryllium	1.4	MC01, 1993	NA	NA	W ^(d)	W	4.0
Cadmium	<4.7	NA	1.79	0.66	W	W	5.0
Chromium	6.1	FCBG, 1993	984 (Cr III) 16 (Cr VI)	117 (Cr III) 11 (Cr VI)	W	W	100
Copper	3.8	FCBG, 1993	9.22	6.54	1300	NA	1300 ^(d) 1000 SMCL ^(f)
Iron	8200	GS02, 1993	NA	1000	300 (SMCL)	NA	300 SMCL
Lead	0.91	GS00, 1993	33.78	1.32	W	W	15 ^(d)
Manganese	1900	GS00, 1993	NA	NA	50 (SMCL)	100 (marine)	50 SMCL
Nickel	<17.9	NA	789	87.71	610	4600	NA
Silver	2.9	FC03, 1993	1.23	NA	NA	NA	100 SMCL
Zinc	8.7	GS05, 1993	65.04	58.91	NA	NA	5000 SMCL
Benzene	1.8	GS01, 1993	NA	NA	1.2	71	5.0
TCE	0.75	GS05, 1994	NA	NA	2.7	81	5.0
Methylene Chloride	0.94	FC02, 1993	NA	NA	4.7	1600	5.0
Tetrachloroethylene	0.071	PS01, 1993	NA	NA	0.8	8.85	5.0
Dieldrin	0.026	FC02, 1993	2.5	0.0019	0.00014	0.00014	NA
4,4'-DDD	0.052	GS01, 1993	NA	NA	0.00083	0.00084	NA
4,4'-DDE	0.0035	GS03, 1993	NA	NA	0.00059	0.00059	NA

(a) EPA Region IV Toxic Substance Spreadsheet, January 1995.
(b) MCL = Maximum Contaminant Level, federal (40 CFR 141) and state (18 AAC 80) drinking water standards.
(c) NA = Not applicable.
(d) W = Criteria withdrawn in National Toxics Rule.
(e) Action level; concentration allowable in not more than 10% of the samples.
(f) SMCL = Secondary MCL.

Table 2.5. Alaska Water Quality Criteria^(a)

(1) Fresh Water Uses	Toxic and Other Deleterious Organic and Inorganic Substances	Petroleum Hydrocarbons, Oils and Grease
(A) Water Supply (i) drinking, culinary, and food processing	Substances may not exceed Alaska Drinking Water Standards (18 AAC 80) or, where those standards do not exist, EPA <i>Quality Criteria for Water</i> .	May not cause a visible sheen upon the surface of the water. May not exceed concentrations that individually or in combination impart odor or taste as determined by organoleptic tests.
(A) Water Supply (ii) agriculture, including irrigation and stock watering	Same as (1)(A)(i) where contact with a product destined for human consumption is present. Same as (1)(C) or Federal Water Pollution Control Administration, <i>Water Quality Criteria</i> (WQC/FWPCA), as applicable to substances for stockwaters; concentrations for irrigation waters may not exceed WQC/FWPCA or WQC 11972.	May not cause a visible sheen upon the surface of the water.
(A) Water Supply (iii) aquaculture	Same as (1)(C).	Total aqueous hydrocarbons (TAQH) in the water column may not exceed 15 µg/l. There may be no concentrations of petroleum hydrocarbons, animal fats, or vegetable oils in shoreline or bottom sediments that cause deleterious effects to aquatic life. Surface waters and adjoining shorelines must be virtually free from floating oil, film, sheen, or discoloration.
(A) Water Supply (iv) industrial	Substances that pose hazards to worker contact may not be present.	May not make the water unfit or unsafe for the use.
(B) Water Recreation (i) contact recreation	Same as (1)(A)(i).	May not cause a film, sheen, or discoloration on the surface or floor of the water body or adjoining shorelines. Surface waters must be virtually free from floating oils.
(B) Water Recreation (ii) secondary recreation	Substances that pose hazards to incidental human contact may not be present.	Same as (1)(B)(i)
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Individual substances may not exceed criteria in EPA, <i>Quality Criteria for Water</i> or, if those criteria do not exist, may not exceed the Primary Maximum Contaminant Levels of the Alaska Drinking Water Standards (18 AAC 80). If those criteria are absent, or if the department finds that the criteria are not appropriate for sensitive resident Alaskan species, the department will, in its discretion, establish in regulation chronic and acute criteria to protect sensitive and biologically important life stages of resident Alaskan species, using methods approved by EPA or alternate methods approved by the department. There may be no concentrations of toxic substances in water or in shoreline or bottom sediments, that, singly or in combination, cause, or reasonably can be expected to cause, toxic effects on aquatic life, except as authorized by this chapter. Substances may not be present in concentrations that individually or in combination impart undesirable odor or taste to fish or other aquatic organisms, as determined by either bioassay or organoleptic tests.	Same as (1)(A)(iii)
(a) From 18 AAC 70, as amended by revisions that became effective on January 4, 1995.		

4,4-DDD, and 4,4'-DDE. The criteria for petroleum hydrocarbons, oil, and grease for all classes of water use in Garrison Slough are violated at some locations, where a visible sheen is present on the water.

Sediment. No chemical-specific ARARs for the contaminants of concern in freshwater sediment currently exist. The State of Alaska has established cleanup standards for leaks and spills of petroleum products from storage tanks. These standards are also used by ADEC as numeric guidance for the cleanup of petroleum products from other types of releases (18 AAC 75). The guidance includes numeric soil cleanup target levels for diesel range hydrocarbons (100 mg/kg) and gasoline range hydrocarbons (100 mg/kg), benzene (0.1 mg/kg) and total benzene, toluene, ethylbenzene, and xylene (BTEX) (10 mg/kg). The highest concentration of petroleum hydrocarbons detected in sediment at Eielson AFB in 1993 and 1994 was 41 mg/kg diesel range hydrocarbons in Flightline Pond, which is well below the ADEC target cleanup level.

Fish. No chemical-specific ARARs are defined for the contaminants of concern in aquatic biota. The Food and Drug Administration (FDA) action levels for the marketability of fish may be a TBC for the protection of human health. These levels are used as guidance to determine whether contaminated food should be removed from the marketplace. Sport fishing is common on Eielson AFB.

The action level for total DDT is 5 mg/kg wet weight (FDA Guideline 7420.08, 1978). The highest fish tissue total DDT concentration was about 2 mg/kg wet weight (USAF 1995a). No action level exists for PCBs or any PAH. The FDA, however, has established a temporary tolerance level for PCB residues in food for human consumption until these contaminants are eliminated from the environment (21 CFR 109.30). The temporary tolerance level for PCB residues in the edible portion of fish and shellfish is 2 mg/kg. PCBs in two grayling caught in lower Garrison Slough exceeded this level at 2.4 and 3.0 mg/kg.

2.4.2 Location-Specific Requirements

The following location-specific requirements may apply to any action taken to remediate contaminated fish or sediments.

Floodplain or Stream. For activities on a floodplain, action must be taken to avoid adverse effects, minimize potential harm, and restore and preserve natural and beneficial values (40 CFR 6, Appendix A). Eielson AFB is located on the floodplain of the Tanana River.

Under the Fish and Wildlife Coordination Act, if any activity requires diversion, channeling, or other modification of a stream or river and affects fish or wildlife, action must be taken to protect the fish or wildlife (40 CFR 6.302).

Wetlands. Designated wetlands are protected under the Clean Water Act. Any remedial activities conducted in wetland areas must be implemented in a manner that avoids adverse effects, minimizes potential harm, and preserves and enhances the wetlands to the extent possible. Although permit requirements are waived under CERCLA, excavation or fill would require special planning and could require wetland replacement, if a significant area were affected.

2.4.3 Action-Specific Requirements

Action-specific requirements for the treatment, storage, and disposal of PCB-contaminated material are derived from two sets of regulations: the Toxic Substances Control Act (TSCA) PCB regulations (40 CFR 761), and the Resource Conservation and Recovery Act (RCRA) land disposal restrictions (40 CFR 268).

TSCA requirements do not apply to PCBs at concentrations less than 50 ppm; however, PCBs can not be diluted to escape TSCA requirements. Response actions and clean up levels under CERCLA should evaluate the form and concentration of PCB contamination "as found" at the site (EPA 1990). Therefore, TSCA should apply to only a small stretch (~50 m [160 ft]) of Garrison Slough, where the sediment concentration equals or exceeds 50 mg/kg.

Disposal of Non-Liquid PCB Waste With Concentrations Greater Than or Equal to 50 ppm: Non-liquid PCB waste in the form of soil, rags, or other debris, with concentrations of 50 ppm or greater are to be disposed of:

- in an incinerator (40 CFR 761.70);
- treated by an equivalent method (40 CFR 761.60(e)); or
- in a chemical waste landfill (40 CFR 761.75).

A special allowance is made under TSCA for dredge materials that contain PCBs with concentrations of 50 ppm or greater. If, based on technical, environmental, and economic considerations, it can be shown that disposal in an incinerator or chemical waste landfill is not reasonable or appropriate and that an alternative disposal method will provide adequate protection to health and the environment, this alternate disposal method will meet the substantive requirements of TSCA (EPA, 1990; 40 CFR 761.60(a)). Since these showings are integral components of any remedy selected at a Superfund site, Superfund actions involving PCB-contaminated dredged material generally will be consistent with TSCA (EPA, 1990).

Storage For Disposal: If any contaminated sediments are stored prior to permanent disposal, those PCBs at concentrations of 50 ppm or greater must be disposed of within one year after being placed in storage (40 CFR 761.65). The storage facility must comply with the following criteria (40 CFR 761.65(b)):

- adequate roof and walls to prevent rain water from reaching stored PCBs;
- adequate floor with continuous 15 cm (6 in.) high curbing;
- no drain valves, floor drains, expansion joints, etc. that would permit liquids to escape from the curbed area;
- floors and curbing of continuous smooth and impervious materials; and
- not located below the 100-year flood water elevation.

However, contaminated soil, rags, and debris may be temporarily stored (up to 30 days) in an area that does not comply with these facility criteria (40 CFR 761.65(c)). An interim remedy waiver under CERCLA could also be invoked to waive some of these requirements.

On-site Disposal or Containment: General requirements for chemical waste landfills used for the disposal of PCBs (i.e., ≥ 50 ppm) include the following (40 CFR 761.75):

- Located in thick, relatively impermeable formation, such as large clay pans, or on soil with high clay and silt content, or use of a synthetic membrane liner.
- Bottom of the landfill liner system or natural in-place soil barrier at least 15 m (50 ft) above the historical high groundwater table.
- Adequate surface water controls. If located below the 100-year floodwater elevation, diversion dikes should be constructed to a height 0.7 m (2 ft) above the 100-year floodwater elevation.
- Located in an area of moderate to low relief to minimize erosion and mass wasting.
- Surface water monitoring at a minimum of three points.
- Leachate collection/monitoring system.
- Fencing.

Where superfund remedial action will leave PCBs in place or where PCB-contaminated material is excavated, treated, and re-disposed at concentrations that still pose a threat, capping consistent with RCRA chemical waste landfill requirements is generally appropriate (EPA 1990). Long-term management control for PCB-contaminated material generally will also parallel RCRA closures. However, it may be appropriate to waive certain TSCA chemical waste landfill requirements (40 CFR 761.75), such as liners, when containing existing waste disposal sites.

PCB contaminated RCRA hazardous waste (as defined by 40 CFR 261) may be subject to land disposal restrictions if:

- the concentration of PCBs in liquid hazardous waste is greater than or equal to 50 ppm; or
- the total concentration of Halogenated Organic Compounds (HOCs) in non-liquid hazardous waste exceeds 1000 ppm.

The total concentration of HOCs in sediment from Garrison Slough would not exceed 1000 ppm; therefore, land disposal restriction should not apply.

2.5 REMEDIAL ACTION OBJECTIVES

RAOs are media-specific objectives developed from CERCLA remedial action goals, consideration of potential risk, and regulatory requirements. The BLRA (USAF 1995b) calculated the excess cancer risk to humans from the ingestion of PCB contaminated fish from the lower reach of Garrison Slough may be on the order of 10^{-3} . Thus, this stretch of the slough is being considered for remedial action.

A strong spatial relationship exists between PCB concentrations in sediment and in fish at Garrison Slough (Figure 2.1). The highest sediment concentrations were measured near Arctic Avenue, and the highest fish tissue concentrations were measured in fish caught in the same reach of the

Figure 2.1. Relationship Between Sediment and Fish Concentrations in Garrison Slough, Based on 1994 Sediment and Fish Tissue Sampling.

slough. Both sediment and tissue concentrations were orders of magnitude lower at other sampling locations within the slough. Additionally, concentrations of PCBs in fish tissue were approaching background levels in tributary streams upstream of the Garrison Slough-Moose Creek confluence. PCBs were detected in invertebrates only from lower Garrison Slough (USAF, 1995a). Therefore, it is assumed a complete bioaccumulation pathway exists from the sediment to the fish in lower Garrison Slough, and the high tissue concentrations in fish are a direct result of exposure of fish and their food source to the contaminated sediment. The uptake of PCBs by fish may occur through incidental ingestion of contaminated sediment while feeding, gill exchange with surface waters, and ingestion of contaminated water and prey. Although PCBs were not detected in surface water samples, they may be present at concentrations below the detection limit and contribute to their bioaccumulation in fish. Because fish inhabiting Garrison Slough will presumably continue to accumulate PCBs from accumulated sediment either directly or indirectly (prey and interstitial/surface water), both the fish and the sediments are the focus for development of RAOs.

State of Alaska or federal freshwater sediment cleanup criteria for PCBs do not currently exist. In its guidance for PCB-contaminated sites, EPA (1990) uses the equilibrium partitioning approach to

derive sediment quality criteria (SQC) that will achieve the chronic ambient water quality criteria of .014 $\mu\text{g/L}$ in interstitial water (EPA 1990). EPA recommends, if the sediment concentration at a site exceeds the SQC value, water column species should be monitored to determine if prey contain unacceptable contaminant levels. The Air Force has monitored water column species in lower Garrison Slough, and it appears the PCB levels in fish tissue may pose an unacceptable risk to human health. EPA guidance, however, does not suggest a method for determining a cleanup criterion if unacceptable contaminant levels in water column species are found. In addition, EPA points out that an established cleanup concentration, based on total PCB, may show little relationship to biological phenomena because not all PCB congeners have the same toxicological effects.

No direct relationship can be established between sediment PCB concentration and resultant fish tissue concentration in lower Garrison Slough. Any relationship would be time, concentration, and species dependent, and the relative importance of each variable is not known. Therefore, it is not possible to derive a reliable site-specific sediment cleanup criterion that could translate into fish tissue concentrations that would not present an unacceptable risk to human health.

Another approach to developing a preliminary remediation goal for sediment is to reduce the mass of PCBs available for fish uptake. This approach assumes that removing or isolating the sediment with the highest PCB concentrations and reducing the overall mass available for uptake by water column organisms would, over time, lead to a reduction in the average concentration of PCBs in the fish population. Because of the long half-life of PCBs in aquatic organisms (approximately 8 years [De Boer et al. 1994]), a reduction in average fish tissue concentrations for the general population may not be evident until fish with high body burdens either die or migrate out of the system.

The primary goal of remediation is to reduce the potential risk to human health from the consumption of PCB-contaminated fish. This goal can be achieved by:

- Preventing ingestion of contaminated fish from Lower Garrison Slough
- Reducing the highest concentrations and mass of PCBs available for uptake by water column organisms, including fish, so that concentrations of PCBs in the area's fish population will eventually achieve acceptable tissue concentrations.

To achieve the remediation goal and meet the general goals of the CERCLA program, RAOs were developed to define media-specific contaminant concentrations or mass reduction goals. Table 2.6 presents these RAOs.

Table 2.6. Remedial Action Objectives

Medium	Contaminant of Concern	Exposure Route	Receptor	Preliminary Remediation Goal
Fish	PCBs (Aroclor 1260)	Food Chain	Human	0.69 $\mu\text{g/kg}$ (wet weight)
Sediment	PCBs (Aroclor 1260)	Food Chain	Human (through fish uptake)	Reduce the peak concentrations and a preponderance of the PCB mass

The PRG for fish was developed based on a back calculation for the fish tissue concentration that would produce a total excess cancer risk of less than 10^{-6} . This calculation used a recreational exposure scenario (for example, ingestion of fish by an adolescent [300 grams of fish, 30 times/year for 12 years]; using a body weight of 22.6 kg and a life span of 70 years [USAF 1995a]).

The peak concentrations and mass reduction goal is based on the strong spatial relationship between sediment PCB concentrations, invertebrate concentrations, and fish tissue concentrations. Conceptually, the accumulation of PCBs in fish is through their ingestion of contaminated sediment, prey, or surface water, and/or gill exchange. As Figure 2.1 shows, the major contamination peak (and a preponderance of the PCB mass) lies upstream of Arctic Avenue. A plot of the cumulative mass percentage vs. distance from the start of PCB contamination (Figure 2.2) using recently acquired sampling results^(a) indicates that approximately 80% of the PCB mass lies upstream from Arctic Avenue. At this point, the cumulative mass curve flattens out, indicating that less PCB mass is present for a given distance of the slough, and suggesting less return on the investment per the remediation dollars. Arctic Avenue is also a logical and convenient geographic barrier for cessation of remedial actions. Thus, for the purposes of this focused feasibility study, the RAO will be considered to be achieved by remediating the relatively short (300-m [1000-ft]) stretch of the slough just upstream of Arctic Avenue (Figure 1.3). Many assumptions and extrapolations are involved in defining this preliminary remediation goal; thus, any remediation scheme that may be adopted will require verification and, if necessary, further remediation.

2.6 TARGET AREA FOR REMEDIAL ACTION

An evaluation of the potential media, contaminants of concern, and areas to be targeted for remedial action was conducted based on:

- nature and extent of contamination described in the Surface Water and Sediment Investigation Draft Report (PNL 1994a), the technical memo: "Preliminary Assessment of PCB Sediment Contamination in Garrison Slough^(b)," the Sitewide Remedial Investigation (RI) Report (USAF 1995a) (summarized in Section 1.2), and recent (Spring 1995) sediment sampling^(a).
- findings in the Screening Baseline Risk Assessment (PNL 1994b), Biological Risk Assessment (PNL 1994c), and Sitewide Baseline Risk Assessment (USAF 1995b) (summarized in Section 2.2).
- chemical specific ARARs (outlined in Section 2.4)
- RAOs and PRGs (presented in Section 2.5).

(a) Personal communication with Steve McNiel (Eielson Air Force Base), via telephone and FAX on May 17 and 18, 1995.

(b) Technical Memo. "Preliminary Assessment of PCB Sediment Contamination in Garrison Slough, Eielson Air Force Base, Alaska". Prepared by the Pacific Northwest Laboratory, Richland, Washington, for the U. S. Air Force Environmental Restoration Program, Eielson Air Force Base, Alaska.

Figure 2.2. Cumulative Mass Percent of PCBs (includes recent [Spring 1995] sediment sampling data [open diamonds] received from Steve McNeil [Eielson Air Force Base], via telephone and FAX on May 17 and 18, 1995; refer to Appendix A).

As indicated in the previous section, both fish and sediment are targeted for remedial action. The area of principal threat is located in the lower portion of Garrison Slough, just upstream of Arctic Avenue (Figure 2.1). This 300-m (1000-ft) stretch of the slough contains most of the contamination (80%) present in bottom sediment. Assuming a stream channel 3.3 m (10 ft) wide filled with 0.6 m (2 ft) of contaminated sediment, would result in a volume estimate of 600 m³ (780 yd³).

Many assumptions and extrapolations have been made regarding the impacts of remediating a relatively short distance of Garrison Slough on the reduction of PCB concentrations in fish tissue samples. Any remediation scheme that may be adopted for lower Garrison Slough will require verification and, if necessary, further remediation.

3.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

The purpose of this section is to identify, develop, and evaluate a focused range of potentially applicable response actions, remedial technologies, and process options for Garrison Slough. Garrison Slough was selected for possible remediation because of potential human health risk from current and future unrestricted access and exposure to PCBs through the ingestion of contaminated fish.

The potential response actions, technologies, and process options identified in this section focus on those that are most viable for remediation of aquatic sediments and fish populations contaminated with PCBs and located in an active industrial area within the subarctic environment. The physical characteristics of the site, as well as ongoing base activities, greatly influence the effectiveness and implementability of many of the potential response actions and remedial technologies. The following site-specific factors are considered in the technology screening:

- The subarctic environment will generally reduce the rate of most natural or man induced biodegradation, and will limit certain types of excavation or dredging to a short field season. Surface water and sediment freezing may either hinder or facilitate certain types of excavation or spread of contamination. This situation will also strongly affect the type and design of surface caps that can be installed.
- Seasonally altered surface water flow rates affect stream erosion and resuspension of contaminated sediments.
- Garrison Slough is thought to be lower than the water table throughout the year over most of the slough's length (except perhaps near the water treatment plant [WTP] pond), and thus receives water from and acts as a drain for the shallow aquifer (PNL 1993b).
- The strong sorption characteristics of PCBs and the long-term presence of surface water overlying these contaminated sediments limits the viability of in situ sorption or leaching technologies.
- The lack of permitted hazardous waste incinerators which could receive PCB contaminated soil within Alaska markedly increases the cost of incineration alternatives because of the high mobilization or transportation costs.
- No permitted Toxic Substances Control Act/Resource Conservation and Recovery Act (TSCA/RCRA) chemical waste landfills are located in Alaska. The absence of chemical waste landfills will markedly increase the cost of transportation and disposal.

This screening process focuses on identifying possible remedial technologies and process options to achieve the RAOs. A range of general response actions is reviewed and possible remedial technologies are identified for actions that seem most applicable to source reduction in aquatic sediments and fish populations in Garrison Slough.

