Operable Unit C

Final Feasibility Study Report

Fort Richardson, Alaska
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Abbreviations

ADEC	Alaska Department of Environmental Conservation
ARAR	applicable or relevant and appropriate requirement
BTAG	Biological Technical Assistance Group
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund)
cm	centimeter
COE	U.S. Army Corps of Engineers
CRREL	U.S. Army Cold Regions Research and Engineering Laboratory
ERF	Eagle River Flats
FFA	Federal Facility Agreement
FS	feasibility study
GIS	geographical information system
gpm	gallons per minute
ha	hectare
HE	high explosive
m	meter
µg/g	micrograms per gram
NCP	National Contingency Plan
NPL	National Priorities List
O&M	operations and maintenance
OB	open burning
OD	open detonation
OUC	Operable Unit C
RAO	remedial action objective
RI	remedial investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
TMV	toxicity, mobility, and volume
USARAK	U.S. Army, Alaska
USEPA	U.S. Environmental Protection Agency
UXO	unexploded ordnance
WP	white phosphorus

Glossary of Terms

Baseline sampling	Sampling performed before implementation of an alternative
Breaching	Using explosive charges to create a ditch that will connect a pond to a nearby gully or creek, permitting the water to drain from the pond
Conceptual site model	Description of a series of working hypotheses of how the stressor might affect ecological components. The conceptual site model also describes the ecosystem potentially at risk, the relationship between measurement and assessment endpoints, and exposure scenarios.
Ditch	A waterway created by blasting with explosives
Ecological effects characterization	A portion of the analysis phase of an ecological risk assessment that evaluates the ability of a stressor to cause adverse effects under a particular set of circumstances
Exposure	Co-occurrence or contact between a stressor and an ecological component
Exposure characterization	A portion of the analysis phase of ecological risk assessment that evaluates the interaction of the stressor with one or more ecological components. Exposure can be expressed as co-occurrence or contact depending on the stressor and ecological component involved.
Exposure assessment	A quantification of the magnitude and type of actual and/or potential exposures of ecological receptors to site contaminants
Gully recession	The movement of a gully away from the river, toward the pond, as erosion and current scour remove material from the gully. As the gully recedes, it can eventually break through to an adjacent pond, allowing the water to drain from the pond.
Hot pond	A pond that is a hot zone
Hot spot	A small portion of a hot pond

Glossary of Terms

Hot zone	A zone of Eagle River Flats that is believed to have a relatively high environmental risk, as determined from a combination of duck mortality, white phosphorus concentrations or quantity, duck usage, and crater density
Hydraulic permeability	The degree by which water is able to percolate through the soil between ponds
Ice plucking	The movement of sediment, soil, and other material that is lifted and carried on the bottom of the ice during the winter
Intermittent pond	Usually a mud flat area that floods during spring tides and then dries by evaporation during occasional summer periods without flooding tides, low precipitation, and hot dry weather
Measurement endpoint	A measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint. A measurement endpoint often is expressed as the statistical or arithmetic summary of the observation that comprises the measurement.
Natural attenuation	This term was used in previous documents and technical reports to refer specifically to the sublimation/oxidation process.
Natural restoration	A method of reducing the risk of white phosphorus exposure to dabbling ducks and swans through natural processes, most often from sublimation/oxidation, sedimentation, or gully recession.
Net sedimentation	The sedimentation that remains after sediment has been deposited and resuspended. This differs from gross sedimentation, which measures only deposition.
Oxidation	For ERF, the transformation (complete or incomplete combustion) of white phosphorus gas to phosphates and phosphate salts.
Permanent pond	Brackish to freshwater ponds that do not usually dry out between flooding tides.
Pond elevation	The elevation of the bottom of the pond, typically expressed in feet above mean sea level.
Receptor	An individual organism, population, or community that can be exposed to a contaminant

Glossary of Terms

Recharge	The flow of water into a pond or pond group from groundwater, surface creeks, or springs
Reference mortality	For ERF, the duck mortality rate if the ducks are not affected by white phosphorus
Remediation	For ERF, any of several methods to block or remove the exposure of receptors to white phosphorus
Restoration	The act of restoring damaged habitat
Risk characterization	In ecological assessment, a process of applying professional judgment to determine whether adverse effects are occurring or will occur as a result of contamination associated with a site
Sediment elevation	The solid surface level in the ponds, which is determined by a survey of pond elevations
Sublimation/oxidation	For ERF, the conversion of solid white phosphorus to a gas that will dissipate
Threshold elevation	The point along the perimeter of a pond that would flood first
Toxicity testing	Toxicity tests evaluate the effects of contaminated media on the survival, growth, reproduction, and/or metabolism of test organisms
Verification sampling	White phosphorus (WP) sampling performed at the end of a field season after treatment is conducted to verify the success of treatment

Executive Summary

This report presents the results of the Feasibility Study (FS) for Operable Unit C (OUC) on Fort Richardson, Alaska. Operable Unit C represents the Eagle River Flats (ERF) and the former open detonation/open burning (OB/OD) Pad area at Fort Richardson. The U.S. Army Corps of Engineers (COE), Alaska District, on behalf of the U.S. Army, Alaska (USARAK), contracted with CH2M HILL to prepare the FS under Delivery Order 1, Modification 5, of Contract Number DAC85-95-D-0015.

Site Description and Contamination

Eagle River Flats

Eagle River Flats is an 876-hectare estuarine salt marsh at the mouth of Eagle River. Approximately 25 targets placed in ERF have been used for artillery training since 1949, creating thousands of craters in the wetlands and associated mud flats and leaving an estimated 100,000 unexploded mortar and artillery shells buried in the shallow subsurface. Although ERF is an active impact area, it remains a productive wetland that serves as an important staging ground for migrating waterfowl during the spring and fall migrations. ERF also supports local populations of fish, birds, mammals, and macroinvertebrates. A series of ponds distributed throughout ERF provide excellent habitat for dabbling waterfowl.

Previous sampling results and detailed observation of various populations within ERF have identified WP as the primary contaminant and waterfowl as the primary receptors.

Since the initial reports of elevated waterfowl mortality in the early 1980s, a multidisciplinary investigation has been conducted to identify the cause of the mortality (shown in 1990 to be white phosphorus [WP]) (Racine *et al.*, 1992), the extent of the WP contamination, and the potential effects of WP and other munitions on the biota in ERF. WP was released into ERF by ordnance used to create smoke for marking. WP that does not fully oxidize can remain as particles in the sediment. Ingestion of WP particles by feeding waterfowl has created high levels of mortality. Birds have been observed to die within minutes to hours of ingesting WP in a number of ponds in ERF.

The results of the investigations to characterize the nature and extent contamination and the baseline risk assessment for the site were presented in the OUC remedial investigation (RI) report (CH2M HILL, 1997).

The RI report was based largely on data collected before the CERCLA process was implemented at OUC.

The findings documented in the RI report are based primarily on data collected before implementing the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process at OUC. Compilation and review of all the data have led to the following conclusions:

1. WP is the primary cause of waterfowl mortality.
2. WP was deposited in the sediment primarily during range firing activities.
3. Craters in ERF potentially indicate the level of range firing activity.
4. WP particles are not homogeneous throughout ERF.
5. The detection frequencies and concentrations for WP in sediment are highest in Area C, Bread Truck, and Racine Island.
6. WP particles can break down (sublimate/oxidize) when exposed to air, but are long lasting in water-saturated sediment.
7. Waterfowl are exposed to WP from the sediment of ponds and sedge marshes while they are feeding.
8. Dabbling ducks and swans are the primary receptors of WP.
9. Predation and human exposure to WP by consumption are not high-level concerns at present.
10. Permanent ponds, with associated sedge marsh, having confirmed presence of WP and/or moderate to high crater density and observed moderate to high dabbling duck and/or swan use are the most significant exposure areas (called hot ponds).
11. The movement of WP through Eagle River to Knik Arm appears to be minimal.

Predation and human exposure to WP by consumption are not high-level concerns at present.

Open Burning/Open Detonation Pad

Open Burning/Open Detonation (OB/OD) Pad is about 3.2 hectares (about 8 acres) in size and consists of a gravel pad placed as fill at the edge of ERF. Open burning and open detonations of explosive materials historically have occurred on this pad.

The following are major findings of the RI (CH2M HILL, 1997) for OB/OD Pad:

1. The groundwater is at a depth of 6 to 11 meters (m) below the surface, the gradient is shallow, and groundwater moves toward the southwest, toward ERF.

2. The site investigation detected only a limited number of organic chemicals and metals in the soil and groundwater.
3. OB/OD Pad will meet clean closure requirements.
4. The ecological and human health risk assessments found very low risks associated with exposures to these chemicals at the measured concentrations.

Because OB/OD Pad meets clean closure guidance from Title 40 of the *Code of Federal Regulations*, Part 264, and no significant environmental or human health risks were determined, remediation of OB/OD Pad is not included in the FS.

FS Process

The OUC FS is intended to provide the USARAK, U.S. Environmental Protection Agency, and Alaska Department of Environmental Conservation (the Agencies) and the public with an assessment of the remedial alternatives, including their relative strengths and weaknesses. The overall goal is to provide sufficient information to the decisionmakers so that they can select a proposed alternative to be applied to OUC. The decisions will be used to develop a proposed plan and a Record of Decision (ROD) to achieve remediation at OUC. There were five steps used to prepare this FS:

1. **Develop remedial action objectives (RAOs).** The overall remedial objective is the protection of the environment and human health.
2. **Develop pond groups.** Twenty-two ponds at ERF were identified for remediation. They were divided into six pond groups on the basis of physical site characteristics and expectation of similar response to remediation. This pond grouping forms the geographical basis for making decisions.
3. **Develop remedial alternatives.** Five remedial alternatives were developed.
4. **Evaluate each remedial alternative** against nine criteria as required by the National Contingency Plan (NCP).
5. **Compare alternatives for each pond group.** This step involved evaluating how each alternative would perform under the NCP criteria at each pond group. Because of differing physical characteristics, each pond group is expected to perform differently under each alternative. Thus, a different alternative may be ultimately selected for each pond group.

Remedial Action Objectives

As introduced in the OUC RI report (CH2M HILL, 1997), the overall remedial objectives at ERF are the protection of the environment and human health. There are three specific RAOs:

Remedial action objectives for ERF focus on duck mortality, hot zones, and the WP exposure pathway.

1. **Reduce dabbling duck mortality**. This RAO addresses the single most important issue associated with WP contamination. Because dabbling ducks have been the most affected, their mortality will be assessed specifically in support of the achievement of this goal. Mallards have been chosen as the indicator species. The specific objective in 5 years is to reduce the mallard mortality rate by 50 percent compared to the value in 1996. The objective in 20 years is to reduce that mortality rate to no more than 1 percent above the reference value.
2. **Reduce hot zones**. This RAO supplements the RAO for duck mortality. The number of hectares characterized as "hot" will be used to measure achievement of this objective. In general, a hot zone will be determined by a combination of duck mortality, WP concentrations or quantity, duck usage, and crater density. The specific objective is to reduce hot zones by 50 percent in 5 years and by 99 percent in 20 years compared to the number of hectares in January 1996.
3. **Reduce WP exposure pathways**. This RAO will be used as the basis for measuring the success of remedial actions. It is technology specific and designed to provide near-term feedback on the success of a specific remedial action performed at a specific area. The specific objective is no bioavailable WP for ducks and swans.

Develop Pond Grouping

The 22 hot ponds identified in the RI have been divided into six groups. This was done to aid in the evaluation of alternatives for the FS and to allow for the selection of different remedies at different pond groups based on the different characteristics of each group. These pond groups are as follows:

- Northern A (7 ponds)
- Pond 290 (1 pond)
- Pond 183 (1 pond)
- Pond 146 (1 pond)
- Northern C and C/D Ponds (8 ponds)
- Ponds 109, 285, 293, and 297 (4 ponds)

The first five groups were made based on nearby types of vegetation, topography, knowledge of the extent of contamination, and hydrologic interconnections. The ponds in each group have similar physical characteristics and are expected to respond similarly to remedial actions. These five pond groups are separately evaluated in this FS.

Eighteen of the 22 hot ponds have been divided into 5 pond groups for FS analysis. The other group of 4 hot ponds has already received treatment or will receive treatment in 1997 and is not included in this FS.

The sixth group of ponds either have had treatment or will have treatment in 1997. Hence, these ponds will not be evaluated in this FS. They are included in the overall monitoring program for ERF.

Development of Remedial Alternatives

There were three steps in the development of remedial alternatives for this FS:

1. Identify potential remedial technologies
2. Screen technologies
3. Assemble technologies into alternatives

Technologies were identified that may be effective in reducing the impacts of the WP exposure at ERF. This may occur by reducing the concentration of WP in the sediment or by reducing the exposure of the receptors to WP. Fifteen potential technologies were identified based on previous treatability studies at ERF. These technologies represented the range of technologies that were considered to be potentially feasible after many previous years of study and testing at ERF.

On the basis of information available from the treatability studies and vendors, the technologies were screened on the criteria of effectiveness, implementability, and cost. This screening resulted in 10 technologies being screened out and the following 6 retained:

- AquaBlok™
- Detailed monitoring of natural processes
- No action
- Pond draining by breaching
- Pond draining by pumping
- Hazing

The technologies that passed through screening were assembled into five alternatives, which were assembled to meet several objectives. First, the no action alternative was included as required by the NCP. Second, technologies were combined into action alternatives in such a way that the alternatives would be complete; that is, each alternative would address the range of exposure pathways identified for WP.

The five assembled alternatives are as follows:

- **Alternative 1, No Action.** No remedial action or monitoring is performed.

- **Alternative 2, Detailed Monitoring.** No remedial action is performed, but detailed monitoring is conducted to observe whether natural processes that assist RAO success are occurring at the flats. Hazing is performed as a temporary interim measure.
- **Alternative 3, Pumping and AquaBlok™.** Pumps are used to drain the pond groups so that the drying sediment can allow the existing WP to sublimate/oxidize and therefore decrease concentrations. After 5 years of pond draining, AquaBlok™ is then spread over any remaining contaminated areas. Detailed monitoring is included in this alternative. Hazing is also conducted as a temporary interim measure.
- **Alternative 4, Breaching, Pumping, and AquaBlok™.** Ditches are first created to drain the ponds via existing gullies or Eagle River. Pumps are also installed to drain areas of pond groups that do not drain via the man-made ditch. The pond draining allows the sediment to dry so that the existing WP can sublimate/oxidize. After a few years of pond draining, AquaBlok™ is then spread over any remaining contaminated areas. Detailed monitoring is included in this alternative. Hazing is also performed as a temporary interim measure.
- **Alternative 5, AquaBlok™. AquaBlok™** is applied over the surface area of the pond groups. Detailed monitoring is included in this alternative. Hazing is also performed as a temporary interim measure.

A review will be conducted after 5 years of remedy implementation and monitoring to determine whether RAOs are being met.

Environmental Impacts

ERF supports a diverse community of waterfowl and shorebirds. Observations have shown that the ducks prefer specific types of habitat: sedge marsh, permanent ponds, and intermittent ponds. This preference for habitat type has been considered in this FS.

Remedial Alternatives 3 and 4 involve draining the selected pond or pond group. These treatments are expected to modify ERF habitat to varying degrees. Pond draining by pumping (Alternative 3) is expected to lead to only temporary changes in the habitat, whereas pond drainage by breaching (Alternative 4) is expected to result in a more permanent change in habitat. High residual risk is expected to remain as a result of AquaBlok™ application under Alternative 5.

A breached pond will fill and drain with lower high tides than a pond drained by pumping. Changes in plant species composition would be most dramatic under Alternative 4 and will modify the habitat quality for selected bird species. In addition, it is unlikely that breached ponds can be restored. The erosion patterns that would be created over time reduce the feasibility of reversing the process and restoring the ponds (as permanent or intermittent ponds) once remediation of the ponds is completed.

Monitoring Strategy

Because of the nature of the RAOs, the contamination at ERF, and the remedial alternatives, detailed monitoring will be necessary to determine if and when the RAOs will be met. The first RAO, reducing dabbling duck mortality, is not specific to an area of ERF or to the application of a specific remedial alternative. It must be achieved on the basis of information about ERF as a whole because the ducks have been observed to fly all over the flats, and WP has been detected in many areas. The following monitoring will be performed annually to improve understanding of the baseline condition and to determine progress toward achieving RAO number 1 for Alternatives 2 through 5:

- **Telemetry.** As discussed in the RI report, birds are captured, small radio transmitters are attached to them, and then they are released in the area in which they were captured. In this study, approximately 100 to 150 mallards will be tracked during the 2-month fall migration period.
- **Aerial bird population surveys.** Annual population surveys will provide knowledge of trends in the use of ERF, which can help in understanding specific or unusual results from the telemetry studies.
- **Aerial photography.** Aerial photography provides confirmation information about bird populations at specific ponds when it is coordinated with the aerial bird surveys.

The hot zone RAO is evaluated annually by maintaining an inventory of hot zones that have been identified, treated, and verified for remedial action completion.

The evaluation for RAO number 2, reduction of hot zones, is maintained by updating a yearly inventory of treated hot ponds that have successfully reduced WP exposure pathways in implementing Alternatives 2 through 5. Monitoring for reduction in WP exposure pathways (the third RAO) will be achieved by sampling for WP and conditions that foster containment or sublimation/oxidation of WP in sediments.

Detailed Analysis

The NCP requires that each alternative be analyzed on the basis of nine decisionmaking criteria:

1. Overall protection of human health and the environment.

2. Compliance with applicable or relevant and appropriate requirements (ARARs)
3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, or volume through the use of treatment
5. Short-term effectiveness
6. Implementability
7. Cost
8. State acceptance
9. Community acceptance

The first seven criteria are used in the detailed analysis of the remedial alternatives in this FS. The last two will be evaluated following receipt of comments on this FS and the proposed plan from the public and government agencies. The last two criteria will be addressed in the ROD.

The detailed analysis was conducted for each pond group individually. This will allow for a determination of the applicability of each of the five alternatives to each pond group. Because of the differences among the pond groups, different alternatives may be better suited for different pond groups. This approach will provide the necessary information to the public and the RPMs to allow different remedies to be selected in different areas of ERF.

Comparison of Alternatives

A comparative analysis of the alternatives was conducted for each pond group using the seven criteria that were used in the detailed analysis. For each pond group, the differences in the ability of each alternative to meet each criterion are presented. In addition, for each pond group, the alternatives are ranked in terms of their ability to meet each criterion.

The preferred alternatives for each pond group will be presented in the final Proposed Plan. The Draft Proposed Plan will be available for public review and comment before the final selection of remedial alternatives.

SECTION 1

Introduction

This report on the OUC FS has been prepared to satisfy CERCLA requirements.

In June 1994, the U.S. Environmental Protection Agency (USEPA) listed Fort Richardson, Alaska, on the National Priorities List (NPL). This listing designated the post as a federal Superfund site subject to the remedial response requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986.

Following inclusion of Fort Richardson on the NPL, the U.S. Army Alaska (USARAK), USEPA, and the Alaska Department of Environmental Conservation (ADEC) negotiated the Federal Facility Agreement (FFA) for Fort Richardson. All three parties signed the FFA on December 5, 1994. Under the terms of the FFA, all remedial response activities will be conducted to protect public health and welfare and the environment in accordance with CERCLA, the National Contingency Plan (NCP), the Resource Conservation and Recovery Act, and applicable state law.

This report presents the results of the feasibility study (FS) of Operable Unit C (OUC) on Fort Richardson. Specifically, on the basis of the results of the remedial investigation (RI) conducted at Eagle River Flats (ERF) and the open burning/open detonation (OB/OD) Pad portions of OUC, this FS addresses only the ERF portion of OUC. The U.S. Army Corps of Engineers (COE), Alaska District, on behalf of the USARAK, contracted with CH2M HILL to prepare the FS report under Delivery Order 1, Modification 5, of Contract Number DACA85-95-D-0015. The OUC RI report (CH2M HILL, 1997) summarized the data on which this FS report is based.

The primary objective of the feasibility study is to compare remedial alternatives at ERF areas so that the RPMs can select a preferred alternative.

1.1 Purpose and Objectives of the Feasibility Study

The OUC FS is intended to provide the USARAK, USEPA, and ADEC (the Agencies) and the public with an assessment of the remedial alternatives, including their relative strengths and weaknesses. The overall goal of this FS is to provide sufficient information to the Agencies so that they are able to decide which remedial alternative should be applied at specific areas of OUC. The decisions will be used to develop a Proposed Plan and Record of Decision (ROD) to achieve site remediation at OUC.

The following are specific objectives of the OUC FS:

- Identify remedial action objectives (RAOs), which provide the basis for knowing when remediation is complete.
- Identify parts of ERF that require remediation because of their effect on affected species.
- Develop and screen remedial technologies to determine which might be appropriate for use at the site.
- Develop remedial alternatives, which are combinations of remedial technologies.
- Prepare detailed analyses of the effects of the remedial alternatives on the parts of ERF to be remediated.
- Document the results of this assessment in a format suitable for public review and comment.

This FS addresses the impacts of white phosphorus (WP) contamination on waterfowl mortality rates. Because ERF is still an active impact area, this FS does not address impacts of unexploded ordnance (UXO) on human health and the environment. Ordnance with WP are no longer used at ERF.

The detailed analysis of effects is based on the nine criteria in the NCP.

The OUC FS is part of the Fort Richardson Administrative Record and will be included in the Fort Richardson Community Relations Plan.

1.2 FS Process

There were five steps in the process that was used to prepare this FS:

1. **Develop remedial action objectives.** The overall remedial objective is the protection of the environment and human health. The three specific RAOs address dabbling duck mortality, hot zones, and WP exposure pathway. RAOs are discussed in Section 1.3.
2. **Develop pond groups.** The pond group forms the geographical basis for making decisions. Pond groups were formed on the basis that remedial alternatives would perform similarly on all ponds within the group, and so a preferred alternative is assumed to be implemented equally on all members of the group. Development of pond groups is discussed further in Section 2.3.
3. **Develop remedial alternatives.** Potential remedial technologies were identified and then screened based on effectiveness, implementability, and cost. The technologies that remained were

then assembled into alternatives. Five remedial alternatives were developed:

- Alternative 1, No Action
- Alternative 2, Detailed Monitoring
- Alternative 3, Pumping and AquaBlok™
- Alternative 4, Breaching, Pumping, and AquaBlok™
- Alternative 5, AquaBlok™

Each alternative is presented in Section 3 and discussed in detail in Appendix C. Each alternative also has a monitoring program appropriate for examining the achievement of the RAOs.

4. **Evaluate remedial alternatives.** The NCP requires that each remedial alternative be evaluated against the following nine decisionmaking criteria:

   - **Overall protection of human health and the environment.** Evaluates how well a remedial alternative provides and maintains adequate protection of human health and the environment.

   - **Compliance with applicable or relevant and appropriate requirements (ARARs).** Used to determine whether an alternative would attain federal and state ARARs, or a waiver to specific ARARs is adequately justified. Applicable requirements are those cleanup standards, criteria, or limitations promulgated under federal or state law that specifically address the situation at a CERCLA site. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements promulgated under federal or state law that, while not applicable, address problems or situations sufficiently similar to the circumstances of the proposed remedial action and are well suited to the conditions of the site.

   - **Long-term effectiveness and permanence.** Evaluates the ability of the remedy to protect the environment and human health in the long term as well as the short term.

   - **Reduction of toxicity, mobility, or volume through the use of treatment.** Assesses the ability of the alternative to reduce toxicity, mobility, and/or volume of hazardous materials.

   - **Short-term effectiveness.** Evaluates the effects of the remedial alternative on the protection of the environment and human health during the construction and implementation phase of an alternative.

   - **Implementability.** Evaluates the technical feasibility (that is, difficulties and uncertainties in the construction and operation of the alternative) and administrative feasibility (that is, ability to coordinate the required actions of government agencies) of implementing the alternative, and the availability of required services and materials.

- **Cost.** Evaluates total cost, including engineering, construction, and operations and maintenance costs incurred over the life of the project.
- **State acceptance.** Concurrence by the state on the preferred alternative.
- **Community acceptance.** Agreement by the local community that the alternative is acceptable.

The first two criteria are called "threshold criteria," and they must be met for a remedial alternative to be selected. The other five are called "balancing criteria," and they weigh the tradeoffs between alternatives. A low rating on one balancing criterion can be compensated for by a high rating on another criterion. These first seven criteria are used in the detailed analysis of the remedial alternatives in this FS. The last two, state and community acceptance, will be evaluated following receipt of comments on this FS and the Proposed Plan from the public and government agencies. The last two criteria will be addressed in the ROD.

These criteria are assessed for each remedial alternative by pond group. This detailed analysis forms the basis for the next step. It involves considering each criterion for each pond group. The detailed analysis of alternatives is presented in Section 6.

5. **Compare alternatives for each pond group.** This step involved examining each criterion for each pond group and determining what the key differences area. The details of this comparison are summarized in Section 7 and Appendix F.

1.3 Remedial Action Objectives

The overall remedial objective at ERF is the protection of the environment and human health.

As introduced in the OUC RI report (CH2M HILL, 1997), the overall remedial objective at ERF is the protection of the environment and human health. There are three specific RAOs:

1. **Reduce dabbling duck mortality.** This RAO addresses the single most important issue associated with WP contamination. Although several effects of WP exposure have been measured at ERF or in the laboratory (see the OUC RI [CH2M HILL, 1997]), a number of the effects are not diagnostic of WP toxicity because other agents can cause similar conditions. Measurement of these effects is therefore not likely to provide a good indication of the level of remediation achieved. Dabbling duck mortality is

diagnostic for WP exposure and effects, as long as the background mortality rate is low and confirming evidence of WP in the affected ducks is obtained. Because of their observed numbers at ERF and their sensitivity, mallards have been chosen as the indicator species for measuring the achievement of this RAO. Monitoring for mallards is considered protective of other waterfowl species, such as swans. It is anticipated that the mortality rate of other dabbling ducks will decline with the mallard mortality rate.

The specific objective in 5 years is to reduce the mallard mortality by 50 percent compared to the mortality rate observed in 1996. The objective in 20 years is to reduce that mortality rate to no more than 1 percent above the reference value. It is expected that reducing duck mortality to these levels will lead to insignificant impacts to their predators from WP exposure. Because of natural variability in the duck mortality rate and the low levels of the objectives, it will likely take several years of data to determine whether this RAO has been achieved. If a decrease in mortality is not observed after several years, this RAO will be reevaluated.

2. **Reduce hot zones.** This RAO supplements the RAO for duck mortality. The number of hectares characterized as "hot" (areas believed to have relatively high environmental risk) will be used to measure achievement of this objective. In general, a hot zone will be determined by a combination of duck mortality, WP concentrations or quantity, duck usage, and crater density. The method for determining the hot zones at ERF was discussed in the ERF RI (CH2M HILL, 1997). The specific objective is to reduce hot zones by 50 percent in 5 years and by 99 percent in 20 years while measuring impacts to habitat. The comparison base is the status of the 22 hot ponds identified in the ERF RI (CH2M HILL, 1997) as of January 1996.

3. **Reduce WP exposure pathway.** This RAO will be used as a basis for measuring the success of remedial actions. It is technology specific and designed to provide near-term feedback on the success of a specific remedial action performed at a specific area. The specific goal is no bioavailable WP for ducks and swans.

The achievement of each RAO is assessed independently because the specific objectives are not necessarily correlated. For example, it is unknown whether a certain percentage of decline in the area of the hot zones will result in a corresponding decrease in the dabbling duck mortality. RAO number 1 is of primary importance because its achievement provides the desired long-term protection of the environment and it also covers the entire ERF. If the dabbling duck mortality is reduced to 1 percent above the reference value (which is the 20-year objective in RAO number 1), and at least 50 percent of the currently identified hot zones have been treated (which is the minimum level of the 5-year objective in RAO number 2), remediation may be terminated after 3 to 5 years of verification monitoring. It is then unnecessary to meet the remaining objectives of RAOs numbers 2 and 3. It is possible that RAO numbers 2 and 3 will be achieved even if RAO number 1 has not been met. This possibility identifies the potential need to reconsider areas defined as hot ponds, because site remediation must continue until RAO number 1 is met, either in its current form or with a new definition. These RAOs are used in the evaluation of the remedial alternatives for the pond groups. The monitoring strategy, described in Section 5, has been developed to measure the achievement of these RAOs.

1.4 Organization of Report

Remedial action objectives for ERF focus on duck mortality, hot zones, and the WP exposure pathway.

This FS report is organized as follows:

Section 1, Introduction. This section provides background on several issues associated with the remediation of OUC: purpose and objectives of the FS, the FS process, and RAOs.

Section 2, Physical Setting. This section provides a summary of the RI report and a description of how ERF was evaluated in the FS.

Section 3, Development of Remedial Alternatives. This section discusses how the remedial alternatives analyzed in this FS were chosen, including identification of remedial technologies; screening the technologies on the basis of effectiveness, implementability, and cost; and grouping technologies into remedial alternatives.

Section 4, Performance of Remedial Alternatives. This section describes the physical features of pond groups that affect how each assembled alternative will perform.

Section 5, Monitoring Strategy. This section describes how the achievement of the RAOs will be monitored during the implementation of remedial alternatives.

Section 6, Detailed Analysis. This section discusses the impacts of remedial alternatives on ERF.

Section 7, Comparison of Alternatives. This section compares the impacts of remedial alternatives in different zones.

Section 8, Works Cited.

The appendices contain supporting data:

- Appendix A, Assessment of the Physical Processes
- Appendix B, Technology Screening
- Appendix C, Assembly and Implementation of Alternatives

- Appendix D, Applicable or Relevant and Appropriate Requirements
- Appendix E, Cost Estimate
- Appendix F, Detailed Analysis of Alternatives
- Appendix G, Monitoring Strategy and Implementation
- Appendix H, Responses to Comments

SECTION 2

Physical Setting

OUC is composed of Eagle River Flats and OB/OD Pad.

A roughly triangular lowland, the Anchorage area is located between Turnagain Arm and Knik Arm, at the head of Cook Inlet. Fort Richardson and OUC are located in the northern third of the Anchorage lowland (Figure 1). OUC is composed of two parts: ERF, which is the largest part, and an adjacent gravel pad that was used for the open burning and open detonation of unwanted ordnance (OB/OD Pad), which is on the eastern edge of ERF (Figure 2). For remedial investigation purposes, ERF has been subdivided into nine areas: A, B, C, C/D, D, Racine Island, Bread Truck, Coastal East, and Coastal West.

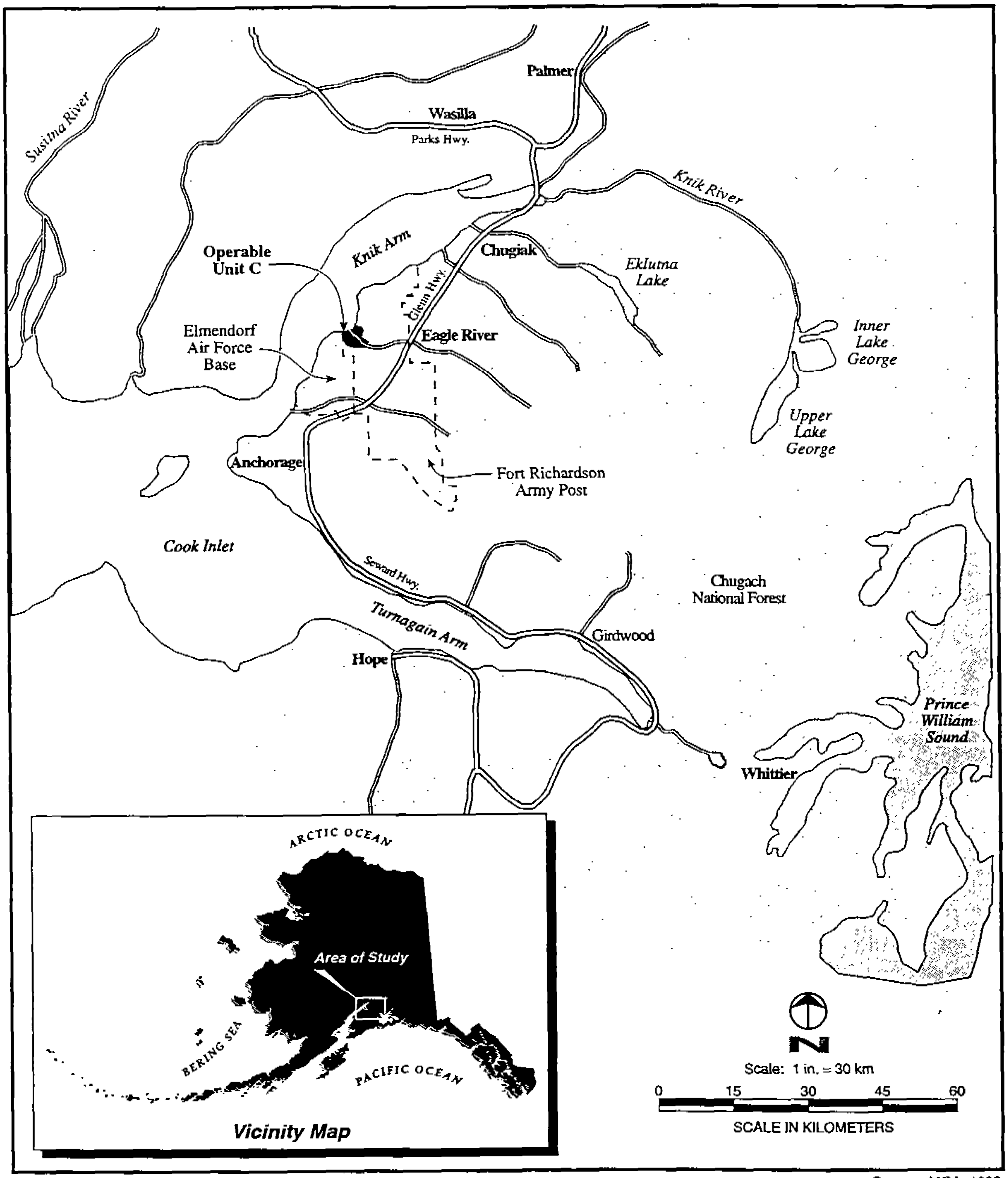
2.1 Summary of RI Report: Eagle River Flats

ERF is an 876-hectare (ha) (2,160-acre) estuarine salt marsh at the mouth of Eagle River (Figure 2). Approximately 25 targets placed in ERF have been used for artillery training since 1949. The artillery shells created thousands of craters in the wetlands and associated mud flats, and left an estimated 10,000 unexploded mortar and artillery shells buried in the shallow subsurface. Although ERF is an active impact area, it remains a productive wetland, serving as an important staging ground for migrating waterfowl during the spring and fall migrations. ERF supports local populations of fish, birds, mammals, and macroinvertebrates. A series of ponds distributed throughout ERF provide excellent habitat for dabbling waterfowl.

Previous sampling results and detailed observations of various populations within ERF have identified WP as the primary contaminant and waterfowl as the primary receptors.

Since the initial reports of elevated waterfowl mortality in the early 1980s, a multidisciplinary investigation has been conducted to identify the cause of the mortality (shown in 1990 to be WP), the extent of the WP contamination, and the potential effects of WP and other munitions on the biota in ERF. WP was released into ERF by ordnance used to create smoke for marking targets. WP that did not fully oxidize can remain as particles in the sediment. Ingestion of WP particles by feeding waterfowl has created high levels of mortality. Birds have been observed to die within minutes to hours of ingesting WP in a number of ponds in ERF.

Sampling results have focused primarily on a relatively small number of areas in ERF where the greatest levels of mortality were observed. The results of this sampling have demonstrated that elevated levels of WP exist in most ponds where the highest mortality levels occur; however, sampling efforts in several ponds where high mortality has been observed have not demonstrated that WP exists extensively in



Source: MOA, 1993.

Figure 1
Location Map
Operable Unit C
Feasibility Study
Fort Richardson, Alaska

CH2MHILL

138545.. .20 OUC LocMap 09/12/97 anc/ra

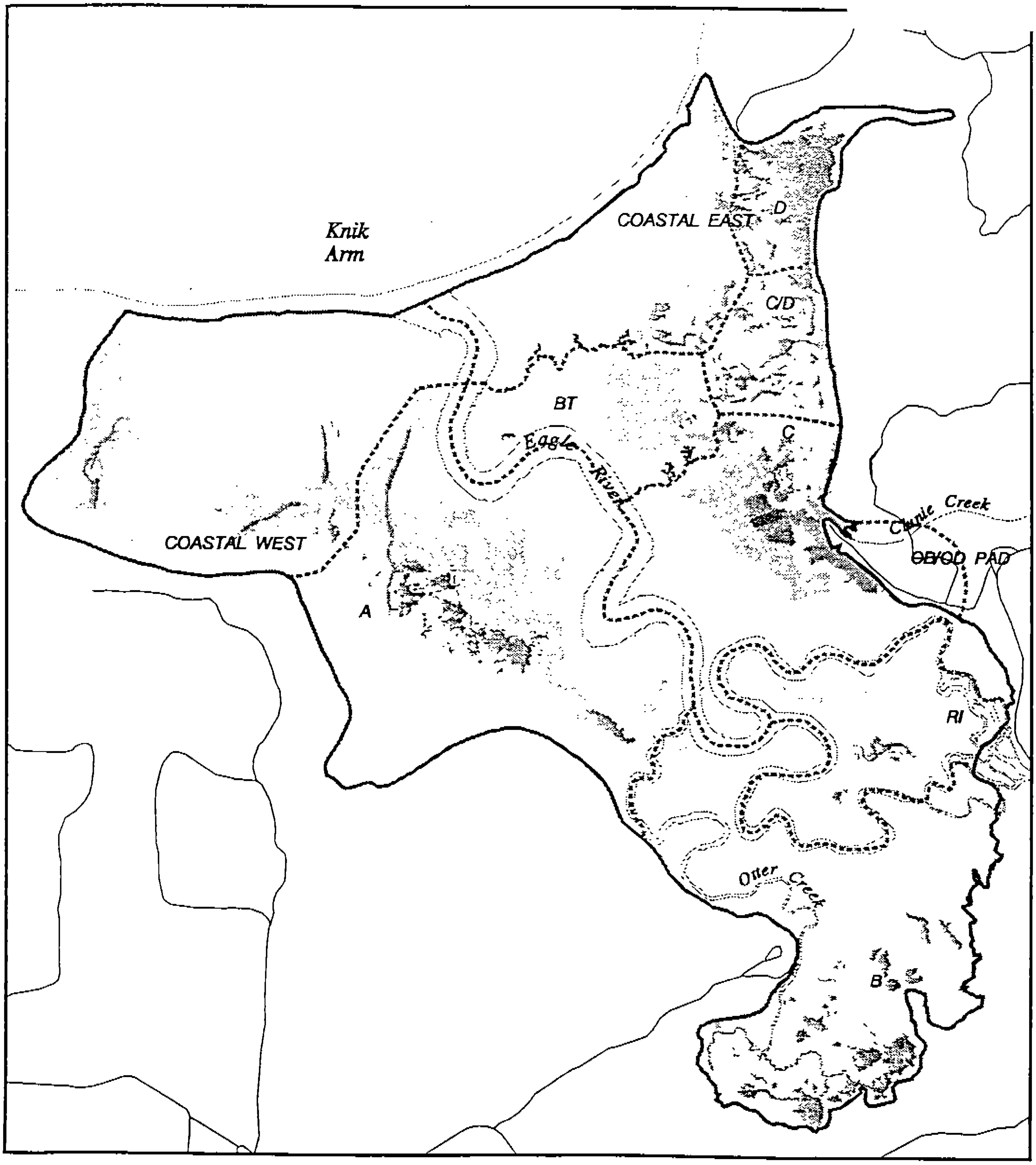


Figure 2

Site Map

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

N

Scale 1:24000
1 cm = 240 m

0 meters 720

Mapping and database source:
Racine et al., 1996.

Intermittent Pond
Permanent Pond
Road
Area Boundary
OUC Site Boundary

CH2M HILL

February 13, 1997 AML: /proj2/art/fig.aml PLOT FILE: /proj2/art/fig2-21.eps the sediment. This finding suggests that some birds may fly away from the point of exposure before succumbing. The potential for birds to move following exposure, coupled with limitations on sampling efforts because of the hazard posed to site workers by UXO, has complicated identification of the horizontal and vertical extent of WP contamination.

It is believed that reducing waterfowl mortality will also reduce effects in secondary receptors.

Previous sampling results and detailed observations of wildlife populations within ERF have identified waterfowl as the primary receptors of WP contamination. Although low levels of WP have been found in plants, macroinvertebrates, and fish, existing data do not show that these populations have been significantly affected by the presence of WP in ERF. There is some evidence indicating that scavengers that feed on waterfowl carcasses in ERF, particularly bald eagles, may have been affected by WP. It is believed, however, that reducing the mortality effect in dabbling waterfowl to acceptable levels also will reduce effects in the predators and scavengers that have been identified as secondary receptors (that is, those that eat the primary receptors, the dabbling ducks) because of the reduction in their exposure concentrations.

Observations of carcass locations, areas preferred by waterfowl, and crater densities were used by researchers to define areas most likely to contain WP. The sediments in these areas were extensively sampled for WP with the use of radial transects and close sampling in open ponds. The distribution of ponds and analytical results of WP in sediment were compiled and used in conjunction with landcovers (that is, combinations of topographical features such as ponds and vegetation) and bird usage data to identify hot ponds that are likely the areas presenting the highest risk. The UXO hazard in ERF makes extensive future sampling efforts infeasible.

The RI report was based largely on data collected before the CERCLA process was implemented at OUC.

The findings documented in the RI report (CH2M HILL, 1997) are based primarily on data collected before implementing the CERCLA process at OUC. Compilation and review of all the data have led to the following conclusions:

1. **WP is the primary cause of waterfowl mortality.** Symptoms exhibited by exposed ducks in ERF are similar to those observed in ducks dosed with WP in the laboratory. WP also was detected in tissue samples collected from duck carcasses found in ERF.

2. **WP was deposited in the sediment primarily during range firing activities.** WP smoke munitions were used during training activities in ERF for several decades. Rounds were fired onto the flats and detonated, dispersing WP particles over large areas. Further distribution of the particles likely occurred when high-explosive (HE) rounds exploded in WP-contaminated soil and sediment.

3. **Craters in ERF potentially indicate the level of range firing activity.** Detonation of HE generally creates a crater at the point of impact. Although WP munitions do not form craters upon detonation, they typically have been used in conjunction with HE training activities. Therefore, it can be deduced that the more craters in an area, the more munitions have likely been fired there, and thus the higher probability of WP contamination.

4. **WP particles are not homogeneous throughout ERF.** WP particles are dispersed after munitions containing WP are detonated. Particle sizes vary because of the nature of an explosive release. Particle size, dispersion pattern, and ultimate resting location also depend on whether the munitions were detonated on land or over water. Even within small areas, the particle density can vary substantially. One- to 2-m "hot spots" typically result from impact of WP shells. These hot spots contain large numbers of WP particles and are generally surrounded by a 1-m ring containing fewer particles.

The detection frequencies and concentrations for WP in sediment are highest in Area C, Bread Truck, and Racine Island.

5. **The detection frequencies and concentrations for WP in sediment are highest in Area C, Bread Truck, and Racine Island.** Sixty-three percent of the overall ERF sampling locations had nondetectable concentrations, but at least 45 percent of the locations in each of these three areas had detectable concentrations. The highest concentration, 3,071 micrograms per gram (µg/g), was found on Racine Island.

6. **WP particles can break down (sublimate/oxidize) when exposed to air and warm temperatures, but are long lasting in water-saturated sediment.** WP particles are readily oxidized under ambient air conditions, but because they are not water soluble, they have an indefinite life when quenched in the water and allowed to settle into pond or marsh bottom sediments.

7. **Waterfowl are exposed to WP from the sediment of ponds and sedge marshes while they are feeding.** Some WP particles match the size of food (such as seeds and macroinvertebrates) sought by dabbling ducks and swans. As the waterfowl forage for food in pond and marsh bottom sediments, it is possible that they cannot differentiate between WP and their normal food source.

Dabbling ducks and swans are primary receptors of WP.

8. **Dabbling ducks and swans are the primary receptors of WP.** Dabbling ducks and swans both forage for food in pond and marsh bottom sediments. In addition, mortality rates of dabbling ducks have been observed to be significantly higher than mortality rates of other waterfowl in ERF as well as other Upper Cook Inlet marshes. Telemetry data in 1996 suggest that the mortality rate among mallards was about 35 percent.

Predation and human exposure to WP by consumption are not high-level concerns at present.

9. **Predation and human exposure to WP by consumption are not high-level concerns at present.** There has been no verified mortality resulting from predators feeding on WP-contaminated waterfowl carcasses. Although a dead eagle was found with WP contamination, current predator mortality appears low. In addition, the results of analyses of tissue collected from dabbling ducks taken by hunters near ERF do not indicate a threat to humans ingesting the meat.

Twenty-two permanent ponds with a total area of 23 hectares already have been identified as the likely areas of most significant exposure.

10. **Permanent ponds, with associated sedge marsh, having confirmed presence of WP and/or moderate to high crater density and observed moderate to high dabbling duck and/or swan use are the most significant exposure areas (called hot ponds).** According to the conceptual site model, areas of greatest concern are where there is a source (WP-contaminated sediment), a receptor (dabbling duck or swan), and a potential for exposure (foraging for food). Twenty-two hot ponds, which include a total area of 23 ha, have been identified in these areas: A, C, C/D, Bread Truck, and Racine Island.

11. **The movement of WP through Eagle River to Knik Arm appears to be minimal.** Low-level amounts of WP have been detected in the sediments traveling through the gullies, but no sediment and water samples from the river have any detected WP. No sampling had been performed in the Knik Arm at the mouth of the Eagle River.

2.2 Summary of RI: OB/OD Pad

OB/OD Pad is about 3.2 ha (about 8 acres) in size and consists of a gravel pad placed as fill on the edge of ERF. Open burning and open detonations of explosive materials occurred in the past on this pad. Materials have included fuses, HE projectiles, smoke pots, mortar rounds, star clusters, flares, mines, rocket motors, shape charges, detonation cord, dynamite, and some flammable solids. Existing records indicate that no liquids were disposed of there. Disposal was either on the surface or in an excavated pit.

The site investigation of soil and groundwater at OB/OD Pad in 1996 found no detected chemicals in concentrations above action levels for clean closure.

A site investigation of the soil and groundwater at OB/OD Pad was completed in 1996. Surface and subsurface soils were sampled. Nine monitoring wells were installed and developed, and groundwater samples were taken. Soil and groundwater samples were analyzed for an extensive list of volatile and semivolatile organic chemicals and metals. Very few chemicals were detected in either the soil or the groundwater. All detected chemicals had concentrations considerably below their action levels for clean closure. In addition, the ecological and human health risk assessments indicate that the risks are very low.

The following are major findings for OB/OD Pad:

1. **Groundwater movement patterns are strongly influenced by the tides, the river and precipitation.** In fall 1996, the groundwater was at a depth of 6 to 11 m below the surface, and the gradient was shallow, with groundwater moving toward the southwest, toward ERF. Groundwater levels fluctuate seasonally. 1996 water levels were significantly lower than 1995 levels (Walsh and Collins, in Collins *et al.*, 1997).

2. **The site investigation detected only a limited number of organic chemicals and metals in the soil and groundwater.** In many cases, observed concentrations in soil were similar to reference area values.

Because OB/OD Pad meets clean closure requirements and no significant environmental or human health risks were identified, it will not be discussed further in this FS.

3. **OB/OD Pad will meet clean closure requirements.** The detected chemicals were all considerably below their clean closure action levels.

4. **The ecological and human health risk assessments found very low risks associated with exposures to these chemicals at the measured concentrations.**

At OB/OD Pad, the USARAK should proceed with clean closure in accordance with the requirements in the closure guidance from Title 40 of the *Code of Federal Regulations*, Part 264. Because OB/OD Pad meets the clean closure requirements, and no significant environmental or human health risks were determined, OB/OD Pad will not be discussed further in this FS.

In addition, OB/OD Pad has restricted public access. Entry onto the pad is by a road with a locked gate. Access is controlled by Range Control at Fort Richardson. These restrictions are not expected to change. Because of the potential UXO hazard in the area, OB/OD Pad is not available for future development.

2.3 Pond Grouping

Eighteen of the 22 hot ponds have been divided into 5 pond groups for FS analysis. The other group of 4 hot ponds has already received treatment or will receive treatment in 1997 and is not included in this FS.

To aid in the evaluation of alternatives for this FS, the 22 hot ponds identified in the RI have been divided into six groups. The first five groups, presented in Table 1, were made based on nearby types of vegetation, topography, knowledge of the extent of contamination, and hydrologic interconnections. The ponds in each group have similar physical characteristics and are expected to respond similarly to remedial actions. These hot ponds, overlaid on vegetation types, are presented in Figure 3.

These five pond groups will be separately evaluated in this FS. Their characteristics are summarized in Table 2. These characteristics will affect the performance of the remedial alternatives and will be discussed further in Section 4. For example, the number of ponds in a

TABLE 1
Groupings of Hot Ponds

Pond Group	Hot Ponds	Rationale for Grouping
Northern A Ponds	138, 208, 226, 228, 246, 256, 258	Ponds are believed to be hydrologically interconnected by surrounding sedge marsh. There is little understanding regarding extent of WP contamination in these ponds.
Pond 290	290	A region of high elevation exists between Pond 290 and the Northern A ponds that separates the two pond groups. Pond 290 is relatively isolated and is adjacent to a small intermittent pond and a small area of sedge marsh. WP contamination has been detected in the northern end.
Pond 183	183	This pond has been heavily sampled. There are confirmed WP hot spots in this pond. This pond is interconnected with Pond 146, but the permeability is low, at least at average to low water levels, and inflow can be controlled by pumping. A treatability study using pond pumping was conducted at this pond in summer 1997. The study demonstrated that Pond 183 could be drained and dried.
Pond 146	146	This pond has been heavily sampled. There are confirmed WP hot spots in this pond. Studies suggest that there is a constant source of recharge (up to 100 gallons per minute [gpm]) along the eastern part of the flats. A dredging treatability study was conducted at this pond in 1995 and 1996, and this changed the pond-bottom elevations. In 1996, the dredge had begun dredging a channel to Pond 183. It breached a shallow portion of Pond 183. This pond is interconnected with Pond 183.
Northern C and C/D Ponds	40, 49, 85, 93, 112, 129, 145, 155	Ponds are believed to be hydrologically interconnected to a large system of permanent ponds and a large area of sedge marsh. There is little understanding regarding the extent of WP contamination in these ponds. Studies suggest that there is a constant source of recharge (up to 100 gpm) along the eastern part of the flats. Ponds 129, 145, and 155 may be more isolated from the rest of this pond group. An aerial survey conducted in June 1997 suggests that these ponds may be drained.

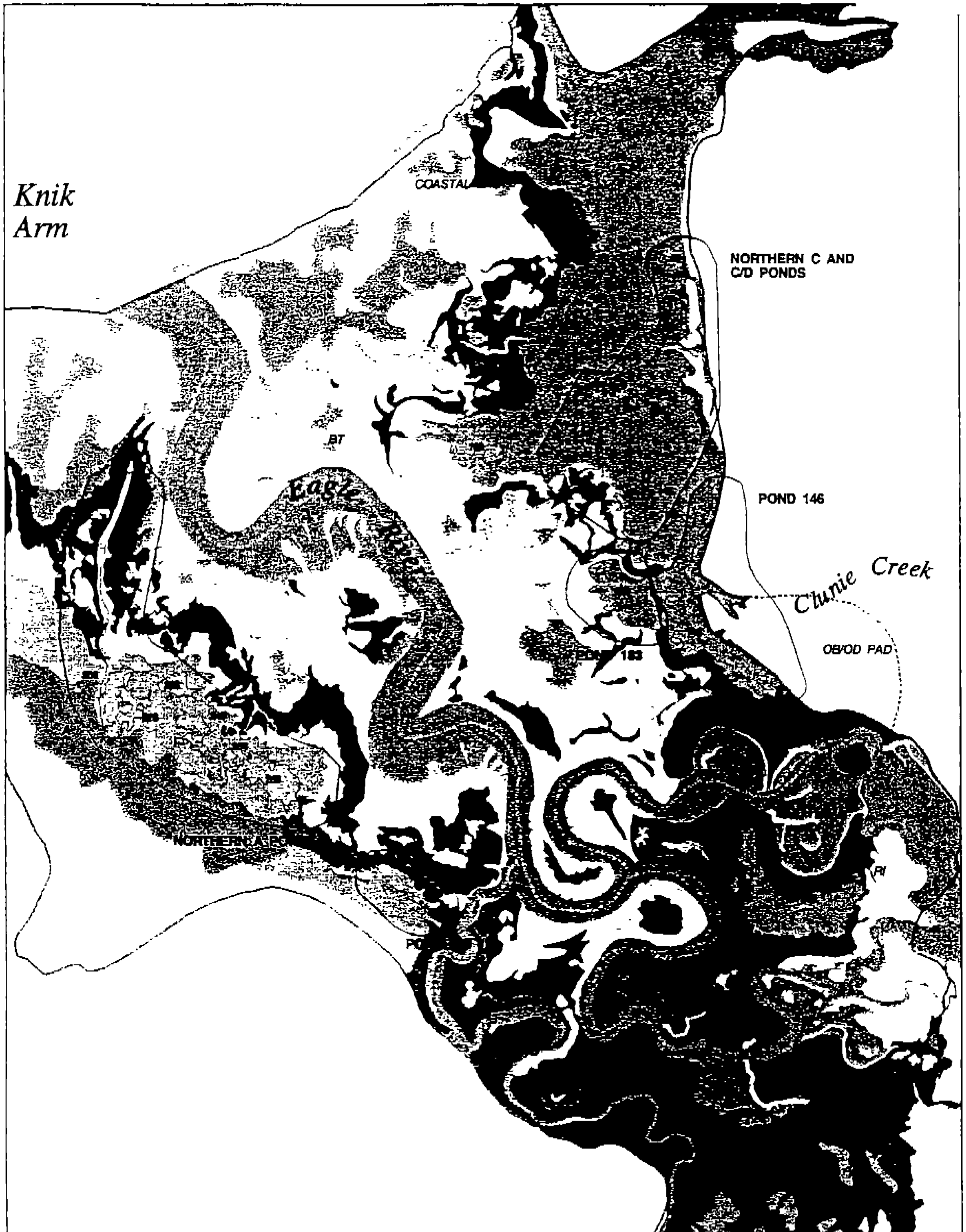


Figure 3

Pond Groups Used in Detailed Analysis of Alternatives

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Note:
Treatment has been or will be conducted at the following Hot Ponds:
Ponds 109, 293, & 297: Pond Draining by Breaching
Pond 285: AquaBlok™

N

Scale 1:12000

0 meters 360

Mapping and database source: CRREL 1996.

OUTSIDE SITE
UNCLASSIFIED
MUD FLAT BARREN
BORDER LOW SHRUB
BORDER SPRUCE WOODLAND
CREEK
GULLEY
HALOPHYTIC HERB MEADOW
INTERIOR SEDGE MEADOW
INTERMITTENT POND
LEVEE GRASS MEADOW
MARINE ALGAE
PERMANENT POND
RIVER
RIVER MEANDER MEADOW
RELICT RIDGE
RAMENSKI 5 SEDGE MEADOW
SEDGE BOG
SEDGE MARSH
WET SWALE
49 HOT POND NUMBER
OUC SITE BOUNDARY
AREA BOUNDARY

Pond grouping based on topography, land form cover and hydraulic interconnectiveness.

CH2MHILL

TABLE 2
Summary of Pond Group Characteristics

Pond Group	Pond Numbers	Pond Group Size (ha)	Potential Area of Connected Landcover (ha)	WP Sampling	Surface Sediment Elevations (m msl)	Other Features
Northern A	138, 208, 226, 228, 246, 256, 258	5.8	42	6 of 57 locations (11%) have detected WP (range: 0.0002 to 0.00617 µg/g)	3.75 to 4.67	Hummocky topography
290	290	0.9	6.9	1 of 6 sampling locations (17%) had detected WP (value: 0.00075 µg/g)	no data	Relatively isolated pond. Few individual depressions.
183	183	2.9	11.7	166 of 219 locations (76%) have detected WP (range: 0.0002 to 58 µg/g)	4.39 to 4.91	Some connection with Pond 146.
146	146	5.5	15.9	20 of 68 locations (30%) have detected WP (range: 0.0008 to 70.1 µg/g)	4.06 to 4.65	Clunie Creek likely source of recharge. Some connection with Pond 183.
Northern C and C/D	40, 49, 85, 93, 112, 129, 145, 155	3.6	74.9	Pond 40 only: 4 of 30 locations (13%) have detected WP (range: 0.003 to 0.01208 µg/g)	3.95 to 5	Moderate rate of recharge from eastern bluffs.

Notes:

Potential Area of Connected Landcover represents the potential area of waterways that may be connected to the ponds in the pond group and therefore may be drained as the pond group is drained. The area presented is the sum of sedge marsh, intermittent pond, and permanent pond landcovers.

Surface sediment elevations were obtained at the WP sampling locations, and therefore may not be representative of the entire pond group.

msl = mean sea level

pond group affects the complexity and cost of some remedial actions. The potential area of landcover connected by waterways will affect the amount of water that needs to be pumped and therefore the pump cost of two of the alternatives. It may also affect the change in waterfowl habitat. Variations in pond depth affect the number of WP sampling stations that may be required to identify current conditions and verify that a remedial action has been successful.

There is a high level of uncertainty with regard to WP distribution at ERF. The WP concentration ranges in the table may be misleading in that several pond groups do not appear to have very high concentrations. This may result from the low density of sampling in the ponds. The sampling may not have discovered higher concentrations that may actually be there. The table may truly represent the absence of high concentrations in the pond group. This is one of the uncertainties in the available database.

Evaluating the pond groups separately will allow for the selection of different remedial alternatives for each pond group. Without this pond grouping approach, it would be difficult for the RPMs to tailor a preferred alternative to the variety of pond types at ERF.

Ponds 109, 285, 293, and 297 comprise a sixth group of ponds that either have had treatment or will have treatment completed in 1997. Hence, these ponds will not be evaluated in this FS.

- Pond 109 (Bread Truck) was breached by blasting in 1996. WP sublimation/oxidation monitoring will be conducted at this pond until nondetectable WP concentrations are achieved. The area of this pond is approximately 3.3 ha.
- AquaBlok™ cover was applied to Pond 285 in the Racine Island area in 1994. Its condition is being monitored periodically and its long-term integrity and performance will be used later to develop detailed monitoring approaches. The area of this pond is approximately 0.4 ha.
- Ponds 293 and 297 (Racine Island) were breached by blasting in spring 1997. Because of high organic content in the sediment, these ponds are not expected to dry. However, breaching did lower water levels to reduce habitat and prevent waterfowl feeding in this highly contaminated area. The combined area of these ponds is approximately 0.63 ha.

Although the remediation of these four ponds is not evaluated in this FS, they will be covered in the long-term monitoring as described later in the FS. In addition, a review will be conducted in 5 years to evaluate the performance of these remedial response actions at these ponds. Detailed costs have not been developed to monitor these pond groups. Removal action documents for these pond groups will be provided as addenda to this FS.

SECTION 3

Development of Remedial Alternatives

There were three steps in the development of remedial alternatives for this FS:

There were three steps in the development of remediation alternatives: identify potential remedial technologies, screen them, and combine technologies into remedial alternatives.

1. Technologies were identified that may be effective in reducing the impacts of the WP exposure at ERF. This may occur by reducing the concentration of WP in the sediment or by reducing the exposure of the receptors to WP.
2. Technologies were then screened on the basis of their effectiveness in reducing WP impacts, implementability (considering the technical and administrative feasibility of implementing the technology), and cost to apply in ERF. Some did not meet these criteria and were eliminated from further consideration.
3. The retained technologies were then combined into alternatives that represent a range of remedial actions that may be taken at ERF.

The first two steps are described further in Section 3.1. The retained technologies were combined into alternatives as described in Section 3.2. Section 3.3 describes an activity schedule. A discussion of the performance of each alternative is in Section 4.

3.1 Screening of Technologies

Fifteen remedial technologies were identified (discussed in more detail in Appendix B). These technologies were identified based on research and treatability testing conducted in the laboratory or at ERF as documented in the RI.

Fifteen remedial technologies were initially identified.

- **Air Sparging.** Air is introduced into WP-contaminated sediment to oxidize WP.
- **AquaBlok™.** This composite of bentonite, gravel, and polymers is applied to pond bottoms. It hydrates after application and expands vertically and horizontally, sealing the interstitial spaces in the gravel. This material acts as a physical barrier to the penetration of the bills of dabbling ducks and swans to the contaminated sediments. Vegetation also grows readily in AquaBlok™ material. AquaBlok™ is a tested cap and fill technology.

- **Cap and fill.** Sand or gravel is used to cover the pond bottoms, as a physical barrier to penetration by the bills of dabbling ducks and swans to contaminated sediments.

- **Chemical oxidation.** Hydrogen peroxide is used to oxidize WP, potentially reducing it to nondetectable levels.

- **Concover®.** This blend of recycled paper mulch with cellulostic polymers as the binding agent is applied to pond bottoms as a physical barrier to the penetration of the bills of dabbling ducks and swans.

- **Detailed Monitoring.** Monitoring is conducted to measure the progress of natural processes.

- **Dredging.** A remote dredge is used to remove contaminated sediment from the pond bottoms. The removed material is pumped as a slurry into a spoils retention basin, where the solids are allowed to settle. After the solids settle, the supernatant is decanted and the sediments are allowed to warm and dry, initiating the sublimation/oxidation process (Walsh and Collins, in Collins *et al.*, 1997)

- **Explosive Charges.** A controlled explosive charge is used to release contaminated sediment into the air so that WP will oxidize.

- **Geosynthetics.** Geosynthetic materials are used to cover contaminated pond bottoms as a physical barrier to penetration by the bills of dabbling ducks and swans to the contaminated sediments.

- **Hazing.** Hazing operations include deployment, use, and daily maintenance of propane exploders, pyrotechnics, scarecrows, flagging, balloons, and other visual, acoustic, and behavioral devices designed to frighten birds from the contaminated areas.

- **Methyl anthranilate.** An encapsulated matrix of this bird repellent is applied and settles to the bottom of contaminated ponds. The material is released when the capsule is broken by feeding ducks. Feeding rates and thus exposure to the contaminated areas would be expected to decrease as ducks avoid the treated areas.

- **Sublimation/oxidation.** WP particles in sediment will sublimate/oxidize and decrease in size under the proper soil moisture and temperature conditions, eliminating the contaminant from the ponds. Monitoring would provide indication of progress. This process was referred to as "natural attenuation" in previous technical reports.

- **Enhanced sublimation/oxidation.** Warming the sediment through artificial means (such as a greenhouse, dark covering, or artificial heat source) is used to increase the sublimation and oxidation rate of the WP. This process was referred to as "enhanced natural attenuation" in previous technical reports.

- **No Action.** Natural processes are allowed to proceed with no monitoring.
- **Pond draining.** Draining the ponds would enhance the drying of the sediments, leading to a higher sublimation/oxidation rate of WP. Two methods were considered: blasting a channel from a contaminated pond to a gully or the Eagle River (also referred to as breaching); and pumping, which would use pumps to discharge the pond water.

On the basis of the information available from previous treatability studies and vendors, the technologies were screened to identify those that do not satisfactorily meet the criteria of effectiveness, implementability, or cost. Details on this analysis are available in Appendix B. AquaBlok™ and pond draining are retained because previous studies demonstrated that they may be effective and because they can be implemented at portions of ERF. AquaBlok™ and pond draining are examples of containment and treatment general response actions, respectively. Sublimation/oxidation is retained because it is a natural process and thus becomes part of the no-action alternative. Although hazing does not provide long-term protection from WP, it may be used as a contingency until an alternative is online. Dredging was initially retained because field-scale treatability tests indicated that it was implementable and effective. The other technologies were eliminated from further consideration as part of a remedial alternative for ERF:

- **Air Sparging.** Bench-scale studies demonstrated that air sparging had little effect on WP-contaminated sediment.
- **Cap and fill.** Cap and fill with gravel is not expected to be as effective a horizontal barrier as application of AquaBlok™ because gravel lacks cohesive properties. Gravel application is expected to be less resistant and more permeable than AquaBlok™ application. In addition, revegetation is expected to be more successful through the AquaBlok™ material than through gravel. Therefore, the AquaBlok™ process option was retained as a specific example of the horizontal barrier technology.
- **Chemical oxidation.** The test application had insufficient effect and difficulties were anticipated for large-scale field application.
- **Concover®.** The application was quickly penetrated by water and floated to the surface within 30 minutes in the test trial. It was also readily damaged by ducks.

- **Explosive Charges.** Field testing demonstrated that conditions were not sufficient for sediment released into the air by an explosive charge to oxidize.
- **Geosynthetics.** A reliable method for anchoring the liners was not identified. In addition, application of geosynthetics is labor intensive and repair of the material (after winter blasting) may be difficult. The liners did not survive the winter ice-out conditions.
- **Methyl anthranilate.** A single application is ineffective over the long term, and continued applications are expensive.
- **Enhanced sublimation/oxidation.** The enhancements did not markedly increase the rate of loss of WP in the field.

Following this initial screening, dredging was considered further. Its unit cost (cost per treated hectare) is about an order of magnitude greater than that of the other technologies. During the 1996 field-scale study, the dredge's rate of application was slow and the dredge was not operated within performance specifications. Although verification sampling following the 1996 dredging demonstrated that substantial reduction of WP was attained, 8 percent of the samples still had detectable WP, ranging in concentrations from 0.076 to 3.800 μg/g (Walsh and Collins, in Collins *et al.*, 1997). Finally, wetlands regulations prohibit dredging in a wetland if another practicable alternative exists. The moderate effectiveness of dredging does not justify its extreme cost. For these reasons, dredging has been eliminated from further consideration.

Of the retained technologies, AquaBlok™ is an example of containment as a general response action and horizontal barrier as a process option. Pond draining is an example of a treatment general response action because its goal is to enhance WP sublimation/oxidation.

3.2 Assembly of Alternatives

The retained technologies were assembled into five alternatives: no action; detailed monitoring; pond draining and AquaBlok™; breaching, pond draining, and AquaBlok™; and AquaBlok™ alone.

Each retained technology was initially considered as a stand-alone application at ERF (that is, it would be the only technology included in an alternative). Because of the uncertainty that any single technology by itself could effectively reduce the hazards of WP exposure, combinations of technologies were assembled into five distinct alternatives as summarized in Figure 4:

1. **No action.** No treatment technologies will be implemented. Only natural processes such as gully recession, sedimentation, and WP sublimation/oxidation will continue at ERF. There will be no monitoring. This alternative is included because of a requirement of the NCP, and serves as the baseline against which the effects of

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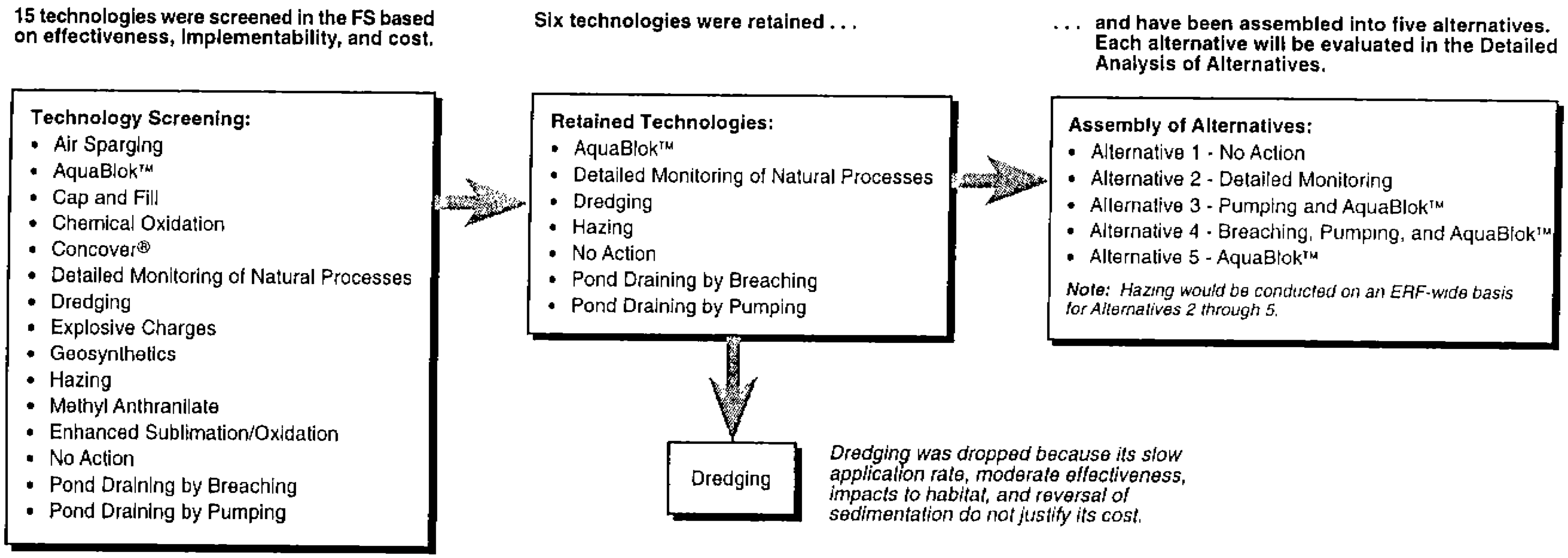

Figure 4

Technology Screening and Alternatives Assembly Process

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

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the other alternatives can be compared. An evaluation of natural processes at ERF is presented in Appendix A.

2. **Detailed monitoring.** This is similar to Alternative 1, but monitoring will be performed to understand whether protection of the environment is achieved. Monitoring will include a telemetry study of mallard mortality, aerial bird population surveys, aerial photography (to measure pond changes and gully recession), measurement of net sedimentation, and an elevation survey. The elevation survey of ground surface and pond bottoms will be used to determine pond interconnectiveness and flooding potential. In addition, baseline WP monitoring will be performed using the composite sampling method to determine current WP levels. Limited sublimation/oxidation conditions monitoring will be performed to detect whether conditions have been suitable for WP sublimation/oxidation. WP verification sampling also will be performed to confirm the success of this alternative if the pond conditions have been sufficient to expect substantial WP sublimation/oxidation and loss. Monitoring methods are discussed further in Section 5 and Appendix G.

3. **Pumping and AquaBlok™.** Pumping will be used to drain pond groups to help WP decrease by sublimation/oxidation. Each year, pumps and monitoring systems will be installed, operated, and then removed. Monitoring will include a mallard mortality telemetry study, aerial bird population surveys, aerial photography (to measure pond changes and gully recession), and an elevation survey. In addition, baseline WP monitoring will be performed at the beginning of the first season of pumping using the composite sampling method to determine current WP levels. WP verification sampling will also be performed if the pond conditions have been conducive to substantial WP loss through sublimation/oxidation. After a few years of operation (assumed to be 5 years after the pond is initially drained), AquaBlok™ will be applied to pond regions that still have detectable WP. AquaBlok™ will be applied only to isolated areas that were not remediated by draining. The integrity of the AquaBlok™ will be periodically monitored after application to test whether it is still effective in blocking access by ducks to the contaminated sediment. Throughout implementation, ponds will be monitored for habitat changes using remote sensing techniques to minimize the need for personnel in ERF and reduce the potential for human exposure to UXO. Aerial photography would be used to estimate vegetation species composition and cover changes over time. Bird counts could also be done at the same time to estimate changes in waterfowl use of the habitats. Sedimentation measurements (with limited ground truthing) may also provide information on habitat changes.

4. **Breaching, Pumping, and AquaBlok™.** Pond groups will be breached to drain them. After breaching, other activities are similar to those described for Alternative 3. In addition, ponds will be monitored for habitat changes using remote sensing techniques. Aerial photography would be used to estimate vegetation species composition and cover changes over time. Bird counts would also be done concurrently to estimate changes in waterfowl use of the habitats. Sedimentation measurements may also provide information on habitat changes.

5. **AquaBlok™.** The surface of the ponds will be covered with AquaBlok™ using either a helicopter or truck (with application while the flats are frozen). Monitoring will include a mallard mortality telemetry study, aerial bird population surveys, aerial photography (to measure pond changes, gully recession, and habitat changes), and an elevation survey. In addition, baseline WP monitoring will be performed using the composite sampling method before the AquaBlok™ is applied to determine current WP levels, and AquaBlok™ integrity will be monitored after application using remote sensing techniques. Aerial photography would be used to estimate vegetation species composition and cover changes over time. Bird counts would also be done concurrently to estimate changes in waterfowl use of the habitats. Sedimentation measurements may also provide information on habitat changes.

In addition, under Alternatives 2 to 5, waterfowl (specifically swans) will be hazed on a flats-wide basis for the first 5 years of remedy implementation. Hazing will be performed as an interim contingency measure until a remedy is in place.

Figures 5 through 8 present the physical layout of the remedial alternatives. For simplicity, each figure presents all pond groups as if the same remedial alternative were implemented at all pond groups. Remedial decisions will be made for each pond group; therefore, different remedial alternatives may be chosen for different pond groups.

Figure 5 presents a summary of Alternatives 1 and 2. The natural processes that may lead to protection include sublimation/oxidation, sedimentation, and gully recession. The rate at which these occur differs across ERF. Therefore, the estimated time to achieve natural restoration will vary, as shown in this figure. Natural processes are discussed further in Appendix A.

Figure 6 shows the location and size of pumps that are included as part of Alternative 3 for each pond group. The larger pumps, with a 3,000 gallons per minute (gpm) capacity, are generally found in Pond 146 and Northern C and C/D pond groups because of the larger volume of water that must be drained. Figure 7 shows the layout of

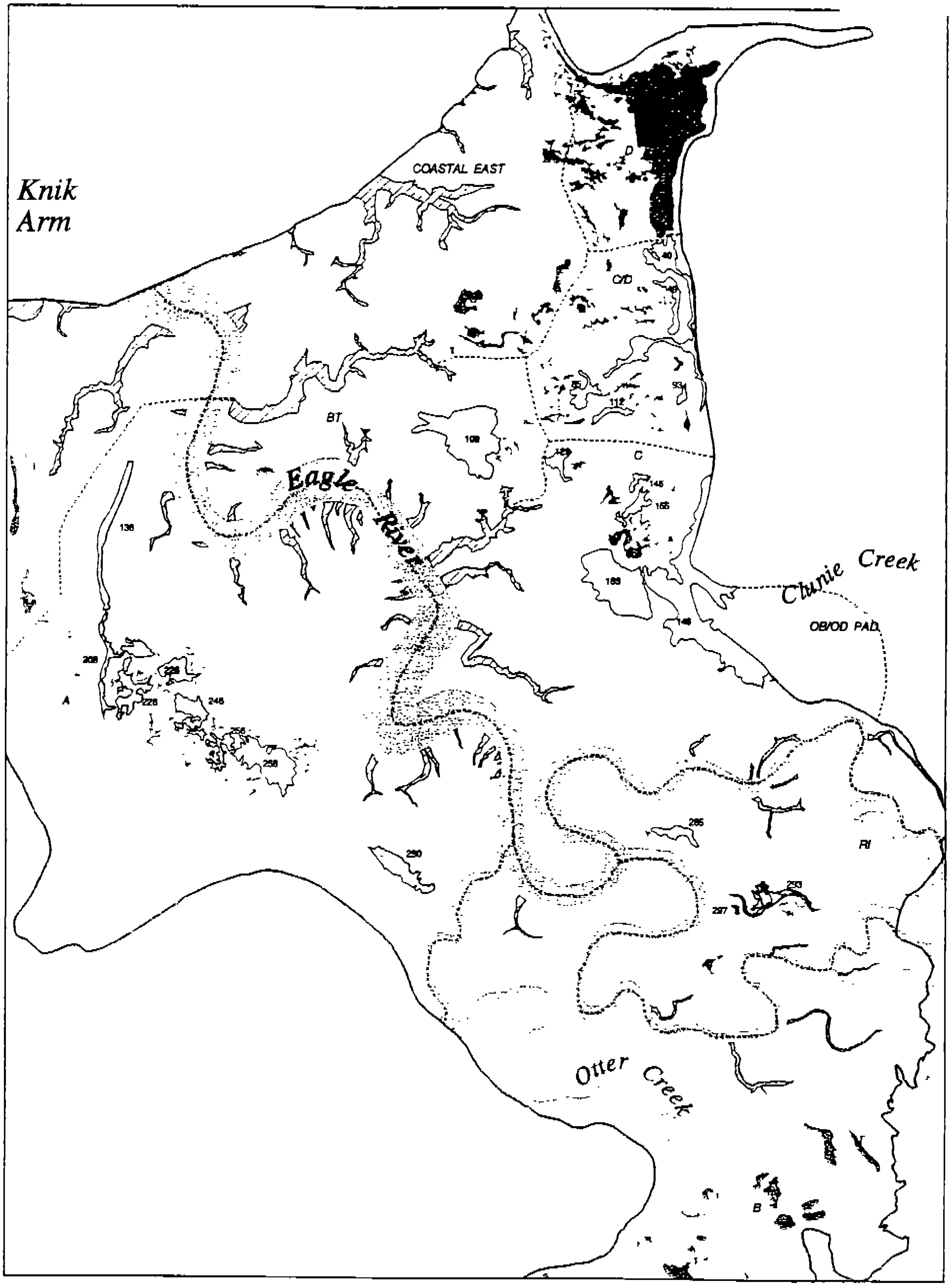

Figure 5

Alternative 1 (No Action) and Alternative 2 (Detailed Monitoring)

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Scale 1:12000

0 meters 360

Mapping and database source: CRREL, 1996.

Note:
Treatment has been or will be conducted at the following Hot Ponds:
Ponds 109, 293, & 297: Pond Draining by Breaching
Pond 285: AquaBlok™

Permanent Pond
49 Hot Pond Number
Intermittent Pond
Gully
River/Creek
Area Boundary
OUC Site Boundary

NATURAL PROTECTION:
Likely within 5 yrs
Possibly within 10 - 15 yrs
May take more than 20 yrs
Very likely to take more than 20 yrs
Note: Assumes past and planned treatment actions

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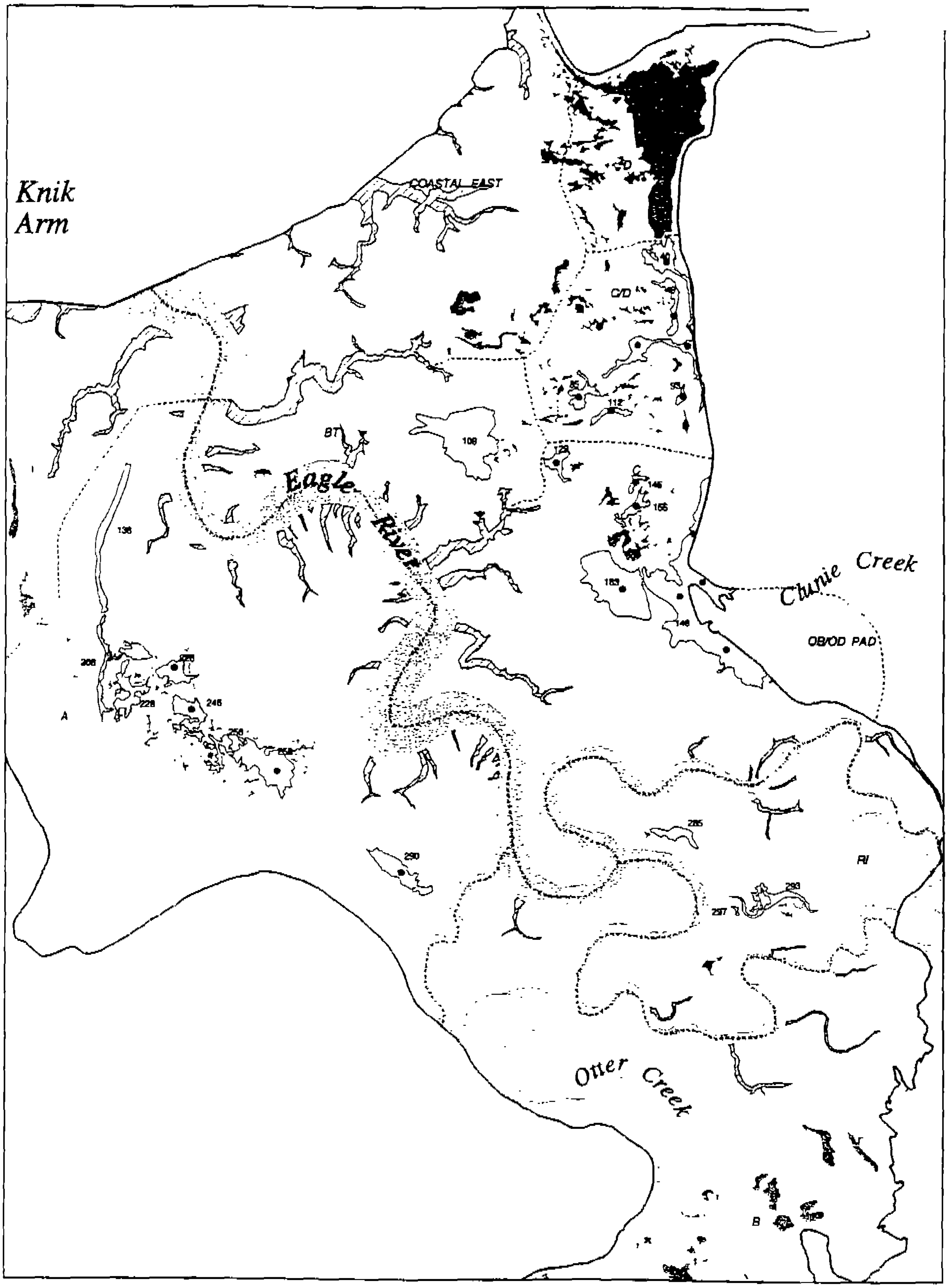


Figure 6

Alternative 3:
Pumping and AquaBlok™

Note: 1. Treatment has been or will be conducted at the following Hot Ponds:
Ponds 109, 293, & 297: Pond Draining by Breaching
Pond 285: AquaBlok™
2. AquaBlok™ application is not shown.
3. Discharge piping is not shown.

N

Scale 1:12000

0 meters 380

Mapping and database source: CRREL, 1996.

- 49 Hot Pond Number
- Intermittent Pond
- Permanent Pond
- Gully
- River/Creek
- Area Boundary
- OUC Site Boundary

- Location of Pump - 1000 GPM Capacity
- Location of Pump - 2000 GPM Capacity
- Location of Pump - 3000 GPM Capacity

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

CH2M HILL

March 27, 1997

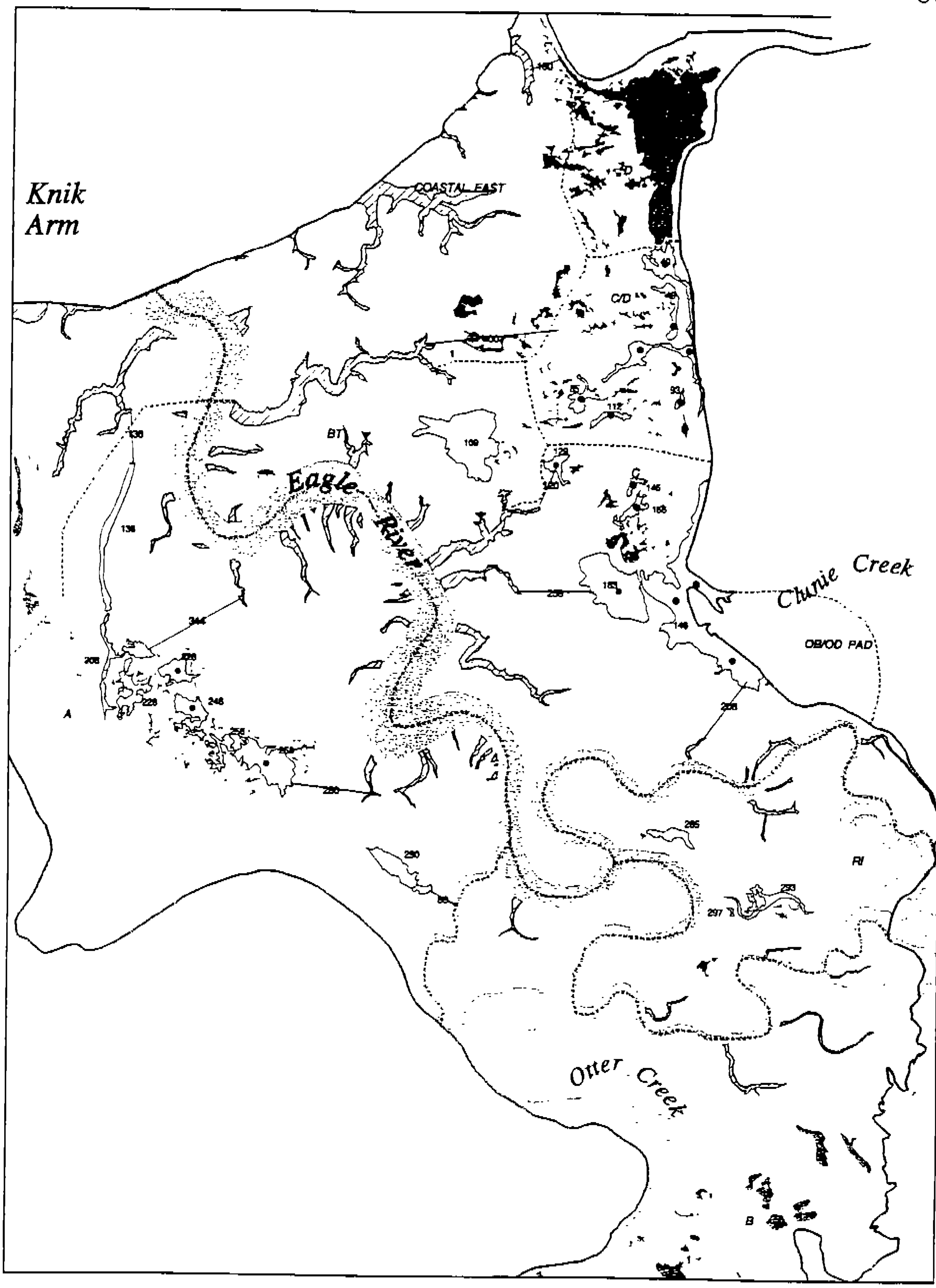


Figure 7

Alternative 4: Breaching, Pumping and AquaBlok™

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Scale 1:12000
1 cm = 120 m
0 meters 360

Mapping and database source: CRREL, 1996.

Note: 1. Treatment has been or will be conducted at the following Hot Ponds:
Ponds 109, 293, & 297: Pond Draining by Breaching
Pond 285: AquaBlok™
2. AquaBlok™ application is not shown.
3. Discharge piping is not shown.

49 Hot Pond Number
Intermittent Pond
Permanent Pond
Gully
River/Creek
Area Boundary
OUC Site Boundary

Proposed Location of Gully to Blast and Length in Meters
Location of Pump - 500 GPM Capacity
Location of Pump - 1000 GPM Capacity
Location of Pump - 2000 GPM Capacity
Location of Pump - 3000 GPM Capacity

CH2MHILL

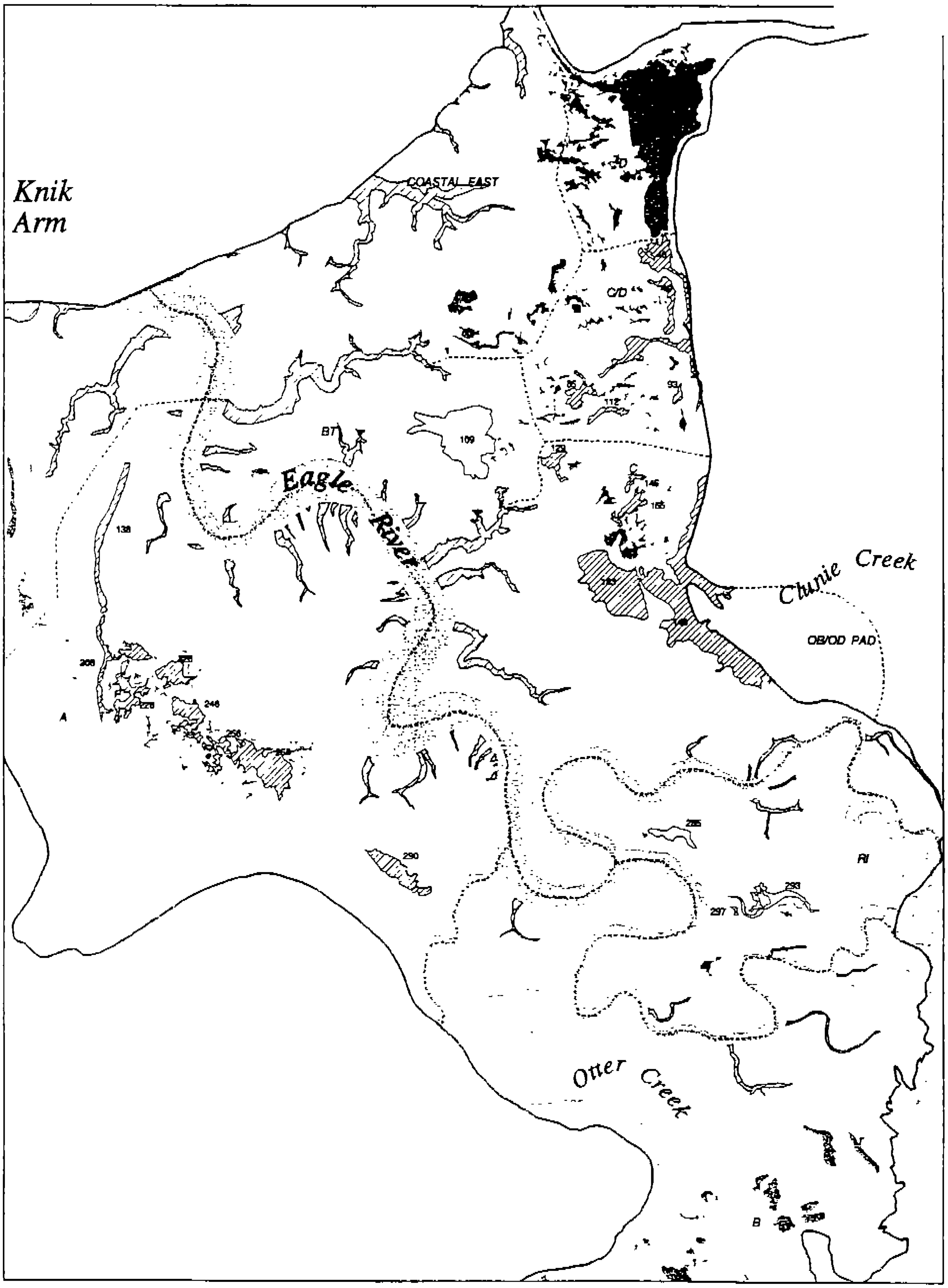
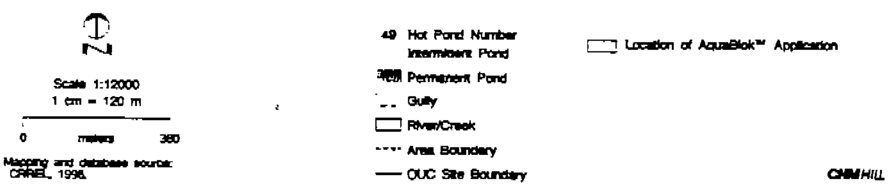


Figure 8

Note:
Treatment has been or will be conducted at the following Hot Ponds:
Ponds 109, 293, & 297: Pond Draining by Breaching
Pond 285: AquaBlok™

Alternative 5: AquaBlok™

Operable Unit C
Feasibility Study
Fort Richardson, Alaska



the new ditches and smaller pumps in Alternative 4. Because new ditches can also help drain the water, the number of large-capacity pumps is reduced. Finally, Figure 8 shows the AquaBlok™ application to the pond groups.

