Supplemental Feasibility Study
Holden Mine Site
Chelan County, Washington

Prepared by
USDA Forest Service

In Cooperation with
US Environmental Protection Agency and
Washington State Department of Ecology

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SUPPLEMENTAL FEASIBILITY STUDY
HOLDEN MINE SITE
CHELAN COUNTY, WASHINGTON

EXECUTIVE SUMMARY

This document is the Supplemental Feasibility Study (SFS) for selection of a cleanup action for the Holden Mine Site (Site). This SFS has been prepared by the USDA Forest Service (Forest Service) along with the Washington State Department of Ecology (Ecology) and the U.S. Environmental Protection Agency (EPA), (collectively referred to as the Agencies).

The Holden Mine is an inactive hard rock mine located in the Railroad Creek valley on the eastern slopes of the Cascade Mountains in Washington State, approximately 10 miles upstream (west) of Lake Chelan. The Site includes the Holden Mine and all areas impacted by hazardous substances associated with it. The Site is situated within the Wenatchee National Forest and is surrounded on three sides by the Glacier Peak Wilderness Area. Figure 1 (presented following the main text of the SFS) shows the vicinity of the Site. Figure 3 shows principal features of the former mine area of the Site.

Background

Holden Mine was an underground copper mine that was operated by the Howe Sound Mining Company from 1938 to 1957. The Agencies have determined that the past mining operations at the Site have resulted in an ongoing release of hazardous substances from the Site, and an appropriate response action is required under both federal and state law.

There are adverse water quality impacts in groundwater beneath the Site, in seeps discharging to Railroad Creek, and in surface water (Railroad Creek and Copper Creek). High concentrations of metals have reduced populations of fish and aquatic macroinvertebrates in Railroad Creek adjacent to and downstream of the mine. Groundwater, soils, and mine tailings have concentrations of hazardous substances that exceed criteria for protection of human health and terrestrial environmental receptors. In the absence of a complete cleanup action, the release of hazardous substances is anticipated to continue for hundreds of years.

In 1993, the Agencies identified and named Alumet Corporation (a successor in interest to Howe Sound) as a potentially responsible party (PRP) for the Holden Mine cleanup action, under the federal Comprehensive Environmental

Response, Compensation and Liability Act (CERCLA) Section 117(a) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR § 300.430(f)(2).[1] On April 11, 1998, Alumet and the Agencies entered into an Administrative Order on Consent/Agreed Order (AOC) to accomplish a remedial investigation and feasibility study (RI/FS) for cleanup of the Site. Alumet completed a Draft Remedial Investigation (DRI) report (Dames & Moore 1999). Alumet Corporation subsequently merged into Intalco Aluminum Corporation and is hereafter referred to in this document as Intalco. Intalco prepared a Draft Final Feasibility Study (DFFS, URS 2004a).

The Agencies reviewed the DFFS and found it was deficient (Forest Service 2007a). The Agencies determined that none of the alternatives presented in the DFFS would meet the threshold requirements[2] for a final remedy under CERCLA or MTCA. Subsequently, both Intalco and the Agencies developed additional alternatives (Alternatives 9, 10, 11, and 12, as described in this document). This SFS is a modification of the Draft Final Feasibility Study (DFFS), prepared by

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[1] Alumet was also named as a potentially liable person (PLP) under Washington State's Model Toxics Control Act (MTCA), WAC 173-340-600(14).

[2] The threshold requirements are the criteria specified in CERCLA [40 CFR 300.430(f)(1)(i)(A)] and MTCA [WAC 173-340-360(2)(a)] that must be satisfied for a remedial alternative to be selected as the final cleanup remedy for a site. The CERCLA threshold criteria for remedy selection are 1) overall protection of human health and the environment and 2) compliance with ARARs [except when an ARAR is waived, as allowed under 40 CFR § 300.430(f)(1)(ii)(C)]. ARARs refer to applicable, or relevant and appropriate requirements.

- Applicable requirements mean those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at the CERCLA site. Under CERCLA, only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable [40 CFR § 300.5].
- Relevant and appropriate requirements mean those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate [40 CFR § 300.5].

Applicable, or relevant and appropriate requirements are similarly defined under MTCA [WAC 173-340-710].

The threshold requirements for selecting a cleanup remedy under MTCA include that the remedy: 1) protect human health and the environment; 2) comply with cleanup standards; 3) comply with applicable state and federal laws; and 4) provide for compliance monitoring. The threshold requirements are further described in Sections 4.1.2 and 4.1.5.1 of this SFS.

Intalco. The Agencies prepared the SFS to address the deficiencies of the DFFS, as provided for in Paragraph 36 of the Administrative Order on Consent.[3]

This document modifies the DFFS by:

- Presenting information omitted from the DFFS;
- Restating the remedial action objectives (RAOs);
- Describing four additional remedial alternatives; and
- Evaluating the four additional remedial alternatives.

Each of these areas is discussed in the SFS.

In addition to differences in the degree to which Alternatives 9 through 12 satisfy the threshold requirements under CERCLA and MTCA, the SFS provides analyses of the degree to which each alternative satisfies the other requirements for remedy selection. These analyses show that Alternative 11 satisfies all the requirements for remedy selection, and that Alternatives 9, 10, and 12 do not satisfy all the requirements. The SFS also includes a number of technical appendices that support the analysis of alternatives.

Cleanup Alternatives Addressed in the DFFS and SFS

The DFFS presented Alternatives 1 through 8, including subalternatives. These alternatives included two principal types of remedial measures:

- Removal or capping of contaminated soils, mine tailings and waste rock to varying degrees to prevent exposure to humans and/or terrestrial receptors; and
- Containment, collection, and treatment of groundwater to varying degrees, to reduce release of hazardous substances into surface water.

None of the DFFS alternatives addressed all the sources of hazardous substances, and all relied to some degree on source depletion and natural

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[3] 1998 Holden Mine Site Administrative Order on Consent/Agreed Order for Remedial Investigation/ Feasibility Study between Alumet Corporation (now Intalco) and the Agencies, USDA Forest Service Docket No. 06-97-01.

attenuation to cleanup the Site.[4] The Agencies' review of the DFFS concluded that none of Alternatives 1 through 8 would meet the threshold criteria for selection of a permanent remedy under CERCLA and MTCA (Forest Service 2007a). As a result, the Agencies proposed a new alternative be considered, that was referred to as the Agencies' Proposed Remedy (Alternative 10).[5] Alternative 10 combined elements of some of the alternatives described in the DFFS and included a partially penetrating barrier to contain groundwater for collection and treatment. The Agencies presented Alternative 10 to the NRRB.

Intalco subsequently developed Alternative 9 (URS 2005e), which consisted of DFFS Alternative 3b, combined with pumping from wells and seeps to clean up groundwater from below a limited area of Tailings Pile 1.

After meeting with the NRRB and reviewing the NRRB's comments, and after meeting with Intalco and Holden Village Inc., the Agencies concluded that none of Alternatives 1 through 9 would meet the threshold criteria for selection of a cleanup action [40 CFR § 300.430(9) and WAC 173-340-360(2)], and that available information was not sufficient to demonstrate that Alternative 10 would satisfy the threshold requirements. Therefore, none of these remedies qualify as a final remedy. Accordingly, the Agencies developed Alternative 11 by combining elements of the earlier alternatives to create a proposed remedy that they believe will satisfy the CERCLA and MTCA threshold criteria.

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[4] Source depletion refers to the depletion of the major source of contamination at the Site: the chemical oxidation of sulfide minerals in rock within the underground mine, tailings, and waste rock. Oxidation of the sulfide minerals releases metals and produces acidic conditions that increase solubility of the metals in groundwater at the Site. Over time, as the sulfide minerals and resulting contamination enter the environment, the quantity of remaining sulfide minerals available to cause future contamination will decrease and the ongoing release of acidic drainage and metals to groundwater will diminish. However, this source depletion of sulfide minerals does nothing to mitigate the maximum potential adverse effects of metals already or continuing to be released to the environment. Similar to allowing a barrel of waste to leak until empty, relying on source depletion is a "no action" approach. In contrast, natural attenuation processes "include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater" (EPA 1999). For metals at the Site, these natural attenuation processes may include dispersion, dilution, and sorption, although these processes have not been quantified in the DRI or the DFFS.

Neither CERCLA nor MTCA allow a remedy to rely on source depletion. CERCLA and MTCA allow an alternative to include natural attenuation provided certain conditions are met [EPA 1999, WAC 173-340-200, WAC 173-340-370(7)]. However, none of the DFFS alternatives satisfied these conditions, as discussed in the SFS.

[5] The Agencies' Proposed Remedy was previously referred to as the APR but is hereafter referred to as Alternative 10. Intalco has referred to Alternative 10 as the 2005 APR, to distinguish it from a previous Agency proposed alternative (APA) discussed after submittal of the first draft FS in June 2002. Intalco modified the APA and presented the modified APA as Alternative 6 in the DFFS.

The DFFS presented Alternative 1 as the "No Action/Institutional Controls" alternative. The Agencies noted Alternative 1 did not satisfy CERCLA criteria for a "no action" alternative. Accordingly, the Agencies have added a no action alternative, Alternative 12, to meet CERCLA requirements. The no action alternative relies solely on natural attenuation and source depletion.

Alternatives 9 through 11 have a number of elements in common (including treatment technologies, engineering controls, institutional controls, and monitoring requirements) that are discussed in detail in this SFS. Features that distinguish these alternatives from one to another affect the degree to which each alternative would satisfy the RAOs and achieve the proposed cleanup levels.

Principal elements of Alternatives 9, 10, 11, and 12 are summarized below.

Alternative 9

Alternative 9 includes diversion of surface water run-on upgradient of the waste rock piles, former mill building, and tailings piles, as well as a groundwater barrier and collection system located immediately north of the former mill and the main waste rock piles in the Upper West Area (UWA). Flow from the main 1500 Level portal of the mine would be controlled with hydrostatic bulkheads so drainage from the underground mine could be collected for treatment. Groundwater collected from the UWA, along with contaminated seeps downgradient of the area referred to as Honeymoon Heights would be treated along with discharge from the mine, using acid neutralization and precipitation prior to discharge to Railroad Creek. Intalco proposed locating this treatment facility in the Lower West Area (LWA) of the Site, northwest of the abandoned mill.

Alternative 9 also includes installation of four pumped wells for groundwater extraction below Tailings Pile 1 (TP-1) and a seep interception system to collect flow from seeps SP-1 and SP-2 that discharge groundwater from the north side of TP-1 into Railroad Creek. Except for the wells and seep collection noted above, Alternative 9 is the same as the DFFS Alternative 3b. Alternative 9 would rely on source depletion and natural attenuation to reduce releases of metals to groundwater and surface water from the LWA, a portion of TP-1, and all of TP-2 and TP- 3. Alternative 9 would include limited regrading and revegetation of portions of the tailings piles to reduce erosion and potential for massive slope failures, but this would not include all of the tailings or closure in accordance with potential ARARs.

Alternative 10

Alternative 10 includes installation of a partially penetrating groundwater barrier and collection system in the LWA along Railroad Creek from the existing main 1500 Level portal discharge point into Railroad Creek to the Copper Creek Diversion, and along both TP-1 and TP-3, adjacent to Railroad Creek.[6]

Alternative 10 also included collection and treatment of discrete seeps, SP-3 and SP-4, on the northern edge of TP-2. Alternative 10 would not include the collection and treatment of groundwater below TP-2 but would rely on source depletion and natural attenuation pending additional monitoring to determine whether the remedy is protective.

Alternative 10 also includes a terrestrial ecological risk assessment (ERA) to determine the final soil cleanup requirements and the extent of soil clean up required in the LWA and north of Railroad Creek.

Alternative 10 would include regrading approximately 580,000 cubic yards of tailings and 160,000 cubic yards of waste rock to improve stability of these piles, as well as closure of the waste rock and tailings piles through placement of a soil cap to support vegetation.

During regrading, the tailings slopes would be pulled back from Railroad and Copper Creeks so that the toe of slope is set back from the normal high water mark to improve flood protection along the creeks. Alternative 10 included this setback to provide room for a flood protection berm to be constructed adjacent to the creek, revegetation, a groundwater collection ditch, and an access road for construction, maintenance, and monitoring along the toe of the regraded tailings slopes.

Alternative 11

Alternative 11 will contain, collect and treat all the identified sources of groundwater that exceed proposed cleanup levels and would otherwise enter Railroad or Copper Creeks along the LWA and the three tailings piles. The barrier would prevent the release of contaminated groundwater into the creeks, thereby improving surface water quality to protect aquatic life.

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[6] Unlike Alternatives 9 and 11, which include fully penetrating groundwater barriers (keyed into glacial till or bedrock below the surficial aquifer), Alternative 10 includes a groundwater barrier that penetrates only part of the saturated thickness of the shallow aquifer in the Railroad Creek Watershed. A detailed hydrologic analysis of the effectiveness of this partial barrier is included in Appendix F of the SFS.

Alternative 11 includes regrading the tailings piles and moving the edge of the piles away from the Railroad and Copper Creeks to reduce the risk of releasing wastes into the creek from future slope failures. Alternative 11 includes removal of the Honeymoon Heights Waste Rock Piles and removal or capping impacted soils in other areas. Alternative 11 will close existing tailings and waste rock piles by capping them in accordance with state landfill standards [WAC 173-350-400] to protect human and terrestrial ecological receptors and reduce impacts to groundwater and surface water. The cap would consist of 2 feet of soil and a geomembrane (the presumptive cover prescribed by state regulations), unless analyses during remedial design indicates an alternative cover would satisfy performance standards in the regulations [WAC 173-350-400(3)(e)(i)].

Alternative 11 includes removal of ferricrete from Railroad Creek. Alternative 11 also includes additional terrestrial ERA to determine the final soil cleanup requirements and the extent of soil cleanup required in the LWA and north of Railroad Creek. Results of the terrestrial ERA may also enable modification of the proposed covers for the tailings and waste rock piles.

Alternative 12

The NCP requires a "no action alternative" to be developed and considered in the analysis of the developed alternatives [40 CFR § 300.430(e)(6)]. No institutional controls, treatment technology, or engineering controls would be used to prevent the release of hazardous substances under this alternative.

Alternative 12 would leave the Site untouched. Under this alternative, groundwater and surface water would continue to flow into Railroad Creek without collection and treatment, and contaminated soils would remain in place. Releases of metals into groundwater and surface water would slowly decrease over time through source depletion and natural attenuation. Metals concentrations in the tailings are expected to decrease over time as a result of source depletion and groundwater transport. Metals concentrations in soils may decrease over time due to natural attenuation, but the effect of this on bioavailibility and protectiveness of human health and the environment has not been assessed in the DRI or DFFS.

Comparative Analysis of Alternatives 9, 10, 11, and 12

Initial implementation of Alternatives 9, 10, and 11 would consist of activities such as constructing a groundwater collection and treatment system, closure of the tailings and waste rock piles, and/or consolidation and capping of contaminated soils, etc. Thereafter, these alternatives would include: a) long-term operation and maintenance of a water treatment facility and b) monitoring to determine whether the remedy is effective and to assure that no future changes in Site conditions would adversely impact human health or the environment.

The SFS discusses the degree to which Alternatives 9 through 12 would or would not satisfy the CERCLA and MTCA criteria for remedy selection. Alternatives 9, 10, 11, and 12 differ significantly in the degree to which they would meet the threshold requirements to protect human health and the environment, and to comply with potential ARARs. The basis for these differences is discussed in detail in the SFS.

Protection of Human Health

Alternatives 9 through 12 differ in the degree to which they are protective of human health.

- Alternatives 9 through 11 would protect humans from exposure to contaminated groundwater as potential drinking water through the use of institutional controls.

- However, Alternatives 10 and 11 would protect human health from risk of exposure to mine tailings to a greater extent than Alternative 9, through consolidation and capping all the existing, exposed tailings.

- Alternative 12 would not protect human health.

Protection of the Environment

Alternatives 9 through 12 differ significantly in their ability to be protective of the aquatic environment.

- Alternative 11 would provide more protection of aquatic life than the other alternatives. Alternative 11 would directly intercept (contain) and collect for treatment all the groundwater above proposed cleanup levels that discharges into Railroad Creek. Containment and collection for treatment would begin immediately after implementation, without relying on source depletion and natural attenuation. Alternative 11 would clean up groundwater where it enters surface water, at the point of compliance, rather than relying on upgradient source depletion and natural attenuation or downstream mixing. Alternative 11 includes removal of ferricrete in Railroad Creek, and monitoring to determine whether additional sediment actions are needed in the future.

- Alternative 10 would immediately address contaminated releases to Railroad Creek from most, but not all, of the Site. Alternative 10 could be implemented as an interim remedy, but additional actions would be needed to satisfy requirements for a final remedy. There is some uncertainty regarding the effectiveness of the PPB wall proposed for Alternative 10, and the effectiveness of the tailings pile and waste rock closure would need to be verified during RD. Alternative 10 includes removal of ferricrete in Railroad Creek, and monitoring to determine whether additional sediment actions are needed in the future.

- Alternative 9 does not stop the release of contaminated groundwater into Railroad Creek from TP-2 and TP-3, part of TP-1, and the LWA. Alternative 9 relies on source depletion and natural attenuation to clean up these areas, which means these sources of groundwater discharging into Railroad Creek would continue to exceed aquatic life protection criteria for hundreds of years. Alternative 9 does not include removal of ferricrete in Railroad Creek, or monitoring to determine whether additional sediment actions are needed in the future.

- Alternative 12 would not stop the release of any contaminated groundwater into Railroad Creek. By relying on source depletion and natural attenuation, Alternative 12 would leave Railroad Creek to continue to exceed aquatic life protection criteria for hundreds of years. Alternative 9 does not include removal of ferricrete in Railroad Creek, or monitoring to determine whether additional sediment actions are needed in the future.

Alternatives 10 and 11 would do more to protect Railroad and Copper Creeks from a potential massive release of reactive tailings compared to Alternatives 9 and 12.

- Alternatives 10 and 11 include regrading all the tailings pile slopes to improve stability and setback of the toe of the slopes to provide protection from erosion and scour.

- Alternative 9 does not include any regrading of TP-3, and does not include any setback of the toe of slope from the creeks.

- Alternative 12 would not reduce the risk of a massive release of tailings into Railroad or Copper Creeks.

The alternatives also differ significantly in the degree to which they would protect terrestrial ecological receptors.

- Alternative 11 provides greater assurance of reducing terrestrial toxicity risks through closure of all the tailings piles and waste rock piles in accordance with potential ARARs. Soils contaminated with hazardous substances would be consolidated and capped, or otherwise addressed as appropriate based on additional terrestrial ERA.

- Alternative 10 may protect terrestrial ecological receptors from exposure to the tailings; however, the protectiveness of the Alternative 10 covers has not yet been demonstrated. Soils contaminated with hazardous substances would be consolidated and capped, or otherwise addressed as appropriate based on additional terrestrial ERA.

- Alternative 9 only includes limited regrading and covering of newly exposed slopes on TP-1 and TP-2. Alternative 9 does not address the waste rock piles, most of the tailings piles, or soils contaminated with hazardous substances north of Railroad Creek.

- Alternative 12 would not be protective of terrestrial receptors.

Compliance with ARARs

Alternatives 9, 10, 11, and 12 differ significantly in their ability to meet potential ARARs, as discussed in the SFS.

- Alternative 11 is anticipated to satisfy all potential ARARs.

- Alternative 10 cannot be shown to satisfy potential chemical-specific ARARs, and potential ARARs related to management of aquatic lands and closure of landfills, on the basis of existing information.

- Alternative 9 would not satisfy potential chemical-specific ARARs and potential ARARs related to closure of landfills, construction stormwater pollution prevention, management of aquatic lands, protection of wetlands, protection of floodplains, and forest management standards.

- Alternative 12 would not satisfy potential ARARs.

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ACRONYMS AND DEFINITIONS

ACS	Aquatic Conservation Strategy
Agencies	USDA Forest Service, acting with the Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology)
AHRA	Archaeological and Historic Preservation Act
AOC	Administrative Order on Consent
AKART	All Known, Available, and Reasonable Methods of Treatment, as referenced in the MTCA regulations [e.g., WAC 173-340-200 (within definition of "All practicable methods of treatment") and WAC 173-340-720(8)(d)]. Note that other state regulations use AKART to refer to All Known, Available, and Reasonable Methods of Prevention, Control, and Treatment [e.g., WAC 173-201A-020], and this definition is also applicable to the Site.
AMD	acid mine drainage
APR	Agencies' Proposed Remedy
ARAR	Applicable, or Relevant and Appropriate Requirement
ARD	acid rock drainage
BLM	United States Department of the Interior, Bureau of Land Management.
BMP	Best Management Practice
CAA	Clean Air Act
CAP	Cleanup action plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act [42 USC §§ 9601-9675]
CFR	Code of Federal Regulations
CWA	Clean Water Act
cy	cubic yards
DFFS	Draft Final Feasibility Study (URS 2004)
DRI	Draft Remedial Investigation report (Dames & Moore 1999)
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
ESA	Endangered Species Act
ESD	Explanation of Significant Differences

Ferricrete	A cemented deposit of iron oxide precipitate that forms in stream channel sediments as a result of the release of iron sulfates and other hazardous substances.
FS	Feasibility Study. For the Holden Mine Site the FS consists of the Draft Final Feasibility Study (DFFS, URS 2004) and Intalco's Description of Alternative 9 (URS 2005) as modified and supplemented by the Agencies' Comments on the Draft Final Feasibility Study for Holden Mine (Forest Service 2007a) and the Agencies' Comments on Intalco's Alternative 9 Description (Forest Service 2007c), together with the Supplemental Feasibility Study (SFS, Forest Service 2007b).
FSQV	Freshwater Sediment Quality Values
gpm	gallons per minute
GRA	general response action
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
LBI	Lutheran Bible Institute
LRMP	Wenatchee National Forest Land and Resource Management Plan
LWA	Lower West Area
MBTA	Migratory Bird Treaty Act
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MGY	million gallons per year
Mining Claims	Portions of public lands claimed for possession of locatable mineral deposits by locating and recording under established rules and pursuant to the 1872 Mining Law.
MNA	Monitored Natural Attenuation
MSHA	Mine Safety and Health Administration
MTCA	Model Toxics Control Act [RCW 70.105D.010-.921]
NCP	National Oil and Hazardous Substances Pollution Contingency Plan [40 CFR Part 300]
NFMA	National Forest Management Act
NHPA	National Historic Preservation Act
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List

NPV	Net Present Values
NRDA	Natural Resource Damage Assessment
NRHP	National Register of Historic Places
NRRB	National Remedy Review Board
NTR	National Toxics Rule
NWFP	Pacific Northwest Forest Plan
NWQC	National Recommended Water Quality Criteria
O&M	Operations and Maintenance (also sometimes referred to as OMM, Operations, Maintenance and Monitoring)
PCB	Polychlorinated Biphenyl, a toxic chemical
PLP	Potentially liable party
Portal	Entrance to an underground mine. Holden Mine has eight portals (300, 550, 700, 800, 1000, 1100, and 1500 Level portals and the 1500 Level Ventilator Portal). The 1500 Level portal is typically referred to as the Main Portal.
PPB	partially penetrating barrier
PRG	preliminary remediation goal
PRP	Potentially responsible party
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RI	Remedial Investigation
ROD	Record of Decision
SDWA	Safe Drinking Water Act
SEPA	State Environmental Policy Act [Chapter 43.21C RCW]
SFS	Supplemental Feasibility Study (Forest Service 2007b).
Site	Holden Mine Site
SMA	Shoreline Management Act
SPCC Plan	Spill Prevention, Control, and Countermeasure Plan
Tailings	Fine-grained waste materials from an ore-processing operation
TBC	to-be-considered (criteria)
TCLP	Toxicity Characteristic Leaching Procedure
TP-1, TP-2, and TP-3	Tailings Pile 1, Tailings Pile 2, and Tailings Pile 3, respectively

TPH	Total Petroleum Hydrocarbons
USFWS	US Fish and Wildlife Service
UWA	Upper West Area
WAC	Washington Administrative Code
WARM	Washington Assessment and Ranking Method
Waste Rock	Rock with no commercial value that is removed from the earth during mining.
WSDFW	Washington State Department of Fish and Wildlife
WMA	Waste Management Act

SUPPLEMENTAL FEASIBILITY STUDY
HOLDEN MINE SITE
CHELAN COUNTY, WASHINGTON

1.0 INTRODUCTION

This document is the Supplemental Feasibility Study (SFS) for the Holden Mine Site[7] (Site). The Site is an inactive hard rock mine located in the Railroad Creek valley on the eastern slopes of the Cascade Mountains in Washington State, approximately 10 miles upstream (west) of Lake Chelan. The Site is situated within the Wenatchee National Forest and is surrounded on three sides by the Glacier Peak Wilderness Area. Figure 1 is a Vicinity Map. This SFS has been prepared by the USDA - Forest Service (Forest Service, also referred to as the Lead Agency) along with the Washington State Department of Ecology (Ecology) and the U.S. Environmental Protection Agency (EPA) (collectively referred to as the Agencies).

This SFS is a modification of the Draft Final Feasibility Study (DFFS), prepared by Intalco (URS 2004a), and has been prepared to address the deficiencies of the DFFS, as provided for in Paragraph 36 of the Administrative Order on Consent.[8] This document modifies the DFFS by:

- Presenting information omitted from the DFFS;
- Restating the remedial action objectives (RAOs);
- Describing four additional remedial alternatives; and
- Evaluating those additional remedial alternatives.

1.1 Purpose and Organization

Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Washington State Model Toxics Control Act (MTCA), the

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[7] The Site includes the Holden Mine and all areas impacted by hazardous substances released from the Holden Mine. Holden Mine refers to all areas of operation of the Holden Mine and sources of hazardous substances as a result of mining.

[8] 1998 Holden Mine Site Administrative Order on Consent/Agreed Order for Remedial Investigation/ Feasibility Study between Alumet Corporation (now Intalco) and the Agencies, USDA Forest Service Docket No. 06-97-01.

Feasibility Study[9] (FS) serves as the mechanism to develop and evaluate remedial alternatives. This document follows both federal and state guidance on CERCLA and MTCA including *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final* (EPA 1988a), provisions of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) [40 Code of Federal Regulations [CFR] Part 300], and the MTCA Cleanup Regulation [Chapter 173-340 Washington Administrative Code (WAC)].

MTCA is being implemented both independently and as a source of potential applicable or relevant and appropriate requirements (ARARs) under CERCLA. Thus, the remedial alternatives evaluated must meet the requirements of both CERCLA and MTCA to be considered for implementation. For clarity, this SFS primarily refers to CERCLA throughout. For the most part, the CERCLA and MTCA feasibility study processes are similar. Where there are differences between CERCLA and MTCA, these differences are identified in this document.

The FS is only part of the remedy selection process. The FS develops and evaluates a range of remedial alternatives and provides information needed to formulate a Proposed Plan. The Proposed Plan identifies the "preferred alternative." Following public and stakeholder review and input on the Proposed Plan, a remedy is selected and documented in a Record of Decision (ROD). The selected remedy documented in the ROD then forms the basis for remedial design (RD) and subsequent remedy construction, termed remedial action. The FS supports the remedy selection process. The FS does not recommend or choose a preferred alternative, and the FS does not select or design a remedy. The FS process and its relationship to the Proposed Plan and ROD are summarized on Figure 2.

The alternatives developed in the FS are not mutually exclusive choices. The selected remedy, as developed in the ROD, can mix, modify, refine, or add to the elements of the various alternatives developed in the FS. Although the FS supplies information for helping select a remedy, additional information may be incorporated into the remedy selection process at any time.

To achieve its purpose, an FS should accomplish the following tasks:

- Integrate and interpret information from the Remedial Investigation (RI), the Human Health Risk Assessment (HHRA), and the Ecological Risk Assessment

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[9] The Feasibility Study for the Site will consist of five documents: the DFFS (URS 2004a), Intalco's Alternative 9 Description (URS 2005b), Agency comments on the DFFS (Forest Service 2007a), Agency comments on Intalco's Alternative 9 Description (Forest Service 2007b), and this SFS.

(ERA) to determine whether and where remedial actions may be necessary to protect human health and the environment;

- Identify potential ARARs;

- Propose remedial action objectives (RAOs) based on potential ARARs and preliminary remediation goals (PRGs)[10];

- Develop remedial action alternatives that will achieve the RAOs; and

- Evaluate the alternatives using the first seven of the nine CERCLA and NCP criteria[11] and, in this case, the MTCA criteria.

This SFS presents a description of the Site and a summary of information set forth in more detail in the RI and DFFS. The SFS also modifies some of the information provided in the DFFS and provides additional information not included in the DFFS.

The DFFS identified potential ARARs and RAOs for the Site. The RAOs that were previously developed for scoping the DFFS are restated in this SFS with some modification.

The DFFS identified, screened, and in some cases eliminated, remedial technologies based on technical applicability, effectiveness, implementability, and relative cost. Using the results from the remedial technology screening, the DFFS developed, screened, and evaluated a number of remedial alternatives, representing a range of options for potential cleanup actions. The DFFS evaluated Alternatives 1 through 8, including various subalternatives (e.g., Alternative 5 included subalternatives 5a, 5b, 5c, and 5d).

This SFS presents four alternatives not included in the DFFS, referred to as Alternatives 9, 10, 11, and 12. For the most part, these additional alternatives

[10] Final ARARs, RAOs, and remediation goals are officially established in the ROD.

[11] The remaining two CERCLA criteria are state and community acceptance. For the Site, the State of Washington, represented by Ecology, is a co-regulator. Ecology is implementing MTCA concurrently with the implementation of CERCLA by the Forest Service and EPA. Thus, state acceptance is more integrated with the CERCLA process at this Site than at other sites. Community acceptance is addressed in the ROD as part of remedy selection, which follows public review of the preferred alternative to be identified in the Proposed Plan.

use remedial technologies described in the DFFS.[12] Intalco submitted Alternative 9 for consideration after the DFFS was completed. The Agencies developed Alternatives 10 and 11 after completion of the DFFS. Alternative 12 is a "no action" alternative, which must be considered under the NCP [40 CFR § 300.430(e)(6)]. Details regarding the evolution of Alternatives 9, 10, 11, and 12 are provided in Section 3 of this document. These four additional alternatives are evaluated in this document using the criteria for remedy selection specified in CERCLA [42 USC § 9601 et seq.] and MTCA [Chapter 70.105D RCW] and are consistent with the evaluation process used in the DFFS.

1.2 Background Information

Details regarding current Site use, physical characteristics of the Site, contaminant fate and transport, and other aspects of the nature and extent of contamination are presented in the DRI and DFFS, and are summarized below.

1.2.1 Site Description

The former mine area of the Site (i.e., tailings piles, former mill building and adjacent waste rock piles, Main Portal, etc.) covers about 125 acres. The Site also includes the Railroad Creek drainage to Lake Chelan, Holden Village, and outlying areas impacted by historical mining (e.g., Honeymoon Heights) and an identified depositional area of wind-blown tailings. Figure 3 shows principal features of the Site. Figure 4 shows sampling locations near the former mine operations.

Holden Mine included an underground mine and a mill building operated by the Howe Sound Company (Howe Sound) from 1938 through 1957, producing copper, zinc, gold, and silver. Howe Sound dumped more than 300,000 cubic yards (cy) of waste rock, produced from tunneling to create access to the ore body, on slopes adjacent to the mill building. Other smaller waste rock piles are located near adits in Honeymoon Heights.

Although not mined as ore, the waste rock contains sulfide minerals that release acid and metals as a result of chemical reactions with oxygen and water. During the RI, samples of seepage from the toe of the East and West Waste Rock Piles and seepage downslope of the Honeymoon Heights Waste Rock Piles had

[12]An exception is Alternative 9, proposed by Intalco, which uses groundwater extraction wells as part of the remedy. Groundwater extraction wells were one of the technologies screened out of the DFFS, which was prepared by Intalco.

concentrations of several metals above state and federal chronic toxicity water quality criteria for the protection of aquatic life.

Howe Sound placed tailings from ore processed in the mill in three large piles (totaling approximately 8.5 million tons of tailings), covering an area of about 90 acres. These tailings piles (identified as TP-1, TP-2, and TP-3) are located south of and adjacent to Railroad Creek, which runs through the Site and drains into Lake Chelan, a pristine water body and Washington's largest natural lake.[13]

Tailings are soil-like waste material, and the tailings currently exposed at the Site contain hazardous substances above MTCA criteria for protection of human health based on direct contact and ingestion, and MTCA ecological protection screening levels. The Forest Service placed an interim soil/gravel cover over most of the tailings piles surfaces in 1989-91 to reduce potential erosion, and subsequently attempted to revegetate the piles. However, the cover was not complete, and erosion has subsequently uncovered some areas of the tailings that were covered, leading to potential exposure for humans and other terrestrial ecological receptors. The tailings piles have remained mostly barren with limited vegetative growth. Residents or visitors to Holden Village occasionally use portions of the tailings pile surface for recreational purposes (Frisbee golf), and Village facilities such as the sauna are located near areas of exposed tailings.

After mining operations ceased, the mine partially filled with water and water began to drain out the Main Portal. The Main Portal of the mine is an ongoing source of hazardous substance discharge from the mine into Railroad Creek. Drainage from the main portal annually varies from about 90 gallons per minute (gpm) in the fall to around 1,200 gpm (and occasionally higher) in the spring . A surge in contaminated water discharge occurred following underground collapse in 1970, which temporarily blocked the discharge from the main 1500 Level portal. Collapsed overburden dammed water flowing from the mine until the water pressure was sufficient to break the dam. The surge of water that was released eroded a portion of the main West Rock Pile and turbid water entered Railroad Creek. The force of the released water eroded a cut approximately 10

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[13] Tailings that are susceptible to erosion represent a source of hazardous substances (metals) into the creek, and erosion likely contributes to the overall exceedance of water quality criteria. Another risk to the aquatic environment is the potential for mass slope failures of the tailings piles, which contain soluble metals including aluminum, cadmium, copper, iron, lead, and zinc. The DRI (Dames & Moore 1999) reports several instances of tailings pile slope failures leading to releases prior to the Forest Service interim actions in 1989-91. In October 2003, erosion displaced an estimated 600 cy of tailings, some portion of which was released into Railroad Creek. Additional stabilization was required in 2006 to prevent ongoing release of tailings resulting from continued erosion of TP-1.

feet deep where it crossed the road by Holden Village's garage (Forest Service 1970a).

The Site is not listed on the National Priorities List (NPL). The Washington Assessment and Ranking Method (WARM) for hazardous sites, ranks the Site as a 1, representing the highest level of concern for Ecology.

Endangered species that may be at the Site include the gray wolf and the plants showy stickseed and Wenatchee Mountain checker-mallow. Threatened species that may be present include bull trout, Canada lynx, grizzly bear, marbled murrelet, northern spotted owl, and the plant Ute ladies' tresses.

1.2.1.1 Land Use

The Site is situated within the Wenatchee National Forest, with the Glacier Peak Wilderness generally bounding the Site to the west, north, and south. After mine operations ceased, Howe Sound transferred the patented and unpatented mining claims property and other assets to the Lutheran Bible Institute (LBI), which subsequently transferred the property to Holden Village, Inc. (a not-for-profit corporation). Holden Village is located immediately to the north of Railroad Creek directly across from Tailings Pile 1 (TP-1). Holden Village has operated since 1961 in conjunction with the Lutheran Church as an interdenominational religious retreat under a Special Use Permit issued by the Forest Service. All of the buildings in the village are located on National Forest System-managed land. Approximately 60 adults and children live at Holden Village year round. In addition, approximately 5,000 people visit the facility each year, each person staying an average of 2 to 7 days.

The Site is also accessible to recreational users of the National Forest. Hikers, backpackers, and horse packers can access the Site from Lake Chelan or the Glacier Peak Wilderness via the trail system. A hiking trail provides access from the mill building and maintenance yard area to Honeymoon Heights. In the fall of 2000, Intalco installed locking bat-friendly gates in the 300 and 1100 Level mine portals to prevent unauthorized persons from freely entering the underground mine. The rehabilitated 1500 Level main portal was fitted with locking steel doors to prevent underground access by unauthorized persons. The remaining portals have collapsed.

The area north of the abandoned mill, referred to as the maintenance yard, and the surface of the West Waste Rock Pile are currently used by Holden Village for equipment maintenance and storage of equipment and miscellaneous materials.

In addition, the residents and visitors to Holden Village, and/or recreational visitors to the National Forest use portions of the Site.[14] Intalco constructed a fence around the abandoned mill building in the fall of 2000 to restrict access based on concerns regarding potential physical hazards associated with the derelict condition of the structure.

1.2.1.2 Surface Water Use

The residents of Holden Village obtain their drinking water from Copper Creek upstream of the mine. Holden Village residents and visitors use Railroad Creek for recreational purposes, such as sport fishing. Approximately 10 miles east of the former mine, at the confluence of Railroad Creek and Lake Chelan, seasonal and potentially year-round residents consume water from Lake Chelan and/or Railroad Creek. Lake Chelan experiences substantial recreational use by visitors and residents of surrounding towns during the summer months.

The following are the designated beneficial uses of surface water (i.e., Railroad and Copper Creeks) at the Site (the use categories are in parentheses): aquatic life (salmonid spawning, rearing, migration, and core summer habitat), recreation (extraordinary primary contact), water supply (domestic, industrial, agricultural, and stock watering), and miscellaneous (wildlife habitat, harvesting, commerce and navigation, boating, and aesthetic values) [WAC 173-201A-600]. In addition, because the Site is within a National Forest, and because Railroad Creek is a feeder stream to Lake Chelan, WAC 173-201A-600(1)(a) requires that Railroad Creek also "be protected for the designated uses of: core summer salmonid habitat; and extraordinary primary contact recreation." Accordingly, cleanup levels for surface water at the Site must be protective of aquatic life, as well as human health and terrestrial receptors.

1.2.1.3 Groundwater Use

The only groundwater well currently used in or near the Site is in Lucerne at the mouth of Railroad Creek. This well provides water for drinking and other purposes and is used by seasonal Forest Service employees and visitors to the nearby campground and Forest Service cabin. Groundwater is not currently used for drinking or other purposes near the former mine operations. For water wells other than for public water supply, WAC 173-160-171(3)(b)(v) establishes a

[14] Holden Village maintains a small museum and a separate improvised basketball court adjacent to the abandoned mill building, a composting area adjacent to the toe of the East Waste Rock Pile, and a “Frisbee golf” course on TP-1. Hiking trails extend across the south side of the tailings piles and to the former adits in Honeymoon Heights.

minimum well setback of "one hundred feet from all. . .sources of or potential sources of contamination except for solid waste landfills. All public water supply wells must be located by the Department of Health or the local health authority [WAC 173-160-171(3)(c)].

Groundwater at the Site discharges to the local surface water bodies, Railroad Creek and Copper Creek. Thus, the beneficial use of Site groundwater is recharge to surface water (see surface water-designated beneficial uses in Section 1.2.1.2) and as a potential future drinking water supply. Washington groundwater protection regulations require the protection of existing and future beneficial uses of the groundwater through the reduction or elimination of discharge of contaminants [WAC 173-200-010]. Therefore, clean up of groundwater that enters Railroad Creek must be protective of human health, terrestrial receptors, and aquatic life. CERCLA and MTCA both provide that groundwater should be returned to its beneficial uses within a reasonable timeframe wherever practicable.

1.2.2 Summary of the Nature and Extent of Contamination

Past mining operations at the Site are causing an ongoing release of hazardous substances from waste rock, tailings, and mine water discharge at the Site. These releases are caused in part by acid rock drainage and acid mine drainage (ARD and AMD).[15] ARD/AMD are generated from weathering (e.g., chemical oxidation) of sulfur- and iron-bearing materials exposed in the underground mine openings, waste rock piles, and tailings piles. This oxidation generates low pH (i.e., acidic) drainage with high concentrations of metals (EPA 2001).

1.2.2.1 Hazardous Substances in Groundwater

Groundwater (including drainage from the Main Portal) exceeds drinking water criteria for several metals, including arsenic, cadmium, copper, lead, and nickel.

Figure 5 shows average concentrations of constituents in groundwater (including seeps) that discharge from various portions of the Site into Railroad Creek.[16]

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[15]ARD refers to acid drainage from exposed waste rock and tailings on the ground surface, whereas AMD refers to acid drainage from the underground mine workings.

[16] Seeps occur where groundwater flows to the land surface. Thus, seeps are expressions of groundwater, and hazardous substance concentrations measured in seeps are indicative of hazardous substance concentrations in the groundwater that is the source of the seep. Hereafter, when groundwater is discussed, it is implicit that groundwater includes seeps unless specifically exempted (e.g., in some models). Water from seeps may flow overland a short distance before entering Railroad Creek or reinfiltrating into groundwater.

This figure shows these concentrations as ratios of the seasonal (spring and fall) average concentration for each area to the proposed cleanup levels.[17]

The DFFS presented a method of quantifying the amount of groundwater that enters Railroad Creek as baseflow (i.e., not including flow from discrete seeps), referred to as a flow net analysis. The flow net analysis provides a means to estimate the quantity of groundwater flow for segments of the aquifer (referred to as flow tubes) that discharge into Railroad Creek, during the spring and fall conditions. The flow tubes are not real, physical tubes, but are a concept used to represent flow in discrete areas. The water quality in each flow tube is represented by concentrations measured in the nearest well or seep, or in some cases by averaging concentrations in adjacent wells or seeps.

Figures 6 and 8 show the location of flow tubes and the individual seeps that were identified in the DFFS as flowing into Railroad Creek. Spring and fall groundwater concentrations that discharge into Railroad Creek expressed as multiples of the proposed surface water cleanup levels (based on protection of aquatic life) are shown on Figures 7 and 9, respectively, based on data provided in the DFFS.

- The highest groundwater exceedances of cadmium, copper, and zinc are more than 100 to more than 1,000 times proposed cleanup levels (as measured in seeps) from the Honeymoon Heights area, the portal drainage, and the Lower West Area (LWA). Spring groundwater concentrations associated with TP-1, and seeps associated with the three tailings piles are somewhat lower but still typically more than 100 times the proposed cleanup levels. Fall concentrations are typically lower than those in the spring for cadmium, copper, and zinc, but still range from about 5 to 75 times the proposed cleanup levels and in some areas exceed the proposed cleanup levels by factors of several hundred to more than 1,000. Figures 6 and 8 only show seeps and flow tubes that discharge from below the tailings

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Groundwater also enters Railroad Creek directly as baseflow through the bottom and sides of the stream channel.

[17] Concentrations vary seasonally due primarily to the effect of spring snowmelt and runoff. Flow in Railroad Creek is generally low from late summer through winter; monthly average stream flow is below about 45,000 gpm at Lucerne. Peak flows in Railroad Creek occur during the months of May and June coinciding with snowmelt in the basin, with average monthly stream flow rates ranging from about 230,000 to 280,000 gpm at Lucerne. As used in this SFS and related documents, spring conditions refer to the May to July period approximately 90 days long when snowmelt causes relatively high groundwater levels, and relatively high flow conditions in Railroad Creek. Fall conditions represent the other 275 days per year (August to April) typified by lower groundwater levels and relatively low flows in Railroad Creek.

piles, directly into Railroad Creek. Even higher metals concentrations were measured in groundwater within the tailings piles.

- The greatest proposed cleanup level exceedances for iron and aluminum occur in groundwater flow tubes and seeps associated with TP-1, where spring concentrations exceed proposed cleanup levels by factors of 50 to several hundred times. Spring concentrations in the west part of the Site, and fall concentrations overall, are variable for iron and aluminum but commonly range from about 2 to more than 100 times proposed cleanup levels.

The tailings and waste rock piles are sources of hazardous substances that seep into groundwater that discharge into Railroad Creek. Concentrations of aluminum, copper, iron, and zinc in seeps from the tailings piles exceed criteria for protection of aquatic life by factors of 56,000, 470, 520,000, and 6,800, respectively. Concentrations of aluminum, copper and zinc in seeps from the waste rock piles exceed aquatic life protection criteria by factors of 12,000, 10,000, and 16,000, respectively.

1.2.2.2 Hazardous Substances in Surface Water

Figure 10 shows that groundwater discharging from the Site elevates surface water concentrations above the surface water protection criteria. As with figures previously discussed, Figure 10 shows existing conditions as ratios of seasonal surface water quality concentrations to proposed cleanup levels.

Hazardous substances released from the Site into groundwater and surface water include the metals cadmium, copper, lead, and zinc, and compounds of the metals iron and aluminum, at concentrations that exceed criteria for protection of aquatic life. These exceedances have reduced populations of fish and aquatic macroinvertebrates in Railroad Creek.

Metals loading to Railroad Creek is typically greater in the spring and early summer, as a result of snowmelt recharged groundwater flushing weathered minerals that accumulate throughout the remainder of the year. The primary sources of hazardous substances vary by constituent. The tailings piles are the primary sources of iron and aluminum to Railroad Creek and are also significant contributors of copper, cadmium, and zinc to Railroad Creek. Surface water and groundwater flows from the mine and waste rock piles are the primary sources of copper, cadmium, and zinc. Some groundwater samples collected across the area of former mine operations at the Site also contain elevated lead concentrations.

1.2.2.3 Hazardous Substances in Soils

Some soils at the Site exceed human health risk-based levels for direct contact and ingestion of arsenic, cadmium, copper, lead, and zinc. Furthermore, mine tailings that are exposed in some portions of the Site exceed human health direct contact and ingestion exposure levels for cadmium and copper.

Soil concentrations of more than a dozen metals and total petroleum hydrocarbons (TPH) exceed proposed cleanup levels at various locations across the area of former mine operations at the Site, including the tailings and waste rock piles, lagoon area, and wind-blown tailings areas. The ecological risk assessment (ERA) completed as part of the RI concluded toxicity risks exist for both plants and earthworms. The ERA also concluded birds and mammals may be subject to toxicity risks from feeding in areas of the Site.

1.2.2.4 Hazardous Substances in Sediments

Iron precipitates have formed in Railroad Creek as a result of the release of ferric sulfate and other hazardous substances from the tailings piles. Observed effects include ferricrete (stream channel gravels cemented with an iron oxide precipitate) and iron flocculent, which fills interstitial pore space in the sediment and coats gravel, cobbles, and boulders in the stream channel. The ferricrete and iron flocculent have caused damage to the aquatic habitat, resulting in the need for sediment cleanup to remove the ferricrete.

Sediment in Railroad Creek has metal concentrations exceeding Washington State freshwater sediment quality guidelines. The Lucerne Bar is an underwater feature resulting from the deposition of sediment suspended in the Railroad Creek water as it discharges into Lake Chelan. Due to releases from the Site, Lucerne Bar sediment has hazardous substance concentrations that exceed sediment quality guidelines. However, bioassay tests on Lucerne Bar sediment identified only minor adverse effects on aquatic organisms. Overall, the Agencies do not consider these effects to be severe enough nor widely distributed enough to require an active sediment cleanup (Forest Service 2003).

2.0 REGULATORY PROCESS FOR REMEDY SELECTION

The regulatory process for remedy selection involves developing RAOs, developing cleanup alternatives, and comparing the cleanup alternatives to the nine CERCLA criteria. The RAOs are based on evaluating the media of concern, constituents of concern, and potential ARARs. Based on potential ARARs and site-specific conditions (e.g., background concentrations, stream classifications, etc.), the Agencies and Intalco evaluated proposed cleanup levels [i.e., preliminary remediation goals (PRGs)]. The Agencies and Intalco developed potential general response actions (GRAs) to address the RAOs and achieve proposed cleanup levels. These RAO evaluations were based on data presented in the RI and FS.

Detailed descriptions of the process for developing proposed cleanup levels, RAOs, and GRAs are presented in this section. Section 2.1 identifies the media of concern. Section 2.2 identifies the constituents of concern. Section 2.3 presents the potential ARARs for the Site. Section 2.4 presents the proposed cleanup levels and point of compliance for each media of concern and constituent of concern. Section 2.5 presents the RAOs and identifies GRAs developed in the DFFS.

The rationale for presenting this information in this SFS is as follows:

- The points of compliance, as related to media of concern, were not clearly established in the DFFS.

- Proposed cleanup levels were not clearly defined as such in the DFFS.

- The Agencies have refined the initial RAOs presented in the DFFS.

- The GRAs developed in the DFFS are presented with the refined RAOs to clearly show that the GRAs have not been affected by the RAO updates.

Following this section, Section 3 describes the new cleanup alternatives that were not addressed in the DFFS, and Section 4 presents the CERCLA criteria evaluation for these new alternatives.

2.1 Media of Concern

Media of concern include four primary and three secondary exposure media. The primary exposure media are:

- Groundwater, including seeps;

- Surface water, including the mine drainage, Copper Creek, and Railroad Creek;

- Surface and subsurface soils and soil-like materials, including waste rock and tailings, as well as natural soils impacted as a result of mining activities; and

- Sediments in surface water bodies, including the existing mine drainage channel, Copper Creek, Railroad Creek, and Lake Chelan.

The secondary exposure media are:

- Air (e.g., fugitive dust);

- Plant tissue; and

- Animal tissue.

The DRI identified no current risk from air emissions. The Agencies found that the DRI and DFFS did not adequately assess potential exposure risk due to existing fugitive dust, and potential bioaccumulation of metals in plant and animal tissue, as discussed in SFS Appendix E. Additional assessment of these secondary exposure media is anticipated as part of the remedy, during the RD stage and/or through long-term biological monitoring, and may be further addressed through modification of the remedy, as needed.

2.2 Constituents of Concern

Constituents of concern at the Site pose unacceptable risks to human health or the environment, and trigger the need for cleanup. Constituents of concern and the associated media of concern related to protection of human health and protection of ecological receptors are presented in Table 1.

The primary human health risks at the Site include concentrations of metals above levels protective of human health in groundwater, soils, and tailings. Arsenic, cadmium, copper, lead, and nickel in groundwater exceed drinking water standards, as summarized in Table 2. Arsenic, cadmium, copper, lead, and zinc in soils and/or mine tailings exceed human health criteria for soil ingestion and dermal contact, as summarized in Table 3.

The primary environmental toxicity risks to the aquatic environment are the result of elevated concentrations of aluminum, cadmium, copper, iron, and zinc in Railroad Creek and in the portal drainage, seeps, and groundwater baseflow that discharge to the creek.[18] The release of waters with elevated concentrations

[18] Concentrations of these constituents exceed aquatic life protection criteria in Railroad Creek all the way to its mouth at Lucerne, at least part of the year; see Figure 10. Additional hazardous substances (e.g., lead), are present in groundwater at concentrations above surface water protection criteria and also pose a risk to aquatic life at and near the point of compliance.

of ferric sulfates and other hazardous substances that precipitate as ferrous oxides to form iron floc and ferricrete in Railroad Creek has caused damage to the aquatic habitat (USDA 2006). Ferricrete is a cemented deposit of iron oxide precipitates that forms in stream channel sediments as a result of the release of iron sulfates and other hazardous substances. Aquatic habitat within the creek may also be damaged through the precipitation of aluminum released in contaminated groundwater.

In addition, soils and mine tailings have concentrations of a number of metals that exceed risk-based screening criteria for protection of terrestrial ecological receptors.

See the discussion of potential chemical-specific ARARs (Section 2.3.3.1) for the basis for selecting these constituents of concern.

2.3 Potential Applicable or Relevant and Appropriate Requirements (ARARs)

This section provides a preliminary identification of potential ARARs and "to-be-considered" (TBCs) criteria for the Site. This section defines potential ARARs and TBCs and discusses them in terms of environmental medium and type of criteria (chemical-specific, action-specific, and location-specific).

2.3.1 Definitions

2.3.1.1 Potential ARARs

ARARs are defined in the NCP [40 CFR Part 300]. "Applicable" requirements are those cleanup standards and other environmental protection requirements promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site. While not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, "relevant and appropriate" requirements address problems or situations sufficiently similar to those encountered at a site that their use is well suited to the site. ARARs are potential or preliminary until finalized in a ROD.

ARARs fall into three broad categories, based on the manner in which they are applied: chemical-, action-, and location-specific. Cleanup levels are based on the most stringent potential ARAR, where more than one potential ARAR exists. In general, only the substantive requirements of an ARAR need to be implemented at the Site.

- Chemical-specific ARARs include requirements that regulate the release to, or presence in, the environment of materials with certain chemical or physical characteristics, or containing specified chemical compounds. The requirements are usually either health- or risk-based numerical values or methodologies that establish the acceptable amount or concentration of a chemical that may remain in or be discharged to the environment.

- Action-specific ARARs set performance, design, or similar controls or restrictions on particular kinds of activities related to the management of hazardous substances, pollutants, or contaminants. The ARARs are activated by the particular remedial action selected for implementation, and indicate how, or to what level, the alternative must achieve the requirements.

- Location-specific ARARs are restrictions based on the concentration of hazardous substances or the conduct of activities in specific locations. They relate to the geographic or physical position of the site. Remedial actions may be restricted or precluded depending on the location or characteristics of the site and the requirements that apply to it. Location-specific ARARs may apply to actions in natural or man-made features. Examples of natural site features include wetlands and floodplains. An example of a man-made feature is an archaeological site.

2.3.1.2 ARAR Waiver

The NCP provides for the waiver of ARARs under certain circumstances [40 CFR § 300.430(f)(1)(ii)(C)]. For example, an ARAR may be waived if "compliance with the requirement [ARAR] is technically impracticable from an engineering perspective" [40 CFR § 300.430(f)(1)(ii)(C)(3)]. The DFFS did not identify any need for ARAR waivers in the evaluation of potential ARARs.

2.3.1.3 TBCs

TBCs are non-promulgated criteria, advisories, guidance, and proposed standards issued by federal, state, or tribal governments that, although not legally enforceable, may be helpful in establishing protective cleanup levels and developing, evaluating, or implementing remedy alternatives. If no ARARs address a particular chemical or situation, or if existing ARARs do not provide adequate information, TBCs are available for use in developing remedial alternatives.

2.3.2 State Regulations

Under CERCLA, State of Washington cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated by the State of Washington are potential ARARs. Determination of whether these State of Washington standards, requirements, criteria, and limitations become ARARs is conducted using the eligibility criteria set forth in Section 121 of CERCLA (i.e., the requirements are promulgated, legally enforceable, generally applicable, more stringent than federal requirements, and identified in a timely manner). The state is working closely with the federal agencies on the identification of potential ARARs, under CERCLA guidelines.

The state is also exercising its independent cleanup authority for this Site under MTCA, which is applicable to the Site according to state law [RCW 70.105D]. MTCA sets forth various ways to determine the numeric values for ARARs (i.e., cleanup levels) for surface water, groundwater, and soil. This includes using tables with cleanup standards for individual contaminants [WAC 173-340-704] and methods for addressing multiple contaminants and pathways [WAC 173-340-705, -706, and -708].

2.3.3 Site-Specific Potential ARARs

Potential ARARs for the Site are discussed in this subsection under the following categories:

- Potential Chemical-Specific ARARs
  - Surface Water Quality
  - Groundwater Quality
  - Soil Quality

- Potential Action-Specific ARARs

- Potential Location-Specific ARARs

A discussion of TBCs follows the discussion of potential ARARs.

2.3.3.1 Potential Chemical-Specific ARARs

2.3.3.1.1 Surface Water Quality

The State of Washington regulations [WAC 173-201A-200 and -600] require that the surface water bodies at the Site, Railroad Creek and Copper Creek, be protected for their designated beneficial uses (see Section 1.2.1.2). Table 4 presents the chemical-specific numeric values for potential surface water ARARs at the Site based on protection of human health and freshwater aquatic life. For hardness dependent metals, the calculated potential ARAR concentrations in Table 4 are based on representative background water hardness conditions in Railroad Creek, i.e., 12 mg/L calcium carbonate ($CaCO_3$).[19] Table 5 shows concentrations of the constituents of concern in surface water at the Site.

Potential chemical-specific ARARs for surface water are discussed below.

A. **National Recommended Water Quality Criteria [Federal Water Pollution Control Act (Clean Water Act) 33 USC § 1251 et seq., Section 304(a)].** The National Recommended Water Quality Criteria (NWQC) is guidance established by the EPA (2006) for evaluating toxic effects on human health and aquatic organisms. The 2006 NWQC and the 2007 copper criterion[20] are potentially relevant and appropriate at the Site under CERCLA [Section 121(d)(2)]. The 2006 NWQC numeric values are listed in Table 4. The 1999 NWQC is potentially applicable to the Site [WAC 173-340-730(3)(b)(i)(B)] as these were the NWQC version available when the MTCA regulations were last updated. Even if not potentially applicable, the 1999 criteria are potentially relevant and appropriate for protection of aquatic life under

[19] Water hardness measured at locations designated RC-1, RC-6, and RC-11 averaged 12.3 with a standard deviation of 3.6. The average hardness for spring conditions was 13.0 based on 27 measurements, and the average hardness for fall conditions was 11.1 based on 14 measurements. This data set includes RC-1 for discussion purposes, although water quality at that location could be affected by releases from the ventilator portal (seep SP-26) and/or groundwater from Honeymoon Heights. Background hardness based only on DRI samples from RC-11 and RC-6 is limited to eleven data points for the spring (average hardness is 12.6) and five data points for fall (average hardness is 10.7). Hardness increases substantially adjacent to, and downstream of, the Site as a result of releases from the Site. The Ecology Permit Writers Manual (Ecology 2005) requires background hardness to be based on the lowest hardness value observed during critical conditions where 20 or less data points are available, or the 10th percentile value, lognormally transformed, where more than 20 data points are available (Ecology 2005). The Agencies consider that fall (low flow) conditions represent critical conditions for aquatic life in Railroad Creek. Background hardness and proposed cleanup levels will be assessed at the time of preparing the ROD, and thereafter cleanup levels could be adjusted in accordance with ARARs when additional data are available.

[20] The Aquatic Life Ambient Freshwater Quality Criteria–Copper 2007 Revision (EPA 2007), (the "2007 copper criterion") was published in the Federal Register on February 22, 2007. The 2007 copper criterion provides a basis to determine acute and chronic concentrations for protection of aquatic organisms based on the Biotic Ligand Model. The model determines concentrations that are protective based on an analysis of ambient conditions for a number of parameters. To date, relatively few data have been collected at the Site to provide a basis for predicting acute and chronic copper concentrations for Railroad Creek under this criterion. The Agencies anticipate the cleanup level established at the time of the ROD would be based on the background concentration for dissolved copper in accordance with WAC 173-340-730(5)(c), and that this could be modified in accordance with ARARs based on additional data collection following implementation of the remedy.

MTCA [WAC 173-340-710(4)]. The 2006 NWQC and subsequent NWQC (such as the 2007 copper criterion) are potentially relevant and appropriate for protection of aquatic life under MTCA [WAC 173-340-710(4)].

B. **National Toxics Rule [40 CFR Part 131].** The National Toxics Rule (NTR) established numeric water quality standards for protection of human health and aquatic organism for states that failed to fully comply with Section 303(c)(2)(C) of the Clean Water Act (CWA). The State of Washington is required to comply with certain standards in the NTR [40 CFR § 131.36(d)(14)], and MTCA identifies the NTR as a potential ARAR [WAC 173-340-730(3)(b)(i)(C)]. The NTR standards mandated for Washington are potentially applicable for the Site.

C. **Maximum Contaminant Levels [40 CFR Part 141].** Under the Safe Drinking Water Act [SDWA; 42 USC § 300 et seq.], EPA establishes health goals based on risk and sets legal limits—maximum contaminant levels (MCLs)—to help ensure consistent quality of the water supply. Since surface water at the Site is potable under MTCA [Chapter 173-340 WAC], the federal MCLs are potentially relevant and appropriate.

D. **National Maximum Contaminant Level Goals [40 CFR Part 141].** Under the SDWA [42 USC § 300 et seq.], EPA has established health-based MCL goals (MCLGs) for public water systems. Non-zero MCLGs are potentially relevant and appropriate for surface water at the Site.

E. **Washington State Drinking Water Standards [RCW 70.119A; Chapter 246-290 WAC].** Washington State has established health-based MCLs to protect consumers using public water supplies. MTCA identifies state MCLs as being potentially relevant and appropriate to potential surface water sources of drinking water at the Site.

F. **Washington State Water Quality Standards for Surface Water [RCW 90.48; Chapter 173-201A WAC].** Washington State has established aquatic life criteria for hazardous substances in freshwater. These provisions and standards in Chapter 173-201A WAC are potentially applicable for the Site, including the antidegradation policy [Section 300] and the narrative criteria [Section 260].

G. **Washington State Model Toxics Control Act [RCW 70.105D; Chapter 173-340 WAC].** The Model Toxics Control Act (MTCA), including WAC 173-340-730, is a potential ARAR under CERCLA, and is applicable to the surface water at the Site under state law. In general, MTCA states that surface water cleanup standards are to be based on estimates of the highest beneficial use and their reasonable maximum exposure expected to occur under current and potential future site uses.

2.3.3.1.2 Groundwater Quality

CERCLA and the NCP provide that groundwater should be returned to its beneficial use (see Section 1.2.1.3) within a reasonable timeframe wherever practicable. When restoration of groundwater is not practicable, it is necessary to prevent further migration of the plume and prevent exposure to the contaminated groundwater [40 CFR § 300.430(a)(1)(iii)(F)]. Since groundwater recharges to surface water at the Site, the more stringent of the groundwater and surface water designated beneficial uses apply to the Site.

Table 6 presents the chemical-specific numeric values for potential groundwater ARARs at the Site. Table 7 shows concentrations of constituents of concern in groundwater.

Drinking water standards for groundwater are discussed below and are listed in Table 6. The Agencies anticipate that groundwater cleanup levels at the Site will be based on protection of aquatic life (see Table 4). In addition, the point of compliance (where the cleanup levels must be met) will be where the groundwater discharges into surface water, as discussed in Section 4 of this SFS.

Potential chemical-specific ARARs for groundwater are discussed below.

A. **Maximum Contaminant Level Goals [40 CFR Part 141].** Under the SDWA [42 USC § 300 et seq.], EPA establishes health goals based on risk and sets legal limits—MCLs—to help ensure consistent quality of the water supply. Since groundwater at the Site is potable under MTCA [Chapter 173-340 WAC], the federal MCLs are potentially relevant and appropriate.

B. **National Maximum Contaminant Level Goals [40 CFR Part 141].** Under the SDWA [42 USC § 300 et seq.], EPA has established health-based MCLGs for public water systems. Non-zero MCLGs are potentially relevant and appropriate for groundwater at the Site.

C. **Washington State Drinking Water Standards [RCW 119A; Chapter 246-290 WAC].** Washington State has established health-based MCLs to protect consumers using public water supplies. MTCA identifies state MCLs as being applicable to potential groundwater sources of drinking water at the Site.

D. **Washington State Model Toxics Control Act [RCW 70.105D; Chapter 173-340 WAC].** MTCA, including WAC 173-340-720, is a potential ARAR under CERCLA, and is applicable to groundwater at the Site under state law. In general, MTCA states that groundwater cleanup standards are to be based on estimates of the highest beneficial use and the reasonable maximum exposure expected to occur under current and potential future site uses. Groundwater cleanup standards are generally set under MTCA for both protection of drinking water and for the protection of surface water uses, including, where appropriate, the protection of aquatic life and human consumption of fish.

2.3.3.1.3 Soil Quality

Table 8 presents the chemical-specific numeric values for potential soil ARARs at the Site based on MTCA. Table 9 shows concentrations of constituents of concern in soils and tailings.

Potential chemical-specific ARARs for soil are discussed below.

A. **Washington State Model Toxics Control Act [RCW 70.105D; WAC 173-340].** MTCA, including WAC 173-340-740 (unrestricted land use soil cleanup standards), -745 (industrial cleanup standards), -747 (soil concentrations for groundwater protection), and -7490 through –7494 (terrestrial ecological evaluation), is a potential ARAR under CERCLA and is applicable to soils across the Site under state law.

2.3.3.1.4 Sediment Quality

Table 10 presents potential chemical-specific numeric values for sediment at the Site based on TBC criteria as discussed in Section 2.3.3.4. At this time neither the state nor federal governments have promulgated standards for sediment quality that would be referred to as potential chemical-specific ARARs. Table 11 shows concentrations of constituents of concern in sediments.

Chemical-specific TBCs for sediment are presented in the Interim Final Sediment Evaluation Framework for the Pacific Northwest (U.S. Army Corps of Engineers et al. 2006) and other scientific studies, which are cited in Table 10. The state's Sediment Management Standards are potentially relevant and appropriate to the Site since as long as there is potential for additional metals release to surface water, including (but not limited to) WAC 173-204-120, which prohibits activities that would degrade existing beneficial uses; WAC 173-204-400, which specifies procedures for managing sources of sediment contamination (including AKART[21]); and WAC 173-204-590, which addresses the establishment and monitoring of sediment recovery zones where cleanups leave sediments that exceed potentially applicable sediment quality standards.

2.3.3.2 Potential Action-Specific ARARs

Potential action-specific ARARs for the Site are discussed below.

A. **Washington Model Toxics Control Act [RCW 70.105D; Chapter 173-340 WAC].** MTCA establishes administrative processes and standards to identify, investigate, and clean up facilities where hazardous substances are located. MTCA is a potential ARAR under CERCLA, and is applicable to the Site under state law. MTCA, including WAC 173-340-760, is potentially applicable to sediment at the Site.

B. **Washington State Sediment Management Standards [Chapter 173-204 WAC].** The intended purposes of the sediment management standards are potentially relevant and appropriate to clean up of sediments at the Site.

C. **Regulation and Licensing of Well Contractors and Operators [RCW 18.104; Chapter 173-162 WAC].** These regulations establish procedures for the examination, licensing, and regulation of well contractors and operators. "Well" means water wells, resources protection wells, instrumentation wells, dewatering wells, and geotechnical soil borings. These requirements are potentially applicable to contractors who install and/or decommission wells and borings at the Site.

D. **Minimum Standards for Construction and Maintenance of Water Wells [RCW 18.104; Chapter 173-160 WAC].** Washington State has developed minimum standards for constructing water and monitoring wells, and for the decommissioning of wells. These standards are potentially applicable to wells constructed at the Site for water withdrawal or monitoring, and for decommissioning of Site wells.

E. **Resource Conservation and Recovery Act [42 USC § 6901], Subtitle C - Hazardous Waste Management [40 CFR Parts 260 to 279].** Federal hazardous waste regulations specify hazardous waste identification,

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[21] AKART is an acronym for "all known, available and reasonable methods of prevention, control and treatment" [WAC 173-204-400]. The State of Washington uses this concept to define requirements for managing point and non-point discharges in the water quality regulations [WAC 173-201A-020].

management, and disposal requirements. These regulations are potentially applicable for generation and management of hazardous waste at the Site. Where Washington has an authorized state hazardous waste program under RCW 70.105 and Chapter 173-303 WAC, it applies in lieu of the federal program.

F. **Resource Conservation and Recovery Act [42 USC § 6901], Subtitle D - Managing Municipal and Solid Waste [40 CFR Parts 257 and 258].** Subtitle D of RCRA establishes a framework for controlling the management of non-hazardous solid waste. These regulations also establish guidelines and criteria from which states develop solid waste regulations. Subtitle D is potentially applicable to solid waste generation and management at the Site.

G. **Washington State Hazardous Waste Management Act and Dangerous Waste Regulations [RCW 70.105; Chapter 173-303 WAC].** Washington State Dangerous Waste regulations govern the handling and disposition of dangerous waste, including identification, accumulation, storage, transport, treatment, and disposal. Washington State has not adopted an exemption for certain mining wastes (such as the Bevill Amendment) from regulation under RCRA Subtitle C.[22] The Dangerous Waste regulations are potentially applicable to generating, handling, and managing Dangerous Waste at the Site, and would be potentially relevant and appropriate even if Dangerous Wastes are not managed during remediation. In particular, the point of compliance regulations for releases from regulated units such as landfills are potentially relevant and appropriate [WAC 173-303-645(6)].

H. **Washington State Solid Waste Handling Standards [RCW 70.95; Chapter 173-350 WAC].** Washington State Solid Waste Handling Standards apply to facilities and activities that manage solid waste. The regulations set minimum functional performance standards for proper handling and disposal of solid waste; describe responsibilities of various entities; and stipulate requirements for solid waste handling facility location, design, construction, operation, and closure. Particular to the Site, tailings and waste rock pile operations ceased prior to enactment of the Solid Waste Management Act, Chapter 70.95 RCW, and before the effective date of Chapter 173-350 WAC, and the tailings and waste rock piles are not currently being operated as limited purpose landfills. However, all substantive requirements for

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[22] Washington did adopt a limited exemption from the Dangerous Waste regulations for mining overburden returned to the Site. However, overburden is defined as a material used for reclaiming a surface mine and is not a discarded material within the scope of RCRA (45 FR 33000; May 19, 1980, and 67 FR 63060; October 10, 2002).

closure and post-closure of limited purpose landfills [WAC 173-350-400] are potential ARARs [WAC 173-340-710(7)(c)]. The tailings and waste rock piles at the Site are landfills that contain solid waste and are releasing hazardous substances above both state and federal cleanup standards.[23]

This regulation is also potentially applicable or relevant and appropriate for management of excavated soil, soil-like material, and debris that will be generated during the Site cleanup. The regulation is potentially applicable to the proposed limited purpose landfill at the Site that will be used for disposal of sludge produced during long-term groundwater treatment operations.

I. **Hydraulic Code [RCW 77.55; Chapter 220-110 WAC].** The Hydraulic Code requires that any construction activity that uses, diverts, obstructs, or changes the bed or flow of state waters must be done under the terms of a Hydraulics Project Approval permit issued by Washington State Department of Fish and Wildlife (WSDFW). Depending on the selected remedial action, substantive provisions of the Hydraulic Code are potentially applicable at the Site.

J. **Federal Water Pollution Control Act–Water Quality Certification [Clean Water Act; 33 USC § 1341, Section 401].** Section 401 of the CWA provides that applicants for a license or permit to conduct any activity, including, but not limited to, the construction or operation of facilities, which may result in discharges into the navigable waters, shall obtain certification from the state that discharges will comply with applicable water quality standards. While no formal certification will be required for the Site, substantive requirements will be potentially applicable to remedial actions that require substantive compliance with federal permit equivalency (e.g., NPDES, Section 404).

(Under Chapter 173-225 WAC: Federal Water Pollution Control Act - Establishment of Implementation Procedures of Application for Certification, the State of Washington designated Ecology as the state's water pollution control agency for purposes of processing applications for certification required under Section 401.)

K. **Federal Water Pollution Control Act–National Pollution Discharge Elimination System [Clean Water Act; 33 USC § 1342, Section 402].** The

[23] Portions of the MM-3 Standard (Forest Service 1990 and subsequent amendments) also include potentially relevant and appropriate requirements for management of mining wastes at the Site. These requirements are described more fully below in Section 2.3.3.3 as location-specific ARARs.

NPDES regulations establish requirements for point source discharges and stormwater runoff. In particular for the Site, these regulations are potentially applicable for any point source discharge of contaminated water (e.g., discharge following treatment of groundwater and portal drainage), stormwater runoff at the Site, and where the construction Site involves 1 acre or more.

L. **Federal Water Pollution Control Act–Discharge of Dredge and Fill Materials [Clean Water Act; 33 USC § 1344, Section 404].** Section 404 of the CWA establishes a program to regulate the discharge of dredged and fill materials into the waters of the United States, including wetlands. The substantive provisions of this requirement are potentially applicable to remedial actions involving dredging, filling, diversion, and/or construction in streams or wetlands at the Site.

M. **Water Quality Standards for Surface Waters of the State of Washington--Mixing Zones [RCW 90.48; WAC 173-201A-400].** In Washington State, mixing zones and the associated effluent limits are established in discharge permits, general permits, or orders. Mixing zones do not apply to discharges directly from the groundwater to surface water per WAC 173-340-730(6)(b). Prior to a mixing zone for a point source discharge being authorized, the discharger must fully apply All Known, Available, and Reasonable Methods of Prevention, Control, and Treatment (AKART). This regulation is potentially applicable where the Site remedial action involves compliance with the substantive requirements of a discharge permit (i.e., NPDES).

N. **Water Quality Standards for Surface Waters of the State of Washington--Short-Term Modifications [RCW 90.48; WAC 173-201A-410].** State water quality criteria can be modified for a specific water body on a short-term basis (e.g., actual periods of non-attainment are generally limited to hours or days rather than weeks or months) when necessary to accommodate essential activities, respond to emergencies, or to otherwise protect the public interest, even though such activities may result in a temporary reduction of water quality conditions. Where the selected remedy for the Site involves activities near or in streams and wetlands that could impact water quality and cause exceedance of water quality criteria, substantive provisions of this regulation are potentially applicable.

O. **Submission of Plans and Reports for Construction of Wastewater Treatment Facilities in Washington State [RCW 90.48; Chapter 173-240 WAC].** Under this law, regulations were established requiring submission of wastewater treatment system design plans, specifications, and reports to Ecology for review and approval. The regulations also include provisions for

Ecology review and approval of proposed methods for operation and maintenance, and for construction modifications. Substantive aspects of these requirements are potentially applicable to the Site under MTCA, since the remedial action involves construction of a wastewater treatment system.

P. **Aquatic Lands Management - Washington State [RCW 79.90; Chapter 332-30 WAC].** The Aquatic Lands Management law develops criteria for managing state-owned aquatic lands. Aquatic lands are to be managed to promote uses and protect resources as specified in the regulations. While not directly applicable to the Site, the criteria in the Aquatic Lands Management are potentially relevant and appropriate to remedial actions involving Railroad and/or Copper Creeks under MTCA.

Q. **Water Code and Regulation of Public Ground Waters of Washington State - Surface Water and Groundwater Withdrawal [RCW 90—90.03 and 90.44].** These laws specify the criteria and procedures for appropriating surface water and groundwater for beneficial use. Any use of surface water and groundwater (except for certain uses of less than 5,000 gallons per day of groundwater) requires a water right permit or certificate. Substantive compliance with these laws is potentially applicable to the Site under MTCA, since remedial actions involve withdrawal and/or diversion of surface water or groundwater that would otherwise require a state water rights permit or certificate.

R. **Maximum Environmental Noise Levels - Washington State [RCW 70.107; Chapter 173-60 WAC].** The Maximum Environmental Noise Levels regulations of Washington State establish maximum noise levels permissible in identified environments, and provide use standards relating to the reception of noise within these environments. These regulations are potentially applicable depending on the remedial activities selected for the Site.

S. **Clean Air Act [42 USC § 7401 et. seq.; 40 CFR Part 50].** The federal Clean Air Act (CAA) creates a national framework designed to protect ambient air quality by limiting air emissions. These regulations are potentially applicable to construction activities at the Site.

T. **Washington Clean Air Act and Implementing Regulations [WAC 173-400-040(8)].** This regulation is potentially relevant and appropriate to remedial actions at the Site. It requires the owner or operator of a source of fugitive dust to take reasonable precautions to prevent fugitive dust from becoming airborne and to maintain and operate the source to minimize emissions.

U. **General Regulations for Air Pollution Sources - Washington State [RCW 70.94; Chapter 173-400 WAC].** These regulations provide for the systematic control of air pollution from air contaminant sources and for the proper development of the state's natural resources. The purpose of the regulations is to establish technically feasible and reasonably attainable standards, and to establish rules generally applicable to the control and/or prevention of the emission of air contaminants. Depending on the remedial action selected, these regulations are potentially applicable to the Site (e.g., generation of fugitive dust during remediation of soil and tailings, or emissions from equipment).

Although not a potential ARAR under CERCLA, proposed remedial activities at the Site will need to be considered in accordance with substantive requirements of the Washington State Environmental Policy Act [SEPA: RCW 43.21C; Chapter 197-11 WAC] based on MTCA ARARs. One of the primary purposes of SEPA legislation is to ensure that state governmental agencies consider the environmental impacts of an action prior to making a decision. SEPA regulations establish a uniform method for identifying possible environmental impacts, considering mitigating measures, and reaching a decision on a proposed action.

2.3.3.3 Potential Location-Specific ARARs

Potential location-specific potential ARARs are discussed below.

A. **National Forest Management Act [16 USC §§ 1600 – 1614] (NFMA) and Land and Resource Management Plan for Wenatchee National Forest (LRMP, Forest Service 1990), as amended by Pacific Northwest Forest Plan (NWFP, 1994) and subsequent amendments of the NWFP (2001, 2004, and 2007).** NFMA, which is the primary statute governing the administration of National Forests, requires management based on multiple-use, sustained-yield principles. The Forest Service promulgated the LRMP, as required by NFMA. Portions of the LRMP (and the NWFP amendments to the LRMP) are potentially applicable or relevant and appropriate for assessing Site remedial alternatives. The LRMP and NWFP include standards and guidelines that are potentially relevant and appropriate to actions at the Site, including activities within, or that affect Riparian Management Areas along Railroad and Copper Creeks, or are otherwise necessary to meet Aquatic Conservation Strategy (ACS) objectives. These standards and guidelines include RF-2 through RF-7, which control the design, construction, and use of temporary and permanent roads and other modifications within Riparian Reserves; and MM-3, which controls solid waste and mine waste facilities within Riparian Reserves. Particular aspects of MM-3 that are potentially relevant and appropriate to closure of the tailings and waste rock piles at the

Site include requirements for: a) analysis based on best conventional methods; b) designing waste facilities using best conventional techniques to ensure mass stability and prevent the release of acid or toxic materials; and c) reclamation and monitoring waste facilities to ensure chemical and physical stability, and to meet ACS objectives.

B. **National Historic Preservation Act [16 USC § 470].** The National Historic Preservation Act (NHPA) requires federal agencies to take into account the effect of any federally assisted undertaking or licensing on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register of Historic Places (NRHP) or as a National Historic Landmark. Depending on the remedial actions selected for the Site and, in particular, determination of the need for demolition of the abandoned mill building, NHPA requirements are potentially applicable and will need to be addressed during RD.

C. **Historic Site, Buildings, Objects, and Antiquities Act [16 USC §§ 461 - 467].** The Historic Site, Buildings, Objects, and Antiquities Act requires preservation of historic sites, buildings, and objects of national significance. This Act is potentially applicable where components of the Site listed or eligible for listing on the Historic Site, Buildings, Objects and Antiquities Federal Register will be impacted by remedial actions.

D. **Archaeological and Historic Preservation Act [16 USC § 469].** The Archaeological and Historic Preservation Act (AHPA) provides for the preservation of archaeological and historic data that might be destroyed through alteration of terrain due to a federal construction project or a federally licensed program or activity. This Act is potentially applicable to the Site where remedial activities would cause loss or adverse impacts to significant scientific, prehistoric, historic, or archaeological data.

E. **Archaeological Resources Protection Act [16 USC § 470].** The Archaeological Resources Protection Act prescribes the steps that must be taken by investigators to preserve archaeological resources. This Act is potentially applicable to the Site where remedial activities would cause loss or adverse impacts to significant scientific, prehistoric, historic, or archaeological data.

F. **Native American Graves Protection and Reparation Act [25 USC § 3001 et seq].** The Native American Graves Protection and Reparation Act protects the remains, funerary objects, and cultural artifacts of Native Americans. The requirements of this Act must be followed when graves are discovered or ground-disturbing activities encounter Native American burial sites. This Act is potentially applicable to the Site where remedial actions involve disturbance/alteration of the ground and/or site terrain.

G. **Fish and Wildlife Coordination Act [16 USC §§ 661-667].** The Fish and Wildlife Coordination Act provides that when the waters or channel of a body of water are modified by a federal entity, the department or agency must first consult with the U.S. Fish and Wildlife Service (USFWS) and with the head of the agency exercising administration over the wildlife resources of the state (WSDFW), with a view to the conservation of wildlife resources. The requirements of this Act are potentially applicable to the Site where the implementation of remedial activities involve impacts to water or stream channels.

H. **Fish and Wildlife Conservation Act [16 USC §§ 2901 - 2911].** The purpose of the Fish and Wildlife Conservation Act is to promote conservation of non-game fish and wildlife through assistance to states and use of federal authority. The requirements of this Act are potentially applicable to Site remedial activities, including action in Railroad Creek and Copper Creek involving stream diversion, dredging, and/or channel altering activities.

I. **Endangered Species Act [16 U.S.C. §§ 1531 - 1544].** The Endangered Species Act (ESA) protects species of fish, wildlife, and plants that are listed as threatened or endangered with extinction. It also protects designated critical habitat for listed species. The Act outlines procedures for federal agencies to follow when taking actions that may jeopardize listed species, including consultation with resource agencies. The requirements of this Act are potentially applicable to the Site since listed threatened or endangered species habitat areas will, or could, be impacted by remedial action. The Agencies anticipate Section 7 consultation will be completed concurrent with the ROD.

The Railroad Creek valley has historically provided habitat to spotted owls, lynx, grizzly bears, gray wolves, and other potentially threatened or endangered species. These species may occur within or adjacent to the Site as recovery of the species and/or the habitat progress. Consistent with ESA Section 7, if any federally designated threatened or endangered species are identified in the vicinity of remediation work, and the action may affect such species and/or their habitat, the Agencies will consult with USFWS to ensure that remedial actions are conducted in a manner to avoid adverse habitat modification and jeopardy to the continued existence of such species.

J. **Wilderness Act [16 USC §§ 1131 - 1136].** The Wilderness Act established the National Wilderness Preservation System, which is to be comprised of federal land designated by Congress as wilderness areas, and administered to leave the land unimpaired for future use as a wilderness. The requirements within the Act are potentially applicable for assessing Site remedial alternatives.

K. **Washington State Shoreline Management Act [RCW 90.58].** The purpose of the Shoreline Management Act (SMA) is to prevent inherent harm in the uncoordinated and piecemeal development of the state's shorelines. It applies to all marine waters; streams with a mean annual flow greater than 20 cfs; water areas larger than 20 acres; plus shorelands 200 feet landward from the edge of the aforementioned waters; and associated wetlands, river deltas, and floodplains. Local governments adopt shoreline master programs based on state guidelines but tailored to specific needs. The requirements of Chelan County's Shoreline Management Plan are potentially applicable on lands deeded to non-federal entities (e.g., the claims owned by Holden Village Inc.) when remedial activities take place in and/or within 200 feet of the 100-year floodplain of creeks and water bodies. On federal lands owned in fee where remedial action will take place within 200 feet of the 100-year floodplain, substantive actions at the Site will need to be consistent with the County Plan, in accordance with potential ARARs.

L. **Executive Order 11990 - Protection of Wetlands.** Executive Order 11990 requires that potential impacts to wetlands be considered, and as practical, destruction, loss, or degradation of wetlands be avoided. EPA promulgated regulations to implement this Executive Order under 40 CFR Part 6. The requirements of this Order are potentially applicable to remedial activities that take place within Railroad and Copper Creeks and Site wetlands.

M. **Executive Order 11988 - Protection of Floodplains.** Executive Order 11988 requires evaluation of the potential effects of actions that take place in a floodplain to avoid, to the extent possible, adverse impacts. EPA promulgated regulations to implement this Executive Order under 40 CFR Part 6. The requirements of this Order are potentially applicable to remedial activities that take place within the 100-year floodplain of Railroad and Copper Creeks.

N. **The American Indian Religious Freedom Act [AIRFA; 42 USC § 1996].** This Act mandates federal agencies to protect the right of Indian Tribes to exercise their traditional religions. It is applicable to land-disturbing activities implemented during remedial action if places and physical paraphernalia needed for religious practice are affected. This Act is potentially applicable to the Site if traditional cultural properties, archaeological resources, or historic sites important to the practice of American Indian religions are present.

O. **Migratory Bird Treaty Act (MBTA), 16 USC § 703 et seq.** The MBTA makes it unlawful to "hunt, take, capture, kill" or take various other actions adversely affecting a broad range of migratory birds, including tundra swans, hawks, falcons, songbirds, without prior approval by the USFWS. (See 50 CFR 10.13 for the list of birds protected under the MBTA.) Under the MBTA, permits may be issued for take (e.g., for research) or killing of migratory birds (e.g., hunting licenses). The mortality of migratory birds due to ingestion of contaminated sediment is not a permitted take under the MBTA. The MBTA and its implementing regulations are potentially relevant and appropriate for protecting migratory bird species identified. The selected response action will be carried out in a manner that avoids the taking or killing of protected migratory bird species, including individual birds or their nests or eggs.

The following listed potential location-specific ARARs that are described above, are also potential action-specific ARARs:

- Fish and Wildlife Coordination Act [16 USC §§ 661-667];
- Fish and Wildlife Conservation Act [16 USC §§ 2901 - 2911];
- Executive Order 11988 - Protection of Floodplains;
- Executive Order 11990 - Protection of Wetlands; and
- Washington State Shoreline Management Act [RCW 90.58].

2.3.3.4 Potential To-Be-Considered Criteria

TBCs for the Site are discussed below.

A. **Natural Background Soil Metals Concentrations in Washington State (Department of Ecology, Publication 94-115, October 1994).** This Ecology document contains information on the natural background concentrations of metals in surficial soil throughout Washington State. The MTCA [WAC 173-340-200] defines natural background as "...concentration of hazardous substances consistently present in the environment which has not been influenced by localized human activities." Natural background values are provided on a statewide basis, and for four areas: Puget Sound, Clark County, Yakima Basin, and Spokane Basin. Since the Site is within the

Yakima Basin, the natural background metals concentrations for the Yakima Basin are TBCs.

B. **Superfund Remedial Design and Remedial Action Guidance [EPA OSWER Directive 9355.0-4A, June 1986].** This guidance is a TBC for the remedial design and remedial action components of the Site remediation. The document provides guidance on such things as design initiation, reviews, compliance with permitting requirements, and community relations.

C. **Permit Writer's Manual (Department of Ecology, Publication 92-109, Rev. July 2002).** The Permit Writer's Manual is a technical guidance and policy manual for permit writers who develop wastewater discharge permits in Washington State. For the Site, the manual is a TBC for the remedial selection process. This consideration will include, but not be limited to, evaluation of discharge limits, AKART, and mixing zones.

D. **Numeric Values for Freshwater Sediment Quality.** As noted in Section 2.3.3.1.4, neither the federal government nor Washington State has current promulgated freshwater sediment standards. However, this is an area that is the subject of active scientific evaluations by EPA and Ecology, as well as other agencies (RSET 2006). The results of the ongoing interagency cooperative assessment provide information that is helpful in establishing protective cleanup levels. Table 10 presents potential chemical-specific numeric values for sediment at the Site, based on recent evaluations that the Agencies believe should be considered in evaluating cleanup at the Site.

E. **Executive Order 11593 - Protection and Enhancement of the Cultural Environment.** Executive Order 11593 directs federal agencies to nominate historic properties to the NRHP and to treat properties eligible for the NRHP as though they were listed. The requirement is potentially applicable to land-disturbing activities implemented during remedial action if archaeological resources or sites are present or encountered. The requirements of this Order are potentially "to be considered" for the Site if archaeological resources or historic sites are encountered.

F. **Executive Order 13007 - Indian Sacred Sites.** Executive Order 13007 requires federal agencies to avoid physical damage to Indian sacred sites and to avoid interfering with access to such sites. The requirement is potentially applicable to land-disturbing activities implemented during remedial action if archaeological resources or sites are present or encountered. The requirements of this Order are potentially "to be considered" for the Site if Indian archaeological resources or historic sites are present.

G. **Executive Order 13112 - Invasive Species.** Executive Order 13112 requires federal agencies prevent the introduction of invasive species and not authorize, fund, or carry out action believed to be likely to cause or promote the introduction or spread of invasive species, unless the benefits of such actions clearly outweigh the potential harm caused by invasive species and actions are taken to minimize harm. This Order is potentially "to be considered" for persons and equipment used during implementation of remedial actions to ensure invasive species are not introduced to the Site.

H. **Executive Order 13186 - Responsibilities of Federal Agencies to Protect Migratory Birds.** Executive Order 13186 requires federal agencies avoid or minimize adverse impacts to migratory bird resources, restore and enhance migratory bird habitat, and prevent or abate pollution or detrimental alteration of the environment for the benefit of migratory birds to the extents practicable. This Order is potentially "to be considered" for the remedial actions at the Site.

2.4 Proposed Cleanup Levels

Effectiveness of the cleanup action will be determined in part by whether soil and water quality improves to meet proposed cleanup levels at designated points of compliance. Points of compliance for groundwater, surface water, and soil are determined under CERCLA and/or MTCA, as discussed in Section 4.1.1.3.[24]

CERCLA requires that remediation goals be developed to satisfy RAOs for contaminants and media of concern, and potential exposure pathways. The remediation goals are initially developed based on readily available information, such as potential chemical-specific ARARs, and may subsequently be modified as more information becomes available [40 CFR § 300-430(e)(2)(i)]. State of Washington regulations [Chapter 173-340 WAC] set forth various ways to determine the appropriate cleanup standards for surface water, groundwater, soil, and sediment. This includes calculated cleanup standards using tables with standards for individual contaminants, multi-contaminant/multi-pathway formulae, as well as recognition that cleanup standards under either of these methodologies do not require cleanup below background levels [e.g., see WAC 173-340-700-(6)(d)]. Since the DRI showed that the Site has elevated background levels for certain constituents in surface water and soil, background

[24] Points of compliance would also be developed to satisfy potential ARARs in the event that any future sediment cleanup is determined to be needed.

is likely to be the default cleanup standard for certain constituents of concern in those media.

The proposed cleanup levels for Site groundwater, surface water, soil, and sediment for protection of human health and the environment are based on potential chemical-specific ARARs, previously discussed in Section 2.3.3, and background concentrations. The potential ARAR-based proposed cleanup level for each constituent of concern is the lowest potential chemical-specific ARAR concentration for that constituent. If the natural background concentration is greater than the potential ARAR-based proposed cleanup level, the natural background concentration becomes the proposed cleanup level for that constituent of concern.

The RI developed background concentrations for surface water and soil but not for groundwater or sediment. Background concentrations for surface water and soil are included with the numerical values for potential ARARs in Tables 4 and 8, respectively. The Agencies and Intalco agreed that the well HV-3 is a potential location where background groundwater quality could be determined, but sampling and analysis to date has not met statistical requirements (Forest Service 2001a). Thus, background concentrations for groundwater at the Site have not been established. Background concentrations for sediment have not been addressed at the Site.

The “proposed cleanup levels” for the Site, as used in this document are the same as “preliminary remediation goals” as used in the NCP [40 CFR § 300.430(e)(2)(i)] and in some CERCLA guidance documents. The proposed cleanup levels will apply to exposure pathways determined to be complete and significant by the Agencies. Results of the HHRA and the ERA completed to date are summarized below. Final remediation goals and cleanup levels will be described in the ROD.

An HHRA was conducted as part of the RI (Dames & Moore 1999). Humans potentially exposed to hazardous substances at the Site include Holden Village residents, visitors, construction workers, and Agency personnel. The following human health risks exist at the Site:

1. Some soils at the Site exceed proposed soil cleanup levels for protection of human health for direct exposure for cadmium, copper, lead, and zinc. Mine tailings that are exposed in some portions of the Site exceed human health direct contact exposure levels for arsenic, cadmium, and copper. Therefore, engineered controls (e.g., removal and capping of contaminated soils and mine wastes) and institutional controls are needed at the Site to prevent human health risks.

2. No metals have been detected above human health-based criteria in Railroad Creek or Copper Creek. However, drainage from the Main Portal and seeps (which are surface expressions of groundwater) exceed drinking water criteria for arsenic, cadmium, copper, lead, and nickel.

3. Groundwater at the Site has metal concentrations that exceed drinking water standards in one or more wells for aluminum, arsenic, cadmium, copper, and zinc. Although groundwater near the former mine is not currently used for drinking water, institutional controls are needed to help prevent potential human exposure through groundwater ingestion in the future.

An ERA was also performed by Intalco and reported in the DRI. The DRI (Sections 7.2.4.1 and 7.2.6.1) concluded the following ecological risks exist at the Site:

1. Toxicity risks exist for trout in surface water at the Site from dissolved copper and possibly zinc. Hazard Quotients (HQs) for dissolved copper ranged from 18 to 26, and HQs for dissolved zinc were as high as 1.0.

2. Toxicity risks exist for benthic invertebrates in the Site's aquatic environment from copper, iron, manganese, and zinc in sediment (HQs ranged from 1.0 to 3.0)[25] and arsenic, cadmium, copper, iron, silver, and zinc in flocculent (HQs ranged from 1.1 to 6.6).

3. Toxicity effects for plants and earthworms result from metals concentrations in soil for various locations at the Site. Birds and mammals may be subject to metals toxicity effects from feeding in Site areas where the highest metals concentrations were measured.

In accepting the DRI, the Agencies took exception to some findings of the ERA, and later with the proposed soil and surface water cleanup levels presented in the DFFS (Forest Service 2001a and 2004a; Hart Crowser 2005c; USFWS 2004 and 2005, also see Appendix E to this SFS).

The USFWS toxicity reviews for the Site determined surface water concentrations of cadmium, copper, zinc, and aluminum exceed concentrations known to be toxic to salmonids (USFWS 2004 and 2005). The release of iron limits usable habitat for benthic macroinvertebrates in Railroad Creek, through the formation of ferricrete and iron floc, and is likely toxic to salmonids. The

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[25] Note that the DRI included Freshwater Sediment Quality Values (FSQV) that have since been superseded by the RSET freshwater sediment quality guidelines (U.S. Army Corps of Engineers et al. 2006).

USFWS also predicted mortality in benthic invertebrates throughout most of the year based on its review of toxicity effects on aquatic organisms resulting from exposure to metals in Railroad Creek. Observed reductions in fish and benthic invertebrates within Railroad Creek during the RI results from toxicity where surface water concentrations exceed aquatic life protection criteria, and habitat reduction from iron oxide precipitation and ferricrete formation in the creek bed.

There is also a significant risk that tailings pile slope failures could produce a mass release of reactive tailings into Railroad Creek.[26] The tailings contain sulfide minerals that would release aluminum, cadmium, copper, iron, lead, and zinc upon exposure to the air or creek waters. A mass release of tailings would significantly increase metals concentrations in Railroad Creek and toxicity to aquatic organisms.

Soil concentrations of more than a dozen metals and petroleum hydrocarbons exceed state criteria for protection of groundwater, surface water, and/or the default Ecology criteria for protection of terrestrial organisms. Cadmium, copper, lead, and zinc concentrations in Holden Village surface soil and in the surface and subsurface soils of the three tailings piles, the lagoon area, and the maintenance yard present toxicity exposure risks for both plants and earthworms. Foraging birds and other animals are subject to toxic effects from cadmium and zinc when feeding in Site areas with the highest metals concentrations, such as the tailings piles, lagoon area, and maintenance yard.

The proposed cleanup levels for each constituent of concern are presented with the potential ARAR concentrations and available background concentrations in Table 4 for surface water, Table 6 for groundwater, Table 8 for soil, and Table 10 for sediment.[27] The groundwater proposed cleanup levels presented in Table 6

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[26] Such a release could occur due to failures of the tailings piles, which could arise due to flooding or scour in Railroad Creek, uncontrolled erosion of the tailings pile slopes, earthquakes, or possibly due to a water surge caused by collapse of the underground mine workings. The DRI reports a tailings slope failure related to a 50-year flood event in 1948, and erosion- and scour-related stability problems have occurred in 2003 and 2006. In 1970, a surge of water from the mine was documented as a result of a collapse within the mine (Forest Service 1970a, 1970b, and 1970c).

[27] MTCA allows Ecology to set cleanup levels based on a site-specific evaluation, and soil cleanup levels protective of surface water may be adjusted for cleanup actions that involve containment of hazardous substances [WAC 173-340-740(6)(f)]. The Agencies believe that at least one alternative for the proposed cleanup (Alternative 11, described later in this SFS) would provide adequate containment, collection, and treatment of hazardous substances for all areas on the south side of Railroad Creek. North of Railroad Creek, there are some areas where surficial soils exceed concentrations deemed protective of groundwater and/or surface water. However, in these areas, there is no indication of contamination at depth within the soil profile, and groundwater contamination is apparently the result of groundwater transport from south of the creek. On this basis, the Agencies have identified proposed cleanup levels for soils as shown in Table 8. Soil

are shown for the beneficial use of groundwater as a drinking water supply, for informational purposes. However, another beneficial use of Site groundwater is recharge to surface water, for which a designated beneficial use is aquatic life habitat. Thus, proposed groundwater cleanup levels are based on the more stringent surface water criteria (Table 4).

2.5 Remedial Action Objectives

RAOs generally describe the site cleanup goals for protecting human health and the environment. Preliminary RAOs were developed to aid in scoping the FS (URS 2004a), and subsequently refined by the Agencies in the submittal to the National Remedy Review Board (NRRB, Hart Crowser 2005e). Based on further consideration; the Agencies have further refined the RAOs for evaluation of alternatives. The latest RAOs are listed below, and are presented in Table 12 along with general response actions from the DFFS to clearly show that the GRAs have not been affected by the RAO updates. The GRAs are potential media-specific actions that may satisfy the RAOs and include the following:

1. Reduce surface water concentrations of hazardous substances to levels that are protective of aquatic life and satisfy ARARs in Railroad Creek and Copper Creek.

2. Remove ferricrete in Railroad Creek to support aquatic life, and monitor sediment quality in Railroad Creek, Copper Creek, and at the Lucerne Bar in Lake Chelan, to determine whether any further action is needed to protect aquatic life and satisfy ARARs.

3. Contain contaminants of concern in groundwater, mine discharge, and stormwater within an on-site waste management area to prevent migration of contaminants, protect aquatic life, and satisfy ARARs.

4. Reduce exposure to hazardous substances in surface soils, tailings, and other wastes to protect terrestrial receptors and satisfy ARARs. Prevent future releases of tailings and other wastes into surface water that would increase surface water and sediment concentrations of hazardous substances.

5. Protect human health and satisfy ARARs by reducing risks of human exposure to hazardous substances through direct contact with soils, tailings, and other wastes; and through groundwater as a drinking water resource.

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cleanup levels may be adjusted on the basis of a terrestrial ecological risk assessment, in which case the ROD may be modified through an Explanation of Significant Differences (ESD) or a ROD Amendment.

6. Implement the remedial action in a manner that satisfies ARARs and protects human health and the environment, including the Holden Village residential community during and after construction.[28]

Remedial action alternatives were developed with the objective of achieving the preliminary RAOs and potential ARARs, based on the reasonably anticipated future land use at the Site. The reasonably anticipated future uses for the Site are residential for the Holden Village use areas and open space for wildlife and recreational use. The alternatives include institutional controls (e.g., restrictions on construction, excavation or drilling, groundwater use, etc.) to ensure the long-term effectiveness of protection of human health and the environment, and to ensure protection of human health immediately following remedy construction, as proposed cleanup levels for groundwater are unlikely to be achieved immediately. The Agencies revised the initial RAOs as provided in 40 CFR § 300.430(e)(2)(i).

The developed remedial actions are expected to be final cleanup actions. For a cleanup action to be considered a final cleanup action, it must meet the two CERCLA threshold criteria, which are 1) be protective of human health and the environment and 2) meet all ARARs. The alternatives evaluated in this SFS and in the DFFS include alternatives that could only serve as interim remedial actions. Such alternatives would be interim because they would address some of the sources of contamination but are not designed to meet all potential ARARs. Any interim action must not exacerbate site problems, must not interfere with the final remedy, and must be followed within a reasonable time by complete measures that attain ARARs [55 Fed Reg 8747, March 8, 1990]. The interim remedies considered for the Site would necessitate further investigation resulting in future delays in implementation of the final response action, while creating uncertainties regarding protectiveness, as well as uncertainties regarding timely implementation. These interim remedies would also exacerbate the effects of remedy construction on the operations of Holden Village Inc. Therefore, the Agencies believe that a final remedy that is protective and meets standards is preferable to an interim remedy.

[28] The Forest Service and Ecology also agreed on an RAO to develop appropriate natural resource damage assessment (NRDA) activities consistent with 43 CFR Part 11, to evaluate the potential for coordinated remediation and natural resource restoration activities. Given the remote location and land use at the Site, this last RAO was designed to take advantage of the potential benefits of combining the NRDA process with the RI and FS processes. However, issues regarding natural resource damages and/or restoration projects are beyond the scope of the FS, and the RAOs for the remedy selection do not include NRDA.

3.0 DESCRIPTION OF ALTERNATIVES 9, 10, 11, AND 12

This section describes the additional remedial alternatives considered by the Agencies that were not included in the DFFS. These additional alternatives include Alternative 9, developed by Intalco (URS 2005b), and Alternatives 10, 11, and 12 developed by the Agencies. Alternatives 11 and 12 are presented for the first time in this SFS. A brief history and discussion of the rationale for these additional alternatives is provided below, followed by subsections that provide detailed descriptions.

The DFFS presented Alternatives 1 through 8, including subalternatives. The Agencies' review of the DFFS concluded none of Alternatives 1 through 8 would meet the threshold criteria, based on information provided in the DFFS.[29] The DFFS alternatives failed to satisfy the threshold requirements for selection of a permanent remedy under CERCLA and MTCA and cannot be considered as a final cleanup action for the Site.[30] As a result, the Agencies proposed a new alternative be considered, that was referred to as the Agencies' Proposed Remedy (Alternative 10).[31] Alternative 10 combined elements of some of the alternatives described in the DFFS and included a partially penetrating barrier to contain groundwater for collection and treatment. The Agencies presented Alternative 10 to the NRRB. Intalco subsequently developed Alternative 9 (URS 2005b), which consisted of DFFS Alternative 3b, combined with pumping from wells and seeps to clean up groundwater from below a limited area of Tailings Pile 1.

[29] The threshold requirements are the criteria specified in CERCLA [40 CFR 300.430(f)(1)(i)(A)] and MTCA [WAC 173-340-360(2)(a)] that must be satisfied for a remedial alternative to be selected as the final cleanup remedy for a site. The CERCLA threshold criteria for remedy selection are 1) overall protection of human health and the environment and 2) compliance with ARARs [except when an ARAR is waived, as allowed under 40 CFR § 300.430(f)(1)(ii)(C)]. The threshold requirements for selecting a cleanup remedy under MTCA include that the remedy: 1) protect human health and the environment; 2) comply with cleanup standards; 3) comply with applicable state and federal laws; and 4) provide for compliance monitoring.

[30] The Agency comments on the DFFS (Forest Service 2007a) address the degree to which the DFFS alternatives fail to satisfy threshold requirements for remedy selection. For example, the DFFS predicted that Alternative 3b would not meet potential surface water criteria for cadmium and copper in the short term (within approximately 50 years of remedy implementation), and that dissolved zinc would not achieve aquatic life protection criteria for approximately 250 years. The Agencies further noted that these predictions only applied to a fully mixed condition in Railroad Creek downstream of the former mine operations area, and the DFFS does not provide a method that would predict metals concentrations in the creek adjacent to source areas, including at the anticipated surface water or groundwater points of compliance for the Site.

[31] The Agencies' Proposed Remedy was previously referred to as the APR but is hereafter referred to as Alternative 10. Intalco has referred to Alternative 10 as the 2005 APR, to distinguish it from a previous Agencies proposed alternative (APA) discussed after submittal of the first draft FS in June 2002. Intalco modified the APA and presented the modified APA as Alternative 6 in the June 2004 DFFS.

After meeting with the NRRB and reviewing the NRRB's comments, and after meeting with Intalco and Holden Village Inc., the Agencies concluded that none of Alternatives 1 through 9 would meet the threshold criteria for selection of a cleanup action [40 CFR § 300.430(9) and WAC 173-340-360(2)], and that available information was not sufficient to demonstrate that Alternative 10 would satisfy the threshold requirements. Therefore, none of these remedies qualify as a final remedy. Accordingly, the Agencies developed Alternative 11 by combining elements of the earlier alternatives to create a proposed remedy that they believe will satisfy the CERCLA and MTCA threshold criteria.

Alternatives 9 through 11 have a number of elements in common (including treatment technologies, engineering controls, institutional controls, and monitoring requirements) discussed later in this section. Features that distinguish one alternative from another affect the degree to which an alternative would satisfy the RAOs and achieve the proposed cleanup levels.

Initial implementation of Alternatives 9, 10, and 11 would consist of activities such as constructing a groundwater collection and treatment system, closure of the tailings and waste rock piles, and/or consolidation and capping of contaminated soils, etc. These alternatives also include: a) long-term operation and maintenance of a water treatment facility and b) monitoring to determine whether the remedy is effective and to assure no future changes in Site conditions would adversely impact human health or the environment.

The DFFS presented Alternative 1 as the "No Action/Institutional Controls" alternative. The Agencies noted Alternative 1 did not satisfy CERCLA criteria for a "no action" alternative. Accordingly, the Agencies have added a no action alternative, Alternative 12, to meet CERCLA requirements. The no action alternative relies solely on natural attenuation and source depletion, which are discussed below.

3.1 Natural Attenuation and Duration of the Remedy

Alternatives 9, 10, 11, and 12 rely to some degree on passive processes that are expected to reduce the magnitude of metals released over time. These processes include a) source depletion, which is not an acceptable part of a remedy under either CERCLA or MTCA; and b) natural attenuation, which may be an acceptable part of a remedy provided certain conditions are met. The DFFS refers to both processes jointly, and incorrectly, as "monitored natural attenuation."

- Source depletion refers to processes that produce low pH conditions that release metals resulting from chemical oxidation of sulfides in the mine, tailings, and waste rock. Over hundreds of years the available sulfide minerals will be "used up" and reduce the rate of ongoing release of acidic drainage and metals to groundwater and surface seeps from the tailings, waste rock, and underground mine. However, this change in the rate of release does nothing to mitigate the adverse effects of metals already or continuing to be released to the environment. In essence, relying on source depletion is a "no action" approach that is similar to letting an oil drum leak on the premise that the release will stop when all oil has left the drum. Neither CERCLA nor MTCA allow a remedy to rely on source depletion.

- Natural attenuation processes "include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater" (EPA 1999[32]). For metals at the Site, these natural attenuation processes may include dispersion, dilution, and sorption. These processes have not been quantified at the Site in the RI or the FS, which is required under MTCA [WAC 173-340-370(7)(c)], and as part of the CERCLA guidance for using natural attenuation as part of a remedy (EPA 1999).

- The effectiveness of the natural attenuation processes depends on the chemical, physical, and biological characteristics of the groundwater and soil at the Site, along with the metals present. CERCLA and MTCA allow an alternative to include natural attenuation provided certain conditions are met [EPA 1999, WAC 173-340-200, WAC 173-340-370(7)]. Under MTCA, reliance on natural attenuation is allowed only after source control work is completed and where leaving contaminants on site does not pose an unacceptable threat to human health and the environment. Under CERCLA, monitored natural attenuation is most appropriate when used in conjunction with other remediation measures, including source control and groundwater extraction, or following implementation of remedial measures. Natural attenuation as a remedial action at the Site is further discussed under the MTCA and CERCLA evaluations in Section 4.

If no remedial action were taken at the Site, metals concentrations in Railroad Creek would continue to exceed proposed surface water cleanup levels for hundreds of years. In the absence of a remedy, the mass load model presented in the DFFS (the "DFFS Model")[33] predicts that metals concentrations in Railroad

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[32] A similar definition is presented in WAC 173-340-200.

[33] The DFFS did not include a metals loading analysis for a no action alternative. The Agencies created one by modifying the model presented for Alternative 2a, which is the DFFS Model alternative nearest to a no action

Creek downstream of Tailings Pile 3 would be above cleanup levels for up to 450 years under spring conditions and 150 years under fall conditions. Analyses described in the DFFS suggest releases to groundwater below the tailings piles would continue to exceed proposed cleanup levels for even longer periods of time. Without a cleanup action, any reduction in metals released from the Site would only result from the source depletion over time for the waste rock piles, underground mine, and the tailings (URS 2004a, Appendix E).

Another analysis completed by the Agencies corroborates the DFFS Model results to some degree. The Batch Flush Model, a groundwater attenuation analysis, was used by the Agencies to evaluate the time required for dissolved metals concentrations in the LWA to reach cleanup levels through natural attenuation following installation of a groundwater barrier and collection system in the Upper West Area (UWA). While the DFFS Model provides results that are for the fully mixed condition in the creek downstream of the sources, the Batch Flush Model provided results for representative groundwater seeps that discharge into Railroad Creek, which more closely approximates conditions at the point of compliance. (Seeps SP-11 and SP-15E were analyzed to represent conditions in the LWA, as described in Appendix A of this SFS). Results indicate that natural attenuation following elimination of the sources of release in the UWA would reduce concentrations of cadmium, copper, and zinc to proposed cleanup levels at the point of compliance in about 40, 150, and 300 years, respectively.

Both the DFFS Model and Batch Flush Model indicate that absent of remedial action to prevent discharges to Railroad Creek, metals concentrations in Railroad Creek will exceed proposed surface water cleanup levels for hundreds of years. Accordingly, the proposed remedy would need to operate for hundreds of years to be protective and satisfy potential ARARs.

3.2 Elements Common to Alternatives 9, 10, and 11

This section discusses the elements that are common to Alternatives 10 and 11, and were identified by Intalco or are assumed by the Agencies to be applicable to Alternative 9.[34]

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alternative. The no action alternative includes only the reduction in metals due to the predicted source depletion over time using the geochemical modeling in the DFFS Appendix E.

[34] Intalco's description of Alternative 9 (Section 2.0 of URS 2005b) listed components in common with DFFS Alternative 3b. Some components of Alternative 3b were not listed. Elsewhere Intalco indicated that Alternative 9 was the same as Alternative 3b, but with the addition of pumped wells and seep collection on

Following the discussion of common elements below, Sections 3.3 through 3.6 discuss the components and distinguishing features of Alternatives 9, 10, 11, and 12 separately.

- **Institutional Controls.** Implement institutional controls, such as proprietary controls on private property or land use restrictions, to limit future exposures to groundwater and source materials that could impact human health and terrestrial ecological receptors. Institutional controls should also ensure remedy components are not compromised by human activity.

  Upon the Forest Service's request, the Bureau of Land Management (BLM) withdrew the area around the Holden Mine Site from mineral entry. This withdrawal includes approximately 1,265 acres of National Forest System lands from location and entry of new mining claims under the United States mining laws [30 U.S.C. Ch. 2]. A legal description of the mineral withdrawal is provided in BLM Public Land Order No. 7533 [67 FR 50894]. Institutional controls would also be applied to land owned by Holden Village Inc., as determined necessary for implementation of the remedy. This is likely to include restrictions that would prevent disturbance of hazardous substances that are capped and left in place (e.g., in the maintenance yard), as well as any changes in land use that would impair collection and treatment of groundwater or surface water that exceeds proposed cleanup levels.

  Institutional controls are part of DFFS Alternative 3b, but were not specifically listed in Section 2.0 of URS (2005b).