The range of actions for sediment and fish remediation includes those actions that eliminate the need for long-term management, those that use treatment as the primary component, and those that to the extent feasible, focus on containment. Only the lower portion of Garrison Slough, which

is contaminated with PCBs, is considered in this FS. No other sites investigated as part of the sitewide RI/FS have been determined as posing an unacceptable risk to human health or the environment (USAF 1995b, USAF 1994e).

3.1 RESPONSE ACTIONS AND TECHNOLOGIES FOR REMEDIATING THE FISH POPULATION

Fish residing in lower Garrison Slough were found to contain PCB (Aroclor 1260) contamination in concentrations that pose a human health risk on the order of 10^{-3} excess cancers (USAF 1995b). Potential response actions, remedial technology types, and process options appropriate for meeting the remedial action objective for the fish population are presented in Table 3.1.

From this initial identification of possible response actions and remedial technologies, a limited set of technologies and process options was developed. An initial screening based on the technical feasibility of the potential technologies and process options is shown in Figure 3.1. Those technologies and process options not eliminated during this initial screening were then further evaluated for their effectiveness, implementability, and relative cost. This evaluation is shown in Figure 3.2.

3.2 RESPONSE ACTIONS AND TECHNOLOGIES FOR REMEDIATING AQUATIC SEDIMENTS

Aquatic sediment in Garrison Slough is believed to be the primary source of PCB (Aroclor 1260) contamination in the fish population. A point source for the PCB contamination appears to be located approximately 300 m (1000 ft) upstream of Arctic Avenue. Potential response actions, remedial technology types, and process options appropriate for meeting the remedial action objective for these aquatic sediments and the fish population are presented in Table 3.2.

From this initial identification of possible response actions and remedial technologies for aquatic sediments, a limited set of technologies and process options was developed. An initial screening based on the technical feasibility of the potential technologies and process options is shown in Figure 3.3. The technologies and process options not eliminated in this initial screening were then further evaluated for their effectiveness, implementability, and relative cost. This evaluation is presented in Figure 3.4. Those technologies/process options identified as being innovative, and thus not fully proven, were to be included in this second evaluation. Instead, they are discussed separately.

3.3 INNOVATIVE TECHNOLOGIES

Three innovative technologies/process options were identified for possible consideration in meeting the RAOs for sediment. A brief description of each follows.

3.3.1 Algal Mats

Microbial (algal) mats are natural heterotrophic communities dominated by cyanobacteria (blue-green algae). These complex laminated structures can be cultured by enriching a water surface with ensiled grass clippings. Specific microbes can then be cultured within the constructed

cyanobacteria/silage mixture to address a specific remediation task. Bender (1993) has shown that constructed mats can degrade a wide variety of organic contaminants, including PCBs, in water or soil.

The effectiveness of this technology in meeting the RAO for sediment is uncertain, especially in an arctic environment. Some treatability studies would be necessary. However, the advantage of this technology is that it can work in place, without removal of the sediments, and without adversely affecting the stream's ecosystem. Depending on the efficiency, significant cost savings could be achieved using this technology.

3.3.2 Ozone, Ultraviolet, Ultrasonics, and Ultrapure Water

The Ozone, Ultraviolet, Ultrasonics, and Ultrapure Water process is a 2-stage system. First, the PCBs are removed from the sediment slurry (30-40% solids) using ultrapure water as the solvent. Then the aqueous solution is treated with ozone, ultraviolet energy, and ultrasonics to oxidize the PCBs and transform them into carbon dioxide, water and harmless salts. The size of systems tested thus far have ranged from 0.03 to 15 m³/hr (1 ft³/hr to 27 cu yd/hr) (Boeve 1989).

One advantage of this system is that it can remediate the dredge materials directly, without dewatering. Another potential advantage is that it promises to produce no solvent or other waste streams that must be treated. However, treatability studies should be performed to determine the efficiency of the extraction and degradation rates, and to ensure that no harmful byproducts are produced.

3.3.3 In Situ Reduction

Reductive dechlorination of PCBs has been demonstrated to achieve performance levels that are considered equivalent to incineration for ex situ treatment. However, in situ application has not been proven. Detailed treatability studies would be required to demonstrate that concentration reductions can be achieved on a consistent basis for the site-specific conditions present at Eielson AFB.

As with most other in situ treatment technologies/process options considered for sediments of Garrison Slough, the stream would first have to be diverted, and perhaps the groundwater table lowered to dewater the sediments, prior to application of the technology. Thus, the use of this technology is not considered further in the development of remedial options.

Table 3.1. Response Actions and Technologies for Remediation of the Fish Population

Remedial Action Objective	General Response Actions	Remedial Technologies	Process Options
Prevent ingestion of fish tissue having a PCB concentration greater than 0.69 $\mu\text{g}/\text{mg}$ (wet weight)	No Action	No Action	No Action
	Institutional Controls	Access Restrictions	Warning Signs and Fences
		Fishing Advisory/Restrictions	State Fishing Advisory/Restrictions
	Containment/Isolation	Fish Controls	Fish Screens
			Fish Control Dam
	Removal	Collect and Remove Fish	Electroshock, Nets, Diversion
		Poison and Remove Fish	Poison (Rotenone, Antimycin), Nets, Diversion
	Ex-situ Treatment (in conjunction with removal)	Thermal Treatment	Incineration
	Disposal (in conjunction with removal)	Landfill	Chemical Waste Landfill
			Solid Waste Landfill

Figure 3.1. Initial Screening of Technologies and Process Options for Remediation of Fish

Figure 3.1. (contd)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
No Action	No Action	No Action	Does not achieve remedial objective.	Easily Implemented; acceptability uncertain.	None.
Institutional Controls	Access Restrictions	Warning Signs and Fences	Effective only for fish within the controlled area. Does not adequately address fish migration.	Fairly easy to implement on base. Implementation off base is uncertain. Difficult to implement for entire migration route.	Very low capital; very low maintenance.
	Fishing Advisory / Restrictions	State Fishing Advisory / Restrictions	Effective.	Easy to implement on base; implementation and acceptability off base uncertain.	Essentially no capital; very low maintenance.
Containment / Isolation	Physical Fish Controls	Fish Screens	Should be fairly effective over the long term (eg. one generation of fish); by reducing bioaccumulation of PCBs in uncontaminated adult fish downstream of screen. Prevents downstream migration of contaminated population.	Fairly easy to implement. May require permitting/approval from State Department of Fish and Game, Corps of Engineers, NOAA, etc. Implementation may also impact potential salmon spawning areas.	Low capital; low maintenance.
		Fish Control Dam	Fairly effective over the long term (one fish generation), by reducing bioaccumulation of PCBs in uncontaminated fish downstream of dam. Has little short term effect on existing contaminated population.	Fairly easy to implement. May require permitting/approval from State Department of Fish and Game, Corps of Engineers, NOAA, etc. Implementation may also impact potential salmon spawning areas.	Low capital; very low maintenance.

Figure 3.2. Evaluation of Process Options for Remediation of the Fish Population

Table 3.2. Response Actions and Technologies for Remediation of Aquatic Sediments

Remedial Action Objective	General Response Actions	Remedial Technologies	Process Options
Reduce the Peak Concentrations and a Preponderance (80%) of the PCB Mass	No Action	No Action	No Action
	Institutional Controls	Access and Use Restrictions	Deed Notice on Land Use Restrictions
			Warning Signs and Fences
			Base Regulations
	Containment/Isolation	Sedimentation Controls	Sedimentation basins and diversion controls
		Line Stream Bottom	Culvert
			Concrete
			Synthetic Liner
			Multilayer Porous Cap
		Divert Stream	Bypass Culvert/Pipeline
			Excavate New Channel
		Cap Old Channel (in conjunction with diverting stream)	Native Soil
			Asphalt
			Clay
			Concrete
			Synthetic Membrane
			Multilayer Cap
			Chemical Sealants
	In Situ Treatment	Biodegradation	Algal Mats ^(a)
	In Situ Treatment (in conjunction with either permanent or temporary stream diversion)	Physical Processes	Solidification (Grouting)
		Chemical Processes	Oxidation
			Reduction
			Hydrolysis
			Carbon Adsorption
		Biodegradation	Bioreclamation
		Thermal Processes	In situ Vitrification
			Thermal Evaporation

Table 3.2. (contd)

Remedial Action Objective	General Response Actions	Remedial Technologies	Process Options
	Removal	Excavation	Mechanical Dredging
			Hydraulic Vacuum Dredging
	Ex Situ Treatment (in conjunction with removal)	Solidification/ Stabilization	Macroencapsulation
			Micorencapsulaton
		Physical Treatment	Soil Washing / Solids Classification
			Dewatering
		Biological Treatment	Land Farming/Composting
			Bioreactors
			Thermal Treatment
		High-Temperature Incineration (Haz. Waste Regulated)	
		Low-Temperature Incineration	
		Pyrolysis	
		Steam Stripping	
		Chemical Treatment	Solvent Washing / Extraction
			Molten Solids Processing
			Dechlorination
			Ozone-ultraviolet exposure ^(b)
			Radiolytically induced decomposition
	Disposal (in conjunction with removal and pretreatment)	Landfill	Chemical Waste Landfill
			On-Site Landfill
		Use as fill	Fill Material

Information taken from:
ReOpt (White and Bryant 1993)
(a) Bender and Phillips, Clark Atlanta University, Atlanta, Georgia. (Bender 1993).
(b) Excalibur Enterprises, Inc., New York, New York. (Boeve 1989).

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
No Action	No Action	No Action	No remedial actions. Includes continued monitoring.	Required under the NCP, does not reduce future risk.
		Deed Notice on Land Use Restrictions	A restriction or notice restricting future land use to commercial/industrial uses.	Would provide additional assurance that land use would not change without further study and possible remediation.
Institutional Controls	Access and Use Restrictions	Warning Signs and Fences	Warning signs and security fences strategically placed to restrict public/Base access to contaminated portions of the slough.	Would reduce direct human exposure and ingestion of fish. Does not reduce exposure of fish to contaminated sediments. Does not reduce risk from transport of contaminated sediments and/or fish out of control area.
		Base Regulations	Restrictions placed on activities in contaminated areas. Personnel who enter/work in contaminated areas may be required to wear protective gear.	Would reduce direct exposure and ingestion of fish for Base personnel. May not be applicable to on-Base civilians. Does not reduce risk from contaminated sediments or fish migrating off Base. Does not reduce exposure of fish to contaminated
	Sedimentation Controls	Sedimentation basin(s) and diversion controls.	Sedimentation basin(s) would trap contaminated sediments being transported down the slough. Diversion controls would reroute spring runoff around the contaminated areas, further reducing erosion and resuspension of contaminated sediments.	Would require periodic maintenance (eg. dredging and disposal of contaminated spoils from sedimentation basin). Does not reduce risk from on-Base human exposure. Does not prevent exposure of fish to contaminated sediments above control point.

Figure 3.3. Initial Screening of Technologies and Process Options for Remediation of Aquatic Sediments

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
	Line Stream Bottom	Culvert	Contaminated sediments would be isolated from the ecosystem and human exposure by placing a half culvert in the stream channel and backfilling.	Implementation may be difficult. May require modification of existing channel (eg. contaminated sediments removed or regraded) and resuspension of sediments. Would have severe impacts on the local ecosystem. Requires maintenance.
		Concrete	Contaminated sediments would be isolated from the ecosystem and human exposure by lining the stream bottom and banks with concrete.	Implementation may be difficult in rerouting water and regrading the slough bottom; may have to lower water table to implement. Would have severe impacts on the local ecosystem. Contamination would remain in place. Requires maintenance.
		Synthetic Liner	Contaminated sediments would be isolated from the ecosystem and human exposure by lining the stream bottom and banks with a synthetic liner.	Implementation may be difficult in rerouting water and regrading the slough bottom. May have to lower water table to implement. Would have severe localized impacts on the ecosystem. Contamination would remain in place. Requires maintenance.
		Multi-layer Porous Cap	Contaminated sediments would be isolated from the ecosystem and human exposure by lining the stream bottom and banks with a combination of clay, sand, gravel, and cobbles.	Implementation should be relatively straightforward. Contaminated sediments may be resuspended during installation. May require maintenance. Will raise stream bed which may adversely affect its hydraulic flow impacting the ecosystem.

Figure 3.3. (contd)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
Containment/ Isolation	Divert Stream	Bypass Culvert/ Pipeline	A culvert/pipeline would be installed to bypass the contaminated portion of the stream to prevent exposure of fish to contaminated sediment and to prevent transport of sediment.	May not be room to route the bypass. Would essentially destroy the ecosystem corridor between the lower and upper portions of the slough.
		Excavate New Channel	A new stream channel would be excavated to bypass the contaminated portion of the stream to isolate contaminants from fish and eliminate migration of contaminated sediments.	May not be room to route the bypass. Would have severe short-term impacts on the local ecosystem.
	Cap Old Channel (in conjunction with diverting stream)	Native Soil	The old stream banks would be scraped into the old channel which would then be backfilled with native soils to isolate contaminants from humans.	Easily implemented. Native soils contain high percentages of sand and gravel.
		Asphalt	The old stream channel would be backfilled with native soils and capped with asphalt or asphaltic concrete to isolate the contaminants from humans.	Provides some protection against inadvertent intrusion. Requires maintenance.
		Clay	Backfill old channel and place clay cap over the contaminated area.	Not suitable for highly industrialized areas or areas with severe freeze and thaw cycle.
		Concrete	The old stream channel would be backfilled with native soils and capped with concrete to isolate the contaminants from humans and fish.	Provides protection against inadvertent intrusion. Surface must be prepared. Not suitable for area subject to settling. Requires maintenance.

Figure 3.3. (contd)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
		Synthetic Membrane	Backfill old channel and install a synthetic liner over the contaminated area.	Difficult to maintain integrity of liner in active industrial area. Requires maintenance.
		Multi-Layer Cap	The old stream channel would be backfilled with native soils and covered with a synthetic liner and a clay and/or soil cap to isolate contaminants from humans.	Will require cold weather engineering. Requires maintenance.
		Chemical Sealants	Spray fixative over the contaminated sediments.	Difficult to maintain seal coating in active industrial area.
In Situ Treatment	Biodegradation	Algal Mats *	Microbial mats, dominated by cyanobacteria, would be constructed over the contaminated sediments to form a natural autotrophic community harboring the desired cultured microbes for degradation of PCBs.	Still in the development stage. Uncertain of the kinetics with PCBs and applicability in an arctic environment. Requires treatability testing.
	Physical Processes	Solidification (Grouting)	Contaminated sediments are solidified in place by mixing them or injecting them with some form of solidifying agent (eg, cement, clay, synthetics, etc.)	May be difficult to implement if below water table. Benefit uncertain. Does not prevent direct exposure to humans.
		Oxidation	Oxidizing agents (eg, ozone, hydrogen peroxide) are added to the contaminated soil to raise the oxidation state.	Not a solution in itself; used to assist microbial degradation. Requires addition and control of reagents. May result in contamination of the groundwater by chemical breakdown products. May require lowering of water table.

Figure 3.3. (contd)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
In Situ Treatment (in conjunction with either permanent or temporary stream diversion)	Chemical Processes	Reduction	Sodium- or potassium-based chemical reagents are applied or injected into a contaminated site to reduce the oxidation state and remove chlorine from PCB molecules (dehalogenation).	Still in development stage for in situ application. Requires treatability studies for the addition and control of reagents and the toxicity of by-products. May require lowering of water table.
		Hydrolysis	Reagents are mixed or injected into contaminated sediments. A chemical reaction (hydrolysis) causes a double decomposition with hydrogen added to one component and hydroxyl added to the other.	May require lowering of water table. Requires the addition and control of reagents. Effectiveness uncertain, may require detailed treatability studies. Practicality uncertain.
		Carbon Adsorption	Granulated activated charcoal is mixed into the contaminated sediments to sorb organic compounds and thus reduce the bioavailability of the contaminants.	Benefits uncertain. Only a temporary containment measure. Does not reduce level of contamination. May require lowering of water table. Does not prevent direct exposure to humans.
	Biodegradation	Bioreclamation	Microbiological degradation and detoxification is enhanced by addition of microbes, nutrients, moisture, and heat, and the pH is adjusted as needed.	Effectiveness questionable. Requires detailed treatability studies to determine effectiveness with the specific congeners, and applicability in an arctic environment. May require lowering of water table.

Figure 3.3. (contd)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
	Thermal Processes	In situ Vitrification	Contaminated soils are converted in place into durable glass and crystalline product by extreme heat caused by passing an electrical current among four electrodes embedded into the contaminated soils.	Experimental process option; not proven in saturated sediments. Probably not cost effective for long narrow sources of low concentrations. Can not be implemented without lowering water table.
		Thermal Evaporation	Electrodes are placed over surface, or in vertical or horizontal boreholes. Electromagnetic energy in radio frequency band is applied to the electrodes to cause rapid heating of the soil by molecular excitation.	Experimental process option. Probably not cost effective for long narrow sources of low concentrations. Practicality uncertain; may require lowering of water table.
Removal	Excavation	Mechanical Dredging	Contaminated sediments are mechanically removed from the stream bottom via clam shell, backhoe, or other mechanism.	Suitable for small areas. Difficult through moving/standing water or saturated sediments. Difficult to control accuracy of excavation. Will cause substantial resuspension of sediments. Would have severe short-term impacts on the local ecosystem.
		Hydraulic Vacuum Dredging	Contaminated sediments are hydraulically vacuumed from the stream bottom.	Suitable for small areas. Accuracy of excavation is good. Causes little resuspension of sediments. Produces large volumes of waste water. Can leave coarse sediments behind. Would have some short term impacts on the local ecosystem.

Figure 3.3. (contd)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
	Solidification/ Stabilization	Macro- encapsulation	Contaminated waste is placed in an inert jacket or container (welded polyethylene, fiberglass, spray on resins)	Used when waste materials are difficult to stabilize, are extremely hazardous, or reactive. For stable on-site storage and stable waste containers for land disposal. Not necessary for Garrison Slough contaminants.
		Micro- encapsulation	Contaminated sediments are mixed or incorporated into a solidification/stabilizing matrix such as cement, polymers, or asphalt.	Used as a pretreatment prior to on-site storage or land disposal. Benefits uncertain. Increases volume.
	Physical Treatment	Soil Washing/ Solids Classification	Uses screens and cyclone separators to segregate contaminated sediments by size, thus reducing the volume, and preparing a uniform composite for treatment or disposal. May be washed with a detergent to remove contaminant from the coarse fraction.	Reduces volume of contaminated sediments. Generates liquid wastes, and potentially contaminated residuals. Used as a pretreatment.
		Dewatering	Removes residual water from saturated sediments, either by drying or use of an absorbent agent.	Used as a pretreatment prior to further treatment or disposal.
		Land Farming/ Composting	Excavated sediments are spread in layers or placed in piles or cells. Microorganisms (white rot fungus) are added with soil amendments (wood chips) and nutrients to degrade the PCBs.	Should be effective over several summers. Treatment and isolation facilities already exists on-site. A low cost large volume treatment option. No continued operator attendance required. Effectiveness in an arctic environment unproven.

Figure 3.3. (contd)

FINAL

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GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
Exsitu Treatment (in conjunction with removal)	Biological Treatment	Bioreactors	Excavated sediments are placed in controlled biocells for rapid biodegradation.	Requires treatability studies. Treatment conducted in small batches. Can be effective only over extended periods. Requires operator attendance. A high cost treatment option.
	Thermal Treatment	Thermal Desorption	Contaminated sediments are heated in a low temperature furnace. The organics are vaporized and the off-gas is collected (eg. on activated carbon) for disposal or further treatment.	Proven technology. Can be effective. Equipment too large and expensive for small volumes (eg. <5000 cu. yd.). May be practical with rental/lease equipment, if available. Requires treatment/disposal of off-gass and residuals.
		Incineration	Contaminated sediment is burned in a TSCA approved incinerator. Contaminants are permanently destroyed.	Very effective (99.9999%). Permitted hazardous waste incinerator unavailable in Alaska. Cost and permitting of on-site incinerator very expensive. Transport to out-of-state incinerator very expensive.
		Pyrolysis	Organic wastes are exposed to high temperature in the absence of sufficient oxygen for complete combustion. Volatile organics are produced that are combusted in an afterburner.	Well-developed commercially available technology. Acceptable for PCBs in conjunction with TSCA approved incinerator. Equipment is large and too expensive for on-site treatment. Permitting the afterburner section may pose a problem.

Figure 3.3. (contd)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
		Steam Stripping	Volatile materials are heated and removed with steam.	PCBs not volatile at practical steam temperatures. Not effective. Residuals and effluents must be disposed or further treated.
		Solvent Washing/ Extraction	Uses a liquid solvent or supercritical fluid to dissolve contaminants from contaminated soils.	Demonstrated to remove PCBs. Cleans and segregates waste into clean coarse fractions suitable for fill, and fine grained residuals for further treatment/disposal. Solvent waste must also be treated. Requires treatability studies.
		Molten Solids Processing	Uses high temperatures to destroy the organic constituents of a waste. This includes molten glass processes, slagging incineration, incineration in molten salt, and incineration by plasma systems.	Technologies are primarily in development stage. Requires detailed treatability studies. Not necessary for Garrison Slough contaminants.
	Chemical Treatment	Dehalogenation	Contaminated soils are placed in reactor with reagents (potassium polyethylene glycol [KPEG]), mixed, and heated. Reaction breaks carbon-chlorine bonds. Soil and reagent are separated and the soil neutralized.	Potentially very effective. Utilizes specialized equipment to reach temperatures of ~150°C. Only one vendor available. Treatability studies required. Generates reagent waste, other liquid wastes, and potentially contaminated residuals.
		Ozone-ultraviolet exposure	The Ozone, Ultraviolet, Ultrasonics, and Ultrapure Water (OUUU) process** uses ultrapure water to remove contaminants from sediment, then treats the aqueous solution to convert the contaminants to CO ₂ , H ₂ O, and salts.	Innovative technology. Still in the development stage for large volumes.