Following the pond draining in Alternatives 3 and 4, the treatment will depend on sublimation/oxidation to reduce the levels of WP. Thus, sublimation/oxidation, which was retained as a technology in Section 3.1, is included in these two alternatives. A detailed discussion of each alternative is presented in Appendix C.

3.3 Implementation Schedule

An implementation schedule for the remedial alternatives, including the monitoring activities, is shown in Figure 9. While it is expected that different remedial alternatives will be started in different years for different pond groups, this level of detail in the schedule is not currently known. Therefore, the figure starts all alternatives at time zero, the start of their implementation, although they may be initiated in different years at different pond groups. This figure further demonstrates the similarities among the alternatives, because many of the same activities (for example, installing pumps and monitoring equipment and performing WP baseline monitoring) occur in different remedial alternatives. These activities can be seen to occur at the same relative time when all alternatives are shown with the same starting time. Also, the figure shows that spring and fall for most alternatives will be periods with high activity, with either the installation of remediation technology and monitoring equipment or their removal.

FIGURE 9: IMPLEM 'ATION SCHEDULE

Activity	Year 0 Spring Summer Fall	Year 1 Spring Summer Fall	Year 2 Spring Summer Fall	Year 3 Spring Summer Fall	Year 4 Spring Summer Fall	Year 5 Spring Summer Fall	Year 6 Through Achieving RAOs (1) Spring Summer Fall
ALTERNATIVE 1							
No monitoring or treatment activities							
ALTERNATIVE 2							
Survey Ponds							
Baseline WP Sampling							
Sublimation Conditions Monitoring (1 station)							
Install Equipment							
Operate Equipment							
Remove Equipment							
Sedimentation Analysis							
Install Equipment							
Operate Equipment							
Remove Equipment							
WP Verification							
Plant particles							
Remove & measure							
WP Sediment sampling							
ERF-WIDE ACTIVITIES							
Telemetry							
Bird Population Aerial Survey							
Aerial Photography - ERF							
Hazing							
ALTERNATIVE 3							
Baseline WP Sampling							
Survey Ponds							
TREATMENT							
Pumping							
Initial Startup/Shakedown							
Yearly Startup/Shakedown							
Install pumps							
Operate pumps							
Remove pumps							
Sublimation Conditions Stations							
Install Equipment							
Operate Equipment							
Remove Equipment							
WP Verification Sampling							
Plant particles							
Remove & measure							
WP Sediment sampling							
AquaBlok™ Application							
Monitor AquaBlok™ Integrity							
Monitor Habitat Changes							
ERF-WIDE Activities							
Telemetry							
Bird Population Aerial Survey							
Aerial Photography - ERF (2)							
Hazing							

FIGURE 9: IMPLEM ATION SCHEDULE

Activity	Year 0			Year 1			Year 2			Year 3			Year 4			Year 5			Year 6 Through Achieving RAOs (1)		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
ALTERNATIVE 4																					
Survey Ponds	■																				
Baseline WP Sampling	■																				
TREATMENT																					
Breach pond	■																				
Pumping																					
Initial Startup/Shakedown	■																				
Yearly Startup/Shakedown				■			■			■			■								
Install pumps	■			■			■			■			■								
Operate pumps	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■						
Remove pumps			■			■			■			■			■						
Sublimation Conditions Stations																					
Install equipment	■			■			■			■			■								
Operate	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■						
Remove			■			■			■			■			■						
WP Verification Sampling																					
Plant particles	■			■			■			■			■								
Remove & measure			■			■			■			■			■						
WP Sediment sampling			■			■			■			■			■						
AquaBlok™ Application																■					
Monitor AquaBlok™ Integrity																			■		
Monitor Habitat changes	■		■			■			■			■			■			■			
ERF-WIDE ACTIVITIES																					
Telemetry			■			■			■			■			■			■			■
Bird Population Aerial Survey	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Aerial Photography - ERF (2)	■		■	■		■	■		■	■		■	■		■	■		■	■		■
Hazing	■		■	■		■	■		■	■		■	■		■	■		■			
ALTERNATIVE 5																					
Baseline WP Sampling	■																				
Survey Pond	■																				
TREATMENT																					
AquaBlokTM Application	■																				
Monitor AquaBlok™ Integrity				■						■						■					
Monitor Habitat Change	■		■			■			■			■			■						
ERF-WIDE ACTIVITIES																					
Telemetry			■			■			■			■			■			■			■
Bird Population Aerial Survey	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Aerial Photography - ERF (2)	■		■	■		■	■		■	■		■	■		■	■		■	■		■
Hazing	■		■	■		■	■		■	■		■	■		■	■		■			

Notes:
1. Activities may change in these later years, depending on the progress to date.
2. Baseline photograph is obtained during low tide after the treatment action.

SECTION 4

Performance of Remedial Alternatives

The performance of each alternative will be incorporated in the detailed analysis of alternatives (Section 6).

The factors that contribute to the performance of each alternative are presented in this section. Because Alternatives 3 and 4 are basically two different ways to implement pond draining, the factors that are common to these two alternatives are discussed together in subsection 4.3, followed by a discussion of the differences between the two alternatives in subsection 4.4.

The performance of Alternatives 1 and 2 depends on natural processes occurring to reduce exposure to WP.

As discussed in Appendix A, tidal flooding is a critical physical factor affecting pond draining. During some summers, there may be no flooding tides (that is, tides that cover the flats) for 2 months or more between May and August. Between these peak tides, the sediment may become dry over large areas because of the relatively warm, dry weather (assuming no substantial rainfall or groundwater recharge). These drying periods are important because they can lead to natural attenuation of WP through sublimation/oxidation, potentially reducing the sediment concentrations below lethal levels. Therefore, the performance of the first four remedial alternatives, particularly Alternatives 1 and 2, is dependent on these flooding tides. Within the next 5 years, 1997, 1998, and 2001 have some of the longest potentially dry periods. Tides during 2002, 2003, 2005, and 2006 also are expected to result in good drying periods. Therefore, the first four alternatives should have improved performance if they are implemented in advance of these years.

4.1 Performance of Alternative 1

The ability of natural processes to reduce exposure of dabbling ducks to WP will vary among the different pond groups. Some ponds would likely experience WP reduction over a short period of time; others would require more than 20 years to show any significant improvement. A summary is presented in Table 3 and a detailed discussion is presented in Appendix A. Alternatives 1 and 2 are equally effective. However, under Alternative 1, the no-action alternative, effectiveness would not be monitored.

TABLE 3
Performance of Alternatives 1 and 2

Pond Group	Natural Restoration	Conclusion
Northern A Ponds	1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation around the perimeter. Gully recession may drain ponds, but time period is uncertain. Pond 258 may obtain sufficient sedimentation.	Some natural restoration at least around the perimeter is likely in a few years if good drying between tides. Protection by sedimentation or gully recession may take longer than 20 years. Pond 258 may have sufficient sedimentation in 10 years.
Pond 290	1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation around the perimeter.	Some natural restoration around the perimeter is likely in a few years if good drying between tides. Protection by sedimentation or gully recession may take longer than 20 years.
Pond 146	1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation. Sediment may build up to 10 cm to 15 cm in 10 to 15 years.	Natural restoration from sedimentation appears possible within 10 to 15 years. Sedimentation would have to be deep and consolidated to prevent duck feeding in WP-contaminated sediment.
Pond 183	1997 and 1998 offer good opportunities for drying and subsequent WP sublimation/ oxidation. Large area of pond may drain in 10 to 15 years. Sediment may build up in similar time frame.	Natural restoration of at least the perimeter is likely in a few years if good drying between tides. Natural restoration from pond draining and sedimentation appears possible within 10 to 15 years.
Northern C and C/D Ponds	1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation, at least around the perimeter.	Natural restoration through sublimation/oxidation of at least the perimeter is likely in a few years if good drying between tides. Natural restoration from sedimentation appears possible within 10 to 15 years.

Note: Assessment is based on only a few years of data collection and is subject to change with new information. The assessment is made on the assumption that the observed processes of the past few years represent the future; however, the short period of these observations makes this assumption highly uncertain.

4.2 Performance of Alternative 2

The performance of Alternative 2 is identical to that of Alternative 1, as presented in Table 3. However, effectiveness would be measured under Alternative 2. Alternative 2 includes a detailed monitoring program of aerial population surveys, telemetry for assessing duck mortality, sedimentation studies, and WP sampling. These monitoring activities are discussed in Section 5 and Appendix G.

4.3 Performance of Alternatives 3 and 4

Performance of Alternatives 3 and 4 is dependent on hydraulic interconnections between the pond systems, recharge, organic content of sediment, surrounding vegetation, and topography.

The degree by which Alternatives 3 and 4 may perform effectively varies by pond group. In these alternatives, the exposure pathway between dabbling ducks and WP sediment is cut by the following mechanisms:

- Lowering the water table by draining to prevent feeding by ducks
- Lowering the water table to dry the pond-bottom sediment and promote sublimation/oxidation of WP. The rate of sublimation/oxidation increases with increased temperature.
- Covering portions of pond bottoms that do not dry with AquaBlok™ to block waterfowl from feeding from contaminated sediment

Factors such as hydraulic interconnections between the pond systems, recharge, organic content of the sediment, surrounding vegetation, and topography affect the effectiveness of the pumping remedy and the rate of WP sublimation/oxidation. These processes are conceptually depicted in Figure 10. The following subsections describe how these factors affect the drainage and drying of each pond group.

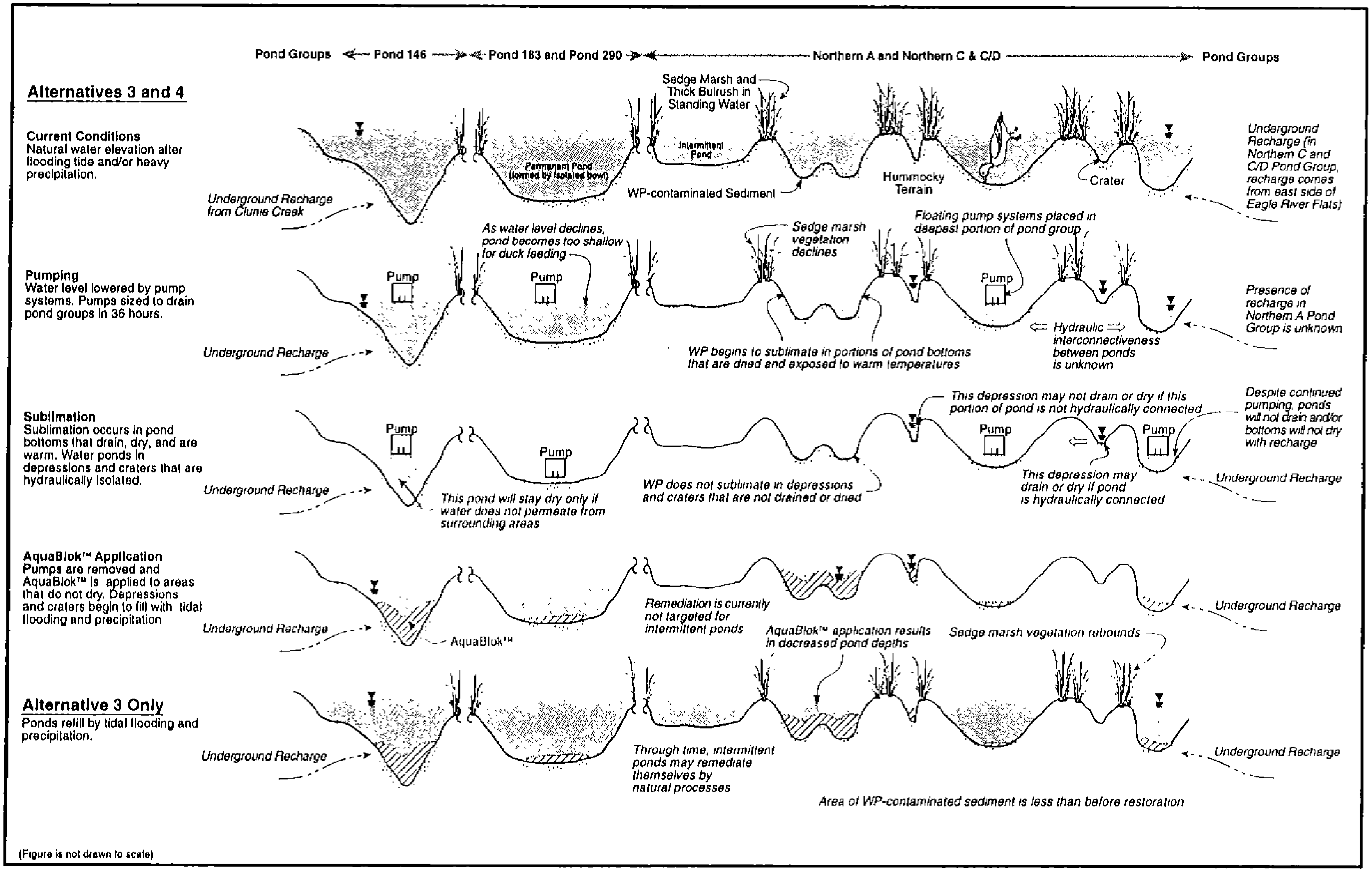
Water-bearing vegetation, such as sedge marsh, links large areas around hot ponds. This increases the pumping requirements for Alternatives 3 and 4.

4.3.1 Vegetation

Water-bearing areas that are highly vegetated hydraulically link permanent and intermittent ponds and affect how well a pond group will drain and dry. For example, the hot ponds in the Northern C and C/D pond group are interconnected by large areas of sedge marsh, permanent ponds, and intermittent ponds. The hot ponds are not hydraulically isolated. The sedge marsh is composed of thick sedges and bulrushes with standing water. Pumping in pond groups with large areas of adjacent sedge marsh would also result in pumping the marsh. Hence, water level reduction in hot ponds by draining would be achieved only by reduction in water levels of the surrounding water-bearing landcovers. The areas of these water-bearing landcovers are presented Figure 3 and Table 4. The degree of interconnectiveness between ponds and sedge marsh can be better understood after detailed surveying of the ponds. Surveying is included as a component of Alternatives 2, 3, 4, and 5.

4.3.2 Topography

The topography of the pond bottom affects how the pond system would dry. For example, the pond bottoms of the Northern A and the Northern C and C/D pond groups are hummocky, with elevated areas where sedge marsh is present and depressed areas where water is ponded. The presence of craters further increases the variability in pond bottom elevations in these pond groups. Although water levels



Alternative 3: Pumping and AquaBlok™
Alternative 4: Breaching, Pumping, and AquaBlok™

Figure 10
Restoration Processes of Alternatives 3 & 4
Operable Unit C
Feasibility Study
Fort Richardson, Alaska

CH2M HILL

TABLE 4
Area of Landcover in Each Pond Group (hectares)

Pond Groups	Hot Pond Area	All Intermittent Ponds	All Permanent Ponds	Sedge Marsh	Total	Hot Pond Area/ Total Area (%)
Northern A	5.8	10.6	6.2	25.2	42.0	14
Pond 290	0.9	0.2	0.9	5.7	6.9	13
Pond 183	2.9	8.8	2.9	0.0	11.7	25
Pond 146	5.5	4.0	11.2	0.7	15.9	35
Northern C & C/D	3.7	2.2	17.9	54.8	74.9	5
TOTAL	**18.8**	**25.8**	**39.1**	**86.4**	**151.3**	**12**

Notes:
1. Permanent pond area includes hot ponds in the pond group
2. The areas presented here would be temporarily drained under Alternative 3 and permanently drained under Alternative 4.

Topography affects the performance of Alternatives 3 and 4. Craters and hummocks increase the difficulty of drying large areas with a minimum number of pumps.

of ponds in this hummocky terrain may be decreased by pumping or a combination of pumping and breaching, only certain portions of the pond system would dry. The depressions that would dry are the depressions (or craters) where pumps are located.

Conversely, Ponds 290, 183, and 146 are basically individual bowls with a few identifiably deep areas. Pumps may be placed in these deep areas and a large fraction of these ponds is expected to be influenced by the pumping system. Hence, the pump system should be able to lower water levels in the entire pond system.

There is currently little understanding of the topography of the pond groups. The pond bottom elevations, depressions, and craters and the threshold elevation will be surveyed as discussed in Appendix G and evaluated before pumping and/or breaching are implemented.

Higher pond threshold elevation (that is, the elevation of the lip around the pond) will decrease the number of times that a pond will flood. It also increases the time it takes for the pond to drain.

4.3.3 Threshold Elevation

The frequency of flooding of a pond is dependent on its threshold elevation with respect to flooding tide elevations. Breaching would lower that threshold elevation and result in more frequent flooding and re-wetting of pond bottom. However, ponds with lower threshold elevations (breached ponds) would also drain more quickly.

4.3.4 Hydraulic Permeability of Sediment

Hydraulic permeability either fosters or inhibits draining and drying, depending on site conditions. The influence of an individual pump on a pond system would be greater in a pond system with permeable sediment and sedge marsh. Pumping a hot pond would drain adjacent depressions and craters (without dedicated pumps), but also would result in more pumping to drain larger adjacent areas. Conversely, the influence of an individual pump would be less in a pond system with less permeable sediment. A depression or crater would not drain (if it did not have a dedicated pump system) despite adjacent pumping, whereas a lower pumping rate would be needed to drain a hot pond if the adjacent pond (possibly clean) was not also drained. In some cases, small, low, ponded impermeable areas may be dried through evaporation. These processes are depicted in Figure 11.

For example, the ponds in the Northern C and C/D pond group are hydraulically interconnected to Area D. To drain the hot ponds in the Northern C and C/D group, the ponds in Area D would also have to be drained. Thus a larger volume of water than that contained in the hot ponds would have to be drained. The same is true, to a lesser extent, of the Northern A pond group.

High hydraulic permeability of the sediment will tend to increase the area drained by pumping because the water will flow more easily in the sediment between areas. This increases the pump size requirements.

The hydraulic permeability of the sediment throughout ERF is not completely understood. This would be resolved by implementing the treatability tests and land and aerial surveys. For example, the degree of interconnectiveness between Ponds 146 and 183 was initially not known. Pond 146 is considerably deeper than Pond 183. The ponds were connected by a dredged channel in 1996. However, a pumping treatability test was conducted in Pond 183 in summer 1997 to determine how water levels will respond to continued pumping. The test demonstrated that a small amount of water infiltrates from Pond 146 to Pond 183, but that amount of inflow can be controlled by pumping Pond 183. Thus, Pond 183 could be drained and dried.

4.3.5 Recharge

Ponds that are recharged by groundwater will need larger pumps to remove the additional water that is entering the pond. Underground recharge has been identified along the eastern portion of ERF (near Areas D and C/D) and from Clunie Creek (into Pond 146).

Ponds that experience recharge are unlikely to dry, although they can be drained. Recharge refers to inflow of water into the pond or pond group from groundwater, surface creeks, or springs. Underground recharge has been identified along the eastern portion of ERF (near Areas D and C/D) and from Clunie Creek (into Pond 146). Surveys have not been performed in Area A to identify areas of recharge.

4.3.6 Organic Content

Sublimation/oxidation of WP is expected to be retarded in areas where sediment has high organic content, because it is unlikely that these areas would dry. However, it is believed that the sediments need not dry completely, only enough to allow sublimation/oxidation to occur through pores to the surface. Surrounding mud flats adjacent to these ponds tend not to be highly organic, promoting sublimation/oxidation if exposed (Walsh, 1997). The distribution of organically rich sediment is unknown in these pond groups. Pond bottom sediment at Racine Island has a high concentration of organic material.

4.3.7 Assessment of Drying Potential by Pond Group

WP will not sublimate in portions of pond groups that do not desaturate. These contaminated areas will be delineated by visual inspection, data from sediment monitoring stations, and post-treatment monitoring. AquaBlok™ will be applied to areas that do not respond to draining and drying.

High organic content in the sediment will increase the time to dry. The distribution of organically rich sediment is unknown in these pond groups.

Three tables have been prepared that emphasize different aspects of the draining and drying process. The physical characteristics of each pond group are presented in Table 5. These characteristics influence the effectiveness of pond draining under Alternatives 3 and 4. An "index" of how well a pond group is expected to dry under Alternatives 3 and 4 is presented in Table 6. This index is actually the percentage of pond group area that is expected to require AquaBlok™. The rationale for these estimates is also presented in Table 6. Pond draining is discussed in the next section.

4.4 Performance Differences Between Alternatives 3 and 4

Alternatives 3 and 4 each have strengths and weaknesses. Both alternatives are essentially pond draining, but each uses a different implementation method and each has a different impact on the environment. The following are fundamental differences between Alternatives 3 and 4:

- Large volumes of water can be drained quickly under Alternative 4. Exposure pathways are more quickly blocked under Alternative 4 than under Alternative 3.

- However, ponds breached by Alternative 4 are also flooded more frequently. WP removal through the sublimation/oxidation process is expected to be more rapid under Alternative 3 than under Alternative 4.

Because the hot ponds in Northern C and C/D are hydraulically connected to a large permanent pond in Area D, this pond would have to be drained to drain the hot ponds. This will increase the pumping requirements.

The discussion presented in this section is based primarily on the results of the summer 1997 Pond 183 pumping study and continued monitoring of Bread Truck, which was breached in 1996.

4.4.1 Alternative 4 Drains Water Quickly

Breaching can move a large volume of water quickly. This is advantageous in two ways: exposure pathways are blocked quickly, and large open water bodies can be drained.

TABLE 5
Physical Characteristics of Each Pond Group

Pond Groups	Hot Pond Area (hectares)	Landcover Drained by Alternatives 3 and 4		Factors Affecting Ability of Ponds to Dry		
		Percentage of Landcover	Total Area (ha)	Topography	Recharge	Ability to Drain
Northern A	5.8	Intermittent Pond: 25 Permanent Pond: 15 Sedge Marsh: 60	42.0	Hummocky topography. High number of shallow depressions expected. Medium to high number of craters.	Unknown whether recharge exists from the western bluffs. No evidence of springs. Strong spring has been identified in Coastal West, but it feeds into the Coastal 6 gully.	The extent of interconnectiveness between the hot ponds and the surrounding sedge marsh is unknown. However, an aerial and land survey conducted in June 1997 indicated that the area encompassed by sedge marsh (area to be drained) is relatively narrow and may be drained.
Pond 290	0.9	Intermittent Pond: 4 Permanent Pond: 13 Sedge Marsh: 83	6.9	Relatively isolated pond. Few individual depressions. Medium number of craters.	Same as above.	Interconnectiveness between Pond 290 and sedge marsh area is unknown.
Pond 183	2.9	Intermittent Pond: 75 Permanent Pond: 25 Sedge Marsh: 0	11.7	Few individual depressions. Pond bottom much shallower than adjacent Pond 146. High number of craters.	Unknown.	The 1997 pumping treatability study at Pond 183 suggests that the amount of water entering from Pond 146 could be contained by the pumping of Pond 183. These two ponds are interconnected by a shallow channel that was advanced by the dredge in 1996. The ponds are separated by sedge bog, which is less permeable than sedge marsh.
Pond 146	5.5	Intermittent Pond: 25 Permanent Pond: 70 Sedge Marsh: 5	15.9	Some individual depressions expected. Very deep along eastern edge of pond. Pond bottoms modified by dredge. High number of craters.	Clunie Creek is a source of underground recharge. It is likely that this creek is part of the recharge from the eastern bluffs (described below).	Recharge from Clunie Creek and inflow from sedge marsh to the north may make drainage and drying difficult.
Northern C & C/D	3.7	Intermittent Pond: 3 Permanent Pond: 24 Sedge Marsh: 73	74.9	Hummocky topography. High number of shallow depressions expected. Medium to high number of craters.	A moderate amount of recharge has been identified from the eastern bluffs.	Recharge from eastern bluffs and inflow from surrounding sedge marsh would make drainage and drying very difficult.

Notes:
1. Only landcovers that are expected to be affected by the alternatives are presented in this table.
2. Craters counts based from ERF GIS (CRREL, 1996). Craters were not observable in large parts of Areas A and C/D. However, crater counts have been estimated in these pond groups based on crater counts in adjacent areas.
3. There is no pond group-specific information on organic content and threshold elevation.

TABLE 6
Drying Potential (Percentage of Hot Ponds to be Covered with AquaBlok™)

Pond Groups	Hot Pond Area (hectares)	Alt. 1&2 : No Action and/or Detailed Monitoring	Alt. 3: Pumping and AquaBlok™	Alt. 4: Breaching, Pumping and AquaBlok™	Alt. 5: AquaBlok™	Rationale for AquaBlok™ Coverage Estimate
Northern A	5.8	0	60	40	100	The Northern A area is hummocky with several deeper pockets of free-standing water and several areas of elevated sedge marsh. Few detailed surveys of Area A have been performed, and the hydraulic system is not well understood. It is unknown whether there is a source of recharge in this Area. Under Alternative 3, there is uncertainty as to whether water levels can be decreased significantly. Under Alternative 4, although water levels may be decreased, it is unknown whether the pond bottoms can be dried. However, an aerial and land surveying conducted in June 1997 suggested that the area may be drained.
Pond 290	0.9	0	15	10	100	Pond 290 is relatively isolated from other ponds. The deepest section of the pond appears to be in the north (best location for pump). The pond is expected to drain and dry successfully under either Alternative 3 or 4 . Breaching is not expected to improve the effectiveness of draining.
Pond 183	2.9	0	30	15	100	Pond 183 is considerably more shallow than neighboring Pond 146. Because 183 is shallow (avg. depth 20 centimeters), moderate lowering of the water table by pumping will expose a large area of contaminated sediment. The deepest portion of Pond 183 appears to be in the northern section of the pond. The two ponds were connected in 1996 with the advancement of the dredge from Pond 146 to Pond 183. A treatability study, conducted in summer 1997, determined that Pond 183 could be pumped dry and that inflow from Pond 146 could be controlled.
Pond 146	5.5	0	50	30	90	Clunie Creek is suspected to provide underground recharge. The eastern portion of Pond 146 is approximately 0.7 meters deep. Although water levels in Pond 146 may be lowered by high pumping and breaching, it is unlikely that pond bottoms will dry and warm long enough to foster WP sublimation/oxidation. Under Alternative 4, only a portion of Pond 146 needs to be drained, because of dredge operation in 1996.
Northern C & C/D	3.7	0	60	40	100	The Northern C and C/D area is hummocky, with several deeper pockets of free standing water and several areas of elevated sedge marsh. Recharge exists from the eastern side of the flats. Under Alternative 3, there is high uncertainty as to whether water levels can be decreased significantly, even with large amount of pumping. By breaching the Large Pond in area D (Alt. 4), water levels in the hot ponds may be decreased, but it is unknown whether hot pond bottoms can be dried. The deepest portion of this pond system is along the eastern side.

By rapidly removing water, the exposure pathway for dabbling ducks is immediately blocked. Thus, dabbling ducks will not feed in the sediment. This was demonstrated at Racine Island and Bread Truck. It takes only 1 or 2 days for a breached pond to drain and expose a large area of pond bottom. In comparison, pumping a pond system initially or after a flooding tide could take 1 to 2 weeks, depending on the amount of rainfall and pump capacity.

Breaching would also make it possible to drain a large open water body, using smaller, more conventional pump systems. For example, the area of hot ponds in the Northern C and C/D area is small (3.7 ha). However, this pond group is hydraulically interconnected to a large permanent pond in the northern part of Area D by a large area of sedge marsh (Figure 3). Pumping after breaching would require many fewer pumps than pumping alone.

Thus, the factors that influence the effectiveness of draining were considered in determining the volume of water that could be drained by breaching. These assumptions determined the designed pumping capacity, as presented in Table 7.

Less pumping and potentially less AquaBlok™ will be needed under Alternative 4 than Alternative 3. Breaching the pond system under Alternative 4 is expected to move a large volume of water initially, resulting in less water to be removed by pumping. The combination of

TABLE 7
Pumping Rates of Alternatives 3 and 4

	Alternative 3	Alternative 4		
Pond Groups	Total Pumping Flow Rate (gpm)	Water to be Drained by Breaching (%)	Water to by Drained by Pumping (%)	Total Pumping Flow Rate (gpm)
Northern A	7,168	60	40	2,867
Pond 290	1,277	80	20	255
Pond 183	1,995	50	50	997
Pond 146	10,122	50	50	5,061
C & C/D	39,228	40	60	23,537

Notes:
1. Water to be drained by breaching was approximated based on topography and hydraulic properties of each pond group.
2. Pumping rate under Alternative 3 was determined by estimating landcover depths and areas from the ERF geographical information system (GIS), and assuming that each pond group would have to be drained in 36 hours. Previous research by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and projected tidal and climatological data indicate that a pond should drain in 36 hours to allow for sublimation/oxidation processes

breaching and pumping (Alternative 4) is expected to be more effective in draining the ponds than pumping alone (Alternative 3). The remaining water could be drained by smaller pumps under Alternative 4. A smaller area of AquaBlok™ is estimated to be needed under Alternative 4.

It was assumed that draining may be more effective under Alternative 4 than Alternative 3 because smaller-capacity pumps could be placed to drain localized depressions. AquaBlok™ will be placed over all areas that do not dry, immobilizing the WP contained in the untreated sediment.

4.4.2 Ponds Breached by Alternative 4 Reflood Frequently

The primary drawback to breaching is that ponds would flood more frequently. Breaching would lower the threshold elevations. This would result in ponds being flooded even during low tides. Even though the tidal water would quickly redrain, this periodic reflooding would result in the slowing of the WP sublimation/ oxidation process (Collins, 1997). These processes were demonstrated during the 1997 treatability studies at Bread Truck Pond (Pond 109) and Area C (Pond 183). During the majority of the summer, the pond bottom of Pond 183 remained dry after several days of pumping. Pond 109 at Bread Truck, however, was breached and repeatedly flooded; drying of the pond bottom was marginal. The tensiometers that were placed in Pond 183 had significantly higher readings than those placed at Pond 109, indicating that the pond bottom drying process was much more effective in Pond 183.

Therefore, although Alternative 4 may remove the exposure pathway more rapidly than Alternative 3, sublimation/oxidation processes may be more effective than under Alternative 3. During low flood years, ponds that are pumped only would experience longer drying periods than ponds that are breached (because of frequent reflooding). As a result of the frequent rewetting of breached ponds, pond bottom drying would be slowed, and it may take more years for cleanup levels to be achieved under Alternative 4 (than under Alternative 3). However, because these conclusions are preliminary, it was assumed in the implementation schedule (Figure 9) that operation of Alternatives 3 and 4 will require the same duration of 5 years.

4.5 Performance of Alternative 5: AquaBlok™

Alternative 5 blocks the exposure pathway by preventing dabbling ducks and swans from feeding from contaminated pond bottoms. The following are factors that affect the success of AquaBlok™ application:

- **Ponds**–AquaBlok™ can be applied in either permanently ponded or intermittently ponded areas.

Several factors influence the performance of AquaBlok™: vegetation cover, tides, craters, gully recession, ice plucking, and sedimentation.

- **Vegetation**–Vegetative cover around the AquaBlok™ helps protect the material from disruption by tides. The vegetative cover contributed to the success of the treatability study completed at Racine Island.
- **Tides**–Areas where tides are slower and more gentle are better suited for AquaBlok™. The stronger and faster tides may disturb or move AquaBlok™. Generally, high tides flow and ebb more slowly in large ponds and quickly in smaller ponds.
- **Craters**–The presence of craters may result in uneven distribution of AquaBlok™, especially if the AquaBlok™ is applied from the air. Reapplication may be needed for this technology to be effective.
- **Gully recession**–Areas that may be drained naturally within the next 10 years may not be good candidates for AquaBlok™. It is unknown what effect the undercutting caused by gully recession may have on the stability of the barrier.
- **Ice Plucking**–Areas that are very close to the Eagle River and that may experience ice plucking are not good candidates for AquaBlok™ because the material might be damaged or dislodged by the ice movement. Ice plucking has been sporadically observed in ponds away from the Eagle River. However, there are no quantitative guidelines on what range is too close.
- **Sedimentation**–AquaBlok™ essentially performs like consolidated sedimentation.

Because an application of AquaBlok™ increases the pond bottom elevation, the pond habitat will likely change.

AquaBlok™ application generally results in an increase in the pond bottom elevation of 20 to 30 centimeters (cm). While it may not necessarily destroy habitat, it may alter it. Applications of AquaBlok™ to limited (deeper) pond areas also will result in habitat changes. From a hydrologic standpoint, water storage capacity will be reduced. The feeding habitat in the bottom sediments covered with AquaBlok™ also will be reduced until habitat is reestablished. Sedimentation and plant establishment on top of the AquaBlok™ may eventually restore these areas for waterfowl feeding; however, the depth will be permanently altered (Pochop *et al.*, in Racine *et al.*, 1996). The effect of depth changes on feeding habitat will depend on the initial water depth and the thickness of AquaBlok™ added.

The design thickness of the AquaBlok™ will range from 5 to 10 cm over level ground. AquaBlok™ may need to be reapplied over craters. Treatability studies indicate that AquaBlok™ may be unevenly distributed over craters. Data on the thickness of the AquaBlok™ barrier applied by air to a test area shows some reduction from 1993 to 1994. The sedimentation and deposition of organic matter measured in 1994 on the test area treated in 1993 was expected. Deposition should not inhibit the effectiveness of the AquaBlok™ in reducing the movement of WP particles below the barrier.

Vegetative growth may be inhibited by either scouring by ice breakup or by the physical characteristics of the area. It is expected that vegetation will recover. Lab tests show that plants will grow on the AquaBlok™ (Pochop *et al.*, in Racine *et al.*, 1994).

Two surveys were performed during fall 1996 and summer 1997 to evaluate the performance of the AquaBlok™ material applied at Racine Island in 1994. During both visits, thick vegetation was observed growing though the material. Along the perimeter of the pond, clean, dry gravel was observed underlain by a layer of pure bentonite. The bentonite appeared to be binding the gravel to the underlying sediment. In the saturated portion of the pond, the AquaBlok™ cover remained a mixture of gravel within swelled bentonite. Although the material has moderately low resistive strength and was penetrable, pen studies performed in 1993 suggest that waterfowl do not prefer dabbling in the AquaBlok™ material. Waterfowl prefer sifting in sediment, whereas the AquaBlok™ material consists of clean gravel (1/2- to 3/4-inch-diameter) within high plasticity clay (Cummings, 1997). In addition, if the cover material were stepped on by a large animal such as a moose, the swelling properties of the saturated bentonite material would likely reseal the penetration (Pochop, 1997). AquaBlok™ thickness measurements were performed during the 1996 survey and compared to previous measurements. The results are presented in Table 8.

TABLE 8
AquaBlok™ Thickness (cm)

	1994	1995	1996
Center of AquaBlok™ Drop	approx. 30	20.3	20.0
Level Ground	6.2	5.2	9.8
Craters	16.0	14.5	7.4

Notes.

1. Measured from core samples taken at Racine Island, Pond 285.
2. Increased thickness is the result of increased swelling of the bentonite.

Source: Pochop, 1997.

It is currently uncertain how effective AquaBlok™ application by truck will be. Concerns include uneven settling, accuracy of application, and completeness of hydration. A treatability study will be conducted during winter 1997-1998 to evaluate implementability of winter application by truck.

SECTION 5

Monitoring Strategy

The primary RAO of reducing dabbling duck mortality is monitored with telemetry, aerial bird population surveys, and aerial photography.

Two key concepts were used in the development of the monitoring strategy. First, monitoring must support the confirmation that RAOs are met. Second, there are three key stages of implementing a remedial alternative that must be monitored: before it is started, while it is being implemented, and at its conclusion. The first stage provides a baseline of current conditions against which future monitoring can be compared. The second stage provides ongoing information about how well the alternative is operating toward achieving its individual remediation goal. The final stage provides the data to verify that an action has been successful. A detailed description of the monitoring program is presented in Appendix G.

The three RAOs were described in Section 1.3. The first RAO, reducing dabbling duck mortality, is not specific to an area of ERF or to the application of a specific remedial alternative. It must be achieved on the basis of information about ERF as a whole because the ducks have been observed to fly all over the flats, and WP has been detected in many areas. The following monitoring will be performed annually to improve understanding of the baseline condition and to determine progress toward achieving RAO number 1 for Alternatives 2 through 5:

The hot zone RAO is evaluated annually by maintaining an inventory of hot zones that have been identified, treated, and verified for remedial action completion.

- **Telemetry.** As discussed in the RI, birds are captured, small radio transmitters are attached to them, and then they are released in the area in which they were captured. Personnel at two radio receiver stations determine the direction of each bird transmitter on at least a daily basis, and the intersection of these directional lines from the transmitters provides the location of the bird at that particular time. If the bird is not observed to move for a set period of time, it is presumed to have died. Personnel in a ground search may then be able to find the bird and submit it for WP analysis. In this study, approximately 100 to 150 mallards will be tracked for a 2-month period (length of typical fall migration). The mortality rate can then be estimated by dividing the number of birds that die from WP poisoning during the course of the study by the number of birds in the study.
- **Aerial bird population surveys.** Studies to date have shown substantial year-to-year variation in the number, species, location, and timing (arrival on and departure from the flats) of birds that populate ERF. Annual population surveys performed biweekly between April and October will provide knowledge of trends in

the use of ERF, which can help in understanding specific or unusual results from the telemetry studies.

The evaluation for RAO number 2, reduction of hot zones, is performed by updating a yearly inventory of treated hot ponds that have successfully achieved WP treatment verification during implementation of Alternatives 2 through 5. Ponds also may be removed from the inventory of hot ponds if sampling confirms that WP is not significantly present even without treatment. The monitoring program for RAO number 3, WP exposure pathway, is summarized for the three stages for each remedial alternative in Table 9. The types of monitoring activities are described at the bottom of the table. Many of the monitoring activities occur for several of the alternatives. The monitoring methods by which each RAO will be measured are presented in Figure 11.

The monitoring program for WP exposure pathways varies with each remedial alternative, but has the same three stages: pre-treatment, treatment, and post-treatment monitoring.

The elements of the monitoring strategy and program are summarized in Table 10. This table summarizes the program by monitoring type, with its associated objective, geographical area, assessment method, schedule, data to be collected, and the test method. Monitoring activities vary in their geographical and temporal scales. Monitoring for two RAOs, mallard mortality and evaluating hot zones, is performed across ERF in the fall. Monitoring for the WP exposure pathway RAO is focused on the treated ponds, and its timing includes periods before and after the treatment. Although no specific RAO has been established for it, monitoring for negative impacts from habitat changes will also be performed throughout remedy implementations.

These actions are assumed to occur at different time periods during the course of the remediation. Figure 9 in Section 3.3 summarizes the assumed schedule of monitoring activities in this FS for each of the five remedial alternatives. The activities in this schedule serve as one of the key inputs to the remedial alternative cost estimates summarized in Section 6.

TABLE 9
Summary of the Monitoring Program for the Reduction of WP Exposure Pathway

Remedial Alternative	Stage		
	Pre-Treatment	**Treatment**	**Post-Treatment**
1. No action	None	None	None
2. Detailed monitoring	Elevation survey Baseline WP monitoring Pond size	Sublimation/oxidation conditions monitoring Pond size Sedimentation Gully recession	WP verification monitoring Pond size
3. Pump and AquaBlok™	Elevation survey Baseline WP monitoring Pond size	Sublimation/oxidation conditions monitoring Gully recession Pond size	WP verification monitoring AquaBlok™ integrity inspection Habitat changes Pond size
4. Breach, Pump, and AquaBlok™	Elevation survey Baseline WP monitoring Pond size	Sublimation/oxidation conditions monitoring Gully recession Pond size	WP verification monitoring AquaBlok™ integrity inspection Habitat changes Pond size
5. AquaBlok™	Elevation survey Baseline WP monitoring Pond size	Gully recession Pond size	AquaBlok™ integrity inspection Habitat changes Pond size

AquaBlok™ integrity inspection. Inspects the integrity of AquaBlok™ to ensure application effectiveness.
Baseline WP monitoring. Composite sampling sediment for WP at the start of treatment for baseline conditions.
Elevation survey. Detailed survey of the ponds and surroundings for sediment elevations.
Gully recession. Gullies can affect pond draining and AquaBlok™ protection when they breach the pond. Gully locations are monitored with aerial photographs.
Habitat changes. Remedial alternative may affect bird habitat. Monitored vegetation with aerial photographs and ground surveys.
Pond size. Remedial actions may affect the pond size. Monitored with aerial photographs.
Sedimentation. Deposition of clean sediment onto contaminated areas will reduce the ability of waterfowl to reach the WP. Monitored with a field study for net consolidated sedimentation.
Sublimation/oxidation conditions monitoring. Warm, dry conditions promote the loss of WP from the sediments through sublimation/oxidation. Pond water elevation, sediment moisture, and temperature are monitored.
WP verification monitoring. Similar to the baseline WP monitoring but is used to confirm that the remedial alternative goal for WP loss has been achieved. Also includes implanted WP particles and water content monitoring.

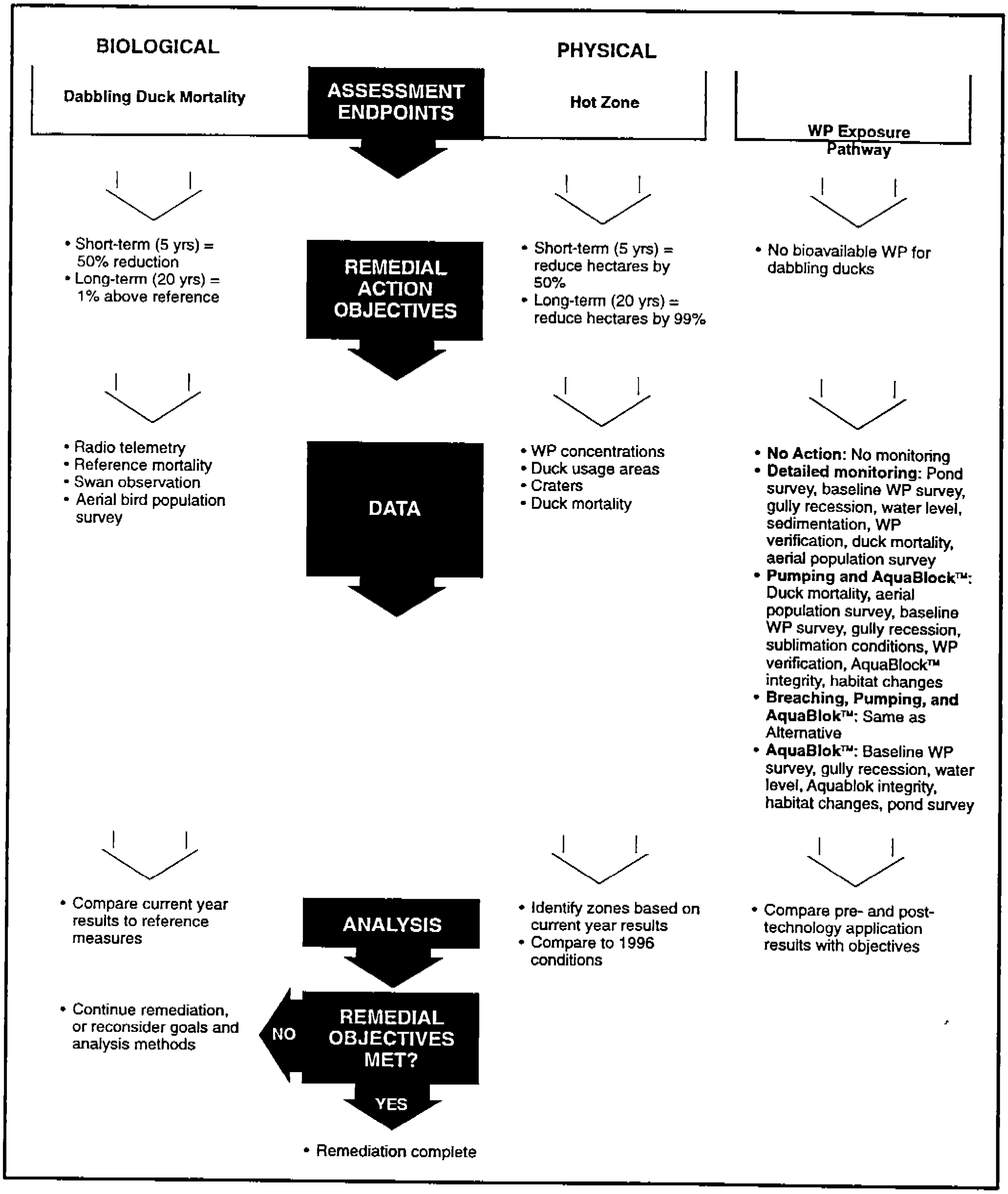


Figure 11
Remedial Action Objectives and Assessment Methods
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TABLE 10
Elements of the Monitoring Strategy

Monitoring Endpoint	Objective	Geographical Area	Assessment Method	Schedule	Data	Test Method
Mallard mortality	50% mortality reduction in 5 years. 1% above reference mortality in 20 years	ERF	Aerial population survey	Fall	Area and pond duck populations	Aerial surveys show duck populations.
			Telemetry		Mortality	Telemetry shows lack of movement and radio collar recovered from a carcass or feather pile.
Hot zones	50% reduction of hot pond area in 5 years and 99% reduction in 20 years	Hot ponds	WP quantity, duck usage	Every fall	WP particles and duck usage	WP sampling Telemetry Aerial bird population surveys
WP exposure pathway	No bioavailable WP for dabbling ducks and swans	Treated area	Sedimentation	Before and after treatment application	Sedimentation rate	Net sedimentation
			Sublimation/ oxidation conditions monitoring	After treatment	Pond water elevation Sediment moisture Temperature	Probes
			Gully recession	After treatment	Gully recession rate	Photointer-pretation
			WP: Verification sampling compares conditions to baseline WP monitoring	After treatment	WP particles	Composite sampling Planted WP particles after treatment
		Areas treated with AquaBlok™	AquaBlok™ integrity		Depth of AquaBlok™. Absence of cracks	Cores Visual inspection
Negative impacts	Habitat changes	Blasted areas Areas treated with AquaBlok™	Observed conditions	Fall	Vegetation changes	Photo interpretation Field surveys

SECTION 6

Detailed Analysis of Alternatives

This section describes the detailed analysis of the alternatives.

The objective of this section is to provide a summary of the effects of the remedial alternatives for each pond group. This section is divided into three main sections: the first section describes the process by which the analysis was developed and the elements of each step of the process; the second section provides a discussion of environmental impacts; the third is a summary of the detailed analysis of the alternatives.

A comprehensive discussion of the detailed analysis of alternatives is presented in Appendix F.

6.1 Process

There are five steps in the process: develop remedial action objectives and evaluation criteria; develop pond groups; develop remedial alternatives; assess criteria for each remedial alternative by pond group; and compare alternatives for each pond group.

There were five steps in the process that was used to prepare the analysis of alternatives:

1. **Develop RAOs and evaluation criteria.** The overall remedial objective is the protection of the environment and human health. The three specific RAOs address dabbling duck mortality, hot zones, and WP exposure pathways. The NCP requires that each remedial alternative be evaluated against nine criteria, seven of which are summarized in Table 11. The other two, state and community acceptance, are addressed later in the Proposed Plan and ROD. The first two criteria, "threshold criteria," must be met for a remedial alternative to be selected. The other five, "balancing criteria," weigh the tradeoffs between alternatives. A low rating on one balancing criterion can be compensated for by a high rating on another criterion. The FS process is shown graphically in Figure 12 where the presence of multiple alternatives is shown narrowing to one with the consideration of these criteria.
2. **Develop pond groups.** The pond group forms the geographical basis for making decisions. Pond groups were formed on the basis that remedial alternatives would perform similarly on all ponds within the group; therefore, a preferred alternative is assumed to be implemented equally on all members of the group. There are five pond groups containing 18 hot ponds:
   - Northern A pond group, a group of 7 ponds in ERF Area A, with a total area of 5.8 ha
   - Pond 290 in the southern portion of ERF Area A, with a surface area of 0.9 ha

TABLE 11
Seven Criteria for Evaluating Remedial Alternatives

Criteria	Analysis Factors	Specific ERF Considerations
1. Overall protection of human health and the environment	Human health protection Environmental protection	Reduce risk to ecological receptors by preventing incidental ingestion of WP particles. Degree of environmental impacts to wetlands.
2. Compliance with ARARs	Chemical-specific Location-specific Action-specific Other criteria and guidance	No chemical-specific ARAR for white phosphorus.
3. Long-term effectiveness and permanence	Magnitude of residual risk Adequacy and reliability of controls	Magnitude of remaining risk from untreated contaminated areas. Long-term care required following treatment.
4. Reduction of toxicity, mobility, or volume through treatment	Treatment process and remedy Amount of hazardous material destroyed or treated Reduction in toxicity, mobility, or volume through treatment Irreversibility of treatment Type and quantity of treatment residual Statutory preference for treatment as principal element	Measured by reduction in contaminated or treated hectares. Pond drying and sublimation/oxidation is treatment that reduces mass. AquaBlok™ application is a containment technology that reduces mobility but does not meet the statutory preference for treatment. Natural processes (e.g., sedimentation) are not considered treatment.
5. Short-term effectiveness	Protection of the community during the remedial action Protection of workers during remedial actions Environmental impacts Time until remedial action objectives are achieved	Blasting (in Alternative 4) is a consideration. Significant concern for UXO exposure to investigators and remedial action workers. Significant pond drying and WP loss may take more than one summer. Potential environmental effects include temporary or permanent loss of habitat.
6. Implementability	Technical feasibility Administrative feasibility Availability of services and materials	Uncertainty in hydraulic connections in ponded areas, and pond topography increases uncertainty in performance estimate. Availability of special vehicles for onsite travel. Availability of laboratory services to measure WP.
7. Cost	Capital Operations and maintenance Present worth	Limited pilot tests of remedial alternatives in wetlands environment. Cost estimates are expected to provide an accuracy of plus 50 percent to minus 30 percent for the defined scope.

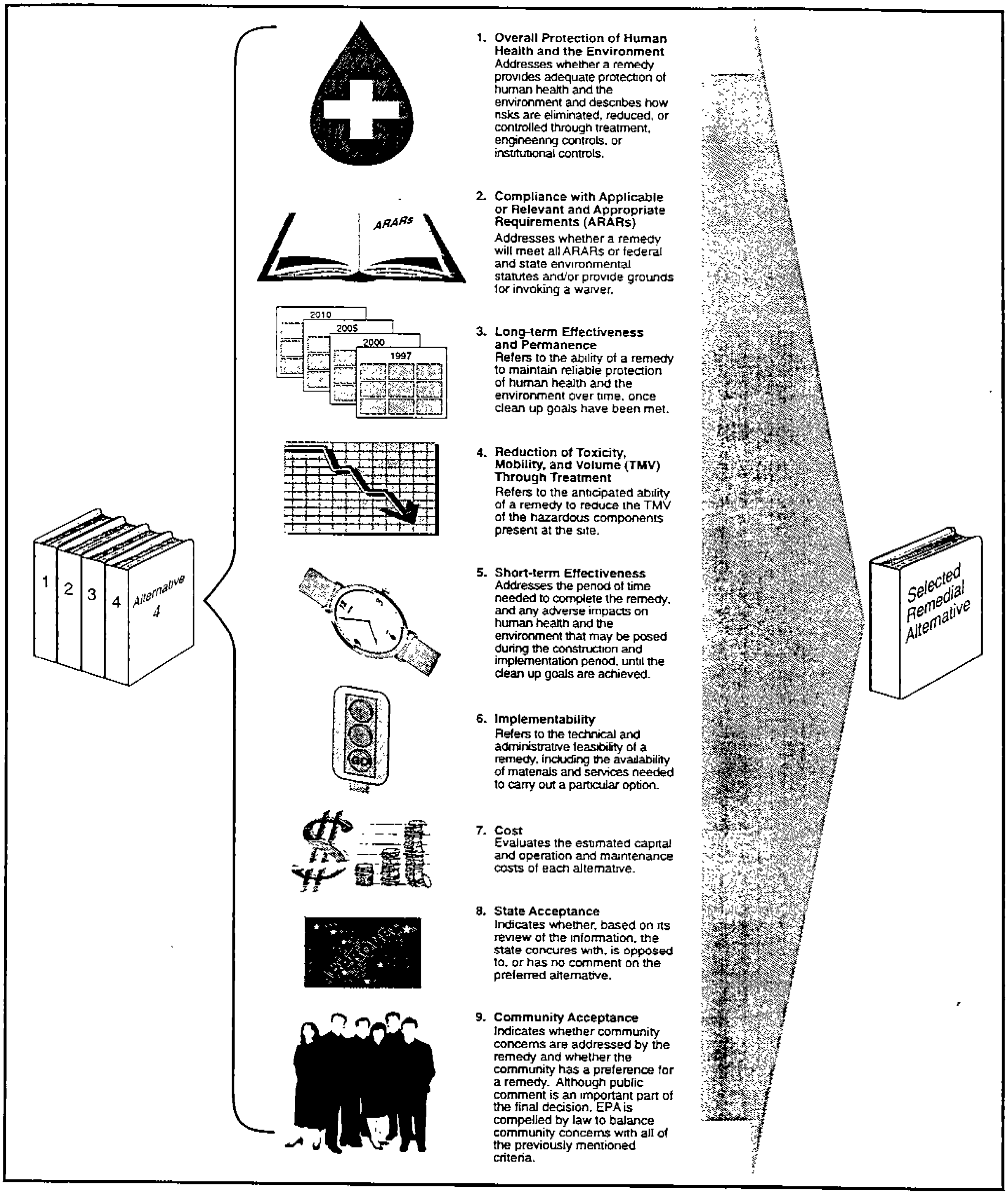

Figure 12

Nine Evaluation Criteria

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NOTE
The nine criteria are from the *Guidance for Conducting Remedial Investigations and Feasibility Studies* (U.S. EPA, 1988) and provide support for the Remedial Alternative.

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- Pond 183 in ERF Area C, with a surface area of 2.9 ha
- Pond 146 in ERF Area C, with a surface area of 5.5 ha
- Northern C and C/D, a group of 8 ponds in ERF Areas C and C/D, with a total area of 3.6 ha.

3. **Develop remedial alternatives.** Five remedial alternatives were developed:

   - **Alternative 1, No Action.** No remedial action or monitoring is performed.
   - **Alternative 2, Detailed Monitoring.** No remedial action is performed, but detailed monitoring is made to observe whether natural processes are remediating ERF.
   - **Alternative 3, Pumping and AquaBlok™.** Pumps are used to drain the pond groups so that the drying sediment can allow the existing WP to sublimate/oxidize and therefore decrease concentrations. After a few years of pond draining, AquaBlok™ is then spread over any remaining contaminated areas.
   - **Alternative 4, Breaching, Pumping, and AquaBlok™.** Ditches are first created to drain the ponds through existing gullies or Eagle River. Pumps are also installed to drain areas of pond groups that do not drain by the man-made ditch. The pond draining allows the sediment to dry so that the existing WP can sublimate/oxidize. After a few years of pond draining, AquaBlok™ is then spread over any remaining contaminated areas.
   - **Alternative 5, AquaBlok™.** AquaBlok™ is applied over the surface area of the pond groups.

   Each alternative also has a monitoring program appropriate for examining the achievement of the RAOs. A different remedial alternative can be chosen for different pond groups.

4. **Assess criteria for each remedial alternative by pond group.** This detailed analysis is described in Appendix F, and forms the basis for the next step. It involves considering each criterion for each pond group.

5. **Compare alternatives for each pond group.** This step involves examining each criterion for each pond group and determining what the key differences are. The details of this comparison are also provided in Appendix F, and are summarized in the next section.

Steps 1 through 3 were described in earlier sections. The summaries on studies of environmental effects of the remedial alternatives are discussed in Section 6.2. The results of Step 4 are discussed in Section 6.3. The comparison of alternatives by pond group (Step 5) is summarized in Section 7.

6.2 Environmental Impacts

This section discusses three environmental issues: impacts to habitat; restoration of breached ponds; and risk and residual risk.

6.2.1 Impacts to Habitat

Alternatives 3 and 4 drain duck habitat. The effect in Alternative 4 is expected to be permanent, whereas that of Alternative 3 is expected to be short term.

ERF supports a diverse community of waterfowl and shorebirds, some of which (dabbling ducks and swans) are primary ecological receptors for WP. The ducks have been observed to prefer specific types of habitat: sedge marsh, permanent ponds, and intermittent ponds. These habitats were ranked based on the proportion of time ducks were observed in each. This preference for habitat type has been considered in this detailed assessment through a consideration of the treated areas, including interconnected waterways, for each remedial alternative for each pond group.

Remedial Alternatives 3 and 4 involve draining the selected pond or pond group, followed by AquaBlok™ treatment of the pond areas that remain contaminated. These treatments are expected to modify ERF habitat to varying degrees. Pond draining by pumping (Alternative 3) is expected to lead to only temporary changes in the habitat. Because the water has been drained, ducks will prefer the habitat less. Following satisfactory treatment, however, the pumping will be stopped, and the ponds are expected to refill as before the treatment was started.

Alternative 5 is expected to lead to change in duck habitat.

Pond draining by breaching (Alternative 4) is expected to result in a more permanent change in habitat. Because the lip of the pond has been breached and the ditch is expected to continue eroding into the pond, it is anticipated that the change in duck habitat will be permanent. The pond will fill and drain with lower high tides than previously because the pond lip has been breached. Plants requiring less saturated conditions could replace the plant species currently at the ponds. Changes in plant species composition will modify the habitat quality for selected bird species, especially those that use certain plants for food or shelter.

Other potential changes in habitat value, such as increased exposure of shorebirds because of pond draining or changes in plant community composition, cannot be accurately predicted. Information on these impacts would be revealed by subsequent monitoring and periodic reporting of changes. However, during the 1997 pond pumping study, no impact to shorebird mortality was observed.

6.2.2 Restoration of Breached Ponds

It is unlikely that breached ponds can be restored.

It is unlikely that breached ponds can be restored. The erosion patterns that would be created over time reduce the feasibility of reversing the process and restoring the ponds (as permanent or intermittent ponds) once remediation of the ponds is completed. It probably is not feasible to redirect the erosion pattern once the pond has been breached, especially if the pond remains breached for 2 or 3 years or more. Water flowing into and out of the pond along the ditch blasted for a drainage is likely to extend the ditch into the pond it drains. Once established, such a drainage system is likely to persist unless a substantial structure is built to redirect the water flow. Construction of that kind of structure is not considered practical on the flats, where there is no solid substrate to which to anchor the structure. Tidal flows onto and off the flats would tend to scour under or around the edges of erosion-control materials that might be used in attempts to restore a pond. In addition, concerns about UXO severely limit construction in the flats.

In addition to the erosion control, restoration of the pond habitat would require replacement of the eroded materials around the pond and revegetation of the habitat. This also would be difficult and perhaps not feasible.

6.2.3 Risk and Residual Risk

Figures 13 through 17 have been developed to qualitatively show the differences between the alternatives in the magnitude and type of risk during the period of implementation. These figures should be considered semi-quantitative, and they represent only an index of risk because the true risk cannot be determined. The following are the key elements contained in these figures:

- **Type of risk.** The environmental risk to dabbling ducks and swans from WP exposure exists only if the WP is bioavailable to these species. If the WP is covered by sufficient clean sediment to prevent exposure, then the exposure pathway is incomplete and there is no risk. On the other hand, physical forces may act to remove the overlying sediment, exposing the waterfowl to WP. Thus, there remains a "potential residual risk," in the sense that it is possible that the existing WP, although covered now, may lead to exposure in the future. The sedimentation may have not filled in the pond completely or physical forces may erode an area to recreate a pond. Thus, covering with clean sediment reduces the risk, but not the potential residual risk. In contrast, WP sublimation/oxidation reduces both the risk and the potential

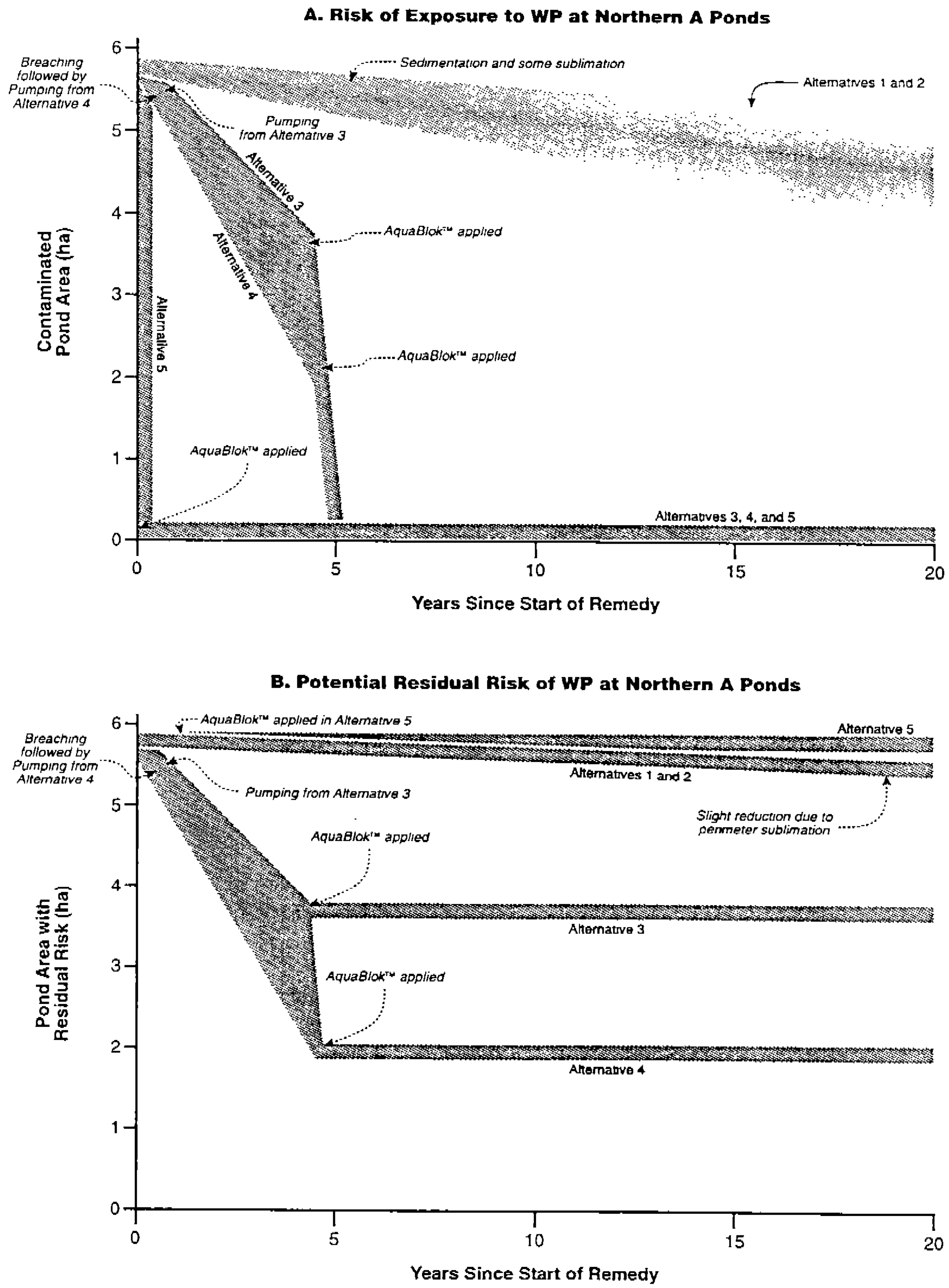

Figure 13
Risk Index of Northern A Ponds
Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Alternative
1. No action
2. Detailed monitoring
3. Pumping and AquaBlok™
4. Breaching, Pumping, and AquaBlok™
5. AquaBlok™

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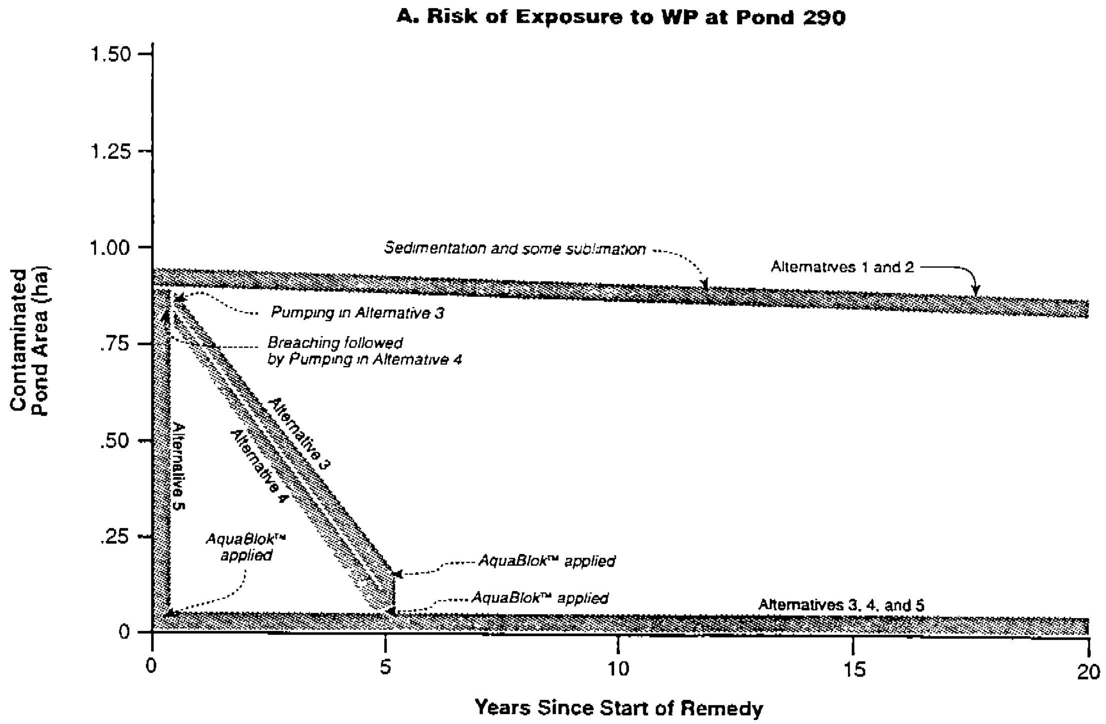

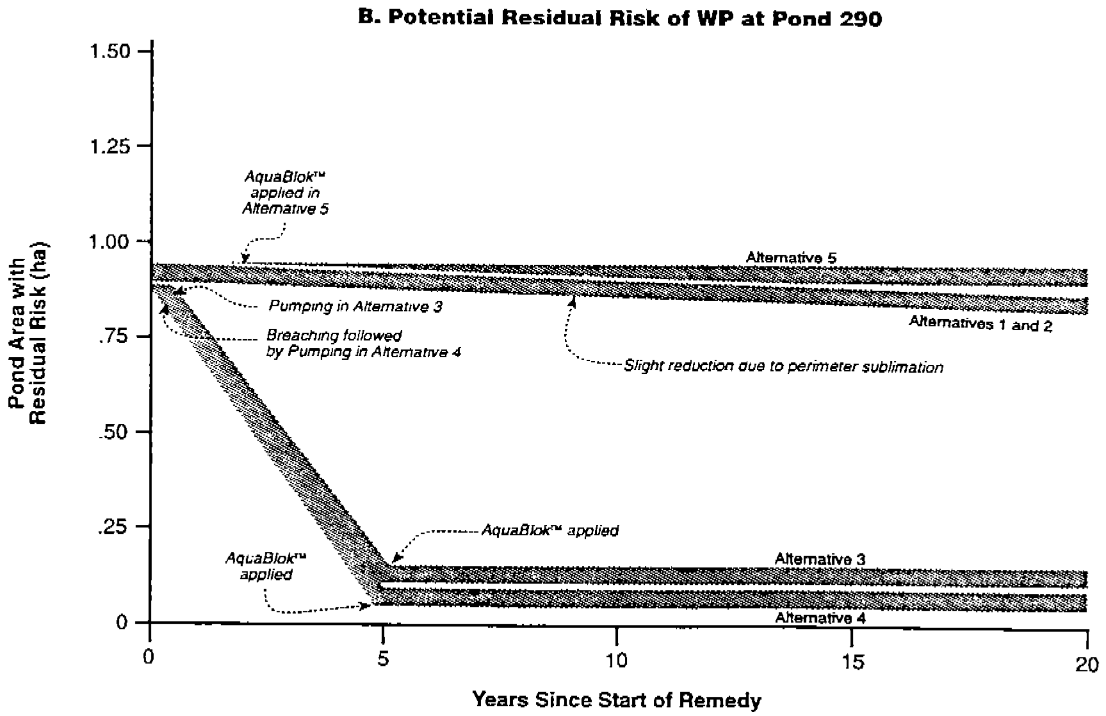

Figure 14

Risk Index of Pond 290

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Alternative
1. No action
2. Detailed monitoring
3. Pumping and AquaBlok™
4. Breaching, Pumping, and AquaBlok™
5. AquaBlok™

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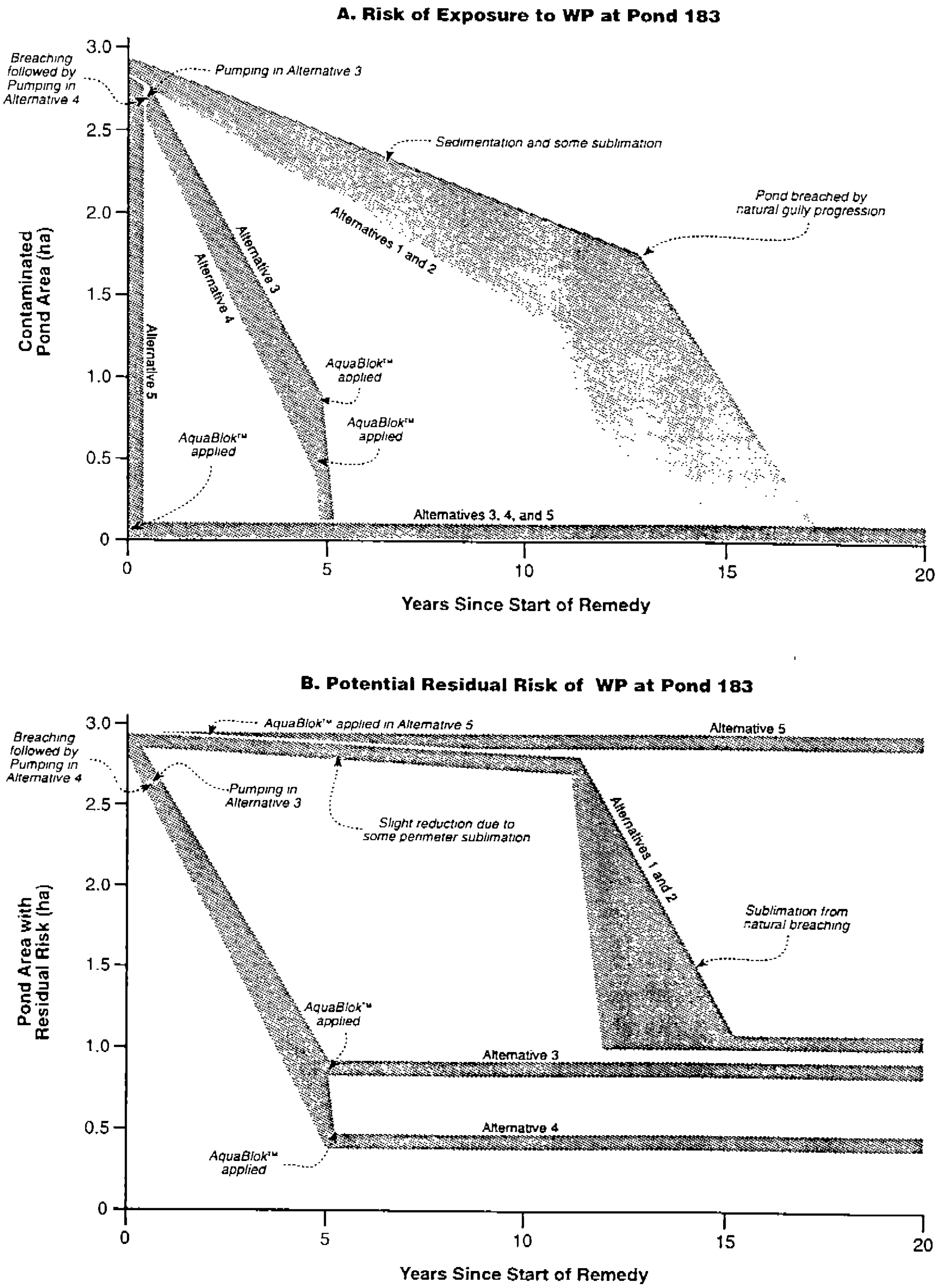

Figure 15

Risk Index of Pond 183

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Alternative
1. No action
2. Detailed monitoring
3. Pumping and AquaBlok™
4. Breaching, Pumping, and AquaBlok™
5. AquaBlok™

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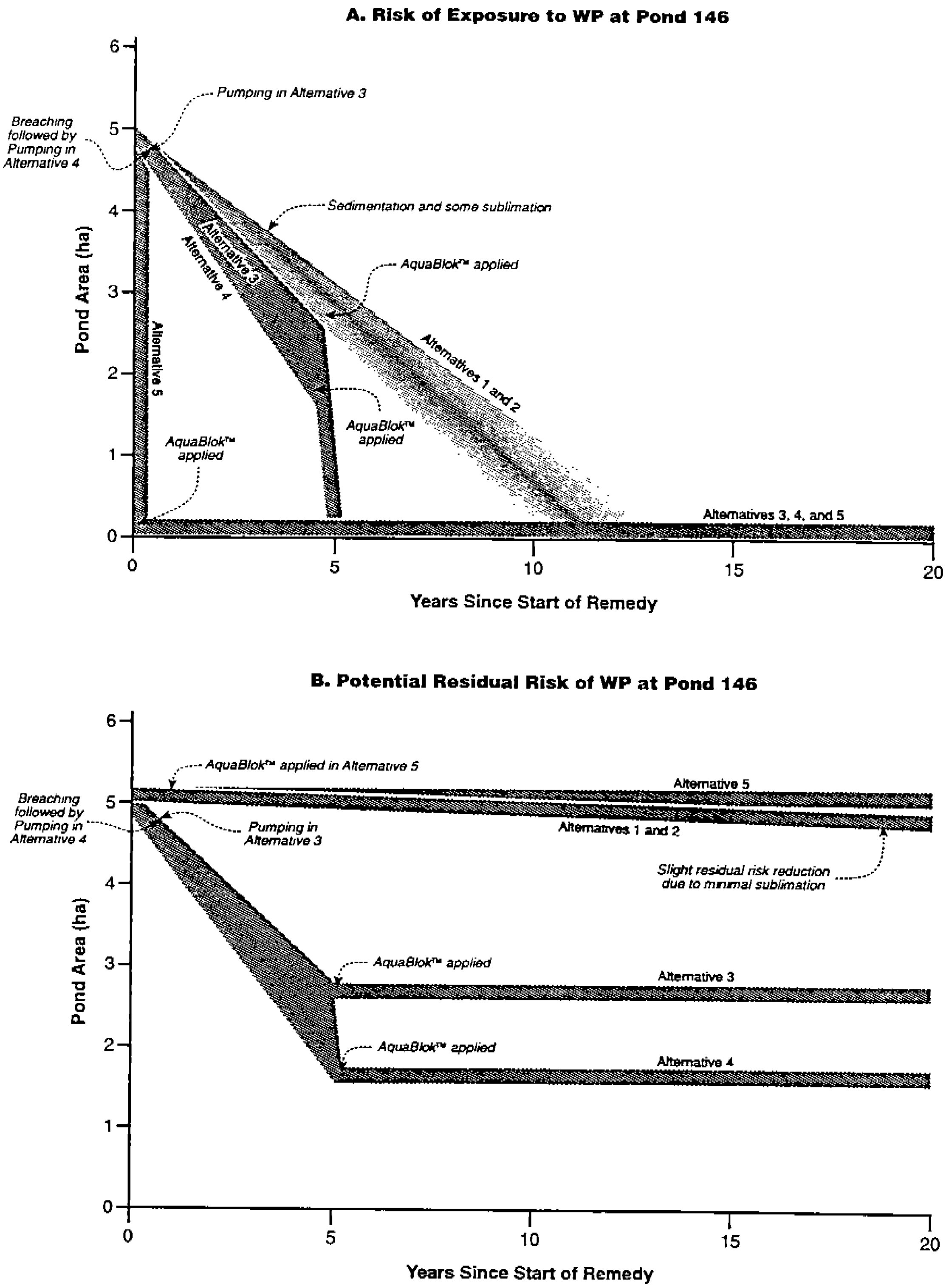

Figure 16

Risk Index of Pond 146

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Alternative
1. No action
2. Detailed monitoring
3. Pumping and AquaBlok™
4. Breaching, Pumping, and AquaBlok™
5. AquaBlok™

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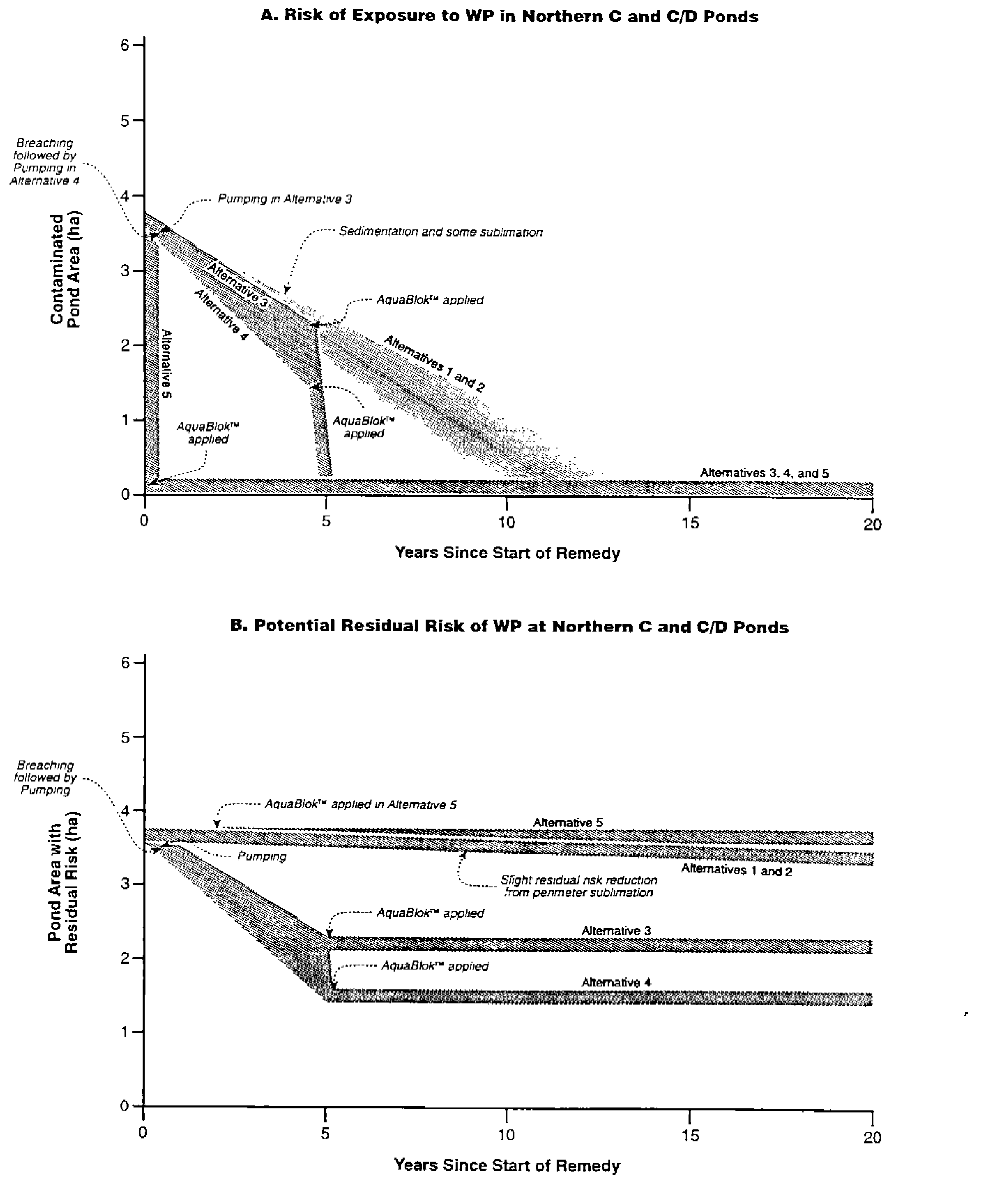

Figure 17

Risk Index of Ponds C and C/D

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Alternative
1. No action
2. Detailed monitoring
3. Pumping and AquaBlok™
4. Breaching, Pumping, and AquaBlok™
5. AquaBlok™

CH2MHILL

residual risk because the lost WP cannot expose waterfowl in the future.

Risk is the effect of current exposure on waterfowl. Contaminated sediment that is covered by clean sediment or AquaBlok™ has low risk. These areas, however, have high residual risk because the contaminated sediment is still present, although covered and not a present risk.

- **Magnitude of risk.** In areas where craters are visible, high crater densities are located in and around the pond groups. WP has been detected in at least one pond of every pond group. Walsh *et al.*, in Collins *et al.*, (1997) have described that any detection of WP is suggestive that larger quantities may be nearby. The characterization of a heterogeneous contaminant such as the particulate WP in ERF is very difficult; therefore, there is uncertainty about the relative risks between pond groups. These figures, however, have assumed that for a single pond, the relative risk is proportional to the area of the pond group that is unprotected from either a covering by sediment or AquaBlok™ or the loss of WP from sublimation/oxidation. Although with increasing uncertainty, these figures also suggest a relative risk between ponds in the comparison of exposed areas.

- **Time frame.** The figures all start with time 0 as the time of a remedial action start. In actuality, different alternatives may be implemented in different years, but these figures have normalized time as years since start of remedy. The maximum time of 20 years was chosen because that is the time frame of the primary RAO (discussed in Appendix G).

- **Changes in risk.** Table A-4 in Appendix A summarizes the potential effects of natural processes on the WP conditions during this time frame. The natural processes of sedimentation and sublimation/oxidation may cause changes in the WP risks to waterfowl over this time. Remedial alternatives also change the magnitude of risk and potential residual risk. Pond draining, because its goal is to reduce the quantity of WP, and the natural process of sublimation/oxidation reduce both the risk and potential residual risk. Sedimentation and the application of AquaBlok™, because they act to reduce WP exposure to dabbling waterfowl by blocking access to the contaminated sediment, reduce risk, but not potential residual risk.

- **Uncertainty.** It is difficult to forecast the effects of natural processes, including the consequences of pond draining. Appendix A summarizes what is known to affect these processes, and there are substantial uncertainties. Judgment has been used in determining the effectiveness of different alternatives on the pond groups in these figures, and this is subject to uncertainty. This is represented in these figures, again semi-quantitatively, by wide lines, indicating that the risk outcome covers a large risk region. On the other hand, the success of the application of AquaBlok™ can be tested fairly quickly, and more AquaBlok™ may be applied in areas where the depth is insufficient for protection. The monitoring program (discussed in Appendix G) describes an annual survey that will be performed to maintain the AquaBlok™ as a highly effective WP exposure block. Therefore, the effects of AquaBlok™ on risk and potential residual risk have been represented by comparatively narrow lines.

Alternatives 1 and 2 may result in lower risks and residual risks if the natural processes reduce the WP sediment concentrations. The risks can be lowered by sedimentation, but this will leave a high residual risk.

With this background, the risk consequences of the remedial alternatives for the individual pond groups can now be examined. Figure 13 shows the case for the Northern A ponds. Table A-4 (Appendix A) describes that sedimentation may cover one of the ponds in the group, Pond 258, sufficiently for natural restoration within 20 years. Thus, Alternatives 1 and 2, which only use natural processes, show a decline in risk. This is shown by a wide line-spread, representing uncertainty, in the risk diagram (Part A). However, the potential residual risk (Part B) shows no decline over this time because the WP has just been covered but is still potentially available depending on the future physical forces. Alternatives 3 and 4 show a more rapid, but still uncertain, decline in the risk (Part A) during pond draining because active measures are being taken to enhance the WP sublimation/oxidation through pumping and the presumed resulting pond drying. It is believed that Alternative 4 will be more effective in drying the ponds compared to Alternative 3; therefore, the risk of this alternative is shown as below that of Alternative 3. The pond risk (Part A) drops abruptly when AquaBlok™ is applied, which is assumed to occur in year 5. The potential residual risk (Part B) does not decline when the AquaBlok™ is applied, because the WP is still present in the environment.

In comparing the alternatives for Northern A ponds, it can be seen that Alternatives 3 and 4 reduce the risk and potential residual risk faster than Alternatives 1 and 2. Alternative 5 can reduce the risk rapidly, but leaves the pond group with a higher potential residual risk than Alternatives 3 and 4. The potential residual risk for Alternatives 1, 2, and 5 are approximately the same because the dominant force reducing the risk in Alternatives 1 and 2 is sedimentation, which does not reduce the potential residual risk.

The technology-oriented alternatives (3 through 5) have the same risk following implementation but different residual risks because of the differing amounts of remaining contaminated sediment.

The pattern of risk is similar in Pond 290 (Figure 14), although it is believed with higher certainty that the pond can be drained and WP losses will be more complete. The potential residual risks of Alternatives 3 and 4 are thus lower compared to Alternatives 1, 2, and 5.

The pattern is somewhat different for Pond 183 (Figure 15). In this case, it is believed there is some chance that the pond may have limited drying on its own, and therefore some WP loss may occur. This is represented by the decline shown for risk and potential residual risk for Alternatives 1 and 2.

The potential for sedimentation appears to be greater for Pond 146 (Figure 16) and the Northern C and C/D pond group (Figure 17) than in the Northern A ponds, so the rate of decline for Alternatives 1 and 2 is faster than shown for those ponds.

6.3 Detailed Analysis

This section summarizes the impacts of the remedial alternatives against seven of the nine NCP criteria. Table 12 presents costs and Tables 13 through 17 present summaries of the impacts of the remedial alternatives against the seven CERCLA evaluation criteria for each of the five pond groups. These summaries were developed from the detailed tables included in Appendix F. The summaries include the most distinguishing results of the detailed analysis of alternatives that were used to compare and rank alternatives.

The comparison and ranking of alternatives is described in Section 7.

The results of the detailed analysis is for those criteria that generally apply to all pond groups:

- **Compliance with ARARs.** There is no chemical-specific ARAR or other criteria for WP. Alternatives 1 and 2 will not meet the location-specific ARAR for the protection of migratory birds and wetlands. Alternatives 3 through 5 are expected to meet the ARARs.

- **Long-term effectiveness.** Generally, residual risk is expected to be lowest under Alternatives 3 and 4 and greatest under Alternatives 1, 2, and 5. The degree of residual risk that would remain under Alternatives 3 and 4 is dependent on the ability of a pond group system to drain and dry before AquaBlok™ application. Alternatives 3 through 5 should produce protective remedies, and they have adequate monitoring programs. The absence of monitoring in Alternative 1 will leave it uncertain as to whether a pond group is remedied. Alternative 2 has adequate monitoring and may produce long-term protection, depending on the success of natural processes at each individual pond group.

- **Reduction of toxicity, mobility, and volume through treatment.** Draining ponds through breaching or pumping are treatment technologies at ERF in Alternatives 3 and 4. Both can lead to pond draining, which can result in the loss of WP. Alternatives 3 and 4 meet statutory preference for treatment for those areas where WP sublimate/oxidizes as a result of treatment. Although Alternative 5 (AquaBlok™)prevents mobility of WP, it does not meet the statutory preference for treatment.

- **Short-term effectiveness.** There are no remedial risks in Alternative 1 because no remediation and no monitoring are performed. Alternatives 2 through 5 require worker exposure to UXO during the installation, maintenance, and removal of monitoring equipment. Alternatives 3 through 5 also result in worker exposure for the installation, monitoring, and removal of remedial action equipment. The workers will be operating under a health and safety plan, which includes inspection for UXO. Impacts to the environment are also considered in the evaluation. Alternative 3 involves temporary draining of habitat, whereas Alternative 4 involves the permanent removal of habitat.

- **Implementability.** No construction is required for Alternative 1. Monitoring activities in Alternative 2 are not expected to lead to problems. No technical difficulties are anticipated for Alternatives 3 through 5. Additional remedial activities may be difficult in areas that have been covered by AquaBlok™. Equipment and the analytical laboratory are not expected to be constraining factors.

- **Cost.** The cost of an alternative encompasses all engineering, construction, and operations and maintenance (O&M) costs incurred over the life of the project. These estimated costs are expected to provide an accuracy of +50 percent to -30 percent for a defined scope of an alternative. The assessment of the NCP criterion on cost is based on the estimated present worth of these costs for each alternative. Present worth is a method for evaluating expenditures such as construction and O&M that occur over different lengths of time. This allows costs for remedial alternatives to be compared by discounting all costs to the year that the alternative is implemented. The present worth of an alternative represents the amount of money which, if invested in the initial year of the remedy and disbursed as needed, would be sufficient to cover all costs associated with that alternative. The discount rate used in the 20-year present worth cost estimate is 5 percent. The details of the cost estimates are described in Appendix F.

Figure 18 shows the budget-level unit cost comparison for each alternative for each pond group. Capital costs and 20-year present worth costs are shown in Table 12 and summarized in Tables 13 through 17.

Note that the cost for ERF-wide activities has not been incorporated into the alternative costs for each alternative at each pond group because the ERF-wide activities are not programmed by pond group. ERF-wide activities will be performed regardless of the selection of Alternatives 2 through 5. The total remedial cost for ERF is thus the sum of ERF-wide activities plus the remedial costs of the pond groups.