- **Mine Access Restrictions.** Maintain and monitor gates restricting mine entry to control access to the mine. Remove debris and metal precipitates. Annually inspect supports in the Main Portal and maintain for safety. Install air restrictions within open portals to reduce oxygen transport through the mine on the premise that this would slow the release of metals in the Main Portal drainage.

  Mine access restrictions are part of DFFS Alternative 3b, but were not specifically listed in Section 2.0 of URS (2005b).

- **Hydraulic Bulkheads.** Install hydraulic bulkheads to control the rate of groundwater discharging from the Main Portal of the mine. The DFFS suggests using equalization pond(s) outside of the mine, rather than

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TP-1. For this discussion the Agencies assume all components of Alternative 3b are part of Alternative 9 even if they were not specifically identified in URS (2005b) as part of Alternative 9.

bulkheads, to control and equalize Main Portal flow, but proposes to defer selection of one or another approach until RD. However, the equalization ponds would not likely perform acceptably during potential underground mine collapses (see Appendix F). The Agencies included hydraulic bulkheads for purposes of comparing Alternatives in this SFS, but propose to make the determination as part of remedy selection.

- **Consolidation and Capping Impacted Soils.** Excavate soils above proposed cleanup levels at various locations at the Site (e.g., the former mill, lagoon area, ventilator portal detention area) and consolidate to a permanent on-Site containment area. In the maintenance yard, cap soil exceeding proposed cleanup criteria with a concrete or asphalt slab.[35]

  The consolidation and capping described above are part of DFFS Alternative 3b, but were not specifically listed in Section 2.0 of URS (2005b).

- **Copper Creek and Copper Creek Diversion Modifications.** Modify the Copper Creek channel to constrain future channel migrations that would erode the tailings. Place the Copper Creek Diversion into a lined channel or culvert from the hydroelectric plant to Railroad Creek, to avoid seepage through tailings in this area.

  Copper Creek and Copper Creek Diversion modifications are part of DFFS Alternative 3b, but were not specifically listed in Section 2.0 of URS (2005b).

- **Tailings Actions.** Alternatives 9, 10, and 11 each include some form of improvement of the tailings pile stability and revegetation, but the degree of improvement differs as discussed for each alternative. This includes incidental closure of an existing decant tower (possible preferred seepage pathway) on TP-1.

- **Upgradient Water Diversion.** Construct upgradient water diversion swales or French drains south of the tailings and waste rock piles, and maintain these in perpetuity to reduce the amount of clean water run-on that would otherwise contact the tailings and waste rock materials.[36]

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[35] Intalco also proposed further consideration of capping soils in the mill and ventilator portal detention area during RD. Institutional controls would require removal and disposal of soils and hazardous substances above proposed cleanup levels if any future change in Site use affects the integrity or ability to maintain a cap.

[36] A French drain is a type of groundwater collection system that typically consists of a perforated pipe installed in a trench that extends below the groundwater level and is backfilled with gravel. French drains intercept and divert groundwater by gravity flow.

- **Construction Material Source Development.** Develop a quarry to provide riprap for stream channel stabilization. The location of the quarry site(s) for source(s) of riprap would be determined during RD. Soil and gravel would be obtained from excavations necessary to implement the cleanup action, an existing Forest Service borrow pit (Dan's Camp), and/or a new borrow source would be developed as part of the remedy. The location of any new borrow source(s) would be determined during RD. The volume of construction materials needed, and the extent of source development would differ, from one alternative to another.

  Development of construction material sources are part of DFFS Alternative 3b, but were not specifically listed in Section 2.0 of URS 2005b.

- **Railroad Creek Bank Protection.** Place riprap for stream bank protection to mitigate potential erosion of the tailings piles and other areas where channel migration could threaten the remedy. The extent of riprap protection varies among the different alternatives.

- **Electric Power.** All of the alternatives require electric power for water treatment and management of the resulting sludge. There is no commercially available power at the Site. Holden Village generates hydroelectric power for its needs but does not have any excess power that could be used to run a treatment plant. While the alternatives that include water treatment all require electricity, the amount of power required varies from one alternative to another, primarily due to differences in the amount of water that would be treated and where the water is collected. The Agencies hope hydroelectric generation for long-term operations will prove feasible because it would reduce the risk of a diesel spill in Lake Chelan or at the site. However, the cost analyses for the alternatives have been generated based on the use of diesel fuel to power a generator at the Site. The means for generating electricity needs to be further considered during RD.

- **Water Treatment Facility.** Alternatives 9, 10, and 11 include one or more facilities for treating groundwater and surface water from different parts of the Site, to reduce metals concentrations to meet the proposed cleanup levels. However, the areas where groundwater and surface water would be collected for treatment, as well as the location and size of the treatment facilities, vary significantly from one alternative to another.

- **Monitoring.** Alternatives 9, 10, and 11 include some degree of surface water and groundwater monitoring to assess effectiveness of the remedy, stability of the tailings and waste rock piles, condition of stream bank riprap, and performance of other components of the remedy.[37]

- **Natural Attenuation.** All the alternatives rely to some degree on passive processes that are expected to reduce the magnitude of metals released over time, as discussed in Section 3.1 of this SFS.

All of the alternatives would also require areas for staging and a temporary construction work camp. This could include areas such as roads within the former Winston Townsite, the baseball field west of Holden Village, and/or the Lucerne construction campsite that was used in 1989-1991, provided the proposed use does not interfere with necessary cleanup activity and conforms to Forest Service requirements. Intalco and the Agencies have discussed potential issues involving each of these locations, but final decisions will need to be made during RD.

3.3 Alternative 9

Estimated Capital Cost per Intalco: $21.7 million
Estimated Annual Operation and Maintenance (O&M) Cost per Intalco[38]: Not provided by Intalco
Estimated Total Project Cost (including 30 percent contingency) per Intalco: $36.3 million

Estimated Capital Cost per the Agencies: $22.6 million
Estimated Annual O&M Cost per the Agencies[39]: $1,210,000
Estimated Total Project Cost per the Agencies[40]: $38.2 million

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[37] Intalco proposed developing a monitoring plan after selection of the remedy, but the Agencies prepared a conceptual monitoring program as part of evaluating Alternatives 10 and 11, see Appendix H. Details of the monitoring will be established by the Agencies during RD and may be modified by the Agencies based on the results obtained. Monitoring will be performed in accordance with a Sampling and Analysis Plan developed during RD and approved by the Agencies.

[38] Intalco provided a net present worth value of $6.2 million for long-term O&M and monitoring costs using a 7 percent discount rate (URS 2005b), but did not provide any specific annual O&M costs.

[39] Estimated annual O&M costs are not anticipated to be the same from one year to the next, due to varying maintenance requirements for different parts of the collection and treatment system. This value is the average annual estimated cost over 50 years following remedy implementation, based on the detailed breakdown provided in Appendix B of this SFS. Also, see Appendix B of the SFS for discussion of how the net present worth for total project cost was estimated.

[40] Intalco's cost estimate for Alternative 9 is provided in URS (2005b). The Agencies prepared an independent cost estimate for the purpose of comparing Alternatives 9, 10, and 11, as discussed in Appendix B. Total cost is based on the estimated capital cost and the net present worth of future O&M costs. Net

The principal components and distinguishing features of Alternative 9 are summarized below and shown on Figure 11.

In addition to the common elements listed above, Alternative 9 includes the following remedial components: 1) collection and treatment of the Main Portal drainage and Honeymoon Heights seeps SP-12 and SP-23, and 2) installation of a groundwater barrier and collection system in the UWA to collect groundwater and surface seeps contaminated by infiltration at the former mill building and adjacent waste rock piles. Alternative 9 also includes installation of four pumped wells for groundwater extraction below Tailings Pile 1 and a pumped seep interception system to collect flow from seeps SP-1 and SP-2. Alternative 9 would collect and treat an estimated 324 million gallons per year (MGY) of contaminated groundwater.

Intalco assumed that construction of the UWA barrier and associated groundwater collection system would reduce seepage below a portion of TP-1 and, as a consequence, discharge of contaminants to Railroad Creek. However, the basis for the assumed reduction was not supported by any fate or transport analysis. Flow tube analyses provided in the DFFS indicate Copper Creek is a drainage divide, and while the flow nets support the idea of UWA flow in part below TP-1, they do not indicate an UWA barrier would have any effect on west-east flow from the LWA and TP-1 to below TP-2 and TP-3. Thus Alternative 9 would not have any direct effect on groundwater flow from below TP-2 and TP-3 into Railroad Creek.

Except for the wells and seep collection noted above, Alternative 9 is the same as Alternative 3b from the DFFS. Alternative 9 would rely on source depletion and natural attenuation to reduce releases of metals to groundwater and surface water from the LWA of the Site, and groundwater below a portion of TP-1, and all of TP-2 and TP-3. Alternative 9 does not include containment, collection, and treatment of groundwater in the LWA, below TP-2 and TP-3, and below a portion of TP-1, that is entering Railroad Creek above proposed cleanup levels.

Alternative 9 includes limited regrading of about 250,000 cy of tailings associated with slopes of TP-1 and TP-2, but would not move the tailings pile slopes away from Railroad Creek, and does not include regrading to improve stability of the slopes of TP-3. Figure 14 illustrates the tailings pile regrading at two representative cross-sections for Alternative 9. Alternative 9 includes placing a 1-foot soil cover over the regraded slopes only, and revegetation of the

present worth was determined over a 50-year period and using a 7 percent discount rate as discussed in Appendix B.

tailings piles, but does not include a cap over all the tailings and waste rock piles. Alternative 9 would not meet presumptive closure requirements for a limited purpose landfill [WAC 173-350-400(3)(e)(ii)]. Alternative 9 does not include ecological assessment and does not address potential risks in other areas such as the wind-blown tailings area.

Alternative 9 does not remove ferricrete from Railroad Creek, and does not include monitoring sediment to determine whether additional sediment cleanup actions are required following the elimination of metals sources.

3.4 Alternative 10

Estimated Capital Cost per the Agencies: $37.0 million
Estimated Annual O&M Cost per the Agencies: $1,430,000[41]
Estimated Total Project Cost per the Agencies: $55.1 million

Estimated Capital Cost per Intalco: $45.1 million
Estimated Annual O&M Cost per Intalco: Not provided by Intalco
Estimated Total Project Cost (including 30 percent contingency) per Intalco: $70.6 million

The principal components and distinguishing features of Alternative 10 are summarized below and shown on Figure 12. Alternative 10 includes the following remedial components, in addition to the proposed common alternative elements previously described:

Installation of a partially penetrating groundwater barrier and collection system in the LWA along Railroad Creek from the existing Main Portal discharge point into Railroad Creek (designated P-5) to the Copper Creek Diversion,[42] and along both TP-1 and TP-3 adjacent to Railroad Creek. Alternative 10 also includes collection and treatment of discrete seeps, SP-3 and SP-4, on the northern edge of TP-2 and the Honeymoon Heights seeps SP-12 and SP-23. Alternative 10 would collect and treat an estimated 485 MGY of contaminated groundwater.

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[41] Estimated annual O&M costs are not anticipated to be the same from one year to the next, due to varying maintenance requirements for different parts of the collection and treatment system. This value is the estimated cost for the first year after remedy implementation, based on the detailed breakdown provided in Appendix B of this SFS. Also, see Appendix B of the SFS for discussion of how the net present worth for total project cost was estimated.

[42] Unlike Alternatives 9 and 11, which include fully penetrating groundwater barriers (keyed into glacial till or bedrock below the surficial aquifer) for parts of the Site, Alternative 10 includes a groundwater barrier that penetrates only part of the saturated thickness of the shallow aquifer in the Railroad Creek Watershed.

Alternative 10 would not include the collection and treatment of groundwater downgradient of TP-2 and Honeymoon Heights but includes monitoring groundwater from these areas.

Alternative 10 would include regrading approximately 580,000 cy of tailings and 160,000 cy of waste rock to improve stability of these waste piles, as well as closure of the tailings and main East and West Waste Rock Piles through placement of a 1-foot-thick soil cap to support vegetation. However, Alternative 10 would not address the Honeymoon Heights Waste Rock Piles other than by collection and treatment of downslope seepage expressed at seeps SP-12 and SP-23. Alternative 10 includes a planned analysis during RD to determine whether the proposed 1-foot-thick soil cover would be protective, or whether the final waste pile covers would need to be enhanced to meet the presumptive closure requirements for a limited purpose landfill [WAC 173-350-400(3)(e)(ii)].

During regrading, the tailings slopes would be pulled back from Railroad and Copper Creeks so that the toe of slope is set back from the normal high water mark to improve flood protection along the creeks. Alternative 10 included this setback to provide room for a flood protection berm to be constructed adjacent to the creek, revegetation, groundwater collection and conveyance facilities, and maintenance/monitoring access road along the toe of the regraded tailings slopes. A schematic of the tailings pile regrading adjacent to Railroad Creek proposed for Alternative 10 is shown on Figure 15.

Alternative 10 would remove ferricrete from Railroad Creek and monitor sediment to determine whether additional sediment cleanup actions are required following the elimination of metals sources.

A more detailed description of Alternative 10 is included in the EPA NRRB Holden Mine Site Information Package (Hart Crowser 2005f), where it is referred to as the APR. For the purpose of analyses in this document, the Agencies have not assumed implementation of any contingent actions that were part of the APR.[43]

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[43] These potential contingent actions primarily included the possibility of extending the barrier wall and collection system along TP-2; possible need to make the partially penetrating barrier a fully penetrating cutoff; and the potential need to improve the tailings and waste rock pile cover to satisfy the state regulations for closure of a limited purpose landfill.

3.5 Alternative 11

Estimated Capital Cost (Agencies Estimate): $65.5 million
Estimated Annual O&M Cost (Agencies Estimate): $1,650,000
Estimated Net Present Worth Total Project Cost (Agencies Estimate): $85.8 million

Alternative 11 combines some elements of Alternatives 5 and 6 from the DFFS and Alternative 10 (see above). The principal components and distinguishing features of the Alternative 11 are summarized below and shown on Figure 13.

Alternative 11 would collect all identified groundwater sources that exceed proposed cleanup levels and discharge into surface water from the Honeymoon Heights seeps, the Main Portal drainage, and groundwater from the LWA, TP-1, TP-2, and TP-3. Alternative 11 includes institutional controls to limit future human exposure to groundwater, waste materials, and contaminated soils; and to prevent changes in Site use that could impair the effectiveness of the remedy.

Contaminated groundwater along Railroad Creek (i.e., from P-5 to SP-5) would be contained, and collected using groundwater barrier wall technology and an associated collection system. A continuous barrier and collection system is more effective than an isolated seep collection system (as proposed for other alternatives). This is because the seep flow is ephemeral in some locations, and there is potential for the seep locations to migrate over time. Alternative 11 would collect and treat an estimated 600 MGY of contaminated groundwater.

The groundwater barrier wall would be fully penetrating (i.e., keyed into a lower permeability layer). Details of the barrier (e.g., how to avoid collection of flow from Copper Creek and to assure cutoff of seep SP-21) would be established during RD. Alternative 11 includes collecting groundwater behind the barrier in a ditch, but the type of collection system utilized (e.g., collection ditch, French drain, wells, or other system) could be further evaluated during RD.

Alternative 11 would not include the collection and treatment of groundwater downgradient of Honeymoon Heights (except seeps SP-12 and SP-23) but would monitor groundwater from these areas.

All collected groundwater and surface water would be treated using acid neutralization and precipitation to remove metals, to the maximum extent practicable, in a treatment plant located downstream of TP-3. After dewatering, metal hydroxide sludge produced as a byproduct of treatment would be disposed of in a limited purpose landfill constructed on the tailings piles in conformance with state standards. RD would include evaluating alternatives for producing energy for the treatment system and sludge disposal, to determine which approach would have the least environmental impact and be cost-effective; including feasibility of developing a new, local hydroelectric generating facility. Treated water would be discharged into Railroad Creek.

Alternative 11 includes regrading about 580,000 cy of the three tailings piles to improve surface water runoff, improve slope stability, and to move the edge of the piles back away from Railroad and Copper Creeks to reduce the risk of future slope failures releasing wastes into the creeks. The amount of setback would be determined during RD to meet the performance requirements of, among other things, permanent flood protection; construction of a groundwater barrier and collection system(s); stormwater management during construction; a permanent access road for maintenance of flood protection (riprap); and monitoring and operation/maintenance of the groundwater collection system. A schematic of the tailings pile regrading adjacent to Railroad Creek proposed for Alternative 11 is shown on Figure 15.

Alternative 11 includes regrading about 207,000 cy of waste rock to consolidate the Honeymoon Heights Waste Rock Piles onto the main West Waste Rock Pile, and improve slope stability of the main East and West Waste Rock Piles prior to closure.

Alternative 11 would close existing tailings and waste rock piles by capping and providing runoff/run-on controls in accordance with potential ARARs to protect terrestrial receptors and reduce impacts to groundwater and surface water. Additionally, the Honeymoon Heights Waste Rock Piles, which are located within Riparian Reserves, would be collected and consolidated onto the existing West Waste Rock Pile before its closure in accordance with potential ARARs. After removing the waste rock and soils above proposed cleanup levels from areas within Riparian Reserves, these and other areas affected by remedy implementation would be re-vegetated.

Alternative 11 includes additional data collection and monitoring to assess compliance, protectiveness, and performance of the remedy.

- Alternative 11 would fully address risk to aquatic receptors and human health. Additional data collection to support design would include a terrestrial ERA of soils with metals concentrations that exceed screening levels performed during RD. This terrestrial ERA would determine the need for source controls or other remediation in additional areas of the Site including the baseball field, Holden Village, and the area of wind-blown tailings. This may lead to revision of the extent of the soil excavation and capping and/or the proposed tailings and waste rock cover requirements to protect terrestrial receptors.

- Following implementation, water quality would be monitored in monitoring wells and at seeps located outside the groundwater containment area (e.g., SP-26, SP-21, and SP-23). The purpose of this and other performance monitoring is to enable additional collection and treatment, or other measures, to be implemented if necessary to enable the remedy to be protective and satisfy potential ARARs. Typically such changes could be implemented following the 5-year review.

Alternative 11 would remove ferricrete from Railroad Creek and monitor sediment to determine whether additional sediment cleanup actions are required following the elimination of metals sources.

3.6 Alternative 12

Alternative 12 is a "no action alternative." The NCP requires a "no action alternative" to be developed and considered in the analysis of the alternatives [40 CFR § 300.430(e)(6)]. The Agencies analyzed Alternative 12 after noting that Alternative 1 in the DFFS did not satisfy CERCLA criteria for a "no action" alternative. Alternative 1 includes institutional controls, monitoring, and some maintenance work within the mine. Under Alternative 12, the Site would remain in its current state (see Figures 3, 5, and 10).

4.0 DETAILED ANALYSIS OF THE ALTERNATIVES 9, 10, 11, AND 12

The objective of the detailed analysis is to assess the alternatives with respect to the nine CERCLA evaluation criteria specified in the NCP at 40 CFR § 300.430(e)(9). Since the state is also exercising its independent cleanup authority under MTCA, the MTCA requirements specified in WAC 173-340-360 are also discussed. A proposed remedial alternative for the Site must meet the criteria of *both* CERCLA and MTCA to be considered for implementation. This analysis provides the basis for identification of a preferred alternative and preparation of the Proposed Plan.

The detailed analysis of Alternatives 9 through 12 is presented in this section. The detailed analysis of Alternatives 1 through 8 is provided in the DFFS and is not repeated in this SFS.

The CERCLA and MTCA evaluation criteria are described in Section 4.1. The detailed analysis of alternatives includes an individual analysis of each alternative in Section 4.2 and a comparative analysis of the alternatives together in Section 4.3.

Although the alternatives have been developed to a sufficient level of detail for feasibility-level analysis in this section, the alternatives are still considered to be conceptual. Design details and cost estimates will be refined following selection of the preferred remedial alternative and through final implementation of the remedial action.

4.1 CERCLA and MTCA Criteria for Remedy Selection

4.1.1 Regulatory Overview and Application

This section provides an overview of the CERCLA and MTCA remedy selection criteria, and the points of compliance where cleanup levels must be achieved.

4.1.1.1 CERCLA Overview

Under CERCLA [40 CFR § 300.430] nine criteria are used to evaluate remedial alternatives. The nine criteria used to evaluate and compare the alternatives are described below.

The CERCLA criteria, grouped by category, are as follows:

Threshold Criteria

1) Overall protection of human health and the environment.

2) Compliance with ARARs.

Primary Balancing Criteria

3) Long-term effectiveness and permanence.

4) Reduction of toxicity, mobility, and volume through treatment.

5) Short-term effectiveness.

6) Implementability.

7) Cost.

Modifying Criteria

8) State acceptance of the alternatives.

9) Community acceptance of the alternatives.

The CERCLA criteria categories are based on the role of each criterion during the evaluation and remedy selection process. Overall protection of human health and the environment, and compliance with ARARs are threshold requirements that each alternative must meet to be eligible for selection [40 CFR § 300.430(f)(1)(i)(A)]. The two threshold criteria relate directly to statutory requirements that must be satisfied by a selected alternative,[44] as ultimately documented in a ROD. The five primary balancing criteria represent the primary technical, cost, institutional, and risk factors that form the basis of the evaluation of alternatives that satisfy the threshold requirements, leading to remedy selection. The two modifying criteria are evaluated in the ROD following the receipt of state and public comments on the RI/FS and the Proposed Plan.[45]

Since the modifying criteria are evaluated following public comment on the RI/FS and Proposed Plan, this SFS evaluation considers only the CERCLA threshold and balancing criteria.

A flow chart of the CERCLA cleanup selection is provided on Figure 16.

As stated in the DFFS, the Administrative Order of Consent (AOC) required Intalco to analyze the alternatives using a tenth criterion, natural resource restoration. Although the AOC includes this criterion, it will not be relied on in determining the preferred alternative in the Proposed Plan or in selecting the alternative under CERCLA.[46]

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[44] An alternative that does not meet an ARAR may be selected under limited circumstances specified in the NCP. [40 CFR 300.430(f)(1)(ii)(C)].

[45] However, for this Site, the state is a co-regulator whose comments are reflected in the documents produced by the Agencies, including this SFS.

[46] Since neither the Proposed Plan nor the ROD will address natural resource damage caused by the release of hazardous substances at the Site, the determination of appropriate natural resource restoration to compensate for that damage remains an open issue to be addressed by the Natural Resource Trustees. 42 USC 9607(a)(4)(C). The Natural Resource Trustees include the Forest Service, Ecology, the USFWS, and the Yakama Nation.

4.1.1.2 MTCA Overview

There are seven requirements to be evaluated for selecting a final remedy under MTCA [WAC 170-340-360]. The first four requirements comprise the threshold requirements, and the remaining three requirements are referred to as the "other requirements." Additionally, MTCA has six action-specific requirements.

The requirements used to evaluate the remedial alternatives under MTCA cleanup regulation [WAC 173-340-360] include:

Threshold Requirements

1) Protect human health and the environment.

2) Comply with cleanup standards.

3) Comply with applicable state and federal laws.

4) Provide for compliance monitoring.

Other Requirements

5) Use permanent solutions to the maximum extent practicable.

6) Provide a reasonable restoration time frame.

7) Consider public concerns.

Action-Specific Requirements (pertaining to)

8) Groundwater.

9) Soils at current or potential future residential areas and for soils at schools and child care centers.

10) Institutional Controls.

11) Releases and Migration.

12) Dilution and Dispersion.

13) Remediation Levels.

A flow chart of the MTCA cleanup selection requirements is provided on Figure 17.

As with threshold criteria under CERCLA, the MTCA threshold requirements must be met for an alternative to be selected as a final remedy. The ”other” requirements are considered along with the threshold requirements in the comparative analysis of alternatives that satisfy the threshold criteria.

For convenience, in this SFS the alternatives are evaluated primarily against the CERCLA criteria. Where appropriate the MTCA criteria are also discussed. Appendix G includes a MTCA practicability analysis prepared to satisfy state-only requirements. The selection of a final remedy for the Site must satisfy both CERCLA and MTCA criteria.

4.1.1.3 Point(s) of Compliance

CERCLA and MTCA require that performance of a potential remedy be assessed at the point of compliance, which refers to the locations where cleanup levels must be attained. There are both standard points of compliance and, in some cases, conditional points of compliance. The anticipated points of compliance for the Site are discussed in more detail in this section. The points of compliance will be established in the ROD for the Holden Mine Site, in accordance with CERCLA and MTCA.

4.1.1.3.1 Groundwater

Under federal law, the point of compliance depends on the designated beneficial use of the surface water. As noted in Section 1.2.1.2, the designated beneficial uses of surface water in Railroad Creek [per WAC 173-201A-600] include (the use categories are shown in parenthesis): aquatic life (salmonid spawning, rearing, migration, and core summer habitat), recreation (extraordinary primary contact), water supply (domestic, industrial, agricultural, and stock watering), and miscellaneous (wildlife habitat, harvesting, commerce and navigation, boating, and aesthetic values). In addition, because the Site is within a National Forest, and because Railroad Creek is a feeder stream to Lake Chelan, WAC 173-201A-600(1)(a) requires that Railroad Creek also "be protected for the designated uses of core summer salmonid habitat, and extraordinary primary contact recreation.” Accordingly, cleanup levels for groundwater at the Site that enters Railroad Creek are based on protection of aquatic life.

Under CERCLA, the preamble to the final NCP [55 FR 8753] states that groundwater remediation levels should generally be attained throughout the contaminated plume, or at and beyond the edge of the waste management area (WMA) when the waste is left in place (see also 53 FR 51426). While EPA acknowledges an alternative point of compliance may also be protective of public health and the environment under "site-specific circumstances," the preamble to the proposed NCP also states "EPA's policy is to attain ARARs...so as to ensure protection at all points of potential exposure" [53 FR 51440]. Under CERCLA the alternative point of compliance for groundwater at this Site is based on the State of Washington's designated beneficial uses of the surface water, as set forth above. The points of potential exposure for the beneficial uses of surface water are at the groundwater-surface water interface.

Normally the point of compliance for groundwater under MTCA is throughout the Site, from the uppermost level of the saturated zone to the lowest depth that could potentially be affected. MTCA requires that groundwater cleanup levels be attained in all groundwater from the point of compliance to the outer boundary of the hazardous substance plume [WAC 173-340-720(8)]. MTCA allows a conditional point of compliance for groundwater for limited circumstances where it is not practicable to meet the cleanup level throughout a site within a reasonable restoration time frame.[47]

Where it is not practicable to meet the proposed groundwater cleanup levels throughout the Site within a reasonable time frame, MTCA requires that a groundwater conditional point of compliance be as close as practicable to the source, not to exceed a point within surface water as close as technically possible to the point(s) where contaminated groundwater flows into surface water [see WAC 173-340-720(8)(c) and WAC 173-340-720(8)(d)(i)]. This also represents an acceptable alternative point of compliance for groundwater under CERCLA as discussed above.

The DFFS indicated that the release of hazardous substances into groundwater would continue for hundreds of years (see Appendix E of the DFFS), and it is not practicable to meet the groundwater proposed cleanup levels throughout the Site within a reasonable time frame. The Agencies are not aware of any information that would contradict this finding. Thus, the Agencies propose to base the proposed remedy selection on the premise that it is not practicable to clean up all Site groundwater within a reasonable restoration time frame. Therefore, provided that the final remedy satisfies the MTCA requirements for a conditional point of compliance [WAC 173-340-720(8)(d)(i) (A) through (G)], the

[47] The test of "practicability" is a key element in remedy selection under MTCA. Practicability is discussed in detail in Appendix G, but it is also referred to in other parts of the SFS text where it is part of the MTCA remedy selection process.

Agencies propose that the Site's groundwater point of compliance be at the interface of contaminated groundwater and abutting surface water (e.g., Railroad and Copper Creeks) all across the Site. Groundwater cleanup levels at the groundwater point of compliance would be based on protection of surface water beneficial uses, including aquatic life protection as discussed in Section 1.2.1.2 of this SFS. The Agencies propose to require institutional controls to protect human health from potential groundwater consumption.

4.1.1.3.2 Surface Water

Under CERCLA, the NCP preamble [55 FR 8713] states the general policy for establishing a point of compliance for surface water cleanup is that "selected levels should be attained at the point or points where the release enters the surface water." The cleanup action needs to preserve beneficial uses of surface water at the Site. The State of Washington's designated beneficial uses of the surface water at the Site are set forth in Section 1.2.1.2.

Under MTCA, the standard point of compliance for surface water cleanup is the point(s) where hazardous substances are released to surface waters. For end of pipe discharges Ecology may establish a mixing zone in accordance with the Washington State Water Quality Standards for surface waters [Chapter 173-201A WAC]. However, no mixing zone is allowed for groundwater discharges to surface water [WAC 173-340-720(8)(d)(i)(C)]. At the Site, the treatment plant discharge outfall is the only point where a mixing zone could be authorized. The surface water point of compliance for all other sources of discharge, such as seeps and groundwater baseflow, remains at the point where such flows enter the surface water.

4.1.1.3.3 Soil

CERCLA does not specify a point of compliance for soil, except in its application of MTCA as a potential ARAR at the Site.

Under MTCA, soil cleanup levels and points of compliance are established separately for human exposure via direct contact, the protection of groundwater, and the protection of terrestrial ecological receptors [WAC 173-340-740]. The MTCA standard point of compliance for soil based on human exposure via direct contact is throughout the Site from the ground surface to a depth 15 feet below the ground surface. This depth may be reduced to a conditional point of compliance where institutional controls are provided to protect human health. For terrestrial receptors, a conditional point of compliance for soils may be established based on risk to terrestrial ecological receptors. This conditional point of compliance may be set at the base of the biologically active zone, which is assumed to extend to a depth of 6 feet, if institutional controls are used to prevent excavation of deeper soil. A site-specific depth may be approved, based on a demonstration that an alternative depth is appropriate per WAC 173-340-7490(4)(a).

The soil point of compliance for protection of groundwater is typically throughout the soils of the Site. Cleanup alternatives that involve containment of hazardous substances left on the Site can meet alternate requirements through the provisions of WAC 173-340-740(6)(f).

The Agencies expect further site-specific analyses to assess risk to terrestrial receptors during RD to address deficiencies in the DRI (see SFS Appendix E) and to establish whether an alternative depth for the conditional point of compliance for soils at the Site is appropriate.

For this analysis, the conditional point of compliance is anticipated to be the biologically active zone, which is assumed to extend to a depth of 6 feet, unless an alternative site-specific depth is later identified as being more appropriate per WAC 173-340-7490(4)(a).

4.1.1.3.4 Sediment

Standard points of compliance have not been established for freshwater sediment remediation. As previously mentioned, the federal government and Washington State have not promulgated freshwater standards for sediment quality management. However, the Agencies anticipate that the 2003 Ecology freshwater sediment quality guidelines will be TBC items in setting cleanup criteria. The Agencies anticipate that additional tests will assess the need for sediment cleanup following elimination of the sources of metals released into the creek, the removal of ferricrete, and the natural redistribution of sediments in the creek system. If it is determined that sediment cleanup is required to protect aquatic organisms, the depth and extent of such cleanup would be determined at that time in accordance with WAC 173-340-730(7)(f).

4.1.1.3.5 Use of the DFFS Model Results to Predict Concentrations at the Anticipated Groundwater and Surface Water Points of Compliance

Intalco used a mass load model (referred to as the DFFS Model) to predict surface water concentrations that may result from implementation of alternatives discussed in the DFFS, and subsequently for Alternatives 9 and the APR (URS 2005b). The DFFS model does not determine the concentration of hazardous substances at the required points of compliance for groundwater or surface water at the Site. Rather, the model estimates average concentrations across the stream width based on the mass load calculated for a fully mixed condition at a point located downstream of source release areas. Thus, the model ignores the adverse impacts to the approximately 1 mile of Railroad Creek, where the contamination is entering the creek. As a result of flaws in the model (see Appendix A), the Agencies have not relied on it to evaluate the anticipated performance of Alternatives 9 through 12, in meeting the CERCLA and MTCA criteria for remedy selection.

4.1.2 Threshold Criteria

This section describes the CERCLA threshold criteria and the application of these criteria to the remedy selection process.

4.1.2.1 Overall Protection of Human Health and the Environment

Overall protection of human health and the environment is one of the two CERCLA threshold criteria [40 CFR § 300.430(e)(9)(iii)(A)] and one of the four MTCA threshold requirements [WAC 173-340-360(2)(a)]. The NCP states: "Alternatives shall be assessed to determine whether they can adequately protect human health and the environment, in both the short- and long-term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site by eliminating, reducing, or controlling exposures to levels established during development of remediation goals..." {40 CFR § 300.430(e)(9)(iii)(A)].

According to the NCP, overall protection of human health and the environment draws on assessments of other CERCLA evaluation criteria, including the following:

- Long-term effectiveness and permanence;
- Short-term effectiveness; and
- Compliance with ARARs.

MTCA requirements are quite similar to these criteria.

4.1.2.1.1 Protection of Human Health

As part of the DRI, Intalco conducted a Human Health Risk Assessment (HHRA) for the Site to evaluate the potential for threats to human health. Groundwater at the Site has metal concentrations exceeding drinking water standards in one or more locations for aluminum, cadmium, copper, lead, and zinc. Although groundwater near the sources of release at the Site is not currently used as a source of drinking water, both state and federal regulations require cleanup of the groundwater to drinking water standards since it would be usable, absent the effects of contamination from the Site.

Groundwater ingestion was not considered to be a significant exposure pathway in the HHRA, since groundwater is not used as drinking water near the sources of release. Although groundwater near the sources of release at the Site is not currently used as drinking water, institutional controls are needed to prevent future potential human exposure through groundwater ingestion.

Although the HHRA in the DRI concluded that no toxicity risks exist for humans at the Site using certain exposure pathways, concentrations of some metals in soils exceed MTCA Method A and B cleanup levels based on the protection of human health. Soil constituents exceed cleanup levels for protection of human health for direct exposure for arsenic, cadmium, copper, lead, and zinc (e.g., in the lagoon and/or maintenance yard areas). Response actions under CERCLA were identified in the DFFS and SFS to avoid human exposure, and incorporated into all alternatives except Alternatives 1 and 12.[48] Based on analysis of samples collected after the DRI was completed, arsenic also exceeds proposed cleanup levels for protection of human health in soils in the LWA.

4.1.2.1.2 Protection of the Environment

Protection of the environment at the Site includes the protection of aquatic and terrestrial life. Discussion of whether Site remedial alternatives are protective of the environment is complicated by the following limitations of the RI and DFFS:

- The only tool provided in the DFFS for estimating post-remediation metals loading to Railroad Creek is a mass loading analysis that estimates concentrations for a fully mixed condition in Railroad Creek downstream of source release areas. As previously discussed, the DFFS does not provide a method to analyze metals concentrations in the stream adjacent to source areas, including the anticipated surface water or groundwater points of compliance for the Site.

- Intalco's ERA understates risks to aquatic life based on both empirical observations and comparison to EPA's NWQC for aluminum, cadmium,

[48] Mine tailings that are exposed in some portions of the Site exceed MTCA direct contact exposure levels for human health for cadmium and copper. Under some alternatives, but not all, the risk to human health would be addressed through closure of the tailings piles in accordance with state landfill criteria.

copper, iron, and zinc, based on aquatic life protection. The Agencies note that review of available toxicological data by the USFWS confirms that the 2002 NWQC values are an appropriate basis for remediation to cleanup surface water at the Site (USFWS 2004 and 2005). Additionally, MTCA specifically incorporates NWQC (1999) as a MTCA requirement under WAC 173-340-730(3)(b)(i)(B), (Forest Service 2003).

- The RI did not evaluate lead for the protection of surface water organisms, even though the portal discharge and some seep discharges exceed the proposed lead surface water cleanup level, which is based on protection of aquatic life.

- There are also limitations to use of the terrestrial ERA presented in the DRI and used in the DFFS and URS (2005a) as a basis for establishing soil cleanup levels. For example, Intalco did not consider the effect of contaminated groundwater on terrestrial receptors in the wetland east of TP-3, and did not satisfy other MTCA requirements as discussed in Appendix E of this SFS.

- The ERA that was completed for the DRI is also not sufficient for determining the need for, or extent of soil cleanup for portions of the Site e.g., the LWA, the baseball field, areas within Holden Village, and the area of observed wind-blown tailings deposition east of the Village.

To reduce the risk to aquatic life within Railroad Creek requires the reduction in metals concentrations within the creek, by decreasing the amount of metals entering the creek through discharge from the mine, groundwater, and seeps. This reduction can be accomplished by changing either the flow rate or concentration, or both (the metals load entering the creek) but compliance is determined by measuring concentration at the designated points of compliance. Surface water criteria, protective of aquatic life, must be met throughout the entire creek.

The removal, containment, or covering of soils with constituents of concern above proposed cleanup levels would reduce toxicity risks to terrestrial life throughout the Site.

4.1.2.2 Compliance with ARARs

The other threshold criterion under CERCLA is compliance with ARARs [40 CFR § 300.430(e)(9)(iii)(B)]. Under this criterion, "the alternatives shall be assessed to determine whether they attain [ARARs] under federal environmental laws and state environmental or facility siting laws, or provide grounds for invoking one of the waivers listed in 40 CFR § 300.430(f)(1)(ii)(C)...”; see 40 CFR § 300.430(e)(9)(iii)(B). Intalco did not identify any need for, or request, ARAR waivers in the DFFS (see Section 3.0, URS 2004a), and the Agencies have not identified any need for an ARAR waiver at the Site.

While MTCA provisions are potential ARARs under CERCLA, the state also has independent authority for remediation of the Site, as previously indicated. The CERCLA threshold criteria of compliance with ARARs is similar to the MTCA threshold requirements to “comply with cleanup standards” and “comply with applicable state and federal laws.”

The potential ARARs and the proposed cleanup levels for the Site were established as discussed in Section 2.3. The proposed cleanup levels for soil and surface water are based on the most stringent potential chemical-specific ARAR or the background concentration at the Site, where background exceeds the most stringent potential ARAR.

4.1.2.2.1 Potential Chemical-Specific Requirements for Surface Water

Proposed cleanup levels for surface water are based on the NWQC for copper and iron, the state water quality standard for zinc, and Railroad Creek background concentrations for aluminum, cadmium, and lead.

4.1.2.2.2 Potential Chemical-Specific Requirements for Groundwater

Proposed cleanup levels for groundwater are based on federal and state MCLs, state MTCA cleanup levels for drinking water, and water quality criteria where groundwater discharges to surface water.

Groundwater is currently not used as a source of drinking water near the sources of release at the Site. However, state law specifies that the highest and best use of groundwater is for drinking water, and, therefore, a goal of remediation should be meeting drinking water standards throughout the Site. Based on information in the DFFS, Intalco concluded that it is not practicable to meet the proposed groundwater cleanup levels in portions of the Site within a reasonable time frame. The Agencies accept this conclusion, as it applies to groundwater within WMAs, see Section 4.1.1.3.1. Thus, institutional controls to prevent exposure to groundwater above drinking water levels are still required. Where groundwater discharges to surface water, under CERCLA and MTCA groundwater must also be cleaned up to meet surface water potential ARARs.

4.1.2.2.3 Potential Chemical-Specific Requirements for Soil

Potential chemical-specific ARARs for soils are based on the MTCA protection of human health, groundwater, surface water, and terrestrial receptors.

MTCA allows Ecology to set cleanup levels based on a site-specific evaluation, and soil cleanup levels protective of surface water may be adjusted for cleanup actions that involve containment of hazardous substances [WAC 173-340-740(6)(f)]. The Agencies believe that at least one alternative for the proposed cleanup (Alternative 11, described later in this report) would provide adequate containment, collection, and treatment of hazardous substances for all areas on the south side of Railroad Creek. North of Railroad Creek, there are some areas where surficial soils exceed concentrations deemed protective of groundwater and/or surface water. However in these areas, there is no indication of contamination at depth within the soil profile, and groundwater contamination is apparently the result of groundwater transport from south of the creek. Where the remedies include cleanup of soil to protect human health and ecological receptors, and where collection and treatment of downgradient groundwater are conducted, the Agencies do not expect any further clean up of soils would be needed to protect groundwater, surface water, and sediment.

Additional terrestrial risk assessment would determine whether any action is needed to address wind-blown tailings north and east of the Site and other areas where metal concentrations in soils exceed potential ARARs.

4.1.2.2.4 Potential Chemical-Specific Requirements for Sediment

At this time there are no potential chemical-specific ARARs for cleanup of sediments at the Site, but sediment concentrations exceed freshwater sediment quality guidelines that are TBCs for cleanup standards. The Agencies anticipate additional sampling and analysis will be used to determine the need for any further cleanup following elimination of the sources of metals released into the creek, the removal of ferricrete, and the natural redistribution of sediments in the creek system, as provided in WAC 173-340-730(7)(f).

4.1.2.2.5 Potential Action- and Location-Specific Requirements

In addition to the potential chemical-specific ARARs discussed above, by media, potential action- and location-specific ARARs, discussed in Sections 2.3.3.2 and 2.3.3.3, are also considered during CERCLA and MTCA remedy selection.

4.1.3 Primary Balancing Criteria

Under CERCLA, only alternatives that meet the CERCLA threshold criteria for selecting a final remedy are typically carried forward and analyzed using the primary balancing criteria. This ensures that the selected remedy will be protective of human health and the environment and be ARAR-compliant. The other selection criteria are considered to select the best alternative that achieves the threshold criteria. Although Alternatives 9, 10, and 12 do not meet the threshold criteria, for completeness, the Agencies have analyzed them using the primary balancing criteria.

4.1.3.1 Long-Term Effectiveness and Permanence

For the first of the primary balancing criteria for selection of a cleanup action under CERCLA, "alternatives shall be assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will be successful." [40 CFR § 300.430(e)(9)(iii)(C)].

Under CERCLA, the two factors considered for long-term effectiveness and permanence include:

- "Magnitude of residual risk remaining from the untreated waste or treatment residuals remaining at the conclusion of the remedial activities. The characteristics of the residuals should be considered to the degree they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate" [40 CFR § 300.430(e)(9)(iii)(C)(1)].

- "Adequacy and reliability of controls such as containment systems and institutional controls that are necessary to manage treatment residuals and untreated waste" [40 CFR § 300.430(e)(9)(iii)(C)(2)].

The CERCLA long-term effectiveness and permanence balancing criteria are similar to the MTCA "other" requirement for use of permanent solutions to the maximum extent practicable.

4.1.3.1.1 Magnitude of Residual Risk Remaining at the Conclusion of the Remedial Activities

This criterion refers to the residual risk that will remain at the Site following implementation of the remedial action. There are substantial differences in the amount of residual risk that would remain following implementation, since the different remedial alternatives provide different degrees of groundwater containment, collection, and treatment.

Based on the DFFS geochemical evaluation of the Holden Mine Site by SRK Consulting (URS 2004a), weathering processes that cause acid mine drainage and release of metals *above* proposed cleanup criteria are predicted to continue for hundreds of years. Thus collection and treatment of groundwater and the portal discharge must operate at the Site for hundreds of years to prevent releases of contaminated water into Railroad Creek. Areas where collection and treatment are not performed would continue to exceed criteria over this same time frame. The remedial alternatives differ in the degree to which they reduce risk of slope failures of the tailings piles that could introduce thousands of tons of reactive tailings into Railroad and Copper Creeks. Analyses in the DRI showed that existing factors of safety for stability of the tailings pile slopes are relatively low (1.0 to 1.2). This indicates that the tailings piles are barely stable in their existing condition. An earthquake, or undercutting from flooding, could cause the tailings pile slopes to collapse and result in a massive release into Railroad and/or Copper Creeks.

The extent of tailings pile stabilization and setback varies among the alternatives and affects the residual risks of releases from large-scale slope failures and erosion. Large-scale slope failures, erosion, and/or flooding of the creek(s) could also damage the tailings pile covers and drainage controls if these issues are not adequately addressed as part of the remedy.

Finally, there is also residual risk due to potential changes in quantity or quality of groundwater that will continue to discharge from the mine. Experience reported in the DRI from other sites suggests installation of hydraulic barriers may degrade water quality over the short term. However, the bulkheads provide a means to control the rate of discharge and could help ensure treatment effectiveness if large changes in flow or water quality follow the collapse of the underground workings.

Different remedial alternatives would produce varying amounts of sludge from water treatment. As part of the remedy, the metal hydroxide sludge would need to be disposed of on Site in a limited purpose landfill. Reported leach test results for treatment sludges at other mine sites suggest the sludge is likely to be relatively stable, and a good means of eliminating the metals from the environment. However, landfill leachate (the water produced during consolidation of the sludge) will likely need to be managed since it may have concentrations of metals that exceed surface water quality criteria.

4.1.3.1.2 Adequacy and Reliability of Controls

To assess the adequacy and reliability of controls at the Site, items to be addressed under CERCLA include: 1) uncertainties associated with land disposal of treatment system residuals; 2) potential need to replace technical components of the remedy; and 3) potential risk if components of the remedy need replacement [40 CFR § 300.430(e)(9)(iii)(C)(2)]. Besides considering these three CERCLA items, it is also important to discuss the overall adequacy of the controls to prevent the discharge of contaminated groundwater into Railroad Creek.

Iron fouling and encrustation of groundwater and seep collection and conveyance systems, (including well screens, French drains, pipelines, ditches, and flow controls) may reduce the effectiveness of these components over time. As a result, collection and conveyance systems that are accessible and simple to maintain are more likely to be reliable.

Maintenance and operation requirements for comparable treatment system components would be similar in nature for the proposed remedial actions, but the extent of those requirements would vary with system size. Each of the alternatives uses acid neutralization and precipitation as the basic approach for treatment. The maintenance and operation requirements would be similar for facilities using similar treatments, but the frequency and cost of such requirements would depend on the volumes of water treated and sludge generated, which vary among alternatives.

Over the long term, the significant volumes of sludge generated would require dewatering and disposal. Each year roughly 19,000 to 32,000 cy of sludge would be generated, depending on the alternative. For comparison, the SFS assumes annual sludge removal from the treatment facility, when it has a solids content of about 4 percent by weight (i.e., while it has more than 95 percent water). Sludge management and reported experience for other AMD treatment systems is discussed in Appendix F of the SFS. Initial dewatering would reduce sludge volume. This volume would further decrease over time from consolidation.[49] Handling the sludge (i.e., moving it from the treatment system to drying beds, extracting the free water, and ultimately disposing of the semi-solid residual in a limited purpose landfill on the Site) would require engineering controls and consume electrical energy for pumping. Landfill management will need to include the removal of excess water, and the closure and reclamation of landfill cells as they are filled with sludge. The DFFS did not examine sludge management in detail, so additional information and analysis are presented in Appendix F of this SFS. Sludge management will need to be addressed further

[49] Geotechnical analyses by the Agencies indicate approximately 50 percent volume reduction from consolidation over a 50-year period, using sludge characteristics reported for other mine site treatment systems.

during RD, since the required facilities and controls contemplated for each alternative are similar.

4.1.3.2 Reduction of Toxicity, Mobility, or Volume through Recycling or Treatment

The second criterion of the primary balancing criteria is assessing "the degree to which alternatives employ recycling or treatment that reduces toxicity, mobility, or volume, including how treatment is used to address the principal threats posed by the site." [40 CFR § 300.430(e)(9)(iii)(D)]. Factors considered under this primary balancing criteria are similar to considerations under the following MTCA "other" requirements—use permanent solutions to the maximum extent practicable and provide for a reasonable restoration time frame.

The CERCLA factors considered in this assessment include:

- "The treatment or recycling processes the alternatives employ and materials they will treat;
- The amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled;
- The degree of expected reduction in toxicity, mobility, or volume of the waste due to treatment or recycling and the specification of which reduction(s) are occurring;
- The degree to which the treatment is irreversible;
- The type and quantity of residuals that will remain following treatment, considering the persistence, toxicity, mobility, and propensity to bioaccumulate of such hazardous substances and their constituents; and
- The degree to which treatment reduces the inherent hazards posed by principal threats at the site" [40 CFR § 300.430(e)(9)(iii)(D)(1)-(6)].

4.1.3.2.1 Treatment or Recycling Processes and Materials Treated

While the treatment method is the same, alternatives differ significantly in the amount of contaminated groundwater collected and treated, and the sources addressed at the Site. The treatment method uses pH adjustment and precipitation to remove aluminum, cadmium, copper, iron, lead, and zinc from the collected water. Published reports indicate that leachate from the sludge is likely to have metals concentrations below proposed groundwater cleanup levels. However, the sludge leachate will require monitoring for several years to confirm that metals concentrations in the leachate meet the proposed surface water cleanup levels.

4.1.3.2.2 Amount of Hazardous Substances, Pollutants, or Contaminants Destroyed, Treated, or Recycled

None of the proposed remedial actions destroy hazardous substances.

The mass, or amount, of metals removed from the environment differs due to differences in where groundwater is collected from the Site and the volume of groundwater collected for treatment.

4.1.3.2.3 Degree of Expected Reduction in Toxicity, Mobility, or Volume

Metals removed from groundwater through the treatment process for each of the alternatives become a relatively stable sludge. These metals are prevented from reaching Railroad Creek.

4.1.3.2.4 Degree of Treatment Irreversibility

Water treated to remove metals will produce metal hydroxide sludge as a by-product of treatment. To assess the degree of irreversibility of the waste treatment process, the Agencies conducted a literature survey to assess sludges from multiple mine sites with wastewater constituent and treatment technologies similar those expected at the Site (Hart Crowser 2004). These studies assessed sludge stability through leaching tests, which determined the potential for metals to be released and to re-enter the environment. Reported results of leaching tests from various sludges indicate that metal concentrations in leachate are typically well below those needed to protect groundwater at the Site. However, the reported results sometimes exceeded the proposed Site surface water cleanup levels, or had detection limits above the proposed surface water criteria.

While the sludge landfill permanently contain the metals from the treated groundwater, and prevent the metals from reaching Railroad Creek, leachate from the sludge would need to be managed to protect surface water quality. The Agencies anticipate the sludge disposal landfill would need to be lined or, possibly, might be unlined if located upgradient of a groundwater barrier and collection system. Performance requirements for sludge disposal facility would need to be further evaluated during RD.

4.1.3.2.5 Type and Quantity of Residuals

Characteristics of the treated water and sludge based on reports from other sites with comparable AMD are summarized in Appendix F of this SFS.

The volume of water that would be collected and treated varies between alternatives. The DFFS reported results of limited "jar shaking" treatment tests that Intalco performed on drainage from the mine portal during planning for the mine entry in 2000. However, the concentrations of different metals in these tests are not the same as the actual influent that would need to be treated for any alternative. Both the DFFS and Appendix F of the SFS provide reported information on the range of effluent water quality from treatment of drainage from other mine sites. These results vary and indicate the difficulty in predicting effluent water quality without site-specific tests. In the absence of treatability tests for the Site, there is no good basis for expecting differences in effluent water quality for one alternative compared to another. Estimates of effluent water quality were prepared for the alternatives evaluated in both the DFFS and the SFS. A comparison of the differences in influent and effluent water quality was used in the SFS to estimate the annual volume of sludge that would be produced by a conceptual treatment facility. The estimated volume of sludge produced by each alternative was compared in the SFS based on the relative volumes of water treated for each alternatives.

The sludge would initially be mostly water.[50] The DFFS assumed passive sludge dewatering except for Alternative 6. While passive dewatering can occur due to both evaporation and freeze-desiccation, Appendix F of the SFS discusses the potential need for sludge recycling (a water-reducing process that has been effective at other mine sites) or mechanical clarification (a water reducing process conventionally used in both municipal and industrial water treatment systems), to enhance passive dewatering. Over time, the solids content of the sludge would increase in the landfill as consolidation occurs. Concurrently the rate of sludge production over time would decrease to less than half its initial rate due to changes in the influent loading to the treatment plant.

The relative proportions of metals present in the Holden sludge is anticipated to vary between alternatives, depending on the effect of differences in location and extent of groundwater collected for treatment. Leachate tests [e.g., toxicity characteristic leaching procedure (TCLP)] reported for other sites with

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[50] For cost estimating purposes, the SFS considered a conceptual treatment system that was sized based on the assumption that sludge would be removed annually from the treatment system when it was about 4 percent solids by weight.

comparable AMD treatment systems suggest that leachate from the sludge sometimes may exceed the proposed Holden surface water cleanup levels, in which case it could be collected and recycled through the water treatment facility.

4.1.3.2.6 Degree to which Treatment Reduces the Inherent Hazards Posed by Principal Threats

Under CERCLA, treatment is expected to be used to address the principal threats posed at a site, wherever practicable [40 CFR § 300.430(a)(1)(iii)(A)]. CERCLA contemplates use of engineering controls, such as containment, for wastes that pose a low long-term threat, or where treatment is impracticable; or use of a combination of approaches to achieve protection of human health and the environment. In appropriate situations, treatment of the principal threats posed by the site is combined with engineering controls, such as containment and institutional controls for treatment residuals and untreated wastes [40 CFR § 300.430(a)(1)(iii)(B) and (C)].

Risk to the aquatic environment at the Site is directly related to the toxicity and quantity of hazardous substances released into Railroad Creek from the mine portal, seeps, and groundwater baseflow. Risk to human health and other terrestrial receptors is associated with soils and mine tailings, and groundwater. The source materials at the Site (i.e., underground mine, waste rock, tailings, contaminated soils, and contaminated sediment) are not considered highly toxic or highly mobile and, therefore, are not considered principal threat wastes as defined by EPA (EPA 1991).[51]

4.1.3.3 Short-Term Effectiveness

Short-term effectiveness is the third primary balancing criteria under CERCLA. The short-term effectiveness criterion addresses items similar to those considered under the MTCA "other" requirement of using permanent solutions to the maximum extent practicable. CERCLA's short-term effectiveness criterion shall be assessed by considering the following items:

- "Short-term risks that might be posed to the community during implementation of an alternative;

[51] As a result, treatment of the source materials (that are not principal threat wastes) is not necessarily required, and engineering controls (e.g., capping, containment) may be suitable for addressing the source materials, as well as other media (i.e., groundwater and surface water) contaminated by the source materials.

- Potential impacts on workers and the effectiveness and reliability of protective measures;

- Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation; and

- Time until protection is achieved" [40 CFR § 300.430(e)(9)(iii)(E)(1)-(4)].

4.1.3.3.1 Short-Term Risks on the Community during Implementation

Short-term health risks to the community during implementation primarily consist of increased exposure to construction traffic. This risk can be mitigated for each alternative, as described later in this document. Potential exposure to construction dust, noise, and vehicle exhaust emissions is not anticipated to present risks to the Holden Village community or other members of the public using the adjacent forest lands.

Provided such measures are taken, there is no difference in the nature of the short-term community risk between alternatives, except the duration of construction traffic would vary depending on the length of time required for construction.

Once construction is complete, there will be more traffic on the Lucerne-Holden Road compared to current conditions, but less than during construction. This traffic will result from deliveries of lime and fuel required for operation and maintenance of the remedy. The Agencies anticipate that fuel import requirements could be minimized by development of a dedicated hydroelectric generating facility (e.g., on Ten-Mile Creek) if this proves to be feasible based on an evaluation during RD. The impacts of routing traffic to supply fuel and lime to the treatment plant following startup would vary depending on the remedial alternative and power source selected.

4.1.3.3.2 Potential Impacts on Workers during the Remedial Action and the Effectiveness and Reliability of Protective Measures

Human health risks to construction workers due to remedy implementation, include mine hazards, construction traffic, open excavations for pipelines, regrading, barrier wall construction, treatment plant construction, exposure to soils with elevated concentrations of petroleum hydrocarbons and possibly other dangerous wastes, noise and dust exposure, demolition of the derelict mill structure, and common-place slips, trips, and falls. The duration and number of workers exposed would vary significantly, depending on the alternative implemented. For construction workers, the risk of worker injury increases with the overall level of construction required by an alternative.

Mitigation for the three alternatives would be based on conformance with state construction safety standards [Chapter 296-155 WAC]; HAZWOPER standards [29 CFR Part 1910.120]; and relevant and appropriate parts of Mine Safety and Health Administration (MSHA) safety standards for underground construction work [30 CFR Part 57]. Federal safety standards prepared by the MSHA are not specifically applicable for work in abandoned mines, but MSHA standards are potentially relevant and appropriate. Most underground construction contractors are familiar with MSHA standards.

4.1.3.3.3 Potential Environmental Impacts of the Remedial Action and the Effectiveness and Reliability of Mitigative Measures during Implementation

Potential environmental impacts of the remedial actions are discussed below.

Risk of Tailings Release during Regrading. There is some risk of slope failure and sloughing of the tailings into Railroad Creek during regrading to improve slope stability. The degree of this risk varies with the extent of regrading performed.

Stormwater runoff during regrading may also cause a release of tailings into Railroad Creek. The regrading work could be performed sequentially along the face of the tailings piles (moving east to west), with the cover placed over tailings that have already been regraded, concurrent with grading slopes further to the west. In this way, the area of unoxidized tailings exposed at any time could be minimized, reducing the risk of stormwater runoff conveying exposed tailings into Railroad Creek.

The DFFS included an analysis that estimated stormwater runoff from tailings exposed for a month would have a pH of 2 and elevated concentrations of metals (especially zinc at 3,500,000 ug/L). Concentrations of metals in the runoff would be increased if the tailings were exposed for longer periods prior to the storm.

For an assumed worst case analysis (all the tailings exposed at the time of a 1-inch 24-hour storm), the DFFS estimated the mass of metals delivered to the creek would be 22 kilograms (kg) cadmium, 149 kg copper, 18,600 kg iron, and 93,200 kg zinc (according to Table 7-8 of the DFFS). Such a release would produce a plume toxic to aquatic life that would extend down Railroad Creek and possibly impact Lake Chelan.

Risk of Slurry Release during Barrier Wall Construction. There is risk of a release to Railroad Creek of the bentonite slurry and concrete during construction of the barrier walls adjacent to the creek. Potential risk of a bentonite or cement release can be minimized by good construction practices, including location of dry materials storage and mixing facilities away from the creek, good housekeeping to minimize spillage during slurry handling, and advance preparation of a spill management contingency plan.[52] The risk of bentonite and cement release varies with the distance between the creek and the barrier wall, the length of wall constructed, and the depth of the wall, which affects the time required to construct the wall.

Risks Associated with Construction of Hydraulic Barriers in the Underground Mine. While the Agencies prefer the use of bulkheads to control the rate of drainage from the mine, the DFFS noted experience at other sites suggesting bulkhead installation may cause short-term water quality degradation, due to the effect of flooding areas where metal salts and/or exposed sulfide-bearing rock is not currently affected by drainage from the mine.

The DFFS notes that this effect has been observed at other mines that are allowed to flood and provides a basis for predicting the resulting water quality degradation (that has been taken into account in analyses of the proposed water treatment plant). However, if the mine drainage is collected for treatment, this should not adversely impact water quality in Railroad Creek.

Risk of Sediment Release in Railroad Creek. There is risk of sediment release to Railroad Creek during construction of the remedial action. This risk varies depending on both the proximity to Railroad Creek and the extent of construction necessary. Conventional construction practices can mitigate risk of sediment release to the creeks from construction of groundwater and seep collection systems, and pipeline creek crossings.

Risk from Construction Vehicle Emissions, Noise, and Dust. The risks from construction vehicles and activities vary with the degree of construction required to implement an alternative. Construction work to implement the remedy would need to conform to Forest Service Standards and Guidelines that were developed under the Wenatchee National Forest LRMP. The Agencies anticipate using a SEPA checklist, prepared as part of the MTCA remedy

[52] The DFFS proposed barrier walls be constructed as soil-bentonite, or cement-bentonite slurry trench walls. This approach is included in the SFS for discussion purposes. The DFFS did not evaluate other types of groundwater barriers (e.g., secant soil mixing or jet grouting barriers). These and other options could be evaluated during RD.

selection process, to identify potential environmental impacts resulting from remedy implementation. Local jurisdictional requirements may also be identified through comments on the draft Proposed Plan. The SEPA checklist and comments would provide the basis to determine required mitigation.

Risk of Fuel and Lime Spills. During construction, there is a risk of fuel spills both on and off the Site. In an assumed worst case, an off-Site spill could release the contents of a tanker truck (typically about 2,000 gallons) into the Railroad Creek Watershed or Lake Chelan. The risk of this is proportional to the total quantity of fuel that would be used. Fuel transport to the Site is regulated by the US Department of Transportation and the State of Washington [Chapter 90.56 RCW], and storage and handling at the Site would be regulated by EPA requirements for spill prevention, control, and countermeasure (SPCC), see 40 CFR Part 112.

During treatment facility operation, there is also some risk of spilling hydrated lime during transport to the Site or transfer from the delivery truck into on-Site storage. Hydrated lime is a caustic chemical that can cause injury to humans and/or environmental damage if released in a spill. Hydrated lime is not classified as a hazardous material by the U.S. Department of Transportation, and recommendations for safe handling and cleanup of spills are available as part of material safety data sheets from manufacturers (e.g., Lafarge North America).

Risk of Mass Release of Tailings due to Slope Failures. During regrading there is a risk that earthwork on the slopes adjacent to Railroad and Copper Creeks could cause failures. While this risk also exists to some degree if no remedial action is taken, it may increase over the short term during construction. The risk of construction-induced slope failure impacts can be mitigated through use of temporary barriers, (e.g., a geo-tube barrier such as Aqua-Dam® or Econo-Dam®).

Risk of Surface Water Quality Violations during Startup and Initial Treatment Operations. There is some risk that the treatment facility effluent may not initially meet water quality criteria due to startup problems. However, the impact of this for any alternative is likely to be less than if no action is taken. The risk of startup problems is similar for each alternative, but the magnitude of a non-compliant discharge could vary depending on the magnitude of flow being treated, which varies from one alternative to another.

4.1.3.3.4 Time until Protection is Achieved

The time until protection is achieved will vary between alternatives, depending on the extent to which remedial actions address contaminant sources and contaminated areas. An alternative addressing all sources and contaminated areas could be protective immediately after implementation. An alternative that relies in whole or in part on natural attenuation could take significantly longer to achieve protection. For example, if waste rock is removed but the existing contaminated groundwater below is not contained or remediated, the action will not achieve protection until natural attenuation reduces constituent concentrations to acceptable levels.

4.1.3.4 Implementability

Implementability is the fourth of the primary balancing criteria under CERCLA. The implementability issues that shall be assessed for the alternatives under CERCLA include:

- "Technical feasibility, including technical difficulties and unknowns associated with construction and operation of a technology; the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy" [40 CFR § 300.430(e)(9)(iii)(F)(1)].

- "Administrative feasibility, including activities needed to coordinate with other offices and agencies, and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions)" [40 CFR § 300.430(e)(9)(iii)(F)(2)].

- "Availability of services and materials, including the availability of adequate off-site treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources; the availability of services and materials; and the availability of prospective technologies" [40 CFR § 300.430(e)(9)(iii)(F)(3)].

Implementability is covered under the MTCA "other" requirement to use permanent solutions to the maximum extent practicable.

4.1.3.4.1 Technical Feasibility

Each of the alternatives is technically feasible. The main issues that affect technical feasibility are related to installation of groundwater barrier walls and the installation and maintenance of groundwater collection systems.

Installation of the Groundwater Barrier Systems. The DFFS described use of cement-bentonite and soil-bentonite groundwater barriers. These types of barrier have been constructed by the "slurry trench" method since the 1960s, in a wide range of soil types. The slurry trench approach is well suited to subsurface conditions at the Site, which includes glacial and alluvial soils with boulders (see Appendix C for additional information). Other types of barriers, such as secant walls constructed by soil mixing or jet grouting, may be further considered during RD. There are a number of specialty contractors with experience in this type of construction. Construction of the groundwater barrier walls proposed is technically implementable at the Site, despite differences in location and geometry. Duration of barrier construction is directly related to length and depth of the barrier.

The Duration and Complexity of Maintaining the Groundwater Collection Systems. Maintenance of the groundwater collection systems would be quite different depending on the proposed method of collection. Maintenance of groundwater collection system is anticipated to be required for the entire duration of the remedy, estimated to be hundreds of years.

Iron fouling is anticipated to be a problem for the groundwater collection system, as experience at other sites indicates iron fouling is a major concern. An analysis of technical feasibility needs to consider the extent of the potential iron fouling problem and the ease with which it could be fixed or avoided through system maintenance.

Maintenance of the treatment system is anticipated to be similar for alternatives implementing water treatment systems. Problems may occur with chemical addition and mixing in winter weather, operation of media filters under freezing conditions, and sludge disposal. Generally the required maintenance to mitigate treatment system problems varies with the amount of water treated.

Holden Village currently has no excess generating capacity from its hydroelectric system. No commercial electrical supply is available at Holden; so alternatives requiring power (e.g., for pumps and water treatment) must rely on a new hydroelectric energy source or possibly generators using imported fuel to provide electricity for necessary pumping, freeze protection, etc.

4.1.3.4.2 Administrative Feasibility

Administrative feasibility refers to activities that need to be coordinated with other agencies, and the ability and time required to obtain any necessary approvals and permits from other agencies. Administrative requirements associated with potential ARARs are discussed in Appendix C of the Site Information Package that was prepared for EPA (Hart Crowser 2005e).

The land affected by the remedy is under the control of the Forest Service, except for patented mine claims owned by Holden Village, Inc. The Agencies expect Holden Village Inc. to be a party to a consent decree or other administrative mechanism for implementing the remedy.

No wastes are anticipated to be moved off the Site for disposal, with the possible exception of residual processing wastes encountered during cleanup of the abandoned mill building, which may designate as state Dangerous Waste. Arrangement for a disposal site for such wastes would not affect selection of one remedial alternative versus another.

4.1.3.4.3 Availability of Services and Materials

The technologies required for the components in the alternatives are known and proven technologies. The Agencies anticipate there will be companies willing to do this work and the contractors bidding for this work will be experienced in the technologies required. Despite the Site's remote geographic location, necessary equipment would be able to be moved to the Site for construction.

4.1.3.5 Cost

Cost is the final primary balancing criteria under CERCLA. An analysis of cost does not necessarily lead to selection of the least cost alternative. Rather CERCLA enables the evaluation of alternatives to eliminate an alternative with comparable effectiveness and implementability, but greater cost compared to another alternative [40 CFR § 300.430(e)(7)(iii)]. Additionally, each remedial action selected for comparison "shall be cost effective, provided that it first satisfies the threshold criteria" [40 CFR § 300.430(f)(1)(ii)(D)]. There are three types of costs that shall be assessed for the alternatives under CERCLA, these include:

- Capital costs (both direct and indirect);
- Annual operations and maintenance (O&M) costs;[53] and
- The net present value (NPV) of capital and O&M costs.

Under MTCA, costs are considered under the "other" requirement as part of the disproportionate cost analysis to determine whether an alternative that meets

[53] Operations and maintenance costs also include monitoring to assess remedy performance and effectiveness, thus O&M costs are also sometimes referred to as OMM costs.

the threshold criteria uses permanent solutions to the maximum extent practicable. A disproportionate cost analysis is provided in Appendix G of this SFS.

The Agencies' cost estimates for the SFS are discussed in Appendix B. The estimates include direct and indirect capital costs; annual and other future recurring costs for operations, maintenance, and monitoring; and the net present worth of capital and future costs, for each alternative. The Agencies estimates were prepared for the SFS since this includes alternatives that are not addressed in the DFFS. The basis for the Agencies estimates and comparison to estimates in the DFFS is discussed in Appendix B of this SFS.

4.1.3.5.1 Direct Capital Costs

Direct capital costs typically include the cost for labor, materials, and equipment that the remediation contractor needs to accomplish the cleanup. Direct capital costs include costs associated with cleanup, such as containment; capping; and/or removal, transport, and disposal of affected soils and waste materials; and construction of permanent treatment facilities.

4.1.3.5.2 Indirect Capital Costs

Indirect costs are the contractor's expenses for overhead and profit, and for other expenses related to coordination and administration of construction, that apply to the project as a whole. Indirect costs are estimated as a mark-up on direct costs, using published rates for guidance. In this SFS, indirect costs have been estimated to be 30 percent of direct capital costs.

4.1.3.5.3 Non-Construction Capital Costs

Non-construction capital costs include expenses associated with implementing the remedy such as engineering design; construction administration; oversight by the Agencies; project management by the PRP; and remedy startup expenses, such as treatment system pilot testing.

4.1.3.5.4 Recurring Costs

Future, recurring costs include annual and less frequent expenses for operations, maintenance, and monitoring necessary for continued effectiveness of the remedial action. Recurring costs include:

- Operating labor, materials, utilities, and administration for the treatment facility;

- Disposal of treatment residues (e.g., sludge from water treatment plant operations);
- Routine and special maintenance;
- Rehabilitation or replacement, as structures and equipment wear out or fail over time; and
- Periodic site reviews[54] of the remedy.

4.1.3.5.5 Present Worth Analysis

The total cost of each alternative is represented as a "present worth cost." The present worth cost is the sum of the direct and indirect capital costs for implementation, and the present worth of the future recurring costs over the period of performance of the alternative. The present worth cost represents the anticipated amount of money that, if invested in the current year and disbursed as necessary, would be sufficient to cover all costs associated with the remedial action over its planned life.

Preparation of the cost estimates followed CERCLA guidance (EPA 2000). Present worth costs were developed assuming a real discount rate of 7 percent; and a 50-year period of performance to estimate the net present worth for remedial alternatives. Appendix B includes a figure that illustrates that compound interest over a 50-year period would essentially cover the cost for remedy operations and maintenance that would be needed for even longer periods, and this was considered adequate for purposes of this SFS.

4.1.3.5.6 Accuracy of Cost Estimates

Consistent with RI/FS guidance (EPA 2000), the goal of the SFS cost estimates is to be accurate within approximately +50 percent to –30 percent of the real present worth cost of each alternative. The methods and assumptions used by the Agencies are consistent with meeting this goal for comparison of alternatives.

The Agencies cost estimates do not include some potential costs that cannot be estimated on the basis of existing information. This includes the cost to make Alternative 9, and potentially Alternative 10, a final remedy. Also the potential cost for cleanup of soils in areas that remain to be assessed by additional terrestrial ERA (e.g., the wind-blown tailings area) are not included in the

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[54] Site reviews must be conducted at least every 5 years if hazardous substances remain on the Site above concentrations that allow for unrestricted use and unlimited access (EPA 1995).

Agencies cost estimates, but would be the same regardless of which alternative is selected.

Details of the SFS cost estimates are presented in Appendix B.

4.1.4 Modifying Criteria

Two additional criteria, referred to as modifying criteria, are also considered for remedy selection under CERCLA [40 CFR § 300.430(f)(1)(i)(C)]. These modifying criteria are state acceptance and community acceptance. Similar to the community acceptance criterion, MTCA includes consideration of public concerns as an "other" requirement.

The CERCLA modifying criteria are significant considerations during remedy selection [40 CFR § 300.430(f)(4)(i)], but are often not available early enough to be considered in development of alternatives or identification of the preferred alternative in the Proposed Plan. For the Site, state input has been available throughout the RI/FS process. Input from Holden Village has been received during evaluation of the DFFS. Additional public input will include comments on the draft Proposed Plan, final RI/FS, and supporting documentation. CERCLA uses the modifying criteria along with the primary balancing criteria to select a remedy that is the most practicable among alternatives that satisfy the threshold criteria (i.e., that are both protective and ARAR-compliant).

4.1.4.1 State Acceptance

CERCLA requires that state concerns be assessed as part of evaluation of alternatives, including the state's position and key concerns related to the recommended alternative and other alternatives; and state comments on ARARs or proposed use of ARAR waivers [40 CFR § 300.430(e)(9)(iii)(H)].

4.1.4.1.1 State's Position and Key Concerns Related to the Alternatives

The State of Washington is concurrently addressing the Site through its independent cleanup authority under MTCA. Key state concerns related to evaluation of alternatives are included in Appendix G of this SFS.

4.1.4.1.2 State Comments on Potential ARARs or the Proposed Use of Waivers

The state has not separately provided any comments on potential ARARs for the Holden cleanup but has participated in joint preparation of documents with the Forest Service and EPA, including the preparation of Applicable or Relevant and

Appropriate Requirements of the Holden Mine Site, Site Information Package (Hart Crowser 2005e, Appendix C) prepared for the NRRB.

No ARAR waivers are being proposed, and the state has not expressed any desire to waive any potential ARARs for the Holden Site.

4.1.4.2 Community Acceptance

Community acceptance of alternatives will be evaluated after the public comment period ends and will be described in the ROD for the Site.

4.1.5 Additional MTCA Requirements

This section briefly discusses additional remedy selection requirements under MTCA that are not directly comparable to the nine CERCLA criteria.

4.1.5.1 Provide for Compliance Monitoring

Compliance monitoring is a threshold requirement under MTCA [WAC 173-340-360(2)(a)(iv)]. WAC 173-340-410 outlines three types of compliance monitoring under MTCA, including protection, performance, and confirmation monitoring.

- Protection monitoring is intended to assess whether human health and the environment are adequately protected during construction and the operation and maintenance period of the cleanup action.

- Performance monitoring is to assess whether the cleanup action has attained cleanup standards and remediation levels or other performance standards.

- Confirmation monitoring is to assess the long-term effectiveness of the cleanup action once cleanup standards and remediation levels or other performance standards have been attained.

While compliance monitoring is not one of the remedy selection evaluation criteria under CERCLA, compliance monitoring is required as part of operations and maintenance (O&M).[55]

[55] Also, where wastes are left in place, CERCLA requires monitoring to provide sufficient information to determine whether the remedy is protective, as part of the 5-year review process (EPA 1995).

4.1.5.2 Groundwater Cleanup Actions

MTCA includes provisions for both permanent and non-permanent groundwater cleanup actions [WAC 173-340-360(2)(c)]. A permanent groundwater cleanup action achieves groundwater cleanup levels throughout the Site, which is the standard point of compliance. As discussed in Section 4.1.1.3, Intalco determined in the DFFS that it is not practicable to meet the proposed groundwater cleanup levels throughout the Site within a reasonable time frame. Thus, a non-permanent groundwater cleanup action can be used, including a conditional point of compliance. To be selected under MTCA, a non-permanent groundwater cleanup action shall take the following measures:

- Treatment or removal of the sources of the releases shall be conducted for liquid wastes, areas contaminated with high concentrations of hazardous substances, highly mobile hazardous substances, or hazardous substances that cannot be reliably contained; and

- Groundwater containment, including barriers or hydraulic control through groundwater pumping, or both, shall be implemented to the maximum extent practicable to avoid lateral and vertical expansion of the volume of affected groundwater.

4.1.5.3 Cleanup Actions for Soils at Current or Potential Future Residential Areas and for Soils at Schools and Child Care Centers

Holden Village is directly to the north, across Railroad Creek from the former mine. Holden Village uses the West Waste Rock Pile for solid waste recycling, and performs vehicle maintenance, composting, and firewood storage immediately down slope from the mill and waste rock piles, and immediately adjacent to TP-1. Village residents and visitors sometimes use the surface of the tailings piles for recreation (“Frisbee golf”). Holden Village residential areas and the public school (for elementary through high school age students) are all located within 300 to 1,000 feet of TP-1.

The DRI indicated that existing soil concentrations in the Village do not exceed human health criteria, thus the MTCA requirement [WAC 173-340-360(2)(d)] for soil cleanup for these areas would not apply to the Village itself.

4.1.5.4 Institutional Controls

MTCA has specific requirements for remedies that include institutional controls, as provided in WAC 173-340-360(2)(e) and WAC 173-340-440. These include a requirement for a quantitative showing (where appropriate) that institutional controls will reduce risks to ensure a protective remedy; not relying on institutional controls where it is technically possible to implement a more permanent cleanup action; and procedural requirements.[56]

4.1.5.5 Releases and Migration

MTCA specifies that cleanup actions shall prevent or minimize present and future releases and migration of hazardous substances in the environment [WAC 173-340-360(f)].

4.1.5.6 Dilution and Dispersion

For remedial alternatives that satisfy other remedy selection criteria, MTCA requires that cleanup actions shall not rely primarily on dilution and dispersion unless the incremental costs of any active remedial measures over the costs of dilution and dispersion grossly exceed the incremental degree of benefits of active remedial measures over the benefits of dilution and dispersion [WAC 173-340-360(g)].

4.1.5.7 Remediation Levels

A remediation level defines the concentration of a hazardous substance above or below which a particular cleanup action component (e.g., soil treatment or containment) will be used [WAC 173-340-355(2)]. Remediation levels are not the same as cleanup levels, which define concentrations above which the contaminated medium must be remediated.[57]

None of the alternatives propose using remediation levels.

4.2 Detailed Analysis of Alternatives 9 through 12

This section presents the detailed analysis of Alternatives 9 through 12 individually based on CERCLA criteria outlined in the previous section. In

[56] Although not a remedy selection criteria under CERCLA, 40 CFR § 300.430(a)(1)(iii)(D) also addresses institutional control requirements.

[57] For further information on remediation levels, see WAC 173-340-200 and WAC 173-340-355.

addition, for Ecology's purposes under MTCA, an additional discussion is provided analyzing the alternatives under MTCA's remedy selection criteria.[58]

4.2.1 Alternative 9

This section describes the Agencies' evaluation of Alternative 9 using each of the CERCLA remedy selection criteria.

4.2.1.1 Overall Protection of Human Health and the Environment

Alternative 9 may be protective of human health based on current and anticipated exposures to constituents of concern within Site surface water, sediment, and air. Additionally, this alternative is considered protective of human health from exposure to constituents of concern in groundwater in the future, for both the short term and long term, if institutional controls and source control measures (e.g., removal and capping of soil) are implemented as outlined in the remedy.

Alternative 9 eliminates direct contact risk to soils above human health criteria in the lagoon and maintenance yard areas through a combination of removal and capping. Alternative 9 includes a soil cover over new areas for the tailings that would be exposed by regrading, but does not include capping of the currently exposed areas of the tailings.[59]

Institutional controls would be implemented to help prevent potential human exposure through groundwater ingestion in the future. Other institutional controls to protect future human health risks for Alternative 9 would include land use restrictions, mine access restrictions, and signage at the Site to notify users about potential risks.

Alternative 9 relies in large measure on natural attenuation and source depletion over time following limited containment, capping, and source removal and surface water run-on diversion to reduce metals concentrations in groundwater before it discharges into Railroad Creek. Following implementation of Alternative 9, seeps and groundwater that exceed proposed surface water

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[58] In addition to having participated in the Agencies review of alternatives and selection of a proposed cleanup action under CERCLA, Ecology has analyzed these alternatives under MTCA. Ecology intends to independently select an alternative pursuant to WAC 173-340-380(4), through adoption of a ROD.

[59] The degree of future maintenance of the tailings pile cap under Alternative 9 is unclear; unless the cap is maintained there may be future direct contact risk and exposures to wind-blown dust from the tailings that pose a human health risk.

cleanup levels would continue to discharge into Railroad Creek for significant portions of the Site. For Alternative 9, this uncontrolled discharge would include groundwater from the LWA and from TP-2 and TP-3. Because it does not include immediate and permanent reduction in the release of metals into Railroad Creek, Alternative 9 is not considered protective of aquatic receptors.

Alternative 9 does not include moving the toe of the tailings pile slopes away from Railroad Creek, thus it does not address risk of erosion and slope failures that would impact the creek. Alternative 9 would rely on enhancing existing riprap to prevent slope failures of the tailings, but this is susceptible to overtopping during flooding, or undermining from scour, e.g., as observed in 2003. Long-term maintenance of riprap is not addressed as part of Alternative 9.

Alternative 9 would provide little reduction in terrestrial toxicity risks on the tailings piles, as it would provide new soil cover only on that portion of the TP-1 and TP-2 slopes that would be regraded. Alternative 9 does not include any remedial action on the waste rock piles to reduce terrestrial toxicity risks.

The Alternative 9 combination of existing and proposed soil cover over portions of the tailings piles may not be protective. Alternative 9 would not do anything to reduce the amount of infiltration through the tailings, which contributes to metals release via groundwater, into Railroad Creek. Also, Alternative 9 does not address soils above proposed cleanup levels in the wind-blown tailings area and other areas of the Site with soils above proposed cleanup levels. As discussed in Appendix E, additional terrestrial risk analysis is required to confirm the remedy components necessary to be protective of terrestrial receptors.

Alternative 9 does not satisfy the presumptive cover requirements of Chapter 173-350 WAC, nor does it include any provision for more detailed terrestrial ecological risk assessment needed to evaluate whether a less robust cover would be protective.

In summary, Alternative 9 does not satisfy the CERCLA threshold requirement for protection of human health and the environment.

4.2.1.2 Compliance with Potential Applicable or Relevant and Appropriate Requirements (ARARs)

4.2.1.2.1 Potential Chemical-Specific Requirements for Surface Water

Alternative 9 would not address all identified, existing sources of release into surface waters at the Site (e.g., groundwater under TP-2 and TP-3 and seeps adjacent to TP-2 and TP-3, and in the LWA). Thus, Alternative 9 would not satisfy potential chemical-specific ARARs for surface water.

Alternative 9 relies on limited containment, capping, and source removal; surface water run-on diversion; natural attenuation; and source depletion to reduce metals loading to the creek over time. Based on rates of source depletion and natural attenuation discussed in DFFS, Alternative 9 would allow continued releases above proposed cleanup levels from portions of the Site over a period estimated to be hundreds of years following remedy implementation, and metals concentrations in surface water adjacent to and downstream of the Site in Railroad Creek would continue to exceed proposed cleanup levels.

4.2.1.2.2 Potential Chemical-Specific Requirements for Groundwater

Alternative 9 will provide institutional controls to prevent future groundwater consumption at the Site, and would partially contain groundwater released from the Site that exceeds proposed surface water cleanup levels to protect aquatic receptors.

Alternative 9 would collect and treat groundwater above proposed cleanup levels that currently discharges from a portion of, but not the entire, Site. Areas that would be addressed include the UWA, Honeymoon Heights seeps, the portal drainage, and a portion of the groundwater that is contaminated by TP-1. However, Alternative 9 relies on natural attenuation in the LWA.[60] Alternative 9 also relies on source depletion and natural attenuation processes to clean up groundwater from below TP-2 and TP-3, and a portion of TP-1 before it discharges into Railroad Creek. Thus, Alternative 9 will not meet proposed cleanup levels for groundwater at all potential points of exposure.

4.2.1.2.3 Potential Chemical-Specific Requirements for Soil

Potential chemical-specific ARARs for soils are based on protection of human health and terrestrial ecological receptors, or in some cases on protection of groundwater or surface water quality. As noted in Section 4.1.2.2.3, MTCA allows Ecology to set cleanup levels based on a site-specific evaluation. Where containment of hazardous substances is achieved, soil cleanup levels protective of groundwater may not need to be achieved; provided certain criteria are met

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[60] For Alternative 9, metals concentrations in the LWA groundwater would remain above proposed cleanup levels for an extended period of time as natural attenuation occurs following the containment and control of releases from the UWA. The EPA Batch Flush Model suggests this would be on the order of decades to hundreds of years, for different constituents of concern.

[WAC 173-340-740(6)(f)]. Where an alternative includes soil cleanup to protect human health and ecological receptors, and there is collection and treatment of downgradient groundwater, the Agencies do not expect further soil cleanup to protect groundwater. Alternative 9 does not qualify for this modification of standards because Alternative 9 does not fully contain groundwater contaminated by releases from soils at the Site. As a result, cleanup levels more stringent than those proposed in Table 8 would be applied if Alternative 9 were selected.

Alternative 9 includes excavation or covering of contaminated soils in the mill building, maintenance yard, lagoon, and ventilator portal detention areas to meet the proposed cleanup levels.

Alternative 9 does not include any cleanup in the LWA, the baseball field, areas within Holden Village, and the area of observed wind-blown tailings deposition east of the Village, nor does it include any additional monitoring and risk evaluation for these areas. Thus, Alternative 9 has not been shown to satisfy proposed soil cleanup levels in all areas of the Site.

4.2.1.2.4 Potential Chemical-Specific Requirements for Sediment

Potential chemical-specific cleanup levels for sediments at the Site are based on TBC criteria. The Agencies propose to assess sediment quality in Railroad Creek 5 and 10 years after the cleanup action has been implemented, to determine whether the remedy has been effective or whether active remedial measures may be required at some time in the future. There is no mention of sediment monitoring or removal of ferricrete in Intalco's description of Alternative 9.

4.2.1.2.5 Potential Action- and Location-Specific Requirements

Potential action- and location-specific ARARs must be considered in selection of the remedy under CERCLA, as discussed in Section 2.3.3.2 and 2.3.3.3, respectively. Based on review of Alternative 9, the Agencies believe it would satisfy most of the potential action- and location-specific ARARs, except as noted below.

Washington Model Toxics Control Act [RCW 70.105D; Chapter 173-340 WAC]. The MTCA is a potential ARAR under CERCLA as well as an independent basis for requiring cleanup of the Site under state law. The Agencies do not believe that Alternative 9 would satisfy MTCA requirements as discussed in Section 4.2.1.8, and thus would not satisfy MTCA as a potential ARAR under CERCLA.

Washington State Solid Waste Handling Standards [RCW 70.95; Chapter 173-350 WAC]. Alternative 9 would not meet the presumptive cover requirements for limited purpose landfills [WAC 173-350-400(3)(e)(ii)] that are potentially relevant and appropriate for the tailings and waste rock piles. Alternative 9 also does not include any additional analyses to determine whether a less robust cover or existing conditions would meet the performance requirements of the landfill criteria [WAC 173-350-400(3)(e)(i)] and be protective of terrestrial receptors [WAC 173-340-7491(2)(a)]. Alternative 9 would not include sufficient regrading of the tailings piles and waste rock piles to provide the required assurance of slope stability for TP-3 [WAC 173-350-400(3)(g) and (h)]. Thus, Alternative 9 would not comply with this potential ARAR.

Federal Water Pollution Control Act - Section 402 National Pollution Discharge Elimination System (NPDES) [33 USC § 1342] and Water Quality Standards for Surface Waters of the State – Short-Term Modifications [RCW 90.48 and WAC 173-201A-410]. Authority for implementing the federal regulation has been granted to the state. These regulations are potentially relevant and appropriate to Alternative 9, in part because implementation will create non-point sources of stormwater runoff greater than 1 acre in area. The State of Washington's Construction Stormwater Permit established in accordance with Chapter 90.48 WAC (Ecology 2004) is not applicable to federal lands, but these requirements are potentially relevant and appropriate. The limited regrading of tailings for Alternative 9 does not provide any means to collect, detain, or treat potentially contaminated stormwater runoff that would discharge to Railroad Creek; thus Alternative 9 would not comply with this potential ARAR.

Aquatic Lands Management - Washington State [RCW 79.90; Chapter 332-30 WAC]. This potential ARAR requires that aquatic lands be managed to ensure environmental protection and, therefore, is potentially relevant and appropriate [WAC 332-30-100]. Alternative 9 does not eliminate the ongoing metals releases from TP-2 and TP-3, and does not entirely address releases from the LWA and TP-1. Groundwater that enters Railroad Creek is toxic to aquatic organisms and reduces aquatic habitat through the mechanism of chemical processes that result from the release of hazardous substances. For this reason, Alternative 9 would not comply with this potential ARAR.

Executive Order 11990 – Protection of Wetlands. This potential ARAR requires that potential impacts to wetlands be considered, and as practical the destruction, loss, or degradation of wetlands be avoided. Alternative 9 does not address ongoing adverse impacts to the wetland east of TP-3, nor does it entirely address impacts to Railroad Creek, thus Alternative 9 would not comply with this potential ARAR.

Executive Order 11988 - Protection of Floodplains. Alternative 9 includes regrading the steepest sections of TP-1 and TP-2, but does not include setback of the tailings to remove unstable fill (the tailings) placed within the floodplain; nor provide regrading to improve stability of the very steep slopes on TP-3. Implementation of Alternative 9 would not eliminate the existing risk of potential future slope failures that may occur from flooding or other causes. Alternative 9 includes construction of a seep interception system, and a water treatment facility within a portion of the Railroad Creek floodplain in the west part of the Site, which may result in both short-term and long-term impacts to Railroad Creek. Alternative 9 may not conform with some of the provisions of this potential ARAR.

Land and Resource Management Plan for Wenatchee National Forest (LRMP, Forest Service 1990) as Amended by Pacific Northwest Forest Plan (NWFP, 1994) and subsequent amendments of the NWFP (2001, 2004, and 2007). The LRMP and NWFP include standards and guidelines that are potentially relevant and appropriate to actions at the Site, including activities within, or that affect Riparian Management Areas along Railroad and Copper Creeks, or are otherwise necessary to meet Aquatic Conservation Strategy (ACS) objectives. As presented by Intalco, Alternative 9 does not include closure and reclamation of the tailings and waste rock piles using best conventional techniques to ensure mass stability and prevent the release of acid or toxic materials. For this reason, Alternative 9 would not comply with this potential ARAR. Alternative 9 may also not meet all aspects of other standards and guidelines that pertain to achieving ACS objectives; a complete analysis of potential ARARs under the LRMP will be performed as part of preparing the ROD.

4.2.1.2.6 Compliance with Potential ARARs

In summary, Alternative 9 does not satisfy the CERCLA threshold requirement for compliance with potential ARARs.

Although Alternative 9 does not satisfy the CERCLA threshold requirements, for completeness, the following sections analyze Alternative 9 using the CERCLA primary balancing criteria.

4.2.1.3 Long-Term Effectiveness and Permanence

CERCLA evaluates long-term effectiveness and permanence by considering the magnitude of residual risk at the conclusion of remedy implementation, and the adequacy and reliability of controls that are part of the remedy.

4.2.1.3.1 Magnitude of Residual Risk Remaining at the Conclusion of the Remedial Activities

Alternative 9 would rely on institutional controls and source controls (e.g., removal of contaminated soils in the lagoon area, capping in the maintenance yard, etc.) but does not improve or provide assurance that the existing tailings caps would protect human health. Also, the existing and proposed tailings pile cover would not protect the environment.

Figure 18 provides an illustration of the effect of continuing groundwater discharges to surface water following implementation of Alternative 9. The Agencies used the EPA Batch Flush Model to evaluate natural attenuation in the LWA as discussed in Appendix A of this SFS. Figure 18 indicates that it would take from roughly 38 years (cadmium) to 330 years (zinc) for seep and groundwater discharges to reach proposed surface water cleanup levels as a result of natural attenuation in the area addressed by this particular analysis. Reliance on natural attenuation would result in similar unacceptable delays in reaching proposed surface water cleanup levels in other areas. The Batch Flush Model results show that the natural attenuation relied upon for Alternative 9 would lead to continued harmful discharge of contaminated groundwater for hundreds of years. Alternative 9 would not satisfy all the requirements for a remedy to rely on natural attenuation. This alternative would not provide source control to the maximum extent practicable.

Tailings regrading under Alternative 9 is limited and does not fully address the potential for future slope failures of the tailings piles. Following implementation of Alternative 9, risk to aquatic life would remain from tailings pile erosion and potential slope failures into Railroad Creek.

Alternative 9 does not include closure of the waste rock piles, nor does it address other areas with metals above ecological screening criteria due to releases from the Site. Alternative 9 does not satisfy the presumptive cover requirements of Chapter 173-350 WAC, nor does the RI/FS show that the existing cover would be protective; therefore, risk would remain following remedy implementation.

Alternative 9 would leave significant risk to aquatic life following implementation. Alternative 9 would not clean up Site groundwater or eliminate the ongoing discharge of groundwater above proposed clean up levels into Railroad Creek. Alternative 9 does not include removal of ferricrete from Railroad Creek.

4.2.1.3.2 Adequacy and Reliability of Controls

To assess the adequacy and reliability of controls at the Site, items to be addressed under CERCLA include: 1) uncertainties associated with land disposal of treatment system residuals; 2) potential need to replace technical components of the remedy; and 3) potential risk if components of the remedy need replacement [40 CFR § 300.430(e)(9)(iii)(C)(2)].

Sludge management was neither addressed in detail in the DFFS for any of the alternatives, nor in URS (2005b), which describes Alternative 9. Intalco's cost estimate for Alternative 9 apparently did not address long-term sludge management requirements; or the need to replace or repair water collection, conveyance, and treatment system components, although this was addressed in the Agencies' cost estimate.

Alternative 9 relies on buried perforated pipe drains for groundwater collection along groundwater barrier walls and discrete seep collection along TP-1. These pipe drains may be susceptible to iron fouling and clogging if exposed to air; although Intalco has indicated that reduced pumping rates could avoid introducing atmospheric oxygen and assure long-term effectiveness (URS 2005b). Alternative 9 would also require maintenance of the dewatering well screens and pumps to maintain the effectiveness of groundwater remediation below a portion of TP-1, over the life of the remedy.

Because of its location, the Alternative 9 treatment system would rely to a large degree on gravity flow rather than pumping. The Alternative 9 treatment system would be located downslope of the portal discharge and UWA groundwater collection system. Pumping would be required for groundwater and seep flow collected from TP-1, and possibly from the Honeymoon Heights seeps. Treatment equipment parts or systems (e.g., lime addition, flow controls) will wear out and need to be replaced over time.

Alternative 9 did not include lined treatment system ponds. Thus, it would not adequately protect groundwater due to release of untreated water from the treatment system ponds that would infiltrate into the groundwater above proposed cleanup levels. Intalco has not addressed the effect of this infiltration on surface water quality. The Alternative 9 treatment facility equipment parts and/or systems will wear out and require replacement. The Agencies' Alternative 9 cost estimate includes the cost to monitor, maintain, and replace water collection, conveyance, and treatment system components.

Alternative 9 relies on interrupting some (but not all) of the exposure pathways (groundwater baseflow and surface seeps) that convey excess metals into surface water at the Site.[61] Failure of these remedial components would result in reestablishing the associated exposure pathways, and the magnitude of resulting risk would depend on the extent and duration of the failure. Planned replacement and other maintenance of components for the groundwater collection, conveyance, and treatment systems likely can be arranged to minimize or avoid shutting down the remediation system.

Failure of any remedial system component could result in an increase in the uncontrolled release of contaminated water to the ground surface or into Railroad Creek or Copper Creek, depending on where the release occurred. Such a failure could have a sudden, acute impact on aquatic life within Railroad Creek, if the metal concentrations were high enough. However, an accidental release due to failure of a remedy component is generally anticipated to have less effect than the existing ongoing releases.

Alternative 9 would not include any active controls to prevent the discharge of contaminated groundwater flows into Railroad Creek for large portions of the Site. This alternative would rely on limited source removal, surface water run-on diversion, source depletion, and natural attenuation to address contaminated groundwater flows from the LWA, TP-2, and TP-3.

Based on the analysis described above, Alternative 9 does not include adequate and reliable controls to provide long-term protection of the environment.

4.2.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 9 would contain and treat the groundwater from the mine, abandoned mill, and main East and West Waste Rock Piles. Alternative 9 would also include partial hydraulic containment and treatment of groundwater from TP-1. Alternative 9 would not treat water entering the creek from the high concentration seeps in the LWA and along TP-2 and TP-3. Alternative 9 would not contain the groundwater plume from the LWA, TP-2, and TP-3. Alternative 9 would remove or cap sources of metals in the lagoon and maintenance yard areas, the ventilator portal detention area, and would hydraulically isolate the Copper Creek Diversion. While the downgradient seeps SP-12 and SP-23 would be collected for treatment, Alternative 9 would not provide containment, capping, or removal of the Honeymoon Heights Waste Rock Piles.

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[61] Large portions of the Site would continue to release groundwater above proposed cleanup levels into Railroad Creek after implementation of the cleanup.

Under Alternative 9, the toxicity of an estimated average of 325 million gallons per year of contaminated water would be reduced using active treatment. The sludge from the treatment plant would be removed and dewatered to reduce the potential leaching of constituents of concern. The process would produce an annual average of approximately 18,000 cy of sludge per year.[62] Over time, the solids content of the sludge would increase in the landfill as consolidation occurs.

Alternative 9 would adequately reduce the toxicity and mobility of metals released from a portion of the Site, but does not address all sources of release above proposed cleanup levels. Alternative 9 does not rely on destruction or recycling any hazardous substance materials.

4.2.1.5 Short-Term Effectiveness

CERCLA requires evaluation of short-term effectiveness of a proposed remedy based on consideration of risks to the community and workers during implementation, potential environmental impacts and mitigative measures, and the time until protection is achieved.

4.2.1.5.1 Short-Term Risks on the Community during Implementation

Short-term health risks to the community during implementation primarily consist of increased exposure to construction traffic. Potential exposure to construction dust, noise, and vehicle exhaust emissions is not anticipated to present risks to the Holden Village community or other members of the public using the adjacent forest lands.

Short-term risks to the local community associated with implementation of Alternative 9 can be adequately mitigated through active measures taken during construction. This would include a traffic control plan for joint use of the Lucerne-Holden Road by construction traffic and the Holden Village community.

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[62] This estimate is based on an assumed 4 percent solids concentration at the beginning of the annual dewatering stage of treatment, and represents an annual average over the first 50 years of treatment. The annual rate of sludge production was adjusted based on changes in concentration over time predicted in the DFFS Appendix E, which may not be realistic (the real rate could be greater or could be less than the DFFS estimate).

4.2.1.5.2 Potential Impacts on Workers during the Remedial Action and the Effectiveness and Reliability of Mitigative Measures during Implementation

Short-term human health risks due to remedy implementation at the Site primarily include construction safety, traffic, and potential longer term risks associated with operation of the treatment facility.

Human health risks to construction workers posed by remedy implementation include the following: underground mine hazards; construction traffic; exposure to soils with elevated concentrations of TPH and possibly other hazardous substances; exposure to noise and dust; and exposure to demolition activities and debris in the removal of the derelict mill structure. Additional safety risks would be related to construction activities (e.g., open excavations, heavy equipment operations) associated with regrading, barrier wall construction, ditch excavations, and treatment plant construction.

Construction activities will need to adhere to applicable OSHA, WISHA, and potentially MSHA regulations. Construction workers will be required to have HAZWOPER training. Dust concerns would be managed through best management practices (BMPs).

4.2.1.5.3 Potential Environmental Impacts of the Remedial Action and the Effectiveness and Reliability of Mitigative Measures during Implementation

Potential environmental impacts of the remedial action include the following:

1. Risk of a tailings release to Railroad or Copper Creeks during regrading from slope failures or stormwater runoff. An estimated 250,000 cy of tailings would be moved during regrading;
2. Risk of tailings or sediment release to the creeks during construction of seep collection components along TP-1, and use of temporary stream crossings during construction;
3. Risks associated with construction of hydraulic barriers in the underground mine;
4. Construction vehicle emissions, noise, and dust;
5. Risk of fuel spills;
6. Risk of mass release of tailings from flood-induced slope failures; and
7. Risk of surface water quality exceedances during and after startup of the treatment plant.

Mitigative measures for tailings and sediment releases include construction BMPs such as sediment fencing and traps; however, very little space is available along the toe of the tailings to install and manage such engineering controls.

Alternative 9 does not include pulling back the tailings from Railroad and Copper Creeks, and relies on riprap alone to mitigate the potential release of tailings resulting from flooding. Riprap alone is unlikely to be effective or reliable in the long term at preventing slope failures from impacting the creeks, as evidenced by failures of the riprap from scour observed in 2003. Alternative 9 would rely completely on long-term maintenance and replacement of the riprap to protect Railroad and Copper Creeks from release of tailings due to erosion and scour related to degradation in performance of the riprap. The riprap is susceptible to displacement due to erosion and scour, and deterioration of the rock. Maintenance to protect the creek from the risk of release of the tailings would require working within the creek. In summary, Alternative 9 would produce considerable negative impacts to Railroad and Copper Creeks during implementation and over the long-term.

The risk of fuel spills would be mitigated through adherence to regulations regarding storage, transportation, and dispensing of fuel, including a spill contingency plan.

In summary, Alternative 9 does not include adequate mitigative measures to prevent potential adverse environmental impacts from risk of a tailings release during regrading, or from potential flooding over the long term.

4.2.1.5.4 Time until Protection is Achieved

Alternative 9 would immediately provide some protection for human health and the environment for a portion of the Site. Institutional controls to protect human health from exposure to constituents of concern in groundwater and soil would be established during remedy implementation. Alternative 9 does not include protection of groundwater and terrestrial ecological receptors through closure of the tailings and waste rock piles, nor would it address other areas of the Site impacted by wind-blown tailings.

Alternative 9 would immediately eliminate some (but not all) sources of contaminated groundwater release such as the portal drainage, a portion of the groundwater from TP-1, and groundwater from the UWA.

Alternative 9 would not protect the environment for other portions of the Site for many years after remedy implementation. Significant sources that discharge directly into Railroad Creek (e.g., TP-2, TP-3, and the LWA) would only be gradually reduced over decades to hundreds of years, as a result of source depletion and natural attenuation. Alternative 9 provides no groundwater or seep collection alongside TP-2 and TP-3, and would locate the UWA groundwater barrier and collection system 450 to 750 feet upgradient from the creek. As discussed in Section 4.2.1.3.1, the simple Batch Flush Model predicts it would take roughly 38 to 330 years for seep and groundwater discharges into Railroad Creek in the LWA to reach proposed surface water cleanup levels for the various constituents of concern.

4.2.1.5.5 Summary of Short-Term Effectiveness

Based on the analyses presented in Sections 4.2.1.5.1 through 4.2.1.5.4, Alternative 9 would not be completely effective over the short term after implementation.

4.2.1.6 Implementability

CERCLA requires evaluation of the implementability of a proposed remedy based on consideration of its technical feasibility, administrative feasibility, and the availability of needed services and materials.

4.2.1.6.1 Technical Feasibility

Alternative 9 may not be technically feasible. The remedy could be implemented using conventional construction equipment and techniques, but long-term operation of the wells may be problematic.

Intalco initially eliminated pumped well technology during screening in the DFFS. The pumped wells included in Alternative 9 have the potential to draw in creek water. To limit this withdrawal of creek water, the rate of pumping, and perhaps the number of pumped wells, would need to be monitored and adjusted to accommodate seasonal changes. However, limiting the number of wells or pumping rate would limit the amount of contaminated groundwater from TP-1 that could be collected for treatment, so the number of wells may need to be increased to achieve the degree of effectiveness that Intalco proposed.

Feasibility may also be limited by iron fouling of pumps, wells screens, French drains for seep collection, and conveyance piping used for the TP-1 groundwater recovery system. If this becomes a problem, it could be addressed through increased maintenance or replacement, although the cost for this is hard to predict.[63] Other potentially significant long-term feasibility issues include

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[63] Maintenance may include mechanical cleaning or acid flushing to remove iron deposits from well screens and the perforated pipe drains used for seep collection. If this is not effective, periodic well replacement may be needed.

supplying the energy required for groundwater conveyance and treatment, sludge management, and the effects of winter freezing on treatment operations.

4.2.1.6.2 Administrative Feasibility

Administrative requirements associated with potential ARARs are discussed in Section 4.2.1.2.5.

The land affected by the remedy is under the control of the Forest Service, except for patented mining claims that are owned by Holden Village, Inc. The Agencies anticipate that the remedy will include access and institutional controls on lands owned by Holden Village, Inc.

No wastes are anticipated to be moved off the Site for disposal, with the possible exception of residual processing wastes encountered during cleanup of the abandoned mill building, which may designate as state Dangerous Waste. The potential need for off-site disposal of such wastes does not affect the feasibility of Alternative 9.

4.2.1.6.3 Availability of Services and Materials

The technologies required for each of the components in Alternative 9 are known and proven technologies. The Agencies anticipate that there will be companies willing to do this work and that the contractors bidding for this work will be experienced in the technologies required for the alternative. Despite the Site's remote geographic location, necessary equipment would be able to be moved to the Site for construction of Alternative 9.

4.2.1.6.4 Summary of Implementability

Based on the analyses presented above, while Alternative 9 is administratively feasible and would not be constrained by availability of services and materials, it may not be technically feasible. Thus, Alternative 9 may not be implementable.

4.2.1.7 Cost

CERCLA requires that an alternative selected as a cleanup action shall be cost-effective, provided that it first satisfies the threshold criteria. Alternative 9 has not been shown to satisfy the threshold criteria; however, the cost for this Alternative is presented here for completeness. Details of the cost estimate are presented in Appendix B. Since Alternative 9 would not achieve criteria for a final remedy, an unknown additional expenditure (not estimated herein) would be needed to make this a final remedy.

EPA guidance requires CERCLA cost estimates to include capital costs (both direct and indirect) and O&M costs. Total estimated costs for a cleanup action are established by calculating the net present value (NPV) of capital and O&M costs. Both Intalco and the Agencies estimated the NPV of capital and O&M costs for Alternative 9. (However, these estimates do not include additional future costs needed to make this a final remedy that is protective of human health and the environment and complies with potential ARARs). The table below summarizes the Agencies' estimated costs for Alternative 9.

	Alternative 9
Estimated Capital Cost	$22,600,000
Estimated Average Annual O&M Cost (one year[64])	$1,210,000
Net Present Value of Capital and O&M Costs (50 years @ 7%)	$38,200,000

These costs would have to increase substantially to complete a remedy that would be protective and comply with potential ARARs. Alternative 9 would not address significant portions of the Site where contaminated groundwater enters Railroad Creek and, therefore, does not satisfy the threshold criteria. Thus, Alternative 9 cannot be selected on the basis of cost.

4.2.1.8 State Acceptance

4.2.1.8.1 State's Position and Key Concerns Related to Alternative 9

The State of Washington has participated with the lead Agency in evaluating remedy alternatives for the Site. Solely for Ecology's purposes under MTCA, the state's MTCA evaluation of Alternative 9 is summarized below. The state has determined that Alternative 9 is not acceptable as a final remedy.

Threshold Requirements

There are seven requirements to be evaluated for selecting a final remedy under MTCA [WAC 170-340-360]. The first four requirements comprise the MTCA threshold requirements, which require that the remedy: 1) protect human health

[64] Note the average annual estimated O&M cost includes an allowance for the present value of future costs that occur less frequently than annually, such as replacement of the treatment system media filter sand that is anticipated to be needed once every 6 years, etc. The average annual cost was estimated based on all costs anticipated over a 50-year period, using estimated costs in the year incurred.

and the environment; 2) comply with cleanup standards; 3) comply with applicable state and federal laws; and 4) provide for compliance monitoring.

Protect Human Health and the Environment. For the same reasons that Alternative 9 does not provide for "overall protection of human health and the environment" under CERCLA (Section 4.2.1.1), Alternative 9 does not satisfy MTCA's requirement that the remedy protect human health and the environment.

Comply with Cleanup Standards. "Cleanup standards" under MTCA refer to the proposed cleanup levels based on potential chemical-specific ARARs; the location(s) where these cleanup levels must be met (points of compliance); and other regulatory requirements that must be met because of the type of action and/or location of the Site (potential action-specific and location-specific ARARs). MTCA requires that for a cleanup action to meet the requirements for a groundwater conditional point of compliance, groundwater discharges need to be provided with all known available and reasonable methods of treatment (AKART) before being released to surface waters [WAC 173-340-720(8)(d)(i)]. For conditions at the Site, groundwater containment and collection are necessary precursors to treatment. Alternative 9 does not constitute AKART, and thus a conditional point of compliance along the groundwater-surface water interface of Railroad and Copper Creeks could not be approved by Ecology for Alternative 9. Since Alternative 9 does not provide containment, it would continue to allow groundwater to enter the creek above proposed cleanup levels for hundreds of years. As discussed in Section 4.2.1.2, Alternative 9 would not satisfy cleanup standards.

Comply with State and Federal Law. Alternative 9 would fail to comply with several potential action- and location-specific ARARs, as required under MTCA, and discussed in Section 4.2.1.2.5.

Provide for Compliance Monitoring. Alternative 9 (URS 2005b) does not specifically address compliance monitoring other than Intalco has indicated that monitoring plans would be developed during RD.

MTCA Other Requirements

Other requirements for remedy selection that must be evaluated under MTCA include: 5) use permanent solutions to the maximum extent practicable; 6) provide a reasonable restoration time frame; and 7) consider public concerns.

Use of Permanent Solutions to the Maximum Extent Practicable. Alternative 9 does not use permanent solutions to the maximum extent practicable, based on the MTCA practicability analysis presented in Appendix G.

Provide a Reasonable Restoration Time Frame. Alternative 9 does not provide for a reasonable restoration time frame for groundwater and surface water. Rather than using active measures to contain and treat contaminated groundwater, Alternative 9 relies on source depletion; limited containment, limited capping, and source removal; surface water run-on diversion; and natural attenuation processes to address releases for large portions of the Site.

Alternative 9 includes a barrier and collection system to control contaminated seeps and groundwater from the UWA, but relies on natural attenuation for groundwater from the LWA that discharges above proposed cleanup levels into surface water. Alternative 9 uses pumped wells and seep collection to collect for treatment a portion of the contaminated groundwater that flows into Railroad Creek from below TP-1. Alternative 9 uses upgradient run-on diversions, but does not contain or significantly reduce the groundwater discharge with metals above proposed cleanup levels from TP-2 and TP-3.

The Agencies expect that the likely future use of the Site and surrounding resource areas will be high value environmental habitat and recreational use. Alternative 9 does not provide a reasonable restoration time frame to clean up the Site, and restore future beneficial uses of the Site.

Consider Public Concerns. Public concerns will be addressed as part of selecting and implementing the final cleanup action in accordance with WAC 173-340-600(14) and (15).

MTCA Action-Specific Requirements

Finally, MTCA has additional potential action-specific remedy selection requirements that apply specifically to cleanup actions that include groundwater cleanup actions; cleanup of soils in residential or school areas; institutional controls; releases and migration; dilution and dispersion; and use of remediation levels.

Non-Permanent Groundwater Cleanup Actions. As discussed in Section 4.2.1.1, Alternative 9 relies in large measure on natural attenuation and source depletion over time following limited containment, capping, and source removal, and surface water run-on diversion, to reduce metals concentrations in the groundwater before it discharges into Railroad Creek. Alternative 9 would only address a portion of the groundwater contaminated by TP-1 and no seeps or groundwater associated with TP-2 and TP-3. Therefore, Alternative 9 does not implement groundwater containment to the maximum extent practicable as discussed in Appendix G.

Cleanup of Soils for Residential and School Areas. The DRI indicated that existing soil concentrations in the Village do not exceed human health criteria, thus the MTCA requirement, WAC 173-340-360(2)(d), for soil cleanup for these areas would not apply within the Village itself. Institutional controls and engineering measures (e.g., capping of tailings) on the remainder of the Site are needed to protect residential areas, schools, and child care centers.

Institutional Controls. Alternative 9 satisfies requirements for institutional controls to protect human health that are specified in WAC 173-340-440.