Figure 3.3. (contd)

Information taken from: ReOpt (White and Bryant 1993)
 EPA (1990)
 • Bender and Phillips, Clark Atlanta University, Atlanta, GA. (Bender 1993).
 ** Excalibur Enterprises, Inc., New York, NY. (Boeve 1989).

Figure 3.3. (contd)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
No Action	No Action	No Action	Does not achieve remedial action objectives.	Easily implemented. Regulatory and public acceptability uncertain.	No capital. Low O & M (monitoring).
Institutional Controls	Access and Use Restrictions	Deed Notice on Land Use Restrictions	Effectiveness depends on continued future implementation. Does not reduce contamination.	Some legal requirements and authority issues to overcome.	No capital. Low O & M (monitoring).
		Warning Signs and Fences	Effective in reducing direct personal exposure and ingestion of fish. Does not reduce contamination.	Easily implemented.	Very low capital. Low O & M (maintenance and monitoring).
		Base Regulations	Effective in reducing direct personal exposure and ingestion of fish. Does not reduce contamination.	Relatively easy to implement. Some authority/approval issues to overcome.	No capital. Low O & M (monitoring).
	Sedimentation Controls	Sedimentation basin(s) and diversion controls	Can be effective in reducing the spread of contaminated sediments, thereby limiting areal extent of exposure to water column organisms. May not significantly affect bioaccumulation.	Can be implemented. May impact the local stream ecosystem. Only temporary. Requires maintenance.	Low capital. Moderate O & M (maintenance and monitoring).

Figure 3.4. Evaluation of Process Options for Remediation of Aquatic Sediments

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
Containment/ Isolation	Line Stream Bottom	Culvert	Effective in reducing direct personal exposure and ingestion of fish. Does not reduce contamination.	Can be implemented. May require regrading of stream channel and resulting resuspension of contaminated sediments. Would have severe impacts on the local ecosystem.	Moderate capital. Low O & M.
		Multi-layer Porous Cap	Effective in preventing direct exposure to water column organisms. Does not prevent exposure to PCBs partitioning into the interstitial and surface water. Long-term integrity uncertain, may be subject to bioturbation.	Can be implemented. Requires maintenance.	Moderate capital. Moderate O & M (maintenance).
	Divert Stream	Excavate New Channel	Effective in reducing migration of contaminated sediments, and bioaccumulation in fish.	May be difficult to implement near the CE maintenance shop, where space is limited. Would have severe short term impacts on the local	Moderate capital. Low O & M.
		Native Soil	Effective in isolating contaminants from humans.	Relatively easy to implement.	Low to moderate capital. Low O & M (maintenance).

Figure 3.4. (contd)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
Removal	Cap Old Channel (in conjunction with diverting stream)	Asphalt	Effective in isolating contaminants from humans.	Relatively easy to implement.	Moderate capital cost. Low to moderate O & M (maintenance).
		Concrete	Effective in isolating contaminants from humans.	Surface must be stabilized and prepared. May require dewatering of aquifer during implementation.	Moderate capital. Low O & M (maintenance).
		Multi-layer Cap	Effective in isolating contaminants from humans and fish. Provides protection against migration of contaminants to groundwater.	Can be implemented. Requires cold weather engineering.	High capital. Low O & M (maintenance).
	Excavation	Mechanical Dredging	Very effective. May cause resuspension and downstream transport of contaminated sediments.	Somewhat difficult to implement through moving water; also difficult handling saturated sediments.	Low Capital. Low to moderate O & M.
		Hydraulic Vacuum Dredging	Very effective.	Can be implemented. Provides better control over depth of dredging. Resuspension of sediments should be minor. Produces large quantities of water to treat.	Moderate capital. Moderate O & M.

Figure 3.4. (contd)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
Ex Situ Treatment (in conjunction with removal)	Physical Treatment	Solidification/ Stabilization	Somewhat effective. PCB migration is reduced but PCBs still present. Used as a pretreatment prior to disposal.	Requires some treatability testing (leaching analyses).	Moderate capital. Moderate O & M.
		Micro- encapsulation			
		Soil Washing/ Solids Classification	Effective for reducing the volume of materials to be treated or disposed. Can be effective at removing PCBs from coarser sediment fractions.	Can be implemented. However, it can produce liquid wastes and residuals that must be treated or disposed.	Moderate capital. Moderate O & M.
	Biological Treatment	Dewatering	Effective for removing residual water from wastes to be further treated and/or disposed.	Can be implemented. May produce liquid and solid wastes.	Low to moderate capital. Low to moderate O & M.
		Land Farming/ Composting	Should be effective for 2 or 3 summers.	Easily Implemented. Treatment and isolation area already on site.	Moderate capital. Moderate O & M.
		Thermal Desorption	Can be effective. Requires additional treatment/ disposal for offgas and residuals.	Not easily implemented. Equipment too large and expensive for small volumes. May be practical with leased equipment (if available).	Moderate to high capital. Moderate O & M.

Figure 3.4. (contd)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
	<pre> graph TD RT[REMEDIAL TECHNOLOGY] --> TT[Thermal Treatment] RT --> INC[Incineration] RT --> SWE[Solvent Washing/Extraction] RT --> CT[Chemical Treatment] TT --> INC SWE --> DC[Decolorination] CT --> DC </pre>	Incineration	Very effective. Can achieve the equivalent of 99.9999% destruction.	Difficult to implement. No permitted hazardous waste incinerators in Alaska. Permitting of a portable on-site incinerator, is expected to be very difficult. Residuals must be disposed. Public acceptance questionable.	High capital. Moderate to high O & M.
		Solvent Washing/Extraction	Can be effective (99.5%). Can reduce concentrations to <2 ppm (EPA 1990) with repeat applications. Residuals may require landfilling. Requires treatability study.	May be difficult for large volumes where repeat application necessary. Contaminated solvents must be recovered and treated. Solvent residues may remain in extracted sediment.	Moderate to high capital. Moderate to high O & M.
		Decolorination	Efficiency varies with Arochlor type and variability of concentrations. Can reduce concentrations to 2 ppm (EPA 1990). Residuals may require	May be difficult to acquire and implement. Requires treatability studies and careful monitoring to ensure sufficient reaction times.	Moderate to high capital. Moderate to high O & M.

Figure 3.4. (contd)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
Disposal (in conjunction with either stream diversion or removal)	Landfill	Chemical Waste Landfill	Effective.	Difficult to implement since closest permitted chemical waste landfill is in Arlington, OR.	High capital. Low O & M (maintenance).
		On-site Waste Landfill	Effective for solids that are not subject to land disposal restrictions.	Can be implemented if PCB concentrations are below 50 ppm. Can be acceptable for all untreated dredge material.	Low Capital. Low O & M.
	Use as fill	Fill Material	Effective.	Can be implemented for non-hazardous materials.	Low Capital. Low O & M.

Figure 3.4. (contd)

4.0 PRELIMINARY DEVELOPMENT AND EVALUATION OF ALTERNATIVES

The purpose of this section is to assemble and screen a focused set of potentially applicable alternatives from the technologies and process options identified in Section 3.0. The alternatives are assembled by identifying appropriate technologies for each medium and then selecting a process option that is representative of those technologies. Each alternative represents a separate level of control and time frame for risk reduction.

4.1 PROCESS FOR THE DEVELOPMENT OF ALTERNATIVES

Remedial action alternatives are assembled by identifying appropriate technologies for each affected medium, and then selecting a representative process option for alternative development. The primary objective of the alternatives development process is to identify remedial alternatives capable of achieving the RAOs identified in Section 2.0. As required by the NCP, the range of alternatives to be developed for source control actions include:

- a no action alternative
- one or more alternatives that involve little or no treatment, but protect human health and the environment through
 - institutional controls, and
 - the use of engineering controls (containment)
- one or more treatment alternatives that reduce the toxicity, mobility, or volume of contaminants, aimed at
 - the principal threat posed by the site, and
 - eliminating or minimizing, to the degree possible, the need for long-term site management.

Each of the assembled alternatives presents a different level of control and risk reduction. After the alternatives are assembled, they are evaluated on the basis of effectiveness, implementability, and relative cost to identify the final list of alternatives for detailed evaluation.

The governing premise in developing a focused set of remedial alternatives for Garrison Slough was to protect human health by reducing the potential for ingestion of PCB-contaminated fish. The secondary, longer term, focus was to reduce the source of PCBs available for bioaccumulation in the fish, by either isolating, or removing and treating, or disposing of the contaminated sediments.

In keeping with the focused nature of this FS, a maximum of five alternatives (including the no action and limited action [institutional control] alternatives) will be retained for detailed evaluation. While several technologies or process options may remain viable for a specific general remedial action alternative, only one technology/process option is selected to represent that alternative.

The alternatives are presented as comprehensive source control actions (for example, fish and sediment remedial actions combined into a single alternative). However, the alternatives were assembled in such a manner that individual components of the alternatives can be mixed and matched to increase the effectiveness of a single alternative. This modular approach allows the Air Force to implement remedial actions in several phases, adding technologies as necessary to achieve the RAOs.

4.2 GENERAL REMEDIAL ACTION ALTERNATIVES

The technologies and process options that were retained from the screening in Section 3.0 have been assembled into a set of general remedial action alternatives (Table 4.1). This range of alternatives includes lower cost and less protective options and high cost options that increase protection by accomplishing the remedial action objectives within a shorter time frame and provide a more permanent reduction in risk. A list of the general remedial action alternatives include:

- No Action
- Limited Action
- In Situ Capping
- Divert Stream
- Dredge and Dispose
- Dredge and Treat

A description of these general remedial action alternatives and the process options retained in them follows.

4.2.1 No Action

The No Action alternative is self-explanatory. It requires that no action be taken with regard to either the fish population or the sediment concentrations. This alternative does not actively seek to reduce the risk from contaminated fish, but relies on natural attenuation/degradation. Ongoing environmental monitoring of fish, sediment, and surface water concentrations would continue.

4.2.2 Limited Action

The Limited Action alternative is aimed at providing a near immediate reduction in human exposure to PCBs, primarily by cutting short the food chain pathway. This alternative uses institutional controls to restrict the amount of fish caught for food, and engineering controls to restrict the migration of fish into contaminated portions of the slough.

Although access and use restrictions (deed notices, warning signs and fences, and base restrictions) also passed the screening process, they have not been included in this alternative, as they would have less direct effect and be more difficult to implement. Restricting access to the more highly contaminated portion of the slough would prevent direct human exposure and the harvesting of fish in that region. However, direct human exposure by itself, does not pose an unacceptable risk (USAF 1995b), and the issuance of a Fishing Advisory and Restrictions would be more effective because they cover a larger area.

Fishing Advisory/Restrictions: The Fishing Advisory/Restrictions would be promulgated by the Alaska State Department of Fish and Game. An advisory would be issued stating the ingestion of more than 1 meal (≥ 300 g) of fish per year from Garrison Slough may pose an unacceptable health risk ($> 10^{-6}$ excess cancers) and should be avoided. This advisory would help to reduce the health risk to the population, but does not prevent exposure to contaminated fish. A further precaution would be to designate Garrison Slough as a catch-and-release-only area. This process would further reduce the potential for ingestion of contaminated fish.

Table 4.1. Assemblage of Alternatives

GENERAL RESPONSE ACTION				NO ACTION	LIMITED ACTION	CONTAINMENT		REMOVE AND DISPOSE	REMOVE AND TREAT
Medium	Technology Type	Process Option	Area or Volume			In Situ Capping	Stream Diversion		
Fish	No Action	No Action (Monitoring)	Lower Garrison	X					
	Access Restrictions	Access Restrictions	Lower Garrison		X	X	X	X	X
	Fishing Advisory	Fishing Advisory / Restrictions	Lower Garrison		X	X	X	X	X
	Physical Fish Controls	Fish Screens	Lower Garrison		X	X	X	X	X
		Fish Control Dam	Lower Garrison		X	X	X	X	X
Sediment	No Action	No Action (Monitoring)	Lower Garrison	X					
	Access & Use Restrictions	Deed Notice on Land Use	Lower Garrison		X				
		Warning Signs and/or Fences	Lower Garrison		X				
		Base Regulations	Lower Garrison		X				
	Sedimentation Controls	Sed. Basin(s) / Diversion Control	Lower Garrison		X	X	X	X	X
	Line Stream Bottom	Culvert	300 m (80% PCBs)			X			
		Multi-Layer Cap	300 m (80% PCBs)			X			
	Divert Stream	Excavate New Channel	300 m (80% PCBs)				X		
	Cap Old Channel (w/stream div)	Native Soil	300 m (80% PCBs)				X		
		Asphalt	300 m (80% PCBs)				X		
		Concrete	300 m (80% PCBs)				X		
		Multi-Layer Cap	300 m (80% PCBs)				X		
	Excavation	Mechanical Dredging	573 m³ (80% PCBs)					X	X
		Hydraulic Dredging	573 m³ (80% PCBs)					X	X
	Ex-Situ Solidification	Micro-encapsulation	Sediment >50 ppm PCB					X	

Table 4.1. (contd)

GENERAL RESPONSE ACTION				NO ACTION	LIMITED ACTION	CONTAINMENT		REMOVE AND DISPOSE	REMOVE AND TREAT
Medium	Technology Type	Process Option	Area or Volume			In Situ Capping	Stream Diversion		
Sediment	Ex-Situ Physical Treatment	Soil Washing / Size Segregation	573 m ³ (80% PCBs)					X	X
		Dewatering	573 m ³ (80% PCBs)					X	X
	Ex-Situ Bio. Treatment	Land Farming / Composting	573 m ³ (80% PCBs)						X
	Ex-Situ Thermal Treat.	Thermal Desorption	100 m ³ (29% PCBs)						X
		Incineration	100 m ³ (29% PCBs)						X
	Ex-Situ Chem. Treatment	Solvent Washing / Extraction	573 m ³ (80% PCBs)						X
		Dechlorination (KPEG)	100 m ³ (29% PCBs)						X
	Landfill	Chemical Waste Landfill	100 m ³ (29% PCBs)					X	
		On Site Landfill	573 m ³ (80% PCBs)					X	X
	Use as Fill	Fill Material	Sediment <1 ppm PCB					X	X

LEGEND:	Selected for Analysis	Not Selected	Not Applicable
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Physical Fish Controls: Physical controls (fish control dam or screens) would be installed in the lower portion of Garrison Slough to prevent the migration of fish into the contaminated portion of the slough. These controls would prevent further bioaccumulation of PCBs by fish that have migrated out of the slough. They would eventually reduce PCB concentrations in the fish population when those previously contaminated reach their life expectancy (~8 years).

Both process options (fish screens and fish control dam) passed the screening process. However, an evaluation of these options (Figure 3.2) suggests that screens would plug with debris and thus would require more maintenance. As a result, the fish screen option has not been included in this alternative. Instead, a rock dam (~ 1 meter [3 ft] high) would be installed just upstream from the slough's confluence with an unnamed stream near the intersection of Flightline and Central Avenues (Figure 4.1).^(a) The rock dam would be constructed with a vertical to very steep downstream face to prevent the upstream migration of fish.

(a) Assuming a gradient of 1 m/km, this dam would back up water in the slough approximately 1 km.

Figure 4.1. Location of Alternative Remedial Actions

4.2.3 In Situ Capping

The In Situ Capping alternative seeks to meet the RAOs by promulgating a fish advisory/restrictions and by isolating the majority of the PCBs from the ecosystem. The Fishing Advisory/Restrictions would provide a near immediate reduction in the amount of fish ingested from Garrison Slough, while isolating the PCBs would (over time) reduce the PCB concentration in the fish population.

Two process options for capping/lining the slough bottom, passed the technology screening. These options were: 1) lining of the stream with a corrugated metal culvert (preferably as a half pipe) directly into the stream, and 2) capping of the stream bottom with a multilayer barrier. The capital cost to install the culvert is estimated to be 2.5 times that for installation of the multilayer cap. For this reason, the multilayer cap process option has been selected to represent the in situ capping alternative.

Fishing Advisory/Restrictions: As discussed previously, Fishing Advisory/Restrictions would be promulgated by the Alaska State Department of Fish and Game, warning residents that ingestion of more than 1 meal of fish per year could pose an unacceptable health risk ($> 10^{-6}$ excess cancers) and designate Garrison Slough as catch-and-release-only. After the concentration in the fish population is shown to have decreased to acceptable levels (due to isolation of the PCBs and the natural death rate of the fish), the fishing restriction will be lifted.

Multilayer Cap: A 300-m (1000-ft) long stretch of lower Garrison Slough would be lined with a multilayer cap to isolate a preponderance of the PCB contaminated sediment from the ecosystem. The portion of the slough to be lined would be from just upstream of sampling station GS41 to Arctic Avenue (Figure 4.1). This portion of the slough contains ~80% of the mass of the PCB contamination.

Capping would be performed in late summer when surface water flows are their lowest, and the groundwater table is near its deepest. Surface water would be routed around the capping area to reduce the potential for sediment resuspension and transport, and to make installation of the liner less complicated. Two small temporary dams, one upstream and one downstream of the targeted dredging area, would be constructed. Water from the slough would be diverted around this portion of the slough, using large trailer-mounted pumps and PVC piping. Another small pump would be used to dewater the now isolated portion of the slough in preparation for capping.

After minimal preparation of the stream bed (devegetation and contouring), a permeable geotextile liner would be installed, and covered by successive 10-15 cm (4-6 in.) thick layers of pea gravel; coarse pebble, and cobble. The permeable liner would permit any gases formed during decomposition of organic matter to escape and not lift the liner. The complete liner is estimated to raise the bed of the slough 30 to 45 cm (12 to 18 in.).

4.2.4 Divert Stream

Another alternative for isolating the PCBs from the aquatic ecosystem, thereby making the PCBs unavailable for bioaccumulation, is to divert the stream through a new channel or a large culvert. Such diversion essentially cuts off the source of PCBs from the fish. A Fishing Advisory and Catch-and-Release Restrictions would be promulgated to control the ingestion of fish over the short term. After the PCBs have been isolated, and the concentration in fish has decreased to acceptable levels, the Fishing Advisory/Restrictions would be lifted.

This alternative is primarily directed at isolating the principal threat, that area containing a predominance of the contamination. The portion of the stream to be bypassed would consist of approximately 300 m (1000 ft) immediately upstream of Arctic Avenue (Figure 4.1). Although diverting the stream via excavation of a new channel passed the initial screening process, implementability is questionable along the narrow corridor between the Civil Engineers' Maintenance Shop and the railroad tracks (Figure 4.1). Thus, lining the stream with a multilayer cap (Section 4.2.3) has been selected to represent the containment/isolation alternative.

4.2.5 Dredge and Dispose

This alternative was developed to meet the RAOs by first promulgating a Fishing Advisory and Restrictions to reduce risks over the short term and second to remove a preponderance of PCB contamination, thereby reducing the long-term risks. In this alternative, the contaminated sediments removed from the slough would then be safely disposed. Several alternatives were assembled based on the choice of removal and disposal options (Section 4.1). However, the alternative selected to be representative of the general disposal response alternative for detailed analysis and comparison against other general response alternatives, consists of a temporary fish advisory/restrictions, and mechanical dredging of the most contaminated sediments, followed by on-site disposal of the dredged material. A brief description of the various components and their selection in the representative disposal alternative follows.

Fishing Advisory/Restrictions: Fishing Advisory/Restrictions would be promulgated by the Alaska State Department of Fish and Game, warning residents that ingestion of more than 1 meal (300 g) of fish per year could pose an unacceptable health risk ($> 10^{-8}$ excess cancers) and/or designate Garrison Slough as catch-and-release-only. When the concentration in the fish population is shown to have decreased to acceptable levels (due to removal of the PCBs and the natural death rate of the fish), the Fishing Advisory/Restriction would be lifted.

Dredging: Removal of the contaminated sediment from the slough would prevent further bio-accumulation in fish. This action would (over time) lead to a reduction in the PCB concentration in the fish population. Two process options for removal of PCB contaminated sediments, passed the technology screening process and were qualitatively evaluated for their efficiency, implementability, and relative cost (Section 3.2). Both mechanical (via backhoe) and hydraulic vacuum dredging were evaluated. Mechanical dredging (in combination with temporary damming and by-passing of the targeted dredging area) was selected as the representative process option because hydraulically dredged material would have a very high water to solids ratio (~85:15). Such a high water ratio would make sediment treatment prior to disposal more difficult, and would necessitate the treatment of large amounts of water, prior to its discharge back into the slough. Mechanical dredging of the 300-m (1000-ft) long zone of principal threat (Figure 4.1) would produce an estimated 660 m³ (860 cu yd) of contaminated sediment.

Disposal: All four disposal process options passed the screening process. These disposal options, together with some pretreatment options, were assembled into four general disposal trains

- Soil Washing and Off-Site Disposal
- Soil Washing, Asphalt Encapsulation, and On-Site Disposal/Reuse
- On-Site Disposal.
- Segregation, On-Site/Off-Site Disposal

Soil Washing and Off-Site Disposal. The soil washing and off-site disposal option consists of separating the contaminant laden fines from the coarse fraction of the sediment, disposal of the

clean coarse fraction on-site, and disposal of the contaminated fines in a TSCA-regulated chemical waste landfill. Dredged material would undergo size classification and the coarse fractions (sand and gravel) washed with a detergent solution to remove the silts and clays. The clean coarse fraction would be tested and disposed of as fill into the slough channel. The fine fraction would be dewatered, stabilized, packaged, and shipped to Arlington, Washington, for disposal.