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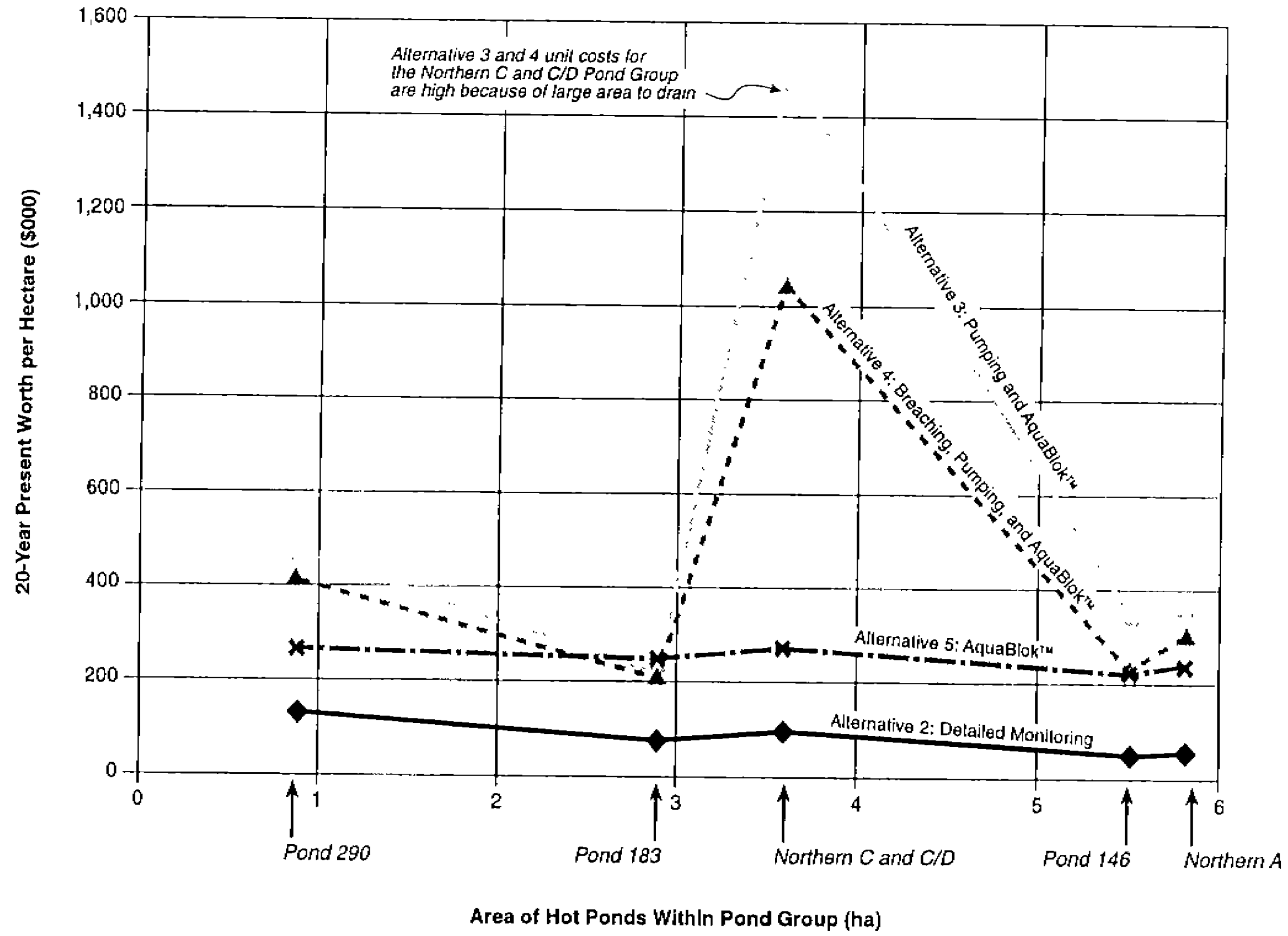

Figure 18

Budget Level Unit Cost Comparison

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

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Table 12 Alternative Costs by Pond Group

Alternative	Location	Capital Cost	10 Year O&M Present Worth	20 Year O&M Present Worth	Total Present Worth Cost (10 Year O&M)	Total Present Worth Cost (20 Year O&M)
ERF-Wide Activities	Throughout ERF	$0	$2,942,912	$4,669,868	$2,942,912	$4,669,868
1-No Action	Throughout ERF	$0	$0	$0	$0	$0
2-Detailed Monitoring	Northern A Ponds	$44,735	$162,813	$225,387	$207,548	$270,123
	Pond 290	$17,118	$73,843	$105,130	$90,961	$122,248
	Pond 183	$21,454	$130,479	$193,053	$151,933	$214,507
	Pond 146	$22,899	$132,370	$194,944	$155,269	$217,843
	Northern C and C/D Ponds	$52,234	$215,667	$309,529	$267,902	$361,763
3-Pumping and AquaBlok	Northern A Ponds	$1,468,711	$673,231	$678,085	$2,141,942	$2,146,796
	Pond 290	$199,208	$198,112	$200,845	$397,320	$400,053
	Pond 183	$396,648	$238,565	$241,298	$635,213	$637,946
	Pond 146	$1,421,652	$504,580	$507,313	$1,926,231	$1,928,965
	Northern C and C/D Ponds	$3,618,421	$1,719,525	$1,727,585	$5,337,946	$5,346,006
4-Pumping, Breaching, an	Northern A Ponds	$1,174,636	$617,625	$623,092	$1,792,261	$1,797,728
	Pond 290	$180,427	$189,154	$191,887	$369,581	$372,314
	Pond 183	$332,393	$247,313	$250,047	$579,707	$582,440
	Pond 146	$878,766	$396,599	$399,333	$1,275,365	$1,278,099
	Northern C and C/D Ponds	$2,431,760	$1,329,695	$1,333,217	$3,761,454	$3,764,977
5-AquaBlok	Northern A Ponds	$1,367,510	$45,487	$56,421	$1,412,997	$1,423,931
	Pond 290	$220,008	$12,865	$15,599	$232,873	$235,607
	Pond 183	$682,683	$12,865	$15,599	$695,549	$698,282
	Pond 146	$1,218,095	$12,865	$15,599	$1,230,960	$1,233,693
	Northern C and C/D Ponds	$895,446	$45,487	$56,421	$940,932	$951,866

Note: ERF-wide Activity Costs are not included in the pond group specific costs because they are programmed and implemented on a flats-wide basis.

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
Overall Protection of Human Health and the Environment				
Ecological risk reduction by natural processes resulting in loss (sublimation/oxidation) or covering (sedimentation) of WP may take from 10 to more than 20 years. No verification monitoring conducted. Human health risk posed by potential exposure to UXO would not be reduced.	Ecological risk reduction by natural processes resulting in loss (sublimation/oxidation) or covering (sedimentation) of WP may take from 10 to more than 20 years. Verification monitoring conducted. Human health risk posed by potential exposure to UXO would not be reduced.	Pumping of the Northern A Ponds would provide adequate protection of the environment by promoting WP sublimation/oxidation. AquaBlok™ application in areas that cannot be drained would also reduce WP exposure via ingestion by placing a barrier between WP particles and waterfowl. Human health risk posed by potential exposure to UXO would not be reduced.	Breaching and pumping would provide adequate protection of the environment by promoting WP sublimation/oxidation. AquaBlok™ application in areas that do not drain and dry sediments would also reduce WP exposure via ingestion by placing a barrier between WP particles and waterfowl. Human health risk posed by potential exposure to UXO would not be reduced.	Application of AquaBlok™ would be protective of the environment because the exposure pathway to WP particles in the sediment would be eliminated. Human health risk posed by potential exposure to UXO would not be reduced.
Compliance with ARARs				
No chemical- or action-specific ARARs apply. Does not meet location-specific ARARs specific to protection of migratory birds and wetlands.	No chemical-specific ARARs apply. Does not meet location-specific ARARs specific to protection of migratory birds and wetlands. Can meet action-specific ARARs if appropriate protective measures are taken.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.
Long-Term Effectiveness and Permanence				
Residual WP risk is estimated to remain in approximately 5.75 hectares (ha) of the total 5.8-ha hot pond area after approximately 20 years, and gradually decrease thereafter. No monitoring conducted.	Residual WP risk is estimated to remain in approximately 5.75 hectares (ha) of the total 5.8-ha hot pond area after approximately 20 years, and gradually decrease thereafter. Detailed monitoring program conducted.	No residual risk will remain in the areas where pumping is effective and WP sublimates/oxidizes. Residual risk is expected to remain in approximately 3.5 ha (60%) of the total 5.8-ha pond area where AquaBlok™ is applied because the WP is covered rather than treated. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.	No residual risk will remain in areas that are successfully dried from breaching and pumping and WP sublimates/oxidizes. Residual risk is expected to remain in approximately 2.3 ha (40%) of total 5.8-ha pond area where AquaBlok™ is applied because the WP is covered rather than treated. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.	Potential residual risk will remain in 5.8 ha, or 100% of the hot pond area, after AquaBlok™ application. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.
Reduction of Toxicity, Mobility, and Volume (TMV) Through Treatment				
It is estimated that the TMV of WP will be reduced through natural processes in 5 ha of the total 5.8-ha hot pond area in the long term (>20 years). No verification monitoring. Does not meet the statutory preference for treatment as a principal element.	It is estimated that the TMV of WP will be reduced through natural processes in 5 ha of the total 5.8-ha hot pond area in the long term (>20 years). Detailed monitoring program conducted. Does not meet the statutory preference for treatment as a principal element.	TMV reduction resulting from WP sublimation/oxidation is estimated to occur in 2.3 ha (40%) of the total 5.8-ha hot pond area. Reduction of WP mobility from AquaBlok™ will occur in the remaining 3.5 ha (60%). Meets the statutory preference for treatment where WP sublimates/oxidizes as a result of pumping.	TMV reduction resulting from WP sublimation/oxidation is estimated to occur in 3.5 ha (60%) of the total 5.8-ha hot pond area. Reduction of WP mobility from AquaBlok™ will occur in the remaining 2.3 ha (40%). Meets the statutory preference for treatment where WP sublimates/oxidizes as a result of breaching and pumping.	Reduction of WP mobility only from AquaBlok™ will occur over the total hot pond area, or 5.8 ha. Does not meet the statutory preference for treatment.
Short-Term Effectiveness				
The time until remedial action objectives are met from natural processes is estimated to be >20 years. No verification monitoring conducted.	The time until remedial action objectives are met from natural processes is estimated to be >20 years. Detailed monitoring program conducted. Construction activities limited to installation,	It is estimated that the RAO of 50% reduction in hot zones can be achieved in 5 years and 99% reduction can be achieved in 20 years. There is uncertainty with regard to whether the long- and short-term mortality	It is estimated that the RAO of 50% reduction in hot zones can be achieved in 5 years and 99% reduction can be achieved in 20 years. There is uncertainty with regard to whether the long- and short-term mortality	The time until hot zone and treatment verification RAOs are met is estimated to be less than 5 years, depending on when the AquaBlok™ is applied. These RAOs are essentially met once the application of AquaBlok™ is complete and adequate

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
	maintenance, and removal of monitoring equipment. Primary risk to workers is posed by potential explosion of unexploded ordnance (UXO). UXO clearance and adherence to health and safety plans would be conducted.	RAOs will be met. Because of the interconnections in the area, pumping would drain approximately 36 ha in addition to the 5.8-ha hot pond area, which would temporarily reduce open-water and sedge marsh feeding habitat. Application of AquaBlok™ in 3.5 ha would cause permanent changes in bottom elevations that would affect 1.7% of ERF open-water and sedge marsh habitat. Environmental impacts could also include fuel spills that may occur during refueling of the pump generators. Impacts to the environment would be minimized by the use of helicopters to bring in floating pumps and lines. Risk to workers is posed by potential explosion of UXO during installation, maintenance, and removal of pumping systems and monitoring equipment. UXO clearance and adherence to health and safety plans would be conducted.	RAOs will be met. Because of the hydraulic interconnections in the area, breaching and pumping could result in draining approximately 36 ha in addition to the 5.8-ha hot pond area. Draining of these areas would represent a permanent 20.6% reduction in open-water and sedge marsh habitat at ERF. Engineering controls would be implemented to minimize effects on existing habitat. Application of AquaBlok™ in 2.3 ha would cause permanent changes in bottom elevations that would affect 1.1% of ERF open-water and sedge marsh habitat. Environmental impacts could also include fuel spills that may occur during refueling of the pump generators. Impacts to the environment would be minimized by the use of helicopters to bring in floating pumps and lines. Primary risk to workers is posed by potential explosion of UXO and/or detonation supplies during placement of detonation charges and installation, maintenance and removal of pumping systems and monitoring equipment. UXO clearance and adherence to health and safety plans would be conducted. Pond breaching activities may also affect the community of Eagle River. The blasts are loud and may be seen and felt. The blasting will be conducted on clear days if possible to reduce the sound and pressure of the blast.	coverage is verified. There is uncertainty with regard to whether the long- and short-term mortality RAOs will be met. If the total area of the Northern A hot ponds (5.8 ha) is covered with AquaBlok™, this would represent a 2.8% reduction in open-water and sedge marsh habitat at ERF. Because of the shallow depths of the Northern A ponds, modifications of the water depth could significantly alter feeding suitability for waterfowl. Sampling will be conducted before application of AquaBlok™ to more clearly define the hot pond areas and minimize the area that will be covered with AquaBlok™.
Implementability				
No treatment technologies implemented	Implementation activities are limited to installation and maintenance of monitoring equipment. The changes in WP particle concentrations, sedimentation, and sediment moisture and temperature will be monitored in order to evaluate the effectiveness of natural processes in drying the sediment, thus fostering WP sublimation/oxidation. RPM and Biological Technical Assistance Group (BTAG) coordination is conducted as	The Northern A hydraulic system and the varying pond bottom elevations of the interconnected ponds are not well understood; however, summer 1997 aerial and land survey determined that it is likely that the Northern A pond group can be drained and dried with two or three pumps. Ponds may need to be rearranged once the deepest portions of the pond system are exposed, and they will have to be pumped at the high tides because they will drain	The Northern A hydraulic system is not well understood; however, summer 1997 aerial and land survey determined that it is likely that the Northern A pond group can be drained and dried with two or three pumps. Breaching would lower threshold elevations, resulting in more frequent flooding and draining (i.e., the pond system will be more susceptible to re-wetting, but will drain faster). Sediment drying may be impaired during years with higher tides because of	Minor technical difficulties are anticipated with application of AquaBlok™ by truck or by air. Reapplication may be necessary in areas where craters are present. Visual inspection and sampling for integrity of the AquaBlok™ cover will be conducted. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation.

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
	part of monitoring program. Access to OUC is coordinated with U.S. Army at Fort Richardson. Equipment and personnel to conduct monitoring are available. Availability of laboratories that can perform WP baseline and verification sampling is very limited.	slowly. High tides and slow drainage may impair sediment drying. Changes in WP particle concentrations, and sediment moisture and temperature, as a result of pumping will be monitored to evaluate the effectiveness of pumping in promoting WP sublimation/oxidation. Visual inspection and sampling for integrity of the AquaBlok™ cover will be conducted. No difficulties associated with construction and operation of pumping systems are anticipated. Minor difficulties may be experienced during application of AquaBlok™ if the product is not laid evenly and reapplication by truck or air is required. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation. Military helicopters and flight personnel required to access OUC for equipment transport and AquaBlok™ application are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct pumping and AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively in the areas where AquaBlok™ has been applied.	more frequent flooding. Changes in WP particle concentrations, and sediment moisture and temperature, as a result of breaching and pumping will be monitored to evaluate the effectiveness of breaching and pumping in promoting WP sublimation/oxidation. Visual inspection and sampling for integrity of the AquaBlok™ cover will be conducted. No technical difficulties that would hinder implementation of breaching activities are expected. No technical difficulties associated with construction and operation of the pumping systems are anticipated. Minor difficulties may be experienced during application of AquaBlok™ if the product is not laid evenly and reapplication by truck or air is required. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation. Military helicopters and flight personnel required to access OUC for equipment transport and AquaBlok™ application and to conduct breaching (detonation) are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct pumping and AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively in the areas where AquaBlok™ has been applied.	Military helicopters and flight personnel required to access OUC for AquaBlok™ application are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively after AquaBlok™ has been applied.
Capital Cost				
$0	$45,000	$1,469,000	$1,175,000	$1,368,000
20-Year Present Worth Based on 5% Discount Rate				
$0	$270,000	$2,147,000	$1,798,000	$1,424,000

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Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
Overall Protection of Human Health and the Environment				
Ecological risk reduction by natural processes resulting in loss (sublimation/oxidation) or covering (sedimentation) of WP may take >20 years. No verification monitoring conducted. Human health risk posed by potential exposure to UXO would not be reduced.	Ecological risk reduction by natural processes resulting in loss (sublimation/oxidation) or covering (sedimentation) of WP may take more than 20 years. Verification monitoring conducted. Human health risk posed by potential exposure to UXO would not be reduced.	Pumping would provide adequate protection of the environment by promoting WP sublimation/oxidation. AquaBlok™ application in areas that cannot be drained would also reduce WP exposure via ingestion by placing a barrier between WP particles and waterfowl. Human health risk posed by potential exposure to UXO would not be reduced.	Breaching and pumping would provide adequate protection of the environment by promoting WP sublimation/oxidation. AquaBlok™ application in areas that do not drain and dry sediments would also reduce WP exposure via ingestion by placing a barrier between WP particles and waterfowl. Human health risk posed by potential exposure to UXO would not be reduced.	Application of AquaBlok™ would be protective of the environment because the exposure pathway to WP particles in the sediment would be eliminated. Human health risk posed by potential exposure to UXO would not be reduced.
Compliance with ARARs				
No chemical- or action-specific ARARs apply. Does not meet location-specific ARARs specific to protection of migratory birds and wetlands.	No chemical-specific ARARs apply. Does not meet location-specific ARARs specific to protection of migratory birds and wetlands. Can meet action-specific ARARs if appropriate protective measures are taken.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.
Long-Term Effectiveness and Permanence				
Residual WP risk is estimated to remain in approximately 0.85 hectares (ha) of the total 0.9-ha hot pond area after approximately 20 years, and gradually decrease thereafter. No verification monitoring conducted.	Residual WP risk is estimated to remain in approximately 0.85 hectares (ha) of the total 0.9-ha hot pond area after approximately 20 years, and gradually decrease thereafter. Actual risk reduction would be evaluated through detailed monitoring.	No residual risk will remain in the areas where pumping is effective and WP sublimates/oxidizes. Residual risk is expected to remain in approximately 0.14 ha (15%) where AquaBlok™ is applied because the WP is covered rather than treated. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.	No residual risk will remain in areas that are successfully dried from breaching and pumping and WP sublimates/oxidizes. Residual risk is expected to remain in approximately 0.9 ha (10%) area where AquaBlok™ is applied because the WP is covered rather than treated. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.	Potential residual risk will remain in 0.9 ha, or 100% of the hot pond area, after AquaBlok™ application. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.
Reduction of Toxicity, Mobility, and Volume (TMV) Through Treatment				
It is estimated that the TMV of WP will be gradually reduced in 0.85 of total 0.9 ha through natural processes, primarily sedimentation, in the long term (>20). No verification monitoring conducted. Does not meet the statutory preference for treatment as a principal element.	It is estimated that the TMV of WP will be gradually reduced in 0.85 of total 0.9 ha through natural processes, primarily sedimentation, in the long term (>20 years). Detailed monitoring program conducted. Does not meet the statutory preference for treatment.	TMV reduction resulting from WP sublimation/oxidation is estimated to occur in 0.765 ha (85%) of the total 0.9-ha hot pond area. Reduction of WP mobility from AquaBlok™ will occur in the remaining 0.14 ha (15%). Meets the statutory preference for treatment for those areas where WP sublimates/oxidizes as a result of pumping.	TMV reduction resulting from WP sublimation/oxidation is estimated to occur in 0.81 ha (90%) of the total 0.9-ha hot pond area. Reduction of WP mobility from AquaBlok™ will occur in the remaining 0.09 ha (10%). Meets the statutory preference for treatment for those areas where WP sublimates/oxidizes as a result of breaching and pumping.	Reduction of WP mobility only from AquaBlok™ will occur over the total 0.9-ha hot pond area. Does not meet the statutory preference for treatment as a principal element.
Short-Term Effectiveness				
Long-term remedial action objectives may be met from natural processes in >20 years. No verification monitoring conducted.	Long-term remedial action objectives may be met from natural processes in >20. Verification monitoring conducted. Construction activities limited to installation, maintenance, and removal of monitoring	It is estimated that the RAO of 50% reduction in hot zones can be achieved in 5 years and 99% reduction can be achieved in 20 years. There is uncertainty with regard to whether the long- and short-term mortality	It is estimated that the RAO of 50% reduction in hot zones can be achieved in 5 years and 99% reduction can be achieved in 20 years. There is uncertainty with regard to whether the long- and short-term mortality	The time until hot zone and treatment verification RAOs are met is estimated to be less than 5 years, depending on when the AquaBlok™ is applied. These RAOs are essentially met once the application of AquaBlok™ is complete and adequate

TABLE 14
Summary of Detailed Evaluation of Alternatives for Pond 290

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
	equipment. Primary risk to workers is posed by potential explosion of unexploded ordnance (UXO). UXO clearance and adherence to health and safety plans would be conducted.	RAOs will be met. Pumping would drain approximately 6.9 ha, which would temporarily reduce open-water and sedge marsh feeding habitat. Application of AquaBlok™ in 0.14 ha may cause permanent changes in bottom elevations that would affect 0.7% of ERF open-water and sedge marsh habitat. Environmental impacts could also include fuel spills that may occur during refueling of the pump generators. Impacts to the environment would be minimized by the use of helicopters to bring in floating pumps and lines. Risk to workers is posed by potential explosion of UXO during installation, maintenance, and removal of pumping systems and monitoring equipment. UXO clearance and adherence to health and safety plans would be conducted.	RAOs will be met. Breaching would result in permanent effects on Pond 290 and surrounding wetland hydrology because the pond would no longer retain water after tidal flooding. It would not be feasible to restore hydrologic conditions after breaching. Breaching and pumping would drain approximately 7 ha, which would permanently reduce open-water and sedge marsh habitats in ERF by 3.4%. Application of AquaBlok™ in 0.09 ha of Pond 290 would cause permanent changes in pond bottom elevations but would affect only 0.04% of ERF open-water and sedge marsh habitat. Environmental impacts could also include fuel spills that may occur during refueling of the pump generators. Impacts to the environment would be minimized by the use of helicopters to bring in floating pumps and lines. Primary risk to workers is posed by potential explosion of UXO and/or detonation supplies during placement of detonation charges and installation, maintenance and removal of pumping systems and monitoring equipment. UXO clearance and adherence to health and safety plans would be conducted. Pond breaching activities may also affect the community of Eagle River. The blasts are loud and may be seen and felt. The blasting will be conducted on clear days if possible to reduce the sound and pressure of the blast.	coverage is verified. There is uncertainty with regard to whether the long- and short-term mortality RAOs will be met Sampling will be conducted before application of AquaBlok™ to more clearly define the hot pond areas and minimize the area that will be covered with AquaBlok™.
Implementability				
No treatment technologies implemented	Implementation activities are limited to installation and maintenance of monitoring equipment. The changes in WP particle concentrations, sedimentation, and sediment moisture and temperature will be monitored. RPM and BTAG coordination is conducted as part of monitoring program. Equipment and personnel to conduct	Pond 290 is relatively isolated and drainage by pumping is expected to be successful. Changes in WP particle concentrations, and sediment moisture and temperature, as a result of pumping will be monitored to evaluate the effectiveness of pumping in promoting WP sublimation/oxidation. Visual inspection and sampling for integrity of the AquaBlok™ cover will be conducted.	Pond 290 is relatively isolated and drainage by pumping is expected to be successful. Changes in WP particle concentrations, and sediment moisture and temperature, as a result of breaching and pumping will be monitored to evaluate the effectiveness of breaching and pumping in promoting WP sublimation/oxidation. Visual inspection and sampling for integrity of the AquaBlok™	Minor technical difficulties are anticipated with application of AquaBlok™ by truck or by air. Reapplication may be necessary in areas where craters are present. Visual inspection and sampling for integrity of the AquaBlok™ cover will be conducted. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation.

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
	monitoring are available. Availability of laboratories that can perform WP baseline and verification sampling is very limited.	No difficulties associated with construction and operation of pumping systems are anticipated. Minor difficulties may be experienced during application of AquaBlok™ if the product is not laid evenly and reapplication by truck or air is required. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation. Military helicopters and flight personnel required to access OUC for equipment transport and AquaBlok™ application are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct pumping and AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively in the areas where AquaBlok™ has been applied.	cover will be conducted. No technical difficulties that would hinder implementation of breaching activities are expected. No technical difficulties associated with construction and operation of the pumping systems are anticipated. Minor difficulties may be experienced during application of AquaBlok™ if the product is not laid evenly and reapplication by truck or air is required. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation. Military helicopters and flight personnel required to access OUC for equipment transport and AquaBlok™ application and to conduct breaching (detonation) are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct pumping and AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively in the areas where AquaBlok™ has been applied.	Military helicopters and flight personnel required to access OUC for AquaBlok™ application are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively after AquaBlok™ has been applied.
Capital Cost				
$0	$17,000	$199,000	$180,000	$220,000
20-Year Present Worth Based on 5% Discount Rate				
$0	$122,000	$400,000	$372,000	$236,000

TABLE 15
Summary of Detailed Evaluation of Alternatives for Pond 183

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
Overall Protection of Human Health and the Environment				
Ecological risk reduction by natural processes resulting in loss (sublimation/oxidation) or covering (sedimentation) of WP may take 10-15 years. No verification monitoring conducted. Human health risk posed by potential exposure to UXO would not be reduced.	Ecological risk reduction by natural processes resulting in loss (sublimation/oxidation) or covering (sedimentation) of WP may take from 10-15 years. Verification monitoring would be conducted. Human health risk posed by potential exposure to UXO would not be reduced.	Pumping would provide adequate protection of the environment by promoting WP sublimation/oxidation. AquaBlok™ application in areas that cannot be drained would also reduce WP exposure via ingestion by placing a barrier between WP particles and waterfowl. Human health risk posed by potential exposure to UXO would not be reduced.	Breaching and pumping would provide adequate protection of the environment by promoting WP sublimation/oxidation. AquaBlok™ application in areas that do not drain and dry sediments would also reduce WP exposure via ingestion by placing a barrier between WP particles and waterfowl. Human health risk posed by potential exposure to UXO would not be reduced.	Application of AquaBlok™ would be protective of the environment because the exposure pathway to WP particles in the sediment would be eliminated. Human health risk posed by potential exposure to UXO would not be reduced.
Compliance with ARARs				
No chemical- or action-specific ARARs apply. Does not meet location-specific ARARs specific to protection of migratory birds and wetlands.	No chemical-specific ARARs apply. Does not meet location-specific ARARs specific to protection of migratory birds and wetlands. Can meet action-specific ARARs if appropriate protective measures are taken.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.
Long-Term Effectiveness and Permanence				
Most residual WP risk is estimated to be removed after approximately 10-15 years. No verification monitoring conducted.	Most residual WP risk is estimated to be removed after approximately 10-15 years. Detailed monitoring program conducted.	No residual risk will remain in the areas where pumping is effective and WP sublimates/oxidizes. Residual risk is expected to remain in approximately 0.87 ha (30%) of total 2.9 ha where AquaBlok™ is applied because the WP is covered rather than treated. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.	No residual risk will remain in areas that are successfully dried from breaching and pumping and WP sublimates/oxidizes. Residual risk is expected to remain in approximately 0.44 ha (15%) area where AquaBlok™ is applied because the WP is covered rather than treated. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.	Potential residual risk will remain in 2.9 ha, or 100% of the hot pond area, after AquaBlok™ application. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.
Reduction of Toxicity, Mobility, and Volume (TMV) Through Treatment				
It is estimated that most TMV of WP will be gradually reduced through natural processes, primarily gully progression, in the long term (10-15 years). No verification monitoring conducted. Does not meet the statutory preference for treatment as a principal element.	It is estimated that most TMV of WP will be gradually reduced through natural processes, primarily gully progression, in the long term (10-15 years). Detailed monitoring program conducted. Does not meet the statutory preference for treatment.	TMV reduction resulting from WP sublimation/oxidation is estimated to occur in 2.0 ha (70%) of the total 2.9-ha hot pond area. Reduction of WP mobility from AquaBlok™ will occur in the remaining 0.87 ha (30%). Meets the statutory preference for treatment for those areas where WP sublimates/oxidizes as a result of pumping.	TMV reduction resulting from WP sublimation/oxidation is estimated to occur in 2.5 ha (85%) of the total 2.9-ha hot pond area. Reduction of WP mobility from AquaBlok™ will occur in the remaining 0.44 ha (15%). Meets the statutory preference for treatment for those areas where WP sublimates/oxidizes as a result of breaching and pumping.	Reduction of WP mobility only from AquaBlok™ will occur over the total 2.9-ha (100%) of hot pond area. Does not meet the statutory preference for treatment as a principal element.
Short-Term Effectiveness				
Long-term remedial action objectives may be met from natural processes in 10-15 years. No verification monitoring conducted.	Long-term remedial action objectives may be met from natural processes in 10-15 years. Verification monitoring conducted. Construction activities limited to installation,	It is estimated that the RAO of 50% reduction in hot zones can be achieved in 5 years and 99% reduction can be achieved in 20 years. There is uncertainty with regard to whether the long- and short-term mortality	It is estimated that the RAO of 50% reduction in hot zones can be achieved in 5 years and 99% reduction can be achieved in 20 years. There is uncertainty with regard to whether the long- and short-term mortality	The time until hot zone and treatment verification RAOs are met is estimated to be less than 5 years, depending on when the AquaBlok™ is applied. These RAOs are essentially met once the application of

TABLE 15
Summary of Detailed Evaluation of Alternatives for Pond 183

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
	maintenance, and removal of monitoring equipment. Primary risk to workers is posed by potential explosion of unexploded ordnance (UXO). UXO clearance and adherence to health and safety plans would be conducted.	RAOs will be met. Pumping would drain approximately 12 ha, which would temporarily reduce open-water and sedge marsh feeding habitat. Application of AquaBlok™ in 0.87 ha may permanently reduce open-water and sedge marsh habitat in ERF by 0.4%. Environmental impacts could also include fuel spills that may occur during refueling of the pump generators. Impacts to the environment would be minimized by the use of helicopters to bring in floating pumps and lines. Risk to workers is posed by potential explosion of UXO during installation, maintenance, and removal of pumping systems and monitoring equipment. UXO clearance and adherence to health and safety plans would be conducted.	RAOs will be met. Breaching and pumping would drain approximately 12 ha, which would permanently reduce open-water and sedge marsh habitats in ERF by 5.9%. Engineering controls, such as breaching a gully that is already naturally progressing toward the pond system, would be implemented to minimize effects on existing habitat. Application of AquaBlok™ in 0 44 would cause permanent changes in bottom elevations that would affect 0.2% of ERF open-water and sedge marsh habitat. Environmental impacts could also include fuel spills that may occur during refueling of the pump generators. Impacts to the environment would be minimized by the use of helicopters to bring in floating pumps and lines. Primary risk to workers is posed by potential explosion of UXO and/or detonation supplies during placement of detonation charges and installation, maintenance and removal of pumping systems and monitoring equipment. UXO clearance and adherence to health and safety plans would be conducted. Pond breaching activities may also affect the community of Eagle River. The blasts are loud and may be seen and felt. The blasting will be conducted on clear days if possible to reduce the sound and pressure of the blast.	AquaBlok™ is complete and adequate coverage is verified. There is uncertainty with regard to whether the long- and short-term mortality RAOs will be met. If the total area (2.9 ha) is covered with AquaBlok™, this would represent a 1.4% reduction in open-water and sedge marsh habitat at ERF.
Implementability				
No treatment technologies implemented	Implementation activities are limited to installation and maintenance of monitoring equipment. The changes in WP particle concentrations, sedimentation, and sediment moisture and temperature will be monitored in order to evaluate the effectiveness of natural processes in drying the sediment, thus fostering WP sublimation/oxidation. RPM and BTAG coordination is conducted as part of monitoring program. Access to	Pond 183 is shallow and moderate lowering of water level by pumping may expose large sediment area. Pumping test in May 1997 showed that Pond 183 can be drained and dried. Changes in WP particle concentrations, and sediment moisture and temperature, as a result of pumping will be monitored to evaluate the effectiveness of pumping in promoting WP sublimation/oxidation. Visual inspection and sampling for integrity of the	Pond 183 is shallow and moderate lowering of water level by pumping may expose large sediment area. Pumping test in May 1997 showed that Pond 183 can be drained and dried. Changes in WP particle concentrations, and sediment moisture and temperature, as a result of breaching and pumping will be monitored to evaluate the effectiveness of breaching and pumping in promoting WP sublimation/oxidation. Visual inspection and	Minor technical difficulties are anticipated with application of AquaBlok™ by truck or by air. Reapplication may be necessary in areas where craters are present. Visual inspection and sampling for integrity of the AquaBlok™ cover will be conducted. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation.

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
	OUC is coordinated with U.S. Army at Fort Richardson. Equipment and personnel to conduct monitoring are available. Availability of laboratories that can perform WP baseline and verification sampling is very limited.	AquaBlok™ cover will be conducted. No difficulties associated with construction and operation of pumping systems are anticipated. Minor difficulties may be experienced during application of AquaBlok™ if the product is not laid evenly and reapplication by truck or air is required. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation. Military helicopters and flight personnel required to access OUC for equipment transport and AquaBlok™ application are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct pumping and AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively in the areas where AquaBlok™ has been applied.	sampling for integrity of the AquaBlok™ cover will be conducted. No technical difficulties that would hinder implementation of breaching activities are expected. No technical difficulties associated with construction and operation of the pumping systems are anticipated. Minor difficulties may be experienced during application of AquaBlok™ if the product is not laid evenly and reapplication by truck or air is required. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation. Military helicopters and flight personnel required to access OUC for equipment transport and AquaBlok™ application and to conduct breaching (detonation) are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct pumping and AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively in the areas where AquaBlok™ has been applied.	Military helicopters and flight personnel required to access OUC for AquaBlok™ application are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively after AquaBlok™ has been applied.
Capital Cost				
$0	$21,000	$397,000	$332,000	$683,000
20-Year Present Worth Based on 5% Discount Rate				
$0	$215,000	$638,000	$582,000	$698,000

TABLE 16
Summary of Deta aluation of Alternatives for Pond 146

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
Overall Protection of Human Health and the Environment				
Ecological risk reduction by natural processes resulting in loss (sublimation/oxidation) or covering (sedimentation) of WP may take 10-15 years. No verification monitoring conducted. Human health risk posed by potential exposure to UXO would not be reduced.	Ecological risk reduction by natural processes resulting in loss (sublimation/oxidation) or covering (sedimentation) of WP may take from 10-15 years. Verification monitoring would be conducted. Human health risk posed by potential exposure to UXO would not be reduced.	Pumping would provide adequate protection of the environment by promoting WP sublimation/oxidation. AquaBlok™ application in areas that cannot be drained would also reduce WP exposure via ingestion by placing a barrier between WP particles and waterfowl. Human health risk posed by potential exposure to UXO would not be reduced.	Breaching and pumping would provide adequate protection of the environment by promoting WP sublimation/oxidation. AquaBlok™ application in areas that do not drain and dry sediments would also reduce WP exposure via ingestion by placing a barrier between WP particles and waterfowl. Human health risk posed by potential exposure to UXO would not be reduced.	Application of AquaBlok™ would be protective of the environment because the exposure pathway to WP particles in the sediment would be eliminated. Human health risk posed by potential exposure to UXO would not be reduced.
Compliance with ARARs				
No chemical- or action-specific ARARs apply. Does not meet location-specific ARARs specific to protection of migratory birds and wetlands.	No chemical-specific ARARs apply. Does not meet location-specific ARARs specific to protection of migratory birds and wetlands. Can meet action-specific ARARs if appropriate protective measures are taken.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.
Long-Term Effectiveness and Permanence				
Residual WP risk is estimated to remain in approximately 5.0 hectares (ha) of total 5.5 ha after approximately 10-15 years, and gradually decrease thereafter. No verification monitoring conducted.	Residual WP risk is estimated to remain in approximately 5.0 hectares (ha) of total 5.5 ha after approximately 10-15 years, and gradually decrease thereafter. Detailed monitoring program conducted.	No residual risk will remain in the areas where pumping is effective and WP sublimates/oxidizes. Residual risk is expected to remain in approximately 2.8 ha (50%) of total 5.5 ha where AquaBlok™ is applied because the WP is covered rather than treated. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.	No residual risk will remain in areas that are successfully dried from breaching and pumping and WP sublimates/oxidizes. Residual risk is expected to remain in approximately 1.7 ha (30%) area where AquaBlok™ is applied because the WP is covered rather than treated. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.	Potential residual risk will remain in 4.95 ha, or 90% of the hot pond area, after AquaBlok™ application. It is assumed that previous dredging removed residual risk in remaining 5% of hot pond area. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.
Reduction of Toxicity, Mobility, and Volume (TMV) Through Treatment				
It is estimated that most TMV of WP will be gradually reduced through natural processes, primarily sedimentation, in the long term (10-15 years). No verification monitoring conducted. Does not meet the statutory preference for treatment as a principal element.	It is estimated that most TMV of WP will be gradually reduced through natural processes, primarily sedimentation, in the long term (10-15 years). Detailed monitoring program conducted. Does not meet the statutory preference for treatment.	TMV reduction resulting from WP sublimation/oxidation is estimated to occur in 2.8 ha (50%) of the total 5.5-ha hot pond area. Reduction of WP mobility from AquaBlok™ will occur in the remaining 2.8 ha (50%). Meets the statutory preference for treatment for those areas where WP sublimates/oxidizes as a result of pumping.	TMV reduction resulting from WP sublimation/oxidation is estimated to occur in 3.9 ha (70%) of the total 5.5-ha hot pond area. Reduction of WP mobility from AquaBlok™ will occur in the remaining 1.7 ha (30%). Meets the statutory preference for treatment for those areas where WP sublimates/oxidizes as a result of breaching and pumping.	Reduction of WP mobility only from AquaBlok™ will occur over 4.95 ha (90%) of total 5.5-ha hot pond area. Does not meet the statutory preference for treatment as a principal element . It is assumed that TMV was reduced by dredging in remaining 5%.
Short-Term Effectiveness				
Long-term remedial action objectives may be met from natural processes in 10-15 years. No verification monitoring conducted.	Long-term remedial action objectives may be met from natural processes in 10-15 years. Verification monitoring conducted. Construction activities limited to installation, maintenance, and removal of monitoring equipment. Primary risk to workers is posed	It is estimated that the RAO of 50% reduction in hot zones can be achieved in 5 years and 99% reduction can be achieved in 20 years. There is uncertainty with regard to whether the long- and short-term mortality RAOs will be met.	It is estimated that the RAO of 50% reduction in hot zones can be achieved in 5 years and 99% reduction can be achieved in 20 years. There is uncertainty with regard to whether the long- and short-term mortality RAOs will be met.	The time until hot zone and treatment verification RAOs are met is estimated to be less than 5 years, depending on when the AquaBlok™ is applied. These RAOs are essentially met once the application of AquaBlok™ is complete and adequate

TABLE 16
Summary of Detailed Evaluation of Alternatives for Pond 146

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
	by potential explosion of unexploded ordnance (UXO). UXO clearance and adherence to health and safety plans would be conducted.	Pumping would drain approximately 16 ha, which would temporarily reduce open-water and sedge marsh feeding habitat. Application of AquaBlok™ in 2.8 ha may permanently reduce open-water and sedge marsh habitat in ERF by 1.4%. Environmental impacts could also include fuel spills that may occur during refueling of the pump generators. Impacts to the environment would be minimized by the use of helicopters to bring in floating pumps and lines. Risk to workers is posed by potential explosion of UXO during installation, maintenance, and removal of pumping systems and monitoring equipment. UXO clearance and adherence to health and safety plans would be conducted.	Breaching would drain approximately 16 ha, which would permanently reduce open-water and sedge marsh habitats in ERF by 7.8%. Engineering controls would be implemented to minimize effects on existing habitat. Application of AquaBlok™ in 1.7 ha would cause permanent changes in bottom elevations that would affect 0.9% of ERF open-water and sedge marsh habitat. Environmental impacts could also include fuel spills that may occur during refueling of the pump generators. Impacts to the environment would be minimized by the use of helicopters to bring in floating pumps and lines. Primary risk to workers is posed by potential explosion of UXO and/or detonation supplies during placement of detonation charges and installation, maintenance and removal of pumping systems and monitoring equipment. UXO clearance and adherence to health and safety plans would be conducted. Pond breaching activities may also affect the community of Eagle River. The blasts are loud and may be seen and felt. The blasting will be conducted on clear days if possible to reduce the sound and pressure of the blast.	coverage is verified There is uncertainty with regard to whether the long- and short-term mortality RAOs will be met If the total contaminated area (4 95 ha) area is covered with AquaBlok™, this would represent a 2.7% reduction in open-water and sedge marsh habitat at ERF.
Implementability				
No treatment technologies implemented	Implementation activities are limited to installation and maintenance of monitoring equipment. The changes in WP particle concentrations, sedimentation, and sediment moisture and temperature will be monitored in order to evaluate the effectiveness of natural processes in drying the sediment, thus fostering WP sublimation/oxidation. RPM and BTAG coordination is conducted as part of monitoring program. Access to OUC is coordinated with U.S. Army at Fort Richardson. Equipment and personnel to conduct	Uncertain if pumping will lower water levels and dry sediments sufficiently for WP sublimation/oxidation. Underground recharge from Clunie Creek is suspected and may inhibit success. Changes in WP particle concentrations, and sediment moisture and temperature, as a result of pumping will be monitored to evaluate the effectiveness of pumping in promoting WP sublimation/oxidation. Visual inspection and sampling for integrity of the AquaBlok™ cover will be conducted. No difficulties associated with construction and operation of pumping systems are	Uncertain if breaching and pumping will lower water levels and dry sediments sufficiently for WP sublimation/oxidation. Underground recharge from Clunie Creek is suspected and may inhibit success. Changes in WP particle concentrations, and sediment moisture and temperature, as a result of breaching and pumping will be monitored to evaluate the effectiveness of breaching and pumping in promoting WP sublimation/oxidation. Visual inspection and sampling for integrity of the AquaBlok™ cover will be conducted. No technical difficulties that would hinder	No technical difficulties anticipated with application of AquaBlok™ by truck or by air. Reapplication may be necessary in areas where craters are present. Visual inspection and sampling for integrity of the AquaBlok™ cover will be conducted. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation. Military helicopters and flight personnel required to access OUC for AquaBlok™ application are not readily available. Trucks used for AquaBlok™ application are readily

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
	monitoring are available. Availability of laboratories that can perform WP baseline and verification sampling is very limited.	anticipated. Minor difficulties may be experienced during application of AquaBlok™ if the product is not laid evenly and reapplication by truck or air is required. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation. Military helicopters and flight personnel required to access OUC for equipment transport and AquaBlok™ application are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct pumping and AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively in the areas where AquaBlok™ has been applied.	implementation of breaching activities are expected. No technical difficulties associated with construction and operation of the pumping systems are anticipated. Minor difficulties may be experienced during application of AquaBlok™ if the product is not laid evenly and reapplication by truck or air is required. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation. Military helicopters and flight personnel required to access OUC for equipment transport and AquaBlok™ application and to conduct breaching (detonation) are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct pumping and AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively in the areas where AquaBlok™ has been applied.	available. Equipment and personnel to conduct AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively after AquaBlok™ has been applied.
Capital Cost				
$0	$23,000	$1,422,000	$879,000	$1,218,000
20-Year Present Worth Based on 5% Discount Rate				
$0	$218,000	$1,929,000	$1,278,000	$1,234,000

Criterion	Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
Overall Protection of Human Health and the Environment	Ecological risk reduction by natural processes resulting in loss (sublimation/oxidation) or covering (sedimentation) of WP may take from 10 to 15 years. No verification monitoring conducted. Human health risk posed by potential exposure to UXO would not be reduced.	Ecological risk reduction by natural processes resulting in loss (sublimation/oxidation) or covering (sedimentation) of WP may take from 10 to 15 years. Verification monitoring conducted. Human health risk posed by potential exposure to UXO would not be reduced.	Pumping would provide adequate protection of the environment by promoting WP sublimation/oxidation. AquaBlok™ application in areas that cannot be drained would also reduce WP exposure via ingestion by placing a barrier between WP particles and waterfowl. Human health risk posed by potential exposure to UXO would not be reduced.	Breaching and pumping would provide adequate protection of the environment by promoting WP sublimation/oxidation. AquaBlok™ application in areas that do not drain and dry sediments would also reduce WP exposure via ingestion by placing a barrier between WP particles and waterfowl. Human health risk posed by potential exposure to UXO would not be reduced.	Application of AquaBlok™ would be protective of the environment because the exposure pathway to WP particles in the sediment would be eliminated. Human health risk posed by potential exposure to UXO would not be reduced.
Compliance with ARARs	No chemical- or action-specific ARARs apply. Does not meet location-specific ARARs specific to protection of migratory birds and wetlands.	No chemical-specific ARARs apply. Does not meet location-specific ARARs specific to protection of migratory birds and wetlands. Can meet action-specific ARARs if appropriate protective measures are taken.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.	No chemical-specific ARARs apply. Can meet action-specific ARARs if appropriate protective measures are taken during implementation of alternative.
Long-Term Effectiveness and Permanence	Residual WP risk is estimated to remain in approximately 3.5 hectares (ha) of the total 3.7-ha hot pond area after approximately 10-15 years, and gradually decrease thereafter. No verification monitoring conducted.	Residual WP risk is estimated to remain in approximately 3.5 hectares (ha) of the total 3.7-ha hot pond area after approximately 10-15 years, and gradually decrease thereafter. Detailed monitoring program conducted.	No residual risk will remain in the areas where pumping is effective and WP sublimates/oxidizes. Residual risk is expected to remain in approximately 2.2 ha (60%) of total 3.7-ha pond area where AquaBlok™ is applied because the WP is covered rather than treated. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.	No residual risk will remain in areas that are successfully dried from breaching and pumping and WP sublimates/oxidizes. Residual risk is expected to remain in approximately 1.5 ha (40%) of total 3.7-ha pond area where AquaBlok™ is applied because the WP is covered rather than treated. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.	Potential residual risk will remain in 3.7 ha, or 100% of the hot pond area, after AquaBlok™ application. The integrity of the AquaBlok™ will be routinely evaluated and managed to provide a permanent control.
Reduction of Toxicity, Mobility, and Volume (TMV) Through Treatment	It is estimated that the TMV of WP will be gradually reduced through natural processes, primarily sedimentation, in the long term (10-15 years). No monitoring conducted. Does not meet the statutory preference for treatment as a principal element.	It is estimated that the TMV of WP will be gradually reduced through natural processes, primarily sedimentation, in the long term (10-15 years). Detailed monitoring program conducted. Does not meet the statutory preference for treatment.	TMV reduction resulting from WP sublimation/oxidation is estimated to occur in 1.5 ha (40%) of the total 3.7-ha hot pond area. Reduction of WP mobility from AquaBlok™ will occur in the remaining 2.2 ha (60%). Meets the statutory preference for treatment for those areas where WP sublimates/oxidizes as a result of pumping.	TMV reduction resulting from WP sublimation/oxidation is estimated to occur in 2.2 ha (60%) of the total 3.7-ha hot pond area. Reduction of WP mobility from AquaBlok™ will occur in the remaining 2.3 ha (40%). Meets the statutory preference for treatment for those areas where WP sublimates/oxidizes as a result of breaching and pumping.	Reduction of WP mobility only from AquaBlok™ will occur over the total hot pond area, or 3.7 ha. Does not meet the statutory preference for treatment as a principal element.
Short-Term Effectiveness	Long-term remedial action objectives may be met from natural processes in estimated 10-15 years. No verification monitoring conducted.	Long-term remedial action objectives may be met from natural processes in estimated 10-15 years. Verification monitoring conducted. Construction activities limited to installation, maintenance, and removal of monitoring	It is estimated that the RAO of 50% reduction in hot zones can be achieved in 5 years and 99% reduction can be achieved in 20 years. There is uncertainty with regard to whether the long- and short-term mortality RAOs will be met.	It is estimated that the RAO of 50% reduction in hot zones can be achieved in 5 years and 99% reduction can be achieved in 20 years. There is uncertainty with regard to whether the long- and short-term mortality RAOs will be met.	The time until hot zone and treatment verification RAOs are met is estimated to be less than 5 years, depending on when the AquaBlok™ is applied. These RAOs are essentially met once the application of AquaBlok™ is complete and adequate coverage is verified. There is uncertainty

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TABLE 17
Summary of Detailed Evaluation of Alternatives for Northern C and C/D Ponds

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
	equipment. Primary risk to workers is posed by potential explosion of unexploded ordnance (UXO). UXO clearance and adherence to health and safety plans would be conducted.	Because of the interconnections in the area, pumping would drain approximately 71 ha in addition to the 3.7-ha hot pond area, which would temporarily reduce open-water and sedge marsh feeding habitat. Application of AquaBlok™ in 2.2 ha may permanently reduce 1.1% of ERF open-water and sedge marsh habitat. Environmental impacts could also include fuel spills that may occur during refueling of the pump generators. Impacts to the environment would be minimized by the use of helicopters to bring in floating pumps and lines. Risk to workers is posed by potential explosion of UXO during installation, maintenance, and removal of pumping systems and monitoring equipment. UXO clearance and adherence to health and safety plans would be conducted.	Because of the hydraulic interconnections in the area, breaching and pumping could result in draining approximately 71 ha in addition to the 3.7-ha hot pond area, resulting in permanent 36.8% reduction in open-water and sedge marsh habitat at ERF. Engineering controls, such as breaching a gully that is already naturally progressing toward the pond system, would be implemented to minimize effects on existing habitat. Application of AquaBlok™ in 1.5 ha would cause permanent changes in bottom elevations would affect 0.7% of ERF open-water and sedge marsh habitat. Environmental impacts could also include fuel spills that may occur during refueling of the pump generators. Impacts to the environment would be minimized by the use of helicopters to bring in floating pumps and lines. Primary risk to workers is posed by potential explosion of UXO and/or detonation supplies during placement of detonation charges and installation, maintenance and removal of pumping systems and monitoring equipment. UXO clearance and adherence to health and safety plans would be conducted. Pond breaching activities may also affect the community of Eagle River. The blasts are loud and may be seen and felt. The blasting will be conducted on clear days if possible to reduce the sound and pressure of the blast.	with regard to whether the long- and short-term mortality RAOs will be met. If the total area (5.8 ha) is covered with AquaBlok™, this would represent a 1.8% reduction in open-water and sedge marsh habitat at ERF. Benthic food sources for waterfowl would be reduced in the short-term, but should be restored as plants become established and invertebrates recognize the treated areas. However, because of the shallow depths of the Northern C and C/D ponds, modifications of the water depth could significantly alter feeding suitability for waterfowl. Sampling will be conducted before application of AquaBlok™ to more clearly define the hot pond areas and minimize the area that will be covered with AquaBlok™.
Implementability				
No treatment technologies implemented	Implementation activities are limited to installation and maintenance of monitoring equipment. The changes in WP particle concentrations, sedimentation, and sediment moisture and temperature will be monitored in order to evaluate the effectiveness of natural processes in drying the sediment, thus fostering WP sublimation/oxidation.	The 10 hot ponds are hydraulically connected with other very large areas of permanent ponds, intermittent ponds, and sedge areas. Recharge from the east makes successful pumping of ponds uncertain. Changes in WP particle concentrations, and sediment moisture and temperature, as a result of pumping will be monitored to	The 10 hot ponds are hydraulically connected with other very large areas of permanent ponds, intermittent ponds, and sedge areas. Recharge from the east makes successful pumping of ponds uncertain. Breaching of large pond to north in Area D may improve pond drainage. Changes in WP particle concentrations, and sediment moisture and temperature, as a	Minor technical difficulties are anticipated with application of AquaBlok™ by truck or by air. Reapplication may be necessary in areas where craters are present. Visual inspection and sampling for integrity of the AquaBlok™ cover will be conducted. RPM, BTAG, and U.S Army Fort Richardson coordination is conducted as

Alternative 1 No Action	Alternative 2 Detailed Monitoring	Alternative 3 Pumping and AquaBlok™	Alternative 4 Breaching, Pumping, and AquaBlok™	Alternative 5 AquaBlok™
	RPM and BTAG coordination is conducted as part of monitoring program. Access to OUC is coordinated with U.S. Army at Fort Richardson. Equipment and personnel to conduct monitoring are available. Availability of laboratories that can perform WP baseline and verification sampling is very limited.	evaluate the effectiveness of pumping in promoting WP sublimation/oxidation. Visual inspection and sampling for integrity of the AquaBlok™ cover will be conducted. No difficulties associated with construction and operation of pumping systems are anticipated. Minor difficulties may be experienced during application of AquaBlok™ if the product is not laid evenly and reapplication by truck or air is required. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation. Military helicopters and flight personnel required to access OUC for equipment transport and AquaBlok™ application are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct pumping and AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively in the areas where AquaBlok™ has been applied.	result of breaching and pumping will be monitored to evaluate the effectiveness of breaching and pumping in promoting WP sublimation/oxidation. Visual inspection and sampling for integrity of the AquaBlok™ cover will be conducted. No technical difficulties that would hinder implementation of breaching activities are expected. No technical difficulties associated with construction and operation of the pumping systems are anticipated. Minor difficulties may be experienced during application of AquaBlok™ if the product is not laid evenly and reapplication by truck or air is required. RPM, BTAG, and U.S. Army Fort Richardson coordination is conducted as part of technology implementation. Military helicopters and flight personnel required to access OUC for equipment transport and AquaBlok™ application and to conduct breaching (detonation) are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct pumping and AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively in the areas where AquaBlok™ has been applied.	part of technology implementation. Military helicopters and flight personnel required to access OUC for AquaBlok™ application are not readily available. Trucks used for AquaBlok™ application are readily available. Equipment and personnel to conduct AquaBlok™ application are readily available. Availability of laboratories that can perform WP baseline and verification sampling is very limited. Future remedial actions involving sediment drying could not be implemented effectively after AquaBlok™ has been applied.
Capital Cost				
$0	$52,000	$3,318,000	$2,432,000	$895,000
20-Year Present Worth Based on 5% Discount Rate				
$0	$362,000	$5,346,000	$3,765,000	$952,000

SECTION 7

Comparison of Alternatives

This section compares the remedial alternatives by pond group using the detailed analysis summarized in Section 6.3 and presented in more detail in Appendix F. This comparison forms the basis for determining the relative ranking of alternatives for each criterion, then across the criteria.

Each comparison includes two tables:

- **Performance of alternatives.** This table includes an assessment of the area of residual risk; the area of sediment expected to be treated by sublimation/oxidation; the area of habitat expected to be covered by AquaBlok™; the area of habitat covered by AquaBlok™ as a percentage of water-bearing habitat in the pond group; the area of habitat removed by draining; certainty of performance success; and the cost (including capital, 10-year present worth, and 20-year present worth).
- **Ranking of alternatives.** This table ranks the five alternatives for each of the seven criteria, and gives comments that provide background on the ranking presented. The alternatives are ranked according to how well they meet the criteria; the highest ranking alternatives are best at meeting each individual criterion.

This comparative analysis serves as the basis by which decisionmakers will choose the preferred alternative and ultimately the selected remedy for each pond group at ERF.

This analysis highlights the relative advantages and disadvantages of each of the five alternatives with respect to seven of the nine NCP criteria. Key tradeoffs of each alternative are identified. For example, an alternative that reduces the largest amount of residual risk may also be the most expensive. These key tradeoffs, coupled with risk management decisions, form the basis for the rationale and development of the Proposed Plan and the ROD. Through this comparative analysis, the Army will select its preferred alternative for each pond group. The preferred alternative will be presented to the public in a Proposed Plan.

Public and state comments on the five alternatives and the Army's preferred alternative will be documented during a public comment period. Following this public comment period, public and state acceptance (the last two NCP criteria) will be evaluated. Public and state input will be incorporated into the comparative analysis presented in this section and included in subsequent versions of this FS and the ROD.

The selected remedy is the outcome of this FS and the public comment. It will be chosen by evaluating all nine NCP criteria and will be documented in the ROD.

7.1 Northern A Pond Group

Table 18 summarizes the performance of the five alternatives for the Northern A pond group. Alternative 5 meets all criteria and would achieve the RAOs for hot zones and reduction of WP exposure pathway. This alternative can easily be implemented by air. Alternative 5 would result in AquaBlok™ coverage over 13.8 percent of the water-bearing habitat in this pond group. It is expected to be successful in blocking waterfowl exposure to contaminated sediment. Alternative 5 would result in the highest amount of residual risk, followed by Alternative 3 and then Alternative 4. Of the three treatment alternatives, the 10- and 20-year present worth costs of Alternative 5 are the lowest.

Alternatives 3 and 4 also meet all criteria. A summer 1997 aerial and land survey indicated that the area can likely be drained and dried with two or three pumps. The topography of the pond group is hummocky and drying of the ponds would also involve drainage of 10.6 ha of intermittent ponds, 6 ha of likely uncontaminated permanent ponds, and 25.2 ha of sedge marsh. Alternative 4 would result in permanent removal of this habitat, while the impacts to habitat under Alternative 3 are expected to be temporary. Because of the large volume of water to drain, it may not be possible to dry WP-contaminated sediment in these hot ponds. Regardless of drying performance, Alternatives 3 and 4 would still be protective because AquaBlok™ would be applied to all areas of hot ponds that do not dry.

Alternatives 1 and 2 do not meet the threshold criteria. They are neither protective of the environment, nor do they achieve location-specific ARARs.

Table 19 shows the ranking of the alternatives for this pond group, including comments about the comparisons.

TABLE 18
Performance of Alternatives, Northern A Pond Group

	Alt 1: No Action	Alt 2: Detailed Monitoring	Alt 3: Pumping and AquaBlok™	Alt 4: Breaching, Pumping, and AquaBlok™	Alt 5: AquaBlok™
Area of residual risk (ha)	5.5	5.5	3.5	2.3	5.8
Area of sediment treated by sublimation/oxidation (ha)	0.3	0.3	2.3	3.5	0
Area of habitat covered by AquaBlok™ (ha)	-[a]	-	3.5	2.3	5.8
Area of habitat covered by AquaBlok™ as a percentage of water-bearing habitat in this pond group (%)[b]	-	-	8.3	5.5	13.8
Area of habitat removed by draining (ha)	-	-	42 (temporary)	42 (permanent)	-
Certainty of performance success within 5 years of implementation	Low	Low	Moderate	Moderate	High
Cost ($)					
Capital	0	45,000	1,469,000	1,175,000	1,368,000
10 Year Present Worth	0	208,000	2,142,000	1,792,000	1,413,000
20 Year Present Worth	0	270,000	2,147,000	1,798,000	1,424,000

[a] "—" indicates that the technology is not a component of the alternative.
[b] The total area of water-bearing habitat in this pond group is 42 ha.
[c] Costs are based on aerial application of AquaBlok™

TABLE 19
Ranking of Alternatives for the Northern A Pond Group

	Ranking of Alternatives				
	Best			**Worst**	**Comments**
Overall Protection of Human Health and the Environment	3	5	4	1, 2	Several factors are considered here: area remaining contaminated, habitat impacted, implementability, time to remediation. Ranking reflects tradeoffs in these factors. Alternatives 3 through 5 are equally protective because they block the exposure pathway. However, they vary in the degree of residual risk. Alternative 4 would result in permanent effect on waterfowl habitat.
Compliance with ARARs	3,4,5			1, 2	No chemical-specific ARARs apply. Alternatives 3, 4, and 5 meet all action- and location-specific ARARs. Alternatives 1 and 2 do not meet the location-specific ARARs (protection of migratory birds and wetlands).
Long-term effectiveness and permanence	3,4	5	2	1	Alternatives 1 and 2 likely take over 20 years for sufficient sedimentation for natural restoration. Pond 258 may take shorter period. Estimated 2.3 and 3.5 ha would lose WP via sublimation/oxidation within 5 years of remediation start in Alternatives 3 and 4, respectively, leaving contaminated sediment under 3.5 and 2.3 ha of AquaBlok™ in these alternatives. Protection of dabbling ducks and swans would be accomplished within 1 year for Alternative 5, but 5.8 ha of contaminated sediment would remain under the AquaBlok™. Thus, residual risk would be highest under Alternative 5 and lowest under Alternative 4. Although pond group has only 5.8 ha area, 42 ha may be drained in Alternatives 3 and 4 because of the area's hydraulic connectivity. This would be temporary (3-5 years for Alternative 3), but may be permanent for Alternative 4.
Reduction of TMV	3,4	5		1,2	Alternatives 3 and 4 reduce waterfowl exposure by first reducing the WP through pond draining and sublimation/oxidation (reducing the mass of contaminant), and then blocking exposure with AquaBlok™ (which reduces the mobility of the contaminant) over the remaining contaminated sediment. Alternative 5 only reduces the mobility through the use of AquaBlok™ in the entire pond. Alternatives 1 and 2 may reduce the mobility of the contaminant through sedimentation, but it will likely take more than 20 years to be effective. Alternatives 3 and 4 meet the statutory preference for treatment, but the others do not.
Short-term effectiveness	3	5		1,2,4	The blasting in Alternative 4 may affect the nearby community because of the noise and shock wave, but this would be reduced by blasting on clear day. Alternatives 2, 3, and 4 involve considerable potential human exposure to UXO because of the equipment installation and removal each field season, but this would be reduced by health and safety plan, which requires UXO clearance. Alternatives 3, 4, and 5 would be completed in 5, 5, and 1 year, respectively. Alternatives 1 and 2 would likely take more than 20 years. Alternative 1 has no monitoring, and therefore the degree of protection would be unknown.
Implementability	1,2,5		4	3	Alternatives 1, 2 can be easily implemented. The method for Alternative 5 has been demonstrated, and thus should be relatively easy to implement. There is higher uncertainty about the implementability of Alternatives 3 and 4 because of the lack of knowledge about the hydraulic connectivity of the area. However, a summer 1997 aerial and land survey indicated that the area can be drained and dried with two or three pumps. Pumps may need to be rearranged during the treatment period. Only a specialist firm is available to perform the particle analysis that forms the basis for evaluating the WP baseline and verification studies.
Cost	1	2	4,5	3	Ranking was based on 20-year present worth. See Table 18.

Note: Each number represents an alternative.

7.4 Pond 146

Table 24 summarizes the performance of the five alternatives for Pond 146. Alternative 5 meets all criteria and would achieve hot zone and WP exposure pathway reduction RAOs, and can easily be implemented by air or truck. Alternative 5 would result in AquaBlok™ coverage of 33 percent of the water-bearing habitat in this pond group. However, because of the natural topography and previous dredge operations, Pond 146 is deep (>0.7 m) in certain sections and water-storage capacity is not expected to be severely impeded. AquaBlok™ application is expected to be successful in blocking waterfowl exposure to WP-contaminated sediment. However, by providing a barrier over WP-contaminated sediment, Alternative 5 also would result in the highest amount of remaining residual risk. Alternative 5 is the least expensive of the remediation-oriented alternatives. Although air application costs are presented in Table F-24, it is likely that AquaBlok™ may be also applied by slurry with the existing retention basin and conveyance system. Slurry application has not been evaluated in this FS because of lack of implementation information. However, it is worth investigating.

Alternatives 3 and 4 meet all criteria. However, drying under these alternatives is not expected to be successful because of the interconnectiveness of adjacent water bodies and recharge from Clunie Creek. Alternative 4 is the least expensive of the three treatment alternatives and may reduce the most amount of residual risk, but it would result in permanent drainage of at least 15.9 ha of water-bearing landcover. Depending on the hydraulic interconnectiveness, areas of the Northern C and C/D pond group may also drain. Alternative 3 would affect habitat the least, but is the most expensive option, and there is a strong possibility that water level reduction and drying would not be successful. Regardless of drying performance, Alternatives 3 and 4 would still be protective because AquaBlok™ would be applied to all areas of hot ponds that do not dry. Alternatives 1 and 2 do not meet threshold criteria. They are neither protective of the environment nor do they achieve location-specific ARARs.

Table 25 shows the rankings of the alternatives for Pond 146.

TABLE 24
Performance of Alternatives, Pond 146

	Alt 1: No Action	Alt 2: Detailed Monitoring	Alt 3: Pumping and AquaBlok™	Alt 4: Breaching, Pumping, and AquaBlok™	Alt 5: AquaBlok™
Area of residual risk (ha)	5.0	5.0	2.8	1.7	5.0
Area of sediment treated by sublimation/oxidation (ha)	0.2	0.2	2.4	3.5	--
Area of habitat covered by AquaBlok™ (ha)	-[a]	–	2.8	1.7	5.0
Area of habitat covered by AquaBlok™ as a percentage of water-bearing habitat in this pond group (%)[b]	-	–	17.6	10.7	32.7
Area of habitat removed by draining (ha)	-	-	15.9 (temporary)	15.9 (permanent)	-
Certainty of performance success within 5 years of implementation	Moderate	Moderate	Low	Low	High
<u>Cost[c] ($)</u>					
Capital	0	23,000	1,422,000	879,000	1,218,000
10 Year Present Worth	0	155,000	1,926,000	1,275,000	1,231,000
20 Year Present Worth	0	218,000	1,929,000	1,278,000	1,234,000

[a] "—" indicates that the technology is not a component of the alternative.

[b] The total area of water-bearing habitat in this pond group is 15.9 ha.

[c] Costs are based on aerial application of AquaBlok™.

TABLE 21
Ranking of Alternatives for Pond 290

	Ranking of Alternatives				
	Best			Worst	Comments
Overall Protection of Human Health and the Environment	3	5	4	1, 2	Several factors are considered here: area remaining contaminated, habitat impacted, implementability, time to remediation. Ranking reflects tradeoffs in these factors. Alternatives 3 through 5 are equally protective because they block the exposure pathway. However, they vary in the degree of residual risk. Alternative 4 would result in permanent effect on waterfowl habitat.
Compliance with ARARs	3,4,5			1, 2	No chemical-specific ARARs apply. Alternatives 3, 4, and 5 meet all action- and location-specific ARARs. Alternatives 1 and 2 do not meet the location-specific ARARs (protection of migratory birds and wetlands).
Long-term effectiveness and permanence	3,4		5,2	1	Residual risk is greatest in Alternative 5, because the application of AquaBlok™ prevents future WP sublimation/oxidation. Risk reduction is greatest in Alternative 4 because it is more effective in lowering water levels and obtaining sediment drying. Pond is isolated, and should allow effective pond draining. Alternatives 2-5 have adequate monitoring.
Reduction of TMV	3,4	5		1,2	Alternatives 3 and 4 treat substantial areas of the pond and reduce the mass of WP. Remaining contaminated areas of Alternatives 3, 4, and 5 have reduced contaminant mobility from the application of AquaBlok™. Sublimation/oxidation of WP in Alternatives 3 and 4 is irreversible. AquaBlok™ covering may degrade, but new material can be applied. Alternatives 1, 2, and 5 do not meet statutory preference for treatment.
Short-term effectiveness	3	5		1,2,4	The blasting in Alternative 4 may affect the nearby community because of the noise and shock wave, but this would be reduced by blasting on clear day. Alternatives 2, 3, and 4 involve considerable potential human exposure to UXO because of the equipment installation and removal each field season, but this would be reduced by health and safety plan, which requires UXO clearance. Alternatives 3, 4, and 5 would be completed in 5, 5, and 1 year, respectively. Alternatives 1 and 2 would likely take more than 20 years. Alternative 1 has no monitoring, and therefore the degree of protection would be unknown.
Implementability	1,2,3,4,5				All alternatives are implementable. Only a specialist firm is available to perform the particle analysis that forms the basis for evaluating the WP baseline and verification studies.
Cost	1, 2	5		4, 3	Ranking was based on 20-year present worth. See Table 20.

Note: Each number represents an alternative.

7.3 Pond 183

Table 22 summarizes the performance of the five alternatives for Pond 183. Alternatives 3, 4, and 5 meet all criteria and would achieve hot zone and WP exposure pathway reduction RAOs. All three alternatives can easily be implemented. The 10- and 20-year present worth costs of all three alternatives are comparable. Alternative 4 is least expensive and would result in the least amount of permanent risk. However, implementation of Alternative 4 also would result in permanent removal of 11.7 ha of habitat. Alternative 5 is the most expensive technology-oriented alternative, and implementation of this alternative would result in significantly higher residual risk.

Alternative 3 is the second most expensive of all alternatives, but would result in a small amount of residual risk. In addition, waterfowl feeding habitat would not be permanently removed under Alternative 3. Vegetation would likely be restored following pump removal.

A field-scale pumping test in May 1997 demonstrated that Pond 183 can be drained and dried under Alternative 3.

Alternatives 1 and 2 do not meet threshold criteria. They are neither protective of the environment nor do they achieve location-specific ARARs.

Table 23 shows the ranking of the alternatives for Pond 183.

TABLE 22
Performance of Alternatives, Pond 183

	Alt 1: No Action	Alt 2: Detailed Monitoring	Alt 3: Pumping and AquaBlok™	Alt 4: Breaching, Pumping, and AquaBlok™	Alt 5: AquaBlok™
Area of residual risk (ha)	1.0	1.0	0.9	0.4	2.9
Area of sediment treated by sublimation/oxidation (ha)	1.9	1.9	2.0	2.5	-
Area of habitat covered by AquaBlok™ (ha)	-[a]	-	0.9	0.4	2.9
Area of habitat covered by AquaBlok™ as a percentage of water-bearing habitat in this pond group (%)[b]	0	0	8.0	3.4	25.0
Area of habitat removed by draining (ha)	-	-	11.7 (temporary)	11.7 (permanent)	-
Certainty of performance success within 5 years of implementation	Low	Low	Moderate	Moderate	High
Cost[c] ($)					
Capital	0	22,000	397,000	332,000	683,000
10 Year Present Worth	0	152,000	635,000	580,000	696,000
20 Year Present Worth	0	215,000	638,000	582,000	698,000

[a] "—" indicates that the technology is not a component of the alternative.
[b] The total area of water-bearing habitat in this pond group is 11.9 ha.
[c] Costs are based on aerial application of AquaBlok™.

TABLE 23
Ranking of Alternatives for Pond 183

	Ranking of Alternatives				
	Best			Worst	Comments
Overall Protection of Human Health and the Environment	3	5	4	1,2	Several factors are considered here: area remaining contaminated, habitat impacted, implementability, time to remediation. Ranking reflects tradeoffs in these factors. Alternatives 3 through 5 are equally protective because they block the exposure pathway. However, they vary in the degree of residual risk. Alternative 4 would result in permanent effect on waterfowl habitat.
Compliance with ARARs	3,4,5			1,2	No chemical-specific ARARs apply. Alternatives 3, 4, and 5 meet all action- and location-specific ARARs. Alternatives 1 and 2 do not meet the location-specific ARARs (protection of migratory birds and wetlands).
Long-term effectiveness and permanence	3	4	5, 2	1	Of the technology-oriented alternatives, residual risk is greatest under Alternative 5. Summer 1997 pond draining studies indicate that it is possible to drain and dry Pond 183, regardless of the potential interconnection with Pond 146. In addition, a large area of contamination may be reduced with relatively small reduction in water level because of the slope of the pond bottom. Alternatives 1 and 2 may leave high amounts of residual risk. Alternatives 2-5 have adequate monitoring.
Reduction of TMV	3,4	5		1,2	Alternatives 3 and 4 treat substantial areas of the pond and reduce the mass of WP. Remaining contaminated areas of Alternatives 3, 4, and 5 have reduced contaminant mobility from the application of AquaBlok™. Sublimation/oxidation of WP in Alternatives 3 and 4 is irreversible. AquaBlok™ covering may degrade, but new material can be applied. Alternatives 1, 2, and 5 do not meet statutory preference for treatment.
Short-term effectiveness	3	5		1,2,4	The blasting in Alternative 4 may affect the nearby community because of the noise and shock wave, but this would be reduced by blasting on clear day. Alternatives 2, 3, and 4 involve considerable potential human exposure to UXO because of the equipment installation and removal each field season, but this would be reduced by health and safety plan, which requires UXO clearance. Alternatives 3, 4, and 5 would be completed in 5, 5, and 1 year, respectively. Alternatives 1 and 2 may take 10 to 15 years. Alternative 1 has no monitoring, and therefore the degree of protection would be unknown.
Implementability	1,2,5	3,4			Alternatives 1, 2, and 5 can be easily implemented. A pumping test in May 1997 showed that Pond 183 can be drained and dried in Alternatives 3 and 4. This pond may also be connected to Pond 146..Only a specialist firm is available to perform the particle analysis that forms the basis for evaluating the WP baseline and verification studies.
Cost	1,2	4	3	5	Ranking was based on 20-year present worth. See Table 22.

Note: Each number represents an alternative.

7.4 Pond 146

Table 24 summarizes the performance of the five alternatives for Pond 146. Alternative 5 meets all criteria and would achieve hot zone and WP exposure pathway reduction RAOs, and can easily be implemented by air or truck. Alternative 5 would result in AquaBlok™ coverage of 33 percent of the water-bearing habitat in this pond group. However, because of the natural topography and previous dredge operations, Pond 146 is deep (>0.7 m) in certain sections and water-storage capacity is not expected to be severely impeded. AquaBlok™ application is expected to be successful in blocking waterfowl exposure to WP-contaminated sediment. However, by providing a barrier over WP-contaminated sediment, Alternative 5 also would result in the highest amount of remaining residual risk. Alternative 5 is the least expensive of the remediation-oriented alternatives. Although air application costs are presented in Table F-24, it is likely that AquaBlok™ may be also applied by slurry with the existing retention basin and conveyance system. Slurry application has not been evaluated in this FS because of lack of implementation information. However, it is worth investigating.

Alternatives 3 and 4 meet all criteria. However, drying under these alternatives is not expected to be successful because of the interconnectiveness of adjacent water bodies and recharge from Clunie Creek. Alternative 4 is the least expensive of the three treatment alternatives and may reduce the most amount of residual risk, but it would result in permanent drainage of at least 15.9 ha of water-bearing landcover. Depending on the hydraulic interconnectiveness, areas of the Northern C and C/D pond group may also drain. Alternative 3 would affect habitat the least, but is the most expensive option, and there is a strong possibility that water level reduction and drying would not be successful. Regardless of drying performance, Alternatives 3 and 4 would still be protective because AquaBlok™ would be applied to all areas of hot ponds that do not dry. Alternatives 1 and 2 do not meet threshold criteria. They are neither protective of the environment nor do they achieve location-specific ARARs.

Table 25 shows the rankings of the alternatives for Pond 146.

TABLE 24
Performance of Alternatives, Pond 146

	Alt 1: No Action	Alt 2: Detailed Monitoring	Alt 3: Pumping and AquaBlok™	Alt 4: Breaching, Pumping, and AquaBlok™	Alt 5: AquaBlok™
Area of residual risk (ha)	5.0	5.0	2.8	1.7	5.2
Area of sediment treated by sublimation/oxidation (ha)	0.2	0.2	2.4	3.5	--
Area of habitat covered by AquaBlok™ (ha)	-[a]	–	2.8	1.7	5.2
Area of habitat covered by AquaBlok™ as a percentage of water-bearing habitat in this pond group (%)[b]	-	–	17.6	10.7	32.7
Area of habitat removed by draining (ha)	-	-	15.9 (temporary)	15.9 (permanent)	-
Certainty of performance success within 5 years of implementation	Moderate	Moderate	Low	Low	High
Cost[c] ($)					
Capital	0	23,000	1,422,000	879,000	1,218,000
10 Year Present Worth	0	155,000	1,926,000	1,275,000	1,231,000
20 Year Present Worth	0	218,000	1,929,000	1,278,000	1,234,000

[a] "—" indicates that the technology is not a component of the alternative.

[b] The total area of water-bearing habitat in this pond group is 15.9 ha.

[c] Costs are based on aerial application of AquaBlok™.

TABLE 25
Ranking of Alternatives for Pond 146

	Ranking of Alternatives				
	Best			Worst	Comments
Overall Protection of Human Health and the Environment	3	5	4	1,2	Several factors are considered here: area remaining contaminated, habitat impacted, implementability, time to remediation. Ranking reflects tradeoffs in these factors. Alternatives 3 through 5 are equally protective because they block the exposure pathway. However, they vary in the degree of residual risk. Alternative 4 would result in permanent effect on waterfowl habitat. There is uncertainty about the effectiveness of Alternative 3 and 4 because of the recharge from Clune Creek, but AquaBlok™ applied on uncontaminated areas would provide protection.
Compliance with ARARs	3,4,5			1,2	No chemical-specific ARARs apply. Alternatives 3, 4, and 5 meet all action- and location-specific ARARs. Alternatives 1 and 2 do not meet the location-specific ARARs (protection of migratory birds and wetlands).
Long-term effectiveness and permanence		3,4,	5,2	1	Residual risk is greatest under Alternative 5. There is uncertainty about the ability to dry pond because of the potential interconnection with Pond 183, potentially reducing the effectiveness of Alternatives 3 and 4. Large area of contamination, however, may be reduced with relatively small reduction in water level because of the slope of the pond bottom. Alternatives 1 and 2 may leave high amounts of residual risk. Alternatives 2-5 have adequate monitoring.
Reduction of TMV	3,4	5		1,2	Alternatives 3 and 4 treat substantial areas of the pond and reduce the mass of WP. Remaining contaminated areas of Alternatives 3, 4, and 5 have reduced contaminant mobility from the application of AquaBlok™. Sublimation/oxidation of WP in Alternatives 3 and 4 is irreversible. AquaBlok™ covering may degrade, but new material can be applied. Alternatives 1, 2, and 5 do not meet statutory preference for treatment.
Short-term effectiveness	3,5			1,2,4	The blasting in Alternative 4 may affect the nearby community because of the noise and shock wave, but this would be reduced by blasting on clear day. Alternatives 2, 3, and 4 involve considerable potential human exposure to UXO because of the equipment installation and removal each field season, but this would be reduced by health and safety plan, which requires UXO clearance. Alternatives 3, 4, and 5 would be completed in 5, 5, and 1 year, respectively. Alternatives 1 and 2 may take 10 to 15 years. Alternative 1 has no monitoring, and therefore the degree of protection would be unknown.
Implementability	1,2,5		3,4		Alternatives 1, 2, and 5 can be easily implemented. The uncertainty about pond draining may lead to some adjustments of the pond draining system in Alternatives 3 and 4 after the first installation. This pond may also be connected to Pond 183. Recharge from Clunie Creek will also impede pond draining. Only a specialist firm is available to perform the particle analysis that forms the basis for evaluating the WP baseline and verification studies.
Cost	1,2	5	4	3	Ranking was based on 20-year present worth. See Table 24.

Note: Each number represents an alternative.

7.5 Northern C and C/D Pond Group

Table 26 summarizes the performance of the five alternatives for the Northern C and C/D pond group. Alternative 5 meets all criteria and would achieve the hot zone and WP exposure pathway reduction RAOs. This alternative can easily be implemented by air or truck. Alternative 5 would result in AquaBlok™ coverage of only 5 percent of the water-bearing habitat in this pond group. AquaBlok™ application is expected to be successful in blocking waterfowl exposure to contaminated sediment. However, by providing a barrier over the contaminated sediment, Alternative 5 would also result in the highest amount of remaining residual risk. Alternative 5 is the least expensive alternative of all three remediation-oriented alternatives. Air application costs for AquaBlok™ are presented in Table 26.

Alternatives 3 and 4 meet all criteria. However, drying under these alternatives is not expected to be successful because of the large area of open water around these hot ponds and recharge from the eastern bluffs. Draining under Alternative 5 may be marginally successful. Breaching of the Area D pond may limit inflow from Area D, but this also would result in the permanent removal of 74.9 ha of habitat (most of which is not contaminated). Because of the large volume of water to be removed, Alternatives 3 and 4 are the most costly.

Alternatives 1 and 2 do not meet threshold criteria. They are neither protective of the environment nor do they achieve location-specific ARARs.

Table 27 shows the rankings of the alternatives for the Northern C and C/D pond group.

TABLE 26
Performance of Alternatives, Northern C and C/D Pond Group

	Alt 1: No Action	Alt 2: Detailed Monitoring	Alt 3: Pumping and AquaBlok™	Alt 4: Breaching, Pumping, and AquaBlok™	Alt 5: AquaBlok™
Area of residual risk (ha)	3.5	3.5	2.2	1.5	3.7
Area of sediment treated by sublimation/oxidation (ha)	0.2	0.2	1.5	2.2	–
Area of habitat covered by AquaBlok™ (ha)	–[a]	–	2.2	1.5	3.7
Area of habitat covered by AquaBlok™ as a percentage of water-bearing habitat in this pond group (%)[b]	–	–	2.9	10.1	4.9
Area of habitat removed by draining (ha)	–	–	74.9 (temporary)	74.9 (permanent)	–
Certainty of performance success within 5 years of implementation	Moderate	Moderate	Low	Low	High
<u>Cost[c] ($)</u>					
Capital	0	52,000	3,618,000	2,432,000	896,000
10 Year Present Worth	0	268,000	5,338,000	3,761,000	941,000
20 Year Present Worth	0	362,000	5,346,000	3,765,000	952,000

[a] "—" indicates that the technology is not a component of the alternative.
[b] The total area of water-bearing habitat in this pond group is 74.9 ha.
[c] Costs are based on aerial application of AquaBlok™.

TABLE 27
Ranking of Alternatives for the Northern C and C/D Pond Group

	Ranking of Alternatives				
	Best			**Worst**	**Comments**
Overall Protection of Human Health and the Environment	5		3,4	1,2	Several factors are considered here: area remaining contaminated, habitat impacted, implementability, time to remediation. Ranking reflects tradeoffs in these factors. Alternatives 3 through 5 are equally protective because they block the exposure pathway. However, they vary in the degree of residual risk. Alternative 4 would result in permanent effect on waterfowl habitat. But the blasted ditch for Alternative 4 severely reduces duck habitat. Very high uncertainty on the effectiveness of Alternatives 3 and 4 because of the possible recharge from the eastern bluffs and large bodies of water.
Compliance with ARARs	3,4,5			1,2	No chemical-specific ARARs apply. Alternatives 3, 4, and 5 meet all action- and location-specific ARARs. Alternatives 1 and 2 do not meet the location-specific ARARs (protection of migratory birds and wetlands).
Long-term effectiveness and permanence		3,4,	5,2	1	Residual risk is greatest under Alternative 5. There is uncertainty about the ability to dry pond because of the hydraulic interconnections among the ponds and recharge from the eastern bluffs, potentially reducing the effectiveness of Alternatives 3 and 4. Alternatives 1 and 2 may leave high amounts of residual risk. Alternatives 2-5 have adequate monitoring.
Reduction of TMV	3,4	5		1,2	Alternatives 3 and 4 treat substantial areas of the pond and reduce the mass of WP. Remaining contaminated areas of Alternatives 3, 4, and 5 have reduced contaminant mobility from the application of AquaBlok™. Sublimation/oxidation of WP in Alternatives 3 and 4 is irreversible. AquaBlok™ covering may degrade, but new material can be applied. Alternatives 1, 2, and 5 do not meet statutory preference for treatment.
Short-term effectiveness	3	5		1,2,4	The blasting in Alternative 4 may affect the nearby community because of the noise and shock wave, but this would be reduced by blasting on clear day. Alternatives 2, 3, and 4 involve considerable potential human exposure to UXO because of the equipment installation and removal each field season, but this would be reduced by health and safety plan, which requires UXO clearance. Alternatives 3, 4, and 5 would be completed in 5, 5, and 1 year, respectively. Alternatives 1 and 2 may take 10 to 15 years. Alternative 1 has no monitoring, and therefore the degree of protection would be unknown.
Implementability	1,2,5		4	3	Alternatives 1, 2, and 5 can be easily implemented. The uncertainty about pond draining may lead to some adjustments of the pond draining system in Alternatives 3 and 4 after the first installation. Recharge from the eastern bluffs and connections with other ponds will impede pond draining. Only a specialist firm is available to perform the particle analysis that forms the basis for evaluating the WP baseline and verification studies.
Cost	1,2	5	4	3	Ranking was based on 20-year present worth. See Table 26.

Note: Each number represents an alternative.

SECTION 8

Works Cited

CH2M HILL. *Operable Unit C Final Remedial Investigation Report*. Prepared for U.S. Army Alaska, Department of Public Works. May 1997.

Collins, C. Comments on Draft Feasibility Study Report. June 1997.

Cummings, J. Personal communication. June 24, 1997.

Pochop, P. Personal communication. June 24, 1997.

Pochop, P. Unpublished data. June 1997.

Pochop, P.A., J.L. Cummings, and C.A. Yoder. Evaluation of AquaBlok™ on Contaminated Sediment to Reduce Mortality of Foraging Waterfowl. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* D.W. Cate and C.H. Racine, eds. FY 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. September 1996. Pp. 205-230.

Pochop, P.A., J.L. Cummings, L. Clark, and J.E. Davis, Jr. Evaluation of Concover® and BentoBalls™ on Contaminated Sediments to Reduce Mortality of Foraging Waterfowl. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* C. H. Racine, ed. FY 93 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. May 1994. Pp. 305-312.

Racine, C.H., M.E. Walsh, C.M. Collins, D.J. Calkins, B.D. Roebuck, and L. Reitsma. *Waterfowl Mortality in Eagle River Flats, Alaska: The Role of Munitions Residues.* CRREL Report 92-5. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). May 1992.

Walsh, M.E., C.M. Collins, and R.N. Bailey. Demonstration of Sample Compositing Methods to Detect White Phosphorus Particles. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* C.M. Collins and D.W. Cate, eds. FY 96 Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. July 1997. Pp. 35-50.

Walsh, M.R. Comments on Draft Feasibility Study Report. April 1997.

Walsh, M.R., and C.M. Collins. Monitoring of Contract Dredge Operations at Eagle River Flats, Alaska. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* C.M. Collins and D.W. Cate, eds. FY 96 Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. July 1997. Pp. 73-100.

Appendix A
Assessment of the Physical Processes

Contents

Abbreviations

CRREL	Cold Regions Research and Engineering Laboratory
°C	degrees Celsius
cm	centimeter
ERF	Eagle River Flats
m	meter
m^3/sec	cubic meters per second
mm/yr	millimeters per year
msl	mean sea level
NOAA	National Oceanic and Atmospheric Administration
WP	white phosphorus

APPENDIX A

Assessment of the Physical Processes

1.0 Introduction

Eagle River Flats (ERF) is a very dynamic environment. The tides are among the highest in the world (11 meters [m]) and flood the lower parts of the gullies daily. The ebb tides pour through natural gullies, causing erosion. The gullies, through this natural erosion process, are in many cases experiencing headward erosion (receding from the river) toward the ponds. Suspended sediment is deposited on the flats during slack high tide. The Eagle River runs through the middle of the flats, and is itself backed up during high tides. The water level on the flats is a function of both the tidal height and the river flow volume. Even major but infrequent forces such as earthquakes have altered the physical processes; the 1964 Alaska earthquake modified the elevation, producing changes in the water flow.

Some of these ongoing physical processes can affect the bioavailability of white phosphorus (WP) to dabbling ducks and swans. These processes can effectively break the exposure pathway and offer natural restoration to these species that have been significantly affected by the WP in sediment over the past several decades. These processes are discussed as the "no action" alternative because they are expected to happen naturally, without any intervention by humans. If these processes can lead to this protection quickly and with sufficient effectiveness, then the costs and other negative effects of the other remedial alternatives may be avoidable.

This appendix discusses these natural processes and the rates at which they can be projected to act to protect the sensitive species of dabbling ducks and swans. Section 2 describes the available general information on the processes under the no-action alternative at ERF. Section 3 describes available pond-specific information. Section 4 draws conclusions on the likelihood that natural processes will lead to a reduction in the availability of WP.

The information contained in Sections 2 and 3 was obtained from Lawson *et al.* (in Racine *et al.*, 1994, 1995, 1996), unless otherwise specified, and is based on their field investigations in 1993, 1994, and 1995. Because of similar physical characteristics of ponds, remedial actions are compared in Appendix C on the basis of the pond groups; therefore, information at the geographical level of pond groups is very useful to this comparison. In contrast to the studies that generally encompass many areas of ERF and are discussed in Section 2, Section 3 focuses on study results that are available at the level of pond groups. Section 4 provides projections as to the future of the potential for the no-action alternative to lead to natural restoration. New data may modify the conclusions and forecasts presented in this appendix.

2.0 Physical System

ERF is a cornucopia-shaped estuarine salt marsh surrounded by forested uplands on the west, south, and east sides and bounded by the Knik Arm on the north. The Eagle River flows through ERF from the southeast to the northwest, ultimately discharging into Knik Arm. Two creeks, Clunie and Otter, also drain into ERF.

Tidal flooding is a major system force at ERF and has the single most significant effect on the exposure concentration of WP. The flooding will continue to saturate the sediment, preventing the sublimation/oxidation of WP. The headward erosion of gullies, which may naturally drain ponds, is driven by the water flow of the tides, particularly the ebb tide. The deposition of "clean" sediment over WP-contaminated sediment, which occurs principally during and immediately after the slack high tide, will make the contaminated sediment unavailable to dabbling ducks and swans. Fifteen centimeters (cm) of overlying clean sediment may be sufficient to substantially reduce the likelihood that dabbling ducks and swans will ingest WP particles (Long, 1997). The weather, particularly rain and wind, and the flow volume of the Eagle River play roles in determining the overall water level (which will in turn determine what part of ERF becomes flooded), the amount of material available for deposition, and the length of the drying period for sediment.

Other forces appear to play a lesser role in the fate and transport of WP at ERF. Erosion and transport processes include waves, disturbance of the sediment by ducks and other organisms, ice plucking, ice shove, and ice scour. Events such as earthquakes and tectonic forces may exert a major influence, but they are infrequent and unpredictable.

The following subsections discuss the tides, gully recession, sedimentation, weather and climate, the flow of the Eagle River, and sublimation/oxidation of WP.

2.1 Tides

Tidal flooding of the entire ERF occurs only during the highest, flooding tides. During some summers, there may be no flooding tides for up to 2 months between May and August. Between these peak tides, the sediment may become dry over large areas because of the relatively warm, dry weather. These drying periods are important because they can lead to sublimation/oxidation of WP (discussed further in Section 2.6), potentially reducing the exposure concentration below lethal levels. From late October to late April, the flooding tides can produce an ice cover over ERF.

The tidal flooding cycle begins with an increase in the water level in the Eagle River and the gullies. The water eventually floods over the banks of the gullies. The Eagle River becomes slowed as the tide comes in, and the tide can dam the river, causing it to slow, pool, and reverse its direction. During the ebb tide, the water begins to drain first nearest the coast.