Releases and Migration/Dilution and Dispersion. Alternative 9 does not provide a permanent closure to protect the tailings and waste rock piles from erosion and slope failures, and to protect receptors from releases from the tailings and waste rock piles. Alternative 9 relies in large measure on dilution and dispersion to cleanup groundwater and surface water above proposed cleanup levels. Alternative 9 does not use active remedial measures to the maximum extent practicable to contain, collect, and treat groundwater and surface seeps above proposed cleanup levels, see Appendix G.

Remediation Levels. Intalco does not propose using remediation levels for Alternative 9.

4.2.1.8.2 State Comments on Potential ARARs or the Proposed Use of ARAR Waivers

The state has not separately provided any comments on potential ARARs for the Holden Site cleanup, but has participated in joint preparation of documents with the Forest Service and EPA, including the preparation of potential ARARs section of this document.

4.2.1.9 Community Acceptance

MTCA, similar to CERCLA, provides that final remedy selection will consider public comment on the remedial alternatives.

Community acceptance of alternatives will be evaluated after the public comment period ends and will be described in the ROD for the Site.

4.2.2 Alternative 10

This section describes the Agencies' evaluation of Alternative 10 using each of the CERCLA remedy selection criteria.

4.2.2.1 Overall Protection of Human Health and the Environment

Alternative 10 is protective of human health based on current and anticipated exposures to constituents of concern within Site surface water, sediment, and air. Additionally, Alternative 10 is protective of human health from exposure to constituents of concern in groundwater and soil in the future, for both the short term and long term, if institutional controls and source control measures (e.g., removal and capping of soil) are implemented as proposed in this alternative.

Alternative 10 eliminates direct contact risk from soils above human health criteria in the lagoon and maintenance yard areas through a combination of removal and capping. Alternative 10 includes a soil cover over all of the tailings piles, including areas exposed by regrading and currently exposed areas of the tailings.

Institutional controls would be implemented to help prevent potential human exposure through groundwater ingestion in the future. Other institutional controls to protect future human health risks for Alternative 10 would include land use restrictions, mine access restrictions, and signage at the Site to notify users about potential risks.

Alternative 10 would directly intercept and remove metals in discharges to Railroad Creek through the immediate collection of groundwater above proposed cleanup levels that would otherwise enter Railroad Creek across most, but not all, of the former mine operations area of the Site. Alternative 10 would use a partially penetrating barrier (PPB) to contain near-surface groundwater, without fully penetrating the alluvial aquifer in the Railroad Creek Valley, as discussed in Appendix F. The increased amount of metals removed and the immediate prevention of metals from entering the creek through Alternative 10 would significantly reduce metals concentrations within the creek immediately following implementation.

Depending on the overall performance of the PPB, Alternative 10 may be protective of aquatic life and achieve proposed cleanup levels in Railroad Creek. However, this cannot be demonstrated with available information, so Alternative 10 would rely on monitoring to determine whether the remedy is protective of aquatic life and whether it satisfies requirements for a final remedy.

Terrestrial toxicity risks would decrease through the removal, containment, or covering of soils with constituents of concern above proposed cleanup levels at the mill building, ventilator portal detention area, the lagoon, and the maintenance yard area.

Alternative 10 would permanently close the tailings piles and the main East and West Waste Rock Piles by regrading to improve stability and reduce infiltration, placement of a 1-foot-thick soil cover, and revegetation. Alternative 10 does not satisfy the presumptive cover requirements of Chapter 173-350 WAC, and would include additional analyses to determine whether it would satisfy the performance requirements for limited purpose landfills. Alternative 10 does not address closure of the Honeymoon Heights Waste Rock Piles.

Finally, Alternative 10 would use a terrestrial ERA and monitoring to determine whether additional soil cleanup is needed in other areas of the Site.

In summary, Alternative 10 may satisfy the CERCLA threshold requirement for protection of human health and the environment, but this cannot be assured on the basis of available information.

4.2.2.2 Compliance with Potential Applicable or Relevant and Appropriate Requirements (ARARs)

4.2.2.2.1 Potential Chemical-Specific Requirements for Surface Water

Alternative 10 collects most identified, existing sources of release into surface waters. Alternative 10 does not include collection or containment of groundwater below TP-2. Alternative 10 includes new monitoring wells adjacent to TP-2 that would be installed after the toe of the tailings piles are pulled back away from Railroad Creek. Information from the new monitoring wells, as well as performance of Alternative 10 following implementation, would be used to determine whether extending or modifying the PPB containment system is needed. However, potential extension or modifying the PPB is not part of Alternative 10 as it is analyzed in this SFS.

Under some hydrologic conditions, contaminated groundwater may bypass the PPB[65] and discharge into Railroad Creek, as discussed in Appendix F. Alternative

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[65] If Alternative 10 was selected as an interim remedy, additional analysis would be needed during RD to determine the final depth of the PPB. The depth of the PPB could vary along the length of Railroad Creek adjacent to the former mine area to accommodate local hydrogeologic conditions.

10 relies on monitoring to determine whether it would satisfy requirements for a final remedy.

4.2.2.2.2 Potential Chemical-Specific Requirements for Groundwater

Alternative 10 would provide institutional controls to prevent future groundwater consumption at the Site, and would contain groundwater released from most of the Site that exceeds proposed surface water cleanup levels, to protect terrestrial and aquatic receptors.

Alternative 10 contains, collects, and treats the identified sources of groundwater above proposed cleanup levels, except groundwater baseflow from below TP-2.[66] Thus, this alternative provides an immediate reduction in the metals that discharge into Railroad Creek and a reduction in the metals in the groundwater plume that migrates downgradient from the former mine.

Where containment and collection are not provided (e.g., adjacent to TP-2), Alternative 10 would rely on further characterization to determine whether proposed cleanup levels are met at all potential points of exposure.

4.2.2.2.3 Potential Chemical-Specific Requirements for Soil

Potential chemical-specific ARARs for soils are based on the protection of human health and terrestrial receptors, or in some cases on protection of groundwater and surface water quality. As noted in Section 4.1.2.2.3, MTCA allows Ecology to set cleanup levels based on a site-specific evaluation. Where containment of hazardous substances is achieved, soil cleanup levels protective of groundwater may not need to be met, provided certain criteria are met [WAC 173-340-740(6)(f)]. Where an alternative includes soil cleanup to protect human health and ecological receptors, and there is collection and treatment of downgradient groundwater, the Agencies do not expect further clean up of soils would be needed to protect groundwater. Alternative 10 does not qualify for this modification of standards because Alternative 10 does not fully contain groundwater contaminated by releases from soils. As a result, cleanup levels more stringent than those proposed in Table 8 may be applied if Alternative 10 were selected.

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[66] Alternative 10 includes collection of seeps SP-3 and SP-4, but not other groundwater that discharges below TP-2.

Alternative 10 includes excavation or covering of contaminated soils in the mill building, maintenance yard, lagoon, and ventilator portal detention areas to meet the proposed cleanup levels.

Alternative 10 includes additional terrestrial ERA to assess the need for soil cleanup action(s) in the LWA, the baseball field, areas within Holden Village, and the area of observed wind-blown tailings deposition east of the Village.

While Alternative 10 has not been shown to satisfy proposed cleanup levels in all areas of the Site, Alternative 10 does include provision to address the areas where there is currently not sufficient information.

4.2.2.2.4 Potential Chemical-Specific Requirements for Sediment

Alternative 10 includes the removal of ferricrete in Railroad Creek, the natural redistribution of sediments, and sediment monitoring to determine whether further sediment cleanup is required to protect aquatic organisms.

4.2.2.2.5 Potential Action- and Location-Specific Requirements

Potential action- and location-specific ARARs must be considered in selection of the remedy under CERCLA as discussed in Section 2.3.3.2 and 2.3.3.3, respectively. Based on review of Alternative 10, the Agencies anticipate it would satisfy most but not all of the potential action- and location-specific ARARs. In some cases the degree to which Alternative 10 would satisfy a potential ARAR would need to be demonstrated based on further analysis or monitoring after implementation, as noted below.

Washington Model Toxics Control Act [RCW 70.105D; Chapter 173-340 WAC]. The MTCA is a potential ARAR under CERCLA as well as an independent basis for requiring clean up of the Site under state law. The Agencies anticipate that Alternative 10 would satisfy MTCA requirements for selection of a permanent remedy, but that its ability to achieve MTCA-required cleanup levels with the PPB would need to be further evaluated based on design-level studies and assessed by monitoring after implementation. Thus, the Agencies believe that additional information would be needed to show whether Alternative 10 would satisfy MTCA as a potential ARAR under CERCLA.

Washington State Solid Waste Handling Standards [RCW 70.95; Chapter 173-350 WAC]. Alternative 10 would not meet the presumptive cover requirements for limited purpose landfills [WAC 173-350-400(3)(e)(ii)] that are potentially relevant and appropriate for the tailings and waste rock piles. However, Alternative 10 does include a 1-foot-thick soil cover, regrading to improve stability, and run-on/runoff controls for the tailings piles and main East and West Waste Rock Piles. Alternative 10 also includes additional analyses to determine whether the proposed cover would meet the performance requirements of the limited purpose landfill criteria [WAC 173-350-400(3)(e)(i)] and be protective of terrestrial receptors [WAC 173-340-7491(2)(a)]. Alternative 10 does not include closure of the Honeymoon Heights Waste Rock Piles. While additional information would be needed to show whether Alternative 10 would satisfy this potential ARAR for the tailings piles and the main East and West Waste Rock Piles, Alternative 10 would not satisfy this potential ARAR for the Honeymoon Heights Waste Rock Piles.

Aquatic Lands Management - Washington State [RCW 79.90; Chapter 332-30 WAC]. This potential ARAR requires that aquatic lands be managed to ensure environmental protection and, therefore, is potentially relevant and appropriate [WAC 332-30-100]. Alternative 10 does not eliminate the ongoing metals releases from TP-2.

Land and Resource Management Plan for Wenatchee National Forest (LRMP, Forest Service 1990), as amended by Pacific Northwest Forest Plan (NWFP, 1994) and subsequent amendments of the NWFP (2001, 2004, and 2007). The LRMP and NWFP include standards and guidelines that are potentially relevant and appropriate to actions at the Site, including activities within, or that affect Riparian Management Areas along Railroad and Copper Creeks, or are otherwise necessary to meet ACS objectives. Alternative 10 includes closure and reclamation of the tailings piles and main East and West Waste Rock Piles using best conventional techniques to ensure mass stability. However, Alternative 10 does not prevent the release of acid or toxic materials from TP-2 or the Honeymoon Heights Waste Rock Piles. For this reason, Alternative 10 would not comply with this potential ARAR. Alternative 10 also may not meet all aspects of the other standards and guidelines that pertain to achieving ACS objectives. A complete analysis of this potential ARAR would need to be performed as part of preparing the ROD if Alternative 10 was selected as an interim remedy for the Site.

4.2.2.2.6 Compliance with Potential ARARs

In summary, Alternative 10 may not completely satisfy the CERCLA threshold requirement for compliance with potential ARARs.

Although Alternative 10 cannot be shown to satisfy the CERCLA threshold requirements on the basis of existing information, for completeness, the following section analyzes Alternative 10 using the CERCLA primary balancing criteria.

4.2.2.3 Long-Term Effectiveness and Permanence

This section discusses how Alternative 10 addresses the CERCLA criteria for long-term effectiveness and permanence. CERCLA requires evaluation of long-term effectiveness and permanence by considering the magnitude of residual risk at the conclusion of remedy implementation, and the adequacy and reliability of controls that are part of the remedy.

4.2.2.3.1 Magnitude of Residual Risk Remaining at the Conclusion of the Remedial Activities

Alternative 10 would reduce risks to human health from exposure to groundwater through institutional controls. Risks to human health from exposure to soils above proposed cleanup levels and soil-like waste materials, would be reduced under Alternative 10 through: 1) institutional controls; 2) constructed caps over the tailings piles, main East and West Waste Rock Piles, and maintenance yard soils; and 3) removal of contaminated soils in the lagoon and ventilator portal detention areas.

Alternative 10 would immediately reduce the seep and groundwater flow with excess metals concentrations into Railroad Creek, thus immediately reducing the risk to aquatic life. The PPB would intercept most of the groundwater and all of the discrete seep flow (see Appendix F). Reduced inflow downgradient of the barrier would reduce concentrations of metals above cleanup levels entering the creek. Reduction in the release of iron and aluminum into Railroad Creek is also anticipated to reduce adverse physiological impacts on salmonids and eliminate ongoing formation of ferricrete that adversely impacts habitat for the benthic macroinvertebrates that sustain the food chain within the creek (USFWS 2005).

Proof-of-concept analyses indicate the PPB contemplated in Alternative 10 is a feasible alternative in comparison to a more costly fully penetrating barrier. The analyses completed by Hart Crowser indicate the PPB would be effective in containment and collection of more than 80 percent of the contaminated groundwater (see Attachment B of Appendix F). However, location of the PPB along the edge of Railroad Creek would also allow some creek water to flow into the collection system during temporary high water conditions when the creek elevation exceeds the adjacent groundwater elevation. The estimated volume of creek water that would be collected is less than 2 percent of the total volume of groundwater collected for treatment and a relatively insignificant part of the total flow through the treatment facility. While this represents a minor loss of efficiency in the treatment system overall, it is likely to have much smaller impact than other potential treatment operation issues related to stormwater inflow and sludge management.

Alternative 10 includes regrading and pulling back the toe of the three tailings piles away from Railroad and Copper Creeks. Flattening the slopes would greatly reduce risk of seismic slope failures or surficial erosion of the tailings piles. Pulling the toe of the slope back from the creek would greatly reduce the risk of slope failures from scour in Railroad Creek that could undermine the riprap, or flooding that could overtop the riprap. Alternative 10 would mitigate the residual risk of erosion or large-scale slope failures that could release significant volumes of tailings with metals above proposed cleanup levels directly into the Railroad Creek and ultimately Lake Chelan.

Closure of the tailings piles and the main East and West Waste Rock Piles using 1-foot-thick soil covers will reduce the risk of exposure to terrestrial receptors. While this cover does not satisfy the presumptive cover requirements of Chapter 173-350 WAC, it may meet the cover performance standards [WAC 173-350-400(3)(e)(i)]. Alternative 10 includes a terrestrial ERA to determine whether the proposed covers are protective. Alternative 10 includes additional terrestrial ERA to assess cleanup requirements in areas such as the LWA, the baseball field, areas within Holden Village, and the area of observed wind-blown tailings deposition east of Holden Village, to address any risk to terrestrial receptors.

Based on the analysis presented above, Alternative 10 leaves some residual risk at the conclusion of remedial activities. Based on uncertainties regarding performance of the PPB; the need for containment, collection, and treatment of groundwater below TP-2; and performance of the tailings and waste rock pile covers, Alternative 10 may leave risks that would require additional cleanup after implementation or rely on natural attenuation. However, Alternative 10 would not satisfy all the requirements for a remedy to rely on natural attenuation. This alternative would not provide source control to the maximum extent practicable.

4.2.2.3.2 Adequacy and Reliability of Controls

To assess the adequacy and reliability of controls at the Site, items to be addressed under CERCLA include: 1) uncertainties associated with land disposal of treatment system residuals; 2) potential need to replace technical components of the remedy; and 3) potential risk if components of the remedy need replacement [40 CFR § 300.430(e)(9)(iii)(C)(2)].

Sludge management was not addressed in detail in the DFFS, so the Agencies reviewed additional information to assess characteristics of the sludge. The Agencies' evaluation of Alternative 10 estimated quantities of metal hydroxides precipitated as sludge, during treatment. The sludge volume estimate included a geotechnical analysis that considered consolidation characteristics of sludges produced by similar treatment at other mines (see Appendix F). The Agencies used this information to estimate sludge handling costs and landfill disposal requirements. The Agencies cost estimate for Alternative 10 also explicitly addressed the need to replace or repair water collection, conveyance, and treatment system components (see Appendix B).

Alternative 10 assumes construction of the sludge disposal landfill in stages using discrete cells over the life of the remedy. Alternative 10 assumes the disposal cells would be lined. However, this requirement could be waived and long-term costs reduced, if design tests show the sludge is stable and monitoring indicates that leachate metals concentrations meet proposed surface water cleanup levels.

Alternative 10 includes riprap to control erosion along the south side of Railroad Creek and portions of Copper Creek to protect the groundwater collection system and maintain long-term stability of the tailings piles.[67] Over time, floods or scour in the creek channel may displace the riprap (as happened in 2003). The Agencies anticipate periodic maintenance or restoration of the riprap. The Agencies' cost estimates include the cost of maintaining the riprap.

Alternative 10 relies on open ditches for collection of groundwater. Ditches and other treatment system components may be susceptible to ice blockage in the winter, and sludge formation following air contact with iron-rich groundwater from below the tailings piles. Maintenance needs are discussed in Appendix F and included in the Appendix B cost estimates for Alternative 10.

The Alternative 10 treatment facility equipment parts and/or systems will wear out and require replacement. The Agencies' Alternative 10 cost estimate includes the cost to monitor, maintain, and replace water collection, conveyance, and treatment system components.

There is some uncertainty with respect to the effectiveness of Alternative 10 components that rely on interrupting exposure pathways (groundwater baseflow and seeps) that convey excess metals into surface water. One aspect of this uncertainty is the effectiveness of the PPB; another aspect is uncertainty associated with the conveyance and treatment components; and a third is the adequacy of groundwater collection.

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[67] Alternative 10 does not rely on riprap alone to protect the tailings piles from flood waters of Railroad Creek, and to prevent failure of the tailings slopes from impacting the creek. Setback of the tailings pile slopes for Alternative 10 satisfies a number of requirements, such as access for maintenance and monitoring, and provides incidental benefits such as enabling restoration of riparian habitat that has been damaged by releases from the tailings. The establishment of vegetation in the riparian zone will further reduce potential flood impacts on the tailings, improve long-term stability, and reduce the need to rely on the riprap.

- If the PPB did not contain groundwater sufficiently to meet surface water quality criteria, it might need to be supplemented or replaced with a fully penetrating barrier.

- Failure of the conveyance and treatment components (e.g., due to winter freezing) could reestablish the associated exposure pathways. The magnitude of resulting risk would depend on the extent and duration of the failure. Planned replacement and other maintenance of components for the groundwater conveyance and treatment systems likely can minimize or avoid shutting down the remediation system.

- Alternative 10 may not adequately prevent the release of groundwater above proposed cleanup levels into Railroad Creek, since it does not include groundwater collection below TP-2.

Failure of any remedial system component could result in an uncontrolled release of contaminated water to the ground surface or into Railroad Creek or Copper Creek, depending on where the release occurred. If the PPB was not effective, it would result in continuation of a long-term release. Failure of the conveyance or treatment system could have a sudden, acute impact on aquatic life within Railroad Creek, if the metal concentrations were high enough. However, an accidental release due to short-term failure of a remedy component is generally anticipated to have less effect than the existing ongoing releases.

Alternative 10 would employ active controls to prevent the discharge of contaminated groundwater and seep flows into Railroad Creek for the Site, except groundwater below TP-2. Alternative 10 includes collection of seeps SP-3 and SP-4 for treatment. Omitting collection of groundwater above cleanup levels below TP-2 would leave risks to the creek.

Based on the analysis described above, Alternative 10 may not include sufficiently adequate and reliable controls to provide long-term protection of the environment.

4.2.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 10 would contain and treat groundwater from the mine. Water entering the creek downgradient of the existing portal drainage, the abandoned mill, the main East and West Waste Rock Piles, the maintenance yard, and the lagoon area would be collected and treated. Alternative 10 would remove or cap sources of metals in the lagoon, maintenance yard area, the former mill, and ventilator portal detention area. The Copper Creek Diversion would be hydraulically isolated. Alternative 10 would collect and treat water entering the creek from the high concentration seeps in the LWA and tailings pile areas, along with groundwater baseflow from the LWA and below TP-1 and TP-3. Alternative 10 would collect and treat individual seeps SP-3, SP-4, SP-12, and SP-23. Alternative 10 would not collect groundwater for treatment downgradient of TP-2 and Honeymoon Heights but would monitor groundwater from these areas to determine whether the remedy is protective.

At the Site, risk to the aquatic environment is directly related to the toxicity and quantity of hazardous substances released into Railroad Creek from groundwater (including the mine portal and seeps). Alternative 10 reduces this risk by collection and treatment of all the seeps and most of the identified contaminated groundwater that enters Railroad Creek.

Alternative 10 would use active treatment to reduce the toxicity of an estimated 490 million gallons per year of contaminated water. Alternative 10 would remove and dewater the sludge from the treatment plant to reduce potential leaching of constituents of concern. The process would produce an average of approximately 27,000 cy of sludge per year during the first 50 years of operation, and this volume would decrease over time (approximately 50 percent in 50 years) as indicated in Section 4.1.3.2.5.

Alternative 10 would greatly reduce the toxicity and mobility of metals in groundwater released into Railroad Creek and includes monitoring to assess whether there is a need to collect any additional groundwater. Alternative 10 does not rely on destruction or recycling any hazardous substance materials.

4.2.2.5 Short-Term Effectiveness

This section discusses how Alternative 10 addresses the CERCLA-required evaluation of short-term effectiveness of a proposed remedy. This includes consideration of risks to the community and workers during implementation, potential environmental impacts and mitigative measures, and the time until protection is achieved.

4.2.2.5.1 Short-Term Risks on the Community during Implementation

Short-term health risks to the community during implementation primarily consist of increased exposure to construction traffic. Potential exposure to construction dust, noise, and vehicle exhaust emissions is not anticipated to present risks to the Holden Village community or other members of the public using the adjacent forest lands.

Short-term risks to the local community from implementation of Alternative 10 can be adequately mitigated through active measures taken during construction. This would include a traffic control plan for joint use of the Lucerne-Holden Road by construction traffic and the Holden Village community.

4.2.2.5.2 Potential Impacts on Workers during the Remedial Action and the Effectiveness and Reliability of Mitigative Measures during Implementation

Short-term human health risks from remedy implementation at the Site primarily include construction safety, traffic, and potentially longer term risks associated with operation of the treatment facility.

Human health risks to construction workers posed by remedy implementation include the following: underground mine hazards; construction traffic; exposure to soils with elevated concentrations of TPH and possibly other hazardous substances; exposure to noise and dust; and exposure to demolition activities and debris in the removal of the derelict mill structure. Additional risks would be related to construction activities (e.g., open excavations, heavy equipment operations) associated with regrading, barrier wall construction, ditch excavations, and treatment plant construction.

Construction activities will need to adhere to applicable OSHA, WISHA, and potentially MSHA regulations. Construction workers will be required to have HAZWOPER training. Dust concerns would be managed through BMPs.

4.2.2.5.3 Potential Environmental Impacts of the Remedial Action and the Effectiveness and Reliability of Mitigative Measures during Implementation

Potential environmental impacts of the remedial action include the following:

1. Risk of a tailings release to Railroad or Copper Creeks during regrading due to slope failures or stormwater runoff. An estimated 580,000 cy of tailings would be moved during regrading;
2. Risk of bentonite or cement releases, depending on material selected for use during RD, to the creeks during barrier wall construction;
3. Risks associated with construction of hydraulic barriers in the underground mine;
4. Risk of sediment release to the creeks during construction of groundwater and seep collection components, and use of temporary stream crossings during construction;
5. Construction vehicle emissions, noise, and dust;
6. Risk of fuel spills; and

7. Risk of surface water quality exceedances during and after startup of the treatment plant.

Mitigative measures for tailings and sediment releases include construction BMPs such as sediment fencing and barriers, which could be advanced along the edge of the creek as the regrading advances. Alternative 10 includes pulling the tailings back from Railroad Creek, as well as enhancing existing riprap to mitigate potential flooding.

The risk of fuel spills, or bentonite or cement releases, would be mitigated through a SPCC Plan implemented for construction, and adherence to regulations regarding storage, transportation, and dispensing of fuel.

In summary, Alternative 10 includes adequate mitigative measures to prevent potential adverse environmental impacts from risk of a tailings release during regrading, or from potential flooding over the long term.

4.2.2.5.4 Time until Protection is Achieved

Alternative 10 would immediately protect human health and may be protective of the environment. However, the degree of protectiveness to Railroad Creek would need to be verified, as it cannot be shown on the basis of existing information. Institutional controls to protect human health from exposure to constituents of concern in groundwater and soil in the future would be established during remedy implementation. Alternative 10 would immediately eliminate sources such as the portal drainage, and groundwater from LWA, TP-1, and TP-3.

4.2.2.5.5 Summary of Short-Term Effectiveness

Based on the analyses presented in Sections 4.2.2.5.1 through 4.2.2.5.4, Alternative 10 may be effective over the short term after implementation, but its acceptability as a final remedy cannot be shown on the basis of existing information.

4.2.2.6 Implementability

This section describes the CERCLA evaluation of the implementability of Alternative 10, based on consideration of its technical feasibility, administrative feasibility, and the availability of needed services and materials.

4.2.2.6.1 Technical Feasibility

Alternative 10 is considered to be technically feasible. The remedy could be implemented using conventional construction equipment and techniques.

The groundwater collection system would intercept a small amount of creek water during high flow periods, resulting in a small additional flow of water volume to be treated. This is not a significant feasibility issue since the hydrograph analysis described in Attachment B of Appendix F estimates that collected stream flow would be less than 2 percent of the total volume of groundwater collected for treatment, and a relatively insignificant part of the total flow through the treatment facility.

Feasibility may be limited by seasonal freezing or iron fouling of ditches used for collection and conveyance of groundwater, conveyance piping, pumps, and treatment facility components. Performance of the ditch system used for collection and conveyance, and its susceptibility to freezing or other problems should be further evaluated during RD to determine whether an alternative approach, such as the seep collection system proposed for Alternative 9, would be more effective.

4.2.2.6.2 Administrative Feasibility

Administrative requirements associated with potential ARARs are discussed in Section 4.2.2.2.5.

The land affected by the remedy is under the control of the Forest Service, except for patented mine claims that are owned by Holden Village, Inc. The Agencies anticipate that the remedy will include access and institutional controls on lands owned by Holden Village, Inc.

No wastes are anticipated to be moved off the Site for disposal, with the possible exception of residual processing wastes encountered during cleanup of the abandoned mill building, which may designate as state Dangerous Waste. The potential need for off-site disposal of such wastes does not affect the feasibility of Alternative 10.

4.2.2.6.3 Availability of Services and Materials

The technologies required for each of the components in Alternative 10 are known and proven technologies. The Agencies anticipate that there will be companies willing to do this work and that the contractors bidding for this work will be experienced in the technologies required for the alternative. Despite the

Site's remote geographic location, necessary equipment would be able to be moved to the Site for construction of Alternative 10.

4.2.2.6.4 Summary of Implementability

Based on the analyses presented in Sections 4.2.2.6.1 through 4.2.2.6.3, Alternative 10 is implementable.

4.2.2.7 Cost

CERCLA requires that an alternative selected as a cleanup action shall be cost-effective, provided that it first satisfies the threshold criteria. Alternative 10 does not satisfy the threshold criteria with respect to all potential ARARs (e.g., it does not address the Honeymoon Heights Waste Rock Piles). Also the protectiveness of Alternative 10 for aquatic receptors cannot be demonstrated on the basis of existing information.

Although Alternative 10 does not satisfy the threshold criteria, the cost for this Alternative is presented here for completeness. Details of the cost estimate are presented in Appendix B. Since Alternative 10 would not achieve criteria for a final remedy, an unknown additional expenditure (not estimated herein) would be needed to make this a final remedy.

The table below summarizes these costs for Alternative 10 based on the Agencies' estimates.

	Alternative 10
Estimated Capital Cost	$37,100,000
Estimated Average Annual O&M Cost	$1,430,000
Net Present Value of Capital and O&M Costs (50 years @ 7%)	$55,100,000

Alternative 10 would address most portions of the Site where contaminated groundwater enters Railroad Creek, and may satisfy the threshold criteria. However, Alternative 10 cannot be selected as a final remedy on the basis of cost because it cannot be shown to meet the threshold criteria on the basis of existing information.

4.2.2.8 State Acceptance

4.2.2.8.1 State's Position and Key Concerns Related to Alternative 10

The State of Washington has participated with the lead Agency in evaluating remedy alternatives for the Site. Solely for Ecology's purposes under MTCA, the state's evaluation of Alternative 10 is summarized below. The state has determined that Alternative 10 cannot today be shown to satisfy requirements for a final remedy.

Threshold Requirements

There are seven requirements to be evaluated for selecting a final remedy under MTCA [WAC 170-340-360]. The first four requirements comprise the threshold requirements, which require that the remedy: 1) protect human health and the environment; 2) comply with cleanup standards; 3) comply with applicable state and federal laws; and 4) provide for compliance monitoring.

Protect Human Health and the Environment. As discussed in Section 4.2.2.1, Alternative 10 may be protective of aquatic life depending on the overall performance of the PPB, collecting groundwater seeps downgradient of the Honeymoon Heights Waste Rock Piles (but otherwise leaving these piles as-is), and the effect of groundwater releases below TP-2. Alternative 10 relies on both chemical and biologic monitoring to assess effectiveness and protectiveness of the alternative and to provide a basis to determine whether Alternative 10 is suitable as a final remedy. Alternative 10 could be implemented as an interim remedy, but additional actions would likely be needed to satisfy the threshold protectiveness requirements for a final remedy.

Comply with Cleanup Standards. "Cleanup standards" under MTCA refers to the proposed cleanup levels based on potential chemical-specific ARARs; the location(s) where these cleanup levels must be met (points of compliance); and other regulatory requirements that must be met because of the type of action and/or location of the Site (potential action-specific and location-specific ARARs). MTCA requires that for a cleanup action to meet the requirements for a groundwater conditional point of compliance, groundwater discharges need to be provided with AKART before being released to surface waters [WAC 173-340-720(8)(d)(i)]. Alternative 10 may constitute AKART, and thus a point of compliance along the groundwater-surface water interface of Railroad and Copper Creeks could be approved by Ecology for Alternative 10. As discussed in Section 4.2.2.2, Alternative 10 may satisfy cleanup standards, but this cannot be adequately demonstrated based on existing information. Furthermore, Alternative 10 would utilize both chemical and biologic monitoring to assess effectiveness of the alternative, so that contingencies could be implemented, if needed.

Comply with State and Federal Law. The Agencies anticipate that Alternative 10 may comply with all applicable state and federal laws, and note that Alternative 10 includes provisions for further terrestrial ERA and monitoring to assure the final remedy will achieve compliance with:

- **Washington Model Toxics Control Act [RCW 70.105D; Chapter 173-340 WAC].** Monitoring would be needed to demonstrate whether Alternative 10 would achieve MTCA-required cleanup levels with the PPB and in areas where containment is not provided.

- **Washington State Solid Waste Handling Standards [RCW 70.95; Chapter 173-350 WAC].** Additional ecological risk analysis would be performed as part of Alternative 10 to determine whether the proposed cover meets performance standards and is protective of terrestrial receptors.

- **Aquatic Lands Management - Washington State [RCW 79.90; Chapter 332-30 WAC].** Alternative 10 does not eliminate the ongoing metals releases from TP-2 and potentially in groundwater downslope of Honeymoon Heights Waste Rock Piles. Alternative 10 includes monitoring as part of implementation to determine whether collection and treatment of this groundwater is needed to ensure environmental protection, as required under WAC 332-30-100.

- **Land and Resource Management Plan for Wenatchee National Forest (LRMP, Forest Service 1990) as Amended by Pacific Northwest Forest Plan (NWFP, 1994) and subsequent amendments of the NWFP (2001, 2004, and 2007).** Alternative 10 does not prevent the release of acid or toxic materials from TP-2 or the Honeymoon Heights Waste Rock Piles. Alternative 10 also may not meet all aspects of the other standards and guidelines that pertain to achieving ACS objectives of the LRMP/NWFP.

Alternative 10 could be implemented as an interim remedy, but additional actions would be needed to satisfy the compliance with ARAR requirements for a final remedy.

Provide for Compliance Monitoring. Alternative 10 would provide for compliance monitoring as discussed in the conceptual monitoring plan developed for it by the Agencies (Hart Crowser 2005d). Final details of monitoring would be established as part of a Sampling and Analysis Plan approved by the Agencies, which would be developed during RD.

MTCA Other Requirements

Other requirements for remedy selection that must be evaluated under MTCA include: 5) use permanent solutions to the maximum extent practicable; 6) provide a reasonable restoration time frame; and 7) consider public concerns.

Use of Permanent Solutions to the Maximum Extent Practicable. Appendix G presents the Agencies' practicability assessment to determine whether Alternative 10 uses permanent solutions to the maximum extent practicable.

Alternative 10 uses potentially permanent solutions for a portion of the Site, but does not use permanent solutions to the maximum extent practicable.

As discussed in Section 4.2.2.1, Alternative 10 provides active collection and treatment of groundwater immediately adjacent to the groundwater-surface water interface. Alternative 10 would immediately reduce the magnitude of seep and groundwater flow with excess metals concentration into Railroad Creek, thus it would immediately reduce toxicity to aquatic life. Some groundwater with elevated metals concentrations may continue to seep past the PPB, thus monitoring would be needed to show that Alternative 10 is protective of aquatic organisms.

Alternative 10 includes regrading and pulling back the toe of the three tailings piles away from Railroad and Copper Creeks. Thus, Alternative 10 provides significant reduction in risk of erosion or large-scale slope failures. Alternative 10 does not include a cover that satisfies the presumptive closure requirements for limited purpose landfills [WAC 173-350-400], but does include an analysis to show whether it meets the performance requirements and is protective. Additional terrestrial ERA is included in Alternative 10 to determine what action is needed for areas of the Site such as the wind-blown tailings area.

Provide a Reasonable Restoration Time Frame. At this time it is not known whether Alternative 10 would provide for a reasonable restoration time frame for surface water, since this alternative does not include groundwater containment or collection adjacent to TP-2. Alternative 10 includes a barrier and groundwater collection system to control migration of contaminated groundwater from the LWA, TP-1, and TP-3, only. Alternative 10 relies on monitoring following remedy implementation to confirm remedy protectiveness and effectiveness.

The Agencies expect that the likely future use of the Site and surrounding resource areas will continue to be high value environmental habitat and recreational use. Alternative 10 collects and treats much of the contaminated groundwater that discharges into Railroad Creek thus benefiting the future use of the Site, surrounding areas, and associated resources.

Consider Public Concerns. Public concerns will be addressed as part of selecting and implementing the final cleanup action in accordance with WAC 173-340-600(14) and (15).

MTCA Action-Specific Requirements

Finally, MTCA has additional remedy selection requirements that apply specifically to clean up actions that include groundwater cleanup actions; clean up of soils in residential and school areas; institutional controls; releases and migration; dilution and dispersion; and use of remediation levels.

Non-Permanent Groundwater Cleanup Actions. Since a permanent groundwater clean up is not practicable, Alternative 10 must meet MTCA's requirements for non-permanent cleanup actions [WAC 173-340-360(2)(c)(ii)]. Alternative 10 includes the removal of some sources (e.g., in the former mill, lagoon area, etc.) and the containment of other sources through capping. Alternative 10 includes containment of some, but not all shallow groundwater to avoid lateral and vertical expansion of the groundwater affected by the hazardous substances. Alternative 10 may not completely prevent expansion of the groundwater plume since this alternative does not provide containment downgradient of TP-2. Monitoring would be needed to show whether Alternative 10 is protective to the same extent as a fully penetrating groundwater barrier all along Railroad Creek adjacent to the LWA and the three tailings piles. For further discussion, see Appendix G.

Cleanup of Soils for Residential and School Areas. The DRI indicated that existing soil concentrations in the Village do not exceed human health criteria, thus the MTCA requirement [WAC 173-340-360(2)(d)] for soil clean up would not require action within the Village. Institutional controls, and engineering measures (e.g., capping of tailings) on the remainder of the Site will need to be implemented to protect residential areas, schools, or childcare centers.

Institutional Controls. Alternative 10 satisfies requirements for institutional controls to protect human health that are specified in WAC 173-340-440.

Releases and Migration/Dilution and Dispersion. Alternative 10 would minimize existing and future releases and migration of hazardous substances through the use of a permanent groundwater containment barrier, permanent closure to protect the tailings and waste rock piles from erosion and slope failures, and removal or capping of areas with hazardous substances above proposed cleanup levels.

Alternative 10 includes installation of a groundwater PPB and collection system in the LWA along Railroad Creek from the existing Main Portal discharge point into Railroad Creek to the Copper Creek Diversion, and along both TP-1 and TP-3 adjacent to Railroad Creek. Alternative 10 also includes collection and treatment of discrete seeps SP-3 and SP-4 on the northern edge of TP-2. Alternative 10 would not include the collection and treatment of groundwater below TP-2.

Alternative 10 does not rely primarily on dilution and dispersion to clean up groundwater and surface water above proposed cleanup levels. Rather, Alternative 10 uses active remedial measures to contain, collect, and treat most groundwater above proposed cleanup levels. However, monitoring would be needed to show whether the PPB and the absence of containment along TP-2, would be protective to the same extent that is practicable with a fully penetrating groundwater barrier all along the LWA and the three tailings piles.

For further discussion, see Appendix G.

Remediation Levels. Remediation levels are not proposed for Alternative 10.

4.2.2.8.2 State Comments on Potential ARARs or the Proposed Use of ARAR Waivers

The state has not separately provided any comments on potential ARARs for the Holden cleanup, but has participated in joint preparation of documents with the Forest Service and EPA, including the preparation of potential ARARs section of this document.

4.2.2.9 Community Acceptance

MTCA, similar to CERCLA, provides that final remedy selection will consider public comment on the remedial alternatives.

Community acceptance of alternatives will be evaluated after the public comment period ends, and will be described in the ROD for the Site.

4.2.3 Alternative 11

This section describes the Agencies' evaluation of Alternative 11 using each of the CERCLA remedy selection criteria.

4.2.3.1 Overall Protection of Human Health and the Environment

Alternative 11 would fully address risk to aquatic receptors and human health, as discussed below. Additional terrestrial ERA of soils with metals concentrations that exceed screening levels would be done during RD to determine what actions are needed in the areas such as the wind-blown tailings area. The terrestrial ERA could also show it is possible to reduce the proposed tailings and waste rock covers and still protect terrestrial receptors.

Alternative 11 is protective of human health based on current and anticipated exposures to constituents of concern within Site surface water, sediment, and air. Additionally, the alternative is protective of human health from exposure to constituents of concern in groundwater and soil in the future, for both the short term and long term, if institutional controls and source control measures (e.g., removal and capping of soil) are implemented as part of the remedy.

Alternative 11 eliminates direct contact risk to soils above human health criteria in the lagoon and maintenance yard areas through a combination of removal and capping. Alternative 11 includes a permanent cap over all of the tailings piles, including areas exposed by regrading as well as currently exposed areas of the tailings.

Institutional controls would be implemented to help prevent potential human exposure through groundwater ingestion in the future. Other institutional controls to protect future human health risks for Alternative 11 would include land use restrictions, mine access restrictions, and signage at the Site to notify users about potential risks.

Alternative 11 includes a cap over all the tailings and waste rock piles to eliminate surface infiltration and reduce contamination of clean water.

Alternative 11 includes a groundwater barrier and a groundwater and seep collection system that would immediately reduce if not eliminate seep and groundwater flow with excess metals concentration into Railroad Creek.[68] Containment and treatment of virtually all sources of hazardous substance releases would immediately reduce the risk of exposure to aquatic life of constituents of concern above proposed cleanup levels. Reduction in the release of iron and aluminum into Railroad Creek is also anticipated to reduce adverse physiological impacts on salmonids and eliminate ongoing formation of

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[68] The efficiency of the barrier and collection system based on experience at other sites is presented in Appendix C.

ferricrete that adversely impacts habitat for the benthic macroinvertebrates that sustain the food chain within the creek (USFWS 2005).

Alternative 11 would be protective of terrestrial receptors through the removal, containment, or covering of soils with constituents of concern above proposed cleanup levels at the mill building, ventilator portal detention area, the lagoon, and the maintenance yard area. Alternative 11 would excavate and consolidate the Honeymoon Heights Waste Rock Piles into the main West Waste Rock Pile. Alternative 11 would permanently close the remaining waste rock piles and the tailings piles to conform with the presumptive cover requirements for closing limited purpose landfills, unless the proposed terrestrial ERA shows a less robust cover would be protective.

Finally, Alternative 11 would use a terrestrial ERA and monitoring to determine whether additional soil cleanup is needed in other areas of the Site.

In summary, Alternative 11 is anticipated to be protective of human health and the environment, which satisfies the first CERCLA threshold criteria for selection of a remedy.

4.2.3.2 Compliance with Potential Applicable or Relevant and Appropriate Requirements (ARARs)

4.2.3.2.1 Potential Chemical-Specific Requirements for Surface Water

Alternative 11 addresses all identified, existing sources of hazardous substance releases into surface waters through containment, collection, and treatment. Thus the alternative is expected to satisfy potential chemical-specific ARARs for surface water. Alternative 11 includes design and operation of the treatment plant to meet discharge limits, which could include a mixing zone, if approved.

4.2.3.2.2 Potential Chemical-Specific Requirements for Groundwater

Alternative 11 would contain and provide active measures to collect and treat all identified groundwater sources that exceed proposed cleanup levels and would otherwise enter Railroad or Copper Creeks. Groundwater barriers are a proven technology for the containment of contaminated groundwater, e.g., below waste piles that are left in place, see Appendix C. By using such a barrier, Alternative 11 provides source control to the maximum extent practicable, which is one of the requirements to enable the cleanup to rely on a conditional point of compliance for groundwater under MTCA. Groundwater that discharges from the Site is anticipated to meet potential chemical-specific ARARs.

Alternative 11 will provide institutional controls to prevent future groundwater consumption at the Site. The combination of institutional controls to protect human health, and containment, collection, and treatment would satisfy potential ARARs.

4.2.3.2.3 Potential Chemical-Specific Requirements for Soil

Potential chemical-specific ARARs for soils are based on protection of human health and terrestrial ecological receptors, or in some cases protection of groundwater or surface water quality. As noted in Section 4.1.2.2.3, MTCA allows Ecology to set cleanup levels based on a site-specific evaluation. Where containment of hazardous substances is achieved, soil cleanup levels protective of groundwater may not need to be met, provided certain criteria are met [WAC 173-340-740(6)(f)]. Where an alternative includes soil clean up (which may include institutional controls) to protect human health and ecological receptors, and there is collection and treatment of downgradient groundwater, the Agencies do not expect further clean up of soils to protect groundwater.

Alternative 11 includes the excavation of soil at the former mill building, ventilator portal detention area, the lagoon, and removal or capping of soils in the maintenance yard or other areas, as needed, to meet proposed soil cleanup levels.

Alternative 11 includes a terrestrial ERA and biological monitoring to determine the extent of cleanup, if any, required for additional areas that have metal concentrations above the proposed soil cleanup levels (e.g., the Holden Village and the area of observed wind-blown tailings deposition east of the Village).

4.2.3.2.4 Potential Chemical-Specific Requirements for Sediment

Alternative 11 includes the removal of ferricrete in Railroad Creek, the natural redistribution of sediments, and sediment monitoring to determine whether further sediment clean up is required to protect aquatic organisms.

4.2.3.2.5 Potential Action- and Location-Specific Requirements

Potential action- and location-specific ARARs must be considered in selection of the remedy under CERCLA as discussed in Section 2.3.3.2 and 2.3.3.3, respectively. Based on review of Alternative 11, the Agencies anticipate it would satisfy all of the potential action- and location-specific ARARs. Monitoring during and after implementation would be used to assess compliance, as required under both CERCLA and MTCA.

4.2.3.2.6 Compliance with Potential ARARs

In summary, based on the analyses discussed in Sections 4.2.3.2.1 through 4.2.3.2.5, Alternative 11 is anticipated to satisfy potential ARARs, which is the second of the threshold criteria for selection of a remedy under CERCLA.

4.2.3.3 Long-Term Effectiveness and Permanence

This section discusses how Alternative 11 addresses the CERCLA criteria for long-term effectiveness and permanence, based on considering the magnitude of residual risk at the conclusion of remedy implementation, and the adequacy and reliability of controls that are part of the remedy.

4.2.3.3.1 Magnitude of Residual Risk Remaining at the Conclusion of the Remedial Activities

Risks to human health from exposure to groundwater would be reduced under Alternative 11 through institutional controls. Risks to human health from exposure to soils above proposed cleanup levels and soil-like waste materials, would be reduced under Alternative 11 through: 1) institutional controls; 2) constructed caps over the tailings piles, main East and West Waste Rock Piles, and maintenance yard soils; and 3) removal of contaminated soils in the lagoon and ventilator portal detention areas.

Alternative 11 includes permanent containment, collection, and treatment of all identified sources of groundwater that exceed proposed cleanup levels.[69] The Site-wide, fully penetrating groundwater barrier and collection system included in Alternative 11 would extend adjacent to Railroad Creek from the existing Main Portal discharge point into Railroad Creek to the east end of Tailings Pile 3. Alternative 11 addresses the concern that a PPB might lead to loss of contaminated groundwater to Railroad Creek and collection of creek water (during temporary high-flow conditions).

Alternative 11 includes regrading and pulling back the toe of the three tailings piles away from Railroad and Copper Creeks. Flattening the slopes would address risk of seismic slope failures or surficial erosion of the tailings piles. Pulling the toe of the slope back away from the creeks would greatly reduce the

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[69] The Agencies note that there is an implicit but unsubstantiated assumption in the DRI and DFFS that groundwater that enters Railroad Creek as baseflow downgradient of Honeymoon Heights does not exceed proposed cleanup levels. Alternative 11 includes monitoring to determine whether potential sources such as this need to be addressed.

risk of slope failures due to scour that could undermine the riprap, or flooding that could overtop the riprap. Alternative 11 would mitigate the residual risk of erosion or large-scale slope failures that could release substantial volumes of tailings with metals above proposed cleanup levels directly into the Railroad Creek and ultimately Lake Chelan.

Closure of the tailings and waste rock piles in conformance with state landfill regulations will immediately result in a reduced risk of exposure to terrestrial receptors.

Alternative 11 also includes additional terrestrial ERA during RD and monitoring to assess potential cleanup requirements in areas such as the LWA, the baseball field, areas within Holden Village, and the area of observed wind-blown tailings deposition east of Holden Village, to address any risk to terrestrial receptors.

Based on the analysis presented above, Alternative 11 is expected to leave very little residual risk at the conclusion of remedial activities.

4.2.3.3.2 Adequacy and Reliability of Controls

To assess the adequacy and reliability of controls at the Site, items to be addressed under CERCLA include: 1) uncertainties associated with land disposal of treatment system residuals; 2) potential need to replace technical components of the remedy; and 3) potential risk if components of the remedy need replacement [40 CFR § 300.430(e)(9)(iii)(C)(2)].

Sludge management was not addressed in detail in the DFFS, so the Agencies reviewed additional information to assess characteristics of the sludge. The Agencies' evaluation of Alternative 11 was based in part on analyses of the volume of sludge that would be produced and how the volume of sludge would change over time, as described in Appendix F. This information was used to estimate, the costs of sludge handling and landfill disposal requirements. The Agencies' cost estimate for Alternative 11 also explicitly addressed the need to replace or repair water collection, conveyance, and treatment system components (see Appendix B).

Alternative 11 assumes construction of the sludge disposal landfill in stages using discrete cells over the life of the remedy. Alternative 11 assumes the disposal cells would be lined. However, this requirement could be waived for future stages and long-term costs reduced if design testing shows the sludge is stable and monitoring indicates the leachate metals concentrations meet proposed surface water cleanup levels.

Alternative 11 includes riprap to control erosion along the south side of Railroad Creek and portions of Copper Creek to protect the groundwater collection system and maintain long-term stability of the tailings piles.[70] Over time, floods or scour in the creek channel may displace the riprap (as happened in 2003). The Agencies anticipate periodic maintenance or restoration of the riprap. The Agencies' cost estimates include the cost of maintaining the riprap.

Alternative 11 relies on open ditches for collection of groundwater. Ditches and other treatment system components may be susceptible to ice blockage in the winter, and sludge formation following air contact with iron-rich groundwater from below the tailings piles. Maintenance needs are discussed in Appendix F and included in the Appendix B cost estimates for Alternative 11.

The Alternative 11 treatment facility equipment parts and/or systems will wear out and require replacement. The Agencies' Alternative 11 cost estimate includes the cost to monitor, maintain, and replace water collection, conveyance, and treatment system components.

Components of Alternative 11 rely on interrupting exposure pathways (groundwater baseflow and surface seeps) that convey excess metals into surface water at the Site. Failure of these remedial components would result in reestablishing the associated exposure pathways, and the magnitude of resulting risk would depend on the extent and duration of the failure. The subsurface groundwater barrier proposed for Alternative 11 is considered to be permanent; provided the design accounts for the potential chemical interaction of the soil-cement or cement-bentonite components with groundwater. Reported experience at other sites provides an adequate basis to design a barrier that will not wear out or degrade in effectiveness over time. Planned maintenance and periodic replacement of components for the groundwater collection, conveyance, and treatment systems are included in the cost estimate for Alternative 11, and typically can be arranged to minimize or avoid shutting down the remediation system.

Unanticipated failure of any remedial system component could result in an uncontrolled release of contaminated water to the ground surface or into Railroad Creek or Copper Creek, depending on where the release occurred.

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[70] Alternative 11 does not rely on riprap alone to protect the tailings piles from flood waters of Railroad Creek, and to prevent failure of the tailings slopes from impacting the creek. Setback of the tailings pile slopes for Alternative 11 provides several incidental benefits, including access for maintenance and monitoring, and restoration of riparian habitat that has been damaged by releases from the tailings. The establishment of vegetation in the riparian zone will further reduce potential flood impacts on the tailings, improve long-term stability, and reduce the need to rely on the riprap.

Such a failure could have a sudden, acute impact on aquatic life within Railroad Creek, if the metal concentrations were high enough. However, an accidental release caused by a short-term failure of a remedy component is generally anticipated to have less effect than the existing ongoing releases.

Based on the analysis described above, Alternative 11 includes sufficiently adequate and reliable controls to provide long-term protection of the environment.

4.2.3.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 11 would contain and treat groundwater from the mine and all other identified source areas that discharge into Railroad Creek above proposed cleanup levels. Water entering the creek downgradient of the existing portal drainage, the abandoned mill, the main East and West Waste Rock Piles, the maintenance yard, and the lagoon area would be collected and treated. Alternative 11 would remove or cap sources of metals in the lagoon and maintenance yard areas, the former mill, and ventilator portal detention area. The Copper Creek Diversion would be hydraulically isolated from tailings and metals-contaminated soils. Alternative 11 would collect and treat water entering the creek from the high concentration seeps in the LWA and tailings pile areas would be collected and treated, along with all the groundwater from below TP-1, TP-2, and TP-3. Finally, monitoring would be performed to determine whether additional groundwater should be collected for treatment downgradient of Honeymoon Heights.

At the Site, risk to the aquatic environment is directly related to the toxicity and quantity of hazardous substances released into Railroad Creek from groundwater (including the mine portal and seeps). Alternative 11 reduces this risk by collection and treatment of all the identified sources of contaminated groundwater that enter Railroad Creek.

Alternative 11 would use active treatment to reduce the toxicity of an estimated average of 600 million gallons per year of contaminated water. Alternative 11 would remove and dewater the sludge from the treatment plant to reduce the potential leaching of constituents of concern. The process would produce an average of approximately 31,000 cy of sludge per year during the first 50 years of operation, and this volume would decrease over time (approximately 50 percent in 50 years) as indicated in Section 4.1.3.2.5.

Alternative 11 would adequately reduce the toxicity and mobility of metals released from all the identified sources on the Site. Alternative 11 includes monitoring to assess whether there is a need to collect the remaining groundwater downgradient of Honeymoon Heights. Alternative 11 does not rely on destruction or recycling any hazardous substance materials.

4.2.3.5 Short-Term Effectiveness

This section discusses how Alternative 11 would address the CERCLA-required evaluation of short-term effectiveness of a proposed remedy, including consideration of risks to the community and workers during implementation; potential environmental impacts and mitigative measures; and the time until protection is achieved.

4.2.3.5.1 Short-Term Risks on the Community during Implementation

Short-term health risks to the community during implementation primarily consist of increased exposure to construction traffic. Potential exposure to construction dust, noise, and vehicle exhaust emissions is not anticipated to present risks to the Holden Village community or other members of the public using the adjacent forest lands.

Short-term risk to the local community due to implementation of Alternative 11 can be adequately mitigated through active measures taken during construction. This would include a traffic control plan for joint use of the Lucerne-Holden Road by construction traffic and the Holden Village community.

4.2.3.5.2 Potential Impacts on Workers during the Remedial Action and the Effectiveness and Reliability of Mitigative Measures during Implementation

Short-term human health risks from remedy implementation at the Site are primarily focused on construction safety and potential longer term risks associated with operation of the treatment facility.

Human health risks to construction workers during remedy implementation include the following: underground mine hazards; construction traffic; exposure to soils with elevated concentrations of TPH and possibly other hazardous substances; exposure to noise and dust; and exposure to demolition activities and debris in the removal of the derelict mill structure. Additional risks would be related to construction activities (e.g., open excavations, heavy equipment operations) associated with regrading, barrier wall construction, ditch excavations, and treatment plant construction.

Construction activities will need to adhere to applicable OSHA, WISHA, and potentially MSHA regulations. Construction workers will be required to have HAZWOPER training. Dust concerns would be managed through BMPs.

4.2.3.5.3 Potential Environmental Impacts of the Remedial Action and the Effectiveness and Reliability of Mitigative Measures during Implementation

Potential environmental impacts of the remedial action include the following:

1. Risk of a tailings release to Railroad or Copper Creeks due to slope failures or stormwater runoff during regrading. An estimated 580,000 cy of tailings would be moved during regrading;
2. Risk of bentonite or cement releases, depending on material selected for use during RD, to the creeks during barrier wall construction;
3. Risks associated with construction of hydraulic barriers in the underground mine;
4. Risk of sediment release to the creeks during construction of groundwater and seep collection components, and use of temporary stream crossings during construction;
5. Construction vehicle emissions, noise, and dust;
6. Risk of fuel spills; and
7. Risk of surface water quality exceedances during and after startup of the treatment plant.

Mitigative measures for potential tailings and sediment releases include construction BMPs such as sediment fencing and barriers, which could be advanced along the edge of the creek as the regrading advances. Alternative 11 includes pulling the tailings back from Railroad Creek, as well as enhancing existing riprap to mitigate potential future flood impacts.

The risk of fuel spills, or bentonite or cement releases would be mitigated through a SPCC Plan implemented for construction, and adherence to regulations regarding storage, transportation, and dispensing of fuel.

In summary, Alternative 11 includes adequate mitigative measures to prevent potential adverse environmental impacts from the risk of a tailings release during regrading, or from potential flooding over the long term.

4.2.3.5.4 Time until Protection is Achieved

Alternative 11 would immediately protect human health and is anticipated to be protective of the environment at the time the remedy is implemented.

4.2.3.5.5 Summary of Short-Term Effectiveness

Based on the analyses presented in Sections 4.2.3.5.1 through 4.2.3.5.4, Alternative 11 is anticipated to be effective over the short term after implementation.

4.2.3.6 Implementability

This section describes the CERCLA evaluation of the implementability of Alternative 11, based on consideration of its technical feasibility, administrative feasibility, and the availability of needed services and materials.

4.2.3.6.1 Technical Feasibility

Alternative 11 is considered to be technically feasible. The remedy could be implemented using conventional construction equipment and techniques.

Feasibility may be limited by seasonal freezing or iron fouling of ditches used for collection and conveyance of groundwater, conveyance piping, pumps, and treatment facility components. Performance of the ditch system used for collection and conveyance, and its susceptibility to freezing or other problems should be further evaluated during RD to determine whether an alternative approach, such as the seep collection system proposed for Alternative 9, would be more effective.

4.2.3.6.2 Administrative Feasibility

Administrative requirements associated with potential ARARs are discussed in Section 4.2.3.2.5.

The land affected by the remedy is under the control of the Forest Service, except for patented mine claims that are owned by Holden Village, Inc. The Agencies anticipate that the remedy will include access and institutional controls on lands owned by Holden Village, Inc.

No wastes are anticipated to be moved off the Site for disposal, with the possible exception of residual processing wastes encountered during cleanup of the abandoned mill building, which may designate as state Dangerous Waste. The potential need for off-site disposal of such wastes does not affect the feasibility of Alternative 11.

4.2.3.6.3 Availability of Services and Materials

The technologies required for each of the components in Alternative 11 are known and proven technologies. The Agencies anticipate that there will be companies willing to do this work and that the contractors bidding for this work will be experienced in the technologies required for the alternative. Despite the Site's remote geographic location, necessary equipment would be able to be moved to the Site for construction of Alternative 11.

4.2.2.6.4 Summary of Implementability

Based on the analyses presented in Sections 4.2.3.6.1 through 4.2.3.6.3, Alternative 11 is implementable.

4.2.3.7 Cost

CERCLA requires that an alternative selected as a cleanup action shall be cost-effective, provided that it first satisfies the threshold criteria. Alternative 11 is anticipated to satisfy the threshold criteria. The estimated cost of Alternative 11 is shown below and discussed in detail in Appendix B. The estimated cost for implementing Alternative 11 includes fully penetrating barrier walls and closure of the tailings and waste rock piles using the presumptive cover for limited purpose landfills. The cost for Alternative 11 could be substantially less than estimated if analyses during RD show that the cutoff wall need not be fully penetrating and/or a less robust cover for the tailings and waste rock piles is protective. The effect of these potential changes, and uncertainty (contingent costs) are addressed in Appendix B of the SFS.

The types of costs estimated for Alternative 11 under CERCLA, as previously discussed for other alternatives, include: capital costs (both direct and indirect) and O&M costs. Total estimated costs are established by calculating the NPV of capital and O&M costs. The table below summarizes these costs based on the Agencies' estimates.

	Alternative 11, as Proposed
Estimated Capital Cost	$65,500,000
Estimated Average Annual Operations, Maintenance, and Monitoring Costs	$1,650,000
Net Present Value of Capital and O&M Costs (50 years @ 7%)	$85,800,000

Alternative 11 would address all areas of the Site where contaminated groundwater has been identified as entering Railroad Creek, and all other areas with constituents of concern above proposed cleanup levels in soil, waste rock, or tailings. This cost estimate shown above is for implementing Alternative 11 as a final remedy based on available information. However, the Agencies expect the cost of implementing Alternative 11 could range from a decrease on the order of $23 million to an increase on the order of $21 million.

- The potential for cost increases is based on EPA guidance (EPA 2000) as discussed in Appendix B. Sources of potential cost increase include changes such as increased volume of earthwork, or increased size of the groundwater treatment facility, etc. that may arise between the time of the Feasibility Study and the time design is completed and the remedy is implemented; as well as uncertainties in bidding climate at the time of construction.

- The potential for cost decreases is based on analysis of specific potential changes in the scope of the cleanup that may be possible based on studies that would be performed during RD. For example, in the event that the additional terrestrial ERA, proposed under Alternative 11, shows that a cover conforming to the presumptive closure requirements for a limited purpose landfill [WAC 173-350-400(3)(e)(ii)] is not needed, and (for example) a simple 1-foot-thick soil cover with revegetation would satisfy the performance requirements for closing the tailings and waste rock piles, the contingent savings for Alternative 11 is estimated to be about $19 million.

Additional construction cost reductions could result from changes in the remedy based on further hydrogeologic analysis of the groundwater barrier. These and other contingencies that may affect the cost of implementing the remedy are discussed in Appendix B.

4.2.3.8 State Acceptance

4.2.3.8.1 State's Position and Key Concerns Related to Alternative 11

The State of Washington has participated with the lead Agency in evaluating remedy alternatives for the Site. Solely for Ecology's purposes under MTCA, the state's evaluation of Alternative 11 is summarized below. The state has determined that Alternative 11 would satisfy requirements for a final remedy.

Threshold Requirements

There are seven requirements to be evaluated for selecting a final remedy under MTCA [WAC 170-340-360]. The first four requirements comprise the threshold requirements, which require that the remedy: 1) protect human health and the environment; 2) comply with cleanup standards; 3) comply with applicable state and federal laws; and 4) provide for compliance monitoring.

Protect Human Health and the Environment. For the same reasons that Alternative 11 provides for "overall protection of human health and the environment" under CERCLA, Alternative 11 satisfies MTCA's requirement that the remedy protect human health and the environment.

Comply with Cleanup Standards. "Cleanup standards" under MTCA refers to the proposed cleanup levels based on potential chemical-specific ARARs; the location(s) where these cleanup levels must be met (points of compliance); and other regulatory requirements that must be met because of the type of action and/or location of the Site (potential action-specific and location-specific ARARs). MTCA requires that for a cleanup action to meet the requirements for a groundwater conditional point of compliance, groundwater discharges need to be provided with AKART before being released to surface waters [WAC 173-340-720(8)(d)(i)]. Alternative 11 does constitute AKART, and thus a conditional point of compliance along the groundwater-surface water interface of Railroad and Copper Creeks could be approved by Ecology for Alternative 11.

The Agencies believe Alternative 11 will satisfy cleanup standards under MTCA. The fully penetrating barrier extending along Railroad Creek will contain all of the identified sources of groundwater above proposed cleanup levels that would otherwise enter Railroad Creek. Groundwater downgradient of the barrier is anticipated to meet proposed cleanup levels at the conditional point of compliance at the interface between the groundwater and Railroad Creek.

Comply with State and Federal Law. As discussed with respect to CERCLA, Alternative 11 is anticipated to comply with federal environmental laws and state environmental and facility siting laws.

Provide for Compliance Monitoring. Alternative 11 would provide for compliance monitoring as discussed in the conceptual monitoring plan developed for it by the Agencies (Hart Crowser 2005d). Final details of monitoring would be established as part of a Sampling and Analysis Plan approved by the Agencies, which would be developed during RD.

MTCA Other Requirements

Other requirements that must be evaluated under MTCA for remedy selection include: 5) use permanent solutions to the maximum extent practicable; 6) provide a reasonable restoration time frame; and 7) consider public concerns.

Use of Permanent Solutions to the Maximum Extent Practicable. Appendix G presents the Agencies' practicability assessment to determine whether Alternative 11 uses permanent solutions to the maximum extent practicable. In summary, Alternative 11 does use permanent solutions to the maximum extent practicable based on the following.

Alternative 11 provides active collection and treatment of groundwater immediately adjacent to the groundwater-surface water interface, for all identified sources that discharge into Railroad Creek. Alternative 11 would immediately reduce the magnitude of seep and groundwater flow with excess metals concentration into Railroad Creek, thus it would immediately reduce toxicity to aquatic life.

Alternative 11 includes regrading and pulling back the toe of the three tailings piles away from Railroad and Copper Creeks. Thus, Alternative 11 provides significant reduction in risk of erosion or large-scale slope failures. Alternative 11 includes closure of the tailings and waste rock piles with a cover that satisfies the presumptive closure requirements for limited purpose landfills [WAC 173-350-400].

Provide for a Reasonable Restoration Time Frame. Alternative 11 provides for a reasonable restoration time frame for the Site. Surface water quality will immediately improve at the point of compliance from containing all the groundwater above proposed cleanup levels. Alternative 11 will also be protective of human health and potential terrestrial ecological receptors immediately following implementation.

Consider Public Concerns. Public concerns will be addressed as part of selecting and implementing the final cleanup action in accordance with WAC 173-340-600(14) and (15).

MTCA Action-Specific Requirements

Finally, MTCA has additional remedy selection requirements that apply specifically to cleanup actions that include groundwater cleanup actions; institutional controls; releases and migration; and dilution and dispersion.

Non-Permanent Groundwater Cleanup Actions. Since a permanent groundwater cleanup is not practicable, Alternative 11 must meet MTCA's requirements for non-permanent cleanup actions [WAC 173-340-360(2)(c)(ii)]. Alternative 11 includes the removal of some sources (e.g., in the former mill, lagoon area, etc.) and the containment of other sources through capping. Alternative 11 also includes groundwater containment to the maximum extent practicable to avoid lateral and vertical expansion of the groundwater affected by the hazardous substances, see Appendix G.

Cleanup of Soils for Residential and School Areas. The DRI indicated that existing soil concentrations in the Village do not exceed human health criteria, thus the MTCA requirement [WAC 173-340-360(2)(d)] for soil cleanup would not require action within the Village. Institutional controls, and engineering measures (e.g., capping of tailings) on the remainder of the Site will need to be implemented to protect residential areas, schools, or childcare centers.

Institutional Controls. Alternative 11 satisfies requirements for institutional controls to protect human health that are specified in WAC 173-340-440.

Releases and Migration/Dilution and Dispersion. Alternative 11 would prevent or minimize existing and future releases and migration of hazardous substances through the use of a permanent groundwater containment barrier, permanent closure to protect the tailings and waste rock piles from erosion and slope failures, and removal or capping of areas with hazardous substances above proposed cleanup levels. Alternative 11 does not rely primarily on dilution and dispersion to cleanup groundwater and surface water above proposed cleanup levels. Rather, Alternative 11 uses active remedial measures to the maximum extent practicable to contain, collect, and treat groundwater and surface seeps above proposed cleanup levels, see Appendix G.

Remediation Levels. Remediation levels are not proposed for Alternative 11.

4.2.3.8.2 State Comments on Potential ARARs or the Proposed Use of ARAR Waivers

The state has not separately provided any comments on potential ARARs for the Holden cleanup, but has participated in joint preparation of documents with the Forest Service and EPA, including the preparation of potential ARARs section of this document.

4.2.3.9 Community Acceptance

MTCA, similar to CERCLA, provides that final remedy selection will consider public comment on the remedial alternatives.

Community acceptance of alternatives will be evaluated after the public comment period ends, and will be described in the ROD for the Site.

4.2.4 Alternative 12

This section describes the Agencies' evaluation of Alternative 12 using each of the CERCLA remedy selection criteria.

4.2.4.1 Overall Protection of Human Health and the Environment

A no action alternative would not protect human health. This alternative would not include institutional controls, source control measures, or access restrictions at the Site. Humans could be exposed to elevated metals concentrations in groundwater if a drinking water well was installed. If soils or tailings with elevated metals were left in place, humans could be exposed to elevated constituents of concern by direct contact (e.g., through recreation, digging, or working in areas with hazardous substances).

A no action alternative would not protect the environment. The mine portal discharge would continue to discharge metals above proposed cleanup levels into Railroad Creek. Groundwater above cleanup levels would continue to flow into Railroad Creek, and surface water concentrations would continue to exceed aquatic life protection criteria. The tailings piles would continue to be at risk of erosion or the collapse and massive release of reactive tailings into Railroad Creek, that could result from seismic shaking or undermining by scour.

If no action were taken terrestrial receptors would continue to be at risk in areas such as the lagoon tailings piles, the wetland east of TP-3, etc.

Alternative 12 is not protective of human health or the environment.

4.2.4.2 Compliance with Potential Applicable or Relevant and Appropriate Requirements (ARARs)

4.2.4.2.1 Potential Chemical-Specific Requirements for Surface Water

Alternative 12 would not comply with potential chemical-specific ARARs for surface water. Analysis of natural attenuation and source depletion, based on extrapolation of the DFFS Model input parameters for Alternative 2a, indicates the no action alternative would leave metals concentrations in Railroad Creek that exceed proposed cleanup levels for hundreds of years downstream of the

Site.[71] Concentrations at the anticipated point of compliance for groundwater would exceed aquatic life criteria for much longer.

4.2.4.2.2 Potential Chemical-Specific Requirements for Groundwater

Alternative 12 would not comply with potential chemical-specific ARARs for groundwater. Alternative 12 does not provide institutional controls to prevent future groundwater consumption at the Site, and does not contain groundwater released from the Site that exceeds proposed surface water cleanup levels to protect terrestrial and aquatic receptors as required "at all points of potential exposure" [53 FR 51440].

4.2.4.2.3 Potential Chemical-Specific Requirements for Soil

Alternative 12 would not comply with potential chemical-specific ARARs for soil. Contaminated soils at the mill building, ventilator portal detention area, the lagoon, and the maintenance yard area, along with exposed tailings and waste rock piles, would remain under the no action alternative resulting in continued risks to terrestrial receptors.

4.2.4.2.4 Potential Chemical-Specific Requirements for Sediment

Since the no action alternative would not include any changes to the sources of metals released to the creek, the no action alternative would not do anything to address sediment. Constituents of concern concentrations in the sediment would remain elevated.

4.2.4.2.5 Potential Action- and Location-Specific Requirements

Alternative 12 would not comply with potential action-specific ARARs for the Site that require a cleanup action, as discussed below.

Washington Model Toxics Control Act [RCW 70.105D; Chapter 173-340 WAC]. Alternative 12 would not satisfy this potential ARAR since it would result in hazardous substances being left on the Site at concentrations above proposed cleanup levels.

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[71] The DFFS did not include a metals loading analysis for a no action alternative. The Agencies created one by modifying the model presented for Alternative 2a, which is the DFFS Model alternative nearest to a no action alternative. The only reduction in metals load for the no action alternative is due to the predicted source depletion over time based on the geochemical modeling described in the DFFS Appendix E. To model the effect of no action over time, Intalco's model for Alternative 2a was modified to remove the load reduction factors except for source depletion.

Washington State Solid Waste Handling Standards [RCW 70.95; Chapter 173-350 WAC]. Alternative 12 would not include closure of the tailings and waste rock piles as required for limited purpose landfills under this potential ARAR.

Federal Water Pollution Control Act - Section 402 National Pollution Discharge Elimination System (NPDES) [33 USC § 1342]. Alternative 12 would not comply with this potential ARAR because of the continued uncontrolled discharge of contaminated water from the Main Portal into Railroad Creek.

Water Quality Standards for Surface Waters of the State of Washington - Short-Term Modifications [RCW 90.48; Chapter 173-201A-410 WAC]. If no action were taken, groundwater quality at the Site would not comply with requirements of this potential ARAR.

Aquatic Lands Management - Washington State [RCW 79.90; Chapter 332-30 WAC]. Alternative 12 would not be protective of aquatic resources.

4.2.4.2.6 Compliance with Potential ARARs

In summary, Alternative 12 would not comply with potential ARARs.

4.2.4.3 Long-Term Effectiveness and Permanence

4.2.4.3.1 Magnitude of Residual Risk Remaining at the Conclusion of the Remedial Activities

Alternative 12 would rely entirely on source depletion and natural attenuation. However, source depletion is not an acceptable part of a remedy, and Alternative 12 would not satisfy all the requirements for a remedy to rely on natural attenuation. This alternative would not provide source control to the maximum extent practicable.

Risks to human health and the environment from exposure to groundwater and soils above proposed cleanup levels would remain under Alternative 12, since institutional controls would not be implemented and constructed caps would not be installed.

Residual risk to aquatic and terrestrial life would remain following implementation of Alternative 12. Continued releases from the Site would result in exceedances in metals concentrations in surface water in Railroad Creek.

Following implementation of Alternative 12, risk to aquatic life from tailings pile erosion and slope failures that could cause a release into Railroad Creek would remain.

4.2.4.3.2 Adequacy and Reliability of Controls

There are no controls under Alternative 12; therefore, the adequacy and reliability of controls cannot be evaluated.

4.2.4.4 Reduction of Toxicity, Mobility, or Volume through Treatment

There would be no reduction of toxicity, mobility, or volume through treatment under Alternative 12.

4.2.4.5 Short-Term Effectiveness

The no action alternative would rely on source depletion and natural attenuation to achieve protection of aquatic life, and surface water concentrations would not achieve potential ARARs for hundreds of years.

Alternative 12 includes no response action; therefore, it would not be effective over the short term based on the following criteria.

4.2.4.5.1 Short-Term Risks on the Community during Implementation

Short-term health risks to the community during implementation primarily consist of increased exposure to construction traffic. There would be no construction traffic risk for the no action alternative. Existing health risks from potential consumption of groundwater or direct contact with soils above proposed cleanup levels would continue under Alternative 12.

4.2.4.5.2 Potential Impacts on Workers during the Remedial Action and the Effectiveness and Reliability of Mitigative Measures during Implementation

There would be no construction risk for the no action alternative.

4.2.4.5.3 Potential Environmental Impacts of the Remedial Action and the Effectiveness and Reliability of Mitigative Measures during Implementation

There would be no new impacts to the environment resulting from implementation of the no action alternative, and the current effects of the uncontrolled release of hazardous substances would continue.

4.2.4.5.4 Time until Protection is Achieved

The no action alternative relies on source depletion and natural attenuation to achieve protection of aquatic life. Surface water concentrations would not achieve potential ARARs for hundreds of years. Groundwater and soil constituents of concern concentrations would likely remain above protective levels for much longer.

4.2.4.6 Implementability

Because Alternative 12 includes no actions, it is not evaluated for implementability.

4.2.4.7 Cost

There would be no capital or annual operations, maintenance, and monitoring costs for Alternative 12.

4.2.4.8 State Acceptance

4.2.4.8.1 State's Position and Key Concerns Related to Alternative 12

The State of Washington has participated with the lead Agency in evaluating remedy alternatives for the Site. Evaluation of a no action alternative such as Alternative 12 is not an explicit requirement under state regulations.

4.2.4.8.2 State Comments on Potential ARARs or the Proposed Use of ARAR Waivers

The state has not separately provided any comments on potential ARARs for the Holden cleanup action, but has participated in joint preparation of documents with the Forest Service and EPA, including the preparation of potential ARARs of this document. No action is not an acceptable alternative to the state.

4.2.4.9 Community Acceptance

Community acceptance of alternatives will be evaluated after the public comment period ends, and will be described in the ROD for the Site.

4.3 Comparative Analysis of Alternatives 9 through 12

This section provides a direct comparison of Alternatives 9, 10, 11, and 12 for each of the nine CERCLA criteria used to select a remedy. While the comparative analysis of each alternative must consider all nine criteria, no alternative can be selected unless it meets the two "threshold criteria" as specified in 40 CFR § 300.430(f)(1)(i)(A).

4.3.1 Threshold Criteria

This section provides a comparative evaluation of how Alternatives 9 through 12 do or do not meet the threshold criteria under CERCLA.

4.3.1.1 Overall Protection of Human Health and the Environment

The overall protection of human health and the environment criterion addresses the degree to which each alternative can adequately protect human health and the environment, considering both the short-term and long-term risks from the Site. This criterion draws on assessments of other CERCLA evaluation criteria, including long-term effectiveness and permanence, short-term effectiveness, and compliance with potential ARARs.

4.3.1.1.1 Overall Protection of Human Health

Although Site groundwater near the sources of release is not currently used as drinking water, both state and federal regulations require cleanup to drinking water standards if the groundwater would be a potential drinking water source absent the effects of Site contamination.

None of the four alternatives will eliminate groundwater exceedances at the Site. Groundwater institutional controls are a common element of Alternatives 9, 10, and 11, but institutional controls are not included in the no action alternative (Alternative 12).

Concentrations of some metals in soils exceed MTCA human health criteria, which are listed as potential ARARs for the Site. Alternatives 9, 10, and 11 rely to varying degrees on removal or capping as well as institutional controls, to protect human health from exposure to constituents of concern within soil and tailings.

- Alternative 9 includes consolidation or capping contaminated soils in the mill building, maintenance yard, lagoon area, and the ventilator portal detention area to meet the proposed soil cleanup levels. Alternative 9 includes a soil cover over areas of TP-1 and TP-2 (only) where tailings would be exposed during regrading, but does not include any cap over existing areas of exposed tailings. Alternative 9 does not include any terrestrial ERA to determine the need for clean up in other areas that may be contaminated, such as Holden Village, the wind-blown tailings area, etc.

- Alternative 10 includes consolidation or capping contaminated soils in the mill building, maintenance yard, lagoon area, and the ventilator portal detention area to meet the proposed soil cleanup levels. Alternative 10 includes a soil cover over the three tailings piles and the main East and West Waste Rock Piles. In addition, Alternative 10 includes an analysis during RD to determine whether the proposed cover is protective. Alternative 10 does not include any cap over the Honeymoon Heights Waste Rock Piles. Alternative 10 includes a terrestrial ERA to determine the need for clean up in other areas that may be contaminated, such as Holden Village, the wind-blown tailings area, etc.

- Alternative 11 includes consolidation or capping contaminated soils in the mill building, maintenance yard, lagoon area, and the ventilator portal detention area to meet the proposed soil cleanup levels. Alternative 11 includes a permanent cap over all of the tailings and waste rock piles (including consolidation of the Honeymoon Heights Waste Rock Piles). Alternative 11 includes a terrestrial ERA to determine the need for clean up in other areas that may be contaminated, such as Holden Village, the wind-blown tailings area, etc.

Based on the differences described above, the alternatives are not equally protective of human health.

Alternative 12 would not be protective of human health since this alternative would not include institutional controls or source control measures to prevent exposure to groundwater and soils above proposed cleanup levels. Alternative 11 is the only alternative that is completely protective of human health.

4.3.1.1.2 Overall Protection of the Environment

Alternatives 9 through 12 are quite different in the degree to which they protect the environment, as described below.

Aquatic Life. Lower metals concentrations within Railroad Creek will reduce toxicity effects to aquatic life, and increase the frequency and diversity of species. Alternatives 9 through 11 would each produce some reduction in risk to aquatic life within Railroad Creek through the reduction in metals concentrations within the creek by decreasing the amount of metals entering the creek in groundwater as well as in seeps and discharge from the mine. Alternative 12 would not produce any reduction in risk to aquatic life.

The DFFS estimated hazardous substance concentrations that Alternatives 2 through 8 would produce for fully mixed conditions in Railroad Creek. Intalco used the same approach to evaluate Alternatives 9 (URS 2005b). However, the DFFS Model is not appropriate for comparing the effectiveness of the alternatives, in part because protectiveness needs to be evaluated at the point of compliance; i.e., where groundwater discharges into the creek. (Appendix A provides additional detail on the shortcomings of the DFFS model as a tool for remedy selection.). Dilution decreases concentrations downstream from the points where groundwater discharges into surface water. MTCA does not allow a mixing zone for groundwater discharges above cleanup levels into surface water [WAC 173-340-720(8)(d)(i)(C)]. Thus, the remedy needs to address all points where contaminated groundwater discharges into Railroad Creek. An alternative that addresses a greater proportion of the stream length where releases occur will be more protective of the aquatic environment than an alternative that addresses a lesser proportion of the stream.

The table below summarizes the relative lengths along Railroad Creek where each alternative would contain and collect groundwater above proposed cleanup levels before it discharges into Railroad Creek.

Alternative	Approximate Length of Creek Where Releases Occur, That Would Have Active Groundwater Collection, in Feet
9	<1,000
10	4,500
11	6,400

Figure 19 shows the relative extent of groundwater that would be collected along the edge of Railroad Creek for Alternatives 9, 10, and 11.[72] The alternatives collect groundwater above proposed cleanup levels along differing lengths of the creek. All of the groundwater that is collected for treatment by these alternatives is above proposed cleanup levels (based on protection of aquatic life), as shown on Figures 6 through 9. This is true although Alternative 10 would also collect a small volume of clean water from the creek during high flow events, as discussed in Attachment B of Appendix F of the SFS.

Only Alternative 11 includes collection of all the identified groundwater sources above proposed cleanup levels along the creek. Figures 6 through 9 show that

[72] Alternative 8 is also depicted on Figure 18, to provide a basis for comparison with Alternatives 9, 10, and 11, as discussed in the SFS appendices.

all the groundwater sources contained and collected by Alternative 11 are above proposed cleanup levels. Alternative 11 does not include collection of any groundwater that does not exceed proposed cleanup levels. Areas where active groundwater collection would be accomplished would have reduced concentrations of hazardous substances immediately following implementation of the remedy. Areas without active collection would have metals concentrations that slowly decline from existing concentrations over long periods as source depletion and natural attenuation occur.

Another way to evaluate each alternative's protectiveness of the aquatic environment is to compare the mass of metals removed from groundwater, where that groundwater would otherwise discharge directly into Railroad Creek. The alternatives differ in the mass of metals that would be removed from the environment due to differences in location and volume of groundwater collection.

For Alternatives 9, 10, and 11, the primary way metals are kept from reaching Railroad Creek is through the collection and treatment of contaminated groundwater that would otherwise be discharged into Railroad Creek. The extent to which this is conducted varies among the alternatives, as shown on Figure 19 and summarized below.

Alternative	Estimated Annual Volume of Contaminated Groundwater Collected and Treated, in Millions of Gallons
9	324
10	483
11	600

As shown on Figures 8, 9, and 18, all the groundwater that would be contained and collected by Alternative 11, is above proposed cleanup levels. The difference in the volume of water collected and treated by Alternative 11 compared to Alternatives 9 and 10 is the quantity of water above proposed cleanup levels that would otherwise discharge into Railroad Creek. Alternative 11 collects substantially more contaminated groundwater that would otherwise enter the creek, compared to Alternatives 9 and 10, as shown in the table above.

Alternative 9 would do the least to reduce the release of groundwater above cleanup levels into Railroad Creek, since it only acts on part of the Site.

Alternative 10 would contain and collect for treatment all the seeps and most, but not all of the groundwater baseflow that discharges into Railroad Creek with metals concentrations above proposed cleanup levels. Alternative 10 would rely on monitoring to determine whether the remedy is protective. However, the PPB used for containment may not be sufficiently effective.

Alternative 11 includes construction of a fully penetrating groundwater barrier and collection system to contain and collect for treatment all of the identified contaminated groundwater that discharges into Railroad Creek. Alternative 10 would directly intercept and remove more metals in discharges to Railroad Creek than Alternatives 9. Alternative 11 would directly intercept and remove more metals in discharges to Railroad Creek than Alternatives 9 or 10, and provides greater certainty of protecting Railroad Creek than do Alternatives 9 or 10.

Fully penetrating groundwater barrier walls are a proven technology that have been successfully implemented as part of containment and collection systems at numerous sites. Appendix C provides information on the effectiveness of barrier walls used for groundwater containment, waste isolation, and to aid in collection of groundwater for treatment based on experience at other cleanup sites. The fully penetrating barrier wall, coupled with collection of groundwater, is the best available technology to reduce seepage of contaminated water into the creek.

Alternative 11 is expected to eliminate the discharge of groundwater above cleanup levels into the wetland east of TP-3. Alternative 10 would reduce, but may not eliminate this discharge. Alternatives 9 and 12 would not reduce the discharge into the wetland east of TP-3.

Alternatives 10 and 11 would provide greater assurance of reducing discharges from below TP-2 and TP-3 compared to Alternative 9:

- Alternatives 10 and 11 would directly intercept and collect groundwater where Alternative 9 relies more on upgradient controls (run-on diversions); and
- Alternative 9 relies on the assumed benefit of an UWA barrier that would reduce the down-valley component of seepage.

Alternative 12 is not predicted to meet the proposed cleanup levels within Railroad Creek downstream of the Site for hundreds of years.

Alternatives 10 and 11 include the removal of ferricrete from Railroad Creek and include provisions for future sediment monitoring following elimination of the sources of metals releases, the removal of ferricrete, and the natural redistribution of sediments in the creek system to determine whether further sediment cleanup is required to protect aquatic organisms. These actions are not included in either Alternatives 9 or 12.

Terrestrial Life. Implementation of Alternatives 9, 10, and 11 would reduce terrestrial life toxicity risks by the removal, containment, or capping of soils with constituents of concern within the mill building, ventilator portal detention area, lagoon, and the maintenance yard area. These toxicity risks would remain with Alternative 12.

Alternative 9 would leave the waste rock piles in their existing condition. Alternative 10 would regrade the main East and West Waste Rock Piles, and close these piles with a 1-foot-thick soil cover, and includes an analysis to determine whether the proposed cover would be protective and satisfy state requirements. Alternative 11 would close the main East and West Waste Rock Piles with a cover that is protective, and complies with state requirements. Further, Alternative 11 would consolidate the Honeymoon Heights Waste Rock Piles for closure as part of the main waste rock piles.

Alternative 9 includes limited regrading to improve stability of parts of the tailings piles, but would not provide any new cover except in the regraded area. Alternatives 10 and 11 include regrading the three tailings piles to improve stability, improve runoff, and reduce risk of flood or scour-related slope failures by moving the toe of slopes back away from Railroad and Copper Creeks. Alternative 11 includes covers that meet performance criteria for limited purpose landfills.[73]

Alternatives 10 and 11 include additional terrestrial ERA of soils with metals concentrations that exceed screening levels, to be done during RD, to determine the need for action in areas such as the wind-blown tailings area. This terrestrial ERA (which is not part of Alternatives 9 or 12) makes Alternatives 10 and 11 more protective than Alternatives 9 and 12.

4.3.1.1.3 Summary – Protection of Human Health and the Environment

In summary, Alternatives 9, 10, and 11 are not equally protective of human health. Only Alternative 11 can be determined to completely protect human

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[73] As previously noted, the 1-foot-thick soil cover proposed for Alternative 10 may need to be made more robust based on an evaluation during RD. Similarly, the proposed Alternative 11 cover, that meets the default criteria in Chapter 173-350 WAC, could be modified if it is shown that a less robust cover meets the performance criteria.

health based on available information. For aquatic life protection, Alternative 11 is the most protective alternative since it reduces the amount of groundwater with metals concentrations above proposed cleanup levels that enters Railroad Creek, more effectively than Alternatives 9 and 10. For the same reason, Alternative 10 is more protective of aquatic life than Alternative 9. Alternatives 10 and 11 are more protective of terrestrial receptors than Alternative 9. Alternative 11 is more protective of terrestrial receptors than Alternative 10, because Alternative 10 does not include closure of the Honeymoon Heights Waste Rock Piles, and because the proposed Alternative 10 cover for the tailings and main East and West Waste Rock Piles may not be protective. Alternative 12 is not protective of human health or the environment. Overall, Alternative 11 is the alternative most protective of human health and the environment.

4.3.1.2 Compliance with Potential ARARs

The other threshold criterion under CERCLA is compliance with potential ARARs [40 CFR § 300.430(e)(9)(iii)(B)]. The alternatives are assessed to determine potential ARARs attainment under federal environmental laws and state environmental or facility siting laws, or whether there are grounds for invoking one of the waivers listed in 40 CFR § 300.430(f)(1)(ii)(C). The DFFS identified no basis for potential ARARs to be waived for the Holden Site.

The ability of Alternatives 9 through 12 to meet potential chemical-specific ARARs, at the points of compliance, for surface water, groundwater, and soil, and to meet potential action-specific and location-specific ARARs, is compared below.

4.3.1.2.1 Potential Chemical-Specific Requirements for Surface Water

Alternative 11 would reduce metals concentrations in Railroad Creek faster than Alternatives 9, 10, and 12, because it includes collection of all identified sources of groundwater above proposed cleanup levels directly adjacent to Railroad Creek, rather than relying on upgradient source controls or natural attenuation. Removal or capping upgradient sources would reduce future groundwater and surface water contamination, but without containment these measures would not prevent the release of already contaminated groundwater into Railroad Creek.. Alternative 10 would likely achieve potential chemical-specific ARARs in Railroad Creek faster that Alternative 9, because it relies less on source depletion and natural attenuation. Alternative 12, the no action alternative, would allow continued releases from the Site so that metals concentrations in surface water downstream of the Site in Railroad Creek will exceed proposed cleanup levels for hundreds of years.

4.3.1.2.2 Potential Chemical-Specific Requirements for Groundwater

Potential ARARs for groundwater cleanup are based on federal and state MCLs, state MTCA cleanup levels for drinking water across the entire Site, and the protection of aquatic life where groundwater discharges into surface water. Groundwater in some parts of the Site is not likely to achieve drinking water standards for any alternative, which is why Alternatives 9 through 11 rely on institutional controls to protect human health.

For groundwater that discharges into surface water, Alternative 11 is likely to achieve potential ARARs sooner than Alternatives 9, 10, or 12, because it provides more containment and collection for treatment. Alternative 11 includes a cap on the tailings and waste rock piles and would do more to reduce infiltration and related discharge of groundwater below the tailings piles, than would Alternative 9 or 10. Alternative 10 is more likely to meet potential ARARs than Alternative 9, but there is more uncertainty regarding Alternative 10 compared to Alternative 11, because of the PPB wall.

Alternative 9 would collect and treat groundwater above proposed cleanup levels only from a portion of the Site. Alternative 9 relies on source depletion and natural attenuation to clean up groundwater from the LWA, TP-2, TP-3, and part of TP-1, before groundwater discharges into Railroad Creek. Thus, Alternative 9 will not meet proposed cleanup levels at all potential points of exposure.

The no action alternative (Alternative 12) does not include any mitigation of groundwater contamination, other than to rely on source depletion within the mine and below and within the tailings and waste rock piles, and natural attenuation downgradient of these source areas. The geochemical analysis provided in the DFFS suggests that groundwater concentrations would exceed aquatic life protection criteria for hundreds of years.

4.3.1.2.3 Potential Chemical-Specific Requirements for Soils

For many of the metals of concern in Site soils, the proposed cleanup levels are based on site-specific natural background concentrations because background values exceed the lowest proposed potential ARARs (Refer to Table 1). For TPH, and those metals where the lowest proposed potential ARAR exceeded the site-specific natural background concentration, the proposed soil cleanup levels are based on the ecological screening criteria in MTCA, or the MTCA Method A or Method B soil cleanup standards.

Alternatives 9, 10, and 11 include consolidation and capping of contaminated soils from in the mill building, maintenance yard, lagoon, and ventilator portal detention area to meet the proposed cleanup levels. Leaving these soils in place under the no action alternative will result in continued toxicity risks to terrestrial organisms.

Additional cleanup may be required in the other areas (e.g., the LWA, the baseball field, areas within Holden Village, and the area of observed wind-blown tailings deposition east of the Village) that are less impacted but still have metal concentrations above the proposed soil cleanup levels. Alternatives 10 and 11 include additional evaluation of risks associated for these other areas with metals in soils above proposed cleanup levels, to determine whether additional soil cleanup is needed. Alternative 9 does not include any cleanup in these areas, nor does this alternative include any additional risk evaluation. Thus, Alternative 9 would not satisfy proposed soil cleanup levels in all areas of the Site. Alternative 12, the no action alternative, does not include any further risk evaluation or remediation of soils with concentrations of hazardous substances above proposed cleanup levels. Thus, it will not satisfy proposed soil cleanup levels.

4.3.1.2.4 Potential Chemical-Specific Requirements for Sediment

At present, proposed cleanup levels for sediments are based on TBC criteria, rather than promulgated requirements. Alternatives 10 and 11 include removal of ferricrete deposits in Railroad Creek. The removal of ferricrete is not mentioned in Intalco's description of Alternative 9, nor is it part of Alternative 12.

Alternatives 10 and 11 include monitoring to determine whether additional remediation is needed following removal of the ferricrete and containment or elimination of the sources of metals released into Railroad Creek. As proposed by Intalco, Alternative 9 allows releases that contribute to sediment risks to continue. Intalco did not propose sediment monitoring as part of Alternative 9, although monitoring, as part of the 5-year review, is a CERCLA requirement where wastes are left on a site (EPA 1995).

4.3.1.2.5 Potential Action- and Location-Specific Requirements

In addition to the potential chemical-specific ARARs discussed above, by media, potential action- and location-specific ARARs are also considered in CERCLA remedy selection. A description of potential action- and location-specific ARARs for the Site is presented in Sections 2.3.3.2 and 2.3.3.3, respectively.

For a number of potential action- and location-specific ARARs, there are no apparent significant differences between Alternatives 9, 10, and 11. The Agencies anticipate that Alternatives 9, 10, and 11 can comply with the substantive provisions of the potential ARARs listed in Table 13. Many of these potential ARARs are not applicable to Alternative 12, the no action alternative.

Alternatives 9, 10, and 11 vary in their ability to meet certain other potential action- and location-specific ARARs, as described below.

Washington Model Toxics Control Act [RCW 70.105D; Chapter 173-340 WAC]. In addition to MTCA providing an independent basis for requiring cleanup of the Site under state law, specific MTCA provisions are potential ARARs under CERCLA.

- Alternative 9 would not satisfy MTCA requirements for selection of a permanent remedy and would not achieve MTCA-required cleanup levels. Thus Alternative 9 would not satisfy specific MTCA provisions that are potential ARARs under CERCLA.

- The Agencies anticipate that Alternative 10 may satisfy MTCA requirements for selection of a permanent remedy, but that its ability to achieve MTCA-required cleanup levels would need to be further evaluated based on design-level studies and verified by monitoring after implementation.

- Alternative 11 would satisfy MTCA requirements for selection of a permanent remedy, and the Agencies anticipate that it would achieve MTCA-required cleanup levels within a reasonable restoration time frame.

- Alternative 12 would not satisfy MTCA requirements for selection of a permanent remedy and would not achieve MTCA-required cleanup levels. Thus Alternative 12 would not satisfy specific MTCA provisions that are potential ARARs under CERCLA.

Washington State Solid Waste Handling Standards [RCW 70.95; Chapter 173-350 WAC]. This potential ARAR applies to closure of the tailings and waste rock piles that are limited purpose landfills.

- Alternative 9 would not meet the presumptive cover requirements for limited purpose landfills that are potentially relevant and appropriate for the tailings and waste rock piles. Alternative 9 also does not include any additional analyses to determine whether a less robust cover as proposed for the tailings regrading area, or existing conditions, are protective of terrestrial receptors. Alternative 9 would not include sufficient regrading of the tailings piles and waste rock piles to provide the required assurance of slope stability. Thus, Alternative 9 would not comply with this potential ARAR.

- Alternative 10 would not meet the presumptive cover requirements for limited purpose landfills that are potentially relevant and appropriate for the tailings and waste rock piles. Alternative 10 does not include closure of the Honeymoon Heights Waste Rock Piles.

- Alternative 11 meets the performance requirements for cover requirements for limited purpose landfills that are potentially relevant and appropriate for the tailings and waste rock piles. Alternative 11 includes closure of the Honeymoon Heights Waste Rock Piles. Alternative 11 would comply with this potential ARAR.

- Alternative 12 would not meet the presumptive cover requirements for limited purpose landfills that are potentially relevant and appropriate for the tailings and waste rock piles. Alternative 12 would not comply with this potential ARAR.

Federal Water Pollution Control Act - Section 402 National Pollution Discharge Elimination System (NPDES) [33 USC § 1342] and Water Quality Standards for Surface Waters of the State – Short Term Modifications [RCW 90.48 and WAC 173-201A-410]. Authority for implementing the federal regulation has been granted to the State.

- Alternative 9 would not comply with regulations applicable to non-point sources of stormwater runoff greater than 1 acre in area. The limited regrading of tailings for Alternative 9 does not provide any means to collect, detain, or treat potentially contaminated stormwater discharge at the base of the tailings piles adjacent to Railroad Creek. Thus Alternative 9 would not comply with this potential ARAR.

- Alternatives 10 and 11 include regrading to pull the toe of the tailings piles back from Railroad and Copper Creeks. The Agencies anticipate that engineering controls (BMPs) can be implemented during regrading to satisfy this potential ARAR.

- This potential ARAR is probably not applicable or relevant and appropriate to Alternative 12.

Aquatic Lands Management - Washington State [RCW 79.90; Chapter 332-30 WAC]. This potential ARAR requires that aquatic lands be managed to protect resources and, therefore, is potentially relevant and appropriate.

- Alternative 9 does not eliminate the ongoing metals releases from TP-2 and TP-3, and does not entirely address releases from the LWA and TP-1. Groundwater that enters Railroad Creek is toxic to aquatic organisms and reduce aquatic habitat through the mechanism of chemical processes that result from the release of hazardous substances. For this reason, Alternative 9 would not comply with this potential ARAR.

- Alternative 10 does not eliminate the ongoing metals releases from TP-2, although it does include provision for future monitoring as part of implementation to determine whether Alternative 10 would comply with this potential ARAR.

- Alternative 11 would comply with this potential ARAR.

- Alternative 12 does not eliminate the ongoing metals releases from the tailings piles, mine portal, or LWA seeps and groundwater. Alternative 12 would not comply with this potential ARAR.

Land and Resource Management Plan for Wenatchee National Forest (LRMP, Forest Service 1990) as Amended by Pacific Northwest Forest Plan (NWFP, 1994) and subsequent amendments of the NWFP (2001, 2004, and 2007). Potential ARARs based on the LRMP and NWFP include standards and guidelines that affect cleanup actions within riparian zones, and specifically relate to closure and reclamation of the tailings and waste rock piles to ensure mass stability and prevent the release of acid or toxic materials.

- Alternative 9 would not comply with this potential ARAR as it does not ensure stability and does not prevent the release of acid or toxic materials from the tailings and waste rock piles.

- Alternative 10 would satisfy this potential ARAR to a greater degree than would Alternative 9, but Alternative 10 does not prevent the release of acid or toxic materials from TP-2.

- Alternative 11 would comply with this potential ARAR.

- Alternative 12 does not eliminate the ongoing metals releases from the tailings or waste rock piles, and would not satisfy other ACS requirements. Alternative 12 would not comply with this potential ARAR.

4.3.1.2.6 Summary – Compliance with Cleanup Standards

In summary, Alternative 11 is the only alternative expected to comply with all of the potential ARARs immediately following implementation. Alternative 10 may comply with all the potential ARARs, but this cannot be shown on the basis of available information. Alternative 9 and Alternative 12 would not comply with potential ARARs.

4.3.1.3 Threshold Criteria Summary

Alternative 9 does not meet the threshold criteria for selection of a remedy under CERCLA, because it does not take any remedial actions needed to protect the environment by stopping the releases of contaminated groundwater into Railroad Creek from TP-2 and TP-3, part of TP-1, and because it relies on natural attenuation in the LWA. Alternative 9 would not satisfy all potential ARARs.

Alternative 10 cannot at this point be shown to completely satisfy the threshold criteria for protection of the environment, as there is some uncertainty regarding the effectiveness of a PPB wall and other aspects of this alternative. Alternative 10 would likely comply with potential ARARs but this would have to be shown in part of additional studies and performance monitoring.

Alternative 11 would protect human health and the environment, and is anticipated to comply with all potential ARARs.

Alternative 12 does not meet the threshold requirements; nor is it likely to meet potential ARARs.

4.3.2 Primary Balancing Criteria

There are five primary balancing criteria under CERCLA [40 CFR § 300.430(f)(1)(i)(B)], which include:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost.

Under CERCLA, only alternatives that meet the CERCLA threshold criteria for selecting a final remedy are carried forward and analyzed using the primary balancing criteria. This ensures that the selected remedy will be protective of human health and the environment and ARAR-compliant, and the other selection criteria are considered to select the best alternative that achieves the threshold criteria.

According to the NCP, the selected alternative must provide the best balance of tradeoffs among alternatives (that satisfy the threshold criteria) in terms of the five primary balancing criteria [40 CFR § 300.430(f)(1)(ii)(D) and (E)]. The selected alternative shall use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable [40 CFR § 300.430(f)(1)(ii)(E)].

With the exception of Alternative 11, none of the other three alternatives discussed above would meet the threshold criteria. Alternative 11 was developed from consideration of other alternatives that individually did not satisfy the threshold criteria. For Alternatives 9, 10, and 12, there is no need to consider the remaining CERCLA criteria; however, the Agencies completed an evaluation of the primary balancing criteria to better compare and understand these three alternatives, and for completeness, that comparative evaluation is presented below.

4.3.2.1 Long-Term Effectiveness and Permanence

For the first of the primary balancing criteria for selection of a cleanup action under CERCLA, alternatives shall be assessed for their long-term effectiveness and permanence, along with the degree of certainty that the alternative will be successful [40 CFR § 300.430(e)(9)(iii)(C)]. The two factors that shall be considered for long-term effectiveness and permanence include:

- Magnitude of residual risk remaining from the untreated waste or treatment residuals remaining at the conclusion of the remedial activities. The characteristics of the residuals should be considered to the degree they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate.

- Adequacy and reliability of controls such as containment systems and institutional controls that are necessary to manage treatment residuals and untreated waste.

4.3.2.1.1 Magnitude of Residual Risk Remaining at the Conclusion of the Remedial Activities

Alternatives 9, 10, 11, and 12 differ significantly in the degree to which residual risk would remain at the conclusion of implementing the cleanup.

Residual Risk to Human Health. Alternatives 9 and 12 would leave more residual risk to human health associated with the tailings piles, compared to Alternatives 10 and 11. The Forest Service placed an interim soil/gravel cover over most of the tailings piles surfaces in 1989-91 to reduce potential erosion, but this cover was incomplete in some areas and has subsequently been removed by erosion in other areas. The mine tailings exceed human health direct contact and ingestion exposure levels for cadmium and copper. Alternatives 10 and 11 would eliminate this risk by capping exposed areas of the tailings, but Alternatives 9 and 12 would not.

Alternatives 9, 10, and 11 are similar in preventing residual risk to human health through use of institutional controls to prevent drinking groundwater, and removal or capping contaminated soils in areas such as the lagoon and maintenance yard. However, Alternative 12 would not address these sources of risk to humans.

Residual Risk to Aquatic Receptors. Risk to the aquatic environment is directly related to the toxicity and quantity of hazardous substances being released to the aquatic environment. At the Holden Mine Site, the primary environmental toxicity risk is elevated concentrations of aluminum, cadmium, copper, iron, lead, and zinc in Railroad Creek and in the portal drainage, seeps, and groundwater that discharge to the creek. In addition, there is damage to the aquatic habitat from the release of waters with elevated concentration of ferric sulfates that precipitates as ferrous oxides to form iron floc and ferricrete in Railroad Creek. Aquatic habitat within the creek may also be damaged through the precipitation of aluminum released in contaminated groundwater.

Alternatives 9, 10, and 12 would not eliminate all identified sources of groundwater above proposed cleanup levels, that discharge into Railroad Creek. Alternative 11 would contain and collect for treatment all identified sources of groundwater above proposed cleanup levels that would otherwise flow into the creek. Implementation of Alternative 11 would leave less residual risk to aquatic receptors compared to the other alternatives.

Risk to the aquatic environment also includes potential for large-scale slope failures and/or erosion of the tailings piles, which contain soluble metals including aluminum, cadmium, copper, iron, lead, and zinc. The DRI reports several instances of tailings pile slope failures leading to releases prior to the Forest Service actions in 1989-91. Erosion in October 2003 displaced an estimated 600 cy of tailings, some portion of which was released into Railroad Creek. Additional stabilization was required in 2006 to prevent ongoing release of tailings caused by continued erosion of TP-1.

Alternative 9 would reduce the risk of slope failures to a limited degree by regrading slopes of TP-1 and TP-2, and by construction of a barrier to contain unstable tailings along TP-3. Alternative 12 does not include any regrading or improvement to stability of the tailings piles. Alternatives 10 and 11 both include regrading to improve stability of the tailings pile slopes and moving the toe of the tailings piles back away from the creeks. Implementation of Alternatives 10 or 11 would leave less residual risk to aquatic receptors from potential large-scale slope failures compared to the other alternatives.

Residual Risk from Terrestrial Receptor Exposure. As discussed in detail above in Section 4.3.1.1.2, terrestrial life exposures to soil with elevated concentrations of constituents of concern would be reduced following remedy implementation of Alternatives 9, 10, and 11 by the removal, containment, or covering of soils at the mill building, ventilator portal detention area, lagoon, and the maintenance yard area. Alternative 9 did not include capping all existing exposed tailings. Intalco left open the possibility of covering, rather than removing contaminated soils in the mill and ventilator portal areas, for resolution during RD.

Terrestrial toxicity risks would be reduced to a greater extent for Alternatives 10 and 11 compared to Alternative 9. Alternative 11 includes permanent closure of the tailings and waste rock piles to protect terrestrial receptors. Alternative 10 includes a cap over the tailings and main East and West Waste Rock Piles; but this may not be fully protective and did not include the Honeymoon Heights Waste Rock Piles. Alternative 9 did not include any cover of the waste rock piles or any improvement of the existing tailings pile cover; so it is less protective than Alternatives 10 and 11.

Additionally, Alternatives 10 and 11 include terrestrial ERA to determine the extent of clean up required in other areas of the Site that exceed soil screening criteria, including the area of visible accumulations of wind-blown tailings north and east of the mine, Holden Village, the baseball field, and the LWA. Alternative 9 does not address these other areas with elevated metals concentrations.

For Alternative 12, all terrestrial toxicity risks currently at the Site would remain, as no action would be taken at the Site.

Risk Associated with the Production and Disposal of Sludge. Alternatives 9, 10, and 11 differ in the degree of residual risk associated with production and disposal of sludge from the water treatment facility. Metal hydroxide sludge produced from the treatment of groundwater would be disposed of on the Site for these three alternatives. A limited purpose landfill would be constructed for disposal of sludge generated over the life of the remedy; this landfill would most likely be located on one of the tailings piles.

Alternative 11 would produce the greatest amount of sludge as it treats the most groundwater, followed (in order of decreasing volume treated) by Alternative 10, and then Alternative 9. Alternative 12 would not produce any sludge. While Alternative 11 produces a greater amount of sludge, it also immobilizes a larger quantity of metals than any of the other three alternatives, preventing these metals from discharging into Railroad Creek and negatively impacting aquatic life.

TCLP tests from similar AMD treatment systems suggest that leachate produced from the sludge would have metals concentrations well below those protective of groundwater, but reported data sometimes exceeded the proposed Holden surface water cleanup levels. Based on these potential exceedances, the Agencies anticipate that the sludge drying ponds and the disposal landfill would need to be lined, or might possibly be unlined if located upgradient of a groundwater barrier and collection system, to protect surface water quality. As needed, leachate could be collected and recirculated through the groundwater treatment facility. Performance requirements for the sludge disposal facility would be further evaluated during RD.

Summary of Residual Risk Following Implementation. In summary, Alternative 11 does more to address all identified sources of contaminated groundwater in comparison to Alternatives 9, 10, and 12, thereby reducing aquatic toxicity risks in Railroad Creek to a greater extent. Comparatively, the magnitude of residual aquatic risk for Alternative 10 will be significantly less than for Alternative 9, which in turn has less risk compared to Alternative 12. Alternatives 10 and 11 both do more to reduce metals loading to Railroad Creek during implementation and have lower residual risk of large-scale slope failures compared to Alternatives 9 and 12.

The magnitude of terrestrial toxicity risks remaining after remedial action is greater for Alternative 9 compared with Alternatives 10 and 11, as Alternative 9 does not include a soil cover on the tailings piles or waste rock piles, nor does it address contaminated soil in other areas of the Site with exceedances of soil cleanup levels (e.g., the wind-blown tailings area). The magnitude of residual terrestrial toxicity risks is greatest for Alternative 12.

Alternatives 9 and 12 would also leave more residual risk to human health associated with the tailings piles, compared to Alternatives 10 and 11.

Sludge production is greatest for Alternative 11 and the potential risks of sludge release on terrestrial or aquatic receptors would be greater than for Alternatives 9 and 10. Risks of handling and disposing of the treatment facility sludge would need to be managed through engineering controls, as described in the next section.

4.3.2.1.2 Adequacy and Reliability of Controls

To assess the adequacy and reliability of controls at the Site, items to be addressed under CERCLA include: 1) uncertainties associated with land disposal of treatment system residuals; 2) potential need to replace technical components of the remedy; and 3) potential risk if components of the remedy need replacement [40 CFR § 300.430(e)(9)(iii)(C)(2)]. In addition to considering these items, it is also important to discuss 4) the overall adequacy of the controls to prevent the discharge of contaminated groundwater into Railroad Creek for Alternatives 9 through 12.

1. Uncertainties Associated with Land Disposal for Providing Long-Term Protection from Residuals, Considering Volume, Toxicity, Mobility, and Propensity to Bioaccumulate. Since Alternatives 9, 10, and 11 would use the same approach for treatment of contaminated groundwater; the by-product sludge would have the same physical characteristics for these three alternatives. The sludges would include different types of metal hydroxides (e.g., Alternative 11 would collect more water with elevated iron concentrations than Alternative 9). The volume of sludge produced would vary from one alternative to another, because the volume of water treated is much greater for Alternative 11 than the other alternatives, as discussed in the previous section. No sludge would be generated under the no action alternative.

The proposed approach and uncertainties associated with land disposal of the sludge are anticipated to be materially the same for the Alternatives 9, 10, and 11.[74] For these alternatives, sludge would accumulate in a settling pond in the treatment plant, and would thicken by gravity settling and evaporation until it reached a solids content of approximately 4 percent (possibly more). The sludge would be removed by pumping and transported to containment cells constructed on one of the tailings piles, where it would undergo additional

[74] Sludge management was not addressed in detail in the DFFS for any of the alternatives, nor in URS (2005b), which describes Alternative 9. Sludge production and management are further discussed in Appendix F.

consolidation and drying over time. Sludge would be added to one cell until filled, then that cell would be closed in accordance with landfill requirements, and a new cell filled. Leachate would be produced from consolidation of the sludge, for any of the three alternatives. It is not yet known whether sludge recycling or use of a clarifier as part of treatment would be needed to reduce water content of the sludge, or whether sludge dewatering could rely on processes such as evaporation and passive desiccation due to freezing. Alternatives 10 and 11 assumed lined disposal cells, but this requirement could be waived for future cell construction if design testing shows the sludge is stable and monitoring indicates the leachate metals concentrations are below proposed surface water cleanup levels.

Alternative 11 would produce an annual average of approximately 15 percent more sludge than Alternative 10 and approximately 70 percent more sludge than Alternative 9. However, the nature of the engineering controls required, and *uncertainties* associated with long-term sludge stability and management of leachate (e.g., potential consequences of leakage from the landfill), are the same for the three alternatives.

Management of the sludge in an engineered landfill on the Site would address concerns about the toxicity, mobility, and potential to bioaccumulate. At the conclusion of the remedy, the final landfill cell must be closed in accordance with the limited purpose landfill requirements.

2. The Potential Need to Replace Technical Components, such as a Cap, a Slurry Wall, or a Treatment System. The DFFS geochemical evaluation of the Holden Mine Site by SRK Consulting (URS 2004a), predicted that weathering processes that cause AMD and release of metals above proposed cleanup criteria will continue for hundreds of years. To prevent releases above proposed cleanup levels, the remedy must operate reliably over this time frame. Although Holden is similar to other remediation sites, there are few examples of industrial processes that have been maintained for hundreds of years. As a result, there is considerable question as to the reliability of any remedy over the time required to clean up the Site.

The need to replace or repair water collection, conveyance, and treatment system components for any of the remedial actions can be reduced by monitoring and routine maintenance, as proposed for the Alternatives 9, 10, and 11. There are no Alternative 12 technical components to replace.