Soil Washing, Asphalt Encapsulation, and On-Site Disposal/Reuse. In this option the dredged material would be screened and washed, with the clean coarse fraction used as fill (back to slough channel). The fine fraction would be mixed with and encapsulated into a cold asphalt emulsion, and either disposed to a landfill (the on-base asbestos landfill) or used as a subgrade material for on-base road construction. An advantage of this option is that a local contractor provides this service.

On-Site Disposal. Disposal on site, would consist of hauling the dredged material directly to a selected landfill (the on-base asbestos landfill). Disposal of dredge material 50 ppm and greater in a method other than in a chemical waste landfill requires the approval of the EPA's regional administrator [EPA 1990; 40 CFR 761.60 (a) (5)]. However, the low concentration of PCBs (65.6 ppm max.), the inherently low solubility (2.7×10^{-3} mg/L), and high sorption (as indicated high octanol-water partitioning [$K_{ow} = 14 \times 10^6$] of Aroclor-1260 [EPA 1990]) indicates that land disposal is a reasonable and prudent option. Based on the expected low cost, on-site disposal was selected as the representative disposal option for detailed analysis.

Segregation, Off-Site/On-Site Disposal. Dredged material from the portion of the slough containing ≥ 50 ppm would be segregated from the material remaining in the principal threat area. The ≥ 50 ppm fraction, estimated at 100 m^3 (130 cu yd) would be dewatered, stabilized, packaged, and shipped to Arlington, WA, for disposal at a permitted chemical waste landfill. The remaining dredge material (< 50 ppm), estimated at 560 m^3 (730 cu yd) would be disposed of directly to an on-base landfill.

4.2.6 Dredge and Treat

The Dredge and Treat alternative focuses on meeting the RAOs by first promulgating a Fishing Advisory/Restrictions and then eliminating a preponderance of the contamination so that fish could no longer bioaccumulate the PCBs. The fishing restrictions would provide nearly immediate reduction in the amount of fish ingested from Garrison Slough; removing most of the PCBs would, over time, reduce the PCB concentration in the fish population. Ex situ treatment of the removed sediment would permanently destroy the PCBs.

Several alternatives were assembled based on the choice of removal and treatment options (Section 4.1). However, the one alternative selected as representative of the general treatment response alternative (and to be used for detailed analysis and comparison against other general response alternatives) consists of temporary fish advisory/restrictions, and mechanical dredging of most contaminated sediments, followed by land farming bioremediation. A brief description of the various components and their selection in the representative treatment alternative follows.

Fishing Advisory/Restrictions: A Fishing Advisory/Restrictions would be promulgated by the Alaska State Department of Fish and Game warning residents that ingestion of more than 1 meal (300 g [10.6 oz]) of fish per year could pose an unacceptable health risk ($> 10^{-6}$ excess cancers) and/or designate Garrison Slough as a Catch-and-Release-only. When the concentration in the fish population is shown to have decreased to acceptable levels (due to removal of the PCBs and the natural death rate of the fish), the Fishing Advisory/Restriction would be lifted.

Dredging: Removal of the contaminated sediment from the slough would prevent further bioaccumulation in fish. This would, over time, lead to a reduction in the PCB concentration in the fish population. Two process options for removal of PCB contaminated sediments, passed the technology screening process and were qualitatively evaluated for their efficiency, implementability, and relative cost (Section 3.2). Both mechanical (via backhoe) and hydraulic vacuum dredging were evaluated. Mechanical dredging (in combination with a temporary damming and bypassing of the target area) was selected as the representative process option because hydraulically dredged material would have a very high water to solids ratio (~85:15) making sediment treatment more difficult, and necessitating the treatment of large amounts of water prior to discharge back into the slough. Mechanical dredging of the 300-m (1000-ft) long zone of principal threat (Figure 4.1) would produce an estimated 660 m³ (860 cu yd) of contaminated sediment.

Ex Situ Treatment: Ex situ treatment technologies and process options that passed through the screening process (Section 3.2) include those that reduce the volume, dewater the sediments, encapsulate the contaminated sediment, remove PCBs from the sediment, and/or permanently destroy the PCBs. These treatment technologies and process options were assembled into several alternative treatment trains (Table 4.1) aimed at the permanent destruction of the PCBs. These alternative treatment trains include:

- On-Site Land Farming
- Soil Washing and Off-Site Incineration
- Segregation and On-Site or Off-Site Incineration
- Extensive Soil Washing, Carbon Sorption, and Off-Site Incineration
- Thermal Desorption and Incineration
- Thermal Desorption and Dehalogenation

Land Farming. Land farming would degrade the PCBs over several months to years. White rot fungus, *Phanerocheate Chrysosporium*, is used with a cellulose/lignin base food source and nutrients to degrade the PCBs. Sawdust is the most likely food source, although straw could also be used. The degradation might normally be complete in a season. However, due to the short growing season in this arctic region, it is expected that up to three seasons may be required with new inoculations and aeration required at the beginning of each growing season.

Incineration. Incineration alternatives eliminate the PCBs by sending them to a hazardous waste incinerator for EPA approved destruction. Several incineration options were examined, and the segregation and incineration treatment train was selected as the representative incineration alternative. Other incineration treatment options have inherent disadvantages for application in a remote area like Eielson AFB.

Soil washing with either solvents or surfactants and water has been shown to successfully remove PCBs from soil. The effectiveness of soil washing can be severely reduced for certain clay mineralogies and several repeated washings may be necessary. A treatability test of sediments from Garrison Slough is necessary.

The use of thermal desorption prior to incineration requires specialized equipment generally too expensive to build for a small scale remediation. Mobilization and demobilization of the equipment to Fairbanks would not be economical. Contractors with smaller equipment may become available in the future and the high treatment confidence of this approach could warrant a second cost/benefit comparison prior to final selection.

Mobile incinerators for PCBs cannot be contracted, and shipping all of the contaminated soil (without volume reduction) to an approved PCB incinerator is cost prohibitive (~\$2.5M).

Segregation with either on-site or off-site incineration is the most reasonable and implementable incineration alternative. Dredged material from the portion of the slough containing ≥ 50 ppm would be segregated from the remaining material in the principal threat area. The ≥ 50 ppm fraction, estimated at 100 m^3 (160 cu yd) would either be incinerated in the base's coal fired boilers (providing the existing air discharge permit can be modified), or dewatered, packaged, and shipped to an off-site incinerator in Utah. Net transportation costs to the Utah site are estimated at approximately \$98,000 and net incineration costs are estimated at \$140,000. The costs for on-site incineration (if permitted) are estimated to be on the order of those for on-site landfarming (~\$30,000). The treated waste would then be disposed as backfill, or recycled for use as a pavement amendment. The remaining dredge material ($< 50 - 3$ ppm), estimated at 560 m^3 (730 cu yd) would be disposed of directly to an on-base landfill.

Dehalogenation. Dehalogenation of sediments is an emerging technology. The current direction, however, is to apply this technology using thermal desorber equipment as a reactor. Dehalogenation is also used to treat the volatilized products from conventional thermal desorption. The advantage of this treatment option is that PCBs are destroyed on site. The disadvantage for Eielson AFB is the unavailability of suitably sized equipment for economical treatment.

4.3 EVALUATION OF ALTERNATIVES

The preliminary evaluation of remedial alternatives for Garrison Slough is summarized in Table 4.2. The full range of alternatives (no action, limited action, containment, disposal, and treatment) has been retained. However, one of the containment/isolation options (divert stream) has not been retained because its implementation is highly questionable due to the narrow corridor between the Civil Engineers' Maintenance Shop and the railroad tracks. Lining the existing stream channel with a culvert was selected as the sole alternative to represent the containment/isolation remedial action.

The alternatives retained for detailed analysis are as follows:

- No Action
- Limited Action
- In Situ Capping
- Dredge and Dispose
- Dredge and Treat

Table 4.2. Preliminary Evaluation of Alternatives

Effectiveness	Implementability	Relative Cost	Evaluation Comments
<p>No Action</p> <p>The no action alternative will not meet the RAOs over the short term; no actions are taken to actively reduce risk from contaminated fish. May be effective over the very long term, due to natural attenuation and degradation of the PCBs.</p>	<p>This alternative is very easily implemented in that it requires nothing but continued environmental monitoring.</p> <p>May not be publicly acceptable.</p>	<p>Essentially no capital or O&M costs.</p> <p>High long-term monitoring costs for both fish and sediment concentrations.</p>	<p>Taking no action will not meet the RAOs of either the fish or the sediment, and will not reduce the risk to human health and environment, at least for quite some time.</p> <p>However, this alternative is retained as required under the NCP.</p>
<p>Limited Action</p> <p><u>Fish Advisory/ Restrictions:</u> Promulgation of fishing advisory should be effective in reducing the health risk from ingestion of fish, particularly over the short term. Issuance of Catch-and-Release-Only restrictions would provide an added level of protection.</p> <p><u>Physical Fish Controls:</u> A fish control dam should be fairly effective in isolating the fish from the PCB contaminated sediments. This should lead to a reduction in the PCB concentrations in fish over time. However, the permanence of this alternative is questionable, due to the possible migration of contaminated sediments downstream, past the fish control dam.</p>	<p>This alternative should be relatively easy to implement, but requires action on the part of the State Department of Fish and Game. However, it may meet with some public resistance.</p> <p>Installation of fish controls should also be relatively easy to implement, requiring only the installation of an earthen dam. Implementation may impact potential salmon spawning areas.</p>	<p>The costs for this alternative would be fairly minimal. The State Department of Fish and Game would be the ones promulgating the fish advisory/restrictions.</p> <p>Installation of the fish control dam is expected to have low capital costs and moderate maintenance costs.</p> <p>Costs for long-term monitoring would remain high.</p>	<p>This alternative will potentially meet the RAOs for fish. It provides a quick solution, which should be fairly easy to implement, and represents the low cost alternative.</p> <p>Thus, this alternative is retained for detailed analysis.</p>

Table 4.2. (contd)

Effectiveness	Implementability	Relative Cost	Evaluation Comments
<p>In Situ Capping</p> <p><u>Fish Advisory/Restrictions:</u> Same as above, only temporary (~8 years).</p> <p><u>Multi-Layer Cap:</u> Isolating most of the contaminated sediments beneath a multi-layer cap should be effective in reducing the bioaccumulation of PCBs. Thus, the concentration in the fish population should be reduced over time (~8 years [one generation]). This should provide a fairly permanent solution.</p>	<p>Implementation may be somewhat difficult, particularly if the water must be temporarily diverted and the slough bottom must be prepared to aid installation.</p> <p>The multilayer cap will severely impact the slough ecology. Implementation may impact potential salmon spawning areas.</p>	<p>High capital costs are expected for installation of the cap.</p> <p>Maintenance costs are expected to be moderate. Long-term monitoring costs are estimated to be moderate to high.</p>	<p>This alternative is expected to meet the RAOs for both fish and sediment. It provides both a quick short-term solution, as well as a longer, more permanent solution than the limited action alternative. However, it may be somewhat difficult to implement, and does not reduce the volume or toxicity of the PCBs.</p> <p>This alternative is retained for detailed analysis as a high cost option.</p>
<p>Dredge and Dispose</p> <p><u>Fish Advisory/Restrictions:</u> Same as above only temporary (~8 years).</p> <p><u>Dredge:</u> Approximately 80% of the PCB contamination would be removed by mechanically dredging, thus meeting the RAO.</p> <p><u>Dispose:</u> The dredged material would be disposed to an on-base landfill, covered with native soils, and vegetated.</p>	<p>Implementation is straight forward. Dredging and disposal of PCB contaminated sediment is often used at Superfund sites.</p> <p>Requires EPA approval to dispose of > 50 ppm PCBs in non-TSCA landfill.</p> <p>Will severely impact the slough ecology.</p>	<p>Moderate capital cost to dredge, haul, and dispose. No operation and maintenance costs. Long-term (post closure) monitoring, cost would be low.</p>	<p>This alternative is expected to meet the RAOs for both fish and sediment. It provides a quick short-term solution, as well as a permanent solution for the sediment. It reduces the volume of the PCBs by 80%.</p> <p>This alternative is retained for detailed analysis as a moderate cost option.</p>

Table 4.2. (contd)

Effectiveness	Implementability	Relative Cost	Evaluation Comments
<p>Dredge and Treat</p> <p><u>Fish Advisory/Restrictions:</u> Same as above, only temporary (~8 years).</p> <p><u>Dredge:</u> Approximately 80% of the PCB contamination would be removed by mechanically dredging, thus meeting the RAO.</p> <p><u>Treat:</u> The dredged material would be biodegraded using landfarming technologies. Treated soils would be left at the treatment site.</p>	<p>Fairly easy to implement as described above. Biodegradation may take several summers to complete. May require some treatability testing.</p> <p>Will severely impact the slough ecology.</p>	<p>Moderate capital costs for dredging and hauling.</p> <p>Moderate operation and maintenance costs during landfarming operations.</p>	<p>This alternative is expected to meet the RAOs for both fish and sediment. It provides a quick, short-term solution, as well as a permanent solution for the sediment. It not only reduces the volume of the PCBs by 80%, it also permanently destroys the PCBs.</p> <p>This alternative is retained for detailed analysis as a moderate to high cost option.</p>

5.0 DETAILED ANALYSIS OF ALTERNATIVES

This section provides the detailed description and evaluation of the alternatives selected for analysis. The alternative descriptions identify the technologies, describe the representative process options, and present the assumptions that were necessary to provide an analysis of each individual alternative against the NCP alternative evaluation criteria outlined in Table 5.1. The detailed analysis is presented by alternative. Each alternative includes consideration of contaminated fish and sediment. Information on the assumptions and calculations used in the development and evaluation of each alternative is provided in Appendix A. The detailed cost analysis for each alternative is provided in Appendix B.

Table 5.1. NCP Criteria for Evaluating Alternatives

Criterion	Description
Overall protection of human health and the environment	Alternatives shall be assessed to determine whether they adequately protect human health and the environment from unacceptable risks, both short- and long-term, by eliminating, reducing, or controlling exposures to contaminants.
Compliance with applicable or relevant and appropriate requirements (ARAR)	Alternatives shall be assessed to determine whether they attain federal and state ARARs or provide grounds for invoking a waiver.
Long-term effectiveness and permanence	Alternatives shall be assessed for the long-term effectiveness and permanence they provide and the degree of certainty they will prove successful. The following factors shall be considered: (1) magnitude of residual risk remaining after the alternative is implemented; and (2) adequacy and reliability of the controls necessary to manage the contaminants.
Reduction of toxicity, mobility, or volume through treatment	Alternatives shall be assessed to determine the degree to which recycling or treatment is expected to reduce the toxicity, mobility, and/or volume of the waste or residual contaminants and the degree to which treatment is irreversible. The quantity, persistence, toxicity, mobility, and propensity to bioaccumulate of each type of residual that will remain after treatment will also be considered.
Short-term effectiveness	Alternatives shall be assessed to determine the short-term impacts during implementation and the time until protection is achieved. The impacts that shall be considered include risks to the community impacts on workers, and potential environmental impacts.
Implementability	Alternatives shall be assessed for the ease or difficulty of implementation, including technical feasibility, administrative feasibility, and the availability of services and materials.
Cost	Alternatives shall be assessed to determine direct and indirect capital costs, annual operation and maintenance costs, and net present value.
Source: 40 CFR 300.430 (e)(9)(iii).	

The PRGs for fish were established to protect human health. The target cleanup level for fish is:

- a PCB concentration of 0.69 $\mu\text{g/kg}$ (wet weight)

This fish tissue concentration would produce a total excess cancer risk of less than 10^{-6} (for an estimated risk reduction of 10^{-3}). This calculation was based on a recreational exposure scenario (ingestion of fish by an adolescent [300 grams of fish, 30 times/yr for 12 years]).

The goal of remediating contaminated sediment is to reduce the biological uptake of PCB contamination by fish, thereby reducing the PCB concentration in the fish population over time. The cleanup goal is to remove a preponderance (~80%) of the PCB contamination in sediments of Garrison Slough.

5.1 DETAILED DEVELOPMENT OF ALTERNATIVES FOR GARRISON SLOUGH

A detailed description has been developed for each of the five alternatives presented in the preliminary screening of alternatives (Section 4.). The descriptions provide the basis for the individual and comparative analyses presented in Section 5.2.

The first two alternatives do not address PRGs. The No Action alternative represents the baseline risk without corrective action. The Limited Action alternative provides a means of limiting human exposures without reducing contaminant concentrations or mobility, except by natural attenuation. The last three alternatives provide increasing levels of control and achievement of PRGs at each level. However, all of the alternatives will require long-term management of the area.

5.1.1 No Action Alternative

The No Action alternative is not expected to achieve remedial action objectives. Natural degradation rates of highly chlorinated PCB congeners (such as those in Aroclor 1260) are extremely slow (Rhee et. al. 1993). Thus, the time required to achieve the PRG for fish without any remedial action is estimated to be on the order of tens of years (Appendix A, Section A.1.1).

5.1.2 Limited Action Alternative

The Limited Action alternative would use institutional controls to limit current and future exposures to contaminated fish, and engineering controls to limit the exposure of fish to the source of PCBs. The Limited Action alternative does not directly address the remedial action objectives except by natural attenuation. Although the natural degradation rate for highly chlorinated PCBs is very slow, isolation of fish from the source of the PCBs is expected to reduce their PCB tissue concentration over time. The time required for the concentration in the fish population to decrease (hopefully to the PRG levels) is estimated to approximate the life expectancy of the fish (~8 years).

The principal components of the Limited Action alternative are presented in Figure 5.1 and summarized as follows.

Fish: Institutional controls would be used to limit current and future exposures to contaminated fish. A Fish Advisory and/or Catch-and-Release restrictions would be promulgated by the Alaska State Department of Fish and Game. The advisory would state that ingestion of more than 1 meal (≥ 300 g) of fish per year from Garrison Slough may pose an unacceptable health risk ($> 10^{-6}$).

excess cancers) and should be avoided. This procedure would help to reduce the health risk to the population, but would not prevent exposure to contaminated fish. Designation of Garrison Slough as a Catch-and-Release-Only area, would essentially prevent the ingestion of contaminated fish.

Physical Fish Controls: Engineering controls would be installed in the lower portion of Garrison Slough to prevent the migration of fish into the contaminated portion of the slough. An earthen dam (~ 1 meter [3.3 ft] high) would be installed just upstream from the slough's confluence with the unnamed stream near the intersection of Flightline and Central Avenues. This earthen dam would be constructed with a vertical to very steep downstream face to prevent the upstream migration of fish. This dam would prevent further bioaccumulation of PCBs by fish; eventually reducing the PCB concentrations in the fish population.

However, this dam would also raise the water level in the slough causing subsequent changes in the slough's ecosystem. PCBs would also continue to move and be available for bioaccumulation within the isolated portion of the slough.

5.1.3 In Situ Capping Alternative

The In Situ Capping alternative seeks to meet the RAOs by promulgating a Fish Advisory and/or Restrictions and by isolating the majority of the PCBs from the ecosystem. The Fishing Advisory/Restrictions would provide a near immediate reduction in the amount of fish ingested from Garrison Slough, while isolating the PCBs is expected, over time, to reduce the PCB concentration in the fish population.

The most important components of the In Situ Capping alternative are summarized in Figure 5.2 and briefly outlined as follows.

Fish: Institutional controls would be used to limit current and short-term future exposures to contaminated fish. A temporary Fish Advisory and/or Catch-and-Release restrictions would be promulgated by the Alaska State Department of Fish and Game to limit and/or prevent the ingestion of contaminated fish. Once the PCB concentration in the fish population is shown to have decreased to meet RAO levels (due to isolation of the PCBs and the natural death rate of the fish), the Fishing Advisory/Restrictions would be lifted.

Sediment Capping: A 300-m (1000-ft) long stretch of lower Garrison Slough would be lined with a multilayer cap to isolate a preponderance of the PCB contaminated sediment from the ecosystem. The portion of the slough to be lined would be located immediately upstream of Arctic Avenue to just upstream of sampling station GS41 (Figure 5.2). This portion of the slough contains ~80% of the mass of the PCB contamination, and thus would meet the RAO for sediment.

Figure 5.1. Limited Action Alternative Schematic

INSTITUTIONAL CONTROLS

Limited Action Alternative

IN SITU CAPPING
Multi-Layer Cap Alternative

Figure 5.2. In Situ Capping Alternative Schematic

The stream here is estimated to be 2.4 to 3 meters (8-10 ft) wide and 0.3 to 0.6 meters (1-2 ft) deep with an estimated flow rate of 0.1 to over 4.2 m³/sec (4 to 150 ft³/sec). Capping would be performed in late summer when surface water flows are their lowest, and the groundwater table is near its deepest. Surface water would be routed around the capping area to reduce the potential for sediment resuspension and transport, and to make installation of the liner less complicated. Two small temporary dams, one upstream and one downstream of the targeted dredging area, would be constructed. Water from the slough would be diverted around this portion of the slough using two 110 l/s (1700 gpm) pumps and 20-cm dia. (8-in.) PVC piping. Another pump would be used to dewater the now isolated portion of the slough in preparation for capping.

After minimal preparation of the stream bed (devegetation and contouring), a permeable geotextile liner would be installed, and covered by successive 10-15 cm (4-6 in.) thick layers of pea gravel; 5-cm dia. very coarse pebble (2-in. drain rock), and finally 5- to 15-cm dia. small cobble (2-6 in. rock). A permeable liner would permit any gases formed during decomposition of organic mater to escape and not lift the liner. The complete liner is estimated to raise the bed of the slough 30 to 45 cm.