Ponds begin to flood at a tidal height of 4.6 m mean sea level (msl) (9.48 m Anchorage tide datum), mud flats are inundated at 4.9 m (9.8 m Anchorage datum), and the levees are covered at 5.2 m (10 m Anchorage datum). Between these high tides, the sediment will begin to dry, and as discussed in Section 2.6, WP may oxidize. This will reduce the concentration of WP particles in the sediment. Table A-1 summarizes the intervals between summer (including the period of April through September) high tides of 9.48 m during the next 20 years (1997 through 2016). In addition, studies by Walsh, Collins, and Bailey (in Racine *et al.*, 1996) have suggested that this tide height for pond flooding is conservative, and that about 9.8 m may be more realistic. The intervals between 9.8-m flooding tides are shown in Table A-2. Only periods longer than 28 days are shown in the tables, as periods

TABLE A-1
Periods with No Flooding Tides Exceeding 9.48 m
(Only intervals longer than 28 days that include summer months are shown.)

Year	Start Date	End Date	Interval (days)
1997	May 9	July 20	72
1998	June 25	August 9	45
2001	May 9	July 21	73
2002	May 28	August 10	74
2003	June 16	August 29	74
2005	April 26	July 22	87
2006	April 30	August 10	102
2007	May 19	August 29	102
2010	April 30	July 13	74
2011	May 19	August 1	74
2015	May 20	August 1	73
2016	July 6	August 19	44

Note: Daily high tides were obtained from Dean Pidgeon at Cold Regions Research and Engineering Laboratory (CRREL), using the NTP4 software from the National Oceanic and Atmospheric Administration (NOAA).

between 23 and 28 days occur often during the summer and have not been sufficient to reduce the levels of WP to below toxic levels.

Within the next 5 years, 1997, 1998, and 2001 have some of the longest potentially dry periods between pond-flooding tides of 9.48 m. If the pond-flooding tide is closer to 9.8 m, then nearly every year has a period longer than 28 days without flooding tides. Often there is an interval of at least 103 days without a flooding tide of this height. Rainfall, river flow, and temperature will also influence the length of the drying period. As discussed in Section 2.4, average daily rainfall rises during the summer, with a peak of 0.2 cm in August and September.

2.2 Gully Erosion and Recession

Gully recession is caused by the draining of the surface waters through the gullies during the ebb tide. The rushing water undercuts the upper, generally vegetative, root-bound surface materials of ERF. The loss of the lower support of 0.5 m or deeper causes failure of the upper part, and the process continues. The current scour during the ebb tide removes the material from the toe of the slope. This material is eventually transported to the Eagle River.

Active gully recession is occurring in the mud flats and ponds in Areas A, C, C/D, D, and Bread Truck. The rate of recession of headwalls and adjacent lateral walls is variable among seasons and years. The rates were 0.1 m to 4.9 m during the summer of 1992, 0.4 m to 6.3 m during the winter of 1992-93, zero to 9.8 m during the summer of 1993, zero to 2.3 m in the

TABLE A-2
Periods with No Flooding Tides Exceeding 9.8 m
(Only intervals longer than 28 days that include summer months are shown.)

Year	Start Date	End Date	Interval (days)
1997	May 7	August 18	103
1998	May 27	September 7	103
1999	June 15	September 26	103
2001	April 10	August 20	132
2002	April 29	September 7	131
2003	May 18	September 27	132
2004	June 4	October 15	133
2005	April 1*	August 20	141
2006	April 29	August 11	104
2007	May 18	August 30	104
2008	May 8	September 17	132
2010	April 2	August 10	130
2011	May 18	August 30	104
2012	June 6	September 17	103
2014	April 2	July 13	102
2015	May 18	August 2	76
2016	June 6	September 17	103

*Interval between two tides actually starts before April 1.
Note: Daily high tides were obtained from Dean Pidgeon at CRREL, using the NTP4 software from NOAA.

winter of 1993-94, zero to 2.6 m in the summer of 1994, 0.1 m to 11.7 m during the winter of 1994-95, and 0.1 m to 20 m during the summer of 1995. Net headwall recession has been as high as 33 m from spring 1994 through summer 1995. In an examination of the aerial photos taken over a 45-year period, the longer-term recession rates range from 3.6 m to 13.7 m per year, with a higher average in the period following the 1964 earthquake. The recent studies on erosion show rates similar to historical data over a long term. Gully recession is viewed as a natural restoration process; although the gully connections to ponds would lead to more frequent flooding, they would also lead to draining and opportunities for ponds to dry between flooding events.

2.3 Sedimentation

The height of the landform will influence the number of tidal flooding events, which in turn affects the sedimentation. The period during and immediately after slack high tide produces sedimentation. As an example of this height factor, the number of flooding events in summer 1995 included 38, 22, and 1 for the ponds, mud flats, and levees (landforms of increasing elevation), respectively. Incomplete pond drainage commonly occurs when two consecutive high tides exceed 5 m locally on ERF, and this prolonged quiet period will also increase sedimentation. Tidal damming of the Eagle River will increase deposition rates because of the increased period of slack water.

Sedimentation in the northern two-thirds of ERF is dominated by the tides. In the southern one-third of ERF, sedimentation is dominated by the river. The tidally dominated sedimentation rates are several millimeters per year (mm/yr) on the levees, 10 to 15 mm/yr on mud flats, and up to 20 mm/yr in ponds. A gross estimate of pond sedimentation rate is 0.4 mm per tidal cycle. It is estimated that 15 cm of clean sediment may provide a sufficient barrier to duck and swan ingestion of WP. This depth might be achieved in 4 to 8 years based on the range of sedimentation rates for the ponds. Lawson *et al.* have estimated 6 to 9 years. However, sedimentation would provide significant natural protection only if sediments are dewatered and consolidated. Such consolidation would require additional time. Lawson did note compaction on sedimentation plates after stations were established for 3 years.

Sedimentation rates also vary with the distance from the material sources. Most of the sediment is derived from Knik Arm tidal waters, so there is a decrease with distance inland. Sedimentation also decreases with distance from the river. Heavily vegetated areas of mud flats have higher rates of accumulation compared to unvegetated areas (for example, Lawson *et al.* found that 2-year total accumulation rates were 6 mm to 18 mm at sites with less than 60 to 65 percent vegetative cover, and 26 mm to 32 mm at sites with a vegetative cover greater than 70 percent) because the vegetation helps trap the suspended sediment and prevents resuspension of that sediment. Net accumulation rates are typically higher during the period of September to May than from May to September. This difference may result from the longer time period, increased total suspended sediment loads during the early winter months, trapping of sediment by snow cover, or the number of flooding tides.

Sediment also may be transported and deposited by ice rafting of eroded materials during tidal action in winter and spring break-up.

2.4 Weather and Climate

A transitional climate zone provides a relatively moderate climate for the Anchorage area. The Alaska Range, north and northwest of Anchorage, prevents the influx of very cold air from the interior, and the waters of Cook Inlet, including Turnagain Arm to the southeast and Knik Arm to the northwest, help moderate temperatures in the area. Average temperature recorded for the period 1952 to 1987 ranged from -2°C to 7°C, with an annual mean of 3°C. Extreme temperatures ranged from -18°C to 33°C.

Air masses from the Gulf of Alaska (to the south) produce relatively heavy rainfall along the Chugach Range and can contribute to high runoff events in the rivers draining the mountains, including Eagle River. The heaviest precipitation occurs from July through September, with an average rainfall of almost 18 cm falling during the 3-month period. Annual average rainfall is between 33 cm and 50 cm (CH2M HILL, 1994).

Figure A-1 summarizes the average (based on the period of 1951 through 1996) daily temperature (minimum and maximum) and rainfall from May through September at Elmendorf Air Force Base. The temperatures increase until early August, and then begin to decline. The daily average rainfall continues upward through the period, and begins a consistent decline during September. The average maximum and minimum temperatures

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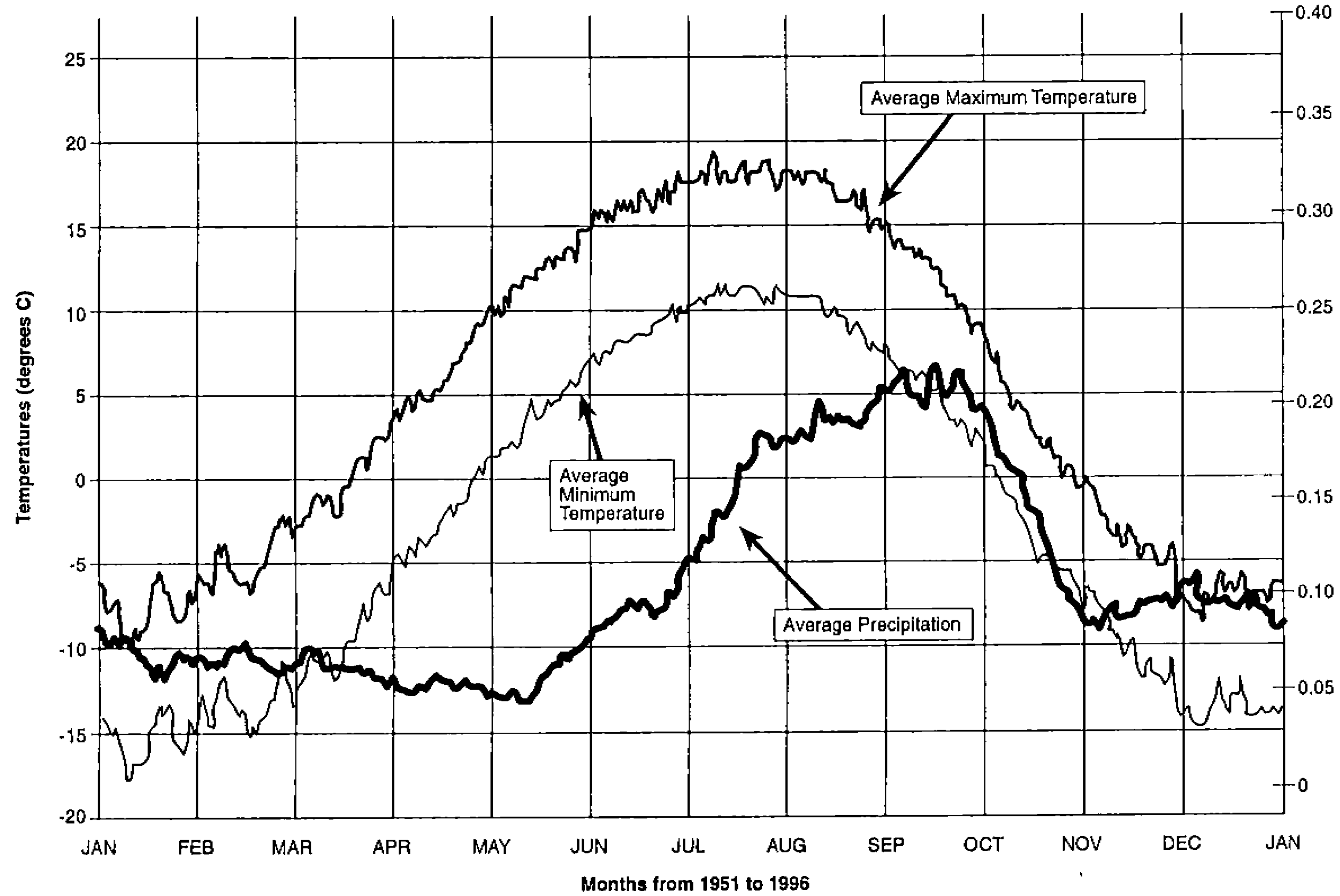

Source: National Weather Service, 1997.

Figure A-1

Average Daily Weather Information at Elmendorf AFB

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during the summer months are about 18°C and 11°C. The average daily temperature is about 14°C to 15°C.

2.5 Eagle River

ERF formed as the Eagle River eroded through the alluvial deposits of the Anchorage lowlands to create a deep valley, which later filled with fine-grained terrestrial and marine sediments. Evidence of the glacial alluviation can be seen as poorly sorted gravels in the steep bluffs surrounding ERF.

With an average daily flow rate of 15 cubic meters per second (m^3/sec), Eagle River drains approximately 50,000 hectares of mountains and lowlands. Glaciers cover 13 percent of the drainage basin. The river reaches average and peak discharges of 43 m^3/sec and more than 70 m^3/sec (respectively) in July and August because of glacial melt. However, a particularly heavy rainfall can generate a discharge greater than 103 m^3/sec (CH2M HILL, 1994). The peak discharge recorded was 291 m^3/sec on September 1995 (Kemper *et al.*, 1995; Brabets, 1996). High river flows will increase the water level height of the flooding tides because of the increased volume of water on the flats.

2.6 Sublimation/Oxidation

Sublimation/oxidation at ERF is the loss of WP by sublimation/oxidation of the contaminant from the sediment. This can occur during periods between flooding tides when the sediment may become unsaturated. This section summarizes the laboratory and field studies that have been performed to identify the best conditions for this action to occur naturally (Walsh in Racine *et al.*, 1994; Walsh and Collins in Racine, *et al.*, 1995).

In 1993, contaminated sediments were excavated from material near Canoe Point in Area C and placed into test plots, with and without greenhouse covers, on land adjacent to the excavation site. The plot with no cover also was tilled. The sediment dropped below water saturation 13 days after excavation. After 56 days, all samples had no detectable WP concentration. The average temperature was 2.4°C higher under the greenhouse cover. Although the weather was unusually warm and dry during this period, the greenhouse cover also could offer protection from rainfall under other circumstances.

In 1994, laboratory and field studies were performed. In the laboratory studies, WP particles were kept in ERF sediment samples held at different temperatures (4°, 15°, and 20°C) and soil moisture conditions (45, 64, 82, 100, and >100 percent saturation), and the particle mass was monitored. At 4°C, there was no change at any level of saturation except approximately 50 percent mass loss after 58 days under conditions of 45 percent saturation. At 15°C, there was no change in WP mass in the samples incubated at saturation or above. Under conditions less than saturation (45 and 64 percent), there was significant reduction (four and five orders of magnitude) after 30 days, and no WP was detected after 57 days. For a saturation of 82 percent, the results were inconsistent. Some samples had substantial rapid loss, and others persisted for more than 60 days. The inconsistent results probably derive from the open air channels present in some samples but not others. At 20°C, there was no change in mass at conditions of saturation and above. The samples at 45 and 64 percent saturation showed significant loss in mass (three to four orders of magnitude) after only 1 day of incubation. As before, the results were inconsistent at 82 percent saturation.

Field studies in 1994 of a transect of elevation changes across part of Area C demonstrated that the length of time at an unsaturated condition increased with elevation. At 5 cm below surface depth, the average temperatures were between 16°C and 17°C for the ponded and mud flat sites and 15°C on the river levee. No WP was lost at permanently flooded sites, but intermittent ponds and mud flats showed variable results that were significantly dependent on the length of time in unsaturated conditions. The incomplete loss of WP suggested the need for more than one summer of drying conditions to achieve substantial decreases in WP concentrations.

These studies have shown that the key to sublimation/oxidation is the achievement of desaturated sediments, particularly during warm summer months. These conditions can be best achieved if the time between flooding tides is long, rainfall is minimal, the sky is clear, and the temperature is warm. At the measured pond temperatures, sediment that is at no more than 65 percent saturation should show substantial (four to five orders of magnitude) reduction in WP concentration in about 30 days and reach nondetectable concentrations in about another 30 days.

3.0 Physical Characteristics of the Pond Groups

In addition to the general information discussed in Section 2, Lawson *et al.* also have reported on the processes of tides, gully recession (that is, erosion away from the river), and sedimentation for areas overlapping the pond groups. Gully names are shown in Figure A-2. Table A-3 summarizes the information available for the pond groups.

Except for the lower-level tidal flooding at Racine Island, all ponds at ERF flood at about the same pond elevation. There is considerable variation in the gully recession rates. Area C (Pond 183) appears to have a combination of gully recession and nearby ponds that could result in a pond breakthrough in possibly 10 to 15 years that would result in pond draining. There are no active gullies in Racine Island; thus, gully recession does not appear to have much impact on the long-term future of WP on the island.

Pond 155 and the ponds in Areas C and C/D tend to have a higher average accumulation of sediment because they have more vegetation, which helps to trap sediment, than do the other ponds. During the first 2 weeks of June 1995, the maximum sediment temperatures at 5-cm depth ranged from about 15°C to 28°C. The minimum temperatures ranged between 9°C and 17°C.

4.0 Summary of Potential WP Surface Sediment Losses

Table A-4 summarizes the potential opportunities and routes by which sublimation/oxidation of WP may occur at the hot ponds (ponds that contain WP). The long periods between flooding tides during 1997 and 1998 offer good opportunities for natural loss of WP in all ponds, at least around the perimeters, with the exception of Racine Island. The low flooding elevation of Racine Island ponds reduces the probability of substantial WP loss at those ponds. If WP loss is not substantial during these years, the next period of substantial drying is from 2001 through 2003. Pond 183 appears to have a good chance for natural pond draining in 10 to 15 years. Pond draining has the immediate effect of reducing the pond's attractiveness for ducks and swans, and the longer-term protection

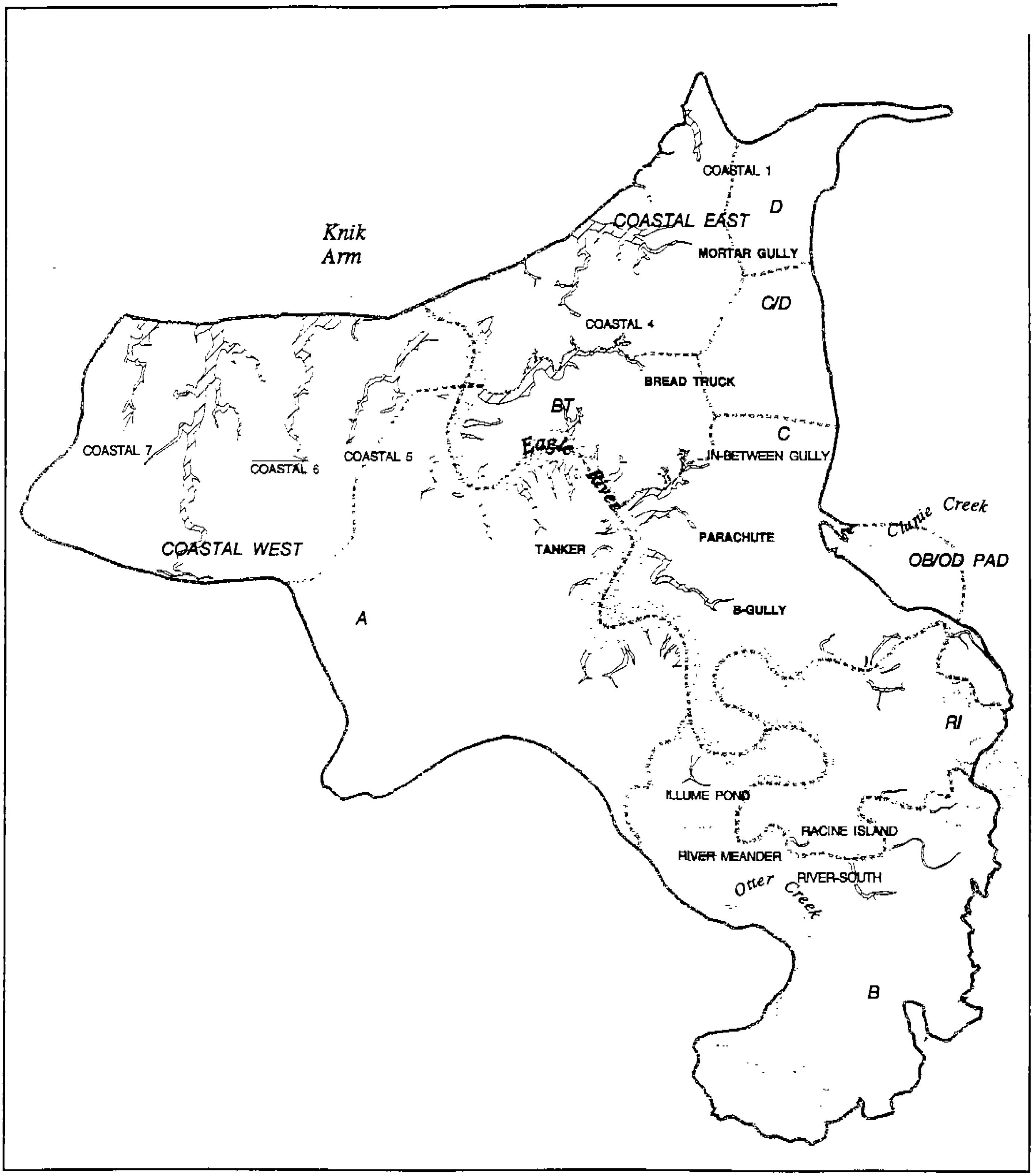

Figure A-2

Gully Names

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Scale 1:24000
1 cm = 240 m

0 meters 720

Mapping and database source:
CRREL, 1996.

River/Creek
Gully/Gully Name
Area Boundary
OUC Site Boundary

CH2M HILL

March 27, 1997 AML: /proj2/ert/rdfig.aml PLOT FILE: /proj2/ert/figa 21.eps

TABLE A-3
Summary of Physical Processes by Pond Group

Pond Group	Tidal Flooding	Gully Recession	Sedimentation
Northern A Ponds	Flooding occurs at 4.6 m msl.	At Tanker Gully, headward recession was less than 0.5 m per season (summer and winter) in 1994 and 1995. Lateral recession has been <0.1 m to 9 m per season.	Net sedimentation was 3.7 mm during the summer of 1995. Pond 258 had 15-20 mm sedimentation during summer 1994.
Pond 290	Flooding occurs at 4.6 m msl.	Headward recession was zero to 2.8 m and lateral recession was zero to 1.2 m in the interior of Area A during 1994.	No measurement specific to this pond. Northern A ponds showed an average net accumulation of 3.7 mm during summer 1995.
146	Flooding occurs at 4.6 m msl.	Distant from observed gully recession.	Northern C stations had net accumulation of about 30 mm over 3 years (1992-1995).
183	Flooding occurs at 4.6 m msl.	Parachute and B-Gullies have headward recession of 0.1 m to 3.4 m per season (winter and summer) and lateral recession of <0.1 m to 5.3 m per season. Large area of pond estimated to drain in 10 to 15 years.	Pond had net accumulation of 8.2 mm during summer 1995 and about 15 mm to 20 mm during summer 1994.
Northern C and C/D Ponds	Flooding occurs at 4.6 m msl.	Mortar Gully had headward recession of 0.3 m to 1.7 m per season (winter and summer), and a lateral recession of <0.1 m to 2.2 m per season. Ponds estimated to drain in more than 20 years.	Northern C stations had net accumulation of about 30 mm over 3 years (1992-95). Pond 155 had an average of 14.3 mm accumulation during summer 1995.
Pond 109 (Bread Truck)	Flooding occurs at 4.6 m msl.	Bread Truck Gully was forecast to drain the pond in 1996. Ditch was opened with explosives in spring 1996.	Average net sedimentation of 4.2 mm during summer 1995.
Racine Island	Flooding occurs at a relatively low elevation (4.35 m msl). Pond bottoms are rich in organic material.	Does not have high gully recession rate.	Average net sedimentation rate of 4.7 mm during summer 1995.

TABLE A-4
Summary of Potential Future Natural Restoration in Pond Groups

Pond Group	No Action Remediation Future	Conclusion
Northern A Ponds	1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation, at least around the perimeter. Gully recession may drain ponds, but time period is uncertain. Pond 258 may obtain sufficient sedimentation.	Some natural restoration at least around the perimeter is likely in a few years if good drying between tides. Protection by sedimentation or gully recession may take longer than 20 years. Pond 258 may have sufficient sedimentation in 10 years. To offer protection, sediment would have to be consolidated.
Pond 290	1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation, at least around the perimeter.	Some natural restoration around the perimeter is likely in a few years if good drying between tides. Protection by sedimentation or gully recession may take longer than 20 years.
Pond 146	1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation. Sediment may build up to 10 cm to 15 cm in 10 to 15 years.	Natural restoration from sedimentation appears possible within 10 to 15 years if sediments are consolidated and deep.
Pond 183	1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation. Large area of pond may drain in 10 to 15 years. Sediment may build up in similar time frame.	Natural restoration of at least the perimeter is likely in a few years if good drying between tides. Natural restoration from pond draining and sedimentation appears possible within 10 to 15 years.
Northern C and C/D Ponds	1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation, at least around the perimeter.	Natural restoration of at least the perimeter is likely in a few years if good drying between tides. Natural restoration from sedimentation appears possible within 10 to 15 years.
Pond 109 (Bread Truck)[a]	Pond was drained through breaching to a gully in 1996. 1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation.	Sublimation/oxidation is very likely to reduce the number and size of WP particles over the next few years.
Ponds 293 and 297 (Racine Island)[a]	Flooding occurs at fairly low elevation, so substantial WP loss through drying and warming not expected. In addition, the organic content of the sediment will make drying difficult. No significant gully recession. Low sedimentation rate.	Natural restoration not likely in 20 years. Planned action through pond breaching in 1997. Action should offer natural restoration by reducing the quality of duck habitat and thus the likelihood of duck exposure.
Pond 285 (Racine Island)[a]	Treated with AquaBlok™ in 1994. Sedimentation and revegetation have been observed.	Treatment prevents bird access to WP in this hot pond. Natural processes of burial and revegetation may enhance this treatment over time.

[a] Assumes past and planned treatment actions.
Note: Assessment is based on only a few years of data collection and is subject to change with new information. The assessment is made on the assumption that the observed processes of the past few years represent the future; however, the short period of these observations makes this assumption highly uncertain.

of waterfowl by WP loss through sublimation/oxidation from the resulting pond drying. From current information, it appears that the ponds in Area A may be protected in the future by gully recession or sedimentation, but probably not until more than 20 years from now. The exception is Pond 258, where sedimentation may provide a sufficient barrier in about 10 years. These conclusions on when natural restoration might be attained are summarized in Figure A-3.

This assessment is based on only a few years of data collection at ERF, and is subject to change with new information. The assessment is made assuming that the observed processes of the past few years represent the future, but the short period of these observations makes this a highly uncertain assumption. The time until effectiveness of sedimentation has been estimated assuming the seasonal sedimentation rates that have been observed and the target depth for clean sediment of about 15 cm. The long periods between flooding high tides create the opportunity for drying, but the amount of actual drying will also be affected by upwelling groundwater, if present; rain; the amount of sunshine; and air temperature.

5.0 Works Cited

Brabets, T.P. *Evaluation of the Streamflow-gaging Network of Alaska in Providing Regional Streamflow Information.* Anchorage, Alaska: U.S. Geological Survey, Water-Resources Investigations Report 96-4001. 1996.

CH2M HILL. *Eagle River Flats Comprehensive Evaluation Report.* Prepared for U.S. Army Garrison, Alaska, Department of Public Works, and Department of the Army, U.S. Army Engineer District Alaska. July 1994.

Kemper, J.E., L.A. Rundquist, D.B. Goldstein, J.E. Perry, and J.N. Marchbanks. *Flood Report: South Central Alaska Floods, September 19-October 2, 1995.* Anchorage, Alaska: National Oceanic and Atmospheric Administration. 1995.

Lawson, D.E., S.R. Bigl, and J.H. Bodette. Physical System Dynamics. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* C.H. Racine, ed. FY 93 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. May 1994. Pp. 25-83.

Lawson, D.E., S.R. Bigl, L.E. Hunter, B.M. Nadeau, P.B. Weyrick, and J.H. Bodette. Physical System Dynamics in Relation to White Phosphorus Transport and Remediation. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* Volume 1. C.H. Racine and D. Cate, eds. FY 94 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. May 1995. Pp. 53-184.

Lawson, D.E., L.E. Hunter, and S.R. Bigl. Physical System Dynamics, WP Fate and Transport, and Remediation. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* D.W. Cate and C.H. Racine, eds. FY 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. September 1996. Pp. 21-112.

Long, Steve. Personal communication with David Lincoln. February 21, 1997.

Walsh, M.E. Field Study of Air-drying Contaminated Sediment. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* C.H. Racine, ed. FY 93 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. May 1994. Pp. 313-321.

Walsh, M.E., and C.M. Collins. Investigation of Natural Size Reduction of White Phosphorus Particles in Eagle River Flats Sediments. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* Volume 2. C.H. Racine and D. Cate, eds. FY 94 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. May 1995. Pp. 471-528.

Walsh, M.E., C.M. Collins, and R.N. Bailey. Enhancement of Intrinsic Remediation of WP Particles by Sediment Warming in Intermittent Ponded Areas of Eagle River Flats. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* D.W. Cate and C.H. Racine, eds. FY 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. September 1996. Pp. 249-266.

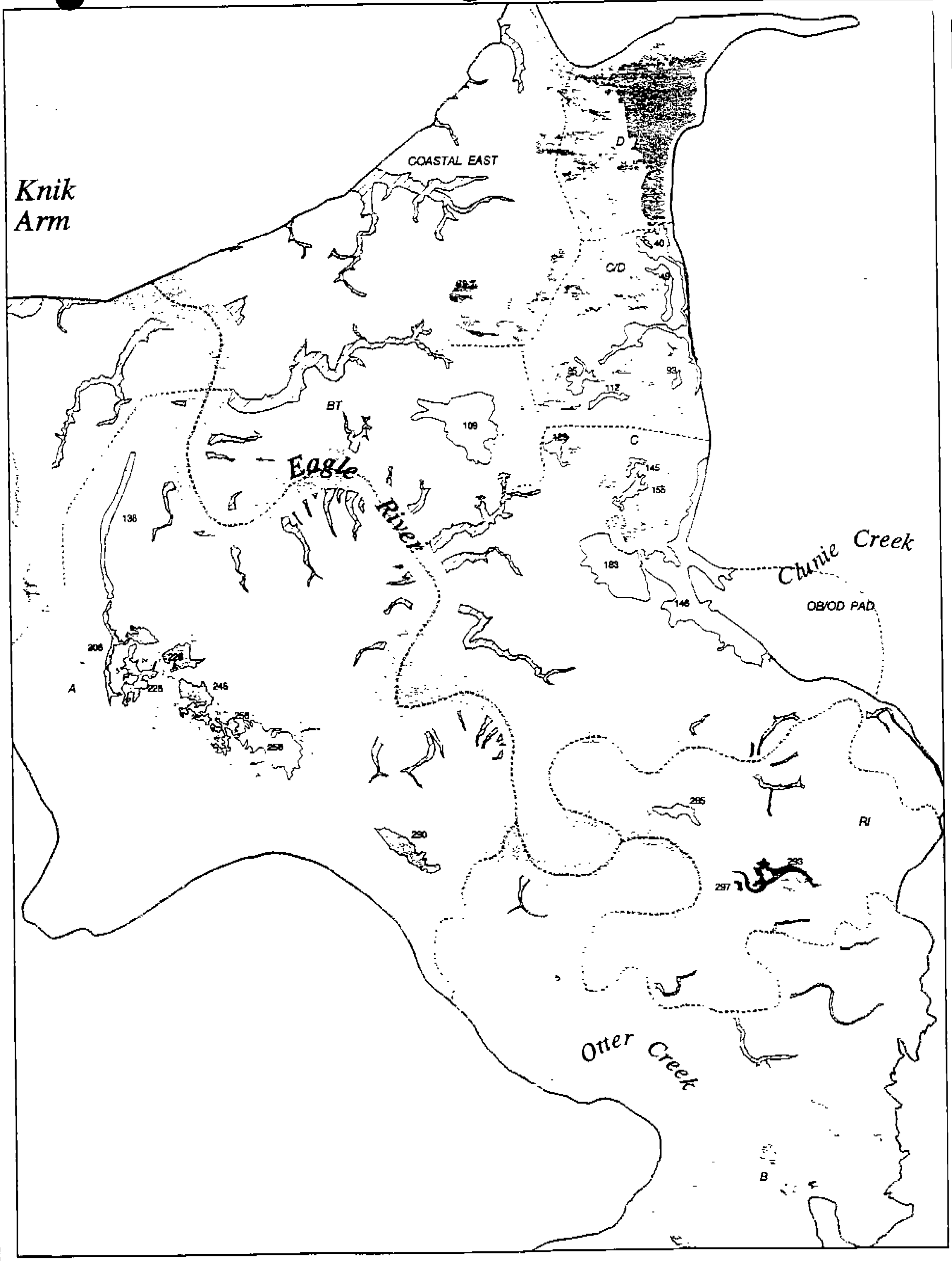

Figure A-3

Note:
Treatment has been or will be conducted at the following Hot Ponds:
Ponds 109, 293, & 297: Pond Draining by Breaching
Pond 285: AquaBlok™

Natural Processes

Scale 1:12000
1 cm = 120 m
0 meters 360
Mapping and database source: CRREL, 1996.

Permanent Pond
49 Hot Pond Number
Intermittent Pond
Gully
River/Creek
Area Boundary
OUC Site Boundary

NATURAL PROTECTION:
Likely within 5 yrs
Possibly within 10 - 15 yrs
May take more than 20 yrs
Very likely to take more than 20 yrs
Note: Assumes past and planned treatment actions

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Appendix B
Technology Screening

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Abbreviations

ARAR	applicable or relevant and appropriate requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
cm	centimeter
COE	U.S. Army Corps of Engineers
CWA	Clean Water Act
ERF	Eagle River Flats
FS	feasibility study
GIS	geographical information system
ha	hectare
m	meter
μg/g	micrograms per gram
NCP	National Contingency Plan
USEPA	U.S. Environmental Protection Agency
UXO	unexploded ordnance
WP	white phosphorus

APPENDIX B

Technology Screening

Under the National Contingency Plan (NCP), the process of analyzing alternatives for the feasibility study (FS) begins by identifying and screening technologies that might eliminate white phosphorus (WP) contamination at Eagle River Flats (ERF). Technologies retained following the screening process are assembled into alternatives that are evaluated further in the FS process (see Appendix F).

A description of the technologies that may be applicable at ERF and the screening process performed for this FS are presented in Section 1 of this appendix. Order of magnitude costs for three technologies that have been field tested are presented in Section 2. The appendix closes with Section 3, a discussion about dredging and why it was not retained as one of the alternatives that are evaluated in this FS.

1.0 Identification and Screening of Technologies

A broad range of restoration technologies has been considered at ERF. Many were not developed because of implementability concerns (such as the possible presence of unexploded ordnance [UXO] at the sites) or problems with effectiveness. The following 15 technologies were identified as being potentially applicable and were screened on the basis of implementability, effectiveness, and cost:

- Air sparging
- AquaBlok™
- Cap and fill
- Chemical oxidation
- Concover®
- Detailed monitoring of natural processes
- Dredging
- Explosive charges
- Geosynthetics
- Hazing
- Methyl anthranilate
- Enhanced sublimation/oxidation
- No action
- Pond draining by breaching
- Pond draining by pumping

These technologies were screened by focusing on the feasibility of each technology to be applied at ERF. Results of previous bench-scale studies, field tests, and treatability studies were reviewed and the screening results are summarized for each technology. The ERF studies that were examined for the technology screening are identified in Table B-1. A description of each technology and a summary of the screening process are presented in Table B-2. (The tables are attached at the end of the appendix.)

Although cost was a consideration during the screening, no technology was rejected solely on the basis of cost. Order-of-magnitude costs for the retaining treatment technologies were prepared and are presented in Section 2.

The technologies were screened to identify those that do not satisfactorily meet the criteria of implementability and effectiveness. The conclusions of this screening process are summarized in the far right column of Table B-2.

AquaBlok™, pond draining by breaching or pumping, and dredging were retained because previous treatability studies demonstrated that they may be effective and because they can be implemented at pond groups at ERF. Hazing was retained because it may be used as an interim measure before full implementation of the selected alternative. However, hazing does not provide long-term protection from WP. Sublimation/oxidation is retained because it is a natural process and is part of the no-action alternative.

The other technologies were eliminated from further consideration in the alternatives for ERF:

- **Air sparging.** Bench studies demonstrated that air sparging had little effect on WP-contaminated sediment.
- **Cap and fill.** Cap and fill may be effective and implementable. However, AquaBlok™ has been selected as the representative technology to be assembled into alternatives for the FS. AquaBlok™ was selected because of its cohesive properties and its ability to support vegetative growth.
- **Concover®.** The test application was quickly penetrated by water and floated to the surface within 30 minutes in the test trial. It was also readily damaged by ducks.
- **Explosive charges.** Field testing demonstrated that conditions were not sufficient for sediment released into the air by an explosive charge to oxidize.
- **Geosynthetics.** A reliable method for anchoring the liners was not identified. The liners did not survive the winter ice-out conditions.
- **Methyl anthranilate.** A single application is ineffective over the long term.
- **Chemical oxidation.** The test application had little effect and difficulties with mixing were anticipated for large-scale field application.
- **Enhanced sublimation/oxidation.** The enhancement did not increase the rate of loss of WP.

The technology screening process and how the retained technologies are assembled into alternatives are presented in Figure B-1. A detailed description of each assembled alternative is presented in Appendix C.

2.0 Order-of-Magnitude Unit Costs

Order-of-magnitude unit costs were prepared for technologies that were retained following the technology screening. These technologies are pond draining, AquaBlok™, and

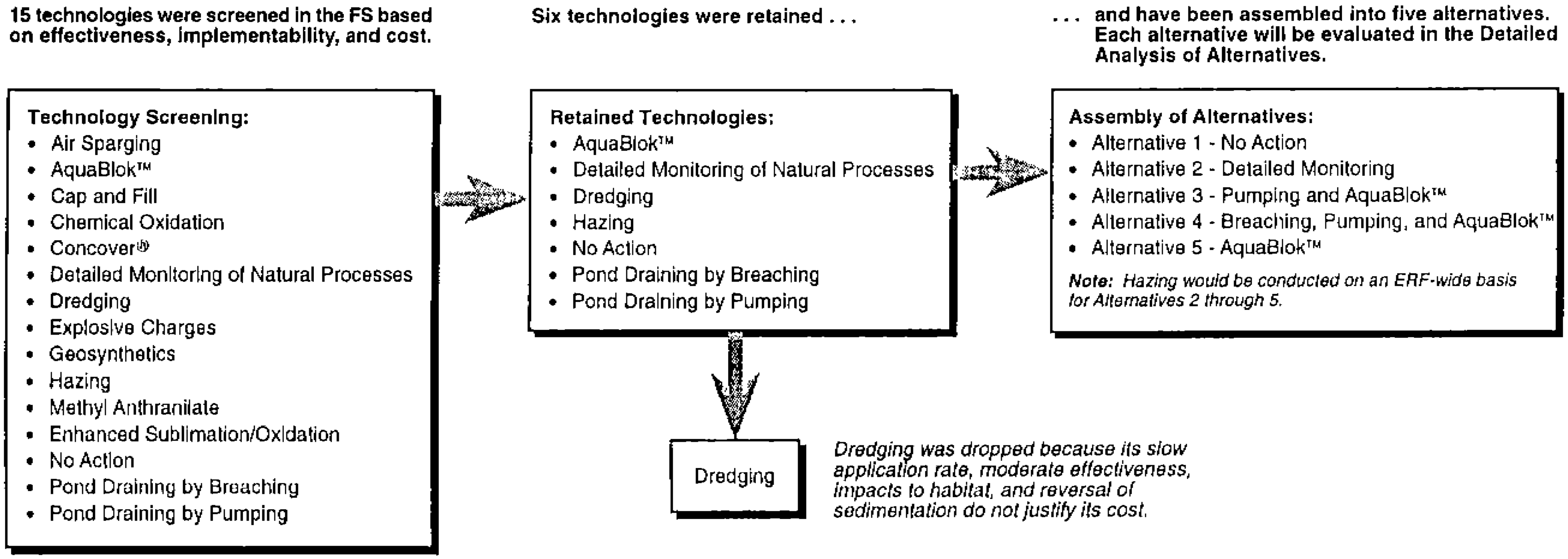

Figure B-1

Technology Screening and Alternatives Assembly Process

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dredging. The term "unit cost" refers to cost ($) per area treated (hectare [ha]). The preliminary cost estimates were based on field-scale treatability studies.

Actual costs to conduct treatability studies at ERF were used to calculate these order of magnitude unit costs. These unit costs, as a function of area treated, are presented in Figure B-2.

These order-of-magnitude estimates are used in the technology screening to rank retained technologies. These initial order-of-magnitude unit cost estimates suggest that AquaBlok™ may be more cost-effective in treating smaller ponds, whereas draining may be more cost-effective in larger ponds. Dredging costs were consistently higher, regardless of the size of the area to be treated. The unit cost of dredging is more than an order of magnitude higher than the cost of the other technologies. The costs of AquaBlok™ and pond draining by breaching or pumping are the same or within one order of magnitude.

Several significant assumptions were made when making these estimates, as described in the following sections. Verification sampling to determine the effectiveness of each technology was not included in the cost analysis.

A much more detailed budget-level cost estimate for assembled alternatives has been prepared and is presented in Appendix E.

2.1 Pond Draining

Pond draining may be conducted by either breaching or pumping. Generally, unit costs for breaching decreased significantly with the size of the area to be drained, because costs are actually a function of the length of ditch blasted to breach the pond.

The value of maintaining habitat was not factored into the costs. Pond drainage by breaching would destroy habitat; pumping would tend to preserve habitat. This issue is discussed in Appendix F.

The following subsections list assumptions that were made in the unit cost calculations.

2.1.1 Drainage by Breaching

- Unit cost as a function of length of ditch to be blasted was included in the cost estimates.
- It was assumed that U.S. Army troops will be available to set up the charges at no cost as part of their ongoing training.
- A cost for explosives of $100 per meter (m) of blasted ditch was assumed.
- A 120-m-long ditch was assumed. For ponds where breaching may be applicable, the average distance to a gully or the river is 80 to 160 m.
- A lump sum of $10,000 for planning was included. It includes design and coordination efforts.

2.1.2 Drainage by Pumping

- Refueling will be required twice per month, after each flooding tide. This is a conservative assumption based on the initial startup and shakedown of the pump system.

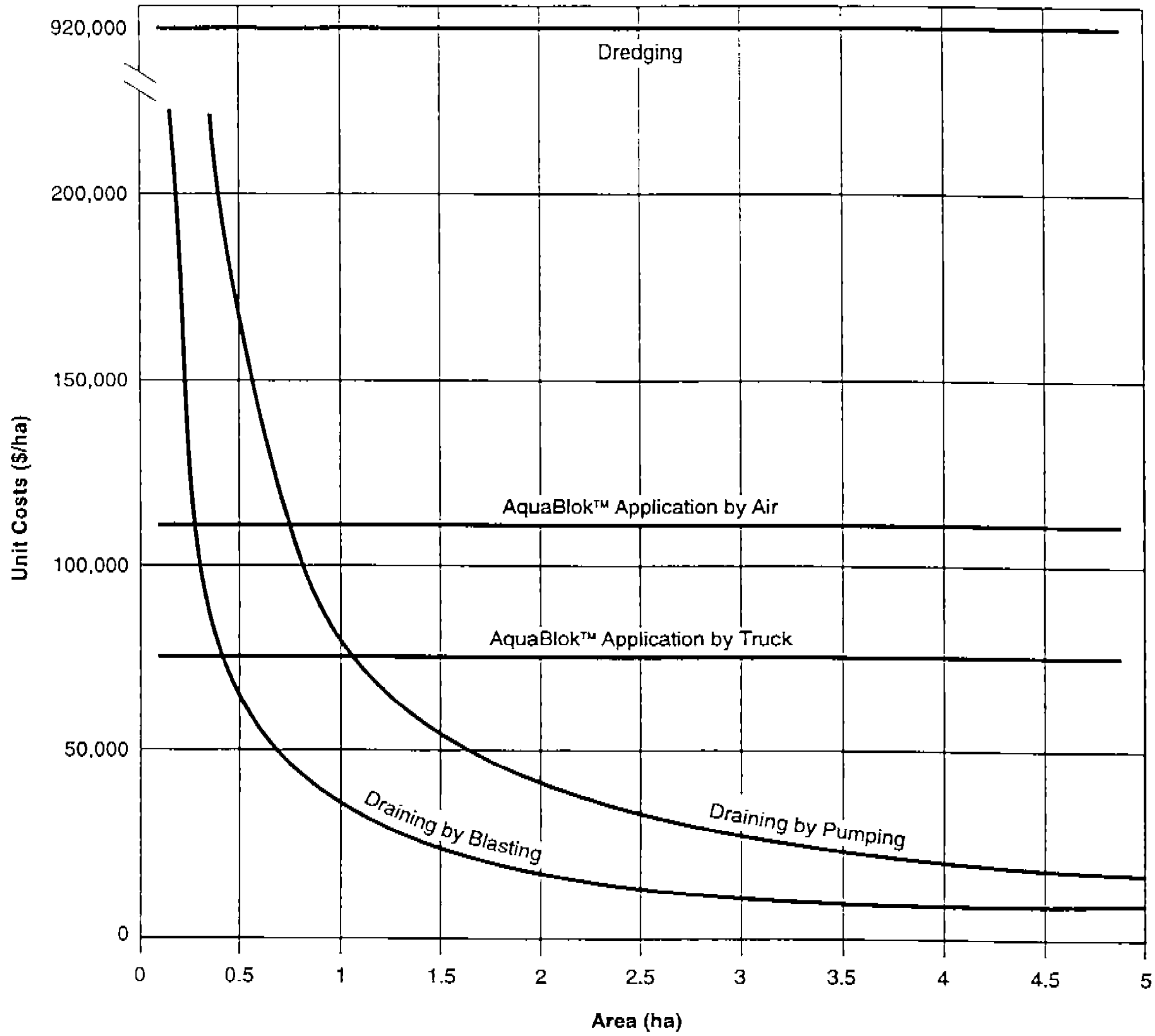

Figure B-2

Preliminary Estimates of Unit Cost as a Function of Area Remediated

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- Cost of blasting a sump for the pump was not included.
- The dry operating season is 5 months per year.
- It was assumed that only one operating season will be needed to dry sediments to achieve sublimation. It is likely that longer seasons will be needed if operation occurs during "wet" periods.
- Unit costs as a function of distance from gully or river were not calculated. A lump sum of $60,000 for the pump, generator, and discharge line was used regardless of the length of discharge line or capacity of pump needed.
- Six hours per month of labor were included to plan refueling efforts for one pump system.
- A lump sum of $10,000 for planning was included. It includes design and coordination efforts.

2.2 AquaBlok™

AquaBlok™ can be applied by either truck or air. Preliminary estimates of unit cost suggest that application by truck is 67 percent the cost of application by air. The following assumptions were made in the cost comparisons:

- Unit costs are directly proportional to area treated.
- Application by truck will be conducted in the winter.
- The AquaBlok™ treatability test at Racine Island was used to establish the application rate (area covered per hour), the quantity of materials needed per hectare, and the cost per quantity of AquaBlok™ material.
- The application rate was assumed to be the same by air and by truck. In the previous test, the 0.5-ha coverage required 9 hours of helicopter time. Although helicopters may be able to travel faster than trucks, trucks can carry greater loads than helicopters.
- Four operators and one helicopter are assumed for application by air.
- Six operators and two trucks are assumed for application by truck.
- From experience in previous studies, the Blackhawk helicopter rate (UH-60) was assumed to be $2,500 per hour and the truck rate was assumed to be $1,000 per day. Industry standards and vendor quotes will be used to calculate cost in the FS.
- Treatability studies indicate AquaBlok™ application is uneven over craters. Measurement of cover thickness and reapplication of AquaBlok™ were not included.
- A lump sum of $10,000 for planning was included. It includes design and coordination efforts.

Implementability and effectiveness of the two methods are not factored into these costs. It is unclear whether application by air or winter application by truck is more effective. Ice plucking and thaw conditions at ERF may reduce the effectiveness of AquaBlok™ if it is applied by truck. Conversely, application from trucks in the winter may be safer because the ice cover should largely protect against the danger of UXO. Travel on the flats in the winter is less restrictive than in the summer.

2.3 Dredging

The operations and maintenance cost of the dredge operation subcontractor was the only cost used to estimate unit costs because only that information was available. During the 1996 field season, 0.30 ha was dredged at a cost of $275,000, resulting in a unit cost of $920,000 per ha. This subcontractor cost is representative of minimum unit costs. The following are additional costs to implement dredging:

- Moving the dredge to different ponds with a Blackhawk (UH-60) helicopter
- UXO clearance
- Recompacting the existing retention basin
- Conducting hydraulic tests of the basin
- Removing spoils from the retention basin after spoils have been treated
- Extending the conveyance system to ponds farther away
- Siting and building an additional retention basin if a new one is required
- Building a new conveyance system to treat ponds on the west side of the Eagle River
- Preparing the implementation plan
- Project management and data interpretation
- Constructing another dredge if one is not enough

Even with only the subcontractor cost, the cost of dredging is at least an order of magnitude higher than costs of the remaining retained technologies. Mobilization costs during the 1996 field season were low because the dredge was already onsite and in operating condition. The 1996 study costs are representative of implementation costs. It is expected that the unit cost of dredging larger or smaller areas would be the same. The additional cost items listed above would only raise the estimates.

3.0 Screening out Dredging as an Alternative

Dredging was originally retained in the general screening of alternatives, presented in Section 1 of this Appendix. Dredging was demonstrated to be effective. However, after further evaluation, this technology has been dropped based on detailed evaluation of implementability and cost. In addition, impacts to physical and biological habitat and applicable or relevant and appropriate requirements (ARARs) were reviewed. These factors are presented in this section.

While dredging was found to be effective in reducing WP contamination, it did not eliminate WP. The 1996 field-scale study showed that performance specifications were not met. Wetlands regulations prohibit dredging in a wetland if another practicable alternative exists.

3.1 Effectiveness

Results from the 1996 field-scale treatability study indicate that dredging was effective in reducing WP, but not in eliminating it. Observations during 1996 and mid-1997 indicate that no ducks or swans died in areas dredged, whereas as recently in 1995, significant numbers of swans and ducks perished in this area. Different WP sampling and analytical methods were used in the pre- and post-dredging studies. Discrete samples were collected before dredge operations, whereas composite samples were collected after dredging. A brief summary of the sampling results is presented in this subsection.

Two sources of information constitute the basis for the following discussion on the effectiveness of dredging for WP removal at ERF. Results from recent dredging operations were documented in a draft report by Collins *et al.* (1997). In addition, the ERF geographical information system (GIS) database was screened to determine the analytical results for WP in sediment samples that had been collected before dredging near the area to be dredged.

After dredging, composite WP sampling was conducted along 27 transects aligned perpendicular to the dredged channels. Of the 31 samples collected to estimate post-dredging WP concentrations in sediment, 3 samples indicated detectable quantities of WP ranging from 0.076 to 3.800 micrograms per gram (μg/g). The average post-dredging concentration in the samples was 1.386 μg/g (Walsh, *et al.*, in Collins *et al.*, 1997).

However, it was felt that comparison of pre-dredging to post-dredging samples would be stronger if the comparison were limited to the specific area of investigation rather that all known contaminated areas at ERF. The screening of the GIS system revealed that 133 discrete sediment samples had been collected in the rectangular area depicted in Figure 7 of the dredging report (Walsh, *et al.*, in Collins *et al.*, 1997). These data are divided into samples classified as known (K, n=51) or unknown (U, n=82) based on previous sampling results. This classification was intended to distinguish sediment grab samples with no previous analytical data from those samples collected in locations with previous WP detections or samples collected in a WP-spike location (associated with sublimation/oxidation studies). To avoid bias associated with resampling in known WP locations, only the 82 unknown WP samples were considered for comparison to the post-dredging results.

The GIS analysis indicated that pre-dredging WP contamination (measured in discrete samples) was detected in 31 of 82 samples. The pre-dredging WP concentrations in the sediment samples where WP was detected ranged from 0.00034 to 70.116 μg/g. The average concentration in the pre-dredging samples where WP was detected was 3.049 μg/g. The results indicate that dredging can be effective for reducing WP in certain areas.

3.2 Implementability

Several problems were encountered during the summer 1996 implementation of dredging. First, the dredge was not operated within performance specifications. A dredge channel depth of 90 centimeters (cm) had been specified. However, post-dredge depth measurements averaged 60 cm.

Dredge performance was reduced by rapidly changing tide elevations, hardpan pond bottom, and vegetation. Performance may be improved in more open areas. During the 1995 operation of the dredge, a depth of 90 cm was achieved in two passes.

Second, the rate of implementation was slow. During the 1996 field season the dredge was capable of dredging only 0.3 ha in 5 weeks. Assuming a 5 month field season each year, only 1.3 ha could be treated every year. The 1996 field season is representative of full scale implementation. The rate of full-scale implementation is expected to be similar to the rate observed in 1996.

The rate of implementation is largely a function of the mobility of the dredge. Although the dredge is remotely operated, it can move around freely in only approximately 0.2 ha. The dredge is connected to a series of guide wires and anchor points. To move the dredge to another area (even within the same point) would involve reestablishing the guide wire and anchor point system. With the short summer field season, it would take several years to reach cleanup goals using only one dredge.

Third, hazards implicit to the setup and operation of the dredge system were high. As discussed previously, the dredge is connected to a series of guide wires and anchor points. Moving the dredge either to a new area or within the same area involves personnel working on ground within the pond system. Visual clearance of pond bottoms is generally not possible because of free-standing water. The dredge requires water in which to operate.

Engineering controls have been implemented to reduce (but not eliminate) risk of human exposure to UXO. The dredge operator resides in an explosion-proof shelter and operates the dredge remotely. All walking pathways and work areas are cleared by UXO specialists for metal debris.

The hazards of UXO to humans in the setup and operation of the dredge system are considerably higher than risks posed by other retained technologies. Breaching, pump installation, and AquaBlok™ application are either performed aerially or in the winter. Setup of the pumping conveyance pipeline is along a designed walkway that is easily established and cleared for UXO. Pond bottoms of drained ponds would be exposed for visual clearance before and during WP Sampling.

Hazards to the costly dredge equipment are also high. The dredge moves 60 to 90 cm of sediment material, some with the high potential of containing UXO. In comparison, the pumping system tested at Pond 183 in summer 1997 moves only water and does not disturb the sediment or pond bottoms.

While the implemented engineering controls described previously do reduce risks, the risks in dredge operations are still considerably higher than in other retained technologies.

3.3 Cost

As discussed in Section 2, the cost of dredging on a unit basis is more than an order of magnitude more than other technologies that were retained after the technology screening process. The unit costs cited in Section 2 included only leasing fees and operations costs. It did not include many costs related to the retention basin, the conveyance system, project management, or sampling that would significantly increase costs.

3.4 Fate and Transport Mechanisms

Dredge depth may be shallower than depth of WP particles. Dredging may redistribute the WP sediments and not remove particles in deeper sediment. These processes are discussed in this subsection.

The WP fate and transport mechanisms involved in dredging are anticipated to be similar to those discussed in Sections 4.4.2 and 4.4.3 of the *Comprehensive Evaluation Report* (CH2M

HILL, 1994). White phosphorus is more dense than water (specific gravity = 1.82) so it will be expected to sink if the particles are large enough. Colloid-size WP particles may stay suspended in the water column for extended periods of time. The ERF conceptual site model indicates that processes that disturb sediments containing WP (such as erosion by water) resuspend the WP particles. Some of these particles sink back through the water column where they may be found at the surface of or mixed with bottom sediments. Very small WP particles can be found suspended in the water column as colloidal particles. However, collodial particles are not considered a threat to waterfowl.

Dredging would be expected to remove a large proportion of the WP particles along with the sediments in the dredge area. This was the case indicated by WP sampling during the 1996 dredging field studies. However, the removal of WP assumes that the depth of WP sediment contamination is not deeper than the depth of dredging. Given the physical dynamics of sedimentation and erosion at ERF, it would be difficult to accurately determine the depth and extent of WP without detailed sampling. In addition, the performance of the dredge in the 1996 field season did not meet specifications (that is, the dredged channel was shallower than specified). It is expected that some of the WP particles will not be taken in by the dredge pump and will resettle on or near the surface of the sediments at the bottom of the dredged channels and ponds.

Another effect of dredging would be the reversal of sedimentation processes. While the degree of sedimentation varies throughout the flats, sedimentation processes are currently occurring (as described in Appendix A). In some areas, sedimentation may cover pond bottoms to such a degree that WP is no longer hazardous to waterfowl. Dredging of such areas would remove this protective layer. If dredging is not completely successful in eliminating WP, as was demonstrated in the 1996 field study, the dabbling ducks would be re-exposed to WP-contaminated sediment.

3.5 Alteration of Waterfowl Habitats

Dredging alters habitat in two ways:

- Shallow ponds or channels that previously provided foraging areas for dabbling ducks may become too deep for the ducks to reach the bottom by their normal feeding behavior.
- Food sources that have been established at the pond bottom would be physically removed by dredging. Such sources include roots, insects, and plants.

If a food source still remained or could be reestablished, the deepening of the ponds could be viewed positively. The shallow-water habitats could be transformed into deeper-water habitats where swans would be more likely to forage, and they would be able to forage among the bottom sediments. The dredging conducted from 1994 to 1996 removed sediments to varying depths, as reported by Walsh, *et al.*, in Collins *et al.* (1997). In some of the dredged areas (especially the channel to "C-Pond"), the post-dredging water depth was relatively shallow (average 47 cm) and ducks may be able to feed in much of that area. However, the Clunie channel and inlet was dredged to a greater depth (average 70 cm), and sediments in this area would be more accessible to swans than to ducks. In addition, five families of ducks, including wigeon, shovelers, and mallards, were observed by dredge operators using the dredged areas off Clunie Point in the spring of 1996.

Draining ponds by blasting alters habitat in the following ways:

- Submerged foraging habitat for dabbling ducks would be greatly decreased in size because the pond would hold water within a much smaller area.
- The sediments exposed by blasting would be completely rewetted during flood events, but retention of the water would be limited. It is anticipated that this would lead to changes in vegetation communities and cover.

After the pond is breached by blasting, the standing water portions will be much smaller. Periodic rewetting and sedimentation would still occur on the newly exposed sediments by flooding. However, because the pond would retain only a small fraction of the water, vegetation communities would likely change to drier plant types. If a pond previously provided regular forage for dabbling ducks, this habitat value would be significantly reduced once the pond was drained by blasting. The changes would be considered permanent alterations in pond habitat.

Pumping ponds alters habitat in the following ways:

- Free water surface areas and submerged feeding habitat will be reduced in the short term. The pond alterations would be temporary.
- The exposed sediments would be completely rewetted at each flooding tide because the ponds will still have their capacity to retain water; therefore, significant modifications to vegetation communities are not anticipated.

With this alternative, the ponds would be drained only during the part of the summer when the most sediment drying can be effected. Periodic flooding of the ponds would return them to their original conditions through sedimentation and complete rewetting of the exposed pond bottoms.

In addition, the alteration of waterfowl habitat may be exacerbated by the fact that the vegetation growing season is the same as the most significant drying season. The greatest waterfowl impact will be during the fall usage period because need for food and resting area follows the drying/growing. Loss of the short growing season may cause significant, but temporary, loss of suitable waterfowl habitat.

3.6 Compliance with Wetland Regulation Requirements

Section 404 of the Clean Water Act (CWA) authorizes the U.S. Army Corps of Engineers (COE) to regulate the discharge of dredged or fill material into all "waters of the United States (including wetlands)." The definition of "discharge of dredged material" was revised by the U.S. Environmental Protection Agency (USEPA) and the COE (*Federal Register* 58:45008) on August 25, 1993, in regulations that incorporated some of the activities that were formally regulated under Section 10 of the Rivers and Harbors Act of 1899. Section 10 was the original legislation that authorized the COE to regulate structures and work in navigable waters of the United States, including bank stabilization, dredging, excavation, and establishment of temporary or permanent structures.

Under the newly defined "discharge of dredged material" the COE regulates discharges associated with mechanized landclearing, ditching, channelization, and other excavation activities that destroy or degrade wetlands or other waters of the United States under

Section 404 of the CWA. This definition specifically excludes from Section 404 regulation discharge activities that have only minimum, inconsequential environmental effects (USEPA, 1994).

The classification of ERF as a Superfund (Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]) site means that activities at the site are governed under CERCLA regulations, which supersede other environmental regulations. Section 404 permits are not required for onsite Superfund actions at ERF. However, compliance with the ARARs of other environmental laws is an important part of CERCLA, as detailed in Section 12(d). As such, the substantive requirements of the CWA Section 404 (b)(1) guidelines (hereinafter referred to as the Guidelines) may be applied as relevant and appropriate to activities conducted in wetlands at ERF.

The Guidelines were promulgated as regulations in the *Code of Federal Regulations* (CFR) Chapter 40, Section 230.10 (40 CFR 230.10). They describe the authority of the COE to deny permits as follows (USEPA, 1994):

- CFR 230.10(a) states that no discharge of dredged or fill material (including dredging) shall be permitted if a practicable alternative exists to the proposed discharge that would have less impact on the aquatic ecosystem, as long as the alternative does not have other significant adverse environmental consequences.
- CFR 230.10(b) states that no discharge of dredged or fill material shall be permitted if it causes or contributes to violations of any applicable State water quality standard; violates any applicable toxic effluent standard or discharge prohibition under CWA Section 307 (Toxic and Pre-treatment Effluent Standards); jeopardizes endangered or threatened species or their habitat designated as critical habitat under the Endangered Species Act of 1973; or violates requirements to protect any marine sanctuary designated under Title III of the Marine Protection, Research, and Sanctuaries Act of 1972.
- CFR 230.10(c) prohibits discharges (or activities) that will cause or contribute to significant degradation of the waters of the United States.
- CFR 230.10(d) states that when a discharge (or activity) would degrade the waters of the United States, and there are no practicable alternatives to the discharge, compliance with the Guidelines can be achieved generally through the use of appropriate and practicable mitigation measures to minimize or compensate for potential adverse impacts of the discharge (or activity) on the aquatic ecosystem.

In applying the Guidelines, the COE requires a hierarchical approach to wetland mitigation measures: (1) impact avoidance; (2) impact minimization; and (3) compensatory mitigation. Based on these approaches, the use of dredging as a remedial strategy at ERF can be justified only if it is decided by the Agencies that there are no practicable alternatives to dredging.

Minimization of impacts would be difficult in a dredging operation because the sediment and plant substrates are completely removed without possibility of replacement. Thus, habitat changes would likely be permanent.

3.7 Summary

Dredging has been dropped from further consideration in this FS because its effectiveness does not justify its cost and implementation problems. In addition, dredging also removes the protectiveness of sedimentation, exposing dabbling ducks and swans to residual contamination. Dredging may also redistribute WP particles.

The rate of dredging application is estimated to be only approximately 1.3 ha per year.

Wetlands regulations prohibit dredging if another, less permanent, alternative is available. Habitat changes that result from other remedial activities such as pond draining by pumping may be considered temporary because original conditions would likely be re-established as ponds are refilled. Dredging may result in permanent changes where the habitat type is modified (for example, shallow-water feeding habitat to deep-water feeding habitat) and food sources are removed.

4.0 Works Cited

CH2M HILL. *Eagle River Flats Comprehensive Evaluation Report.* Prepared for U.S. Army Garrison, Alaska, Department of Public Works, and Department of the Army, U.S. Army Engineer District, Alaska. July 1994.

Walsh, M.R., and C.M. Collins. Monitoring of Contract Dredge Operations at Eagle River Flats, Alaska. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* C.M. Collins and D.W. Cate, eds. FY 96 Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. July 1997. Pp. 73-100.

U.S. Environmental Protection Agency (USEPA). *Considering Wetlands At CERCLA Sites.* Office of Solid Waste and Emergency Response, EPA540/R-94/0199 PB94-963242. May 1994.

Attachment 1
Tables

TABLE B-1
Identification of ERF Treatability Studies

Technology	Year Published[a]	Fiscal Year[b]	Title of Paper	Authors	Organization
AquaBlok™	1996	1995	Evaluation of AquaBlok™ on Contaminated Sediment to Reduce Mortality of Foraging Waterfowl	Pochop, Patricia A., John L. Cummings, and Christi A. Yoder	Denver Wildlife Research Center
AquaBlok™	1995	1994	Evaluation of AquaBlok™ on Contaminated Sediments to Reduce Mortality of Foraging Waterfowl	Pochop, Patricia A., John L Cummings, and Christi A. Yoder	Denver Wildlife Research Center USDA
AquaBlok™	1994	1993	Evaluation of Concover and BentoBalls on Contaminated Sediments to Reduce Mortality on Foraging Waterfowl	Pochop, Patricia, John Cummings, Larry Clark, and James E. Davis, Jr.	Denver Wildlife Research Center USDA
Chemical Oxidation	1993	1992	Chemical Oxidation	Racine, C. H., M.E. Walsh, C.M. Collins, D. Lawson, K. Henry, L. Reitsma, B. Steele, R. Harris, and S.T. Bird	U.S. Army Cold Regions Research and Engineering Laboratory
Chemical Oxidation	1992	1992	Remediation Techniques: Literature Review and Preliminary Studies	Racine, Charles H., Marianne E. Walsh, Charles M. Collins, Susan Taylor, Bill D. Roebuck, Leonard Reitsma, and Ben Steele	U.S. Army Cold Regions Research and Engineering Laboratory and Dartmouth College
Concover®	1994	1993	Evaluation of Concover and BentoBalls on Contaminated Sediments to Reduce Mortality on Foraging Waterfowl	Pochop, Patricia, John Cummings, Larry Clark, and James E. Davis, Jr.	Denver Wildlife Research Center USDA
Dredging	1996	1995	Dredging as a Remediation Strategy for White-Phosphorus-Contaminated Sediments at Eagle River Flats	Walsh, Michael R.	U.S. Army Cold Regions Research and Engineering Laboratory

TABLE B-1
Identification of ERF Treatability Studies

Technology	Year Published[a]	Fiscal Year[b]	Title of Paper	Authors	Organization
Dredging	1996	1996	Dredging in an Active Artillery Impact Area Eagle River Flats, AK. Special Report 96-22	Walsh, Michael R., Edwin J. Chamberlain, Karen S. Henry, Donald E. Garfield, and Ed Sorenson	U.S. Army Corps of Engineers, Cold Regions Research & Engineering Laboratory
Dredging	1996	1996	Monitoring of Contract Dredge Operations Eagle River Flats, AK. 1996 Draft Report.	Walsh, Michael R., and Charles M. Collins	U.S. Army Cold Regions Research and Engineering Laboratory
Dredging	1995	1994	Dredging as a Remediation Strategy for White-Phosphorus-Contaminated Sediments at Eagle River Flats, Alaska	Walsh, Michael R., Edwin J. Chamberlain, and Donald E. Garfield	U.S. Army Cold Regions Research and Engineering Laboratory
Geosynthetics	1995	1994	Screening Study of Barriers to Prevent Poisoning of Waterfowl in Eagle River Flats, Alaska	Henry, Karen S.	U.S. Army Cold Regions Research and Engineering Laboratory
Geosynthetics	1994	1993	Geosynthetic Covering of Contaminated Sediment	Henry, K.	U.S. Army Cold Regions Research and Engineering Laboratory
Geosynthetics	1993	1992	Geosynthetic Covering of Contaminated Sediment	Racine, C. H., M.E. Walsh, C.M. Collins, D. Lawson, K. Henry, L. Reitsma, B. Steele, R. Harris, and S.T. Bird	U.S. Army Cold Regions Research and Engineering Laboratory
Hazing	1996	1995	Hazing at Eagle River Flats	Rossi, Corey	USDA Animal and Plant Health Inspection Service, Animal Damage Control

TABLE B-1
Identification of ERF Treatability Studies

Technology	Year Published[a]	Fiscal Year[b]	Title of Paper	Authors	Organization
Hazing	1996	1996	Movement, Distribution and Relative Risk of Mallards and Bald Eagles Using Eagle River Flats: 1996. U.S. Army Eagle River Flats: Protecting Waterfowl from Ingesting White Phosphorus. Technical Report 96-1.	Cummings, John, Richard Johnson, Kenneth Gruver, Charles Racine, Patricia Pochop, and James Davis	Denver Wildlife Research Center USDA
Hazing	1995	1994	Hazing at Eagle River Flats	Rossi, Corey	USDA Animal and Plant Health Inspection Service, Animal Damage Control
Hazing	1994	1993	Hazing Waterfowl in ERF	O'Neil, P.	USDA
Methyl Anthranilate	1995	1994	Chemical Hazing of Free-Ranging Ducks in Eagle River Flats: Field Evaluation of ReJeX-iT WL-05	Clark, Lawrence, and John Cummings	Denver Wildlife Research Center USDA
Methyl Anthranilate	1994	1993	Laboratory Evaluation of a Methyl Anthranilate Bead Formation for Reducing Mallard Mortality and Feeding Behavior	Cummings, John L., Larry Clark, Patricia A. Pochop, and James E. Davis, Jr.	Denver Wildlife Research Center USDA
Methyl Anthranilate	1994	1993	Field Behavioral Response and Bead Formulations for Methyl Anthranilate Encapsulated Bird Repellents	Clark, L., and J. Cummings	USDA
Methyl Anthranilate	1994	1993	Field Evaluation: Mortality of Mallards Feeding in Areas Treated with Methyl Anthranilate	Cummings, John L., Larry Clark, and Patricia A. Pochop	USDA

TABLE B-1
Identification of ERF Treatability Studies

Technology	Year Published[a]	Fiscal Year[b]	Title of Paper	Authors	Organization
Pond Draining–Blasting a Channel	1996	1996	Pond Draining Treatability Study: 1996 Studies-The Draining of Bread Truck Pond. Draft FY96 Report: Pond Draining Treatability Study Ver. 2.1.	Collins, Charles M., Michael T. Meeks, Marianne E. Walsh, and Ronald N. Bailey	U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory
Pond Draining–Pumping	1994	1993	Pond Draining Treatability Study	Collins, C.M.	U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory
Pond Draining–Pumping	1996	1995	Pond Draining Treatability: 1995 Studies	Collins, Charles M., Edward F. Chacho, Jr., Michael R. Walsh, and Marianne E. Walsh	U.S. Army Cold Regions Research and Engineering Laboratory
Pond Draining–Pumping	1995	1994	Ponding Draining Treatability Study	Collins, Charles M.	U.S. Army Cold Regions Research and Engineering Laboratory
Sublimation/ oxidation	1996	1995	Intrinsic Remediation of WP Particles in Intermittent Ponded Areas of ERF	Walsh, Marianne E., Charles M. Collins, and Ronald N. Bailey	U.S. Army Cold Regions Research and Engineering Laboratory
Sublimation/ oxidation	1996	1996	Natural Attenuation of White Phosphorus Contamination by Physical Processes, Eagle River Flats, Fort Richardson, AK CRREL Report 96-13.	Lawson, Daniel E., Lewis E., and Susan R. Bigl	U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory
Sublimation/ oxidation	1995	1994	Investigation of Natural Size Reduction of White Phosphorus Particles in Eagle River Flats Sediments	Walsh, Marianne E., and Charles M. Collins	U.S. Army Cold Regions Research and Engineering Laboratory
Sublimation/ oxidation	1994	1993	Field Study of Air-Drying Contaminated Sediment	Walsh, M.E.	USDA

TABLE B-1
Identification of ERF Treatability Studies

Technology	Year Published[a]	Fiscal Year[b]	Title of Paper	Authors	Organization
Sublimation/ oxidation	1993	1992	Air-Drying of Contaminated Sediments	Racine, C. H., M.E. Walsh, C.M. Collins, D. Lawson, K. Henry, L. Reitsma, B. Steele, R. Harris, and S.T. Bird	U.S. Army Cold Regions Research and Engineering Laboratory
Sublimation/ oxidation	1992		Remediation Techniques: Literature Review and Preliminary Studies	Racine, Charles H., Marianne E. Walsh, Charles M. Collins, Susan Taylor, Bill D. Roebuck, Leonard Reitsma, and Ben Steele	U.S. Army Cold Regions Research and Engineering Laboratory and Dartmouth College
Enhanced Sublimation/ oxidation	1996	1995	Enhancement of Intrinsic Remediation of WP Particles by Sediment Warming in Intermittent Ponded Areas of Eagle River Flats	Walsh, Marianne E, Charles M. Collins, and Ronald N. Bailey	U.S. Army Cold Regions Research and Engineering Laboratory

[a]Year Published–Year that final report was published.

[b]Fiscal year–Year that study was performed. In most cases, "FY" also indicates the CRREL report volume in which the paper is presented.

TABLE B-2
Summary of Remedial Technology Screening

General Response Action	Technology	Process Option	Description	Implementability	Effectiveness	Cost	Screening Result
Containment	Horizontal barriers	AquaBlok™	AquaBlok™, available from New Wastes Concept, Inc., Erie, Michigan, is a composite material containing calcium bentonite/organoclays, gravel, and polymers. Since 1993, the use of AquaBlok™ as a cap for contaminated pond bottoms has been evaluated first by bench-scale testing and then by treatability testing in ERF. The AquaBlok™ is applied to the pond bottoms by dropping it from a helicopter or truck into the pond. The AquaBlok™ hydrates after application, expanding vertically and horizontally, sealing the interstitial spaces in the gravel. AquaBlok™ barrier permeabilities as low as 10^{-9} centimeters (cm) per hour have been measured.	Since 1993, treatability studies have been conducted at ERF to evaluate the feasibility of using AquaBlok™ to provide a physical barrier to dabbling waterfowl in contaminated ponds. In 1995, AquaBlok™ was applied to Pond 258 on Racine Island. If truck application is used, exposure to unexploded ordnance (UXO) will be minimized by implementation during iced conditions at ERF.	AquaBlok™ on Pond 285 showed minimal deterioration upon examination in 1996. It has been demonstrated that within 1 year of initial application, vegetative growth over the barrier becomes lush and is inhibited only in areas where the AquaBlok™ application was thickest. Fish and invertebrates also were observed in ponded areas treated with AquaBlok™. The new vegetation provides areas where waterfowl can hide or loaf; however, there is a potential habitat loss because the AquaBlok™ reduces the depth of treated ponds and results in the loss of some shallow areas where waterfowl can dabble. The long-term effectiveness of AquaBlok™ is unknown.	Preliminary cost estimates indicate that unit costs for AquaBlok™ application by air and by truck are $101,000 per hectare (ha) and $68,000 per ha, respectively.	AquaBlok™ is retained as a representative technology for horizontal barriers. It has been demonstrated that it might be effective and can be implemented at portions of ERF.
Containment	Horizontal barriers	Cap and fill	Capping and filling also may be used to provide a physical barrier to contaminated pond-bottom sediments. The cap/fill alternative is similar to the use of AquaBlok™; however, untreated sand or gravel is used in place of the composite material. This alternative has not been treatability-tested at ERF. Method(s) of application would be the same as those for the AquaBlok™ alternative.	Capping and filling is similar in principle to the AquaBlok™ alternative. Exposure to UXO would be minimized by implementation during iced conditions at ERF or by aerial release.	Permeability of a gravel cap is likely to be several orders of magnitude greater than the permeability observed for the AquaBlok™ barrier. While the permeability of gravel may permit underlying sediment to dry if water levels decline, the exposure of dabbling ducks to WP would still exist during ponded conditions. Therefore, a thick gravel layer that can resist erosion would be required to overcome permeability problems and break the pathway for ingestion of WP by waterfowl. In addition, gravel does not have the cohesive properties of AquaBlok™ material and its resistance and strength are lower. Vegetation is not expected to rebound successfully through gravel material, whereas the clay substrate of AquaBlok™ encourages vegetative growth.	Because the gravel particles do not require coating, unit costs would be substantially less than the unit costs for the AquaBlok™ alternative. Gravel costs approximately $15 per ton. Application methods likely would be the same as those used for placement of the AquaBlok™ barrier. Aerial application would cost approximately $56,000 per hectare.	Cap and fill with gravel is not expected to perform. AquaBlok™ has been selected as the representative technology.

General Response Action	Technology	Process Option	Description	Implementability	Effectiveness	Cost	Screening Result
					The revegetation rates likely would be longer than those observed for the AquaBlok™ alternative. AquaBlok™ works quicker primarily because the calcium bentonite/ organoclays in AquaBlok™ provide nutrients and also fill the interstitial spaces between gravel particles, allowing the aquatic plants to reestablish roots relatively fast. Over a longer period of time, sedimentation will likely fill the voids of a gravel barrier and provide a particulate and organic mat sufficient for aquatic plants to root.		
Containment	Horizontal barriers	Concover®	Concover®, provided by New Wastes Concept, Inc., Erie, Michigan, is a blend of recycled paper mulch (99 percent) with cellulosic polymers as the binding agent (1 percent). In 1993, Concover® was tested in the laboratory for evaluation of its use in providing a physical barrier to contaminated ERF pond bottom sediments.	Concover® must be applied to dry sediment, maintaining the dry conditions for a 5-day drying period. Therefore, Concover® could not be implemented in permanently ponded areas of ERF without significant effort to dewater the areas. Application would likely involve human exposure to UXO.	Following the 5-day drying period, the Concover® test pool was filled with water. The Concover® was immediately penetrated by the water, and the entire barrier was floating within 30 minutes. The barrier also was readily damaged by activity by ducks.	Costs for full-scale implementation of Concover® were not developed because it was not effective for its intended use at ERF.	On the basis of its ineffectiveness and difficulties associated with its implementation, Concover® has been eliminated from further consideration for application at ERF.
Containment	Horizontal barriers	Geosynthetics	Geosynthetics were tested at ERF for use in lining contaminated pond bottoms to provide a physical barrier to contaminated sediments. Pilot-scale tests were conducted during the 1992, 1993, and 1994 ERF field seasons. The 1994 field tests focused on four geosynthetic systems. The systems were composed of woven and non-woven mesh made of natural and man-made materials as follows: • Needle-punched polyester geotextile overlain by a geomesh material consisting of a nylon-entangled mesh (geocomposite) covered with 8 cm of bentonite • Geocomposite only • Geocomposite covered with 10 cm of gravel • Coir geotextile (biodegradable)	The geotextile systems were installed in test plots ranging in size from 4.5 to 9 square meters (m^2). Full-scale implementation was not tested. The placement and anchoring of the liners exposes personnel to the potential danger of UXO. Methods of liner anchors tested included (1) driving survey rods, corner pins and sediment level stakes into the pond sediments, and (2) placing reinforcing bar (rebar) on top of the liner material and sewing rebar into seams along the edges of the geotextile.	Problems with entrapment of gas bubbles under the liners were solved by providing holes in the geotextiles to permit the gases to escape. The geotextiles were effective in preventing upward movement and resuspension of white phosphorus (WP) particles over the course of a field season. However, in areas subject to winter ice-out conditions, the liners did not survive from one season to the next. Because a reliable method of anchoring the liners has not been identified, they are considered to be ineffective at attaining the overall remediation goal.	Cost per hectare is estimated to be $70,000 for purchasing material and installation. Because the systems have not remained in place from one season to the next, a worst-case situation would require that the systems be replaced on an annual basis.	On the basis of their long-term ineffectiveness, geosynthetics are eliminated from further consideration for application at ERF

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Table B-2
Summary of Remedial Technology Screening

General Response Action	Technology	Process Option	Description	Implementability	Effectiveness	Cost	Screening Result
Removal	Excavation	Dredging	The dredging treatability study was initiated in 1994 and is based on the premise that removing contaminated sediment from pond bottoms would reduce the volume of WP and/or eliminate exposure of dabbling ducks and swans to WP. The sediment and water removed by the dredge are pumped as a slurry into a spoils retention basin that was constructed on the Open Burning/Open Detonation (OB/OD) Pad adjacent to ERF. The spoils retention basin is constructed to allow solids to settle. The supernatant water is decanted and passed through a sediment fence and back into ERF. The remaining sediment is allowed to warm and dry, initiating the natural oxidation/sublimation process (Collins *et al.*, 1997) The dredge-spoils retention basin is equipped with monitoring instrumentation to verify conditions that promote oxidization of WP (thus removing contamination) in the sediment. Final disposal of the sediment, once WP removal has been satisfactorily demonstrated, has not yet been established.	Results obtained through the summer of 1996 indicate that dredging can be implemented in ERF. Dredge performance is reduced by changing tide elevations, hardpan pond bottom, and vegetation. Implementation rate is that is slow; estimated at 1.3 ha in one year. Primary limitation is that it can only move freely in approximately 0.2 ha. Dredging in ERF involves spoils handling, equipment maintenance, retention basin recompactions, and sediment and spoils sampling. Because handling dredge spoils is sufficiently complex, locating and constructing an additional facility at a different location in or adjacent to ERF will entail additional time and expense. For this reason, and because flooding tides limit the number of suitable locations for a second retention basin, spoils-handling considerations could limit where this method is applicable. The dredge and associated equipment require maintenance during operation that affect the cost and schedule of operation. It is believed that the areas that could potentially be dredged extend beyond the channel adjacent to Clunie Point. Spoils generated from these additional areas could be pumped to the spoils retention basin through an extended discharge line by using booster pumps. If dredging continues to be performed, the retention basin will be at capacity in a few years. In addition, the ultimate fate of spoils contained in the retention basin has yet to be decided. Clean Water Act regulations apply to dredging in wetlands. Although dredging is controlled remotely, some exposure to UXO may occur during movement of the dredge or operation of the conveyance system.	Surveying following the 1996 dredging period found that approximately 63 centimeters (cm) of sediment had been removed over an area of 0.30 ha. Dredging reduce the average WP concentration in sediment from 3.0 to 1.4 micrograms per gram (µg/g). Post-dredging water depth ranged from 47 to 70 cm. Dredging will resuspend WP particles. The volume of WP removed or remaining has not been calculated at this time.	Solely on the basis of cost of the dredge operation (O&M) in 1996, unit costs for dredging are approximately $920,000 per ha. These costs are discussed in Section 2.3.	Dredging has been dropped. Dredging has been demonstrated to be moderately effective. However, the order of magnitude unit cost of dredging is one to two orders of magnitude greater than other potentially effective and implementable technologies. The high cost and detrimental impacts to dabbling duck habitat created by dredging are disadvantages of using this remedial method. In addition, it is possible that containing dredge spoils at any location other than OB/OD Pad will be difficult.

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TABLE B-2
Summary of Remedial Technology Screening

General Response Action	Technology	Process Option	Description	Implementability	Effectiveness	Cost	Screening Result
Institutional action	Deterrents	Hazing	An institutional control used to deter waterfowl from frequenting contaminated areas of ERF, hazing occurred during the 1993, 1994, 1995, and 1996 field seasons. Concerns for personnel safety resulted in cessation of hazing in 1996. The hazing operations have included deployment, use, and daily maintenance of propane exploders, pyrotechnics, scarecrows, flagging, balloons, and other visual, acoustic, and behavioral devices designed to frighten birds.	Some of the hazing devices are automatically operated; other methods require personnel to be actively engaged in operations. Most of the methods require daily monitoring or maintenance. Hazed areas are accessed by canoe, hovercraft, helicopter, or foot. The placement, maintenance, and use of the hazing devices exposes personnel to the potential danger of UXO.	Because there is evidence that the waterfowl become habituated to some of the hazing activities, hazing is considered to have only short-term effectiveness. Hazing is considered to be ineffective over the long term because it does not reduce concentrations of WP in sediment.	On average, about 100 ha of ponded area are hazed during the spring and fall migration periods at ERF. Total annual cost including labor, materials, and equipment operation and maintenance expenses is estimated to be $1,000 per ha.	Because hazing does not provide long-term protection from WP exposure, its implementation should only be considered as an interim remedial action, to deter waterfowl use of contaminated areas, until a more permanent alternative can be applied.
Institutional action	Deterrents	Methyl anthranilate	Methyl anthranilate (MA), a bird repellent, was encapsulated and tested in the laboratory and in the field (1994, pilot-scale study) at ERF for its ability to deter birds from feeding in contaminated ponds. The MA bead matrix was designed to settle to the bottom of the ponds and only release MA when broken by feeding ducks. Feeding rates decrease as ducks "learn" to avoid areas treated with the MA.	During the pilot-scale tests, MA was applied to ponded areas by broadcasting the pellets across the pond surface, exposing personnel to the potential danger of UXO. Large-scale implementation would use a fixed-wing aircraft to apply the beads to the ponded areas.	The MA beads were observed to decompose after about 5 days, presumably the result of microbial activity on the gel alginate shell. The decomposition resulted in significant loss of MA, ultimately rendering it ineffective for the long term. Up to 5 days following application of the MA, the results of the field tests suggested that the MA produced the desired repellent effect. On the basis of observations of duck usage of ERF during the spring and fall migration periods, it is estimated that up to four applications of MA (one during spring and three during fall) would be necessary each year.	The cost for one application of MA is about $107,000 per ha.	Because MA is considered to be ineffective over the long term, and because of significant costs for replenishment to achieve short-term effectiveness, MA is eliminated from further consideration for application at ERF.
Monitoring	Natural Processes	Detailed Monitoring of Natural Processes	WP in sediment will sublimate and oxidize under the proper soil moisture (low) and temperature (high) conditions. This process is referred to as sublimation/oxidation. Sublimation will occur if a pond system is breached naturally by gully progression. Sedimentation would also naturally protect ducks from WP. The processes of sublimation/oxidation, gully recession, and sedimentation are referred to in this document as "natural processes."	Implementation of detailed monitoring involves soil sample collection and analysis, observations of waterfowl mortality, aerial photography, monitoring of sediment moisture and temperature conditions, and monitoring of sedimentation (decrease in mortality rate infers decrease in WP concentrations in pond bottom sediments over time). This technology is different from "no action" in that it allows for monitoring of natural restoration processes. Soil sample collection and other monitoring activities may expose personnel to the potential danger of UXO.	Natural restoration by sublimation is not effective in permanently ponded areas because the bottom sediments remain saturated and depleted of oxygen. However, sublimation has been demonstrated to occur in intermittently ponded areas where bottom sediments are exposed to the atmosphere for prolonged periods during summer months. Sublimation may also occur along the perimeter of permanent ponds. Sublimation will occur in these areas if the soil moisture and temperature conditions are sufficient to allow sublimation and diffusion of the WP. Gully breaching and sedimentation may occur in some ponds within the next 10 to 25 years.	Costs will include aerial photography, aerial surveys, baseline sampling, and the installation of water level, sediment moisture/ temperature, and sedimentation stations.	Natural restoration is retained because it has been demonstrated to be effective in the long term (10 to more than 20 years).

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TABLE B-2
Summary of Remedial Technology Screening

General Response Action	Technology	Process Option	Description	Implementability	Effectiveness	Cost	Screening Result
No Action	No Action	No Monitoring	Exposure pathways between dabbling ducks and WP would be broken by natural processes such as sublimation/oxidation, gully breaching, and sedimentation. No monitoring would be involved.	Such processes are occurring naturally throughout the flats at varying rates. No implementation is involved.	Natural restoration by sublimation is not effective in permanently ponded areas because the bottom sediments remain saturated and depleted of oxygen. However, sublimation has been demonstrated to occur in intermittently ponded areas where bottom sediments are exposed to the atmosphere for prolonged periods during summer months. Sublimation may also occur along the perimeter of permanent ponds. Sublimation will occur in these areas if the soil moisture and temperature conditions are sufficient to allow sublimation and diffusion of the WP. Gully breaching and sedimentation may occur in some ponds within the next 10 to 25 years	Cost is $0	No action will continue to be considered in the FS.
Treatment	In situ	Air sparging	Introducing air into WP-contaminated sediment to oxidize WP.	Studies were at a bench-scale level. Field implementation would involve piping, trenching, and installation and operation of blowers. Implementation would likely involve human exposure to UXO.	Bench-scale studies demonstrated that air sparging was not effective in reducing WP concentrations.	Cost for full-scale implementation has not been developed.	Air sparging has been eliminated because of low effectiveness and anticipated difficulties in field applications.
Treatment	In situ	Chemical oxidation	Hydrogen peroxide can oxidize WP, potentially reducing concentrations. The procedure has been tested with 5-milliliter (mL) plugs of ERF bulk sediment in 250-mL flasks. A reduction of WP has been achieved *in vitro* after multiple applications of hydrogen peroxide.	Investigation has been only at a laboratory study scale. Conditions were ideal in that materials were well mixed, and peroxide concentrations were greater than can be expected in the field. Oxidation occurred only on the surface of samples that were not well mixed. Field application, which has not been tested at ERF, would involve a much larger volume of sediment and well mixed conditions would not be possible. Application would involve human exposure to UXO.	WP was still detectable even under the relatively ideal laboratory conditions. Performance in the field would likely be lower because mixing would not be possible.	Cost for full-scale implementation has not been developed.	Chemical oxidation technology has been eliminated because of low effectiveness and anticipated difficulties in field applications.
Treatment	In situ	Explosive charge	WP in contaminated sediment that is released into the air following a controlled explosive charge would oxidize.	Implementation would involve releasing an explosive charge into a contaminated pond.	Field scale studies demonstrated that this technology is not effective. Sediment that was released into the air was analyzed and found to still be contaminated with WP.	Cost for full-scale implementation has not been developed.	In situ treatment by explosive charges has been eliminated because it was not effective.

TABLE B-2
Summary of Remedial Technology Screening

General Response Action	Technology	Process Option	Description	Implementability	Effectiveness	Cost	Screening Result
Treatment	In situ	Enhanced sublimation/ oxidation	Possible enhancements to oxidation/ sublimation include actions or processes that accelerate or augment soil warming. Four passive methods of soil warming have been field tested at ERF: • Black sand to change the surface albedo (reflection) • Reemay, a spun-bonded polyester row cover • Fast Start, a porous polyethylene row cover • Burlap row cover	In 1995, tests were conducted to compare the three fabric row covers with the sand cover. The fabric row covers were held in place by the use of sand bags and wooden planks. The sand was spread to a uniform depth over the test plots. Implementation would likely involve human exposure to UXO.	Although three of the passive systems (black sand, Reemay, and Fast Start) were demonstrated to raise soil temperatures, the systems were not effective at removing WP. The field conditions during the summer of 1995 were wet with high tides and frequent precipitation. The observed temperature increases resulting from enhancement (between 1°C and 4°C) were not sufficient to overcome the saturated soil conditions. It has been demonstrated that WP sublimation will not occur without sediments being dry and unsaturated.	Annual cost to implement an enhanced sublimation/ oxidation program with the use of passive soil warming is estimated to be $5,000 per ha. The costs include labor and materials to install the soil warming system (row cover or sand).	Because the soil warming systems were not effective at removing WP, enhanced sublimation/oxidation is not recommended for future application at ERF. The observed temperature increases were not sufficient to overcome saturated conditions to foster WP sublimation
Treatment	Pond Draining	By Breaching	Pond draining by breaching has been tested at ERF. Presumably WP sublimation/oxidation would follow in the drier sediments, reducing the concentrations of WP in the drained ponds. Dabbling duck habitat would be removed.	In 1996, the 23rd Engineers at Fort Richardson blasted a channel from Bread Truck Pond to a gully that discharges into the Eagle River. In addition, in 1997, a second channel was blasted connecting a Racine Island pond with a gully leading to Eagle River. Future channel blasting at ERF, if implemented, likely also will be conducted by military personnel in conjunction with a training activity.	Bread Truck Pond has been substantially eliminated as a permanent pond by the action of connecting it to an existing gully. WP removal has been measured at Bread Truck but the results are not available yet. However, WP sublimation is expected to occur in 1997 and 1998 because of water level decline and unsaturated sediment (pond draining and few floods) and elevated temperatures (summer temperatures). Dewatered ponds likely will reduce the waterfowl exposure to WP even before there is a loss of WP, because such ponds are no longer preferred duck habitat.	Unit costs for blasting vary according to the length of ditch drained, at a rate of approximately $130 per meter.	Pond draining by breaching will continue to be considered as a remedial technology for ERF.