It is unlikely the barrier walls installed for any of the alternatives will need to be replaced, since these barrier walls would likely be constructed using a cement-bentonite or soil-bentonite slurry to form a low-permeability barrier.[75] There are reports of barrier degradation over time due to chemical changes associated with some types of contaminants in groundwater, but the Agencies are not aware of such problems for the constituents of concern (primarily metals) at Holden.

Riprap is proposed for each alternative as part of protecting the creeks from a mass release due to potential erosion- or scour-induced slope failures of the tailings piles. Riprap will need to be maintained and restored or replaced over time if it degrades due to weathering (as has been observed since about 1991), or displaced due to scour (as occurred in 2003). Alternatives 10 and 11 include moving the toe of the tailings pile slopes away from Railroad and Copper Creeks, which will reduce the risk of tailings pile failure if the riprap is overtopped or degraded. Alternative 9 does not include pulling back the tailings from Railroad Creek and relies on riprap alone to prevent the potential release of tailings related to flooding or scour. Riprap alone is unlikely to be effective or reliable in the long-term at preventing Railroad or Copper Creeks from causing slope failures of the tailings piles.

Alternative 11 includes an impermeable geomembrane cap (e.g., polyethylene with a protective geocomposite drainage layer on each side) topped by a soil cover over the consolidated tailings and waste rock pile. Engineered controls to protect the cover from burrowing animals and deep rooted plants would need to be maintained for hundreds of years, probably by annual spraying to control habitat on the revegetated surface. Penetration of the membrane would reduce the effectiveness of this source control measure, and thus reduce the predicted effectiveness of Alternative 11. Neither Alternative 9 nor 10 include a geomembrane cap, or its associated maintenance. There is some potential that such a cap could be eliminated from Alternative 11, based on further engineering analyses and risk assessment during RD.

Drainage ditches and conveyance pipes must be maintained to prevent the build-up of debris and iron fouling for the life of Alternatives 9, 10, and 11, which may reduce the efficiency of groundwater collection or conveyance.

[75] Potential adverse chemical effects of the groundwater on the barrier wall would be addressed during RD. Other types of barrier walls such as secant walls constructed by soil mixing or jet grouting may also be further considered during RD.

Alternatives 10 and 11 rely on open ditches for collection of groundwater. Such ditches may be susceptible to freezing in the winter, but it is not known whether this would be a problem. The collection and conveyance ditches also would allow sludge formation following air contact with iron-rich groundwater from below the tailings piles, but could be easily maintained with a backhoe or Vactor® truck (i.e., vacuum truck system typically used for cleaning sewer catch basins).

Alternative 9 relies on buried perforated pipe drains for groundwater and seep collection along the UWA groundwater barrier wall, a method similar to the TP-1 seep collection proposed for Alternative 9 (URS 2005b). On TP-1, these pipe drains are susceptible to iron fouling and clogging, if exposed to air, although Intalco has expressed this would not be a problem for the Alternative 9 seep collection components.[76] Alternative 9 also requires maintenance of perforated well screens and pumps to maintain the effectiveness of groundwater remediation below TP-1 over the life of the remedy.

Treatment system equipment parts or systems will wear out and require replacement over time for Alternatives 9, 10, and 11. This includes maintenance of the media filters; lime storage, addition, and mixing components; pumps and generators; controls; and structures. Generally the need for such maintenance is likely to be proportional to the volume of water treated, i.e., Alternative 11 would have greater treatment equipment maintenance requirements compared to Alternative 10, which would have greater treatment maintenance requirements than Alternative 9, based on comparison of the volume of water treated. The treatment system for Alternative 9 would rely on gravity flow, rather than pumping, to a greater degree than Alternatives 10 and 11, due to the treatment system location relative to the groundwater that would be collected for treatment.

In summary, the treatment system for Alternative 11 is anticipated to have a higher degree of required maintenance and replacement of system components than Alternative 10, which would have a higher degree of maintenance than Alternative 9. In addition to the increased size and complexity of the water treatment system for Alternative 11, the membrane caps for Alternative 11 on tailings and waste rock would require long-term biological maintenance that does not currently apply to the other alternatives. However, the need for a cap

[76] If the effectiveness of the perforated pipe drain seep collection components proposed for Alternative 9 is not adversely impacted by iron fouling, this approach could also be suitable for Alternatives 10 and 11, and should be further evaluated during RD.

that meets the presumptive requirements of Chapter 173-350 WAC would be further evaluated as part of RD for either Alternatives 10 or 11.

3. The Potential Exposure Pathways and Risks Posed Should the Remedial Action Need Replacement. Alternatives 9, 10, and 11 rely to varying degrees on interrupting exposure pathways (groundwater baseflow and surface seeps) that convey excess metals into surface water at the Site. Failure of any components of these alternatives would restore the associated exposure pathways, with the magnitude of resulting risk depending on the extent and duration of the failure. Planned replacement and other maintenance of components for the groundwater collection, conveyance, and treatment systems likely can be arranged to minimize or avoid shutting down the remediation system for the three alternatives.

Unanticipated failure of any remedial system component could result in an uncontrolled release of contaminated water to the ground surface or into Railroad Creek or Copper Creek, depending on where the release occurred. Such a failure could have a sudden, acute impact on aquatic life within Railroad Creek, if the metal concentrations were high enough. However, an accidental release from the potential failure of part of the remedy is anticipated to have less effect than the existing uncontrolled releases.

4. Overall Adequacy of the Controls to Prevent the Discharge of Contaminated Groundwater. The evaluation of long-term effectiveness and permanence of a remedy includes completeness (i.e., whether the alternative adequately addresses all the sources of release), and effectiveness of the containment and collection system. Issues involving completeness are discussed below; issues involving effectiveness are discussed in Section 4.3.2.4.1.

Alternative 12 would not include any active controls to prevent the contaminated groundwater and seep flows, and the mine discharge into Railroad Creek.

Alternative 11 includes a site-wide, fully penetrating groundwater barrier and collection system. This alternative adequately addresses all identified sources of release and uses the best available technology to minimize the migration of contaminated water to the creek, as well as to minimize collection of clean water from Railroad Creek.

The Alternative 10 PPB wall and collection system would reduce the flow of contaminated groundwater into Railroad Creek from the majority of the groundwater sources that discharge into the creek above proposed cleanup levels. However, the Alternative 10 PPB would not extend downgradient of TP-2 and may not be as effective as the fully penetrating barrier proposed in Alternative 11 (refer to further discussion in Appendices A and C).

Alternative 9 would not include any active controls to prevent the discharge of contaminated flows into Railroad Creek for large portions of the Site. This alternative would rely on limited capping and source removal; surface water run-on diversion; source depletion; and natural attenuation to address contaminated groundwater flows from the LWA, TP-2, TP-3, and part of TP-1.

In summary, the adequacy and reliability of controls for Alternatives 9, 10, and 11 have the same degree of uncertainty associated with long-term management of residual treatment sludge, and maintenance of the treatment system, although the volumes of sludge generated and the overall cost for maintenance vary in proportion to the volume of water that would be treated.

The potential risks associated with failure of engineering controls that would reestablish existing exposure pathways (groundwater flow and seeps from various parts of the Site) are also similar for the three alternatives—although the pathways that are not addressed, and the associated risk to aquatic receptors are very different from one alternative to another.

When the overall adequacy of the engineering controls implemented at the Site for each of the alternatives is considered, the magnitude of residual risk is greater for Alternative 12 and Alternative 9 than for Alternative 10 or Alternative 11. Alternative 11 provides greater long-term effectiveness and permanence than the other alternatives.

4.3.2.2 Reduction of Toxicity, Mobility, or Volume through Recycling or Treatment

The second criterion of the primary balancing criteria is assessing the degree to which alternatives employ recycling or treatment to reduce toxicity, mobility, or volume, including how treatment is used to address the principal threats posed by the site [40 CFR § 300.430(e)(9)(iii)(D)].

Alternative 12, the no action alternative, does nothing to reduce the toxicity, mobility, or volume of hazardous substances at the Site.

The CERCLA factors that are considered in this comparison of the alternatives include:

- The treatment or recycling processes the alternatives employ and materials they will treat;

- The amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled;

- The degree of expected reduction in toxicity, mobility, or volume of the waste resulting from treatment or recycling and the specification of which reduction(s) are occurring;

- The degree to which the treatment is irreversible;

- The type and quantity of residuals that will remain following treatment, considering the persistence, toxicity, mobility, and propensity to bioaccumulate; and

- The degree to which treatment reduces the inherent hazards posed by principal threats.

4.3.2.2.1 Treatment or Recycling Processes and Materials Treated

Alternatives 9, 10, and 11 use the same general type of groundwater treatment system to convert dissolved metals in the groundwater into a relatively stable hydroxide sludge. While the treatment method is the same, these alternatives differ significantly in the amount of contaminated groundwater collected and treated and the sources addressed (e.g., Alternative 9 would collect a smaller volume of contaminated water for treatment). Each of the alternatives uses a groundwater treatment process involving lime addition to reduce acidity and concentrations of aluminum, cadmium, copper, iron, lead, and zinc. Treatment will produce metal hydroxide sludge, with the metals in a less toxic form than prior to treatment. Leachate from the sludge may have metals concentrations below proposed surface water cleanup levels; however, the leachate will require monitoring during the first several years to assess whether metals concentrations in the leachate are low enough to meet the proposed surface water cleanup levels.

Alternative 12 does not include any treatment or recycling of any waste materials.

Alternatives 9, 10, and 11 do not rely on recycling any hazardous substance materials.

4.3.2.2.2 Amount of Hazardous Substances, Pollutants, or Contaminants Destroyed, Treated, or Recycled

None of the alternatives destroy hazardous substances.

As discussed in Section 4.3.2.1, the alternatives differ in the mass of metals that are removed from the environment due to differences in where groundwater is collected from the Site and the volume of groundwater collected for treatment. Alternative 11 would collect and treat (detoxify) the greatest volume of groundwater compared to the other alternatives. Alternative 11 is estimated to treats approximately 600 million gallons per year (MGY), Alternative 10 about 490 MGY, and Alternative 9 about 325 MGY.

These three alternatives would collect and treat water that is above proposed cleanup levels (except a small amount of water from Railroad Creek that may be incidentally collected during high flow events for Alternative 10 , or inadvertently collected from the pumped wells for Alternative 9). In comparing alternatives, the difference in the amount of water that is not collected represents water above proposed cleanup levels that would otherwise be released into Railroad Creek. No groundwater would be collected or treated under Alternative 12.

In summary, since Alternative 11 collects and treats more contaminated groundwater than the other alternatives; Alternative 11 treats more hazardous substances, pollutants, and contaminants, compared to the other alternatives.

4.3.2.2.3 Degree of Expected Reduction in Toxicity, Mobility, or Volume

Metals removed from groundwater through the treatment process for each of the alternatives become a relatively stable sludge. These metals are prevented from reaching Railroad Creek. Based on the relative volume (and mass) of metal hydroxide sludges produced, Alternative 11 reduces toxicity and mobility of a larger volume of metals than the other alternatives.

Based on the more extensive collection and treatment of contaminated groundwater, Alternative 11 does more to reduce mobility of dissolved metals in groundwater than the other alternatives.

4.3.2.2.4 Degree of Treatment Irreversibility

Water treated to remove metals will produce metal hydroxide sludge as a by-product of treatment. To assess the degree of irreversibility of the waste treatment process, a literature survey was performed to assess sludges from multiple mine sites that had wastewater constituent and treatment technologies similar to what is expected at Holden (Hart Crowser 2004). These studies used TCLP tests to assess potential for metals to be released from the sludge and re-enter the environment. Reported results of TCLP tests from various sludges indicate that metal concentrations in leachate are typically well below those needed to protect groundwater at the Holden Site. However, the reported results sometimes exceeded the proposed Holden surface water cleanup levels, or had detection limits above the proposed surface water criteria. As a result, the Agencies anticipate that the sludge disposal landfill would need to be lined.[77] Performance requirements for sludge disposal facility would need to be further evaluated during RD. So long as the sludge is managed in an appropriately designed landfill, the metals would be prevented from reaching Railroad Creek.

While the sludge would provide permanent containment of the metals from the treated groundwater and prevent them from reaching Railroad Creek, leachate from the sludge would need to be managed. The three alternatives include disposal of the sludge in an on-Site landfill, which would need to conform to the standards for limited purpose landfills [WAC 173-350-400]. Leachate could be recirculated to the water treatment facility where it would aid in metals precipitation by adding alkalinity to the influent groundwater.

The degree of treatment irreversibility is the same for Alternatives 9, 10, and 11. No treatment would be performed for Alternative 12.

4.3.2.2.5 Type and Quantity of Residuals

Alternatives 9, 10, and 11 would produce metal hydroxide sludge as previously described. Characteristics of the sludge based on reports from other sites with comparable AMD are summarized in Appendix F. Sludge from the Alternatives 10 and 11 would contain more iron than sludge from Alternative 9 (due to the difference in collection of groundwater contaminated by the tailings piles) but sludges from these three alternatives would be similar in character. However, the volume of sludge produced by the three alternatives would differ substantially.

Over a period of 50 years, the estimated average annual volume of treatment facility sludge for Alternative 11 is about 31,000 cy, for Alternative 10 it is 27,000 cy, and for Alternative 9 it is 18,000 cy, as discussed in Section 4.1.3. These estimates are based on an assumption that the sludge would have a solids content of about 4 percent at the beginning of the annual dewatering stage of treatment, as discussed in Appendix F of this SFS. The volume of sludge produced annually is anticipated to decrease by about 40 percent in the first 50 years due to the estimated changes in mass loading used in the DFFS Model, and would continue to decrease at a much slower rate thereafter. Once the

[77] Depending on results of further analyses, and possibly monitoring, the landfill cells might not need to be lined if located upgradient of a groundwater barrier and collection system, to protect surface water quality.

sludge is transferred from the treatment system to the landfill, its volume would further decrease based on consolidation, and potentially drying.[78]

No treatment residuals would be generated under Alternative 12.

Final sludge disposal requirements would be further evaluated as part of RD. However, because of site-specific variables including the influent water quality, effectiveness of the treatment system, and effectiveness of sludge drying under local weather conditions, sludge management requirements will not be completely known until the treatment plant is operational. Experience at other sites suggests that treatment system may be enhanced through use of recirculation or a mechanical clarifier to improve sludge density.

Essentially the same landfill disposal, engineering controls, and monitoring would be required for management of the treatment residuals for the Alternatives 9, 10, and 11. However, there would be more sludge to manage for Alternative 11, because of the larger volume of contaminated water collected for treatment, compared to the other alternatives. Similarly, Alternative 10 would require more sludge management compared to Alternative 9.

4.3.2.2.6 Degree to which Treatment Reduces the Inherent Hazards Posed by Principal Threats

Under CERCLA, treatment is expected to be used to address the principal threats posed at a site, wherever practicable [40 CFR § 300.430(a)(1)(iii)(A)]. Treatment (as compared to natural attenuation, for example) is considered to be a priority for liquids, areas contaminated with high concentrations of toxic compounds, and other highly mobile materials. Risk to the aquatic environment at the Site is directly related to the toxicity and quantity of hazardous substances being released into Railroad Creek from the mine portal, seeps, and groundwater baseflow. Risk to human health is associated with soils, mine tailings, and groundwater. The source materials at the Site (i.e., underground mine, waste rock, tailings, contaminated soils, and contaminated sediment) are not considered highly toxic or highly mobile and, therefore, are not considered principal threat wastes as defined by EPA (EPA 1991). As a result, treatment of the source materials (that are not principal threat wastes) is not necessarily

[78] The effect of evaporation and freeze-desiccation would be balanced by input of new moisture due to precipitation. Management of the sludge would probably include decanting free water on the sludge impoundment surface as a normal operating practice. The Agencies' cost estimate for sludge management used an average rate of sludge production based on the DFFS, and included the effect of consolidation to estimate the storage volume required.

required. Engineering controls (e.g., capping, containment) may be suitable for addressing the source materials, as well as other media (i.e., groundwater and surface water) contaminated by the source materials.

4.3.2.3 Short-Term Effectiveness

Short-term effectiveness is the third primary balancing criteria under CERCLA. This criterion considers the following items [40 CFR § 300.430(e)(9)(iii)(E)]:

- Short-term risks that might be posed to the community during implementation of an alternative;
- Potential impacts on workers and the effectiveness and reliability of protective measures;
- Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation; and
- Time until protection is achieved.

4.3.2.3.1 Short-Term Risks on the Community during Implementation

Short-term health risks to the community during implementation primarily consist of increased exposure to construction traffic. Potential exposure to construction dust, noise, and vehicle exhaust emissions is not anticipated to present health risks to the Holden Village community or other members of the public using the adjacent forest lands. Table 14 compares short-term human health risks to Holden Village residents and construction workers for each alternative.

Short-term risks to the local community from traffic can be mitigated through active measures taken during construction, including:

- Construction of a bridge east of TP-3 to enable routing construction traffic around, rather than through, Holden Village; and
- Implementing a traffic control plan for joint use of the Lucerne-Holden Road by construction traffic and the Holden Village community.

These mitigative measures would be part of Alternatives 9, 10, and 11. There would be no construction traffic if Alternative 12 were selected.

The Agencies expect that all traffic to a temporary construction workers' camp west of Holden Village could also be routed across this bridge, south of the mine, and then across the existing Holden Village vehicle bridge, so that there is no increase in construction traffic through the Village for any of the remedial alternatives.

During construction, the contractor is expected to take measures to protect the public from trespass in construction areas. Traffic on the Lucerne-Holden Road will increase compared to before and after remediation. After remediation, there will be more traffic than pre-construction to accommodate long-term delivery requirements for fuel and lime for the treatment system.

- Based on the extent of construction anticipated, Alternative 9 would have less traffic during construction, compared to Alternatives 10 and 11.

- Alternative 10 will have less traffic during construction than Alternative 11.

- Alternative 12 would not cause any increase in traffic for remedy implementation.

4.3.2.3.2 Potential Impacts on Workers during the Remedial Action and the Effectiveness and Reliability of Protective Measures

Short-term human health risks due to remedy implementation at the Holden Site are primarily focused on construction safety, including traffic. Table 14 compares short-term human health risks due to construction and presumed mitigation for Alternatives 9, 10, and 11. There would be no construction human health risks associated with Alternative 12.

Human health risks to construction workers during remedy implementation, include mine hazards previously discussed, construction traffic, open excavations for pipelines, regrading, barrier wall construction, treatment plant construction, exposure to soils with elevated concentrations of TPH and possibly other dangerous wastes, noise and dust exposure, demolition of the derelict mill structure, and common place slips, trips, and falls. The nature of these risks is consistent between the three alternatives, although the duration and number of workers exposed varies significantly. For construction workers, the risk of worker injury increases with the overall level of construction required by the alternative. Alternative 9 would have the least risk. Alternative 11 would have the most risk (since it is anticipated to have a greater number of workers and duration of construction). Risk to workers for Alternative 10 would be between the extremes noted above. Alternative 12 would not introduce any construction risk to workers.

Health and safety risks due to implementation can be mitigated by conventional construction safety measures, including conformance with state construction safety standards and HAZWOPER standards. Federal safety standards prepared by the MSHA are not specifically applicable for work in abandoned mines, but MSHA standards are potentially relevant and appropriate since most underground construction contractors are familiar with them.

4.3.2.3.3 Potential Environmental Impacts of the Remedial Action and the Effectiveness and Reliability of Mitigative Measures during Implementation

Implementation of any alternative brings with it short-term construction risks to the environment, with the exception of Alternative 12, the no action alternative. Short-term construction risks to the environment include:

1. Risk of a tailings release to Railroad or Copper Creeks during regrading;
2. Risk of bentonite or cement releases to the creek during barrier wall construction, depending on material selected;
3. Risks associated with construction of hydraulic barriers in the underground mine;
4. Risk of sediment release to the creeks during construction of groundwater and seep collection components, and use of temporary stream crossings during construction;
5. Risk of fuel and lime spills;
6. Risk of mass release of tailings from flood-induced slope failures; and
7. Risk of surface water quality exceedances during and after startup of the treatment plant.

Table 15 compares short-term environmental risks due to construction and presumed mitigation for Alternatives 9, 10, and 11.

There would be no potential impact to the environment resulting from the no action alternative, but of course the current effects of the uncontrolled release of hazardous substances would continue.

Regrading Tailings. There is some risk of slope failures and sloughing of the tailings into Railroad Creek during regrading to improve slope stability. Alternatives 10 and 11 involve regrading larger volumes of tailings adjacent to Railroad Creek than Alternative 9, which would extend the time over which this risk is present, but not change the nature of the risk. Alternatives 10 and 11 also include pulling the toe of the tailings back from Railroad Creek, which would reduce risk of slope failures impacting the creek.

Stormwater runoff during regrading may also cause a release of tailings into Railroad Creek. For Alternatives 10 and 11, the regrading work could be performed sequentially along the face of the tailings piles (moving east to west), with the cover placed over tailings that have already been regraded, concurrent with grading slopes further to the west. In this way, the area of exposed unoxidized tailings could be minimized for each alternative, thus reducing the risk of stormwater runoff conveying exposed tailings into Railroad Creek. More important, both Alternatives 10 and 11 would include installation of a runoff collection ditch alongside Railroad Creek, which would enable collection of runoff from the regraded slopes and downstream detention and treatment of potentially contaminated stormwater in the new treatment facility (that would need to be constructed prior to tailings regrading).

This approach to protect against tailings release in stormwater runoff is not available under Alternative 9, since there would be no room for a ditch unless the toe of the tailings slope is pulled back from the creek side. The DFFS included an analysis that estimated stormwater runoff from tailings exposed for a month would have a pH of 2, and elevated concentrations of metals (especially zinc at 3,500,000 ug/L, according to Appendix E of the DFFS). Concentrations of metals in the runoff would increase if the tailings were exposed for longer periods prior to the storm.

For an assumed worst-case analysis (all the tailings exposed at the time of a 1-inch 24-hour storm), the DFFS estimated the mass of metals delivered to the creek would be 22 kg cadmium, 149 kg copper, 18,600 kg iron, and 93,200 kg zinc (according to Table 7-8 of the DFFS). If the release predicted by this analysis were to occur, such an event would produce a plume toxic to aquatic life that would extend down Railroad Creek and possibly impact Lake Chelan. Accordingly, the inability to collect and detain stormwater runoff during regrading is a major flaw in Alternative 9.

Barrier Wall Construction. Alternatives 10 and 11 involve the placement of groundwater barrier walls adjacent to Railroad Creek, while the barrier wall for Alternative 9 is several hundred feet upgradient from the creek. During construction of the cutoff for Alternatives 10 and 11, there is risk of a release to Railroad Creek of the bentonite slurry and concrete used for construction of the barrier, which is nearly non-existent for Alternative 9 based on the barrier wall location in relation to Railroad Creek. Potential risk of a bentonite or cement release can be minimized by good construction practices, including location of dry materials storage and mixing facilities away from the creek, good housekeeping to minimize spillage during slurry handling, and advance preparation of a spill management contingency plan.[79]

Alternatives 9 and 11 include groundwater cutoff walls keyed into the underlying till or bedrock, while Alternative 10 includes a PPB. The depth of the barrier for Alternative 11 ranges from about 20 to 100 feet below ground surface, whereas the depth of the barrier for the Alternative 10 is expected to be on the order of 30 feet. Barrier wall depths for Alternative 9 are predicted to be approximately 15 to 20 feet deep. Although installation of the deeper barrier for Alternative 11 is well within the depth of similar barriers constructed at other sites, implementation of the cutoff wall for Alternative 11 would be somewhat more difficult and take longer compared to shallower barrier walls for Alternative 9 or 10. Additionally, the length of the cutoff wall for Alternative 11 is longer than for either Alternatives 9 or 10. As a result, Alternative 11 would require more time for barrier construction adjacent to the creek, and thus has a greater risk of a construction accident causing a release of bentonite, cement, or sediment into Railroad Creek.

Underground Mine Work. Alternatives 9, 10, and 11 include the installation of two hydraulic bulkheads within the 1500 Level portal of the mine. However, Alternative 9 has left open the option of installing a detention pond in lieu of mine bulkheads. Depending on results of analyses during RD, the ponds could be used to provide some equalization of portal flow rates prior to treatment.[80] While the bulkheads are the preferred way to control the rate of drainage from the mine, the DFFS noted experience at other sites that suggests that bulkhead installation may cause degradation of water quality over the short term, due to the effect of flooding areas where metal salts and/or exposed sulfide-bearing rock is not currently affected by drainage from the mine.

The DFFS notes that this effect has been observed at other mines that are allowed to flood, and provides a basis for predicting the resulting water quality degradation (that has been taken into account in analyses of the proposed water

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[79] The DFFS proposed that barrier walls would be constructed as soil-bentonite, or cement-bentonite slurry trench walls, and this approach is included for discussion and preliminary cost estimating purposes in Alternatives 9, 10, and 11. The DFFS did not include an explicit evaluation of other types of groundwater barriers (e.g., secant soil mixing or jet grouting barriers); however, alternatives such as this could be evaluated during RD.

[80] A further advantage of bulkheads over ponds is the ability of bulkheads to contain a discharge surge that could develop following a collapse or cave-ins within the mine. An underground collapse in the abandoned McDonald Mine in 2005 near Barton, Maryland, caused a seven-fold increase in the rate of drainage and reduced the pH and increased metals concentration in the mine discharge that lasted more than 7 months (Fahrenthold 2006). Such an increase in flow at Holden could not be contained in a detention pond.

treatment plant). The effect of this for the three alternatives is the same, if bulkheads are installed for Alternative 9. Since the portal drainage would be collected for treatment under Alternatives 9, 10, and 11, this should not adversely impact water in Railroad Creek.

Work in the underground mine will also cause risk to workers that is different from other types of construction. For this work, adherence to the MSHA standard safety protocols may be required to reduce potential risks to workers. The construction risk during underground work is the same for the three alternatives unless equalization ponds were selected for Alternative 9 during RD.

Risk of Sediment Release in Railroad Creek. Following regrading of the tailings piles, there is some additional potential risk of sediment release to Railroad or Copper Creeks due to excavation of groundwater and seep collection trenches adjacent to the creek for Alternative 11 and to a lesser degree for Alternative 10. Alternative 9 does not involve construction of any groundwater collection trenches along Railroad Creek, but there is a modest risk of sediment release associated with installation of seep collection systems for SP-1 and SP-2, especially since there would not be any setback of TP-1 from the edge of Railroad Creek.

Alternative 10 and 11 also include construction of two pipeline creek crossings, one across Copper Creek near the confluence with Railroad Creek, and one across Railroad Creek near the east end of TP-3. Alternative 9 does not include any pipeline creek crossings.

Conventional construction practices can mitigate risk of sediment release to the creeks during construction of groundwater and seep collection systems, and pipeline creek crossings.

Risk of Fuel and Lime Spills. During construction, there is a risk of fuel spills both on and off the Site. In an assumed worst case, an off-Site spill could release the contents of a tanker truck (typically about 2,000 gallons) into Lake Chelan. The risk of this is proportional to the total quantity of fuel that would be used during construction; Alternative 11 would have the greatest risk, with Alternative 10 having less, and Alternative 9 the least risk of an off-Site spill. There would be no spill risk associated with Alternative 12.

After treatment plant construction, there is some potential risk of spilling fuel or hydrated lime during transport to the Site or transfer from delivery trucks into storage on the Site.

- Potential long-term risk of fuel spills can be minimized by development of a local hydroelectric generating capacity to support the treatment system, for any alternative.

- The degree of risk associated with a potential hydrated lime spill during treatment system operation is less for Alternative 9 than Alternative 10, and less for Alternative 10 compared to Alternative 11, simply because these alternatives would not require as much lime since they do not treat the same volume of water over time.

Risk of Mass Release of Tailings from Flooding or Seismically Induced Slope Failures. Implementation of Alternative 9 would not reduce risk of flooding-induced slope failures, or seismically induced slope failures as much as Alternatives 10 and 11, since it does not include setback of the tailings from the edge of Railroad and Copper Creeks. For Alternatives 10 and 11, moving the toe of the tailings piles away from the creeks would create a wider floodplain, which would reduce flood velocities and potential for erosion or scour undercutting the tailings. Alternative 9 also does not include regrading to flatten the slopes of TP-3, and Alternative 12 would not include any improvement in stability.

Risk of Surface Water Quality Exceedances after Startup of the Treatment Plant. Alternatives 10 and 11 would use an open ditch for collection of groundwater and seep flow around the tailings piles. This ditch would also collect snowmelt and stormwater runoff, thus there is more variability in flow to the treatment systems than for Alternative 9. Engineering measures to reduce risk of effluent with excess metal concentrations include increasing the size of the detention ponds to increase residence time for pH neutralization and precipitation of metals.

In summary, Alternatives 10 and 11 have the potential for the greatest adverse impacts on water quality in Railroad Creek resulting from construction adjacent to Railroad Creek, large volumes of unoxidized tailings exposed during regrading and consolidation, and greater potential for material erosion and potentially contaminated runoff. These short-term risks during construction can generally be mitigated with conventional construction practices. The potential impact for Alternative 9 would be significantly less, since there would be less regrading on the tailings piles and a groundwater collection system near the creek would only be built on TP-1. However, Alternative 9 does not accomplish the same reduction in metals toxicity in Railroad Creek as either Alternative 10 or 11. Additionally, Alternative 9 does not reduce the risk of tailings slope failures or stormwater runoff during regrading, which could cause significant releases of metals to Railroad and Copper Creeks.

4.3.2.3.4 Time until Protection is Achieved

Alternative 11 would decrease the concentration of metals in Railroad Creek immediately after implementation along the entire length of the Site by active collection and treatment of groundwater before it enters Railroad Creek. Alternative 11 would have the least time until protection is achieved.

Alternative 10 provides active collection and treatment of groundwater before it enters Railroad Creek, across most of the Site, and includes groundwater monitoring to determine whether additional groundwater containment or collection for treatment is needed along TP-2. Alternative 10 would also begin decreasing the concentration of metals in Railroad Creek immediately after implementation, but over a slightly smaller portion of the Site compared to Alternative 11.

Alternative 9 provides no groundwater or seep collection alongside TP-2 and TP-3, and would locate the UWA groundwater barrier and collection system 450 to 750 feet upgradient from the creek. Thus, while Alternative 9 would immediately eliminate some sources such as the portal drainage and a portion of the groundwater from TP-1, other significant sources would only be gradually reduced over long periods (decades to hundreds of years) from source depletion and natural attenuation.

Finally, Alternative 12 would rely on source depletion and natural attenuation to achieve protection of aquatic life, and concentrations would not achieve potential ARARs for hundreds of years.

In summary, Alternative 11 would have the shortest time until protection of aquatic life is achieved throughout Railroad Creek, followed closely by Alternative 10. Alternative 9 would not protect aquatic life throughout Railroad Creek for hundreds of years.

4.3.2.3.5 Summary of Short-Term Effectiveness

A significant aspect of short-term effectiveness involves construction-related impacts. Construction-related impacts are not directly comparable for the different alternatives, since Alternatives 9, 12, and possibly Alternative 10, would not be final remedies. The potential effects of implementing these alternatives as an interim remedy are described above, but the additional remedial work (and associated impacts) to complete the cleanup action to provide the same degree of protectiveness as Alternative 11, have not been identified to date.

The other significant aspect of short-term effectiveness involves the time until protection is achieved.

- Alternative 11 will immediately reduce risk to the aquatic environment by reducing metals concentrations in Railroad Creek along the entire length of the Site.

- Alternative 10 will also immediately reduce concentrations in Railroad Creek across most, but not all of the Site.

- Alternative 9 relies on natural attenuation, and a combination of source depletion and natural attenuation, respectively, to reduce risk over time for significant parts of the Site. The DFFS Model indicates aquatic toxicity risks would be substantially reduced after 50 years for Alternative 9 but only for a fully mixed condition downstream of the Site, and much longer at the required points of compliance.[81]

- Alternative 12 would rely entirely on source depletion and natural attenuation.

In addition to the time required to achieve groundwater and surface water quality criteria described above, Alternatives 10 and 11 would reduce risk to terrestrial receptors, and reduce risk of a mass release of tailings into Railroad and Copper Creeks, immediately upon implementation, whereas Alternatives 9 and 12 would not.

In summary, Alternative 11 has greater short-term effectiveness, the third primary balancing criteria under CERCLA, compared to the other alternatives.

4.3.2.4 Implementability

Implementability is the fourth of the primary balancing criteria under CERCLA. The implementability issues that shall be assessed for the alternatives under CERCLA include [40 CFR § 300.430(e)(9)(iii)(F)]:

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[81] Since the estimated rate of contaminant reduction in groundwater that Intalco assumed for the LWA is not supported by the EPA Batch Flush Model (see Appendix A), the time to reach proposed cleanup levels for Alternative 9 at the points of compliance in the LWA would be much longer than assumed in the DFFS Model, on the order of decades to hundreds of years. Similarly reliance on source depletion and natural attenuation below the tailings piles would leave groundwater above proposed cleanup levels for hundreds of years.

- **Technical Feasibility.** This includes technical difficulties and unknowns associated with construction and operation of a technology; the reliability of the technology; the ease of undertaking additional remedial actions; and the ability to monitor the effectiveness of the remedy.

- **Administrative Feasibility.** This includes activities needed to coordinate with other offices and agencies; and the ability and time required to obtain any necessary approvals and permits from other agencies.

- **Availability of Services and Materials.** This includes the availability of adequate off-site treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provision to ensure any necessary additional resources; the availability of services and materials; and the availability of prospective technologies.

4.3.2.4.1 Technical Feasibility

Each of the alternatives is technically feasible. The main issues that affect technical implementation of Alternatives 9, 10, and 11 are related to installation of the groundwater barrier and collection systems, and maintaining operation of the groundwater collection and treatment system over time. There are no technical feasibility issues associated with the Alternative 12.

Installation of the Groundwater Barrier Systems. The DFFS described use of cement-bentonite and soil-bentonite groundwater barriers. These types of barriers have been constructed by the "slurry trench" method since the 1960s, in a wide range of different soils types. This approach is well suited to subsurface conditions at the Site that include glacial and alluvial soils with boulders. Barrier wall systems are frequently used for groundwater containment and waste isolation, and may be considered "best available technology" for this type of application, as discussed in Appendix C.

Construction of the groundwater barrier for each of the alternatives is technically feasible, despite their differences in location and geometry. Duration of barrier construction from one alternative to another is directly related to length and depth of the barrier.

- Construction of the barrier for Alternative 9 is anticipated to be less difficult compared to the other alternatives. This barrier would be only 15 to 20 feet in depth and about 2,500 feet in length, since it is intended to affect only a limited portion of the groundwater moving across the former mine operations area of the Site.

- The barrier for Alternative 10 is also relatively shallow; its depth is anticipated to average about 30 feet, depending on final design. The Alternative 10 barrier would be about 5,870 feet in length.[82]

- Construction of the Alternative 11 groundwater barrier wall would be the most technically challenging, as this barrier wall would extend from about 20 to 100 feet below ground surface (depending on the depth of underlying glacial till or bedrock) over a length of about 7,700 feet. However, cutoff walls at this depth have also been constructed at other sites.

The DFFS found that barrier walls were feasible as part of the cleanup action, and this is supported by the extensive case history experience presented in Appendix C of this SFS.

Intalco assumed that the fully penetrating barriers such as used for Alternatives 9 and 11 would be only 80 to 90 percent effective in collecting contaminated groundwater that would otherwise enter the creek. The 80 percent effectiveness for the fully penetrating barrier wall was only applied to the groundwater collection in the east portion of the Site (the tailings piles). Intalco indicated this 10 percent reduction in collection effectiveness compared to other parts of the Site would occur from iron precipitation in the groundwater collection system; however, no data or experience were cited to support this assumption. Also, the DFFS did not discuss whether regular maintenance of the collection system would eliminate this potential decrease in collection efficiency.

Proof-of-concept analyses completed by the Agencies indicate the PPB contemplated for Alternative 10 is a feasible alternative, but do not demonstrate that Alternative 10 would be suitable as a final remedy. The analyses completed by Hart Crowser indicate that where installed, the PPB would be effective in containment and collection of more than 80 percent of the contaminated groundwater as discussed in Attachments A and B to Appendix F of this SFS.

The pumped wells included in Alternative 9 have the potential to draw in creek water. To limit this withdrawal of creek water, the rate of pumping, and perhaps the number of pumped wells must be monitored and adjusted to accommodate seasonal changes. However, limiting the number of wells or pumping rate would reduce the amount of contaminated groundwater from TP-1 that could potentially be collected for treatment. Final implementation of Alternative 9

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[82] The APR included monitoring to determine whether the final remedy should include extension of the groundwater barrier and collection system along TP-2, which would add an additional length of about 1,800 feet to the barrier. However, the analysis of Alternative 10 in the SFS does not include this contingency.

could require more than the four wells proposed by Intalco to meet the performance goals for Alternative 9.

The Duration and Complexity of Maintaining the Groundwater Collection and Treatment Systems. Maintenance of the groundwater collection and treatment systems would be different for the three alternatives. Maintenance of groundwater collection system is anticipated for the entire duration of the remedy, potentially for hundreds of years. The most significant long-term maintenance and operations issues include supplying the energy required to convey and treat the groundwater, accommodating the effects of winter freezing, and iron fouling.

Alternatives 9, 10, and 11 would require electrical energy to some degree. Alternatives 9 would require less power than either Alternative 10 or 11, and Alternative 10 would require less power than Alternative 11, because of the smaller volumes of water and sludge that would require pumping.

Holden Village currently has no excess generating capacity from its hydroelectric system. No commercial electrical supply is available at Holden; so each of the remedy alternatives would need to rely a new hydroelectric energy source or possibly on generators using imported fuel, for necessary pumping, freeze protection, etc. The means of producing electrical power need to be evaluated during RD.

For the collection of groundwater, Alternative 9 uses a “trench drain” (a perforated pipe in a trench backfilled with gravel) along the upgradient side of the barrier wall. Alternative 9 also includes collection of groundwater by pumping from wells and collection of seeps with trench drains that discharge to buried sumps that can be pumped to the treatment facility. These systems are subject to clogging due to inflow of sediment and potential chemical precipitation (e.g., fouling by iron or aluminum hydroxides), but flow can be maintained by periodic jetting or use of a pipe-cleaning tool (referred to as a “pig”).

Iron fouling is an anticipated problem for the seep collection drains in Alternative 9. Intalco indicates fouling can be minimized or avoided by keeping the perforated pipes continuously below the groundwater level, to avoid entry of air that would enable conversion of dissolved ferrous iron to ferric iron sludge within the drain. Similarly, Intalco has suggested that iron fouling of the pumped wells in TP-1 for Alternative 9 can be minimized or avoided by proper well installation and by controlling pumping rates. Pumping rate controls would potentially avoid groundwater drawdown that would expose the well screens to air, and avoid pumping relatively oxygen-rich creek water into the wells (URS 2005b).

Experience at other sites indicates that iron fouling is a major concern, and it is unclear whether Intalco's approach is viable, see Appendix F and URS (2004d). Monitoring would be needed if Alternative 9 is implemented, to determine whether this approach is viable as a permanent remedy. Also, pilot testing would be needed to determine the magnitude of groundwater collection (and whether there was any consequent surface water quality improvement) accomplished by the pumped wells for Alternative 9, since the rate of pumping would be limited to reduce iron fouling and to avoid pumping in clean water from Railroad Creek.

In contrast, Alternatives 10 and 11 would collect groundwater in open ditches, which would provide ready access for removal of iron or aluminum sludges if sludge build-up is a maintenance issue. Alternatives 10 and 11 have only limited lengths of pipe (e.g., across Railroad and Copper Creeks, and within the treatment system) that would require use of a cleanout pig for maintenance.

Intalco has suggested that winter maintenance of the ditches used in Alternatives 10 and 11 would be a problem if they became frozen and ice dams caused release of contaminated groundwater into Railroad Creek. No information is available at the Site to indicate whether flow in collection ditches would continue below a surficial ice crust, and or whether ice dams would be a problem. Also, there is potential for replacing the open trenches with submerged drains (as proposed for the Alternative 9 seep collection) or using wood plank covers as have been used for railway ditches.

Maintenance of the treatment system components is anticipated to be similar for Alternatives 9, 10, and 11. Problems may occur with chemical addition and mixing in winter weather, operation of media filters under freezing conditions, and sludge disposal. Generally the maintenance to mitigate treatment system problems becomes more difficult for alternatives that have larger water treatment volume requirements. However, a system with higher winter flow rates (e.g., Alternative 11) may be less susceptible to freezing-related problems than systems with lower flow rates. The fall low flow rate for the treatment system for Alternative 11 is estimated to be about 615 gpm, while the low flow rate for Alternatives 9 and 10 would be about two-thirds that magnitude.

In summary, while Alternative 11 is not the smallest or least complex alternative, its size and complexity are not disproportionate to the degree of clean up accomplished. Alternative 11 is the only alternative that could be implemented as a final cleanup action for the Site, based on presently available information.

The size and complexity of implementing Alternative 11 are well within the range of cleanups accomplished at other sites.

4.3.2.4.2 Administrative Feasibility

Administrative requirements associated with potential ARARs and the ability of Alternatives 9, 10, and 11 to comply with these potential action- and location-specific ARARs for the Site are presented in Section 4.3.1.2.5.

The land affected by the remedy is under the control of the Forest Service, except for patented mine claims that are owned by Holden Village, Inc. The Agencies anticipate that the remedy will include access and institutional controls on lands owned by Holden Village, Inc.

No wastes are anticipated to be moved off the Site for disposal, with the possible exception of residual processing wastes that could be encountered during clean up of the abandoned mill building, which may designate as state Dangerous Waste. Arrangement for a disposal site for such wastes would not affect selection of one remedial alternative versus another, for Alternatives 9, 10, and 11. Alternative 12 would not include removal or disposal of such wastes.

4.3.2.4.3 Availability of Services and Materials

The technologies required for each of the components in the three alternatives are known and proven technologies. The Agencies anticipate that there will be companies willing to do this work and that the contractors bidding for this work will be experienced in the technologies required for each alternative. Despite the Site's remote geographic location, necessary equipment would be able to be moved to the Site for construction of Alternatives 9, 10, or 11. The availability of off-Site facilities, services, and materials is not anticipated to be a factor in selection of, or successful implementation of, any of the alternatives. There would not be any services or materials required for Alternative 12.

4.3.2.4.4 Summary of Implementability

In summary, considering the issues specified under CERCLA for the fourth of the primary balancing criteria, implementability (technical and administrative feasibility, and availability of services and materials), Alternatives 9, 10, and 11 are similar to one another and each are considered to be implementable.

Each of the alternatives is technically feasible, although construction of the groundwater barrier and collection systems would be more difficult for

Alternative 11, as this has a longer and deeper barrier wall, compared to Alternatives 9 and 10.

The alternatives face similar challenges with cold winters and iron fouling in maintaining operation of the groundwater collection and treatment system over time. Administrative feasibility is not anticipated to affect the alternatives differently.

The necessary services and materials are available to the Site for the three alternatives, but Alternative 9 requires less of these services and materials, as it is more limited in its extent.

Alternative 12 would not require implementation.

4.3.2.5 Cost

Cost is the final primary balancing criteria under CERCLA. This does not enable simple selection of the least cost alternative; rather CERCLA enables the evaluation of alternatives to eliminate an alternative that has comparable effectiveness and implementability but greater cost compared to another alternative [40 CFR § 300.430(e)(7)(iii)]. Additionally, each remedial action selected for comparison "shall be cost effective, provided that it first satisfies the threshold criteria," that is the alternatives should be protective and ARAR compliant [40 CFR § 300.430(f)(1)(ii)(D)].

Of Alternatives 9 through 12, only Alternative 11 meets the CERCLA threshold criteria for selection of a remedy. No other alternative has comparable effectiveness and implementability. The comparison presented below shows cost for the four alternatives for information only, since the alternatives are not equivalent.

Additional expenditures beyond these initial estimates, would be required to make Alternatives 9 and 10, an acceptable final cleanup action that would protect human health and the environment, and meet potential ARARs. On the other hand, the estimated cost for Alternative 11 covers all the work anticipated to be needed for a final remedy at the Site.

	Alternative 9	Alternative 10	Alternative 11
Estimated Capital Cost	$22,600,000	$37,000,000	$65,500,000
Estimated Average Annual O&M Cost	$1,210,000	$1,430,000	$1,650,000
Net Present Value of Capital and O&M Costs (50 years @ 7%)	$38,200,000	$55,100,000	$85,800,000

A summary of cost differences for each alternative is presented in Appendix B.

The future costs for each alternative differ primarily due to differences in the fuel and lime consumption to treat groundwater, and the anticipated treatment system O&M. These differences are largely a function of the different volume of groundwater treated by each alternative. The table below shows the difference in volume of contaminated groundwater that would be collected and treated, compared to the NPV for groundwater treatment over 50 years.

Alternative	Estimated NPV of O&M Cost for 50 Years	Estimated Annual Volume of Contaminated Water Collected and Treated in Millions of Gallons	Unit Cost in $/Million Gallons over 50 Years
9	$6,410,000	324	$396
10	$8,980,000	483	$372
11	$11,000,000	600	$367

These costs are discussed in further detail in Appendix B. There would be no capital or annual operations and maintenance cost for Alternative 12.

4.3.2.6 Primary Balancing Criteria Summary

In summary, there are five primary balancing criteria under CERCLA (long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost), which are used to compare those alternatives that meet the CERCLA threshold criteria. Only Alternative 11 satisfies the threshold criteria. While Alternatives 9, 10, and 12 have not been shown to satisfy the threshold criteria, these three alternatives were compared, along with Alternative 11, with respect to the primary balancing criteria.

Considering the primary balancing criteria under CERCLA, Alternative 11 has significant positive attributes relative to Alternatives 9, 10, and 12, including:

- Alternative 11 provides greater long-term effectiveness and permanence than the other alternatives, because the magnitude of residual risk is greater for Alternative 9, Alternative 12, and possibly Alternative 10; and the adequacy and reliability of controls for Alternatives 9, 10, 11, and 12 are comparable.

- Alternative 11 would reduce toxicity, mobility, and volume of wastes through treatment, the second primary balancing criteria under CERCLA, to a greater degree than the other alternatives.

- Alternatives 9 and 12 have the least potential impact during implementation, but Alternatives 10 and 11 would achieve protection in significantly less time. Alternative 11 poses greater short-term risk for humans and the environment compared to the other alternatives, but only because Alternative 11 would involve more extensive construction than the other alternatives, to addresses all sources of release.

- Considering the issues specified under CERCLA for evaluation of implementability (technical and administrative feasibility, and availability of services and materials), Alternatives 9, 10, and 11 are similar to one another and each are considered to be implementable. Alternative 12 would not require implementation.

- Finally, there is a significant spread in cost for the alternatives, but cost alone is not an acceptable basis for remedy selection.

4.3.3 Modifying Criteria

Two additional criteria, referred to as modifying criteria, are also considered for remedy selection under CERCLA [40 CFR § 300.430(f)(1)(i)(C)]. These modifying criteria are state acceptance and community acceptance.

The CERCLA modifying criteria are a significant consideration during final remedy selection [40 CFR § 300.430(f)(4)(i)]. In the case of this Site, state input has been available throughout the RI/FS process, but little is known about input from the public (other than the PRP). Input from Holden Village Inc. was received during evaluation of the DFFS. Additional public input will include comments on the draft Proposed Plan and supporting documentation. CERCLA uses the modifying criteria along with the primary balancing criteria to determine what is the most practicable among alternatives that are both protective and ARAR-compliant.

4.3.3.1 State Acceptance

CERCLA requires that state concerns be assessed as part of evaluation of alternatives, including the state's position and key concerns related to the recommended alternative and other alternatives; and state comments on ARARs or proposed use of ARAR waivers [40 CFR § 300.430(e)(9)(iii)(H)].

4.3.3.1.1 State's Position and Key Concerns Related to the Alternatives

The State of Washington is concurrently addressing the Site through its independent cleanup authority under MTCA. Key state concerns related to evaluation of the Alternatives 9, 10, and 11, and selection of a remedy under MTCA, are discussed in this document.

Based on the discussion in Section 4.2 and Appendix G, the state has determined that the Alternative 11 is the only alternative acceptable as a final remedy, as it is the only alternative that meets the MTCA threshold requirements for remedy selection.

4.3.3.1.2 State Comments on Potential ARARs or the Proposed Use of Waivers

The state has not separately provided any comments on potential ARARs for the Site clean up, but has participated in joint preparation of documents with the Forest Service and EPA, including the preparation of this document.

4.3.3.2 Community Acceptance

Community acceptance of alternatives will be evaluated after the public comment period ends, and will be described in the ROD for the Site.

4.3.4 Summary of CERCLA Comparative Analysis of Alternatives

Under CERCLA, a detailed analysis "consists of an assessment of individual alternatives against each of the nine evaluation criteria and a comparative analysis that focuses upon the relative performance of each alternative against those criteria" [40 CFR § 300.430(e)(9)(ii)]. The purpose of the comparative analysis is to identify the relative advantages and disadvantages among the alternatives and to provide information necessary for the lead Agency to select a remedy [55 FR 8719]. Alternative 12 would not satisfy potential ARARs or protect human health and the environment. This section provides a summary of the comparative analysis of Alternatives 9 through 11.

Alternative 11 meets the threshold criteria under CERCLA. Alternative 10 cannot at this point be shown to completely satisfy the threshold criteria. Alternatives 9 does not satisfy the threshold criteria.

Alternatives 9, 10, and 11 differ in the degree to which they are protective of human health.

- These three alternatives would protect humans from exposure to contaminated groundwater as potential drinking water through the use of institutional controls.

- However, Alternatives 10 and 11 would protect human health from risk of exposure to mine tailings to a greater extent that Alternative 9, through consolidation and capping all the existing exposed tailings.

Alternatives 9, 10, and 11 differ significantly in their ability to be protective of the environment.

Alternative 11 would provide more protection of aquatic life than the other alternatives.

- Alternative 11 would directly intercept (contain) and collect for treatment all the groundwater above proposed cleanup levels that discharges into Railroad Creek. Containment and collection for treatment would begin immediately after implementation, without relying on source depletion and natural attenuation. Alternative 11 would clean up groundwater where it enters surface water, at the point of compliance, rather than relying on upgradient source depletion and natural attenuation or downstream mixing.

- Alternative 10 would immediately address contaminated releases to Railroad Creek from most but not all of the Site. Alternative 10 could be implemented as an interim remedy, but additional actions would be needed to satisfy requirements for a final remedy. There is some uncertainty regarding the effectiveness of the PPB wall proposed for Alternative 10, and the effectiveness of the tailings pile and waste rock closure would need to be verified during RD.

- Alternative 9 does not meet the threshold criteria, because it does not stop the release of contaminated groundwater into Railroad Creek from TP-2 and TP-3, part of TP-1, and the LWA. As previously discussed, reliance on source depletion and natural attenuation means groundwater discharging from parts of the Site would continue to exceed aquatic life protection criteria for hundreds of years.

Alternatives 10 and 11 would do more to protect Railroad and Copper Creeks from a potential massive release of reactive tailings compared to other alternatives.

- Alternatives 10 and 11 include regrading all the tailings pile slopes to improve stability and setback of the toe of the slopes to provide protection from erosion and scour.

- Alternative 9 does not include any regrading of TP-3, and does not include any setback of the toe of slope from the creeks.

Alternative 11 would provide more protection of terrestrial ecological receptors than the other alternatives.

- Alternative 11 provides greater assurance of reducing terrestrial toxicity risks associated with the tailings piles.

- Alternative 10 may protect terrestrial ecological receptors from exposure to the tailings; however, the protectiveness of the Alternative 10 covers has not yet been demonstrated.

- Alternative 9 only includes limited regrading and covering of newly exposed slopes on TP-1 and TP-2.

In addition, Alternatives 10 and 11 (but not Alternative 9) provide for additional terrestrial risk assessment to determine whether soil cleanup would be required in other areas of the Site with soils above proposed cleanup levels.

Alternatives 9, 10, and 11 differ significantly in their ability to meet potential ARARs.

- Alternative 11 is anticipated to satisfy all potential ARARs.

- Alternative 10 cannot be shown to satisfy potential chemical-specific ARARs, and potential ARARs related to management of aquatic lands and closure of landfills, on the basis of existing information.

- Alternative 9 would not satisfy potential chemical-specific ARARs and potential ARARs related to closure of landfills, construction stormwater pollution prevention, management of aquatic lands, protection of wetlands, protection of floodplains, and forest management standards.

Alternative 11 is the only alternative that would satisfy the CERCLA threshold criteria and could be selected as a final remedy.

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Table 1 - Summary of Constituents of Concern and Proposed Cleanup Levels

Media of Concern	Constituent of Concern	Proposed Cleanup Level (i)	Basis
Groundwater Used for Drinking Water (b)	Dissolved Metals in ug/L		
	Aluminum	16,000	MTCA Method B (o, w)
	Cadmium	5	Federal MCLGs (j), Federal MCLs (k), State MCLs (m), and MTCA Method A (n)
	Copper	592	Adjusted Federal MCLs (l), Adjusted State MCLs (l), and MTCA Method B (o)
	Iron	--	
	Lead	15	State MCLs (m) and MTCA Method A (n)
	Zinc	4,800	MTCA Method B (o)
Surface Water and Groundwater Discharging to Surface Water (a)	Dissolved Metals in ug/L		
	Cadmium	0.07	Background (c)
	Copper	1.06	Section 304 of the CWA (chronic) (d) (x)
	Lead	0.54	Background
	Zinc	17	Chapter 173-201A WAC (chronic) (e) (c)
	Total Metals in ug/L		
	Aluminum	144	Background
	Iron	1,000	Section 304 of the CWA (chronic) (d)
Soil and Tailings	Total Metals in mg/kg		
	Aluminum	20,900	Background
	Arsenic	20	MTCA Method A (h)
	Barium	310	Background
	Cadmium	5.4	Background
	Chromium	42	Ecological Protection Screening Level (f)
	Copper	57.4	Background
	Lead	250	MTCA Method A (h)
	Mercury	0.1	Ecological Protection Screening Level (f)
	Molybdenum	2	Ecological Protection Screening Level (f)
	Nickel	30	Ecological Protection Screening Level (f)
	Selenium	0.3	Ecological Protection Screening Level (f)
	Silver	2	Ecological Protection Screening Level (f)
	Thallium	1	Ecological Protection Screening Level (f)
	Uranium	5	Ecological Protection Screening Level (f)
	Zinc	253	Background
	Other Constituents in mg/kg		
	Gasoline-Range Hydrocarbons	30/100	MTCA Method A (h) (u)
	Diesel-Range Hydrocarbons	200	Ecological Protection Screening Level (f)
	Heavy Oil-Range Hydrocarbons	2,000	MTCA Method A (h)
Sediment (p)	Total Metals in mg/kg		
	Aluminum	58,000	Literature SQVs (q)
	Beryllium	0.46	State of Washington freshwater SQVs (r)
	Cadmium	0.6	State of Washington freshwater SQVs (r)
	Chromium	95	State of Washington freshwater SQVs (r) and Northwest Regional SEF (s)
	Copper	80	State of Washington freshwater SQVs (r) and Northwest Regional SEF (s)
	Iron	40,000	Literature SQVs (t)
	Silver	0.55	State of Washington freshwater SQVs (r)
	Zinc	130	Northwest Regional SEF (s)

Notes:
-- Not established or not applicable.
TBD = To Be Determined
(a) Proposed cleanup levels shown are based on surface water aquatic life protection criteria and assuming groundwater discharging to surface water.
(b) Drinking water criteria should also be considered for surface water if classified as a current or future potential domestic water supply under Chapter 173-201A WAC.
(c) Proposed cleanup level is hardness-dependent; value shown is for a hardness of 12 mg/L as $CaCO_3$ (see SFS text for further discussion).
(d) Water quality criteria published under Section 304 of the Clean Water Act. EPA, National Recommended Water Quality Criteria.
(e) WAC 173-201A. Water Quality Standards for Surface Waters of the State of Washington.
(f) WAC 173-340-740(3)(b)(ii), WAC 173-340-749, WAC 173-340-900 (Table 749-3).
(h) WAC 173-340-740(2)(b)(iii)(A), WAC 173-340-900 (Table 740-1). MTCA Method A.
(i) Proposed cleanup levels based on potential ARARs or background concentrations as applicable (see SFS text for further discussion).
(j) Maximum Contaminant Level Goals (MCLGs) for non-carcinogens. Non-zero MCLGs are potentially relevant and appropriate. 40 CFR 141.50 and 141.51 and Drinking Water Standards and Health Advisories Office.
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(l) WAC 173-340-720(7)(b). MCL was adjusted based on a cancer risk of 1×10^{-5} or a HQ of 1.0.
(m) WAC 246-290-310. State of Washington MCLs.
(n) WAC 173-340-900, Table 720-1. MTCA Method A.
(o) WAC 173-340-720. MTCA Method B Groundwater cleanup levels. For carcinogenic constituents, the value presented is the lower of the non-carcinogenic and carcinogenic level calculated using Equations 720-1 and 720-2. Information from CLARC 3.1 was used unless otherwise noted.
(p) No promulgated freshwater standards for sediment quality. Refer to SFS text for additional information.
(q) Ingersoll et al. 1996.
(r) Updated Sediment Quality Values (SQVs) listed in Avocet 2003. Note that final SQVs have not been selected by Ecology and may differ from the values presented.
(s) US Army Corps of Engineers et al. 2006.
(t) Persaud et al. 1993.
(u) 100 mg/kg is applicable when no benzene is present in soil and the total of BTEX is less than 1% of the gasoline mixture, otherwise 30 mg/kg is applicable.
(w) Reference dose and/or cancer potency factor from EPA Region 9 Preliminary Remediation Goals table, October 2004.
(x) Proposed cleanup level for dissolved copper to be based on the Aquatic Life Ambient Freshwater Quality Criteria - Copper 2007 Revision or background concentration, whichever is higher. Value shown is background.

Table 2 - Areas of the Site with Groundwater Concentrations That Exceed Drinking Water Criteria

Area of Site	Constituent of Concern	Lowest Potential Drinking Water ARAR	Location of Potential Drinking Water ARAR Exceedance (a)	Maximum Concentration at Location in ug/L
Honeymoon Heights	Cadmium	5 ug/L (Federal MCLG, Federal MCL, State MCL, MTCA Method A)	Seep SP-12	18.0
			Seep SP-23	41.8
			Seep SP-23B	28.0
	Copper	592 ug/L (MTCA Method B)	Seep SP-12	2,000
			Seep SP-14	830
			Seep SP-23	6,980
			Seep SP-23B	4,900
Portal	Arsenic	0.058 ug/L (MTCA Method B - carcinogen)	P-1	0.64
			P-5	0.23
	Cadmium	5 ug/L (Federal MCLG, Federal MCL, State MCL, MTCA Method A)	P-1	170
			P-5	80
	Copper	592 ug/L (MTCA Method B)	P-1	10,400
			P-5	4,800
	Lead	15 ug/L (Federal MCL, State MCL, MTCA Method A)	P-1	64
			P-5	37
Mill Building	Cadmium	5 ug/L (Federal MCLG, Federal MCL, State MCL, MTCA Method A)	Seep SP-7	48.0
			Seep SP-22	47.5
			Seep SP-28	51.2
	Copper	592 ug/L (MTCA Method B)	Seep SP-7	7,560
			Seep SP-22	2,140
			Seep SP-28	6,760
Waste Rock Piles	Cadmium	5 ug/L (Federal MCLG, Federal MCL, State MCL, MTCA Method A)	Seep SP-6	173
			Seep SP-8	87.8
			Seep SP-15W	9.4
			Seep SP-15E	74
	Copper	592 ug/L (MTCA Method B)	Seep SP-6	12,700
			Seep SP-8	7,880
			Seep SP-15E	4,930 J
Lower West Area	Arsenic	0.058 ug/L (MTCA Method B - carcinogen)	Seep SP-11	0.30
			Well MW4S	0.40
			Well HBKG-1	0.20
	Cadmium	5 ug/L (Federal MCLG, Federal MCL, State MCL, MTCA Method A)	Seep SP-10E	7.0
			Seep SP-10W	36.0
			Seep SP-11	12.8
			Seep SP-16	53.5
			Seep SP-19	50.1
			Seep SP-24	47.7
			Seep SP-25	34.1
			Well MW2	9.8
			Well MW3	25.5
			Well MW4S	19.9
			Well MW4D	19.8
			Well HBKG-1	55.6
	Copper	592 ug/L (MTCA Method B)	Seep SP-10E	760
			Seep SP-10W	2,210
			Seep SP-16	3,450
			Seep SP-19	4,180
			Seep SP-24	3,660
			Seep SP-25	1,880
			Well MW3	1,340
			Well MW4S	713
			Well HBKG-1	4,030
	Lead	15 ug/L (Federal MCL, State MCL, MTCA Method A)	Seep SP-10E	20

Table 2 - Areas of the Site with Groundwater Concentrations That Exceed Drinking Water Criteria

Area of Site	Constituent of Concern	Lowest Potential Drinking Water ARAR	Location of Potential Drinking Water ARAR Exceedance (a)	Maximum Concentration at Location in ug/L
Tailings Pile 1	Arsenic	0.058 ug/L (MTCA Method B - carcinogen)	Seep SP-2	1.5
	Cadmium	5 ug/L (Federal MCLG, Federal MCL, State MCL, MTCA Method A)	Seep SP-1	22.7
			Seep SP-2	22.8
			Well TP1-6A	100
			Well TP1-7L	2,620
	Copper	592 ug/L (MTCA Method B)	Seep SP-1	698
			Seep SP-2	914
			Well TP1-6A	1,100
			Well TP1-7L	239,000
	Nickel	100 ug/L (State MCL)	Seep SP-2	200
			Well TP1-5A	120
			Well TP1-7L	760
Tailings Pile 2	Arsenic	0.058 ug/L (MTCA Method B - carcinogen)	Seep SP-3	1.6
			Well PZ-3A	6.0
	Cadmium	5 ug/L (Federal MCLG, Federal MCL, State MCL, MTCA Method A)	Seep SP-3	40.3
			Seep SP-4	11.4
			Well TP2-8A	7.0
	Copper	592 ug/L (MTCA Method B)	Seep SP-3	1,280
			Seep SP-4	670
			Well TP2-12L	1,180
	Lead	15 ug/L (Federal MCL, State MCL, MTCA Method A)	Well PZ-3A	69
Tailings Pile 3	Cadmium	5 ug/L (Federal MCLG, Federal MCL, State MCL, MTCA Method A)	Seep SP-5	9.5
			Seep SP-18	25
	Copper	592 ug/L (MTCA Method B)	Seep SP-5	1,100
			Seep SP-18	1,220

(a) Exceedances based on analytical data collected between 1997 and 2006.
(b) Groundwater includes seeps and the Portal discharge, which are surface expressions of groundwater.

Table 3 - Areas of Site with Soil and Tailings Metals Concentrations Exceeding Human Health Direct Exposure Levels

Area of Site	Constituent of Concern	Proposed Cleanup Level in mg/kg (a)	Range of Soil or Tailings (b) Concentration in mg/kg	Number of Samples Analyzed	Number of Samples with Human Health Exceedances (c)	Human Health Critieria Exceedance
Lagoon	Cadmium	5.4	0.7 to 184	20	5	MTCA Method B Soil Ingestion (80 mg/kg) MTCA Method B Soil Ingestion and Dermal Contact (74 mg/kg)
	Copper	57.4	294 to 24,100	20	10	MTCA Method B Soil Ingestion (2,960 mg/kg) MTCA Method B Soil Ingestion and Dermal Contact (2,700 mg/kg)
	Lead	250	52 to 800	20	8	MTCA Method A (250 mg/kg) (d)
	Zinc	253	244 to 23,700	10	1	MTCA Method B Soil Ingestion and Dermal Contact (22,000 mg/kg)
Lower West Area	Arsenic	20	18 to 22	3	1	MTCA Method A (20 mg/kg) (e) MTCA Method B Soil Ingestion (0.67 mg/kg) MTCA Method B Soil Ingestion and Dermal Contact (0.62 mg/kg)
Maintenance Yard	Arsenic	20	1.7 to 60	7	1	MTCA Method A (20 mg/kg) (e) MTCA Method B Soil Ingestion (0.67 mg/kg) MTCA Method B Soil Ingestion and Dermal Contact (0.62 mg/kg)
	Copper	57.4	260 to 3,160	7	1	MTCA Method B Soil Ingestion (2,960 mg/kg) MTCA Method B Soil Ingestion and Dermal Contact (2,700 mg/kg)
	Lead	250	7 to 1,070	7	2	MTCA Method A (250 mg/kg) (d)
Tailings Pile 1	Copper	57.4	230 to 12,400	16	1	MTCA Method B Soil Ingestion (2,960 mg/kg) MTCA Method B Soil Ingestion and Dermal Contact (2,700 mg/kg)
Tailings Pile 2	Cadmium	5.4	0.1 U to 147	14	1	MTCA Method B Soil Ingestion (80 mg/kg) MTCA Method B Soil Ingestion and Dermal Contact (74 mg/kg)
	Copper	57.4	71 to 16,500	14	1	MTCA Method B Soil Ingestion (2,960 mg/kg) MTCA Method B Soil Ingestion and Dermal Contact (2,700 mg/kg)

(a) Proposed cleanup levels based on potential ARARs or background concentrations as applicable (see SFS text for further discussion).
(b) Tailings concentrations included for samples with depths ranging from 0 to 6 feet.
(c) Potential ARAR exceedance included only if the soil concentration was above the proposed cleanup levels (see note a).
(d) Based on prevention of unacceptable blood lead concentrations.
(e) State-accepted background value.

Table 4
Potential Applicable or Relevant and Appropriate Requirements
Chemical-Specific for Surface Water

Analyte	Intalco-Reported Area Background Concentrations	Chapter 173-201A WAC (b) Acute	Chapter 173-201A WAC (b) Chronic	Section 304 of the Clean Water Act (c) Acute	Section 304 of the Clean Water Act (c) Chronic	Section 304 of the Clean Water Act (c) Consumption of Water and Organism	Section 304 of the Clean Water Act (c) Consumption of Organism Only	National Toxics Rule Criteria (d) Acute	National Toxics Rule Criteria (d) Chronic	National Toxics Rule Criteria (d) Consumption of Water and Organism	National Toxics Rule Criteria (d) Consumption of Organism Only	MTCA Method B (e) WAC 173-340-730 (Fish Ingestion)	Lowest Potential Surface Water ARAR (f)	Proposed Agency-Selected Surface Water Cleanup Level (h)
Total Metals in µg/L														
Aluminum	144	--	--	750	87	--	--	--	--	--	--	--	87	144
Arsenic	1.44	--	--	--	--	0.018	0.14	--	--	0.018	0.14	0.098	0.018	
Barium	6.24	--	--	--	--	1,000	--	--	--	--	--	--	1,000	
Beryllium	<0.04	--	--	--	--	--	--	--	--	--	--	273	273	
Cadmium	0.10	--	--	--	--	--	--	--	--	--	--	20	20	
Calcium	6,814	--	--	--	--	--	--	--	--	--	--	--	--	
Chromium III	0.46	306	36	--	--	--	--	--	--	--	--	243,000(Cr^{III})/ 486(Cr^{VI})	36	
Copper	1.83	--	--	--	--	1,300	--	--	--	--	--	2,660	1,300	
Iron	177	--	--	--	1,000	300 (g)	--	--	--	--	--	--	1,000	1,000
Lead	0.3	--	--	--	--	--	--	--	--	--	--	--	--	
Magnesium	647	--	--	--	--	--	--	--	--	--	--	--	--	
Manganese	5.06	--	--	--	--	50	100	--	--	--	--	--	50	
Mercury	0.00066	--	0.012	--	--	--	--	--	0.012	0.14	0.15	--	0.012	
Molybdenum	0.79	--	--	--	--	--	--	--	--	--	--	--	--	
Nickel	0.4	--	--	--	--	610	4,600	--	--	--	--	1,100	610	
Potassium	672	--	--	--	--	--	--	--	--	--	--	--	--	
Selenium	<0.2	20	5.0	--	5.0	170	4,200	20	5	610	4,600	2,700	5.0	
Silver	0.1	--	--	--	--	--	--	--	--	--	--	25,900	25,900	
Sodium	1034	--	--	--	--	--	--	--	--	--	--	--	--	
Thallium	<0.04	--	--	--	--	0.24	0.47	--	--	1.7	6.3	1.6	0.24	
Uranium	0.06	--	--	--	--	--	--	--	--	--	--	--	--	
Zinc	5	--	--	--	--	7,400	26,000	--	--	--	--	16,500	7,400	
Dissolved Metals in µg/L														
Aluminum	37.4	--	--	--	--	--	--	--	--	--	--	--	--	
Arsenic	0.9	360	190	340	150	0.018	0.14	360	190	0.018	0.14	0.098	0.018	
Barium	17.5	--	--	--	--	1,000	--	--	--	--	--	--	1,000	
Beryllium	<0.04	--	--	--	--	--	--	--	--	--	--	273	273	
Cadmium	0.07	0.37	0.21	0.26	0.06	--	--	0.37	0.21	--	--	20	0.06	0.07
Calcium	6,703	--	--	--	--	--	--	--	--	--	--	--	--	
Chromium III	<0.02	96.7	31	100	13	--	--	96.7	31	--	--	243,000	13	
Chromium VI	<0.02	15	10	16	11	--	--	15	10	--	--	486	10	
Copper	1.06	2.3	1.9	(i)	(i)	1,300	--	2.3	1.9	--	--	2,660	(i)	1.06
Iron	40	--	--	--	1,000	300 (g)	--	--	--	--	--	--	1,000	
Lead	0.54	6.0	0.24	6.0	0.24	--	--	6.0	0.24	--	--	--	0.24	0.54
Magnesium	626	--	--	--	--	--	--	--	--	--	--	--	--	
Manganese	2.42	--	--	--	--	50	100	--	--	--	--	--	50	
Mercury	0.05	2.1	--	1.4	0.77			2.1	--	0.14	0.15	--	0.14	
Molybdenum	0.78	--	--	--	--	--	--	--	--	--	--	--	--	
Nickel	0.39	235	26	77.9	9.0	610	4,600	235	26	610	4,600	1,100	9.0	
Potassium	660	--	--	--	--	--	--	--	--	--	--	--	--	
Selenium	<0.2	--	--	--	4.6	170	4,200	--	--	--	--	2,700	170	
Silver	<0.04	0.09	--	0.09	--	--	--	0.09	--	--	--	25,900	0.09	

Table 4
Potential Applicable or Relevant and Appropriate Requirements
Chemical-Specific for Surface Water

		Chapter 173-201A WAC (b)		Section 304 of the Clean Water Act (c)				National Toxics Rule Criteria (d)				MTCA Method B (e)		
Analyte	Intalco-Reported Area Background Concentrations	Acute	Chronic	Acute	Chronic	Consumption of Water and Organism	Consumption of Organism Only	Acute	Chronic	Consumption of Water and Organism	Consumption of Organism Only	WAC 173-340-730 (Fish Ingestion)	Lowest Potential Surface Water ARAR (f)	Proposed Agency-Selected Surface Water Cleanup Level (h)
Sodium	1,078	--	--	--	--	--	--	--	--	--	--	--	--	
Thallium	<0.04	--	--	--	--	0.24	0.47	--	--	1.7	6.3	1.6	0.24	
Uranium	0.172	--	--	--	--	--	--	--	--	--	--	--	--	
Zinc	7.81	19	17	19	20	7,400	26,000	19	17.3	--	--	16,500	17	17

Notes:
Drinking water criteria shown in Table 6 should also be considered if surface water is classified as a current or future potential domestic water supply under Chapter 173-201A WAC.
-- Not established or not applicable.
Underlined values require hardness correction specific to the sample data. The values presented in this table are based on a hardness of 12 mg/L $CaCO_3$.
(a) Forest Service 2002.
(b) Chapter 173-201A WAC. Water Quality Standards for Surface Waters of the State of Washington (Last update November 20, 2006).
(c) Water quality criteria published under Section 304 of the Clean Water Act. EPA, National Recommended Water Quality Criteria, 2006.
(d) National Toxics Rule. 40 CFR 131.26(b)(1).
(e) Chapter 173-340-730 WAC. MTCA Method B surface water cleanup levels. For carcinogenic constituents, the value presented is the lower of the non-carcinogenic and carcinogenic level calculated using Equations 730-1 and 730-2 and information from CLARC 3.1, unless otherwise noted.
(f) Lowest potential ARAR from shaded source.
(g) For purposes of the Holden Mine Cleanup, the Agencies agreed with Intalco that secondary MCLs not defined to be health-based standards will not be enforced (see Forest Service 2003).
(h) Proposed cleanup levels were selected for constituents of concern at the site. If the background level was above the lowest potential surface water ARAR, the background concentration was selected as the cleanup level, as neither CERCLA nor MTCA requires cleanup below background concentrations.
(i) The Aquatic Life Ambient Freshwater Quality Criteria--Copper 2007 Revision (EPA 2007), was published in the Federal Register on February 22, 2007, but to date, there are insufficient data to provide a basis for predicting acute and chronic copper concentrations for Railroad Creek. The Agencies anticipate additional information will be available to establish cleanup levels at the time of the ROD.

Table 5 - Concentrations of Constituents of Concern in Surface Water

Constituents of Concern	Proposed Cleanup Levels (b)	Range of Seasonal Concentrations in Surface Waters (a)									
		RC-6		RC-4		RC-2		RC-5		RC-3	
		Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Dissolved Metals in ug/L											
Cadmium	0.07 (c)	0.03	0.02	**0.42**	0.05	**0.35**	**0.12**	**0.58**	**0.13**	**0.2**	**0.09**
Copper	1.06 (d)	0.81	0.48	**23**	**1.7**	**14**	**1.1**	**24**	**1.6**	**6.8**	0.8
Lead	0.54	0.29	0.5	0.34	0.3	0.33	0.08	0.23	0.1	0.13	0.15
Zinc	17 (c)	7.6	6	**71**	11	**64**	**27**	**91**	**30**	**34**	**20**
Total Metals in ug/L											
Aluminum	144	114	43	118	38	**180**	93	**230**	120	140	60
Iron	1000	133	83	103	70	577	**1,650**	615	**1,440**	486	652
Flow in gpm		231,000	58,900	144,000	55,200	261,000	44,800	239,000	58,000	303,000	52,300

(a) Concentrations shown are average spring concentrations and average fall concentrations of point measurements taken at different times during the spring and fall at each station. When calculating average concentrations, values of one half the detection limit were used to represent samples in which a
(b) See Table 4 for basis for proposed cleanup levels.
(c) Proposed cleanup level is hardness-dependent; value shown is for a hardness of 12 mg/L as $CaCO_3$ (see SFS text for further discussion).
(d) Proposed cleanup level for dissolved copper to be based on the Aquatic Life Ambient Freshwater Quality Criteria - Copper 2007 Revision (EPA 2007) or background concentration, whichever is higher. Value shown is background.
Sample concentrations used to generate the information presented in this table were obtained from the URS Holden Lab Results database updated through October 2003.
Bolded value indicates concentration exceeds the proposed cleanup level.

Table 6
Potential Applicable or Relevant and Appropriate Requirements
Chemical-Specific for Groundwater

Analyte	Potential Area Background (a)	Potential Drinking Water ARARs: Federal MCLGs (b)	Federal MCLs (c)	State MCLs (e)	Adjusted State MCLs (d)	MTCA Method A (f)	MTCA Method B (g)	Lowest Potential Drinking Water ARAR (h)	Proposed Cleanup Levels: Groundwater Used for Drinking Water (n)	Groundwater Discharging to Surface Water (o)
Dissolved Metals in µg/L										
Aluminum	20 U to 100	--	--	--	--	--	16,000 (i)	16,000	16,000	144 (p)
Arsenic	0.1 U to 0.2 U	--	10	10	0.58	5	0.058	0.58		
Barium	1.6 to 14 U	2,000	2,000	2,000	--	--	1,120 (j)	1,120		
Beryllium	0.04 U to 1.0 U	4	4	4	--	--	32	4		
Cadmium	0.04 U to 0.2 U	5	5	5	--	5	8	5	5	0.07
Calcium	12,400 to 16,100	--	--	--	--	--	--	--		
Chromium (total)	0.5 U to 5 U	100	100	100	--	100/50 (k)	24,000/48 (l)	100/50 (k)		
Copper	0.5 U to 3.2 J	1,300 at tap	1,300 at tap (action level)	1,300	--	--	592	592	592	1.06
Iron	20 U to 80	--	--	300 (m)	--	--	--	--	--	1000 (p)
Lead	1 U to 2.6	0 at tap	15 at tap (action level)	15	--	15	--	15	15	0.54
Magnesium	1,800 to 2,380	--	--	--	--	--	--	--		
Manganese	0.5 U to 2.3	--	--	50 (m)	--	--	2,240 (j)	2,240		
Mercury	n/a	2	2	2	--	2	4.8	2		
Molybdenum	0.9 to 1.1	--	--	--	--	--	80	80		
Nickel	0.1 U to 10 U	--	--	100	--	--	320	100		
Potassium	860 to 3,140	--	--	--	--	--	--	--		
Selenium	n/a	50	50	50	--	--	80	50		
Silver	0.1 U to 0.5 U	--	--	100 (m)	--	--	80	80		
Sodium	1,400 to 4,750	--	--	--	--	--	--			
Thallium	n/a	0.5	2	2	--	--	1.1	0.5		
Uranium	n/a	--	30	--	--	--	48 (i)	30		
Zinc	4 U to 8	--	--	5,000 (m)	--	--	4,800	4,800	4,800	17

Notes:

-- Not established or not applicable.

n/a = not available

(a) Potential range in values shown for discussion only. Sufficient data are not available to calculate area background.
Forest Service (2002) recommended that data from HV-3 be used as an estimate, with a footnote that the area background concentration values will be calculated when data are available that satisfy statistical criteria.

(b) Maximum Contaminant Level Goals (MCLGs) for non-carcinogens. Non-zero MCLGs are potentially relevant and appropriate. 40 CFR 141.50 and 141.51 and Drinking Water Standards and Health Advisories Office.

(c) Maximum Contaminant Levels (MCLs). 40 CFR 141.62 and Drinking Water Standards and Health Advisories, Office of Water, US EPA, EPA 822-B-00-001, Summer 2000.

(d) WAC 173-340-720(7)(b). MCL was adjusted based on a cancer risk of 1×10^{-5} or a HQ of 1.0.

(e) WAC 246-290-310. State of Washington MCLs.

(f) WAC 173-340-900, Table 720-1. MTCA Method A.

(g) WAC 173-340-720. MTCA Method B Groundwater cleanup levels. For carcinogenic constituents, the value presented is the lower of the non-carcinogenic and carcinogenic level calculated using Equations 720-1 and 720-2. Information from CLARC 3.1 was used unless otherwise noted.

(h) Lowest potential drinking water ARAR from shaded source.

(i) Reference dose and/or cancer potency factor from EPA Region 9 Preliminary Remediation Goals table, October 2004.

(j) Using an inhalation correction factor of 1 for metals, rather than 2, which is listed in CLARC 3.1.

(k) Adjusted MCL/MTCA Method A value of 50 µg/L based on chromium VI. If only chromium III is present, an MCL of 100 µg/L may be used.

(l) 24,000 µg/L (Chromium III), 48 µg/L (Chromium VI).

(m) Secondary State of Washington MCLs, per 246-290-310 WAC. For purposes of the Holden Mine Cleanup, the Agencies agreed with Intalco that secondary MCLs not defined to be health-based standards will not be enforced (see Forest Service, 2003).

(n) Proposed cleanup levels were selected for constituents of concern at the site using the lowest potential drinking water ARAR.

(o) Proposed cleanup levels are based on surface water criteria assuming a point of compliance at the groundwater-surface water interface. Surface water criteria are established in Table 4.

(p) Proposed cleanup levels are for total Aluminum and Iron.

Table 7 - Concentrations of Constituents of Concern in Groundwater (Including Seeps)

			Range of Seasonal Concentrations for Areas of Interest (a)																	
	Proposed Cleanup Levels (l)		Honeymoon Heights (c)		Portal Drainage (d)		Mill Building (e)		Waste Rock Piles (f)		Lower West Area (g)		Tailings Pile 1 (h)		Tailings Pile 2 (i)		Tailings Pile 3 (j)		Wells East of Tailings Pile 3 (k)	
Constituents of Concern	**Groundwater Used for Drinking Water**	**Groundwater Discharging to Surface Water**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**
Dissolved Metals in ug/L																				
Aluminum	16,000	144 (m)	**6,800**	10	**5,800**	20	**190**	**1800**	**12,000**	--	**1,200**	**550**	**56,000**	**23,000**	**12,000**	**870**	**1,400**	**3,000**	**880**	**1,100**
Cadmium	5	0.07 (n)	**35**	**0.3**	**53**	**8**	**36**	**48**	**130**	--	**16**	**26**	**19**	**11**	**9.5**	**1.8**	**0.20**	**2.0**	**1.10**	**0.90**
Copper	592	1.06 (o)	**6,100**	**22**	**2,300**	**28**	**2,700**	**7,600**	**10,000**	--	**1,200**	**1,600**	**340**	**470**	**440**	**20**	**48**	**42**	**2.7**	**3.9**
Iron	--	1000 (m)	10	10	190	10	100	710	30	--	500	620	**310,000**	**520,000**	**54,000**	**43,000**	**3,000**	**37,000**	25	70
Lead (b)	15	0.54	**10**	0.5	**33**	0.5	**3.0**	**13**	**15**	--	**20**	0.50	**50**	**5.0**	**69**	**52**	**280**	**100**	0.50	0.50
Zinc	4,800	17 (n)	**4,500**	**20**	**8,800**	**3,000**	**4,900**	**6,400**	**16,000**	--	**2,300**	**3,500**	**6,800**	**3,800**	**980**	**260**	**100**	**170**	**140**	**120**
Flow in gpm			288	4.76	1530	68.2	83.0	2.00	16.0	--	149	72.9	247	127	639	203	1030	269	nd	nd

(a) Unless otherwise noted, the spring and fall data used to determine the concentrations shown in this table were obtained from the DFFS, which used May 1997 data to represent spring and September 1997 data to represent fall. Flow measurements are compiled from the DFFS seeps and flow tubes with the exception of the Lower West Area, which uses a groundwater discharge estimate calculated by the Agencies (Hart Crowser 2005a). Values of one half the detection limit were used to represent samples in which a metal was not detected.
(b) Lead concentrations shown are not average concentrations, but are peak spring and fall concentrations from point measurements within the specified area, and these concentrations may not be representative of the entire area. The peak spring and fall concentrations of lead were obtained from the URS Holden Lab Results database updated through October 2003.
(c) Honeymoon Heights concentrations are average concentrations from seeps SP-12, SP-23, SP-23B, and SP-26. In the fall only SP-26 was flowing.
(d) Portal Drainage concentrations shown are from individual samples taken at the point where the drainage intersects Railroad Creek (P-5).
(e) Mill Building concentrations are average concentrations from seeps SP-7 and SP-22. In the fall only SP-7 was flowing.
(f) Waste Rock Piles concentrations are average concentrations from seeps SP-6 and SP-8. Neither SP-6 nor SP-8 were flowing during the fall.
(g) Lower West Area spring concentrations are average concentrations from seeps SP-9, SP-10E, SP-10W, SP-11, SP-24, and SP-25 and groundwater monitoring wells MW-1 and HBKG-1. Spring concentration data for MW-1 and HBKG-1 from June 2006 were used and were obtained from the URS Holden Lab Results database updated through June 2006. Lower West Area fall concentrations are average concentrations from groundwater monitoring wells MW-1 and HBKG-1; none of the seeps were flowing during the fall. MW-1 fall concentration data were only available for October 2003 and were obtained from the URS Holden Lab Results database updated through October 2003.
(h) Tailings Pile 1 spring concentrations are average concentrations from seeps SP-1 and SP-2 and groundwater monitoring wells TP1-2A,TP1-3A,TP1-5A, and TP1-6A. Tailings Pile 1 fall concentrations are average concentrations from seep SP-2 and groundwater monitoring wells HBKG-1, TP1-2,TP1-3,TP1-5,and TP1-6A.
(i) Tailings Pile 2 spring concentrations are average concentrations from seeps SP-3 and SP-4 and groundwater monitoring wells TP2-11, TP2-4A, TP3-8A, and PZ-3A. Tailings Pile 2 fall concentrations are average concentrations from seeps SP-3 and SP-4 and groundwater monitoring wells TP2-11A, TP2-4A, and PZ-3A.
(j) Tailings Pile 3 spring concentrations are average concentrations from seeps SP-4 and SP-21 and groundwater monitoring wells TP3-8A, TP3-10, and PZ-6A. Tailings Pile 3 fall concentrations are average concentrations from seep SP-21 and groundwater monitoring wells DS-1, PZ-6A, and TP3-9.
(k) Wells East of Tailings Pile 3 spring concentrations are peak concentrations from wells DS-3D, DS-3S, DS-4D, DS-4S, and DS-5 in June 2002. Wells East of Tailings Pile 3 fall concentrations are peak concentrations from wells DS-3D, DS-3S, DS-4D, DS-4S, and DS-5 in November 2001 and October 2002. Discharge into creek not determined (nd).
(l) See Table 6 for basis for proposed cleanup levels.
(m) Proposed cleanup levels are for total Aluminum and Iron.
(n) Proposed cleanup level is hardness-dependent; value shown is for a hardness of 12 mg/L as $CaCO_3$ (see SFS text for further discussion).
(o) Proposed cleanup level for dissolved copper to be based on the Aquatic Life Ambient Freshwater Quality Criteria - Copper 2007 Revision or background concentration, whichever is higher. Value shown is background.
Bolded value indicates concentration exceeds the surface water proposed cleanup level.
-- No cleanup level established or no flow.

Table 8
Potential Applicable or Relevant and Appropriate Requirements
Chemical-Specific for Soil

Analyte	Intalco-Reported Area Background Concentrations	Ecology-Reported Natural Background (b)	MTCA Method A (c)	MTCA Method B							Lowest Potential Soil ARAR (i)	Proposed Agency-Selected Soil Cleanup Level (n)
				Soil Ingestion (d)	Soil Ingestion and Dermal Contact (d)	Protection of Groundwater (e, f)	Protection of Surface Water (e, f, g)	Protection of Plants (o)	Protection of Soil Biota (p)	Protection of Wildlife (q)		
Total Metals in mg/kg												
Aluminum	20,900	33,400	--	--	--	--	--	50	--	--	50	20,900
Arsenic	11.6	5	20	0.67	0.62	0.034	0.011	-- / 10 (j)	-- / 60 (j)	7 / 132 (j)	0.011	20
Barium	310	--	--	5,600	5,000	925	820	500	--	102	102	310
Beryllium	0.2	2	--	160	140	63	4,300	10	--	--	10	10
Cadmium	5.4	1	2	80	74	0.69	0.012	4	20	14	0.012	5.4
Calcium	12,100	--	--	--	--	--	--	--	--	--	--	
Chromium III	37.2	38 (k)	2,000	120,000	110,000	2,000	260	42 (r, s)	42 (r, s)	67 (r, s)	42	42
Chromium VI	--	38 (k)	19	240	220	19	3.8				3.8	
Copper	57.4	26	--	2,960	2,700	260	0.67	100	50	217	0.67	57.4
Iron	24,100	51,500	--	--	--	--	--	--	--	--	--	
Lead	20.6	11	250	--	--	3,000	48	50	500	118	48	250
Magnesium	9,200	--	--	--	--	--	--	--	--	--	--	
Manganese	1,430	1,100	--	11,200	10,100	--	--	1,100 (s)	--	1,500	1,100	1,430
Mercury (inorganic)	0.05	0.05	2	24	18	2.1	0.013	0.3	0.1	5.5	0.013	0.1
Molybdenum	1.2	--	--	400	360	--	--	2	--	7	2	2
Nickel	22.7	46	--	1,600	1,400	130	12	30	200	980	12	30
Potassium	1,260	--	--	--	--	--	--	--	--	--	--	
Selenium	--	--	--	400	360	5.3	0.48	1	70	0.3	0.3	0.3
Silver	0.5	--	--	400	360	13.7	0.015	2	--	--	0.015	2
Sodium	827	--	--	--	--	--	--	--	--	--	--	
Thallium	0.4	--	--	5.6	5	1.6	0.34	1	--	--	0.34	1
Uranium	1	--	--	240	220	--	--	5	--	--	5	5
Zinc	253	79	--	24,000	22,000	6,000	21	86 (s)	200	360	21	253
Total Petroleum Hydrocarbons in mg/kg												
Gasoline-Range Hydrocarbons	--	--	30 / 100 (l)	--	--	--	--	--	100	5000 (t)	30 / 100	30 / 100
Diesel-Range Hydrocarbons	--	--	2,000	--	--	--	--	--	200	6000 (t)	200	200
Heavy Oil-Range Hydrocarbons	--	--	2,000	--	--	--	--	--	--	--	2,000	2,000
Polychlorinated Biphenyls in µg/kg												
Aroclor 1016	--	--	1,000 (m)	5,600	4,100	210	0.14	40,000 (m)	--	650 (m)	0.14	650
Aroclor 1221	--	--	1,000 (m)	500 (m)	360 (m)	270	0.40	40,000 (m)	--	650 (m)	0.40	360
Aroclor 1232	--	--	1,000 (m)	500 (m)	360 (m)	270	0.40	40,000 (m)	--	650 (m)	0.40	360
Aroclor 1242	--	--	1,000 (m)	500 (m)	360 (m)	270	0.40	40,000 (m)	--	650 (m)	0.40	360
Aroclor 1248	--	--	1,000 (m)	500 (m)	360 (m)	270	0.40	40,000 (m)	--	650 (m)	0.40	360
Aroclor 1254	--	--	1,000 (m)	500 (m)	360 (m)	270	0.40	40,000 (m)	--	650 (m)	0.40	360
Aroclor 1260	--	--	1,000 (m)	500 (m)	360 (m)	720	1.10	40,000 (m)	--	650 (m)	1.10	360
Total PCBs	--	--	1,000	500	360	270	0.40	40,000	--	650	0.40	360

Notes:
-- Not established or not applicable.
(a) Forest Service 2002.
(b) Data from Natural Background Soil Metals Concentrations in Washington State, Yakima Basin (Ecology 1994).
(c) WAC 173-340-740(2), WAC 173-340-900 (Table 740-1). Model Toxics Control Act (MTCA) Method A.
(d) WAC 173-340-740(3). MTCA Method B Unrestricted land use soil cleanup standards. For carcinogenic constituents, the value presented is the lower of the non-carcinogenic and carcinogenic level calculated using Equations 740-1 and 740-2 for ingestion only. Equations 740-4 and 740-5 for ingestion and dermal contact. Information from CLARC 3.1 was used unless otherwise noted.
(e) WAC 173-340-740(3)(b)(iii)(A); MTCA Method B unrestricted land use soil cleanup standards, groundwater protection. Values calculated using the MTCA three-phase partitioning model WAC 173-340-747(4). MTCA allows development of alternative soil cleanup values for the protection of groundwater through other methods. If any of the values in these columns become significant remedy cost drivers, an alternative soil cleanup value for these pathways may be developed, consistent with MTCA.
(f) Based on lowest potential groundwater and surface water ARARs under MTCA. Not used for proposed cleanup level in accordance with WAC 173-340-740(6)(f); see SFS Section 2.4.
(g) Protection of surface water assumes that groundwater contaminants are likely to reach surface water.
(i) Lowest potential ARAR from shaded source.
(j) Based on Arsenic III / Arsenic V.
(k) Background values based on total chromium.
(l) 100 mg/kg is applicable when no benzene is present in soil and the total of BTEX is less than 1% of the gasoline mixture, otherwise 30 mg/kg is applicable.
(m) These PCB levels based on Total PCBs.
(n) Proposed cleanup levels were selected for constituents of concern at the site. If the site background level was above the lowest potential soil ARAR, the background concentration was selected as the cleanup level, as neither CERCLA nor MTCA requires cleanup below background concentrations. These cleanup levels are tentative, as further assessment of the ecological risk will occur at the Site. MTCA Method A values selected for arsenic and lead based on state-wide background concentrations.
(o) MTCA 173-340-900 (Table 749-3).
(p) MTCA 173-340-900 (Table 749-3).
(q) MTCA 173-340-900 (Table 749-3).
(r) Based on total Chromium.
(s) Benchmark replaced by Washington state natural background concentration.
(t) Except that the concentration shall not exceed the residual saturation at the soil surface.

Table 9 - Concentrations of Constituents of Concern in Soil and Tailings

Constituents of Concern	Proposed Cleanup Levels (a)	Range of Surface Soil Concentrations							Range of Tailings Concentrations From 0 to 6 Feet Deep		
		Wilderness Area	Baseball Field	Lower West Area	Lagoon	Maintenance Yard	Holden Village	Wind-Blown Tailings Area	Tailings Pile 1	Tailings Pile 2	Tailings Pile 3
Total Metals in mg/kg											
Aluminum	20,900	15,200 to 17,500	20,300	15,500 to 16,500	**20,000 to 51,500**	**14,700 to 23,900**	**15,300 to 25,900**	6,510 to 20,700	**5,280 to 39,000**	**4,810 to 38,000**	**5,780 to 44,000**
Arsenic	20	10.7 to 11.4	10.8	**18 to 22**	1.9 to 5.0	**1.7 to 60**	1.1 to 5.1	1.9 to 3.1	1.9 to 6.5	0.4 to 2.8	0.3 to 2.9
Barium	310	79 to 93	101	55 to 71	**287 to 343**	**34 to 717**	**102 to 380**	**79 to 388**	**180 to 860**	**101 to 1,200**	**100 to 900**
Cadmium	5.4	0.9 to 3.1	1.3	0.4 to 3.9	**0.7 to 184**	**0.9 to 21.6**	0.7 to 2	0.4 to 0.6	**0.1 U to 43**	**0.1 U to 147**	**0.1 U to 20**
Chromium	42	21 to 28	29	24 to 26	21 to 21	17 to 33	**11 to 58**	10 to 29	5 to 13	**6.4 to 50**	**6 to 62**
Copper	57.4	**81 to 147**	**63**	**41 to 255**	**294 to 24,100**	**260 to 3,160**	**34 to 523**	**107 to 332**	**230 to 12,400**	**71 to 16,500**	**85 to 677**
Lead	250	16 to 37	15	11 to 13	**52 to 800**	**7 to 1,070**	5 to 103	7 to 62	59 to 140	4 to 83	4 to 89
Manganese	1,430	365 to 455	537	396 to 401	206 to 625	150 to 426	301 to 1,270	135 to 292	113 to 470	122 to 657	128 to 500
Mercury	0.1						0.02 to 0.06		**0.33 to 0.52**	**0.19 to 0.51**	**0.13 to 0.40**
Molybdenum	2	**1.5 to 2.4**	1.0		**6.6 to 74**	**0.6 U to 16**	**0.6 U to 5**	**0.7 U to 32**	**21 to 33**	**1.0 to 34**	**1.3 to 32**
Nickel	30	12 to 17	18	14 to 14	10 U to 13	11 to 23	11 to 27	3 to 17	1.1 U to 20	**1.0 to 70**	**1.0 to 39**
Selenium	0.3						0.9 U to 1.1 U		**2.5 to 28**	**1.3 U to 17.9**	**1.3 U to 17.1**
Silver	2	0.5 to 0.6	0.5	0.3 U to 0.3 U	**0.7 to 27**	**0.3 U to 5**	0.3 U to 2	**0.4 U to 2.8**	**1.6 to 7.5**	**0.5 to 6.7**	**0.5 to 7.2**
Thallium	1	0.6 U to 0.6 U	0.6 U		**3.0 U to 3.0**	0.6 U to 2 U	0.1 U to 0.8 U	0.7 U to 3 U	**1.0 U to 3**	0.5 U to 0.7	0.5 to 0.9
Uranium	5	2 U to 4	2 U		**6 to 7**	2 U to 2 U	2 U to 3 U	2 U to 3 U	**2 U to 16**	**1.2 U to 7**	**2.0 U to 16**
Zinc	253	**121 to 303**	129	**80 to 346**	**244 to 23,700**	**147 to 3,240**	**90 to 456**	**75 to 260**	**75 to 3,920**	**85 to 6,580**	**78 to 2,880**
Other Constituents in mg/kg											
Gasoline-Range Hydrocarbons	30/100 (b)				9 U to 11 U	**6 U to 1,200**					
Diesel-Range Hydrocarbons	200				**86 to 2,200**	**6 U to 12,000**					
Heavy Oil-Range Hydrocarbons	2,000				120 to 1,900	**11 U to 9,800**					
Aroclor 1260	0.36				0.046 U to 0.051 U	0.017 to 0.046					
No. of Samples (not including background)		2	1	3	20	7	13	5	16	14	16

(a) See Table 8 for basis for proposed cleanup levels. Cleanup levels are potential pending results of further risk-based analyses.
(b) 100 mg/kg is applicable when no benzene is present in soil and the total of BTEX is less than 1% of the gasoline mixture, otherwise 30 mg/kg is applicable.
Blank indicates constituent was not analyzed in samples from this area.
-- Not applicable.
Notes: Ranges of values provided since the number of samples per area is typically not sufficient to determine 95% upper confidence limit.
Background values are omitted from the range of concentrations shown.
Sample concentrations used to generate the information presented in this table were obtained from the URS Holden Lab Results database updated through October 2003.
U: Not detected at detection limit indicated

Table 10 - Potential To Be Considered Chemical-Specific Criteria for Sediments

Analyte	State of Washington Sediment Quality Values (a)				Northwest Regional Sediment Evaluation Framework (h)		Proposed Cleanup Level (g)
	SQS(b)	CSL(b)	LAET(c)	2LAET(c)	SL1 (i)	SL2 (i)	
Total Metals in mg/kg							
Antimony	0.4	0.6	0.6	1.9	--	--	
Arsenic	20	51	31.4	50.9	20	51	
Beryllium	--	--	0.46	--	--	--	0.46
Cadmium	0.6	1	2.39	2.9	1.1	1.5	0.6
Chromium	95	100	95	133	95	100	95
Copper	80	830	619	829	80	830	80
Lead	335	430	335	431	340	430	
Mercury	0.5	0.75	0.8	3.04	0.28	0.75	
Nickel	60	70	53.1	113	60	70	
Silver	2	2.5	0.545	3.5	2.0	2.5	0.55
Zinc	140	160	683	1,080	130	400	130

Total Metals in mg/kg	Literature Sediment Quality Values	Proposed Cleanup Level (g)
Aluminum	58,000(d)	58,000
Iron	40,000(e)	40,000
Manganese	1,800(f)	

Notes:

-- Not established or not applicable.

(a) Updated Sediment Quality Values (SQVs) listed in Avocet (2003). Note that final SQVs have not been selected by Ecology and may differ from the values presented.

(b) Sediment Quality Standards (SQS) and Cleanup Screening Levels (CSLs) as listed for Floating Percentile Approach example presented in Avocet (2003). Example uses mid-point of sensitivity options above 85% and individual polycyclic aromatic hydrocarbons (PAHs) (rather than summed). Example assumes 15% false negatives, approximately 25% false positives, and better than 80% overall accuracy. SQS represents no adverse effects screening level. CSL represents assumed screening level above which cleanup may be required. Avocet (2003) recommends development of SQVs using the Floating Percentile Approach.

Table 10 - Potential To Be Considered Chemical-Specific Criteria for Sediments

Notes (cont'd):

(c) Lowest Apparent Effects Threshold (LAET) and 2LAET as listed in Avocet (2003). Avocet (2003) does not recommend using the AET approach for establishing SQS and CSL standards because of relatively low statistical sensitivity. However, Avocet (2003) indicates that this approach may be appropriate for establishing maximum contaminant concentrations for dredging programs, and as hot spot and early action levels for cleanup programs.

(d) Ingersoll et al., 1996.

(e) Persaud et al., 1993.

(f) Cubbage et al., 1997.

(g) Proposed cleanup levels were selected for constituents of concern at the site using the lowest sediment guideline.

(h) US Army Corps of Engineers et al. 2006.

(i) Interim freshwater sediment quality guidelines. Lower screening level (SL1) corresponds to a concentration below which adverse effects to benthic organisms would not be expected. Upper screening level (SL2) corresponds to a concentration at which minor adverse effects may be observed in the more sensitive groups of benthic organisms.

Table 11 - Concentrations of Constituents of Concern in Sediments

Constiuents of Concern	Proposed Cleanup Levels (a)	Concentrations in Railroad Creek Sediments																Range of Concentrations in Lucerne Bar Sediments
		355	**356**	**367**	**RC-1**	**347**	**BKG 1/2**	**350**	**RC-2**	**345**	**DG-1**	**351**	**352**	**353**	**MP-7**	**354**	**RC-3**	
Total Metals in mg/kg																		
Aluminum	58,000	**86,000**	**87,000**	**78,000**	10,400	**83,000**	11,300	34,000	8,540	**78,000**	9,380	**89,000**	**75,000**	**88,000**	13,300	**76,000**	7,890	9,400 to 19,000
Beryllium	0.46	**1.0**	**1.0**	**1.0**		**1.0**	0.08	1 U		**1.0**	0.07	**1.0**	**1.0**	**1.0**		**1.0**		
Cadmium	0.6	0.5	0.09	**2.0**	0.3 U	**2.0**	**0.9**	0.05 U	0.3 U	0.6	**1.1**	0.06	0.5	0.05 U	**0.9**	0.6	0.5	**0.4 to 3.9**
Chromium	95	79	36	**97**		85	17	18		70	4.4	44	93	52		74		
Copper	80	74	12	37	29	**240**	77	**200**	**101**	**140**	**184**	26	**130**	13	**147**	**150**	59	**46 to 308**
Iron	40,000	**63,000**	**47,000**	**99,000**	15,700	**71,000**	17,000	**150,000**	19,000	**50,000**	20,600	**66,000**	**71,000**	40,000	26,300	**60,000**	14,800	**15,400 to 52,800**
Silver	0.55	0.067 U	0.067 U	0.067 U		0.067 U	**0.64**	**1.2**		0.17	**0.73**	0.067	0.11	0.45		0.01		
Zinc	130	**180**	110	130	62	**270**	110	**250**	113	**280**	126	110	**230**	82	**216**	**330**	**144**	**131 to 580**

(a) Proposed cleanup levels are based on current State of Washington Freshwater Sediment Quality Values, Literature Freshwater Sediment Quality Values, and Northwest Regional Sediment Evaluation Framework Screening Levels. See Table 10 for additional information.
Bolded value indicates concentration exceeds the potential cleanup guideline.
Blank indicates constituent was not analyzed in the sample.
U = Not detected at detection limit indicated.

Media/Area of Concern	Remedial Action Objectives [a]	General Response Actions
Source Areas: • Mine • Mill	Reduce surface water concentrations of hazardous substances to levels that are protective of aquatic life and satisfy ARARs in Railroad Creek and Copper Creek. Contain contaminants of concern in groundwater, mine discharge, and stormwater within an on-site waste management area to prevent migration of contaminants, protect aquatic life, and satisfy ARARs. Reduce exposure to hazardous substances in surface soils, tailings, and other wastes to protect terrestrial organisms and satisfy ARARs. Prevent future releases of tailings into surface water that would increase surface water and sediment concentrations of hazardous substances. Protect human health and satisfy ARARs by reducing risks of human exposure to hazardous substances through direct contact with soil, tailings, and other wastes; and through groundwater as a drinking water resource. Implement the remedial action in a manner that satisfies ARARs and protects human health and the environment, including the Holden Village residential community during and after construction.	• No Action • Institutional Controls and Physical Restrictions 1. Physical Access Controls 2. Legal Access Controls • Monitoring 1. Environmental monitoring • Physical Controls 1. Closure of Underground Mine Portals 2. Underground Mine Backfilling 3. In-mine Water Controls • Source Material/Soil Treatment 1. Monitored Natural Attenuation 2. *Ex situ* Treatment 3. *In situ* Treatment • Source Material/Soil Removal

Media/Area of Concern	Remedial Action Objectives [a]	General Response Actions
Surface Water: • Portal Drainage • Copper Creek Diversion • Railroad Creek • Copper Creek	Reduce surface water concentrations of hazardous substances to levels that are protective of aquatic life and satisfy ARARs in Railroad Creek and Copper Creek. Contain contaminants of concern in groundwater, mine discharge, and stormwater within an on-site waste management area to prevent migration of contaminants, protect aquatic life, and satisfy ARARs. Reduce exposure to hazardous substances in surface soils, tailings, and other wastes to protect terrestrial organisms and satisfy ARARs. Prevent future releases of tailings into surface water that would increase surface water and sediment concentrations of hazardous substances. Implement the remedial action in a manner that satisfies ARARs and protects human health and the environment, including the Holden Village residential community during and after construction	• No Action • Institutional Controls 1. Legal Access Controls • Monitoring 1. Environmental Monitoring • Physical Controls 1. Upgradient Surface Water Controls 2. Downgradient Groundwater Controls • Water Treatment 1. Physical/Chemical/Biological Treatment Options • In-mine Treatment 1. Physical/Chemical/Biological Treatment Options
Groundwater [b]	Contain contaminants of concern in groundwater, mine discharge, and stormwater within an on-site waste management area to prevent migration of contaminants, protect aquatic life, and satisfy ARARs. Protect human health and satisfy ARARs by reducing risks of human exposure to hazardous substances through direct contact with soil, tailings, and other wastes; and through groundwater as a drinking water resource. Implement the remedial action in a manner that satisfies ARARs and protects human health and the environment, including the Holden Village residential community during and after construction	• No Action • Institutional Controls 1. Legal Access Controls • Monitoring 1. Environmental monitoring • Physical Controls 1. Upgradient Groundwater Controls 2. Downgradient Groundwater Controls • Water Treatment 1. Physical/Chemical Treatment 2. Physical/Chemical/Biological Treatment

Table 12 - Remedial Action Objectives and General Response Actions

Media/Area of Concern	**Remedial Action Objectives** [a]	**General Response Actions**
Soil and Soil-Like Wastes • Soils • Tailings • Waste Rock	Reduce exposure to hazardous substances in surface soils, tailings, and other wastes to protect terrestrial organisms and satisfy ARARs. Prevent future releases of tailings into surface water that would increase surface water and sediment concentrations of hazardous substances. Protect human health and satisfy ARARs by reducing risks of human exposure to hazardous substances through direct contact with soil, tailings, and other wastes; and through groundwater as a drinking water resource. Implement the remedial action in a manner that satisfies ARARs and protects human health and the environment, including the Holden Village residential community during and after construction	• No Action • Institutional Controls and Physical Restrictions 1. Physical Access Controls 2. Legal Access Controls • Monitoring 1. Environmental monitoring 2. Stability Monitoring • Containment 1. Erosion Controls 2. Stability Enhancement • Physical Controls 1. Reduce Infiltration 2. Upgradient Diversion and Controls • Source Material/Soil Treatment 1. Monitored Natural Attenuation 2. *Ex situ* Treatment 3. *In situ* Treatment • Source Material/Soil Removal 1. Excavation, Transport and Disposal Options • Consolidation

Table 12 - Remedial Action Objectives and General Response Actions

Media/Area of Concern	Remedial Action Objectives [a]	General Response Actions
Sediment	Remove ferricrete in Railroad Creek to support aquatic life, and monitor sediment quality in Railroad Creek, Copper Creek, and at the Lucerne Bar in Lake Chelan, to determine whether any further action is needed to protect aquatic life and satisfy ARARs. Contain contaminants of concern in groundwater, mine discharge, and stormwater within an on-site waste management area to prevent migration of contaminants, protect aquatic life, and satisfy ARARs. Reduce exposure to hazardous substances in surface soils, tailings, and other wastes to protect terrestrial organisms and satisfy ARARs. Prevent future releases of tailings into surface water that would increase surface water and sediment concentrations of hazardous substances. Implement the remedial action in a manner that satisfies ARARs and protects human health and the environment, including the Holden Village residential community during and after construction	• No Action • Monitoring 1. Environmental monitoring • Sediment Removal 1. Excavation and Disposal

a. Some portions of an RAO may be more or less applicable to the specified media/area of concern than other parts of the same RAO; the entire RAO is provided for completeness. The Forest Service and Ecology also agreed on an RAO to develop appropriate natural resource damage assessment (NRDA) activities consistent with 43 CFR Part 11, to evaluate the potential for coordinated remediation and natural resource restoration activities. While this last RAO was designed to take into account potential benefits of combining the NRDA process with the RI and FS processes, given the remote location and land use at the Site, decisions regarding natural resource damages and/or restoration projects are beyond the scope of this SFS and the RAOs for the remedy selection do not include NRDA.

b. Seeps are considered to be surface expressions of groundwater.

Table 13 - Potential Action- and Location-Specific ARARs that Alternatives 9, 10, and 11 can Comply with in an Equivalent Manner

Potential Action-Specific ARARs:

- Regulation and Licensing of Well Contractors and Operators [RCW 18.104; Chapter 173-162 WAC];
- Minimum Standards for Construction and Maintenance of Water Wells [RCW 18.104; Chapter 173-160 WAC];
- Washington State Hazardous Waste Management Act and Dangerous Waste Regulations [RCW 70.105; Chapter 173-303 WAC];
- Hydraulic Code [RCW 77.55; Chapter 220-110 WAC];
- Water Quality Standards for Surface Waters of the State of Washington - Mixing Zones [RCW 90.48; WAC 173-201A-400];
- Submission of Plans and Reports for Construction of Wastewater Treatment Facilities in Washington State [RCW 90.48; Chapter 173-240 WAC];
- Water Code and Regulations of Public Ground Waters of Washington State - Surface and Groundwater Withdrawal [RCW 90 - 90.03 and 90.44];
- Maximum Environmental Noise Levels - Washington State [RCW 70.107; Chapter 173-60 WAC];
- Clean Air Act [42 USC 7401 et seq.; 40 CFR 50];
- General Regulations for Air Pollution Sources - Washington State [RCW 70.94; Chapter 173-400 WAC]; and
- Washington State Environmental Policy Act [SEPA: RCW 43.21C; Chapter 197-11 WAC].

Potential Location-Specific ARARs:

- National Historic Preservation Act [16 USC 470];
- Historic Site, Buildings, Objects, and Antiquities Act [16 USC 461- 467];
- Archaeological and Historic Preservation Act [16 USC 469];
- Archaeological Resources Protection Act [16 USC 470];
- Native American Graves Protection and Reparation Act [25 USC 3001 et seq];
- Endangered Species Act [16 USC 1531 - 1544];
- Wilderness Act [16 USC 1131 - 1136];
- National Forest Management Act [16 USC 1600 - 1614];
- Executive Order 11990 - Protection of Wetlands;
- The American Indian Religious Freedom Act [AIRFA: 42 USC 1996];
- Executive Order 11593 - Protection and Enhancement of the Cultural Environment;
- Executive Order 13007 - Indian Sacred Sites;
- Executive Order 13112 – Invasive Species; and
- Executive Order 13186 – Responsibilities of Federal Agencies to Protect Migratory Birds.