5.1.4 Dredge and Dispose Alternative

The Dredge and Dispose alternative was developed first to meet the RAOs by promulgating a temporary Fishing Advisory and/or Catch-and-Release restrictions to reduce risks over the short term, and second to remove and dispose of a preponderance of PCB contamination, thereby reducing the long term risks. In this alternative, the contaminated sediments will be removed from the slough and safely disposed in an existing base landfill.

The most important components of the Dredge and Dispose alternative are summarized in Figure 5.3 and briefly outlined below.

Fish: A Fishing Advisory/Restrictions would be promulgated by the Alaska State Department of Fish and Game warning residents that ingestion of more that 1 meal (300 g) of fish per year could pose an unacceptable health risk (10^{-6} excess cancers) and/or designate Garrison Slough as a Catch-and-Release-Only. Once the concentration in the fish population is shown to have decreased to acceptable levels (due to removal of the PCBs and the natural death rate of the fish), the Fishing Advisory/Restriction would be lifted.

Sediment Removal and On-Base Disposal: The preponderance of PCB contamination would be removed by mechanically dredging (in combination with temporary damming and bypassing of the targeted dredging area) approximately 300 linear meters (1000 ft) of Garrison Slough, immediately upstream of Arctic Avenue (Figure 5.3). This portion of the slough is estimated to contain ~80% of the mass of the PCB contamination. Thus, this action would meet the RAO for sediment.

Dredging activities would be performed in late summer when surface water flows are their lowest, and the groundwater table is near its deepest. Surface water would be routed around the targeted dredging area to reduce the potential for sediment resuspension and transport, and to reduce the amount of water picked up during the dredging operation.

Figure 5.3. Dredge and Dispose Alternative Schematic

Two small temporary dams, one upstream and one downstream of the targeted dredging area, would be constructed. Water from the slough would be diverted around this portion of the slough using two 110 ℓ/s (1700 gpm) pumps and 20-cm dia. (8 inch) PVC piping. A trackhoe would be used to excavate the sediment to a depth of approximately 0.6 m (2 ft) plus a 10% over dig and place the spoil directly into dump trucks. Each truckload of dredge material from the >50 ppm contamination zone would be sampled to determine its bulk concentration. Assuming the bulk concentration is <50 ppm and/or if disposal of 50 ppm PCB in onsite landfill has been accepted, the estimated 660 m^3 (860 cu yd) of dredge material would be hauled to an on-base landfill (the asbestos landfill) and disposed directly to an unlined trench. The dredge materials would be covered with native soils, and revegetated.

5.1.5 Dredge and Treat Alternative

The Dredge and Treat alternative was developed first to meet the RAOs by promulgating a temporary Fishing Advisory and/or Catch-and-Release restrictions to reduce risks over the short term, and second to remove a preponderance of the PCB contaminated sediment, thereby reducing the long-term risks. In this alternative, the contaminated sediments would be removed from the slough, treated, and safely disposed.

The most important components of the Removal and Treatment alternative are summarized in Figure 5.4 and briefly outlined below.

Fish: A Fishing Advisory/Restrictions would be promulgated by the Alaska State Department of Fish and Game warning residents that ingestion of more than 1 meal (300 g) of fish per year could pose an unacceptable health risk ($>10^{-6}$ excess cancers) and/or designate Garrison Slough as a Catch-and-Release-Only. Once the concentration in the fish population is shown to have decreased to acceptable levels (due to removal of the PCBs and the natural death rate of the fish), the Fishing Advisory/Restriction would be lifted.

Sediment Removal and Treatment: The preponderance of PCB contamination would be removed by mechanically dredging (in combination with temporary damming and by-passing of the targeted dredging area) approximately 300 linear m (1000 ft) of Garrison Slough immediately upstream of Arctic Avenue (Figure 5.4). This portion of the slough is estimated to contain ~80% of the mass of the PCB contamination. Thus, this action would meet the RAO for sediment.

Dredging activities would be performed in late summer when surface water flows are their lowest, and the groundwater table is near its deepest. Surface water would be routed around the targeted dredging area to reduce the potential for sediment resuspension and transport, and to reduce the amount of water picked up during the dredging operation. Two small temporary dams, one upstream and one downstream of the targeted dredging area, would be constructed. Water from the slough would be diverted around this portion of the slough using two 110 ℓ/s (1700 gpm) pumps and 20 cm diam. (8 in.) PVC piping. A trackhoe would be used to excavate the sediment to a depth of approximately 0.6 m (2 ft) plus a 10% over dig. This process would produce an estimated 660 m^3 (860 cu yd) of dredge spoil which would be placed into dump trucks. Each truckload from the >50 ppm contamination zone would be sampled to determine its bulk concentration.

Figure 5.4. Land Farming Alternative Schematic

The dredged material would be hauled to an existing on-base land farming facility. Here the dredge material would be evenly spread over a 15 cm (6 in.) thick bed of soil amendments (that is, straw or sawdust) and inoculated with white rot fungus (*Phanerocheate Chrysosporium*) and nutrients. The sediment, soil amendments, and nutrients would then be tilled and evenly mixed. The addition of soil amendments is estimated to increase the volume of the waste materials by a factor of 2.

Land farming would degrade the PCBs over several months to years (see Appendix A). The degradation might normally be complete in a season. However, due to the short growing season in this arctic region it is expected that up to three seasons may be required with new inoculations and aeration required at the beginning of each growing season. A treatability study would be conducted prior to full implementation to optimize the amounts and types of soil amendments and nutrients to be added.

5.1.6 Summary of the Alternatives for Garrison Slough

The primary components of each of the alternatives are summarized in Table 5.2.

Table 5.2. Primary Components in Alternatives for Garrison Slough

Alternative	Fish	Sediment
No Action	<ul style="list-style-type: none">• No Action	<ul style="list-style-type: none">• No Action
Limited Action	<ul style="list-style-type: none">• Fishing Restrictions• Physical Fish Controls	<ul style="list-style-type: none">• No Action
In Situ Capping	<ul style="list-style-type: none">• Fishing Restrictions	<ul style="list-style-type: none">• Temporarily Divert Surface Water• Line 300 m of Slough with a Multilayer Cap
Dredge and Dispose	<ul style="list-style-type: none">• Fishing Restrictions	<ul style="list-style-type: none">• Temporarily Divert Surface Water• Dredge 300 m of Slough• Dispose to On-base Landfill
Dredge and Treat	<ul style="list-style-type: none">• Fishing Restrictions	<ul style="list-style-type: none">• Temporarily Divert Surface Water• Dredge 300 m of Slough• Bioremediate via Land Farming

5.2 INDIVIDUAL EVALUATION OF ALTERNATIVES

This section presents an analysis of each of the five alternatives for Garrison Slough described in Section 5.1. The alternatives are evaluated against the seven NCP criteria presented in Table 5.1. The analyses are presented in table format as indicated below:

Table 5.3	No Action
Table 5.4	Limited Action
Table 5.5	In Situ Capping
Table 5.6	Dredge and Dispose
Table 5.7	Dredge and Treat

5.3 COMPARATIVE EVALUATION OF ALTERNATIVES

A comparative evaluation of the alternatives for Garrison Slough is provided in Table 5.8. The alternatives are compared based on how each alternative measures against the seven NCP criteria presented in Table 5.1.

Table 5.3. Individual Analysis of the Garrison Slough No Action Alternative

Individual Technical Components: None (natural attenuation)	
Criteria	Evaluation
Overall Protection of Human Health and Environment	
Fish Ingestion for current users	No reduction in risk except by natural attenuation.
Fish Ingestion for future users	No reduction in risk except by natural attenuation.
Compliance with ARARs	
Chemical Specific	Not Applicable
Location Specific	No action would be taken to restore and preserve the flood plain, stream, and/or wetland area.
Action Specific	Not Applicable
Long Term Effectiveness and Permanence	
Magnitude of residual risk	Risks will eventually be reduced through natural attenuation.
Adequacy of reliable controls	No controls are provided.
Reduction of Toxicity, Mobility, and Volume	
Treatment processes used and materials treated	None.
Amount of hazardous material destroyed or treated	None.
Expected reduction in toxicity, mobility, and volume	None.
Irreversibility of treatment	None.
Type and quantity of treatment residual	None.
Short-Term Effectiveness	
Protection of community during remedial action	No increased risk to community. No remedial action taken.
Protection of workers during remedial action	Not Applicable.
Time until remedial objectives are achieved	Fish and sediment remedial action objectives will not be achieved through natural attenuation for 10s to 100s of years.
Environmental impacts	PCB contamination will continue to move through the ecosystem via contaminated biota (including fish) and sediment.
Implementability	
Technical feasibility of operation and construction	Not Applicable.
Reliability of technology	Not Applicable.
Availability of services and material	Not Applicable.
Administrative feasibility	Acceptability to the community and regulatory agencies is uncertain.
Cost	
Capital	\$0
Annual O & M	\$0
Annual Monitoring	\$6,400
Present Worth (5%, 30 years)	\$98,384

Table 5.4. Individual Analysis of the Garrison Slough Limited Action Alternative

Individual Technical Components: Fishing Restrictions and Fish Control Dam	
Criteria	Evaluation
Overall Protection of Human Health and Environment	
Fish Ingestion for current users	A Fish Advisory and Catch-and-Release fishing restrictions would reduce the short-term risk to humans by preventing the ingestion of potentially contaminated fish.
Fish Ingestion for future users	The fishing restrictions in conjunction with a fish control dam would reduce the longer term risks, by preventing the ingestion of fish, and by inhibiting the migration of fish into the contaminated portion of the slough, thereby reducing their bioaccumulation of PCBs.
Compliance with ARARs	
Chemical Specific	Not Applicable.
Location Specific	No long-term actions would be taken to minimize potential harm and/or restore and preserve the flood plain, stream, and/or wetland area. Installation of the fish control dam would cause some impacts to Garrison Slough
Action Specific	Not Applicable.
Long Term Effectiveness and Permanence	
Magnitude of residual risk	Risks may eventually be reduced through natural attenuation.
Adequacy of reliable controls	Promulgation of Catch-and-Release fishing restrictions is expected to provide adequate controls to greatly reduce (if not totally prevent) the ingestion of contaminated fish. However, the adequacy of the fish control dam in preventing the migration of fish into the contaminated portion of the slough is uncertain.
Reduction of Toxicity, Mobility, and Volume	
Treatment processes used and materials treated	None.
Amount of hazardous material destroyed or treated	None.
Expected reduction in toxicity, mobility, and volume	None.
Irreversibility of treatment	None.
Type and quantity of treatment residual	None.

Table 5.4. (contd)

Individual Technical Components: Fishing Restrictions and Fish Control Dam	
Criteria	Evaluation
Short-Term Effectiveness	
Protection of community during remedial action	The risk to the community should be greatly reduced following promulgation of the Catch-and-Release fishing restrictions.
Protection of workers during remedial action	Virtually no risk to workers as fish control dam would be installed far enough downstream that PCB concentrations pose virtually no risk.
Time until remedial objectives are achieved	The RAO for fish would be met shortly after promulgation of the fishing restrictions, by cutting off the exposure route. The sediment RAO would not be achieved through natural attenuation for 10s to 100s of years.
Environmental impacts	PCB contamination would continue to move through the ecosystem via contaminated biota (including fish) and sediment. The fish control dam would raise the surface water level behind the dam and would inhibit migrating fish from reaching some spawning grounds.
Implementability	
Technical feasibility of operation and construction	Promulgation of the fishing restrictions and installation of the fish control dam are both implementable. Catch-and-Release restrictions are already in place at Piledriver Slough. Installation of the rock dam is not technically difficult.
Reliability of technology	The fishing restrictions are reliable, if not totally preventing the ingestion of fish (due to poaching), at least greatly reducing the potential. The reliability of the fish control dam, however, is uncertain.
Availability of services and material	All necessary services and materials are available and easily accessible.
Administrative feasibility	Acceptability to the community and regulatory agencies is uncertain.
Cost	
Capital	\$10,327
Annual O & M	\$2,032
Annual Monitoring	\$6,400
Present Worth (5%, 30 years)	\$139,948

Table 5.5. Individual Analysis of the Garrison Slough In Situ Capping Alternative

Individual Technical Components: Temporary fishing restrictions; temporary diversion of the slough; and In Situ Capping (via multilayer barrier) of ~80% of the PCB contaminated sediment.	
Criteria	Evaluation
Overall Protection of Human Health and Environment	
Fish Ingestion for current users	A Fish Advisory and/or Catch-and-Release fishing restrictions would reduce the short-term risk to humans by prevent the ingestion of potentially contaminated fish.
Fish Ingestion for future users	Isolation of most PCBs should reduce their bioaccumulation in fish thus, eventually reducing the PCB concentration in the fish population; and thereby reducing the human health risk due to ingestion.
Compliance with ARARs	
Chemical Specific	Not Applicable.
Location Specific	Remedial actions would be performed to minimize potential harm and/or restore and preserve the flood plain, stream, and/or wetland area. However, temporary diversion of the surface water and installation of a liner would cause some adverse impacts to a portion of Garrison Slough
Action Specific	Not Applicable.
Long Term Effectiveness and Permanence	
Magnitude of residual risk	Risks may eventually be reduced through natural attenuation.
Adequacy of reliable controls	The reliability of a permeable multilayer barrier to isolate the PCBs in these sediments is good as long as the integrity of the liner is not disrupted by vegetation or other bioturbation, and/or is not disrupted by changing stream flow conditions. Requires monitoring and maintenance to preserve integrity of liner.
Reduction of Toxicity, Mobility, and Volume	
Treatment processes used and materials treated	None.
Amount of hazardous material destroyed or treated	None.
Expected reduction in toxicity, mobility, and volume	Contaminants in fish and sediment may eventually be dispersed and degraded below toxic levels through natural processes.

Table 5.5. (contd)

Individual Technical Components: Temporary fishing restrictions; temporary diversion of the slough; and In Situ Capping (via multilayer barrier) of ~80% of the PCB contaminated sediment.	
Criteria	Evaluation
Irreversibility of treatment	None.
Type and quantity of treatment residual	None.
Short-Term Effectiveness	
Protection of community during remedial action	The risk to the community should be greatly reduced following promulgation of the Catch-and-Release fishing restrictions. Resuspension and downstream migration of contaminated sediments will be controlled by isolating the construction area and diverting the surface water.
Protection of workers during remedial action	Workers would be subjected to direct contact/exposure to PCBs during installation and maintenance of the cap.
Time until remedial objectives are achieved	The RAO for fish would be met shortly after promulgation of the fishing restrictions, by cutting off the exposure route. The sediment RAO would be achieved following installation of the surface cap.
Environmental impacts	Installation of the surface cap will essentially destroy the existing stream bed and will raise it 30 to 45 cm. This procedure will dramatically affect the ecology of this portion of the slough for many years.
Implementability	
Technical feasibility of operation and construction	Promulgation of Catch-and-Release restrictions is very feasible and is already in place at Piledriver Slough. Temporary damming and re-routing of the surface water is also fairly easily implemented. However, installation of the multilayer cap may be somewhat problematic in that it may have to be installed through standing water and over soft sediment.
Reliability of technology	The reliability of a permeable multilayer barrier to isolate the PCBs in these sediments is good as long as the integrity of the liner is not disrupted by vegetation or other bioturbation, and/or is not disrupted by changing stream flow conditions.
Availability of services and material	Materials are readily available. However, the availability of qualified contractors to properly design and install the cap is uncertain.

Table 5.5. (contd)

Individual Technical Components: Temporary fishing restrictions; temporary diversion of the slough; and In Situ Capping (via multilayer barrier) of ~80% of the PCB contaminated sediment.	
Criteria	Evaluation
Administrative feasibility	Acceptability to the community and regulatory agencies is uncertain.
Cost	
Capital	\$182,086
Annual O & M	\$2,132
Annual Monitoring	\$6,400
Present Worth (5%, 30 years)	\$290,080

Table 5.6. Individual Analysis of the Garrison Slough Dredge and Dispose Alternative

Individual Technical Components: Temporary fishing restrictions; temporary diversion of the slough; dredging of ~80% of the PCBs in contaminated sediment; and on-base disposal.	
Criteria	Evaluation
Overall Protection of Human Health and Environment	
Fish Ingestion for current users	Catch-and-Release fishing restrictions would reduce the short term risk to humans by prevent the ingestion of potentially contaminated fish.
Fish Ingestion for future users	Removal of most PCBs should reduce their bioaccumulation in fish,thus eventually reducing the PCB concentration in the fish population; and thereby reducing the human health risk due to ingestion.
Compliance with ARARs	
Chemical Specific	Not Applicable.
Location Specific	Remedial actions would be performed to minimize potential harm and/or restore and preserve the flood plain, steam, and/or wetland area. However, temporary diversion of the surface water and dredging activities would cause some adverse impacts to a portion of Garrison Slough. Remedial actions would have to minimize these effects and protect the fish and wildlife.
Action Specific	Requires EPA approval for alternate disposal of dredge materials ≥ 50 ppm.
Long Term Effectiveness and Permanence	
Magnitude of residual risk	Approximately 20% of the PCB contamination [in low concentrations (<10 ppm)] will be left in place. The risks from this residual contamination may eventually be reduced through natural attenuation.
Adequacy of reliable controls	The removal of PCBs from the slough is a very reliable way to control the contamination.
Reduction of Toxicity, Mobility, and Volume	
Treatment processes used and materials treated	None.
Amount of hazardous material destroyed or treated	None.
Expected reduction in toxicity, mobility, and volume	Approximately 80% of the PCB contamination would be removed from the slough. Natural attenuation should reduce the PCB contamination in the fish population.
Irreversibility of treatment	None.

Table 5.6. (contd)

Individual Technical Components: Temporary fishing restrictions; temporary diversion of the slough; dredging of ~80% of the PCBs in contaminated sediment; and on-base disposal.	
Criteria	Evaluation
Type and quantity of treatment residual	None.
Short-Term Effectiveness	
Protection of community during remedial action	The risk to the community should be greatly reduced following promulgation of the Catch-and-Release fishing restrictions. Resuspension and downstream migration of contaminated sediments during dredging will be controlled by isolating the area and diverting the surface water.
Protection of workers during remedial action	Workers would be subjected to direct contact and exposure to PCBs during dredging, transportation, and treatment. Some increased worker risk due to the used of heavy equipment.
Time until remedial objectives are achieved	The RAO for fish would be met shortly after promulgation of the fishing restrictions, by cutting off the exposure route. The sediment RAO would be achieved when dredging was complete.
Environmental impacts	Dredging will essentially destroy the existing stream bed and will lower its base level 30 to 60 cm. This will dramatically affect the ecology of this portion of the slough for many years. And will result in some short term water quality impacts (eg turbidity) as the stream bed re-equilibrates. It should be noted that this portion of the slough channel is man made, and a significant portion of the surface water flow is a result of discharges from the base Water Treatment Plant.

Table 5.6. (contd)

Individual Technical Components: Temporary fishing restrictions; temporary diversion of the slough; dredging of ~80% of the PCBs in contaminated sediment; and on-base disposal.	
Criteria	Evaluation
Implementability	
Technical feasibility of operation and construction	Promulgation of Catch-and-Release restrictions is very feasible and is already in place at Pile Driver Slough. Temporary damming and re-routing of the surface water is also fairly easily implemented. Dredging and on-site disposal is straight forward and should present no problems.
Reliability of technology	Dredging and disposal of PCB contaminated sediment is proven technology, and has been selected as the preferred remedial action alternative in the RODs of many superfund sites.
Availability of services and material	Dredging and hauling service are readily available in both the local and regional area.
Administrative feasibility	Acceptability to the community and regulatory agencies is uncertain.
Cost	
Capital	\$163,826
Annual O & M	\$0
Annual Monitoring	\$6,400 ^(a)
Present Worth (5%, 30 years)	\$190,979
(a) Drops to \$6,000 after 3 years, and \$0 after 8 years.	

Table 5.7. Individual Analysis of the Garrison Slough Dredge and Treat Alternative

Individual Technical Components: Temporary fishing restrictions; temporary diversion of the slough; dredging of ~80% of the PCBs in contaminated sediment; and land farming treatment.	
Criteria	Evaluation
Overall Protection of Human Health and Environment	
Fish Ingestion for current users	Catch-and-Release fishing restrictions would reduce the short term risk to humans by preventing the ingestion of potentially contaminated fish.
Fish Ingestion for future users	Removal of most PCBs should reduce their bioaccumulation in fish thus eventually reducing the PCB concentration in the fish population; and there by reducing the human health risk due to ingestion.
Compliance with ARARs	
Chemical-Specific	Not Applicable.
Location-Specific	Remedial actions would be performed to minimize potential harm and/or restore and preserve the flood plain, stream, and/or wetland area. However, temporary diversion of the surface water and dredging activities would cause some adverse impacts to a portion of Garrison Slough. Remedial actions would have to minimize these effects and protect the fish and wildlife.
Action-Specific	Must demonstrate performance equivalent to incineration by showing that solid residuals contain less or equal to 2 ppm PCBs (EPA 1990).
Long-Term Effectiveness and Permanence	
Magnitude of residual risk	Approximately 20% of the PCB contamination [in low concentrations (<10 ppm)] will be left in place. The risks from this residual contamination may eventually be reduced through natural attenuation.
Adequacy of reliable controls	The removal of PCBs from the slough is a very reliable way to control the contamination.
Reduction of Toxicity, Mobility, and Volume	
Treatment processes used and materials treated	Bioremediation via land farming (using sawdust, white rot fungus, and nutrients) would be used to treat approximately 660 m ³ (860 cu yd) of dredge spoils containing ~80% of the PCB contamination.
Amount of hazardous material destroyed or treated	An estimated 27 kg of PCBs would be removed in the 660 m ³ of sediment dredged from the slough. Land farming would dehalogenate greater than 91% of these PCBs, leaving a residual concentration of <2 ppm (see Appendix A).
Expected reduction in toxicity, mobility, and volume	Approximately 80% of the PCB contamination would be removed from the slough. And greater than 91% of the PCBs removed would be destroyed.