TABLE B-2
Summary of Remedial Technology Screening

General Response Action	Technology	Process Option	Description	Implementability	Effectiveness	Cost	Screening Result
Treatment	Pond Draining	By Pumping	Pond draining by pumping would lower water levels. Pump stations would activate after flooding tides and need to be regularly refueled. WP sublimation/oxidation will follow in the drier sediments, reducing the concentrations of WP in the drained ponds.	In 1995, the pump system was pilot-scale tested at ERF to assess the function of the pump and generator, mounted on a floating platform. Full-scale implementation of the pump system was tested in summer 1997. Regular operations and maintenance work and refueling would likely involve human exposure to UXO. However, walkways will be cleared by a UXO contractor prior to operations.	Testing the pumping system in Pond 183 in 1997 has proven that pumping is effective in dewatering a large pond with some interconnectivity with large water-bearing areas. Extensive drying of previously permanent-ponded sediments has been demonstrated. Dewatered ponds will reduce the waterfowl exposure to WP even before there is a loss of WP, because such ponds are no longer preferred duck habitat. However, an increase in shorebird activity was observed, without the predicted mortality from WP exposure.	A 2,000-gallons-per-minute pump system was acquired in 1995 at a cost of approximately $60,000. This system included float, pump, generator, discharge piping, and power cords. Costs would increase with larger pumps.	Pond draining by pumping will continue to be considered as a remedial technology for ERF.

Appendix C
Assembly and Description of Alternatives

Contents

Contents, Continued

Abbreviations

°C	degrees Celsius
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
CRREL	Cold Regions Research and Engineering Laboratory
ERF	Eagle River Flats
FS	feasibility study
GIS	Geographical Information System
gpm	gallons per minute
lb	pound
m	meter
O&M	operations and maintenance
OB	open burning
OD	open detonation
OUC	Operable Unit C
RAO	remedial action objective
TNT	trinitrotoluene
UXO	unexploded ordnance
WP	white phosphorus

APPENDIX C

Assembly and Description of Alternatives

The results from the technology screening (Appendix B) were used to assemble five remedial alternatives that reduce exposure of waterfowl to white phosphorus (WP). These five alternatives, listed below, are evaluated in the detailed analysis of alternatives and comparison of alternatives presented in Appendix F.

- Alternative 1: No Action
- Alternative 2: Detailed Monitoring
- Alternative 3: Pumping and AquaBlok™
- Alternative 4: Breaching, Pumping, and AquaBlok™
- Alternative 5: AquaBlok™

A detailed description of each alternative is provided in this appendix, followed by a discussion of the effectiveness of each alternative and how each would be implemented. As a convenience to the reader, Figures C-1 to C-6 have been attached to the end of this appendix.

1.0 Assembly of Alternatives

The technologies of AquaBlok™, pond draining by pumping, pond draining by breaching, and sublimation/oxidation were retained after the technology screening process, presented in Appendix B.

Stand-alone application of each retained technology was initially considered for implementation at Operable Unit C (OUC). However, there is some uncertainty about how certain pond systems would respond to pond draining. For example, it is not known whether the ponds in Area C/D can be drained by pumping alone, or whether the pond bottoms will dry and remain warm long enough to foster sublimation/oxidation of WP. Sublimation/ oxidation is currently occurring at ERF, but the extent and rate of WP and waterfowl mortality reduction are unknown. In addition, draining a pond by breaching alone would require a large amount of explosives, which would destroy habitat.

Therefore, the five alternatives were assembled to increase effectiveness and decrease negative effects on habitat. Evaluation of Alternative 1, the no-action alternative, is a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirement. No action implies allowing the natural restoration processes such as sedimentation, WP sublimation/oxidation, and gully recession to occur at ERF without enhancement. Although such processes are a remedial response action that occurs regardless of other actions, the extent of sublimation/oxidation is unknown.

Alternative 2, Detailed Monitoring, recognizes that natural restoration is occurring and measures the extent of WP and waterfowl mortality reduction through detailed monitoring.

AquaBlok™ was included in Alternative 3 (Pumping and AquaBlok™) and Alternative 4 (Breaching, Pumping, and AquaBlok™). Under these alternatives, AquaBlok™ would be applied to the bottom of ponds that do not drain or dry, thus addressing concerns about the effectiveness of the pond draining technologies. In Alternative 4, pumping would be performed in conjunction with breaching to minimize the extent to which breaching would need to be implemented. For example, five gullies may be needed to drain a pond by only breaching the pond system, whereas only three gullies would be needed if pumping were used in conjunction with breaching.

Each alternative varies in cost, achieves clean-up levels at different rates, and blocks different contaminant exposure pathways. In addition, each alternative affects habitat to varying degrees and offers different degrees of effectiveness.

To aid in the evaluation of alternatives for the feasibility study (FS), the 22 hot ponds have been divided into six groups. The first five groups, presented in Table C-1, were made based on nearby types of vegetation, topography, knowledge of the extent of contamination, and hydrologic interconnections. The ponds in each group have similar physical characteristics and are expected to respond similarly to remedial actions. These ponds, overlaid on vegetation, are presented in Figure C-1.

These five pond groups will be separately evaluated in the FS. Their characteristics are summarized in Table C-2. These characteristics will affect the effectiveness of the remedial alternatives and will be discussed further in Section 3. For example, the number of ponds in a pond group affects the complexity and cost of some remedial actions. The potential area of landcover connected by waterways will affect the amount of water that needs to be pumped and therefore the pump cost of two of the alternatives. It may also affect the change in waterfowl habitat. Surface elevations affect the number of WP sampling stations that may be required to identify current conditions and verify that a remedial action has been successful. Note that the WP concentration ranges in the table may be misleading, in that several pond groups do not appear to have very high concentrations. This may result from the low density of sampling in the ponds. The sampling may not have discovered higher concentrations that may actually be there. Or, the results may truly represent the absence of high WP concentrations in the pond group. This is one of the uncertainties in the available database. This uncertainty leads to one element of the monitoring program, baseline WP monitoring, which is performed before implementation of a remedial alternative.

In the sixth group, Ponds 109, 285, 293, and 297 have either had treatment or will have treatment in 1997. Hence, these ponds will not be evaluated in the FS.

2.0 Description of Each Alternative

A description of each alternative is presented in this section. Regardless of the alternative selected, hazing (described in Appendix B) will be performed as an interim response action until a remedy is in place.

2.1 Alternative 1: No Action

The no-action alternative includes sublimation/oxidation, gully recession, and sedimentation. Evaluation of the no-action alternative in the FS is a CERCLA requirement. In addition, published studies suggest that these natural physical and chemical processes are occurring at ERF and may lead to some degree of natural restoration in different pond groups over time.

TABLE C-1
Groupings of Hot Ponds

Pond Group	Hot Ponds	Rationale for Grouping
Northern A Ponds	138, 208, 226, 228, 246, 256, 258	Ponds are believed to be hydrologically interconnected by surrounding sedge marsh There is little understanding regarding extent of WP contamination in these ponds
Pond 290	290	A region of high elevation exists between Pond 290 and the Northern A ponds that separates the two pond groups. Pond 290 is relatively isolated and is adjacent to a small intermittent pond and a small area of sedge marsh. WP contamination has been detected in the northern end.
Pond 183	183	This pond has been heavily sampled. There are confirmed WP hot spots in this pond. This pond is interconnected with Pond 146, but the permeability is low at least at average to low water levels, and inflow can be controlled by pumping. A treatability study using pond pumping was conducted at this pond in summer 1997. The study demonstrated that Pond 183 could be drained and dried.
Pond 146	146	This pond has been heavily sampled. There are confirmed WP hot spots in this pond. Studies suggest that there is a constant source of recharge (up to 100 gallons per minute[gpm]) along the eastern part of the flats. A dredging treatability study was conducted at this pond in 1995 and 1996, and this changed the pond bottom elevations. In 1996, the dredge had begun dredging a channel to Pond 183. It breached a shallow portion of Pond 183. This pond is interconnected with Pond 183.
Northern C and C/D Ponds	40, 49, 85, 93, 112, 129, 145, 155	Ponds are believed to be hydrologically interconnected to a large system of permanent ponds and a large area of sedge marsh. There is little understanding regarding the extent of WP contamination in these ponds. Studies suggest that there is a constant source of recharge (up to 100 gpm) along the eastern part of the flats. Ponds 145 and 155 may be more isolated from the rest of this pond group. An aerial survey conducted in June 1997 suggests that these ponds may be drained.

Note: Treated ponds have not been assembled into a pond group.

TABLE C-2
Physical Characteristics of Each Pond Group

Pond Groups	Hot Pond Area (hectares)	Landcover Drained by Alternatives 3 and 4: Percentage of Landcover	Landcover Drained by Alternatives 3 and 4: Total Area (ha)	Factors Affecting Ability of Ponds to Dry: Topography	Factors Affecting Ability of Ponds to Dry: Recharge	Factors Affecting Ability of Ponds to Dry: Ability to Drain
Northern A	5.8	Intermittent Pond: 25 Permanent Pond: 15 Sedge Marsh: 60	42.0	Hummocky topography. High number of shallow depressions expected. Medium to high number of craters.	Unknown whether recharge exists from the western bluffs. No evidence of springs. Strong spring has been identified in Coastal West, but it feeds into the Coastal 6 gully.	The extent of interconnectiveness between the hot ponds and the surrounding sedge marsh is unknown. However, an aerial and land survey conducted in June 1997 indicated that the area encompassed by sedge marsh (area to be drained) is relatively narrow and may be drained.
Pond 290	0.9	Intermittent Pond: 4 Permanent Pond: 13 Sedge Marsh: 83	6.9	Relatively isolated pond. Few individual depressions. Medium number of craters.	Same as above.	Interconnectiveness between Pond 290 and sedge marsh area is unknown.
Pond 183	2.9	Intermittent Pond: 75 Permanent Pond: 25 Sedge Marsh: 0	11.7	Few individual depressions. Pond bottom much shallower than adjacent Pond 146. High number of craters.	Unknown.	The 1997 pumping treatability study at Pond 183 suggests that the amount of water entering from Pond 146 could be contained by the pumping of Pond 183. These two ponds are interconnected by a shallow channel that was advanced by the dredge in 1996. The ponds are separated by sedge bog, which is less permeable than sedge marsh.
Pond 146	5.5	Intermittent Pond: 25 Permanent Pond: 70 Sedge Marsh: 5	15.9	Some individual depressions expected. Very deep along eastern edge of pond. Pond bottoms modified by dredge. High number of craters.	Clunie Creek is a source of underground recharge. It is likely that this creek is part of the recharge from the eastern bluffs (described below).	Recharge from Clunie Creek and inflow from sedge marsh to the north may make drainage and drying difficult.
Northern C & C/D	3.7	Intermittent Pond: 3 Permanent Pond: 24 Sedge Marsh: 73	74.9	Hummocky topography. High number of shallow depressions expected. Medium to high number of craters.	A moderate amount of recharge has been identified from the eastern bluffs.	Recharge from eastern bluffs and inflow from surrounding sedge marsh would make drainage and drying very difficult.

Notes:
1. Only landcovers that are expected to be affected by the alternatives are presented in this table.
2. Craters counts based from ERF GIS (CRREL, 1996). Craters were not observable in large parts of Areas A and C/D. However, crater counts have been estimated in these pond groups based on crater counts in adjacent areas.
3. There is no pond group-specific information on organic content and threshold elevation.

The no-action alternative includes only natural processes that lead to protection of waterfowl from WP exposure: sublimation/oxidation of WP; gully recession (which leads to pond draining, reduction in waterfowl habitat, and, presumably, ultimately sublimation/oxidation of WP); and sedimentation (which protects waterfowl by covering the WP with clean sediment, making WP unavailable for consumption). These processes and their effect on different pond groups are discussed in more detail in Appendix A. In this alternative, there are no remedial technologies or monitoring activities conducted at ERF to protect waterfowl or to evaluate change in WP exposure.

No costs are associated with the no-action alternative.

2.2 Alternative 2: Detailed Monitoring

Alternative 2 is similar to the no-action alternative in that it includes only natural processes, but this alternative also includes monitoring to determine whether natural restoration is occurring, and at what rate. This alternative includes ERF-wide activities. Natural restoration refers to sedimentation processes, gully recession, and sublimation/oxidation. The details of the monitoring program are discussed in Appendix G. The elements of this alternative are discussed in the following bullets.

- **Telemetry.** This includes monitoring for mallard mortality. Mallards have been selected as an indicator species because they are widespread at ERF and they are sensitive to the effects of WP. The telemetry study will include 100 to 150 mallards and will be performed during the fall migration. A transmitter will be attached to each bird and their locations will be determined on a daily basis if an activity transmitter was used, or at death if a mortality transmitter was used. The mortality rate will be estimated based on the proportion of birds in the study that die from WP exposure during the study period.

- **Aerial surveys.** Waterfowl populations will be assessed by aerial surveys. The aerial surveys will be conducted from spring through fall to determine the magnitude of the populations from year to year and the preferred locations of waterfowl use on ERF.

- **Aerial photography.** Aerial photography can be used to meet several monitoring objectives: determining the area of ponds before and after major drying periods and before and after treatment is applied to pond groups; identifying gully recession; identifying vegetation stress; and supporting the population surveys by providing a way to count birds.

- **Sedimentation.** Net sedimentation also will be assessed annually in each pond group by installing sedimentation stations along transects. Natural sedimentation is a major component of natural restoration processes.

In addition, hazing will be performed on an ERF-wide basis to deter waterfowl (specifically swans) from frequenting contaminated areas. Hazing is considered to be ineffective over the long term. Therefore, it will be conducted as an interim contingency until a remedy is in place.

Telemetry, aerial photography, aerial surveys, sedimentation studies, and hazing are ERF-wide activities that also apply to Alternatives 3, 4, and 5. They will be performed annually.

Alternative 2 also includes sampling for the presence of WP using baseline sampling at the start of the remedy and WP verification sampling after periods when sediment may have dried enough to lead to a reduction in WP. For example, as discussed in Appendix A, the potential for substantial drying periods is high during the summers of 1997 and 1998. In addition, pond bottom elevation surveys will be performed under Alternative 2.

In addition, sublimation/oxidation monitoring stations will be installed in each pond group. WP sublimation/oxidation in sediments surrounding these ponds may occur in the upcoming dry years. These stations will include water level indicators and a data logger.

2.3 Alternative 3: Pumping and AquaBlok™

Alternative 3 involves pumping the pond system initially and after every flooding cycle and/or rain. Pumped water will be discharged to an adjacent unconnected pond, river, gully, or open area. The objective of this pumping is to drain ponds and allow drying of the pond sediments to foster WP sublimation/oxidation (Walsh, *et al.*, in Racine *et al.*, 1996). After several extended drying periods and verification sampling, AquaBlok™ (formerly known as Bento Balls™) will be applied to areas of the pond systems that do not dry and still contain WP.

Each pond system will have a dedicated pump system that will be installed after spring breakup and removed before the winter freeze. The useful drying season is from mid-May to mid-September. The pump system will be on floats and will be completely automated to start and stop at established pond surface elevations. The pump system will require scheduled operations and maintenance (O&M) service and refueling.

Pond draining through pumping uses the processes of sublimation and oxidation. This alternative is expected to be successful because sublimation/oxidation studies indicate that if pond sediments contaminated with WP are allowed to dry below saturation, the WP particles within the sediment begin to sublimate at soil temperatures above approximately 15°C. The unsaturated condition of the sediment allows WP vapors to disseminate through the soil pores away from the WP particle and oxidize into phosphoric oxide (P_4O_{10}). For sublimation and oxidation to proceed, the pond bottom sediments need to be subaerially exposed long enough for the sediments to dry to below saturation. This occurs normally in the intermittently flooded shallow ponds during periodic long intervals between flooding tides when the ponds dry up by evaporation (Walsh *et al.*, 1995; Collins *et al.*, in Collins *et al.*,1997). Complete sublimation/oxidation of WP will occur only when sediments are warm and dry. Neglecting precipitation, tide charts indicate that extended periods of pond drying at ERF are expected during 1997 and 1998. The WP sublimation/oxidation process is discussed further in Appendix A.

The duration of pumping will depend on several factors, including frequency of flooding tides, temperature, precipitation, and ability of ponds to drain. Operation of Alternative 3 is currently estimated to be 5 years based on tidal predictions.

Following approximately 5 years of pond pumping and sediment drying, verification sampling will be conducted to determine whether WP has been removed from sediments. This sampling will be performed with a combination of composite grid sampling and planting and analysis of WP. This verification sampling will be performed to determine which areas require further remediation. Sampling strategy is discussed further in Appendix G.

Areas requiring remediation either will continue to be pumped or will be covered with AquaBlok™. The choice between continued pumping or AquaBlok™ application will be made based on a cost analysis of pumping O&M costs versus AquaBlok™ application costs. AquaBlok™ will be applied to areas that do not dry and cannot be otherwise remediated. AquaBlok™ application is described in Section 2.5.

After a pond is remediated, it will be restored by removing the pump system and allowing the pond to refill from precipitation and tidal flooding.

This alternative also includes the ERF-wide activities discussed in Section 2.2. It also includes baseline and verification monitoring for WP with the composite sampling approach, which includes before- and after-treatment sampling at each pond group and planted WP pellets. These sampling studies will continue annually for approximately 5 years until it is determined which specific areas have not achieved sufficient protection (that is, have not met remedial action objectives [RAOs]), and those areas will receive AquaBlok™ treatment. The areas that receive AquaBlok™ will then be regularly inspected for integrity.

2.4 Alternative 4: Breaching, Pumping, and AquaBlok™

This alternative involves using explosives to blast a ditch from a hot pond (or pond system) to the Eagle River or a nearby gully or creek to permit water to ultimately drain into Cook Inlet (Collins *et al.*, in Collins *et al.*, 1997). Areas that do not drain through the breached gully would be pumped with an automated, dedicated pumping system. Portions of ponds may not drain by breaching because their pond bottom elevations are lower than the breached gully elevation. The objective of breaching and pumping is to dry the pond bottom long enough to allow the WP in the pond bottom sediment to sublimate. Areas that do not sufficiently dry will be covered with AquaBlok™.

Alternative 4 is similar to Alternative 3 in that both alternatives achieve cleanup through drying and AquaBlok™ application. However, Alternative 4 achieves draining through pumping and breaching, whereas Alternative 3 uses only pumping.

Previous studies at Bread Truck Pond and Racine Island indicate that to blast a 6-meter (m)-wide, 1.8-m-deep ditch, one 40-pound cratering charge would need to be placed every 3.5 m. Blasting will be conducted during March, when the flats are frozen and access is easier.

Water will likely collect in the deeper portions of a breached pond where the head of the gully is at a higher elevation than the pond bottom. Portions of the pond system that do not drain through the gully system will be pumped in a manner similar to that in Alternative 3. Smaller pumps will be used in Alternative 4, because most of the water is expected to be drained through the breached gully system.

As discussed in the description of Alternative 3, sublimation/oxidation studies indicate that warm temperatures are required for complete sublimation/oxidation of WP. Complete sublimation/oxidation of WP will occur only when sediments are warm and dry. Neglecting precipitation, tide charts indicate that extended periods of pond drying at ERF are expected during 1997 and 1998. The WP sublimation/oxidation process is discussed further in Appendix A.

The duration of pumping will depend on several factors, including frequency of flooding tides, temperature, precipitation, and ability of ponds to drain. Operation of Alternative 4 is currently estimated to be 5 years based on tidal predictions.

Following approximately 5 years of pond pumping and sediment drying, verification sampling will be conducted to determine whether WP has been removed from sediment. Sampling strategy will be similar to that of Alternative 3: a combination of composite grid sampling and planting and analysis of WP. After several periods of drying when, based on sublimation monitoring, it is believed that large areas of the ponds have dried sufficiently, verification sampling will be performed to determine areas that require further remediation.

Areas requiring further remediation either will continue to be pumped or will be covered with AquaBlok™, as in Alternative 3. The choice between continued pumping or AquaBlok™ application will be based on a cost analysis of pumping O&M costs and sampling costs versus AquaBlok™ application costs. AquaBlok™ will be applied to areas that do not dry and cannot be remediated otherwise. Issues pertaining to AquaBlok™ are described in Section 2.5.

Engineering judgment will be implemented to minimize negative effects on existing habitat. Several factors will be considered when selecting the breaching route. When possible, a gully that is naturally progressing toward the pond system will be selected to be further extended by breaching. In addition, the shortest possible drainage route and the shallowest possible ditch will be selected.

The feasibility and practicality of restoring disturbed habitat resulting from implementation of Alternative 4 will be evaluated in a literature search planned for 1997.

Alternative 4 also includes the ERF-wide activities discussed in Section 2.2, as well as baseline and verification WP sampling using the composite sampling approach, which includes before- and after-treatment sampling at each pond group and planted WP pellets. These sampling studies will continue annually for approximately 5 years until it is determined which specific areas have not achieved sufficient protection (RAOs), and those areas will receive AquaBlok™ treatment. The areas that receive AquaBlok™ will then receive a regular inspection for integrity. Sampling strategy is discussed further in Appendix G.

2.5 Alternative 5: AquaBlok™

Alternative 5 involves applying AquaBlok™ over entire hot ponds. The objective of the AquaBlok™ application is to cover WP-contaminated sediment to prevent WP ingestion by ducks (Pochop *et al.*, in Racine *et al.*, 1996). The areal extent of AquaBlok™ application may be reduced by delineating hot ponds by baseline sampling. Alternative 5 is suited for and can be implemented in areas that cannot be drained or dried.

AquaBlok™ is a composite material containing calcium bentonite/organoclays, gravel, and polymers. Since 1993, the use of AquaBlok™ as a cap for contaminated pond bottoms has been evaluated first by bench-scale testing and then by treatability testing at ERF. AquaBlok™ hydrates, expanding vertically and horizontally, sealing the interstitial spaces in the gravel. AquaBlok™ barrier permeabilities as low as 10^{-9} centimeters (cm) per hour have been measured.

AquaBlok™ may be applied by air, by truck, or by slurry. Dropping dry AquaBlok™ material from a helicopter may be more precise, but helicopter time is expensive, and it is difficult to get even coverage, especially over the craters. Truck application involves driving heavy equipment with the AquaBlok™ material to the pond during the winter when the flats are iced over and spreading the material with graders. During cold winters, ice thickness would be sufficient to support construction equipment. If proven technically implementable and effective, this method would be less costly than application by helicopter. The application of AquaBlok™ by truck and air are presented in Appendix E. Area C and C/D ponds may be treated with AquaBlok™ that is pumped in a slurry through the existing dredge line.

A treatability study of AquaBlok™ application by air was conducted in 1994 at Pond 283 in Racine Island. A treatability study may be conducted in winter 1997-1998 to determine whether application of AquaBlok™ in the winter by truck is effective. The vendor is exploring the possibility of pumping AquaBlok™ in slurry.

The monitoring under this alternative includes the ERF-wide activities discussed in Section 2.2. It also includes baseline sampling for WP and a regular inspection of the integrity of the AquaBlok™. Monitoring is discussed further in Appendix G.

3.0 Performance of Each Alternative

The factors that contribute to the performance of each alternative are presented in this section. Because Alternatives 3 and 4 are basically two different ways to implement pond draining, the factors that are common to these two alternatives are discussed together in subsection 3.3, followed by a discussion of the differences between the two alternatives in subsection 3.4.

Layouts of Alternatives 1, 2, 3, 4, and 5 are presented in Figures C-2 to C-5. (These figures are attached at the end of this appendix.)

3.1 Performance of Alternative 1

The effectiveness of natural processes to reduce exposure of dabbling ducks to WP will vary among the different pond groups. Some ponds would likely experience WP reduction over a short period of time, while others would require more than 20 years to have any significant improvement. A summary is presented in Table C-3. The effectiveness is equal in Alternatives 1 and 2. However, under Alternative 1, the no-action alternative, effectiveness would not be monitored.

3.2 Performance of Alternative 2

The effectiveness of Alternative 2 is identical to that of Alternative 1, as presented in Table C-3. However, effectiveness would be measured under Alternative 2. Alternative 2 includes a detailed monitoring program of aerial surveys, telemetry censuses, sedimentation studies, and WP sampling. Hazing performed during implementation of Alternative 2 may provide increased effectiveness over Alternative 1, but it would be temporary and localized.

TABLE C-3
Effectiveness of Alternatives 1 and 2

Pond Group	No Action Remediation Future	Conclusion
Northern A Ponds	1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation, at least around the perimeter. Gully recession may drain ponds, but time period is uncertain. Pond 258 may obtain sufficient sedimentation.	Some natural restoration at least around the perimeter is likely in a few years if good drying between tides. Protection by sedimentation or gully recession may take longer than 20 years. Pond 258 may have sufficient sedimentation in 10 years.
Pond 290	1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation, at least around the perimeter.	Some natural restoration around the perimeter is likely in a few years if good drying between tides. Protection by sedimentation or gully recession may take longer than 20 years.
Pond 146	1997 and 1998 offer good opportunities for drying and subsequent WP sublimation/oxidation. Sediment may build up to 10 cm to 15 cm in 10 to 15 years.	Natural restoration from sedimentation appears possible within 10 to 15 years. Sedimentation would have to be deep and consolidated to prevent duck feeding in WP-contaminated sediment.
Pond 183	1997 and 1998 offer good opportunities for drying and subsequent WP sublimation/oxidation. Large area of pond may drain in 10 to 15 years. Sediment may build up in similar time frame.	Natural restoration of at least the perimeter is likely in a few years if good drying between tides. Natural restoration from pond draining and sedimentation appears possible within 10 to 15 years.
Northern C and C/D Ponds	1997 and 1998 offer good opportunity for drying and subsequent WP sublimation/oxidation, at least around the perimeter.	Natural restoration through sublimation/oxidation of at least the perimeter is likely in a few years if good drying between tides. Natural restoration from sedimentation appears possible within 10 to 15 years.

3.3 Performance of Alternatives 3 and 4

The degree by which Alternatives 3 and 4 may perform varies by pond group. In these alternatives, the exposure pathway between dabbling ducks and WP sediment is cut by the following mechanisms:

- Lowering the water table by draining to prevent feeding by ducks
- Lowering the water table to dry the pond-bottom sediment and promote sublimation/oxidation of WP. The rate of sublimation/oxidation increases with lower saturation and increased temperature.
- Covering portions of pond bottoms that do not dry with AquaBlok™ to block waterfowl from feeding from contaminated sediment

Factors such as hydraulic interconnections between the pond systems, recharge, organic content of sediment, surrounding vegetation, and topography affect the effectiveness of the pumping remedy and the rate of WP sublimation/oxidation. These processes are conceptually depicted in Figure C-6. The following subsections describe how these factors affect the drainage and drying of each pond group.

3.3.1 Vegetation

Water-bearing areas that are highly vegetated hydraulically link permanent and intermittent ponds and affect how well a pond group will drain and dry. For example, the hot ponds in the Northern C and C/D pond group are interconnected by large areas of sedge marsh, permanent ponds, and intermittent ponds. The hot ponds presented in Figure C-1 are not hydraulically isolated. They are interconnected by areas of sedge marsh. The sedge marsh is composed of thick sedges and bulrushes with standing water. Pumping in pond groups with large areas of adjacent sedge marsh would also result in pumping the marsh. Hence, water level reduction in hot ponds by draining would be achieved only by reduction in water levels of the surrounding water-bearing landcovers. The areas of these water-bearing landcovers are presented in Figure C-6 and Table C-4. The degree of interconnectiveness between ponds and sedge marsh can be better understood after detailed surveying of the ponds. Pond surveying is included as a component of Alternatives 2, 3, 4, and 5.

TABLE C-4
Area of Landcover in Each Pond Group (hectares)

Pond Groups	Hot Pond Area	All Intermittent Ponds	All Permanent Ponds	Sedge Marsh	Total	Hot Pond Area/ Total Area (%)
Northern A	5.8	10.6	6.2	25.2	42.0	14
Pond 290	0.9	0.2	0.9	5.7	6.9	13
Pond 183	2.9	8.8	2.9	0.0	11.7	25
Pond 146	5.5	4.0	11.2	0.7	15.9	35
Northern C & C/D	3.7	2.2	17.9	54.8	74.9	5
TOTAL	18.8	25.8	39.1	86.4	151.3	12

Notes:
1. Permanent pond area includes hot ponds in the pond group
2. The areas presented here would be temporarily drained under Alternative 3 and permanently drained under Alternative 4.

3.3.2 Topography

The topography of the pond bottom affects how the pond system would dry. For example, the pond bottoms of the Northern A and the Northern C and C/D pond groups are hummocky, with elevated areas where sedge marsh is present and depressed areas where water is ponded. The presence of craters further increases the variability in pond bottom elevations in these pond groups. Although water levels of ponds in this hummocky terrain may be decreased by pumping or a combination of pumping and breaching, only certain portions of the pond system would dry. The depressions that would dry are the depressions (or craters) where pumps are located.

Conversely, Ponds 290, 183, and 146 are basically individual bowls with a few identifiably deep areas. Pumps may be placed in these deep areas and a large fraction of these ponds is expected to be influenced by the pumping system. Hence, the pump system should be able to lower water levels in the entire pond system.

There is currently little understanding of the topography of the pond groups. The pond bottom elevations, depressions, and craters and the threshold elevation will be surveyed and evaluated before pumping and/or breaching are implemented.

3.3.3 Threshold Elevation

The frequency of flooding of a pond is dependent on its threshold elevation with respect to flooding tide elevations. Breaching would lower that threshold elevation and result in more frequent flooding and re-wetting of pond bottom. However, ponds with lower threshold elevations (breached ponds) would also drain more quickly.

The rate of sublimation/oxidation in pond sediments of a breached pond is expected to be much lower than in a pumped pond. Therefore, complete remediation in a breached pond may take several seasons because it is expected to be flooded more often.

3.3.4 Hydraulic Permeability of Sediment

Hydraulic permeability either fosters or inhibits draining and drying, depending on site conditions. The influence of an individual pump on a pond system would be greater in a pond system with permeable sediment and sedge marsh. Pumping a hot pond would drain adjacent depressions and craters (without dedicated pumps), but also would result in more pumping to drain larger adjacent areas. Conversely, the influence of an individual pump would be less in a pond system with less permeable sediment. A depression or crater would not drain (if it did not have a dedicated pump system) despite adjacent pumping, whereas a lower pumping rate would be needed to drain a hot pond if the adjacent pond (possibly clean) was not also drained. In some cases, small, low, ponded impermeable areas may be dried through evaporation. These processes are depicted in Figure C-6.

For example, the ponds in the Northern C and C/D pond group are hydraulically interconnected to Area D. To drain the hot ponds in the Northern C and C/D group, the ponds in Area D would also have to be drained. Thus a larger volume of water than that contained in the hot ponds would have to be drained. The same is true, to a lesser extent, of the Northern A pond group.

The hydraulic permeability of the sediment throughout ERF is not completely understood. This would be resolved by implementing treatability tests and land and aerial surveys. For example, the degree of interconnectiveness between Ponds 146 and 183 was initially not known. Pond 146 is considerably deeper than Pond 183. The ponds were connected by a dredged channel in 1996. However, a pumping treatability test was conducted in Pond 183 in summer 1997 to determine how water levels will respond to continued pumping. The test demonstrated that a small amount of water infiltrates from Pond 146 to Pond 183, but that amount of inflow can be controlled by pumping Pond 183. Thus, Pond 183 could be drained and dried.

3.3.5 Recharge

Ponds that experience recharge are unlikely to dry, although they can be drained. Recharge refers to inflow of water into the pond or pond group from groundwater, surface creeks, or springs. Underground recharge has been identified along the eastern portion of ERF (near

Areas D and C/D) and from Clunie Creek (into Pond 146). Surveys have not been performed in Area A to identify areas of recharge.

3.3.6 Organic Content

Sublimation of WP is expected to be retarded in areas where sediment contains high organic content, because it is unlikely that these areas would dry. The distribution of organically rich sediment is unknown at the flats, with the exception of Racine Island. A high concentration of organic material has been found in pond bottom sediment at Racine Island.

3.3.7 Assessment of Drying Potential by Pond Group

WP will not sublimate in portions of pond groups that do not desaturate. These contaminated areas will be delineated by visual inspection, data from sediment monitoring stations, and treatment verification monitoring. AquaBlok™ will be applied to all areas that do not respond to draining and drying.

However, it is believed that sediments need not dry completely, only enough to allow sublimation/oxidation to occur through pores to the surface. Surrounding mud flats adjacent to these ponds tend not to be highly organic, promoting sublimation/oxidation if exposed.

Three tables have been prepared that emphasize different aspects of the draining and drying process. The physical characteristics of each pond group are presented in Table C-2. These characteristics influence the effectiveness of pond draining under Alternatives 3 and 4. An "index" of how well a pond group is expected to dry under Alternatives 3 and 4 is presented in Table C-5. This index is actually the percentage of pond group area that is expected to require AquaBlok™. The rationale for these estimates is also presented in Table C-5.

3.4 Comparison of Alternatives 3 and 4

Alternatives 3 and 4 each have strengths and weaknesses. Both alternatives are essentially pond draining, but each uses a different implementation method and each has a different impact on the environment. The following are fundamental differences between Alternatives 3 and 4:

- Large volumes of water can be drained quickly under Alternative 4. Exposure pathways are more quickly blocked under Alternative 4 than under Alternative 3.
- However, ponds breached by Alternative 4 are also flooded more frequently. WP removal through the sublimation/oxidation process is expected to be more rapid under Alternative 3 than under Alternative 4.

The discussion presented in this section is based primarily on the results of the summer 1997 Pond 183 pumping study and continued monitoring of Bread Truck, which was breached in 1996.

TABLE C-5
Drying Potential (Percentage of Hot Ponds to be Covered with AquaBlok™)

Pond Groups	Hot Pond Area (hectares)	Alt. 1&2 : No Action and/or Detailed Monitoring	Alt. 3: Pumping and AquaBlok™	Alt. 4: Breaching, Pumping and AquaBlok™	Alt. 5: AquaBlok™	Rationale for AquaBlok™ Coverage Estimate
Northern A	5.8	0	60	40	100	The Northern A area is hummocky with several deeper pockets of free-standing water and several areas of elevated sedge marsh. Few detailed surveys of Area A have been performed, and the hydraulic system is not well understood. It is unknown whether there is a source of recharge in this Area. Under Alternative 3, there is uncertainty as to whether water levels can be decreased significantly. Under Alternative 4, although water levels may be decreased, it is unknown whether the pond bottoms can be dried. However, an aerial and land survey conducted in June 1997 suggested that the area may be drained.
Pond 290	0.9	0	15	10	100	Pond 290 is relatively isolated from other ponds. The deepest section of the pond appears to be in the north (best location for pump). The pond is expected to drain and dry successfully under either Alternative 3 or 4 . Breaching is not expected to improve the effectiveness of draining.
Pond 183	2.9	0	30	15	100	Pond 183 is considerably more shallow than neighboring Pond 146. Because 183 is shallow (avg. depth 20 centimeters), moderate lowering of the water table by pumping will expose a large area of contaminated sediment. The deepest portion of Pond 183 appears to be in the northern section of the pond. The two ponds were connected in 1996 with the advancement of the dredge from Pond 146 to Pond 183. A treatability study conducted in summer 1997 determined that Pond 183 could be pumped dry and that inflow from Pond 146 could be controlled.
Pond 146	5.5	0	50	30	90	Clunie Creek is suspected to provide underground recharge. The eastern portion of Pond 146 is approximately 0.7 meters deep. Although water levels in Pond 146 may be lowered by high pumping and breaching, it is unlikely that pond bottoms will dry and warm long enough to foster WP sublimation/oxidation. Under Alternative 4, only a portion of Pond 146 needs to be drained, because of dredge operation in 1996.
Northern C & C/D	3.7	0	60	40	100	The Northern C and C/D area is hummocky, with several deeper pockets of free standing water and several areas of elevated sedge marsh. Recharge exists from the eastern side of the flats. Under Alternative 3, there is high uncertainty as to whether water levels can be decreased significantly, even with large amount of pumping. By breaching the Large Pond in area D (Alt. 4), water levels in the hot ponds may be decreased, but it is unknown whether hot pond bottoms can be dried. The deepest portion of this pond system is along the eastern side.

3.4.1 Alternative 4 Drains Water Quickly

Breaching can move a large volume of water quickly. This is advantageous in two ways: exposure pathways are blocked quickly, and large open water bodies can be drained.

By rapidly removing water, the exposure pathway for dabbling ducks is immediately blocked. Thus, dabbling ducks will not feed in the sediment. This was demonstrated at Racine Island and Bread Truck. It takes only 1 or 2 days for a breached pond to drain and expose a large area of pond bottom. In comparison, pumping a pond system initially or after a flooding tide could take 1 to 2 weeks, depending on the amount of rainfall and pump capacity.

Breaching would also make it possible to drain a large open water body, using smaller, more conventional pump systems. For example, the area of hot ponds in the Northern C and C/D area is small (3.7 hectares). However, this pond group is hydraulically interconnected to a large permanent pond in Area D by a large area of sedge marsh. Pumping after breaching would require many fewer pumps than pumping alone.

Thus, the factors that influence the effectiveness of draining were considered in determining the volume of water that could be drained by breaching. These assumptions determined the designed pumping capacity, as presented in Table C-6.

TABLE C-6
Pumping Rates of Alternatives 3 and 4

	Alternative 3	Alternative 4		
Pond Groups	Total Pumping Flow Rate (gpm)	Water to be Drained by Breaching (%)	Water to by Drained by Pumping (%)	Total Pumping Flow Rate (gpm)
Northern A	7,168	60	40	2,867
Pond 290	1,277	80	20	255
Pond 183	1,995	50	50	997
Pond 146	10,122	50	50	5,061
C & C/D	39,228	40	60	23,537

Notes:
1. Water to be drained by breaching was approximated based on topography and hydraulic properties of each pond group.
2. Pumping rate under Alternative 3 was determined by estimating landcover depths and areas from the ERF Geographical Information System (GIS), and assuming that each pond group would have to be drained within 36 hours of post-flooding tide pond level stabilization. Previous research by Cold Regions Research and Engineering Laboratory (CRREL) and projected tidal and climatological data indicate that a pond should drain in 36 hours to allow for sublimation/oxidation processes.

Hence, less pumping and potentially less AquaBlok™ will be needed under Alternative 4 than Alternative 3. Breaching the pond system under Alternative 4 is expected to move a large volume of water initially, which would result in less water to be removed by pumping. The combination of breaching and pumping (Alternative 4) is expected to be more effective in draining than pumping alone (Alternative 3). The remaining water could be drained by smaller pumps under Alternative 4. A smaller area of AquaBlok™ is estimated to be needed under Alternative 4.

Less Residual Risk. It was assumed that draining might be more effective under Alternative 4 than Alternative 3 because smaller-capacity pumps could be placed to drain localized depressions. AquaBlok™ will be placed over all areas that do not dry, immobilizing the WP contained in the untreated sediment. Because the area that will not dry is expected to be smaller under Alternative 4 than Alternative 3, the amount of residual risk is also expected to be lower. Residual risks resulting from the implementation of Alternatives 1 to 5 are presented in Appendix F.

3.4.2 Ponds Breached by Alternative 4 Reflood Frequently

The primary drawback to breaching is that ponds would flood more frequently. Breaching would lower the threshold elevations. This would result in ponds being flooded even during low tides. Even though the tidal waters would quickly redrain, this periodic reflooding would result in the slowing of the WP sublimation/oxidation process (Collins, 1997). These processes were demonstrated during the 1997 treatability studies at Bread Truck Pond (Pond 109) and Area C (Pond 183). During the majority of the summer, the pond bottom of Pond 183 remained dry after several days of pumping. Pond 109 at Bread Truck, however, was breached and repeatedly flooded; drying of the pond bottom was marginal. The tensiometers that were placed in Pond 183 had significantly higher readings than those placed at Pond 109, indicating that the pond bottom drying process was much more effective in Pond 183.

Therefore although Alternative 4 may remove the exposure pathway more rapidly than Alternative 3, sublimation/oxidation processes may be more effective than under Alternative 3. During low flood years, ponds that are pumped only would experience longer drying periods than ponds that are breached (because of frequent reflooding). As a result of the frequent rewetting of breached ponds, pond bottom drying would be slowed, and it may take more years for cleanup levels to be achieved under Alternative 4 (than under Alternative 3). However, because these conclusions are preliminary, it was assumed in the implementation schedule that operation of Alternatives 3 and 4 will require the same duration of 5 years.

3.5 Performance of Alternative 5: AquaBlok™

Alternative 5 blocks the exposure pathway by preventing dabbling ducks and swans from feeding from contaminated pond bottoms. The following are factors that affect the success of AquaBlok™ application:

- Ponds–AquaBlok™ can be applied in either permanently ponded or intermittently ponded areas.
- Vegetation–Vegetative cover around the AquaBlok™ helps protect the material from disruption by tides. The vegetative cover contributed to the success of the treatability study completed at Racine Island.
- Tides–Areas where tides are slower and more gentle are better suited for AquaBlok™. The stronger and faster tides may disturb or move AquaBlok™. Generally, high tides flow and ebb more slowly in large ponds and quickly in smaller ponds.

- Craters–The presence of craters may result in uneven distribution of AquaBlok™, especially if the AquaBlok™ is applied from the air. Reapplication may be needed for this technology to be effective.
- Gully recession–Areas that may be drained naturally within the next 10 years may not be good candidates for AquaBlok™. It is unknown what effect the undercutting caused by gully recession may have on the stability of the barrier, but it would likely erode and destroy the cover effectiveness.
- Ice Plucking–Areas that are very close to the Eagle River and that may experience ice plucking are not good candidates for AquaBlok™ because the material might be damaged or dislodged by the ice movement. Ice plucking has been sporadically observed in ponds away from the Eagle River. However, there are no quantitative guidelines on what range is too close. Ice plucking can, on occasion, occur in large ponds when the ice sheet freezes to the bottom of the ponds and is then lifted by a high tide in the spring before the ice has a chance to melt in place.
- Sedimentation–AquaBlok™ essentially performs like consolidated sedimentation.

AquaBlok™ application generally results in an increase in the pond bottom elevation of 20 to 30 cm. While it may not necessarily destroy habitat, it may alter it. Applications of AquaBlok™ to limited (deeper) pond areas also will result in habitat changes. From a hydrologic standpoint, water storage capacity will be reduced. The feeding habitat represented by the bottom sediments covered with AquaBlok™ will also be reduced until habitat is reestablished. Sedimentation and plant establishment on top of the AquaBlok™ may eventually restore these areas for waterfowl feeding; however the depth will be permanently altered (Pochop *et al.*, in Racine *et al.*, 1996). The effect of depth changes on feeding habitat will depend on the initial water depth and the thickness of AquaBlok™ added.

Studies at Racine Island show that AquaBlok™ supports the growth of vegetation, but fills shallow ponds. It has been demonstrated that within 1 year of initial application vegetative growth over the barrier becomes lush and is inhibited only in areas where the AquaBlok™ application was thickest. Fish and invertebrates also were observed in ponded areas treated with AquaBlok™. The new vegetation provides areas where waterfowl can hide or loaf; however, AquaBlok™ reduces the depth of treated ponds and results in the loss of some shallow areas where waterfowl can dabble. Conversely, habitat may be created in deeper ponds if pond bottoms rise to the optimum feeding depth for dabbling ducks. The resulting depth would be difficult to predict, because it depends on many factors, including existing pond elevation, tide elevation, flooding cycles, and sedimentation.

After application, the thickness of the AquaBlok™ will be sampled. An 8-cm-diameter plastic tube will be used to pull up a plug of AquaBlok™ to measure its thickness (Nauchman, 1997). The number of core samples to be measured will be determined during remedial design.

The design thickness of the AquaBlok™ will range from 5 to 10 cm over level ground (Nauchman, 1997). AquaBlok™ may need to be reapplied over craters. Treatability studies indicate that AquaBlok™ may be unevenly distributed over craters.

Data on the thickness of the AquaBlok™ barrier applied by air to a test area shows some reduction from 1993 to 1994. The sedimentation and deposition of organic matter measured in 1994 on the test area treated in 1993 was expected. Deposition should not inhibit the effectiveness of the AquaBlok™ in reducing the movement of WP particles below the barrier.

Vegetative growth may be inhibited by either scouring by ice breakup or by the physical characteristics of the area. It is expected that vegetation will recover. Lab tests show that plants will grow on the AquaBlok™ (Pochop *et al.*, in Racine *et al.*, 1994).

Two surveys were performed during fall 1996 and summer 1997 to evaluate the performance of the AquaBlok™ material applied at Racine Island in 1994. During both visits, thick vegetation was observed growing though the material. Along the perimeter of the pond, clean, dry gravel was observed underlain by a layer of pure bentonite. The bentonite appeared to be binding the gravel to the underlying sediment. In the saturated portion of the pond, the AquaBlok™ cover remained a mixture of gravel within swelled bentonite. Although the material has moderately low resistive strength and was penetrable, pen studies performed in 1993 suggest that waterfowl do not prefer dabbling in the AquaBlok™ material. Waterfowl prefer sifting in sediment, whereas the AquaBlok™ material consists of clean gravel (1/2- to 3/4-inch-diameter) within high plasticity clay (Cummings, 1997). In addition, if the cover material were stepped on by a large animal such as a moose, the swelling properties of the saturated bentonite material would likely reseal the penetration (Pochop, 1997). AquaBlok™ thickness was measured during the 1996 survey and compared to previous measurements. The results are presented in Table C-7.

TABLE C-7
AquaBlok™ Thickness (cm)

	1994	1995	1996
Center of AquaBlok™ Drop	approx. 30	20.3	20.0
Level Ground	6.2	5.2	9.8
Craters	16.0	14.5	7.4

Notes.
1. Measured from core samples taken at Racine Island, Pond 285.
2. Increased thickness is the result of increased swelling of the bentonite.
Source: Pochop, 1997.

It is currently uncertain how effective AquaBlok™ application by truck will be. Concerns include uneven settling, accuracy of application, and completeness of hydration. The accuracy of application and the evenness of layer thickness should be improved with a thick application on an ice surface rather than summer application by helicopter. It is uncertain how even settlement of cover will be as ice melts out. A treatability study will be conducted during winter 1997-1998 to evaluate the implementability of winter application by truck.

4.0 Implementation of Alternatives

The factors that contribute to the implementation of Alternatives 1 through 5 are presented in this section. Because Alternatives 3 and 4 are basically two different ways to implement pond draining, the factors that are common to these two alternatives will be discussed together in Section 4.3, followed by a discussion of the differences between in the two alternatives in Section 4.4.

Clearance of unexploded ordnance (UXO) must be considered when implementing any of the alternatives. Current health and safety rules at Fort Richardson require that pathways at ERF be visually or electronically (with magnetometers) inspected once during each field season. UXO clearance has been included in the cost estimates in Appendix E.

An implementation schedule for each of these alternatives is presented in Figure C-7.

4.1 Implementation of Alternative 1

The no action alternative does not include any treatment technology or monitoring activities.

4.2 Implementation of Alternative 2

The following studies will be performed annually at ERF to determine if and when RAOs are met:

- Mallard mortality telemetry study
- Aerial bird population surveys
- Aerial photography, to cover gully recession, pond draining, and bird populations. After two flyovers in the first year, it is assumed that there would be only one flyover per year.

Verification monitoring using WP composite sampling and particle planting will be done in any pond group that has been observed to be dry for more than 21 days during the summer. It is anticipated that sampling will be done only in 1997 and 1998 during the next 5 years because of the substantial interval of potential pond drying during those 2 years. Water elevations, temperature, and water saturation also will be monitored. Sedimentation also will be monitored throughout the flats. The detailed monitoring strategy is discussed in Appendix G.

4.3 Implementation of Alternative 3

Alternative 3 involves installing a series of pumps to drain an entire pond group or system. Because some portions of the pond system will not drain or dry, AquaBlok™ will be applied to certain portions of the hot ponds. This alternative will be implemented in the following stages:

- Detailed topographic survey and baseline monitoring
- Installation of pump and monitoring system after spring breakup

FIGURE C-7: IMPLE. .TATION SCHEDULE

Activity	Year 0 Spring Summer Fall	Year 1 Spring Summer Fall	Year 2 Spring Summer Fall	Year 3 Spring Summer Fall	Year 4 Spring Summer Fall	Year 5 Spring Summer Fall	Year 6 Through Achieving RAOs (1) Spring Summer Fall
ALTERNATIVE 1							
No monitoring or treatment activities							
ALTERNATIVE 2							
Survey Ponds							
Baseline WP Sampling							
Sublimation Conditions Monitoring (1 station)							
Install Equipment							
Operate Equipment							
Remove Equipment							
Sedimentation Analysis							
Install Equipment							
Operate Equipment							
Remove Equipment							
WP Verification							
Plant particles							
Remove & measure							
WP Sediment sampling							
ERF-WIDE ACTIVITIES							
Telemetry							
Bird Population Aerial Survey							
Aerial Photography - ERF							
Hazing							
ALTERNATIVE 3							
Baseline WP Sampling							
Survey Ponds							
TREATMENT							
Pumping							
Initial Startup/Shakedown							
Yearly Startup/Shakedown							
Install pumps							
Operate pumps							
Remove pumps							
Sublimation Conditions Stations							
Install Equipment							
Operate Equipment							
Remove Equipment							
WP Verification Sampling							
Plant particles							
Remove & measure							
WP Sediment sampling							
AquaBlok™ Application							
Monitor AquaBlok™ Integrity							
Monitor Habitat Changes							
ERF-WIDE Activities							
Telemetry							
Bird Population Aerial Survey							
Aerial Photography - ERF (2)							
Hazing							

FIGURE C-7: IMPLEI TATION SCHEDULE

Activity	Year 0 Spring Summer Fall	Year 1 Spring Summer Fall	Year 2 Spring Summer Fall	Year 3 Spring Summer Fall	Year 4 Spring Summer Fall	Year 5 Spring Summer Fall	Year 6 Through Achieving RAOs (1) Spring Summer Fall
ALTERNATIVE 4							
Survey Ponds							
Baseline WP Sampling							
TREATMENT							
Breach pond							
Pumping							
Initial Startup/Shakedown							
Yearly Startup/Shakedown							
Install pumps							
Operate pumps							
Remove pumps							
Sublimation Conditions Stations							
Install equipment							
Operate							
Remove							
WP Verification Sampling							
Plant particles							
Remove & measure							
WP Sediment sampling							
AquaBlok™ Application							
Monitor AquaBlok™ Integrity							
Monitor Habitat changes							
ERF-WIDE ACTIVITIES							
Telemetry							
Bird Population Aerial Survey							
Aerial Photography - ERF (2)							
Hazing							
ALTERNATIVE 5							
Baseline WP Sampling							
Survey Pond							
TREATMENT							
AquaBlokTM Application							
Monitor AquaBlok™ Integrity							
Monitor Habitat Change							
ERF-WIDE ACTIVITIES							
Telemetry							
Bird Population Aerial Survey							
Aerial Photography - ERF (2)							
Hazing							

Notes:

1. Activities may change in these later years, depending on the progress to date.
2. Baseline photograph is obtained during low tide after the treatment action.

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- Equipment refueling and servicing approximately every 3 weeks, depending on infiltration rates and tidal conditions
- Removal of pump and monitoring system before winter freeze-up
- WP verification sampling after several years of draining and drying
- AquaBlok™ application

A layout of Alternative 3 is presented in Figure C-3. The activities to be performed to implement Alternative 3 are summarized in this subsection. These activities form the basis for the cost assumptions presented in Appendix E.

4.3.1 Detailed Topographic Survey and Baseline Monitoring

Each pond group will be surveyed in detail to determine topography and surface-water flow patterns. Transits, global positioning systems, and/or aerial photographs will be used to survey the pond group. Information about topography and surface-water flow will be used to size and site pumps. For example, pumps will be placed in the deepest portion of each pond. Predictions of the success of drying will be made from the number of depressions and craters within the pond group. Knowledge about the threshold elevation of each pond will assist in determining how often a pond system will flood with the flooding tide. With that information, the length of time to implement the remedy at each pond group will be estimated.

Baseline monitoring before treatment implementation also will be performed, as discussed in Appendix G.

4.3.2 Installation of Pump and Monitoring System after Breakup

The pump and monitoring systems will be installed by helicopter. Deployment will likely occur within the first week of the first dry period (after breakup). In 1998, the first dry, warm period is predicted to occur in late April (National Oceanic and Atmospheric Administration, 1997).

The pump system will be composed of an electrically powered pump, diesel-powered generator, fuel tank, heavy duty power cord (between the generator and the pump), and 200 to 1,000 m of discharge piping. The length of discharge piping is dependent on the distance of the pump system to the Eagle River or one of its gullies. Detailed specifications of the pump system and the generator are presented in Table C-8.

Each pump and each generator will be mounted on floats. These two components will be connected by a heavy-duty power cord capable of salt water immersion. The generator will be located near the pond edge, approximately 67 m away from the pump, for three reasons:

1. Allow for regular refueling in a safe manner by locating the fuel tank on the pond edge.
2. Reduce the extent of equipment loss in the event that live UXO is ingested by the pump and explodes.
3. Reduce the possibility of spilling fuel and motor oil.

TABLE C-8
Pump and Generator Specifications

Component	Specifications	Description/Comment
Pump Specifications		
Power	Electrically powered Static discharge head of 8 ft	Pump separated from the generator to prevent fuel spills in the unlikely event that the pump detonates a UXO.
Motor	3-phase, 480 volt, 60 Hz, totally enclosed/fan cooled	Electrical connections to the pump motor shall be through a waterproof quick-disconnect fitting.
Suction	Direct	Located approximately flush with bottom of floats (no suction hose or pipe)
Pump discharge	Quick couplers	For attaching the discharge hose
Discharge pumping	Flexible rubber hose and polyethylene pipe with mating galvanized quick couplers on both ends	Rubber hose in 50-foot lengths. Polyethylene piping will come in 5-foot, 10-foot and 20-foot lengths. Rubber hose will be used in ponds, and rigid pipe will run on dry land.
Power cable between pump and generator	Four-conductor 220 feet long. Voltage drop of less than 10% at full load Withstand salt water immersion.	One conductor to ground motor to generator
Sensors	Float switch (on/off)	Detects water levels and actuates the generator and pump controls while on automatic mode: Low level shutoff, high level actuate, and flood level shutoff.
Sensor cable between sensors on pump and automated controls on generator	Withstand salt water immersion	Waterproof, quick-disconnect fittings Strapped to power cable
Generator Specifications		
Power	Diesel, with output of 480 volts AC, 3-phase, 60 Hz	Sized to start and continuously operate the pump motor
Transformer	Two-kVA, 115-volt, single phase One ground-fault protected 115-volt duplex outlet	Mounted outside of control panel.
Fuel Tank	100 gallons (for 200 gpm system)	Provide 48 hours of continuous operation under full load

TABLE C-8
Pump and Generator Specifications

Component	Specifications	Description/Comment
Electrical Switches and Controls	Manual, automatic, or time powered	Located on generator module. Manual system operation Automatic operation controlled by float switches on pump or time powered by generator battery. Timer adjustable to set up to four start times and four stop times within a 24-hour period. In all operating modes, an adjustable time delay shall be built to allow the generator to warm up before energizing the pump motor.
Electrical Meters	Voltage, current and frequency	
Engine indicators	Tachometer, hour meter, engine temperature gauge, fuel pressure gauge, oil pressure gauge, temperature, fuel, and pressure indicator lights.	Engine protection shutdown system during low coolant (high temperature), low fuel, low oil pressure. Shutdown will include provisions for operator to determine cause of shutdown.
Other	Circuit breakers, ground fault protection, waterproof NEMA 4 enclosures	All wire into enclosure shall be routed through waterproof strain-relief fittings.

Notes:
1. Specifications for 500, 1,000, 2,000, 3,000, and 5,000 gpm pumps.
2. Source: Walsh, 1995.

Because of human safety concerns, the pumping system should be capable of automatic operation. Once the system is initially turned on after installation, the pump will continue operating until the pond is pumped dry. The system will then automatically shut down.

There will likely be limited continuous water flow into the pond from the surrounding high water table. A detection system will sense when the water depth reaches a desired level and automatically start the system to again pump out the water.

The pump system will be sling-loaded from a Blackhawk helicopter. It is estimated that three helicopter trips will be needed to mobilize a 2,000-gallons-per-minute (gpm) pump system. Because the sling-load capacity of the Blackhawk is 8,000 pounds (lbs), no single component of the pump system can be greater than 8,000 lbs. Three personnel will be needed to install a 2,000-gpm pump system. More helicopter sling-load trips and more personnel may be needed to install larger pump systems because of the weight of discharge piping for larger-diameter pump systems.

Monitoring stations with data loggers will be installed after installation of the pump system. An average of three stations will be placed in each hot pond to be drained. All systems will have sediment temperature and moisture probes. A water-level indicator will be placed in the deepest portion of each pond. A more detailed discussion of the monitoring stations is presented in Appendix G, Monitoring Plan.

4.3.3 Operation and Maintenance of the Pump Systems

The pumps will have to be refueled approximately 3 days after each flooding tide. The threshold elevation of each pond will determine the height of tide that will flood the pond system, and subsequently the frequency of refueling and servicing. The threshold elevation will be higher for Alternative 3 than for Alternative 4. Refueling frequency is also based on the frequency of high tides.

For cost estimating purposes, it was assumed that refueling will be needed every 3 weeks. It was also assumed that refueling will be performed with a UH-1 helicopter and that the open burning/open detonation pad (OB/OD Pad) will be used as a staging area. A fiberglass tank will be sling-loaded to each pump location. Refueling costs may be reduced by transporting fuel by truck/and or hovercraft to some of the Northern C and C/D ponds, as well as Pond 183 and Pond 146. It was also assumed that two CRREL personnel (one mechanic and one junior engineer) will be required to refuel and maintain each pump system, at a rate of 4 hours per pump per person per fueling.

4.3.4 Removal of Pump and Monitoring System Before Freeze-up

On average, freeze-up at ERF occurs in October. The pump system and monitoring system will need to be removed before freeze-up occurs. Equipment will be stored at Fort Richardson. For cost estimating purposes, it was assumed that it would take as much manpower and helicopter time to remove equipment as it did to install it.

4.3.5 Monitoring

For ERF as a whole, the following studies will be performed annually as described in detail in Appendix G:

- Mallard mortality telemetry study

- Aerial bird population surveys
- Aerial photography, to cover gully recession, pond draining, and bird populations. After two flyovers in the first year, it is assumed that there would be only one flyover per year.

Baseline WP monitoring will be conducted before each pond group is treated by draining, and WP verification sampling will take place after treatment. Water elevations, temperature, and water saturation of sediment also will be monitored using data loggers and probes during this period.

4.3.6 AquaBlok™ Application

AquaBlok™ will be applied to portions of ponds where water levels do not decline or sediment does not dry. Sublimation/oxidation monitoring and verification sampling will be performed to determine those areas.

For the area that receives AquaBlok™, integrity monitoring will begin the following year and the area will not be sampled for WP.

4.4 Implementation of Alternative 4

Alternative 4 will include all the components of Alternative 3. In addition, it will include the breaching of each pond system, with a minimum of one ditch per pond system. A discussion of how pond breaching will be conducted is presented in this subsection, followed by a presentation of the differences in implementation between Alternatives 3 and 4. Deploying pump systems would be the same under Alternative 4 as Alternative 3.

4.4.1 Implementation of Breaching

The following summary is based on the description of the breaching in 1996 of Bread Truck Pond (Pond 109) (Collins *et al.*, in Collins *et al.*, 1997).

Because ERF is an artillery impact range, there is a possibility of encountering UXO if digging or ditching is done with standard mechanical excavation equipment. To minimize the risk from UXO, explosives will be used to excavate the drainage ditch connecting the pond system with nearby gullies or the Eagle River. Military engineer units that train to use explosives to excavate such features as tank trap ditches and breaches across roadbeds will set the explosives.

Perform Detailed Survey. Surveys will be completed at each pond group to determine preferential flow paths, areas of potential recharge, threshold elevations, and optimum ditch locations. The shortest distance between ponds to discharge will be selected to minimize effects on the habitat. In addition, where possible, gullies that are predicted to breach a pond system will be extended. The surveying will be conducted in the fall.

Conduct Breaching When Flats are Frozen. Breaching will be conducted in early spring, before the ice covering the ponds and the surrounding area thaws. The ice cover will facilitate access to the area, keeping personnel from having to wade through water as they place explosive charges. The ground would then be seasonally frozen to some unknown depth, estimated at 60 cm. The soil beneath the frozen layer would be fairly dense but saturated. Within the pond, normal water depths would vary from zero to 30 cm, with the ice frozen to the bottom by spring. Beneath the ice, sediment may be frozen to some unknown depth or may be unfrozen and saturated.

Perform Blasting on a Clear Day. Fort Richardson is adjacent to the community of Eagle River and noise from range use is a concern to the Army Command. The presence of a low cloud cover would reflect and intensify the sound of the explosive blasts, disturbing civilian areas off post. Therefore, breaching will be conducted only on days with clear skies. OB/OD Pad will be used as the base of operations.

UXO Clearance. Before breaching, the area to be blasted will be cleared by military personnel or UXO contractor to ensure that there is no UXO exposed on the surface in the immediate vicinity that may pose hazards to the personnel carrying out the operation.

Survey Ditches. The ditches will be excavated in two stages. The beginning and endpoint of the planned ditch will be located and flagged. The beginning point will be the head of the existing gully system or the Eagle River. The endpoint will be the pond system to be breached.

Set Charges. Blasting of the ditches will occur in two stages:

Stage 1: Set Shaped Charges. To produce the optimum-sized crater for the amount of explosive, the cratering charge needs to be placed at depth in a 30-cm-diameter borehole in the ground. Standard procedures call for either using a drill rig to auger the boreholes or use standoff shaped-charge explosives to excavate the boreholes. The cratering charges are then placed in the boreholes and detonated, producing the final crater. Again, because of the possibility of encountering UXO in ERF, the boreholes needed for the cratering charges would also have to be excavated using shaped charges. The first stage will use 40-lb shaped charges to form boreholes in the sediment. Nominal 1x2-inch wooden boards will be duct-taped to the shaped charges, forming a stand to hold the shaped charge 0.6 m above the surface with the charge pointing down. The charges will be spaced every 4 m along the centerline of the planned ditch. A detonation cord will connect all shaped charges.

Once charges are secured to the detonation cord, all personnel will depart the area, returning to OB/OD Pad. Key personnel will board a helicopter and depart the area. The helicopter will stay airborne, outside the safety zone, until after the blast.

When detonated, the shaped charge will produce a plasma jet that punches a 0.3-m-diameter hole straight down into the ground. The detonation of the shaped charges will produce a very loud, sharp explosive noise. After the blast, the helicopter will return to the area, landing away from the explosive blast area. The UXO personnel will again inspect the area for any possible newly exposed UXO and look for duds. Once the area is cleared, the remaining personnel will be ferried in by helicopter to begin setting up the cratering charges.

Stage 2: Set Cratering Charges. In the second stage of the explosive evacuation, cratering charges will be placed in each of the boreholes created by the shaped charges, with an attached 1-lb block of trinitrotoluene (TNT). The charges will be wired together similarly to the way the shaped charges were. For normal soils, 40-lb cratering charges placed every 4 m along the centerline of the ditch at 1.2-m depths would result in a ditch 6 m wide and 1.8 m deep.

Again, once all charges are secured to the detonation cord, all personnel will depart the area by helicopter, returning to OB/OD Pad. The detonation of the cratering charges will produce a very loud, deep, rumbling explosive noise that is expected to shake the ground and a shock wave that may be felt several thousand meters away (Collins *et al.*, 1996).

It was estimated that three staff and one UXO personnel will be needed during the blasting. To minimize noise impacts to the surrounding community, no more than 120 m of ditch will be advanced per day.

Following the blasting, the pond system will have to be surveyed to determine topography and surface-water flow patterns. The blasted ditch should be approximately 6 m wide and 1.8 m deep. The remaining activities described in Section 4.3 will also be implemented under this alternative.

4.4.2 Differences between Implementation of Alternatives 3 and 4

Pump Sizing. A larger pumping flow rate would be needed for Alternative 3 than for Alternative 4. Therefore, pumps sized for Alternative 3 may be larger than those needed for Alternative 4. These larger pumps may require significantly more manpower and helicopter time to deploy. For example, 15,000 gpm of water would need to be pumped from the pond in Area D to drain the pond in 36 hours. Such a large single pump system would require a 60-cm-diameter discharge. Six-meter lengths of rigid poly pipe at that diameter may weigh 500 pounds and require 5 to 10 men to move. These problems will be overcome by using more, smaller pumps. Capital costs will be higher (with more smaller pumps versus one large pump), but the lower installation costs will compensate. This is discussed further in Appendix E.

However, breaching under Alternative 4 would likely drain a large portion of Area D. Thus such a large capacity pump (as in Alternative 3) would not be required. Because hot ponds have not been identified in Area D, it would not be necessary to dry Area D. Breaching would be performed only to prevent water flow to the Northern C and C/D pond group.

Refueling. Much more water would be initially moved in Alternative 4 than Alternative 3. However, the pond system would likely flood more frequently under Alternative 4 than Alternative 3. Hence more fuel will be needed during refueling in Alternative 3, but there may be more refueling trips under Alternative 4 because ponds would flood more often (lowered threshold elevation). Refueling trips may be optimized by using larger fuel tanks at the pump sites.

Amount of AquaBlok™. Less AquaBlok™ will be needed under Alternative 4 than Alternative 3, because pond draining is expected to be more successful under Alternative 4 than Alternative 3. This was discussed in Section 3.4.2.

4.4.3 Monitoring

The same monitoring conducted under Alternative 3 will be conducted under Alternative 4. The only additions would be surveys of the ditches and vegetation changes. The data will be entered into the ERF Remediation Database. Ditch changes in subsequent years will be tracked with aerial photos. Aerial photography will also be used to observe vegetation changes in these areas.

4.5 Implementation of Alternative 5

AquaBlok™ may be applied in three ways:

- By air in the summer
- By truck in the winter over frozen flats
- By slurry from OB/OD Pad, using the existing conveyance system from the former dredge operations

The potential modes of AquaBlok™ application are presented in Table C-9. Air application is considerably more expensive because of the high cost of the helicopter time. Hence, the cost estimate in Appendix E presents the cost of application both by truck and by air. However, there is less uncertainty regarding the success of application by truck in the winter, as discussed in Section 3.5.

TABLE C-9
Methods of Applying AquaBlok™

Pond Group	Mode of Application	Comments
Northern A	By air or possibly truck	If there is space between Otter Creek and the bluffs, truck may be able to enter the flats by the road from Cole Point.
Pond 290	By air or possibly truck	Same as above.
Pond 183	By air, truck, or slurry	Truck could easily enter from OB/OD Pad. Existing conveyance system can be used to apply AquaBlok™ as a slurry.
Pond 146	By air, truck, or slurry	Same as above.
Northern C and C/D	By air or truck, or possibly slurry	Hot ponds can be accessed from either OB/OD Pad or the road along the eastern bluffs. Existing conveyance system may be expanded to apply by slurry.

The application of AquaBlok™ by air and by truck is summarized in the following sub-sections.

4.5.1 Application by Air

The AquaBlok™ will be produced at OB/OD Pad. Materials (gravel, bentonite, and polymers) will be purchased locally and mixed using a 8-cubic-meter concrete truck. The drop bag that will be used for applying the AquaBlok™ is a polyvinyl chloride bulk bag, model HD 32-36, Springfield Special Products, Springfield, MO. A forklift will be used to hold the bag while a front end loader fills it with up to 2,500 kilograms of AquaBlok™. The bag will be rigged approximately 10 m below a Blackhawk helicopter for application. The AquaBlok™ will be applied in a 1.8-m swath from a height of about 27 m at an airspeed of approximately 8 kilometers per hour. Rate of application will be about 30 hours per hectare.

Volume of material will be approximately 336 tons per hectare. This application method was used successfully in the aerial application of AquaBlok™ in 1994 (Pochop *et al.*, 1995).

4.5.2 Application by Truck

AquaBlok™ may be applied by truck in the winter, when access to the flats is less restricted. During a cold winter, sufficient ice thickness on the frozen flats provides a protection for heavy loads from UXO. Fort Richardson access restriction are less. The material will be trucked to the flats over existing roads. The following bullets summarize the process of truck application of AquaBlok™:

- **Flag hot ponds.** The summer before winter application, all hot ponds or portions of hot ponds will need to be surveyed and flagged. Flagging will be high enough to be seen above winter ice and snow.
- **Regrade roads.** Because of winter conditions, the existing roads leading to ERF would have to be regraded with scraper and graders.
- **UXO clearance.** UXO should be cleared from all truck pathways before mobilization. Winter-time firing would be halted during this implementation period.
- **Mix AquaBlok™.** AquaBlok™ will be prepared in cement mixers at a staging area at Fort Richardson.
- **Transport AquaBlok™ with trucks.** Materials will be loaded into dump trucks and transported to ERF. It was assumed that three dump trucks could cover 3 hectares per day. Each truck would carry approximately 10 tons per load at 6 to 8 loads per day.
- **Spread materials on ice-covered flats.** AquaBlok™ would be spread by the dump trucks on the ice-covered flats by following the flagging. The material would sink and hydrate as the ice thaws. During winter, flooding tides slowly saturate snow and ice. Transport of AquaBlok™ by tides is not expected.
- **Check coverage.** AquaBlok™ coverage would be checked within 1 month of spring breakup.

4.5.3 Application by Slurry

AquaBlok™ may be mixed at OB/OD Pad and transported to ponds on the east side of the river by the existing conveyance system. The AquaBlok™ vendor is currently exploring AquaBlok™ application by slurry (Nauchman, 1997).

4.5.4 Monitoring

For ERF as a whole, the following studies will be performed annually:

- Mallard mortality telemetry study
- Aerial bird population surveys
- Aerial photography, to cover gully progression, pond draining, and bird populations. After two flyovers in the first year, it is assumed that there would be only one flyover per year.

Pond survey and baseline WP monitoring will also be done for each pond group before it is treated with AquaBlok™.

Integrity monitoring in the area that receives AquaBlok™ will begin the following year. Integrity monitoring will involve checking the thickness and cohesiveness of the AquaBlok™ material. Plant growth and disturbances from wildlife will also be evaluated.

5.0 Works Cited

Collins, C.M., Maj. M.T. Meeks, M.E. Walsh, and R.N. Bailey. Pond Draining Treatability Study: 1996 Studies–The Draining of Bread Truck Pond. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* C.M. Collins and D.W. Cate, eds. FY 96 Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. July 1997. Pp. 51-71.

Cummings, J. Personal communication. June 24, 1997.

National Oceanic and Atmospheric Administration. NTP4 software that predicts daily high tides, run by Dean Pidgeon of CRREL.

Nauchman, T. Personal communication with Mey Wong/CH2M HILL. 1997

Pochop, P. Personal communication. June 24, 1997.

Pochop, Patricia A., John L. Cummings, and Christi A. Yoder. *Evaluation of AquaBlok™ on Contaminated Sediment to Reduce Mortality of Foraging Waterfowl.* Denver Wildlife Research Center. 1995.

Pochop, P.A., J.L. Cummings, and C.A. Yoder. Evaluation of AquaBlok™ on Contaminated Sediment to Reduce Mortality of Foraging Waterfowl. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* D.W. Cate and C.H. Racine, eds. FY 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. September 1996. Pp. 205-230.

Walsh, M.E., C.M. Collins, and R.N. Bailey. Enhancement of Intrinsic Remediation of WP Particles by Sediment Warming in Intermittent Ponded Areas of Eagle River Flats. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* D.W. Cate and C.H. Racine, eds. FY 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. September 1996. Pp. 249-266.

Walsh, M.R. Comments on OUC *Draft Feasibility Study Report*. April 1997.

Walsh, Michael R. *Justification Review Document for Other Than Full and Open Competition–Program Equipment: Floating 2,000 gpm Pumping Station and Generator.* U.S. Army Cold Regions Research and Engineering Laboratory. May 30, 1995.

Figures C-1 to C-6

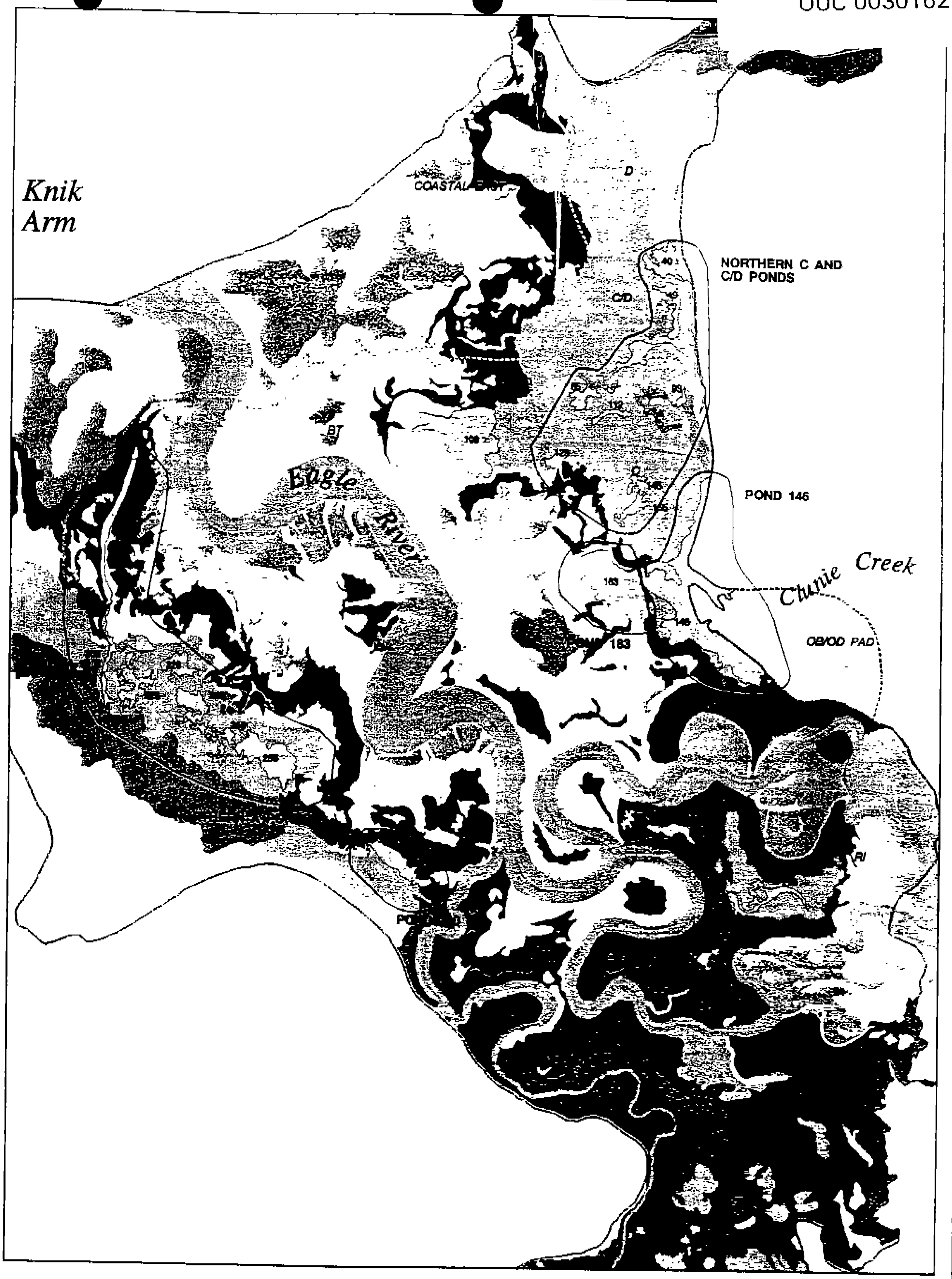

Figure C-1

Pond Groups Used in Detailed Analysis of Alternatives

Note:
Treatment has been or will be conducted at the following Hot Ponds:
Ponds 109, 293, & 297: Pond Draining by Breaching
Pond 285: AquaBlok™

Scale 1:12000
1 cm = 120 m
0 meters 350

Mapping and database source: CRREL, 1996.

OUTSIDE SITE
UNCLASSIFIED
MUD FLAT BARREN
BORDER LOW SHRUB
BORDER SPRUCE WOODLAND
CREEK
GULLEY
HALOPHYTIC HERB MEADOW
INTERIOR SEDGE MEADOW
INTERMITTENT POND
LEVEE GRASS MEADOW
MARINE ALGAE
PERMANENT POND
RIVER
RIVER MEANDER MEADOW
RELICT RIDGE
RAMENSKI S SEDGE MEADOW
SEDGE BOG
SEDGE MARSH
WET SWALE
49 HOT POND NUMBER
OUC SITE BOUNDARY
AREA BOUNDARY

Pond grouping based on topography, land form cover and hydraulic interconnectiveness.

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

CH2M HILL

March 26, 1997 AML: /proj/ba/d11/ct/fz.aml PLOT FILE /proj/bw/fig1.eps

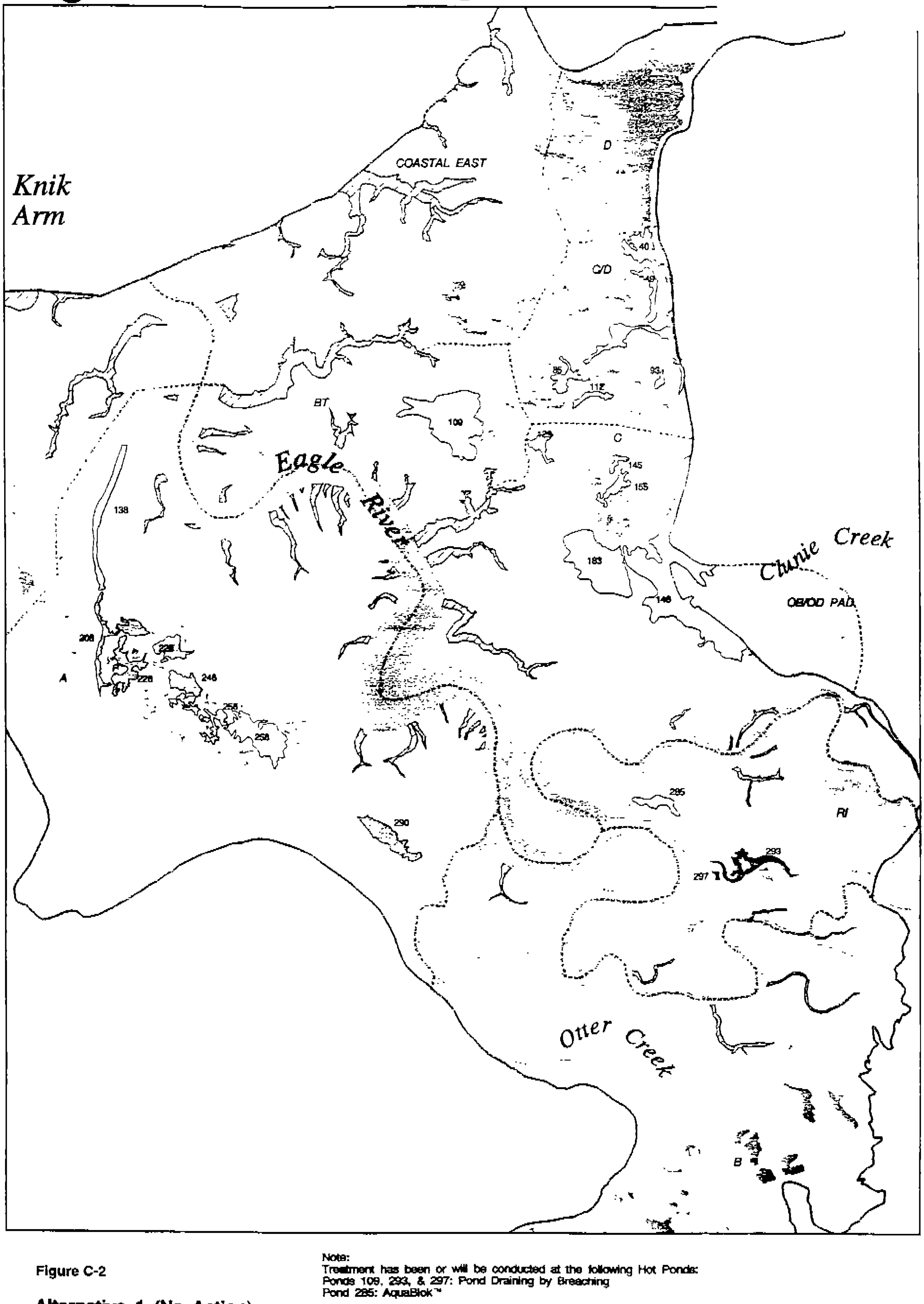

Figure C-2

Alternative 1 (No Action) and Alternative 2 (Detailed Monitoring)

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Note:
Treatment has been or will be conducted at the following Hot Ponds:
Ponds 109, 293, & 297: Pond Draining by Breaching
Pond 285: AquaBlok™

Scale 1:12000
1 cm = 120 m

0 meters 360

Mapping and database source: CRREL, 1996.

Permanent Pond
49 Hot Pond Number
Intermittent Pond
Gully
River/Creek
Area Boundary
OUC Site Boundary

NATURAL PROTECTION:
Likely within 5 yrs
Possibly within 10 - 15 yrs
May take more than 20 yrs
Very likely to take more than 20 yrs
Note: Assumes past and planned treatment actions

CH2M HILL

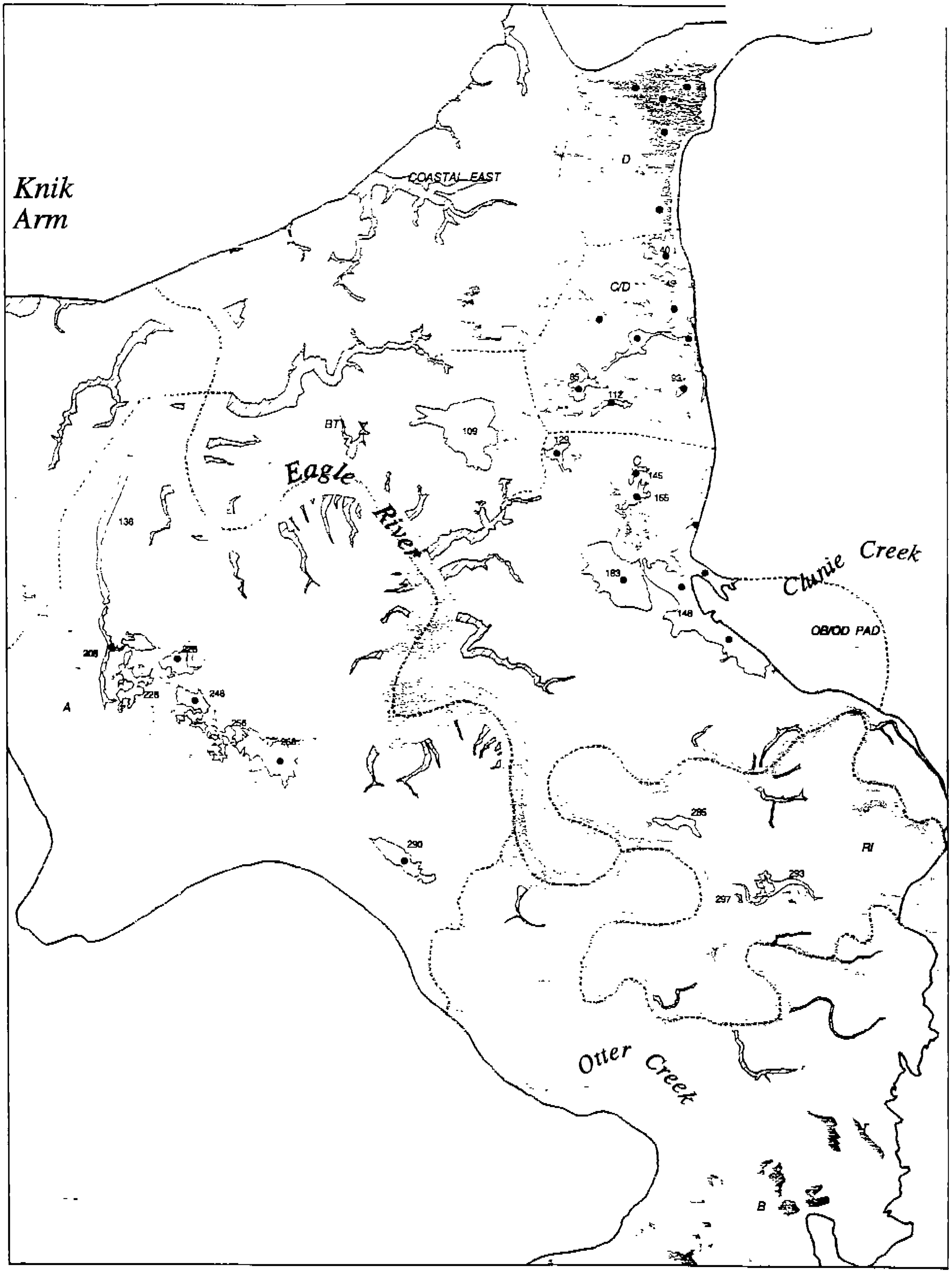

Figure C-3

Alternative 3:
Pumping and AquaBlok™

Note: 1. Treatment has been or will be conducted at the following Hot Ponds:
Ponds 109, 293, & 297: Pond Draining by Breaching
Pond 285: AquaBlok™
2. AquaBlok™ application is not shown.
3. Discharge piping is not shown.

N

Scale 1:12000
1 cm = 120 m

0 meters 360

Mapping and database source: CRREL, 1996.

49 Hot Pond Number
Intermittent Pond
Permanent Pond
Gully
River/Creek
Area Boundary
OUC Site Boundary

- Location of Pump - 1000 GPM Capacity
- Location of Pump - 2000 GPM Capacity
- Location of Pump - 3000 GPM Capacity

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

CH2MHILL

March 27, 1997

OUC 0030165

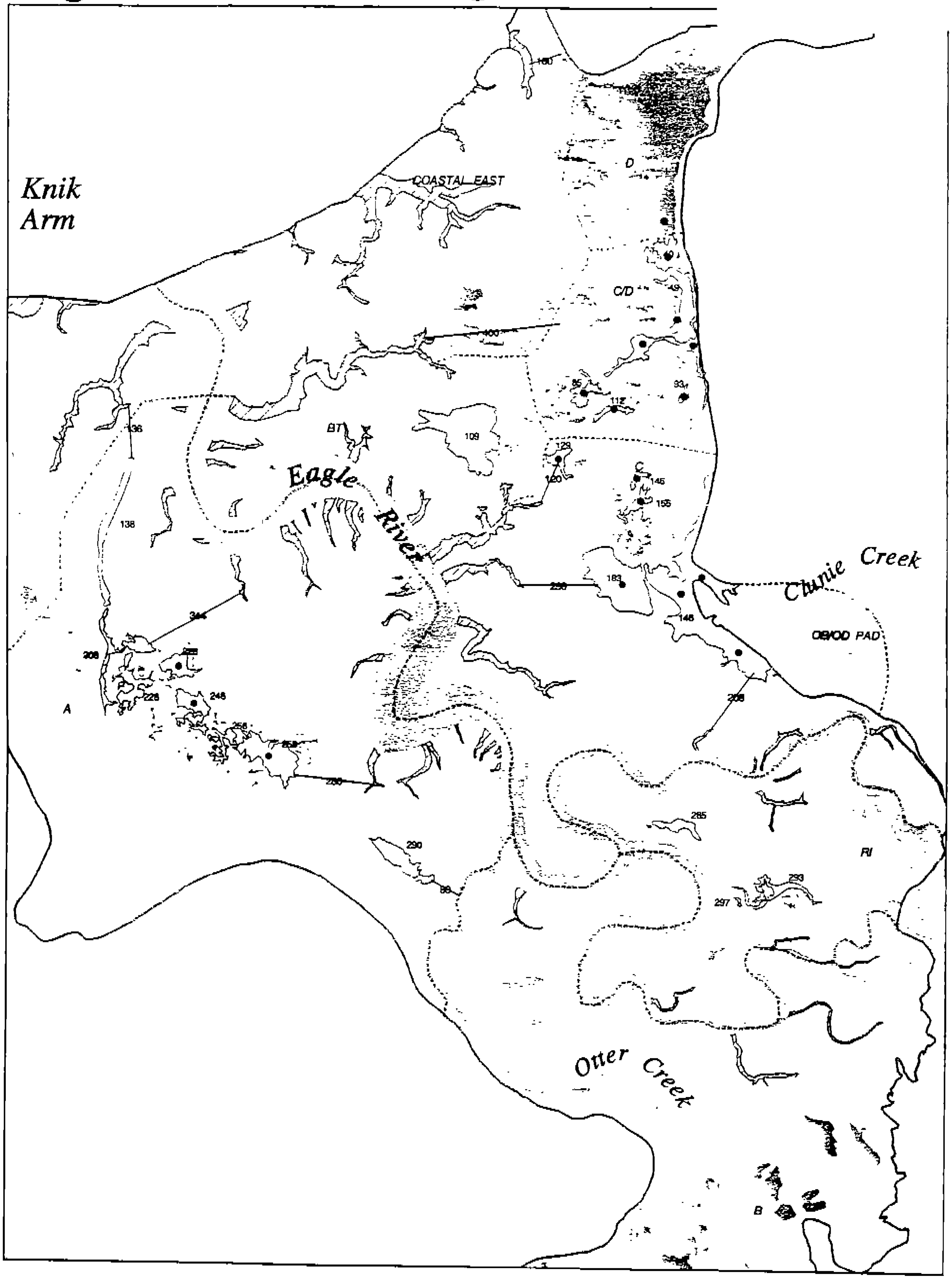

Figure C-4

Alternative 4: Breaching, Pumping and AquaBlok™

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Scale 1:12000
1 cm = 120 m
0 meters 360

Mapping and database source: CRREL, 1996.

Note: 1. Treatment has been or will be conducted at the following Hot Ponds:
Ponds 109, 293, & 297: Pond Draining by Breaching
Pond 285: AquaBlok™
2. AquaBlok™ application is not shown.
3. Discharge piping is not shown.