Table 14 - Short-Term Human Health Risk - Alternative Comparison

Potential Impacts	Alternative 9	Alternative 10	Alternative 11
Vehicle Traffic			
Risk	Worker or Holden Resident/Visitor Injury. The duration and number of vehicles required for implementation would be less than Alts. 10 and 11.	Worker or Holden resident/visitor injury. The duration and number of vehicles required for implementation would be greater than Alt. 9, but less than Alt. 11.	Worker or Holden resident/visitor injury. The duration and number of vehicles required for implementation would be greater than Alts. 9 and 10.
Mitigation	Minimize traffic through Holden Village, develop construction traffic control plan for Lucerne-Holden Road.		
Excavations/Regrading			
Risk	Worker injury. Estimated volume of tailings pile regrading is 250,000 cubic yards. Barrier wall construction estimated length is 2,500 linear feet. Reduced risk due to shorter work duration compared to Alts. 10 and 11.	Worker injury. Estimated volume of tailings pile and waste rock regrading is 740,000 cubic yards. Barrier wall construction estimated length is 5,870 linear feet. Increased risk due to increased duration of work compared to Alt. 9, reduced compared to Alt. 11.	Worker injury. Estimated volume of tailings pile and waste rock regrading is 790,000 cubic yards. Barrier wall construction estimated length is 7,700 linear feet. Increased risk due to increased duration of work compared to Alts. 9 and 10.
Mitigation	Adherence to applicable OSHA and WISHA regulations. Constructions workers required to have HAZWOPER training.		
Mine Work			
Risk	Worker injury. Mine actions the same for Alternatives 9, 10, and 11.		
Mitigation	Adherence to appropriate MSHA standards.		
Treatment Plant Construction			
Risk	Worker injury. One treatment plant constructed in Alternatives 9, 10, and 11.		
Mitigation	Adherence to appropriate OSHA and WISHA regulations.		
Noise and Dust Concerns			
No Risk Anticipated	Possible effects on workers and Holden residents/visitors. Noise duration from construction less than Alts. 10 and 11. Less potential for dust generation compared to Alts. 10 and 11, due to limited regrading of tailings.	Possible effects on workers and Holden residents/visitors. Noise duration from construction increased compared to Alt. 9, but less than Alt. 11. Similar potential for dust generation compared to Alt. 11, due to same regrading area, but greater potential for dust generation than Alt. 9.	Possible effects on workers and Holden residents/visitors. Noise duration from construction increased compared to Alts. 9 and 10. Similar potential for dust generation compared to Alt. 10, due to same regrading area, but greater potential for dust generation than Alt. 9.
Mitigation	Best Management Practices to limit dust generation. Adherence to applicable OSHA and WISHA regulations, including HAZWOPER.		

Table 15 - Short-Term Environmental Risk - Alternative Comparison

Potential Impacts	Alternative 9	Alternative 10	Alternative 11
Tailings Regrading Risk	Dust generation, potential tailings release into Railroad Creek, and potential for short-term water quality degradation due to impacted runoff for the three alternatives.		
	Estimated volume of tailings pile regrading is 250,000 cubic yards. Less risk compared to Alts. 10 and 11.	Estimated volume of tailings pile and waste rock regrading is 740,000 cubic yards. Greater risk compared to Alt. 9. Same risk as Alt. 11.	Estimated volume of tailings pile and waste rock regrading is 740,000 cubic yards. Greater risk compared to Alt. 9. Same risk as Alt. 10.
Mitigation	No apparent option to collect and treat stormwater runoff impacted by tailings regrading.	The groundwater treatment facility could treat impacted runoff.	The groundwater treatment facility could treat impacted runoff.
	For the three alternatives stormwater pollution prevention could include diversion of surface water run-on; use of silt fences or temporary berms; spraying mist to control dust; and concurrent placement of soil cover with regrading.		
Groundwater Barrier and Collection System Installation Risk	Potential release of construction materials (e.g., cement, bentonite), contaminated soil, or runoff into Railroad Creek. Groundwater extraction and seep interception system construction next to creek on Tailings Pile 1. Less risk compared to Alts. 10 and 11.	Potential release of construction materials (e.g., cement, bentonite), contaminated soil, or runoff into Railroad Creek. Barrier wall construction over approximately 5,870 linear feet adjacent to the creek. Greater risk compared to Alt. 9, less compared to Alt. 11.	Potential release of construction materials (e.g., cement, bentonite), contaminated soil, or runoff into Railroad Creek. Barrier wall construction over approximately 7,700 linear feet adjacent to the creek. Greater risk compared to Alts. 9 and 10.
Mitigation	The groundwater treatment facility could treat impacted runoff for the three alternatives.		
	For the three alternatives stormwater pollution prevention could include diversion of surface water run-on; use of silt fences or temporary berms; and construction of temporary sedimentation basins.		
Groundwater Conveyance System (Stream Crossings) Installation Risk	Groundwater conveyance not required over creeks for Alt. 9. No ferricrete removal so no risk associated with construction equipment working in creek.	Two pipeline stream crossings. Potential release from construction equipment working in creek (e.g., fuel spill, hydraulic fluid), or sediment into Railroad Creek. Risk of release increased compared to Alt. 9.	Two pipeline stream crossings. Potential release from construction equipment working in creek (e.g., fuel spill, hydraulic fluid), or sediment into Railroad Creek. Risk of release increased compared to Alt. 9.
Mitigation	No mitigation required for this item.	Diversion of surface water; use of silt fences; temporary spill booms; SWPPP implementation.	
Fuel Delivery and Usage Risk	Potential for fuel spills and exhaust emissions related to construction equipment and vehicles. Due to shorter construction duration, decreased risk for Alt. 9 compared to Alts. 10, and 11.	Potential for fuel spills and exhaust emissions related to construction equipment and vehicles. Due to construction extent, increased risk for Alt. 10 compared to Alt. 9, but less than Alt. 11.	Potential for fuel spills and exhaust emissions related to construction equipment and vehicles. Due to construction extent, increased risk for Alt. 11 compared to Alts. 9 and 10.
Mitigation	Adhere to state and federal regulations regarding storage, transportation, and dispensing of fuel; including a contingency plan in case a release occurs.		

Table 15 - Short-Term Environmental Risk - Alternative Comparison

Potential Impacts	Alternative 9	Alternative 10	Alternative 11
Surface Water Quality/Wastewater Production			
Risk	Potential for wastewater release to Railroad Creek. Less risk for Alt. 9 compared to Alts. 10 and 11 due to smaller volume treated.	Potential for wastewater release to Railroad Creek. Increased risk for Alt. 10 compared to Alt. 9. Less risk for Alt. 10 compared to Alt. 11.	Potential for wastewater release to Railroad Creek. Increased risk for Alt. 11 compared to Alts. 9 and 10.
Mitigation	Obtain a Washington State wastewater discharge permit and comply with the state's wastewater discharge regulations.		
Net Gain (Loss) of Forest Habitat			
Risk	Some forest habitat lost during construction of the treatment facility in the Lower West Area, adjacent to Railroad Creek. Loss would include mature riparian forest considered to have high habitat value.	Some forest habitat loss due to construction of the treatment facility. Treatment facility located downstream of tailings piles on the northern side of Railroad Creek.	Some forest habitat loss due to construction of the treatment facility. Treatment facility located downstream of tailings piles on the northern side of Railroad Creek.
Mitigation	Minimize treatment facility footprint within wooded area west of lagoon.	Minimize treatment facility footprint.	Minimize treatment facility footprint.

Vicinity Map

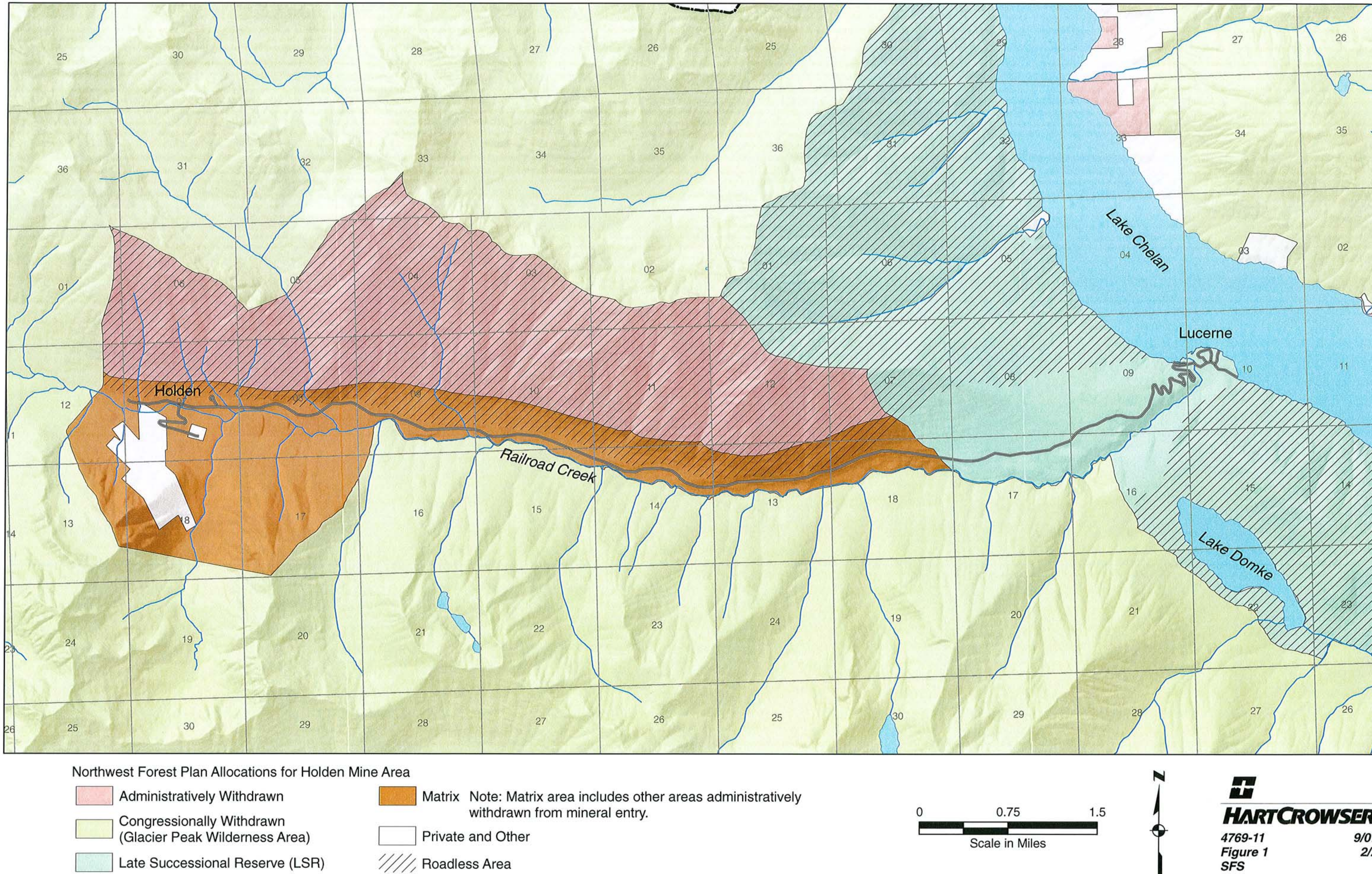
476911AJ.cdr EAL 08/16/07

Note: Base map prepared from Microsoft Streets and Trips 2005.

HARTCROWSER

4769-11 ***5/07***
Figure 1 ***1/2***
SFS

Vicinity Map

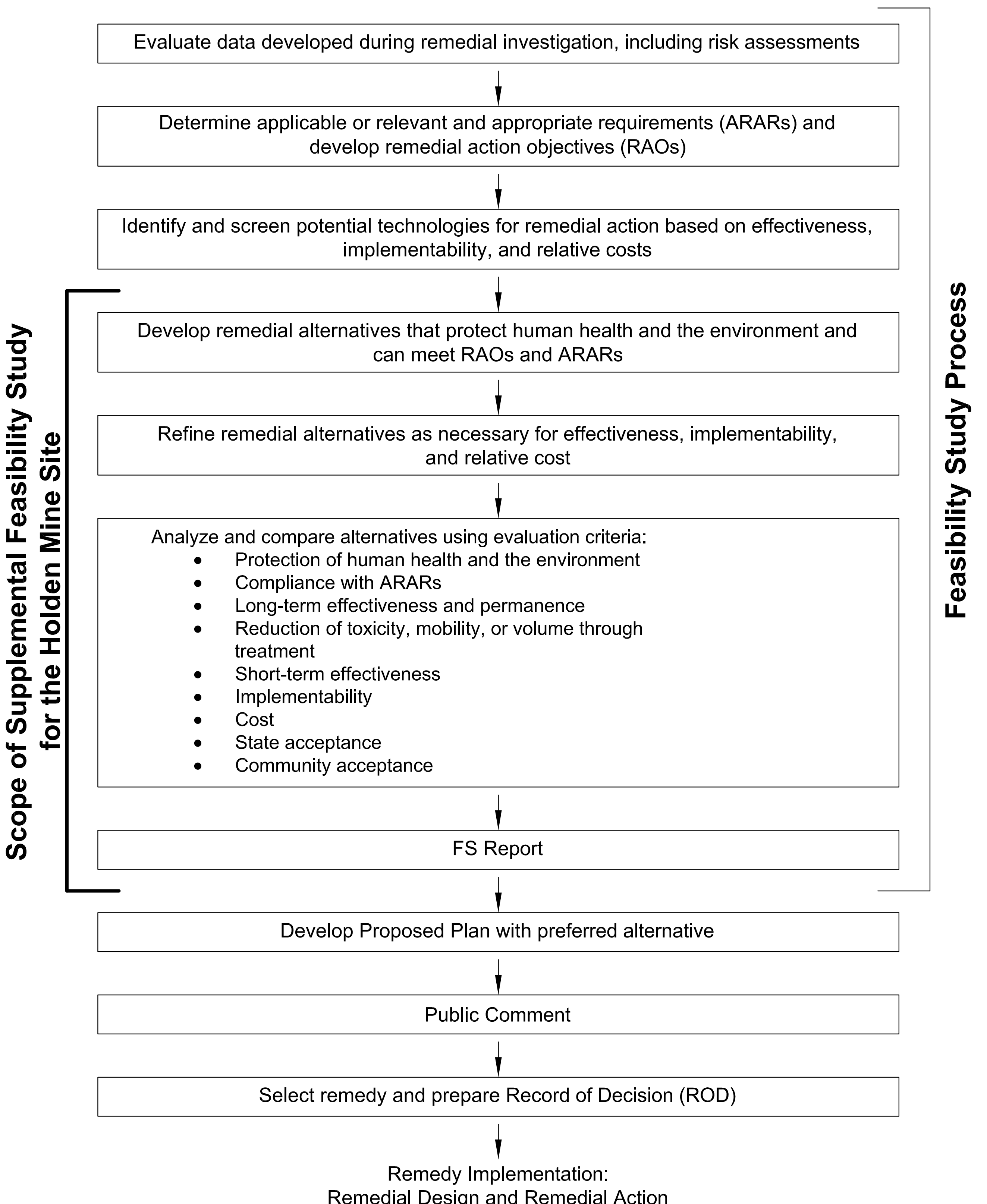


4769-11 9/07
Figure 1 2/2
SFS

HARTCROWSER

4769l107AL.mxd EAL 08/16/07

CERCLA Feasibility Study Process and Scope of Supplemental Feasibility Study for the Holden Mine Site



EAL 08/29/07 476911-022.dwg Layout: Figure 2 - SFS

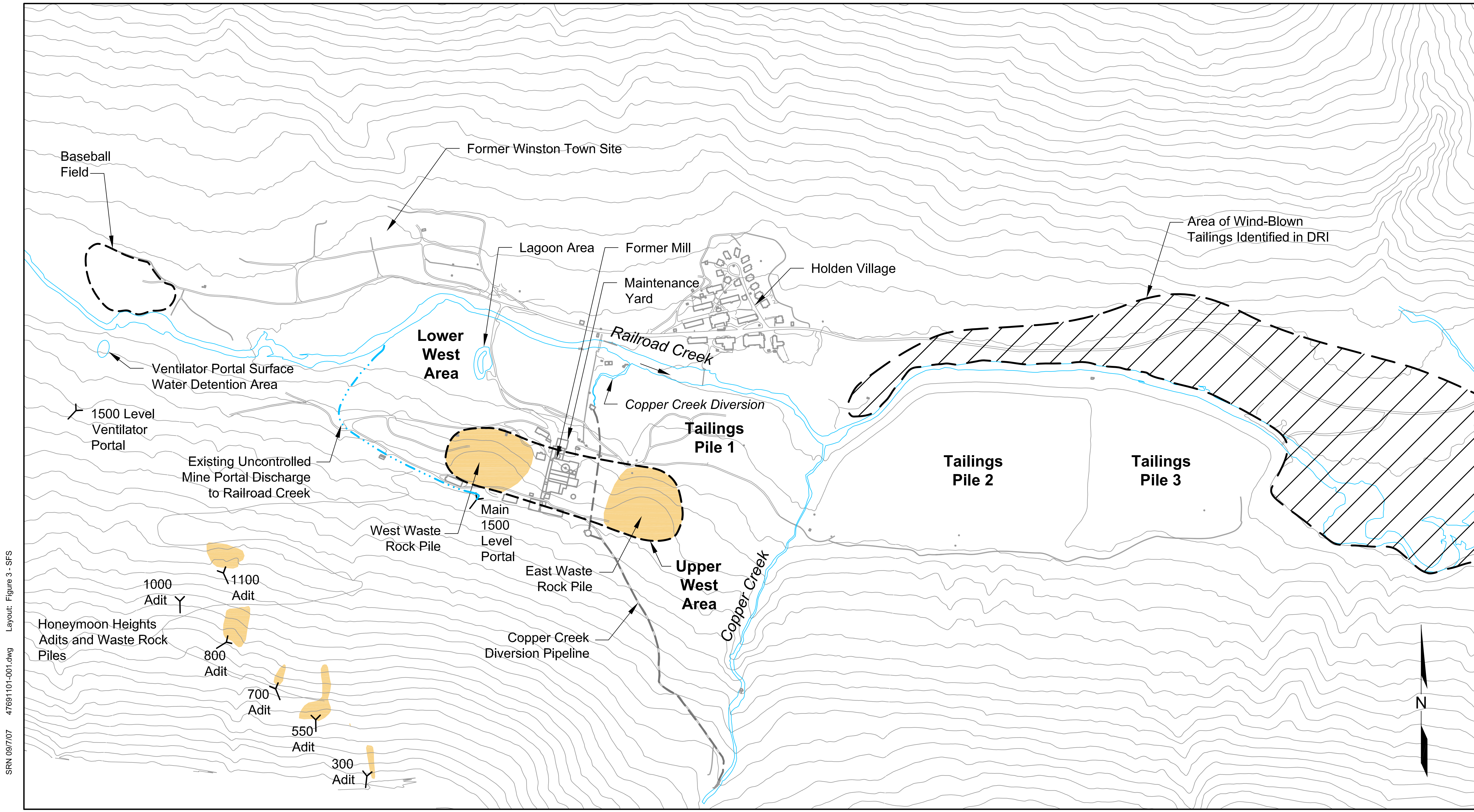
HARTCROWSER

4769-11 9/07

Figure 2

SFS

Principal Features Map



Source: Base map prepared from LiDAR topographic survey provided by URS 2004, various features from DRI and DFFS.

0 600 1200
Scale in Feet

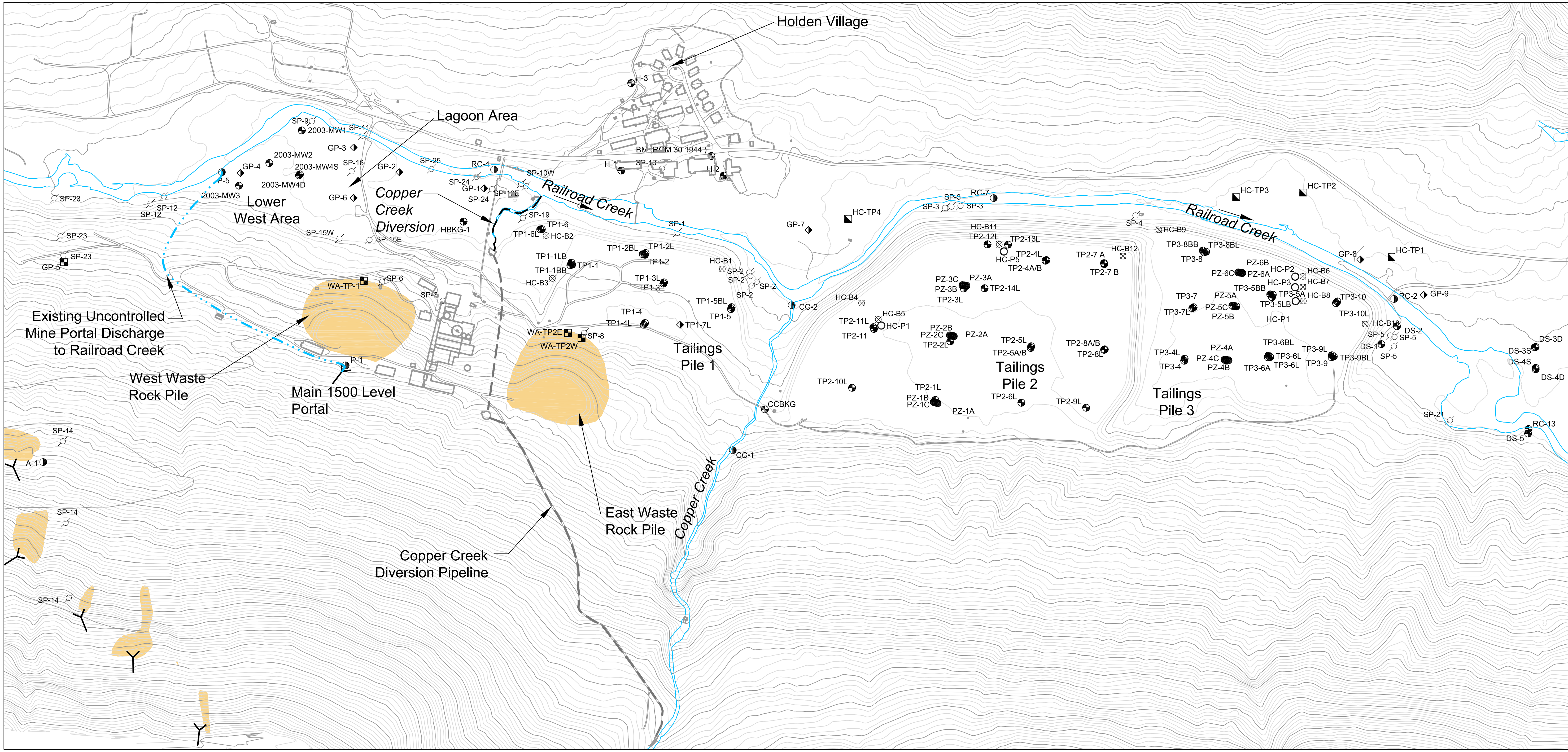
HARTCROWSER

4769-11 *9/07*

Figure 3

SFS

Sampling Location Plan



SRN 08/29/07 47691101-002.dwg Layout: Figure 4 - SFS

Approximate Exploration Location

- Monitoring Well
- Boring
- Test Pit
- Percolation Test
- Seep Sample
- Surface Water Sample
- Waste Rock Pile

N

0 500 1000

Scale in Feet

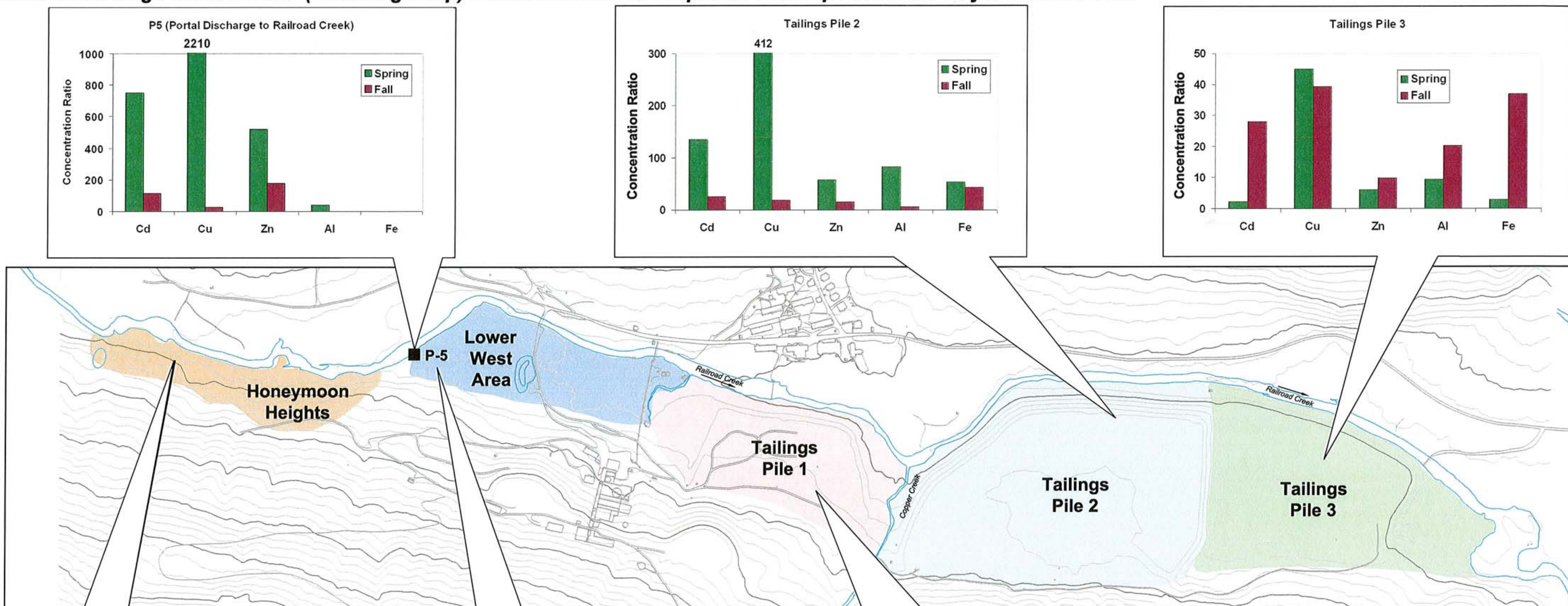
HARTCROWSER

4769-11 *9/07*

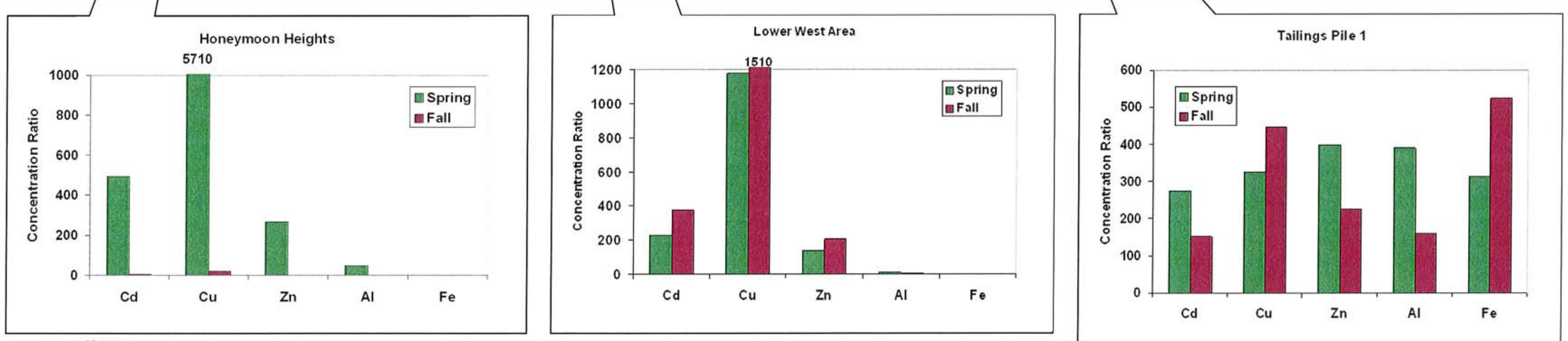
Figure 4

SFS

Ratio of Average Groundwater (Including Seep) Concentrations to Proposed Cleanup Levels for Major Source Areas



Source: Base map prepared from LIDAR topographic survey provided by URS 2004.



	Proposed Cleanup Level in ug/L (See Note 2)
Dissolved Cd	0.07
Dissolved Cu	1.06
Dissolved Zn	17
Total Al	144
Total Fe	1000

N

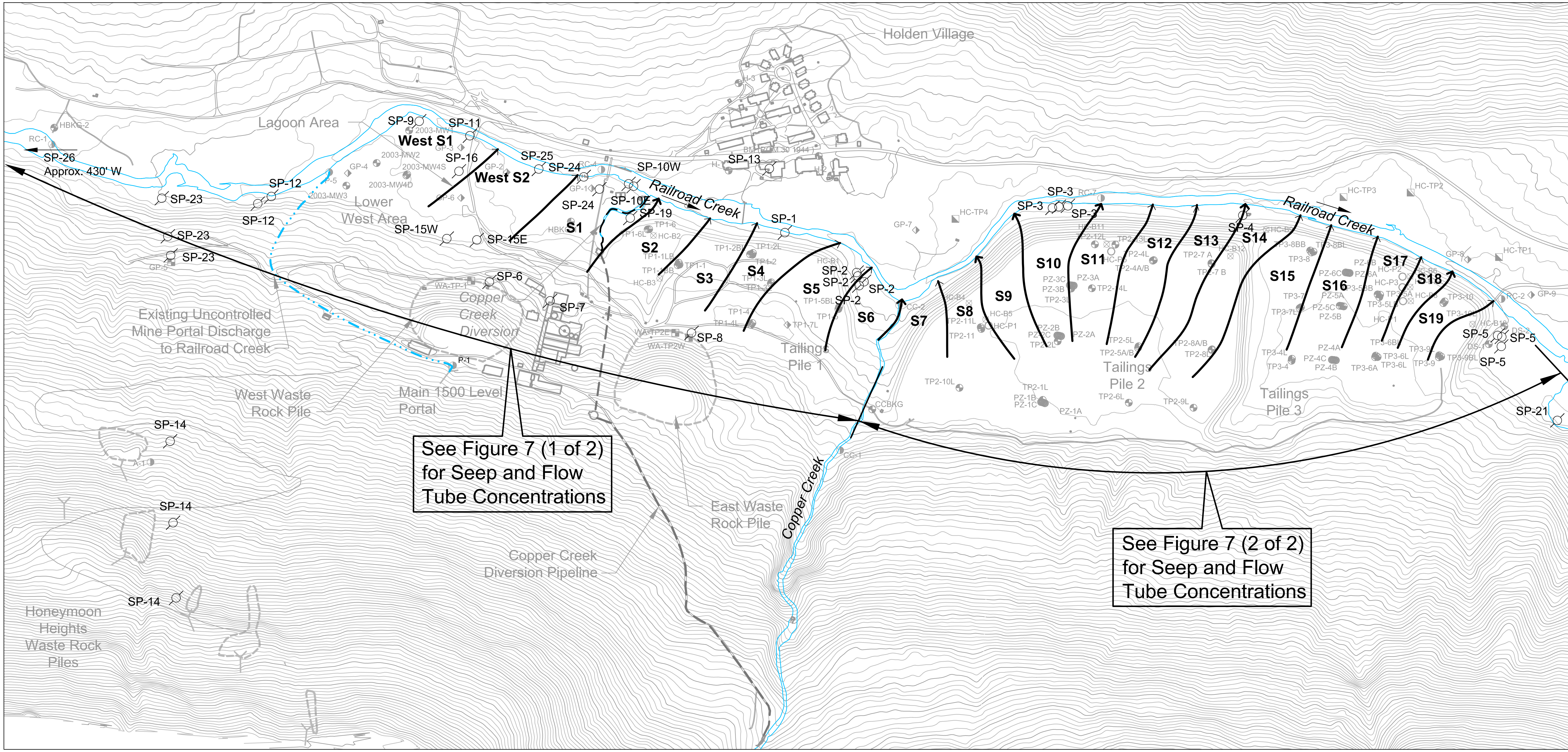
0 600 1200
Scale in Feet

Notes:
1. Plots shown are average metal concentrations for each area from seeps and wells closest to Railroad Creek, expressed as ratios of proposed cleanup levels.
2. Proposed cleanup levels are based on lowest potential ARAR (including correction for hardness based on 12 mg/L $CaCO_3$, where applicable) or background, whichever is greater. Proposed cleanup levels for dissolved copper based on background concentration, pending further analysis.
3. Dissolved concentrations of Cd, Cu, and Zn and total concentrations of Al and Fe were compared to proposed cleanup levels.
4. Fall concentrations are assumed to be representative of all low flow seasons (i.e., summer, fall, and winter). See text for explanation. Fall Lower West Area concentrations are based on values from MW-1 and HBKG-1 as seeps in the area had no flow during the fall.
5. Vertical axis scales vary.

EAL 08/29/07 47691101-003.dwg Layout: Figure 5 - SFS

HARTCROWSER
4769-11 *9/07*
Figure 5
SFS

Seeps and Flow Tubes that Discharge into Railroad Creek for Spring Conditions



SRN 09/14/07 4769101-009.dwg Layout: Figure 6 - SFS

Approximate Exploration Location

- Monitoring Well
- Boring
- Test Pit
- Percolation Test
- Surface Water Sample
- Waste Rock Pile

- Inferred Groundwater Flow Path
- **S4** Flow Tube Designation
- SP-25 Seep Location and Designation

Notes: Seep and flow tube locations and designations from URS, 2004a and Hart Crowser, 2005a.

Groundwater flow and concentrations vary seasonally due primarily to the effect of snowmelt and runoff. As used in the SFS and related documents, spring conditions refer to the May to June period approximately 90 days long when snowmelt causes relatively high groundwater levels. See text for additional discussions.

N

0 500 1000

Scale in Feet

HARTCROWSER

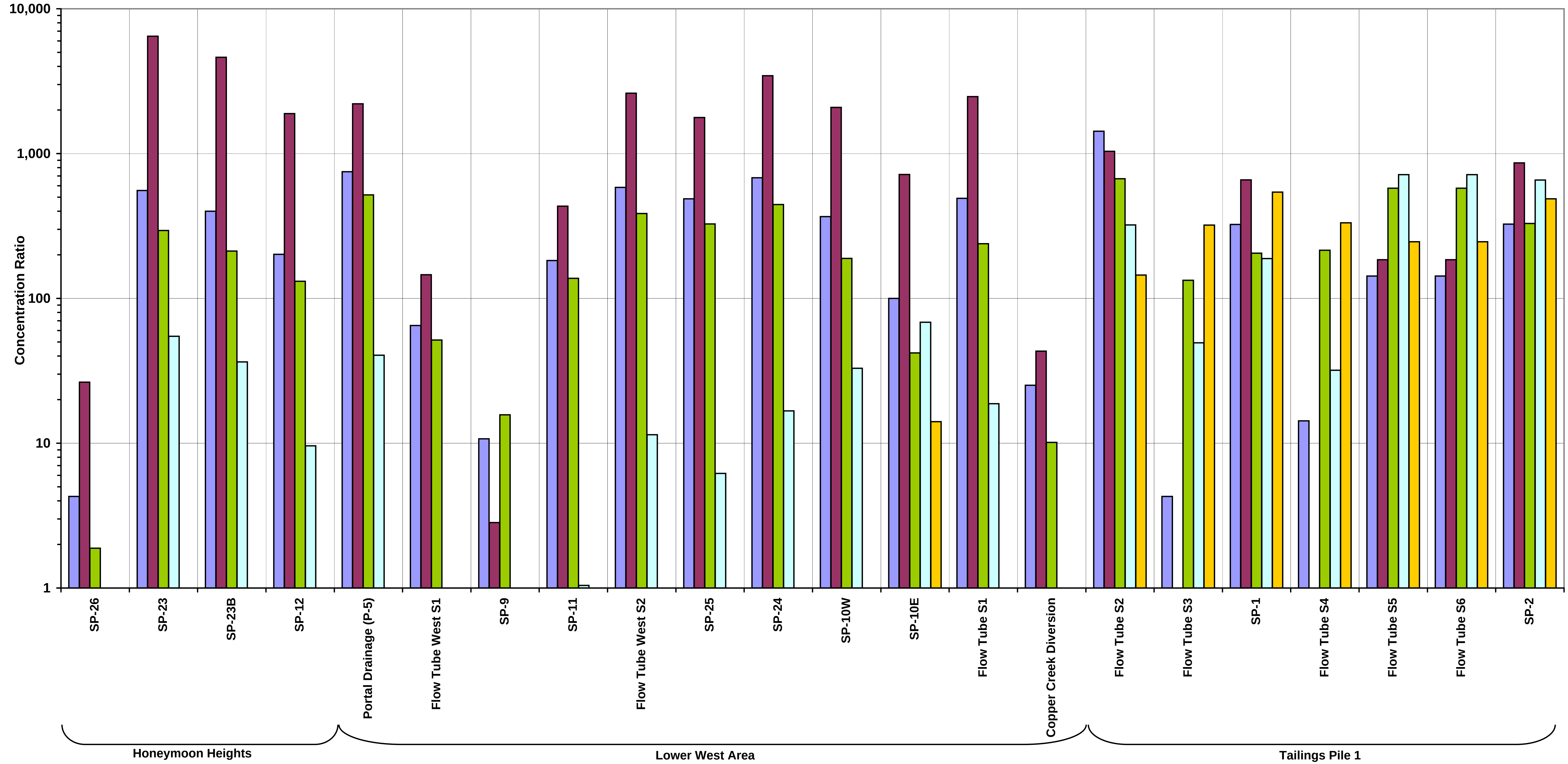
4769-11 ***9/07***

Figure 6

SFS

Ratio of Groundwater (Including Seep) Concentrations to Proposed Cleanup Levels for Spring Conditions

Sources Discharging into Railroad Creek from West to East



Notes

1. Plot shows the ratio of metal concentrations to proposed cleanup levels in Railroad Creek, for seeps and flow tubes that discharge into the creek.
2. Groundwater and seep concentrations are from URS 2004a, except concentrations for Flow Tubes West S1 and West S2 are based on data from URS 2006 and URS 2004a using the same method as described in URS 2004a.
3. See Figure 6 for location of seeps and flow tubes.

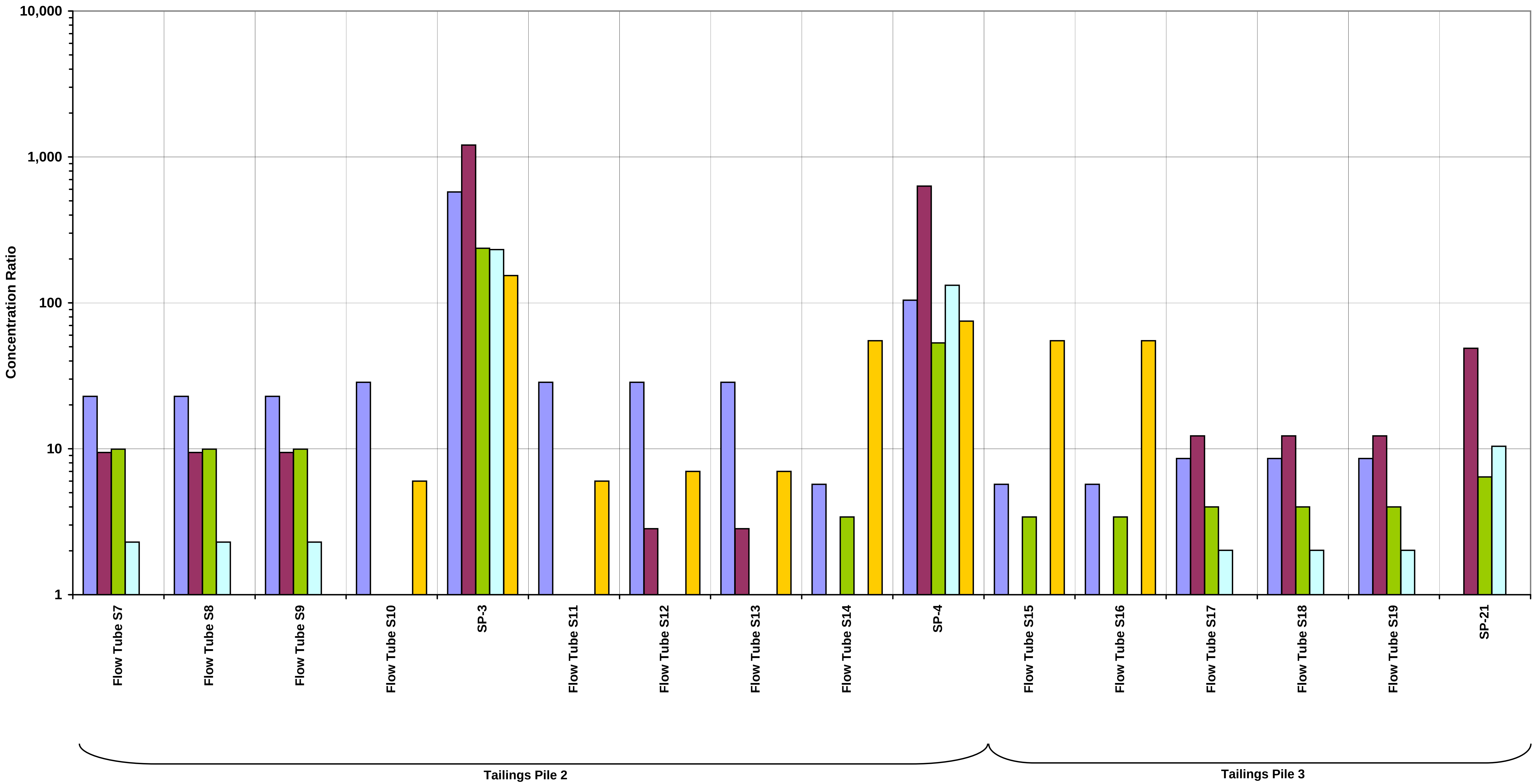
Figure 8 9 Holden Conc Ratios 080707.xls - Spring Figure SFS 7

HARTCROWSER

4769-11 *9/07*
Figure 7 *1/2*
SFS

Ratio of Groundwater (Including Seep) Concentrations to Proposed Cleanup Levels for Spring Conditions

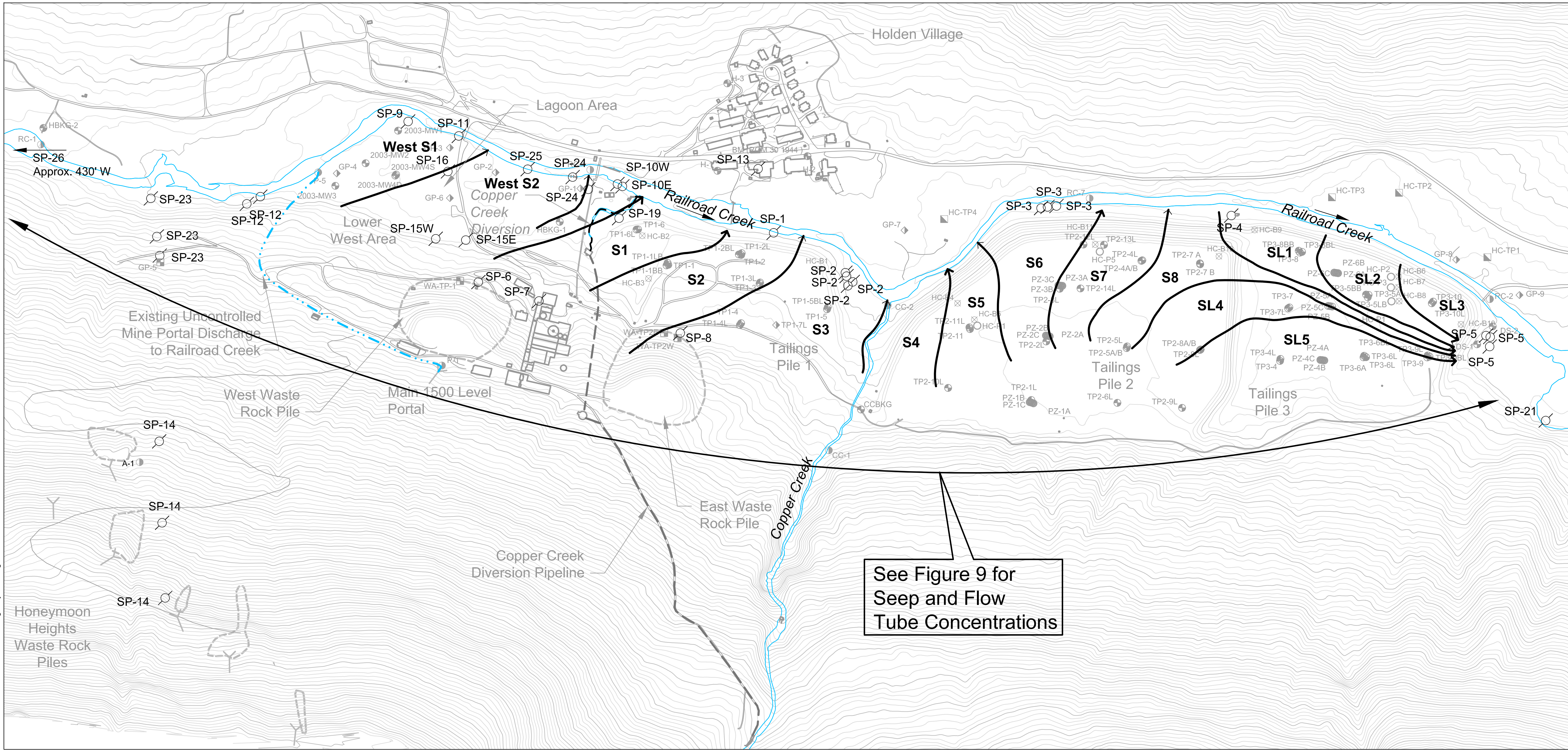
Sources Discharging into Railroad Creek from West to East



Notes

1. Plot shows the ratio of metal concentrations to proposed cleanup levels in Railroad Creek, for seeps and flow tubes that discharge into the creek.
2. Groundwater and seep concentrations are from URS 2004a, except concentrations for Flow Tubes West S1 and West S2 are based on data from URS 2006 and URS 2004a using the same method as described in URS 2004a.
3. See Figure 6 for location of seeps and flow tubes.

Seeps and Flow Tubes that Discharge into Railroad Creek for Fall Conditions



SRN 08/29/07 47691101-008.dwg Layout: Figure 8 - SFS

Approximate Exploration Location

- Monitoring Well
- Boring
- Test Pit
- Percolation Test
- Surface Water Sample
- Waste Rock Pile

→ Inferred Groundwater Flow Path

S4 Flow Tube Designation

SP-25 Seep Location and Designation

Note: Seep and flow tube locations and designations from URS, 2004a and Hart Crowser, 2005a.

Groundwater flow and concentration vary seasonlly due primarily to the effect of snowmelt and runoff. As used in the SFS and rlated documents, fall flow conditions are assumed to be representative of all low flow seasons (i.e., July through April). See text for additional discussion.

N

0 500 1000

Scale in Feet

HARTCROWSER

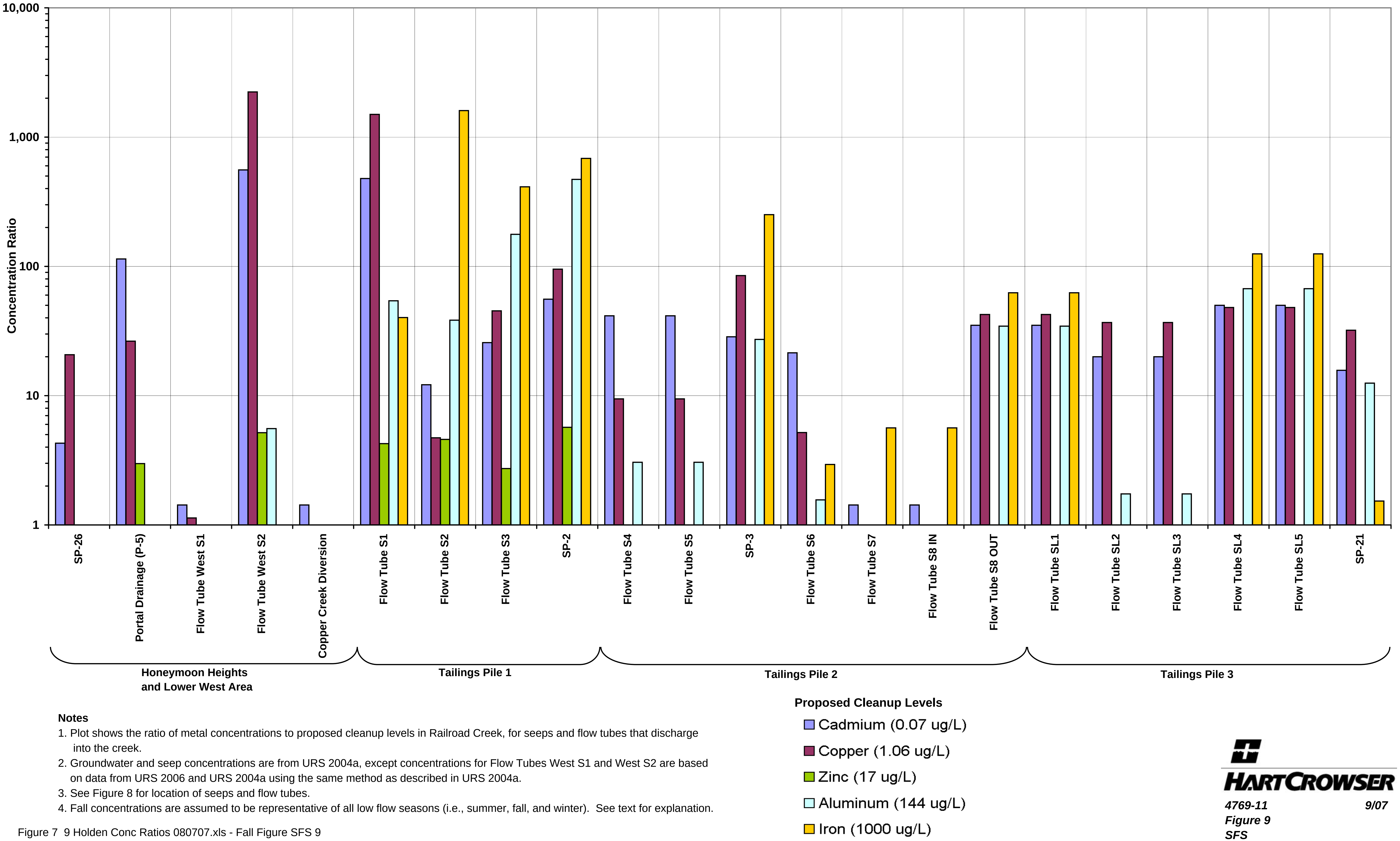
4769-11 ***9/07***

Figure 8

SFS

Ratio of Groundwater (Including Seep) Concentrations to Proposed Cleanup Levels for Fall Conditions

Sources Discharging into Railroad Creek from West to East



Notes

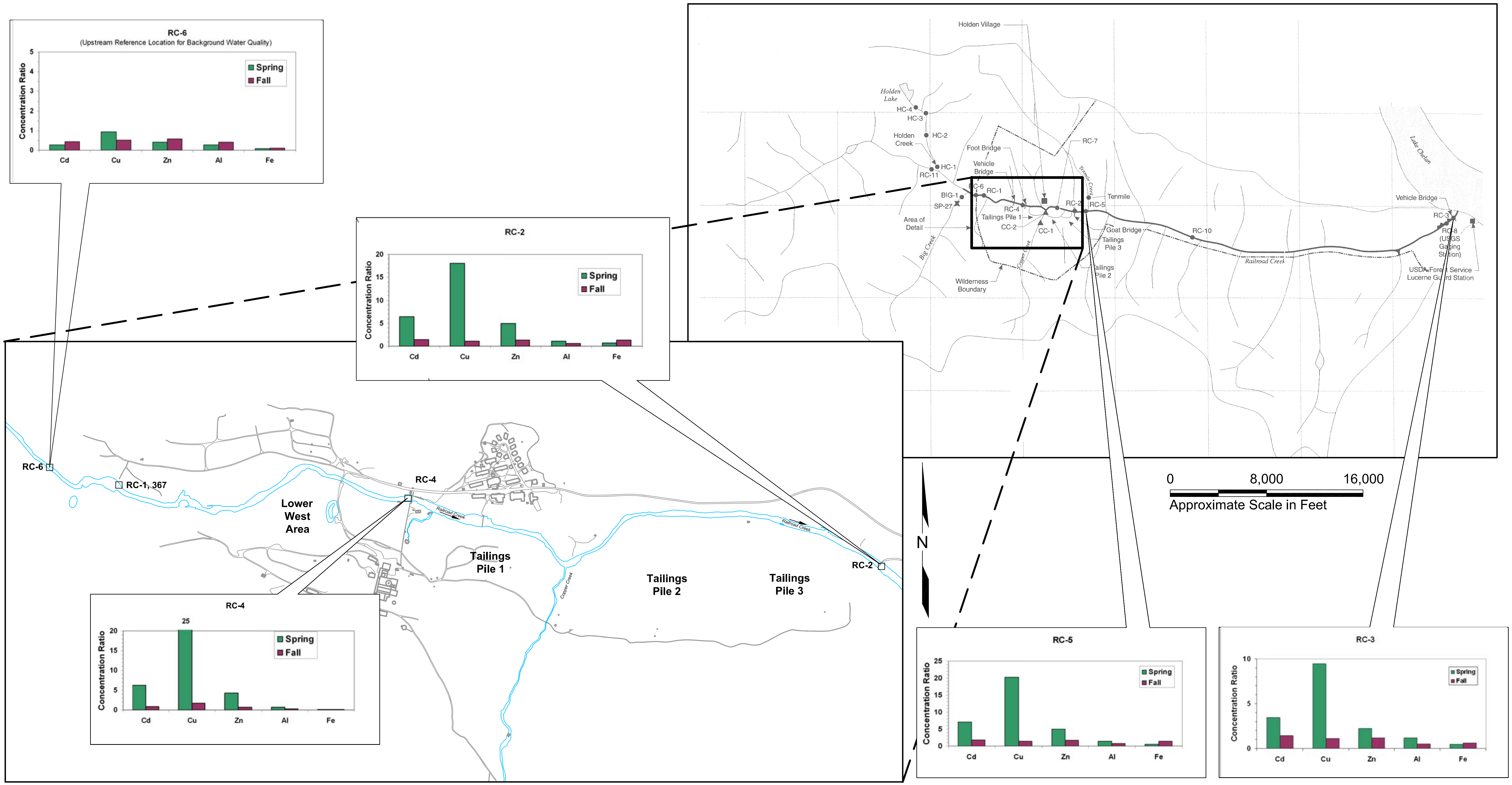
1. Plot shows the ratio of metal concentrations to proposed cleanup levels in Railroad Creek, for seeps and flow tubes that discharge into the creek.
2. Groundwater and seep concentrations are from URS 2004a, except concentrations for Flow Tubes West S1 and West S2 are based on data from URS 2006 and URS 2004a using the same method as described in URS 2004a.
3. See Figure 8 for location of seeps and flow tubes.
4. Fall concentrations are assumed to be representative of all low flow seasons (i.e., summer, fall, and winter). See text for explanation.

Figure 7 9 Holden Conc Ratios 080707.xls - Fall Figure SFS 9

HARTCROWSER

4769-11 *9/07*
Figure 9
SFS

Ratio of Surface Water Concentrations to Proposed Cleanup Levels



RC-6 □ Railroad Creek Sampling Location and Number

0 900 1,800
Approximate Scale in Feet

Notes:

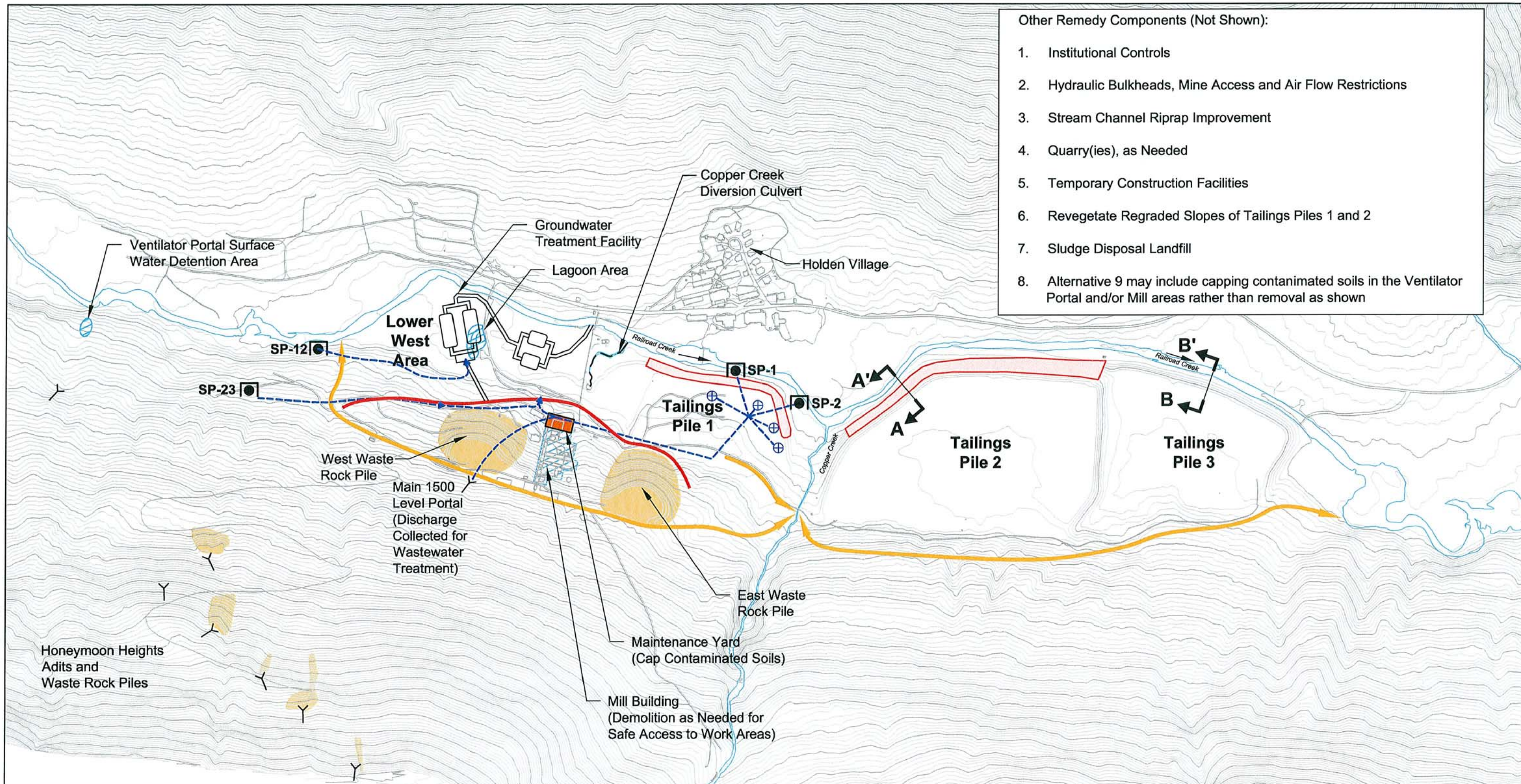
1. Plots show ratio of metal concentrations to proposed cleanup levels in a fully mixed condition within Railroad Creek. Plots do not reflect metal concentrations at the point within Railroad Creek where a point of compliance could be established under MTCA. Metals concentration at the point of compliance will be higher than in the fully mixed stream.
2. Proposed cleanup levels are based on lowest potential ARAR (including correction for hardness based on 12 mg/L CaCO3, where applicable) or background, whichever is greater. Proposed cleanup level for dissolved copper based on background concentration, pending further analysis.
3. Railroad Creek surface water metals data are from May 1997 and September 1997.
4. Dissolved concentrations of Cd, Cu, and Zn and total concentrations of Al and Fe were compared to proposed cleanup levels.
5. Small scale base map prepared from Draft Final Feasibility Study, URS 2004a. Large scale base map prepared from LIDAR topographic survey provided by URS 2004.
6. Fall concentrations are assumed to be representative of all low flow seasons (i.e., summer, fall, and winter). See text for explanation.

Proposed Cleanup Level in ug/L (See Note 2)	
Dissolved Cd	0.07
Dissolved Cu	1.06
Dissolved Zn	17
Total Al	144
Total Fe	1000

HARTCROWSER
4769-11 9/07
Figure 10
SFS

SRN 8/29/07 47691107-017.dwg Layout: Figure 10 - SFS

Principal Components of Alternative 9



SRN 9/18/07 4769101-005.dwg Layout: Figure 11 - SFS

Source: Base map prepared from LiDAR topographic survey provided by URS 2004.
Remediation feature layout from URS 2005e.

A A' Approximate Cross Section Location and Designation See Figure 14

Capping Contaminated Soils

Regrade Tailings Pile Slopes

Removal of Contaminated Soils

Waste Rock Piles (No Remedial Action in this Alternative)

Upgradient Runoff Diversion Swale

Groundwater and Seep Collection for Treatment

SP-12 Discrete Seep Collected for Treatment Location and Number

Groundwater Extraction Well Location

Intercepted Groundwater and Seep Pipeline

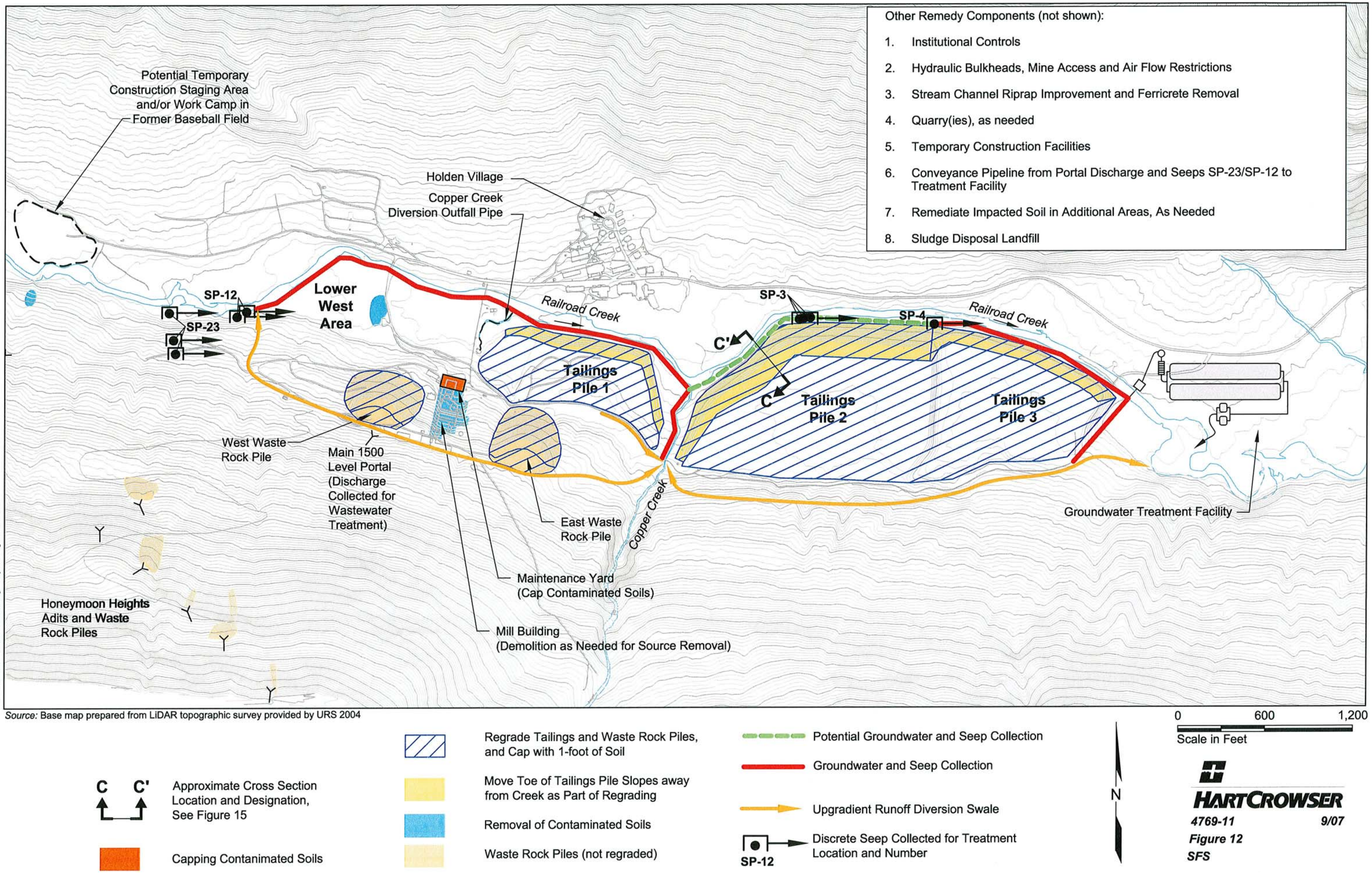
N

0 600 1,200
Scale in Feet

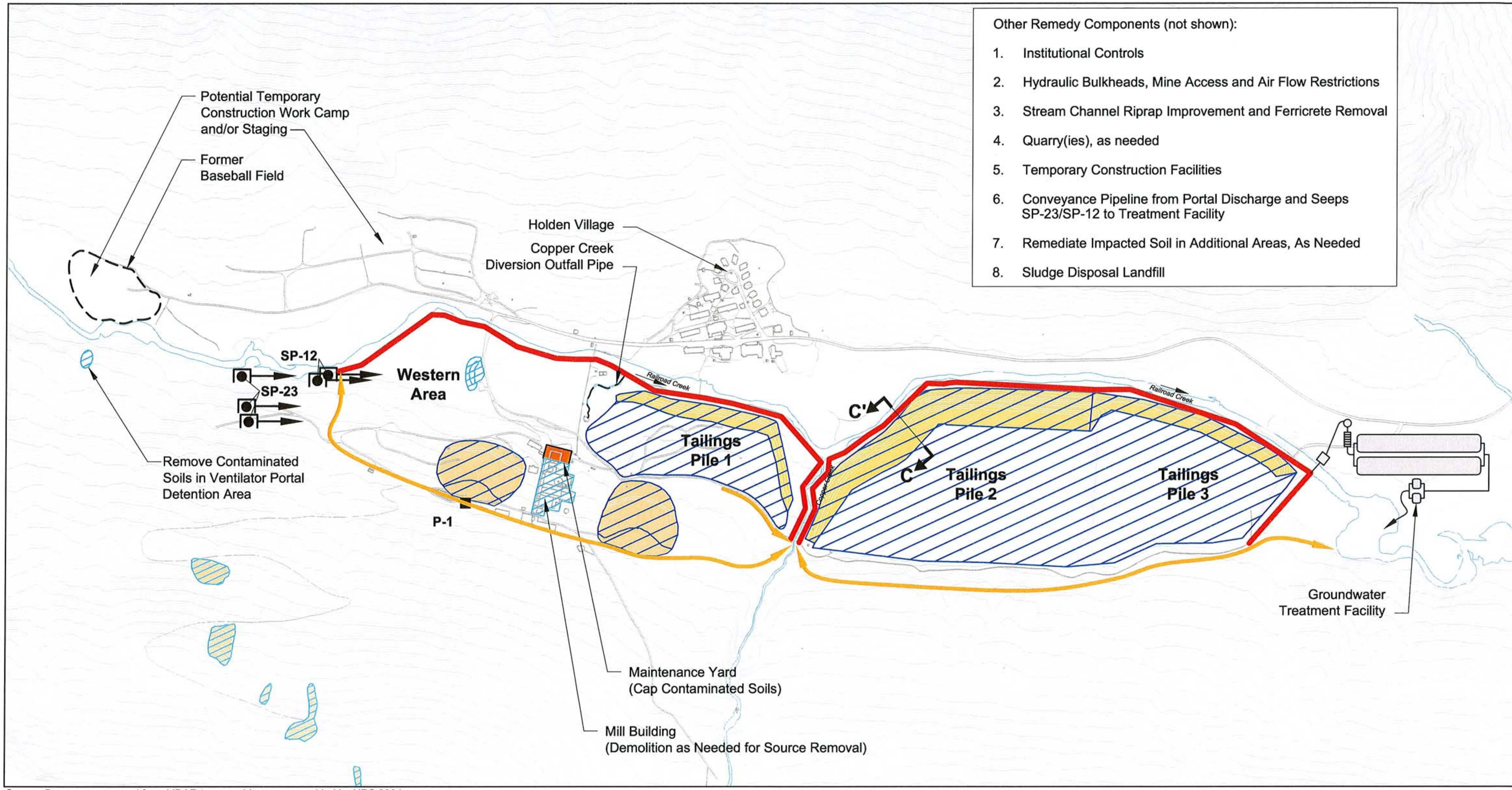
HARTCROWSER

4769-11 9/07
Figure 11
SFS

Principal Components of Alternative 10



Principal Components of Alternative 11



Source: Base map prepared from LiDAR topographic survey provided by URS 2004

C C' Approximate Cross Section Location and Designation, See Figure 15

Capping Contaminated Soils

Regrade Tailings and Waste Rock Piles, and Cap with 2-foot of Soil and Geomembrane

Move Toe of Tailings Pile Slopes away from Creek as Part of Regrading

Removal of Contaminated Soils or Waste Rock

Waste Rock Piles

● SP-4 Seep Sampling Location and Number

■ P-1 Portal Sampling Location and Number

Groundwater and Seep Collection

Upgradient Runoff Diversion Ditch

Discrete Seep Collection System

N

0 600 1,200

Scale in Feet

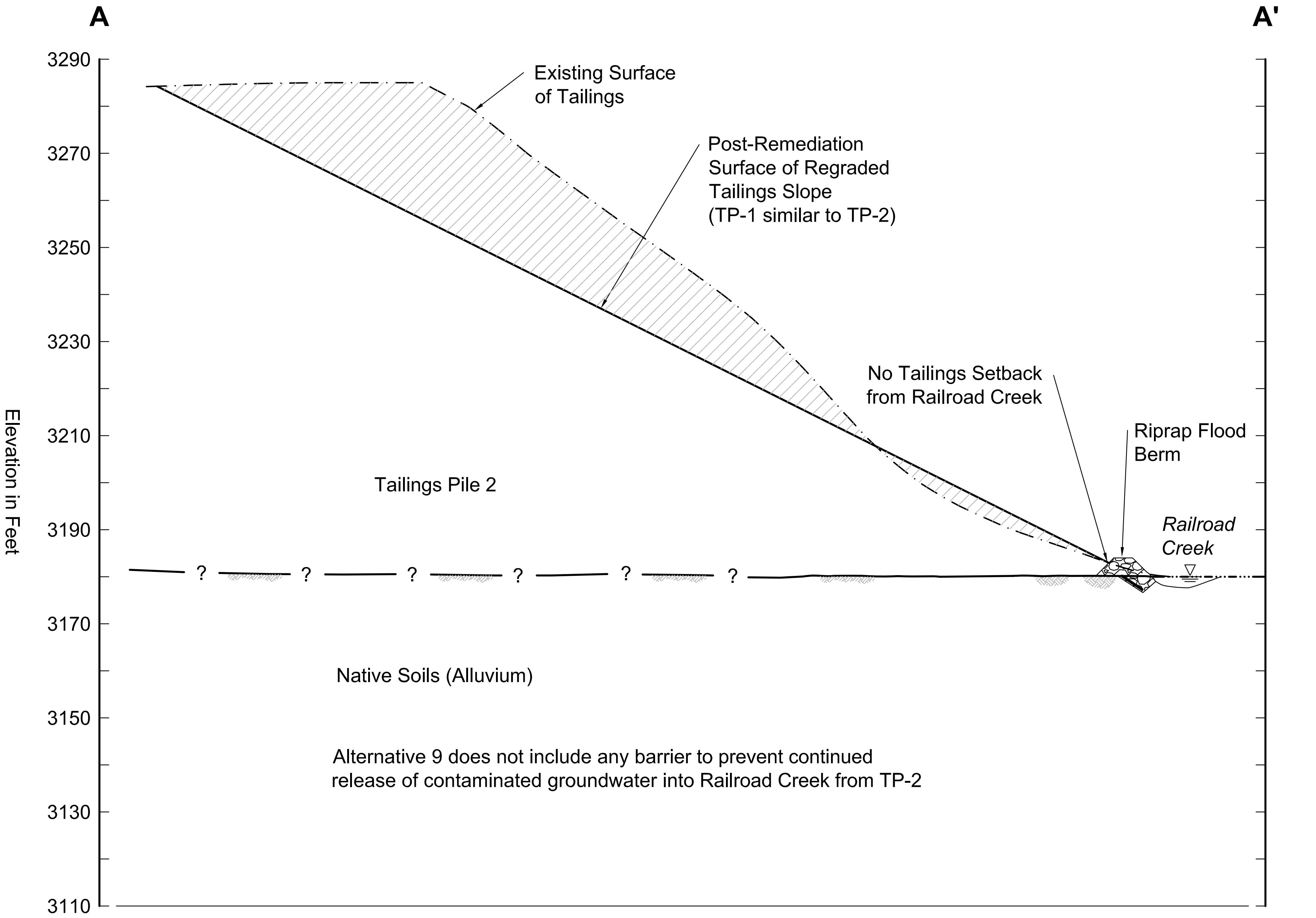
HARTCROWSER

4769-11 9/07

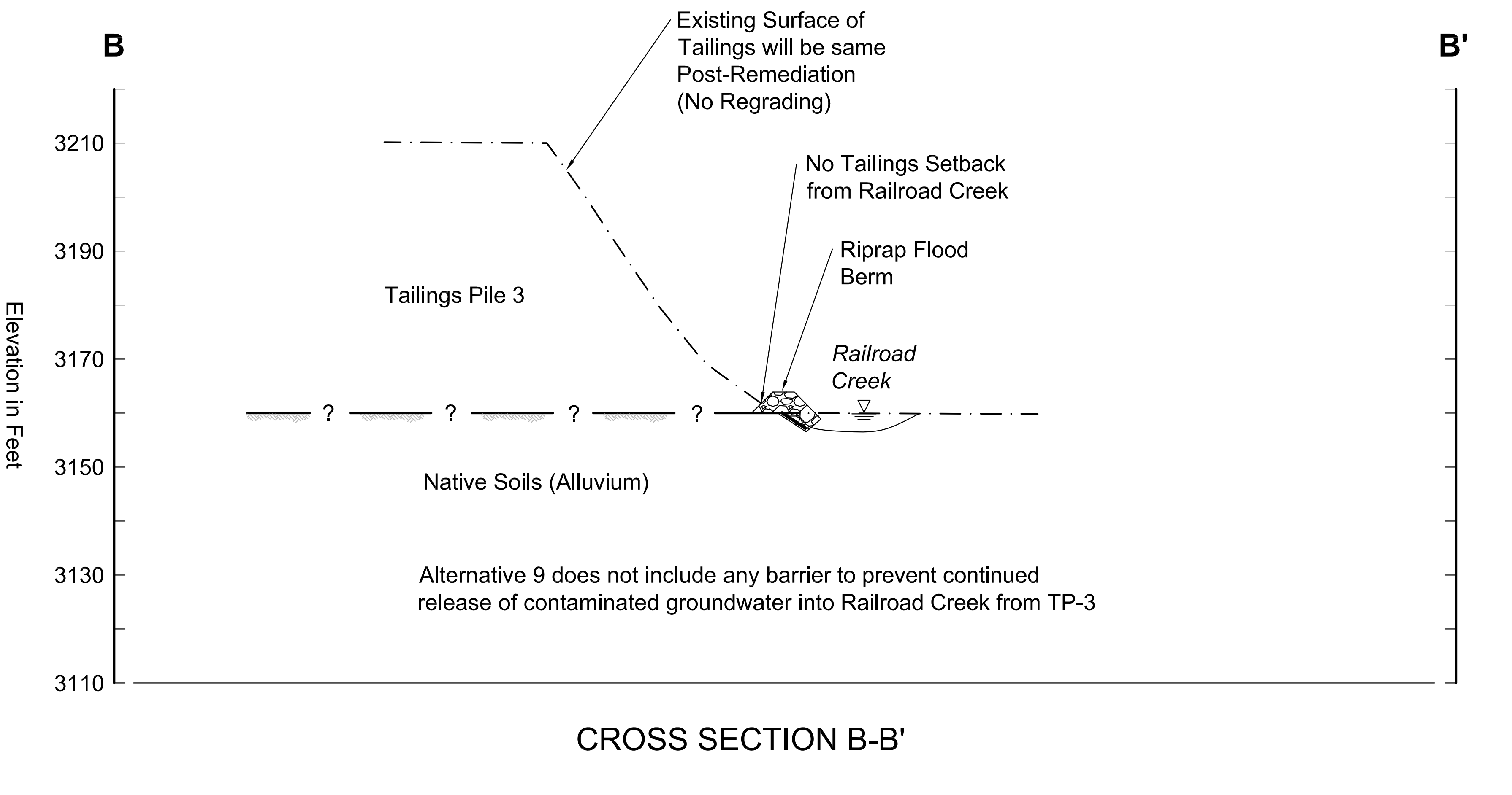
Figure 13

SFS

Schematic of Proposed Tailings Pile Regrading adjacent to Railroad Creek for Alternative 9



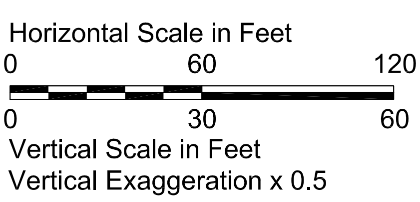
CROSS SECTION A-A'



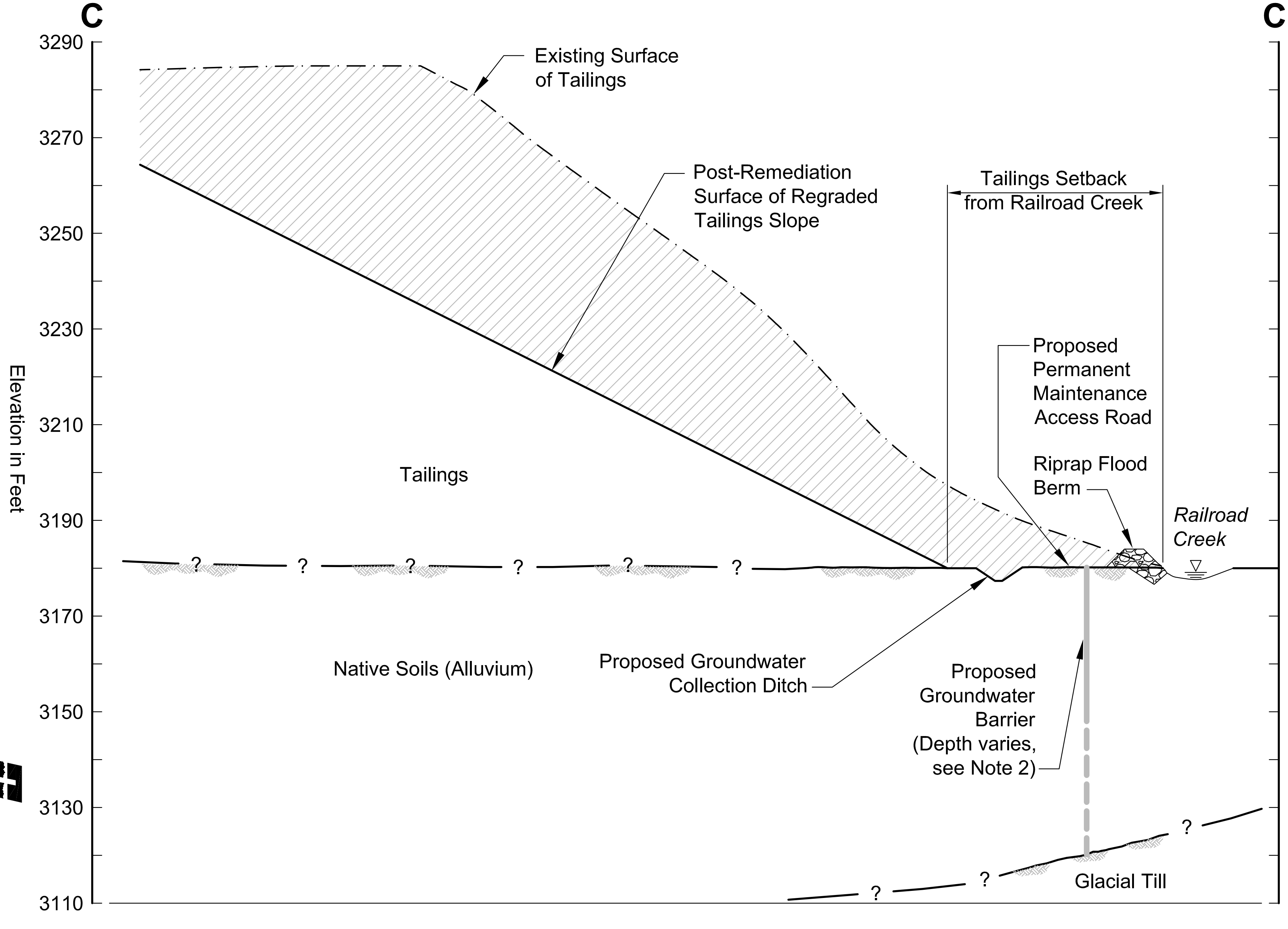
CROSS SECTION B-B'

EAL 09/14/07 47691107-020.dwg

HARTCROWSER
4769-11 9/07
Figure 14
SFS



Schematic of Proposed Tailings Pile Regrading adjacent to Railroad Creek for Alternatives 10 and 11



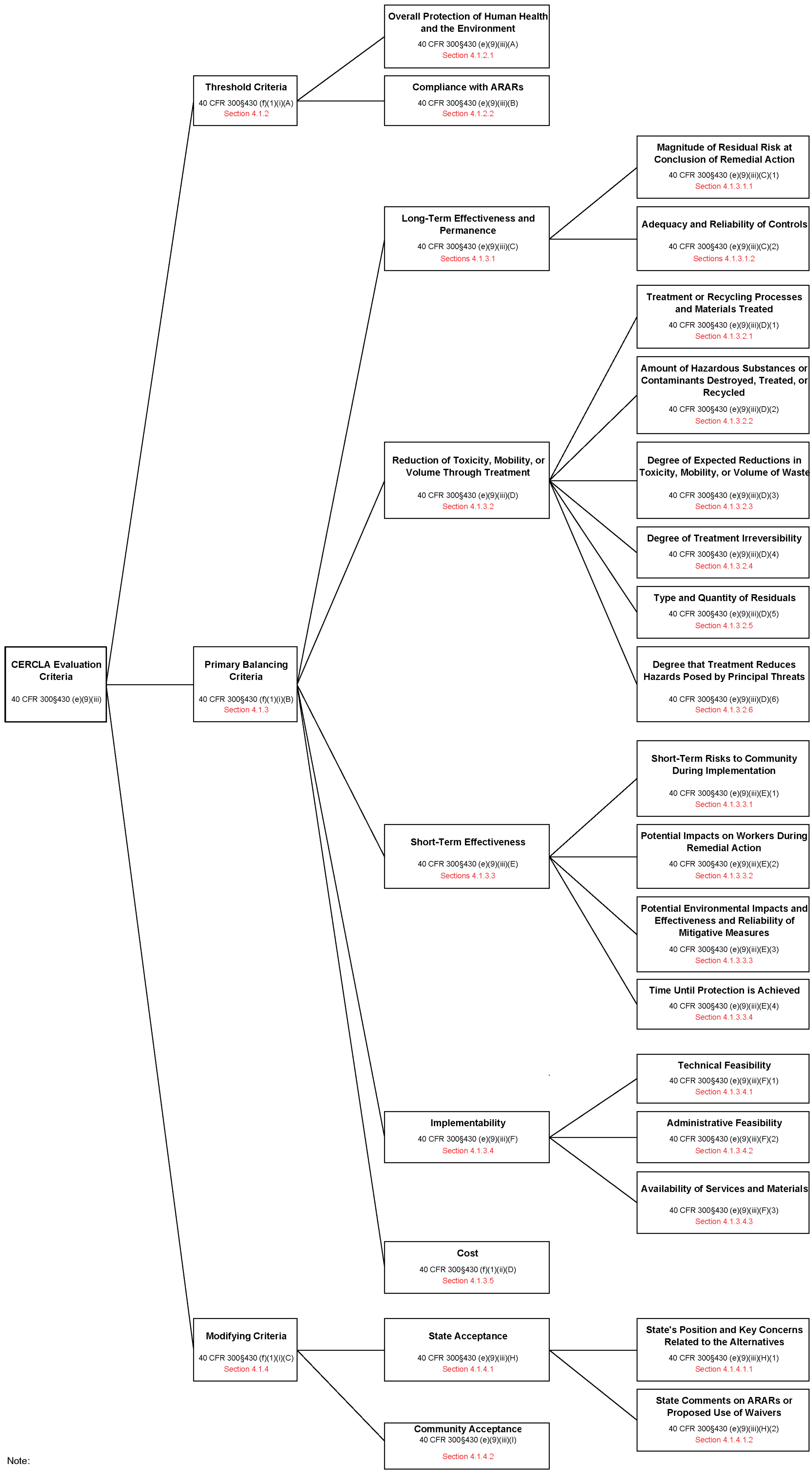
Note:

1. Final setback distance and slope of tailings pile to be determined during remedial design. Nominal 45-foot setback and 2H:1V tailings slope shown for discussion purposes only.
2. Depth of partially penetrating groundwater barrier for Alternative 10 assumed to be 30 feet, to be determined during remedial design. Groundwater barrier for Alternative 11 will extend into glacial till. Depth to glacial till varies.

HARTCROWSER
4769-11 ***9/07***
Figure 15
SFS

EAL 9/18/07 476911-024.dwg Layout: Figure 15 - SFS

CERCLA Selection of a Cleanup Action

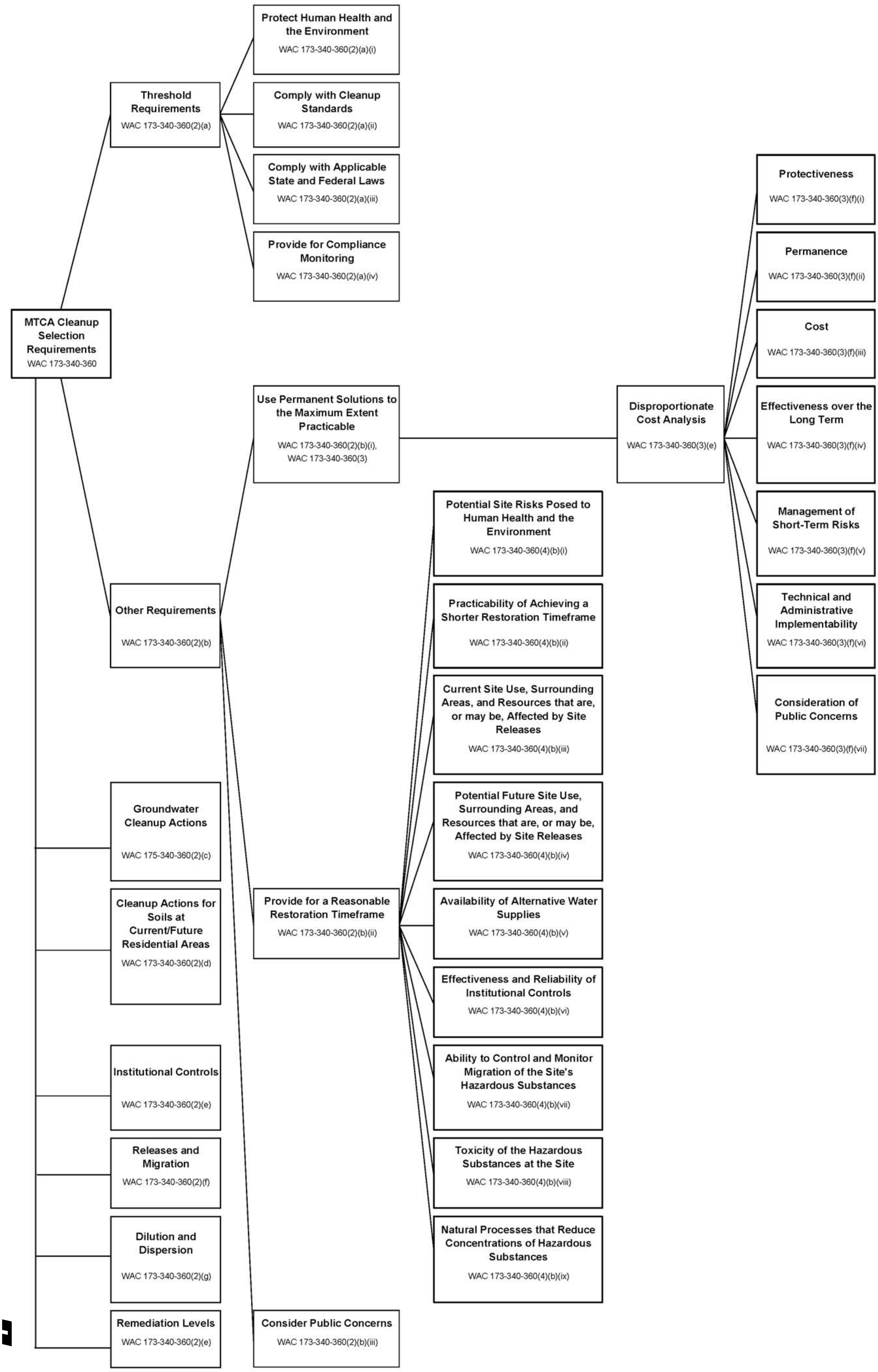


Note:
Red section numbers refer to sections in this document.

HARTCROWSER
4769-11 9/07
Figure 16
SFS

476911AL.cdr EAL 09/13/07

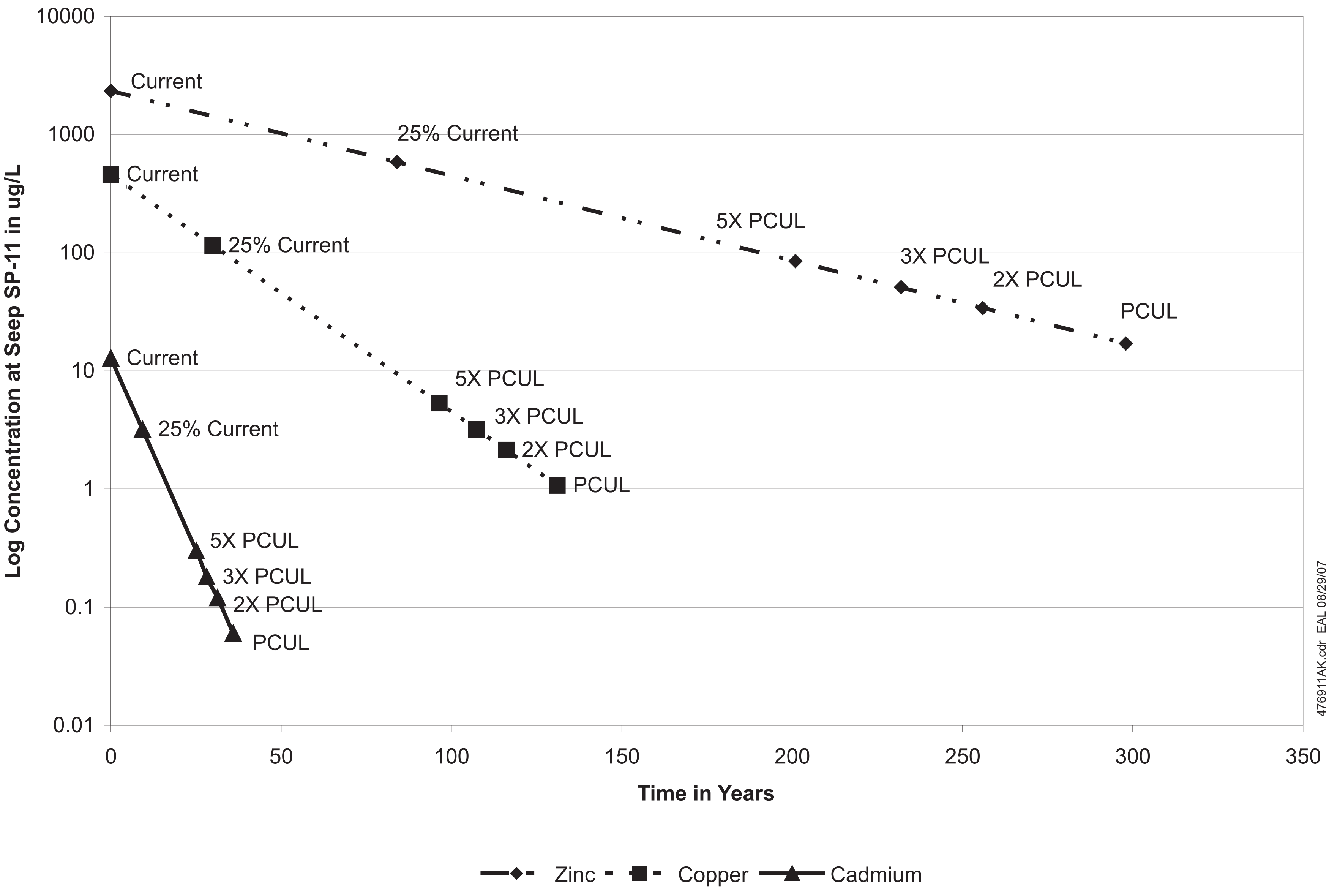
MTCA Selection of a Cleanup Action



HARTCROWSER
4769-11 9/07
Figure 17
SFS

476911AM.cdr EAL 09/13/07

Estimated Time to Reduce Zinc, Copper, and Cadmium Concentrations in Lower West Area Following Source Control in Upper West Area for Alternative 9

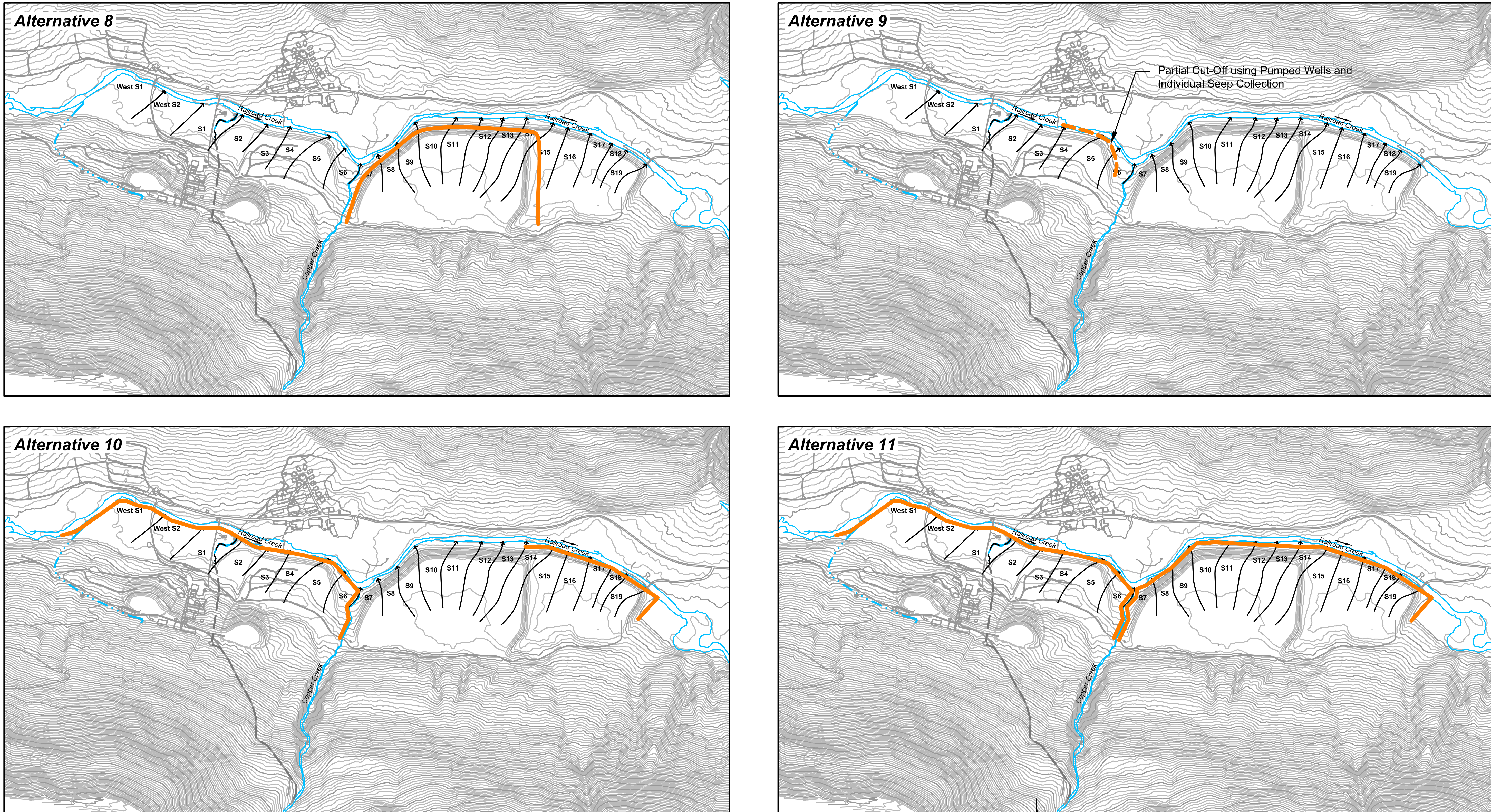


Notes:
1. Representative change in concentration shown for Seep SP-11 as an example.
2. PCUL refers to proposed surface water cleanup level based on aquatic life protection criteria (see text).

HARTCROWSER
4769-11 9/07
Figure 18
SFS

476911AK.cdr EAL 08/29/07

Portion of Groundwater Entering Railroad Creek that will be Directly Cut-off by Alternatives 8, 9, 10, and 11 (Spring Conditions)



EAL 09/14/07 476911-025.dwg Layout: Figure 19 - SFS

Source: Base map prepared from LiDAR topographic survey provided by URS 2004

Extent of groundwater containment and collection along Railroad Creek

Note: Flow tube limits are different for fall flow conditions but the extent of groundwater containment and collection is similar. Fall flow conditions are assumed to be representative of all low flow seasons (i.e., summer, fall, and winter). See text for explanation. Extent of groundwater collection of Honeymoon Heights seeps and portal discharge not shown.

N

0 1000 2000
Scale in Feet

HARTCROWSER
4769-11 *9/07*
Figure 19
SFS

APPENDIX A
USE OF MODELS IN COMPARING THE EFFECTIVENESS OF REMEDIAL ALTERNATIVES

APPENDIX A
USE OF MODELS IN COMPARING THE EFFECTIVENESS OF REMEDIAL ALTERNATIVES

Executive Summary

This appendix discusses the four models that have been used to assess the effectiveness of remedial alternatives for the Holden Mine Site (Site).

The four models include:

- **The DFFS Post-Remediation Loading Analysis Model (DFFS Model)** is a mass-loading model presented in the Draft Final Feasibility Study (DFFS, URS 2004a) and subsequently used by Intalco to compare Alternatives 9 and 10;
- **The South Bank Analysis** was presented by Intalco to try to relate results of the DFFS Model to concentrations at the anticipated conditional point of compliance (CPOC)[1] for groundwater at the Site (URS 2004c);
- **The Treatment Plant Model** (TPM) was used by the Agencies to estimate the amount of sludge produced and the mass of metals removed by the treatment systems for Alternatives 8, 9, 10, and 11; and
- **The Batch Flush Model**, a groundwater attenuation analysis, was used by the Agencies to evaluate the time required for natural attenuation of dissolved metals concentrations in the Lower West Area (LWA) (Hart Crowser 2005b).

This Executive Summary provides a brief description of how each model was used in the evaluation of remedial alternatives, and the suitability (or limitations) of each model for its intended purpose. Following the Executive Summary, the remainder of this appendix discusses how each model works, whether it is suitable for the purpose it was used for, and other supporting information.

DFFS Post-Remediation Loading Analysis Model

Groundwater (including seeps and baseflow) and drainage from the mine and other areas of the Site are sources of metals loading to Railroad Creek. The DFFS Post-Remediation Loading Analysis Model (DFFS Model) attempts to

[1] The point of compliance is the location where cleanup levels must be met. The meaning and potential applicability of a conditional point of compliance at the Site are discussed later in this appendix.

calculate the anticipated change in metals concentrations within the creek based on changes in these sources due to remediation.

Intalco used the DFFS Model to compare estimated metals concentrations in Railroad Creek for Alternatives 2 through 9, and the APR (Alternative 10). However, the Agencies do not consider the DFFS Model to be an acceptable basis for selection of a remedy, for the reasons outlined below.

- **Results of the model are not relevant for the point of compliance.** The DFFS Model does not predict metals concentrations at the required points of compliance for groundwater or surface water. The DFFS Model relies on a loading analysis that only predicts concentrations for fully mixed conditions at two locations in Railroad Creek. The DFFS Model is not capable of predicting water quality concentrations at the points where cleanup levels must be achieved, i.e., at the points of compliance. Due to the effects of dilution within the stream, metals concentrations at the points of compliance required under CERCLA and MTCA would be much higher than the model predicts.[2]

- **Load reduction assumptions are unsupported.** The DFFS Model uses load reduction factors to calculate the effect of a remedial action on each of the different sources of release. Intalco selected these factors based on professional judgment. No published experience, site-specific data, or calculations were provided to support the assumed effectiveness factors for upgradient controls and groundwater collection efficiency. A particular source of concern, the assumed 75 percent load reduction factor applied to seeps in the LWA is discussed in detail in Sections 2 and 5 of this appendix. Analysis by the Agencies (using EPA's Batch Flush Model) indicates that cleanup of the LWA of the Site will take much longer than assumed by Intalco. Another example of concern is differences in the load reduction factors used downgradient of the tailings piles compared to other areas of the Site.

[2] The DFFS Model can only be used to predict surface water concentrations at the two Railroad Creek locations (designated RC-4 and RC-2) that were used for surface water sampling. Metals concentrations within the creek at these two locations are orders of magnitude less than concentrations discharging into the creek at other locations at the Site. Even if the DFFS Model predicted a remedy would achieve water quality criteria at RC-4 and RC-2, such a remedy would not be protective of aquatic life throughout the creek. Points of compliance required under CERCLA and MTCA are discussed in more detail later in this appendix, and elsewhere in the Supplemental Feasibility Study (SFS, Forest Service 2007).

- **"Unaccounted load" terms were used to eliminate discrepancies in data.** Intalco created input terms for the DFFS Model as correction factors to reconcile differences between measured and predicted load at different reference points in Railroad Creek. The unaccounted load terms were used in the model to make the amount of metal measured at sources flowing into the creek add up to exactly match the amount of metal measured downstream. These unaccounted loads are a catch-all used to eliminate discrepancies in measured vs. expected concentrations that may have arisen due to changes in creek flow; potential errors in measurement of flow or concentrations; precipitation of metals into creek sediment; chemical reactions within the water column; potential releases from unidentified sources; etc. The difference in the mass of metals measured entering the creek from the Site compared to the mass of metal measured downstream varies locally and seasonally. At the Railroad Creek sampling location RC-4 the maximum difference is more than 20 percent for cadmium and zinc, −50 percent for aluminum, and more than 100 percent for copper, depending on the season (as illustrated on Figures A-2 and A-4 in Appendix A of the DFFS). At the sampling location RC-2, the model includes maximum seasonal unaccounted load terms of −50 percent for aluminum, −128 percent for copper, and –67 percent for iron, and 18 percent for zinc (see Figures A-5 and A-6 of Appendix A of the DFFS).[3]

  Load reduction factors assumed by Intalco for different remedial actions are also applied to the unaccounted loads in the DFFS Model. However, since the reasons for differences in expected and measured metals load in the creek are not known, the Agencies find it inappropriate to rely on a model that assumes that remediation will reduce these unaccounted loads to the same degree as for identified sources of metals.

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[3] An unaccounted load expressed as a negative percentage simply means that more metals were measured for sources discharging into the creek than were measured downstream, so a negative unaccounted load term was added to take the excess metals out of the model. A positive unaccounted load means the percentage of metal measured downstream was less than could be accounted for by the identified sources of metals release. The percentages listed herein are the maximum values for spring or fall conditions. The DFFS Model includes two sets of calculations to account for seasonal variations in flow and concentration. Concentrations vary seasonally due primarily to the effect of spring snowmelt and runoff. As used herein and in related documents, spring conditions refer to the May – July period, approximately 90 days long, when snowmelt causes relatively high groundwater levels, and relatively high flow conditions in Railroad Creek (e.g., 230,000 to 280,000 gallons per minute [gpm] at Lucerne). Fall conditions represent the other 275 days per year (August – April), typified by lower groundwater levels and relatively low flows in Railroad Creek (e.g., about 45,000 gpm at Lucerne).

The DFFS Model does not adequately address groundwater discharge from the LWA. With the exception of some seep flow during the spring, the DFFS Model does not include any source terms to represent metals released into Railroad Creek from the LWA.[4] The flow nets developed by the Agencies (Hart Crowser 2005a) indicate there is a substantial volume of groundwater flow into Railroad Creek from the LWA throughout the year.[5] Monitoring well samples reported in the Draft Remedial Investigation (DRI, Dames & Moore 1999), and the DFFS show that groundwater concentrations in the LWA exceed proposed surface water cleanup levels for cadmium, copper and zinc based on protection of aquatic life. Concentrations in five of six wells exceed the proposed cleanup levels for these metals by factors ranging from 30 to more than 3,000 times the proposed cleanup levels. Not considering LWA metals loading to Railroad Creek from baseline groundwater flow is a serious deficiency of the DFFS Model.

Each one of the problems outlined above is a critical flaw, and each one by itself would make the DFFS Model unsuitable as the basis for comparing alternatives for selection of a remedy. These problems, and additional limitations of the DFFS Model, are discussed in more detail later in this appendix.

South Bank Analysis

Intalco presented an analysis (URS 2004c), referred to as the South Bank Analysis, to extrapolate metals loading results of the DFFS Model to predict changes in concentrations within Railroad Creek near the south bank following remediation. The Agencies do not consider the South Bank Analysis to be an acceptable basis for selection of a remedy, for the reasons outlined below.

- **The South Bank Analysis relies on an incorrect assumption that changes in concentration are proportional to changes in total load in the creek.** Intalco assumed that the ratio of the metal concentration near the south bank of Railroad Creek to the concentration for a cross-channel composite creek sample is directly proportional to the metals loading in Railroad Creek. The analysis does not reflect that changes in load to the creek (e.g. due to collection and treatment of the portal drainage) will not affect the

[4] For alternatives that include a barrier and groundwater collection in the LWA, (e.g., DFFS Alternative 6a and 6b), a volume estimate for collected groundwater is included as part of the treatment system effluent line item in the model.

[5] Flow estimates for the fall low flow conditions based on the flow nets vary from about 11,500 gallons per day to 576,000 gallons per day due to the range of hydraulic conductivity values measured at the Site.

concentration of groundwater seeps and baseflow that discharge into the creek.

- **The South Bank Analysis does not predict concentrations at the point of compliance for groundwater.** The South Bank Analysis is based on comparison of samples collected in Railroad Creek near the south bank of the creek and composite samples collected across the channel. The analysis is intended to predict changes in concentration for samples that were collected in open water near the south bank, which is not the point of compliance.

- **The South Bank Analysis relies on results from the flawed DFFS Model.** The South Bank Analysis predicts changes in concentration near the south bank of the creek based on extrapolating results of the DFFS Model for fully mixed conditions at RC-4 and/or RC-2. However, the results of the DFFS Model are unreliable as noted above and as discussed in detail later in this appendix.

Each of the problems outlined above is a critical flaw, and each one by itself would make the South Bank Analysis unsuitable as the basis for comparing alternatives for selection of a remedy. These problems are discussed in more detail later in this appendix.

Treatment Plant Model

The TPM is also a mass loading model, but it differs from the DFFS Model in some key aspects. The Agencies used the TPM to estimate the amount of sludge that would be produced as a result of groundwater treatment. Also, the results were previously used to estimate the mass of metals that would be prevented from discharging into Railroad Creek due to groundwater collection and treatment. The TPM is well suited for use as part of the process for comparing cleanup alternatives, for the following reasons.

- The TPM provides a realistic starting point for estimating long-term operation and maintenance (O&M) requirements for each alternative. Following initial implementation of the cleanup, collection and treatment of groundwater at the Site will need to continue for hundreds of years to prevent the future release of hazardous substances into Railroad Creek. Both capital and O&M costs are related to the volume and metals concentration of contaminated water that will be treated, and to the long-term management of sludge that will be produced by treatment. The TPM uses site-specific data to provide a basis for evaluating the reduction in toxicity, mobility, and volume of hazardous substances, and the cost for each alternative, as required under

CERCLA. The TPM also provides information on the incremental effectiveness of each alternative, which is needed for the practicability analysis under MTCA.

- The TPM also enables calculation of the mass of metals in groundwater that would be collected for treatment. However, the mass of metals collected by each alternative is not a good indication of the relative improvement in surface water quality that will result, since the alternatives differ in where groundwater is collected. An alternative that collects water at some distance from the creek will require a much longer restoration time frame to protect surface water, compared to an alternative that immediately prevents contaminated water form entering the creek.

Although the TPM provides information that is needed as part of the analysis of alternatives, application of this model alone is not a sufficient basis for selection of a remedy.

The TPM is a mass-loading model similar to the DFFS Model, but it differs with respect to the main problems of the DFFS Model as follows.

- The TPM is <u>not</u> used to predict concentrations in Railroad Creek, so the issue of whether it represents conditions at the point of compliance is irrelevant.