Table 5.7. (contd)

Individual Technical Components: Temporary fishing restrictions; temporary diversion of the slough; dredging of ~80% of the PCBs in contaminated sediment; and land farming treatment.	
Criteria	Evaluation
Irreversibility of treatment	The treatment is not reversible. Once dehalogenated the residual compounds would remain stable.
Type and quantity of treatment residual	The residual would primarily consist of the degraded sediment and soil amendments with PCB concentrations <2 ppm. The estimated quantity would be approximately 1300 m ³ (1700 cu yd).
Short-Term Effectiveness	
Protection of community during remedial action	The risk to the community should be greatly reduced following promulgation of the Catch-and-Release fishing restrictions. Resuspension and downstream migration of contaminated sediments during dredging will be controlled by isolating the area and diverting the surface water. Institutional controls would prevent direct contact during the land farming treatment.
Protection of workers during remedial action	Workers would be subjected to direct contact and exposure to PCBs during dredging, transportation, and treatment. Some increased worker risk due to the use of heavy equipment.
Time until remedial objectives are achieved	The RAO for fish would be met shortly after promulgation of the fishing restrictions, by cutting off the exposure route. The sediment RAO would be achieved when dredging was complete.
Environmental impacts	Dredging will essentially destroy the existing stream bed and will lower its base level 30 to 60 cm. This procedure will dramatically affect the ecology of this portion of the slough for many years. It may result in some short-term water quality impacts (such as, turbidity) as the stream bed re-equilibrates.

Table 5.7. (contd)

Individual Technical Components: Temporary fishing restrictions; temporary diversion of the slough; dredging of ~80% of the PCBs in contaminated sediment; and land farming treatment.	
Criteria	Evaluation
Implementability	
Technical feasibility of operation and construction	Promulgation of Catch-and-Release restrictions is very feasible and is already in place at Pile Driver Slough. Temporary damming, re-routing of the surface water, and dredging are straightforward and fairly easily implemented. Land farming practices are also easily implemented and were recently demonstrated at Eielson.
Reliability of technology	Biodegradation of PCBs via land farming, particularly with the highly chlorinated heavy congeners, such as those found in Aroclor 1260, and in an Arctic environment, is not well established. Some treatability testing should be performed.
Availability of services and material	Dredging and hauling services are readily available in both the local and regional area. Land farming facilities are also present at Eielson. Inoculum would be shipped from Utah.
Administrative feasibility	Acceptability to the community and regulatory agencies is uncertain.
Cost	
Capital	\$138,743
Annual O & M	\$18,700 ^(a)
Annual Monitoring	\$6,400 ^(b)
Present Worth (5%, 30 years)	\$216,821
(a) Drops to \$0 after 3 years.	
(b) Drops to \$6,000 after 3 years, and \$0 after 8 years.	

Table 5.8. Comparative Analysis of the Garrison Slough Alternatives

Criteria	Evaluation
Overall Protection of Human Health and Environment	
Fish Ingestion for current users	The NO ACTION alternative relies on eventual natural attenuation. The LIMITED ACTION alternative uses permanent fishing restrictions to prevent the ingestion of fish. All others use temporary fishing restrictions.
Fish Ingestion for future users	NO ACTION and LIMITED ACTION alternatives rely on natural attenuation. All others either isolate or remove most PCBs from possible bioaccumulation, thereby reducing the PCB concentration in the fish population and the human health risk due to ingestion.
Compliance with ARARs	
Chemical-Specific	Not Applicable.
Location Specific	<p>Neither the NO ACTION nor LIMITED ACTION alternative take direct action to minimize the potential harm and/or protect the fish and wildlife in this stream/wetland area.</p> <p>In addition, the rock dam used in the LIMITED ACTION alternative would inhibit the migration of fish and remove much of the slough from spawning grounds for an indefinite period of time.</p> <p>The IN SITU CAPPING and REMOVAL alternatives would cause some dramatic effects to the slough bottom and entire ecosystem in the disturbed area. However, these impacts should be relatively short-lived (within a few years).</p>
Action-Specific	Not Applicable for NO ACTION, LIMITED ACTION, or IN SITU CAPPING.

Table 5.8. (contd)

Criteria	Evaluation
Long-Term Effectiveness and Permanence	
Magnitude of residual risk	<p>The NO ACTION, LIMITED ACTION, and IN SITU CAPPING alternatives leave all of the contamination in place.</p> <p>However, the IN SITU CAPPING alternative isolates all but ~20% of the contamination from the ecosystem.</p> <p>Both removal alternatives (ON BASE DISPOSAL and EX-SITU TREATMENT) leave ~20% of the PCB contamination [in low concentrations (< 10 ppm)] in place. The risks from this residual contamination may eventually be reduced through natural attenuation.</p> <p>The DREDGE AND DISPOSE alternative would comply with TSCA for dredged material (EPA 1990). The DREDGE AND TREAT alternative would comply with TSCA if it can be shown that the residual PCB concentrations would be ≤ 2 ppm (EPA 1990).</p>
Adequacy of reliable controls	<p>The NO ACTION alternative provides no reliable controls. All other alternatives provide good controls for preventing the ingestion of potentially contaminated fish.</p> <p>However, the LIMITED ACTION alternative provides little control for isolating the PCB contaminated sediment from the ecosystem and fish population.</p> <p>The IN SITU CAPPING alternative isolates 80% of the contamination. Long-term reliability requires monitoring and maintenance to preserve integrity of liner.</p> <p>The two removal alternatives ensure a very high degree of reliability to isolate the contamination from the ecosystem of the slough.</p>
Reduction of Toxicity, Mobility, and Volume	
Treatment processes used and materials treated	Only the DREDGE AND TREAT alternative uses a treatment process. Treatment would be accomplished via land farming. An estimated 660 m ³ (860 cu yd) of dredge spoils, containing ~80% of the PCB contamination, would be treated.
Amount of hazardous material destroyed or treated	Only the DREDGE AND TREAT alternative would treat the PCB contamination. Greater than 25 kg (55 lb) of the estimated 27 kg (60 lb) (93%) of PCBs removed would be dehalogenated, leaving a residual concentration of <2 ppm.
Expected reduction in toxicity, mobility, and volume	Only the DREDGE AND TREAT alternative would reduce the PCB contamination through treatment. Permanent reduction of the toxicity is estimated at >91% of the PCBs removed from the slough.

Table 5.8. (contd)

Criteria	Evaluation																								
Irreversibility of treatment	Only the DREDGE AND TREAT alternative treats the contamination. This treatment is not reversible. Once dehalogenated,the residual compounds would remain stable.																								
Type and quantity of treatment residual	Only the DREDGE AND TREAT alternative leaves are treatment residual. This residual would consist of the degraded sediment and soil amendments with PCB concentrations <2 ppm. The estimated quantity of the residual would be approximately 1300 m ³ (1700 cu yd).																								
Short-Term Effectiveness																									
Protection of community during remedial action	<p>The NO ACTION alternative would neither increase nor decrease the risk to the community.</p> <p>All other alternatives would reduce the risk to the community through promulgation of the Catch-and-Release fishing restrictions. The IN SITU CAPPING, and dredging alternatives present the potential for some resuspension and downstream migration of contaminated sediments, which would be controlled by isolating the area and diverting the surface water.</p> <p>The DREDGE AND TREAT alternative presents some potential for direct contact exposure during land farming. Institutional controls would mitigate this potential.</p>																								
Protection of workers during remedial action	<p>The NO ACTION and LIMITED ACTION alternatives present no risk to workers.</p> <p>The remaining alternatives would subject workers to direct contact and exposure to PCBs during installation of the cap, dredging, transportation, and/or treatment. They would also present some increased risk due to the use of heavy equipment.</p>																								
Time until remedial objectives are achieved	<table><tr><td></td><td>Prevent Ingestion of Fish</td><td>Reduce Fish Tissue Concentrations</td><td>Sediment</td></tr><tr><td>NO ACTION</td><td>Tens of years.</td><td>Tens of years.</td><td>Tens of years.</td></tr><tr><td>LIMITED ACTION</td><td>A few weeks.</td><td>8-10 years.</td><td>Tens of years.</td></tr><tr><td>IN SITU CAPPING</td><td>A few weeks.</td><td>8-10 years.</td><td>A few weeks.</td></tr><tr><td>DREDGE AND DISPOSE</td><td>A few weeks.</td><td>8-10 years.</td><td>A few weeks.</td></tr><tr><td>DREDGE AND TREAT</td><td>A few weeks.</td><td>8-10 years.</td><td>A few weeks.</td></tr></table>		Prevent Ingestion of Fish	Reduce Fish Tissue Concentrations	Sediment	NO ACTION	Tens of years.	Tens of years.	Tens of years.	LIMITED ACTION	A few weeks.	8-10 years.	Tens of years.	IN SITU CAPPING	A few weeks.	8-10 years.	A few weeks.	DREDGE AND DISPOSE	A few weeks.	8-10 years.	A few weeks.	DREDGE AND TREAT	A few weeks.	8-10 years.	A few weeks.
	Prevent Ingestion of Fish	Reduce Fish Tissue Concentrations	Sediment																						
NO ACTION	Tens of years.	Tens of years.	Tens of years.																						
LIMITED ACTION	A few weeks.	8-10 years.	Tens of years.																						
IN SITU CAPPING	A few weeks.	8-10 years.	A few weeks.																						
DREDGE AND DISPOSE	A few weeks.	8-10 years.	A few weeks.																						
DREDGE AND TREAT	A few weeks.	8-10 years.	A few weeks.																						

Table 5.8. (contd)

Criteria	Evaluation
	<p>The NO ACTION and LIMITED ACTION alternatives would allow PCB contamination to continue to move through the ecosystem.</p> <p>In addition, the LIMITED ACTION alternative would raise the base level of the slough behind the rock dam, and inhibit migrating fish from reaching spawning grounds.</p> <p>The remaining alternatives will essentially destroy 300 m (1000 ft) of the existing channel and dramatically affect the ecology of the slough over the area subjected to remediation.</p> <p>IN SITU CAPPING will also raise the bottom 30 to 45 cm (1 to 1.5 ft), and continued maintenance of the liner may continue to adversely affect the slough.</p> <p>The DREDGING alternatives will lower the bed of the slough approximately 60 cm (2 ft) and some short-term degradation of the surface water (turbidity) may occur. However, the slough is expected to fully recover within a few years.</p>
Implementability	
Technical feasibility of operation and construction	<p>The NO ACTION alternative is the most easily implemented.</p> <p>Promulgation of Catch-and-Release restrictions in the remaining alternatives is feasible and is already in place at Pile Driver Slough.</p> <p>Temporary damming and rerouting of the surface water is fairly straightforward and easily implemented.</p> <p>IN SITU CAPPING may be some what problematic if installed through standing water and/or over soft sediment.</p> <p>DREDGING and ON-SITE DISPOSAL is straightforward and the preferred remedial action at many sites.</p> <p>LAND FARMING TREATMENT practices are easily implemented and have been demonstrated at Eielson AFB.</p>

Table 5.8. (contd)

Criteria	Evaluation										
Reliability of technology	<p>Fishing restrictions are reliable for preventing the ingestion of fish; if not totally (due to poaching), then at least for greatly reducing the potential.</p> <p>The reliability of the fish control dam used in the LIMITED ACTION alternative is uncertain.</p> <p>The reliability of IN SITU CAPPING is good as long as the integrity of the liner is not disrupted via bioturbation or changing stream flow conditions.</p> <p>DREDGING AND DISPOSAL of PCB contaminated sediment is proven technology, and has been selected as the preferred remedial action alternative in the RODs of many Superfund sites.</p> <p>BIOLOGICAL TREATMENT of PCBs via land farming, particularly with the highly chlorinated heavy congeners, such as those found in Aroclor 1260, and in an arctic environment, is not well established. Some treatability testing should be performed.</p>										
Availability of services and material	<p>All service and materials are readily available and accessible.</p> <p>However the availability of qualified contractors to install the IN SITU CAPPING is uncertain.</p> <p>The availability of an existing landfill at Eielson for the DISPOSAL alternative is uncertain.</p> <p>The availability of the existing land farming facilities at Eielson for the TREATMENT alternative is also some what uncertain. The white rot fungus inoculum would be shipped in from Utah.</p>										
Administrative feasibility	The acceptability to the community and regulatory agencies for any of these alternatives is uncertain.										
Cost											
Capital	<table> <tr><td>NO ACTION</td><td>\$0</td></tr> <tr><td>LIMITED ACTION</td><td>\$10,327</td></tr> <tr><td>IN SITU CAPPING</td><td>\$182,086</td></tr> <tr><td>DREDGE AND DISPOSE</td><td>\$164,826</td></tr> <tr><td>DREDGE AND TREAT</td><td>\$138,743</td></tr> </table>	NO ACTION	\$0	LIMITED ACTION	\$10,327	IN SITU CAPPING	\$182,086	DREDGE AND DISPOSE	\$164,826	DREDGE AND TREAT	\$138,743
NO ACTION	\$0										
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DREDGE AND TREAT	\$138,743										
Annual O & M	<table> <tr><td>NO ACTION</td><td>\$0</td></tr> <tr><td>LIMITED ACTION</td><td>\$2,032</td></tr> <tr><td>IN SITU CAPPING</td><td>\$2,132</td></tr> <tr><td>DREDGE AND DISPOSE</td><td>\$0</td></tr> <tr><td>DREDGE AND TREAT</td><td>\$18,700^(a)</td></tr> </table>	NO ACTION	\$0	LIMITED ACTION	\$2,032	IN SITU CAPPING	\$2,132	DREDGE AND DISPOSE	\$0	DREDGE AND TREAT	\$18,700 ^(a)
NO ACTION	\$0										
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DREDGE AND DISPOSE	\$0										
DREDGE AND TREAT	\$18,700 ^(a)										
Annual Monnitoring	<table> <tr><td>NO ACTION</td><td>\$6,400</td></tr> <tr><td>LIMITED ACTION</td><td>\$6,400</td></tr> <tr><td>IN SITU CAPPING</td><td>\$6,400</td></tr> <tr><td>DREDGE AND DISPOSE</td><td>\$6,400^(b)</td></tr> <tr><td>DREDGE AND TREAT</td><td>\$6,400^(b)</td></tr> </table>	NO ACTION	\$6,400	LIMITED ACTION	\$6,400	IN SITU CAPPING	\$6,400	DREDGE AND DISPOSE	\$6,400 ^(b)	DREDGE AND TREAT	\$6,400 ^(b)
NO ACTION	\$6,400										
LIMITED ACTION	\$6,400										
IN SITU CAPPING	\$6,400										
DREDGE AND DISPOSE	\$6,400 ^(b)										
DREDGE AND TREAT	\$6,400 ^(b)										

Table 5.8. (contd)

Criteria	Evaluation	
Present Worth (5%, 30 years)	NO ACTION	\$98,384
	LIMITED ACTION	\$139,948
	IN SITU CAPPING	\$290,080
	DREDGE AND DISPOSE	\$190,979
	DREDGE AND TREAT	\$216,821
(a) Drops to \$0 after 3 years.		
(b) Drops to \$6000 after 3 years, and \$0 after 8 years.		

6.0 REFERENCES

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APPENDIX A

**ASSUMPTIONS AND CALCULATIONS
USED IN THE DEVELOPMENT
AND EVALUATION OF ALTERNATIVES**

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APPENDIX A

ASSUMPTIONS AND CALCULATIONS USED IN THE DEVELOPMENT AND EVALUATION OF ALTERNATIVES

This appendix provides backup information relevant to the development and analysis of the alternatives for Garrison Slough presented in Section 5. It briefly identifies the technical assumptions, methodologies used in making preliminary calculations, input parameters for the hydrogeological modeling, and other relevant information.

The appendix is comprised of six sections. Section A.1 describes the assumptions used in the development of the No Action alternative. Section A.2 describes the assumption used in development of the Limited Action alternative. Section A.3 describes the assumptions and calculations used in developing the In Situ Capping alternative. Section A.4 describes the assumptions and calculations used in developing the Dredge and Dispose alternative. Section A.5 describes the assumptions and calculations used in developing the DREDGE AND TREAT alternative.

A.1 NO ACTION ALTERNATIVE

Without any remedial action, it was estimated that tens of years may be required to naturally degrade the PCBs to meeting the RAOs for both fish and sediment. However, it is extremely difficult to predict the time required for natural attenuation of PCBs in aquatic sediment due to the variation in behavior between various congeners and the variability in site specific environmental factors.

Estimate of Natural Degradations. Harkness et al. (1993) reiterate that PCBs can undergo biodegradation both anaerobically and aerobically. Anaerobic bacteria typically attack higher chlorinated PCB congeners through reductive dechlorination. This process removes chlorines, but leaves the biphenyl rings intact, and results in a corresponding increase in lower chlorinated congeners. Aerobic bacteria can degrade the lower chlorinated PCB congeners through oxidative degradation, producing the corresponding chlorobenzoic acids, which are readily degraded by other aerobic bacteria.

Rhee et al. (1993) reported that dechlorination of PCBs in anaerobic environments is generally considered to be slow, with major changes not observed for months or years. The results of their study reconfirmed that dechlorination was congener-specific and affected by sediment conditions. Thus, in situ dechlorination in contaminated sediments can be understood only through direct investigation of in-place congeners in their own sediments.

Because of these uncertainties, the estimated time frame to achieve the RAOs for sediment through natural attenuation was assumed to take at least an order of magnitude longer than the time required using an active land farming treatment system. The time required for PCB degradation through land farming with active inoculation of white rot fungus, soil amendments, and nutrient additions, was estimated to range from 1 to 3 years. Using the order of magnitude assumption, it may take more than 10 to 30 years to sufficiently reduce PCB concentrations in aquatic sediments to meet the RAOs (~80% reduction) by natural attenuation.

Natural attenuation in fish is estimated to be longer than the natural life span of the fish (~8 years). De Boer et al. (1994) found that the half-life of PCBs in eels under natural conditions ranged from 340 days to over 8 years, with half-life proportional to the number of chlorine atoms, and with the primary change due to growth dilution.

A.2 LIMITED ACTION ALTERNATIVE

The Limited Action alternative would use a Fish Advisory and/or Catch-and-Release fishing restrictions to limit current and future exposures to contaminated fish, and a rock dam to inhibit the migration of fish into the source area for the PCBs. The Limited Action alternative relies on natural attenuation to reduce their concentration in sediment and fish over time (see Section A.1).

A.2.1 Fishing Advisory/Restrictions

It was assumed that any Fish Advisory and/or Catch-and-Release restrictions would be promulgated by the Alaska State Department of Fish and Game. The fishing advisory would state that ingestion of more than 1 meal (≥ 300 g) of fish per year from Garrison Slough may pose an undue health risk and should be avoided. This number of fish meals was back calculated using a human health risk threshold of 10^{-6} excess cancers in the recreational exposure scenario (USAF 1995b).

It was also assumed that designation of Garrison Slough as a Catch-and-Release-only area (in spite of poaching) would essentially prevent the ingestion of contaminated fish.

A.2.2 Rock Dam

If properly designed, a rock dam can severely inhibit, if not prevent, the migration of fish into the contaminated portion of the slough. A sufficient height for a dam, to present a severe obstacle to Grayling fish (estimated to range up to 45 cm [18 in.] in length) was estimated to be approximately 1 meter (3.3 ft).

The slope of the channel was estimated from the difference in staff gauge readings at Central Avenue and Arctic Avenue. The difference in July and October, 1992 observations was 2.14 m (7 ft) (USAF 1995a). The distance between gauging stations is approximately 2.23 km (7300 ft). This figure results in a grade of approximately 1 m / km (1 ft / 1000 ft). Thus, a 1-m rock dam could back water up the slough to a distance of approximately 1 km.

A.3 IN SITU CAPPING ALTERNATIVE

The In Situ Capping alternative consists of temporary Fishing Advisory/Restrictions as discussed in Section A.2 and a multilayer cap to isolate the majority of the PCBs in sediment from the ecosystem. Approximately 240 m of Garrison Slough just upstream of Arctic Avenue would be lined with a multilayer cap to isolate a preponderance of the PCB-contaminated sediment from the ecosystem. This portion of the slough contains ~80% of the mass of the PCB contamination, and thus would meet the RAO.

A.3.1 PCB Mass Estimates from Garrison Slough

The mass of PCBs found in Garrison Slough was estimated using both the August/September 1994 sediment analyses as well as a recent (May, 1995) set of sediment screening analyses^(a). These two data sets were combined and organized in a spread sheet with distances relative to the location of sampling station GS00 (Figure A.1). These data are provided in Table A.1.

The slough was divided into segments surrounding each sample location. The length of each segment (L_s) was taken as the distance between the midpoints between the designated sampling location and its upstream and downstream neighbors. The Aroclor 1260 concentration at that sampling location was used as the average concentration (C) for that segment in the mass balance estimates. These estimates assume that the slough was 3.3 meters (10 ft) wide (W_s), and that contamination was evenly spread to a depth (D_s) of 0.6 m (2 ft). The bulk density (ρ_b) of the sediment was assumed to be 1.8 g/cc (3000 lbs/yd³). The mass for each segment was then calculated as follows:

$$\text{MPCB (kg)} = C (\mu\text{g/kg}) * \text{MS (kg)}$$

$$\text{MPCB (kg)} = C (\mu\text{g/kg}) / 10\text{E9} (\mu\text{g/kg}) * (L_s * W_s * D_s) (\text{m}^3) * \rho_b (\text{kg/m}^3)$$

The cumulative mass percent was calculated by summing (from upstream to downstream) the PCB mass in each segment, and then dividing this sum by the total estimated PCB mass. Table A.2 presents the mass estimates for each segment and the cumulative percent mass. Note that for this evaluation those analyses that were reported to be less than the detection limit, were taken as zero.