49 Hot Pond Number
Intermittent Pond
Permanent Pond
Gully
River/Creek
Area Boundary
OUC Site Boundary

Proposed Location of Gully to Blast and Length in Meters
Location of Pump - 500 GPM Capacity
Location of Pump - 1000 GPM Capacity
Location of Pump - 2000 GPM Capacity
Location of Pump - 3000 GPM Capacity

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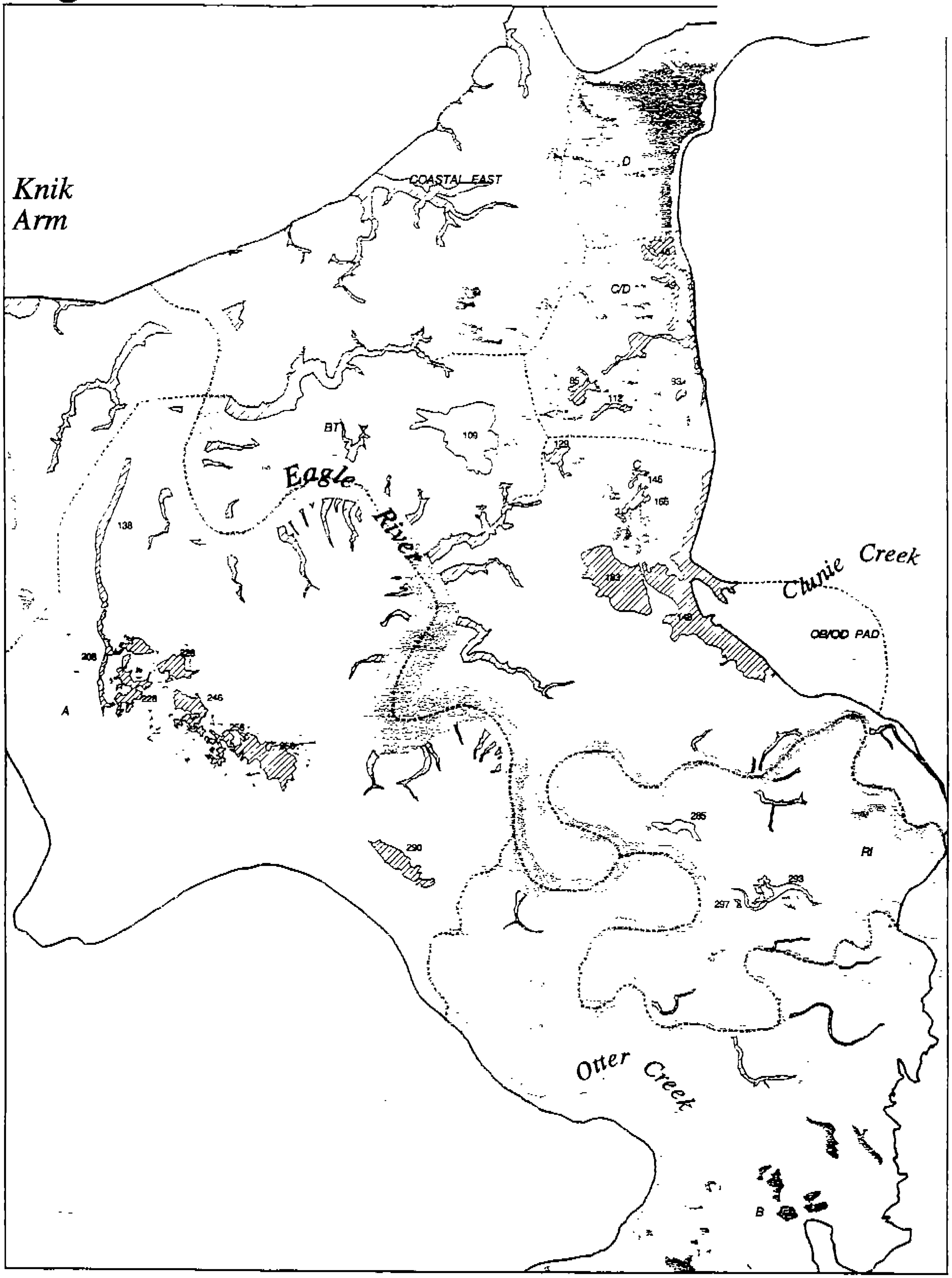

Figure C-5

Note:
Treatment has been or will be conducted at the following Hot Ponds:
Ponds 109, 293, & 297: Pond Draining by Breaching
Pond 285: AquaBlok™

Alternative 5: AquaBlok™

Scale 1:12000
1 cm = 120 m
0 meters 360
Mapping and database source: CRREL, 1996.

49 Hot Pond Number
Intermittent Pond
Permanent Pond
Gully
River/Creek
Area Boundary
OUC Site Boundary

Location of AquaBlok™ Application

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

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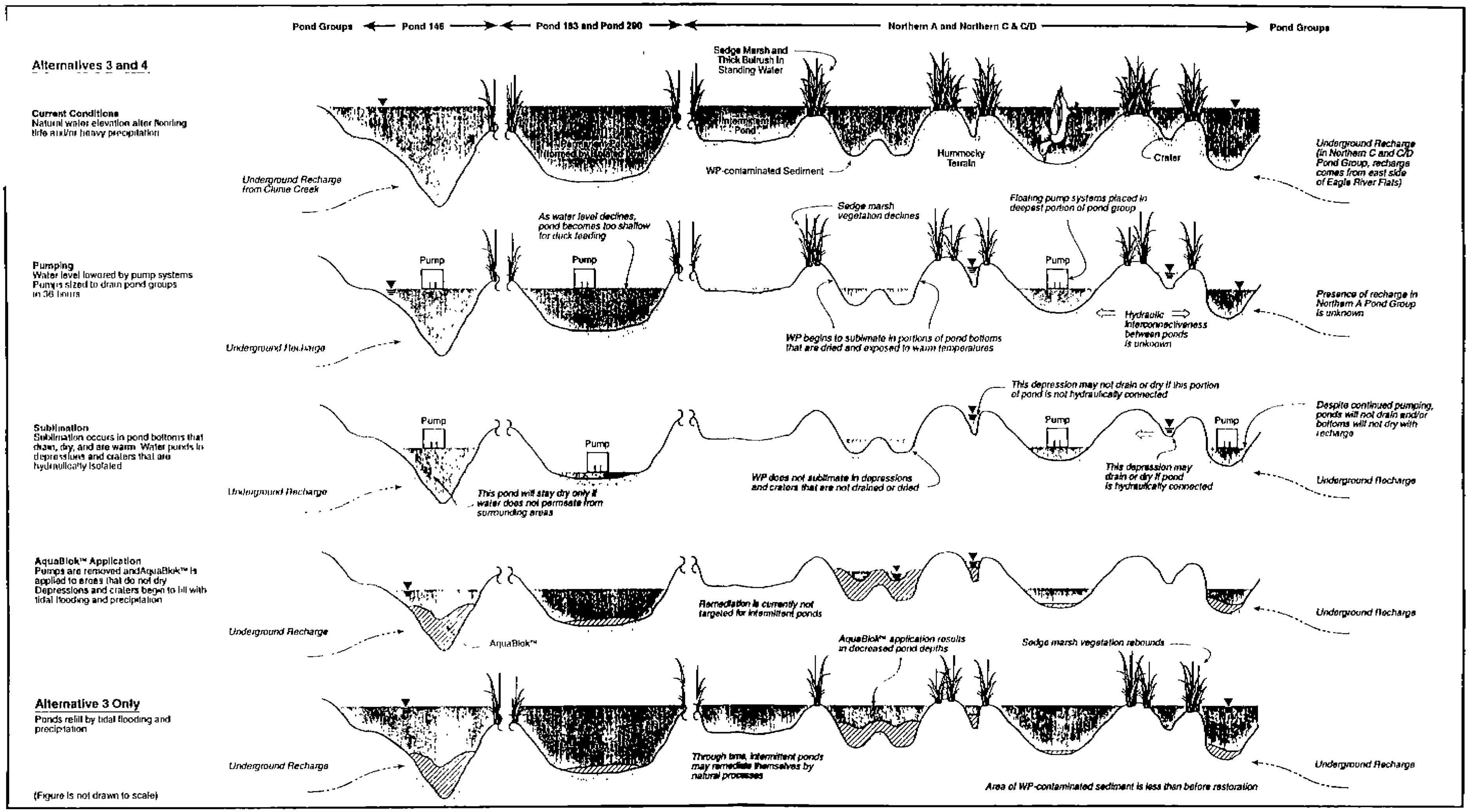
March 27, 1997 AML PLOT FILE



Alternative 3: Pumping and AquaBlok™
Alternative 4: Breaching, Pumping, and AquaBlok™

Figure C-6
Restoration Processes of Alternatives 3 & 4
Operable Unit C
Feasibility Study
Fort Richardson, Alaska

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Appendix D
Applicable or Relevant and Appropriate Requirements

Contents

Abbreviations

AAC	*Alaska Administrative Code*
ADEC	Alaska Department of Environmental Conservation
ARAR	applicable or relevant and appropriate requirement
BTAG	Biological Technical Assistance Group
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
COC	contaminant of concern
COE	U.S. Army Corps of Engineers
CWA	Clean Water Act
DO	dissolved oxygen
EOD	explosive ordnance disposal
ERF	Eagle River Flats
FS	feasibility study
µg/L	micrograms per liter
mg/L	milligrams per liter
mL	milliliter
NTU	nephelometric turbidity unit
OB	open burning
OD	open detonation
OUC	Operable Unit C
RA	remedial action
RCRA	Resource Conservation and Recovery Act
RPM	remedial project manager
SARA	Superfund Amendments and Reauthorization Act
SWMU	solid waste management unit
TAH	total aromatic hydrocarbon
Ta_qH	total aqueous hydrocarbon
TBC	to be considered
TDS	total dissolved solids
USC	*United States Code*
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
WP	white phosphorus

APPENDIX D

Applicable or Relevant and Appropriate Requirements

1.0 Introduction

The analysis of applicable or relevant and appropriate requirements (ARARs) during the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process is an iterative process. Different ARARs that may apply to a site and its remedial actions are identified at multiple points. The more information about the site is obtained or the further the remedial alternatives are developed, the more refined the ARARs analysis becomes. For Operable Unit C (OUC), the potential ARARs that have been identified to date have focused primarily on the potential contaminants of concern (COCs) and the regulations that apply to those constituents and on the regulations that are triggered because of the geographical location of OUC. The potential ARARs that apply to possible actions at OUC have been developed to a lesser degree.

This ARARs analysis further refines the requirements that potentially apply to OUC and, in particular, those requirements that are triggered by the remedial alternatives that have been developed and presented for the Eagle River Flats (ERF) portion of OUC in this feasibility study (FS).

The open burning/open detonation (OB/OD) Pad within OUC has been identified as a solid waste management unit (SWMU) under the federal Resource Conservation and Recovery Act (RCRA). A December 1993 document titled *Demolition Area Number One Closure Guidelines, Fort Richardson, Alaska* (EMCON, 1993), outlines investigations and documentation required for closure of OB/OD Pad in accordance with RCRA. The site investigation completed at OB/OD Pad was conducted to meet or exceed the intent of RCRA. Results of the site investigation, discussed in detail in the OUC *Remedial Investigation Report* (CH2M HILL, 1997), indicate that OB/OD Pad will meet clean closure according to the procedures outlined in the 1993 guidelines. Closure of OB/OD Pad under the CERCLA program and compliance with ARARs will be conducted to meet or exceed the intent of RCRA.

2.0 ARARs Analysis Process

Section 121(d) of CERCLA states that remedial actions on CERCLA sites must attain (or justify the waiver of) any federal or more stringent state environmental standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate. Applicable requirements are those cleanup standards, criteria, or limitations promulgated under federal or state law that specifically address the situation at a CERCLA site. A requirement is applicable if the jurisdictional prerequisites of the environmental standard show a direct correspondence when objectively compared with the conditions at the site.

If a requirement is not legally applicable, the requirement is evaluated to determine whether it is relevant and appropriate. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable, address problems or situations sufficiently similar to the circumstances of the proposed response action and are well-suited to the conditions of the site. The criteria for determining relevance and appropriateness are listed in Title 40, *Code of Federal Regulations* (CFR), Section 300.400(g)(2) (40 CFR 300.400(g)(2)).

ARARs are concerned only with substantive, not administrative, requirements of a statute or regulation. The substantive portions of the regulation are those requirements that pertain directly to actions or conditions in the environment. Administrative requirements are the mechanisms that facilitate implementation of the substantive requirements. Administrative requirements include issuance of permits, documentation, reporting, record keeping, and enforcement. Thus, in determining the extent to which onsite CERCLA response actions must comply with environmental laws, a distinction should be made between substantive requirements, which may be ARARs, and administrative requirements, which are not.

Furthermore, the ARARs provision in CERCLA applies to onsite actions. "Onsite" is defined as the areal extent of contamination and includes the areas to be remediated. According to CERCLA Section 121(e), a remedial response action that takes place entirely onsite may proceed without the obtaining of permits. This permit exemption applies to all administrative requirements, as well as to permits. Actions taken offsite will need to comply with the substantive as well as the administrative requirements of all applicable regulations.

Pursuant to U.S. Environmental Protection Agency (USEPA) guidance, ARARs generally are classified into three categories: chemical-specific, location-specific, and action-specific requirements. This classification was developed to help identify ARARs, some of which do not fall precisely into one group or another. These categories of ARARs are defined below:

- **Chemical-specific ARARs** include those laws and requirements that regulate the release to the environment of materials possessing certain chemical or physical characteristics or containing specified chemical compounds. These requirements generally set health- or risk-based concentration limits or discharge limitations for specific hazardous substances. If, in a specific situation, a chemical is subject to more than one discharge or exposure limit, the more stringent of the requirements should generally be applied.

- **Location-specific ARARs** are those requirements that relate to the geographical or physical position of the site, rather than the nature of the contaminants or the proposed site remedial actions. These requirements may limit the placement of remedial action and may impose additional constraints on the cleanup action.

- **Action-specific ARARs** are requirements that define acceptable handling, treatment, and disposal procedures for hazardous substances. These ARARs generally set performance, design, or other similar action-specific controls or restrictions on particular kinds of activities related to management of hazardous substances or pollutants. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. Because a remedial site usually involves several alternative actions, very different action-specific requirements can apply.

The ARARs presented below focus primarily on the chemical-, location-, and action-specific ARARs that apply to the alternatives that have been assembled for ERF. There are five alternatives presented for ERF in this FS:

- Alternative 1 - No Action
- Alternative 2 - Detailed Monitoring
- Alternative 3 - Pumping and AquaBlok™
- Alternative 4 - Breaching, Pumping, and AquaBlok™
- Alternative 5 - AquaBlok™

ARARs have been included for OB/OD Pad only to address clean closure according to procedures outlined in the 1993 closure guidelines.

3.0 Chemical-Specific ARARs

The first step in identifying chemical-specific ARARs is identifying the COCs. On the basis of available information collected to date regarding the COCs associated with past activities at OUC, white phosphorus (WP) at ERF has been identified as the primary COC and is the focus of this FS. Currently, there no promulgated numerical cleanup or discharge limitation values for WP; therefore, there are no chemical-specific ARARs for potential remedial actions at OUC.

4.0 Location-Specific ARARs

Location-specific ARARs are those requirements that relate to the geographical or physical position of the site, rather than the nature of the contaminants or the proposed site remedial actions. These ARARs may restrict or preclude certain remedial actions because of where ERF is located. Location-specific factors that may trigger ARARs include sensitive habitats, floodplains, wetlands, endangered species habitat, locations of faults, historic or archeological resources, and oceans, rivers, and coastlines. Federal and state location-specific ARARs for ERF and how implementation of the alternatives may be affected by the ARARs are presented in Table D-1. Because ERF is a wetland area, the location-specific ARARs that are intended to protect wetlands, in particular Section 404 of the Clean Water Act (CWA), are the primary location-specific ARARs. This ARAR, as well as other location-specific ARARs, are described in more detail below.

4.1 Clean Water Act, Section 404

Section 404 of the CWA authorizes the Army Corps of Engineers (COE) to regulate the discharge of dredged or fill material into all "waters of the United States (including wetlands)." The definition of "discharge of dredged material" was revised by USEPA and the COE (Federal Register, 58:45008) on August 25, 1993. Under the newly defined "discharge of dredged material," the COE regulates discharges associated with mechanized landclearing, ditching, channelization, and other excavation activities that destroy or degrade wetlands or other waters of the United States under Section 404 of the CWA.

TABLE D-1
Potential Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	Applicability
Wetlands	Action to prohibit discharge or fill material without permit	Wetlands as defined in U.S. Army Corps of Engineers regulations	Clean Water Act Section 404; 40 CFR 230, 33 CFR 320-330	Substantive requirements are applicable to Alternatives 3, 4, and 5 because breaching and depositing AquaBlok™ would cause permanent impacts to wetlands. Coordination with COE, BTAG, Natural Resource Trustees, and other appropriate agencies may be required prior to implementation of the alternative. Impacts will be minimized to the extent practicable.
	Action to avoid adverse effects, minimize potential harm, and preserve and enhance wetlands to the extent possible	Action involving construction of facilities or management of property in wetlands, as defined by 40 CFR 6, Appendix A, Section 4(j)	40 CFR 6, Appendix A[a]	Relevant and appropriate to Alternatives 2, 3, 4, and 5 where construction activities may impact wetlands.
Within floodplain	Action to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values	Action that will occur in a floodplain, such as lowlands, and relative flat areas adjoining inland and coastal waters and other flood-prone areas	Protection of floodplains (40 CFR 6, Appendix A); Fish and Wildlife Coordination Act (16 USC 661 *et seq.*); 40 CFR 6.302 Executive Order 11988 Executive Order 11990	Relevant and appropriate to Alternative 5, which may permanently alter hydrology. Actions will be taken during implementation of the alternative to minimize impacts to floodplains.
Area affecting stream or river	Action to protect fish or wildlife	Diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife	Fish and Wildlife Coordination Act (16 USC 661 *et seq.*) 40 CFR 6.302; Rivers and Harbors Act of 1899, Section 10 (33 USC 401-413) Protection of Fish and Game AS 16.05.870 5 AAC 95.010	Relevant and appropriate to Alternative 5, which may permanently modify hydrology.
Oceans and coastlines	Prevent or strictly limit the dumping into ocean waters of any material that would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities	Action that involves dumping materials into ocean	Marine Protection, Research and Sanctuaries Act (33 USC 1401)	Impacts to oceans and coastlines will be evaluated prior to implementation of the remedial alternative. Potentially applicable to Alternatives 3,4, and 5.

TABLE D-1
Potential Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	Applicability
	Ensure that federal actions are consistent with state management plans to protect and preserve the coastal zone	Action that will occur in coastal zone	Coastal Zone Management Act of 1972 (16 USC 1451) and relevant Alaska State Management Plans	
	Protect all marine mammals	Action that affects marine mammals	Marine Mammal Protection Act of 1972 (16 USC 1361)	
	Ensure protection for use, management, restoration, and enhancement of the overall quality of the coastal environment	Action occurs within Alaska Coastal Zone	Alaska Coastal Management Law (46 AS 40); Alaska Coastal Management Regulations (6 AAC 80, 85)	
Bird migratory routes	Protect almost all species of native birds in U.S. from unregulated "take," which can include poisoning at waste sites	Action that affects migratory birds, including eagles	Migratory Bird Treaty Act of 1972 (16 USC 703-712) 50 CFR Parts 10, 20, 21 Bald Eagle and Golden Eagle Protection Act (16 USC 668-668d)	Applicable to all alternatives. Actions are required to prevent poisoning of waterfowl at ERF.
Critical habitat upon which endangered species or threatened species depend	Action to conserve endangered species or threatened species, including consulting with the Department of the Interior	Determination of endangered or threatened species	Endangered Species Act (16 USC 1531 *et seq.*) 50 CFR Part 200; 50 CFR Part 402	Potentially applicable to Alternatives 3, 4, and 5 if endangered species are identified. No threatened or endangered plant or animal species are resident on Fort Richardson. The American peregrine falcon, a threatened species, is a confirmed transient, and both bald eagles and golden eagles, singled out for special attention by the Army in Alaska, are frequently seen in the Fort Richardson area.

[a]40 CFR 6, Subpart A sets forth USEPA policy for carrying out the provisions of Executive Orders 11988 (Floodplain Management) and 11990 (Protection of Wetlands). Executive orders are binding on the level of government (federal or state) for which they are issued.

USC = United States Code

BTAG = Biological Technical Assistance Group

The substantive requirements of the CWA Section 404 (b)(1) guidelines (hereinafter referred to as the Guidelines) are applicable to activities conducted in wetlands at ERF. The Guidelines were promulgated as regulations in 40 CFR 230.10 and they describe the authority of the COE to deny permits as follows (USEPA, 1994):

- 40 CFR 230.10(a) states that no discharge of dredged or fill material shall be permitted if a practicable alternative exists to the proposed discharge that would have less impact on the aquatic ecosystem, as long as the alternative does not have other significant adverse environmental consequences.
- 40 CFR 230.10(b) states that no discharge of dredged or fill material shall be permitted if it causes or contributes to violations of any applicable State water quality standard; violates any applicable toxic effluent standard or discharge prohibition under CWA Section 307; jeopardizes endangered or threatened species or their habitat designated as critical habitat under the Endangered Species Act of 1973; or violates requirements to protect any marine sanctuary designated under Title III of the Marine Protection, Research, and Sanctuaries Act of 1972.
- 40 CFR 230.10(c) prohibits discharges (or activities) that will cause or contribute to significant degradation of the waters of the U.S.
- 40 CFR 230.10(d) states that when a discharge (or activity) would degrade the waters of the U.S. and there are no practicable alternatives to the discharge, compliance with the Guidelines can be achieved generally through the use of appropriate and practicable mitigation measures to minimize or compensate for potential adverse impacts of the discharge (or activity) on the aquatic ecosystem.

In applying the Guidelines, the COE requires a hierarchical approach to wetland mitigation measures: (1) impact avoidance; (2) impact minimization; and (3) compensatory mitigation. Before undertaking any remedial alternative that may affect the ERF wetlands, the potential wetland impacts would need to be discussed with Biological Technical Assistance Group (BTAG) members and representatives of the Natural Resource Trustees associated with wetland regulation in Alaska (including Federal and State agencies). Agreements will need to be in place between the regulatory agencies and the remedial project managers (RPMs) that will set the conditions for implementing activities such as breaching or AquaBlok™ application at ERF in accordance with the substantive requirements of the CWA.

4.2 Other Location-Specific ARARs

The Fish and Wildlife Coordination Act requires that the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service be consulted regarding any action that modifies a stream or river or other water of the United States. The intent of this regulation is to protect fish and wildlife that may be adversely affected by changes in the quality or quantity of water in a river, stream, or other water body. USFWS is currently a member of the ERF BTAG and is an active participant in studies and decisions affecting ERF. Coordination with USFWS will occur before implementation of remedial actions.

According to the Endangered Species Act (16 USC 1531 *et seq.*), habitat upon which endangered or threatened species depend must be protected. The *Fort Richardson Natural Resource Plan* (Gossweiler, 1984) and the *Draft Integrated Natural Resources Plan, 1997-2001, U.S. Army Alaska* Vol. 2, Fort Richardson (Center for Ecological Management of Military

Lands and Gene Stout and Associates, 1996) were reviewed for preliminary information pertaining to threatened or endangered species and habitat. No threatened or endangered plant or animal species are resident on Fort Richardson. The American peregrine falcon, a threatened species, is a confirmed transient, and both bald eagles and golden eagles, singled out for special attention by the Army in Alaska, are frequently seen in the Fort Richardson area. The Endangered Species Act would be considered an ARAR if endangered or threatened species habitat is identified at ERF.

Remedial actions that take place in a floodplain (100 year or otherwise) will be subject to Executive Order 11988, "Protection of Floodplains." This order requires that actions in floodplains avoid adverse effects, minimize potential harm, and restore and preserve natural and beneficial values.

5.0 Action-Specific ARARs

The federal and state action-specific ARARs for the remedial alternatives generally set performance, design, or other similar action-specific controls or restrictions on certain activities related to management of hazardous substances or pollutants. Action-specific ARARs for OUC are summarized in Table D-2 and include requirements described below that may apply during or as a result of implementation of the remedial alternatives:

- **Alaska Oil Pollution Regulations (Title 18, *Alaska Administrative Code*, Chapter 75 [18 AAC 75])**–These regulations set requirements for discharge reporting, cleanup, and disposal of hazardous substances for spills of hazardous substances to Alaska's land or water within specified time frames. The Alaska Department of Environmental Conservation's (ADEC's) broad definition of "hazardous substance" includes constituents such as oil and other petroleum products. Implementation of Alternatives 3 or 4 will involve the use of diesel generators to power the pump systems. Discovery and cleanup of spills of diesel fuel or other hazardous substances at OUC that are regulated by the State of Alaska will need to consider these regulations as ARARs.
- **Alaska Water Quality Standards (18 AAC 70)**–In general, these standards apply to groundwater and surface water and establish criteria for protected classes of water use. General water-quality criteria potentially applicable to OUC are summarized in Table D-2. Where water is used for more than one purpose, the most stringent water-quality criteria ARARs shall be used. Eagle River is protected for all water use classes. Specific criteria applicable to Eagle River will depend on the parameter being evaluated and the potential impact or discharge that may occur as a result of implementation of the remedial alternative. In most cases the "Criteria for Growth, Propagation of Fish, Shellfish, other Aquatic Life and Wildlife" are the most stringent and, therefore, applicable to OUC. Because breaching and AquaBlok™ application may impact surface water (for example, breaching may increase the sediment loading in Eagle River), these ARARs will need to be considered before implementation of the alternative.

Requirements for compliance with closure for SWMUs under RCRA for OB/OD Pad are included in Table D-3.

TABLE D-2
Action-Specific ARARs for ERF
Alaska Water Quality Standards (18 AAC 70.020)

	Class (1)(A)(i) Water Supply (Drinking)	Class (1)(A)(ii) Water Supply (Agriculture)	Class (1)(B)(ii) Water Recreation (Secondary Recreation)	Class (1)(C) Aquatic Life and Wildlife
Dissolved oxygen (DO)	DO ≥ 4 mg/L (surface water only)	DO ≥ 3 mg/L (surface water only)	DO ≥ 4 mg/L	DO > 7 mg/L Total not to exceed 110% of saturation at any sampling point.
PH	6.0 ≤ pH ≤ 8.5 Shall not vary by more than 0.5 pH units from natural	5.0 ≤ pH ≤9.0	5.0 ≤ pH ≤ 9.0	6.5 ≤ pH ≤9.0 Shall not vary more than 0.5 pH units from natural.
Turbidity	Shall not exceed 5 NTU above natural when the natural <50 NTU and no more than 10% increase when the natural is >50 NTU, not to exceed a maximum increase of 25 NTU	Shall not cause detrimental effects	Shall not exceed 10 NTU above natural when the natural <50 NTU and no more than 20% increase when the natural is >50 NTU. Not to exceed an increase of 15 NTU.	Shall not exceed 25 NTU above natural conditions.
Dissolved inorganic substances	TDS shall not exceed 500 mg/L chlorides or sulfates shall not exceed 200 mg/L	TDS shall not exceed 1,000 mg/L Sodium absorption ration <2.5 Sodium percentage less than 60% Residual carbonate <1.25 mg/L Boron <0.3 mg/L	Not applicable	TDS shall not exceed 1,500 mg/L. Increase shall not exceed one-third of the natural.
Sediment	No measurable increase above natural	Shall not exceed 200 mg/L	Shall not pose hazards	Sediment loads shall not cause adverse effects on aquatic animal or plant life, their reproduction, or habitat
Petroleum hydrocarbons, oil, and grease	Shall not cause a visible sheen or impart odor or taste	Shall not cause a visible sheen on the surface	Shall not cause a film, sheen, or discoloration on the surface or floor of the water body or adjoining shoreline	Ta_qH in water column may not exceed 15 µg/L; TAH may not exceed 10 µg/L; no deleterious effects to aquatic life; no sheens or discoloration to surface waters.

Notes:
mL = Milliliter.
mg/L = Milligrams per liter.
NTU = Nephelometric turbidity units.
Ta_qH = Total aqueous hydrocarbon.
TAH = Total aromatic hydrocarbon.
TDS = Total dissolved solids.
µg/L = Micrograms per liter.

TABLE D-3

Potential Action-Specific ARARs

Activity	Standard Requirement, Criteria, or Limitation	Federal Citation	State Citation	Applicability
Clean Water Act		**33 USC Sec. 1251-1376**		
Remedial action requiring point source discharge to U.S. waters or potential construction activities in navigable waters	• Restrictions and regulations for dredge and fill activities for navigable waters	40 CFR 230 33 CFR 320-330	18 AAC 70 18 AAC 72 18 AAC 15	Substantive action-specific requirements are applicable to Alternatives 3,4, and 5, which may affect wetlands at ERF
Additional Activities Affecting Wildlife Handling or Collection				
Onsite actions involving handling or collection of live animals	• Requirements for handling and collecting live animals	9 CFR	Alaska Fish and Game Exempted Activities Regulations–	Applicable to Alternatives 2, 3, 4, and 5, which involve handling of ducks for telemetry studies
	Permit requirements for collection of migratory birds, bald eagles	50 CFR	AS 16.05.930(a)	
State of Alaska, Oil Pollution Control Law			**AS Title 46, Chapters 3, 4, 9**	
Oil or hazardous substance discharge	• Permit requirements for discharge of oil or residual petroleum product • Approval required for cleanup of oil or hazardous substance discharge		Alaska Oil and Hazardous Substances Pollution Control Regulations--18 AAC 75	Applicable to Alternatives 3 and 4, where fuel could be released from pump generators
Resource Conservation and Recovery Act		**42 USC Sec. 6901-6987**		**AS Title 46, Chapter 3**
Closure of OB/OD Pad	• Requirements for closure of RCRA solid waste management unit (SWMU)	40 CFR 264	18 AAC 62	Alaska Hazardous Waste Regulations Applicable to clean closure of OB/OD Pad

USC = United States Code
CFR = Code of Federal Regulations
AS = Alaska Statutes
AAC = Alaska Administrative Code

6.0 To Be Considered Criteria or Guidance

Although ARARs are promulgated, enforceable requirements, other types of information may be useful for designing remedies or may be necessary for determining what is protective at a specific contaminated area. In some instances, for example, because of multiple contaminants or pathways, compliance with ARARs will not achieve an acceptable degree of protection from the contaminants. In such cases, nonpromulgated criteria, advisories, and other guidance need to be considered.

Examples of to-be-considered criteria or guidelines (TBCs) include guidance or policy documents developed to implement regulations. If no ARARs address a particular situation identified during the remediation process at OUC, or if existing ARARs do not provide protection, TBCs may be used to set cleanup targets.

Information available from several acute and chronic toxicity studies that have been conducted for waterfowl as part of past investigations at ERF may also be used as TBCs. Acute toxicity tests on mallards in 1993 and 1994 (Sparling *et al.*, in Racine *et al.*, 1994; Sparling *et al.*, in Racine *et al.*, 1995) estimated that the lethal particulate WP dose for 50 percent mortality (LD50) in male mallards was 4 mg/kg. An average weight of mallards has been estimated at 1.25 kg. (Racine *et al.*, 1996). Studies of WP particle size and distribution at ERF conducted by CRREL in 1994 concluded that for a 1.25 mg. adult male mallard, WP particles ranging from 1.4 mm (cube) to 1.7 mm (sphere) would represent the LD50 (5 mg.) As a generalization, CRREL research indicates that the ingestion of a single WP particle approximately 1 mm or greater in length represents serious risk to waterfowl. (M.E. Walsh *et al.*, in Racine *et al.*, 1996). Verification sampling for WP particle size, in addition to distribution, may be TBCs for determining a cleanup level for WP in ERF sediments.

Military activities are currently conducted at OUC; therefore, all future investigations, treatability studies, and remedial activities will need to be coordinated with local U.S. Army activities, such as ongoing operations with firings of test weapons and other related EOD practices and activities. Personnel access into the OUC areas is restricted by the U.S. Army because of active firing of munitions and the existence of old, unexploded ordnance. The status of ERF as an active firing range and the restricted entry to the OUC areas represent additional TBCs for the ERF site.

Table D-4 summarizes potential TBCs for OUC areas.

7.0 ARAR Waivers

Section 121 of CERCLA/Superfund Amendments and Reauthorization Act (SARA) provides that under certain circumstances ARARs may be waived. These waivers apply only to meeting ARARs with respect to remedial actions at the contaminated area; other statutes requiring remedies that protect human health and the environment cannot be

TABLE D-4
Potential Other Criteria or Guidelines to be Considered

Federal

- Drinking Water Health Advisories.
- Toxic Substances Control Act Chemical Advisories.
- USEPA Water Quality Advisories.
- Applicable USEPA RCRA and CERCLA Guidance Documents
- DEMO 1 RCRA Closure Guidelines, December 1993
- Applicable U.S. Army internal policies, directives, and facility regulations for Fort Richardson
- Cooperative Agreement for Management of Fish and Wildlife Resources on Army Lands in Alaska (U.S. Army, 1986)
- Draft Integrated Natural Resources Plan, 1997-2001, Volume 2–Fort Richardson. (U.S. Army Alaska, 1996).

State of Alaska

- Alaska Department of Environmental Conservation. Guidance for Storage, Remediation, and Disposal of Non-UST Petroleum Contaminated Soils, July 29, 1991.
- Alaska Department of Environmental Conservation. Interim Guidance for Non-UST Contaminated Soil Cleanup Levels, July 17, 1991.
- Alaska Department of Environmental Conservation. Underground Storage Tanks Procedures Manual, September 22, 1995.
- Alaska Department of Environmental Conservation. Guidance for Storage, Remediation and Disposal of Petroleum Contaminated Soils (UST), March 15, 1991.
- Alaska Department of Environmental Conservation, Interim Guidance for Surface and Groundwater Cleanup Levels, September 26, 1990.
- Alaska Department of Environmental Conservation. Draft Water Quality Standards Revision and Oil and Hazardous Substances Cleanup Standards, December 18, 1996.
- Alaska Department of Environmental Conservation. Draft 18 AAC 75 Cleanup Standards, December 18, 1996.
- Alaska Department of Environmental Conservation. Draft revisions to 18 AAC 78 UST regulations and UST Procedures Manual, March 13, 1997.

waived. A waiver must be invoked for each ARAR that will not be attained or achieved. Waivers of ARARs may include the following:

- **Interim measures**–The remedial action (RA) selected is only part of a total RA that will meet the ARAR when completed; it may apply to sites where a final remedy is divided into several smaller actions.
- **Greater risk**–Compliance with the ARAR will result in greater risk to human health or the environment; magnitude, duration, and reversibility of adverse effects are considered.

- **Technically impracticable**–Compliance is technically impracticable from an engineering perspective; engineering feasibility and reliability are considered.
- **Equivalent to other standard**–The selected action would attain a standard of performance equivalent to the standard required by the ARAR; it may be used where the ARAR specifies design, or where operating standards by equivalent or better results are available from an alternative design or method of operation.
- **Inconsistent application**–The standard may not be applied consistently in similar circumstances; similarity of sites or response circumstances is considered.
- **Fund balancing**–For action under CERCLA Section 104, if the need to balance Trust Fund across many sites requires another remedy; consider cost of remedy, availability of Fund, and significant threats that may not be addressed if ARAR is met (USEPA, 1988).

8.0 Works Cited

Center for Ecological Management of Military Lands, Colorado State University; and Gene Stout and Associates. *Draft Integrated Natural Resources Management Plan, 1997-2001, U.S. Army Alaska*. Vol. 2, Fort Richardson. 1996.

CH2M HILL. *Operable Unit C Draft Final Remedial Investigation Report*. Prepared for U.S. Army Alaska, Department of Public Works. February 1997.

EMCON Alaska Inc. *Demolition Area Number One Closure Guidelines, Fort Richardson, Alaska*. Prepared for Department of the Army, U.S. Army Engineer District, Alaska. December 1993.

Gossweiler, W.A. *Fort Richardson Natural Resource Plan*. U.S. Army. 1984.

Sparling, D.W., R. Grove, E. Hill, M. Gustafson, L. Comerci. Toxicological Studies of White Phosphorus in Waterfowl. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska*. C.H. Racine, ed. FY 93 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. May 1994. Pp. 133-151.

Sparling, D.W., R. Grove, E. Hill, M. Gustafson, and P. Klein. White Phosphorus Toxicity and Bioindicators of Exposure in Waterfowl and Raptors. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska*. Volume 1. C.H. Racine and D. Cate, eds. FY 94 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. May 1995. Pp. 201-233.

U.S. Environmental Protection Agency (USEPA). *CERCLA Compliance with Other Laws Manual, Part I, Draft Guidance*. EPA/540/G-89/006. August 1988.

Walsh, M. W., C. M. Collins, and R.N. Bailey. Intrinsic Remediation of WP Particles in Intermittent Ponded Areas of ERF. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska*. D.W. Cate and C.H. Racine, eds. FY 95 Final Report. U.S. Army Cold Regions Research and

Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. September 1996. Pp. 173-176.

Appendix E
Cost Estimate

Contents

APPENDIX E

Cost Estimate

This appendix provides the cost estimates for the alternatives developed to address white phosphorus (WP)-contaminated pond sediments at Eagle River Flats (ERF). There are five alternatives:

- Alternative 1–No Action
- Alternative 2–Detailed Monitoring
- Alternative 3–Pumping and AquaBlok™
- Alternative 4–Breaching, Pumping, and AquaBlok™
- Alternative 5–AquaBlok™

Cost estimates are provided in the tables attached to this appendix for each alternative at each of the five pond groups at ERF:

- Northern A Ponds
- Pond 290
- Pond 183
- Pond 146
- Northern C and C/D Ponds

1.0 ERF-Wide Activities

In addition to the costs of the five alternatives at each of the five pond groups for this feasibility study (FS), several ERF-wide activities will be conducted in Alternatives 2 through 5. The costs of these studies are not directly associated with any specific pond group, but will be a direct project cost. Therefore, the cost of the ERF-wide studies will be in addition to the costs of the alternatives. The studies include a mallard mortality telemetry study, an aerial bird population survey, and aerial photography. Additional costs will also be incurred for maintenance of the ERF remediation data base.

1.1 Telemetry Study

The costs of conducting annual telemetry studies are based on a previous study conducted in 1996. Mallards will initially be tracked in a baseline study for about 2 months. A second, more intensive, study will be conducted 24 hours per day, for a 2-week period, in approximately early September. One week of a laboratory scientist's time will be required to confirm WP in the banded ducks that die and are recovered. Telemetry studies will be conducted annually for the duration of Alternative 2.

1.2 Aerial Bird Population Survey

Aerial bird population surveys will be conducted within the Upper Cook Inlet (UCI) and at ERF. Within the UCI, 25 surveys will be conducted each year. Forty annual surveys will be conducted at ERF. The annual costs for the surveys are $31,000 per year in the UCI and $16,000 per year at ERF.

1.3 Aerial Photography

Annual aerial photography will be conducted at ERF to support assessments of topographic relief, vegetation changes, and gully recession. Topographic maps will not be developed from the aerial photography. An initial flight will be made at the beginning of the baseline year to provide a comparison to later flights. Subsequently, annual photography will be conducted in the spring and fall of each year.

1.4 ERF Remediation Database

The annual cost of maintaining the ERF database is estimated at $114,000. This cost assumes that the database users already have the recommended hardware and software (described in Appendix G) and no purchase of additional equipment is required. Appropriate equipment already exists at the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) facility in Hanover, New Hampshire, and at Fort Richardson.

1.5 Hazing

Hazing will also be performed in Alternatives 2 through 5 as an interim measure during critical migration periods during the first 5 years of remedy implementation. The costs for hazing are presented as an annual lump sum of $30,000.

2.0 ERF Alternatives

The following sections describe the basic assumptions used in developing cost estimates for each alternative and pond group. Specific details regarding quantities, implementation rates, and unit costs are shown in the cost estimate tables provided at the end of this appendix. Additional information regarding the implementation of the alternatives is provided in Section 4.

Key staff for implementing each alternative will be provided by CRREL. The raw labor rates for all CRREL labor classifications are multiplied by 56.25 percent to account for overhead costs. The burdened labor rates of field staff working at ERF are multiplied by an additional 25 percent for hazardous duty pay. AquaBlok™ vendor labor rates and unexploded ordnance (UXO) clearance staff labor rates are provided in the cost estimate tables.

Bid and scope contingencies are applied to the direct costs of each alternative at rates of 15 and 20 percent, respectively.

Administration costs for the U.S. Army Corps of Engineers are estimated at 10 percent of the direct costs plus contingencies subtotal. Similarly, reporting and permitting and legal costs are each estimated at 5 percent of the subtotal. Bonding and insurance is assumed to be 3 percent of the subtotal. A discount rate of 5 percent was used to calculate the present worth value of the long-term operations and maintenance.

2.1 Alternative 1–No Action

Under Alternative 1, no action is taken and no costs are incurred.

2.2 Alternative 2–Detailed Monitoring

Under Alternative 2, monitoring conducted at each of the five pond groups includes pond surveys (topographic), baseline and verification WP sampling, sublimation/oxidation conditions monitoring, and sedimentation analyses.

2.2.1 Pond Surveys

Each pond group will be surveyed to determine topography and surface-water flow patterns. Personnel required to conduct the detailed surveys of the ponds will include one CRREL field engineer, one CRREL junior engineer, one CRREL technician, and one UXO clearance technician. Transportation of personnel and equipment to each pond group will be by UH-1 helicopter.

2.2.2 Baseline and Verification WP Sampling

A comprehensive evaluation of the distribution of WP in the pond groups at ERF has not yet been conducted. A baseline WP sampling of the ponds will be conducted to characterize WP concentrations and distribution. Baseline WP sampling will include the collection of composite sediment samples from each pond group. The number of samples collected at each pond group will vary. Sample quantities are listed by pond group in Table E-1. The samples will be collected by one CRREL field engineer and one CRREL junior engineer. The sampling effort will be coordinated and supported by an offsite CRREL engineer and junior engineer. Each sample will be analyzed for WP content by an offsite CRREL engineer.

In addition to baseline WP sampling, it is assumed that WP verification sampling will be performed after 5 years to confirm that WP has been lost after implementing the alternative.

TABLE E-1
Baseline WP Samples by Pond Group
Alternative 2–Detailed Monitoring

Pond Group	Number of Baseline WP Monitoring Samples
Northern A	16
Pond 290	4
Pond 183	7
Pond 146	8
Northern C and C/D	17

Note: Samples are composite samples.

2.2.3 Sublimation/oxidation Conditions Monitoring

Sublimation/oxidation conditions will be monitored at each pond group to collect data about the conditions that will promote sublimation/oxidation of WP particles. These data include water elevation, time between flooding tides, sediment temperature, and water saturation. The equipment used to conduct sublimation/oxidation conditions monitoring includes a sonic sounder for water depth with associated air temperature sensor, radiation shield (one each per area in a permanently ponded region), data logger, tripod, enclosure, solar panel, two thermistors, two moisture sensors, recording tensiometer, and data storage module. The number of sublimation/oxidation monitoring stations at each of the pond groups is summarized in Table E-2.

TABLE E-2
Sublimation/Oxidation Monitoring Stations by Pond Group
Alternative 2–Detailed Monitoring

Pond Group	Number of Sublimation/oxidation Monitoring Stations
Northern A	2
Pond 290	1
Pond 183	1
Pond 146	1
Northern C and C/D Ponds	2

Note: Monitoring equipment will be installed after the breakup of ice in the spring and be removed before pond freeze-up in the fall.

2.2.4 Sedimentation Monitoring

Sedimentation monitoring will be conducted at representative ponds within each pond group. The cost of conducting sedimentation monitoring at each pond group are provided in the cost estimate tables. The cost includes equipment, materials, and CRREL labor.

2.3 Alternative 3–Pumping and AquaBlok™

Under Alternative 3, pond systems will be dewatered to the maximum practical extent by dedicated pump/generator systems. The systems will be operational for approximately 5 months of each year. Pumps and generators will be installed on floating platforms after the breakup of ice in about mid-May and removed before the ponds are frozen in about mid-September. Five years of seasonal pumping will be conducted until cleanup goals are achieved. After five pumping cycles, the contaminated portion of each pond not remediated by dewatering will be covered with AquaBlok™.

Capital costs associated with Alternative 3 will include the following:

- **Pond surveys**–Each pond group will be surveyed to determine topography and surface-water flow patterns. Personnel required to conduct the detailed surveys of the ponds will include one CRREL field engineer, one CRREL junior engineer, one CRREL technician, and one UXO clearance technician. Transportation of personnel and equipment to each pond group will be by UH-1 helicopter.

- **Baseline WP sampling**–Similarly to Alternative 2, composite sediment samples will be collected from each pond group and analyzed for WP content. The number of samples collected from each pond group under Alternative 3 is summarized in Table E-3.

TABLE E-3
Baseline WP Samples by Pond Group
Alternative 3–Pumping and AquaBlok™

Pond Group	Number of Baseline WP Monitoring Samples
Northern A	16
Pond 290	4
Pond 183	7
Pond 146	8
Northern C and C/D	17

Note: Samples are composite samples.

- **Pump/generator/monitoring systems**–Electric pump and diesel generator systems will be used to dewater pond groups. Depending on the volume to be pumped, the pump capacities will range from 500 to 3,000 gallons per minute (gpm). Water will be discharged though polyethylene pipe and flexible hose with adequate flow capacities (6 to 12 inches in diameter). A diesel generator mounted on a separate floating platform will provide power to each floating electric pump. A 150-gallon diesel tank has been assumed to supply fuel to each generator. However, during remedy implementation, the fuel capacity of the system will be sized to take into account the pump/generator capacity, the volume of water to be pumped, and the anticipated run time between fuelings.

- **Initial systems startup and shakedown**–Following the initial installation of the pump/generator/monitoring systems, 1 or 2 days will be required to assess the performance of the various systems and to resolve any operational problems. A CRREL engineer, a CRREL junior engineer, and a CRREL technician will perform this phase of work in the field. An offsite CRREL engineer will provide technical support and troubleshoot with equipment vendors. A UH-1 helicopter will be used to ferry personnel and equipment to each pond area.

- **Application and testing of AquaBlok™**–After five seasonal cycles of pumping, the areas of ponds that remained saturated and are still contaminated will be covered with AquaBlok™. One CRREL engineer and two AquaBlok™ vendor personnel will direct the aerial application of AquaBlok™ with drop bags suspended from a UH-60 Blackhawk helicopter. The AquaBlok™ material will be applied at a rate of 336 tons per hectare. About 30 hours will be required for each hectare treated (labor and helicopter time). Following approximately 5 days of hydration, the areal distribution and thickness of the applied AquaBlok™ will be evaluated. One CRREL engineer, two AquaBlok™ vendor personnel, and one UXO clearance technician will be required to conduct this evaluation. A UH-1 helicopter will be used to ferry personnel and equipment to each pond group. Approximately 0.25 hours of UH-1 helicopter time will be required for each pond. One initial application of AquaBlok™ is assumed to be sufficient and no costs for additional applications will be incurred.

Over the duration of the alternative, recurring annual operations and maintenance (O&M) costs will include the following:

- **Annual pump/generator system installation**–Each pump/generator system will be positioned using a UH-60 Blackhawk helicopter. Approximately 1.5 hours of helicopter time will be required for each system. The installations will be directed by two CRREL engineers and one CRREL junior engineer. Ten hours of labor will be required for each system. UXO clearance will be provided by one vendor personnel at a rate of 3 hours per system. Pipe and hose deployment with a UH-1 Huey would take approximately 2 hours.

- **Annual setup of monitoring equipment**–Following the annual installations of pump systems following the breakup of ice, monitoring equipment will be re-installed at the pond groups. Two CRREL engineers and a CRREL junior engineer will perform the setups. About 4 hours per system will be required for each labor classification. A UH-1 helicopter will be used to ferry personnel and equipment to each pond area. Approximately 0.25 hours of helicopter time will be required for each system.

- **Annual system startup/shakedown**–Following the annual installation of the pump/generator/monitoring systems, 1 or 2 days will be required to assess the performance of the various systems and to resolve any operational problems. A CRREL engineer, a CRREL junior engineer, and a CRREL technician will perform this phase of work in the field. An offsite CRREL engineer will provide technical support and troubleshoot with equipment vendors. Less time will required to perform this task than for the initial startup/shakedown. One hour per system will be required for each field labor classification. A UH-1 helicopter will be used to ferry personnel and equipment to each pond area. Approximately 1 hour of helicopter time will be required for each pump/generator/monitoring system.

- **Routine maintenance and refueling**–Pump/generator/monitoring systems will require regular refueling and maintenance. Six routine maintenance checks and generator refueling trips will required. The personnel during each of these trips will include a CRREL engineer, a CRREL junior engineer, and a CRREL technician. One hour per system for each field labor classification will be required. A UH-1 helicopter will be used to ferry personnel, equipment, and fuel during each of the maintenance/refueling trips. Approximately 1.5 hours of helicopter time will be required for each pump/generator/monitoring system.

- **Annual pump/generator system removal**–At the onset of freezing temperatures (about October), the pump/generator systems will be removed from each pond group using a UH-60 Blackhawk helicopter. CRREL staff during this phase will include 1 engineer, 1 junior engineer, and 1 technician. The effort required to remove the pump/generator systems will be similar to that required to install the systems. Pipe and hose removal with a UH-1 Huey would take approximately 2 hours.

- **Annual removal of monitoring equipment**–Monitoring equipment associated with pump/generator systems will be removed from each pond group before winter freeze-up. The removal will be conducted by two CRREL engineers and one CRREL junior engineer. Approximately 4 hours per system will be required. A UH-1 helicopter will ferry personnel and equipment into each pond area. Approximately 0.25 hours of helicopter time will be required for each system.
- **Annual monitoring**–Annual monitoring of each pond group will be conducted to assess the integrity of AquaBlok™ cover and to verify that sublimation/oxidation of WP is occurring in dewatered areas. AquaBlok™ integrity monitoring will require only a partial day of labor for a CRREL engineer and junior engineer. A UH-1 helicopter will ferry personnel and equipment into each pond area. Approximately 0.25 to 0.5 hours of helicopter time will be required for each system. No reapplication of AquaBlok™ is assumed. A detailed discussion of the WP monitoring conducted under Alternative 3 is provided in Appendix G. The number of WP verification samples for each pond group is the same as listed for Baseline WP samples in Table E-3.
- **Annual monitoring for habitat changes.**

2.4 Alternative 4–Breaching, Pumping, and AquaBlok™

Alternative 4 is similar to Alternative 3, except that the draining of pond systems is accomplished through a combination of excavated drainage channels to breach the ponds and pumping the water that doesn't drain through the breach. Explosives will be used to excavate the drainage channels. Dedicated pump/generator systems are then used to dewater the remainder of each pond to the maximum practical extent. The portion of each pond that cannot be effectively remediated by dewatering is covered with AquaBlok™.

Capital costs associated with Alternative 4 are similar to those of Alternative 3, except for the costs associated with blasting drainage ditches. Military explosive munitions will be used to excavate drainage ditches for each of the pond groups. Military personnel trained in the use of explosives will set the explosives. Before blasting operations begin, UXO clearance will be obtained and the centerline of the ditch surveyed. Two CRREL engineers will determine the alignment of the ditch and perform the surveying. Estimates of the ditch lengths at each pond group are provided in the cost estimate tables. Ditch blasting will be implemented at a rate of about 120 meters (m) per day. Assuming a 4-m spacing of explosives, the cost of explosive munitions will be about $116 per meter of ditch. No labor costs are assumed to be associated with the Army explosives demolition team setting the explosives. Following excavation, a second UXO clearance will be conducted and the length of the ditch will be inspected by the two CRREL engineers. A UH-1 helicopter will be used to ferry personnel and equipment to each blasting location. About 3 hours of helicopter time per blast will be required.

The O&M costs associated with Alternative 4 are similar to those of Alternative 3. Following ditch blasting, pump/generator systems will be installed and operated in a manner similar to that described for Alternative 3. The criteria for application and testing of AquaBlok™ material in the ponds will also be similar to those for Alternative 3.

2.5 Alternative 5–AquaBlok™

Under Alternative 5, contaminated pond sediments are covered with AquaBlok™. No dewatering of the ponds by pumping or use of explosives to excavate drainage channels is conducted. The capital costs of implementing this alternative are associated with conducting WP sampling, pond surveys, applying AquaBlok™, and initially testing the application. Similarly to Alternatives 3 and 4, the AquaBlok™ material is aerially applied to each contaminated pond by UH-60 helicopter as directed by CRREL and vendor staff. The O&M costs of Alternative 5 are limited to annual monitoring of the pond groups to assess the integrity of the AquaBlok™ cover and the costs of annually assessing potential habitat changes.

A cost estimate for truck application of AquaBlok™ also has been prepared. One CRREL engineer and two AquaBlok™ vendor personnel will direct truck application. AquaBlok™ would be prepared and mixed a staging area on Fort Richardson. The material will be applied at a rate of 0.5 ha per day with dump trucks and front end loaders. Roads to ERF will be graded with heavy equipment.

A summary of AquaBlok™ truck application costs for each pond group is presented in Table E-4.

TABLE E-4
Summary of Costs of Application of AquaBlok™ by Truck

Northern A	Capital ($)	10-yr Present Worth ($)	20-yr Present Worth ($)
Northern A	697,000	743,000	754,000
Pond 290	117,000	130,000	133,000
Pond 183	348,000	361,000	364,000
Pond 146	584,000	597,000	600,000
Northern C/CD	463,000	509,000	520,000

Note: A discount rate of 5 percent was used.

Appendix F
Detailed Analysis of Alternatives

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Figure

Abbreviations

ADEC	Alaska Department of Environmental Conservation
ARAR	applicable or appropriate and relevant requirement
BTAG	Biological Technical Assistance Group
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
ERF	Eagle River Flats
FS	feasibility study
GIS	geographical information system
ha	hectare
NCP	National Contingency Plan
NEILE	New England Institute of Landscape Ecology
OB	open burning
OD	open detonation
O&M	operations and maintenance
OUC	Operable Unit C
RAO	remedial action objective
ROD	Record of Decision
TMV	toxicity, mobility, and volume
USEPA	U.S. Environmental Protection Agency
UXO	unexploded ordnance
WP	white phosphorus
WSDABS	waterfowl species distribution and behavior surveys

APPENDIX F

Detailed Analysis of Alternatives

1.0 Introduction

The detailed analysis of alternatives presents the relevant information needed to compare the remedial alternatives assembled for Eagle River Flats (ERF) at Operable Unit C (OUC). The detailed analysis follows the development of alternatives. The extent to which alternatives are fully evaluated is influenced by the available data and the number and types of alternatives being analyzed. The detailed analysis provides the basis for identifying a preferred alternative and preparing the proposed plan, and consists of the following components:

- An assessment and summary profile of each alternative against the evaluation criteria
- A comparative analysis among the alternatives to assess the relative performance of each alternative with respect to each evaluation criterion

2.0 Detailed Evaluation Criteria

Provisions of the National Contingency Plan (NCP) require each alternative to be evaluated against nine criteria listed in the *Code of Federal Regulations* (CFR) under 40 CFR 300.430(e)(9). These criteria provide grounds for comparison of the relative performance of the alternatives and identify their advantages and disadvantages. This approach is intended to provide sufficient information to adequately compare the alternatives and to eventually select the most appropriate alternative for implementation at the site. There are nine evaluation criteria considered in the detailed evaluation phase:

1. Overall protection of human health and the environment
2. Compliance with applicable or relevant and appropriate requirements (ARARs)
3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, and volume through treatment
5. Short-term effectiveness
6. Implementability
7. Cost
8. State acceptance
9. Community acceptance

The nine criteria are divided into three categories: threshold, balancing, and modifying criteria. Threshold criteria must be met by a particular alternative for it to be eligible for selection as a remedial action. The two threshold criteria are overall protection of human health and the environment and compliance with ARARs.

Unlike the threshold criteria, the five balancing criteria weigh the trade-offs between alternatives. A low rating on one balancing criterion can be compensated for by a high rating on another. The five balancing criteria are long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost.

The two modifying criteria are state acceptance and community acceptance. These criteria will be evaluated following receipt of comments on the feasibility study (FS) and the proposed plan and will be addressed in the Record of Decision (ROD). These two criteria will not be considered further in this FS. A summary of the nine evaluation criteria is presented in Figure F-1.

The following sections provide descriptions of the first seven evaluation criteria. A list of issues that will need to be considered to evaluate the alternatives against each criterion has been developed. These considerations are presented in the tables in the following sections.

2.1 Criterion 1–Overall Protection of Human Health and the Environment

This evaluation criterion assesses how each alternative provides and maintains adequate protection of human health and the environment. Alternatives are assessed to determine whether they can adequately protect human health and the environment from unacceptable risks posed by contaminants present at the site, in both the short and long term. This criterion is also used to evaluate how risks posed by each pathway would be eliminated, reduced, or controlled through treatment, engineering, controls, or other remedial activities. The considerations evaluated during the analysis of each alternative for overall protection of human health and the environment at OUC are presented in Table F-1.

TABLE F-1
Overall Protection of Human Health and the Environment

Analysis Factor	Considerations
Human health protection	Likelihood that the alternative reduces risk to human health.
Environmental protection	Likelihood that the alternative reduces risk to ecological receptors by preventing incidental ingestion of WP particles contained in hot pond sediments.
	Likelihood that the alternative reduces risk to receptors by reducing or eliminating WP particles contained in hot pond sediments.
	Degree to which the alternative poses unacceptable impacts on the ERF wetlands.

WP = White phosphorus

2.2 Criterion 2–Compliance with ARARs

This evaluation criterion is used to determine if each alternative would attain federal and state ARARs, or whether invoking waivers to specific ARARs is adequately justified. Other information, such as advisories, criteria, or guidance, is considered, where appropriate, during the ARARs analysis. The considerations evaluated during the analysis of the ARARs applicable to each alternative are presented in Table F-2.

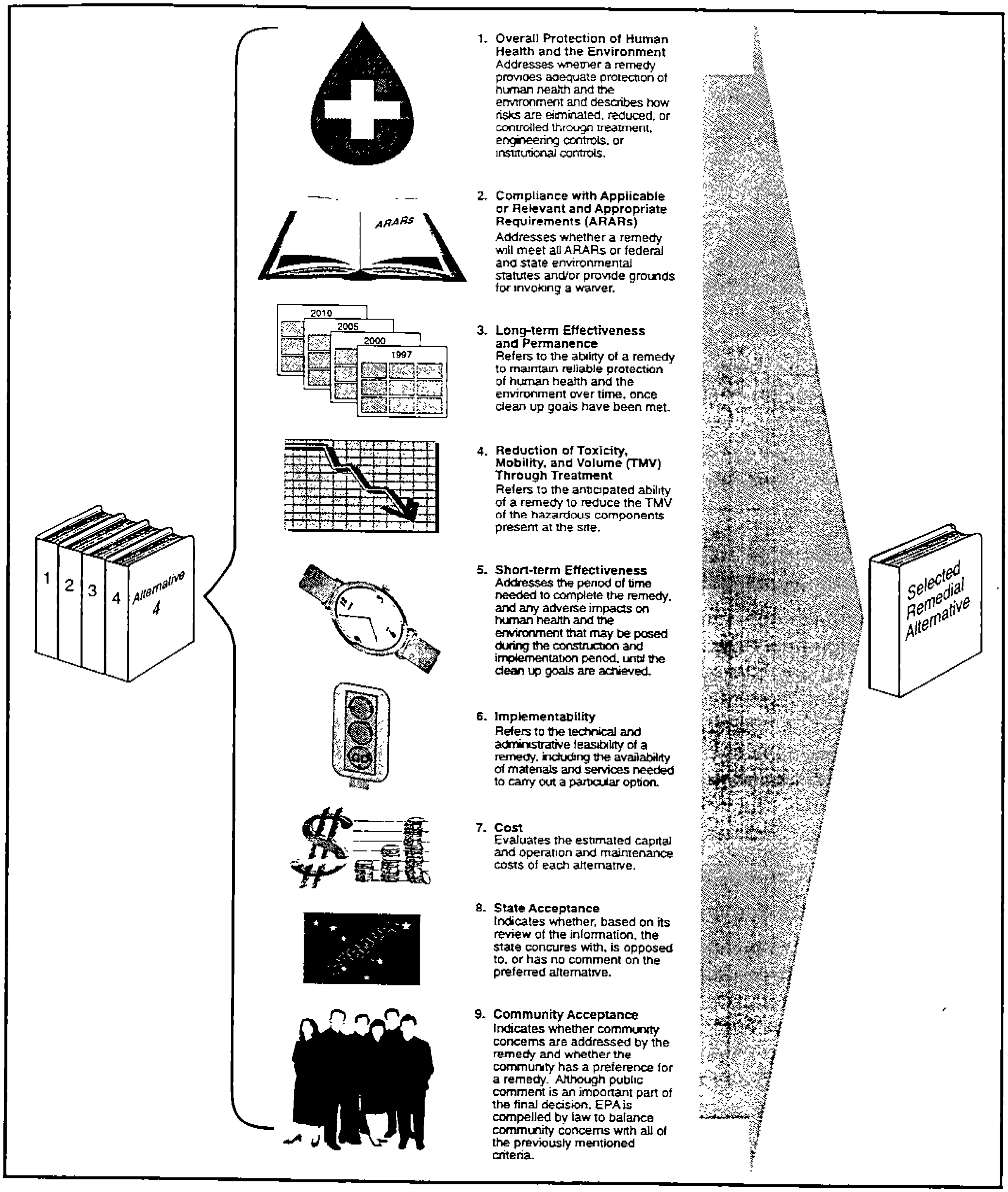

Figure F-1

Nine Evaluation Criteria

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

NOTE
The nine criteria are from the *Guidance for Conducting Remedial Investigations and Feasibility Studies* (U.S. EPA, 1988) and provide support for the Remedial Alternative.

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TABLE F-2
Compliance with ARARs

Analysis Factor	Considerations
Chemical-specific ARARs	Likelihood that the alternative will achieve compliance with chemical-specific ARARs
	Evaluation of whether a waiver is appropriate if it appears that compliance with chemical-specific ARARs will not be achieved
Location-specific ARARs	Likelihood that the alternative will achieve compliance with the location-specific ARAR
	Evaluation of whether a waiver is appropriate if the location-specific ARAR cannot be met
Action-specific ARARs	Likelihood that the alternative will achieve compliance with action-specific ARARs
	Evaluation of whether a waiver is appropriate if the action-specific ARAR cannot be met
Other criteria and guidance	Likelihood that the alternative will achieve compliance with other criteria, such as risk-based criteria

2.3 Criterion 3–Long-Term Effectiveness and Permanence

This evaluation criterion reflects the emphasis of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) on implementing remedies that will ensure protection of human health and the environment in the long term as well as the short term. The primary components of this criterion are the magnitude of residual risk remaining at the site after remedial objectives have been met and the extent and effectiveness of controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes. The considerations evaluated during the analysis of each alternative for long-term effectiveness and permanence at ERF are presented in Table F-3. The components addressed for each alternative are described in more detail in the following subsections.

2.3.1 Magnitude of Residual Risk

The magnitude of residual risk at the end of remedial activities is measured by numerical standards such as risk levels or the volume or concentration of contaminants remaining on the site. The characteristics of the WP residuals remaining onsite also are evaluated, considering their volume, toxicity, mobility, and propensity to bioaccumulate.

2.3.2 Adequacy and Reliability of Controls

The adequacy and reliability of controls that are used to manage either treatment residuals or untreated materials that remain at the site after preliminary remedial goals are attained are evaluated. This criterion includes an assessment of containment systems and institutional controls to evaluate the degree of confidence that they adequately handle potential problems and provide sufficient protection. The criterion also addresses long-term reliability, the need for long-term management and monitoring of the site, and the potential need to replace technical components of the alternative.

TABLE F-3
Long-Term Effectiveness And Permanence

Analysis Factor	Considerations
Magnitude of residual risks	Magnitude of remaining risks from untreated residual WP contamination in sediments at the conclusion of the remedial action
	Characteristics (i.e., toxicity, mobility) of residual contamination
Adequacy and reliability of controls	Likelihood that the technologies will meet required process efficiencies or performance specifications
	Type and degree of long-term management required
	Long-term monitoring requirements
	Operations and maintenance (O&M) functions that must be performed
	Difficulties and uncertainties associated with long-term O&M functions
	Potential need for replacement of technical components
	Magnitude of threats or risks should the remedial action need replacement
	Degree of confidence that controls can verify that exposure of human and environmental receptors to untreated WP sediments is within protective levels

2.4 Criterion 4–Reduction of Toxicity, Mobility, or Volume Through Treatment

This evaluation criterion addresses how well the alternative's treatment technologies may permanently and significantly reduce toxicity, mobility, and/or volume (TMV) of hazardous materials at the site. The NCP prefers remedial actions where treatment is used to reduce the principal threats at a site by destroying toxic contaminants, irreversibly reducing contaminant mobility, or reducing the total volume of contaminated media. The considerations evaluated during the analysis of each alternative for reduction of toxicity, mobility, or volume of white phosphorus (WP) at ERF are presented in Table F-4.

2.5 Criterion 5–Short-Term Effectiveness

This evaluation criterion addresses the effects of each remedial alternative on the protection of human health and the environment during the construction and implementation process. The evaluation of the short-term effectiveness criterion involves only the protection aspect before meeting the response objectives. The considerations evaluated during the analysis of each alternative for short-term effectiveness are presented in Table F-5.

2.6 Criterion 6–Implementability

This criterion evaluates the technical feasibility and administrative feasibility (that is, the ease or difficulty) of implementing each alternative and the availability of required services and materials during its implementation. The considerations evaluated during the analysis of each alternative for implementability are presented in Table F-6.

TABLE F-4
Reduction Of Toxicity, Mobility, Or Volume

Analysis Factor	Considerations
Treatment process and remedy	Likelihood that the treatment process addresses the principal threat (i.e., WP in sediment)
	Special requirements for the treatment process
Amount of hazardous material destroyed or treated	Portion of contaminated material (sediment contaminated with WP) that is treated (measured by number of hectares treated and reduction in WP)
Reduction in toxicity, mobility, or volume through treatment	Extent that the toxicity from WP particles in sediment is reduced by treatment
	Extent that the mobility of WP particles is reduced by treatment
	Extent that the volume (hectares contaminated with WP) is reduced by treatment
Irreversibility of treatment	Extent that the effects of the treatment are irreversible
Type and quantity of treatment residual	Type and quantity of treatment residuals that will remain
	Risk posed by the treatment residuals
Statutory preference for treatment as a principal element	Extent to which the scope of the action covers the principal threats
	Extent to which the scope of the action reduces the inherent hazards posed by the principal threats at the site

TABLE F-5
Short-term Effectiveness

Analysis Factors	Considerations
Protection of the community during the remedial action	Identify risks posed to the community during the remedial action
	How the risks will be addressed and mitigated
	Remaining risks that cannot be readily controlled
Protection of workers during remedial actions	Risks to the workers that must be addressed
	How the risks will be addressed and mitigated
	Remaining risks that cannot be readily controlled
Environmental impacts	Environmental impacts to ERF that are expected with the construction and implementation of the alternative
	Mitigation measures that are available and their reliability to minimize potential impacts
	Impacts that cannot be avoided, should the alternative be implemented
Time until remedial action objectives are achieved	Time to achieve protection against the threats posed by WP in sediment
	Time until any remaining threats posed by WP in sediment are addressed
	Time until remedial action objectives are achieved

TABLE F-6
Implementability

Analysis Factors	Considerations
Technical Feasibility	
Ability to construct and operate the technology	Difficulties and uncertainties associated with the construction
Reliability of the technology	Likelihood that technical problems will lead to schedule delays
Ease of undertaking additional remedial action	Likely future remedial actions that may be anticipated
	Difficulty implementing additional remedial actions
Monitoring considerations	Existence of migration or exposure pathways that cannot be adequately monitored
	Risks of exposure, should the monitoring be insufficient to detect failure
Administrative Feasibility	
Coordination with other agencies	Steps required to coordinate with regulatory agencies
	Steps required to establish long-term or future coordination among agencies
	Ease of obtaining permits for offsite activities, if required
Availability of Services and Materials	
Availability of treatment, storage capacity, and disposal services	Adequacy of available of adequate treatment, storage capacity, and disposal services
	Additional capacity that is necessary
	Whether lack of capacity prevents implementation
	Additional provisions required to ensure that additional capacity is available
Availability of necessary equipment and specialists	Availability of necessary equipment and specialists
	Additional equipment or specialists that are required
	Whether lack of equipment or specialists prevents implementation
	Additional provisions required to ensure that equipment and specialists are available
Availability of prospective technologies	Whether technologies under consideration are generally available and sufficiently demonstrated
	Further development that may be necessary before the technologies may be applied full scale to the type of waste at the site
	When technology should be available for full scale use
	Whether more than one vendor will be available to provide a competitive bid

2.7 Criterion 7–Cost

This criterion evaluates the cost of implementing each alternative. The cost of an alternative encompasses all engineering, construction, and operations and maintenance (O&M) costs incurred over the life of the project. The assessment against this criterion is based on the estimated present worth of these costs for each alternative. Present worth is a method for evaluating expenditures such as construction and O&M that occur over different lengths of time. This allows costs for remedial alternatives to be compared by discounting all costs to the year that the alternative is implemented.

The present worth of a project represents the amount of money which, if invested in the initial year of the remedy and disbursed as needed, would be sufficient to cover all costs associated with the remedial action. As stated in the remedial investigation/feasibility study guidance (U.S. Environmental Protection Agency, 1988), these estimated costs are expected to provide an accuracy of plus 50 percent to minus 30 percent.

3.0 Detailed Analysis of Alternatives

Because of the complexity of ERF and the number of pond groups that are being evaluated, the detailed analysis of the alternative is summarized in Tables F-7 through F-12 (which are attached at the end of this appendix). In general, the detailed analysis of the alternatives was performed by pond group. The ponds in each group have similar physical characteristics and are expected to respond similarly to the remedial actions. In some cases, however, the evaluation of a criterion did not vary from one pond group to another. For instance, under Criterion 5, Short-term Effectiveness, the risks to workers and the community during implementation of the alternative did not vary by pond group.

The detailed analysis is presented in table format to facilitate the comparative analysis, presented in Section 4. These tables, which are provided in the attachment to this Appendix, are as follows:

- Table F-7–Detailed analysis against criteria that are generally applicable to all pond groups.
- Table F-8–Detailed analysis of alternatives for the Northern A pond group
- Table F-9–Detailed analysis of alternatives for the Pond 290 pond group
- Table F-10–Detailed analysis of alternatives for the Pond 183 pond group
- Table F-11–Detailed analysis of alternatives for the Pond 146 pond group
- Table F-12–Detailed analysis of alternatives for the Northern C and C/D pond group

The characteristics of each pond group and each alternative that supports this detailed analysis were presented in the following previous appendices:

- Appendix A–Natural restoration processes that would occur throughout Alternatives 1 and 2, and in later years (>5 years) of Alternatives 3, 4, and 5

- Appendix C–Performance and implementation of alternatives 1, 2, 3, 4, and 5. Physical characteristics of each pond group are also presented in this appendix
- Appendix D–ARARs
- Appendix E–Budget level cost estimates of Alternatives 1, 2, 3, 4, and 5 for all pond groups

3.1 Assumptions

When performing the detailed evaluation for the criteria that address treatment (for example, reduction of TMV through treatment) and treatment technologies at ERF, some assumptions were made as to what constitutes treatment. These evaluation criteria address the anticipated performance of the alternative's treatment technologies in permanently and significantly reducing toxicity, mobility, and/or volume of hazardous materials at the site. The alternatives that have been developed for ERF do not employ traditional treatment techniques in that contaminants are not extracted from the environment and placed in a treatment unit where the contaminants are destroyed or entrained. However, breaching and pumping do constitute treatment because they employ processes that permanently and significantly reduce toxicity, mobility and volume. For the purposes of the detailed analysis, natural processes that may occur under Alternative 1 (No Action), Alternative 2 (Detailed Monitoring), and Alternative 5 (AquaBlok™) do not constitute treatment and do not employ treatment technologies.

3.2 Environmental Impacts

Under the short-term effectiveness criteria, the environmental impacts that are expected as a result of implementing the alternatives at each pond group have been evaluated and are summarized in the Tables F-8 through F-12 (Attachment). The information in the tables focuses on the specific environmental impacts that are anticipated because of the size or physical features of the pond group as a result of the alternative (such as hectares of open-water habitat that are lost).

Because impacts to habitat play a critical role in the analysis of alternatives, the relative values of different habitats at ERF are presented in this subsection. In determining the potential environmental impacts that are anticipated at each pond group as a result of the alternative, the overall value of the habitat that would be affected or lost was considered. This is followed by a discussion of the effects of the alternatives. The subsection concludes with a discussion of the potential restoration of breached ditches.

3.2.1 Effects on Relative Habitat Value at ERF

Eagle River Flats support a diverse community of waterfowl and shorebirds, some of which serve as primary ecological receptors for WP exposure. Field studies have shown that waterfowl (especially the dabbling ducks such as mallards, northern pintail, and green-winged teal) have accounted for most of the bird mortality encountered at ERF. Although field studies have focused primarily on habitat use by waterfowl, it has been suggested that ERF may also serve as an important staging area for shorebirds (Steele and Reitsma, in Racine *et al.*, 1996). A detailed analysis of remediation alternatives requires an evaluation of the expected changes in habitat characteristics that may favor or adversely affect use by particular bird species.

Relatively little fieldwork (other than aerial census and limited telemetry work) has been done to characterize shorebird use at ERF. However, field studies conducted on waterfowl provide information that can be used to infer the relative importance of different habitat types for waterfowl at ERF. Observations of waterfowl behavior were recorded and summarized by the New England Institute of Landscape Ecology (NEILE) (Reitsma and Steele, in Racine *et al.*, 1995). Additional information can be derived from the summary of telemetry observations collected during the non-hazing periods from 1993 through 1996. The information makes it possible to determine the different types of waterfowl uses that a particular habitat type might support and the relative proportion of time the birds spend in an area.

During the 1994 field season, NEILE conducted waterfowl species distribution and behavior surveys (WSDABS). These field observations were recorded into the geographical information system (GIS) database and summarized in their annual report (Reitsma and Steele, in Racine *et al.*, 1995). The WSDABS were conducted during two hazing-free periods in 1994 (April 18 to May 3 and August 12 to September 5) for mallards, northern pintail, and green-winged teal. Field observers also recorded use by shorebirds and swans in the WSDABS areas.

During WSDABS, each duck was categorized as feeding, loafing, preening, or swimming (Reitsma and Steele, in Racine *et al.*, 1995). Specific duck behavior was summarized by ERF area rather than by habitat type; this limits the use of this information to relate habitat type to types and quantity of bird use. The study did show, however, that the ducks spent most of their time feeding, with the proportion of time ranging from 85 percent in the spring to 74 percent in the fall. Some different feeding area preferences were described for the three observed duck species.

The telemetry studies (Cummings *et al.*, in Racine *et al.*, 1993, 1994, 1995, 1996; and in Collins *et al.*, 1997) were summarized to estimate the relative proportions of use for different waterfowl habitat cover types. The data collected during non-hazing periods from 1993 through 1996 indicated the following proportions of duck use: sedge marsh (28.7 percent); permanent ponds (11.4 percent); and intermittent ponds (7.4 percent). It is assumed that the proportion of telemetry hits in these habitat types is representative of the overall duck use at ERF. These proportions can also be used to rank the relative habitat importance for waterfowl use.

The potential impacts of remedial alternatives were incorporated into the detailed evaluation of remedial alternatives by pond group shown in Tables F-8 through F-12 (Attachment). It should be noted, however, that the evaluation of remedial alternatives was focused on the impacts that could be predicted most reasonably, such as areal extent and habitat types that would be drained. Comparison of habitat types to each other (relative ranking) was based primarily on the estimated proportion of waterfowl use as indicated by the telemetry studies.

Other potential changes to habitat value, such as increased exposure of shorebirds because of pond draining or changes in plant community composition, cannot be accurately predicted. Information on these impacts would be revealed through subsequent monitoring and periodic reporting of changes. The information on these potential impacts may necessitate future actions by remedial project managers as regards the remedial alternative chosen for a particular area.

3.2.2 Impacts to Habitat

Remedial Alternatives 3 and 4 involve draining the selected pond or pond groups by pumping alone (Alternative 3) or by pumping and breaching the ponds (Alternative 4). Both of these alternatives will use AquaBlok™ applied to areas that cannot be adequately dried by pond draining. These remedial alternatives are expected to modify ERF habitat to varying degrees.

If the ponds are breached by extending the natural gullies back into the ponds by blasting, the ponds will likely be permanently changed because of the difficulty in restoring the pond to its original hydrologic condition. Pond draining by pumping would be expected to have short-term effects similar to the pond breaching, but conditions should return to normal after the tidal flooding has replenished water in the ponds. To fully remediate a particular pond, it may be necessary to pump the pond over multiple drying cycles. Nevertheless, it is expected that no permanent change will result in habitat quality from pumping alone.

Pond draining by breaching will result in immediate habitat changes because the open-water ponded areas will be reduced, effectively reducing the area in which dabbling ducks might feed. (This would, however, result in more mud flat habitat becoming available to shorebirds.) As the sediments in the newly-drained pond dry, other changes may occur in the established vegetative communities around the pond margins. If the amount of water in the root zone becomes insufficient to support the hydrophytic vegetation, these communities may become water-stressed or die. Species replacement with plants requiring less saturated conditions also could occur. The fine-textured soils in the ponded areas of ERF have high water retention capacities; therefore, substantial, permanent changes in vegetation are not expected in the course of one drying cycle. Changes in plant species composition will modify the habitat quality for selected bird species, especially those that use certain plants for food or shelter.

3.2.3 Restoration of Breached Ditches

Perhaps the greatest difference between Alternatives 3 and 4 is the long-term effect on habitat. In the short term, both Alternatives 3 and 4 would remove submerged feeding habitat for waterfowl. This would be protective, because the waterfowl would be discouraged from feeding in these areas and therefore would not ingest lethal WP particles from the hot ponds. However, pond breaching under Alternative 4 would potentially result in the long-term destruction of waterfowl habitat. It is assumed that the sedge marsh, intermittent ponds, and permanent ponds adjacent to hot ponds would be drained under Alternatives 3 and 4. The areas of vegetation that would be affected by draining are presented in Figure F-2.

It is unlikely that breached ditches can be restored. The erosion patterns that would be created over time reduce the feasibility of reversing the process and restoring the ponds (as permanent or intermittent ponds) once remediation of ponds is completed. It probably is not feasible to redirect the erosional pattern once the pond has been breached, especially if the pond remains breached for 2 or 3 years or more. Water flowing into and out of the pond along the ditch blasted for drainage is likely to extend the gully into which it drains. Once established, such a drainage pathway is likely to persist unless a substantial structure is built to redirect the water flow. Construction of that kind of structure is not considered practical on the flats, where there is no solid substrate to which to anchor the structure. In addition, concerns about unexploded ordnance (UXO) severely limit construction in the

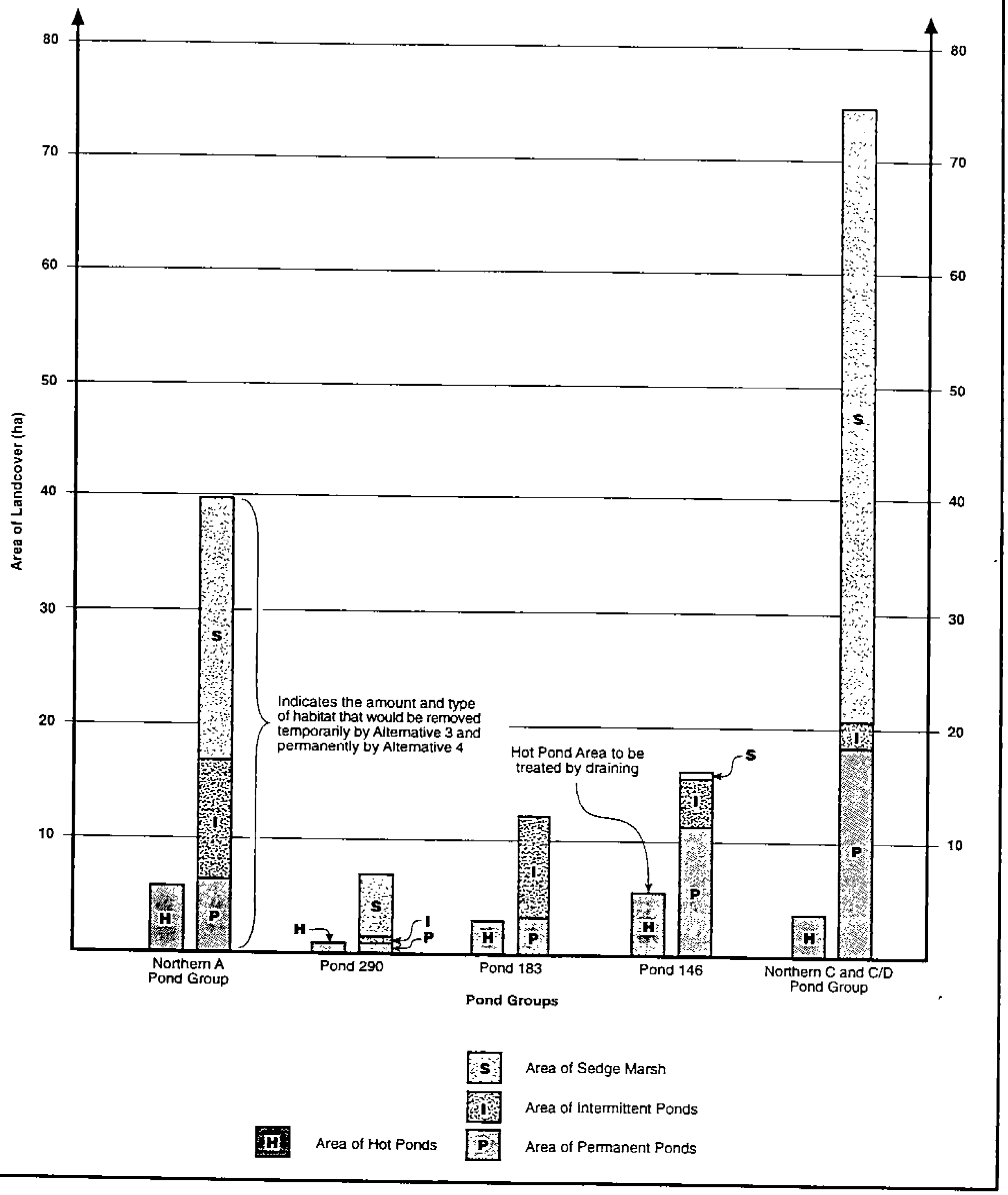

Figure F-2

Impacts of Pond Draining on Vegetation

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

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flats. Tidal flows onto and off of the flats would tend to scour under or around the edges of erosion-control materials (such as gabions) that might be used in attempts to restore a pond.

In addition to needing to control erosion of the channel that had become established, restoration of the pond habitat would require replacement of eroded materials around the pond and revegetation of the habitat. This also would be difficult, and perhaps not feasible.

A literature search will be conducted during 1997 to determine whether restoration of coastal wetlands has been performed under other programs.

3.3 Risk and Residual Risk

Figures F-3 through F-7 have been developed to show the differences between the alternatives of the magnitude and type of risk during the period of implementation. These figures will be used in the detailed analysis to determine protectiveness and residual risk of each alternative in each pond group. These figures should be considered semi-quantitative, and they represent only an index of risk because the true risk cannot be determined. The figures include the following key elements:

- **Type of risk.** The environmental risk to dabbling ducks and swans from WP exposure exists only if the WP is bioavailable to these species. If the WP is covered by sufficient clean sediment to prevent exposure, then the exposure pathway is incomplete and there is no risk. On the other hand, physical forces may act to remove the overlying sediment, exposing the waterfowl to WP. There remains a "potential residual risk" in the sense that it is possible that the existing WP, although covered now, may lead to exposure in the future. Thus, covering with clean sediment reduces the risk but not the potential residual risk. In contrast, sublimation/oxidation of WP reduces both the risk and the potential residual risk because the lost WP cannot expose waterfowl in the future.

- **Magnitude of risk.** In areas where craters are visible, high crater densities are located in and around the pond groups. WP has been detected in at least one pond of every pond group. Walsh *et al.*, in Collins *et al.* (1997) have stated that any detection of WP is suggestive that larger quantities may be nearby. The characterization of a heterogeneous contaminant such as the particulate WP at ERF is very difficult; therefore, there is uncertainty about the relative risks between pond groups. These figures, however, have been based on the assumption that for a single pond the relative risk is proportional to the area of the pond group that is unprotected from either a covering by sediment or AquaBlok™ or the loss of WP from sublimation/oxidation. Although with increasing uncertainty, these figures also suggest a relative risk between ponds in the comparison of exposed areas.

- **Time frame.** The figures all have time zero as the start of a remedial action. In actuality, different alternatives may be implemented in different years, but these figures have normalized time as years since start of remedy. The maximum time of 20 years was chosen because that is the time frame of the primary remedial action objectives (RAOs) (discussed in Appendix G).