- The TPM uses the same unsupported load reduction factors that Intalco assumed for the DFFS Model. The TPM uses load reduction factors in the same way for similar components of each alternative (e.g., effectiveness of collecting the portal drainage, or barrier wall effectiveness), to provide a consistent basis for comparing the alternatives. The TPM illustrates some relative differences in alternatives (e.g., the volume of sludge produced during long-term O&M). However, if Intalco's assumed factors for source control and groundwater collection efficiency have inappropriate values, errors in the TPM would not lead to selection of an inappropriate remedy.[6]

- The TPM does not use any unaccounted load factors.

Based on the differences between the TPM and the DFFS Model, and the way the TPM is used, the TPM is an appropriate tool for comparing alternatives as

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[6] This is not the case for the DFFS Model however. If the load reduction factors in the DFFS Model have inappropriate values, it could mean the predicted concentrations in Railroad Creek would not satisfy ARARs, and/or would not be protective within the restoration timeframe predicted by the model.

part of selecting a remedy for the Site. The issues summarized above are discussed in more detail later in this appendix.

Batch Flush Model

The Batch Flush Model was used by the Agencies to assess the time required for contaminated groundwater to reach proposed cleanup levels in the LWA, after elimination of hazardous substance releases to groundwater. The time required for clean up depends on groundwater flow characteristics in areas impacted by upgradient releases and the rate of metals desorption from soil into groundwater. The Environmental Protection Agency (EPA) Batch Flush Model (EPA 1988, Zheng et al. 1991, NRC 1994) was used to assess the restoration time frame for natural attenuation. Natural attenuation in the LWA is a component of some alternatives (e.g., Alternatives 8 and 9), but not part of Alternatives 10 and 11.

The Agencies used the Batch Flush Model to examine Intalco's assertion in the DFFS that a groundwater barrier and collection system in the Upper West Area (UWA) would reduce downgradient loading from seeps that discharge into Railroad Creek by 75 percent in 5 years.[7] However, Intalco did not provide any analytical or empirical basis to support the predicted load reduction for the LWA. In contrast, the Batch Flush Analysis indicates it would take from about 12 years to more than 200 years (different periods for different metals) to achieve a 75 percent reduction in metals concentration in seeps that discharge into Railroad Creek in the LWA.

The Batch Flush Model used site-specific data such as groundwater flow rate, distance from the barrier to the creek, and metals concentrations measured in seeps and monitoring wells in the LWA. The model used published values for some soil characteristics including partitioning coefficients, bulk density, and porosity, where site-specific data were not available.

The type of analysis used in the Batch Flush Model is recommended for evaluation of natural attenuation processes including characterization of changes in contaminated groundwater plumes, and estimating the time required for achieving remediation goals (EPA 1999). Although well suited for use at the Site, the Batch Flush Model has the following limitations.

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[7] Intalco contends this is a reasonable restoration time frame, and proposed using the UWA barrier and collection system as part of Alternative 9 and other alternatives examined in the DFFS.

- **The Batch Flush Model assumes linear, non-reversible desorption of metals between the groundwater and soil matrix**. Desorption of metals from soils into groundwater is a non-linear relationship. This assumption has the effect of making the actual cleanup time longer than predicted by the model.

- **The Batch Flush Model does not account for heterogeneities in the aquifer matrix**. Local variations in site soils will affect the rate of contaminant reduction, and actual cleanup time could be less than or greater than predicted. Depending on the variability of conditions along the groundwater flow path across the Site, the model could over-predict the rate of clean up in some areas and under-predict it in other areas. In the absence of additional site data, there is no basis to assume the actual cleanup time would be less than or greater than predicted by the model.

- **The Batch Flush Model assumes that clean water enters the contaminated zone and flushes the metals from the soil matrix**. The model would likely under-predict the actual rate of clean up for the groundwater in the LWA, since groundwater from the UWA that bypasses the barrier wall (e.g., for Alternative 9) is expected to contain elevated concentrations of metals.

- **The model relies in part on the distribution coefficient (designated as K_d) that provides a measure of the degree to which metals are transferred from soil into groundwater, and this parameter is sensitive to changes in pH**. Intalco commented that metals concentrations in groundwater are controlled by pH and, because the Batch Flush Model does not account for changes in K_d due to changes in pH, the results are incorrect. While other approaches may be used that would account for the variability in pH, these approaches require extensive site-specific data to implement, and Intalco has not proposed collecting any of the data required by these alternative methods.

Two of the four limitations described above indicate that the Batch Flush Model would likely underestimate the actual time to achieve groundwater clean up in the LWA, and there is insufficient existing information to assess the effect of the other two limitations. Although there is some uncertainty in results based on using published data where site-specific data are not available, the Batch Flush Model is an appropriate tool for comparing alternatives as part of selecting a remedy. The issues summarized above are discussed in more detail later in this appendix.

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TABLE

APPENDIX A
USE OF MODELS IN COMPARING THE EFFECTIVENESS OF REMEDIAL ALTERNATIVES

1.0 Introduction

This appendix discusses four spreadsheet-based models that were used by Intalco or the Agencies for comparing remedial alternatives for the Holden Mine Site (Site). Each of these models (the DFFS Model, the South Bank Analysis, the Treatment Plant Model, and the Batch Flush Model) is discussed separately in the following sections of this appendix. For each model, the discussion includes a brief description of how the model was used; how the model works; assumptions and limitations of the model; and a summary.

2.0 DFFS Post-Remediation Loading Analysis Model (DFFS Model)

Intalco used the DFFS Model to estimate post-remediation surface water concentrations in Railroad Creek at two sampling locations designated RC-2 and RC-4. The DFFS Model was run for different intervals following implementation of remedial action to predict the time until surface water concentrations meet potential ARARs. The model was run for DFFS Alternatives 2 through 8 (URS 2004a), and Alternative 9 and Alternative 10 (URS 2005b) that were developed after completion of the DFFS.

The DFFS Model estimates changes in metals concentrations in Railroad Creek resulting from the reduction of metal loads from various sources by each remedial alternative. Model results are provided for cadmium, copper, iron, and zinc.[8] Details on how the model works and its limitations are provided below.

2.1 How the DFFS Model Works

The DFFS Model is based on a series of spreadsheets that tabulate influent loads to Railroad Creek from different sources, and modifies these loads mathematically to reflect the effects of remedial action. For each remedial alternative, there are two spreadsheets to address seasonal differences in flow and concentration. One spreadsheet represents high flow conditions that is based on spring 1997 data and are inferred to occur for about 90 days per year. Another spreadsheet represents low flow conditions based on fall 1997 data that

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[8] The other potential constituents of concern, aluminum and lead, were not included in the DFFS analysis, apparently due to limitations in the RI data.

are inferred to occur for about 275 days each year. The DFFS Model also includes a short-term analysis and long-term analyses. According to the DFFS, short term is 5 years after remedy implementation and long term covers 25 to 2,500 years following remedy implementation.

The DFFS Model evaluates the effect of remediation by modifying the sources of metals loading to Railroad Creek. These sources or baseline loading input terms are modified for each remedial alternative using performance factors or load reduction factors. A brief discussion of these terms is provided below.

2.1.1 Sources of Metal Load

The contaminant load for each groundwater source is the product of flow from the source multiplied by the source concentration. The DFFS Model uses load expressed in units of kilograms per day (kg/D). The DFFS Model incorporates the following sources of metal loading to Railroad Creek:

- Railroad Creek background load at the upstream side of the Site;
- Individual surface water seeps (or groups of seeps located in close proximity to one another);
- Surface water inflows (1500 Level portal drainage, Copper Creek Diversion, and Copper Creek);
- Groundwater baseflow for some but not all portions of the Site;
- Effluent from the proposed treatment plant(s) for each alternative; and
- "Unaccounted load" adjustments.

The upstream load for each metal is the product of creek flow and concentration measured upstream of the Site at Railroad Creek sampling location RC-1. The calculated load in Railroad Creek is increased within the model by adding the sources of load that discharge into the south side of the creek, progressing from west to east. The load from these sources is calculated using measured or estimated flow multiplied by the measured concentration. Some of the seeps were only observed during spring flow conditions, thus these sources are not included in the fall spreadsheets.

The amount of groundwater that enters or leaves the creek as baseflow has not been directly measured. In the DFFS Model, groundwater baseflow from the tailings piles into Railroad Creek was estimated using a hydrologic flow net analysis, which was presented in the DFFS.[9] Results from the flow net analysis

[9] The DFFS did not include a flow net for the Lower West Area (LWA) even though Intalco drilled wells there in the fall of 2003. The DFFS Model (e.g., for Alternative 6) used an analysis of upgradient precipitation to

for the tailings were used in the model to input discrete components of groundwater flow, referred to as flow tubes. Some of the flow tubes represent negative loading conditions in the fall, indicating the creek is losing flow into the ground within a particular reach.

The flow net analysis assumed that groundwater recharging Railroad Creek is likely shallow groundwater from the upper 10 feet of flow in the aquifer (URS 2004b). This estimate was based on a sensitivity analysis Intalco performed on the baseline loading analysis. During the sensitivity analysis, the aquifer thickness was varied in the flow tube analysis between 10 and 40 feet. While the 10-foot aquifer thickness makes the arithmetic in the DFFS Model balance better, the actual depth of groundwater that flows into the creek may vary.

During the RI, surface water samples and flow measurements were obtained upstream of the Site (RC-6), and adjacent to the mine area at locations RC-1, RC-4, and RC-2. The DFFS Model considers the Site in three creek segments or reaches: RC-6 to RC-1, RC-1 to RC-4, and RC-4 to RC-2. For each of these reaches, the DFFS Model compares the sum of load measured at the upstream location (e.g., RC-6 for the first reach) plus the loads from sources within the segment reach, to the load measured downstream location (e.g., RC-1 for the first reach). The model reconciles any differences between measured and calculated load at the downstream end of each reach (e.g., RC-1) by addition or subtraction of unaccounted load terms to correct any discrepancy. These unaccounted load adjustments vary for each metal and stream reach, and are quite significant.

There are several potential sources of the unaccounted load, but the DFFS Model does not differentiate between them. Sources of unaccounted load include the effects of:

- Measurement error;
- Differences in timing of flow measurements;
- Groundwater baseflow, that may differ from what was predicted with the flow nets;
- Groundwater baseflow that was not included in the DFFS Model;
- Inflow from the north side of Railroad Creek; and/or

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produce an estimated LWA flow. This estimate is very similar to the high end of the range based on a flow net subsequently prepared by the Agencies (Hart Crowser 2005a) based on the 2003 wells, seeps, and creek elevation stages recorded by URS.

- Chemical reactions within the water column, and precipitation or sorption of metals within the creek bed.

Intalco accounts for long-term changes in metals loading using an estimated source depletion rate based on extrapolation of limited data from other sites. The DFFS Model estimates long-term changes in surface water quality by modifying the influent sources by this source depletion term, in addition to the load reduction terms for each remedial alternative. While this approach seems reasonable, the actual rate of source depletion at the Site is not subject to independent verification other than by monitoring to see what happens over time.[10]

2.1.2 Performance Factors

In the analysis of the various alternatives, performance factors were assigned to the various sources of load to Railroad Creek based on the different components of each alternative. These performance factors for the DFFS alternatives are presented in Tables D1-1 through D1-14 and D2-1 through D2-14 in Appendix D of the DFFS. The performance factors for Alternatives 8, 9, 10, and 11 are also included in Table A-1 of this appendix.

The performance factors used in the DFFS Model include:

- Load reduction terms due to upgradient controls;
- Downgradient collection efficiencies; and
- Water treatment system effectiveness.

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[10] Source depletion should not be confused with natural attenuation. Source depletion refers to the depletion of the major source of contamination at the Site: the chemical oxidation of sulfide minerals in rock within the underground mine, tailings, and waste rock. Oxidation of the sulfide minerals releases metals and produces acidic conditions that increase solubility of the metals in groundwater at the Site. Over time, as the sulfide minerals and resulting contamination enter the environment, the quantity of remaining sulfide minerals available to cause future contamination will decrease (i.e., deplete) and the ongoing release of acidic drainage and metals to groundwater will diminish. However, this source depletion of sulfide minerals does nothing to mitigate the maximum potential adverse effects of metals already or continuing to be released to the environment. Similar to allowing a barrel of waste to leak until empty, relying on source depletion is a "no action" approach. In contrast, natural attenuation processes "include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater" (EPA 1999). For metals at the Site, these natural attenuation processes may include dispersion, dilution, and sorption, although these processes have not been quantified in the DRI or the DFFS.

The load reduction terms are percentages that are applied to a particular source of load based on the remedial action that may impact that source. For example, the DFFS assumes that placing the Copper Creek Diversion into a culvert or lined channel will decrease the load from that source by 95 percent. Therefore, for those alternatives that include that action, the DFFS Model calculations indicate that only 5 percent of the baseline load from the Copper Creek Diversion would enter Railroad Creek following implementation of the remedy.

Downgradient collection efficiencies are applied to sources that are collected for treatment prior to discharge to Railroad Creek. Collection efficiencies used in the DFFS Model range from 80 to 97 percent depending on the source. For example, the model uses an efficiency factor of 90 percent for collection of seep SP-23. Therefore, the DFFS Model calculates that 10 percent of the flow from seep SP-23 would continue to discharge into Railroad Creek, and 90 percent of this seep flow would become part of the flow to the treatment plant.

The flow to the treatment plant from all collected sources is multiplied by a treatment effluent concentration factor in the DFFS Model, and the resultant load is added to the uncollected sources (e.g., the 10 percent of flow from seep SP-23 referred to above, etc.) to calculate the resulting downstream surface water quality in Railroad Creek.

2.1.3 DFFS Model Results

For each remedial alternative, the DFFS Model was used to assess the effect of load reductions for both the spring and fall conditions. The model summed the changes for each source of metals discharging to the creek, after modifying the sources with load reduction factors as described above. The result produced the predicted metals load in the creek at RC-2 and RC-4, for each alternative for both spring and fall conditions. Concentrations of metals in the creek were calculated by dividing the calculated load by the measured creek flow at RC-4 and RC-2. These concentrations differed for each alternative because each alternative affected different portions of the Site. Intalco compared the effectiveness of the various alternatives by using the model to estimate the post-remediation concentration downstream of RC-2 for spring and fall conditions, and plotting these concentrations over time (i.e., years after remedy implementation) for each constituent of concern.

2.2 Limitations of the DFFS Model

The DFFS Model is intended to provide a basis for describing the relative effect of changes in the magnitude of metals loading from different source areas of the Site. However, it does not provide a good basis for remedy selection since the limitations of the DFFS Model prevent it from clearly distinguishing the effectiveness of one alternative compared to another at the appropriate point of compliance. These limitations are discussed below.

2.2.1 Model Results Are for Fully Mixed Conditions Downstream of Where the Contamination Sources Discharge into the Creek

Compliance with water quality criteria under both CERCLA and MTCA is based on the concentration of metals (total and dissolved), not the load in Railroad Creek or the change in load. The DFFS Model provides an estimate of the surface water concentration based on the predicted load of four metals (cadmium, copper, iron, and zinc) at only two locations within Railroad Creek. There are significant problems with this:

- **The DFFS Model does not estimate water quality at the points of compliance required under CERCLA and MTCA.**[11] Both CERCLA and MTCA

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[11] Points of compliance refer to the locations where cleanup levels must be met. CERCLA and MTCA both define points of compliance for groundwater and surface water. Under federal law, the point of compliance depends on the designated beneficial use of the surface water, which for Railroad Creek is defined under WAC 173-201A-600. This includes the following (the use categories are shown in parenthesis): aquatic life (salmonid spawning, rearing, migration, and core summer habitat), recreation (extraordinary primary contact), water supply (domestic, industrial, agricultural, and stock watering), and miscellaneous (wildlife habitat, harvesting, commerce and navigation, boating, and aesthetic values). In addition, because the Site is within a National Forest, and because Railroad Creek is a feeder stream to Lake Chelan, WAC 173-201A-600(1)(a) requires that Railroad Creek also to be protected for the designated uses of salmon and trout spawning, non-core rearing, and migration; and extraordinary primary contact recreation. Accordingly, cleanup levels for groundwater at the Site that enters Railroad Creek are based on protection of aquatic life.

Under CERCLA, the preamble to the final NCP [55 FR 8753] states that groundwater remediation levels should generally be attained throughout the contaminated plume, or at and beyond the edge of the waste management area when the waste is left in place [53 FR 51426]. While EPA acknowledges an alternative point of compliance may also be protective of public health and the environment under "site-specific circumstances," the preamble to the proposed NCP also states "EPA's policy is to attain ARARs...so as to ensure protection at all points of potential exposure" [53 FR 51440]. Under CERCLA the alternative point of compliance for groundwater at this Site is based on the State of Washington's designated beneficial uses of the surface water, as set forth above. The points of potential exposure for the beneficial uses of surface water for protection of aquatic life are at the groundwater-surface water interface.

Normally the point of compliance for groundwater under MTCA is throughout the Site, from the uppermost level of the saturated zone to the lowest depth that could potentially be affected. MTCA requires that groundwater cleanup levels be attained in all groundwater from the point of compliance to the outer boundary of the hazardous substance plume [WAC 173-340-720(8)]. Subject to certain conditions, MTCA allow the point of compliance at the Site to be located at the groundwater-surface water interface. However, the metals concentrations that are calculated in the DFFS Model represent the fully mixed conditions in the creek at RC-4 and RC-2, which are quite different from conditions at the required points of compliance.

- The concentrations at RC-4 and RC-2 are derived from changes in the estimated cumulative *load* due to changes in the various sources that discharge into Railroad Creek. The model does not directly evaluate changes in *concentration at the points where the sources discharge*. By relying on changes in downstream load to estimate changes in concentration, the presence or absence of any effects of a remedial alternative on individual source(s) are obscured by the effect of dilution, since the flow in Railroad Creek is much larger than any of the individual sources.

The DFFS Model results for fully mixed conditions ignore whether an alternative would reduce concentrations of contaminated seeps and groundwater that discharge into the creek. The discharge of every seep that has elevated metals concentrations will adversely influence some length of stream by increasing the surface water concentration in the vicinity of the discharge. A remedial alternative is not effective if areas adjacent to seeps continue to exceed concentrations that are protective of aquatic life, regardless of whether dilution produces acceptable water quality farther downstream.

The distance over which the discharge from any one seep will adversely influence water quality in the creek depends on things such as the rate of flow in the creek, rate of flow at the seep, local bank and creek channel configuration that affect mixing, and the metals concentrations in the seep water. The same process occurs when groundwater discharges as baseflow. Metal concentrations for each flow tube[12] adversely impact surface water quality in the

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allows a conditional point of compliance for groundwater for limited circumstances where it is not practicable to meet the cleanup level throughout a site within a reasonable restoration time frame. The conditional point of compliance allowed under MTCA is within surface water as close as technically possible to the point or points where groundwater flows into the surface water. The DFFS indicated that it is not practicable to cleanup groundwater throughout the Site within a reasonable restoration time frame. Thus, under MTCA as well as CERCLA, the required points of compliance for groundwater at the Site are all along the groundwater-surface water interface.

[12] The DFFS presented a method of quantifying the amount of groundwater that enters Railroad Creek as base flow (i.e., not including flow from discrete seeps), referred to as a flow net analysis. The flow net analysis

vicinity of the flow tube discharging into the creek. Therefore by only predicting metals load for fully mixed conditions at RC-4 and RC-2, the DFFS Model does not address the localized impact that the seeps and groundwater baseflow have on Railroad Creek, i.e., at the required points of compliance.

2.2.2 Load Reduction Factors Used in the DFFS are Unsupported

Analysis of the effectiveness of the alternatives is driven by Intalco's load reduction factors that are presented in the DFFS. The DFFS load reduction factors represent the professional judgment of Intalco's consultants without any supporting data or published experience from other sites. The load reduction factors are qualitative judgments that have the effect of making the DFFS Model appear to produce quantitative conclusions, but without any supporting data needed to make such conclusions.

The load reduction factors assumed by Intalco for groundwater (including seeps) from the LWA, tailings, and waste rock piles are a particular concern because the DFFS does not include any evaluation of the effect of changes in these factors. The DFFS does not discuss the effect on predicted concentrations if the actual effect of a cleanup action is different from that represented by the assumed load reduction factors. Since the DFFS relies on the effect of these unsupported factors to predict concentrations in Railroad Creek, there is legitimate concern whether post-remediation concentrations in Railroad Creek will be protective within the time period predicted by Intalco, if any of the assumed values for the load reduction factors are incorrect.

Specific concerns regarding two examples of Intalco's assumed load reduction factor are discussed in more detail below, for the LWA, and collection efficiency downgradient of the tailings piles.

LWA Load Reduction Factor. Alternative 9, and a number of the DFFS alternatives, are assigned an assumed 75 percent load reduction factor for seep sources in the LWA on a short-term basis, and 85 percent for the long term. Intalco reported this assumed load reduction factor was based on the combined effects of a groundwater barrier wall and collection system in the UWA, collection of the portal drainage for treatment, and seepage from unlined treatment system ponds located in the LWA. Intalco assumed the 75 percent load reduction would occur within 5 years after remedy implementation, and

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provides a means to estimate the quantity of groundwater flow for segments of the aquifer (referred to as flow tubes) that discharge into Railroad Creek.

would increase to 85 percent over the long term. In the DFFS Model, this load reduction factor was applied to seeps SP-9, SP -11, SP-25, SP-24, SP-10W, and SP-10E, which flow into Railroad Creek all across the LWA some 300 to 400 feet downgradient from the proposed UWA barrier wall. This load reduction factor was also applied to the unaccounted metals load at RC-4 (located near the LWA), which is discussed in detail later in Section 2.2.3.

Since load is the result of concentration times flow, the assumed LWA load reduction could occur as a result of reductions in flow, concentration, or both. Based on these two components of the load, flaws in the assumed LWA load reduction factor in the DFFS Model are the following:

- **Flow.** Collection of the 1500 Level portal drainage and installation of the UWA barrier wall may decrease load by intercepting groundwater and surface water flow that would typically enter the LWA from the UWA to the south. However, flow nets show groundwater flow in the LWA is southeasterly, i.e. its sources are both from the UWA *and* up valley to the west (Hart Crowser 2005a). Therefore, collection of the portal drainage and installing the UWA barrier would likely have little or no effect on groundwater flow through the LWA into Railroad Creek.

- **Concentration.** Groundwater concentrations in the LWA may not change appreciably in the short term following installation of the UWA barrier and collection of the portal drainage. Metals that remain in the soil and groundwater in the LWA will contribute to the continued release of contaminated groundwater and seeps to Railroad Creek following UWA remedial actions. (The rate of change is discussed in more detail in Section 4. of this appendix).

Due to these flaws, the Agencies believe that the DFFS Model over-predicts the effectiveness of Alternative 9 as well as those DFFS alternatives that rely on a load reduction factor for the LWA. If the assumed 75 percent (short-term) to 85 percent (long-term) load reductions were not achieved, it would reduce the overall effectiveness of these alternatives for the LWA and TP-1.[13]

The Agencies analyzed the change in effectiveness of Alternative 9 if this 75 percent LWA load reduction does not occur. This analysis showed that for Alternative 9, the DFFS Model underestimates the annual amount of metals in

[13] Intalco maintains the effect of a groundwater barrier and collection system in the UWA would also improve groundwater quality below Tailings Pile 1 (TP-1).

Railroad Creek at RC-2 by 9, 7, and 5 percent for cadmium, copper, and zinc, respectively; i.e., if the 75 percent load reduction for the LWA does not occur within 5 years as assumed by Intalco. The magnitude of the underestimated load, expressed as a percentage, is even greater, upstream of RC-2. Also, these values are for metals from the LWA seeps only, since the DFFS Model does not consider the effect of metals loading to the creek from LWA groundwater baseflow. Groundwater baseflow discharges metals above proposed cleanup levels into the creek all year long, but the LWA seeps only flow during the spring months. The DFFS Model would underestimate metals in Railroad Creek in the same way (but by different percentages) if the values assumed for load reduction factors for other sources were also not achieved as assumed by Intalco.

Subsequent to review of the DFFS, the Agencies requested Intalco provide quantitative backup to the assumed 75 percent reduction factor used for the LWA (Forest Service 2004). In response, Intalco maintained that all sources of metals loading to the LWA have been identified, and therefore, reduction or elimination of these sources would control discharge from the LWA. Intalco described three factors that it thought would influence the timing of metals loading reductions from the LWA to Railroad Creek (URS 2004d).

- **Groundwater Travel Time.** Intalco estimated that 3 to 140 pore volumes of groundwater would flush through the LWA in a 5-year period. The range is due to the variable nature of the glacial and alluvial soils present, as indicated by the range in hydraulic conductivity measured during the RI. However, Intalco did not provide any specific estimate of the effect of this flushing on changes in groundwater or soil concentrations. While the concentration in groundwater is known, without a distribution coefficient[14] for the mass of metals in the saturated zone soils, the effect of pore volume flushing alone cannot be used to predict the rate of contaminant reduction or time to achieve proposed cleanup levels.

- **Accumulation and Release of Metals within the Saturated Zone.** Intalco's analysis indicated that metals loading from the UWA to the LWA are greater than the annual loading from the LWA groundwater and seeps into Railroad Creek. This suggests that a portion of the metals released from the UWA is

[14] A distribution coefficient compares the amount of a contaminant divided between two phases in the environment. In this case, it refers to the distribution (ratio) of a given metal between the solid phase sorbed onto the soil matrix, and the dissolved phase in the groundwater. Intalco did not determine distribution coefficients for any metals at the Site. Use of published values to predict changes in water quality is discussed further in Section 4 of this appendix.

being stored, via sorption, in soils in the LWA. If this is occurring, then all or a portion of these metals stored in the saturated zone of the LWA may be released to groundwater and Railroad Creek over time after the UWA sources (and the portal drainage) have been cut off. Intalco agreed that the rate of release of stored metals would depend on soil and groundwater parameters such as organic carbon content, redox potential, pH, alkalinity, and concentration of the dissolved metals; but Intalco did not provide any quantitative estimate for the rate of release. Since these data were not obtained during the RI for soil below the water table in the LWA, the quantity of stored metals available for re-release, and the rate of such re-release, are unknown.

- **Effect of Unlined Treatment Ponds in LWA.** Finally, Intalco contended that infiltration from unlined treatment ponds in the LWA will contain excess alkalinity and reduce solubility of metals in groundwater in that area. Intalco's assumption ignores the likelihood that treatment ponds may need to be lined if influent water quality exceeds proposed groundwater cleanup levels (for protection of surface water) or to conform to potential action-specific ARARs for treatment system design. Further, any dissolved metals that are adsorbed below unlined ponds could be remobilized and transported into Railroad Creek if groundwater conditions change over the long term.

In summary, Intalco (URS 2004d) has not justified the assumed 75 percent load reduction for the LWA that was used in the DFFS Model.

Collection Efficiency Factor Downgradient of the Tailings Piles. The DFFS applies lower collection efficiencies for barrier walls that are installed in the east area relative to walls installed in the west area. The DFFS assumed 90 percent effectiveness for a barrier wall and collection system in the UWA, but only 80 percent effectiveness for the same barrier and collection system adjacent to the tailings piles, where the groundwater has elevated iron concentrations. The difference in the selected values makes some alternatives arbitrarily look better than others in the DFFS Model.

The DFFS says the difference in barrier and collection efficiency factors from west to east is because of the effects of iron fouling in the collection system adjacent to the tailings piles. However, a) no data are provided in the DFFS to support the estimated difference in efficiency, and b) there is no discussion in the DFFS of whether maintenance could be used to reduce the impact of anticipated fouling.

By using a lower collection efficiency factor downgradient of the tailings piles, the DFFS Model estimates less cadmium, copper, and zinc would be prevented from being released into the creek. Alternatives that include a tailings pile barrier and collection system (e.g., Alternative 5b) thus have less incremental benefit compared to the incremental cost increase, relative to alternatives that do not include a tailings pile barrier and collection system (e.g., Alternative 3b).

2.2.3 Unaccounted Load Terms Obscure Potential Effects of Remedial Actions

As previously discussed, the DFFS Model uses unaccounted load terms to make the sum of source loads within a reach of the creek equal to the load measured at the downstream end of the reach, i.e., to make the math in the model correct. Intalco reported the terms reflect some combination of measurement errors; differences in when flow or concentration measurements were made across the Site; groundwater baseflow from the north or south side of the creek; and/or precipitation or sorption of metals within the creek bed. The DFFS Model uses unaccounted load terms to correct discrepancies in conditions measured at the Site so that the cumulative sum of the source loads (including the unaccounted load) can be used to predict the load downstream of a given stream reach.

The table below shows that in many instances, the magnitude of the unaccounted load in the DFFS Model is a substantial portion of the load measured downstream of the identified sources. The following table summarizes the magnitude of unaccounted load, i.e., discrepancies in the DRI data used in the DFFS Model, based on Appendix A of the DFFS.[15]

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[15] Unaccounted load for some constituents of concern is not shown in this table for locations/seasons where the unaccounted load was less than 10 percent of the load measured at RC-2.

Reach in Railroad Creek	Season	Constituent of Concern	Magnitude of Unaccounted Load in Reach, Compared to Load Measured at RC-2[16]
RC—1 to RC-4	Spring	Aluminum	- 51 %
	Fall	Cadmium	26 %
		Copper	101 %
		Zinc	21 %
RC-4 to RC-2	Spring	Aluminum	- 34 %
		Copper	- 17 %
		Iron	- 68 %
	Fall	Aluminum	- 50 %
		Cadmium	12 %
		Copper	- 128 %
		Iron	- 17 %
		Zinc	18 %

An unaccounted load expressed as a negative percentage value means that more metals were measured for sources discharging into the creek than were measured downstream; so a negative unaccounted load term was added to take the excess metals out of the model. A positive unaccounted load means the percentage of metal measured downstream was less than could be accounted for by the identified sources of metals release; so additional metal load needed to be added to make the arithmetic work in the DFFS Model.

The DFFS applies the same load reduction factors to the unaccounted load terms that it applies to groundwater sources in the same reach. However, without knowing what the unaccounted load really represents, there is no way to know whether this approach accurately reflects the effect of a remedial alternative. Not all the potential sources of unaccounted load would be decreased following remedy implementation. Therefore, applying load reduction factors to the unaccounted load terms as was done in the DFFS Model, obscures the effect of different remedial alternatives on metals concentrations in the Railroad Creek.

Even if the DFFS Model had not included changes in the unaccounted load corresponding to the effects of the remedy on groundwater, the magnitude of

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16 The DFFS represented unaccounted load as a percentage of load measured at RC-2, for all reaches, although for each reach the unaccounted load was calculated as the difference in the amount of metal measured in the sources within a reach and the amount of metal measured at the downstream end of that reach.

the unaccounted load is sufficiently large relative to the RC-2 baseline load that the effect of a remedial alternative on the known sources cannot be relied on to predict changes in surface water quality

Because of the limitations in the DRI data that are represented by unaccounted load in the DFFS Model, the DFFS Model cannot adequately reflect the effect of a cleanup action on identified source terms. Given the multiple potential sources of unaccounted load, and the magnitude of metals loading attributed to unaccounted load, there is no basis for assuming the DFFS Model realistically predicts the relative effectiveness of any remedial alternative.

As a result, the DFFS Model does not provide a good assessment of whether remedial actions on specific sources would have a meaningful impact on the surface water conditions, from those that would not. Also, the unaccounted load is insensitive to any compensating changes (an increase in one source combined with a decrease in another) that may vary from one remedial alternative to another, or that may vary over time. This is a problem because the various remedial alternatives differ primarily in which source(s) of contamination they affect.

2.2.4 DFFS Model Does Not Accurately Address Groundwater Discharge from the LWA

With the exception of some seep flow during the spring condition, the DFFS Model does not include any source terms to represent metals released from the LWA.[17] The flow nets developed by the Agencies (Hart Crowser 2005a) indicate there is a substantial volume of groundwater flow (mean value about 80 gpm) into Railroad Creek from the LWA throughout the year. Thus, not considering LWA load to Railroad Creek from baseline groundwater flow is a serious deficiency of the DFFS Model.

The DFFS Model did not include any groundwater load to Railroad Creek from the LWA. The problem with this approach is that metal concentrations measured in the LWA monitoring wells show groundwater exceeded water quality criteria in five of six wells sampled by factors of 30 to more than 3,000, as summarized below for spring and fall conditions.

[17] For alternatives that include a barrier and groundwater collection in the LWA, a volume estimate for collected groundwater is included as part of the treatment system effluent line item in the model.

Constituent of Concern	Ratio of Groundwater Concentration to Proposed Cleanup Levels[18] in Monitoring Wells						
	Spring 1997	Spring 2006					
	HBKG-1	HBKG-1	MW-1	MW-2	MW-3	MW-4S	MW-4D
Cadmium	616	421	ND	36	34	113	111
Copper	2860	2430	1.1	30	208	226	208
Zinc	288	254	2.7	31	121	101	91

ND - Not Detected

Constituent of Concern	Ratio of Groundwater Concentration to Proposed Cleanup Levels[19] in Monitoring Wells						
	Fall 1997	Fall 2003					
	HBKG-1	HBKG-1	MW-1	MW-2	MW-3	MW-4S	MW-4D
Cadmium	557	794	ND	140	364	284	283
Copper	2240	3800	1.1	190	1260	672	555
Zinc	304	358	0.8	118	279	235	242

For the remainder of the Site, the DFFS Model uses the spring data to represent conditions over 3 months of the year, and the fall data to represent conditions over 9 months of the year. The flow nets developed by the Agencies (Hart Crowser 2005a) indicate there is groundwater flow into Railroad Creek from the LWA throughout the year, thus not considering the concentration of metals in this groundwater and the load to Railroad Creek is a serious deficiency of the DFFS Model. Since the DFFS Model does not include any term for groundwater discharge from the LWA, the model cannot accurately compare the benefits of remedial alternatives that address this discharge.

2.2.5 Other Areas of Concern with DFFS Model

In addition to the main concerns outlined above, there are a number of other problems with the DFFS Model that make it unsuitable to rely on for remedy selection. These concerns are described below.

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[18] Proposed cleanup levels for groundwater based on protection of aquatic life in surface water, using a surface water hardness value of 12 mg/L $CaCO_3$. At the time this analysis was done, the proposed cleanup level for copper was based on the 2006 NWQC. The analysis has not been revised using the 2007 NWQC (biotic ligand model) criterion, since a specific value for copper has not yet been determined for the Site. ND means a constituent was not detected.

Questionable Long-Term Effectiveness of the Upgradient Run-on Diversion and Reduced Infiltration Remedy Components. The DFFS suggests that release of metals from the tailings and waste rock piles would decrease as a result of remedial measures that reduced infiltration in the waste rock piles and tailings piles. Tables D1-1 through D1-14, and D2-1 through D2-14 in Appendix D of the DFFS show a 15 percent reduction in infiltration of precipitation was estimated for the waste rock piles based on the assumption that 30 percent of the surface is regraded and 50 percent of precipitation then runs off rather than infiltrating. The DFFS assumed an estimated 80 to 95 percent reduction in infiltration for alternatives that involved regrading and revegetating, or capping the tailings piles. However, the geochemical analysis presented in Appendix E of the DFFS indicated that engineered controls that reduce the volume of infiltration probably have no effect on the availability of oxygen to sustain the chemical reaction that releases the metals in the waste rock and tailings, and therefore, potentially no beneficial effect on releases to Railroad Creek.

The analysis of the West Waste Rock Pile showed that predicted concentrations of most metals (including cadmium, copper, iron, and zinc) actually increased in proportion to the flow reduction, see Table 2 in Section 3.4 of Appendix E of the DFFS. With oxygen still available to oxidize the waste rock, metal sulfate salts would still be formed and available for release. The analysis in Appendix E of the DFFS predicts the same quantity of metal would be available for release even though there is less water flushing through the waste rock, thus resulting in an overall increase in metals concentrations (i.e., less dilution from infiltrating water) in groundwater downgradient.

For the tailings piles, Intalco's geochemical modeling also indicated that regrading and revegetation would not be effective in reducing load for most metals, as noted in DFFS Appendix E, Section 5.5.2: "*predicted future cadmium, copper and zinc loadings would remain relatively unchanged from the base case, because they would not exceed solubility limits at the lower infiltration rates.*"

Accordingly, there are considerable questions as to whether it would be reasonable to rely on the DFFS Model predicted changes in long-term load reduction as part of remedy selection.

Effect of Consolidating and Capping the Tailings and Waste Rock Piles for Alternatives 7 and 8. In addition to potential changes in load due to run-on diversion and reduced infiltration on the tailings and waste rock piles described above, the DFFS Model assumed there would be beneficial effects from consolidating and capping the tailings and a portion of the waste rock at the Site. The analysis in Appendix E of the DFFS assumes that such actions would result in reducing the availability of oxygen to the tailings and waste rock. The geochemical analysis predicted that this reduction in the availability of oxygen would reduce the rate of metals released. However, the DFFS notes that the geochemical modeling does not take into account the time required for existing water within the tailings to drain down to the toe of the consolidated pile. Thus release of metals is likely to continue for an indeterminate amount of time after implementation of the remedy, and the timing to achieve drainage and the reduced rate of metals release is not clear in the DFFS.

Appendix E of the DFFS also notes: "*it is known that significant amounts of stored oxidation products* (i.e., metals) *exist within the tailings. A change in redox conditions could impact their stability. Potential effects have however not been modeled.*" As a result, the long-term load reduction assumed in the DFFS Model may not be reliable in perpetuity after implementation of the remedy.

The discussion of load reduction in the DFFS does not address the metals that are likely stored in (sorbed onto) the soils below the existing tailings and waste rock piles as a result of releases to date. The assumed DFFS Model load reduction factors do not consider the potential for mobilization of these stored metals following consolidation of the tailings and waste rock piles. Exposure of these soils following removal (consolidation) of the tailings and/or waste rock, could conceivably increase infiltration and change the redox potential within the exposed soils.

Long-term Analysis Relies on 1997 Data that May Not be Representative. Intalco uses the DFFS Model to estimate changes in metals loading in Railroad Creek over a period of hundreds of years, using baseline data from spring and fall sampling events in 1997. Due to the limited scope in the data collected in the DRI, these data may not adequately represent potential variability in concentrations and flows that occur at the Site both annually and daily. There is little basis to assess representativeness of the 1997 data relative to concentrations and flows that may occur in other years, or that would have been measured earlier or later in the spring and fall seasons of the same year.

There are further limitations in comparing the 1997 data to conditions in other years. One concern involves the unknown effect of hydraulic lag on timing and duration of groundwater and surface water sampling. The spring 1997 data were collected over a period of 6 days.[19] Spring flow and concentration data

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[19] The fall data appear more reliable since sampling took place over only 2 days and there is less diurnal variation in the late summer months.

are influenced by the time of day the sources were sampled, as there is more dilution due to snowmelt later in the day. This is a problem since the model has to rely on unaccounted loads to equate the sum of all the source terms in a reach to the flow and concentrations measured downstream of the Site.

Reliance on Source Depletion. The long-term loading changes used in the DFFS Model are based on extrapolation of empirical data from a few other mine sites to predict the reduction in the release of metals over time due to source depletion in seepage from the waste rock piles and the portal discharge. Attenuation of seepage from the tailings piles was based on geochemical modeling.[20] The results of the source depletion analyses, summarized in Appendix E of the DFFS, were used to modify the DFFS Model.

While there is some basis to support use of empirically based predictions for the change over time in metals concentrations in seepage from the mine, tailings piles, and waste rock piles, this process is source depletion and not natural attenuation, as it was referred to in the DFFS. Also, the rate predictions built into the DFFS Model may not accurately predict actual conditions at the Site since the predicted reduction in metals released from the Site is based on a conceptual model for the tailings and empirical data reported from other sites for the mine and waste rock discharge.

As a result of the potential long-term inaccuracies, the DFFS Model may not provide an adequate basis for predicting the relative long-term effectiveness of one alternative compared to another. Considering this as well as other limitations of the model described herein, there is no basis to rely on Intalco's conclusion that all the alternatives will produce very similar effects in Railroad Creek after 50 years (URS 2005a).

Questionable Basis for Discrete Seep Flow Values. The Agencies question the representativeness of some of the baseline data used in the DFFS Model since it is unclear how the discrete flow values were derived. Discrete seep flow values used in the loading analysis appear to be up to fifteen times the actual flows measured in the 1997 sampling events.

[20] The predicted long-term change in metals released from the tailings piles is based on a complex model that includes assumptions on the extent of fine and coarse tailings, variable thickness of the tailings piles, and the way in which the rate of oxidation will change over time. The model was not provided for review as part of the DFFS, and it is unclear how much data exist from the DRI or DFFS to support it.

The baseline loading analysis presented in the DFFS references various tables in the DRI as the source of the flow values. However, neither the DFFS nor the DRI provides sufficient explanation of how and why these flow volumes were increased. Notes provided in DFFS Tables A-1 through A-4 indicate much of the seep flow data came from DRI Table 6.6-1. Intalco stated in DRI Section 6.6.1.2 that the baseline mass loading analysis "incorporates the uncertainties in the measurements of flow." The uncertainties in the seep flow measurements were either ±25 or ±50 percent depending on measurement technique. However, discrete seep flow values used in the baseline loading analysis and DFFS model range appear to be 25 to 1,500 percent greater than the measured flow rates. For example, in May and June 1997, the recorded flow from seep SP-3 ranged from 0.1 to 0.3 L/sec with an uncertainty of ±50 percent (DRI Table 4.3-6). However, the DFFS model for spring uses a flow of 4.7 L/sec for seep SP-3, a value more than ten times the measured flow.

2.3 Summary

According to the DFFS Model, most of the alternatives that Intalco assessed would produce similar concentrations at RC-2. Also, none of the alternatives proposed by Intalco would meet proposed cleanup levels in Railroad Creek in a reasonable restoration time frame. However, the DFFS Model has the following limitations:

- The DFFS Model does not address conditions at the required points of compliance;
- The DFFS Model uses unsupported load reduction factors for evaluation of cleanup alternatives;
- The DFFS Model uses unaccounted load terms to eliminate discrepancies in the baseline loading analysis that the model is based on;
- The DFFS Model does not address water quality discharge accurately from the LWA; and
- The DFFS Model also has various other deficiencies as described in Section 2.2.5.

As a result, the DFFS Model is not a good basis for selection of a cleanup alternative.

3.0 South Bank Analysis

Intalco presented an analysis (URS 2004c), referred to as the South Bank Analysis, to show that the results of the DFFS Model could be extrapolated to predict changes in concentration within Railroad Creek near the south bank, which Intalco considered to represent conditions at the conditional point of compliance (CPOC) allowed under MTCA. The Agencies identified flaws with a key assumption in the analysis and do not agree that samples collected in open water represent conditions at the point of compliance. The Agencies do not consider the South Bank Analysis to be an acceptable basis for selection of a remedy, as discussed below.

3.1 How the South Bank Analysis Works

Intalco's South Bank Analysis used concentration data from samples collected near the south bank of the creek and composite samples collected across the width of the channel to extrapolate results from the DFFS Model. Intalco assumed that the ratio of metal concentration in the south bank samples to the composite sample concentration is proportional to the metal loading in Railroad Creek, for each constituent of concern. Intalco assumed this proportional relationship would continue after implementation of a remedy. Intalco used the DFFS Model to predict changes in the metals load in the creek over time following implementation of Alternative 3b, and asserted that the concentration near the south bank would decrease proportionately.

3.2 Flaws in South Bank Analysis

The Agencies disagree with Intalco's assertion that samples collected within the creek near the south bank represent concentrations at the CPOC allowed under MTCA. MTCA requires that a CPOC be located no further from the source and no further into surface water, than as close as technically possible to the point or points where groundwater flows into the surface water [WAC 173-340-720(8)(d)(i)]. A sample collected in open water (the type of sample that Intalco refers to as south bank samples) does not meet the MTCA requirement of being "as close as technically possible," nor does it satisfy CERCLA requirements for a site-specific point of compliance given the stream classification and the need to protect aquatic receptors, e.g., benthic macroinvertebrates, at the point of exposure.

Rather than relying on samples taken from within the surface water, concentrations at the required points of compliance can be monitored in upland monitoring wells located between the surface water and the source [WAC 173-340-720(8)(e)], or possibly in the interstitial voids in stream channel sediments (techniques for interstitial monitoring are described in ITRC [2006]). The South Bank Analysis predicts changes in concentration for surface water samples collected near the south bank, which is not the point of compliance.

Furthermore, the South Bank Analysis is technically flawed. Intalco's analysis is based on assuming that the ratio of the south bank concentration to the composite concentration is proportional to the metals loading in Railroad Creek, both prior to and after remediation. Metal loading is the concentration in the stream multiplied times the flow rate. Intalco asserted that the expected concentration at the south bank would decrease as the metals loading in Railroad Creek decreases. However, the ratio of the south bank and the composite creek concentrations would not decrease at the same rate as the metals loading in Railroad Creek, as shown by the following example.

The rate of metals load reduction in Railroad Creek will depend on how comprehensive the remedy implementation is. Since flow in the creek will be essentially unchanged, the metals concentrations in the creek composite sample will decrease, along with metals load, as sources of groundwater above proposed cleanup levels are eliminated. However, concentrations in groundwater that discharges from the south bank will remain essentially unchanged where the remedy does not include active measures to provide containment. Where groundwater containment is not provided, concentrations at the south bank will be unchanged in the short term and will only slowly decrease over time as a result of source depletion and natural attenuation. The rate of decrease due to source depletion of uncontained sources would be much slower than the decrease in the composite creek concentration that results from active measures in other portions of the site (e.g., collection and treatment of the portal discharge). Thus, the ratio of the concentration at the south bank to the composite concentration will not be proportional to the metals loading in Railroad Creek following remediation, if the remedy does not include containment of all known sources of groundwater above proposed cleanup levels at the Site.

Where a remedy does not contain all the groundwater above cleanup levels to prevent it from entering the creek, the ratio of the south bank concentration to the composite concentration will increase as some sources are eliminated, thus the ratio is inversely proportional to the metals loading in Railroad Creek. For example, in Alternative 3b, the portal drainage would be collected and treated prior to discharge to Railroad Creek. This would decrease the metals loading to Railroad Creek. However, groundwater discharging in the LWA and below the tailings piles would not be contained and treated. Therefore, the elevated metals concentration of the groundwater that discharges from the south bank would remain unchanged following implementation of Alternative 3b except through the processes of source depletion and natural attenuation.[21] In this example, the loading in Railroad Creek would decrease since a considerable source of loading, the portal drainage, is treated, but concentrations at the point of compliance would remain unchanged.

3.3 Summary

Since one of the key assumptions in Intalco's South Bank Analysis is not satisfied, the analysis is not able to predict concentrations in water quality near the south bank of Railroad Creek. Even if correct, the results of the analysis would not predict concentrations at the point of compliance. The South Bank Analysis also relies on results of the DFFS Model, and does not eliminate any of the deficiencies that are summarized above. Therefore, the South Bank Analysis does not provide a reasonable basis for comparison of alternatives for selection of a remedy.

4.0 Treatment Plant Model

The Agencies developed the Treatment Plant Model (TPM) to estimate the amount of metals that would be prevented from discharging into Railroad Creek, and the amount of sludge that would be produced by water treatment. The TPM compares the effectiveness of remedial alternatives by calculating how much metal is prevented from entering the aquatic environment through collection and treatment of metals-impacted groundwater (including seeps and the portal drainage).

The TPM initially was developed to estimate the amount of sludge that would be generated by groundwater treatment. The TPM also provides insight into the anticipated performance of remedial alternatives, since it enables estimating the mass of metals removed by treatment, and preliminary sizing of the treatment system and sludge disposal facilities for cost estimating purposes. The Agencies have referred to results from the TPM in the MTCA disproportionate cost analysis (Appendix G of the SFS).

Unlike the DFFS Model, the TPM includes aluminum along with the other constituents of concern, thus providing a means to estimate how the alternatives compare in preventing release of this metal into Railroad Creek.

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[21] Intalco has argued that UWA groundwater collection and treatment would substantially decrease metals concentration in the LWA. The Agencies disagree with this assertion as discussed in the Batch Flush Model and Limitations to the DFFS Model sections of this appendix.

4.1 How the TPM Works

The TPM is a mass-loading model similar to the DFFS Model, but it differs with respect to these main problems of the DFFS Model:

- The TPM is not used to predict post-remediation concentrations in Railroad Creek, so point of compliance is not an issue;
- The TPM does not use any unaccounted load terms; and
- The TPM includes all identified sources of groundwater above proposed cleanup levels that discharge into Railroad Creek (whereas the DFFS Model does not consider the release of metals into Railroad Creek from groundwater baseflow in the LWA, or for Alternatives 7 and 8, from the areas formerly occupied by TP-1 and TP-3).

The calculation of metals removed via treatment uses the same source terms for flow and concentration that are used in the DFFS Model. The TPM uses the same 1997 spring and fall values, so the same questions on representativeness of the data apply to the TPM that were noted above for the DFFS Model.[22]

The TPM uses the load reduction factors for upgradient source controls and collection efficiency that were presented in the DFFS. Some of the factors that Intalco assumed for the DFFS Model were not supported, and appeared arbitrary, as previously discussed. However, the TPM is used to evaluate treatment system performance, and not to predict concentrations in Railroad Creek. Accordingly, the potential consequences of these factors being incorrect are less severe for the TPM than those for the DFFS Model.

The TPM uses the flows and concentrations for the collected sources to calculate the blended concentration and flow for the influent into the treatment plant. The influent concentration and flow are then multiplied together for each metal to calculate the influent load. Similarly, the anticipated effluent concentration (see Appendix F of the SFS) and flow are multiplied together to calculate the effluent load. The difference between these two loads provides an estimate of the metals removed via treatment.

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[22] The Agencies have not accomplished a sensitivity analysis to assess the effect of variations in TPM results using all the data available, since this was not necessary as part of remedy selection. However, such analyses would be appropriate during remedial design, as part of sizing the sludge disposal landfill.

4.2 Assumptions and Limitations of the TPM

This method of calculating the metals removed via treatment assumes the following:

- The rate of flow and influent concentrations for seeps and groundwater baseflow collected for treatment are based on data presented in the DFFS. There is no adjustment required for unaccounted load since the values do not need to be forced to fit measurements in Railroad Creek.

- The TPM used the same treated effluent concentrations that Intalco presented in the DFFS for cadmium, copper, iron, and zinc. The TPM used 300 μg/L for the treated effluent concentration of aluminum based on published reports (see Appendix F of the SFS).[23]

- Blended influent concentrations do not consider any potential reactions that may occur in the collection and conveyance system before the water reaches the treatment plant (e.g., low pH precipitation of ferric iron and potentially other metals co-precipitating with the iron).

Table A-1 shows the load reduction factors and related information used in the TPM for Alternatives 8, 9, 10, and 11.

The analysis of remedial alternatives via the TPM is limited since it only accounts for the metals that would be removed by collection and treatment of groundwater. The method only considers the effect of upgradient controls that act to decrease the load from sources that are collected for treatment. Thus this analysis is not by itself a reasonable basis for selection of one alternative over another. For example, Alternative 8 relies on consolidation and capping the tailings and most of the waste rock, to prevent the release of metals to groundwater rather than relying on collection and treatment. The TPM shows Alternatives 9, 10, and 11, which focus on collection and treatment may remove more of some metals. However, this does not mean these alternatives are necessarily more effective remedies than Alternative 8, which would prevent the release of some metals and thereby reduce the need for their subsequent collection and treatment.

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[23] The effluent concentrations that Intalco used are within the range of reported values for similar systems at other sites, but the actual treated effluent concentrations for Holden remain to be demonstrated.

Another limitation of the TPM for comparing the effectiveness of remedial alternatives is that the mass of metals removed is sensitive to the differences in both the estimated amount and concentration of groundwater that is collected. As a result, the model can be construed to show that two alternatives are roughly equivalent (i.e., remove about the same mass of metals) when actually the alternatives are quite different (e.g., where containment is accomplished).

Consistent with the DFFS, the TPM assumes that groundwater concentrations in the UWA and LWA are comparable to the concentrations observed in adjacent seeps. The TPM does not rely on the DFFS Model assumption of a 75 percent load reduction in the LWA over 5 years. Unlike the DFFS Model, the TPM does not need any unaccounted load terms.

The TPM uses the same load reduction factors that Intalco assumed for the DFFS Model, except in the LWA. While Intalco did not provide support for these assumed factors, the consequence of having inappropriate values is much less for the TPM than the DFFS Model, because of the way these models are used.

- The DFFS Model relies on the load reduction factors to predict concentrations in Railroad Creek. If the factors are wrong, it could mean the predicted concentrations in Railroad Creek would not satisfy ARARs, and/or would not be protective within the restoration timeframe predicted by the model.

- The TPM uses the load reduction factors to estimate the volume of metals prevented from entering Railroad Creek, and the volume of sludge produced during long-term O&M. The TPM is not being used to predict concentrations of metals in Railroad Creek. If the load reduction factors are wrong, it does not indicate an alternative is or is not protective. (For example, Alternative 11 is anticipated to be protective because it contains and collects all the sources of groundwater above proposed cleanup levels that discharge into Railroad creek, not because of the TPM results. Similarly, Alternative 9 is not protective, because it does not contain and collect all the sources of groundwater above proposed cleanup levels; not because of what the TPM predicts).

4.3 Summary

The TPM enables calculation of the mass of metals in groundwater that is collected for treatment, which would otherwise enter Railroad Creek. The mass of metals removed by each alternative is an indicator of the relative improvement in water quality that will result from implementing that alternative, but is not the sole basis for selection of a remedy.

The TPM also provides the basis for estimating lime usage and sludge production during treatment plant operations. This information is necessary as part of evaluating long-term O&M requirements for each alternative. Both capital and O&M costs are related to the volume and metals concentration of contaminated water that will be treated, and to the long-term management of sludge that will be produced by treatment. The TPM uses site-specific data to provide a basis for evaluating the reduction in toxicity, mobility, and volume of hazardous substances, and the cost for each alternative, as required under CERCLA. The TPM also provides information on the incremental effectiveness of each alternative, which is needed for the practicability analysis under MTCA.

5.0 EPA's Batch Flush Model

As discussed above, one of the main limitations of the DFFS loading analysis is the usage of load reduction factors that Intalco assumed to quantify the effect of upgradient source controls and groundwater collection efficiency. In particular, the Agencies take exception to the assumed 75 percent load reduction in the LWA over the first 5 years after installation of a groundwater barrier and collection system in the UWA. Even with upgradient source control actions, dissolved metals in groundwater may not be transported out of the saturated soil matrix at the same rate that groundwater flows through the matrix. The metals adsorbed on soils in the saturated zone may still be available for re-release to groundwater and transport into Railroad Creek. To better assess the timing of desorption of the metals from the soil into groundwater, the Agencies used EPA's Batch Flush Model (EPA 1988), as discussed below.

The Batch Flush Model provides an estimate of the time it takes groundwater with specified concentrations of dissolved metals to achieve a specified concentration at the point of discharge into Railroad Creek. This model was selected because it uses available data or readily estimated data for the Site. The Agencies presented the analysis to Intalco at a meeting and in handouts dated June 28, 2005. The presentation specifically focused on Intalco's DFFS assertion that the UWA groundwater barrier and collection system proposed as part of Alternative 3b would reduce downgradient load from seeps in the LWA that discharge into Railroad Creek by 75 percent in 5 years. Since that discussion, Intalco provided additional comments on the analysis in a memorandum (URS 2005a). These comments are addressed below.

5.1 How the Batch Flush Model Works

The Batch Flush Model estimates the rate of contaminant reduction based on the flushing effect of groundwater that flows through the soil pores in the aquifer that discharges into Railroad Creek. The Batch Flush Model analysis was carried out for the LWA using discrete seep and upgradient groundwater concentrations. As part of the model, the water quantity stored in the contaminated portion of the aquifer is defined as one pore volume. The amount of groundwater flow expressed as the number of pore volume flushes (PVs) to reach cleanup levels is defined by the following relationship:

$$PVs = -R_f \ln(C_c/C_i)$$

Where:
ln is the natural logarithm;
C_c is the cleanup concentration for groundwater;
C_i is the initial groundwater constituent concentration; and
R_f is the retardation factor.

The groundwater flowpath in the LWA was simulated in the model between monitoring well MW-4S and seep SP-11.[24] Concentrations measured at MW-4S in October 2003 were set as the initial groundwater concentration (C_i). Two cleanup concentration (C_c) scenarios were modeled: 1) the time to reach 75 percent of the current concentration measured at seep SP-11 for comparison to Intalco's assumption of a 75 percent reduction in 5 years; and 2) the time to reach the proposed cleanup levels for cadmium, copper, and zinc.

The retardation factor used in the model is the groundwater flow velocity relative to the velocity of dissolved contaminant movement. The retardation factor (R_f) is defined by the following relationship:

$$R_f = 1 + (p_b/ n_e) K_d$$

Where:
p_b is the bulk density of the aquifer in grams/cubic centimeter;
K_d is the distribution coefficient in liters/kilogram; and
n_e is the effective porosity of the formation.

The distribution coefficient (K_d) refers to distribution of a given metal between the dissolved phase in the groundwater and the solid phase sorbed onto the soil matrix. Under equilibrium conditions at a given water pH and oxidation-reduction potential, K_d defines the relative concentrations of a constituent

[24] A second flow path was also analyzed between seeps SP-15E and SP-25. For simplicity, the discussion only refers to the MW-4S to SP-11 flow path, but results are presented later for both analyses.

dissolved in water and adsorbed to soil within the saturated zone. EPA uses this parameter to estimate groundwater cleanup times (NRC 1994).

The K_d values that are presented in MTCA Table 747-3 [WAC 173-340-900] were used for this analysis. MTCA specifically intended that these values be used in a "fixed parameter three-phase partitioning model" for deriving soil concentrations that could be used for groundwater protection [WAC 173-340-747(4)(B)(ii)]. Use of the tabulated K_d values in the current application is appropriate; since the goal of this analysis is to estimate the time it would take for groundwater to reach concentrations that are protective of surface water. The analysis considers the effect of existing dissolved phase constituents as well as constituents that will desorb from the soil and dissolve from precipitates.

MTCA also allows use of other types of partitioning analysis using site-specific K_d values; leaching tests; and alternative fate and transport models [WAC 173-340-747(3)]. Site-specific data may be used in place of tabulated K_d values. However, Intalco did not collect such data at the Site. Bulk density and porosity of the aquifer also were not measured, so the analysis used the default MTCA value for bulk density and a porosity value based on published data (Fetter 1980).

Aquifer parameters (i.e., gradient, hydraulic conductivity, length of flow path) were used to estimate the time for one pore volume to flush through the contaminated plume. The time to flush one pore volume through a contaminated plume (T_f) is defined by the following relationship:

$$T_f = L^*(K\ i\ /n_e)$$

Where:
L is the length of contaminated aquifer along a flow path in feet;
K is the hydraulic conductivity in ft/day; and
i is the gradient.

The length of the flow path is the measured distance between MW-4S and seep SP-11. Gradient and hydraulic conductivity were based on measurements reported in the DFFS (URS 2004a) and the Fall 2003 Hydrogeologic Investigation Data report (URS 2004b).

From the time to flush one pore volume (T_f) and the number of pore volumes (PVs) required to achieve cleanup goals, the time to achieve clean up (T_c) was estimated using the following equation:

$$T_c = T_f\ PVs$$

The pore volume flushing and the rate of metals release estimates are used to estimate the time returned for groundwater metals concentrations to be reduced to proposed cleanup levels that are protective of surface water.

5.2 Limitations of the Batch Flush Model

The time for groundwater to reach proposed cleanup levels is likely to be longer than the Batch Flush Model estimates as pointed out by consultants for both the Agencies and Intalco. The Batch Flush Model includes some simplified assumptions that result in *underestimating* cleanup times. These assumptions and limitations are described below.

5.2.1 Linear Desorption

The model assumes linear, non-reversible desorption of metals between the groundwater and soil matrix. The desorption of metals from soils into groundwater is a non-linear relationship. This has the effect of making the actual cleanup time longer than predicted by the model (and much longer than assumed by Intalco).

5.2.2 Homogenous Aquifer

The model does not account for heterogeneities in the aquifer matrix. Analyses of the limited aquifer slug test data collected by Intalco suggest the range of groundwater flow rates extend over two orders of magnitude (hydraulic conductivity values range from 0.2 to 0.009 cm/sec). Local variations in Site soils will probably mean that actual cleanup times in some parts of the LWA may be less than predicted by the model, and other parts of the LWA may take longer to reach proposed cleanup levels.

5.2.3 Clean Water as Input

The model assumes that clean water enters the contaminated zone and flushes the metals from the soil matrix. However, in the case of the LWA, groundwater from the UWA not captured by the barrier wall in Alternative 9 is expected to contain elevated concentrations of metals. Intalco assumed the UWA barrier and collection system would be 90 percent effective. This would have the effect of making the actual cleanup time longer than predicted by the model (and much longer than assumed by Intalco).

5.2.4 Flow Not Considered

The Batch Flush Model analysis predicts change in concentration, but does not account for changes in flow. It is not possible to reasonably predict the effect of an UWA groundwater barrier on changes in LWA groundwater flow with the data that are currently available. However, flow nets indicate a substantial portion of the groundwater moving through the LWA is from up valley (west), and would not be affected by a UWA barrier.

Even if the UWA barrier collects 90 percent of the groundwater flow as predicted in the DFFS; precipitation, groundwater flow from the west, and Railroad Creek will remain as sources of recharge to groundwater in the LWA. If overall groundwater flow through the LWA is reduced by the UWA barrier, the number of pore water volume flushes each year would decrease, thus increasing the time for clean up.

5.2.5 Use of Tabulated Distribution Coefficients

In its comments regarding the Agencies' use of the Batch Flush Model, Intalco indicated (URS 2005c) that the use of the distribution coefficients (K_d) from MTCA Table 747-3 was not appropriate because the table was intended for a different purpose (i.e., developing soil concentrations that are protective of groundwater). A wide range of K_d values for cadmium, copper, and zinc is documented in literature, with ranges that span several orders of magnitude for different metals. While MTCA presents default values of K_d to be used for the fixed parameter analysis (to set soil cleanup levels), MTCA also allows other approaches for determining K_d, including site-specific measurements of soil and soil pore water or groundwater concentrations, or batch equilibrium tests using site-specific soil [WAC 173-340-747(5)]. Intalco has had ample opportunity to provide site-specific data or to propose K_d alternative values.

5.2.6 Changes in pH Not Considered

Intalco commented that metals concentrations in groundwater are controlled by pH and it is inappropriate to use a model that does not account for changes in K_d due to changes in pH. The Agencies agreed that most metal concentrations in water are sensitive to pH and that soil-water distribution coefficients vary with pH. However, no time frame or site-specific data were provided to support Intalco's conjecture that this is applicable to the Site. Intalco referenced alternative approaches discussed in papers by Bethke and Brady (2000) and Brady and Bethke (2000). These approaches require extensive site-specific data to implement, and while these approaches may be acceptable, Intalco has not proposed collecting any of the data required by these alterative methods.

5.3 Model Results

The analysis was accomplished for cadmium, copper, and zinc in the LWA groundwater. The results of this analysis, for the flow path from monitoring well 2003-MW-4S to seep SP-11, and from seep SP-25 to seep SP-15E, are summarized below.[25] The results in the table are expressed in years. For example, the model predicts that seep SP-11 will not reach proposed cleanup levels for zinc for 330 years following installation of the UWA groundwater barrier and collection system.

	Cd	Cu	Zn
Time in years to reach proposed cleanup levels at seep SP-11, starting with Oct. 2003 concentration at monitoring well 2003-MW-4S.	39	133	330
Time in years to reach 75 percent reduction in spring concentration at seep SP-11, starting with Oct. 2003 concentration at monitoring well 2003-MW-4S.	12	39	216
Time in years to reach 75 percent reduction in spring concentration at seep SP-25, starting with May 1997 concentration at seep SP-15E.	12	44	106

The results of the Batch Flush Model predict that metals concentrations at seeps SP-11 and SP-25 would decrease to about 25 percent of their current values over periods of about 12, 39 to 44, and 106 to 216 years, for cadmium, copper, and zinc, respectively. While the value for cadmium is closest to the change predicted in the DFFS, the estimated time to attenuate concentrations of copper and zinc are considerably longer than 5 years.

Based on the Batch Flush Model, groundwater discharging into Railroad Creek from the LWA would reach proposed groundwater cleanup levels for cadmium about 40 years after installation of the UWA barrier wall proposed in the DFFS. Copper and zinc would reach proposed cleanup levels after about 130 and 330 years, respectively.

[25] Proposed groundwater cleanup levels for protection of surface water based on a surface water hardness of 12 mg/L $CaCO_3$. At the time this analysis was done, the proposed cleanup level for copper was based on the 2006 NWQC. The analysis has not been revised since a specific value for copper has not yet been determined for the Site using the 2007 NWQC (biotic ligand model) criterion.

5.4 Intalco's Alternative Analysis

Intalco attempted to bolster its objections to the Batch Flush Model results by providing its own contaminant leaching analysis prepared by SRK (URS 2005a). The Agencies are not sure this analysis is relevant since it used concentrations from surficial soil samples (0 to 28 inches in depth) that are not likely to represent conditions in the LWA aquifer. Also, the theoretical calculation on solubility of aluminum compounds that Intalco provided may not be relevant to the transport of cadmium, copper, and zinc.

Even if the provided calculation is relevant, the Agencies note that SRK concluded: "The calculation also demonstrates that it is not reasonable to expect the target ARARs assumed by Hart Crowser (Cd 0.06 ug/L, Cu 1.5 ug/L, Zn 17 ug/L) to be met in groundwater. Actual concentrations can be expected to be an order of magnitude greater than the Hart Crowser's proposed ARAR concentrations." This conclusion suggests the Alternative 3b UWA barrier wall may not enable groundwater in the LWA to meet proposed cleanup levels, even with longer durations for groundwater flushing than predicted by the Batch Flush Model.

5.5 Summary

The Agencies concur with Intalco that the Batch Flush Model is a simple model and better estimates of the time to clean up could be developed if certain site-specific data were available, such as the K_d parameter. While published values of porosity, bulk density, and K_d are used in the Batch Flush Model; other input parameters are based on available information developed by Intalco.

The Batch Flush Model was used to assess the validity of the 75 percent load reduction over 5 years that Intalco assumed for the LWA as part of Alternative 9 and some of the DFFS alternatives. Results indicate that the 75 percent load reduction for the LWA would not be realized for periods ranging from about a decade to more than one hundred years (depending on the constituent) following installation of a UWA groundwater barrier and collection system.

6.0 References for Appendix A

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Endnote

During the preparation of the SFS, some calculations used in the EPA NRRB package (Hart Crowser 2005c) were found incorrect as explained below. The NRRB report compared short-term results for metals removed by collecting and treating groundwater (5 years after remedy implementation) and cumulative results over 50 years following implementation. The analysis presented to the NRRB calculated the East Area and West Areas of the Site separately, and then summed the results for the total mass of each metal prevented from reaching the creek for each alternative. During the preparation of the SFS, it was determined that these calculations include some double counting for the load from the tailings piles in the long-term analysis. The source of this double counting has been corrected in the TPM as explained below.

Metals loading over time from the tailings piles will vary depending on the future configurations of the tailings piles. As part of the DFFS, SRK conducted geochemical modeling to predict the long-term changes in load emanating from the tailings piles for the various alternatives. Modeling results are represented as loading ratios of predicted load relative to current load. These loading ratios are used in the long-term post-remediation loading analysis. Three different tailings configurations were modeled resulting in three different sets of loading ratios (DFFS Table D4-1): 1) current configuration, 2) regrading and gravel cover placement, and 3) consolidation and capping. The Alternative 1 considers the tailings piles to remain in their current configuration. Alternatives 9 and 10 use the regrading and gravel cover loading ratios, while Alternative 8 uses the consolidation and capping loading ratios.

When determining the mass of metals prevented from reaching the creek for alternatives that include regrading or capping of the tailings piles, it is necessary to compare the tailings loading to the current configuration. This was not done for those calculations presented in the report to the NRRB. The removal of metals based on the tailings piles actions (capping or regrading) were counted twice. This error, which led to a reduction in the predicted metals removal over time, particularly for Alternative 8, has been corrected in the analyses used to support Appendix G of the SFS.

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Table A-1 - Load Reduction Factors Used in DFFS Model and/or Treatment Plant Model

Alternative 8

Source Area [a]	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			
	Short-Term		Long-Term	
	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]
SP-26 and Unaccounted Load Upstream of RC-1	50%	0%	60%	0%
Honeymoon Heights (Seeps SP-23, SP-23B, SP-12)	0%	90%	0%	90%
Underground Mine (Main Portal) [b]	0%	97%	0%	97%
West Waste Rock Pile [d] (Seeps SP-6, SP-15W)	90%	0%	90%	0%
Mill Building [d] (Seeps SP-22, SP-7)	50%	90%	60%	90%
West Area Seeps [e] (Seeps SP-9, SP-11, SP-25, SP-24, SP-10W/10E)	80%	0%	90%	0%
Unaccounted Load to RC-4	80%	0%	90%	0%
East Waste Rock Pile (Seeps SP-8/19)	90%	0%	90%	0%
Groundwater Flow from Native Material - Flow Tube S1 (Spring Only)	80%	0%	90%	0%
Copper Creek Diversion	95%	0%	95%	0%
Tailings Pile 1 Flow Tubes and Seeps SP-1 & SP-2	90%	0%	90%	0%
Copper Creek	0%	0%	0%	0%
Tailings Pile 2 Flow Tubes and Seeps SP-3 & SP-4	0%	80%	0%	80%
Tailings Pile 3 Flow Tubes Upstream of RC-2	0%	See Below	0%	See Below
Unaccounted Load to RC-2	0%	80%	0%	80%
Seep SP-21	0%	95%	0%	95%
Tailings Pile 3 Flow Tubes Downstream of RC-2 - Affects Fall analysis only	0%	90%	0%	90%

Treatment System	Estimated Treatment System Performance in mg/L				
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Aluminum [e] $E[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.130
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.130

Tailings Pile 3 Flow Tubes Upstream of RC-2 [c]		E[CE]
Spring Flow tubes below Consolidated Tailings Pile:	TP-12 & TP-13	80%
	TP-14 thru TP-16	0%
	S15	80%
	S16 thru S19	0%
Fall Flow tubes below Consolidated Tailings Pile:	TP-11 & TP-12	80%
	TP-13 thru TP-15	0%
	S8 IN	80%

Notes

Alternative 8 analysis assumes no diffuse groundwater collection in West Area and no deep groundwater is collected by East Area barrier wall.

(a) Source areas are generally listed as they are located at the Site from west to east along Railroad Creek.

(b) Hydrostatic bulkheads placed in 1500-level portals. Main Portal drainage concentrations assumed to be equal to the "best estimates" due to flooding provided in DFFS Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L.

(c) The collection efficiency is applied to those groundwater flow tubes anticipated to be intercepted by the groundwater collection system around the base of the consolidated tailings pile.

(d) Load from this source area does not discharge directly into Railroad Creek. Therefore, a reduction factor due to upgradient controls applied to these sources would not reduce the load calculated at RC-2. If a collection efficiency is applied to these sources, that collected water is included in the treatment plant effluent calculation line item.

(e) No West Area groundwater is collected.

Table A-1: Load Reduction Factors Used in DFFS Model and/or Treatment Plant Model

Alternative 9

Source Area [a]	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			
	Short-Term		Long-Term	
	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]
SP-26 and Unaccounted Load Upstream of RC-1	50%	0%	60%	0%
Honeymoon Heights (Seeps SP-23, SP-23B, SP-12)	0%	90%	0%	90%
Underground Mine (Main Portal) [b]	0%	97%	0%	97%
West Waste Rock Pile [f] (Seeps SP-6, SP-15W)	0%	90%	0%	90%
Mill Building [f] (Seeps SP-22, SP-7)	50%	90%	60%	90%
West Area Seeps [g] (Seeps SP-9, SP-11, SP-25, SP-24, SP-10W, SP-10E)	75%	0%	85%	0%
Unaccounted Load to RC-4	75%	0%	85%	0%
East Waste Rock Pile (Seeps SP-8/19)	0%	90%	0%	90%
Groundwater Flow from Native Material - Flow Tube S1 (Spring Only)	75%	0%	85%	0%
Copper Creek Diversion	95%	0%	95%	0%
Tailings Pile 1 Seeps SP-1 & SP-2	50%	90%	50%	90%
Tailings Pile 1 Flow Tube in Tailings	50%	0%	50%	0%
Tailings Pile 1 Flow Tubes in Native Material	50%	See Below	50%	See Below
Copper Creek	0%	0%	0%	0%
Tailings Pile 2 Flow Tubes and Seeps SP-3 & SP-4	0%	0%	0%	0%
Tailings Pile 3 Flow Tubes Upstream of RC-2	0%	0%	0%	0%
Unaccounted Load to RC-2	0%	8% Spring 18% Fall	0%	8% Spring 18% Fall
Loading Downstream of RC-2 - Seep SP-21	0%	0%	0%	0%
Tailings Pile 3 Flow Tubes Downstream of RC-2 - Affects Fall analysis only	0%	0%	0%	0%

Treatment System	Estimated Treatment System Performance: Treatment System Effluent Concentration (mg/L)				
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Aluminum [e] $E[C_{Eff,Zn}]$
West Area Treatment System	0.005	0.024	0.200	0.240	0.130

Upper West Area Groundwater Collection [c]		$E[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$ in L/sec	Spring	32
	Fall	18

TP-1 Groundwater Extraction Well Pumping Rates [c]		$E[Q_{GW}]$ in gpm	$E[Q_{GW}]$ in L/sec
Estimated Collection per Well	Spring	15	0.95
	Fall	15	0.95

Estimated TP-1 Native Material Groundwater Flowtube Collection [d]		E[CE]
TP-1 Spring Flowtubes:	S2, S3, S6	0%
	S4	19%
	S5	91%
TP-1 Fall Flowtubes:	S1	0%
	S2	52%
	S3	47%

Notes

(a) Source areas are generally listed as they are located at the Site from west to east along Railroad Creek.

(b) Hydrostatic bulkheads placed in 1500-level portals. Main Portal drainage concentrations assumed to be equal to the "best estimates" due to flooding provided in DFFS Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L.

(c) Assumes 90 percent collection of intercepted flows of 36 L/sec for Spring and 20 L/sec for Fall.

(d) Note that the collection efficiency is for calculating load reduction to Railroad Creek, and is not used to calculate the volume of water sent to the treatment plant (see note f).

(e) These flow rates are used to calculate the amount of water sent to the treatment plant from the Tailings Pile 1 extraction wells.

(f) Load from this source area does not discharge directly into Railroad Creek. Therefore, a reduction factor due to upgradient controls applied to these sources would not reduce the load calculated at RC-2. If a collection efficiency is applied to these sources, that collected water is included in the treatment plant effluent calculation line item.

(g) No Lower West Area groundwater is collected.

Table A-1 - Load Reduction Factors Used in DFFS Model and/or Treatment Plant Model

Alternative 10

Source Area [a]	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection [b]			
	Short-Term		Long-Term	
	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG] [b]	Downgradient Collection Efficiency (%), E[CE]	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG] [b]	Downgradient Collection Efficiency (%), E[CE]
SP-26 and Unaccounted Load Upstream of RC-1	50%	0%	60%	0%
Honeymoon Heights (Seeps SP-23, SP-23B, SP-12)	0%	90%	0%	90%
Underground Mine (Main Portal) [c]	0%	97%	0%	97%
West Waste Rock Pile [e] (Seeps SP-6, SP-15W)	0%	0%	0%	0%
Mill Building [e] (Seeps SP-22, SP-7)	50%	0%	60%	0%
West Area Seeps (Seeps SP-9, SP-11, SP-25, SP-24, SP-10W/10E)	25%	89% Spring 83% Fall	30%	89% Spring 83% Fall
West Area Flow Tubes [f] (West S1, West S2)	25%	89% Spring 83% Fall	30%	89% Spring 83% Fall
Unaccounted Load to RC-4	25%	89% Spring 83% Fall	30%	89% Spring 83% Fall
East Waste Rock Pile (Seeps SP-8/19)	0%	89% Spring 83% Fall	0%	89% Spring 83% Fall
Groundwater Flow from Native Material - Flow Tube S1 (Spring Only)	25%	89% Spring	30%	89% Spring
Copper Creek Diversion	95%	0%	95%	0%
Tailings Pile 1 Flow Tubes and Seeps SP-1 & SP-2	0%	89% Spring 83% Fall	0%	89% Spring 83% Fall
Copper Creek	0%	0%	0%	0%
Tailings Pile 2 Flow Tubes	0%	0%	0%	0%
Tailings Pile 2 Seeps SP-3 & SP-4	0%	80%	0%	80%
Tailings Pile 3 Flow Tubes and Seep SP-21	0%	89% Spring 83% Fall	0%	89% Spring 83% Fall
Unaccounted Load to RC-2	0%	40%	0%	40%

Treatment System	Estimated Treatment System Performance in mg/L				
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Aluminum [e] $E[C_{Eff,Zn}]$
Northeast of TP-3	0.005	0.035	0.200	0.350	0.13

Lower West Area Groundwater Collection [d]		$E[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$) in L/sec	Spring	26
	Fall	12

Notes

(a) Source areas are generally listed as they are located at the Site from west to east along Railroad Creek.
(b) Loading reduction factors are similar to those used in the DFFS analyses as discussed in DFFS Section 7.2.1.1.
(c) Hydrostatic bulkheads placed in 1500-level portals. Main Portal drainage concentrations assumed to be equal to the "best estimates" due to flooding provided in DFFS Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L.
(d) Assume 89% collection of intercepted flows of 29 L/sec (spring) and 83% collection of intercepted flows of 15 L/sec (fall). Based on Method C as discusse in a Hart Crowser memorandum titled Lower West Area Groundwater Discharge Estimate, dated 3/2/2005.
(e) Load from this source area does not discharge directly into Railroad Creek. Therefore, a reduction factor due to upgradient controls applied to these sourc would not reduce the load calculated at RC-2. If a collection efficiency is applied to these sources, that collected water is included in the treatment plant effluent calculation line item.
(f) See Hart Crowser memorandum titled Lower West Area Groundwater Discharge Estimate, dated 2/3/2005.

Table A-1 - Load Reduction Factors Used in DFFS Model and/or Treatment Plant Model

Alternative 11

Source Area [a]	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection [b]			
	Short-Term		Long-Term	
	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG] [b]	Downgradient Collection Efficiency (%), E[CE]	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG] [b]	Downgradient Collection Efficiency (%), E[CE]
SP-26 and Unaccounted Load Upstream of RC-1	50%	0%	60%	0%
Honeymoon Heights (Seeps SP-23, SP-23B, SP-12)	0%	90%	0%	90%
Underground Mine (Main Portal) [c]	0%	97%	0%	97%
West Waste Rock Pile [f] (Seeps SP-6, SP-15W)	0%	0%	0%	0%
Mill Building [f] (Seeps SP-22, SP-7)	50%	0%	60%	0%
West Area Seeps (Seeps SP-9, SP-11, SP-25, SP-24, SP-10W/10E)	25%	90%	30%	90%
West Area Flow Tubes [g] (West S1, West S2)	25%	90%	30%	90%
Unaccounted Load to RC-4	25%	90%	30%	90%
East Waste Rock Pile (Seeps SP-8/19)	0%	90%	0%	90%
Groundwater Flow from Native Material - Flow Tube S1 (Spring Only)	25%	90%	30%	90%
Copper Creek Diversion	95%	0%	95%	0%
Tailings Pile 1 Flow Tubes and Seeps SP-1 & SP-2	0%	90%	0%	90%
Copper Creek	0%	0%	0%	0%
Tailings Pile 2 Flow Tubes	0%	90%	0%	90%
Tailings Pile 2 Seeps SP-3 & SP-4	0%	90%	0%	90%
Tailings Pile 3 Flow Tubes	0%	90%	0%	90%
Seep SP-21	0%	90%	0%	90%
Unaccounted Load to RC-2	0%	90%	0%	90%

Treatment System	**Estimated Treatment System Performance in mg/L**				
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Aluminum [e] $E[C_{Eff,Zn}]$
Northeast of TP-3	0.005	0.035	0.200	0.350	0.13

Lower West Area Groundwater Collection [d]		$E[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$ in L/sec	Spring	26
	Fall	14

Notes

(a) Source areas are generally listed as they are located at the site from west to east along Railroad Creek.
(b) Loading reduction factors are similar to those used in the DFFS analyses as discussed in DFFS Section 7.2.1.1.
(c) Hydrostatic bulkheads placed in 1500-level portals. Main Portal drainage concentrations assumed to be equal to the "best estimates" due to flooding provided in DFFS Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L.
(d) Assume 90% collection of intercepted flows of 29 L/sec (spring) and 15 L/sec (fall). Based on Method C as discussed in a Hart Crowser memorandum titled Lower West Area Groundwater Discharge Estimate, dated 3/2/2005.
(e) Removal of aluminum was evaluated in the Treatment Plant Model but not the DFFS Model.
(f) Load from this source area does not discharge directly into Railroad Creek. Therefore, a reduction factor due to upgradient controls applied to these sources would not reduce the load calculated at RC-2. If a collection efficiency is applied to these sources, that collected water is included in the treatment plant effluent calculation line item.
(g) See Hart Crowser memorandum titled Lower West Area Groundwater Discharge Estimate, dated 2/3/2005.

APPENDIX B
PRELIMINARY REMEDIATION COST ESTIMATES

APPENDIX B
PRELIMINARY REMEDIATION COST ESTIMATES

Executive Summary

This appendix presents remediation cost estimates for the Holden Mine Site (Site), and describes how these estimates were prepared by the Agencies. The Agencies developed cost estimates for Alternatives 8, 9, 10, and 11 as part of the Supplemental Feasibility Study (SFS, Forest Service 2007), since Alternatives 9, 10, and 11 were not part of Intalco's Draft Final Feasibility Study (DFFS, URS 2004). The approach used by the Agencies to prepare these estimates differs significantly from the approach used in the DFFS, so the Agencies also prepared an estimate for Alternative 8 to provide a point of comparison for the three post-DFFS alternatives.[1]

The preliminary estimated costs for each remedial alternative vary based on the extent of cleanup accomplished by the alternative. An alternative that annually contains and treats a larger volume of contaminated groundwater that would otherwise enter Railroad Creek costs more than an alternative that contains and treats a smaller volume of water. In the same way, an alternative that does more to protect human health and the environment in ways other than by containing and treating groundwater (e.g., through permanent closure of the tailings and waste rock piles) costs more than an alternative that is less protective.

Cost is considered as part of selecting a remedial action from among alternatives that satisfy the threshold criteria for remedy selection under both CERCLA and MTCA.[2] The Agencies' cost estimates for Alternatives 8 through 11 use similar cost elements, applied in a consistent way to provide a reasonable basis for comparing the cost of these alternatives. As discussed in the SFS, cost is one of the primary balancing criteria under CERCLA, for selection among alternatives

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[1] Alternatives 9, 10, and 11 are described in more detail in the SFS, which is the parent document for this appendix. Alternative 8 is described in the DFFS. For conciseness, information in the SFS (including its other appendices) and the DFFS is typically not repeated herein.

[2] The threshold requirements for remedy selection under both CERCLA and MTCA are that a proposed cleanup action must protect human health and the environment, and must meet all applicable, or relevant and appropriate requirements (ARARs), unless such requirements are waived in accordance with 40 CFR § 300.430(f)(1)(ii)(C). MTCA also has an additional threshold requirement, to provide for compliance monitoring [WAC 173-340-360(2)(a)(iv)].

that satisfy the threshold criteria [40 CFR S 300.430(f)(1)(ii)(D)]. CERCLA does not dictate selection of the least cost alternative; rather CERCLA provides a process for selecting a cleanup action that has comparable effectiveness and implementability but less cost compared to another alternative [40 CFR § 300.430(e)(7)(iii)]. Cost is also considered as part of the remedy selection process under MTCA as part of the analysis used to select a cleanup action (from among those alternatives that meet the MTCA threshold requirements) that uses permanent solutions to the maximum extent practicable [WAC 173-340-360(3)]. For the state's purposes under MTCA, the estimated costs for Alternatives 8, 9, 10, and 11 have been compared for the purpose of evaluating the practicability of groundwater collection and treatment versus source depletion and natural attenuation as proposed in the alternatives. This "practicability analysis" is presented in Appendix G of the SFS.

As discussed in the SFS, Alternative 11 is the only alternative that meets the threshold criteria under CERCLA and MTCA. However, costs are presented herein for Alternatives 8, 9, and 10, in addition to Alternative 11, to enable comparison even though Alternatives 8 through 10 do not meet the criteria for selection of a permanent cleanup action at the Site.

EPA guidance includes a contingent cost allowance for potential cost changes to address areas of uncertainty between actual costs and estimated costs, and between the actual extent of cleanup and the estimated extent. Contingent costs may also refer to the cost change if the proposed scope of the remedy is modified. Contingent costs were not included in the Agencies' previous estimates but have been included herein for Alternative 11. Contingent costs for Alternatives 8, 9, and 10 are not comparable to contingent costs for Alternative 11 because Alternative 11 is the only alternative expected to satisfy the CERCLA and MTCA threshold requirements for selection of a final remedy.

Additional action would be needed for Alternatives 8, 9, or 10 to become part of a final remedial action that meets ARARs. Those specific actions are elements of Alternative 11 that are not part of Alternatives 8, 9, and 10 (e.g., the fully penetrating barrier along Railroad Creek). The cost of adding such contingent measures after implementing Alternatives 8, 9, or 10 would increase the overall cost to significantly more than the cost for implementing Alternative 11. Therefore, the Agencies have not prepared a detailed contingent cost comparison for these alternatives.

Each alternative discussed in this appendix involves containment and treatment of groundwater for hundreds of years, in order to complete cleanup of the Site. Estimated costs for each alternative include initial costs (referred to as capital costs) for initial remedy implementation, as well as future costs needed for long-term operation and maintenance of the remedy. The net present value (NPV) of future costs to implement the remedy is the amount that is needed today to set aside sufficient funds in an interest-bearing account to cover anticipated future costs.[3] The table below summarizes the estimated cost for Alternatives 8 through 11.

	Alternative 8	Alternative 9	Alternative 10	Alternative 11
Total Estimated Capital Cost	$98,200,000	$22,600,000	$37,000,000	$65,500,000
Estimated Average Annual Operations, Maintenance, and Monitoring Costs	$1,349,000	$1,208,000	$1,434,000	$1,651,000
NPV of Future Costs for Operations, Maintenance, and Monitoring	$17,500,000	$15,600,000	$18,100,000	$20,200,000
Total Estimated Capital plus NPV Future Costs	$116,000,000	$38,200,000	$55,100,000	$85,800,000

The remainder of this appendix discusses what the cost estimates include and how they were prepared, and the ways in which costs for Alternatives 8 through 12 are similar and dissimilar.

[3] Current costs referred to in this appendix were estimated using price indices published in 2005, and vendor quotes obtained in 2005. The NPV was based on a 7 percent discount rate and a 50-year return period as explained herein.

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APPENDIX B
PRELIMINARY REMEDIATION COST ESTIMATES

1.0 Introduction

This appendix presents preliminary cost estimates for four proposed alternatives for cleanup of the former Holden Mine Site (Site). The estimates are referred to as preliminary because they were prepared during the feasibility study stage, prior to remedial design (RD).

Cost is a primary balancing criteria used for remedy selection under CERCLA. The cost estimates presented in this appendix were used as part of comparing Alternatives 9, 10, and 11 in the SFS. CERCLA requires that a cleanup action satisfy the threshold criteria for protection of human health and the environment, and comply with applicable, or relevant and appropriate requirements (ARARs), before cost is considered. Cost is one of the primary balancing criteria under CERCLA, for selection among alternatives that satisfy the threshold criteria [40 CFR S 300.430(f)(1)(ii)(D)]. Additionally, each remedial action selected for comparison "shall be cost effective, provided that it first satisfies the threshold criteria" [40 CFR § 300.430(f)(1)(ii)(D)].

Cost is also considered as part of the remedy selection process under MTCA as part of the analysis to select a cleanup action (from among those alternatives that meet the MTCA threshold requirements) that uses permanent solutions to the maximum extent practicable [WAC 173-340-360(3)]. MTCA uses the disproportionate cost analysis to determine whether a cleanup action uses permanent solutions to the maximum extent practicable. Costs are disproportionate to benefits if the incremental cost of an alternative over that of a lower cost alternative exceeds the incremental degree of benefits achieved by the alternative over that of the lower cost alternative [WAC 173-340-360(3)(e)(i)]. The cost estimates presented in this appendix were used as part of comparing Alternatives 8, 9, 10, and 11 in the MTCA practicability assessment presented in Appendix G of the SFS.

The Agencies prepared these cost estimates using guidance from the EPA (EPA 2000), and conventional construction cost estimating data (e.g., Means 2004a, 2004b, and 2005). Both capital costs (construction-related costs) and future recurring costs for operation, maintenance, and monitoring (O&M) were included in the estimates. Each of these costs is described in this appendix, including how the individual cost components were obtained. Total estimated costs for each alternative were based on the sum of the capital costs and the net present value (NPV) of anticipated future costs for O&M of the remedy. Use of the NPV to express future costs in current dollars is a standard method for financial evaluation of long-term projects.[4]

Differences in approach and level of detail between the Agencies' estimate and the estimates prepared by Intalco obscured the effect of differences in the alternatives. As a result, the Agencies prepared estimates for Alternatives 8, 9, 10, and 11 using the same approach and level of detail so that the cost for these alternatives could be compared.

Cost estimates for each alternative were developed using Excel® spreadsheets to calculate capital costs and O&M costs. Cost estimates were based on descriptions provided by Intalco (URS 2004 and 2005b) for Alternatives 8 and 9, respectively, and descriptions of Alternatives 10 and 11 in the SFS. Areas of uncertainty in the scope of Alternatives 8 and 9 were addressed as described herein.[5] Capital costs were estimated using the following general approach:

- Identification of major capital cost elements, including construction and non-construction costs. For example, regrading the tailings piles was identified as a major component of the construction cost element for Alternatives 8, 10, and 11.
- Estimation of construction material quantities, types of labor, and equipment needed to complete construction of each element (e.g., the number of cubic yards of tailings that would be regraded, and the number and types of heavy equipment needed to accomplish the regrading).
- Estimation of unit costs for labor, equipment, and materials using published construction cost indices and/or quotes from local vendors and contractors.
- Calculation of estimated costs for each component as the product of the number of units and the estimated unit cost, including adjustment for construction productivity rates or regional price differences where appropriate.

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[4] The NPV calculation used in this document is based on a 7 percent discount rate and a 50-year return period. The meaning of these terms and the values used are discussed later in this appendix.

[5] For example, Alternative 9 includes capping contaminated soils in the maintenance yard area, but the method of capping was not discussed. The DFFS refers to capping the maintenance yard with an asphalt or concrete pavement for Alternative 3b as well as other alternatives. Alternative 9 is based on Alternative 3b, so the Agencies' estimate for Alternative 9 included the cost for a concrete cap. Similar items are noted in this appendix where applicable.

- Finally, calculation of the estimated total cost for each cost element was determined by summing the component costs.

A similar approach was followed for estimating the future O&M costs. The estimate included an assessment of the frequency that future costs would be incurred, so that allowance could be made for costs over the long period (hundreds of years) when O&M will be required.

The cost estimates were developed using a work breakdown structure, including nationally published cost and productivity rates for construction labor and equipment (e.g., Means 2005, and CAT® 1997).

The Agencies' original estimate for Alternative 10 used cost factors published in 2003 to provide a basis for comparison to costs in the DFFS. The cost estimates in this appendix reflect more recent cost factors published in 2005. The Agencies' revised estimates considered the comments received from Intalco (URS 2005a).[6]

Table B-1 presents a comparison of the preliminary cost estimates for Alternatives 8, 9, 10, and 11. Detailed breakdowns of the estimated costs for these alternatives are presented in Tables B-2 through B-5. Table B-6 provides a detailed breakdown of the anticipated future recurring costs for each alternative. Additional information used to prepare the cost estimates is provided in spreadsheets included in the Administrative Record. The main elements of each alternative that affect the estimated cost are summarized below, followed by a discussion of the basis for these estimates.

2.0 Summary of Major Elements that Affect Cost for Alternatives 8, 9, 10, and 11

The SFS includes a detailed description of Alternatives 9, 10, and 11, and the extent to which each alternative would or would not satisfy CERCLA criteria for selection of a cleanup action. Alternative 8 is described in the DFFS, and is evaluated in Appendix G of the SFS. Elements of these alternatives that have a substantial effect on their overall cost are summarized below. The bases for the

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[6] For example, the Agencies adjusted their estimates after Intalco pointed out that the remote location of the Site and the need for the Contractor to provide a camp for housing the workers made it appropriate to adjust labor rates to a 6-day week, 9-hour day, which is commonly used for remote site construction. In other cases, the Agencies did not revise their estimates as proposed by Intalco, such as by increasing all costs by an arbitrary 30 percent contingency factor.

estimated costs for each alternative are presented following the summary descriptions.

2.1 Alternative 8

Alternative 8 includes consolidation of the main East and West Waste Rock Piles and the three tailings piles into a single pile that would have a cap that conforms to Washington's requirements for closure of limited purpose landfills [WAC 173-350-400(3)(e)(ii)], which is a potential ARAR. The slopes of the consolidated tailings pile (CTP) would be graded and the toe of the CTP slopes would be set back from Railroad and Copper Creeks to reduce the risk that future mass releases due to instability would impact the creeks. Alternative 8 also includes containment, collection, and treatment of the portal drainage, seeps downslope of Honeymoon Heights, and groundwater (including seeps) below the CTP.

Alternative 8 would not include containment, collection, and treatment of groundwater (including seeps) above proposed cleanup levels in the Lower West Area (LWA) or the areas formerly occupied by Tailings Piles 1 and 3 (TP-1 and TP-3). As a result, Alternative 8 is not expected to be protective of the environment or to satisfy all potential ARARs, as discussed in Appendix G of the Supplemental Feasibility Study (SFS, Forest Service 2007).

The total estimated cost for Alternative 8 (capital cost plus NPV for future O&M costs) is $116,000,000.

2.2 Alternative 9

Alternative 9 includes regrading slopes of TP-1 and TP-2, but not TP-3. Alternative 9 also includes containment, collection, and treatment of the portal drainage, seeps downslope of Honeymoon Heights, and groundwater (including seeps) from the Upper West Area (UWA) and below a portion of TP-1.

Alternative 9 does not include a cap to close the tailings piles or waste rock piles, and does not include setting back the toe of tailings pile slopes away from the creeks. Alternative 9 also does not include containment, collection, and treatment of groundwater and seeps above proposed cleanup levels in the LWA, or the areas below TP-2, TP-3, and a portion of TP-1. As a result, Alternative 9 is not expected to be protective of the environment or to satisfy all potential ARARs, as discussed in the SFS.

The total estimated cost for Alternative 9 (capital cost plus NPV for future O&M costs) is $38,200,000.

2.3 Alternative 10

Alternative 10 includes regrading the slopes of TP-1, TP-2, TP-3, and the main East and West Waste Rock Piles to reduce the risk of slope instability. Alternative 10 also includes setting back the toe of slopes away from Railroad and Copper Creeks to reduce the risk that future slope instability would impact the creeks.

The cost estimate for Alternative 10 assumes capping of the tailings and main East and West Waste Rock Piles with 1 foot of soil and revegetation; which may meet the performance requirements for landfill closure [WAC 173-350-400(3)(e)(i)] but this cannot be demonstrated on the basis of existing information. Alternative 10 includes an ecological risk assessment (ERA) during RD to determine whether a more robust cover would be needed to satisfy performance requirements for this potential ARAR.[7]

Alternative 10 includes containment, collection, and treatment of the portal drainage, seeps downslope of Honeymoon Heights, and groundwater (including seeps) from the LWA and below TP-1 and TP-3. Seeps SP-3 and SP-4, but not other groundwater below TP-2, would be collected under this alternative. The cost for Alternative 10 is based on groundwater containment with a partially penetrating barrier (PPB), which may not be completely effective as discussed in the SFS. Alternative 10 would not include closure of the waste rock piles on Honeymoon Heights. As a result of uncertainties over the effectiveness of the PPB and provisions for closing the tailings and waste rock piles, Alternative 10 cannot be shown to be protective of the environment or to satisfy all potential ARARs based on currently available information, as discussed in the SFS.

The total estimated cost for Alternative 10 (capital cost plus NPV for future O&M costs) is $55,100,000.

2.4 Alternative 11

Alternative 11 includes regrading the slopes of TP-1, TP-2, TP-3; moving the toe of the slopes back from Railroad and Copper Creeks; and closure of the tailings piles to meet all potential ARARs. Alternative 11 includes consolidation of the Honeymoon Heights Waste Rock Piles into the main East and West Waste Rock

[7] The cost for the ERA was included in the estimate for Alternative 10, but potential cost to modify the cover was not included, since there is no way to know today whether this contingent measure would be needed.

Piles, and closure to meet all potential ARARs. Alternative 11 includes containment, collection, and treatment of the portal drainage, seeps downslope of Honeymoon Heights, and groundwater (including seeps) from the LWA and below TP-1, TP-2, and TP-3.

The Agencies anticipate that Alternative 11 would be protective of human health and the environment, and would comply with all potential ARARs.

The total estimated cost for Alternative 11 (capital cost plus NPV for future O&M costs) is $85,800,000.

Alternative 11 is the only alternative that is anticipated to protect human health and the environment, and to satisfy all potential ARARs, as discussed in the SFS. Thus Alternative 11 is the only alternative that satisfies the threshold requirements for selection of a remedy under both CERCLA and MTCA. The remainder of this appendix discusses the basis for the cost estimates and significant elements that affect the cost estimates for Alternatives 8 through 11.

3.0 Basis for Estimated Costs

The estimates presented herein were prepared following guidance from EPA (2000). EPA provides guidance to facilitate preparation of cost estimates that are consistent and complete enough for the purpose of comparing alternatives during the remedy selection process. EPA's guidance for feasibility study cost estimates recommends achieving an accuracy within the range of 30 percent less, to 50 percent more, than the actual cost of implementing the remedy (EPA 2000). That means that a feasibility study estimate of $60,000,000 for an alternative is considered sufficiently accurate if it is prepared so the actual cost is within the range of $42,000,000 to $90,000,000. However, it is the estimated cost, not the range of intended accuracy, which is used in the CERCLA remedy selection process.[8] The Agencies believe the estimates provided herein are within the accuracy range goal, based on the approach used and the level of detail considered.

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[8] It is generally impractical to compare the cost range for two alternatives even if both achieve the same degree of protectiveness and equally comply with ARARs. For example, if two equivalent alternatives cost $60,000,000 and $70,000,000, respectively, the cost ranges overlap so significantly ($42,000,000 to $90,000,000, compared to $49,000,000 to $105,000,000), that a comparison of the ranges does not provide a helpful perspective.

The estimated cost for each remedial alternative is the sum of capital costs and the NPV for future costs. The largest cost element of the capital costs for each alternative is construction, whereas the largest elements for future costs are operations and maintenance (including replacement of capital items that will be needed over time).

This section includes a summary and description of how capital costs were estimated for the alternatives, followed by a description of how future costs were estimated.

3.1 Capital Costs

There are three types of capital costs—direct costs, indirect costs, and non-capital construction costs, which are described as follows.

- **Direct costs** include the cost of labor, materials, and equipment that the general contractor responsible for remediation (the Contractor) provides to accomplish the cleanup. Direct costs to the Contractor are grouped by elements or types of work required within specific areas of the Site.
- **Indirect costs** include the Contractor's overhead and profit, and the Contractor's expenses related to construction coordination and administration of construction that apply to the project as a whole. Indirect costs are estimated as a mark-up on direct costs, using published rates for guidance. However, every Contractor has its own indirect cost structure, so estimates for these costs are typically less well defined than are direct costs.
- **Non-construction capital costs** include expenses associated with implementing the remedy such as engineering design, construction administration by the Responsible Party [i.e., Intalco, the entity responsible for the cleanup under CERCLA], project management, and remedy startup expenses such as treatment system pilot testing.

Direct costs were estimated prior to calculation of indirect and non-construction capital costs as described herein.

3.1.1 Direct Capital Costs for Remedial Construction

Direct costs for each of the alternatives include about sixty separate components that fall within nine major elements of work at the Site, as discussed below. For each component, the estimate included an assessment of the type and quantity of work required. An engineer developed a conceptual construction approach that was used to estimate the type and amount of labor, equipment, and materials needed to accomplish the work. Costs for the labor, equipment, and materials were summed to develop an estimated cost for each component, and the costs for all the direct cost elements were then summed.

3.1.1.1 Elements of Direct Cost

Direct costs for each alternative are based on the cost of individual components for each of the following nine elements.

Job Startup and Construction Infrastructure. This element includes estimated costs for the Contractor to mobilize and demobilize from the Site, including the cost of winter shut downs for multi-year construction. This element also includes the cost to set up and operate a temporary construction camp to house workers on site; provide construction site supervision; maintain the road from Lucerne to Holden over the duration of construction for each alternative; install a construction access bridge across Railroad Creek east of TP-3; upgrade the existing bridge across Ten-Mile Creek; and install monitoring wells.

Upgradient Run-on Diversions. This element includes the cost to improve and extend existing run-on control swales and an access road for construction across the south side of the tailings piles and UWA. A Forest Service contractor built the existing swales and an access road south of the tailings piles around 1990. Improvement and use of the existing run-on control swales and access roads are common to all of the remedial alternatives addressed in this appendix.[9]

Mine and Mill Site Remediation. This element includes work in the mine, adjacent mill site, and some other areas affected by mine operations, which are now sources of hazardous substance releases to the environment. Cleanup work in the mine includes mine entry and limited rehabilitation to enable construction of hydraulic bulkheads, and construction of airflow restrictions in open portals to reduce oxygen transport through the mine. Cleanup work in the abandoned mill includes limited demolition to enable safe removal of residual ore and mineral processing residuals, and contaminated soils that are sources of ongoing releases. This element also includes stabilization of the disturbed soils within and around the mill with vegetation to protect against long-term erosion.

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[9] However, the cost for this element would be somewhat higher for Alternative 8 compared to the other alternatives, since construction of the CTP would mean less of the existing swale and road system could be reused, and, therefore, more new road and swale construction would be required.

Other cleanup activities associated with the mine and mill site include removal of contaminated soils from the ventilator portal area, backfilling, and post-cleanup revegetation; capping contaminated soils in the maintenance yard area; and removal of contaminated soils in the lagoon area. Alternatives 10 and 11 include backfilling the lagoon area excavation with clean soil, but the excavation would presumably be incorporated into the proposed groundwater treatment facility for Alternatives 8 and 9. Revegetation in these areas and the areas described below includes placement of slash from necessary clearing to aid in habitat restoration, hydroseeding, and (except where noted) planting trees and shrubs.

Groundwater Containment, Collection, and Conveyance. This element includes construction of groundwater barrier walls and ditches, pipelines, or other facilities for containment and collection of groundwater (including seeps) with metals concentrations above cleanup levels that would otherwise discharge into Railroad Creek. The extent of the groundwater barriers and the collection and conveyance components differ markedly from one alternative to another, as discussed in the SFS. The alternatives also differ in the extent to which they would require pipeline crossings for water conveyance across Railroad and Copper Creeks.

This element also includes installation of pipelines to convey the portal drainage and seepage from the Honeymoon Heights area to the treatment system.

Waste Rock Pile Remediation. This element covers remediation of the two main East and West Waste Rock Piles, located adjacent to the abandoned mill, and for Alternative 11, this element includes the Honeymoon Heights Waste Rock Piles. Alternatives 10 and 11 include regrading the waste rock pile slopes to improve stability, but differ in the type of cap used for the piles after regrading. The waste rock removed during regrading in Alternatives 10 and 11 would be consolidated and capped on the existing waste rock piles, or on TP-1. Alternative 11 is the only alternative that includes consolidation of the Honeymoon Heights Waste Rock Piles into the other waste rock piles prior to closure. Alternative 8 includes relocation of both waste rock piles to the CTP, and revegetation of the disturbed area after removal of the waste rock. Alternative 9 does not include any remediation or closure of the waste rock piles.

Tailings Pile Remediation. This element includes regrading the tailings pile slopes to improve stability, and except for Alternative 9, includes setting back the toe of the piles away from Railroad and Copper Creeks. Associated with the regrading, Alternatives 8, 10, and 11 include sloping the top surface of the tailings piles to decrease precipitation infiltration and promote runoff toward the south; this is apparently not part of Alternative 9 (URS 2005b). Alternative 8 and Alternative 11 cost estimates include a cap for all tailings consisting of 2 feet of soil and an impermeable membrane that would conform to Washington State regulations for closure of limited purpose landfills [WAC 173-350-400]. Alternative 10 also includes a cap consisting of 1 foot of soil. For cost estimating purposes, the Agencies assumed that half the soil needed for cap construction would be imported from a Forest Service borrow pit (Dan's Camp). The remaining soil required for cap construction is anticipated to come excavations for groundwater treatment facility and run-on control swale construction as part of the cleanup.

Groundwater Treatment Facilities. This element includes construction of a single facility to treat collected groundwater (including seeps) and the mine drainage for Alternatives 9, 10, and 11, and two facilities for Alternative 8 as described in the DFFS. This cost includes clearing trees and brush for the treatment facility for Alternatives 10 and 11 (i.e., not in the lagoon area or former TP-3 footprint for the Alternative 8 and 9 treatment plant locations). This element also includes excavation for settling ponds and media filters; concrete lining of the ponds; energy supply and pumps; controls and piping; a small permanent building at each treatment facility location; and installation of chemical storage, chemical addition, and aeration facilities. This element includes pumps and a pipeline to convey the sludge produced as a by-product of treatment to a permanent disposal facility that would likely be located on TP-2.

Landfills. This element includes construction of a limited purpose landfill for each alternative to contain sludge generated by the groundwater treatment system. Sludge management assumptions are discussed in Appendix F of the SFS. The capital cost estimate for each alternative included construction of a lined disposal facility sized for accumulation of sludge over a 50-year period. Sludge management during that period, closure of the initial landfill cell, and construction of a new cell after 50 years were included in the estimate for future costs.

The Agencies assumed that materials other than sludge that are generated during implementation of the remedy (e.g., soils impacted by hazardous substances, waste rock, and demolition debris) would be consolidated into TP-1, and the sludge landfill would be constructed on TP-2 for Alternatives 9, 10, and 11. For Alternative 8, the consolidated materials would be part of the CTP, and the sludge landfill would be located on the CTP.

Surface Water Remediation. This element includes channel improvements for the Copper Creek Diversion to eliminate contact with tailings in TP-1;

development of a riprap source; placement of riprap; and ferricrete removal for the alternatives except Alternative 9. The use of riprap varies from one alternative to another; it would be used to protect the CTP for Alternative 8; the LWA groundwater barrier and collection system for Alternatives 10 and 11; and the tailings piles for Alternatives 9, 10, and 11.

3.1.1.2 Quantity Estimates for Direct Costs

The cost estimate relied on quantity estimates for each component of the nine direct cost elements, to define the extent of work required and the types of labor, equipment, and materials needed to complete construction of that element. This section describes how these quantities were obtained and the related costs for labor, equipment, and materials.

The remediation estimates were based on conceptual descriptions of each alternative, including the type and approximate size of the principal features that would be constructed. These principle features are shown on figures in the DFFS for Alternative 8, and in the SFS for Alternatives 9 through 11.

Approximate locations and extent of groundwater collection ditches, clean water diversion ditches, temporary and permanent roads associated with the remedy, areas of revegetation and regrading, and other site features and proposed facilities were determined from maps of the Site for each alternative. Quantities were obtained by scaling from these maps, except in the case of earthwork for regrading the tailings and waste rock piles, which were calculated using a computer method based on the topographic mapping provided by Intalco.[10]

A hydrogeologic-based analysis [the Treatment Plant Model (TPM)] was developed to estimate the annual volume and constituent concentrations of

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[10] Intalco commented that the 90-acre area for the tailings piles cited in the DRI was inconsistent with their more recent LiDAR-based assessment that showed the tailings piles extend over only about 67 acres (Covington & Burling 2006). The Agencies note that review of aerial photos and topography provided by Intalco indicates there are peripheral areas where tailings extend outside the footprint of the main tailings piles (e.g., adjacent to the Copper Creek Diversion east of TP-1, and between TP-1 and TP-2 along Copper Creek), and that vegetation encroaches on the south side of the tailings piles, which may explain some differences in interpretation. Using an AutoCAD base map provided by URS, the Agencies estimated that the area of tailings after regrading for Alternatives 10 and 11 is about 78 acres, and used this value in the cost estimates for reclamation and capping.

contaminated groundwater collected for each alternative, as discussed in Appendix A of the SFS. The estimated seasonal concentrations were used to estimate sludge volume generated by water treatment. Sludge volumes and sizes of the treatment system components for Alternatives 8 and 9 were determined by extrapolating results for Alternative 10, based on calculated flow volume estimates.

Quantity Calculations. Direct cost sheets for construction work were prepared using Excel ® spreadsheets, to tabulate quantities required to accomplish the work. These spreadsheets are included in the Administrative Record.

Where excavation, material hauling, or other unit operations were required (e.g., concrete lining for treatment system ponds), assumptions were developed for the type of equipment needed, along with corresponding labor and production rates. Production rates were typically based on published construction operations information (e.g., CAT® 1997, Church 1981, and Means 2004b). However, in some cases (e.g., groundwater barrier construction), Hart Crowser contacted contractors to discuss the project and obtain cost and production rate estimates.

Equipment utilization time was calculated based on the input quantities (e.g., cubic yards of earth to be hauled, haul distance) and production rates (e.g., average truck speed). The total number of trucks hauling material and additional supporting equipment such as excavators and dozers were also considered in determining equipment utilization.

Quantity Adjustments. Some of the major earthwork volume estimates included a "swell factor" to account for the difference in material volume in a loose state (e.g., in a stockpile or truck) compared to a compact state (e.g., *in situ* earth prior to excavation, or after compaction). However, swell factors were not applied to excavated mine tailings since the tailings were originally deposited hydraulically and remain in a relatively loose state. Swell factors were also not applied to excavated waste rock, since the waste rock piles remain in a relatively loose, angle of repose condition. A swell factor of 15 percent was applied to riprap volumes, based on published experience (Church 1981).

3.1.1.3 Unit Costs

Unit prices for equipment, labor, and materials were obtained primarily from Means (2003, 2004a, 2004b, and 2005) but the estimates also included input from other sources. Sources are typically cited in the cost estimating spreadsheets, rather than in this text, including the following.