These results indicate that the portion of the slough considered to be the principal threat (from just upstream of sampling station GS41 to Arctic Avenue (just downstream from station GS25), accounts for about 81% of the total PCB mass present in Garrison Slough.

A.3.2 Temporary Diversion of Surface Water

Capping would be performed in late summer when surface water flows are their lowest, and the groundwater table is near its deepest. Surface water would be routed around the capping area to reduce the potential for sediment resuspension and transport, and to make installation of the liner less complicated. Two small temporary dams, one upstream and one downstream of the targeted dredging area, would be constructed. Water from the slough would be diverted around this portion of the slough using two diesel-powered pumps and 20 cm dia. (8-in.) PVC piping. A third pump would be used to dewater the now isolated portion of the slough in preparation for capping.

(a) Personal communication with Steve McNeil, Eielson Air Force Base, via telephone and fax, on May 17 and 18; and with Patricia White, Pacific Northwest Laboratory, via express mail on May 19, and via electronic mail (for distances) on May 23, 1995.

Figure A.1. Location of 1994 and 1995 Garrison Slough sediment sampling locations

Table A.1. Aroclor 1260 concentrations in 1994 and 1995 sediment samples from Garrison Slough.

Station ID	Distance from GS00 (ft)	Distance from GS00 (m)	Aroclor 1260 ($\mu\text{g/kg}$)
GS00	0	0	<13
GS01	1691	515	<13
GS03	3588	1094	<13
GS04	5466	1666	<13
GS05	9585	2922	<13
GS10	10279	3133	<18
GS11	10956	3339	<29
GS53	11006	3355	<38
GS52	11056	3370	<36
GS51	11106	3385	<33
GS50	11156	3400	<40
GS49	11206	3416	<40
GS48	11256	3431	<49
GS47	11306	3446	<24
GS46	11356	3461	<38
GS45	11406	3477	<53
GS44	11456	3492	<51
GS43	11506	3507	<47
GS42	11556	3522	<62
GS41	11606	3538	52300
GS12	11656	3553	55000
GS40	11706	3568	65600
GS39	11756	3583	40200
GS38	11806	3598	42400
GS37	11856	3614	22100
GS36	11906	3629	32400
GS35	11956	3644	28000
GS34	12006	3659	24800
GS34(D)	12006	3659	19600
GS33	12056	3675	23300
GS32	12106	3690	17700
GS31	12156	3705	24700

Table A.1. (contd)

Station ID	Distance from GS00 (ft)	Distance from GS00 (m)	Aroclor 1260 ($\mu\text{g/kg}$)
GS30	12206	3720	18300
GS29	12256	3736	9820
GS28	12306	3751	6510
GS27	12406	3781	5880
GS07	12431	3789	3200
GS26	12456	3797	5220
GS25	12506	3812	6050
GS08	12643	3854	2100
GS13	13356	4071	3500
GS24	13406	4086	5290
GS23	13456	4101	9110
GS22	13506	4117	5290
GS21	13556	4132	7940
GS20	13606	4147	7620
GS19	13656	4162	6030
GS18	13706	4178	1370
GS17	13756	4193	3240
GS16	13806	4208	658
GS15	13856	4223	1370
GS14	13906	4239	1430
GS14 (D)	13906	4239	741
GS09	13941	4249	130
GS06	20568	6269	230
BOLD denotes the 1994 sample data. (D) denotes duplicate samples.			

Table A.2. PCB Mass Estimates.

Station ID	Aroclor 1260 (C) ($\mu\text{g/kg}$)	Segment Length, L_s (m)	Segment Width, W_s (m)	Segment Depth, D_s (m)	Mass of Sediment (kg)	Mass PCB (kg)	Cumulative Mass (%)
GS00	<13	258	3.3	0.6	918473	0.00	0%
GS01	<13	547	3.3	0.6	1948835	0.00	0%
GS03	<13	575	3.3	0.6	2050405	0.00	0%
GS04	<13	914	3.3	0.6	3257292	0.00	0%
GS05	<13	734	3.3	0.6	2614198	0.00	0%
GS10	<18	209	3.3	0.6	744664	0.00	0%
GS11	<29	111	3.3	0.6	394873	0.00	0%
GS53	<38	15	3.3	0.6	54315	0.00	0%
GS52	<36	15	3.3	0.6	54315	0.00	0%
GS51	<33	15	3.3	0.6	54315	0.00	0%
GS50	<40	15	3.3	0.6	54315	0.00	0%
GS49	<40	15	3.3	0.6	54315	0.00	0%
GS48	<49	15	3.3	0.6	54315	0.00	0%
GS47	<24	15	3.3	0.6	54315	0.00	0%
GS46	<38	15	3.3	0.6	54315	0.00	0%
GS45	<53	15	3.3	0.6	54315	0.00	0%
GS44	<51	15	3.3	0.6	54315	0.00	0%
GS43	<47	15	3.3	0.6	54315	0.00	0%
GS42	<62	15	3.3	0.6	54315	0.00	0%
GS41	52300	15	3.3	0.6	54315	2.84	9%
GS12	55000	15	3.3	0.6	54315	2.99	18%
GS40	65600	15	3.3	0.6	54315	3.56	28%
GS39	40200	15	3.3	0.6	54315	2.18	35%
GS38	42400	15	3.3	0.6	54315	2.30	42%
GS37	22100	15	3.3	0.6	54315	1.20	46%
GS36	32400	15	3.3	0.6	54315	1.76	51%
GS35	28000	15	3.3	0.6	54315	1.52	56%
GS34	24800	15	3.3	0.6	54315	1.35	60%
GS34(D)	19600	NA					
GS33	23300	15	3.3	0.6	54315	1.27	63%
GS32	17700	15	3.3	0.6	54315	0.96	66%
GS31	24700	15	3.3	0.6	54315	1.34	70%

Table A.2. (contd)

Station ID	Aroclor 1260 (C) ($\mu\text{g/kg}$)	Segment Length, L_s (m)	Segment Width, W_s (m)	Segment Depth, D_s (m)	Mass of Sediment (kg)	Mass PCB (kg)	Cumulative Mass (%)
GS30	18300	15	3.3	0.6	54315	0.99	73%
GS29	9820	15	3.3	0.6	54315	0.53	75%
GS28	6510	23	3.3	0.6	81473	0.53	77%
GS27	5880	19	3.3	0.6	67894	0.40	78%
GS07	3200	8	3.3	0.6	27158	0.09	78%
GS26	5220	11	3.3	0.6	40737	0.21	79%
GS25	6050	28	3.3	0.6	101570	0.61	81%
GS08	2100	130	3.3	0.6	461681	0.97	84%
GS13	3500	116	3.3	0.6	414426	1.45	88%
GS24	5290	15	3.3	0.6	54315	0.29	89%
GS23	9110	15	3.3	0.6	54315	0.49	90%
GS22	5290	15	3.3	0.6	54315	0.29	91%
GS21	7940	15	3.3	0.6	54315	0.43	93%
GS20	7620	15	3.3	0.6	54315	0.41	94%
GS19	6030	15	3.3	0.6	54315	0.33	95%
GS18	1370	15	3.3	0.6	54315	0.07	95%
GS17	3240	15	3.3	0.6	54315	0.18	96%
GS16	658	15	3.3	0.6	54315	0.04	96%
GS15	1370	15	3.3	0.6	54315	0.07	96%
GS14	1430	13	3.3	0.6	46168	0.07	96%
GS14 (D)	741	NA					
GS09	130	1015	3.3	0.6	3618489	0.47	97%
GS06	230	1010	3.3	0.6	3599479	0.83	100%
Total						33.03	

Estimated Stream Flow. HLA (1989) reported the stream near Arctic Avenue to be 2.4 to 3 m (8-10 ft) wide and containing 0.3 to 0.6 m (1-2 ft) of water. In August, 1987, they estimated the flow velocity at 0.3 to 1.6 m/s (1-5 ft/s) and a flow rate of 0.14 to 0.28 m³/s (5 to 10 cfs).

Observations during the August, 1994 sampling effort, indicated water velocities were on the order of 0.16 to 0.25 m/s (0.5 to 0.75 ft/s) at stations GS08 and GS07, respectively (USAF 1995a) (see Table A.3). Given the previous channel width and depth estimates, this yields an estimated flow rate of 0.1 to 0.3 m³/s (4 to 10 cfs); consistent with HLA (1989) estimates.

Maximum flow in the slough occurs in April and May. Water elevations measured at the gauging station near Arctic Avenue in 1991-92 show an increase in the water level of approximately 0.3 m between August and May. Using the maximum flow velocity of 1.6 m/s (5 ft/s), the maximum channel width of 3 m (10 ft), and maximum water depth of 1 m (3 ft), yields a maximum flow rate of 4.25 m³/s (150 cfs).

A.3.3 Installation of Liner

It is assumed that only minimal preparation of the slough stream bed (devegetation and contouring) will be required. A permeable geotextile liner would then be installed, and covered by successive 10-15 cm (4-6 in.) thick layers of pea gravel; 5 cm dia. very coarse pebble (2-in. drain rock), and finally 5 to 15 cm dia. small cobble (2-6 in. rock). The use of a permeable liner was selected to permit any gases formed during decomposition of organic mater to escape and not lift the liner. The complete liner is estimated to raise the bed of the slough 30 to 45 cm (12 to 18 in.).

Table A.3. Depth and Description of Slough Sediment near Arctic Avenue

Sample Station	Water Depth (cm ^(a))	Flow Velocity (m/s)	Sediment Depth (cm)	Sediment Description
GS11 (upstream)	≤30 (1 ft)	-	30 (1 ft)	Very sticky much, very soft, greenish brown, fine sand/silt/clay, a lot of decaying organics (leaves).
GS12	≤30 (1 ft)	-	-	Soft, greenish-brown, fine grain sand & silt (near banks); more gravel in gaster moving water (near weir).
GS07	-	.23 (0.75 ft/s)	-	Sediment was mostly poorly sorted sand & gravel with some silty clay.
GS08 (downstream)	30-45 (1-1.5 ft)	.15 (0.5 ft/s)	-	Channel bed mostly gravel. Clayey silt (brown) near banks.
(a) Estimated from sampling method (ponar sampler used when water depth greater than 30 cm [1 ft]). Based on field logs, Sediment Sample Field Records, and personal communication with Patricia White.				

A.4 DREDGE AND DISPOSE ALTERNATIVE

The Dredge and Dispose alternative consists of temporary Fishing Advisory/restrictions as discussed in Section A.2, dredging of a preponderance of the contaminated sediment from the slough, and disposal of the dredge material to an on-base landfill. An estimate of the volume of materials to be handled is provided in the following subsection.

A.4.1 Volume of Sediment to be Dredged

The preponderance of PCB contamination that would be removed by dredging is located in approximately 300 liner m (1000 ft) of Garrison Slough immediately upstream of Arctic Avenue (Section A.3). The stream here is estimated to be 2.4 to 3 m (8-10 ft) wide and containing an estimated 0.3 to 0.6 m (1-2 ft) thick layer of sediment (Table A.3). The depth of contamination in the slough bottom sediments is unknown. For the purposes of this FS, the PCB contamination is assumed to be uniformly distributed throughout the thickness of the slough sediment. Thus, a conservative estimate of the amount of sediment to be removed assuming a contaminated volume of sediment 300 m x 3 m x 0.6 m⁽³⁾ (1000'x10'x2'), yields approximately 600m³ (780 yd³). Assuming a 10 percent over dig, to ensure capture of all contamination, this estimate yields a total sediment volume of 660 m³ (860 yds³).

HLA (1989) described the substrate of this portion of Garrison Slough, as being sand and gravel. Observations made during the August 1994 sampling suggest the sediment consists of half gravel and half finer-grained material, with roughly equal amounts of fine sand, silt and clay, and some decayed organic mater. Total organic carbon content was estimated at approximately 1%.

A.4.2 Disposal

The dredge material (660 m³ [860 cu yd]) would be hauled via dump truck to an on-base landfill. It is assumed the asbestos landfill is available for this purpose. The dredge material would be disposed directly to an unlined trench and covered with native soils. Final closure of the landfill would be conducted per existing plans.

Disposal of dredge material 50 ppm and greater in a method other than in a chemical waste landfill requires the approval of the EPA's regional administrator (EPA, 1990; 40 CFR 761.60[a] [5]). However, the low concentration of PCBs (55 ppm max.), and the inherently low solubility (2.7EE-3 mg/L), and high sorption (as indicated by high octanol-water partitioning [K_{ow} = 14EE6]) of Aroclor-1260 (EPA, 1990) indicates that land disposal is a reasonable and prudent option.

A.5 DREDGE AND TREAT ALTERNATIVE

This alternative consists of temporary fishing restrictions (per Section A.2); sediment removal (temporary surface water diversion and dredging, per Section A.4); and treatment (land farming) to address source area contaminants.

A.5.1 Land Farming Area

After the sediment has been removed from the slough, a land farming area with simple components like a liner, piping, and valves would be needed. The actual area needed depends on the amount of sediment removed, the amount of soil amendment to be added, and the spreading thickness. The

maximum volume of sediment to be removed and assumed to require treatment was about 660 m³ (860 yd³). An equal amount (660 m³ [860 yd³]) of soil amendment (sawdust and straw) is assumed to be required. The required spreading thickness is estimated at 15 cm each for the soil amendment and the dredge material. Thus, the following estimation was used to determine the size of the land farm area:

$$(2 \times 660 \text{ m}_3) \div (2 \times 0.15 \text{ m}) = 4400 \text{ m}^2 \approx 66 \text{ m} \times 66 \text{ m} (220 \text{ ft} \times 200 \text{ ft})$$

A.5.2 Efficiency

The amount of PCBs destroyed during land farming was estimated from the volume of dredge material to be treated, the estimated mass of PCB before treatment, and the estimated average concentration after treatment. The volume of contaminated sediment (to be treated) is estimated at 660 m³ (860 yd³) (Section A.4).

The estimated mass of PCBs, calculated by summing the mass in each slough sement (Table A.2) between GS41 and Artic Avenue, is approximately 26.6kg.

Land farming treatment (after 1 to 3 years) is estimated to reduce the concentration of PCBs to <2 ppm (mg/kg). Thus, the PCB mass after treatment is estimated at:

$$660 \text{ m}^3 \times 1800 \text{ kg/m}^3 \times <2 \text{ mg/kg} \times \text{kg}/10^6 \text{ mg} <2.4 \text{ kg}$$

This is a reduction of approximately 91%.

A.6 REFERENCES

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APPENDIX B

**REMEDIAL ACTION ALTERNATIVE
COST ESTIMATES**

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APPENDIX B

REMEDIAL ACTION ALTERNATIVE COST ESTIMATES

This appendix presents an order-of-magnitude construction cost estimate for each of the five alternatives described in Section 5.0. Cost is one of the seven criteria to evaluate the alternatives. A summary of the capital costs, annual operation and maintenance (O & M) costs, and the present worth costs is provided in Table B.1.

B.1 OVERVIEW OF FEASIBILITY COST ESTIMATES

Cost estimates were prepared using current pricing data, when available, to aid in the evaluation of alternatives. Final project cost will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project cost will differ from the estimates presented here. Because of the inherent variability, financial needs and resources must be carefully reviewed before decisions are made or final remedial action budgets are estimated.

The cost estimates are order-of-magnitude cost estimates with an intended accuracy of +50 percent and -30 percent. This range applies only to the alternatives as described in Section 5.0 and does not account for major changes in the scope of any alternative. The specific technologies for each alternative were not selected with the intent of limiting flexibility in the remedial approach, but rather to provide a basis for cost estimating. The actual remedial actions and their associated costs will be determined when EPA selects the approach for the final design.

Cost estimates include total capital cost, annual O&M costs, and total present worth costs for each alternative. Both capital and unit price costs are based on information solicited from Alaska and local contractors and from engineering judgement.

B.1.1 Capital Costs

Capital costs are the direct and indirect costs required to initiate and install the components of a remedial action. They include only those expenditures needed to design, construct, and install a remedial action. They exclude the costs needed to maintain a remedial action throughout its design life.

Installation costs include items such as costs for construction, site development, and buildings and services. Construction costs include costs needed to prepare for or implement the actions, such as the costs for materials, labor, and equipment. These costs have been adjusted for Alaska wherever possible. Decontamination facilities, health and safety equipment, and costs associated with confirmatory sampling have also been included where possible.

Indirect costs consist of engineering, supervision during construction, licenses and permits, and other services necessary to carry out a remedial action. They are not incurred as part of the remedial action but are ancillary to installation and construction costs. Indirect capital costs include bid and scope contingencies that reduce the likelihood of a cost overrun. Bid contingencies cover unknowns associated with the construction of the project, such as material or labor shortages.

Scope contingencies include provisions for changes that normally occur as part of the final design and implementation. EPA and ADEC administration are also indirect costs, but they have not been included in the cost estimate.

B.1.2. Annual Operating Costs

Annual operating costs for a remedial action include the costs incurred each year following construction or installation of a project. For the purposes of the economic evaluation, they are assumed to be paid at the end of the year in which they occur.

B.1.3 Present Worth Costs

Annual O&M costs occur over different periods of time for different alternatives. Present worth analyses provide a method for comparing costs that occur over different periods of time by discounting future costs to the present year. Present worth calculations were based on a maximum 30-year period. O&M costs that are incurred beyond the 30-year period become insignificant in the present worth analysis. The present worth analyses were calculated assuming 3, 5, and 10 percent interest rates in order to provide a range of values. Future costs are not escalated for inflation.

B.2 PRESENTATION OF ALTERNATIVE COSTS

The estimated costs calculated for each alternative are presented in the following attachments:

Attachment B.1	No Action Alternative
Attachment B.2	Limited Action Alternative
Attachment B.3	In Situ Capping Alternative
Attachment B.4	Dredge and Disposal Alternative
Attachment B.5	Dredge Treat Alternative

**ATTACHMENT B.1.
NO ACTION ALTERNATIVE
ORDER OF MAGNITUDE COST ESTIMATE**

Description:

Requires no action. But does include routine monitoring and sampling of the fish and sediment concentrations.

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
CAPITAL COSTS					
A) Fish Remediation					\$0
No Action Required	0			0	
B) Sediment Remediation					\$0
No Action Required	0			0	
CONSTRUCTION COST SUBTOTAL					\$0
Mobilization and & Gen'l Req'm'ts @15%					\$0
CONSTRUCTION COST SUBTOTAL					\$0
Contingencies					
Bid Contingency @ 10%			10%		\$0
Scope Contingency @ 20%			20%		\$0
Other Costs					
Administrative @ 5%			5%		\$0
Services During Construction @ 10%			10%		\$0
Legal @ 5%			5%		\$0
IMPLEMENTATION COST TOTAL					\$0
Engineering/Design @15% (\$1500 min.)			15%		\$0
CAPITAL COST TOTAL					\$0
ANNUAL OPERATIONS & MAINTENANCE COST					
A) Fish Remediation (Years 1-30)					\$0
No Action Required	0			0	
B) Sediment Remediation (Years 1-30)					\$0
No Action Required	0			0	
ANNUAL OPERATIONS & MAINTENANCE COST TOTAL					\$0
ANNUAL MONITORING COSTS					
A) Fish Remediation (Years 1-30)					\$2,600
Sample Analyses (Yearly)	4	EA	150	600	
Collection, Data Management & Reporting (Yearly)	40	HR	50	2000	
B) Sediment Remediation (Years 1-30)					\$3,800
Sample Analyses (Yearly)	12	EA	150	1800	
Collection, Data Management & Reporting (Yearly)	40	HR	50	2000	
ANNUAL MONITORING COSTS TOTAL					\$6,400

ATTACHMENT B.1. (Contd)

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
PRESENT WORTH COSTS					
PRESENT WORTH OF OPERATIONS & MAINTENANCE COSTS					
Present Worth of Fish Remediation O & M Costs for Years 1-30					
Assuming annual cost for 1-30 years @			3%		\$0
Assuming annual cost for 1-30 years @			5%		\$0
Assuming annual cost for 1-30 years @			10%		\$0
Present Worth of Sediment Remediation O & M Costs for Years 1-30					
Assuming annual cost for 1-30 years @			3%		\$0
Assuming annual cost for 1-30 years @			5%		\$0
Assuming annual cost for 1-30 years @			10%		\$0
PRESENT WORTH OF MONITORING COSTS					
Present Worth of Fish Monitoring Costs for Years 1-30					
Assuming annual cost for 1-30 years @			3%		\$50,961
Assuming annual cost for 1-30 years @			5%		\$39,968
Assuming annual cost for 1-30 years @			10%		\$24,510
Present Worth of Sediment Monitoring Costs for Years 1-30					
Assuming annual cost for 1-30 years @			3%		\$74,482
Assuming annual cost for 1-30 years @			5%		\$58,415
Assuming annual cost for 1-30 years @			10%		\$35,822
ESTIMATED CAPITAL COST (from previous page)					\$0
TOTAL PRESENT WORTH (CAPITAL + O&M + MONITORING COSTS)					
Assuming 30 years @			3%		\$125,443
Assuming 30 years @			5%		\$98,384
Assuming 30 years @			10%		\$60,332

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project costs will differ from the estimates presented here. Because of the inherent variability, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help ensure proper project evaluation and adequate funding.

ATTACHMENT B.2. LIMITED ACTION ALTERNATIVE ORDER OF MAGNITUDE COST ESTIMATE

Description:

A fishing advisory/restrictions would be promulgated by the Alaska Department of Fish and Game. Cost to the Air Force is assumed to be negligible.