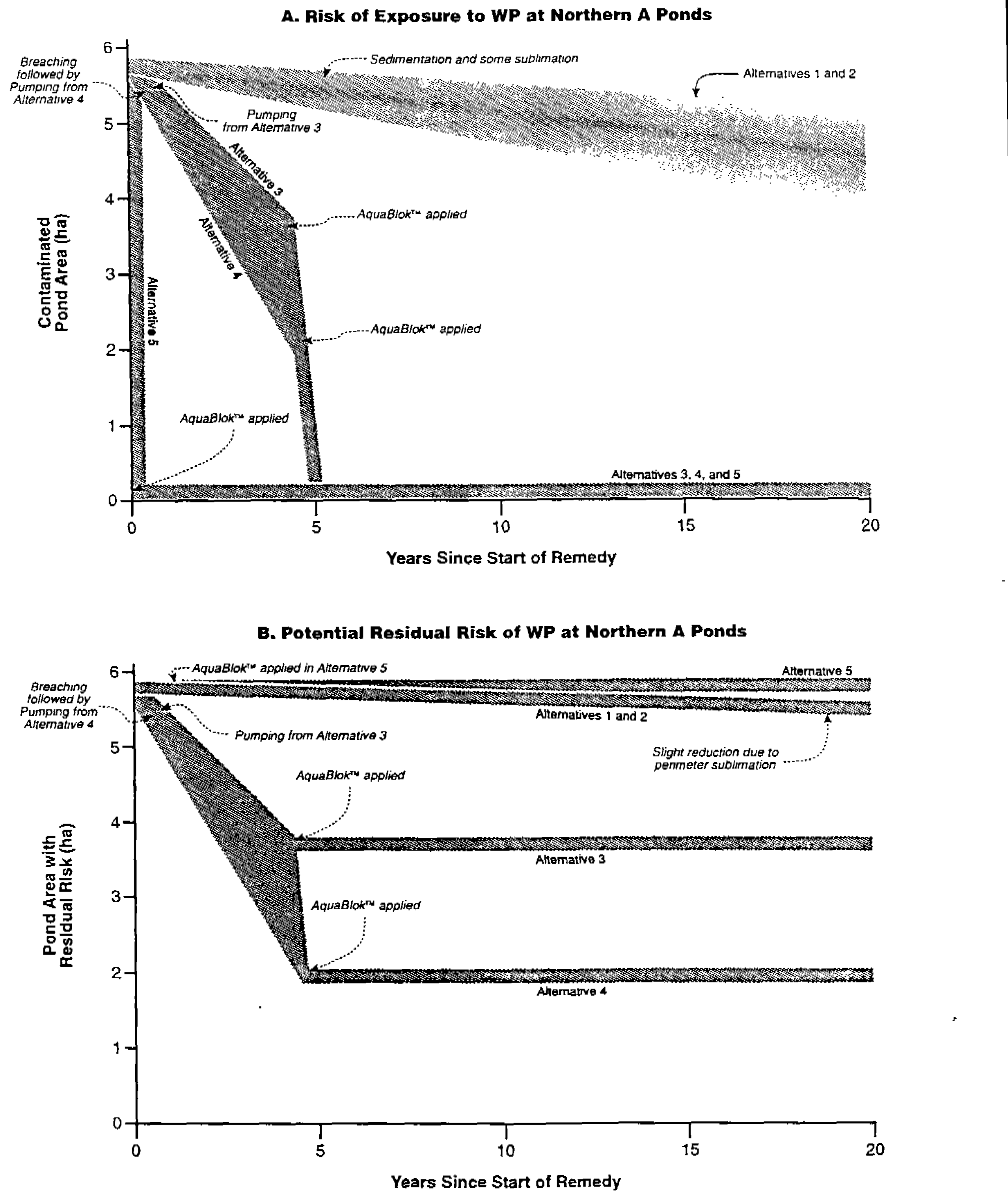

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Figure F-3

Risk Index of Northern A Ponds

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Alternative
1. No action
2. Detailed monitoring
3. Pumping and AquaBlok™
4. Breaching, Pumping, and AquaBlok™
5. AquaBlok™

CH2M HILL

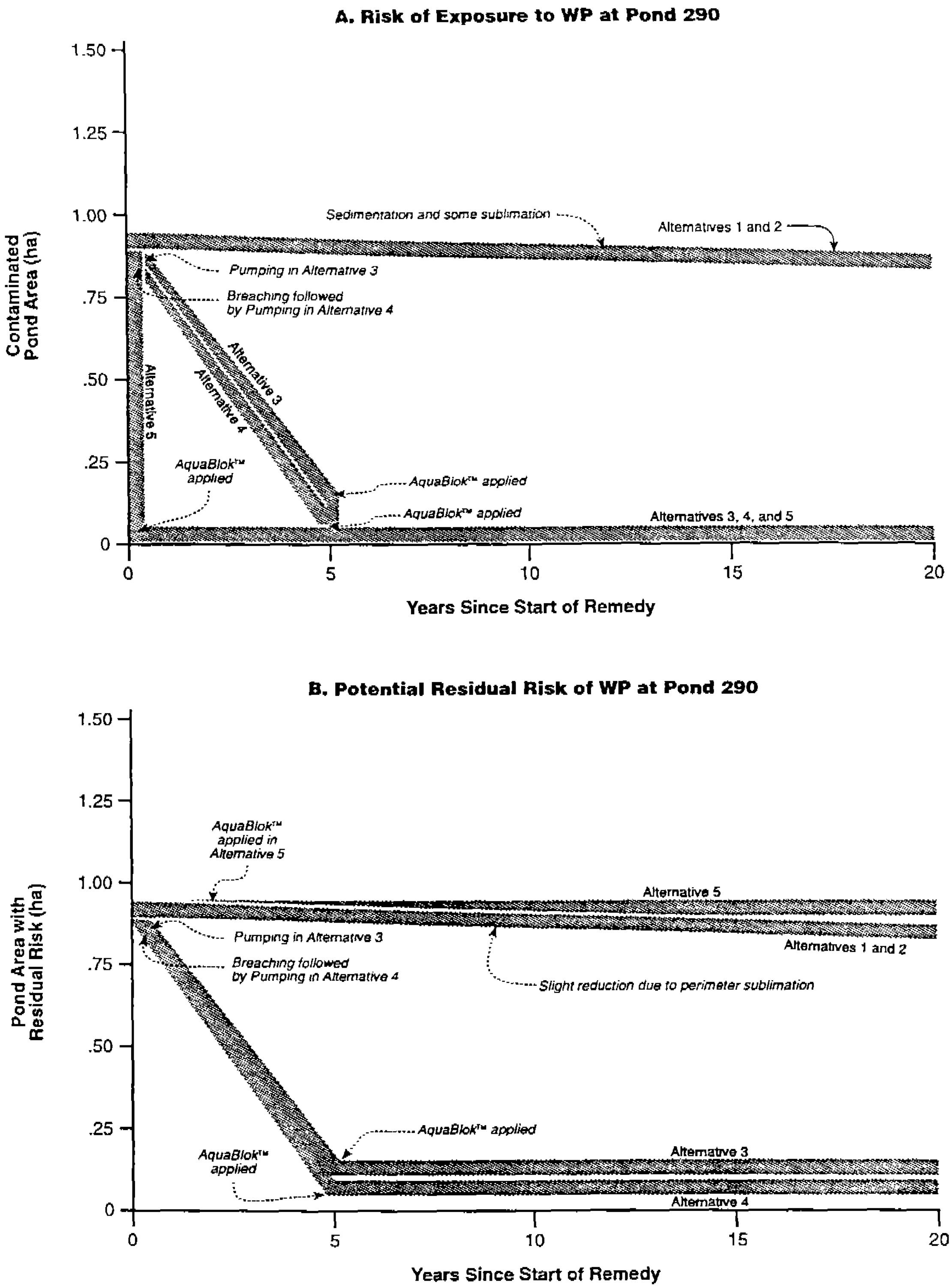

Figure F-4

Risk Index of Pond 290

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Alternative
1. No action
2. Detailed monitoring
3. Pumping and AquaBlok™
4. Breaching, Pumping, and AquaBlok™
5. AquaBlok™

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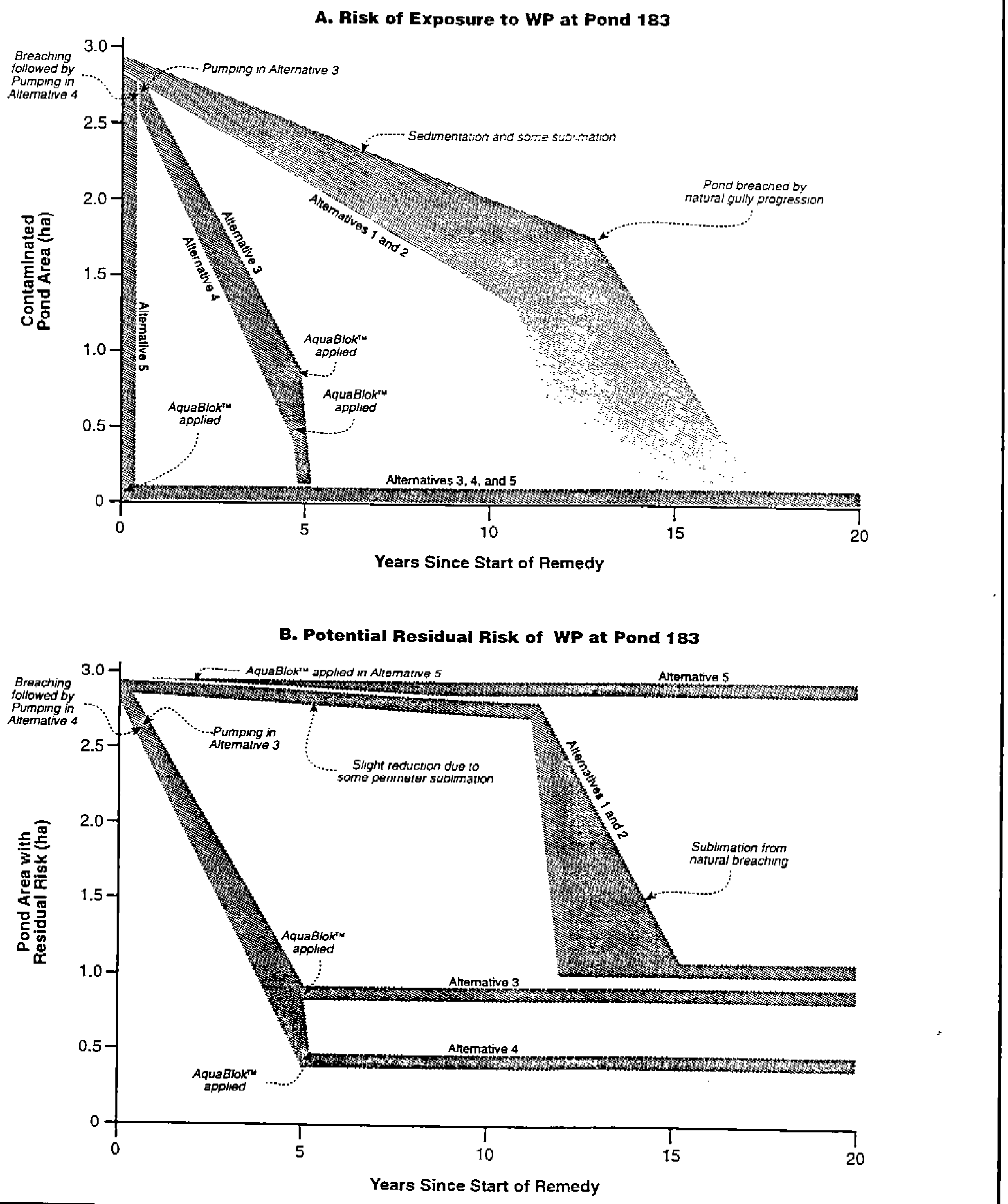

Figure F-5

Risk Index of Pond 183

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Alternative
1. No action
2. Detailed monitoring
3. Pumping and AquaBlok™
4. Breaching, Pumping, and AquaBlok™
5. AquaBlok™

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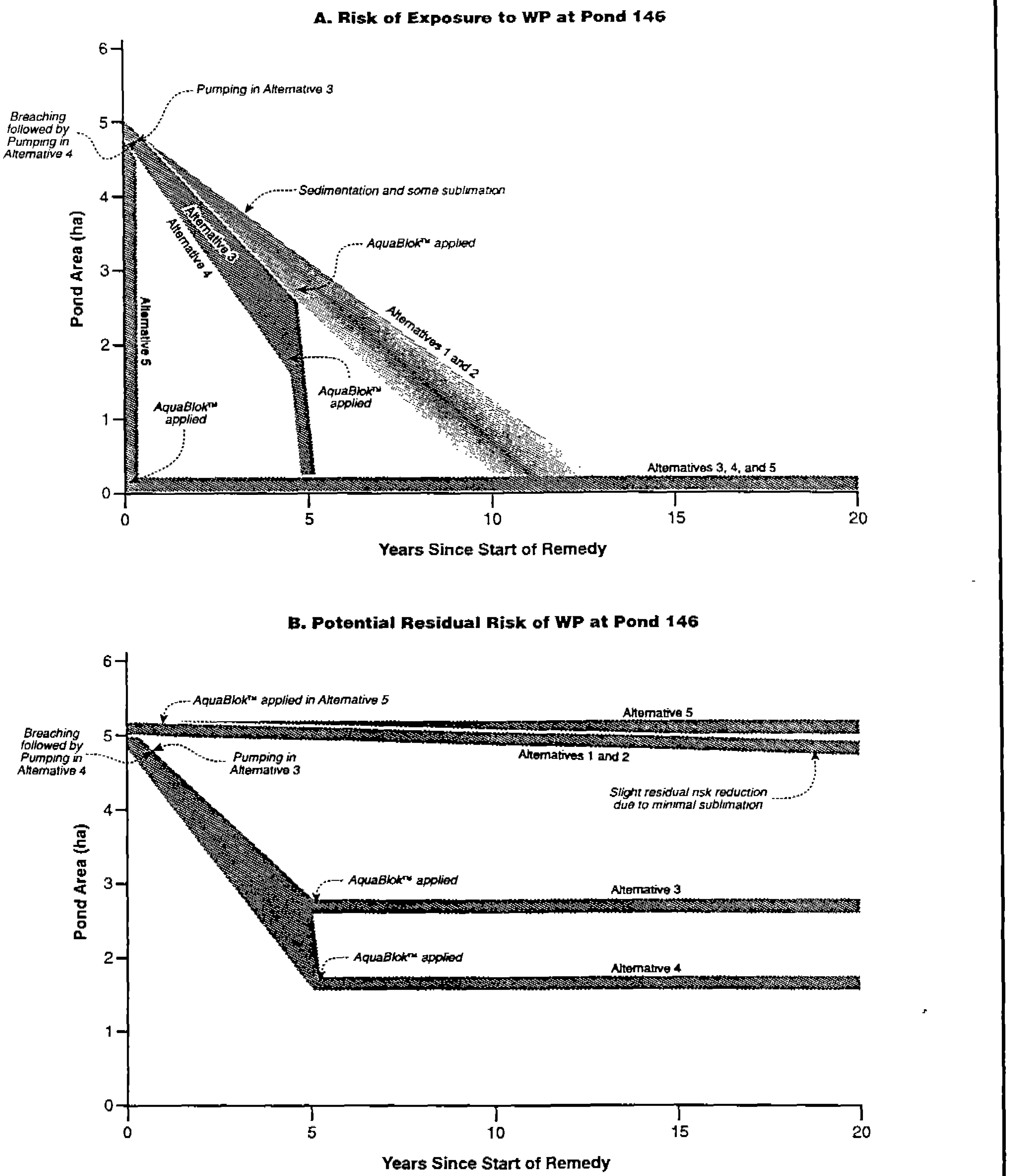

Figure F-6

Risk Index of Pond 146

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Alternative
1. No action
2. Detailed monitoring
3. Pumping and AquaBlok™
4. Breaching, Pumping, and AquaBlok™
5. AquaBlok™

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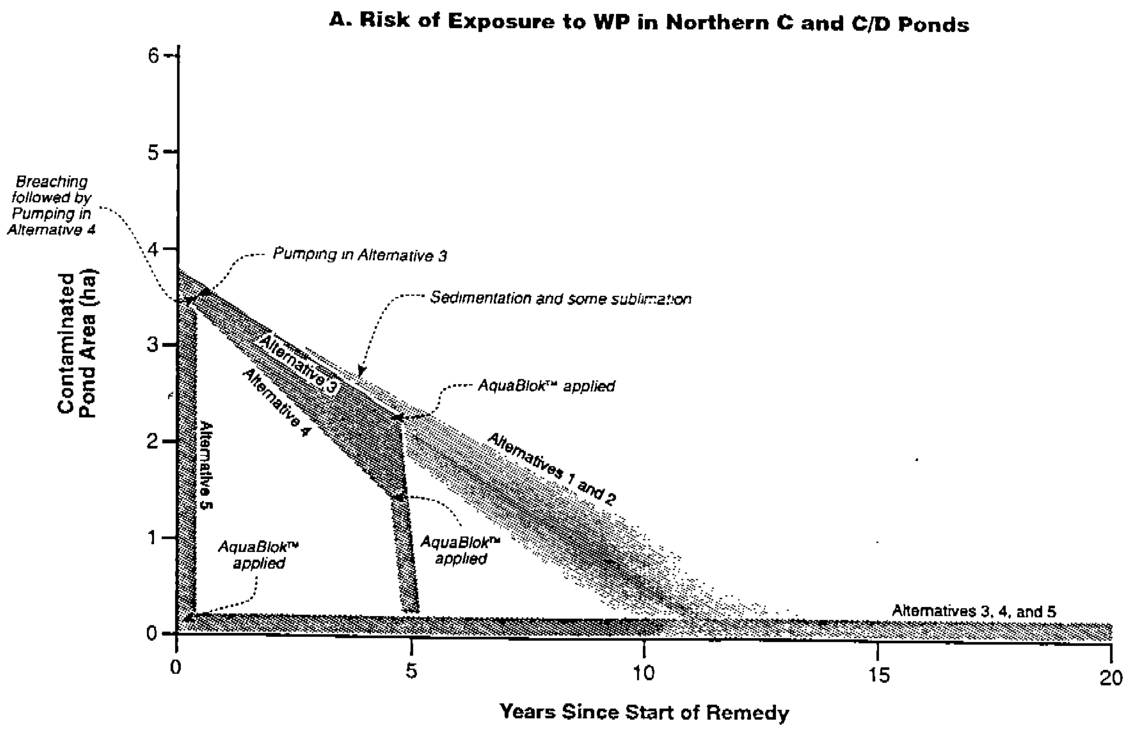

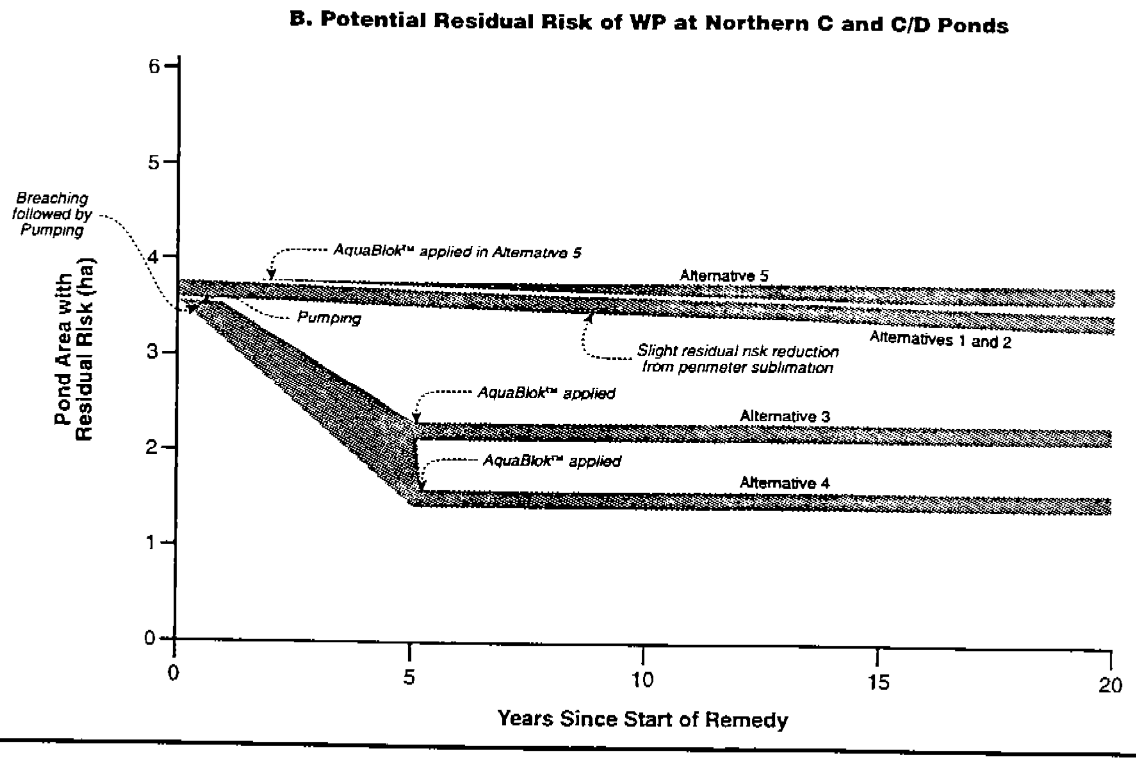

Figure F-7

Risk Index of Ponds C and C/D

Operable Unit C
Feasibility Study
Fort Richardson, Alaska

Alternative
1. No action
2. Detailed monitoring
3. Pumping and AquaBlok™
4. Breaching, Pumping, and AquaBlok™
5. AquaBlok™

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- **Changes in risk.** Table A-4 (Appendix A) summarizes the potential effects of natural processes on the WP conditions during the 20-year time frame. The natural processes of sedimentation and sublimation/oxidation may cause changes in the WP risks to waterfowl over this time. Remedial alternatives also change the magnitude of risk and potential residual risk. Pond draining, because its goal is to reduce the quantity of WP, and the natural process of sublimation/oxidation reduce both the risk and potential residual risk. Sedimentation and the application of AquaBlok™, because they act to reduce WP exposure to dabbling waterfowl by blocking access to the contaminated sediment, reduce risk, but not potential residual risk.

- **Uncertainty.** It is difficult to forecast the effects of natural processes, including the consequences of pond draining. Appendix A summarizes what is known to affect these processes, and there are substantial uncertainties. Judgment has been used in determining the effectiveness of different alternatives on the pond groups in these figures, and this is subject to uncertainty. This is represented in these figures, again semi-quantitatively, by wide lines, which indicate that the risk outcome covers a large risk region. On the other hand, the success of the application of AquaBlok™ can be tested fairly quickly, and more AquaBlok™ may be applied in areas where the depth is insufficient for protection. The monitoring program (discussed in Appendix G) describes an annual inspection that will be performed to maintain the AquaBlok™ as a highly effective WP exposure block. Therefore, the effects of AquaBlok™ on risk and potential residual risk have been represented by comparatively narrow lines.

With this background, the risk consequences of the remedial alternatives for the individual pond groups can now be examined. Figure F-3 shows the risk index for the Northern A ponds. Table A-4 describes that sedimentation may cover one of the ponds in the group, Pond 258, sufficiently for natural restoration within 20 years. Thus, Alternatives 1 and 2, which only use natural processes, show a decline in risk, with a wide line spread representing uncertainty in the risk diagram (Part A). The potential residual risk (Part B) shows no decline over this time because the WP has only been covered but is still potentially available, depending on the future physical forces. Alternatives 3 and 4 show a more rapid, but still uncertain, decline in the risk (Part A) during pond draining because active measures are being taken to enhance the WP sublimation/oxidation through pumping and the presumed resulting pond drying. It is believed that Alternative 4 will be more effective than Alternative 3 in drying the ponds; therefore, the risk of this alternative is shown as lower than that of Alternative 3. The pond risk (Part A) drops abruptly when AquaBlok™ is applied, which is assumed to occur in year 5. Once again, the potential residual risk (Part B) does not decline when the AquaBlok™ is applied, because the WP is still present in the environment.

In comparing the alternatives for Northern A ponds, it can be seen that Alternatives 3 and 4 reduce the risk and potential residual risk faster than Alternatives 1 and 2. Alternative 5 can reduce the risk rapidly, but leaves the pond group with a higher potential residual risk than Alternatives 3 and 4. The potential residual risk for Alternatives 1, 2, and 5 are approximately the same because the dominant force reducing the risk in Alternatives 1 and 2 is sedimentation, which does not reduce the potential residual risk.

The pattern of risk is similar in Pond 290 (Figure F-4), although it is believed with higher certainty that the pond can be drained and WP losses will be more complete. Thus, the potential residual risks of Alternatives 3 and 4 are lower than those in Alternatives 1, 2, and 5.

The pattern is somewhat different for Pond 183 (Figure F-5). In this case, it is believed there is some chance that the ponds may dry to a limited degree on their own; therefore, some WP loss may occur. This is represented by the decline shown for risk and potential residual risk for Alternatives 1 and 2.

4.0 Comparative Analysis

A comparative analysis for each pond group has been conducted to evaluate the relative performance of each alternative in relation to the seven evaluation criteria. This is in contrast to the preceding analysis, in which each alternative was analyzed independently without consideration of other alternatives. The purpose of this comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another so that the key tradeoffs can be balanced and identified.

Each subsection begins with a table summarizing the comparative analysis, followed by a discussion comparing all alternatives to each criterion.

4.1 Northern A Pond Group

The expected performance of each alternative as implemented in the Northern A pond group is presented in Table F-13. This assessment is based on pond group characteristics and alternative properties presented in Appendix C. This information supports the comparative analysis of alternatives presented in this subsection.

4.1.1 Overall Protection of Human Health and the Environment

Alternatives 3, 4, and 5 are all equally protective of public health and the environment but result in varying degrees of residual risk, depending on the level of WP sublimation/oxidation. WP is treated and removed in Alternatives 3 and 4. Alternative 5 is protective in that it blocks exposure of dabbling ducks to WP, but does not remove WP. All three alternatives involve application of AquaBlok™ in areas where WP is not treated.

Alternative 3 would result in short-term habitat removal. Open water habitat would be temporarily removed, thus reducing WP exposure. Alternative 4 would result in permanent effect on waterfowl habitats. There is uncertainty as to the technical implementability of Alternatives 3 and 4, given the hummocky topography.

Alternatives 1 and 2 will not be protective of the environment. The sedimentation rate is expected to be low in the Northern A pond group. Hence, waterfowl would continue to be exposed to WP. Measurement of progress would be possible only with Alternative 2.

4.1.2 ARARs

No chemical-specific ARARs apply to ERF. Alternatives 3, 4, and 5 meet all action- and location-specific ARARs. Alternatives 1 and 2 do not meet location-specific ARARs.

TABLE F-13
Performance of Alternatives, Northern A Pond Group

	Alt 1 &2: No Action and/or Detailed Monitoring	Alt 3: Pumping and AquaBlok™	Alt 4: Breaching, Pumping, and AquaBlok™	Alt 5: AquaBlok™
Area of residual risk (ha)	5.5	3.5	2.3	5.8
Area of sediment treated by sublimation/oxidation (ha)	0.3	2.3	3.5	0
Area of habitat covered by AquaBlok™ (ha)	- [a]	3.5	2.3	5.8
Area of habitat covered by AquaBlok™ as a percentage of water-bearing habitat in this pond group (%)[b]	-	8.3	5.5	13.8
Area of habitat removed by draining (ha)	-	42 (temporary)	42 (permanent)	-
Certainty of performance success within 5 years of implementation	Low	Moderate	Moderate	High
Cost ($)				
Capital	45,000[d]	1,469,000	1,175,000	1,368,000
10 Year Present Worth	207,000[d]	2,142,000	1,792,000	1,413,000
20 Year Present Worth	270,000[d]	2,147,000	1,798,000	1,424,000

[a] "—" indicates that the technology is not a component of the alternative.
[b] The total area of water-bearing habitat in this pond group is 42 ha.
[c] Costs are based on aerial application of AquaBlok™
[d] For Alternative 2 only; Alternative 1 has no associated costs.

4.1.3 Long-term Effectiveness and Permanence

Magnitude of Residual Risk. The amount of residual risk would be lowest under Alternative 4 (2.3 hectares [ha]) and highest under Alternative 5 (5.8 ha), as presented in Table F-13. Alternative 5 only provides a barrier between WP and dabbling ducks. Residual risk from Alternatives 3 and 4 would equal the drying performance of each alternative. Alternative 3 would result in slightly lower performance effectiveness. It is assumed that the combination of breaching and pumping in Alternative 4 would be more effective in lowering water levels, promoting drying and, thus, fostering WP sublimation/oxidation.

Alternatives 1 and 2 would likely result in high amounts of residual risk (5.5 ha). Protection under these alternatives would be through sedimentation and minimal sublimation/oxidation at the perimeters of the ponds. Residual risk resulting from each alternative is presented in Figure F-3.

Adequacy and Reliability of Controls. With the exception of Alternative 1, all alternatives have adequate controls and monitoring requirements. ERF-wide activities such as telemetry, aerial surveys, and aerial photography would determine whether Alternatives 2, 3, 4, or 5 meet the mortality RAO. Sedimentation stations would be established under Alternative 2 to determine the rate of natural restoration achieved. Water level indicators would be installed under Alternatives 3 and 4 to determine the amount of water level decline. Sublimation/oxidation stations would be installed to evaluate WP sublimation/oxidation. AquaBlok™ integrity monitoring would be conducted regularly under Alternatives 3, 4, and 5. No monitoring is scheduled under Alternative 1.

4.1.4 Reduction in Toxicity, Mobility, and Volume

Likelihood that Treatment Process Addresses Principal Threat. Within 5 years, Alternatives 3, 4, and 5 would reduce risk of exposure to WP. Risk reduction would occur most quickly under Alternative 5. Drainage in Alternatives 3 and 4 would lower water levels and remove feeding habitat, so waterfowl would be less likely to be exposed. Under these alternatives, WP would sublimate/oxidize in areas that do dry. WP contaminated sediment that does not dry under Alternatives 3 and 4 would be covered with AquaBlok™. It is very uncertain when natural restoration processes would occur under Alternatives 1 and 2. Sedimentation is the most likely natural restoration process, but rate of deposition in the Northern A pond group is currently not known.

Amount of Hazardous Material Destroyed through Treatment. Alternatives 3 and 4 would treat the largest area of WP-contaminated sediment (2.3 ha and 3.5 ha, respectively), through water level reduction, pond sediment drying, and sublimation/oxidation. A very small area of WP-contaminated sediment would be treated through perimeter sublimation/oxidation under Alternatives 1 and 2. No treatment would occur in Alternative 5. Estimates of treatment are presented in Table F-13.

Irreversibility. WP sublimation/oxidation under Alternatives 3 and 4 would be irreversible. AquaBlok™ application under Alternatives 3, 4, and 5 would be reversible if the AquaBlok™ cover is degraded or damaged as a result of weather, tidal action, or earthquakes. The protection of sedimentation, a natural process under Alternatives 1 and 2, would also be reversed as a result of damage to the sedimentation layer or from earthquakes.

Quantity of Risk and Residual Risk. No treatment residuals would be produced by any of the alternatives.

Statutory Preference for Treatment. Alternatives 3 and 4 meet the statutory preference for treatment. Alternatives 1,2, and 5 do not.

4.1.5 Short-term Effectiveness

Protection of the Community during Remedial Action. There are no significant short-term effects to the community under Alternatives 1, 2, 3, and 5.

Pond breaching under Alternative 4 may affect the community of Eagle River. Loud blasts may result in complaints of noise and vibration. Range Control regulations require that blasting be conducted on clear days to reduce sound and pressure impacts. A rigorous community relations program would be conducted to alert the community of upcoming blasting activities.

Protection of Workers during Remedial Action. Alternative 1 poses no risks to workers because it involves no activity. Alternative 2 requires only WP sampling and sedimentation studies. Alternatives 3, 4, and 5 would require baseline sampling for WP. Alternative 5 involves minimal risks because AquaBlok™ application would be applied either aerially or in the winter over the frozen flats. In addition, monitoring requirements under Alternative 5 are low. Alternatives 3 and 4 would require high access to the flats for the installation, removal, and maintenance of pump systems and sublimation/oxidation monitoring systems, as well as verification monitoring. All areas where workers would be exposed would be cleared visually and/or electronically of UXO.

Environmental Impacts. No new environmental impacts would result from Alternatives 1 and 2. Alternative 2 would be limited to WP sampling and installation of sublimation/oxidation and sedimentation monitoring stations. Environmental impacts resulting from Alternative 3 would be short term. Temporary draining under Alternative 3 would result in the temporary removal of 42 ha of habitat and thus reduced exposure of waterfowl to WP. Pond habitat would likely reestablish after pump systems are removed and ponds refill from flooding tides and precipitation. The 42 ha of habitat removal under Alternative 4 would likely be permanent. There is low certainty regarding feasibility and practicality of restoring a ditch after it has been breached. Pond bottom elevations and open-water feeding habitat would be altered by application of AquaBlok™ under Alternatives 3, 4, and 5. Under Alternatives 3, 4, and 5, 3.5 ha, 2.3 ha, and 5.8 ha, respectively, of AquaBlok™ would be applied (as presented in Table F-13). Waterfowl food sources would be reduced in the short term, but it is expected that they will reestablish. AquaBlok™ application may significantly raise pond bottom elevations in the Northern A pond group.

Time Until Remedial Action Objectives Are Met. Protection of waterfowl, as measured by RAOs, would be achieved under Alternatives 3, 4, and 5. The 5-year RAO of 50 percent mortality reduction would not be achieved under Alternatives 1 and 2, and it is unlikely that the 20-year RAO of 1 percent mortality would be achieved.

4.1.6 Implementability

Technical Feasibility. Alternatives 1, 2, and 5 could be easily implemented; however, only Alternative 5 would result in protection. After a summer 1997 aerial and land survey, it appears that several ponds in the Northern A pond group can be drained and dried with pumps. The hydraulic system of the Northern A pond group is not well understood. The ponds in this group are interconnected, with varying pond bottom elevations. Pumps may need to be rearranged once the deepest portion of the pond system is exposed. Breaching under Alternative 4 would lower threshold elevations and result in more frequent flooding but more rapid draining. The certainty of performance success of each alternative is presented in Table F-13.

Administrative Feasibility. No agency coordination difficulties are anticipated under Alternatives 2, 3, 4, and 5. Coordination of the U.S. Army with U.S. Environmental Protection Agency (USEPA), and Alaska Department of Environmental Conservation (ADEC), and the Biological Technical Assistance Group (BTAG) would be conducted before implementing alternatives. There would be no coordination needed under Alternative 1.

Availability of Services and Materials. No services are required for Alternative 1. Lack of commercial laboratories to perform WP sampling affects Alternatives 2, 3, 4, and 5 equally. Alternatives 3, 4, and 5 all require a specialist firm to coordinate application of AquaBlok™.

Although the pump system designed for Alternatives 3 and 4 is highly specialized, the technology is readily available.

4.1.7 Cost

Capital cost and 10- and 20-year present worth analyses are presented in Table F-13. AquaBlok™ application under Alternative 3 is the least expensive. The costs of Alternatives 3 and 4 are approximately 50 and 25 percent more, respectively, than Alternative 5. Cost assumptions are provided in Appendix E.

4.1.8 Summary

Alternative 5 meets all criteria and would achieve RAOs. This alternative can easily be implemented by air. Alternative 5 would result in AquaBlok™ coverage over 13.8 percent of the water-bearing habitat in the Northern A pond group. It is expected to be successful in blocking waterfowl exposure to WP-contaminated sediment. However, because it blocks exposure by providing a barrier over WP-contaminated sediment, Alternative 5 would result in the highest amount of residual risk, followed by Alternative 3, then Alternative 4. Of the three treatment alternatives, the 10- and 20-year present worth costs of Alternative 5 are lowest. Costs presented in Table F-15 are of aerial application of AquaBlok™. Capital costs of Alternative 5 may be reduced by as much as 50 percent by truck application, as presented in Appendix G.

Alternatives 3 and 4 meet all criteria. The topography of the Northern A pond group is hummocky and drying of the hot ponds would also involve the drainage of 10.6 ha of intermittent ponds, 6 ha of uncontaminated permanent ponds, and 25.2 ha of sedge marsh. Alternative 4 would result in permanent removal of this habitat, while the impacts to habitat under Alternative 3 would be temporary. Because of the large volume of water to drain, it may not be possible to dry WP-contaminated sediment in these hot ponds. Regardless of drying performance, Alternatives 3 and 4 would still be protective because AquaBlok™ would be applied to all areas of hot ponds that do not dry.

Alternatives 1 and 2 do not meet threshold criteria. They are neither protective of the environment, nor do they achieve location-specific ARARs.

Table F-14 shows the ranking of the alternatives for the Northern A pond group. The alternatives are ranked according to how well they meet the criteria; the highest ranking alternatives are the best at meeting each individual criterion.

4.2 Pond 290

The expected performance of each alternative as implemented in Pond 290 is presented in Table F-15. This assessment is based on pond group characteristics and alternative properties that are described in Appendix C. This information supports the comparative analysis of alternatives in this subsection.

4.2.1 Overall Protection of Human Health and the Environment

Alternatives 3, 4, and 5 are all equally protective of public health and the environment, but result in varying degrees of residual risk, depending on the level of WP sublimation/oxidation. WP is expected to be successfully treated and removed under

TABLE F-14
Ranking of Alternatives for the Northern A Pond Group

Criteria	Meeting Criteria			
	Best			Worst
Overall protection of human health and the environment	3	5	4	1, 2
Compliance with ARARs	3,4,5			1, 2
Long-term effectiveness and permanence	3,4	5	2	1
Reduction of TMV	3,4	5		1,2
Short-term effectiveness	3	5		1,2,4
Implementability	1,2,5		4	3
Cost	1	2	4,5	3

Notes:
1. Each number represents an alternative.
2. The ranking refers to performance under each criterion. High ranking indicates that the alternative performed well under the individual criterion.

TABLE F-15
Performance of Alternatives, Pond 290

	Alt 1 &2: No Action and/or Detailed Monitoring	Alt 3: Pumping and AquaBlok™	Alt 4: Breaching, Pumping, and AquaBlok™	Alt 5: AquaBlok™
Area of residual risk (ha)	0.85	0.14	0.10	0.90
Area of sediment treated by sublimation/oxidation (ha)	0.05	0.76	0.80	0
Area of habitat covered by AquaBlok™ (ha)	- [a]	0.14	0.10	0.90
Area of habitat covered by AquaBlok™ as a percentage of water-bearing habitat in this pond group (%)[b]	-	2.0	1.5	13.0
Area of habitat removed by draining (ha)	-	6.9 (temporary)	6.9 (permanent)	-
Certainty of performance success within 5 years of implementation	Low	High	High	High
Cost[c] ($)				
Capital	17,000[d]	199,000	180,000	220,000
10 Year Present Worth	91,000[d]	397,000	370,000	233,000
20 Year Present Worth	122,000[d]	400,000	372,000	236,000

[a] "—" indicates that the technology is not a component of the alternative.
[b] The total area of water-bearing habitat in this pond group is 6.9 ha.
[c] Costs are based on aerial application of AquaBlok™.
[d] For Alternative 2 only; Alternative 1 has no associated costs.

Alternatives 3 and 4. Alternative 5 is protective in that it blocks exposure of dabbling ducks to WP, but does not remove WP. All three alternatives involve application of AquaBlok™ in areas where WP is not treated.

Alternative 3 would result in short-term habitat removal. Open-water habitat would be temporarily removed, thus reducing WP exposure. Alternative 4 would result in permanent effect on waterfowl feeding habitats in Pond 290 and the surrounding water-bearing vegetation. Alternatives 3 and 4 are expected to be successful at Pond 290 because of the relatively isolated nature of this pond.

Alternatives 1 and 2 will not be protective of the environment. Sedimentation rates are expected to be low in Pond 290. Hence, waterfowl would continue to be exposed to WP. Measurement of progress would be possible only with Alternative 2. Protection would likely be achieved by sublimation/oxidation.

4.2.2 ARARs

No chemical-specific ARARs apply at ERF. Alternatives 3, 4, and 5 meet all action- and location-specific ARARs. Alternatives 1 and 2 do not meet location-specific ARARs.

4.2.3 Long-term Effectiveness and Permanence

Magnitude of Residual Risk. Residual risk reduction would be greatest under Alternative 4, followed by Alternative 3, and then Alternative 5. The amount of remaining residual risk under Alternatives 4, 3, and 5 would be 0.10 ha, 0.14 ha, and 0.90 ha, respectively. Residual risk from Alternative 3 and 4 would equal the drying performance of each alternatives. It is expected that Alternative 4 would be slightly more successful in drying than Alternative 3. The combination of breaching and pumping in Alternative 4 would be more effective in lowering water levels, promoting drying and thus fostering WP sublimation/oxidation than under Alternative 4 (which involves only pumping). Draining and drying in Pond 290 are expected to be successful in removing WP from contaminated sediment because of the relative isolated nature of this pond. Therefore, residual risk under Alternatives 3 and 4 will still be low.

Residual risk would be highest under Alternative 5. Alternative 5 only provides a barrier between WP and dabbling ducks and does not treat WP-contaminated sediment.

Alternatives 1 and 2 would likely result in high amounts of residual risk (0.85 ha). Protection under these alternatives would be through sedimentation and minimal sublimation/oxidation at the perimeters of the ponds. Residual risk will exist in areas that experience sedimentation. Residual risk as a result of each alternative is presented in Figure F-4.

Adequacy and Reliability of Controls. With the exception of Alternative 1, all alternatives have adequate controls and monitoring requirements. ERF-wide activities such as telemetry, aerial surveys, and aerial photography would determine whether Alternatives 2, 3, 4, or 5 meet the mortality RAO. Sedimentation stations would be established under Alternative 2 to determine the rate of natural restoration achieved. Sedimentation is the most likely natural restoration process to occur in Pond 290. Water level indicators would be installed under Alternatives 3 and 4 to determine the amount of water level decline. Sublimation/oxidation stations would be installed to evaluate WP sublimation/oxidation.

AquaBlok™ integrity monitoring would be conducted regularly under Alternatives 3, 4, and 5. No monitoring is scheduled under Alternative 1.

4.2.4 Reduction in Toxicity, Mobility, and Volume

Likelihood that Treatment Process Addresses Principal Threat. Within 5 years, Alternatives 3, 4, and 5 would reduce risk of exposure to WP. Drainage in Alternatives 3 and 4 would lower water levels and remove feeding habitat, so waterfowl would be less likely to be exposed. Drying under Alternatives 3 and 4 is expected to be successful, leaving a small area of WP-contaminated sediment to be covered with AquaBlok™. It is uncertain when natural restoration processes would occur under Alternatives 1 and 2. Sedimentation and perimeter sublimation/oxidation are the most likely natural restoration process.

Amount of Hazardous Material Destroyed through Treatment. Alternatives 3 and 4 would treat a largest area of WP-contaminated sediment, through water level reduction, pond sediment drying, and sublimation/oxidation. Alternatives 3 and 4 would result in 0.76 ha and 0.80 ha of treated sediment, respectively. A very small area of WP-contaminated sediment would be treated through perimeter sublimation/oxidation under Alternatives 1 and 2 (0.05 ha). No treatment would occur in Alternative 5. Estimates of treatment are presented in Table F-13.

Irreversibility. WP sublimation/oxidation under Alternatives 3 and 4 would be irreversible. AquaBlok™ application under Alternatives 3, 4, and 5 would be reversible if the AquaBlok™ cover is degraded or damaged as a result of weather, tidal action, or earthquakes. The protection of sedimentation, a natural process under Alternatives 1 and 2, would also be reversed as a result of damage to the sedimentation layer or from earthquakes.

Quantity of Risk and Residual Risk. No treatment residuals would be produced by any of the alternatives.

Statutory Preference for Treatment. Alternatives 3 and 4 meet the statutory preference for treatment. Alternatives 1, 2, and 5 do not.

4.2.5 Short-term Effectiveness

Protection of the Community during Remedial Action. There are no significant short-term effects to the community under Alternatives 1, 2, 3, and 5. Pond breaching under Alternative 4 may affect the community of Eagle River. Loud blasts may result in complaints of noise and vibration. Range Control regulations require that blasting be conducted on clear days to reduce sound and pressure impacts. A rigorous community relations program would be conducted to alert the community of upcoming blasting activities.

Protection of Workers during Remedial Action. Alternative 1 poses no risks to workers because it involves no activity. Alternative 2 requires only WP sampling and sedimentation studies. Alternatives 3, 4, and 5 would require baseline sampling for WP. Alternative 5 involves minimal risks because AquaBlok™ application would be applied either aerially or in the winter over the frozen flats. In addition, monitoring requirements under Alternative 5 are low. Alternatives 3 and 4 would require high access to the flats for the installation, removal, and maintenance of pump systems and sublimation/oxidation monitoring systems, as well as verification monitoring. All areas where workers would be exposed would be cleared visually and/or electronically of UXO.

Environmental Impacts. No new environmental impacts would result from Alternatives 1 and 2. Alternative 2 would be limited to WP sampling and installation of sublimation/oxidation and sedimentation monitoring stations. Environmental impacts resulting from Alternative 3 would be short term. Temporary draining under Alternative 3 would result in the temporary removal of 6.9 ha of habitat and thus reduced exposure of waterfowl to WP. Pond habitat would likely reestablish after pump systems are removed and ponds refill from flooding tides and precipitation. The 6.9 ha of habitat removed under Alternative 4 would likely be permanent. There is low certainty regarding feasibility and practicality of restoring a ditch after it has been breached. Pond bottom elevations and open-water feeding habitat would be altered by application of AquaBlok™ under Alternatives 3, 4, and 5. Waterfowl food sources would be reduced in the short term, but it is expected that they will reestablish. AquaBlok™ application may raise pond bottom elevation. Although no depth measurements have been made specifically at Pond 290, measurements at the Northern A pond group suggest that Pond 290 is deep. Under Alternatives 3, 4, and 5, 0.14 ha, 0.10 ha, and 0.90 ha of AquaBlok™ would be applied (as presented in Table F-15). AquaBlok™ applications under Alternatives 3, 4, and 5 are not expected to remove all water storage.

Time Until Remedial Action Objectives are Met. Protection of waterfowl, as measured by RAOs, would be achieved under Alternatives 3, 4, and 5. RAOs would be achieved even if pond draining is not successful under Alternatives 3 and 4 because pond bottom sediment that does not dry would be covered with AquaBlok™. The 5-year RAO of 50 percent mortality reduction would not be achieved under Alternatives 1 and 2, and it is unlikely that the 20-year RAO of 1 percent mortality would be achieved. These estimates are presented in Figure F-4.

4.2.6 Implementability

Technical Feasibility. Alternatives 1, 2, 3, 4, and 5 could be easily implemented. Draining and drying under Alternatives 3 and 4 are expected to be successful at Pond 290 because of its relatively isolated nature. Pumps may need to be rearranged once the deepest portion of Pond 290 is exposed, but that should occur within the first 24 hours of pumping. Breaching under Alternative 4 would lower threshold elevations and result in more frequent flooding.

Administrative Feasibility. No agency coordination difficulties are anticipated under Alternatives 2, 3, 4, and 5. Coordination of the U.S. Army with the USEPA, ADEC, and BTAG would be conducted before implementing alternatives. There would be no coordination needed under Alternative 1.

Availability of Services and Materials. No services are required for Alternative 1. Lack of commercial laboratories to perform WP sampling affect Alternatives 2, 3, 4, and 5 equally. Alternatives 3, 4, and 5 all require a specialist firm to coordinate application of AquaBlok™. Although the pump system designed for Alternatives 3 and 4 is highly specialized, the technology is readily available.

4.2.7 Cost

Capital cost and 10- and 20-year present worth analyses are presented in Table F-15. The cost of Alternative 4 is less than that of Alternative 3 because the savings from breaching and purchasing a smaller pump are greater than the cost of a larger pump system. Although the capital cost of Alternative 5 is greater than that of Alternative 4, the lower O&M costs under Alternative 5 result in lower present worth costs. Cost assumptions are provided in Appendix E.

4.2.8 Summary

Alternatives 3, 4, and 5 meet all criteria and would achieve RAOs. All three alternatives can easily be implemented. The 10- and 20-year present worth costs of Alternative 5 are clearly less than Alternatives 3 and 4. However, Alternative 5 results in significantly higher residual risk (0.90 ha). Alternative 4 is the least expensive of the remediation-oriented alternatives, and would treat the largest quantity of WP. However, this alternative would result in the permanent removal of 6.9 ha of habitat.

Alternative 3 is the most expensive of all alternatives, but would result in only a small amount of residual risk. Alternative 3 is expected to perform well at Pond 290 because of the relative isolated nature of the pond. In addition, waterfowl feeding habitat would not be permanently removed under Alternative 3; vegetation would likely be restored following pump removal.

Alternatives 1 and 2 do not meet threshold criteria. They are neither protective of the environment nor do they achieve location-specific ARARs.

Table F-16 shows the ranking of the alternatives for Pond 290. The alternatives are ranked according to how well they meet the criteria; the highest ranking alternatives are the best at meeting each individual criterion.

TABLE F-16
Ranking of Alternatives for Pond 290

Criteria	Meeting Criteria			
	Best			Worst
Overall protection of human health and the environment	3	5	4	1, 2
Compliance with ARARs	3,4,5			1, 2
Long-term effectiveness and permanence	3,4		5, 2	1
Reduction of TMV	3,4	5		1,2
Short-term effectiveness	3	5		1,2,4
Implementability	1,2,3,4,5			
Cost	1	2	5	4, 3

Notes:
1. Each number represents an alternative.
2. The ranking refers to the performance of each alternative under each criterion. High ranking indicates that the alternative performed well under the individual criterion.

4.3 Pond 183

The expected performance of each alternative as implemented in Pond 183 is presented in Table F-17. This assessment is based on pond group characteristics and alternative properties that are described in Appendix C. This information supports the comparative analysis of alternatives in this subsection.

4.3.1 Overall Protection of Human Health and the Environment

Alternatives 3, 4, and 5 are all equally protective of public health and the environment, but result in varying degrees of residual risk, depending on the level of WP sublimation/oxidation. WP is treated and removed in Alternative 3 and 4. Alternative 5 is protective in that it blocks exposure of dabbling ducks to WP, but does not remove WP. All three alternatives involve application of AquaBlok™ in areas where WP is not treated.

TABLE F-17
Performance of Alternatives, Pond 183

	Alt 1 &2: No Action and/or Detailed Monitoring	Alt 3: Pumping and AquaBlok™	Alt 4: Breaching, Pumping, and AquaBlok™	Alt 5: AquaBlok™
Area of residual risk (ha)	1.0	0.9	0.4	2.9
Area of sediment treated by sublimation/oxidation (ha)	1.9	2.0	2.5	-
Area of habitat covered by AquaBlok™ (ha)	-[a]	0.9	0.4	2.9
Area of habitat covered by AquaBlok™ as a percentage of water-bearing habitat in this pond group (%)[b]	0	8.0	3.4	25.0
Area of habitat removed by draining (ha)	-	11.7 (temporary)	11.7 (permanent)	-
Certainty of performance success within 5 years of implementation	low[c]	Moderate	Moderate	High
Cost[d] ($)				
Capital	22,000[e]	397,000	332,000	683,000
10 Year Present Worth	152,000[e]	635,000	580,000	696,000
20 Year Present Worth	215,000[e]	638,000	582,000	698,000

[a] "—" indicates that the technology is not a component of the alternative.

[b] The total area of water-bearing habitat in this pond group is 11.7 ha.

[c] Very low residual risk if gully recession to Pond 183 occurs. However, there is high uncertainty regarding whether natural breaching would occur.

[d] Costs are based on aerial application of AquaBlok™.

[e] For Alternative 2 only; Alternative 1 has no associated costs.

Alternative 3 would result in short-term habitat removal. Open-water habitat would be temporarily removed, thus reducing WP exposure. Alternative 4 would result in permanent effect on waterfowl feeding habitats in Pond 183. Because the northwest portion of 183 has contributed to a large percentage of duck deaths at ERF, removal of habitat would achieve reduction in mortality. There is uncertainty as to the technical implementability of Alternatives 3 and 4, given the likely hydraulic interconnections between Pond 183 and Pond 146.

Alternatives 1 and 2 may be protective of the environment, but risk reduction may take more than 10 to 20 years. During that time, waterfowl would continue to be exposed to WP. Measurement of progress would be possible only with Alternative 2. Protection would likely be achieved by sublimation/oxidation and natural gully recession.

4.3.2 ARARs

No chemical-specific ARARs apply to ERF. Alternatives 3, 4, and 5 meet all action- and location-specific ARARs. Alternatives 1 and 2 do not meet location-specific ARARs.

4.3.3 Long-term Effectiveness and Permanence

Magnitude of Residual Risk. Residual risk reduction would be greatest under Alternative 4 (0.4 ha remaining), followed by Alternatives 1 and 2 (1.0 ha remaining), followed by Alternative 3 (0.9 ha remaining), and then Alternative 5 (2.9 ha remaining). Residual risk as a result of each alternative is presented in Figure F-5.

Residual risk from Alternatives 3 and 4 would equal the drying performance of each alternative. It is expected that the combination of breaching and pumping in Alternative 4 would be slightly more effective in lowering water levels, promoting drying and thus fostering WP sublimation/oxidation than under Alternative 3, which involves only pumping. The summer 1997 pond draining study indicates that Pond 183 can be drained and dried by pumping regardless of the interconnectiveness between Pond 183 and 146. A large amount of residual risk may be removed from a small decrease in water levels in Pond 183. High WP contamination has been detected in the pond bottom sediment of the shallow northwestern portion of Pond 183. Draining may expose this area to promote the sublimation/oxidation of a large portion of the WP in Pond 183. Although it is unknown if complete drying and sublimation/oxidation of pond bottom sediments would occur, a large amount of residual risk could potentially be removed with a small decrease in water level elevation under Alternatives 3 and 4.

Alternative 5 only provides a barrier between WP and dabbling ducks.

Alternatives 1 and 2 may result in high amounts of residual risk, depending on whether natural gully recession would occur. Protection under these alternatives would, at a minimum, be through sedimentation and minimal sublimation/oxidation at the perimeter of Pond 183. There is a potential that gully recession would breach Pond 183 within the next 10 to 15 years, resulting in drainage and possible sublimation/oxidation. Residual risk would exist in areas that experience sedimentation, but would decrease substantially if Pond 183 were breached naturally. It was assumed in Figure F-5 that natural gully recession would not be as successful in fostering sublimation/oxidation as Alternatives 3 and 4.

Adequacy and Reliability of Controls. With the exception of Alternative 1, all alternatives have adequate controls and monitoring requirements. ERF-wide activities such as telemetry, aerial surveys, and aerial photography would determine whether Alternatives 2, 3, 4, or 5 meet the mortality RAO. Sedimentation stations would be established under Alternative 2 to determine the rate of natural restoration achieved. Aerial photographs would be examined to determine the rate of gully recession. Natural pond breaching and sedimentation are the most likely natural restoration process to occur in Pond 183. Water level indicators would be installed under Alternatives 3 and 4 to determine the amount of water level decline. Sublimation/oxidation stations would be installed to evaluate WP sublimation/oxidation. AquaBlok™ integrity monitoring would be conducted regularly under Alternatives 3, 4, and 5. No monitoring is scheduled under Alternative 1.

4.3.4 Reduction in Toxicity, Mobility, and Volume

Likelihood that Treatment Process Addresses Principal Threat. Alternatives 3, 4, and 5 would block the exposure of waterfowl to WP. Drainage in Alternatives 3 and 4 would lower water levels and remove feeding habitat, so waterfowl would be less likely to be exposed. Although there is a high degree of uncertainty regarding whether sediment drying would be successful under Alternatives 3 and 4, all WP-contaminated sediment that is not treated would be covered with AquaBlok™. It is very uncertain when natural restoration processes would occur under Alternatives 1 and 2. Gully recession and sedimentation are the most likely natural restoration processes; however, the likelihood of gully recession occurring is currently not known.

Amount of Hazardous Material Destroyed through Treatment. Alternatives 3 and 4 would treat the largest area of WP-contaminated sediment (2.0 ha and 2.5 ha, respectively) through water level reduction, pond sediment drying, and sublimation/oxidation. A very small area of WP-contaminated sediment would be treated by perimeter sublimation/oxidation under Alternatives 1 and 2, although 2.9 ha of WP-contaminated sediment would be treated if gully recession were to breach Pond 183. No treatment would occur in Alternative 5. Estimates of treatment are presented in Table F-17.

Irreversibility. WP sublimation/oxidation under Alternatives 3 and 4 would be irreversible. AquaBlok™ application under Alternatives 3, 4, and 5 is possibly reversible if the AquaBlok™ cover is degraded or damaged as a result of weather, tidal action, or earthquakes. The protection of sedimentation, a natural process under Alternatives 1 and 2, would also be reversed as a result of damage to the sedimentation layer or from earthquakes.

Quantity of Risk and Residual Risk. No treatment residuals would be produced by any of the alternatives.

Statutory Preference for Treatment. Alternatives 3 and 4 meet the statutory preference for treatment. Alternatives 1, 2, and 5 do not.

4.3.5 Short-term Effectiveness

Protection of the Community during Remedial Action. There are no significant short-term effects to the community under Alternatives 1, 2, 3, and 5.

Pond breaching under Alternative 4 may affect the community of Eagle River. Loud blasts may result in complaints of noise and vibration. Range Control regulations require that blasting be conducted on clear days to reduce sound and pressure impacts. A rigorous community relations program would be conducted to alert the community of upcoming blasting activities.

Protection of Workers during Remedial Action. Alternative 1 poses no risks to workers because it involves no activity. Alternative 2 requires only WP sampling and sedimentation studies. Alternatives 3, 4, and 5 would require baseline sampling for WP. Alternative 5 involves minimal risks because AquaBlok™ application would be applied either aerially or in the winter over the frozen flats. In addition, monitoring requirements under Alternative 5 are low. Alternatives 3 and 4 would require high access to the flats for the installation, removal, and maintenance of pump systems and sublimation/oxidation monitoring systems, as well as verification monitoring. Pond 183 may be accessed via the open burning/open detonation (OB/OD) pad. In addition to helicopter travel, workers may enter and perform work by foot or boat. All areas where workers would be exposed would be cleared visually and/or electronically of UXO.

Environmental Impacts. No new environmental impacts would result from Alternatives 1 and 2. Alternative 2 would be limited to WP sampling and installation of sublimation/oxidation and sedimentation monitoring stations. Environmental impacts resulting from Alternative 3 would be short term. Temporary draining under Alternative 3 would result in the temporary removal of 11.7 ha of habitat and thus reduced exposure of waterfowl to WP. Pond habitat would likely reestablish after pump systems are removed and ponds refill from flooding tides and precipitation. The 11.7 ha of habitat removal under Alternative 4 would be permanent. There is low certainty regarding feasibility and practicality of restoring a ditch after it has been breached. Pond bottom elevations and open-water feeding habitat would be altered by application of AquaBlok™ under Alternatives 3, 4, and 5 (0.9 ha, 0.4 ha, and 2.9 ha, respectively). Waterfowl food sources would be reduced in the short term, but it is expected that they will reestablish. AquaBlok™ application may significantly raise pond bottom elevations in the western portion of Pond 183, where the pond is more shallow, but adequate water storage would be available in the eastern portion.

Time Until Remedial Action Objectives are Met. Protection of waterfowl, as measured by RAOs, would be achieved under Alternatives 3, 4, and 5. RAOs would be achieved even if pond draining is not successful under Alternatives 3 and 4, because pond bottom sediment that does not dry would be covered with AquaBlok™. The 5-year RAO of 50 percent mortality reduction would not be achieved under Alternatives 1 and 2. Because Pond 183 may naturally drain by gully recession, there is a chance that the 20-year RAO of 1 percent mortality would be achieved. These estimates are presented in Figure F-5.

4.3.6 Implementability

Technical Feasibility. Alternatives 1, 2, and 5 could be easily implemented, however only Alternative 5 would result in protection. The summer 1997 pond draining study indicates that Pond 183 can be drained and dried by pumping, regardless of the interconnectiveness between Pond 183 and Pond 146. The hydraulic system of this area is not well understood. The ponds were connected by a dredged channel in 1996. The certainty of performance success of each alternative is presented in Table F-13.

However, because of the topography of the pond bottom, there is a likelihood that a small lowering of water levels in Pond 183 may result in a large residual risk reduction. The highest concentrations of WP in Pond 183 are at the northwest portion. This area is also much shallower than the western portion. Lowering water levels by a small amount may expose this area sufficiently to promote WP sublimation/oxidation. Pumps may need to be rearranged once the deepest portion of the pond system is exposed. Breaching under Alternative 4 would lower threshold elevations and result in more frequent flooding.

Administrative Feasibility. No agency coordination difficulties are anticipated under Alternatives 2, 3, 4, and 5. Coordination of the U.S. Army with USEPA, ADEC, and BTAG would be conducted before implementing alternatives. There would be no coordination needed under Alternative 1.

Availability of Services and Materials. No services are required for Alternative 1. Lack of commercial laboratories to perform WP sampling affect Alternatives 2, 3, 4, and 5 equally. Alternatives 3, 4, and 5 all require a specialist firm to coordinate application of AquaBlok™. Although the pump system designed for Alternatives 3 and 4 is highly specialized, the technology is readily available.

4.3.7 Cost

Capital cost and 10- and 20-year present worth analyses are presented in Table F-17. The capital costs of Alternatives 3 and 4 are nearly half the capital cost of Alternative 5. However, the present worth costs of Alternatives 3, 4, and 5 are comparable. Cost assumptions are provided in Appendix E.

4.3.8 Summary

Alternatives 3, 4, and 5 meet all criteria and would achieve RAOs. All three alternatives can be easily implemented. The 10- and 20-year present worth costs of all three alternatives are comparable. Alternative 4 is least expensive and would result the least amount of residual risk. However, implementation of Alternative 4 also would result in permanent removal of 11.7 ha of habitat. Alternative 5 is the most expensive technology-oriented alternative, and implementation of this alternative would result in significantly higher residual risk.

Alternative 3 is the second most expensive of all alternatives, but would result in a small amount of residual risk. In addition, waterfowl feeding habitat would not be permanently removed under Alternative 3. Vegetation would likely be restored following pump removal.

There is a high degree of confidence that Pond 183 could be dried successfully under Alternative 3. A field-scale pumping treatability study was performed at this pond in summer 1997 that determined that the hydraulic interconnectiveness between Pond 183 and adjacent areas was controllable.

Alternatives 1 and 2 do not meet threshold criteria. They are neither protective of the environment nor do they achieve location-specific ARARs.

Table F-18 shows the ranking of the alternatives for Pond 183. The alternatives are ranked according to how well they meet the criteria; the highest ranking alternatives are the best at meeting each individual criterion.

TABLE F-18
Ranking of Alternatives for Pond 183

Criteria	Meeting Criteria Best			Worst
Overall protection of human health and the environment	3	5	4	1, 2
Compliance with ARARs	3,4,5			1, 2
Long-term effectiveness and permanence	3	4	5, 2	1
Reduction of TMV	3, 4	5		1,2
Short-term effectiveness	3	5		1,2,4
Implementability	1,2,5	3,4		
Cost	1, 2	4	3	5

Notes:
1. Each number represents an alternative.
2. The ranking refers to performance under each criterion. High ranking indicates that the alternative performed well under the individual criterion.

4.4 Pond 146

The expected performance of each alternative as implemented in Pond 146 is presented in Table F-19. This assessment is based on pond group characteristics and alternative properties that are described in Appendix C. This information supports the comparative analysis of alternatives in this subsection.

4.4.1 Overall Protection of Human Health and the Environment

Alternatives 3, 4, and 5 are all equally protective of public health and the environment, but result in varying degrees of residual risk, depending on the level of WP sublimation/oxidation. WP is may be treated and removed in Alternative 3 and 4. Alternative 5 is protective in that it blocks exposure of dabbling ducks to WP, but does not remove WP. All three alternatives involve application of AquaBlok™ in areas where WP is not treated.

Alternative 3 would result in short-term habitat removal. Open-water habitat would be temporarily removed, thus reducing WP exposure. Alternative 4 would result in permanent effect on waterfowl feeding habitats in Pond 146. There is high uncertainty as to the technical implementability of Alternatives 3 and 4, given the hydraulic interconnections between Pond 183, the Northern C and C/D pond group, and recharge from Clunie Creek.

Alternatives 1 and 2 may be protective of the environment, but risk reduction may take more than 10 to 20 years. During that time, waterfowl would continue to be exposed to WP. Measurement of progress would be possible only with Alternative 2. Protection would likely be achieved by sedimentation.

TABLE F-19
Performance of Alternatives, Pond 146

	Alt 1 &2: No Action and/or Detailed Monitoring	Alt 3: Pumping and AquaBlok™	Alt 4: Breaching, Pumping, and AquaBlok™	Alt 5: AquaBlok™
Area of residual risk (ha)	5.0	2.8	1.7	5.0
Area of sediment treated by sublimation/oxidation (ha)	0.2	2.4	3.5	--
Area of habitat covered by AquaBlok™ (ha)	–[a]	2.8	1.7	5.0
Area of habitat covered by AquaBlok™ as a percentage of water-bearing habitat in this pond group (%)[b]	–	17.6	10.7	32.7
Area of habitat removed by draining (ha)	-	15.9	15.9	
Certainty of performance success within 5 years of implementation	Moderate	Low	Low	High
<u>Cost[c] ($)</u>				
Capital	23,000[d]	1,422,000	879,000	1,218,000
10 Year Present Worth	155,000[d]	1,926,000	1,275,000	1,231,000
20 Year Present Worth	218,000[d]	1,929,000	1,278,000	1,234,000

[a] "—" indicates that the technology is not a component of the alternative.
[b] The total area of water-bearing habitat in this pond group is 15.9 ha.
[c] Costs are based on aerial application of AquaBlok™.
[d] For Alternative 2 only; Alternative 1 has no associated costs.

4.4.2 ARARs

No chemical-specific ARARs apply to ERF. Alternatives 3, 4, and 5 meet all action- and location-specific ARARs. Alternatives 1 and 2 do not meet location-specific ARARs.

4.4.3 Long-term Effectiveness and Permanence

Magnitude of Residual Risk. Residual risk reduction would be greatest under Alternative 4, followed by Alternative 3 and then Alternative 5. Remaining residual risk under Alternatives 3, 4, and 5 are 2.8 ha, 1.7 ha, and 5.0 ha, respectively. Residual risk as a result of each alternative is presented in Figure F-6.

Residual risk from Alternatives 3 and 4 would equal the drying performance of each alternative. It is expected that the combination of breaching and pumping in Alternative 4 would be slightly more effective in lowering water levels, promoting drying and thus fostering WP sublimation/oxidation, than under Alternative 3, which involves only pumping. However, the success of draining and drying in Pond 146 is highly questionable. There is a high degree of uncertainty regarding whether Alternatives 3 and 4 would be capable of drying pond bottom sediment, because of the interconnectiveness between Pond 183 and the Northern C and C/D pond group and recharge from Clunie Creek.

Application of AquaBlok™ under Alternative 5 only provides a barrier between WP and dabbling ducks. Residual risks would not be not be reduced.

Alternatives 1 and 2 may result in high amounts of residual risk (5.0 ha). Protection under these alternatives would be through sedimentation and minimal sublimation/oxidation at the perimeter of Pond 146. Residual risk will exist in areas that experience sedimentation.

Adequacy and Reliability of Controls. With the exception of Alternative 1, all alternatives have adequate controls and monitoring requirements. ERF-wide activities such as telemetry, aerial surveys, and aerial photography would determine whether Alternatives 2, 3, 4, or 5 meet the mortality RAO. Sedimentation stations would be established under Alternative 2 to determine the rate of natural restoration achieved. Water level indicators would be installed under Alternatives 3 and 4 to determine the amount of water level decline. Sublimation/oxidation stations would be installed to evaluate WP sublimation/oxidation. AquaBlok™ integrity monitoring would be conducted regularly under Alternatives 3, 4, and 5. No monitoring is scheduled under Alternative 1.

4.4.4 Reduction in Toxicity, Mobility, and Volume

Likelihood that Treatment Process Addresses Principal Threat. Alternatives 3, 4, and 5 would reduce risk of waterfowl exposure to WP. Drainage in Alternatives 3 and 4 would lower water levels and remove feeding habitat, so waterfowl would be less likely to be exposed. WP would sublimate/oxidize in areas that do dry. Although there is a high degree of uncertainty regarding whether sediment drying would be successful under Alternatives 3 and 4, all WP- contaminated sediment that is not treated would be covered with AquaBlok™. It is very uncertain when natural restoration processes would occur under Alternatives 1 and 2. Sedimentation is the most likely natural restoration process. The rate of deposition is currently not known.

Amount of Hazardous Material Destroyed through Treatment. Alternatives 3 and 4 would treat the largest area of WP-contaminated sediment (2.4 ha and 3.5 ha, respectively), through water level reduction, pond sediment drying, and sublimation/oxidation. A very small area of WP-contaminated sediment would be treated by perimeter sublimation/oxidation under Alternatives 1 and 2. No treatment would occur in Alternative 5. Estimates of treatment are presented in Table F-19.

Irreversibility. WP sublimation/oxidation under Alternatives 3 and 4 would be irreversible. AquaBlok™ application under Alternatives 3, 4, and 5 would be reversible if the AquaBlok™ cover is degraded damaged as a result of weather, tidal action, or earthquakes. The protection of sedimentation, a natural process under Alternatives 1 and 2, would be reversed as a result of damage to the sedimentation layer or from earthquakes.

Quantity of Risk and Residual Risk. No treatment residuals would be produced by any of the alternatives.

Statutory Preference for Treatment. Alternatives 3 and 4 meet the statutory preference for treatment. Alternatives 1, 2, and 5 do not.

4.4.5 Short-term Effectiveness

Protection of the Community during Remedial Action. There are no significant short-term effects to the community under Alternatives 1, 2, 3, and 5. Pond breaching under Alternative 4 may affect the community of Eagle River. Loud blasts may result in complaints of noise and vibration. Range Control regulations require that blasting be conducted on clear days to reduce sound and pressure impacts. A rigorous community relations program would be conducted to alert the community of upcoming blasting activities.

Protection of Workers during Remedial Action. Alternative 1 poses no risks to workers because it involves no activity. Alternative 2 requires only WP sampling and sedimentation studies. Alternatives 3, 4, and 5 would require baseline sampling for WP. Alternative 5 involves minimal risks because AquaBlok™ application would be applied either aerially or in the winter over the frozen flats. In addition, monitoring requirements under Alternative 5 are low. Alternatives 3 and 4 would require high access to the flats for the installation, removal, and maintenance of pump systems and sublimation/oxidation monitoring systems, as well as verification monitoring. Pond 146 may be accessed via OB/OD pad. In addition to helicopter travel, workers may enter and perform work by foot or boat. All areas where workers would be exposed would be cleared visually and/or electronically of UXO.

Environmental Impacts. No new environmental impacts would result from Alternatives 1 and 2. Alternative 2 would be limited to WP sampling and installation of sublimation/oxidation and sedimentation monitoring stations. Environmental impacts resulting from Alternative 3 would be short term. Temporary draining under Alternative 3 would result in the temporary removal of 15.9 ha of habitat and thus reduced exposure of waterfowl to WP. Pond habitat would likely reestablish after pump systems are removed and ponds refill from flooding tides and precipitation. The 15.9 ha of habitat removal under Alternative 4 would be permanent. In addition, breaching of Pond 146 would have a significant effect on the whole eastern side of ERF because of the interconnectiveness of the ponds, especially along shore. It will also affect flooding of ERF. There is low certainty regarding feasibility and practicality of restoring a ditch after it has been breached. Pond bottom elevations and open-water feeding habitat would be altered by application of AquaBlok™ under Alternatives 3, 4, and 5. Under Alternatives 3, 4, and 5, 2.8 ha, 1.7 ha, and 5.2 ha, respectively, of AquaBlok™ would be applied, as presented in Table F-19. Waterfowl food sources would be reduced in the short term, but it is expected that they will reestablish. AquaBlok™ application may significantly raise pond bottom elevations in the western portion of Pond 146, where the pond is more shallow. Water storage and feeding habitats are not expected to be altered significantly in the eastern portion of Pond 146, where pond depth is approximately 0.7 m.

Time Until Remedial Action Objectives are Met. Protection of waterfowl, as measured by RAOs, would be achieved under Alternatives 3, 4, and 5. RAOs would be achieved even if pond draining is not successful under Alternatives 3 and 4 because pond bottom sediment that does not dry would be covered with AquaBlok™. The 5-year RAO of 50 percent mortality reduction would not be achieved under Alternatives 1 and 2. Because of sedimentation, there is potential that the 20-year RAO of 1 percent mortality would be achieved. The estimates are presented in Figure F-6.

4.4.6 Implementability

Technical Feasibility. Alternatives 1, 2, and 5 could be easily implemented; however, only Alternative 5 would result in protection. It is uncertain whether pond draining and drying under Alternatives 3 and 4 would be would be successful in Pond 146 because of the interconnectiveness between Pond 183 and the Northern C and C/D pond group. In addition, recharge from Clunie Creek may impede the drying process even if water levels decline through drainage. The hydraulic system of this area is not well understood. Pumps may need to be rearranged once the deepest portion of the pond system is exposed. Breaching under Alternative 4 would lower threshold elevations and result in more frequent flooding. The certainty of alternative performance success is presented in Table F-19.

Administrative Feasibility. No agency coordination difficulties are anticipated under Alternatives 2, 3, 4, and 5. Coordination of the U.S. Army with USEPA, ADEC, and BTAG would be conducted before implementing alternatives. There would be no coordination needed under Alternative 1.

Availability of Services and Materials. No services are required for Alternative 1. Lack of commercial laboratories to perform WP sampling affect Alternatives 2, 3, 4, and 5 equally. Alternatives 3, 4, and 5 all require a specialist firm to coordinate application of AquaBlok™. Although the pump system designed for Alternatives 3 and 4 is highly specialized, the technology is readily available.

4.4.7 Cost

Capital cost and 10- and 20-year present worth analyses are presented in Table F-19. The capital cost of Alternative 4 is less than Alternatives 3 and 5. However, the low O&M costs of Alternative 5 make it comparable with Alternative 4. Cost assumptions are provided in Appendix E.

4.4.8 Summary

Alternative 5 meets all criteria and would achieve RAOs. This alternative can easily be implemented by air or truck. Alternative 5 would result in AquaBlok™ coverage of 33 percent of the water-bearing habitat in this pond group. However, because of the natural topography and previous dredge operations, Pond 146 is deep (>0.7 m) in certain sections and water-storage capacity is not expected to be severely impeded. AquaBlok™ application is expected to be successful in blocking waterfowl exposure to WP-contaminated sediment. However, by providing a barrier over WP-contaminated sediment, Alternative 5 also would result in the highest amount of remaining residual risk. Alternative 5 is the second most expensive alternative. Air application costs are presented in Table F-19. Because of the proximity of Pond 146 to OB/OB pad, it is likely that AquaBlok™ may be also applied by slurry with the existing retention basin and conveyance system. Slurry application has not been evaluated in this FS because of lack of implementation information. However, slurry application is worth investigating.

Alternatives 3 and 4 meet all criteria. However, drying under these alternatives is not expected to be successful because of interconnectiveness between adjacent water bodies and recharge from Clunie Creek. Alternative 4 is the least expensive of the three treatment alternatives and it may reduce the most amount of residual risk, but it would result in the permanent drainage of a minimum of 15.9 ha of water-bearing landcover. Depending on the hydraulic interconnectiveness, areas of the Northern C and C/D pond group may also drain. Alternative 3 would affect habitat the least, but is the most expensive option and there is a very strong possibility that water level reduction and drying would not be successful. Regardless of drying performance, Alternatives 3 and 4 would still be protective because AquaBlok™ would be applied to all areas of hot ponds that do not dry.

Alternatives 1 and 2 do not meet threshold criteria. They are neither protective of the environment nor do they achieve location-specific ARARs.

Table F-20 shows the ranking of the alternatives for Pond 146. The alternatives are ranked according to how well they meet the criteria; the highest ranking alternatives are the best at meeting each individual criterion.

TABLE F-20
Ranking of Alternatives for Pond 146

Criteria	Meeting Criteria			
	Best			Worst
Overall protection of human health and the environment	3	5	4	1,2
Compliance with ARARs	3,4,5			1,2
Long-term effectiveness and permanence		3,4,	5,2	1
Reduction of TMV	3,4	5		1,2
Short-term effectiveness	3,5			1,2,4
Implementability	1,2,5		3,4	
Cost	1,2	5	4	3

Notes:
1. Each number represents an alternative.
2. The ranking refers to performance under each criterion. High ranking indicates that the alternative performed well under the individual criterion.

4.5 Northern C and C/D Pond Group

The expected performance of each alternative as implemented in the Northern C and C/D group is presented in Table F-21. This assessment is based on pond group characteristics and alternative properties that are described in Appendix C. This information supports the comparative analysis of alternatives in this subsection.

4.5.1 Overall Protection of Human Health and the Environment

Alternatives 3, 4, and 5 are all equally protective of public health and the environment, but result in varying degrees of residual risk, depending on the level of WP sublimation/oxidation. WP is treated and removed in Alternatives 3 and 4. Alternative 5 is

TABLE F-21
Performance of Alternatives, Northern C and C/D Pond Group

	Alt 1 &2: No Action and/or Detailed Monitoring	Alt 3: Pumping and AquaBlok™	Alt 4: Breaching, Pumping, and AquaBlok™	Alt 5: AquaBlok™
Area of residual risk (ha)	3.5	2.2	1.5	3.7
Area of sediment treated by sublimation/oxidation (ha)	0.2	1.5	2.2	–
Area of habitat covered by AquaBlok™ (ha)	–[a]	2.2	1.5	3.7
Area of habitat covered by AquaBlok™ as a percentage of water-bearing habitat in this pond group (%)[b]	–	2.9	10.1	4.9
Area of habitat removed by draining (ha)	–	74.9 (temporary)	74.9 (permanent)	–
Certainty of performance success within 5 years of implementation	Moderate	Low	Low	High
<u>Cost[c] ($)</u>				
Capital	52,000[d]	3,618,000	2,432,000	896,000
10 Year Present Worth	268,000[d]	5,338,000	3,761,000	941,000
20 Year Present Worth	362,000[d]	5,346,000	3,765,000	952,000

[a] "—" indicates that the technology is not a component of the alternative.
[b] The total area of water-bearing habitat in this pond group is 74.9 ha.
[c] Costs are based on aerial application of AquaBlok™.
[d] For Alternative 2 only; Alternative 1 has no associated costs.

protective in that it blocks exposure of dabbling ducks to WP, but does not remove WP. All three alternatives involve application of AquaBlok™ in areas where WP is not treated.

Alternative 3 would result in short-term habitat removal. Open-water habitat would be temporarily removed, thus reducing WP exposure. Alternative 4 would result in permanent effect on waterfowl feeding habitats in a large area of uncontaminated ponds. There is uncertainty as to the technical implementability of Alternatives 3 and 4, given the hummocky topography and recharge from the eastern bluffs.

Alternatives 1 and 2 may be protective of the environment, but risk reduction may take more than 10 to 20 years. During that time, waterfowl would continue to be exposed to WP. Measurement of progress would be possible only with Alternative 2. Protection would likely be achieved by sublimation/oxidation.

4.5.2 ARARs

No chemical-specific ARARs apply to ERF. Alternatives 3, 4, and 5 meet all action- and location-specific ARARs. Alternatives 1 and 2 do not meet location-specific ARARs.

4.5.3 Long-term Effectiveness and Permanence

Magnitude of Residual Risk. Residual risk reduction would be greatest under Alternative 4, followed by Alternative 3 and then Alternative 5. Remaining residual risk under Alternatives 3, 4, and 5, would be 2.2 ha, 1.5 ha, and 3.7 ha, respectively. Residual risk as a result of each alternative is presented in Figure F-7.

Residual risk from Alternatives 3 and 4 would equal the drying performance of each alternative. It is expected that the combination of breaching and pumping in Alternative 4 would be more effective in lowering water levels, promoting drying and thus fostering WP sublimation/oxidation than Alternative 3, which involves only pumping. However, draining and drying in the Northern C and C/D pond group are not expected to be very successful under Alternatives 3 and 4 because of the high level of pond interconnectiveness and recharge from the eastern bluffs. Therefore, residual risk under Alternatives 3 and 4 will still be high, but not as high as under Alternative 5. Alternative 5 only provides a barrier between WP and dabbling ducks.

Alternatives 1 and 2 would likely result in high amounts of residual risk (3.5 ha). Protection under these alternatives would be through sedimentation and minimal sublimation/oxidation at the perimeters of the ponds. Residual risk will exist in areas that experience sedimentation.

Adequacy and Reliability of Controls. With the exception of Alternative 1, all alternatives have adequate controls and monitoring requirements. ERF-wide monitoring such as telemetry, aerial surveys, and aerial photography would determine whether Alternatives 2, 3, 4, or 5 meet the mortality RAO. Sedimentation stations would be established under Alternative 2 to determine the rate of natural restoration achieved. Sedimentation is the most likely natural restoration process to occur in the Northern C and C/D pond group. Water level indicators would be installed under Alternatives 3 and 4 to determine the amount of water level decline. Sublimation/oxidation stations would be installed to evaluate WP sublimation/oxidation. AquaBlok™ integrity monitoring would be conducted regularly under Alternatives 3, 4, and 5. No monitoring is scheduled under Alternative 1.

4.5.4 Reduction in Toxicity, Mobility, and Volume

Likelihood that Treatment Process Addresses Principal Threat. Alternatives 3, 4, and 5 would block the exposure of waterfowl to WP. Drainage in Alternatives 3 and 4 would lower water levels and remove feeding habitat, so waterfowl would be less likely to be exposed. WP would sublimate/oxidize in areas that dry. Although drying under Alternatives 3 and 4 is expected to be marginal, all WP-contaminated sediment that is not treated would be covered with AquaBlok™. It is very uncertain when natural restoration processes would occur under Alternatives 1 and 2. Sedimentation is the most likely natural restoration process. Deposition is expected to be high in the Northern C and C/D pond group; however the rate of deposition is currently not known.

Amount of Hazardous Material Destroyed through Treatment. Alternatives 3 and 4 would treat the largest area of WP-contaminated sediment (1.5 ha and 2.2 ha, respectively), through water level reduction, pond sediment drying, and sublimation/oxidation. A very small area of WP-contaminated sediment would be treated by perimeter sublimation/oxidation under Alternatives 1 and 2. No treatment would occur in Alternative 5. Estimates of treatment are presented in Table F-21.

Irreversibility. WP sublimation/oxidation under Alternatives 3 and 4 would be irreversible. AquaBlok™ application under Alternatives 3, 4, and 5 is possibly reversible if the AquaBlok™ cover is degraded or damaged as a result of weather, tidal action, or earthquakes. Sedimentation, a natural process under Alternatives 1 and 2, would also be reversed as a result of damage to the sedimentation layer or from earthquakes.

Quantity of Risk and Residual Risk. No treatment residuals would be produced by any of the alternatives.

Statutory Preference for Treatment. Alternatives 3 and 4 meet the statutory preference for treatment. Alternatives 1,2, and 5 do not.

4.5.5 Short-term Effectiveness

Protection of the Community during Remedial Action. There are no significant short-term effects to the community under Alternatives 1, 2, 3, and 5. Pond breaching under Alternative 4 may affect the community of Eagle River. More than 800 meters of blasted ditch would be required under this alternative. Loud blasts may result in complaints of noise and vibration. Range Control regulations require that blasting be conducted on clear days to reduce sound and pressure impacts. Blasting would also be conducted over a series of 7 to 8 days to minimize the extent of daily nuisance. A rigorous community relations program would be conducted to alert the community of upcoming blasting activities.

Protection of Workers during Remedial Action. Alternative 1 poses no risks to workers because it involves no activity. Alternative 2 requires only WP sampling and sedimentation studies. Alternatives 3, 4, and 5 would require baseline sampling for WP. Alternative 5 involves minimal risks because AquaBlok™ application would be applied either aerially or in the winter over the frozen flats. In addition, monitoring requirements under Alternative 5 are low. Alternatives 3 and 4 would require frequent access to the flats for the installation, removal, and maintenance of pump systems and sublimation/oxidation monitoring systems, as well as verification monitoring. Access to some ponds may be eased by truck travel on the road that leads to the eastern bluffs. All areas where workers would be exposed would be cleared visually and/or electronically of UXO.

Environmental Impacts. No new environmental impacts would result from Alternatives 1 and 2. Alternative 2 would be limited to WP sampling and installation of sublimation/oxidation and sedimentation monitoring stations. Environmental impacts resulting from Alternative 3 would be short term. Temporary draining under Alternative 3 would result in the temporary removal of 74.9 ha of habitat and thus reduced exposure of waterfowl to WP. Pond habitat would likely reestablish after pump systems are removed and ponds refill from flooding tides and precipitation. The 74.9 ha of habitat removal under Alternative 4 would likely be permanent. A large area of uncontaminated open water and sedge marsh in Areas C, C/D, and D would be permanently removed as habitat under Alternative 4. There is low certainty regarding feasibility and practicality of restoring a ditch after it has been breached. Pond bottom elevations and open-water feeding habitat would be altered by application of AquaBlok™ under Alternatives 3, 4, and 5. Under Alternatives 3, 4, and 5, 2.2 ha, 1.5 ha, and 3.7 ha, respectively, of AquaBlok™ would be applied (as presented in Table F-21). Waterfowl food sources would be reduced in the short term, but it is expected that they will reestablish. AquaBlok™ application may significantly raise pond bottom elevations in the western ponds in the Northern C and C/D pond group.

Ponds along the bluff are deep, and feeding habits of waterfowl in these ponds would not likely be affected by the application of AquaBlok™. Under Alternative 5, only 10 percent of the water-bearing habitat in this portion of ERF would be covered with AquaBlok™.

Time Until Remedial Action Objectives are Met. Protection of waterfowl, as measured by RAOs, would be achieved under Alternatives 3, 4, and 5. Under Alternatives 3 and 4, RAOs would be achieved even if pond draining were not successful because pond bottom sediment that does not dry would be covered with AquaBlok™. The 5-year RAO of 50-percent mortality reduction would not be achieved under Alternatives 1 and 2. Because of the expected high sedimentation rates in the Northern C and C/D pond group, there is a chance that the 20-year RAO of 1 percent mortality would be achieved. These estimates are presented in Figure F-7.

4.5.6 Implementability

Technical Feasibility. Alternatives 1, 2, and 5 could be easily implemented; however, only Alternative 5 would result in protection. It is uncertain whether pond draining and drying under Alternatives 3 and 4 would be successful in the Northern C and C/D pond group because of the hummocky topography and recharge from the eastern ERF bluffs. The hydraulic system of the Northern C and C/D pond group is not well understood. The ponds in this group are interconnected, with large areas of open water and sedge marsh in Areas C, C/D, and D. Ponds in these areas have varying pond bottom elevations. Some ponds may contain water despite continued pumping. As mentioned previously, draining this pond group would require the draining of large areas of clean ponds. Alternative 4 may be more successful than Alternative 3 in reducing water levels in the hot ponds because of the breaching and quick water level reduction of the Area D Pond. Pumps may need to be rearranged once the deepest portion of the pond system is exposed. Breaching under Alternative 4 would lower threshold elevations and result in more frequent flooding.

Administrative Feasibility. No agency coordination difficulties are anticipated under Alternatives 2, 3, 4, and 5. Coordination of the U.S. Army with the USEPA, ADEC, and BTAG would be conducted before implementing alternatives. There would be no coordination needed under Alternative 1.

Availability of Services and Materials. No services are required for Alternative 1. Lack of commercial laboratories to perform WP sampling affect Alternatives 2, 3, 4, and 5 equally. Alternatives 3, 4, and 5 all require a specialist firm to coordinate application of AquaBlok™. Although the pump system designed for Alternatives 3 and 4 is highly specialized, the technology is readily available.

4.5.7 Cost

Capital cost and 10- and 20-year present worth analyses are presented in Table F-21. The costs of Alternative 4 is less than that of Alternative 3 because breaching of the Area D Pond would result in fewer pump systems to purchase, install, and maintain. However, Alternative 5 is clearly the least costly. Cost assumptions are provided in Appendix E.

4.5.8 Summary

Alternative 5 meets all criteria and would achieve RAOs. This alternative can be easily implemented by air or truck. Alternative 5 would result in AquaBlok™ coverage of only

5 percent of the water-bearing habitat in this pond group. AquaBlok™ application is expected to be successful in blocking waterfowl exposure to WP-contaminated sediment. However, by providing a barrier over WP-contaminated sediment, Alternative 5 would also result in the highest amounts of remaining residual risk. Alternative 5 is the least expensive alternative of all three remediation-oriented alternatives. Aerial application costs are presented in Table F-19.

Alternative 3 and 4 meet all criteria. However, drying under these alternatives is not expected to be successful because of the large area of open water around the Northern C and C/D hot ponds and recharge from the eastern bluffs. Draining under Alternative 4 may be marginally successful. Breaching of the Area D pond may limit inflow from Area D, but this also would result in the permanent removal of 74.9 ha of habitat (most of which is not contaminated). Because of the large volume of water to be removed, Alternatives 3 and 4 are the most costly.

Alternatives 1 and 2 do not meet threshold criteria. They are neither protective of the environment nor do they achieve location-specific ARARs.

Table F-22 shows the ranking of the alternatives for the Northern C and C/D pond group. The alternatives are ranked according to how well they meet the criteria; the highest ranking alternatives are the best at meeting each individual criterion.

TABLE F-22
Ranking of Alternatives for the Northern C and C/D Pond Group

	Meeting Criteria			
Criteria	**Best**			**Worst**
Overall protection of human health and the environment	5		3,4	1,2
Compliance with ARARs	3,4,5			1,2
Long-term effectiveness and permanence		3,4,	5,2	1
Reduction of TMV	3,4	5		1,2
Short-term effectiveness	3	5		1,2,4
Implementability	1,2,5		4	3
Cost	1,2	5	4	3

Notes:
1. Each number represents an alternative.
2. The ranking refers to performance under each criterion. High ranking indicates that the alternative performed well under the individual criterion.

5.0 Works Cited

Cummings, J.L., R.E. Johnson, K.S. Gruver, P.A. Pochop, and J.E. Davis. Movement, Distribution, and Relative Risk of Mallards and Bald Eagles Using Eagle River Flats: 1996.

In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* C.M. Collins and D.W. Cate, eds. FY 96 Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. July 1997. Pp. 21-30.

Cummings, J.L., P.A. Pochop, and J.E. Davis, Jr. Waterfowl Distribution and Movements in Eagle River Flats. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* C.H. Racine, ed. FY 93 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. May 1994. Pp. 229-233.

Cummings, J.L., C.A. Yoder, R.E. Johnson, P.A. Pochop, K.S. Gruver, J.E. Davis, and K.L. Tope. Movement, Distribution and Relative Risk of Waterfowl and Bald Eagles Using Eagle River Flats. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* D.W. Cate and C.H. Racine, eds. FY 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. September 1996. Pp. 179-196.

Cummings, J.L., C.A. Yoder, R.E. Johnson, P.A. Pochop, K.S. Gruver, J.E. Davis, Jr., K.L. Tope, J.B. Bourassa, and R.L. Phillips. Movements, Distribution and Relative Risk of Waterfowl, Bald Eagles and Dowitchers Using Eagle River Flats. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* Volume 1. C.H. Racine and D. Cate, eds. FY 94 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. May 1995. Pp. 321-334.

Racine, C.H., M.E. Walsh, C.M. Collins, D. Lawson, K. Henry, L. Reitsma, B. Steele, R. Harris, and S.T. Bird. *White Phosphorus Contamination of Salt Marsh Sediments at Eagle River Flats, Alaska. Report I. Remedial Investigations. Report II, Treatability Studies.* U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). November 1993.

Reitsma, L.R., and B.B. Steele. Waterfowl Use and Mortality at Eagle River Flats. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* Volume 1. C.H. Racine and D. Cate, eds. FY 94 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. May 1995. Pp. 289-320.

Steele, B.B., and L.R. Reitsma. Waterfowl Use and Mortality at Eagle River Flats. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* D.W. Cate and C.H. Racine, eds. FY 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. September 1996. Pp. 157-174.

Walsh, M.E., C.M. Collins, and R.N. Bailey. Demonstration of Sample Compositing Methods to Detect White Phosphorus Particles. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* C.M. Collins and D.W. Cate, eds. FY 96 Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. July 1997. Pp. 35-50.

U.S. Environmental Protection Agency (USEPA). *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*. Office of Emergency and Remedial Response (OSWER Directive 9355.3-01). 1988.

Appendix G
Monitoring Strategy and Implementation

Contents

Abbreviations

cm	centimeter
CRREL	Cold Regions Research and Engineering Laboratory
ERF	Eagle River Flats
FS	feasibility study
ft	foot
GIS	geographical information system
GPS	Global Positioning System
ha	hectare
in.	inch
m	meter
msl	mean sea level
µg/g	micrograms per gram
mL	milliliter
mm	millimeter
OB	open burning
OD	open detonation
OUC	Operable Unit C
RAO	remedial action objective
RGIS	Remediation Geographical Information System
RI	remedial investigation
UCI	Upper Cook Inlet
UXO	unexploded ordnance
WP	white phosphorus

APPENDIX G

Monitoring Strategy and Implementation

Eagle River Flats (ERF) is a large and dynamic environment. The proposed remedial alternatives (discussed in Appendix C) achieve protection of the environment by acting on different parts of the exposure pathway (for example, reduction in the amount of white phosphorus [WP] or blocking access to the contaminant). The monitoring strategy also anticipates that the remediation of ERF will take several years. This appendix describes the monitoring program for observing specific changes at ERF over time and outlines how data will be collected and analyzed to determine when remediation activities can conclude because the remediation objectives have been achieved.

The first section of this appendix describes the remedial action objectives (RAOs). Section 2 describes how the achievement of the RAOs will be monitored and assessed for each remedial alternative. Section 3 describes the components of the ERF Remediation Geographical Information System (RGIS), which will be used to store and retrieve information to analyze progress toward the attainment of the RAOs. The appendix concludes with a summary of the overall monitoring program. The attachment provides an overview of the monitoring methods applied in this appendix.

1.0 Remedial Action Objectives

As introduced in the Operable Unit C (OUC) remedial investigation (RI) report (CH2M HILL, 1997), the overall remedial objective at ERF is the protection of the environment and human health. There are three specific RAOs (Figure G-1):

1. **Reduce dabbling duck mortality**. This RAO addresses the single most important issue associated with WP contamination. Because dabbling ducks have been the most affected, their mortality rate will be assessed specifically in support of the achievement of this goal. The specific objective in 5 years is to reduce the mallard mortality rate by 50 percent compared to the value in 1996. The objective in 20 years is to reduce that mortality rate to no more than 1 percent above the reference value.

2. **Reduce hot zones**. This RAO supplements the RAO for duck mortality. The number of hectares (ha) characterized as "hot" (that is, areas believed to have relatively high environmental risk) will be used to measure this objective. In general, a hot zone will be determined by a combination of duck mortality, WP concentrations or quantity, duck usage, and crater density. The specific objective is to reduce hot zones by 50 percent in 5 years and by 99 percent in 20 years compared to the hectares of hot ponds in January 1996.

3. **Reduce WP exposure pathway**. This RAO will measure the success of remedial actions. It is technology specific and designed to provide near-term feedback on the success of a specific remedial action performed at a specific area. The specific objective is no bioavailable WP for dabbling ducks and swans.