- Costs for providing and operating lodging facilities for remote site construction were obtained from published information and vendor prices.
- Equipment lease rates for some of the large earthmoving machines were obtained directly from rental companies.
- Local vendors provided cost information for materials such as lime, fuel, cement, and crushed rock, and barge transport for delivery to Lucerne.
- Contractors provided estimated costs for the groundwater barrier walls, steel bridge fabrication, demolition of the abandoned mill superstructure, and on-site concrete production.
- Costs for some items were obtained from the DFFS. For example, the Agencies used Intalco's estimate for mine entry to accomplish bulkhead construction, since Intalco had direct experience with this work at Holden in 2000 and 2001. However, Hart Crowser priced the actual bulkhead construction based on their construction experience at other abandoned mine sites.

3.1.1.4 Adjustments to Direct Costs

The estimate used adjustments to direct costs to address differences in regional construction costs relative to national cost indices. The national cost indices (Means 2003, 2004a, 2004b, and 2005) were factored to reflect typical construction costs in eastern Washington, based on recommendations from Means. Costs of equipment, materials, and labor for most items in the estimates were adjusted on individual worksheets to account for regional differences in market conditions, since Means reported these costs in eastern Washington were generally 3.4 percent below national average costs at the time the estimate was prepared. This adjustment was not applied to cost estimates obtained from local contractors or vendors (e.g., groundwater barrier wall construction), since these estimates were obtained locally.

3.1.2 Indirect Capital Costs for Construction

Estimated direct costs determined as discussed above were summed and used as the basis to calculate indirect capital costs. This included application of factors to account for the remediation Contractor's overhead and profit, and what are referred to as Division 1 costs. Division 1 costs are for work by the Contractor that is ancillary to actual construction activities, but necessary for completion of the project. This includes items such as scheduling and surveying, quality control testing,[11] preparation of submittals, and costs for project bonds and insurance.

The unit costs used in the direct cost estimates included overhead and profit for operations performed by subcontractors, since subcontractors typically accomplish most of the work on large construction projects that include many different kinds of work, as will be the case for remedy implementation at the Site. However, the cleanup would be accomplished under the overall direction of a general contractor, so a markup was added to the direct costs to account for general contractor's overhead and profit. This markup was estimated to be 12 percent based on the size and complexity of the project. For comparison, Means (2003) reported typical rates of 10 to 15 percent. Division 1 costs were estimated at 8 percent of estimated direct costs.

3.1.3 Non-Construction Capital Costs

Non-construction capital costs refer to costs of preparation for and administration of construction. Non-construction capital costs were estimated as a percentage of the total construction costs (direct costs plus indirect costs to the Contractor) based on published guidelines, as summarized below.[12]

- Engineering Design covers the cost of preparing the plans and specifications for remedial construction. This cost was estimated to be 6 percent of total construction costs based on guidance from the American Society of Civil Engineers (ASCE 2003).

- Construction Administration and Oversight refers to the cost to administer the remediation construction contract, during its implementation, to assure the work is completed properly and that the Contractor is paid equitably as construction progresses. This cost was estimated to be 4 percent of total construction costs based on guidance from the ASCE (ASCE 2003).

- Project Management covers the costs for planning and reporting, community relations, bid offering and award, and potential permitting and legal services.

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[11] Some direct cost items also have special quality control testing included in cost (e.g., for installation of the HDPE membrane as part of the tailings and waste rock pile caps in Alternatives 8 and 11).

[12] Costs for Agency oversight during implementation, including establishment of institutional controls, were not separately estimated. These costs are not anticipated to be a distinguishing element for comparison of alternatives for the Site.

This cost was estimated to be 5 percent of the total construction costs based on EPA guidance (EPA 2000).

- Treatment system pilot testing is a lump sum cost item identified by Intalco in the DFFS and retained by the Agencies for comparison purposes. This lump sum item ($120,000 for each treatment facility) is included separately since it arguably does not fit within either engineering design or the first year operating expenses for the treatment facility. Similarly the estimates for Alternatives 10 and 11 included an allowance of $100,000 for an ERA, based on an estimate from Stratus Consultants Inc., a company regularly engaged in such work.

- Pre-Construction Environmental Baseline Monitoring is the cost estimated by the Agencies to accomplish 2 years of baseline monitoring during RD, based on the Conceptual Monitoring Program, Appendix H of the SFS. The monitoring would provide a basis for evaluating the effectiveness of the remedy. The Agencies assumed this cost would be the same for each alternative.

The sum of direct costs for construction, indirect costs for construction, and non-construction capital costs represents the total estimated capital cost for construction of each remedial alternative.

3.2 Future Costs

Future costs are costs for operations, maintenance, and monitoring (O&M) of the remedial action over time. Typically these are ongoing or periodic recurring costs that occur as long as the remedy is needed. Future costs include:

- The annual cost of operations and maintenance for the groundwater collection, conveyance and treatment;
- Monitoring performance of the remedy to determine whether it is protective of human health and the environment, and complies with ARARs;
- Costs for Agencies' oversight of the remedy; and
- Future capital costs to replace treatment system equipment as it wears out over time.

The conceptual design evaluation for groundwater collection and treatment (Appendix F of the SFS) provided the basis for estimating future O&M costs for the alternatives. Conceptual design evaluations were not completed to the same degree for each of the alternatives. For some alternatives, estimated O&M costs were calculated by adjusting cost relative to the volume of water that would be treated on an annual basis. The approach of using relative flow as the basis to adjust costs for process equipment and operations is based on experience in the chemical engineering industry (NCEES 2005).

3.2.1 Future Cost Elements

Table B-6 lists the future cost elements and estimated recurring costs for each alternative. The table shows estimated cost both at the time incurred and in terms of present worth or NPV. The costs were estimated over a period of 50 years, with different recurrence times for each element as noted. Annual recurring costs include routine labor and administrative expense to operate and maintain the groundwater collection and treatment system (for routine non-specific maintenance), as well as direct costs for fuel and lime used as the treatment reagent.

Specific annual maintenance items were identified and cost estimates were prepared to include:

- Maintenance of the groundwater and seep collection ditches and run-on diversion swales;
- Removal of treatment system sludge from the treatment facility settling ponds and pumping to disposal in the sludge landfill;
- Removal of a portion of the media filter sand bed to maintain treatment system effectiveness;
- Pumping sludge leachate from the sludge landfill back to the treatment facility; and
- For Alternatives 8 and 11 only, spraying to control vegetation to protect the integrity of the landfill caps over the tailings and waste rock piles.

Estimated future costs for sludge and leachate removal, pipeline maintenance, and the equipment and facility replacement costs included an allowance for mobilization and support of an off-site Contractor, including indirect cost markups and non-construction capital costs as described above. In contrast, costs for routine operations and maintenance were assumed to use local labor and equipment as part of ongoing operation of the treatment facility.

An important part of future costs is the cost for Agencies' oversight and environmental monitoring to determine whether the remedy accomplishes its intended purpose. The estimated costs for Agencies' oversight and environmental monitoring following remedy implementation were assumed to be the same for each alternative, but to vary over time. For example, during years 1 through 15, the Agencies anticipate they would review reports and monitoring data on a quarterly basis. Ecological monitoring was considered an exception because a relatively high level of Agencies involvement will likely be needed. Additional costs associated with the 5-year review required under CERCLA and MTCA were also included in the cost estimate. The 5-year review is an extensive review process to assess the effectiveness of the remedial efforts following each 5-year increment of operations. The annual level of Agencies' oversight was assumed to decrease by about 33 percent after the first 15 years, assuming the remedy functions effectively and cleanup proceeds in a satisfactory manner. The average annual effort was also assumed to decrease by about 33 percent again after another 15 years (i.e., in the 31st year after implementation).

Estimated annual monitoring costs were handled in a similar manner. Annual monitoring costs were assumed to be essentially the same during the first 15 years after implementation, and then to decrease by 33 percent after 15 and 30 years.

Estimated costs for Agencies' oversight and environmental monitoring costs do not provide a basis for distinguishing one alternative from another; however, they are included in the Agencies' estimates because these costs contribute significantly to the overall post-construction costs of the alternatives.

3.2.2 Frequency of Occurrence of Future Costs

Table B-6 shows the anticipated frequency of recurring cost items. Maintenance anticipated to occur less often than annually includes items such as replacement of the filter sand in the media filters every sixth year, and cleanout of the untreated groundwater conveyance pipelines by pigging and jetting, every third year. While the actual frequency of these specific maintenance items remains to be determined based on treatment system performance, the frequency and cleanout costs were estimated on a consistent basis for each alternative to provide a basis for comparison.[13] Some items, such as closure of one sludge disposal landfill cell and opening of a new sludge disposal landfill cell, were assumed to occur only once every 50 years. Estimated life cycle replacement periods for the treatment system equipment were obtained from published data (e.g., Schultz and Webber 2003).

[13] For instance the costs for pipeline maintenance varied based on the location and length of the conveyance pipes for each alternative, but the frequency of cleanout was the same for alternatives that had pipes in similar locations.

3.2.3 Determination of Net Present Value

Table B-6 sums the anticipated recurring costs for each alternative and shows the NPV for each. This value was added to the capital cost for each remedial alternative to produce the total estimated cost, as shown in Tables B-1 through B-5.

Groundwater collection and treatment at the Site is anticipated to continue for hundreds of years until releases from the underground mine, tailings piles, and other source areas at the Site decrease to proposed cleanup levels through the processes of source depletion and natural attenuation. The Agencies selected a 50-year period for calculating NPV to address the anticipated long duration of cleanup. As shown on Figure B-1, there is very little change in present value for periods longer than 50 years.[14]

The NPV for all future O&M costs was calculated using a period of 50 years and a discount rate of 7 percent. The discount rate of 7 percent is in accordance with EPA (2000) guidance, based on the assumption that the Intalco finances the cleanup. A lower discount rate would be used for determination of appropriate financial guarantees for completion of the remedy. The intent of such a guarantee would be to provide adequate assurance that cleanup could be completed by the Agencies if Intalco were to become no longer viable.

3.3 Total Estimated Cost for Alternatives 8 through 11

The NPV for all anticipated future costs over a 50-year period were summed as shown in Table B-6, and added to the estimated capital costs for each alternative, as shown in Tables B-1 through B-5. The total estimated cost for each alternative is the sum of the estimated capital cost and the NPV of estimated future costs.

4.0 Contingent Costs for Alternative 11

At the time a feasibility study estimate is prepared, there are generally unknown factors that may affect the final cost either positively or negatively. These factors are referred to as "contingencies." The two main types of contingency are

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[14] Upon completion of the remedy, the Agencies assumed that the treatment system and other remedy components would be shut down and removed for the same cost as assumed for normal component replacement. Riprap maintenance and monitoring may need to continue in perpetuity.

referred to as "scope" and "bid," and these are considered for both the capital and O&M costs (EPA 2000).

- Scope contingencies estimate the magnitude of change a remedy may undergo during design. Scope contingencies are typically low for sites that are well characterized and where the magnitude of the cleanup is well known at a time the remedy is selected. Typical cost ranges for scope contingencies are 10 to 25 percent of the capital cost; but EPA (2000) cites some examples that range from 5 to 55 percent.

- Bid contingencies account for unforeseen changes that may occur after the start of remedial construction. This may include changes in quantities, modifications to design, changes in regulations, or unanticipated conditions during construction.[15] Typical cost ranges for bid contingencies are 10 to 20 percent of the capital cost (EPA 2000).

Contingencies are typically expressed as percentages added to estimated capital and O&M costs, but this approach is not always appropriate for several reasons. Most notably, a percentage applied to the overall construction cost may not accurately represent specific areas of uncertainty associated with different alternatives. For this reason, EPA (2000) provides different contingency factors for different types of remediation, and suggests weighting the factors by the type of cost elements included in a proposed cleanup action. Also, while contingencies are typically considered as an allowance for unanticipated cost increases, there is also a potential for contingent cost reductions due to anticipated or unanticipated circumstances.

Listed below are examples that illustrate why it is inappropriate to apply a simple contingency percentage to all alternatives for cleanup of the Site.

- The potential need for soil cleanup actions in the wind-blown tailings area east of Holden Village (for example) is the same for all alternatives, and will not be known until additional ERA work is completed during RD. This contingent cost cannot be accounted for by applying a simple percentage factor to the cost of a remedial alternative that is based on relatively well defined regrading, groundwater collection, and treatment.

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[15] The EPA guidance does not address the potential effect of market conditions on construction bidding at the time of remedy implementation; and the effect of commodity price changes between the time the estimate was prepared and the end of construction, e.g., for fuel.

- Alternative 11 includes provisions for an ERA to evaluate final cover requirements for closure of the tailings and waste rock piles. Since the ERA completed for the DRI (Dames & Moore 1999) did not adequately address closure of the tailings piles (see Appendix E of the SFS), use of a cover that conforms to the presumptive requirements for limited purpose landfills [WAC 173-350-400(3)(e)(ii)] was assumed for Alternative 11.[16] In the event that additional ERA shows that the presumptive cover is not needed, and (for example) a simple 1-foot-thick soil cover with revegetation would satisfy the performance requirements for closing the tailings and waste rock piles, the contingent construction cost savings for Alternative 11 would be about $19,200,000.[17] As noted above, this contingent savings cannot be accounted for by addition of a simple percentage to the estimated cost for Alternative 11.

- Similarly, there could be a significant reduction of about $4,300,000 in the barrier wall cost for Alternative 11, if analyses during RD indicated that a partially penetrating barrier (as proposed for Alternative 10) would be as effective as the fully penetrating barrier in preventing groundwater above proposed cleanup levels from discharging into Railroad Creek. A simple percentage factor applied to the total estimated capital cost for each alternative does not accurately represent this potential contingent cost savings.

The Agencies have not included contingencies in previous estimates for the Site (e.g., Hart Crowser 2005b) because of the difficulty in applying these on a consistent basis from one alternative to another. EPA guidance suggests that contingencies be applied to construction and O&M costs, before professional and technical services costs (i.e., non-construction capital costs) are included, and before calculation of the NPV.

The following discussion focuses on Alternative 11, since it is the only alternative that meets the CERCLA and MTCA criteria for selection. A contingent cost analysis has not been completed by the Agencies for the other alternatives.

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[16] Final closure of the tailings and waste rock piles would need to meet the performance requirements or the presumptive cover requirements for limited purpose landfills [WAC 173-350-400(3)(e)], which is a potential ARAR as discussed in the SFS.

[17] The difference in direct cost is about $13,700,000, and addition of indirect and non-construction capital costs (about 40 percent) of the direct costs would increase the difference to about $19,200,000.

EPA provides guidance for estimating scope contingencies for a number of different types of remedial construction, including the following that are potentially applicable to the Site.

Type of Construction	Range of Scope Contingency Applied to Construction Cost
Surface Grading	5 to 10 percent
Synthetic Cap	10 to 20 percent
Vertical Containment Barriers	10 to 30 percent
Groundwater Treatment	5 to 10 percent

Note that EPA does not provide contingency factors for all types of remediation, so for Alternative 11, the potential scope contingency for groundwater collection and conveyance was considered to be within the range noted above for groundwater treatment in the analysis described below. Contingency factors for various elements of the estimate for Alternative 11 were selected as described below.

A contingency value representing the middle of the range for surface grading was selected for regrading the tailings and waste rock piles, since this involves pulling the toe of slop back from the creek and is more complex than simple regrading to achieve stable slopes and control stormwater runoff.[18]

Using the same type of reasoning presented for earthwork, there is no reason for the Agencies to expect that the other types of contingencies applicable to Alternative 11 will be at the high end of the range suggested by EPA, so mid-range values were selected to provide a reasonable contingency value for the main cost elements as shown below.

[18] There are several reasons for not selecting a contingency value associated with the high end of the range for regrading the tailings and waste: 1) The topography of the pile slopes is well established based on LiDAR mapping provided by Intalco; 2) The post-regrading tailings pile slopes used in the estimate (2H:1V) is consistent with results of preliminary stability analyses that have been accomplished, see Appendix D of the SFS); 3) The nominal 45-foot setback from the creek is adequate to achieve the intended goals of increased flood protection, access for maintenance and monitoring, etc., and there is some potential that the amount of setback could be reduced (i.e., require a lower volume of earthwork during regrading) pending further analysis during RD; and 4) the process used to develop the estimate for regrading was based on a rigorous analysis (as shown in the back-up spreadsheets that are included in the Administrative Record).

Type of Construction Used for Alternative 11	Selected Value for Scope Contingency
Soil Excavation	8 percent
Synthetic Cap	15 percent
Vertical Containment Barriers	20 percent
Groundwater Treatment	8 percent

These scope contingency values were used to calculate contingent costs for the corresponding cost elements for Alternative 11, taken from Table B-5, as shown below.

The primary direct cost components of Alternative 11 are the tailings and waste rock piles regrading and closure cap (about $23,400,000), and the collection conveyance and treatment of groundwater (about $9,400,000).[19] Using the contingency factors noted in the previous table, the scope contingency cost increase for Alternative 11 was estimated to be $4,530,000, as shown in the table below.

Alternative 11	Original Estimate of Capital Cost Component[20]	Contingency Factor	Contingent Cost
Regrading of Tailings and Waste Rock Piles	$8,240,000	8%	$659,000
Tailings and Waste Rock Cap	$15,200,000	15%	$2,280,000
Groundwater Containment	$7,000,000	20%	$1,400,000
Groundwater Collection and Conveyance and Treatment Facilities	$2,390,000	8%	$191,000
Subtotals	$32,800,000		$4,530,000

[19] These costs and the costs in the table above are direct costs, and do not include indirect or non-construction capital costs. For Alternative 11 the indirect and non-construction capital costs represent about 40 percent of the direct costs. Other than these four elements, no other element of Alternative 11 represents more than 10 percent of the estimated direct cost, except the job set-up and construction infrastructure. Therefore, use of a contingency factor based on weighting the main construction elements (as suggested by EPA) is justified.

[20] Original estimate from Table 5, pro-rated as described above, all values rounded.

The EPA guidance includes no published contingency factors for the remainder of the remedial elements of Alternative 11 (e.g., mine and mill site remediation, surface water remediation, and landfills). However, the above calculation applies to only $32,800,000 of a total estimated direct cost of $46,600,000 (see Table B-5). Applying the same relative contingency proportion to the remaining remedial elements (e.g., $4,530,000 is about 14 percent of $32,800,000) would suggest an overall scope contingency increase for Alternative 11 of about $7,830,000 (14 percent of the total capital cost for Alternative 11 of $55,900,000).

A similar analysis using a median value for EPA's bid contingency range (15 percent of construction subtotal) could potentially add another $8,390,000 to this, for a total scope and bid contingent increase on the order of $16,200,000.[21]

EPA guidance also indicates that contingency factors should be included in estimating long-term (O&M) costs, prior to the calculation of NPV. EPA suggests that the total (scope plus bid) contingency for O&M should generally be greater than the percent used for the capital cost estimate. Using a contingency of 25 percent for future costs (prior to calculating NPV) for Alternative 11, the Agencies estimated the total cost could potentially increase by an additional $5,100,000 (i.e., after calculating NPV as recommended by EPA), for a total contingent increase on the order of $21,300,000.

In contrast, favorable results of an additional ERA that would allow using a 1-foot soil cover with vegetation in place of the currently proposed impermeable cap on the waste rock and tailings piles could reduce the total capital cost of Alternative 11 by an estimated $19,200,000.[22] Also, using a PPB for Alternative 11 rather than a fully penetrating barrier could reduce the total capital cost by about $4,300,000 for a potential contingent cost reduction of $23,500,000 for these two elements alone.

In summary, the Agencies recognize there are potential unknown factors that could produce an increase or decrease in scope and/or bid costs for the capital and future cost components of Alternative 11. The estimated potential

[21] This potential cost increase of $16,200,000 should be viewed in context with a potential savings of $19,200,000 for the tailings and waste rock cap, and potential savings of $4,300,000 as described earlier in this section.

[22] Savings in total capital cost through construction, including markups for job startup, contractor's markup, engineering design, administration and project management.

contingent cost increase is roughly the same as the potential cost reduction identified for two of the major cost elements of Alternative 11.

5.0 Significant Elements that Affect the Cost Estimates

This section discusses the principal elements that affect the estimated cost for the alternatives considered in the MTCA practicability analysis. Differences in cost are largely based on differences in the amount of cleanup accomplished, and the differences to which the alternatives protect human health and the environment, and satisfy potential ARARs, by each of the alternatives.

5.1 Areas Where Costs of Each Alternative Are Similar

Estimated cost for the upgradient run-on diversion swales, access roads, and the mine and mill-site remediation were similar for Alternatives 8, 9, 10, and 11.

Mine entry for construction of hydraulic bulkheads was the largest single component of these costs. The estimate for mine entry for each alternative used the cost allowance ($750,000) developed by Intalco. The estimated cost for bulkhead construction varied only slightly from one alternative to another, primarily because the cost of concrete varied slightly between alternatives depending on the overall volume of concrete used for other elements of each alternative.

Estimated costs for mill site demolition and cleanup were similar for each alternative, but varied slightly based on assumed haul distance to consolidate the waste materials. The swale and road costs were also similar except for Alternative 8. More road and swale construction would be required for Alternative 8 because the CTP would reduce the amount of existing facilities that can be reused.

Estimated cost for the proposed groundwater treatment facilities is also relatively similar for each alternative, but varies based primarily on the expected facility size and the annual volume of water to be treated.

Finally, future costs for environmental monitoring and Agencies' oversight were the same for each alternative.

5.2 Areas Where Costs of Each Alternative Differ Significantly

The primary areas where the costs differ from one alternative to another are discussed below. In the following discussion, direct costs are discussed as shown in Tables B-1 through B-6, not including the effect of non-construction capital costs or indirect cost mark-ups.

5.2.1 Construction Mobilization and Duration

Construction mobilization includes the cost for providing labor, equipment, and materials at the Site and, therefore, is affected by the scope of work to be accomplished for each alternative.

The anticipated duration of construction is another aspect of capital cost that differentiates the alternatives, and is indirectly related to the amount of cleanup accomplished. This has been addressed in a consistent way to enable comparison of costs. Since the Site is located in the Cascade Mountains, the construction season for earth moving activities is limited to the period between early June after the snow melts, and late October before cold, wet weather typically sets in. Based primarily on the amount of work required for regrading the tailings piles, the estimated construction of Alternatives 10 and 11 would require about 5 months per year for 3 years; Alternative 9 would require a similar construction season each year over 2 years; and that Alternative 8 would require double shifts for earthwork for two construction seasons to be completed in 3 years, because of the significantly larger volume of earthwork.

This cost estimate was prepared using the base year 2005. No inflation factors have been applied to account for potential cost increases over the estimated duration of construction, which is anticipated to be 3 years at most. The potential effect of future changes in commodity and labor prices over time presents a source of uncertainty for each alternative.

The anticipated construction duration period for each alternative was used to estimate worker-housing costs and supply costs, as well as the cost premium associated with second shift labor rates for Alternative 8 earthwork. However, the Agencies have not attempted to develop a detailed construction schedule.

5.2.2 Groundwater Containment, Collection, and Conveyance

Costs for this element varied significantly, from about \$1.5 million for Alternative 9, to \$7.7 million for Alternative 11. Alternative 9 has a relatively short, shallow barrier wall containment system that would only extends across the UWA. For comparison, Alternative 11 has a fully penetrating barrier that extends along Railroad Creek to contain all identified sources of groundwater above proposed cleanup levels that discharge into Railroad Creek.

The estimated cost for this element of Alternative 8 is $3.8 million for a fully penetrating barrier that only extends around the CTP; while the Alternative 10 cost was $3.7 million for a PPB along the LWA, TP-1, and TP-3.

Differences in the estimated costs for this element also reflect differences in the length of ditches and pipelines to convey collected groundwater to the treatment facilities for each alternative.

5.2.3 Waste Rock Piles

Costs for this element varied from $5.2 million for Alternative 11 to zero for Alternative 9. Alternative 9 did not include any cleanup action for the waste rock piles except upslope diversion of run-on and downslope collection of seeps, which were estimated as part of other cost elements. Alternative 11 included consolidation of the Honeymoon Heights Waste Rock Piles, and regrading and closure of the main East and West Waste Rock Piles in accordance with potential ARARs.

Costs for Alternatives 8 and 10 were intermediate to the estimates noted above. The estimate for Alternative 8 was $2.5 million for consolidation of the main East and West Waste Rock Piles (but not the Honeymoon Heights Waste Rock Piles) into the CTP. Alternative 10 included regrading for stability and placement of a vegetated soil cap on the main East and West Waste Rock Piles, but not the Honeymoon Heights Waste Rock Piles. The waste rock cap for Alternative 10 does not satisfy the presumptive cover requirements, but may satisfy the performance criteria for closure of limited purpose landfills [WAC 173-350-400(3)(e)].

5.2.4 Tailings Piles

Estimated costs for this element varied substantially, from $50 million for Alternative 8 to $2.8 million for Alternative 9. This cost element includes regrading slopes to improve stability, and for some alternatives, setting back the toe of slopes away from Railroad and Copper Creeks to reduce risk of instability affecting the creeks. However, the biggest cost component was related to capping the tailings piles.

- Alternative 8 includes consolidating all the tailings into a single CTP, flattening the existing slopes and pulling the toe back from Railroad Creek, and a cover that meets potential ARARs, for an estimated cost of $50 million.
- Alternative 9 includes regrading to improve stability for only the slopes of TP-1 and TP-2, and does not include any new cover except for 1 foot of soil

on the regraded slope area (about 19 acres), for an estimated cost of $2.8 million.

- Alternative 10, includes regrading the slopes of the three tailings piles, regrading the tops of the piles to improve runoff, pulling the toe of slope back from the creeks, and a 1-foot-thick soil cover and revegetation overall, for an estimated cost of about $6 million.
- Alternative 11 includes regrading the slopes of the three tailings piles, regrading the tops of the piles to improve runoff, pulling the toe of slope back from the creeks, and a cover overall that meets potential ARARs, for an estimated cost of about $18 million.

5.2.5 Landfills

The estimated cost of the permanent sludge disposal facility varies from about $2.3 million for Alternative 9 to $4.3 million for Alternative 11, with the estimates for Alternatives 8 and 10 between these estimates. The basis for this difference in cost is the volume of sludge that would be generated over the assumed 50-year life of the initial landfill cell. The difference in sludge volumes is directly related to differences in the volume of water that would be collected and treated to prevent seepage above proposed cleanup levels into Railroad Creek.

5.2.6 Surface Water Remediation

This cost element includes removal of ferricrete for Alternatives 8, 10, and 11, but not for Alternative 9.[23] The surface water remediation cost element also includes improvements to the Copper Creek Diversion and enhancing existing riprap along Railroad Creek for all the alternatives. Estimated costs vary from about $400,000 for Alternative 8 to $1.2 million for Alternatives 10 and 11, based largely on the estimated amount of riprap that would be needed.

5.2.7 Long-Term Costs

The future costs for each alternative can be differentiated primarily based on the amount of fuel and lime consumption anticipated as part of treating groundwater, and the anticipated treatment system O&M, which are largely a function of the different volume of groundwater treated by each alternative. The

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[23] Intalco did not specifically address ferricrete removal for Alternative 9, but said that Alternative 9 was similar to Alternative 3b (URS 2005b). Alternative 3b did not include ferricrete removal (see DFFS Appendix J).

table below shows the difference in volume of contaminated groundwater that would be collected and treated, compared to the NPV for groundwater treatment over 50 years.

Alternative	Estimated NPV of O&M Cost for 50 Years	Estimated Annual Volume of Contaminated Water Collected and Treated in Millions of Gallons	Unit Cost in $/Million Gallons Over 50 Years
8	$8,350,000	357	$467
9	$6,410,000	324	$396
10	$8,980,000	483	$372
11	$11,000,000	600	$367

5.3 Items Not Included in the Agencies Cost Estimates

The estimates presented herein are preliminary since they are based only on information available from the feasibility study process, which does not provide the level of detail that would be available following final design for any of the proposed alternatives.[24] Final design is anticipated to include detailed surveys, additional analyses, and may include treatability tests to better define the scope and details of the remedy.

To provide a comparison of alternatives, the estimates presented herein have been prepared in a consistent manner. The level of detail used in these estimates is greater than was presented in the DFFS, but is comparable to other estimates provided by Intalco for Alternatives 3b and 9 (URS 2005a and 2005b). While the approach used to develop the estimates presented herein was based on EPA guidance (EPA 2000), there are some potential elements of the remedy that cannot be the subject of a cost estimate on the basis of existing information. The potential cost for these elements does not play a role in comparing one alternative to another, since these unknown elements are common to all the alternatives that were evaluated. The elements for which costs cannot be estimated on the basis of existing information are summarized below.

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[24] Appendix F presents a conceptual engineering design evaluation completed for Alternative 10, but is not an actual design. This evaluation provided information used to develop the cost estimate for Alternative 10, and by extension, the estimates for the other alternatives, but does not provide the same degree of detail or precision in estimating that will be available at the completion of remedial design.

The Agencies' cost estimate did not include any allowance for remediation of impacted soils within areas such as Holden Village, the wind-blown tailings area, the ballfield, or the LWA (except for the lagoon area, which is adjacent to or within the LWA). Costs were not estimated for these areas because 1) sampling and analysis accomplished for the DRI were not sufficient to support delineation of the actual extent of soils above proposed cleanup levels; 2) additional ERA may result in revision to the proposed cleanup levels; and 3) the cost for additional cleanup in these areas (if needed) is the same for each alternative.

The Agencies have also identified some areas where long-term O&M costs are uncertain and were not adequately addressed in the DFFS. In addition to potential problems associated with seasonal freezing and potential iron fouling that are discussed in Appendix F of the SFS, the issues noted below will need to be addressed as part of RD, since they likely represent the most important area of uncertainty and potential O&M contingent cost.

- The approach used for treatment of groundwater was proposed by Intalco in the DFFS and adopted by the Agencies for Alternatives 10 and 11. At this time it is not known with certainty that the proposed treatment system will achieve metals removal effectiveness sufficient for the effluent to meet discharge criteria, or whether the treatment system design will need to be modified from that proposed.
- Similarly, it is not known how seasonal precipitation and snow melt will affect the feasibility of sludge dewatering using passive methods (evaporation and consolidation), or whether treatment system modifications such as high-density sludge recirculation, mechanical clarification, chemically assisted flocculation, or other means will need to be added to achieve reasonable sludge disposal capacity and sludge handling costs.

Several additional items were not included in this cost estimate. For example, replacement costs for the geomembrane and geotextiles used for closure of the tailings piles, waste rock piles, and sludge disposal landfills were not included; because no information is available on longevity of these components. However, maintenance cost to control root penetration of geotextiles was included in the cost estimates for Alternatives 8 and 11. Cost to replace the groundwater barrier walls was also not included, again because no data are available that indicate whether or when replacement may be required.

Bridge and road replacement costs were not included in the future O&M costs because these are assumed to be part of National Forest Service maintenance unrelated to cleanup at the Site. Finally, contingency costs for overall treatment system failure or the need for additional consultants to the Agencies were not included in this cost estimates.

6.0 Comparison of Cost Estimates Prepared for the SFS to Estimates Prepared by Intalco

There are a number of significant assumptions in any cost estimate, and differences in assumptions made by the Agencies and Intalco have a pronounced effect on the relative magnitude of estimates prepared by the Agencies and Intalco.

Intalco provided cost estimates in the DFFS for Alternatives 1 through 8. The DFFS estimates included a breakdown of capital costs, recurring costs for O&M, plus a 50 percent contingency. The DFFS cost estimates did not provide the level of detail required for CERCLA feasibility studies (EPA 2000). Since the DFFS did not address Alternatives 9, 10, and 11, the Agencies developed additional cost estimates for these alternatives. Intalco also provided its own estimates of costs for Alternative 9 (URS 2005b) and Alternative 10 (referred to as the APR, URS 2005a).

The purpose of this appendix is to explain the cost estimates for Alternatives 8, 9, 10, and 11 prepared by the Agencies, as described above. While the primary purpose of this appendix is not to provide a detailed analysis of the differences in estimates prepared by the Agencies and Intalco, it is useful to identify some of the differences in approach, since Intalco has stated that the Agencies' estimate for Alternative 10 underestimated the "real cost" of the remedy.

The "real cost" of the remedy is uncertain at this time for all the alternatives, for a number of reasons, including:

- Design has not been completed. Design will include more complete analyses of treatment system requirements, surveying to better define topographic impacts on regrading and excavations for groundwater collection, conveyance, and treatment components, etc.
- Market conditions in the construction industry at the time of bidding are not known, and will not be evident until the time bids are completed. The relative abundance or scarcity of work, and contractor perceptions of construction risk associated with cleanup work at the Site relative to other available work, will significantly influence bidding.
- Costs of construction may change from the award cost to the low bidder, e.g., if differing site conditions are encountered, regulations change, or fuel costs increase, etc.
- Finally, the portion of the NPV of future costs varies from about 15 percent (Alternative 8) to 42 percent (Alternative 9) of the total estimated cost of the remedy. Future O&M costs will be affected by the areas of uncertainty noted above, treatment system operating experience, changes in the labor

and material costs, the real discount rate, and potential changes in technology.

For all of the reasons noted above, no cost estimate at the feasibility study stage is likely to represent the "real cost," regardless of whether it is prepared by the Agencies or Intalco. Cost comparisons for the different alternatives should be based on consistent assumptions and a consistent approach, as the Agencies have done.

The Agencies' concerns with the DFFS estimates included the following:

- The DFFS did not clearly define what was included in various line items;
- Some of the costs used in the DFFS differed significantly from what the Agencies expected for comparable construction;
- The DFFS did not provide backup for many of the cost items, and correspondence from Intalco showed a large degree of reliance on "engineering judgment" for significant costs (URS 2004);
- The DFFS applied a 50 percent contingency to everything in each estimate, which arbitrarily magnified the difference between low and high cost alternatives; and
- The total cost in the DFFS breakdown for each alternative included a value for NPV of the recurring costs, and a notation that this was based on 7 percent. However, back analysis of several of the DFFS alternatives using this rate produced periods ranging from 17.5 to 30 years, indicating either mathematical errors or changing assumptions.

Intalco's cost estimate for Alternative 9 (URS 2005b) included a breakdown of its estimate of capitol costs; a net present worth value but no breakdown for long-term O&M costs; and a 30 percent contingency.

The Agencies disagreed with some of the assumptions Intalco used for comparing Alternatives 9 and 10; the more significant of which (on a cost basis) are summarized below.

- Intalco applied the same contingency factor (30 percent) to alternatives that are dissimilar. This gives a false perspective on the relative difference in the cost of one alternative compared to another.[25]

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[25] For example, if two alternatives have estimated costs of $40,000,000 and $60,000,000, the difference is $20,000,000. If the comparison is based on the estimated

- Intalco adjusted the percentage factors on Contractor markups and engineering applied to the total indirect costs, based on URS' experience at similar sites and professional judgment. The net effect of these changes was to increase the capital cost for each alternative by 9 percent.

- Intalco estimated there would be about $2,000,000 in additional labor costs for Alternative 10, by adding overtime pay and travel costs for the workers during construction. Intalco also estimated a cost of $660,000 to provide each worker with six paid trips “home” to Wenatchee for each construction season. The Agencies note the need for this kind of expense is subjective, and depends on market conditions at the time of construction. For instance, no increase in costs associated with the remote location of the Site, or worker leave costs, are apparent in the bids received for the 1989-1991 interim remediation accomplished by the Forest Service.

- The Agencies assumed that the groundwater treatment facility ponds would need to be lined to prevent release of water that does not meet water quality standards. For the Agencies’ cost estimate that was used by Intalco, a concrete lining was preliminarily selected over a membrane liner considering the potential for damage during sludge removal and effect of winter freezing on long-term durability. The need for a concrete lining could be further considered during RD, but should be consistent for the basis of comparing alternatives. Intalco kept this concrete lining cost for Alternative 10, but did not include costs for treatment pond lining for Alternative 9.

- Based on discussion in Section 6.3.5 of the DFFS, the Agencies assumed the cap in the maintenance yard area would be a concrete slab, so Holden Village could continue to use area for vehicle maintenance. Intalco’s Alternative 9 estimate included a substantial cost reduction by using a geosynthetic cover, but Intalco did not use a similar approach in comparing to Alternative 10. While such a cap may or may not be acceptable, Intalco’s use of different assumptions for one alternative and not another, does not produce a consistent basis for comparison.

- The Agencies’ cost estimates are based on using the Lightning Ridge quarry site that was used in 1989. Intalco’s estimate for Alternative 9 used a lower cost (because of a much shorter haul distance) based on use of two potential quarry sites close to Holden Village, which is another example of

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cost plus a 50 percent contingency, the spread appears to be $60,000,000 to $90,000,000, and the difference appears to be $30,000,000.

an apparent cost difference that is not based on consistent assumptions. The Agencies' estimates presented in Tables B-2 through B-5 for Alternatives 8 through 11, avoid such inconsistency by assuming use of the same quarry site for the four alternatives.

There were a number of other factors that affected Intalco's estimate relative to the Agencies' estimates, to a lesser degree. For example, Intalco felt that bulking of materials during transport was not adequately taken into consideration in the Agencies' estimate, and the Agencies disagreed. The Agencies assumed seep collection would be needed at five locations on Honeymoon Heights, based on observations in the RI, whereas Intalco's estimate was based on collection at two locations.

The Agencies modified the estimates presented in this appendix from their initial estimates where Intalco's comments seemed reasonable. For example, Intalco noted that cost estimates must account for remote site location construction. The estimates presented in Tables B-2 through B-5 are based on a 9-hour day, 6-day workweek during the construction season of early June to late October, which is typical of remote site construction (except Alternative 8 that uses double shifts for consolidation of the tailings and waste rock piles). The Agencies' cost estimate was also updated to include 2005 labor rates in place of the 2003 labor rates used in the previous estimates.

7.0 References to Appendix B

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Table B-1 - Comparison of Estimated Costs for Alternatives 8, 9, 10, and 11

Item	Alt. 8	Alt. 9	Alt. 10	Alt. 11
CAPITAL COSTS				
Remedial Construction				
Job Setup & Construction Infrastructure	$6,500,000	$3,850,000	$4,840,000	$5,750,000
Upgradient Diversions and Access Roads	$274,000	$194,000	$194,000	$194,000
Mine & Mill Site Remediation	$2,280,000	$2,310,000	$2,320,000	$2,320,000
Groundwater Containment, Collection & Conveyance	$3,770,000	$1,520,000	$3,670,000	$7,740,000
Waste Rock Piles	$2,460,000	$0	$1,760,000	$5,170,000
Tailings Piles	$49,700,000	$2,750,000	$6,180,000	$18,300,000
Groundwater Treatment Facilities	$2,040,000	$1,590,000	$2,040,000	$1,640,000
Landfills	$2,970,000	$2,740,000	$3,810,000	$4,360,000
Surface Water Remediation	$393,000	$663,000	$1,170,000	$1,170,000
Subtotal Direct Costs	$70,300,000	$15,600,000	$26,000,000	$4,700,000
Contractor Markups	$14,100,000	$3,120,000	$5,200,000	$9,330,000
Total Construction Costs	$84,400,000	$18,700,000	$31,200,000	$56,000,000
Non-Construction Capital Costs	$13,800,000	$3,850,000	$5,820,000	$9,540,000
TOTAL COSTS THROUGH CONSTRUCTION	$98,200,000	$22,600,000	$37,000,000	$65,500,000
PRESENT WORTH OF POST-CONSTRUCTION COSTS	$17,500,000	$15,600,000	$18,100,000	$20,200,000
TOTAL ESTIMATED PRESENT WORTH COST	$116,000,000	$38,200,000	$55,100,000	$85,800,000

Table B-2 - Breakdown of Estimated Costs for Alternative 8

Item	Quantity	Units	Unit Cost	Subtotal Cost	Subtotal
CAPITAL COSTS					
Construction					
Job Setup & Construction Infrastructure					
Mobilize & Demobilize (material, equipment, workers, & two winter shut-downs)	1	ls	$2,500,000	$2,500,000	
Site Supervision	1	ls	$1,132,030	$1,130,000	
Operate Camp (55 people ave)	24,750	day	$72	$1,780,000	
New/Upgrade Construction Bridges	1	ls	$361,929	$361,929	
Road Maintenance (for three Construction Seasons)	1	ls	$657,442	$657,442	
Monitoring Well Installation	1	ls	$66,072	$66,072	
Subtotal Job Setup & Construction Infrastructure					*$6,495,000*
Upgradient Diversions and Access Roads					
West Area	1	ls	$150,648	$150,648	
East Area	1	ls	$123,059	$123,059	
Subtotal Upgradient Diversions and Accexs Roads					*$274,000*
Mine & Mill Site Remediation					
Access/Air Flow Restrictions	2	ea	$7,500	$15,000	
Mine Entry/Rehabilitation	1	ls	$750,000	$750,000	
Hydraulic Bulkheads	1	ls	$348,176	$348,176	
Mill Demolition (remove unsafe superstructure)	1	ls	$825,000	$825,000	
Removal of Residual Processing Waste and Contaminated Soils at Mill Area	500	cy	$56.68	$28,340	
Revegetate Mill Area (after cleanup)	2	ac	$7,901	$15,802	
Place Woody Debris at Mill Area	2	ac	$2,180	$4,360	
Hydroseed Mill Area	2	ac	$3,165	$6,330	
Plant Tree Tubes and Shrubs on Mill Area	2	ac	$2,709	$5,418	
Pave Existing Maintenance Yard	1	ls	$162,778	$162,778	
Excavate Lagoon Area Impacted Soils	9,000	cy	$10.42	$93,780	
Excavate Ventilator Portal Retention Area Impacted Soils	400	cy	$20.63	$8,252	
Access Road to Ventilator Portal Retention Area	1,000	lf	$9.50	$9,500	
Abandon Road to Ventilator Portal Retention Area	1,000	lf	$4.40	$4,400	
Subtotal Mine & Mill Site Remediation					*$2,277,000*
Groundwater Containment, Collection & Conveyance					
Portal Discharge Pipe	1	ls	$21,970	$21,970	
Work Platform Grading and Maintenance Road	2,500	lf	$35.18	$87,950	
Collect & Convey Seeps from SP-12 and SP-23 to Ponds	1	ls	$88,541	$88,541	
Seep and GW Collection Ditch	7,010	lf	14.67	$102,837	
Copper Creek Pipeline Crossing	1	ea	$58,425	$58,425	
Gravel Roadway along Base of TP-2	3,560	lf	$7.35	$26,166	
CTP Barrier Wall	213,600	sf	$15.00	$3,200,000	
CTP Remove Barrier Wall Spoils	22,667	cy	$8.26	$187,227	
Subtotal Groundwater Containment, Collection & Conveyance					*$3,773,000*
Waste Rock Piles					
Relocate Waste Rock to TP-2	307,000	cy	$7.71	$2,366,970	
Revegetate Former Waste Rock Piles and Place Topsoil	1	ls	$27,465	$27,465	
Place Woody Debris on Former Waste Rock Piles	9	ac	$1,342	$12,078	

Table B-2 - Breakdown of Estimated Costs for Alternative 8

Item	Quantity	Units	Unit Cost	Subtotal Cost	Subtotal
Hydroseed Former Waste Rock Piles	9	ac	$3,165	$28,485	
Plant Tree Tubes and Shrubs on Former Waste Rock Piles	9	ac	$2,709	$24,381	
Subtotal Waste Rock Piles					*$2,459,000*
Tailings Piles					
TESC	4,200	lf	$1.59	$6,678	
Pull Toe of TP-2 Back from RR Creek. Consolidate Tailings Piles 1 and 3 onto TP-2.	3,900,000	cy	$10.48	$40,872,000	
Low Permeable Cover for CTP	50	ac	$175,459	$8,772,950	
Subtotal Tailings Piles					*$49,652,000*
Groundwater Treatment Facilities					
West Treatment Plant					
West Area Water Treatment Ponds - Clearing	2.5	ac	$14,564	$36,410	
West Area Water Treatment Ponds - Excavation	3,712	cy	$12	$45,000	
West Area Water Treatment Ponds - Concrete Lining	483	cy	$184	$89,000	
Chemical storage and addition facilities	1	ea	$137,000	$137,000	
Mixing and aeration facilities	1	ls	$20,000	$20,000	
Filtration ponds wi/ media	1	ls	$36,967	$36,967	
Energy supply	1	ls	$27,000	$27,000	
Miscellaneous Treatment.	1	ls	$92,000	$92,000	
Building for Office/Storage	250	sf	$200	$50,000	
Sludge conveyance from WWTP to TP-2	1	ls	$149,176	$149,176	
East Treatment Plant					
East Area Treatment Ponds - Excavation	34,300	cy	$7.64	$262,052	
East Area Treatment Ponds - Concrete Lining	890	cy	$184.00	$163,770	
Chemical Storage and Addition Facilities	1	ls	$208,000	$208,000	
Mixing and Aeration Facilities	1	ls	$30,000	$30,000	
Filtration Ponds with Media	1	ls	$155,698	$155,698	
Energy Supply	1	ls	$54,000	$54,000	
Miscellaneous Treatment	1	ls	$124,000	$124,000	
Building for Office/Storage	500	sf	$200	$100,000	
Sludge Conveyance from WWTP to TP-2	1	ls	$259,607	$259,607	
Subtotal Groundwater Treatment Facilities					*$2,040,000*
Landfills					
Landfill for Sludge Disposal	1	ls	$2,963,311	$2,963,000	
Consolidate Cleanup Derived Waste	1	ls	$7,065	$7,000	
Subtotal Landfills					*$2,970,000*
Surface Water Remediation					
Copper Creek Diversion Channel Improvement	350	lf	$83	$29,050	
Ferricrete Removal	1	ls	$44,860	$44,860	
Develop Riprap Source	1	ls	$75,000	$75,000	
Place Riprap Berm along Creek Channel	3,271	cy	$74.76	$244,521	
Subtotal Surface Water Remediation					*$393,000*
Subtotal Direct Costs					**$70,330,000**

Table B-2 - Breakdown of Estimated Costs for Alternative 8

Item	Quantity	Units	Unit Cost	Subtotal Cost	Subtotal
Contractor Markups					
Contractor's OH&P			12.0%	$8,440,000	
Insurance, Div 1 Items, Contractor's Engr, Surveying			8.0%	$5,630,000	
Total Construction Costs					**$84,400,000**
Non-Construction Capital Costs					
Engineering Design			6.0%	$5,064,000	
Construction Administration & Oversight			4.0%	$3,376,000	
Project Management			5.0%	$4,220,000	
Treatment System Pilot Testing	2	ls	$120,000	$240,000	
Baseline Monitoring	1	ls	$923,000	$923,000	
Total Non-Construction Capital Costs					**$13,820,000**
TOTAL COSTS THROUGH CONSTRUCTION					**$98,220,000**
PRESENT WORTH OF POST-CONSTRUCTION COSTS					**$17,510,000**
TOTAL ESTIMATED PRESENT WORTH COST					**$115,730,000**

Note: Rounding of significant figures is typically applied only at summary of subtotals, and does not materially affect the overall estimate.

Table B-3 - Breakdown of Estimated Costs for Alternative 9

Item	Quantity	Units	Unit Cost	Subtotal Cost	Subtotal
CAPITAL COSTS					
Construction					
Job Setup & Construction Infrastructure					
Mobilize & Demobilize (material, equipment, workers, & one winter shut-down)	1	ls	$1,500,000	$1,500,000	
Site Supervision	1	ls	$695,615	$695,615	
Operate Camp (35 people ave)	10,500	day	$72	$756,000	
New/Upgrade Construction Bridges	1	ls	$369,967	$369,967	
Road Maintenance	1	ls	$466,000	$466,000	
Monitoring Well Installation	1	ls	$66,072	$66,072	
Subtotal Job Setup & Construction Infrastructure					*$3,854,000*
Upgradient Diversions and Access Roads					
West Area	1	ls	$110,943	$110,943	
East Area	1	ls	$83,120	$83,120	
Subtotal Upgradient Diversions and Access Roads					*$194,000*
Mine & Mill Site Remediation					
Access/Air Flow Restrictions	2	ea	$7,500	$15,000	
Mine Entry/Rehabilitation	1	ls	$750,000	$750,000	
Hydraulic Bulkheads	1	ls	$348,176	$348,176	
Mill Demolition (remove unsafe superstructure)	1	ls	$825,000	$825,000	
Removal of Residual Processing Waste and Contaminated Soils at Mill Area	500	cy	$51.76	$25,880	
Revegetate Mill Area (after cleanup)	2	ac	$15,021	$30,042	
Pave Existing Maintenance Yard	1	ls	$162,764	$162,764	
Excavate Lagoon Area Impacted Soils	9,000	cy	$14.72	$132,480	
Excavate Ventilator Portal Retention Area Impacted Soils	400	cy	$20.63	$8,252	
Access Road to Ventilator Portal Retention Area	1,200	lf	$9.50	$11,400	
Abandon Road to Ventilator Portal Retention Area	1,200	lf	$4.40	$5,280	
Subtotal Mine & Mill Site Remediation					*$2,314,000*
Groundwater Containment, Collection & Conveyance					
Portal Discharge Pipe to WWTP	1	ls	$21,970	$21,970	
Work Platform Grading and Maintenance Road	2,500	lf	$35.18	$87,950	
Collect & Convey Seeps from SP-12 and SP-23 to Ponds	1	ls	$72,231	$72,231	
Work Platform Steep Area	2,500	lf	$35.17	$87,925	
Seep Groundwater Collection (5 ft deep, closed trench)	2,500	lf	$32	$80,000	
UWA Barrier Wall (cement bentonite)	62,500	sf	$15	$937,500	
UWA Barrier Wall Excavation Removal	6,944	cy	$8.62	$59,861	
Groundwater Extraction Wells	1	ls	$118,451	$118,451	
Collect & Convey Seeps from SP-1 and SP-2 to Ponds	1	ls	$51,572	$51,572	
Subtotal Groundwater Containment, Collection & Conveyance					*$1,517,000*
Waste Rock Piles					
Subtotal Waste Rock Piles					*$0*
Tailings Piles					
TESC	6,160	lf	$1.59	$9,794	
Tailings Pile Slope Regrading (TP-1 and TP-2)	250,000	cy	$6.83	$1,707,500	
Place Topsoil on Regraded Slopes	38,720	cy	$16.58	$641,978	
Place Woody Debris on Three Tailings Piles	90	cy	$1,081	$97,290	

Table B-3 - Breakdown of Estimated Costs for Alternative 9

Item	Quantity	Units	Unit Cost	Subtotal Cost	Subtotal
Hydroseed Regraded Tailings Pile Slopes	16	ac	$3,165	$50,640	
Tree Tubes and Shrubs on Tailings Piles	90	ac	$2,709	$243,810	
Subtotal Tailings Piles					*$2,751,000*
Groundwater Treatment Facilities					
Forest Clearing and Stockpile	3.9	ac	$14,575	$56,843	
Excavate Ponds	36,360	cy	$11.10	$403,596	
Concrete Lining	1,119	cy	$184.00	$205,896	
Chemical Storage and Addition Facilities	1	ls	$199,000	$199,000	
Mixing and Aeration Facilities	1	ls	$29,000	$29,000	
Filtration Ponds with Media	1	ls	$191,535	$191,535	
Energy Supply	1	ls	$46,000	$46,000	
Miscellaneous Treatment (piping & etc.)	1	ls	$118,000	$118,000	
Building for Office/Storage	500	sf	$200	$100,000	
Sludge Conveyance from WWTP to TP-2	1	ls	$183,883	$183,883	
Copper Creek Sludge Pipeline Crossing	1	ls	$53,351	$53,351	
Subtotal Groundwater Treatment Facilities					*$1,587,000*
Landfills					
Sludge Disposal Landfill	1	ls	$2,729,450	$2,729,450	
Consolidate Cleanup Derived Waste	1	ls	$7,065	$7,065	
Subtotal Landfills					*$2,737,000*
Surface Water Remediation					
Copper Creek Diversion Channel Improvement	350	lf	$83	$29,050	
Creek Channel Habitat Restoration	1	ls	$0	$0	
Develop Riprap Source	1	ls	$75,000	$75,000	
Place Riprap Berm along Creek Channel	7,476	cy	$74.76	$558,906	
Subtotal Surface Water Remediation					*$663,000*
Subtotal Direct Costs					**$15,620,000**
Contractor Markups					
Contractor's OH&P			12.0%	$1,870,000	
Insurance, Div 1 Items, Contractor's Engr, Surveying			8.0%	$1,250,000	
Total Construction Costs					**$18,740,000**
Non-Construction Capital Costs					
Engineering Design			6.0%	$1,124,000	
Construction Administration & Oversight			4.0%	$750,000	
Project Management			5.0%	$937,000	
Treatment System Pilot Testing	1	ls	$120,000	$120,000	
Baseline Monitoring (Pre-Construction)	1	ls	$923,000	$923,000	
Total Non-Construction Capital Costs					**$3,850,000**
TOTAL COSTS THROUGH CONSTRUCTION					**$22,590,000**
PRESENT WORTH OF POST-CONSTRUCTION COSTS					**$15,580,000**
TOTAL ESTIMATED PRESENT WORTH COST					**$38,170,000**

Note: Rounding of significant figures is typically applied only at summary of subtotals, and does not materially affect the overall estimate.

Table B-4 - Breakdown of Etimated Costs for Alternative 10

Item	Quantity	Units	Unit Cost	Cost	Subtotal
CAPITAL COSTS					
Remedial Construction					
Job Setup & Construction Infrastructure					
Mobilize & Demobilize (material, equipment, & workers, including two winter shut-downs)	1	ls	$2,000,000	$2,000,000	
Site Supervision	1	ls	$695,615	$695,615	
Operate Camp (35 people avg)	15,750	days	$72	$1,134,000	
New/Upgrade Construction Bridges	1	ls	$344,410	$344,410	
Road Maintenance (for three construction seasons)	1	ls	$600,000	$600,000	
Monitoring Well Installation	1	ls	$66,072	$66,072	
Subtotal Job Setup & Construction Infrastructure					*$4,840,000*
Upgradient Diversions and Access Roads					
West Area	1	ls	$110,944	$110,944	
East Area	1	ls	$83,121.56	$83,122	
Subtotal Upgradient Diversions and Access Roads					*$194,000*
Mine & Mill Site Remediation					
Mine Access/Air Flow Restrictions	2	ea	$7,500	$15,000	
Mine Entry/Rehabilitation	1	ls	$750,000	$750,000	
Hydraulic Bulkheads	1	ls	$348,176	$348,176	
Mill Demolition (remove unsafe superstructure)	1	ls	$825,000	$825,000	
Removal of Residual Processing Waste and Contaminated Soils at Mill Area	500	cy	$51.76	$25,880	
Revegetate Mill Area (after cleanup)	2	ac	$7,901	$15,802	
Place Woody Debris at Mill Area	2	ac	$2,180	$4,360	
Hydroseed Mill Area	2	ac	$3,165	$6,330	
Plant Tree Tubes and Shrubs on Mill Area	2	ac	$2,709	$5,418	
Pave Existing Maintenance Yard	1	ls	$162,682	$162,682	
Excavate Lagoon Area Impacted Soils & Reclaim Area	9,000	cy	$14.72	$132,480	
Excavate Ventilator Portal Retention Area Impacted Soils & Reclaim Area	400	cy	$20.63	$8,252	
Access Road to Ventilator Portal Retention Area	1,200	lf	$9.50	$11,400	
Abandon Road to Ventilator Portal Retention Area	1,200	lf	$4.40	$5,280	
Subtotal Mine & Mill Site Remediation					*$2,316,000*
Groundwater Containment, Collection & Conveyance					
Portal Discharge Pipe to WWTP	1	ls	$163,306	$163,306	
Work Platform Grading and Maintenance Road	2,500	lf	$35.17	$87,925	
Seep Collection and Conveyance (pipe and ditch)	1	ls	$84,545	$84,545	
LWA & TP-1 Barrier Wall	113,400	sf	$15.00	$1,701,000	
LWA &TP-1 Barrier Wall Excavation Removal	12,600	cy	$10.02	$126,252	
GW Trench and Seep Collection Piping along Toe of TP-1, TP-2, and TP-3	1	ls	$211,564	$211,564	
Maintenance Road for GW Trench and Seep Collection Pipe	5,200	lf	$7.35	$38,220	
TP-3 Barrier Wall	63,000	sf	$15.00	$945,000	
TP-3 Barrier Wall Excavation Removal	7,000	cy	$8.60	$60,200	
RR Creek Pipeline Crossing	1	ea	$116,878	$116,878	
Copper Creek Pipeline Crossing	1	ea	$58,439	$58,439	
Pipe to Treatment Pond	1300	lf	$60.85	$79,105	
Subtotal Groundwater Containment, Collection & Conveyance					*$3,672,000*

Table B-4 - Breakdown of Etimated Costs for Alternative 10

Item	Quantity	Units	Unit Cost	Cost	Subtotal
Waste Rock Piles					
Regrade Waste Rock Slopes and Haul	158,000	cy	$9.52	$1,504,160	
Place Topsoil to Support Revegetation on Waste Rock Piles	15,972	cy	$12.03	$192,143	
Place Woody Debris on Waste Rock Piles	9	ac	$1,342	$12,078	
Hydroseed Waste Rock Piles	8.9	ac	$3,165	$28,169	
Plant Tree Tubes and Shrubs on Waste Rock Piles	8.9	ac	$2,709	$24,110	
Subtotal Waste Rock Piles					*$1,761,000*
Tailings Piles					
TESC	6,160	lf	$32.22	$198,475	
Regrade Top of Tailings Pile 1	13.6	ac	$18,767	$255,231	
Tailings Pile Slope Regrading (TP-1, TP-2, and TP-3)	580,000	cy	$7.03	$4,077,400	
Topsoil for Top and Side Slopes	125,840	cy	$8.69	$1,093,550	
Place Woody Debris on Tailings Piles	78	ac	$1,180	$92,040	
Hydroseed Tailings Piles	78	ac	$3,165	$246,870	
Tree Tubes and Shrubs on Tailings Piles	78	ac	$2,709	$211,302	
Subtotal Tailings Piles					*$6,175,000*
Groundwater Treatment Facilities					
Forest Clearing and Stockpile	7.2	ac	$14,475	$104,475	
Excavate Ponds	60,200	cy	$5.92	$356,384	
Concrete Lining	1,869	cy	$184.00	$343,896	
Chemical Storage and Addition Facilities	2	ea	$279,000	$558,000	
Mixing and Aeration Facilities	2	ls	$40,000	$80,000	
Filtration Ponds with Media	1	ls	$117,387	$117,387	
Energy Supply	1	ls	$72,760	$72,760	
Miscellaneous Treatment.	1	ls	$165,600	$165,600	
Building for Office/Storage	500	sf	$200	$100,000	
Sludge Conveyance from WWTP to TP-2	1	ls	$143,088	$143,088	
Subtotal Groundwater Treatment Facilities					*$2,042,000*
Landfills					
Sludge Disposal Landfill	1	ls	$3,749,520	$3,749,520	
Consolidate Cleanup Derived Waste	1	ls	$63,554	$63,554	
Subtotal Landfills					*$3,813,000*
Surface Water Remediation					
Copper Creek Diversion Channel Improvement	350	lf	$83	$29,050	
Remove Ferricrete	1	ls	$115,513	$115,513	
Develop Riprap Source	1	ls	$75,000	$75,000	
Place Riprap Berm along Creek Channel	12,683	cy	$74.76	$948,144	
Subtotal Surface Water Remediation					*$1,168,000*
			Subtotal Direct Costs		**$25,980,000**
Contractor Markups					
Contractor's OH&P			12.0%	$3,120,000	
Insurance, Div 1 Items, Contractor's Engr, Surveying			8.0%	$2,080,000	
			Total Construction Costs		**$31,180,000**

Table B-4 - Breakdown of Etimated Costs for Alternative 10

Item	Quantity	Units	Unit Cost	Cost	Subtotal
Non-Construction Capital Costs					
Ecological Risk Assessment	1	ls	$100,000	$100,000	
Engineering Design			6.0%	$1,871,000	
Construction Administration & Oversight			4.0%	$1,247,000	
Project Management			5.0%	$1,559,000	
Treatment System Pilot Testing	1	ls	$120,000	$120,000	
Baseline Monitoring (Pre-Construction)	1	ls	$923,000	$923,000	
Total Non-Construction Capital Costs					**$5,820,000**
TOTAL COSTS THROUGH CONSTRUCTION					**$37,000,000**
PRESENT WORTH OF POST-CONSTRUCTION COSTS					**$18,140,000**
TOTAL ESTIMATED PRESENT WORTH COST					**$55,140,000**

Note: Rounding of significant figures is typically applied only at summary of subtotals, and does not materially affect the overall estimate.

Table B-5 - Breakdown of Estimated Costs for Alternative 11

Item	Quantity	Units	Unit Cost	Subtotal Cost	Subtotal
CAPITAL COSTS					
Remedial Construction					
Job Setup & Construction Infrastructure					
Mobilize & Demobilize (material, equipment, workers, & two winter shut-downs)	1	ls	$2,500,000	$2,500,000	
Site Supervision	1	ls	$913,823	$913,823	
Operate Camp (35 people ave)	18,900	day	$72	$1,360,800	
New/Upgrade Construction Bridges	1	ls	$344,407	$344,407	
Road Maintenance (for three Construction Seasons)	1	ls	$560,000	$560,000	
Monitoring Well Installation	1	ls	$66,072	$66,072	
Subtotal Job Setup & Construction Infrastructure					*$5,745,000*
Upgradient Diversions and Access Roads					
West Area	1	ls	$110,943	$110,943	
East Area	1	ls	$83,120	$83,120	
Subtotal Upgradient Diversions and Access Roads					*$194,000*
Mine & Mill Site Remediation					
Access/Air Flow Restrictions	2	ea	$7,500	$15,000	
Mine Entry/Rehabilitation	1	ls	$750,000	$750,000	
Hydraulic Bulkheads	1	ls	$348,200	$348,200	
Mill Demolition (remove unsafe superstructure)	1	ls	$825,000	$825,000	
Removal of Residual Processing Waste and Contaminated Soils at Mill Area	500	cy	$51.76	$25,880	
Revegetate Mill Area (after cleanup)	2	ac	$7,901	$15,802	
Place Woody Debris at Mill Area	2	ac	$2,359	$4,718	
Hydroseed Mill Area	2	ac	$3,165	$6,330	
Plant Tree Tubes and Shrubs on Mill Area	2	ac	$2,709	$5,418	
Pave Existing Maintenance Yard	1	ls	$162,764	$162,764	
Excavate Lagoon Area Impacted Soils	9,000	cy	$14.72	$132,480	
Excavate Ventilator Portal Retention Area Impacted Soils	400	cy	$20.63	$8,252	
Access Road to Ventilator Portal Retention Area	1,200	lf	$9.50	$11,400	
Abandon Road to Ventilator Portal Retention Area	1,200	lf	$4.40	$5,280	
Subtotal Mine & Mill Site Remediation					*$2,317,000*
Groundwater Containment, Collection & Conveyance					
Portal Discharge Pipe to WWTP	1	ls	$163,306	$163,306	
Work Platform Grading and Maintenance Road	2,500	lf	$35.17	$87,925	
LWA & TP-1 Seep Collection and Conveyance	1	ls	$84,545	$84,545	
LWA and TP-1 Barrier Wall Installation	225,000	sf	$15.00	$3,375,000	
LWA and TP-1 Barrier Wall Excavation Removal	25,000	cy	$7.24	$181,000	
GW Trench and Seep Collection Pipe along Toe of TP-2 and TP-3	8,280	lf	$11.59	$95,965	
Maintenance Road for GW Trench and Seep Collection Pipe	8,280	lf	$7.35	$60,858	
TP-2 and TP-3 Barrier Wall (cement bentonite)	215,000	sf	$15.00	$3,225,000	
TP-2 and TP-3 Barrier Wall Excavation Removal	23,889	cy	$9.02	$215,479	
RR Creek Pipeline Crossing	1	ea	$116,878	$116,878	
Copper Creek Pipeline Crossing	1	ea	$58,439	$58,439	
Pipe to Treatment Pond	1300	lf	$60.85	$79,105	
Subtotal Groundwater Containment, Collection & Conveyance					*$7,743,000*
Waste Rock Piles					

Table B-5 - Breakdown of Estimated Costs for Alternative 11

Item	Quantity	Units	Unit Cost	Subtotal Cost	Subtotal
Regrade Waste Rock Slopes and Haul	158,000	cy	$9.52	$1,504,160	
Cap Regraded Waste Rock Piles	8.9	ac	$175,459	$1,561,585	
Hydroseed Waste Rock Piles	8.9	ac	$3,165	$28,169	
Upper WR Pile Removal	1	ls	$2,078,373	$2,078,373	
Subtotal Waste Rock Piles					*$5,172,000*
Tailings Piles					
TESC	1	ls	$198,482.54	$198,483	
Regrade Top of Tailings Pile 1	13.6	ac	$26,116	$355,178	
Tailings Pile Slope Regrading (TP-1, TP-2, and TP-3)	580,000	cy	$7.03	$4,077,400	
Cap for Top and Side Slopes	78	ac	$175,459	$13,685,802	
Subtotal Tailings Piles					*$18,317,000*
Groundwater Treatment Facilities					
Forest Clearing and Stockpile	2.8	ac	$14,658	$41,236	
Excavate Ponds	53,768	cy	$5.92	$318,307	
Concrete Lining	1,426	cy	$184	$262,470	
Chemical Storage and Addition Facilities	1	ea	$296,000	$296,000	
Mixing and Aeration Facilities	1	ls	$42,000	$42,000	
Filtration Ponds with Media	1	ls	$183,164	$183,164	
Energy Supply	1	ls	$77,000	$77,000	
Miscellaneous Treatment	1	ls	$176,000	$176,000	
Building for Office/Storage	500	sf	$200	$100,000	
Sludge conveyance from WWTP to TP-2	1	ls	$143,088	$143,088	
Subtotal Groundwater Treatment Facilities					*$1,639,000*
Landfills					
Sludge Disposal Landfill	1	ls	$4,298,715	$4,298,715	
Consolidate Cleanup Derived Waste	1	ls	$63,554	$63,554	
Subtotal Landfills					*$4,362,000*
Surface Water Remediation					
Copper Creek Diversion Channel Improvement	350	lf	$83	$29,050	
Ferricrete Removal	1	ls	$115,513	$115,513	
Develop Riprap Source	1	ls	$75,000	$75,000	
Place Riprap Berm along Creek Channel	12,683	cy	$74.76	$948,144	
Subtotal Surface Water Remediation					*$1,168,000*
Subtotal Direct Construction Costs					**$46,660,000**

Table B-5 - Breakdown of Estimated Costs for Alternative 11

Item	Quantity	Units	Unit Cost	Subtotal Cost	Subtotal
Contractor Markups					
Contractor's OH&P			12.0%	$5,600,000	
Insurance, Div 1 Items, Contractor's Engr, Surveying			8.0%	$3,730,000	
			Total Construction Costs		**$55,990,000**
Non-Construction Capital Costs					
Ecological Risk Assessment	1	ls	$100,000	$100,000	
Engineering Design			6.0%	$3,359,000	
Construction Administration & Oversight			4.0%	$2,240,000	
Project Management			5.0%	$2,799,500	
Treatment System Pilot Testing	1	ls	$120,000	$120,000	
Baseline Monitoring (Pre-Construction)	1	ls	$923,000	$923,000	
			Total Non-Construction Capital Costs		**$9,540,000**
TOTAL COSTS THROUGH CONSTRUCTION					**$65,530,000**
PRESENT WORTH OF POST-CONSTRUCTION COSTS					**$20,160,000**
			TOTAL ESTIMATED PRESENT WORTH COST		**$85,690,000**

Note: Rounding of significant figures is typically applied only at summary of subtotals, and does not materially affect the overall estimate.

Table B-6 - Comparison of Estimated OMM Costs and NPV of Future Costs for Alterantives 8, 9, 10, and 11

	Alternative 8						Alternative 9						Alternative 10						Alternative 11					
ITEM	ANNUAL QUANTITY	UNIT	COST PER UNIT	COST IN YEAR INCURRED	YEARS IN WHICH COST IS INCURRED	PRESENT WORTH	ANNUAL QUANTITY	UNIT	COST PER UNIT	COST IN YEAR INCURRED	YEARS IN WHICH COST IS INCURRED	PRESENT WORTH	ANNUAL QUANTITY	UNIT	COST PER UNIT	COST IN YEAR INCURRED	YEARS IN WHICH COST IS INCURRED	PRESENT WORTH	ANNUAL QUANTITY	UNIT	COST PER UNIT	COST IN YEAR INCURRED	YEARS IN WHICH COST IS INCURRED	PRESENT WORTH
ROUTINE OPERATOR LABOR																								
System Operations/Monitoring	0.75	FTE	$80,000	$60,000	1 to 50	$828,000	0.5	FTE	$80,000	$40,000	1 to 50	$552,000	0.5	FTE	$80,000	$40,000	1 to 50	$552,000	0.5	FTE	$80,000	$40,000	1 to 50	$552,000
Equipment Maintenance	0.3	FTE	$100,000	$30,000	1 to 50	$414,000	0.2	FTE	$100,000	$20,000	1 to 50	$276,000	0.2	FTE	$100,000	$20,000	1 to 50	$276,000	0.2	FTE	$100,000	$20,000	1 to 50	$276,000
Project Management/Reporting	0.3	FTE	$140,000	$42,000	1 to 50	$580,000	0.3	FTE	$140,000	$42,000	1 to 50	$580,000	0.3	FTE	$140,000	$42,000	1 to 50	$580,000	0.3	FTE	$140,000	$42,000	1 to 50	$580,000
Subtotal - Routine Operator Labor	1.35					**$1,822,000**	1					**$1,408,000**	1			$102,000		**$1,408,000**	1					**$1,408,000**
DIRECT COSTS																								
Diesel Fuel for Electrical Generators	11,300	gal	$3.66	$41,358	1 to 50	$571,000	5,900	gal	$3.66	$21,594	1 to 50	$298,000	22,800	gal	$3.66	$83,448	1 to 50	$1,152,000	27,700	gal	$3.66	$101,382	1 to 50	$1,399,000
Lime	384	ton	$368	$141,236	1 to 50	$1,949,000	348	ton	$368	$128,153	1 to 50	$1,769,000	519	ton	$368	$191,120	1 to 50	$2,638,000	598	ton	$368	$220,064	1 to 50	$3,037,000
Miscellaneous Office Admin for Reports & Subcontracts	1	ls	$21,622	$21,622	1 to 50	$298,000	1	ls	$15,700	$15,700	1 to 50	$217,000	1	ls	$20,000	$20,000	1 to 50	$276,000	1	ls	$22,800	$22,800	1 to 50	$315,000
Subtotal - Consumables						**$2,818,000**						**$2,284,000**				$294,568		**$4,066,000**						**$4,751,000**
SPECIAL MAINTENANCE ITEMS																								
Sludge Removal from Settling Ponds	1	ls	$48,424	$48,424	1 to 50	$668,000	1	ls	$44,801	$44,801	1 to 50	$618,000	1	ls	$61,681	$61,681	1 to 50	$851,000	1	ls	$67,673	$67,673	1 to 50	$934,000
Filter Sand Layer Removal	1	ls	$1,675	$1,675	1 to 50	$23,000	1	ls	$1,169	$1,169	1 to 50	$16,000	1	ls	$1,986	$1,986	1 to 50	$27,000	1	ls	$2,205	$2,205	1 to 50	$30,000
Filter Sand Replacement	1	ls	$15,379	$15,379	6,12,18,...	$30,000	1	ls	$10,734	$10,734	6,12,18,...	$21,000	1	ls	$18,234	$18,234	6,12,18,...	$35,000	1	ls	$20,246	$20,246	6,12,18,...	$39,000
Spraying to Control Vegetation on Landfill Cover	1	ls	$51,791	$36,924	1 to 50	$510,000	0	n/a					0	n/a					1	ls	$66,005	$66,005	1 to 50	$911,000
Landfill Leachate Removal	2	ls	$18,298	$36,596	1 to 50	$505,000	2	ls	$18,298	$36,596	1 to 50	$505,000	2	ls	$18,298	$36,596	1 to 50	$505,000	2	ls	$19,769	$39,538	1 to 50	$546,000
Diversion Swale/Conveyance Ditch Maintenance	9,600	lf	$2.29	$21,984	1 to 50	$303,000	7,300	lf	$2.29	$16,717	1 to 50	$231,000	13,200	lf	$2.00	$26,400	1 to 50	$364,000	15,600	lf	$2.29	$35,724	1 to 50	$493,000
Conveyance Pipe Cleaning (pigging/jetting)	11,400	lf	$6.09	$69,426	3,6,9,...	$297,000	10,200	lf	$8.06	$82,212	3,6,9,...	$351,000	13,320	lf	$6.65	$88,578	3,6,9,...	$378,000	11,420	lf	$7.20	$82,224	3,6,9,...	$351,000
Subtotal - Special Maintenance Items						**$2,336,000**						**$1,742,000**				$233,475		**$2,160,000**						**$3,304,000**
EQUIPMENT/FACILITY REPLACEMENT																								
New Sludge Landfill Cell	1	ls	$5,178,171	$5,178,171	50	$176,000	1	ls	$4,838,193	$4,838,193	50	$164,000	1	ls	$6,396,903	$6,396,903	50	$217,000	1	ls	$7,017,370	$7,017,370	50	$238,000
Old Sludge Landfill Cell Cover	1	ls	$5,316,485	$5,316,485	50	$180,000	1	ls	$4,967,408	$4,967,408	50	$169,000	1	ls	$6,567,834	$6,567,834	50	$223,000	1	ls	$7,204,906	$7,204,906	50	$245,000
Riprap Maintenance	1	ls	$19,975	$19,975	10,20,30,...	$20,000	1	ls	$45,657	$45,657	10,20,30,...	$46,000	1	ls	$77,453	$77,453	10,20,30,...	$77,000	1	ls	$154,907	$154,907	10,20,30,...	$155,000
Electrical Generators	1	ls	$87,778	$87,778	20,40	$29,000	1	ls	$70,108	$70,108	20,40	$23,000	1	ls	$97,635	$97,635	20,40	$32,000	1	ls	$104,234	$104,234	20,40	$34,000
Misc. Treatment Components	1	ls	$337,128	$337,128	15,30,45	$183,000	1	ls	$194,312	$194,312	15,30,45	$105,000	1	ls	$270,605	$270,605	15,30,45	$147,000	1	ls	$288,896	$288,896	15,30,45	$156,000
Lime Silo	1	ls	$350,093	$350,093	50	$12,000	1	ls	$201,785	$201,785	50	$7,000	1	ls	$281,012	$281,012	50	$10,000	1	ls	$300,006	$300,006	50	$10,000
Tank Vibrators	1	ls	$44,779	$44,779	20,40	$15,000	1	ls	$25,809	$25,809	20,40	$8,000	1	ls	$35,943	$35,943	20,40	$12,000	1	ls	$38,372	$38,372	20,40	$12,000
Mechanical Lime Addition	1	ls	$223,897	$223,897	20,40	$73,000	1	ls	$129,049	$129,049	20,40	$42,000	1	ls	$179,717	$179,717	20,40	$58,000	1	ls	$191,864	$191,864	20,40	$62,000
Controls, Motor Starters, Transformer, Heater, etc.	1	ls	$516,998	$516,998	10,20,30,...	$516,000	1	ls	$297,985	$297,985	10,20,30,...	$298,000	1	ls	$414,983	$414,983	10,20,30,...	$415,000	1	ls	$443,033	$443,033	10,20,30,...	$443,000
Fuel Tanks (15,000 gal steel AST)	1	ls	$26,460	$26,460	20,40	$9,000	1	ls	$15,251	$15,251	20,40	$5,000	1	ls	$21,239	$21,239	20,40	$7,000	1	ls	$22,675	$22,675	20,40	$7,000
Aeration Equipment	1	ls	$162,834	$162,834	50	$6,000	1	ls	$93,853	$93,853	50	$3,000	1	ls	$130,703	$130,703	50	$4,000	1	ls	$139,538	$139,538	50	$5,000
GWTP Sludge Removal Equipment (includes pipeline)	1	ls	$291,245	$291,245	20,40	$95,000	1	ls	$167,867	$167,867	20,40	$55,000	1	ls	$233,776	$233,776	20,40	$76,000	1	ls	$249,577	$249,577	20,40	$81,000
Water Conveyance Pipelines	1	ls	$373,076	$373,076	50	$13,000	1	ls	$514,726	$514,726	50	$17,000	1	ls	$829,557	$829,557	50	$28,000	1	ls	$829,557	$829,557	50	$28,000
Structures	1	ls	$245,069	$245,069	40	$16,000	1	ls	$163,379	$163,379	40	$11,000	1	ls	$163,379	$163,379	40	$11,000	1	ls	$163,379	$163,379	40	$11,000
Treatment Pond Linings and Media Filters	1	ls	$676,326	$676,326	50	$23,000	1	ls	$642,104	$642,104	50	$22,000	1	ls	$628,598	$628,598	50	$21,000	1	ls	$1,171,083	$1,171,083	50	$40,000
Monitoring Wells	1	ls	$107,994	$107,994	50	$4,000	1	ls	$107,994	$107,994	50	$4,000	1	ls	$107,994	$107,994	50	$4,000	1	ls	$107,994	$107,994	50	$4,000
Subtotal - Equipment/Facility Replacement						**$1,370,000**						**$979,000**				$16,437,331		**$1,342,000**						**$1,531,000**
SUBTOTAL O&M						**$8,346,000**						**$6,413,000**						**$8,976,000**						**$10,994,000**
ENVIRONMENTAL MONITORING																								
Year 1																						$732,756	1	
Year 2																						$563,233	2	
Year 3																						$604,894	3	
Year 4																						$445,798	4	
Year 5																						$615,321	5	
Present Worth of Environmental Monitoring Costs in Years 1 to 5			(Costs assumed to be same as Alt. 11)						(Costs assumed to be same as Alt. 11)						(Costs assumed to be same as Alt. 11)									$2,449,000
Average Annual Environmental Monitoring in Years 1 to 5																						$592,400		
Years 6 to 15																						$592,400	6 to 15	$2,967,000
Years 16 to 30																						$394,933	16 to 30	$1,304,000
Years 31 to 50																						$263,289	31 to 50	$366,000
Subtotal - Environmental Monitoring						**$7,086,000**						**$7,086,000**						**$7,086,000**						**$7,086,000**
AGENCY REVIEW & OVERSIGHT																								
Baseline Annual Costs for Years 1 to 5																						$157,000	1 to 5	
Additional Costs for 5-Year Annual Review																						$89,000	5	
Present Worth of Agency Review & Oversight Costs in Years 1 to 5			(Costs assumed to be same as Alt. 11)						(Costs assumed to be same as Alt. 11)						(Costs assumed to be same as Alt. 11)									$707,000
Average Annual Environmental Monitoring in Years 1 to 5																						$174,800		
Years 6 to 15																						$175,000	6 to 15	$876,000
Years 16 to 30																						$117,000	16 to 30	$386,000
Years 31 to 50																						$78,000	31 to 50	$109,000
Subtotal - Agency Review & Oversight						**$2,078,000**						**$2,078,000**						**$2,078,000**						**$2,078,000**
TOTAL PW OF POST-CONSTRUCTION COSTS						**$17,510,000**						**$15,580,000**						**$18,140,000**						**$20,160,000**

Notes:
1. Discount Rate for Present Worth Calculation: 7.0%

Comparison of Change in Present Value by Years Used in NPV Calcuation

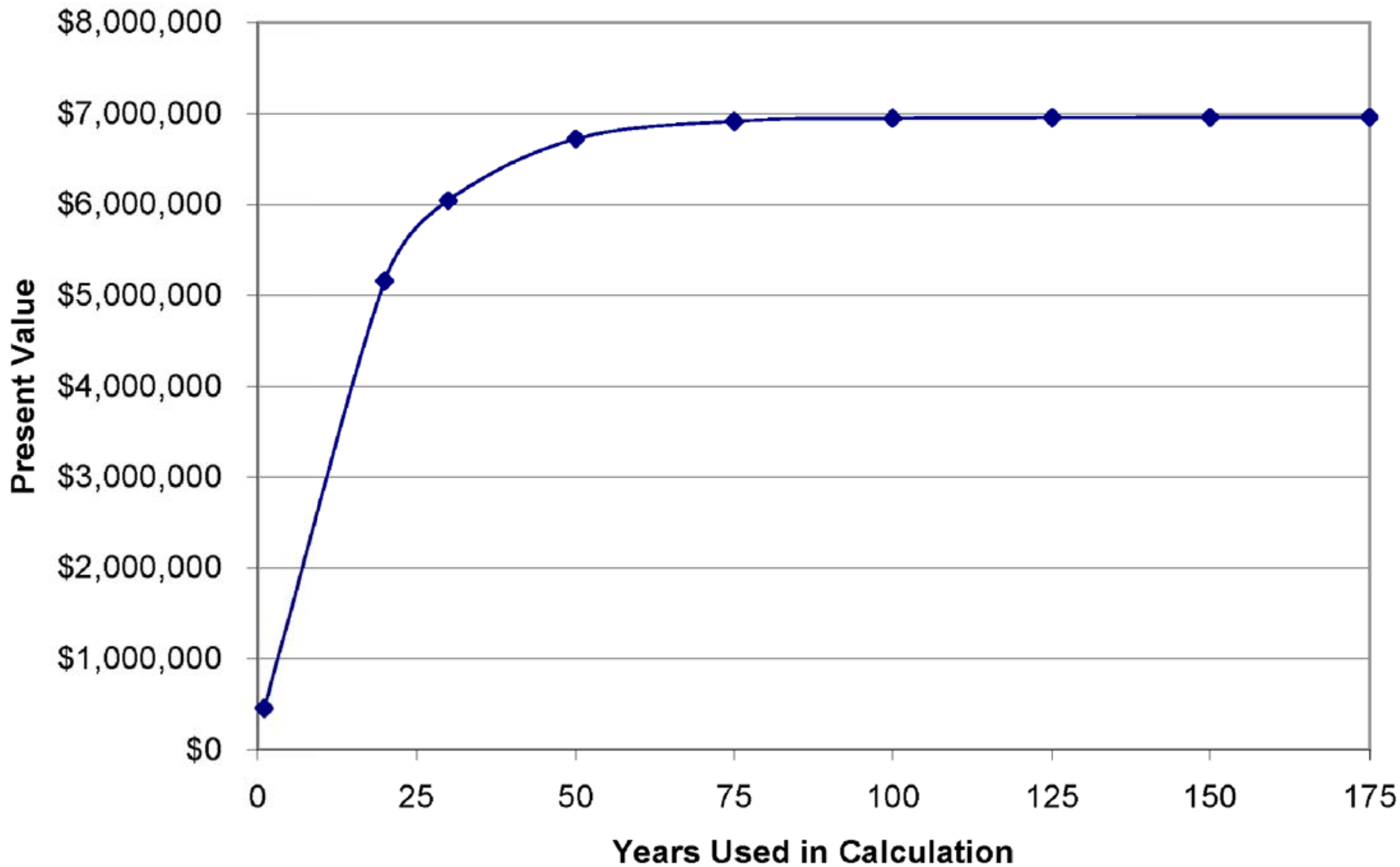

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Figure B-1

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APPENDIX C
GROUNDWATER BARRIER WALL TECHNOLOGY

APPENDIX C
GROUNDWATER BARRIER WALL TECHNOLOGY

Executive Summary

This appendix discusses the feasibility of using groundwater barrier walls as part of the cleanup at the former Holden Mine Site (Site). Groundwater barrier walls would be used for containment of groundwater above proposed cleanup levels that would otherwise discharge into Railroad Creek. Groundwater barrier walls are proposed as part of Alternatives 3 through 8 in the Draft Final Feasibility Study (DFFS, URS 2004) and Alternatives 9 through 11 discussed in the Supplemental Feasibility Study (SFS, Forest Service 2007).

The Agencies conducted an extensive literature review to document the success of groundwater barrier walls installed in combination with groundwater collection systems at more than a hundred sites over the past 25+ years as part of containment and remediation systems. During this process the Agencies interviewed EPA Project Managers and others responsible for cleanup at 48 sites where groundwater barriers have been used as part of remediation.

Current design, construction, and monitoring procedures for barrier walls have been developed based on evaluation of sites where this technology was, or was not found to be effective in containment of contaminated groundwater (EPA 1998a). Use of the experience from other sites provides a basis for assuring future remedial actions benefit from past lessons learned.

This review focuses on "slurry trench" barrier walls (i.e., slurry walls), which are the most common barrier wall implemented at Superfund sites (Rumer and Ryan 1995). However, other types of barrier walls have been used at a number of sites, and should be further evaluated as part of remedial design (RD).

The effectiveness of a barrier wall is related to a number of factors including appropriate design; construction quality control; and hydraulic considerations that may include keying the wall into an underlying less permeable stratum, a cap over the contained area, upgradient controls, and/or removal of water within the containment by pumping from wells or collection ditches.

The Federal Remediation Technologies Roundtable (an organization sponsored by the U.S. Department of Defense and other Federal Agencies) reported that slurry wall technology has been demonstrated to be more than 95 percent effective in containing uncontaminated groundwater (FRTR 2006). Effectiveness of containing contaminated groundwater is comparable, provided barrier materials are selected to be compatible with (i.e., resist the potential for degrading effects of) the site-specific groundwater contaminants[1].

Construction of groundwater barrier walls is a mature technology. A number of studies have specifically addressed design and construction measures based on past experience, to avoid or mitigate the factors that contribute to containment inefficiency (Rumer and Mitchell 1996, and EPA 1998a).

The Agencies screened information on barrier wall construction, monitoring, and performance at 51 sites, using information from the Superfund Program Annual Status Report Remediation Database, Records of Decision System, and the Five-Year Reviews Online. Metals in the groundwater at the Holden Mine Site were also constituents of concern at nine of these Superfund sites, including cadmium, copper, iron, lead, and zinc. These nine sites were reviewed in more detail. At eight of these nine sites, the containment systems were effective in meeting the site remedial action objectives (e.g., preventing contaminant migration) as indicated by the groundwater quality monitoring data or water level measurements, or both.

Subsequently the Agencies contacted 45 EPA remedial project managers (RPMs) responsible for cleanup actions that included barrier walls at 48 sites throughout the United States. A number of these sites specifically selected groundwater barriers to protect surface water bodies from release of impacted groundwater, i.e., for conditions that are similar to the Holden Site. The RPMs reported that the barrier wall systems were effective at 38 sites. The barrier wall was clearly ineffective at only one site, where construction encountered an underground deposit of trash with large voids, and groundwater containment could not be accomplished. Barrier walls at three other sites were reported to have questionable effectiveness and are being further evaluated. Finally, for the remaining six sites, the RPMs indicated that additional information was needed to evaluate effectiveness of the barriers. A number of the RPMs had recommendations based on experience at their sites, that they thought would increase the likelihood of success on future remedial actions.

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[1] No compatibility problems or the need for special barrier wall materials have been identified for the Site. However, should such a need arise during RD, there exists extensive technical literature discussing compatibility testing and use of special barrier materials, where needed to resist the effects of constituents dissolved in groundwater, for example see Day 1993; Garvin et al. 1994; Zappi et al. 1989; and Zappi et al. 1990.

Based on large number of sites where barrier walls have been successfully used to contain groundwater as part of remedial actions, the Agencies consider this technology would reasonably be effective as part of a cleanup action at the Holden Site.

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GROUNDWATER BARRIER WALL TECHNOLOGY

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APPENDIX C
GROUNDWATER BARRIER WALL TECHNOLOGY

Introduction

This appendix summarizes the findings of the Agencies' literature review and interviews that are pertinent to selection of a remedy for the Site. The Agencies' literature review and interviews identified numerous cases that demonstrate a properly designed and constructed barrier wall and groundwater collection system will effectively address the release of groundwater (including seeps) with metals concentrations above proposed cleanup levels into Railroad Creek.

Various groundwater barrier wall technologies exist; the most common are soil-bentonite and cement-bentonite slurry walls, and sheet pile walls.[2] Bentonite, a type of clay with an extremely low hydraulic conductivity, can be mixed with soil or Portland cement to produce a material with a significantly lower hydraulic conductivity than the native soils at most sites. Other types of clay such as attapulgite are used where bentonite is susceptible to long-term degradation from dissolved constituents in groundwater.

Construction of a slurry trench barrier wall involves a mixture of soil-bentonite or cement-bentonite placed in a vertical trench to cut off the horizontal flow of groundwater. The literature reviewed by the Agencies did not identify compatibility problems for bentonite (either soil bentonite or cement bentonite mixtures), with dissolved metals or moderately acidic conditions, but strong acids or bases may affect long-term integrity of bentonite barriers if not adequately addressed as part of design (Rumer and Ryan 1995). The DFFS did not identify any compatibility issues at the Site.

Groundwater barrier walls have been constructed by the slurry trench method since the 1950s and began to be used for isolation of groundwater with hazardous wastes in the late 1970s (EPA 1998a). Barrier wall technology is mature, and its effectiveness in containment and collection of impacted groundwater has been demonstrated by studies over a number of years at

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[2] Most of the sites considered in this review used slurry trench construction. Steel sheet piles are commonly installed by driving or vibration, which may be problematic in soils with boulders as expected at the Site. Steel or concrete sheet piles, and other types of barriers could be further considered during RD. Other construction technologies (e.g., secant pile barrier walls constructed by soil mixing or jet grouting) have been used at other remediation sites and could also be further evaluated for the Site.

various sites. "The expert consensus is that these barriers, if properly designed and constructed, can serve very useful and environmentally protective containment functions at contaminated sites" (Rumer and Mitchell 1996).

Groundwater barrier walls have been successfully constructed to depths comparable to and greater than anticipated at the Site, in similar alluvial and glacial soils with cobbles and boulders (e.g., Davidson et al. 1992; Koelling et al. 1997; McMahon et al. 1994; Thompson et al. 1997; and Recon-net 2005) and on steep slopes (Stamnes et al. 1997). Table C-1 provides examples of barrier walls constructed in soils that are similar to those anticipated at the Site.

The method of construction varies depending on the barrier wall technology being applied. Slurry walls are typically constructed by excavating a trench, typically about 2 to 3 feet wide, to the desired depth, using a hydraulic excavator or clamshell bucket suspended from a crane, with bentonite slurry (i.e., viscous, high density liquid) used to stabilize the walls of the trench. Special excavation techniques can be used in very hard soils; very soft or loose soils; soils with boulders; and bedrock. The permanent barrier wall material (e.g., a mixture of soil and bentonite) is placed as a slurry backfill into the trench, in most cases displacing the slurry used for temporary support, which can then be recycled.

Environmental remediation systems using slurry walls are often referred to as "passive," where groundwater containment is achieved without pumping or other groundwater withdrawal, or "active" where groundwater is extracted from inside the barrier.[3]

Sometimes the goal of extraction is to collect impacted groundwater for treatment. Groundwater extraction is also used to improve containment by creating an inward gradient.[4]

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[3] A third type of system, referred to as a "permeable reactive barrier," chemically removes dissolved constituents as groundwater flows through portions of the barrier that have relatively higher conductivity. Experience with this type of barrier is generally for constituents that are not of concern at the Site, and no analysis of the potential applicability of permeable reactive barriers to the Site conditions has occurred. Thus, this type of barrier was not further addressed in this review.

[4] An inward gradient occurs when the groundwater level inside the barrier (that contains the hazardous substances) is kept below the groundwater level on the outside of the

Active systems used to create inward flow toward the containment system may result in collecting some amount of clean groundwater. This is done because it is better to have some clean water flow into the system than to allow any contaminated groundwater to flow out of the system. The degree of hydraulic control (i.e., head differential) may also be adjusted to help control the diffusion of contaminants through the barrier wall, where this is a concern (EPA 1998a).

Barrier walls are sometimes used for upgradient diversion of clean groundwater to prevent contact with hazardous substances; or as downgradient barriers to protect sensitive receptors, (e.g., LaGrega et al. 1994; Sharma and Lewis 1994; and Rumer and Ryan 1995). Containment systems commonly use barrier walls that completely surround the contamination source area (e.g., Barvenik and Ayers 1987; Stamnes et al. 1997; Koelling et al. 1997; LaGrega et al. 1994; Rumer and Ryan 1995).

The barrier wall system proposed for Alternative 11 would fully penetrate the shallow alluvial aquifer that underlies the Site and is the source of groundwater above cleanup levels that discharges into Railroad Creek. This is unlike Alternative 10 that had a partially penetrating barrier (PPB) intended to cutoff groundwater that enters Railroad creek as base flow.[5] Partially penetrating barriers have been used for seepage control at some sites (Day et al. 2001; Schwank 2003; and Markley 2005). However, EPA (1998a) and others report better effectiveness for fully penetrating barriers that are keyed into relatively less permeable underlying strata.

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barrier. This improves containment by producing seepage forces from the aquifer into the contained area that reduces potential for migration of the hazardous substances.

[5] The PPB may be effective in protecting Railroad Creek, since Intalco reported that groundwater that recharges Railroad Creek is likely shallow groundwater, extending from the water table surface to approximately 10 feet below the water table (URS 2004), i.e. about 10 feet deep where groundwater baseflow enters Railroad Creek. However, there is not sufficient existing information to demonstrate effectiveness of the PPB at this time. Also, analyses by the Agencies indicate there is a high potential for downward migration of dissolved metals. Three shallow/deep well pairs completed in the alluvium at the Site (one pair in the lower west area (MW-4S/D) and two east of Tailings Pile 3 (DS-3S/D and DS-4S/D) indicate a downward component to groundwater flow. This is based on long-term monitoring of pressure transducers deployed in the wells from October 2003 to August 2004 for the Lower West Area and May 2002 to October 2003 east of Tailings Pile 3.

Assessments of Barrier Walls Used for Containment/Remediation

The following sections describe three independent lines of inquiry that provide an assessment of the effectiveness of barrier walls for containment as part of remediation.

EPA's 1998 Evaluation of Subsurface Engineered Barriers at Waste Sites

The EPA (1998a) performed an assessment of containment systems implemented in the United States since 1980, focusing on groundwater barrier walls. EPA initially considered 130 sites and subsequently narrowed the list to 36 for detailed evaluation, based on available monitoring data. EPA reported significant improvements in groundwater and surface water quality occurred at 25 of the 36 sites, and identified reasons why water quality improvements were not observed at other sites.

The EPA (1998a) study was based on performance data acquired over an extended period, although the majority of sites included had been in operation for less than 10 years. None of the monitoring data reviewed by EPA indicated a decrease in barrier effectiveness as a function of time.

EPA found containment using groundwater barrier walls could be effectively implemented to protect human health and the environment. EPA found performance standards varied from one site to another within the study group and identified three specific areas where performance could be improved in future remedial construction.

- EPA recommended implementing specific design measures including sufficient geotechnical and hydrogeologic investigations; groundwater modeling as part of design; and design assessment of long-term compatibility of barrier materials relative to chemically aggressive groundwater contaminants.

- EPA recommended improving construction quality assurance programs and construction quality control testing (CQA/CQC). This includes sampling trench key material and inspecting trench key conditions where a hydraulic cutoff into underlying stratum is an essential performance objective; improving control of mixing and placing backfill materials; improving trench bottom cleaning prior to placement of the permanent slurry barrier; and sampling and testing after construction but prior to demobilization of the construction contractor.

- EPA recommended improving performance monitoring during and following construction. EPA recommended monitoring groundwater head in paired piezometers along the barrier alignment; systematic quarterly groundwater quality monitoring downgradient of the barrier; and hydraulic stress tests of the barrier wall after construction. EPA recommended reviewing and analyzing the monitoring data consistently with periodic reporting to compare measurements with performance requirements.

EPA also recommended improving long-term monitoring, including provision for maintaining access along the perimeter of the barrier for periodic inspection.

These recommendations could be readily implemented through RD as part of clean up at the Site.

Agencies Evaluation of Nine Sites

In addition to other engineering literature, the Agencies screened slurry wall barrier performance reports for 51 sites, using the most recent information available from the Superfund Program Annual Status Report Remediation Database, Records of Decision System, and the Five-Year Reviews Online.

The constituents of concern in groundwater at nine of these sites included metals similar to those in the groundwater at the Holden Site, including arsenic, cadmium, copper, iron, lead, and zinc. These nine Superfund sites were therefore reviewed in more detail.

Two of the nine sites had partial barriers (one was an upgradient barrier to prevent migration of clean groundwater into the contaminated region, the other was a downgradient barrier to prevent migration of contaminated groundwater away from the site) while the other seven had barriers that surrounded the contaminant source area. These nine sites had relatively impermeable, RCRA-type caps over the contaminant source area.

Remedial action objectives (e.g., preventing contaminant migration) were met at eight of the nine sites, as indicated by groundwater quality monitoring data or water level measurements, or both. Since details of the nine sites varied considerably, the evaluation of performance is an evaluation of the whole containment system, not necessarily just the groundwater barrier wall component.

The nine sites reviewed are listed below.

- E.H. Schilling Landfill, Hamilton Township, OH;

- Hooker (102nd Street) Landfill, Niagara, NY;
- Hunts Disposal Landfill Site, Caledonia, WI;
- Lone Pine Landfill, Freehold Township, NJ;
- Ninth Avenue Dump, Gary, IN;
- Peak Oil/Bay Drum (Operable Unit 1), Tampa, FL;
- Queen City Farms, Maple Valley, WA;
- Rocky Mountain Arsenal, Adams County, CO; and
- South Brunswick Landfill, South Brunswick, NJ.

Performance evaluations for these nine sites were based on first, second, or in one case a third Five-Year Review Report. For the five sites where more than one Five-Year Review Report was available, the performance in the second review was as good as noted in the initial review, except for the South Brunswick Landfill site.

Despite the very good performance at eight of the nine sites, two specific problems were reported, as summarized below.

- At the Hunts Disposal Landfill Site, concentrations of volatile organic compounds (VOCs; constituents of concern that were present in addition to the metals) were found to have increased downgradient of the site after 5 years. This could be attributed to a possible failure of the groundwater extraction system, since the barrier originally only went around part of this site and relied on groundwater pumping to collect impacted groundwater between the landfill and a near-by river. The Five-Year Review Report recommended further evaluation of the efficacy of extraction wells to establish a sufficient inward gradient and eliminating the opening of the slurry wall, thus completely encircling the landfill. Subsequent contact with EPA's project manager for the site indicated the system is now working well.

- For the South Brunswick Landfill site, the third Five-Year Review Report concluded that the slurry wall containment system was intact, effective, and functioning as intended. However, the groundwater monitoring data showed an increasing trend in VOC concentrations in downgradient monitoring wells, indicating a downgradient area of contamination not contained by the barrier wall. The report recommended additional investigations be performed to determine the source of the VOCs in groundwater, and this investigation is continuing.

Agencies Interviews with Cleanup Site Managers

Subsequent to the literature review described above, the Agencies contacted EPA RPMs responsible for clean up of sites across the United States. Table C-2 summarizes results of telephone interviews with the 45 RPMs that were contacted. The Agencies initiated these calls to assess the circumstances where barrier walls had been selected as part of the remedial action, how effective the barriers are, and what the RPMs would recommend for new sites where barriers are being considered.

The overwhelming majority of the RPMs responded that the groundwater barrier walls of the type contemplated for use at the Holden Site are an effective part of the overall cleanup action, and in only a few cases are there questions as to effectiveness of the barriers.

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Table C-1 - Examples of Groundwater Barriers Constructed in Soils with Boulders

Site	Wall Type and Purpose	Length in Feet	Depth in Feet	Reported Soil Conditions
ACNA Organic Chemical Plant, Italy	FP, C, S	9,200	46	Alluvial Deposit with Cobbles and Boulders
Boston Harbor, MA	FP, ST	750	50	Fill with Granite Blocks and Glacial Till with Boulders
Diavik Mine, NW Territories, Canada	PP, S	12,500	33	Glacial Till with Boulders
Former Refinery, Flying J Transportation, Cody, WY.	PP, C	300	20	Alluvium and Fill with Numerous Cobbles and Boulders
Hogback Diversion Dam, Shiprock, NM	PP, S	1,110	20	Sand, Cobbles and Boulders
Island Copper Mine, Vancouver Island, BC	FP, C, S	4,100	105	Glacial Till with Boulders
Pinal Creek Aquifer Remediation	FP, C, S	1,200	100	Alluvial Deposit with Cobbles and Boulders
Queen City Farms Superfund, Near Seattle, WA	FP, C, S	2,200	70	Glacial Till with Open Work Gravel
Raffles Hotel, Singapore	FP, ST	1,500	82	Clay with Boulders
Soldier's and Sailor's Mem. Bldg, Pittsburgh, PA	FP, ST	1,200	25	Alluvial Soils with Boulders
Wasco Dam, Clear Lake, OR	PP, S	250	20	Sand, Gravel, Cobbles, and Boulders
Wells Dam, Azwell, WA	FP, S	1,000	230	Riverbed Deposits with Boulders

Notes

Dimensions shown are as reported, and depth may vary along length of barrier.

Barrier Wall Type and Purpose Abbreviations:

FP	Aquifer Fully Penetrated
PP	Aquifer Partially Penetrated
S	Seepage Control
C	Contamination Control
ST	Structural Wall
lf	linear feet

Table C-2 - Summary of Barrier Wall Performance Information from EPA Project Managers

Site Name/ Location/EPA ID/Site Type/EPA PM Interviewed & Date	Barrier Wall Type	Fully Encom-passing ?	Keyed into Underlying Confining Unit?	Impermeable Cap?	Wall Length and Depth	Groundwater Pumping from Interior?	What is/are Remediation Goal(s) of Barrier Wall?	Performance Monitoring	Constituents of Concern	How Effective or Non-Effective was Barrier Wall? Why?	Why was Barrier Wall Selected Instead of Other Remediation Technologies?	What Would You Do Different If Specifying a New Wall for a Similar Site?	Additional Information
American Chemical Services, Inc. Griffith, IN IND016360265 Kevin Adler – 2/6/2007	Soil Bentonite A layer of 60 mil plastic is between the two soil bentonite layers.	Yes	Yes – clay	Part of the site is capped.	Wall encompasses approximately 19 acres. Wall depth: approximately 25 feet bgs.	Yes, collection trenches are used instead of wells.	Groundwater containment with treatment within wall.	Piezometers located inside and outside of wall to measure groundwater levels and inside wall gradient along with chemical groundwater monitoring.	VOCs	Effective. The system is a combination of dewatering and treatment. Dewatering of the soil inside the wall is needed for the SVE system to operate. Currently, the system is working well.	The original ROD dated 1992 was determined unsafe and very expensive to implement. The 1999 ROD Amendment proved more cost effective and included the SVE system.	The EPA PM stated that he did not know because he was not involved with construction. He does not know if the plastic layer in the middle of the wall is effective.	A smeared zone is located outside of the wall. The levels in the smear zone had benzene levels at 10 to 20 ppb. The benzene levels have fallen to 5 to 10 ppb.
Bofors Nobel Muskegon, MI MID006030373 Sludge Lagoons John Fagiolo – 2/9/2007	Soil Bentonite	No	Yes – 4.5 feet into clay	Not yet. Protective cap that will be a treatment wetland scheduled for 2007 construction.	Wall length: approximately 2,700 linear feet. Wall depth: 75 to 100 feet bgs.	Yes. Wells pump groundwater to treatment plant.	Replace old series of 12 extraction wells. 10 of 12 wells pumping since 1987.	Wall completed in 12/2005. Monitoring hasn't started yet, but is proposed to consist of hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, pesticides, VOCs.	Will not know effectiveness for a few years. The remedy is still under construction. Currently, containment is being provided by extraction well pumping of groundwater.	Cost. The PRP proposed the barrier wall to EPA. The barrier wall was the least expensive alternative to obtain hydraulic control of groundwater.	Not available.	The slurry wall is U-shaped with top of U on upgradient side to capture incoming groundwater. A floodgate at bottom of U controls release through wall.
Brunswick Naval Air Station Brunswick, ME ME8170022018 Landfill Christine Williams – 2/1/2007	Not Available	No	Yes - clay	Yes	Not available	Not currently. There has been groundwater pumping in the past.	Lower the groundwater level throughout the waste.	Hydraulic and chemical groundwater monitoring.	VOCs, metals, low level pesticides.	The wall is effective in keeping upgradient flow away from a brook near the site.	Not available. PM stated the information would be in the ROD.	The EPA PM stated that she would fully encompass the site. The barrier wall could not fully encompass the site because landfill near area where military items (possibly weapons) are buried.	There are data that indicate contaminant migration is still occurring. The PM stated that residual contaminants sorbed onto the soils are a problem.
Delaware Sand and Gravel New Castle, DE DED000605972 Landfill Debbie Rossi – 2/13/2007	Soil Bentonite	Yes	Yes – clay	No	Wall depth: 17 to 57 feet bgs.	Yes	To prevent lateral migration. The wall was intended to help dewater the soil for bio-venting remediation.	Internal and external piezometers installed.	From EPA website: Base neutral acids, PAHs, PCBs, VOCs.	Barrier is effective, but the underlying clay unit is more permeable than originally determined and dewatering the soil could not be accomplished to enable bio-venting.	Cost. Original remedy was excavation and incineration, but that was too expensive. The barrier was more cost effective.	The PM would not do a barrier wall for this site because the shallow soils needed to be dewatered. The wall is effective, it is the underlying clay unit that failed.	
Dupont – Necco Park Niagara Falls, NY NYD980532162 Landfill Gloria Sosa – 2/1/2007	Grout Curtain	Yes	Yes – fractured limestone	Yes	Wall length: 3,500 feet Wall depth: 80 feet	Yes	To assist in pumping groundwater and to create an inward groundwater gradient. Containment of DNAPL.	Hydraulic and chemical groundwater monitoring.	Not available	The whole system is working well.	The bedrock was shallow (80 feet) and the barrier wall was the most effective remedy to reduce the rate of contaminant /groundwater flow.	The PM would do nothing different because the system is working at the site.	Some of the DNAPL flows into the limestone fractures and sorbs into the bedrock.

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Dupont – Newport Pigment Landfill Newport, DE DED980555122 Landfill Randy Sturgeon – 2/5/2007	3 Walls – 1 - Soil Bentonite 2- Sheet Piling	No	Yes	Yes	Wall length: 1,730 feet	Yes	To keep contaminated groundwater from entering the river.	High amount of construction QA/QC during the remedy construction.	Dissolved metals. From EPA website: Base neutral acids, inorganics, metals, VOCs.	Effective. Pumping is a big component of this system because a river flows through the site. Pumping helps keep the contaminated groundwater out of the river and reduces flood risk to a nearby town.	Due to the complexity of the site, a technical review committee (several professionals with many years of experience) selected the remedy because "the barrier wall appeared to be the best remedy for the site".	The PM stated that he would do nothing different.	
E.H. Schilling Landfill Hamilton Township, OH OHD980509947 Scott Hansen 1/31/2007	Soil Bentonite and Grouted Native Soils	No	Yes – keyed into underlying grout curtain	Yes	Soil Bentonite: 1,400 feet long, 15 feet deep. Grout Curtain: 1,400 feet long, 55 feet deep (installed from 15 to 70 feet bgs)	Yes	Prevent lateral infiltration of groundwater into landfill.	Hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, metals, PAHs, pesticides, VOCs	The whole system works well. There was a good design and construction QA for the barrier.	Not available	The PM stated that he would do nothing different.	COC concentrations generally low in downgradient wells. Generally COC decreases observed.
Fairchild Semiconductor Crop (Mountain View Plant) Mountain View, CA CAD095989778 Alana Lee – 2/16/2007	Not available. Three barrier walls assumed to be soil or cement bentonite.	Yes	Yes	No	Wall depth: 40 feet bgs to 100 feet bgs (Raytheon site)	Yes	Containment of contamination. Pumping used in combination with barriers to maintain an inward and upward groundwater gradient.	Hydraulic and chemical groundwater monitoring.	VOCs	Two of the slurry walls are effective but the third wall is not able to maintain desired groundwater gradient	Not available	Would not rely only on barrier wall containment. The PM would try a permeable remediation wall on the downgradient side of the site.	Pumping occurs from multiple zones at this site. The zones may influence each other, making it difficult to maintain groundwater gradient.
Field Brook Ashtabula, OH OHD980614572 Terese Van Donsel	Soil Bentonite	No	Yes – 3 feet into glacial till	No	Wall length: approximately 1,500 feet	Yes. Passive groundwater trench collection and active DNAPL pumping.	Containment. Protect a stream from movement of DNAPL.	Hydraulic and chemical groundwater monitoring.	VOCs and SVOCs	Questionable effectiveness. Currently, the barrier wall is being evaluated to determine if the wall is efficient, breached, or if monitoring is detecting residuals from historical contamination.	Not available	The PM would do compatibility tests between the barrier wall material and the DNAPL to assess long-term effectiveness of the barrier wall.	
Florence Land Recontouring, Inc. Florence Township, NJ NJD980529143 Landfill Mark Austin – 2/12/2007	Soil Bentonite	Yes	Yes	Yes	Wall installed on average 25 feet bgs.	Yes	To intercept groundwater.	Hydraulic and chemical groundwater monitoring.	VOCs and SVOCs	The whole system appears to be working well.	Not available	The PM stated that he would do nothing different.	The PM reported that the 5-year review noted that total VOCs in 1989 were approximately 200 ppb. After 5 years the VOCs were not detected above method reporting limits.