A dam of 4"-2' rock would be constructed to allow water flow and prevent fish migration. The dam will be 4' thick at the top with side sloping at 45 deg. On the down stream side there will be a 4' shelf 1 1/2' thick to prevent erosion.

Basis:

The total rock volume of the dam (assuming a 10' wide stream) is 12 cu. yd. An additional 15 cu. yd of smaller rock will be laid to cover the bank above and below the dam to prevent wash out. Assumes the dam can be constructed during low water without diverting the stream or using other sediment controls. The dam can be constructed with a backhoe from the stream bank to maneuver the rocks.

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
CAPITAL COSTS					
A) Fish Remediation					\$5,206
Fishing Advisory/Restrictions					
No Action Required	0		0	0	
Fish Control Dam					
Site Preparation	8	HR	179	1532	
4' - 6" Rock (delivered)	12	YD	30	360	
Dam Construction	8	HR	179	1432	
2" - 4" Rock (delivered)	15	YD	30	450	
Bank Stabilization Rock	8	HR	179	1432	
B) Sediment Remediation					\$0
No Action Required	0			0	
CONSTRUCTION COST SUBTOTAL					\$5,206
Mobilization and & Gen'l Reqm'ts @15%					\$781
CONSTRUCTION COST SUBTOTAL					\$5,987
Contingencies					
Bid Contingency @ 10%			10%		\$599
Scope Contingency @ 20%			20%		\$1,197
Other Costs					
Administrative @ 5%			5%		\$299
Services During Construction @ 10%			10%		\$599
Legal @ 5%			5%		\$299
IMPLEMENTATION COST TOTAL					\$8,980
Engineering/Design @15%			15%		\$1,347
CAPITAL COST TOTAL					\$10,327

ATTACHMENT B.2. (Contd)

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
ANNUAL OPERATIONS & MAINTENANCE COST					
A) Fish Remediation (Years 1-30)					\$2,032
Fishing Advisory/Restrictions (Yearly)					
No Action Required	0		0	0	
Fish Control Dam					
Monthly Monitoring	12	HR	50	600	
Annual maintenance	8	HR	179	1432	
B) Sediment Remediation (Years 1-30)					\$0
No Action Required	0		0	0	
ANNUAL OPERATIONS & MAINTENANCE COST TOTAL					\$2,032
ANNUAL MONITORING COST					
A) Fish Remediation (Years 1-30)					\$2,600
Fish Sample Analyses (Yearly)	4	EA	150	600	
Collection, Data Management & Reporting (Yearly)	40	HR	50	2000	
B) Sediment Remediation (Years 1-30)					\$3,800
Sediment Sample Analyses (Yearly)	12	EA	150	1800	
Collection, Data Management & Reporting (Yearly)	40	HR	50	2000	
ANNUAL MONITORING COST TOTAL					\$6,400
PRESENT WORTH COSTS					
PRESENT WORTH OF OPERATIONS & MAINTENANCE COSTS					
Present Worth of Fish Remediation O & M Costs for Years 1-30					
Assuming annual cost for 1-30 years @			3%		\$39,828
Assuming annual cost for 1-30 years @			5%		\$31,237
Assuming annual cost for 1-30 years @			10%		\$19,155
Present Worth of Sediment Remediation O & M Costs for Years 1-30					
Assuming annual cost for 1-30 years @			3%		\$0
Assuming annual cost for 1-30 years @			5%		\$0
Assuming annual cost for 1-30 years @			10%		\$0
PRESENT WORTH OF MONITORING COSTS					
Present Worth of Fish Monitoring Costs for Years 1-30					
Assuming annual cost for 1-30 years @			3%		\$50,961
Assuming annual cost for 1-30 years @			5%		\$39,968
Assuming annual cost for 1-30 years @			10%		\$24,510
Present Worth of Sediment Monitoring Costs for Years 1-30					
Assuming annual cost for 1-30 years @			3%		\$74,482
Assuming annual cost for 1-30 years @			5%		\$58,415
Assuming annual cost for 1-30 years @			10%		\$35,822
ESTIMATED CAPITAL COST (from previous page)					\$10,327

ATTACHMENT B.2. (Contd)

TOTAL PRESENT WORTH (CAPITAL + O&M + MONITORING COSTS)

Assuming 30 years @	3%	\$175,598
Assuming 30 years @	5%	\$139,948
Assuming 30 years @	10%	\$89,815

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project costs will differ from the estimates presented here. Because of the inherent variability, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help ensure proper project evaluation and adequate funding.

ATTACHEMENT B.3. IN SITU CAPPING ALTERNATIVE ORDER OF MAGNITUDE COST ESTIMATE

Description:

A fishing advisory/restrictions would be promulgated by the Alaska Department of Fish and Game. Cost to the Air Force is assumed to be negligible.

The contaminated area would be isolated by installing temporary dams above and below the contaminated area. The stream flow would be pumped around the isolated area and the area pumped out to facilitate work in the stream bed. The stream bed is near ground water level so continued pumping may be required. The stream bed would be covered with a porous liner and successive layers of sand, gravel, and rock. The bottom of the stream bed will be raised 12-18".

Basis:

Assumes local material can be used for dam construction. Assumes the slough bed can be sufficiently pumped to allow access with a front end loader and hand contouring. The porous liner will retain the sediment and still allow any gases formed during decomposition of organic material to escape and not "lift" the bed. Liner area and rock requirements are based on half-round stream bed 12' wide. Over liner will be spread: 6" of pea gravel, 6" of 2" drain rock, and 6" of 2"-6" rock.

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
CAPITAL COSTS					
A) Fish Remediation					\$0
Fishing Advisory/Restrictions					
No Action Required	0		0	0	
B) Sediment Remediation					\$91,789
Dam Construction & Stream Diversion					
Dam Construction	16	HR	179	2964	
Hydraulic Pumps (1700 gpm; trailer mounted)	3	MO	1050	3150	
3 req'd - monthly rental.					
8" PVC Pipe	2200	LF	16	35222	
Pipe Installation	16	HR	49	784	
Lining Installation					
Bed Preparation (Loader plus 3 men)	16	HR	179	2964	
Geotextile Liner	20000	SF	1	20000	
Liner Installation	8	HR	179	1432	
Pea Gravel (delivered)	195	YD	25	4875	
Gravel Contouring	24	HR	179	4396	
Small Rock (delivered)	195	YD	18	3510	
Rock Contouring	24	HR	179	4296	
Large Rock	195	YD	20	3900	
Rock Contouring	24	HR	179	4296	
CONSTRUCTION COST SUBTOTAL					\$91,789
Mobilization and & Gen'l Req'm'ts @15%					\$13,768

ATTACHMENT B.3. (Contd)

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
CONSTRUCTION COST SUBTOTAL					\$105,557
Contingencies					
Bid Contingency @ 10%			10%		\$10,556
Scope Contingency @ 20%			20%		\$21,111
Other Costs					
Administrative @ 5%			5%		\$5,278
Services During Construction @ 10%			10%		\$10,556
Legal @ 5%			5%		\$5,278
IMPLEMENTATION COST TOTAL					\$158,336
Engineering/Design @15%			15%		\$23,750
CAPITAL COST TOTAL					\$182,086
ANNUAL OPERATIONS & MAINTENANCE COST					
A) Fish Remediation (Years 1-8)					\$0
No Action Required	0		0	0	
B) Sediment Remediation (Years 1-30)					\$2,132
Monthly Monitoring	12	HR	50	600	
Annual maintenance	8	HR	179	1532	
ANNUAL OPERATIONS & MAINTENANCE COST TOTAL					\$2,132
ANNUAL MONITORING COST					
A) Fish Remediation (Years 1-8)					\$2,600
Fish Sample Analyses (Yearly)	4	EA	150	600	
Collection, Data Management & Reporting (Yearly)	40	HR	50	2000	
B) Sediment Remediation (Years 1-30)					\$3,800
Sediment Sample Analyses (Yearly)	12	EA	150	1800	
Collection, Data Management & Reporting (Yearly)	40	HR	50	2000	
ANNUAL MONITORING COST TOTAL					\$6,400
PRESENT WORTH COSTS					
PRESENT WORTH OF OPERATIONS & MAINTENANCE COSTS					
Present Worth of Fish Remediation O & M Costs for Years 1-8					
Assuming annual cost for 1-8 years @			3%		\$0
Assuming annual cost for 1-8 years @			5%		\$0
Assuming annual cost for 1-8 years @			10%		\$0
Present Worth of Sediment Remediation O & M Costs for Years 1-30					
Assuming annual cost for 1-30 years @			3%		\$41,788
Assuming annual cost for 1-30 years @			5%		\$32,774
Assuming annual cost for 1-30 years @			10%		\$20,098

ATTACHMENT B.3. (Contd)

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
PRESENT WORTH OF MONITORING COSTS					
Present Worth of Fish Remediation O & M Costs for Years 1-8					
Assuming annual cost for 1-8 years @			3%		\$18,251
Assuming annual cost for 1-8 years @			5%		\$16,804
Assuming annual cost for 1-8 years @			10%		\$13,871
Present Worth of Sediment Remediation O & M Costs for Years 1-30					
Assuming annual cost for 1-30 years @			3%		\$74,482
Assuming annual cost for 1-30 years @			5%		\$58,415
Assuming annual cost for 1-30 years @			10%		\$35,822
ESTIMATED CAPITAL COST (from above)					\$182,086
TOTAL PRESENT WORTH OF CAPITAL COST & OPERATIONS & MAINTENANCE COST					
Assuming 30 years @			3%		\$316,607
Assuming 30 years @			5%		\$290,080
Assuming 30 years @			10%		\$251,878

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project costs will differ from the estimates presented here. Because of the inherent variability, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help ensure proper project evaluation and adequate funding.

ATTACHMENT B.4. DREDGE AND DISPOSE ALTERNATIVE ORDER OF MAGNITUDE COST ESTIMATE

Description:

Fishing advisory/restrictions would be promulgated by the Alaska Department of Fish and Game. Cost to the Air Force is assumed to be negligible.

Sediment would be removed from the slough and buried on site. Temporary dams would be constructed above and below the primary contamination area. Surface water (currently flowing at 4 10 cfs) would be pumped around the 1000 ft area targeted for remediation. The steam bed would then be dredged to a depth of 1-2 ft with a trackhoe. The sediment would then be trucked to the disposal area. A disposal trench would be excavated to hold the estimated 860 yd³ of dredge material. The sediment would be dumped in the disposal trench and covered with 1' of native soil, and the area with reseeded with grass.

Basis:

Total material to be dredged is assumed to be 780 yd³ plus 10% overdig (860 yd³). It is assumed that an acceptable disposal area is already on site, and that there are no costs for disposal except for excavation necessary to use site. The clean soil from excavation of the disposal trench would be spread over the contaminated soil and planted w/ grass.

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
CAPITAL COSTS					
A) Fish Remediation					\$0
Fishing Advisory/Restrictions					
No Action Required	0		0	0	
B) Sediment Remediation					\$82,584
Dam Construction & Stream Diversion					
Dam Construction	16	HR	179	2864	
Backhoe Mobilization	1	EA	100	100	
Hydraulic Pumps (1700 gpm; trailer mounted)	3	MO	1050	3150	
3 req'd - monthly rental.					
8" PVC Pipe	2200	LF	16	35222	
Pipe Installation	16	HR	49	784	
Dredging & Material Testing					
Excavator & Operator (150 cu yd/day)	48	HR	155	7440	
Excavator Mobilization/Demobilization	2	EA	500	1000	
Bulk Material Sampling (Screening -1.1/truck)	100	EA	60	6000	
Haulage of Dredge Material					
Truck and Operator (3)	96	HR	65	6240	
Disposal					
Bulldozer Mobilization	1	EA	500	500	
Excavate Trench & Cover Dredgings	56	HR	224	12544	
Prepare area for reseeded	8	HR	50	400	
Tractor Mobilization	1	EA	100	100	
Hydroseeding	50,000	SF	0.08	4000	

ATTACHMENT B.4. (Contd)

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
Verification Sampling					
Sample collection	4	HR	50	200	
Analyses	12	EA	170	2040	
CONSTRUCTION COST SUBTOTAL					\$82,584
Mobilization and & Gen'l Reqm'ts @15%					\$12,388
CONSTRUCTION COST SUBTOTAL					\$94,972
Contingencies					
Bid Contingency @ 10%			10%		\$9,497
Scope Contingency @ 20%			20%		\$18,994
Other Costs					
Administrative @ 5%			5%		\$4,749
Services During Construction @ 10%			10%		\$9,497
Legal @ 5%			5%		\$4,749
IMPLEMENTATION COST TOTAL					\$142,457
Engineering/Design @15%			15%		\$21,369
CAPITAL COST TOTAL					\$163,826
ANNUAL OPERATIONS & MAINTENANCE COST					
A) Fish Remediation (Years 1-8)					\$0
No Action Required	0		0	0	
B) Sediment Remediation (Years 1-3)					\$0
No Action Required	0		0	0	
ANNUAL OPERATIONS & MAINTENANCE COST TOTAL					\$0
ANNUAL MONITORING COST					
A) Fish Remediation (Years 1-8)					\$2,600
Fish Sample Analyses (Yearly)	4	EA	150	600	
Collection, Data Management & Reporting (Yearly)	40	HR	50	2000	
B) Sediment Remediation (Years 1-3)					\$3,800
Sediment Sample Analyses (Yearly)	12	EA	150	1800	
Collection, Data Management & Reporting (Yearly)	40	HR	50	2000	
ANNUAL MONITORING COST TOTAL					\$6,400
PRESENT WORTH COSTS					
PRESENT WORTH OF OPERATIONS & MAINTENANCE COSTS					
Present Worth of Fish Remediation O & M Costs for Years 1-8					
Assuming annual cost for 1-8 years @			3%		\$0
Assuming annual cost for 1-8 years @			5%		\$0
Assuming annual cost for 1-8 years @			10%		\$0

ATTACHMENT B.4. (Contd)

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
Present Worth of Sediment Remediation O & M Costs for Years 1-3					
Assuming annual cost for 1-3 years @			3%		\$0
Assuming annual cost for 1-3 years @			5%		\$0
Assuming annual cost for 1-3 years @			10%		\$0
PRESENT WORTH OF MONITORING COSTS					
Present Worth of Fish Monitoring Costs for Years 1-8					
Assuming annual cost for 1-8 years @			3%		\$18,251
Assuming annual cost for 1-8 years @			5%		\$16,804
Assuming annual cost for 1-8 years @			10%		\$13,871
Present Worth of Sediment Monitoring Costs for Years 1-3					
Assuming annual cost for 1-3 years @			3%		\$10,749
Assuming annual cost for 1-3 years @			5%		\$10,348
Assuming annual cost for 1-3 years @			10%		\$9,450
ESTIMATED CAPITAL COST (from above)					\$163,826
TOTAL PRESENT WORTH OF CAPITAL COST & OPERATIONS & MAINTENANCE COST					
Assuming 30 years @			3%		\$192,826
Assuming 30 years @			5%		\$190,979
Assuming 30 years @			10%		\$187,147

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project costs will differ from the estimates presented here. Because of the inherent variability, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help ensure proper project evaluation and adequate funding.

ATTACHMENT B.5. DREDGE AND TREAT ALTERNATIVE ORDER OF MAGNITUDE COST ESTIMATE

Description:

Fishing advisory/restrictions would be promulgated by the Alaska Department of Fish and Game. Cost to the Air Force is assumed to be negligible.

Sediment would be removed from the slough and biologically treated on site, via land farming. Temporary dams would be constructed above and below the primary contamination area. Surface water (assumed to flow at 4-10 cfs) would be pumped around the 790 ft area targeted for remediation. The steam bed would be dredged to a depth of 1-2 ft with a backhoe, and the sediment trucked to the treatment area. Soil amendments of straw, saw dust, and/or wood residues would be spread to thickness of about 6 inches over the treatment area. The dredged sediment would then be spread over the soil amendments and inoculated with white rot fungus, Phanerocheate Chrysosporium, and nutrients. The sediment, amendments, and nutrients would be tilled until evenly mixed.

Basis:

Total material to be dredged is assumed to be 580 yd³ plus 10% overdig (640 yd³). The saturated dredged sediment is assumed to contain 30% moisture. Density is 2877 lbs/yd³. Inoculum and nutrients must be added yearly (worst case). It is assumed that an acceptable treatment area is already on site, and that there are no added costs to use the site except for any necessary grading. The inoculum must be shipped from Utah in drums @ 40 lbs/ft³ and is applied at a rate of 1 yd³/100 yd³ sediment; nutrient addition is ammonium nitrate @ 1lb/200 ft². Assumes treated soil can be left

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
CAPITAL COSTS					
A) Fish Remediation					\$0
Fishing Advisory/Restrictions					
No Action Required	0		0	0	
B) Sediment Remediation					\$69,940
Dam Construction & Stream Diversion					
Dam Construction	16	HR	179	2864	
Backhoe Mobilization	1	EA	100	100	
Hydraulic Pumps (1700 gpm; trailer mounted)	3	MO	1050	3150	
3 req'd - monthly rental.					
8" PVC Pipe	2200	LF	16	35222	
Pipe Installation	16	HR	49	784	
Dredging & Material Testing					
Excavator & Operator	48	HR	155	7440	
Excavator Mobilization/Demobilization	2	EA	500	1000	
Bulk Material Sampling (Screening -1.1/truck)	100	EA	60	6000	
Haulage of Dredge Material					
Truck and Operator (3)	96	HR	65	6240	
Verification Sampling					
Sample collection	4	HR	50	200	
Analyses	12	EA	170	2040	

ATTACHMENT B.5. (Contd)

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
Land Farming Biological Treatment					
Level and Till Treatment Area (included Tractor & Operator)	8	HR	50	400	
Tractor Mobilization	1	EA	100	100	
Sawdust Soil Amendment (600 yd3, delivered)	20	TL	180	3600	
Spread and Level Amendment (via Tractor)	8	HR	50	400	
Spread and Level Dredged Sediment	8	HR	50	400	
Nutrient and Inoculum Addition (Included in O&M Costs)					
CONSTRUCTION COST SUBTOTAL					\$69,940
Mobilization and & Gen'l Reqm'ts @15%					\$10,491
CONSTRUCTION COST SUBTOTAL					\$80,431
Contingencies					
Bid Contingency @ 10%			10%		\$8,043
Scope Contingency @ 20%			20%		\$16,086
Other Costs					
Administrative @ 5%			5%		\$4,022
Services During Construction @ 10%			10%		\$8,043
Legal @ 5%			5%		\$4,022
IMPLEMENTATION COST TOTAL					\$120,647
Engineering/Design @15%			15%		\$18,097
CAPITAL COST TOTAL					\$138,743
ANNUAL OPERATIONS & MAINTENANCE COST					
A) Fish Remediation (Years 1-8)					\$0
No Action Required	0		0	0	
B) Sediment Remediation (Years 1-3)					\$18,700
Treatment Testing of Dredge Spoils (Years 1-3)					
Sample collection	4	HR	50	200	
Analyses	6	EA	150	900	
Nutrient and Inoculum Addition (Years 1-3)					
Spread Nutrients and Inoculum, and Till (disk)	8	HR	50	400	
Tractor (w/Disk) Mobilization	1	EA	100	100	
Inoculum	6	CY	2500	15000	
Inoculum Shipping (Freight for 25 drums)	1000	LB	2	2000	
Nutrients (Ammonium Nitrate)	200	LB	1	100	
ANNUAL OPERATIONS & MAINTENANCE COST TOTAL					\$18,700
ANNUAL MONITORING COSTS					
A) Fish Remediation (Years 1-8)					\$2,600
Fish Sample Analyses (Yearly)	4	EA	150	600	
Collection, Data Management & Reporting (Yearly)	40	HR	50	2000	
B) Sediment Remediation (Years 1-3)					\$3,800
Sediment Sample Analyses (Yearly)	12	EA	150	1800	
Collection, Data Management & Reporting (Yearly)	40	HR	50	2000	
ANNUAL MONITORING COSTS TOTAL					\$6,400

ATTACHMENT B.5. (Contd)

<u>Cost Component Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Component Cost</u>	<u>Category Subtotal</u>
PRESENT WORTH COSTS					
PRESENT WORTH OF OPERATIONS & MAINTENANCE COSTS					
Present Worth of Fish Remediation O & M Costs for Years 1-8					
Assuming annual cost for 1-8 years @			3%		\$0
Assuming annual cost for 1-8 years @			5%		\$0
Assuming annual cost for 1-8 years @			10%		\$0
Present Worth of Sediment O&M Costs for Years 1-3					
Assuming annual cost for 1-3 years @			3%		\$52,895
Assuming annual cost for 1-3 years @			5%		\$50,925
Assuming annual cost for 1-3 years @			10%		\$46,504
PRESENT WORTH OF MONITORING COSTS					
Present Worth of Fish Monitoring Costs for Years 1-8					
Assuming annual cost for 1-8 years @			3%		\$18,251
Assuming annual cost for 1-8 years @			5%		\$16,804
Assuming annual cost for 1-8 years @			10%		\$13,871
Present Worth of Sediment Monitoring Costs for Years 1-3					
Assuming annual cost for 1-3 years @			3%		\$10,749
Assuming annual cost for 1-3 years @			5%		\$10,348
Assuming annual cost for 1-3 years @			10%		\$9,450
ESTIMATED CAPITAL COST (from above)					\$138,743
TOTAL PRESENT WORTH OF CAPITAL COST & OPERATIONS & MAINTENANCE COST					
Assuming 30 years @			3%		\$220,638
Assuming 30 years @			5%		\$216,821
Assuming 30 years @			10%		\$208,568

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