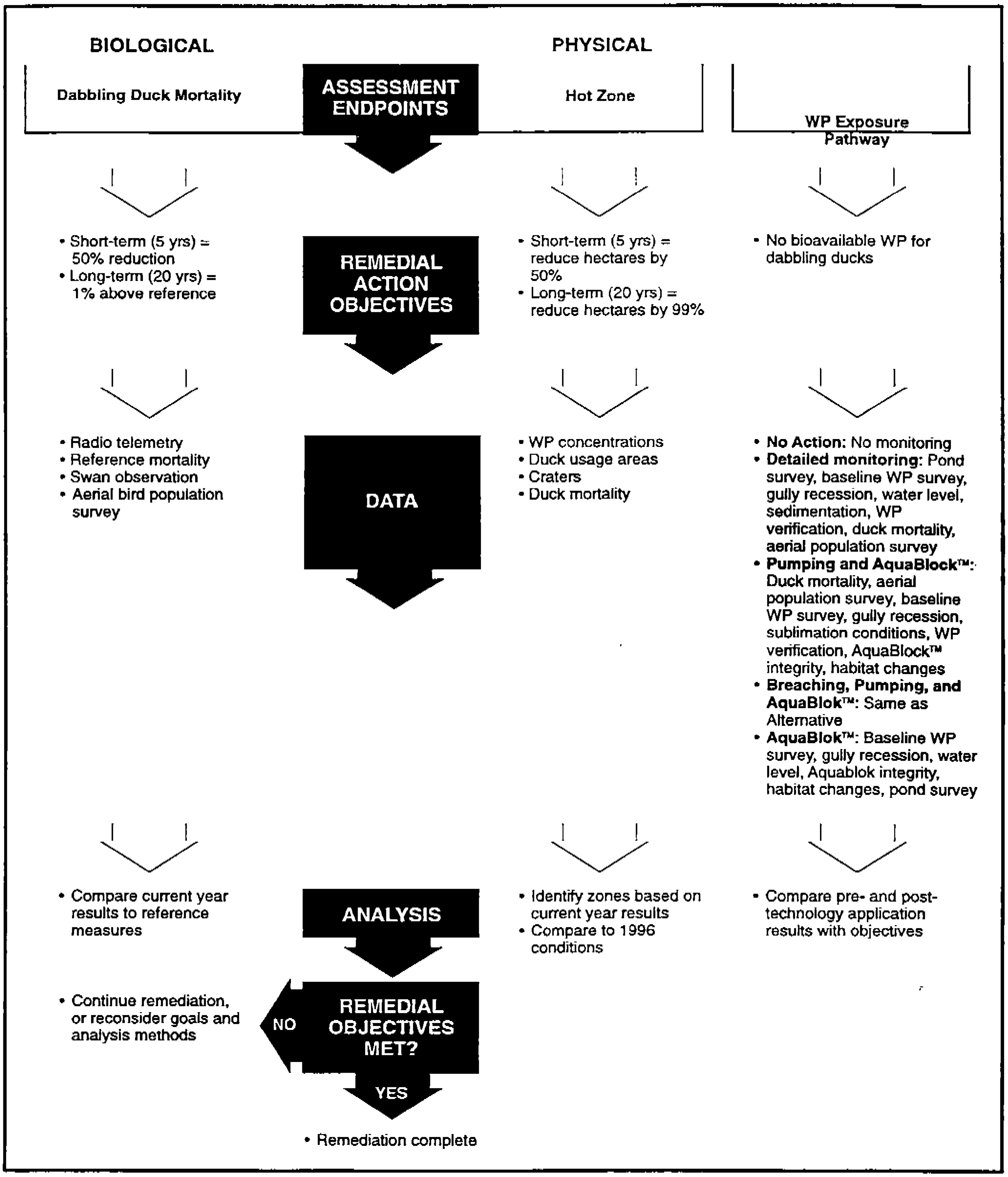

Figure G-1

Remedial Action Objectives and Assessment Methods

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Feasibility Study
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138545.A3.40 Fig G-1 09/15/97 anc/hd

The achievement of the RAOs is assessed independently because the specific objectives are not necessarily correlated. For example, it is unknown whether a certain percentage decline in the area of the hot zones will result in a corresponding decrease in the dabbling duck mortality. Thus, RAO number 1 is of primary importance because its achievement provides the desired long-term protection of the environment and it also covers the entire ERF. If the dabbling duck mortality is reduced to 1 percent above the reference value (which is the 20-year objective in RAO number 1), and at least 50 percent of the currently identified hot zones have been treated (which is the minimum level of the 5-year objective in RAO number 2), then remediation may be terminated. It is then unnecessary to meet the remaining objectives of RAO numbers 2 and 3. It is possible that RAO numbers 2 and 3 will be achieved even if RAO number 1 has not been met. This possibility identifies the potential need to reconsider areas defined as hot zones (see Section 2.2). Because dabbling duck mortality in RAO number 1 is used as an indicator of the overall protection of the environment, additional species and effects will be considered as additional indicators for a remediation goal following the achievement of RAO number 1.

2.0 Monitoring Strategies

The following sections discuss the monitoring strategies to be used to measure progress toward achieving each RAO.

2.1 Monitoring of Dabbling Duck Mortality

Monitoring described in this section will be performed for Alternatives 2 through 5. The achievement of the first RAO will be measured by using radio telemetry of duck activity, based on the methods and conditions previously described (Cummings, *et al.*, in Collins *et al.*, 1997; and Cummings *et al.* in Racine *et al.*, 1996). Mallards have been chosen as the indicator species because they are one of the dominant species of dabbling ducks present during the fall and are susceptible to WP toxicity.

Radio telemetry devices will be attached to 100 to 150 mallards during the fall migration season. Depending on the specific study objectives each year, mortality transmitters can be used to record only mortality, and activity transmitters can be used to record daily movements of the birds. Although it requires more personnel time per bird, activity transmitters can show what areas the birds prefer, and possibly also where they were when they ingested a lethal dose of WP. The mortality transmitters emit a signal only when the bird has remained motionless for a set period of time, indicating that it has died. Activity transmitters also can track bird mortality because recordings of their positions will show a lack of movement over a few days, indicating that death has probably occurred. The birds will be released in the same areas in which they were captured. The positions of the birds will be recorded each day, or only as needed for those with mortality transmitters. The mortality rate will be determined by dividing the number of mallards that die from WP exposure during the measurement intervals (typically about 2 months) by the number of mallards in the study.

The current estimates of the ERF mallard and reference mortality rates are 35 and 3 percent, respectively. The confidence limit on the mortality rate is about ±8 percentage points. These values may be revised as new data become available. Injuries and deaths to the mallards during handling and deaths of tagged birds from non-WP causes also should be recorded to improve the understanding of the reference mortality rate.

Ducks are susceptible to other diseases that also may cause a high mortality rate. Necropsy and laboratory analyses will be used to confirm the cause of death. An attempt will be made to locate the tagged birds that die at ERF and ship them to an analytical lab for sampling and WP analysis of the gastrointestinal tract. If WP is detected in this tissue, it will be assumed that the duck died from WP toxicity.

Because the mortality rate may be highly variable from year to year, an annual change may or may not be significant. Several years of data may be necessary to detect a significant effect and to confirm that the RAO has been met. Trends and appropriate statistical analyses will be necessary to determine whether any changes are significant.

An annual report will discuss the methods and observed mortality during that year's study (including birds lost from handling and predation); turnover rate; and results of the WP analysis of tissue samples. The report also will include a discussion of the implications of numbers and trends of birds observed in aerial surveys and photographs, and compare the results with previous years.

The 1996 telemetry data in the ERF RGIS for the 49 mallards with activity transmitters showed that 2,258 locations were determined for the birds over 2 months. The intervals between location records of individual birds are shown in Table G-1. The 3-day and 4-day intervals between locations are because no data were collected over weekends, including the long Labor Day weekend.

TABLE G-1
1996 Telemetry Data for 49 Mallards with Activity Transmitters

Days Between Location Determinations	Approximate Number of Telemetry Locations for Individual Birds (%)
<1	43
1	43
3	10
4	2
Other	2

These long periods between determinations have negated the ability to use the data to determine where ducks that die during the telemetry study were just before death, which might represent the location where they received the lethal dose. An intensive, 24-hour-per-day observation period for 2 weeks in September is proposed to try to identify areas contributing lethal doses.

Aerial surveys of bird populations are also proposed at ERF. The objective of these surveys is to monitor the magnitude and changes in the size and timing of the bird migration. This will assist in understanding the context of the telemetry results within ERF and the Upper

Cook Inlet (UCI). The methods for the aerial bird population survey have been described by Eldridge (in Racine *et al.*, 1995, 1996).

2.2 Evaluating Hot Zones

The evaluation described in this section will be performed for Alternatives 2 through 5. Twenty-two hot ponds were identified in the OUC RI report (CH2M HILL, 1997). These were identified on the basis of information available on duck mortality, WP concentrations, craters, pond type (currently, only permanent ponds have been chosen), and usage by ducks. They are shown in Figure G-2 and the characteristics of the ponds that are subjects of this feasibility study (FS) are summarized by pond groups in Table G-2.

In the Northern A Ponds, the greatest number of WP sample locations are around Ponds 246, 256, and 258, but only 5 of the 42 locations (12 percent) have detected concentrations of WP, and they are scattered across the three ponds. Pond 226 has 12 sediment sample locations, mostly in the northern half, and only 1 had a detected concentration of WP. The pond sediment samples were at an elevation of 3.75 to 4.67 meters (m) mean sea level (msl).

Pond 290, which also is in Area A, has a pond area of only 0.9 ha. Of the six WP sediment sample locations, only one (17 percent) had a detected concentration of WP, located in the northwestern part of the pond. No sediment elevation data are available.

Pond 183, which is in Area C, has a pond area of 2.9 ha. Of the 219 sediment sample locations, 166 (76 percent) had detected WP. Most of the sample locations are in the northern half of the pond. The detected concentrations are scattered around the northern half, and there are a few in the southern half. Sediment sample elevations range from 4.39 to 4.91 m (msl).

Pond 146 also is in Area C and has an area of 5.5 ha. It is a long, generally narrow pond with its southern section having an eastern border with the open burning/open detonation pad (OB/OD Pad). Most of the sampling has been in the southern and middle parts of the pond. Of the 68 sample locations, 20 (30 percent) had detected WP. The sediment sample elevations were at elevations of 4.06 to 4.65 m (msl).

The Northern C and C/D Pond group consists of eight ponds with a total area of 3.6 ha. Only Pond 40 has had WP sediment sampling. Of the 30 sample locations, only 4 (13 percent) had detectable WP, and these are located in the northwestern and southwestern parts of the pond. The available sediment elevation data for the pond group come from this pond, and the range was from 3.95 to 5 m (msl).

Because sediment sampling and WP analysis have not been performed in all hot ponds and available data often suggest low WP concentrations, it is possible that some identified hot ponds may not have significant quantities of WP. Baseline WP sampling (discussed in Attachment 1) before treatment may determine that WP is not present at significant levels, and therefore no further action is required.

A few of the 22 hot ponds already have undergone some treatment. The total area of the 22 hot ponds is 23 ha, based on data from early 1995. The total area of ponds treated as of early 1997 includes Pond 285 (0.4 ha), treated with AquaBlok™ in 1994; Pond 109 (3.3 ha), which was breached in 1996; portions (0.3 to 0.6 ha) of Pond 146 that were dredged in 1995 and 1996; Pond 183 (2.9 ha), which was pumped in 1997; and Ponds 293 and 297

TABLE G-2
Summary of Hot Pond Groups

Pond Group	Pond ID	Size (ha)	Number of WP Sediment Sample Locations	Number of Sediment Sample Locations with Detected WP	Range of Detected WP Concentrations (µg/g)	Elevation Range (msl, m)
Northern A	138	0.9	0			
	208	0.8	1	0		
	226	0.5	12	1	0.0002	
	228	0.7	2	0		
	246	0.8	8	0		
	256	0.4	5	1	0.00617	
	258	1.7	29	4	0.00057-0.00109	
Pond Group Total	**7 ponds**	**5.8**	**57**	**6**	**0.0002 - 0.00617**	**3.75 - 4.67**
Pond 290		0.9	6	1	0.00075	no data
Pond 183		2.9	219	166	0.0002-58	4.39 - 4.91
Pond 146		5.5	68	20	0.0008-70.1[a]	4.06 - 4.65
Northern C and C/D	129	0.3	0			
	145	0.1	0			
	155	0.4	0			
	40	1.8	30	4	0.003-0.01208	
	49	0.4	0			
	85	0.4	0			
	93	0.09	0			
	112	0.2	0			
Pond Group Total	**8 ponds**	**3.6**	**30**	**4**	**0.003-0.01208**	**3.95 - 5**

[a]Before dredging.

Notes:

ID = identification

µg/g = micrograms per gram

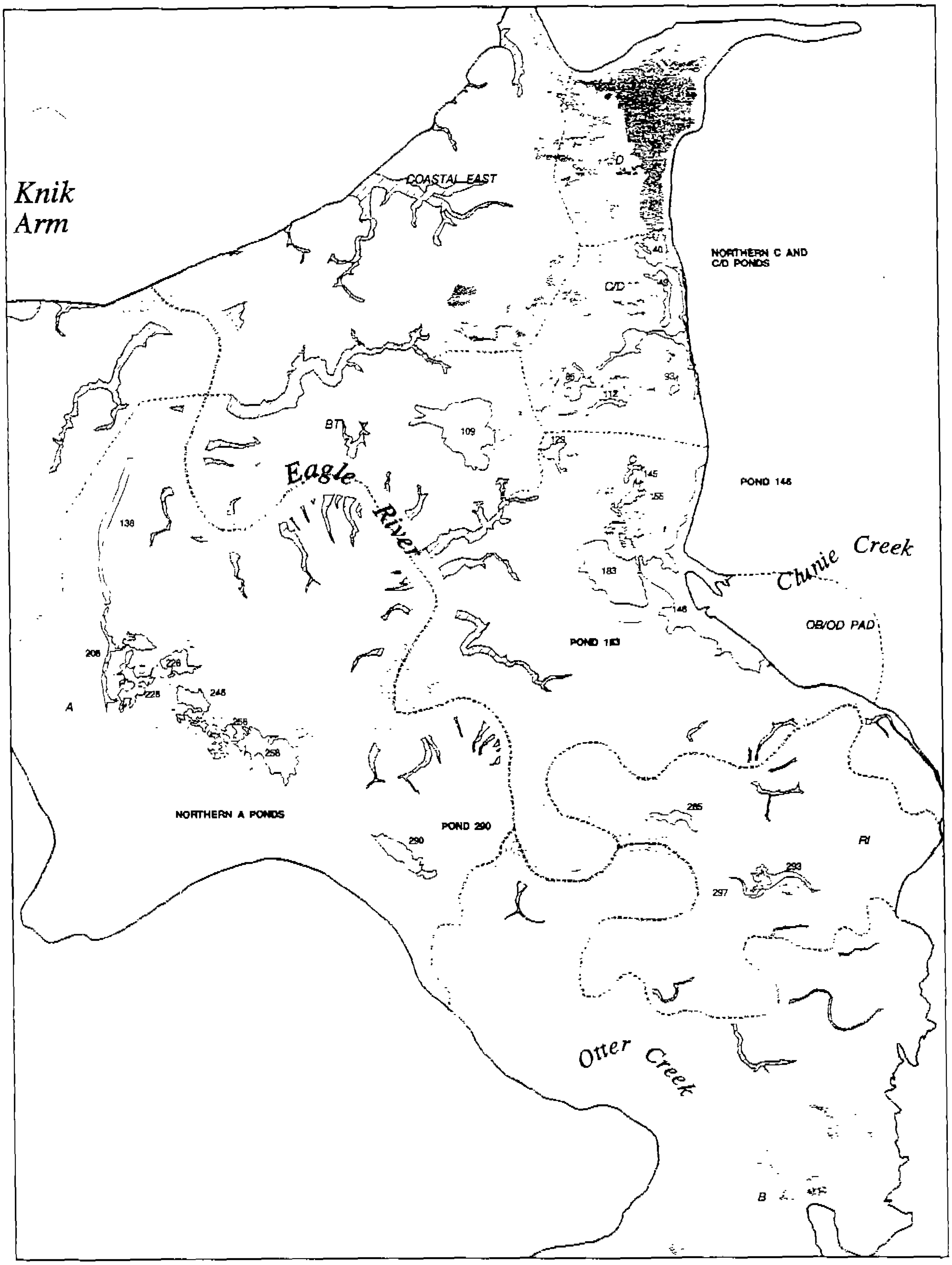

Figure G-2

Ponds

Note: Treatment has been or will be applied at the following Hot Ponds:
Pond draining by bleeding - Ponds 109, 293, & 297. AquaBlok™ Pond 285.

Scale 1:12000
1 cm = 120 m

0 meters 360

Mapping and database source: CRREL, 1996.

49 Hot Pond Number
Intermittent Pond
Permanent Pond
Gully
River/Creek
Area Boundary
OUC Site Boundary

Pond grouping based on topography, land form cover and hydraulic interconnectiveness.

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(0.63 ha), which were breached in 1997. The total treated area is about 8 ha. Although treatment verification studies have not been performed at some of these ponds, treatment actions taken since early 1996 potentially may have reduced the area of the hot ponds by 16 percent.

Progress toward achieving the objective of reducing hot zones by 50 percent in 5 years and by 99 percent in 20 years is accepted when verification sampling demonstrates that treatment goals have been reached at treated hot ponds. The area of the identified hot pond with demonstrated achievement of the treatment objective is no longer added into the total area of hot ponds.

Additional sampling to discover additional hot ponds may be necessary if the hot zone RAO is achieved but the dabbling duck mortality RAO is not. This would mean that there are additional areas contributing substantial WP exposure to dabbling ducks and swans. Current candidates for potential future designation as hot ponds are the intermittent ponds identified in Table 10-6 of the OUC RI report (CH2M HILL, 1997). The identification numbers and size of these intermittent ponds are summarized in Table G-3. These ponds have characteristics similar to the hot ponds, except that it is currently believed likely that detectable WP is not present because intermittent ponds have been frequently dry, leading to conditions appropriate for the sublimation/oxidation of WP. This hypothesis has not been verified, but could be by using the baseline WP sampling method discussed in the Attachment. Extensive sampling in new areas at ERF has not been justified yet because of the high cost and the presence of unexploded ordnance (UXO).

Another source of potential hot spot ponds is the many very small ponds and open pools within the bulrush-sedge marsh area of Northern C and especially C/D. Most of these ponds are less than 0.1 ha in size and have not been sampled for WP. These small ponds are favorite loafing areas and, to a lesser degree, feeding areas, especially for mallards (Walsh, 1997).

TABLE G-3
Summary of Intermittent Ponds with Characteristics Similar to Hot Ponds

ERF Area	Pond ID	Size (ha)	ERF Area	Pond ID	Size (ha)
A	187	2.7	C	158	0.7
	190	0.55		164	5.5
	199	2.5		205	3.3
	204	2.9	Bread Truck	88	0.71
	243	3.2		99	5.4
	282	0.2	**Total**	**12 ponds**	**28**
	291	0.2			

2.3 Monitoring of WP Exposure Pathways

Monitoring programs vary with the remedial alternative; therefore, they are discussed individually below. The monitoring methods are summarized in the Attachment.

2.3.1 Alternative 1: No Action

Under this alternative, only natural processes (such as sublimation/oxidation, gully recession, and sedimentation) are assumed to be active. Consistent with the definition of this alternative, no monitoring will be performed.

2.3.2 Alternative 2: Detailed Monitoring

In this alternative, it is assumed that only natural processes are active, as with the no-action alternative, but WP quantity, gully recession, and sedimentation will be monitored each year. Aerial photographs from annual overflights also will be used to monitor physical changes in and around each pond group. The elevations of the pond groups also will be surveyed.

WP Quantity. Because many areas of pond groups Northern A, Pond 290, and Northern C and C/D have had little sediment sampling and WP analysis, these pond groups will first be evaluated for WP concentrations using the baseline WP monitoring method discussed in the Attachment. In general, the number of monitoring sites for this evaluation was chosen based on elevation changes in the pond bottom. The time period between flooding tides, which is the major factor in determining time available for sediment drying and therefore WP sublimation/oxidation, is dependent generally on the bottom sediment elevation. For all pond groups except Pond 290, a 10-centimeter (cm) change in elevation was used to determine the number of monitoring sites. Because of its small size (and therefore lower overall potential remediation cost), the frequency of stations was reduced to one per 30 cm of elevation change for Pond 290. With these criteria, the number of sampling sites is shown in Table G-4. As long as the pond is wet (that is, it is a permanent pond), no further WP sampling will be performed, as no WP loss is expected until a pond has remained sufficiently dry. During this wet period, only one station per pond group will be established to monitor sublimation/oxidation conditions (discussed in the Attachment). Temperature and water saturation sensors do not need to be included, although the costs saved by omitting them are minimal.

Following an interval when the pond surface has been below much of the sediment surface for at least 30 days (equivalent to approximately 40 days between tidal floodings, with no heavy rainfall or groundwater upwelling), WP sampling may be initiated using WP treatment verification monitoring and the monitoring of sublimation/oxidation conditions at the same number of sites as shown in Table G-4. This monitoring will continue until it is confirmed that WP is not detectable.

Gully Recession. Gully recession will be monitored by observing changes in gully positions from aerial photographs. The photography program is discussed in the Attachment.

Sedimentation. The sediment monitoring program is described in the Attachment.

TABLE G-4
Number of Monitoring Sites for Sublimation/Oxidation Conditions and WP Sampling

Pond Group	Elevation Change[a] (cm)	Number of Sites
Northern A	100	16
Pond 290	80[b]	4
Pond 183	60	7
Pond 146	70	8
Northern C & C/D	110	17

[a]Rounded up to the next 10 cm.
[b]Assumed similar to Pond 258.
Notes: Sites were assumed to be placed at every 10-cm elevation change, except for Pond 290, where a 30-cm elevation change was used. Five additional sites are included for each pond group having multiple ponds to cover the geographical distribution of sites across the ponds.

2.3.3 Alternative 3: Pumping and AquaBlok™

Aerial photographs from annual overflights will be used to monitor physical changes in and around each pond group. The pond groups will be surveyed for elevation. Before the alternative is applied, baseline WP sampling will be performed as described in the Attachment. The number of sampling sites is shown in Table G-4.

After the pumping has begun and water is removed from the pond, an aerial photograph of the pond group will be taken and the stations to monitor sublimation/oxidation conditions established. The number of sampling sites is shown in Table G-4. Following an interval when much of the pond group surface has remained dry for at least 30 days (equivalent to approximately 40 days between tidal floodings, with no heavy rainfall or groundwater upwelling), WP sampling may be initiated using the treatment verification method described in the Attachment. The verification sampling will be continued annually until it becomes more cost-effective to just cover the remaining contaminated area with AquaBlok™.

It is assumed in this alternative that AquaBlok™ will be applied to those areas that still contain detectable levels of WP based on the WP treatment verification monitoring using the method described in the Attachment. Beginning 1 year after application, AquaBlok™ will be monitored for integrity on an annual basis for 2 years after application and thereafter at an appropriate rate dependent on the observations of the first 3 years. The method for assessing AquaBlok™ integrity is discussed in the Attachment. Because it is assumed that pond draining by pumping will be a short-term activity, it is not expected that the pond vegetation will be negatively affected. Therefore, it is assumed that no assessment for habitat change will be performed.

2.3.4 Alternative 4: Breaching, Pumping, and AquaBlok™

The monitoring program includes the activities described for Alternative 3 (Section 2.3.3). In addition, the size of the blasted channel and annual gully recession into the pond will be analyzed using aerial photographs as discussed in the Attachment.

It is anticipated that pond breaching may lead to long-term changes in pond vegetation; therefore, ponds that are breached will be monitored for changes with aerial photography. This method is discussed in the aerial photography section in the Attachment.

2.3.5 Alternative 5: AquaBlok™

Aerial photographs will be used to monitor physical changes in and around the pond group. The elevation of the pond will be surveyed. Before the alternative is applied, baseline WP sampling will be performed as described in the Attachment.

Beginning 1 year after the AquaBlok™ application, the AquaBlok™ integrity will be checked annually as described in the Attachment. Habitat changes also will be monitored as discussed in the Attachment.

3.0 ERF Remediation Database

The objective of the ERF Remediation Geographical Information System (ERF RGIS) is to assist the integration of the variety of monitoring information that will assess the attainment of the RAOs at ERF. This may require evaluating conditions over the next 10 to 20 years as remedial actions are taken to reduce waterfowl mortality. The recommended system has the following components:

- Hardware, including a workstation and peripherals (Pentium Pro® 200 processor, 5 gigabyte online storage, 128 megabyte RAM, CD drive, 1.44 megabyte diskette drive, large-capacity diskette drive, and network controller are recommended)
- Software, including GIS and various personal computer applications packages (recommended are Windows NT Revision 4.0 operating system, ARC/INFO NT Revision 7.1 with ArcPress and GRID modules, Microsoft Office Suite, Internet access and file transfer protocol server, and networking software)
- Database, derived from the ERF RGIS database and augmented by the additional monitoring data discussed in this appendix
- Staff to manage and run the system (senior GIS manager and technician)
- Miscellaneous office supplies

Note that the recommendations for hardware and software are general, and do not include all components that may be required for the functioning ERF RGIS. The information technology manager of the host organization should be consulted before system configuration and purchase.

The first phase of activity is to set up the system and establish the procedures for subsequent annual activities. It is assumed that the system will be located at either Fort Richardson or the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and will be maintained by staff at those respective organizations. This phase includes acquiring and installing hardware and software, if needed, and establishing written protocols for the data center (such as data management plan, GIS data dictionary, system for organizing paper and electronic documents, quality control procedures on information exchanges with the monitoring data collectors). For this FS, it is assumed that the hardware and software are already available.

Annual activities will be required to maintain the system, add data, perform analyses, and produce maps and reports in support of ERF site remediation. Information likely to be added to the system and analyses to be performed include the following:

- Existing baseline information about ERF (such as ponds, WP, elevations)
- Telemetry surveys
- Aerial surveys of bird populations for different areas of ERF and the UCI
- Pond group analyses before and after application of a remediation alternative
- Surveys on habitat changes
- Integrity of AquaBlok™
- Sampling other areas to find whether WP is present
- Aerial photographs

4.0 Summary of ERF Monitoring Program

This appendix describes a multi-faceted monitoring program to evaluate the attainment of the RAOs for ERF and the potential for negative effects from treatment (that is, habitat changes). The key elements in the monitoring program are summarized in Table G-5. Although no specific RAO on minimizing negative effects has been developed, monitoring for changes in habitat has been included. Note that individual monitoring studies will be performed in different areas during different parts of the field season, providing a broad scale of data, geographical and temporal, for the assessment of ERF. Some activities will be performed at a flats-wide level and others are specific to particular pond groups, depending on the remedial action chosen. Coordination of activities in the program will be important. The monitoring program schedule is summarized by remedial alternative in Figure G-3. As can be seen, many of the monitoring activities are similar between remedial alternatives and occur at similar times when time zero is defined as the start of the remedial action. The ERF RGIS provides the tool to integrate the information for the assessment of the attainment of the RAOs.

5.0 Works Cited

CH2M HILL. *Draft Final Operable Unit C Remedial Investigation Report.* Prepared for Department of the Army, U.S. Army Engineer District, Alaska. February 1997.

Cummings, J.L., R.E. Johnson, K.S. Gruver, P.A. Pochop, and J.E. Davis. Movement, Distribution, and Relative Risk of Mallards and Bald Eagles Using Eagle River Flats: 1996. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* C.M. Collins and D.W. Cate, eds. FY 96 Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. July 1997. Pp. 21-30.

Cummings, J.L., C.A. Yoder, R.E. Johnson, P.A. Pochop, K.S. Gruver, J.E. Davis, and K.L. Tope. Movement, Distribution and Relative Risk of Waterfowl and Bald Eagles Using Eagle River Flats. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus*

Contamination and Potential Treatability at Eagle River Flats, Alaska. D.W. Cate and C.H. Racine, eds. FY 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. September 1996. Pp. 179-196.

Eldridge, W. Waterbird Utilization of Eagle River Flats. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* Volume 1. C.H. Racine and D. Cate, eds. FY 94 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. May 1995. Pp. 277-288.

Eldridge, W.D., and D.G. Robertson. Waterbird Utilization of Eagle River Flats and Upper Cook Inlet: April-October 1995. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* D.W. Cate and C.H. Racine, eds. FY 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. September 1996. Pp. 131-155.

TABLE G-5

Elements of the Monitoring Program

Monitoring Endpoint	Objective	Geographical Area	Assessment Method	Schedule	Data	Test Method
Mallard mortality	50% mortality reduction in 5 years. 1% above reference mortality in 20 years	ERF	Aerial population survey	Fall	Area and pond duck populations	Aerial surveys show duck populations.
			Telemetry		Mortality	Telemetry shows lack of movement and radio collar recovered from a carcass or feather pile.
Hot zones	50% reduction of hot pond area in 5 years and 1% above reference in 20 years	Hot ponds	WP quantity, duck usage	Every fall	WP particles and duck usage	WP sampling Telemetry Aerial bird population surveys
WP exposure pathway	No bioavailable WP for dabbling ducks and swans	Treated area	Sedimentation	Before and after treatment application	Sedimentation rate	Net sedimentation
			Sublimation/ oxidation conditions monitoring	After treatment	Pond water elevation, sediment moisture, temperature	Probes
			Gully recession	After treatment	Gully recession rate	Photointerpretation
			WP: Verification sampling compares conditions to baseline WP monitoring	After treatment	WP particles	Composite sampling Planted WP particles after treatment
		Areas treated with AquaBlok™	AquaBlok™ integrity		Depth of AquaBlok™. Absence of cracks	Cores Visual inspection
Negative impacts	Habitat changes	Blasted areas Areas treated with AquaBlok™	Observed conditions	Fall	Vegetation changes	Photo interpretation Field surveys

FIGURE G-3: IMPLEMENTATION SCHEDULE

Activity	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6 Through Achieving RAOs (1)
	Spring Summer Fall	Spring Summer Fall	Spring Summer Fall	Spring Summer Fall	Spring Summer Fall	Spring Summer Fall	Spring Summer Fall
ALTERNATIVE 1							
No monitoring or treatment activities							
ALTERNATIVE 2							
Survey Ponds							
Baseline WP Sampling							
Sublimation Conditions Monitoring (1 station)							
Install Equipment							
Operate Equipment							
Remove Equipment							
Sedimentation Analysis							
Install Equipment							
Operate Equipment							
Remove Equipment							
WP Verification							
Plant particles							
Remove & measure							
WP Sediment sampling							
ERF-WIDE ACTIVITIES							
Telemetry							
Bird Population Aerial Survey							
Aerial Photography - ERF							
Hazing							
ALTERNATIVE 3							
Baseline WP Sampling							
Survey Ponds							
TREATMENT							
Pumping							
Initial Startup/Shakedown							
Yearly Startup/Shakedown							
Install pumps							
Operate pumps							
Remove pumps							
Sublimation Conditions Stations							
Install Equipment							
Operate Equipment							
Remove Equipment							
WP Verification Sampling							
Plant particles							
Remove & measure							
WP Sediment sampling							
AquaBlok™ Application							
Monitor AquaBlok™ Integrity							
Monitor Habitat Changes							
ERF-WIDE Activities							
Telemetry							
Bird Population Aerial Survey							
Aerial Photography - ERF (2)							
Hazing							

FIGURE G-3: IMPLEMENTATION SCHEDULE

Activity	Year 0 Spring Summer Fall	Year 1 Spring Summer Fall	Year 2 Spring Summer Fall	Year 3 Spring Summer Fall	Year 4 Spring Summer Fall	Year 5 Spring Summer Fall	Year 6 Through Achieving RAOs (1) Spring Summer Fall
ALTERNATIVE 4							
Survey Ponds							
Baseline WP Sampling							
TREATMENT							
Breach pond							
Pumping							
Initial Startup/Shakedown							
Yearly Startup/Shakedown							
Install pumps							
Operate pumps							
Remove pumps							
Sublimation Conditions Stations							
Install equipment							
Operate							
Remove							
WP Verification Sampling							
Plant particles							
Remove & measure							
WP Sediment sampling							
AquaBlok™ Application							
Monitor AquaBlok™ Integrity							
Monitor Habitat changes							
ERF-WIDE ACTIVITIES							
Telemetry							
Bird Population Aerial Survey							
Aerial Photography - ERF (2)							
Hazing							
ALTERNATIVE 5							
Baseline WP Sampling							
Survey Pond							
TREATMENT							
AquaBlokTM Application							
Monitor AquaBlok™ Integrity							
Monitor Habitat Change							
ERF-WIDE ACTIVITIES							
Telemetry							
Bird Population Aerial Survey							
Aerial Photography - ERF (2)							
Hazing							

Notes:
1. Activities may change in these later years, depending on the progress to date.
2. Baseline photograph is obtained during low tide after the treatment action.

OUC 0030266

Attachment
Monitoring Methods

ATTACHMENT 1

Monitoring Methods

Monitoring of Sublimation/Oxidation Conditions

This type of monitoring includes measurement of water depth, sediment temperature, and water saturation with a data logger. Activities include installing the equipment at the beginning of the season, recording the information, and removing the equipment at the end of the season. These methods have been described by Walsh and Collins (in Racine *et al.*, 1995).

Baseline WP Monitoring

The baseline white phosphorus (WP) monitoring provides the initial WP particle concentrations before the area is treated. The WP treatment verification method is used after treatment (for Alternatives 2 through 4) to verify that WP has been removed.

For the baseline WP monitoring, the washed composite sediment sampling method (Walsh *et al.*, in Collins *et al.*, 1997) is used. Monitoring sites are located on a transect across the site for every elevation change of 10 centimeters (cm) or more, depending on the size of the pond. This sampling is done from a boat or hovercraft if the area is still covered with water, or on foot if the area is not covered with water. At each monitoring site, sediment subsamples (50 milliliters [mL]) are collected perpendicular to the transect at every 2 meters (m) up to 20 m on either side, depending on the size of the monitoring area. These subsamples are composited and sieved (0.59 millimeter [mm] mesh sieve) to remove the smaller sediment particles and retain the WP particles. Duplicate composites are collected. Samples are sent to a laboratory for particle counting. Quality control samples also are analyzed.

WP Treatment Verification

The sampling sites and WP composite sampling method are the same as in the baseline WP method except the method is now applied after treatment. In addition, five WP particles of known size are implanted in the spring, at the beginning of the potential drying season, into the top 5 cm of the sediment at each monitoring site. The implanted particles, if still present, are removed and measured in the fall. This method has been described in Walsh and Collins (in Racine *et al.*, 1995).

Sedimentation

Monitoring techniques for net sedimentation have been described by Lawson *et al.* (in Racine *et al.*, 1994, 1995, 1996). This assessment focuses on the pond groups. Transects to measure net sedimentation will be established across representative ponds from each pond group. The scope of the sedimentation monitoring program encompasses only those ponds that have not been treated (that is, those areas that have not yet implemented Alternatives 3 through 5).

AquaBlok™ Integrity

This method includes visually inspecting the AquaBlok™ application and taking representative sample plugs of the material to measure the cover's thickness (Pochop *et al.*, in Racine *et al.*, 1996).

Aerial Photography

At Eagle River Flats (ERF), the presence of unexploded ordnance (UXO) poses a significant threat for personnel on most portions of the site. This danger underlines the importance of finding alternate, safer means to gather information for remedial decisionmaking. Remote sensing methods allow the collection and interpretation of data from target areas without being in physical contact with them.

Aerial photographs can be acquired with a variety of cameras, films, and filters. Two types of film photography, color film and infrared color film, have potential uses for monitoring remediation activities at ERF. Multispectral scanning is another technique that produces images of the target area instead of photographs.

Conventional color film is sensitized to all visible colors and can provide positive transparencies (slides) with natural color rendition. Slides are viewed on a light table and provide more detailed information than color prints, which lose some of their resolution in the transfer process. Color film has good qualities for water penetrability and can be used to identify subsurface and shoreline features. Color film needs the correct exposure and proper filter to produce high quality photography. This requirement for adequate light conditions means that overflights should be scheduled accordingly (for example, mid- to late morning).

Infrared color photography is also referred to as false color photography. The emulsion for this type of film is sensitive to green, red, and infrared radiation. A yellow filter is used to absorb blue wavelengths of radiation. The resulting transparencies display colors that are false for most natural features. Although infrared film was originally developed to detect camouflaged military targets, it has also proved useful in specialized interpretations for early detection of plant stress, once the typical spectral reflectance of normal, healthy vegetation has been established. For example, healthy deciduous or evergreen vegetation may appear red/magenta or bluish-purple, respectively. Deciduous or evergreen vegetation that is dead or dying usually photographs as bright green because the vegetation has lost its infrared reflectivity. Normally aging deciduous vegetation that has turned yellow or red will appear white or yellow, respectively, on infrared photographs because some of the infrared reflectivity of the leaves is retained.

Multispectral scanning imagery focuses on specific electromagnetic bandwidths that also can allow interpretation of stressed vegetation. The cost of obtaining multispectral imagery is roughly equal to that of obtaining aerial photography; however, post-processing costs are higher. It is probable that infrared color photography will be sufficient for interpretation of vegetation stress; therefore, it is assumed that multispectral imagery will not be required. The following discusses potential uses of aerial photography at ERF.

Topography. Currently, there is no detailed topographic map of ERF. Topographic information is critical to an engineering study of the feasibility of pond draining. The more detailed and accurate the topographic information is, the more useful it will be for the design of realistic pond draining systems. Aerial photography in conjunction with ground control can be used to develop topographic maps. Useable topographic information could provide an important basis for a number of the remedial evaluations at ERF such as tidal flooding, surface water movement, and pond draining.

Orthophotographs are aerial photographs that have been corrected for parallax (actual position displacement error). In 1993, color and color infrared photography of ERF was controlled for orthophotograph production. The result was a set of six sheets of monochromatic orthophotographs at 1 inch (in.) = 200 foot (ft) scale. This controlled photography is suitable for producing a 1 in. = 400 ft scale topographic map of ERF with a 10-ft contour interval. A topographic map of this scale is not sufficient for predicting pond drainage and interconnectivity.

More precise topographic mapping of ERF (2-ft or even 0.25-ft contour interval) is possible. To obtain the more precise topographic mapping would require additional aerial photography (ortho-controlled) and ground control. This work should be scheduled when ground conditions are most visible (early spring, after iceout). Photographic methods should be chosen to obtain the most information about topography in shallow water areas. Because of the cost of the mapping for these smaller contour intervals (discussed in Appendix E), it is assumed in this feasibility study (FS) that the details will be obtained by surveying of the individual pond groups rather than through the detailed mapping of the entire ERF through aerial photography.

Gully Recession. Using high quality, small-scale aerial photography, it should be possible to identify the locations of gully headwalls in the prominent drainages on ERF. Initially, it may be necessary to conduct limited field missions by helicopter overflight to verify the headwall locations and establish ground control where needed. Global Positioning System (GPS) can be used to record gully headwall locations for geographical information system (GIS) mapping. Field verification can be eliminated when an acceptable degree of correlation has been established.

In gullies where headwall recession is proceeding at a significant rate, it should be possible to see this movement in photographs taken of the same area over time. The periodic rate of gully headwall erosion can estimated by measuring the scaled distance between the headwall locations shown on two successive photographs. This method can be used to identify gullies that are eroding quickly enough to naturally intercept and drain ponds that would otherwise require pumping for remediation. The method also may be useful for predicting the time that it will take for a gully to intercept and drain a pond.

In most cases, vegetation cover should not significantly obscure the ground surface, although this may become problematic as the camera angle varies from the vertical. The photography used for this evaluation should not be done at a time when the gullies are in spate (overflowing) because the water itself may obscure microtopographic changes. Again, photographic method and filters should be chosen to optimize the usefulness of the photographs for this particular application.

Habitat Changes. Aerial photography can be used to gather information about habitat changes caused by remedial activities. In the first year of remediation, baseline aerial photography can be used to record existing conditions before startup of the remedial activities. This baseline photography can be used to quantify pond areas, identify depositional/erosional areas, and establish gully headwall locations. It is recommended that the baseline photographs be taken when ground conditions are least obscured (spring, after iceout).

A second round of aerial photography would be used to monitor conditions soon after pond draining. This photography could be used to quantify the reductions of pond surface areas, map potentially affected pond areas, and document conditions within selected gullies (especially if blasting has been used). The photographs will document habitat conditions at the remediation startup (that is, at time zero). If the second set of aerial photographs is taken immediately after pond draining when the vegetation is in full growth (mid-summer), they may also provide a record of spectral reflectance for healthy vegetation.

A final set of aerial photographs should be collected toward the end of the field season. The last overflight should be made before any anticipated snowfall or tidal flooding events. These photographs would serve to document the periodic changes in habitat conditions that occurred through the remedial activities conducted during the field season. After the first year, aerial photography overflights could be limited to two per year by eliminating the baseline photography.

Quantitative habitat changes that could be monitored by aerial photography include areas where vegetation is stressed or dying or gullies have been modified. These areas could be spatially located for inclusion in the ERF RGIS. Some field verification may be required to correlate actual conditions to the photographic interpretations.

AquaBlok™. Aerial photography can be used to qualitatively monitor applications of AquaBlok™. Aerial photographs should be taken immediately after the AquaBlok™ is applied to document the initial condition of the application and determine the location and areal extent of the application. Subsequent aerial photography could be used qualitatively to document changes in treated areas.

If the contrast between the color of AquaBlok™ and the color of the pond bottom sediments is not sufficient to distinguish easily on aerial photographs, it may be possible to enhance the contrast by adding some inert coloring agent to the AquaBlok™ before application. The coloring agent may be distinctive enough to also help identify areas where AquaBlok™ may be eroded and transported by surface water.

Works Cited

Lawson, D.E., S.R. Bigl, and J.H. Bodette. Physical System Dynamics. In *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* C.H. Racine, ed. FY 93 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Contract Report to U.S. Army, Alaska, Directorate of Public Works. May 1994. Pp. 25-83.

ANC/10040680.DOC

Appendix H
Responses to Comments

RESPONSES TO COMMENTS ON DRAFT FINAL FEASIBILITY STUDY REPORT, OPERABLE UNIT C, FORT RICHARDSON, ALASKA

Reviewer: Howard Orlean/U.S. EPA

Item No.	Page	Comment	CH2M HILL Response
1	1-5, Sec. 1.3, bottom of page	*This paragraph describes the conditions...*	The discussion has been modified to state that if RAOs are achieved, remediation may be terminated after 3 to 5 years of verification monitoring.
2	3-1, Sec. 3.1, Screening of Technologies	*AquaBlok™ is still listed as a separate...*	AquaBlok™ was listed separately because its swelling properties and ability to hold vegetation make it very different from traditional cap and fill using gravel. However, the following sentence has been added to the short summary of AquaBlok™: "AquaBlok™ is a cap and fill technology that has been tested at ERF." AquaBlok™ was selected as the representative process option for the cap and fill technology.
3	4-2, Table 3, "Conclusion" column	*As stated in EPA's comments on the Draft...*	The term "natural protection" has been revised throughout the document to read "natural restoration."
4	5-2, second full paragraph, last sentence	*This sentence states that monitoring for...*	The discussion has been modified to state that monitoring for negative impacts from habitat changes will be performed throughout remedy implementation.

Reviewer: Matt McAtee/CHPPM

Item No.	Page	Comment	CH2M HILL Response
1	General	*The U.S. Army Center for Health...*	Comment noted.
2	General	*The responses to our comments on the...*	The comment is appreciated.
3	General	*Because the primary weakness of the...*	The comment will be considered in preparing the monitoring program.
4	General	*Our reviewing scientist and point of contact...*	Comment noted.

OUC 0030274

Reviewer: Bruce Duncan/BTAG			
Item No.	**Page**	***Comment***	**CH2M HILL Response**
1	Tables 25, 27, etc.	*Suggest deleting the part of the footnote...*	The portion of the footnote has been deleted.
2	Figures such as A-2	*The label "Coastal East" overlaps into...*	No change has been made per this comment.
3	Response to Comments	*generally should proof it for typos such as:...*	These response to comments have been proofed.

Reviewer: Michael R. Walsh/CRREL and Charles M. Collins/CRREL			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
General Comments			
1	General	*The FS Draft Final is very much...*	The results of the Pond 183 pumping have been more consistently integrated into the FS.
2	General	*Much better job in documenting the source...*	The comment is appreciated.
3	General	*I feel there is still an overemphasis on the...*	Additional text regarding the significance of sediment consolidation has been added to the FS text, as well as to Appendix A.
4	General	*I also feel that AquaBlok™ is overrated as a...*	AquaBlok™ was selected because of it swelling properties and its ability to support vegetative growth. It is recognized that sublimation and oxidation processes will not occur in sediment covered by AquaBlok™.
5	General	*Preliminary tensiometer data from pumping...*	The increased effectiveness of pumping vs. breaching has been discussed in Section 4.4: Performance Differences between Alternatives 3 and 4. An explanation of the tradeoffs between the rapid removal of exposure pathway and achievement of cleanup levels has also been added. The discussion of residual risk has not been revised.
6	General	*Great maps! Unfortunately, the review...*	Color maps have been provided in the Final FS.
7	General	*There still is some confusion over discrete...*	All discussion of contamination rates and discrete versus composite sampling has been deleted from the text.
8	General	*There is some confusion in nomenclature...*	The guidance provided in the comment has been used in the Proposed Plan and will be used in the Record of Decision. However, in the FS, only the distinction between gully (natural) and ditch (exploded) has been made.

OUC 0030275

Reviewer: Michael R. Walsh/CRREL and Charles M. Collins/CRREL			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
Specific Comments			
1	VII, Abbreviations	*CEREAL = > CERCLA*	The typo has been corrected.
2	1-5, Para. 1	*Swans were also quite hard hit in the past,...*	The sentence"No other species has such a major observable effect as the dabbling ducks" has bee replaced with the sentence, "Monitoring for mallards is considered protective of other waterfowl species, such as swans."
3	Para. 2	*The 1996 data used as baseline data for...*	Text has been added to the FS explaining that RAOs will be reevaluated if mortality rates do not decline after several years of treatment implementation.
4	2-1, Sec. 2.1, 2nd Para.	*WP was never used for ground troop cover...*	The text has been revised to state that the WP smoke was used for marking targets.
5	2-8, Table 1	*Under Pond 146 & Northern C and C/D...*	The recharge rates in the table have been revised.
6	2-9, Figure 3	*Use a fold-out map like Figure C-1. Print...*	The up-front FS report was intentionally made an 8.5 by 11 document to make it easier to manage. Enlarged versions of the figures are provided in the appendices.
7	2-10, Table 2	*Northern C and C/D. Change to "moderate"...*	The text has been revised.
8	3-4, *Geosynthetics*	*K. Henry did work on using gravel and...*	There is concern that it would be very difficult to place large pieces of geosynthetics. Although AquaBlok™ was highlighted in the FS, the proposed plan does not rule out any cover or cap and fill options.
9	3-4, Para. 1	*No work was done to investigate the...*	The text about investigating redistribution of WP has been revised.
10	3-6, 2. Detailed Monitoring	*Where will the elevation survey data be...*	The following sentence has been added to the text: "The elevation survey of ground surface and pond bottoms will be used to determine pond interconnectiveness and flooding potential."
11	3-13, Figure 9, Alternative 3	*Aerial photography appears twice under...*	The figure has been revised to show the activity "Aerial Photography" as appearing only once under Alternatives 3, 4 and 5. In addition, aerial photography has been added as an activity to Years 6 and beyond.
12	3-14	*See above. Alts. 4 & 5.*	See above response.
13	4-2, Table 3	*...opportunity... = ...opportunities...*	The typo has been corrected.
14	4-2	*Need at least 4" of consolidated...*	The following sentence has been added to Table 3: "Sedimentation would have to be deep and consolidated to prevent duck feeding in WP-contaminated sediment."

OUC 0030276

Reviewer: Michael R. Walsh/CRREL and Charles M. Collins/CRREL			
Item No.	Page	Comment	CH2M HILL Response
15	4-2	*Based on eight years of observations,...*	The sentence regarding perimeter drying of 146 has been deleted.
16	4-2	*Any drying in these ponds will probably...*	Because intermittent ponds have the potential to dry naturally, intermittent ponds were not selected as hot ponds. No change has been made to the FS text as a result of this comment.
17	4-3	*Need to emphasize the frequent flooding...*	The problems concerning frequent reflooding have been added to section 4.4.
18	4-5	*Extensive surveying may not be possible...*	The phrase "in detail" has been deleted.
19	4-5	*Permeable vs. impermeable argument is...*	The following sentence has been added: "In some cases, small, low, ponded impermeable areas may be dried through evaporation."
20	4-6, Para. 3	*The term "breached" as used elsewhere...*	The sentence has been revised to read "The ponds were connected by a dredged channel in 1996."
21	4-7, Para. 1	*Add "contaminated" before "areas."*	The word has been added.
22	4-7, Para. 3	*Each Alternative also has a different...*	The comment has been incorporated into the text.
23	4-7, Para. 4	*...area => ...areas*	The paragraph has been deleted and thus the change was not incorporated.
24	4-8, Table 5	*Under Northern C & C/D. Change high...*	The table has been revised to state "moderate" recharge.
25	4-10, Para. 1	*Breaching and pumping probably will not...*	The text has been revised to state that Alternative 4 may be more effective. However, Section 4.4 also discussed the tradeoffs between Alternative 3 and 4.
26	4-10, Para. 2	*Intake location of pumps is irrelevant due...*	The discussion of intakes has been deleted.
27	4-10, Para. 3	*Contradicts paragraph 1.*	The text in this section has been revised.
28	4-11, Sedimentation	*AquaBlok™ performs like consolidated...*	The text has been revised per the comment.
29	4-11	*Was there really 30 cm of AquaBlok™ ...*	The data presented in Table 8 were provided by Denver Wildlife.
30	4-12, Para. 1	*I don't think that ice block transport of...*	The discussion of scouring of ice has been deleted per the comment.
31	5-1, Telemetry	*"...birds that die during..." => "...birds that...*	The text has been revised per the comment.
32	5-1, Aerial bird population surveys	*"Annual population surveys" Currently, ...*	The text has been revised to state that surveys will be performed biweekly between April and October.

OUC 0030277

Reviewer: Michael R. Walsh/CRREL and Charles M. Collins/CRREL			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
33	5-2, Aerial Photography	*Aerial photography has not been used in...*	The discussion of using aerial photography to count birds has been deleted from the text.
34	5-3, Table 9	*Baseline monitoring - Sampling is...*	The table has been revised per the comment.
35	5-3, Table 9	*Sedimentation - Net sedimentation is not...*	The table has been revised to state that net consolidated sediment will be monitored.
36	5-3, Table 9	*WP Monitoring - Pore pressure is also...*	The table has been revised revised per the comment.
37	5-3, Table 9	*Habitat - Would monitoring of vegetation...*	Monitoring for vegetation was not intended to be a method for assessing physical conditions. However the possibility should not be ruled out.
38	6-5, Para. 4	*Water retention capability is more...*	The discussion of fine-textured sediments has been deleted from the text.
39	6-6, Top of page	*No impact on shorebird mortality has been...*	The following sentence was added to the text: "However, during the 1997 pond pumping study, no impact to shorebird mortality was observed."
40	6-6, Sec. 6.2.2	*Change gully to ditch as per general...*	The change has been made.
41	Figures 13-17	*May want to reassess the contaminated...*	The residual risk assessment was not revised in the FS, but may be revised for the ROD, depending on the chemical sampling results of the 1997 breaching and pumping tests.
42	6-14, Long-term effectiveness	*I am still having difficulties seeing...*	The difference between a no action alternative and an alternative involving monitoring stems from the long-term effectiveness and permanence criteria and the implementability criteria. The former criteria stipulate the need to verify protection with reliable controls, and the latter considers monitoring. The difference between no action and monitoring is the knowledge that exposure pathways do or do not exist.
43	6-27, Implementability/ Alt. 3	*long = > large*	The typo has been corrected.
44	7-2, Para. 2	*Adding affected area I get 51/1 ha, as...*	The areas in the text have been revised.
45	7-4, Para. 2	*There may be some problems with...*	The effects of organic content is discussed in Section 4.3.6. No change to the text has been made per the comment.
46	7-6, Para. 1	*Removal of 5.7 ha or habitat differs from...*	The text has been revised to be consistent with the table.
47	7-6, Para. 3	*Only applies to Para. 3. No need to breech...*	Reference to Alternative 4 has been deleted.

OUC 0030278

Reviewer: Michael R. Walsh/CRREL and Charles M. Collins/CRREL			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
48	7-7, LT Effectiveness	*May want to move Option 3 to "Best."*	The change has been made.
49	8-1	*Some inconsistencies in reference citations.*	The text and references have been reviewed by an editor and where possible citations have been revised following the format presented in the comment.
50	A-1, 1st Para.	*The term "receding from the river" is a...*	The text has been revised per the comment. However the term "receding from the river" was retained in parentheses for those who do not know that "headward erosion" means.
51	A-2, 1st Para.	*Again "headward erosion of gullies"*	The text has been revised per the comment.
52	A-4, Para. 1	*Gully connections to ponds leads to...*	The content of the comment has been incorporated into the text.
53	A-5, Para. 1	*Using the tidal sedimentation rate of...*	The text has been revised to state that tidally dominated sedimentation rates are up to 20 mm/yr in ponds.
54	A-7, Sec. 2.5, 2nd Para.	*A much higher, unmeasured, peak...*	The flow rates and reference provided in the comment have been used to update the text. The information provided in the comment is appreciated.
55	A-6, Figure A-1	*Can axes be labeled with °C and mm to...*	The units of the axes have been converted to the metric system.
56	A-9, Figure A-2	*There are two arrows for Coastal 6 gully.*	The two arrows are intentional.
57	B-4, Para. 5	*Unit cost vs. Length applies only to...*	The text has been revised to clarify that unit costs apply only to breaching.
58	B-4, 2.1.2	*Need to include cost of blasting sump for...*	The following statement was added: "Cost of blasting a sump for the pump was not included."
59	B-6, 2nd	*It was assumed that only one operation...*	Agreed. Only one drying season was assumed for the order-of-magnitude cost estimate. However, it was stated in the text that it is likely that longer seasons will be needed. Therefore, in the budget-level cost estimates in Appendix E, a five-year implementation period was assumed for Alternatives 3 and 4.
60	B-6, 2.2	*Do not see the cost of measuring thickness...*	For the order-of-magnitude cost estimate presented in Appendix B, AquaBlok™ integrity was not considered. However, this monitoring was included in the budget-level cost estimate presented in Appendix E.
61	B-7, 3.0	*Where did data for distribution of WP come...*	Discussion of WP distribution has been deleted from the text.
62	B-7, 3.1	*Include 1996 in observations.*	No change was made per this comment because it was not clear what observations the comment was referring to.

OUC 0030279

Reviewer: Michael R. Walsh/CRREL and Charles M. Collins/CRREL			
Item No.	Page	Comment	CH2M HILL Response
63	B-8, Top of page	*Do not directly compare different sampling...*	All text regarding contamination rates and comparisons between composite and discrete sampling have been deleted. Information provided in the comments regarding the differences between these two sampling methods is appreciated.
64	B-9, Para. 4, last line	*Delete "with."*	The typo has been corrected.
65	B-10, 3.4, Para. 2	*Colloidal particles are not considered a...*	The following sentence has been added to the text: "However, colloidal particles are not considered a threat to waterfowl."
66	B-10, Para. 3	*Although the area was not dredged to...*	Comment noted. No change to the text has been made per the comment.
67	ATT-4	*Some technologies have been duplicated...*	The duplicate technologies have been deleted.
68	B Table B-2, pg. 3 Under effectiveness	*Can't compare discrete to composite...*	The text comparing the sampling methods has been deleted.
69	B Table B-2, pg. 3 Under Screening Result	*Dredging has been dropped, not retained.*	The table has been corrected.
70	B Table B-2, pg. 6, Treatment (By Breaching)	*Description - Habitat has also been removed...*	Under pond draining by breaching, the following sentence has been deleted: "Dabbling duck habitat would be removed."
71	B Table B-2, pg. 6, Treatment (By Breaching)	*Add Racine Island ditch in 1997 to...*	References to Racine Island have been added to the text.
72	B Table B-2, pg. 6, Treatment (By Breaching)	*Effectiveness - Some measurement of WP...*	The text has been revised to state: "WP removal has been measured at Bread Truck but the results are not available yet."
73	B Table B-2, pg. 6, Treatment (By Pumping)	*Description - Replace "Presumably...would..."*	The text has been revised per the comment.
74	B Table B-2, pg. 6, Treatment (By Pumping)	*Effectiveness– Remove first paragraph. Add...*	The recommended text has been added to Table B-2.

Reviewer: Michael R. Walsh/CRREL and Charles M. Collins/CRREL			
Item No.	Page	Comment	CH2M HILL Response
75	C-1, 1.0, Para. 2	*This year's work shows that pumping alone...*	The text has been revised to state that there is some uncertainty about how certain pond systems would respond to pond draining. An example given is the ponds in Area C/D.
76	C-3, Table C-1	*Pond 146 & Northern C and C/D Ponds.*	The recommended changes have been made.
77	C-4, Table C-2	*Northern C and C/D Ponds. Replace "high...*	The recommended change has been made.
78	C-6/C-7	*Sediments only need to be desaturated, not...*	Agreed. However, the rate of sublimation increases with decreasing water content. The text does say that sublimation occurs when sediments are allowed to dry below saturation. The text was revised to state that WP will not sublimate in sediment that does not desaturate.
79	C-15, Table C-6	*Note 2 - "...drained within 36 hours of post...*	The note has been revised per the comment.
80	C-15, Para. 3	*Breaching may be more effective in...*	The text has been revised to reflect the comment.
81	C-23, Table C-8, Discharge Pumping	*Rubber hose in 50' lengths, pipe in 5, 10, ...*	The lengths of hose have been revised.
82	C-24, Table C-8, Electrical Switches	*Change "switch" to "switches" under desc.*	The recommended change has been made.
83	C-26	*Use "ditch" instead of "gully" as per...*	The recommended changes have been made.
84	C-26/C-27	*Based on results from last year and this...*	The text has been revised to state that charges will be placed every 4 m.
85	C-27 Pump sizing	*Won't necessarily need more manpower...*	The text has been revised to state that more manpower may be needed. In the context of this FS, manpower refers both to number of people and the time needed to deploy the pump system.
86	E-1, 1.1	*Delete first "be" in line 2.*	The typo has been corrected.
87	E-6, Annual pump/...	*Change "installed" to "positioned." Add pipe...*	The recommended changes have been made.
88	E-7, 2.4, Para. 2	*Crater spacing - Use one number.*	The text has been revised to state that charges will be placed every 4 m.
89	F-11, 3.2.2, Para. 2	*...ponds will likely be permanently changed...*	The word "likely" has been added.
90	F-11, 3.2.3, Para. 2	*Change "channel" to "ditch"*	The recommended changes have been made to the text.
91	F-21, Para. 1	*You may want to change the assumption...*	Please see response to CRREL comment 41.

OUC 0030281

Reviewer: Michael R. Walsh/CRREL and Charles M. Collins/CRREL			
Item No.	Page	Comment	CH2M HILL Response
92	F-33, 4.3.6, 3rd sentence	*Again, the term "breached" as used...*	The text has been revised to read "The ponds were connected by a dredged channel in 1996."
93	F-34, 4.3.8	*Check wording, first paragraph. Not much...*	The wording has been revised to state that there is a high degree of confidence that Pond 183 could be dried.
94	F-38, Environmental Impacts	*Breaching of 146 would have a significant...*	The content of this comment has been incorporated into the text.
95	Table F-7, pg. 2, S.T. Effectiveness, Alt. 4	*I can't imagine anybody's windows be...*	The reference of broken windows has been deleted. The following sentence has been added to the text: "Range Control regulations require blasting be conducted on clear days to reduce the sound and pressure of the blast."
96	G-9, Para. 1	*Total dredged area is closer to 0.6 ha, half...*	The text has been modified to reflect the comment.
97	G-9, Para. 3	*Another source of potential hot spot ponds...*	The content of the comment has been incorporated into the text.

Reviewer: W. Ferrell/COE			
Item No.	Page	Comment	CH2M HILL Response
1	1-5, 1.3.1	*The second paragraph seems to consider...*	The sentence relating dabbling ducks to a species has been deleted.
2	6-2, bullet	*Under the first bullet magnitude of risk.*	The heterogeneous distribution of WP is partly the result of the method by which it was discharged (i.e., smoke markers for targets). The comment stating that sublimation of WP does not take place does not agree with the extensive research performed on WP. WP can exist as a gas, and only when it is a gas will it oxidize.
3	B-11	*The alteration of waterfowl habitat may be...*	The content of this comment has been incorporated into the text in Section 3.5.

Reviewer: Mellema/COE			
Item No.	Page	Comment	CH2M HILL Response
1	General	*In general, the report is well written and...*	The following sentence has been added to Section 1.0 of Appendix B: "AquaBlok™ was selected because of its cohesive properties and its ability to support vegetative growth." However, different cover materials may be performed during winter 1997/8 treatability studies. In addition, the draft proposed plan does not currently specify the type of cap and fill material that will be used.

Reviewer: Osborn/COE			
Item No.	Page	Comment	CH2M HILL Response
1	General	*The cost estimates shown for the...*	The information provided in the comment is appreciated.
2	General	*The unit of measure of costs for Bulldozer...*	The different rates were used for two separate cost estimates that were performed at different stages of the FS preparation. More detailed information was available during later stages of the project, which result in different unit cost values.

OUC 0030283

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue
Seattle, Washington 98101

September 2, 1997

Reply to
Attn of; ECL-113

W. A. Gossweiler
Department of the Army
Directorate of Public Works
600 Richardson Drive #6500
Attn: APVR-RPW-EV
Fort Richardson, Alaska 99505-6500

Re: Operable Unit C/Eagle River Flats
Draft Final Feasibility Study Report

Dear Bill;

The U.S. Environmental Protection Agency (EPA) has completed our review of the document entitled *Operable Unit C Draft Final Feasibility Study Report* (Draft Final FS). EPA received this document on July 14, 1997. EPA informally presented these comments at our meeting in Seattle on August 12, 1997.

The Draft Final FS has adequately addressed the vast majority of EPA's previous comments. EPA concurs on the Remedial Action Objectives (RAOs) for Eagle River Flats (ERF) as appropriate for measuring remedial success. For the most part the specific comments which are attached are for clarification purposes.

If you have any questions, please call me at 206-553-6903.

Sincerely,

Howard Orlean

Howard Orlean
Superfund Project Manager

cc: Bruce Duncan, ES-098
Jennifer Roberts, ADEC
Joann Walls, Army Engineer District, Alaska

EPA Comments on ERF Draft Final FS
September 2, 1997

Specific Comments

1. Page 1-5, Section 1.3, Bottom of Page --

This paragraph describes the conditions under which the RAOs would be considered to have been achieved. While EPA agrees with the concept of using mortality rate as the primary RAO, some additional provision should be included which allows for verification monitoring over a specified period of time should physical conditions at ERF change which would potentially re-expose waterfowl to white phosphorus (WP) contamination.

2. Page 3-1, Section 3.1, Screening of Technologies --

Aquablok™ is still listed as a separate technology. EPA believes that Aquablok™ is a form of "cap and fill" technology, and should not be listed separately.

3. Page 4-2, Table 3, "Conclusion" Column --

As stated in EPA's comments on the Draft FS, the term "natural protection" is confusing. While EPA understands that natural processes can aid in reducing or eliminating exposure to WP, natural processes such as erosion can also act to potentially re-expose WP contamination to waterfowl.

4. Page 5-2, Second Full Paragraph, Last Sentence --

This sentence states that monitoring for negative impacts from habitat changes will be performed. This monitoring should somehow be tied into a "long-term" monitoring program to ensure that the remedial actions are achieving the RAOs. (See specific comment 1.)

5. Section 7, Tables 7-19, 7-21, 7-23 & 7-25 --

EPA suggests deleting the portion of the footnote reading "higher rank is better than a lower rank" since the numbers presented correspond to alternatives and not ranks.

6. Page A-9, Figure A-2 --

The label "Coastal East" overlaps into Area D. Is Area D part of Coastal East?

DEPARTMENT OF THE ARMY
U.S. ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND, MARYLAND 21010-5422

REPLY TO
ATTENTION OF

MCHB-DC-EHR (40)

11 AUG 1997

MEMORANDUM FOR Commander, U.S. Army Engineer District, Alaska,
ATTN: CENPA-EN-EE-AI/Ms. Joann Walls, P.O. Box 898,
Anchorage, AK 99506-0898

SUBJECT: Draft Final Feasibility Study Report, Operable Unit C, Fort Richardson, Alaska, July 1997

1. The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) reviewed the subject document on behalf of the Office of The Surgeon General. Our review consisted of a cursory review of the report text and a review of the response to comments.

2. The responses to our comments on the previous draft are acceptable and we concur with the approach to be taken on each of those issues. The text added to Section 1.3 (Remedial Action Objectives) has gone a long ways toward satisfying our primary concern regarding the long-term remediation goals and their role in the decision making process.

3. Because the primary weakness of the current long-term PRGs is that the necessary data and analysis are not yet completed to justify an aggressive hot spot removal of 99%, we urge the risk managers to request an outline of the techniques and data quality objectives needed to link the preliminary long-term mortality and hot-zone goals. In order to provide the necessary information to refine the long-term goals of the project we strongly recommend that each year's monitoring report include the biometric and physiochemical data needed to refine and justify the long-term remediation goals.

4. Our reviewing scientist and point of contact for questions or consultations is Mr. McAtee and he can be reached at DSN 584-2953 or commercial (410) 671-2953 and via the Internet at Matthew_McAtee@chppm-ccmail.apgea.army.mil.

FOR THE COMMANDER:

DENNIS E. DRUCK
Acting Program Manager, Environmental Health
Risk Assessment and Risk Communication

Readiness thru Health

MCHB-DC-EHR
SUBJECT: Draft Final Feasibility Study Report, Operable Unit C, Fort Richardson, Alaska, July 1997

CF:
HQDA(DASG-HS-PE)
CDR, USAMEDCOM, ATTN: MCHO-CL-W
CDR, USAPAC, ATTN: APVR-RPW-EV
CDR, USAMC, ATTN: AMCEN-A/Mr. Pete Cunanan
CDR, USAEC, ATTN: SFIM-AEC-RPO
CDR, CEMRD, ATTN: CEMRD-ET-EH

From: BRUCE DUNCAN
To: WASTE.ORLEAN-HOWARD, ERF-BTAG
Date: 8/6/97 2:10pm
Subject: OU-C Draft Final FS Report - July 1977

ERF RPMs,

I have reviewed the report and have only very minor comments. As mentioned before, I am keenly interested in how the FS information will be used in developing the ROD.

Thanks,

Bruce

Tables 25, 27, etc.: Suggest deleting the part of the footnote reading "higher rank is better than lower" since the numbers are not ranks.

Figures such as A-2: The label "Coastal East" overlaps into area D.

Response to Comments - generally should proof it for typos such as:
P6-No.34 - typo, should read "suitable for blasting"
P15-No. 15 - should read "submit it for "
P16-No. 30 - "et al."

CC: CIRONE-PATRICIA

CECRL-GL 11 August 1997

MEMORANDUM TO CEPOA-EN-EE, JoAnn Walls

SUBJECT: Comments on Draft Final Feasibility Study Report (CH2M Hill: 7/97)

Reviewers:	Michael R. Walsh, PE	USA CECRL-TE	(MRW)
	Charles M. Collins	USA CECRL-GL	(CMC)

1. General Comments

The FS Draft Final is very much up to date, reflecting recent and ongoing work at the Flats. This is a very significant improvement over previous documents, but has led to some inconsistencies in the FS Report. Most notably are the contradictions between the reported performance of the pumping work being conducted in Pond 183 and the projected performance of the pumping system, also in the FS. These contradictions, which appear throughout the report, need to be reconciled to make the report consistent. These results, although preliminary, are quite significant, and CH2 is right in trying to integrate them into the report

Much better job in documenting the source materials for the information contained within this document.

I feel there is still an overemphasis on the role of unconsolidated sedimentation in breaking the pathway to the ducks. Unless this sediment is allowed to dewater, it will prove to be only a minor hindrance to dabbling waterfowl. (MRW)

I also feel that AquaBlok is overrated as a remediation method. Field observances (undocumented) indicate that the upper portion of bentonite washes away from the gravel, and that in areas where AquaBlok is applied that have dried, the surface covered by this material remains wet, thus inhibiting the attenuation of the WP. I would also be worried about ice plucking, as this material is quite cohesive and pulling up a bit may result in the removal of larger areas. (MRW)

Preliminary tensiometer data from pumping and breaching tests at Pond 183 and Bread Truck Pond respectively, indicate that pumping is more effective in creating conditions conducive to the sublimation of WP. This is a limited observation due to the small amount of data available, but the difference is quite clear. The more frequent flooding of BT Pond versus the long, dry period in Pond 183 clearly demonstrates that the residual risk for pumping is likely to be less than that for breaching. If you can incorporate this into the report, it would be helpful in the analysis of alternatives.

Great maps! Unfortunately, the review copies were all B&W and thus a bit harder to read. (MRW)

There still is some confusion over discrete vs. composite sampling of the dredged area. These numbers can not be compared in any way, and should not appear as if they are related in any way. A more detailed explanation is given under Specific Comments, B-8. (MRW)

There is some confusion in nomenclature regarding drainage features. We have gullies, channels, sloughs, and ditches all being used, sometimes interchangeably. This needs to be sorted out. I would suggest the following protocol: "channel" be used for natural river or stream channels; "gully" be use for natural tidal distributary and drainage gullies; and "ditch" be used for explosively excavated drainage ditches. (CMC)

Due to the short time I had to review this document, I did not do as careful a job as I would have liked. However, I think CH2 has done a very good job, and their willingness to incorporate changes and include current work is an indication of their seriousness doing a good job. (MRW)

I also commend CH2M Hill on the good job they have done on pulling together a very detailed and complex document. (CMC)

2. Specific Comments

VII: Abbreviations. CEREAL => CERCLA.

p. 1-5: Para. 1: Swans were also quite hard hit in the past, especially in areas not normally used by ducks for dabbling. (MRW)

Para. 2: The 1996 data used as baseline data for comparison is, I assume, the telemetry data. The deaths recorded as attributable to WP were never backed up by chemical analysis, to my knowledge. At the December 1996 meeting, it was even admitted that one of the birds that died as a result of capture was included in the WP-attributed death total. From a legal standpoint, I think the use of this data is suspect if not confirmed analytically. (MRW)

p. 2-1 Sec. 2.1, 2nd para. WP was never used for ground troop cover in ERF. It was used for marking targets. (CMC)

p. 2-8 Table 1. Under Pond 146 & Northern C and C/D: These values for rate of recharge are off by an order of magnitude. As reported in the FY95 work we did (Collins et al. in Cate and Racine, 1996) the maximum estimated influx of fresh water in the C/D area was approximately 100 gpm (530 m^3/day). We would estimate approximately the same order of magnitude for freshwater inflow for the C area. Our experience in pumping pond #183 this tends to confirm this. (CMC)

Pumping of pond 183 this summer has been shown to affect the water levels in ponds 129, 145, and 155, as well as lowering the level of 146 to the point of no more infiltration into 183.

2-9 Figure 3: Use a fold-out map like Figure C-1. Print is too small to read.

2-10 Table 2: Northern C and C/D. Change to "moderate" rate of recharge from eastern bluffs. See comment for p. 2-8 above. (CMC)

3-4 Geosynthetics. K. Henry did work on using gravel and geosynthetic combination to provide a stable liner and anchor system. Test cells in Pond 183 were inspected this summer, three years after their installation, and are still in good shape. (CMC)

3-4 Para 1: No work was done to investigate the redistribution of WP after dredging. Post-dredging composite sampling was done only to determine the extent of residual WP contamination after cessation of dredging. (MRW)

3-6 2. Detailed Monitoring: Where will the elevation survey data be used, and what is being measured? (MRW)

3-13 Figure 9, Alternative 3: Aerial photography appears twice under Activity. It should only be under ERF-WIDE Activities. Also, under Year 6..., I think at least one aerial photo should be taken each year for documentation purposes. (MRW)

3-14 See above. Alts. 4 & 5.

4-2 Table 3: ...opportunity... => ...opportunities...

Need at least 4" of <u>consolidated</u> sedimentation to be an effective barrier (MRW)

Based on eight years of observations, pond 146 is not likely to dry up much in 1997 or 1998. (CMC)

Any drying in these ponds will probably only occur along the edges of the ponds, in the intermittent mudflats.

4-3 Need to emphasize the frequent flooding of breached ponds as problematic to the remediation process.

4-5 Extensive surveying may not be possible due to the presence of UXOs and the current (and justifiable) range safety restrictions.

Permeable vs. unpermeable argument is confusing. I feel that an impermeable area is better, as evaporative drying in low area is more likely without the influx of water. (MRW)

4-6 Para. 3: The term "breached" as used elsewhere in FS implies pond is connected to a drainage system. I would suggest rewording to " The ponds were connected via a dredged channel in 1996." The dredged channel in 183 ends in a shallow part of the pond so water flows between the ponds only during higher water levels. During part of the summer, no transfer of water from 146 to 183 was observed, indicating either a reduction of influx into 146 or an evaporation/ evapotranspiration rate in excess of the influx. (CMC, MRW)

4-7 Para. 1: Add "contaminated" before "areas".

Para. 3: Each also has a different impact on the environment.

Para. 4: ...area => ...areas

p. 4-8 Table 5. Under Northern C & C/D. Change high amount of recharge to moderate amount. See comments on p. 2-8 above. (CMC)

4-10 Para. 1: Breaching and pumping probably will not be more effective in remediating the WP in most cases, as 1997 field studies have demonstrated. (MRW)

Para. 2: Intake location of pumps is irrelevant due to the use of blasted sumps for the pumps. (MRW)

Para. 3: Contradicts paragraph 1. (MRW)

4-11 • Sedimentation: AquaBlok performs like consolidated sedimentation, but is not like sedimentation. (MRW)

Was there really 30 cm of AquaBlok applied? This seems very thick. (MRW)

4-12 Para. 1: I don't think that ice block transport of AquaBlok is a reliable means of covering contaminated areas. This should probably be taken out, as it points out that the application of this material is not a thorough means of remediation. (MRW)

5-1 • Telemetry: "... birds that die during..." => "... birds that die from WP poisoning during...".

• Aerial bird population surveys: "Annual population surveys" Currently, aerial bird surveys are repeated biweekly throughout the season. This repeated survey technique is necessary because of the variability of numbers of birds on the flats throughout the season and year to year variability of arrival and departure dates of large numbers of migrating birds. An annual survey as implied in this paragraph would do little to quantify numbers of birds using ERF. (CMC)

5-2 • Aerial Photography: Aerial photography has not been used in the past in ERF for bird census data. The proper scale of photography would have to be determined. Aerial photography is also very useful for determining the impact of various remedial alternatives on the environment, as well as confirming physical dynamics predictors. Whether the same scale photography can be used for both missions would have to be addressed. (CMC, MRW)

5-3 Table 9: Baseline monitoring - Sampling is composite sampling. (MRW)

Sedimentation - Net sedimentation is not as useful as net consolidated sedimentation. (MRW)

WP Monitoring - Pore pressure is also measured (tensiometers). (MRW)

Habitat - Would monitoring of vegetation be a method of determining physical conditions, i.e. *Hippuris* = wet? (MRW)

6-5 Para. 4: Water retention capability is more related to organic content than grain size. In 183, the *Hippuris* is taking a beating because the sediments are drying so well. (MRW)

6-6 Top of page: No impact on shorebird mortality has been observed to date at Pond 183, although this is only an observation and not a study. We were, however, specifically looking at shorebird behavior and the possibility of mortality at the time of initial pond draining, when we felt the risk would be highest. One Pectoral Sandpiper (*Calidris melanotos*)was found dead on the newly drained mudflat of 183 in June. Laboratory analysis of the gizzard confirmed that it did not die of WP poisoning (M.E. Walsh, pers. communication). (CMC, MRW)

6-6 Sec 6.2.2. change gully to ditch as per general comments at beginning of this memo. (CMC)

Figures 13-17: May want to reassess the contaminated areas and residual risks based on this season's work to date. (MRW)

6-14 • Long-term effectiveness: I am still having difficulties seeing how monitoring will differ from doing nothing. Neither of these will "produce" long term effectiveness, although some of the physical dynamics occurring will have some impact on the availability of the contaminant. (MRW)

6-27 Implementability / Alt. 3: long => large

7-2 Para. 2: Adding affected area I get 51/1 ha, as opposed to the 42 ha in Table 18. (MRW)

7-4 Para. 2: There may be some problems with effectiveness of pumping or breaching in Pond 290 if the bottom sediment is highly organic. We have not analyzed organic content of bottom sediment. However, based on strictly visual observations, the bottom sediments appear similar to 183. (MRW, CMC)

7-6 Para. 1: Removal of 5.7 ha of habitat differs from that in Table 22. (MRW)

Para. 3: Only applies to Para. 3. No need to breach. (MRW)

7-7 LT Effectiveness: May want to move Option 3 to "Best". (MRW)

p 8-1. Some inconsistencies in reference citations. Also applies to references in the Appendixes. This is how we have cited the referenced reports:

Collins, C.M. and D. Cate (Eds.) (1997) Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska. FY96 Final Report. CRREL Contract Report to US Army, Alaska, Directorate of Public Works. July 1997.

Individual sections within report are cited as:

Collins, C.M., M.T. Meeks, M.R. Walsh, M.E. Walsh, and R.N. Bailey (1997) Pond draining treatability: 1996 studies-the draining of Bread Truck Pond. In Collins, C.M. and D. Cate (Eds.) (1997) ...pp. 51-71.

Racine, C.H. and D. Cate (Eds.) (1996) Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska. FY95 Final Report. CRREL Contract Report to US Army, Alaska, Directorate of Public Works. September 1996.

Racine, C.H. and D. Cate (Eds.) (1995) Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska. FY94 Final Report. CRREL Contract Report to US Army, Alaska, Directorate of Public Works. May 1995. Vol. 1&2.

A-1 1st para. The term "receding from the river" is a little confusing. I would suggest using headward erosion of the gully. (CMC)

A-2 1st para. Again "headward erosion of gullies" instead of "erosion and recession." (CMC)

A-4 Para. 1: Gully connections to ponds leads to more frequent flooding and wetting, not necessarily longer drying periods. More of the ex-ponded area has an opportunity to dry between flooding events, however. (MRW)

A-5 Para. 1: Using the tidal sedimentation rate of 0.4 mm/event, and multiplying by the maximum number of events (14), I get 5.6 mm/year of sedimentation, not 20 to 40 mm. Again, the sediment needs to be consolidated to be effective. (MRW)

A-7 Sec. 2.5, 2nd para. A much higher, unmeasured, peak discharge occurred in September 1995. The resulting flood event washed out the bridge across the river at the head of ERF and the CRREL gauging station at the bridge. The USGS gauging station further upstream at the town of Eagle River measured the peak discharge at 291 m^3/sec. (CMC)

Dr. Lew Hunter, CRREL prepared the following summary that may be useful:

> Mean annual discharge of the Eagle River at a gauging station in the town of Eagle River is about 528 ft^3/s (14.95 m^3/s), with a peak discharge of 10,300 ft^3/s (291.67 m^3/s) during the >500 year flood event of September 1995 (Kemper et al., 1995; Brabets, 1996).
>
> Brabets, T.P. (1996) Evaluation of the streamflow-gaging network of Alaskain providing regional streamflow information. Anchorage, Alaska: U.S. Geological Survey, Water-Resources Investigations Report 96-4001.
>
> Kemper, J.E., L.A. Rundquist, D.B. Goldstein, J.E. Perry and J.N. Marchbanks (1995) Flood Report: South Central Alaska Floods, September 19-October 2, 1995. Anchorage, Alaska: National Oceanic and Atmospheric Administration.

A-6 Fig. A-1. Can Axes be labeled with °C and mm to match text? (CMC)

A-9 Figure A-2: There are two arrows for Coastal 6 gully. (MRW)

B-4 Para. 5: Unit cost vs. Length applies only to breaching (Alt. 4). (MRW)

2.1.2: Need to include cost of blasting sump for pump (2 x 40# shape charges., 2 x 40# cratering charges. Required). (MRW)

B-6 2nd • It was assumed that only one operation season... Two operating seasons may be a better, more conservative estimate for amount of time needed to dry sediments to achieve sublimation of WP. We will know better in

September how effective pumping was in 183. We had almost ideal drying conditions in June and July, which may not be repeated in future years. (CMC)

2.2: Do not see the cost of measuring thickness, uniformity, and completeness of AquaBlok cover in estimate. (MRW)

B-7 3.0: Where did the data for distribution of WP come from? (MRW)

3.1: Include 1996 in observations. (MRW)

B-8 Top of page: Do not directly compare different sampling methods (30% vs. 10%). The explanation does not remove the link between the two. (MRW)

Para. 3: of the three samples testing positive, one was a Q.C. duplicate. Therefore, only two positives were actually found. This lowers the composite positive rate to about 8% (2 of 24). (MRW)

The contamination rate would probably have been significantly lower if discrete sampling had been performed. During the course of collecting our composite subsamples, 98 discrete sub-samples were taken to make up the 24 composite samples. If only one of each of the composite sample's subsamples was positive, this leads to a hit rate of about 2%. (MRW)

B-9 Para 4, last line: Delete "with".

B-10 3.4, Para.2: Colloidal particles are not considered a threat. (MRW)

Para. 3: Although the area was not dredged to specification, it is of sufficient depth to prevent dabbling by ducks. (MRW)

ATT-4 Some technologies have been duplicated under the Treatability Studies.

B Table B-2, Pg. 3, Under effectiveness: Can't compare discrete to composite detections and detection levels.

Under Screening Result: Dredging has been dropped, not retained.

B Table B-2, Pg. 6, Treatment (By Breaching): Description - Habitat has also been removed from the targeted species: Not enough water to dabble.

Add Racine Island ditch in 1997 to implementability.

Effectiveness - Some measurement of WP removal has been done in 1997, although the data may not yet be available.

B Table B-2, Pg. 6, Treatment (By Pumping): Description - Replace "Presumably...would..." with "...will...".

Effectiveness - Remove first paragraph. Add something like... Testing of the pumping system in Pond 183 in 1997 has proven the effectiveness of the pump in dewatering a large pond with some interconnectivity with large water-bearing areas. Extensive drying of previously permanent-ponded sediments has been demonstrated". Also, remove likely from second paragraph, based on observations this Spring, Also, add something about the increased shorebird activity which has been observed, without the resultant predicted mortality due to WP. (MRW)

C-1 1.0, Para. 2: This year's work shows that pumping alone can dry out an extensive pond system. See Table C-1, under Pond 183.

C-3 Table C-1. Pond 146 & Northern C and C/D Ponds. Replace (200 to 1000 gpm) with maximum 100 gpm. See comments for p. 2-8 above. (CMC)

C-4 Table C-2. Northern C and C/D Ponds. Replace "high amount" with "moderate amount." Reference previous comment above.

C-6 /C-7 Sediments only need to be desaturated, not dry, for sublimation to initiate. (MRW)

C-15 Table C-6: Note 2 - "...drained within 36 hours of post-flooding-tide pond level stabilization." (MRW)

Para.3: Breaching may be more effective in draining, but it isn't more effective in drying the sediments due to more frequent flooding. (MRW)

C-23 Table C-8, Discharge pumping: Rubber hose in 50' lengths, pipe in 5,10, and 20' lengths. (MRW)

Sensors: Add subcategories Low level shutoff, High level actuate, and Flood level shutoff. (MRW)

C-24 Table C-8, Electrical Switches...: Change "switch" to "switches" under desc. (MRW)

Engine...: Temperature, fuel, and pressure indicator lights.

Other: Pump hour meter.

C-26 Use "ditch" instead of "gully" as per discussion in general comments. (CMC)

C-26 / C-27: Based on results from last year and this spring, optimum crater charge spacing is 4 to 4.5 m. That is predicated on the charges being tamped with sandbags to confine the explosion to maximize the crater size. Refer to spacing of 4 m in Stage 1 and 3.5 m in Stage 2. Use one number. (CMC).

C-27 Pump sizing: Won't necessarily need more manpower, although deployment times may differ somewhat. (MRW)

Refueling: Dependent on tank size.

E-1 1.1: Delete first "be" in line 2.

E-6 • Annual pump/...: Change "installed" to "positioned". Add pipe and hose deployment via UH-1 Huey, approximately 2 hours (Also add to removal).

E-7 2.4, Para. 2: Crater spacing - Use one number. (CMC).

F-11 3.2.2, Para. 2: ...ponds will likely be permanently changed... We still haven't given up hope on BT! (MRW)

3.2.3, Para. 2: Change "channel" to "ditch" (CMC)

F-21 Para 1: You may want to change the assumption of residual risk based on the results of Pond 183 pumping vs. 109 breaching this year. (MRW)

F-33 4.3.6 3rd sentence. Again, the term "breached" as used elsewhere in FS implies pond is connected to a drainage system. I would suggest rewording to " the ponds were connected via a dredged channel in 1996." (CMC)

F-34 4.3.8: Check wording, first paragraph. Not much uncertainty regarding 183 drying anymore in para. 3.

F-38 Environmental Impacts: Breaching of 146 would have a significant impact on the whole eastern side of the Flats, due to the interconnectiveness of the ponds, especially along shore. It will also affect flooding of the Flats. (MRW)

Table F-7 Pg. 2, S.T. Effectiveness, Alt. 4: I can't imagine anybody's windows be broken by a detonation at the Flats. (MRW) Range Control regulation require blasting only on clear days because of concern of low cloud cover reflecting and magnifying sound of blasting. You may want to modify paragraph to reflex this regulation. (CMC)

G-9 Para 1: Total dredged area is closer to 0.6 ha, half of which was done in 1995. Also, you may want to include the draining of Pond 183 and the surrounding area in 1997. Not sure the extent, but probably around 15 ha. (MRW)

Para 3. Another source of potential hot spot ponds are the many very small ponds and open pools within the bulrush sedge marsh area of Northern C and especially C/D. Most of these ponds are less than 0.1 ha in size and have not been sampled for WP. These small ponds are favorite loafing areas and to a lessor degree feeding areas, especially for mallards. I think it is more likely that these many small permanent ponds are a greater potential source of WP poisoning than the intermittent ponds (CMC)

Michael R. Walsh, PE
Mechanical Engineer
Engineering Resources Branch

Charles M. Collins
Research Physical Scientist
Geological Sciences Division

CEPOA-EN-G-MI (200-c) 20 Aug 97

MEMORANDUM FOR CEPOA-EN-EE-AI

SUBJECT: Contract Number DACA85-95-D-0015, Order Number 1, Draft Final Feasibility Study, Operable Unit C, Fort Richardson, Alaska

1. Reference Memorandum CEPOA-EN-EE-AI dated 15 Jul 97, subject as above.

2. Review comments are enclosed.

3. Questions should be addressed to Willard Ferrell, x-2691.

encl

DELWYN F. THOMAS
Chief, Geotechnical Branch

D-0015 DO#1: ERF OPU C at FORT RICHARDSON. ALASKA - Draft Final

File: 0015ERF.DBF

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-544	FERRELL	EN-G-MI	INH	intro 1-5	1.3.1	1

The second paragraph seems to consider dabbling ducks as a species. Dabbling refers or to feeding habits of several waterfowl species. Species is a biological term referring to genetics of interbreeding groups. Mallard is name of one from many duck/waterfowl species that indulge in the practice of dabbling.

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-545	FERRELL	EN-G-MI	INH	6-2	bullet	2

Editorial

Under the first bullet magnitude of risk. Heterogenous White Phosphorus seems like a misnomer. White phosphorous is basically one "breedof" contaminant. The White Posphorus variability of contaminant level and location seems to be the problem for characterization.

Most chemistry books define sublimination as the changing of phase directely from solid to gas without formation of liquid from melting. White/yellow phosphorous (P4) is considered a flammable solid. The molecule (P4) does not exist as a gas. Sublimation / volatilization does not take place.

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-546	FERRELL	EN-G-MI	INH	B-11		3

The alteration of waterfowl habitat may be exarbated by the fact that the vegetation growing season is the same as the most significant drying season. Significant loss of vegetative growth, if such occurs, will be for essentially a full growing season. The greatest waterfowl impact will be during the fall usage period because need for, use of, availability of food, and resting area follows the drying/growing. Loss of the short growing season may cause significant, probably temporary, loss of suitable waterfowl habitat.

HTRW-CX COMMENT TRANSMITTAL

08/11/97

Comments Transmitted to	Commander, Alaska District
Attention	CEPOA, Joann Walls
Submittal #	004770 · 64967
Action	Comments are transmitted with this record.
Project Information — Location	Fort Richardson
Site	Eagle River Flats
Project	Operable Unit C
Doc Title	Draft Final Feasibility Study Report, July 1997, Operable Unit C (OU-C), Eagle River Flats (ERF), Fort Richardson, AK.
Phase	Draft Final
Designed by	Ch2m Hill, Anchorage

DISCIPLINE	ACTION*	SIGNIFICANT OR UNRESOLVED TECHNICAL COMMENTS
Chemistry	NC	
Compliance	NC	
Cost Engineering	RCA	
Geotechnical	RCA	
Health & Safety	NC	
Health Physics	NT	
Innovative Tech	NC	
Process Engineer	NC	
Risk Assessment	NC	

REQUESTED ACTION	HTRW-CX Point of Contact
To further our understanding of the issues that affect this project and your district's execution, please provide this office a copy of annotated responses to comments made by your office, other agencies and interested parties.	KellieAnn Kachek Telephone: (402) 697-2630
	Transmittal of comments approved by:
	Kenneth L. Gregg Ken L. Gregg, P. E. Chief, Environmental Studies and Liaison Branch

*NC = Reviewed; No Comments
NT = No tech involvment
RCA = Reviewed, Comments Attached
CT = Conferred/Deferred to District Counterpart
SCA = Reviewed w/Significant Comments attached

[X] CEPOA-EN-EE-AI Joann Walls
[ ] POD
[ ] CENWO-HX-S Kellieann Kachek
CENWO-HX-S (Files)

64967: Operable Unit C at Fort Richardson, AK. - Draft ...

File: 64967MRD.DBF

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
1531067-129	MELLEMA	CENWO-HX-G	GEO	General		

In general, the report is well written and documented. However, the report is fairly biased regarding the use of "Aquablok." "Aquablok" is primarily used to line pond bottoms to prevent leakage through the underlying soils, by sealing the pond bottom with bentonite. The report states that the objective is to reduce exposure pathways for the waterfowl which may ingest WP. A plan to install a horizontal blanket of sand or gravel was briefly looked at (Table B-2), and appears promising, less expensive, etc., but was rejected only because it has not been tested at ERF, and because "Aquablok" had been selected. -- Highly recommend that this alternative be looked at again in further detail.

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
1531067-130	MELLEMA	CENWO-HX-G	GEO	General		

64967: OU-C at FT Richardson, AK - Draft Final FS

File: 64967RLO.DBF

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
8599854-246	OSBORN	CEMRO-HX-T	EST	General		

1.) The cost estimates shown for the alternatives are adequate for "order of magnitude" type estimates in that notes and assumptions for costs are documented. In the event that Alternative 2,3,4 or 5 is chosen, a detailed cost estimate for the project needs to done using the HTRW Work Breakdown Structure (WBS). ER 1110-1301, dated 15 April 94, requires in paragraph 8.b.(1), "Cost estimates for HTRW remedial action shall use the latest HTRW remedial action work breakdown structure (RA-WBS)..." The latest HTRW RA-WBS and O&M WBS was distributed to USACE offices in February 96. Structuring cost estimates using these documents helps to insure that remedial action and operation and maintenance cost estimates are standardized, complete and that cost engineering offices are involved in the preparation or review of the estimates.

2.) The unit of measure of costs for Bulldozer, Front-end Loader and Dump truck shown in the list of equipment differ from that used in the estimate. The list shows "per hour" and the estimates shows "per day". Considering the rate used for each it seems that the "per day" unit of measure is correct as per the estimate details. For future estimates the list should be changed to match the detail estimates.