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G. E. Moreau Site South Glen Falls, NY NYD980528335 Jack O'Dell – 1/26/2007	Soil Bentonite	Yes	Yes	Yes	Wall encompasses 3.6-acre site. Wall depth: 95 feet deep	Intermittent pumping every 4 to 5 years.	Source containment and to minimize groundwater migration.	Hydraulic and chemical groundwater monitoring.	VOCs and PCBs	Effectiveness mixed; there may be a possible gap at the base of the escarpment indicated by measured TCE concentrations. The area within the barrier wall is dewatered and there is no evidence of barrier wall failure.	G.E. made the decision to install barrier wall and didn't evaluate other remedial technologies.	Look at *in situ* treatments or another barrier wall upgradient to reduce groundwater flow through source area.	VOC reductions generally occur in shallow, downgradient wells.
G & H Landfill Utica, MI MID980410823 Landfill Bill Ryan – 2/12/2007	Not available	No	Yes	Yes	Not available	Yes	Containment of contamination and hydraulic control from pumping groundwater.	Hydraulic and chemical groundwater monitoring.	From EPA website: Metals, PCBs, VOCs	The system appears to be very effective.	The PM stated most likely because of cost effectiveness and long-term stability.	Would fully encompass wall. The wall was not fully encompassed because of a main water line that runs through the site that brings water from Lake Huron.	There is a wetland next to the downgradient area of the wall. Immediate COC concentration reduction was evident in the wetland. The contaminant concentrations were below the MCLs after wall installation.
Hooker (102nd Street) Landfill Niagara, NY NYD980506810 Landfill Paul Olivio – 1/29/2007	Cement Bentonite	Yes	Yes – clay	Yes	The wall is around the 22-acre site (4,800 feet long). Wall depth: 10 to 35 feet bgs	Yes.	Source containment for 150,000 tons of buried waste.	Hydraulic and chemical groundwater monitoring. Piezometers inside and outside of wall.	From EPA website: Base neutral acids, metals, organics, PAHs, PCBs, pesticides, VOCs.	Effective. The key to effectiveness is leachate pumping to maintain inward gradient.	The barrier wall was the most cost effective remedy.	The PM stated nothing different.	Water quality monitoring shows no COCs above leve of concern in adjacent river and most downgradient wel Three downgradient wells consistently show COCs, possibly due to residual contaminants in subsurface soils.
Hooker (S Area) Landfill Niagara Falls, NY NYD980651087 Landfill Kevin Willis – 2/6/2007	Soil Bentonite except for riverside portion the wall is sheet piling.	Yes	Yes - Limestone / dolostone bedrock	Yes	The slurry wall encompasses the whole property. The landfill is only a portion of the property.	Yes. Both groundwater and NAPL pumping.	Curtail NAPL migration under river. Hydraulic control.	Hydraulic pumping to attain an inward and upward gradient within wall (referred to as a negative gradient).	From EPA website: Base neutral acids, pesticides, VOCs.	Effective. The NAPL is contained. The wall is working well because of the constant gradient monitoring.	There weren't other remedies to choose from that would contain the NAPL.	Would put sheet piling for whole wall because of breakthrough (due to chemical incompatibility) unlikely, however sheet wall more expensive than soil bentonite.	The PM stated that COC concentrations have dropped outside of the wall because the source area has been contained.
Hunts Disposal Caledonia, WI WID980511919 Landfill Tom Wentland – 1/26/2007	Soil Bentonite	No	Yes – clay	Yes	Wall length: 4,000 feet Wall depth: 30 to 48 feet bgs.	Yes	Source containment, control off-site migration, maintain inward gradient.	Hydraulic and chemical groundwater monitoring.	From EPA website: Metals, PAHs, Vocs	The system works well.	The barrier wall was the only option due to the size of the landfill.	The PM stated that he would do nothing for the site.	Generally saw reductions in concentrations of COCs.

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J.H. Baxter and Co. Weed, CA CAD000625731 Travis Cain – 2/13/2007	Cement Bentonite	Yes	Yes	Yes	Wall depth: 27 to 52 feet bgs. Wall length: 4377 feet	Yes	To contain the DNAPL.	Hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, dioxins/dibenzofurans,, metals, PAHs, pesticides, VOCs.	The whole system appears to be effective.	The best remedy to contain the DNAPL in conjunction with the underlying aquitard beneath the site.	The PM stated that he would do nothing different.	The PM stated that the COC concentrations have significantly dropped.
Kin-Buc Landfill Edison Township, NJ NJD049860836 Grisell Diaz-Cotto – 2/14/2007	Not available	Yes	Yes – to bedrock	Yes	Wall length: 7,000 feet	Yes	To confine contaminants and create and inward and upward groundwater gradient.	Hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, metals, PAHs, PCBs, VOCs.	Effective. The placement of monitoring wells was crucial in determining barrier effectiveness. There are three different water-bearing units.	The best remedy to contain the contaminants.	The PM would have extended the wall to cover additional contaminant areas.	The PM stated that there was significant COC concentration reduction where pumping occurred.
Lakeland Disposal Services Claypool, IN IND064703200 Scott Hansen – 1/31/2007	Soil Bentonite	No	Yes – clay	Yes	Wall length: 2,820 feet Wall depth: 20 to 40 feet bgs	No. Subsurface drain installed inside of barrier wall to reduce groundwater mounding.	Source containment. Prevent groundwater contaminant migration.	Hydraulic and chemical groundwater monitoring.	Metals, VOCs	The system works well.	The barrier wall was the most cost-effective remedy.	Some slurry lost in peat layer during construction; however, this was not a big issue.	COC concentrations downgradient were low to begin with. Decreasing trend for benzene downgradient, but increasing trend for mercury.
Lauer 1 Sanitary Landfill Menomonee Fall, WI WID058735994 Landfill Tom Wentland – 1/26/2007	Soil Bentonite	No	Yes – 20 to 30 feet into the key	Yes	Wall depth: 20 to 30 feet bgs.	Yes	To cutoff groundwater and maintain and inward gradient.	Hydraulic and chemical groundwater monitoring.	From EPA website: Data not available	The system works well to control the gradient.	The barrier wall was the most cost-effective remedy.	The PM stated that he would do nothing different.	COC concentration reductions observed in down gradient wells over time.
Lemberger Landfill Whitelaw, WI WID980901243 Landfill Darryl Owens – 2/6/2007	Not available	Yes and no. Appears to be one corner where the key is not present.	Yes - clay	Yes – subtitile D cap	Not available	Yes. Leachate collection system.	To confine waste within slurry wall and remove the leachate from the landfill.	Hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, pesticides, VOCs.	Effective - wall appears to be containing leachate and also making good progress in removing leachate, but the key unit is missing in one corner of wall.	Not available	Not available	There are two adjacent sites that are contaminated and the majority of contamination comes from the Transport site that is located up gradient.
Lipari Landfill Pitman, NJ NJD980505416 Landfill Betsy Donovan – 2/2/2007	Soil Bentonite	Yes	Yes – clay	Yes	Wall length: encloses 16 acres Average depth approximately 30 feet bgs	Yes	To provide a containment for flushing system (batch flushing through injection and extraction).	Hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, metals, VOCs.	Everything is performing as planned and system is working well.	Not available	Not available	The PM stated that COC concentrations have dropped by orders of magnitude through the years, but the levels are still high.

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Liquid Disposal, Inc. Utica, MI MID067340711 Katherine Rodriguez – 2/1/2007	Soil Bentonite	Yes	Yes	Yes, but PM unsure if impermeable.	Wall depth: approximately 30 feet bgs	Yes	To contain the contaminants.	Hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, metals, PAHs, PCBs, VOCs	The system appears to be working well. There is one area down gradient that is still contaminated. The EPA not sure if this is because the wall not keyed, hole in wall, or residual contamination.	Not available	Not available	The PM stated that there is a general decrease of COC concentrations outside of wall. The COC concentrations inside of the wall are high.
Lone Pine Landfill Freehold Township, NJ NJD980505424 Nigel Robinson – 3/19/2007	Soil Bentonite	Yes	No – not keyed in all places	Yes	Wall depth: Deepest is 30 feet bgs Wall length: 5,965 feet	Yes	To contain the contaminants. Cap and pumping to prevent infiltration of groundwater.	Hydraulic and chemical groundwater monitoring. Management of pump and treat system.	From EPA website: Base neutral acids, metals, organics, PAHs, pesticides, VOCs	Effective. Everything appears to be working well and there has been no infrastructure failure as far as EPA knows.	Not available	Not available	
McCormick & Baxter Portland, OR ORD009020603 Former wood treating facility Nancy Harney (EPA) Kevin Parrett (DEQ) – 2/21/2007 Rene Fuentes – 3/28/2007	Soil Bentonite The side along the river is sheet piling	Yes	Yes. The western portion is not keyed.	Yes. Area along Willamette River not capped.	Wall length: 3,792 feet Wall depth: 45 to 80 feet bgs	No	Containment of DNAPL.	Monitoring hasn't started yet, but is proposed to consist of hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, dioxins/dibenzofurans, metals, PAHs	Too early to tell effectiveness for groundwater, but the wall successfully contained the main source of DNAPL.	Most cost-effective remedy. Also selected as a contingency remedy if the creosote extraction from groundwater was not working. NAPL removal is still occurring at the site.	The PM stated would do nothing different. The wall construction was straightforward because good geotechnical investigations were performed.	
Naval Surface Warfare Dahlgren, VA VA7170024684 Landfill Bruce Beach	Soil Bentonite	No	Yes - clay	Yes	Wall depth: approximately 15 feet bgs	No	Restrict groundwater from flowing into landfill and force the groundwater to flow around landfill.	Measuring groundwater levels on both sides of the wall.	From EPA website: Base neutral acids, dioxins/dibenzofurans,, inorganics, metals, nitroaromatics,, PAHs, PCBs, pesticides, petroleum hydrocarbon, VOC	Effective. The wall is 3 feet thick and keyed into impermeable clay and the impermeable cap is restricting groundwater infiltration.	The soil bentonite wall was easier to install than sheet piling. The wall was also an easier alternative to a continuous pump and treat system.	The PM would increase the number of piezometers on the inside and outside of the wall.	

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Ninth Avenue Dump Gary, IN IND980794432 Landfill Bernard Schorle – 1/26/2007	Soil Bentonite	Yes	Yes	Yes	Outer wall length: 3,400 feet (encompasses 17 acres); Wall depth: 30 feet bgs Inner wall: 1,578 feet long Inner wall depth: 30 feet bgs	Yes – periodically	Containment of groundwater and source area.	Hydraulic and chemical groundwater monitoring	From EPA website: Base neutral acids, dissolved solids (total) inorganics, metals, PAHs, PCBs, VOCs.	The overall system appears to be working effectively. However, the aquitard may not be consistent throughout entire length of barrier wall and some leakage may be occurring.	The barrier wall was the most cost-effective remedy. An SVE system will be constructed when water levels are low enough.	The PM stated that he would do nothing different except perhaps more construction QA.	There are two walls – one perimeter and one interior.
Northside Sanitary Landfill Zionsville, IN IND050530872 Landfill Jeffrey Gore – 2/5/2007	Not available	No	Yes	Yes	Not available	Yes. Intermittent pumping based on hydraulic gradient (more during warmer months when higher groundwater flow).	Primary – restrict contaminant migration to surface water stream.	Hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, inorganics, metals, PAHs, PCBs, VOCs.	Whole system appears to be working effectively.	The barrier wall appeared to be the most effective when looking at criteria during remedy selection process.	The EPA PM stated that he would do nothing different.	
Onondaga Lake Syracuse, NY NYD986913580 Lake Robert Nunes – 2/16/2007	Soil Bentonite Sheet piling is being installed at lake shore	Yes	Yes – glacial till	Not currently.	Not available	The wells are being installed.	Hydraulic containment. There is some mercury NAPL in subsurface.	Monitoring hasn't started yet, but when is proposed to consist of hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, metals, PAHs, PCBs, pesticides, VOCs.	Too early to determine effectiveness. The permeability of the glacial till will be critical component to hydraulic containment.	Barrier to contain NAPL was more cost-effective than excavating to remove NAPL.	Compatibility testing of the key unit. For this site, make sure the integrity of the glacial till is well documented.	The remedy is still under construction.
Osborne Landfill Grove City, PA PAD980712673 Landfill Frank Vavra – 2/16/2007	Soil Bentonite	Yes	Yes	Yes	Wall depth: approximately 40 feet bgs.	Yes	Containment of contaminants	Hydraulic and chemical groundwater monitoring.	VOCs, metals	Effective. They system appears to be performing well. The constant pumping to maintain the 1-foot head difference for the inward gradient is crucial to effectiveness.	Most cost-effective.	The PM stated would do nothing different for this site. Perhaps use different wall material if had higher level of contaminants.	
Peak Oil/Bay Drum Tampa, FL FLD004091807 Scott Martin – 3/15/2007	Attapulgite clay	Yes	Yes – clay	Yes	Wall depth: average 28 feet bgs	No	Containment of contaminants	Hydraulic and chemical groundwater monitoring. Visual inspections to check cap and slurry that is above ground.	From EPA website: Base neutral acids, metals, PAHs, PCBs, pesticides, VOCs.	Effective. Thus far the system is working well. Construction was just completed last year.	Not available	Not available	
Petro-Chemical Systems (Turtle Bayou) Liberty, TX TXD980873350 Chris Villareal – 1/31/2007	Soil Bentonite	Yes	Yes – clay	Asphalt road over most of the area.	Wall depth: 30 to 55 feet bgs	No. Pumping was stopped 1.5 years ago.	Prevent further migration of contaminants.	Hydraulic and chemical groundwater monitoring.	From EPA website; PAHs, VOCs	Effective. The barrier was designed to cutoff flow.	The barrier wall was the most effective remedy for contaminant containment.	The PM stated would do nothing different.	

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Philip Services Corporation - Georgetown Seattle, WA WAD000812909 Former Treatment, Storage, and Disposal (TSD) facility Ed Jones – 3/16/2007	Attapulgite clay (Impermix)	Yes	Yes	Concrete and asphalt cover	Wall depth: 40 to 50 feet bgs on up gradient side, 80 to 90 feet bgs on down gradient side	Yes	Containment and to prevent further migration of contaminants.	Hydraulic and chemical groundwater monitoring.	VOCs	Effective. The wall appears to be working well.	Most cost-effective and the PRP decided to use this remedy.	The PM stated that he would look more seriously at technology where water could flow through wall or a floodgate and be treated as it passed through. The PM is not crazy about the "dirty bath tub water" sitting on the site. Would find some way to treat it. The PM would not use pump and treat.	
Pollution Abatement Services Oswego, NY NYD000511659 Former liquid waste incineration facility Joel Singerman – 2/13/2007	Not available	Yes	No	Yes	Not available	Yes	Containment of contaminants.	Hydraulic and chemical groundwater monitoring.	VOC	Mixed effectiveness. After contamination found outside of wall, the pumping rate was increased. With the increased pumping rate, the whole system appears to be working effectively.	This was one of the few remedies available over 20 years ago. Appeared to be the most effective.	The PM said he would make sure that an adequate pumping rate to maintain an inward and upward gradient was achieved at the beginning of remediation.	
Queen City Farms Maple Valley, WA WAD980511745 Neil Thompson – 1/8/2007	Soil Bentonite	Yes	Yes – glacial till	Yes	Wall length: 2,000 feet Wall depth: 50 feet bgs	No	Aquifer cleanup – to contain source material in area of old ponds and reduce groundwater flow through source area.	Hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, inorganics metals, PAHs, PCBs, VOCs., petroleum hydrocarbons (from the PM).	Effective. The system works wells.	Not available	The PM stated that he would do nothing different. The construction QA was essential and critical for installation success.	Immediate reduction outside of wall. Reductions seen in petroleum hydrocarbons, PCBs, and TCE.
Rentokil, Inc. Richmond, VA VAD071040752 Former wood treating facility Andrew Palestini – 2/6/2007	Soil Bentonite	Yes	Hard to key into granite bedrock without blasting. Uncertain how much of the wall is keyed.	Yes	Wall depth: 25 to 30 feet bgs	Yes and no. Pumping stopped a year ago to determine whether any leakage out of the wall. Pumping may resume.	To obtain an inward gradient of groundwater.	Piezometers installed inside and outside of wall.	From EPA website: Base neutral acids, dioxins/dibenzofurans,, metals, PAHs, pesticides, and VOCs.	Effective. The wall appears to have been designed and constructed well.	Most cost-effective.	The PM stated that he would like to have had a better idea of the extent of competent bedrock as it affected keying the wall.	
Rhone Poulenc former Monsanto Chemical facility Tukwila, WA Rene Fuentes – 3/21/2007	Attapulgite clay (Impermix)	Yes	Yes – silt	No – there is a cap, but it is asphalt with a drainage system in it.	Wall depth: approximately 60 to 65 feet bgs. Wall length: 2,300 feet	Yes - Intermittent	Containments of contaminants	Hydraulic and chemical groundwater monitoring.	VOCs, Metals	Effective. Construction of the wall went well, keyed into what was available (silt), and keeping good hydraulic gradient (inward gradient).	The PRP did not want to fully characterize site at the time and EPA wanted to the contaminants to stop further migrating. PRP chose to build the wall.	The PM stated that he would do nothing different.	Water quality improved immediately outside of the barrier wall with the exception of the area that was not originally contained within the barrier wall.

Table C-2 - Summary of Barrier Wall Performance Information from EPA Project Managers

Site Name/ Location/EPA ID/Site Type/EPA PM Interviewed & Date	Barrier Wall Type	Fully Encom-passing ?	Keyed into Underlying Confining Unit?	Impermeable Cap?	Wall Length and Depth	Groundwater Pumping from Interior?	What is/are Remediation Goal(s) of Barrier Wall?	Performance Monitoring	Constituents of Concern	How Effective or Non-Effective was Barrier Wall? Why?	Why was Barrier Wall Selected Instead of Other Remediation Technologies?	What Would You Do Different If Specifying a New Wall for a Similar Site?	Additional Information
Rhone Poulenc/Zoecon East Palo Alto, CA CAT000611350 Rosemarie Caraway – 2/13/2007	Not available	No	Yes – clay	Yes	Wall depth: approximately 35 feet bgs.	Pumping has occurred, but currently not actively pumping.	To cutoff an upland source area that discharged to a tidal marsh, and cutoff groundwater flow.	Hydraulic and chemical groundwater monitoring.	Metals	Effective. The wall was keyed into the underlying unit very well.	The most effective way to stop flow of groundwater into marsh. Digging up the contamination would have caused more damage to ecosystem than the wall.	The PM stated that she would do nothing different.	Within the first year the COC concentrations significantly lowered.
Sauget Area 2 Sauget, IL **ILD000605790** Landfill Tim Fischer – 3/27/2007	Soil Bentonite	No (U-shaped)	Yes - bedrock	No	Wall depth: 132 to 143 feet Wall length: 3,273	Yes	Containment of contaminants. To keep the groundwater plume from reaching the Mississippi River (the wall is up against the Mississippi River).	Hydraulic and chemical groundwater monitoring. Sediment and surface water sampling in the Mississippi River.	The main contaminant is chlorobenzene, VOCs	Effective. The whole system appears to be working well.	This site is part of three sites. CERCLIS and RCRA decided upon the wall as an interim remedial measure and the two main PRPs paid for the barrier wall. The wall may become part of the final remedy design.	Not available	The wall was just completed in August 2006. Containment has appeared to be effective with the exception of a chlorobenzene plume outside of the wall. The plume may have been there before wall construction. The site is still under the remedial investigation and feasibility study phase.
Savage Municipal Water Supply Milford, NH NHD980671002 Richard Goehlert – 2/9/2007	Soil Bentonite	Yes	No. The wall sits on top of the bedrock (granite)	No	Not available	Yes	Containment of contaminants	Hydraulic and chemical groundwater monitoring.	From EPA website: Metals, PCBs, VOCs	Effective. The wall was installed properly and the thickness of the wall appears to be sufficient. There is no contaminant migration through the wall; however, there is migration of contaminants through the underlying fractured bedrock.	The state made the decision to use a barrier wall and performed the design. PM did not have information as to why the state selected the barrier wall over other technologies.	The PM would examine the possible use of *in situ* technologies before installing barrier. The PM thinks *in situ* would be the same cost as wall. Would rather do *in situ*.	Up to 50 to 70% reduction in some wells. The PM stated that there were major reductions from the ppm range to below MCLs. 17 of 34 wells had contaminant levels below MCLs or were not detected above the method reporting limit.
Scientific Chemical Processing Carlstadt, NJ NJD070565403 Former industrial chemical wastes treatment facility. Stephanie Vaughn – 2/6/2007	Soil Bentonite on three sides, sheet pile will be installed on remaining side.	Not yet, but will be.	Yes	Yes	Not available	Yes	Control migration of contamination (containment of contaminants). Prevent human exposure.	Monitoring hasn't started yet, but when it does it will consist of hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, inorganics, metals, organics, PAHs, PCBs, pesticides, VOCs.	Effective. The soil bentonite wall was a temporary action and because it is working so effectively, the wall will become a part of the permanent remedial design.	Not available.	Not available	The remedy is still under construction.

Table C-2 - Summary of Barrier Wall Performance Information from EPA Project Managers

Site Name/ Location/EPA ID/Site Type/EPA PM Interviewed & Date	Barrier Wall Type	Fully Encom-passing?	Keyed into Underlying Confining Unit?	Impermeable Cap?	Wall Length and Depth	Groundwater Pumping from Interior?	What is/are Remediation Goal(s) of Barrier Wall?	Performance Monitoring	Constituents of Concern	How Effective or Non-Effective was Barrier Wall? Why?	Why was Barrier Wall Selected Instead of Other Remediation Technologies?	What Would You Do Different If Specifying a New Wall for a Similar Site?	Additional Information
Skinner Landfill West Chester, OH OHD063963714 Landfill Scott Hansen – 1/31/2007	Soil Bentonite	No	Yes – bedrock	Yes	Wall depth: 10 to 30 feet bgs.	No. 3 interceptor trenches installed downgradient of landfill.	Source containment. Prevent contaminated groundwater from entering the creek.	Hydraulic and chemical groundwater monitoring	From EPA website: Base neutral acids, inorganics, metals, PAHs, PCBs, pesticides, VOCs.	The system works well. Groundwater interceptor system consisting of cutoff wall and interceptor trenches has lowered groundwater table below landfill such that groundwater is no longer in contact with the waste.	The first remedy, incineration of waste, created too much opposition from the public, thus the barrier wall was selected.	Upgradient barrier wall as a contingency if groundwater still was in contact with the waste. Currently, the system is performing well and the groundwater is not in contact with the waste.	No COC concentration trends observed. The downgradient concentrations were relatively low from the beginning.
South Brunswick Landfill South Brunswick, NJ NJD980530679 Landfill Farnaz Saghafi – 1/30/2007	Soil Bentonite	Yes	Yes	Yes	Wall length: 7,315 feet Wall depth: 25 feet bgs	No. There is a leachate collection system.	Source contaminant and minimize contaminant migration.	Hydraulic and chemical groundwater monitoring	From EPA website: Metals, PAHs, VOCs.	The system works well overall. However, there is a contaminant area that is not captured by the wall. Uncertain whether breach in wall or contamination that is outside of the wall.	The barrier wall and cap were constructed pre-ROD. No other technologies were evaluated.	The PM would ensure that the barrier wall is keyed into the confining unit. Would also focus on construction QA.	There currently is an investigation as to the source of the contaminants in the downgradient well.
Sullivan's Ledge New Bedford, MA MAD980731343 Dave Lederer – 3/19/2007	Soil Bentonite	No	No (The wall was supposed to be keyed).	Yes	Wall depth: 25 to 30 feet bgs	Yes	To contain the contaminants and hydraulic control.	Hydraulic and chemical groundwater monitoring.	From EPA website: Base neutral acids, PAHs, PCBs, VOCs	Non-effective. During slurry wall construction, a large underground trash deposit was discovered that contained huge voids. The site used to be an old quarry area and the holes where filled in with trash back in the 1930s.	Originally simple trenches were going to be used as the remediation technology. However, the site conditions did not allow for the simple trenches and warranted the use of the slurry wall.	More extensive geotechnical study to better understand below ground surface conditions.	Pumping has been substituted at the site because the barrier wall could not be used due to site conditions.
Sylvester Dump Nashua, NH NHD099363541 Landfill Darryl Luce – 27/2007	Soil Bentonite	Yes	Yes – bedrock (schist)	Yes	Wall encompasses 20-acre landfill. Wall depth: up to 90 feet bgs.	No. Pumping stopped in 1996.	To minimize fish kills in Nashua River. The PM believes this was one of the first barrier walls installed.	Hydraulic and chemical groundwater monitoring	From EPA website: Base neutral acids, inorganics, metals, VOCs.	Effective. The wall was installed to contain a large area of contamination and allow for natural attenuation.	Not available. The wall was one of the first of its design installed.	The PM would do nothing different in terms of wall construction.	COC concentrations outside of wall dropped below MCLs. Inside the wall the contaminant concentrations are still above MCLs.
Texaco Refinery, North Platte River Casper, WY Jerry Breed (Wyoming DEQ) – 3/13/2007	Sheet Piling and grout.	No – just along river	Yes – clay	No	Wall length: 3,400 feet Wall depth: 10 to 40 feet bgs	Yes	Containment of contaminants. To keep contaminants from river.	Hydraulic and chemical groundwater monitoring. Have to maintain certain groundwater levels inside of wall to maintain inward gradient.	Not available	Effective. The sheet piling in combination with grout and tagging a certain depth into bedrock was key. Whole system performing well.	The previous remedy that was all ready in place (groundwater pumping) was not working effectively. Wall was more effective than previous remedy and the wall addressed some concerns of the stakeholders.	The PM would do nothing different.	

Table C-2 - Summary of Barrier Wall Performance Information from EPA Project Managers

Site Name/ Location/EPA ID/Site Type/EPA PM Interviewed & Date	Barrier Wall Type	Fully Encom-passing ?	Keyed into Underlying Confining Unit?	Impermeable Cap?	Wall Length and Depth	Groundwater Pumping from Interior?	What is/are Remediation Goal(s) of Barrier Wall?	Performance Monitoring	Constituents of Concern	How Effective or Non-Effective was Barrier Wall? Why?	Why was Barrier Wall Selected Instead of Other Remediation Technologies?	What Would You Do Different If Specifying a New Wall for a Similar Site?	Additional Information
Texas-Tin Texas City, TX TXD062113329 Former smeltering Carlos Sanchez – 2/9/2007	Soil Bentonite	No. Two walls exist along the east and west sides.	Yes. 2 to 3 feet into the clay.	No	Wall east of OU1/OU2 boundary is 1,800 feet long (other wall length not reported); wall depths vary: 24 to 35 feet bgs	No	Main goal was to prevent migration of contaminated groundwater (containment). The walls are used to channel groundwater movement to southeast portion of the site.	Monitoring wells placed on both sides of wall and chemical and hydraulic monitoring of the groundwater.	Metals	Slurry wall has only been in place for 2 to 3 years, and appears to be effective. Will have a better understanding after more data accumulated.	The wall was the best remediation technology to stop groundwater migrating into surface waters with COCs above regulatory levels.	The PM stated that he would do nothing different and that this type of barrier appears appropriate for this site.	
Wayne Waste Oil Columbia City, IN IND048989479 Former oil reclamation facility Jeffrey Gore – 2/14/2007	Not available	Yes	Yes	No	Not available	Yes	Containment of contaminants and to prevent migration of contaminants to a stream.	Hydraulic and chemical groundwater monitoring.	VOCs	The whole system appears to be work well (groundwater pumping and the SVE system).	The wall was selected in combination with other remedy components as a precaution.	The PM stated that he would try some modeling to determine whether the groundwater pumping and SVE system would be sufficient without the barrier wall.	The COC concentrations significantly reduced with the slurry wall (SVE system in place).
Whitehouse Oil Pits Whitehouse, FL FLD980602767 David Keefer – 2/6/2007	Attapulgite. The wall was originally proposed to be soil/bentonite, but concern that low pH levels in the ground would breakdown soil/bentonite, led to selection of attapulgite clay.	Yes	Yes	Yes	Wall depth: approximately 55 to 65 feet bgs	No	Prevent groundwater migrating from beneath waste oil pits and downgradient containment.	Hydraulic and chemical groundwater monitoring. Also, QC testing to ensure target permeability.	From EPA website: Base neutral acids, metals, organics, PAHs, PCBs, pesticides, VOCs	Effective.	The barrier wall was the most effective way to deal with the source materials and prevent human exposure.	The PM stated that he thinks there are no other barrier sites with acidification problem with breaking down clay.	Testing indicates contaminant concentrations outside of the wall were not detected above the method reporting limits, and COCs downgradient have most likely been eliminated.

Notes:
bgs – below ground surface
COC – Constituent of Concern
D/LNAPL – Dense/Light Non-Aqueous Phase Liquid
DEQ – Department of Environmental Quality
EPA – Environmental Protection Agency
MCL – Maximum Contaminant Level
PAH – Polycyclic Aromatic Hydrocarbon
PCB – Polychlorinated Biphenyl
PM – Project Manager
ppb – parts per billion
PRP – Potentially Responsible Party
QA/QC – Quality Assurance/Quality Control
ROD – Record of Decision
SVE – Soil Vapor Extraction
SVOC – Semi-Volatile Organic Compounds
VOC – Volatile Organic Compounds

APPENDIX D
TAILINGS AND WASTE ROCK PILES

APPENDIX D
TAILINGS AND WASTE ROCK PILES

Executive Summary

During operations at Holden Mine, Howe Sound Mining Co. produced an estimated 10 million tons of tailings (sand and silt sized particles from processing the ore to extract metals) and dumped an estimated 8.5 million tons of the tailings in three large piles. The tailings piles (identified as TP-1, TP-2, and TP-3) are located adjacent to Railroad Creek, which runs through the Site and drains into Lake Chelan, a pristine water body and Washington's largest natural lake. Copper Creek flows north between TP-1 and TP-2 before it discharges into Railroad Creek. In addition to the tailings piles, an estimated 356,000 cubic yards (cy) of waste rock were produced during development of the mine workings. The waste rock was dumped on the ground surface in seven piles located near former entries into the mine.[1] The location of the tailings and waste rock piles at the Holden Mine Site (the Site) are shown on Figure D-1.

Both the tailings and waste rock contain sulfide minerals that are reacting with water and oxygen to produces low pH (acidic) drainage. This drainage has high concentrations of hazardous substances (the metals cadmium, copper, lead, and zinc, and some aluminum and iron compounds), which contaminate groundwater and surface water at the Site.[2] US Fish and Wildlife Service (USFWS) toxicity reviews for the Site determined that surface water concentrations of cadmium, copper, zinc, and aluminum exceed levels known to be toxic to salmonids based on published scientific studies (USFWS 2004 and 2005). Iron concentrations at the Site also have adverse effects on both salmonids and benthic macroinvertebrates (USFWS 2005).

Erosion of the tailings also releases hazardous substances into the aquatic and terrestrial environment. Ongoing erosion contributes to the overall exceedance of water quality criteria in Railroad Creek. In October 2003, erosion displaced an estimated 600 cy of tailings, some portion of which was released into

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[1] While tailings are fine-grained waste materials left from the processing the ore in the mill to extract minerals with economic value, waste rock refers to rock excavated from the mine that was not processed in the mill.

[2] Acid rock drainage (ARD) is the term that refers to groundwater or surface water discharge that is contaminated by metals, released due to oxidation of the sulfide minerals in the tailings and waste rock, as is occurring at the Site.

Railroad Creek. Additional stabilization was required in 2006 to prevent ongoing release of tailings resulting from continued erosion of TP-1.

Another risk to the environment is the potential for large-scale slope failure of the tailings piles, which contain soluble metals including aluminum, cadmium, copper, iron, lead, and zinc. The Draft Remedial Investigation (DRI, Dames & Moore 1999) reports several instances of tailings pile slope failures leading to releases prior to the Forest Service interim actions in 1989-91. The tailings are not chemically inert. Tailings released into the creek during slope failure(s) could increase toxicity to aquatic organisms. Emergency stabilization work was required in both 2003 and 2006 to prevent portions of TP-2 from being undermined by Railroad and Copper Creeks, respectively.

Exposed tailings present a risk to human health through direct contact and ingestion. Gravel placed in 1989-91 incompletely covers the tailings piles, and is deteriorating through erosion. A slope failure of the tailings piles would increase exposure to humans and terrestrial receptors.

This appendix summarizes the Agencies' review of potential applicable or relevant and appropriate requirements (ARARs) for closure of the tailings and waste rock piles as part of remedial action at the Site. Potential ARARs include both state and federal requirements to prevent release of metals above proposed cleanup levels to groundwater and surface water; assure slope stability of the tailings and waste rock piles; move the toe of the tailings pile slopes back from the creeks a safe distance to avoid a mass release into the creeks; and close the tailings and waste rock piles.

The tailings and waste rock piles are waste piles. Thus, the closure requirements of Washington's solid waste handling standards for limited purpose landfills [WAC 173-350-400] are potential ARARs. Closure of these waste piles must be protective of human health and the environment, and any alternative method of closure that does not satisfy the presumptive cover requirements [WAC 173-350-400(3)(e)(ii)] would need to satisfy the final closure performance requirements [WAC 173-350-400(3)(e)(i)] and MTCA requirements for cleanup actions [WAC 173-340-360].

The Land and Resource Management Plan (LRMP) for Wenatchee National Forest (Forest Service 1990) as Amended by Pacific Northwest Forest Plan (NWFP 1994) and Subsequent Amendments of that Plan (2001, 2004, and 2007) is also a potential ARAR. The LRMP includes standards and guidelines that are potentially relevant and appropriate to actions within, or that affect Riparian Management Areas along Railroad and Copper Creeks, or are otherwise necessary to meet Aquatic Conservation Strategy objectives. These standards and guidelines include RF-2 through RF-7, which control design, construction, and use of temporary and permanent modifications within Riparian Reserves; and MM-3, which controls solid waste and mine waste facilities with Riparian Reserves. Particular aspects of MM-3 that are potentially relevant and appropriate to closure of the tailings and waste rock piles at the Site include requirements for a) analysis based on best conventional methods; b) designing waste facilities using best conventional techniques to ensure mass stability and prevent the release of acid or toxic materials; and c) reclamation and monitoring waste facilities to ensure chemical and physical stability, and to meet Aquatic Conservation Strategy objectives.

The Site is located within a seismic impact zone as defined by the State of Washington [WAC 173-350-100]. Limited purpose landfills located in seismic impact zones, including the landfill closure system (i.e., permanent slopes and cover) must be designed and constructed to resist the maximum earthquake acceleration as specified in WAC 173-350-400(3)(g). Seismic impact zones are areas subject to an earthquake with a 10 percent probability of exceedance in 250 years, which is a much larger design earthquake event than was considered in the DRI analyses prepared by Intalco (10 percent probability of exceedance in 50 years).

This appendix summarizes existing slope stability analyses for the tailings piles conducted by Intalco and the Agencies. More complete evaluations of slope stability will be required as part of remedial design (RD). In general, slope stability analyses to date indicate the slopes of the tailings piles are barely stable under current conditions and would be unstable during a moderate earthquake that is less than the design level earthquake specified under the limited purpose landfill requirements. Thus, there is unacceptable risk of future release of tailings to Railroad and Copper Creeks, and increased tailings exposure to terrestrial receptors; if actions are not taken to increase the stability of the tailings pile slopes.[3]

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[3] The Agencies have not evaluated stability of the waste rock piles. However, many of the problems described herein for the tailings piles are also applicable to the waste rock piles. The waste rock was likely dumped in a relatively loose, angle of repose condition, and as such, would have little if any factor of safety against slope failure. The Agencies have observed the toe of the main West Waste Rock Pile is retained by rotted timber cribbing. Stability of the waste rock piles is not assured and will need to be addressed as part of the remedy.

In addition to regrading to increase slope stability, the toe of the slopes of the tailings piles must be set back from Railroad and Copper Creeks to prevent erosion and exposure of the wastes, ensure the integrity of these landfills, reduce floodplain impacts, control surface water runoff, enable groundwater monitoring, and provide post-closure access that would not degrade the creek habitat. These reasons for setting the toe of the tailings slopes back from the creeks are based on the performance requirements for limited purpose landfills [WAC 173-350-400]. Setback of the tailings piles from the creeks is also required to meet the objectives of the Aquatic Conservation Strategy, which includes restoration of the riparian, aquatic, and wetland ecosystems.

Finally, closure of the tailings and waste rock piles will need to include capping to prevent direct contact by human and terrestrial receptors; prevent erosion; and/or control surface water run-on, runoff, and limit infiltration.

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TAILINGS AND WASTE ROCK PILES

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TAILINGS AND WASTE ROCK PILES

1.0 Introduction

During the period of operations at Holden Mine, Howe Sound produced and dumped an estimated 8.5 million tons of tailings in three large piles (TP-1, TP-2, and TP-3), which extend over about a combined area estimated to be about 67 to 90 acres, alongside Railroad Creek.[4] Based on information in the Draft Remedial Investigation (DRI, Dames & Moore 1999), maximum height of the tailings piles adjacent to the creek is about 130 feet and maximum slope inclinations typically exceed 45 degrees (1H:1V). In addition, an estimated 600,000 tons of waste rock were dumped in seven piles over an estimated combined area of about 11 acres.[5]

The tailings and waste rock piles contain reactive sulfide minerals. Over time these minerals react with air and water to release acid and dissolved metals. The tailings piles contain concentrations of metals that exceed human health criteria for direct contact and ingestion of cadmium and copper. Groundwater impacted by the tailings piles exceeds drinking water standards for arsenic, cadmium, and copper. Groundwater impacted by the tailings piles discharges into Railroad Creek with concentrations of aluminum, cadmium, copper, iron, lead, and zinc above state and federal chronic toxicity water quality criteria for the protection of aquatic life.

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[4] Intalco commented that the 90-acre area for the tailings piles cited in the DRI was inconsistent with its more recent assessment that indicated the tailings piles extend over only about 67 acres (Covington & Burling 2006). The Agencies note that review of aerial photos and LiDAR-based topography provided by Intalco indicates there are peripheral areas where tailings extend outside the footprint of the main tailings piles (e.g., adjacent to the Copper Creek Diversion east of Tailings Pile 1, and between Tailings Pile 1 and Tailings Pile 2 along Copper Creek), and that forest vegetation encroaches on the south side of the tailings piles, which may explain some differences in estimates of the area covered. The Agencies expect that a final determination will need to be made on the basis of field surveying.

[5] Most of the waste rock (an estimated 307,000 cy) is in two main piles, referred to as the main East and West Waste Rock Piles adjacent to the former mill building. The remaining waste rock, with a total estimated volume of about 49,000 cy, is distributed in five smaller piles in the Honeymoon Heights portion of the Site.

This appendix summarizes the Agencies' review of regulatory considerations with respect to closure of the tailings and waste rock piles, including the slope stability of the piles, setback of the tailings piles from Railroad and Copper Creeks, and cover requirements for closure of the piles. This appendix also summarizes existing slope stability analyses of the tailings piles performed by Intalco, and the Agencies' review of Intalco's slope stability analyses. More complete evaluations of slope stability and setback from the creeks will be required as part of remedial design (RD).

In general, slope stability analyses indicate the slopes of the tailings piles are barely stable under current conditions and would be unstable during a design level earthquake, as specified under the limited purpose landfill requirements. Thus, there is risk of future release of tailings to Railroad and Copper Creeks and exposure of tailings after closure of the tailings piles, if actions are not taken to increase the stability of the tailings pile slopes.

In addition to increasing slope stability, setback of the toe of the slopes of the tailings piles from Railroad and Copper Creeks is required to prevent erosion and exposure of the wastes, ensure the integrity of the landfill, reduce floodplain impacts, control surface water runoff, enable groundwater monitoring, and provide post-closure access that would not degrade the creek habitat. These reasons for setting the toe of the tailings slopes back from the creeks are performance requirements for limited purpose landfills. Setback of the tailings slopes from the creeks is also required to meet the objectives of the Aquatic Conservation Strategy, which includes restoration of the riparian, aquatic, and wetland ecosystems.

Several of the Draft Final Feasibility Study (DFFS, URS 2004) alternatives, and Alternatives 9, 10, and 11 include regrading the tailings piles to varying degrees to reduce infiltration and/or improve slope stability. For some alternatives, regrading also includes pulling the toe of the tailings piles back from Railroad and Copper Creeks to improve protection to the creeks from mass instability and/or erosion; reduce risk of flood waters triggering such instability; provide room for installation of a groundwater barrier and collection system; and for other reasons as discussed in this appendix.

2.0 Regulatory Overview

The tailings and waste rock piles at the Holden Mine Site are uncontrolled waste piles that are releasing hazardous substances to groundwater and surface water at concentrations that are above proposed cleanup levels.[6] Intalco has documented that groundwater, discharging as seeps downgradient of the tailings and waste rock piles, has concentrations of various metals that exceed aquatic life protection criteria by factors ranging from around ten to several thousand. Because the tailings and waste rock are solid wastes that do not meet state criteria for certain other types of wastes [WAC 173-350-100], the tailings piles are considered limited purpose landfills [WAC 173-350-400].

While the tailings and waste rock piles are existing landfills, the standards for new landfills are relevant and appropriate as potential criteria for final closure as part of remediation at Holden. Since the tailings and waste rock release hazardous substances to the environment, the tailings and waste rock must be managed in a way that is protective of human health and the environment, including protection of all potential ecological (aquatic and terrestrial) receptors [40 CFR § 300.430(e)(9)(iii)(A)]. A permanent cap for the tailings and waste rock piles that conforms to the presumptive closure requirements of WAC 173-350-400(3)(e)(ii) would be protective; any alternative methods of closure must satisfy the performance requirements of WAC 173-350-400(3)(e)(i)(A through J).

Closing the tailings and waste rock piles with a permanent cover that meets potential ARARs will require flattening the tailings and waste rock pile slopes. This will assure stability and prevent erosion that could expose the wastes, and support vegetation as required under WAC 173-350-400(3)(e)(i). Although there is some vegetation on the tailings pile slopes, and some portions of the slopes have been covered with gravel, netting, and/or forest duff to reduce erosion, significant portions of the tailings are exposed and are eroding, as documented in the DRI (Dames & Moore 1999). Erosion is an ongoing problem that has required interim actions by Intalco to stabilize the tailings in 2003, 2004, and 2006. Figure D-2 shows photographs of erosion of the existing gravel cover on tailings piles, exposed tailings, and other conditions.

The Washington Solid Waste Handling Standards [WAC 173-350-400(6)(a)] requires that as limited purpose landfills, the tailings piles and waste rock piles be closed in a manner that:

(i) Minimizes the need for further maintenance;

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[6] The tailings piles historically have also been a source of air pollution in the form of wind-blown dust, although the Forest Service substantially abated this through an interim action in 1989-1991. That action reduced, but did not eliminate, the release of hazardous substances through wind and water erosion of the tailings.

(ii) Controls, minimizes, or eliminates threats to human health and the environment from post-closure escape of solid waste constituents, leachate, landfill gases, contaminated runoff, or waste decomposition products to the ground, groundwater, surface water, and the atmosphere; and

(iii) Prepares the facility for the post-closure period.

To satisfy these closure requirements, the tailings piles must also be set back from Railroad and Copper Creeks to 1) prevent exposure of the waste; 2) prevent erosion; 3) provide sufficient stability to ensure the integrity of the landfill; 4) provide for management of surface water run-on and runoff; and 5) minimize the need for post-closure maintenance [WAC 173-350-400(3)(e)(i)]. Setback of the toe of the tailings pile slopes from Railroad Creek is also needed to provide access for construction of the remedy under some alternatives, and for post-closure maintenance [WAC 173-350-400(7)(a)(i)] and monitoring, [WAC 173-350-400(7)(a)(iii)].[7]

Regrading to improve slope stability and to set back the toe of the tailings piles from the creeks is also required to achieve the Aquatic Conservation Strategy objectives, which include: 1) maintain and restore water quality necessary to support healthy riparian, aquatic, and wetland ecosystems; and 2) maintain and restore habitat to support well distributed populations of native plant, invertebrate, and vertebrate riparian-dependent species [see the Record of Decision (ROD) for the NWFP, page B-11]. The LRMP provides standards and guidelines for accomplishing these objectives, which are potential ARARs for the Site.

The standard/guideline MM-3 for minerals management in Riparian Reserves (NWFP ROD pages C-34 and C-35) requires specific measures to assure chemical and physical stability if no alternative to locating mine wastes

[7] Most of the alternatives considered in the DFFS, and Alternatives 10 and 11 that were subsequently developed, include a groundwater barrier and collection system along all or a portion of the margin of the tailings piles and Railroad Creek. Access to install and maintain such a system, and to monitor its performance, would require pulling the toe of the tailings piles back from the creek to avoid operating construction equipment and other vehicles in the creek during and after the remedy. Even Alternative 9 would require construction access to install and maintain the proposed seep collection systems on the toe of TP-1, although Intalco did not address this.

(including waste rock and tailings) within Riparian Reserves exists. The required procedures include:

- Analyze the waste material using the best conventional sampling methods and analytic techniques to determine its chemical and physical stability characteristics;

- Locate and design the waste facilities using best conventional techniques to ensure mass stability and prevent the release of acid or toxic materials;

- Monitor waste and waste facilities after operations to ensure chemical and physical stability and to meet Aquatic Conservation Strategy objectives; and

- Reclaim waste facilities after operations to ensure chemical and physical stability and to meet Aquatic Conservation Strategy objectives.

Note that these Forest Plan requirements include: 1) regrading to ensure slope stability, and 2) use of the best conventional techniques to prevent instability from erosion and scour. This must include normal stream flow and flood conditions in Railroad and Copper Creeks, as well the ephemeral and any perennial drainages associated with Honeymoon Heights. This potential ARAR specifically prohibits mine waste facilities in Riparian Reserves, if the best conventional technology is not sufficient to prevent releases and ensure long-term stability.

The following sections address more specific requirements for slopes, setbacks from Railroad and Copper Creeks, and other closure considerations for the tailings and waste rock piles.

3.0 Tailings Pile Slopes

The DRI and the DFFS identified portions of the existing tailings pile slopes as barely stable under current conditions, and unstable under relatively low levels of earthquake shaking. Thus, current slope conditions do not ensure long-term stability, which is required for solid waste facilities in Riparian Reserves under standard/guideline MM-3 of the LRMP (see the NWFP ROD, pages C-34 and C-35).

Limited purpose landfill slopes must be flat enough for placement of a topsoil cover to support permanent vegetation to prevent erosion [WAC 173-330-400(3)(e)(i)(D)]. Slope inclination may also be controlled by other factors such as sliding resistance of the soil placed on a geomembrane cap.

In commenting on the DRI, the Agencies noted that they did not agree with Intalco that the DRI was based on sufficient information related to regrading the tailings. Lack of sufficient information meant that potential impacts of instability of the tailings could affect feasibility of alternatives, which would need to be addressed as a part of the Feasibility Study (Comment 6.9b, Forest Service 2001). The DFFS failed to adequately address slope stability, and, as a result, the Agencies have reviewed and reanalyzed the slope stability analyses of the DRI and performed further analyses as discussed below. These analyses show the tailings piles do not have adequate stability in their existing condition, and that further analyses will be needed to design slopes that will assure long-term stability.

3.1 Geotechnical Slope Stability Analyses

In general, the tailings pile slopes are of questionable stability under current conditions. Minor changes to slope geometry due to erosion or fluctuations in water levels could lead to major failures. The tailings pile slopes would be unstable during a moderate earthquake.

Based on the stability analyses reported in the DRI and the DFFS, Intalco suggests regrading to flatten the tailings pile slopes as part of remedial action to increase slope stability. The DFFS suggests reducing existing tailings pile slopes for TP-1 and TP-2 to 1-1/2H:1V to 2H:1V to increase stability. This reduction would require a substantial amount of regrading to achieve stability. Intalco's proposed slope inclination is between 26 to 34 degrees, and average existing slopes for TP-1 and TP-2 typically range up to and sometimes exceed 60 degrees. Table D-1 presents information on the height and slope inclination of different portions (slope reaches) of the tailings piles, from the DRI. For the portion of TP-3 along Railroad Creek, Intalco suggests there is sufficient room at the base (toe) of the tailings slopes that regrading is not necessary to protect the creek from the effects of slope failure. Intalco suggests the space available at the toe of slope would contain the tailings in the event of a slope failure and/or that a rock buttress could be constructed. However, this approach would not satisfy potential ARAR requirements to ensure stability, and prevent exposure and release of the wastes.

Intalco used the limit equilibrium method for slope stability analyses, which is a commonly accepted approach. However, this approach relies on a number of simplifying assumptions and does not address deformations or pore pressure changes, which can cause instability during seismic shaking. The Agencies note that Intalco's stability analyses rely, to a large degree, on 30-year-old shear strength data for the tailings (Hart Crowser 1975, included as Appendix E of the DRI). Better methods of measuring shear strength and for analyzing stability are available today. The methods Intalco used do not satisfy the potential ARAR to use the best conventional sampling methods, analytic techniques, and design techniques to ensure mass stability.[8]

Despite limitations of the stability analyses conducted by Intalco, the results illustrate the risk of potential long-term stability problems. The Agencies conducted limited additional analyses to check the DRI evaluation, as described below. However, additional, more complete stability analyses will be needed during RD to confirm the final tailings pile slopes will satisfy potential ARARs. Figures and tables from the DRI and DFFS are included at the end of this appendix to support the following discussion.

Intalco assessed slope stability and erosion potential for different areas along the tailings pile slopes, referred to as slope reaches. Each reach represented a discrete area along the slope that had relatively consistent height and slope inclination, which affect stability and erosion potential. Figure D-3 shows the reaches defined by Intalco, along with four additional slope reaches (designated as 1-F East, 2-G, 2-H, and 3-D) defined by the Agencies. The Agencies evaluated slope stability and estimated the volume of tailings regrading using Intalco's reaches and the additional Agency reaches. Figure D-4 (five sheets) shows cross sections developed by the Agencies for the tailings slope reaches shown on Figure D-3.

Stability of slopes is discussed in the DRI and DFFS in terms of a "factor of safety" that is the ratio of the available shear strength to the minimum shear strength necessary to maintain equilibrium of the slope. Intalco used the calculated factors of safety for the tailings piles to assess the need for slope regrading that was included in the DFFS alternatives. Both the DRI and the DFFS state that, while factors of safety between 1.0 and 1.2 are marginally stable, factors of safety greater than 1.2 indicate a suitably stable slope for static

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[8] In particular, the method of seismic analysis that Intalco used does not reflect current engineering standards of practice. Intalco relied on pseudo-static limit-equilibrium analysis for seismic stability using a single value horizontal acceleration component. A more appropriate approach would use deformation-based analyses, and an assessment of yield acceleration for potential failure surfaces compared to maximum accelerations predicted by a site response analysis. Since the lower portions of the tailings piles remain saturated all year, a dynamic pore pressure analysis would also be appropriate to assess the effect of potential effective stress reduction on seismic stability (see Marcuson et al., 1992; Kramer 1996).

conditions.[9] For comparison, permanent slopes for embankments, dams, and levees are typically designed to have minimum static factors of safety of 1.3 to 1.5 (Ecology 1993, Corps of Engineers 2000), and factors of safety of 1.5 or higher may be reasonable for waste embankments (Mitchell and Mitchell 1992).[10] The Washington State Department of Transportation requires factors of safety for embankment design in excess of 1.25 "if there is significant uncertainty in the slope analysis input parameters" (WSDOT 2005). The information provided by Intalco shows there is significant variability in the cohesive properties of the tailings, and hence results of analyses that use this parameter are uncertain, as discussed below.

The DRI and DFFS report factors of safety for static and seismic stability for two sections of the tailings piles, one each for TP-2 and TP-3, as illustrated on Figures 4.2-17 through 4.2-20 of the RI (see Attachment D-1). The DRI does not specify location of the two cross sections that were analyzed, why these two sections were selected, or how these results might compare to other portions of the tailings piles.

Intalco's analysis produced a factor of safety of 1.034 for static conditions, and 0.979 for the seismic condition it analyzed for TP-2. Intalco's analysis produced a factor of safety of 1.096 for static conditions, and 1.034 for the seismic condition it analyzed for TP-3. Intalco did not report factor of safety results for TP-1.

In contrast to these findings in the DRI, the DFFS reported in Section 6.4.4.1: "the top portions of tailings pile 1 slopes located adjacent to Railroad Creek are

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[9] In this context, static refers to steady state or non-seismic conditions. Normal engineering practice requires checking stability for both static and seismic conditions, since an acceptable static factor of safety does not assure seismic stability, and vice versa. Most engineers accept a lower factor of safety (i.e., a greater potential risk of instability) for seismic conditions than for static conditions, since earthquakes are uncommon events. However, selection of acceptable factors of safety value for both static or seismic conditions should be based on the consequences of slope failure, and the degree to which engineering properties of the tailings or waste rock are known.

[10] Mitchell and Mitchell (1992) notes that California regulations require solid waste landfills with side slopes steeper than 3H:1V have a factor of safety of at least 1.5 under seismic loading, using the type of analysis that Intalco used in the DRI. If a 1.5 factor of safety cannot be achieved with that type of analysis, Mitchell notes that California requires a dynamic deformation analysis (e.g., see footnote 8) and this would require site-specific information on dynamic properties of the waste to be useful and reliable.

marginally stable with factors of safety between 1.0 and 1.2." For TP-2, Intalco also reported "a minimum static factor of safety between 1.0 and 1.2." On the basis of these findings and its analysis of erosion potential, Intalco proposed regrading portions of TP-1 and TP-2 for Alternative 2 and other alternatives based on Alternative 2 (e.g., Alternative 3b).

Although Intalco reported in the DFFS that the top portions of some of the TP-3 slopes are steeper than the estimated angle of repose, Intalco concluded that these slopes "*appear to be stable in their current configuration.*" Intalco suggested that rather than disturb the TP-3 slopes, a low rock-fill buttress should be constructed at the base as necessary to contain tailings potentially transported down slope due to sloughing or slope failure.

As a check on the DRI static results, the Agencies evaluated the factor of safety for each of the reaches Intalco used, using the range of slope heights and inclinations presented in DRI Table 4.2-3 (see Attachment D-1). As a check, the Agencies used a conservative, simplified limit equilibrium analysis (similar but not identical to what Intalco used) that was developed for soil and tailings slopes (Hoek & Bray 1981). Results of the Agencies' analyses are presented in Table D-1. The results indicate average slope conditions are only marginally stable, with average factors of safety less than or equal to 1.1 for sixteen of the eighteen slope reaches analyzed. The Agencies' analyses generally confirm Intalco's findings that significant portions of the tailings pile slopes have factors of safety well below the values considered acceptable for permanent slopes. Based on the Agencies' analyses, all the tailings pile slopes need to be regraded to improve stability. The extent of regrading, final slope inclination, and slope geometry[11] need to be determined based on more complete analyses during RD. The DFFS proposed final slopes of 1-1/2H:1V to 2H:1V are premature, and may need to be revised based on more complete analyses during RD.[12]

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[11] It may be appropriate to include benches in the final slope configuration, particularly on the higher portions of the tailings piles. Benches are an accepted means of improving stability and reducing erosion on slopes. Benches may also be needed for access to maintain the cap on the tailings piles (e.g., vegetation control).

[12] For discussion purposes, the Agencies have adopted the 2H:1V slopes referred to in the DFFS as a basis for remedial Alternatives 10 and 11 cost estimates. Design of final slope inclinations during RD will need to include demonstration of minimum acceptable factors of safety based in part on variability of the geotechnical properties for the tailings that are used in the analyses.

3.2 Areas of Uncertainty in Stability Analyses Conducted to Date

The analyses presented in the DRI are based on limited information on properties of the tailings piles that affect stability. Potential areas of uncertainty involve questions of whether the shear strength of the tailings used in the analyses represents the actual shear strength available; and whether the groundwater level assumed in the analyses represents reasonable worst-case conditions. Finally, the seismic analysis conducted by Intalco was incomplete and does not address an earthquake of the magnitude required by potential ARARs.

3.2.1 Shear Strength

Most of the shear strength information reported by Intalco is from a series of direct shear tests conducted more than 30 years ago (Hart Crowser 1975).[13] The Agencies' analyses indicate the factor of safety is sensitive to the input value selected for the shear strength parameter referred to as cohesion. Cohesion is a measure of the degree to which the tailings are cemented. This sensitivity is an important concern because the limited available information to date indicates the degree of cementation in the tailings varies widely. Test data reported in the DRI (from Hart Crowser 1975) showed cohesion values typically ranging from 0 to 75 pounds per square foot (psf), with one value as high as 250 psf, while results obtained by Intalco in the fall of 2001 produced much higher values (475 and 862 psf). The variation in the magnitude of tailings cohesion is not well defined, nor is the distribution of relatively cemented and non-cemented zones of the tailings. The effect of the variation in cohesion on overall stability requires further evaluation during RD.

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[13] Cone penetrometer tests at the Site represent an alternative to or supplement laboratory tests that should be evaluated during RD. Direct shear tests are much less commonly relied on today than they were in 1975. This test has numerous disadvantages that limit its suitability to provide accurate data input for slope stability analyses. These limitations include: 1) change in the area of the surface of sliding as the test progresses, 2) non-uniform distribution of shear strains, 3) non-uniform distribution of shearing stresses, 4) inability to control drainage as the test progresses, 5) inability to measure changes in pore pressure, and 6) inability to control principal stress direction, which means that principal stresses are not well defined. The laboratory direct shear test has largely been replaced in contemporary engineering practice by triaxial tests; see for example Terzaghi, Peck, and Mesri (1996).

Another area of uncertainty involving shear strength is whether the values used in the analysis represent the real shear strength that will be available during an earthquake. Soils that have similar properties to the tailings (sands and non-plastic silts) and are below the water table, typically undergo a substantial decrease in shear strength as a result of pore pressures developed during seismic shaking. This process is termed liquefaction.

There is some basis for concern that the tailings piles could be subject to seismic liquefaction, based on conditions at the Site. The groundwater level is 20 feet or more above the base of the tailings piles in the spring in some areas, and some portions of the tailings are below groundwater throughout the year (e.g., as indicated by monitoring well TP 3-5). Intalco evaluated the potential for liquefaction using a somewhat outdated approach (Seed, Idriss, and Arango 1983); did not consider the full range of groundwater level within the tailings piles; and based its analysis on samples without adequate gradation data.[14] As a result, the potential loss of shear strength due to liquefaction will need to be further addressed during RD using appropriate methods such as described by Idriss and Boulanger (2004) and Boulanger and Idriss (2006).

3.2.2 Water Level Assumptions

Another area of uncertainty is whether the available data on groundwater levels within the tailings piles are adequate. The analyses completed by both Intalco and the Agencies assumed groundwater seepage at the toe of the slopes. This is consistent with observations at the Site, especially during spring high-flow periods. However, most information on water levels within the tailings is limited to spot measurements at a number of monitoring wells. Long-term data logging has been conducted in just a few wells, and it is unclear how representative these data are of conditions over the long term. Water seeping through the toe of a slope reduces the stability of the slope. Water seepage varies seasonally, and the stability of the tailings slopes would decrease, possibly leading to slope failure, if the water level in the tailings increased above the level that was analyzed. During RD, it will be necessary to determine reasonable worst-case groundwater conditions within the tailings piles to use for final design.

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[14] Intalco evaluated liquefaction using field measurements (blow counts) for three samples collected in 1975, but did not have any gradation data for these samples. Sample classification data for these samples indicate two of the three samples had silt contents within the range where liquefaction could occur, based on Intalco's analysis.

3.2.3 Seismic Basis of Design is Inadequate

None of the seismic stability analyses referred to in the DRI and the DFFS considered the magnitude of ground shaking required in WAC 173-350-400(3)(g). Thus, Intalco overestimated the factors of safety and resistance to liquefaction for earthquake conditions.

The DRI analyzed two tailings pile sections for a moderate earthquake with an average return period of 475 years, or a 10 percent probability of exceedance in 50 years. Results indicated a slope failure would occur for the TP-2 section (factor of safety of 0.979), and the TP-3 section had a factor of safety of only 1.034, barely above the level where failure is anticipated. Although TP-1 was not analyzed, the results are likely similar to those noted for TP-2 and TP-3.

The design earthquake required for limited purpose landfills is much larger than Intalco analyzed in the DRI, with a return period of 2,373 years, or a 10 percent probability of exceedance in 250 years. The tailings piles would be less stable during the larger, required design earthquake, than the earthquake analyzed in the DRI (i.e., the slopes would have even lower factors of safety for seismic conditions than those estimated in Intalco's analysis).

Further analysis described in the DRI indicated that TP-2 slopes would be unstable for a relatively small earthquake with a return period of only about 40 years, which is a much smaller event than the earthquake with a return period of 2,373 years.

4.0 Tailings Pile Setback from Railroad Creek

The primary reasons for setting the tailings piles back from Railroad and Copper Creeks are to: 1) prevent erosion and exposure of the wastes, 2) ensure the integrity of the landfill, 3) reduce floodplain and wetland impacts, 4) control surface water runoff, 5) enable groundwater monitoring, and 6) provide post-closure access that would not degrade the creek habitat.

Preventing erosion and exposure of the tailings, and ensuring integrity of the tailings landfill are a necessary part of achieving protection of the environment. The tailings piles are sources of hazardous substances being released to the environment. Therefore, one of the proposed remedial action objectives for the Site is to "Reduce exposure to hazardous substances in surface soils and tailings to protect terrestrial organisms and satisfy potential ARARs. Prevent future releases of tailings into surface water that would increase surface water and sediment concentrations of hazardous substances."

The six reasons cited above are based on performance requirements for limited purpose landfills [WAC 173-350-400], which are addressed below for the Site. Set back of the tailings piles from the creeks is required to meet the objectives of the Aquatic Conservation Strategy of the LRMP/NWFP, which includes restoration of the riparian, aquatic, and wetland ecosystems. The following discussion applies to the location of the toe of the tailings pile slopes relative to Railroad and Copper Creeks.

4.1 Prevent Erosion and Exposure of the Wastes

Erosion of the stream channel can cause exposure of the wastes in the tailings piles, and cause the release of hazardous substances to the environment. Therefore, the remedy needs to prevent the tailings pile slopes from failure due to erosion and scour from Railroad and Copper Creeks, to prevent exposure of the tailings and releases into the creeks. Closure of the tailings piles requires a design that, among other requirements, will achieve the following:

- Prevent exposure of waste;
- Prevent erosion from water;
- Provide sufficient stability and mechanical strength; and
- Minimize the need for post-closure maintenance.

The existing bases of the tailings piles have the potential to be undercut or eroded by Railroad and/or Copper Creeks during flood events, and/or due to normal stream activity over the long-term. Erosion and/or scour could cause the mass release of tailings and increase the already high metals concentrations in the creeks.

Addition of more riprap alone will not prevent erosion or slope failure. A portion of the existing riprap along TP-2 failed in October 2003 when scour in the Railroad Creek channel undermined the riprap, (see Photograph 2 on Figure D-2). A time critical removal action was needed to restore the riprap and avoid a massive slope failure. Another time critical removal action was needed in 2006 when normal meandering of Copper Creek threatened to undermine a different portion of the TP-2 slopes. Regrading the tailings, without moving the toe of the slope away from the creeks, does not protect the toe of the slopes from erosion and scour. The addition of more riprap would narrow the channels of both creeks and, therefore, would increase the scour potential.

Moving the toe of the tailings piles back from the creeks is essential to providing sufficient stability, preventing exposure of waste, preventing erosion, and minimizing post-closure maintenance.

4.2 Ensure Integrity of the Landfill

The solid waste standards require that the owner/operator of a limited purpose landfill located "in an unstable area" demonstrate that engineering measures have been incorporated into the landfill's design to ensure that the integrity of the structural components of the landfill will not be disrupted [WAC 173-350-400(3)(h)]. Unstable areas include geomorphic features such as creeks, as well as areas "susceptible to mass movements" (e.g., by undermining). Moving the toe of the tailings piles back from the creeks is a necessary part of protecting the integrity of these waste piles.

4.3 Reduce Floodplain and Wetland Impacts

Executive Order 11988 for the Protection of Floodplains is a potential ARAR for the Holden tailings piles. This ARAR requires avoidance of adverse impacts, to the extent possible, of actions that take place in a floodplain. Executive Order 11990 for the protection of wetlands requires that potential impacts to wetlands be considered, and as practical, destruction, loss, or degradation of wetlands be avoided. EPA promulgated regulations to implement both of these Executive Orders under 40 CFR Part 6.

Moving the toe of the tailings pile slopes away from the creeks would avoid adverse impacts to the extent possible for existing tailings piles, as required under Executive Orders 11988 and 11990.

Although the Holden tailings piles are existing landfills, the location standards for new limited purpose landfills are potentially relevant and appropriate. The location standards for new limited purpose landfill facilities [WAC 173-350-400(2)(c)] do not allow location within a channel migration zone or within 200 feet of a stream. Moving the toe of the tailings back from Railroad and Copper Creeks would reduce constrictions within the normal floodplain of these streams, and could allow more room for channel meandering.

Finally, moving the toe of slopes back from the creek would avoid or reduce the potential impact to the creek in the event a slope failure were to occur.

4.4 Control Surface Water Runoff

WAC 173-350-400(3)(d) requires construction of limited purpose landfills in accordance with a design that (when located within a 100-year floodplain) does not restrict flow of the base flood. The flood scour in Railroad Creek in 2003 and the meandering of Copper Creek in 2006 are examples of surface water problems that could have caused a massive release, had either of these events triggered a large tailings pile failure.[15] Since the amount of tailings pile regrading to assure stable slopes involves significant construction activity, the Agencies consider this construction requirement to be potentially relevant and appropriate.

The closure design standards [WAC 173-350-400(3)(e)] also require that the final closure design provide for the management of runoff to prevent erosion or other damage to the tailings pile covers. The beneficial effect of soil placed to cover the regraded tailings slopes would be reduced if the cover erodes. Tailings could be exposed and released to the creeks by runoff if gullies erode through the cover. Erosion or instability could damage a geomembrane, if that is part of the cover. It would not be feasible to access the slopes adjacent to the creeks for slope and cover maintenance unless the toe of slope is moved back from the creeks.

Runoff from the tailings pile slopes currently discharges directly into Railroad and Copper Creeks. This runoff cannot be adequately managed with the existing toe of the tailings pile slopes immediately adjacent to the creeks.

Moving the toe of the tailings slopes away from the creeks would also allow room for a runoff collection ditch (and access to maintain it). Interflow (shallow infiltrated precipitation) that seeps from the toe of the tailings may contain elevated metals concentrations. Setback of the tailings from the edge of the creek would allow collection of this seepage for treatment. A toe collection ditch is a standard engineering measure to control slope runoff, to prevent erosion of the toe of the slope, and to collect contaminated seepage.

4.5 Enable Groundwater Monitoring

WAC 173-350-400(3)(i) requires that limited purpose landfills be designed with a setback of at least 100 feet from the “property line” to allow for a space for

[15] Hazardous substances were released by erosion during both of these events, but large-scale slope failures did not occur.

monitoring wells, run-on/runoff controls, and other design elements. Although Railroad and Cooper Creeks are not property lines *per se*, they do represent hydrologic boundaries (since groundwater from below the tailings piles enters the creeks as base flow). Also, the groundwater-surface water interface is anticipated to be the point of compliance for groundwater at the Holden Mine Site. Accordingly, the Agencies believe the tailings piles must be set back from the creeks to provide locations for monitoring wells and access for environmental monitoring.

The solid waste regulations specify that the amount of the setback may be increased if needed, for instance to provide access to environmental monitoring systems and facility structures [WAC 173-350-400(3)(i)(iii)]. The reference to facility structures is relevant and appropriate for the tailings pile cover, and groundwater barrier and collection ditch facilities that are anticipated to be part of the final remedy. However, the Agencies note that a 100-foot setback is probably more than adequate for monitoring alone, and anticipate that the magnitude of the setback for Holden would be determined during RD.[16]

4.6 Provide Post-Closure Access That Will Not Degrade the Creek Habitat

WAC 173-350-400(7) specifies post-closure requirements for limited purpose landfills that include provisions for continued maintenance of the landfill and monitoring "*for a period of twenty years, or as long as necessary for the landfill to stabilize and to protect human health and the environment.*"

It is necessary for the toe of the tailings pile slopes to be set back from the edge of Railroad and Copper Creeks to assure unrestricted access for monitoring and maintenance, as described above. The expected duration of monitoring and/or maintenance is more than 200 years. Although access for emergency repair of the failed riprap protection was accomplished by driving construction equipment across and within the creek channels in 2003 and 2006, operation of vehicles and/or heavy equipment within the creek channel is generally not acceptable.

Setback of the toe of the tailings piles some distance from the creeks will enable construction, operation, and maintenance of a groundwater barrier and

[16] For discussion and cost estimating purposes only, the Agencies assumed 45 feet as the necessary setback to accommodate construction of a groundwater barrier wall, groundwater collection system, monitoring wells, and a maintenance access road.

collection system, as variously depicted on Figure D-5; and on Figures 6-17 and 6-27 from the DFFS, that are included in Attachment D-2 to this appendix.

5.0 Magnitude of Tailings and Waste Rock Pile Regrading

The volume of soils to be regraded for stability and setback from Railroad and Copper Creeks varies among DFFS alternatives. DFFS Alternatives 3b and 8 are discussed here, to provide a frame of reference for alternatives addressed in the DFFS but not in the SFS. As discussed below Alternative 8 would require the most extensive regrading, while Alternative 9 would require the least amount of regrading.

DFFS Alternative 8 proposes the largest amount of regrading to consolidate the tailings and main East and West Waste Rock Piles into a single consolidated tailings pile (CTP) in the current location of TP-2. The toe of the CTP slope adjacent to Railroad Creek would be pulled back and flattened to provide a 50-foot buffer between the pile and creek at a slope of 2H:1V. Intalco estimated the required regrading of TP-2, to provide the setback and flattened slopes, to be approximately 1,000,000 cy. In addition, the volumes of TP-1 and TP-3 that would be moved into the CTP would involve approximately 1,400,000 and 1,600,000 cy, respectively. Intalco also anticipated moving about 307,000 cy of waste rock into the CTP.

The proposed Alternative 9 regrading is the same as that proposed in DFFS Alternative 3b. Alternative 3b included regrading portions of TP-1 and TP-2 to flatten the slopes adjacent to Railroad Creek to slopes ranging from 1.5H:1V to 2H:1V, while leaving the toe of the slope in the same location abutting Railroad Creek. Alternative 3b would not regrade the slopes of TP-3 but proposes low rock-fill buttresses to contain slope failures. For Alternative 3b (or 9), Intalco estimated regrading about 250,000 cy. No waste rock regrading was assumed as part of Alternatives 3b or 9.

The Agencies estimated the regrading volume for Alternatives 10 and 11 for cost estimating purposes. The Agencies estimated regrading of about 580,000 cy would provide 2H:1V slopes and a 45-foot setback from Railroad Creek for all three tailings piles. The estimate for Alternative 10 included regrading an additional 158,000 cy to flatten slopes for the main East and West Waste Rock Piles. The estimate for Alternative 11 included this, as well as about 49,000 cy to consolidate the Honeymoon Heights Waste Rock Piles into the main West Waste Rock Pile prior to closure.

The final volume of regrading will need to be determined during RD, after selection of a remedy. The final setback of the tailings piles from Railroad and

Copper Creeks will depend in part on hydrologic analyses of the creek flows, as well as requirements for construction and maintenance of the remedy. Selection of final slopes will be based, in part, on improved stability analyses. This will include identifying minimum factors of safety considering variability in properties of the tailings and waste rock, and the anticipated consequences of potential slope failures.

6.0 Limited Purpose Landfill Cover Requirements

Final closure standards for limited purpose landfills include a cover that meets specific performance requirements, as previously noted.

None of the DFFS alternatives include covers over the tailings piles and waste rock piles that would satisfy the presumptive cover requirements in WAC 173-350-400(3)(e)(ii). Although DFFS Alternative 7 includes capping the tailings piles and the flat upper surface of the East and West Waste Rock Piles, it does not address closure of the slope portions of the East and West Waste Rock Piles, or any of the waste rock piles on Honeymoon Heights. Alternative 8 would meet the presumptive cover requirements in WAC 173-350-400(3)(e)(ii) for the CTP (that would include the tailings and the main East and West Waste Rock Piles), but does not address closure of the Honeymoon Heights Waste Rock Piles.

Alternative 9 apparently does not include any cover for the tailings piles except for a 1-foot layer of topsoil that would be placed over the regraded slope areas only (per the cost estimate that was submitted with URS 2005). Alternative 9 may or may not satisfy final closure system performance requirements in WAC 173-350-400(3)(e)(i) for the tailings piles. The existing gravel cover and proposed addition of topsoil to regraded areas has not been shown to be protective of terrestrial receptors. This would need to be addressed during RD. Alternative 9 does not meet the final closure system performance requirements in WAC 173-350-400(3)(e)(i) or the presumptive cover requirements at (e)(ii) for any of the waste rock piles.

Alternative 10 included a 1-foot-thick soil cover over the tailings and main waste rock piles, on the assumption that this would satisfy the performance requirements for final closure of limited purpose landfills, and that further ecological risk assessment would show this cover would be protective. However, Alternative 10 did not address the waste rock piles on Honeymoon Heights. Currently available information does not show that the proposed 1-foot soil cover would be protective, and this would need to be addressed during RD.

Alternative 11 includes consolidation of the Honeymoon Heights Waste Rock Piles into the main West Waste Rock Pile; and construction of a cap for the East and West Waste Rock Piles and the three tailings piles, that would satisfy the state's presumptive cover requirements. However, the proposed cover for the tailings and waste rock piles could be modified if additional ecological and engineering analyses during RD show that an alternative final closure cover satisfies the performance requirements in WAC 173-350-400(3)(e)(i).

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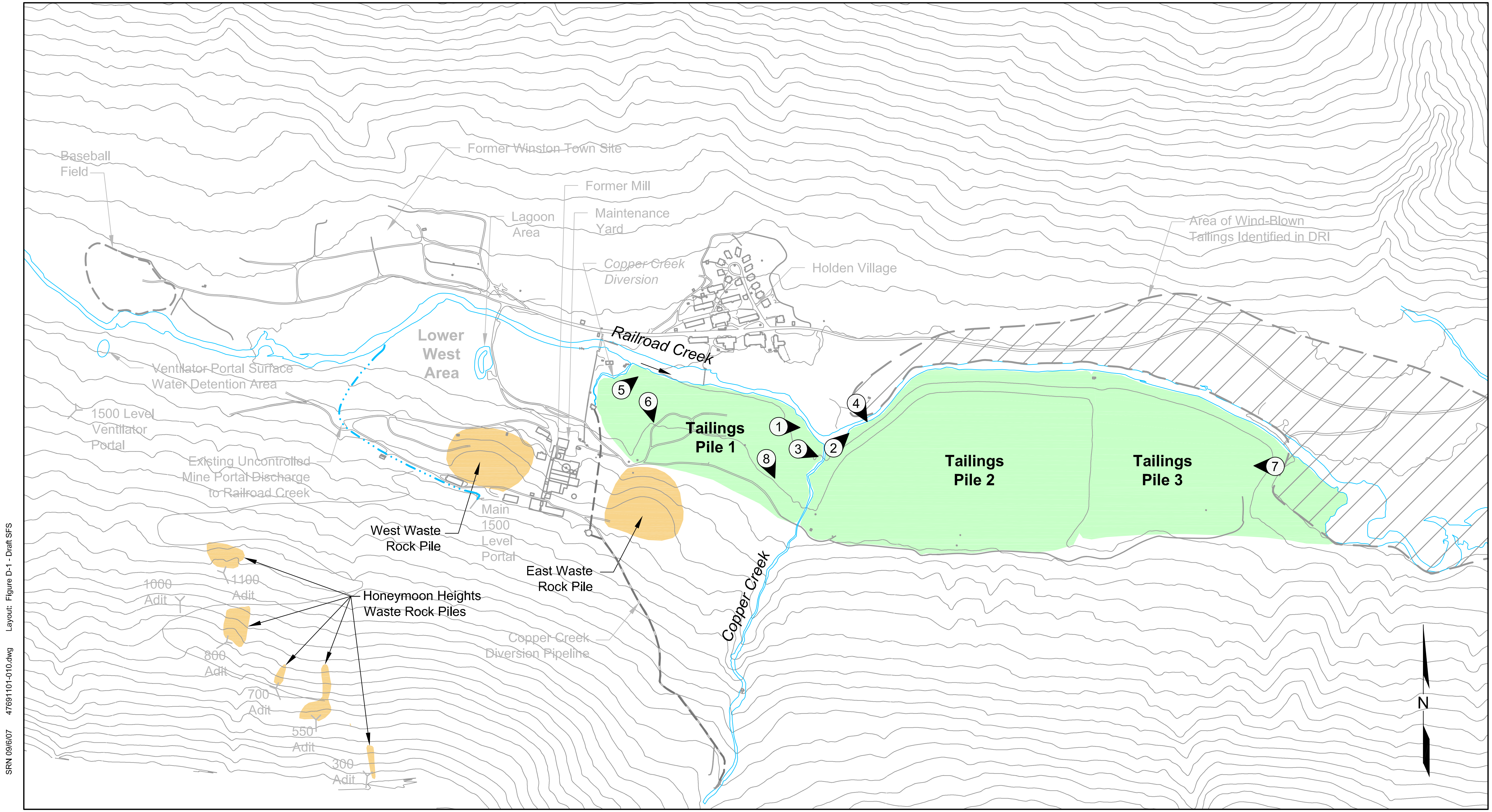
Table D-1 - Tailings Slope Geometry and Hart Crowser Stability Analysis Results

Tailings Pile	Slope Reach	Slope Height Range in Feet		Slope Angle Range in Degrees		Factor of Safety Range		Average Factor of Safety
		Min	Max	Min	Max	Min	Max	Ave
1	1-A	5	10	30	60	0.9	2.0	1.6
	$1\text{-}B_{west}$	30	65	25	75	0.4	1.4	1.3
	$1\text{-}B_{east}$	50	65	25	75	0.4	1.3	1.0
	1-C	60	65	25	80	0.4	1.3	0.9
	1-D	65	70	30	85	0.4	1.1	0.9
	1-E	68	72	25	75	0.4	1.2	1.0
	1-F	55	75	17	75	0.4	1.6	1.1
2	$2\text{-}A_{south}$	50	80	20	90	0.4	1.5	1.1
	$2\text{-}A_{north}$	80	110	20	60	0.5	1.4	1.0
	2-B	100	110	30	60	0.5	1.1	0.9
	2-C	105	115	30	60	0.5	1.0	0.9
	2-D	110	120	10	50	0.7	2.2	0.9
	2-E	120	125	30	55	0.6	1.0	0.8
	$2\text{-}F_{west}$	125	130	30	60	0.5	1.0	0.9
3	$2\text{-}F_{east}$	50	55	30	50	0.8	1.2	0.9
	3-A	50	60	30	50	0.8	1.2	1.1
	3-B	55	65	20	45	0.8	1.4	1.0
	3-C	60	65	15	32	1.0	1.7	1.1

Slope reach geometry from DRI Table 4.2-3 or scaled from maps provided by Intalco.

Site Map Showing Location of Tailings and Waste Rock Piles



Source: Base map prepared from LiDAR topographic survey provided by URS 2004, various features from DRI and DFFS.

Waste Rock Piles

Tailings Piles

1 Photograph Location, Number, and Direction

0 600 1200

Scale in Feet

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Figure D-1

SFS - Appendix D

Photograph 1 Exposed slopes on TP-2 near confluence of Railroad and Copper Creeks, May 2006

Photograph 2 Undercut Bank of Railroad Creek adjacent to TP-2, October 2003

Photograph 3 Undercut Bank of Copper Creek adjacent to TP-2, June 2006. ←Up

Photograph 4 TP-2 Sloughing adjacent to Railroad Creek, August 2005. ←Up

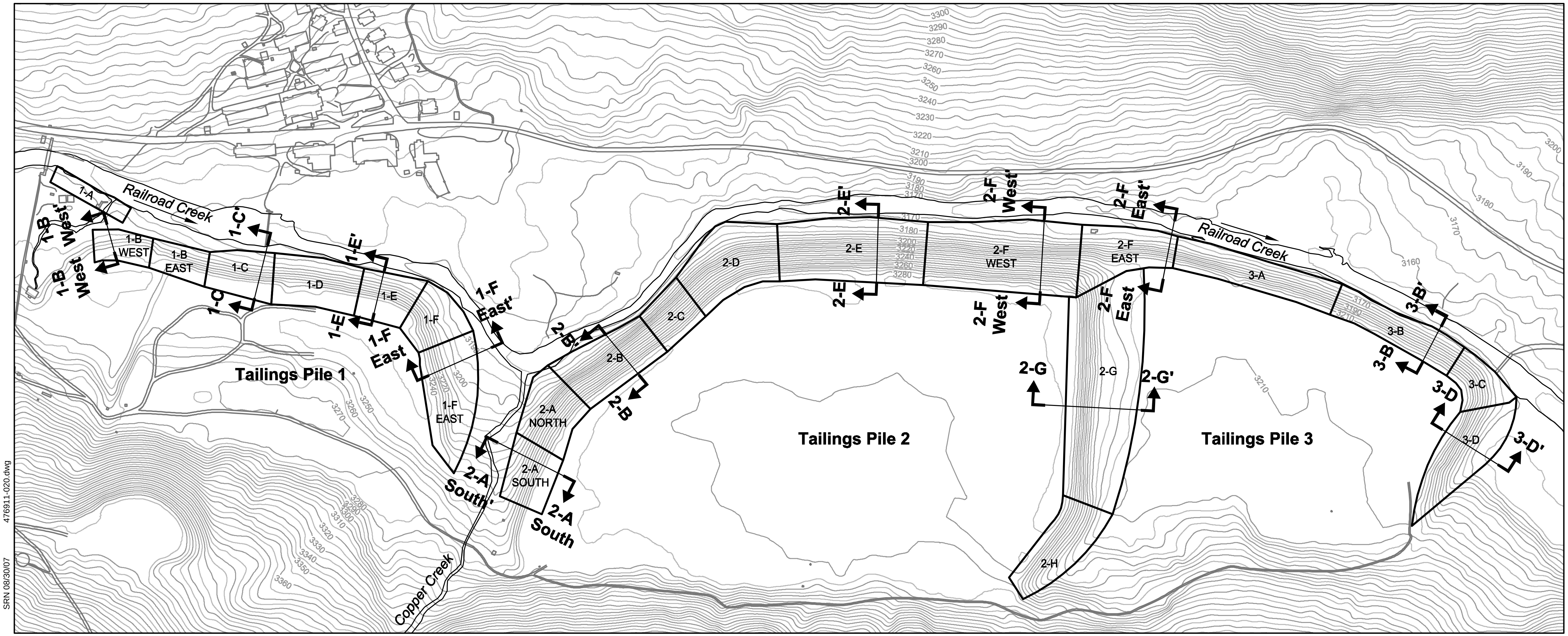
Photograph 5 Active Erosion on TP-1, August 2006

Photograph 6 Erosion of exposed tailings on top of TP-1, May 2006

Photograph 7 Exposed TP-2 Slopes, Looking across Barren Top of TP-3

Photograph 8 Erosion of Gravel Cover on Top of TP-1, October 2003

Location of Slope Reaches on Tailings Piles



Source: Base Map prepared from LIDAR survey provided by URS 2004. Figure adapted from Figure 4.2-21 of the RI. (Dames & Moore, 1999)

1-B WEST — Tailings Pile Slope Reach Boundary and Number

2-G 2-G' — Cross Section Location and Designation

0 300 600
Scale in Feet

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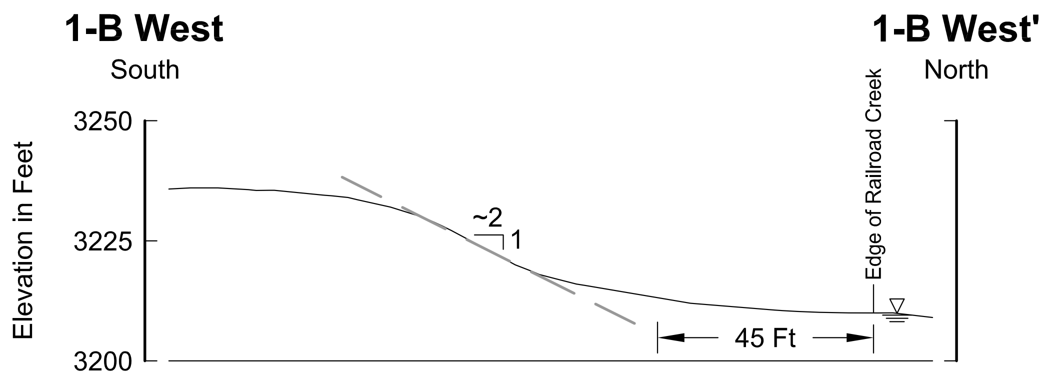
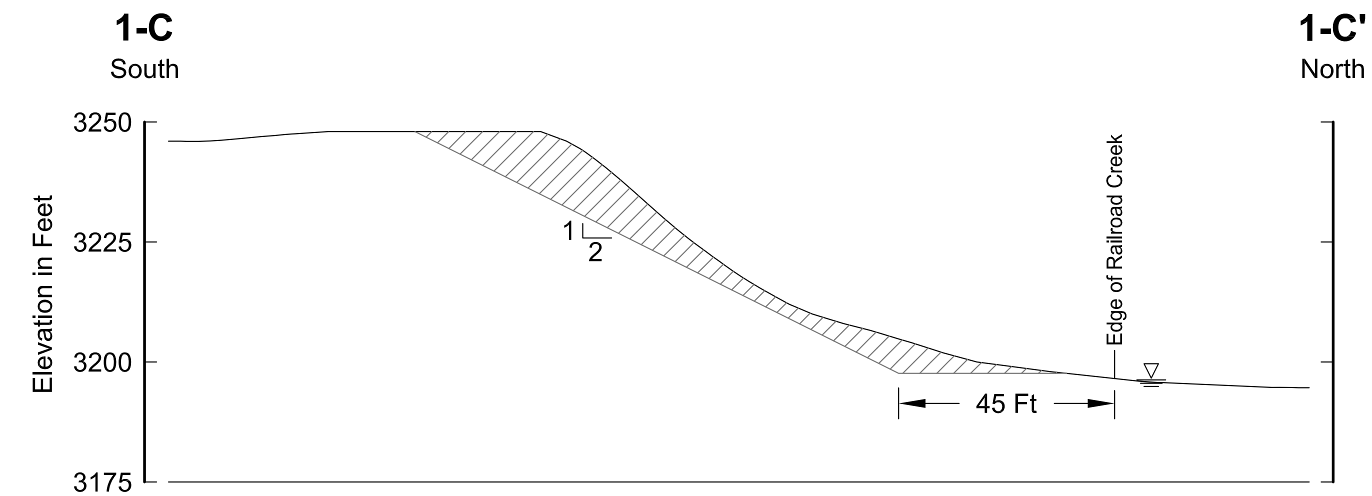
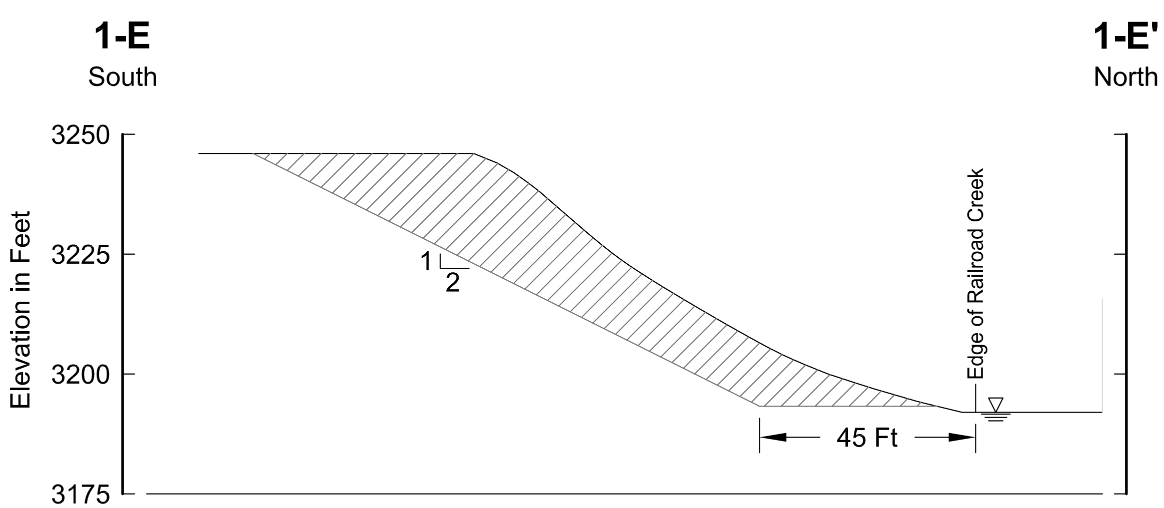
4769-11 9/07
Figure D-3
SFS - Appendix D

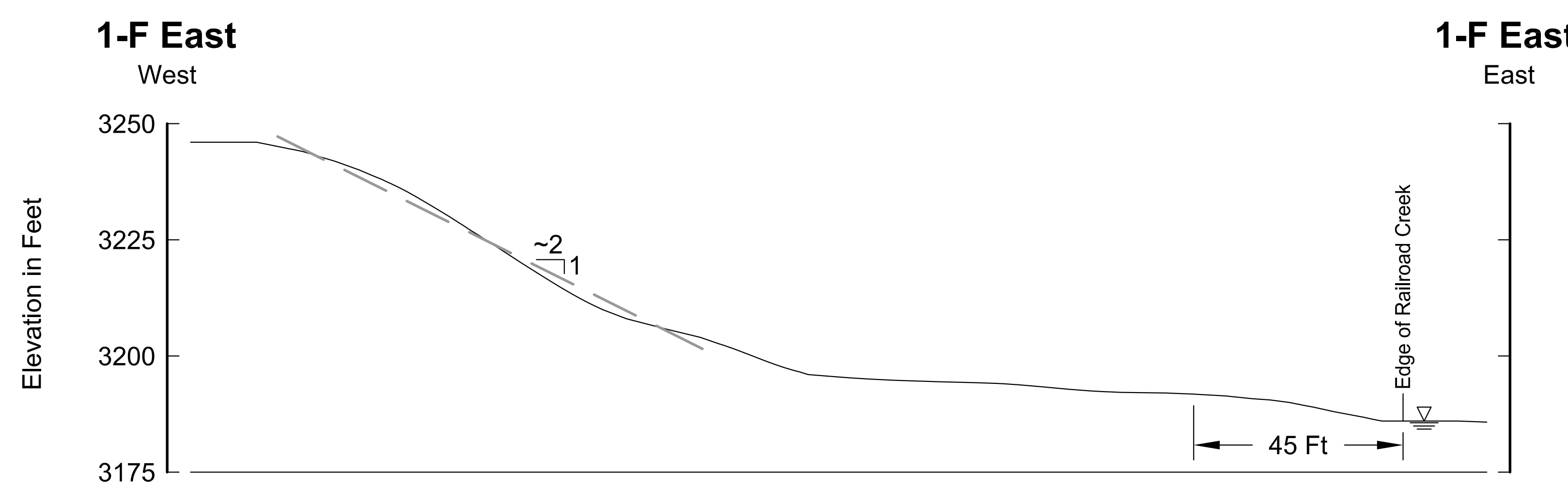
Tailings Pile Cross Sections



Note: Nominal, if any, regrading expected in the area represented by this section.







Note: Nominal, if any, regrading expected in the area represented by this section.

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Volume to Regrade

0 40 80
Scale in Feet

Note: Nominal 2H:1V slope and 45-foot setback is shown for discussion purposes only and may be modified during remedial design.

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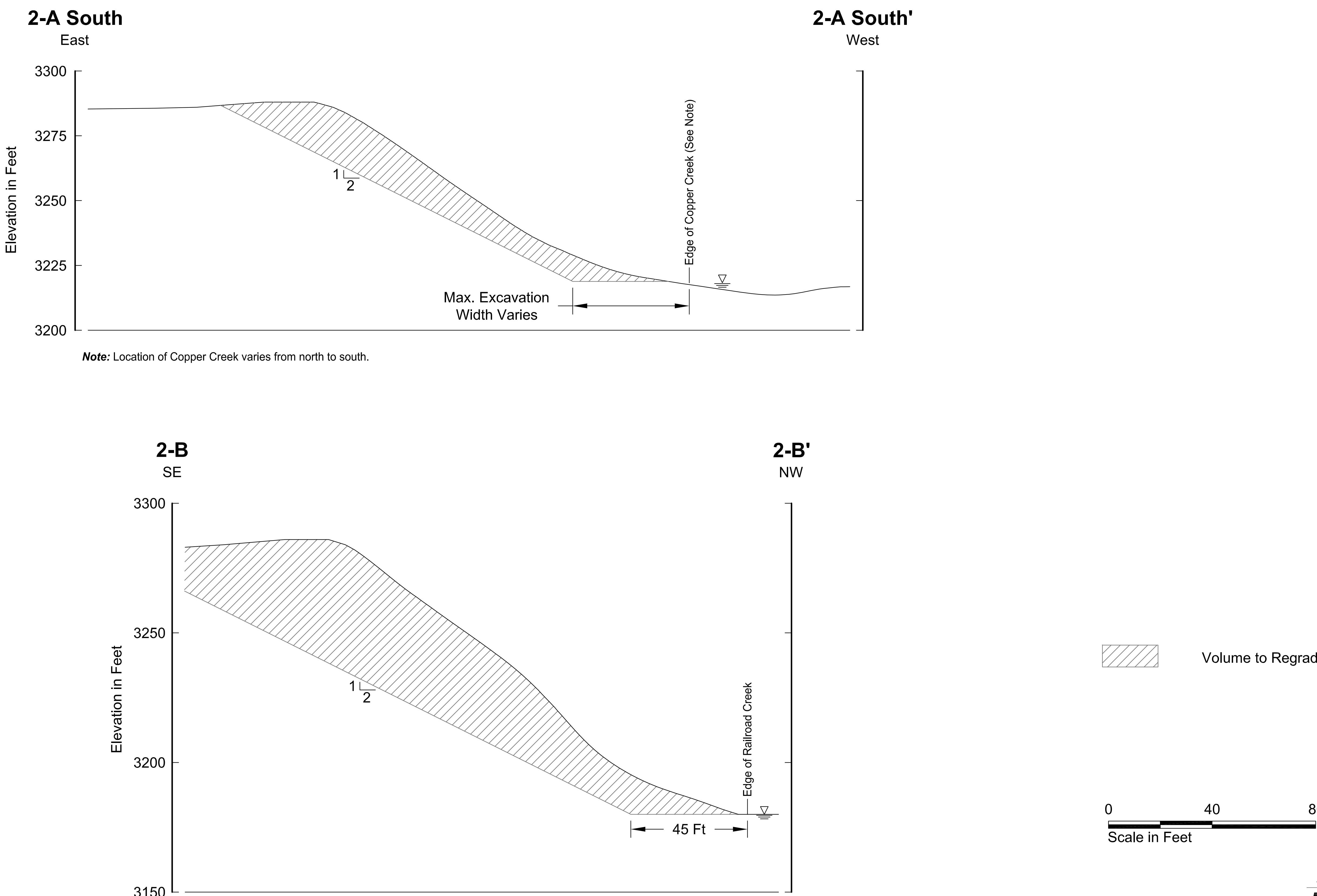
4769-11	***9/07***
Figure D-4	***1/5***
SFS - Appendix D	

Tailings Pile Cross Sections



Note: Nominal 2H:1V slope and 45-foot setback is shown for discussion purposes only and may be modified during remedial design.

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HARTCROWSER

4769-11 ***9/07***

Figure D-4 ***2/5***

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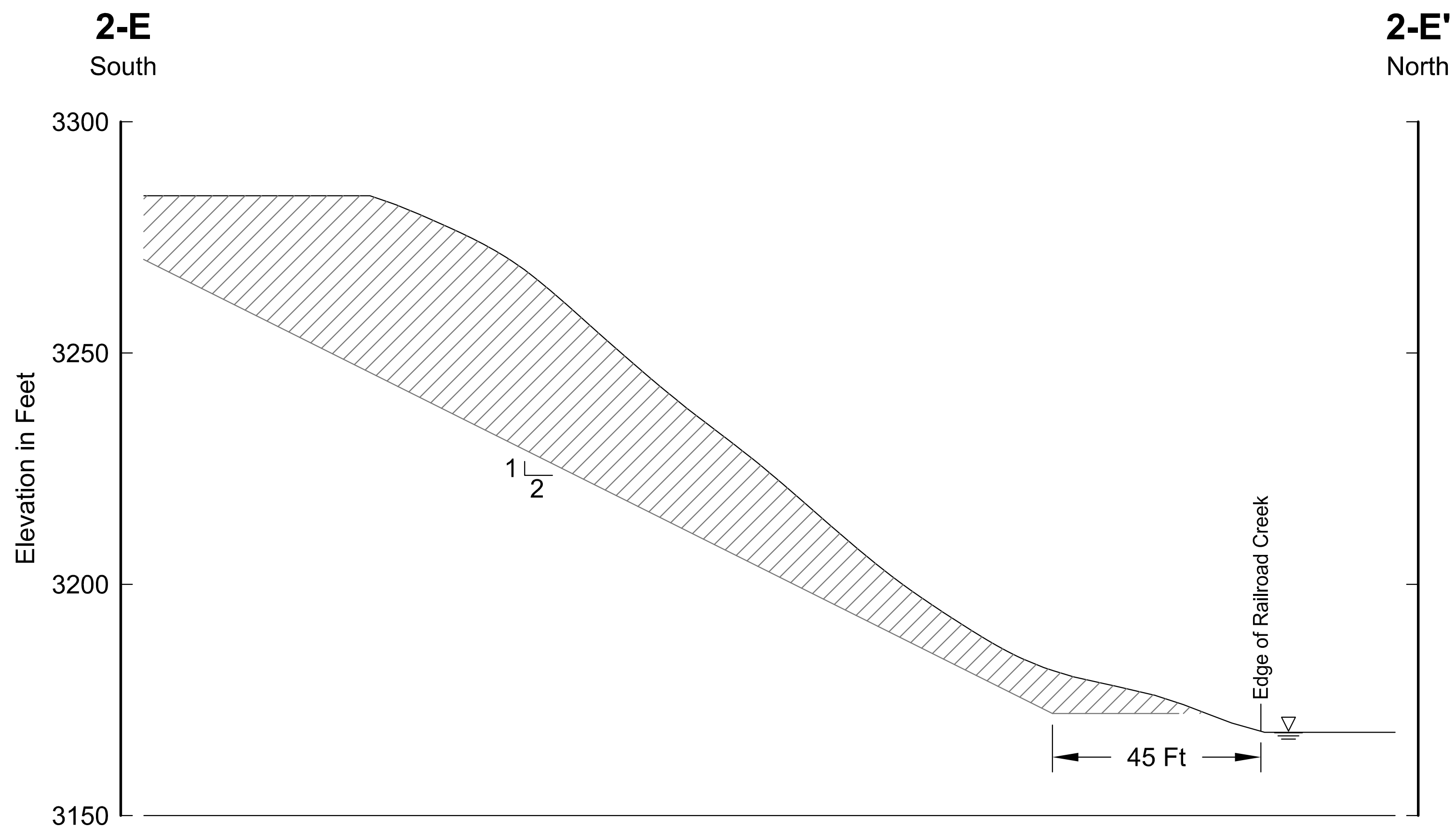
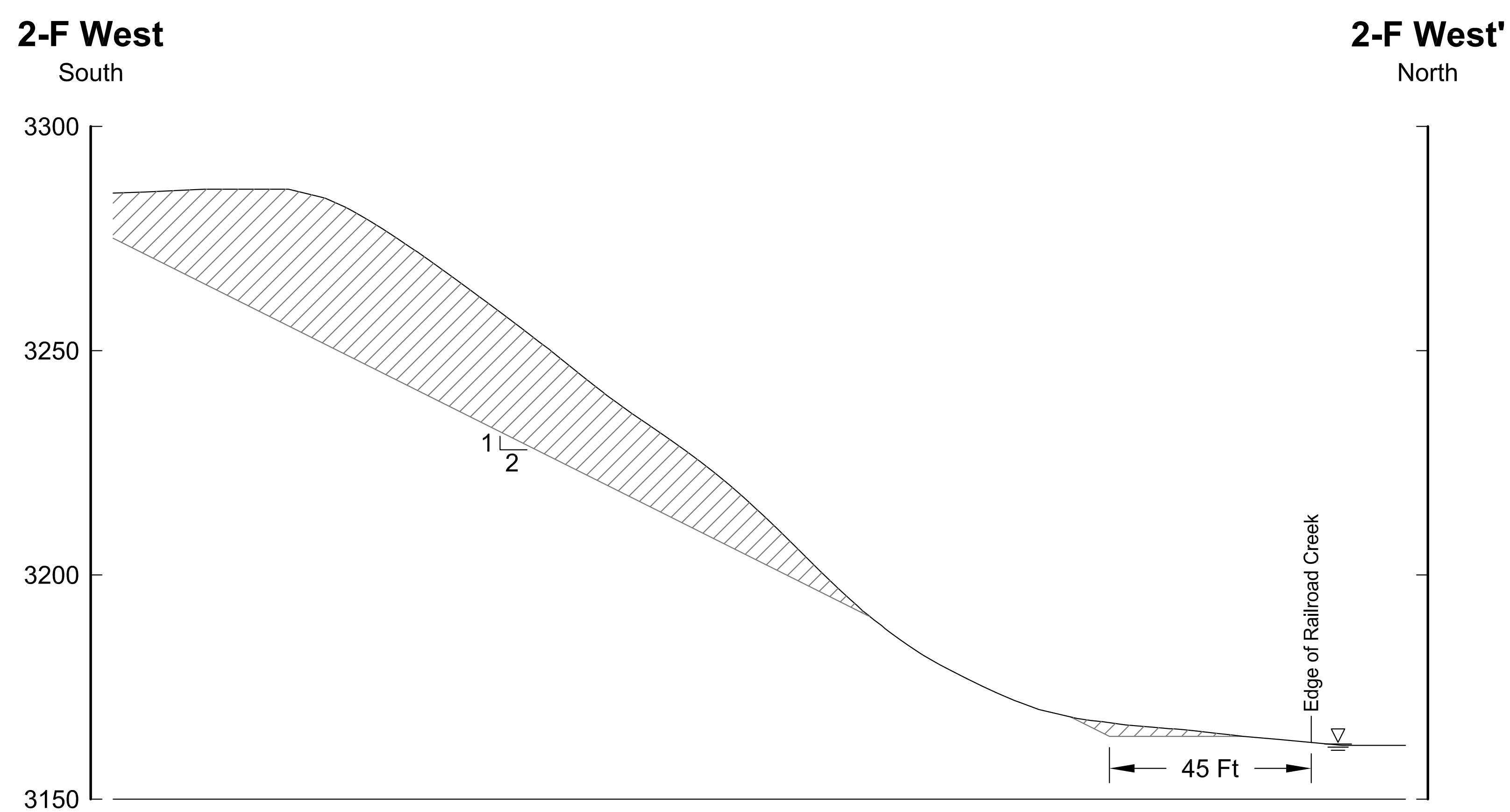
Tailings Pile Cross Sections





Volume to Regrade

Note: Nominal 2H:1V slope and 45-foot setback is shown for discussion purposes only and may be modified during remedial design.

0 40 80
Scale in Feet

EAL 08/30/07 476911-028.dwg

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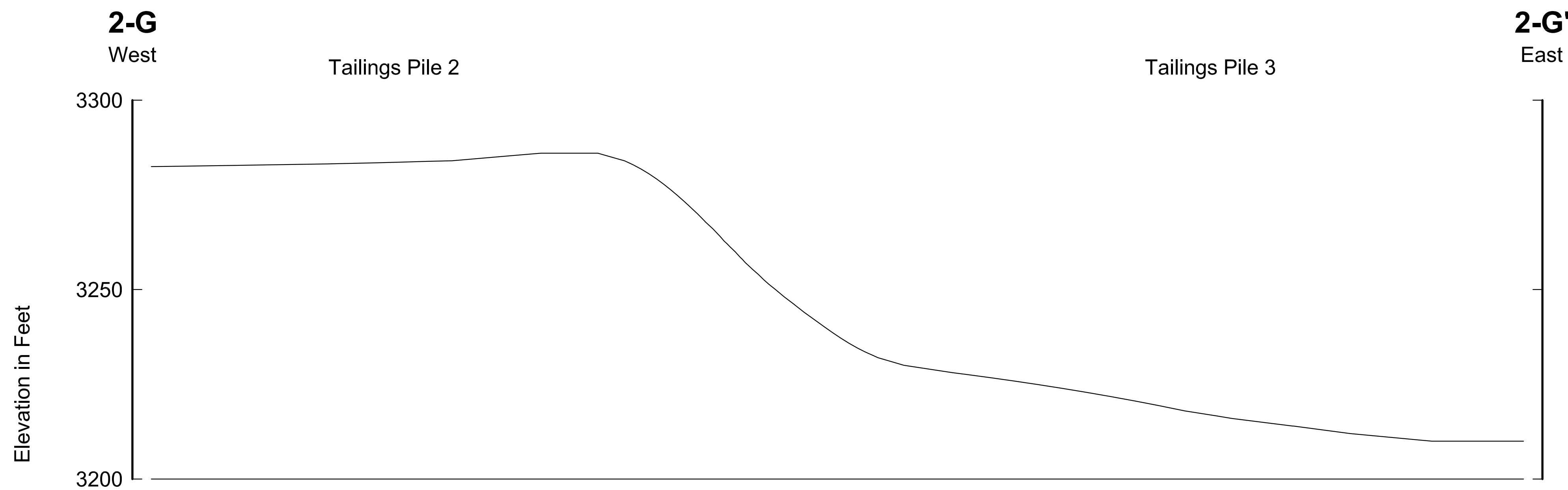
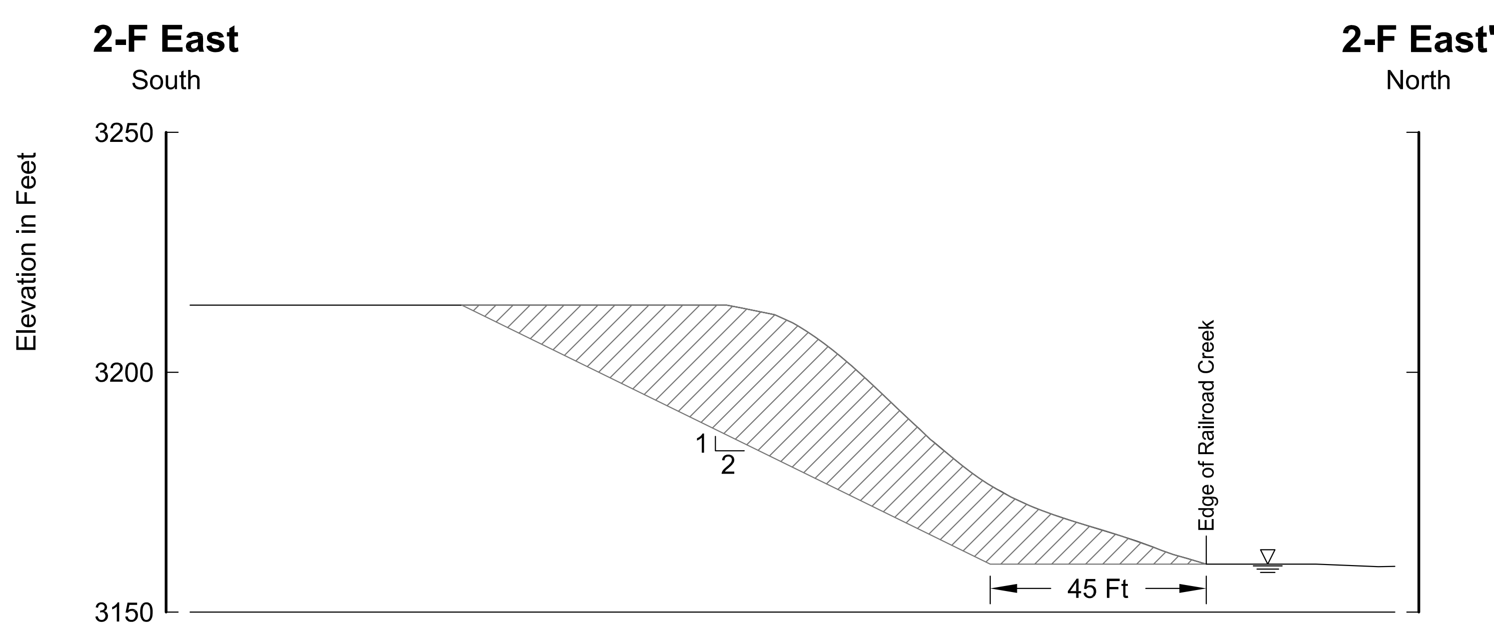
Figure D-4 ***3/5***
SFS - Appendix D

Tailings Pile Cross Sections



Note: Potential future fill on Tailings Pile 3 not shown.



Volume to Regrade

0 40 80

Scale in Feet

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Note: Nominal 2H:1V slope and 45-foot setback is shown for discussion purposes only and may be modified during remedial design.

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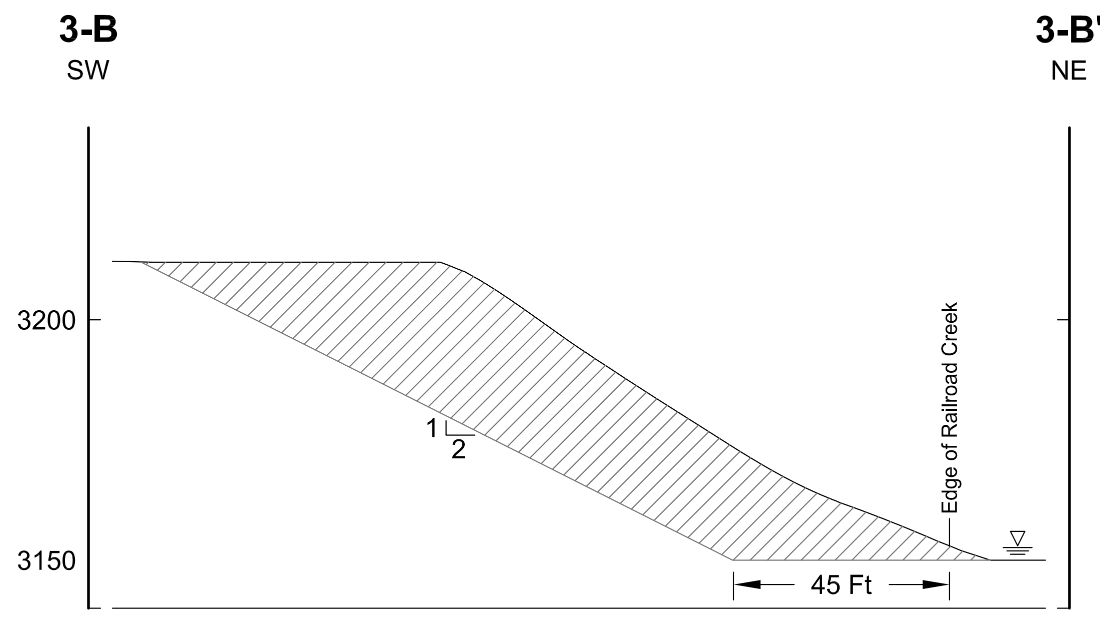
Figure D-4 *4/5*

SFS - Appendix D

Tailings Pile Cross Sections



Note: Nominal, if any, regrading expected in the area represented by this section.

Note: Nominal 2H:1V slope and 45-foot setback is shown for discussion purposes only and may be modified during remedial design.

Volume to Regrade

0 40 80
Scale in Feet

EAL 08/30/07 476911-028.dwg

HARTCROWSER

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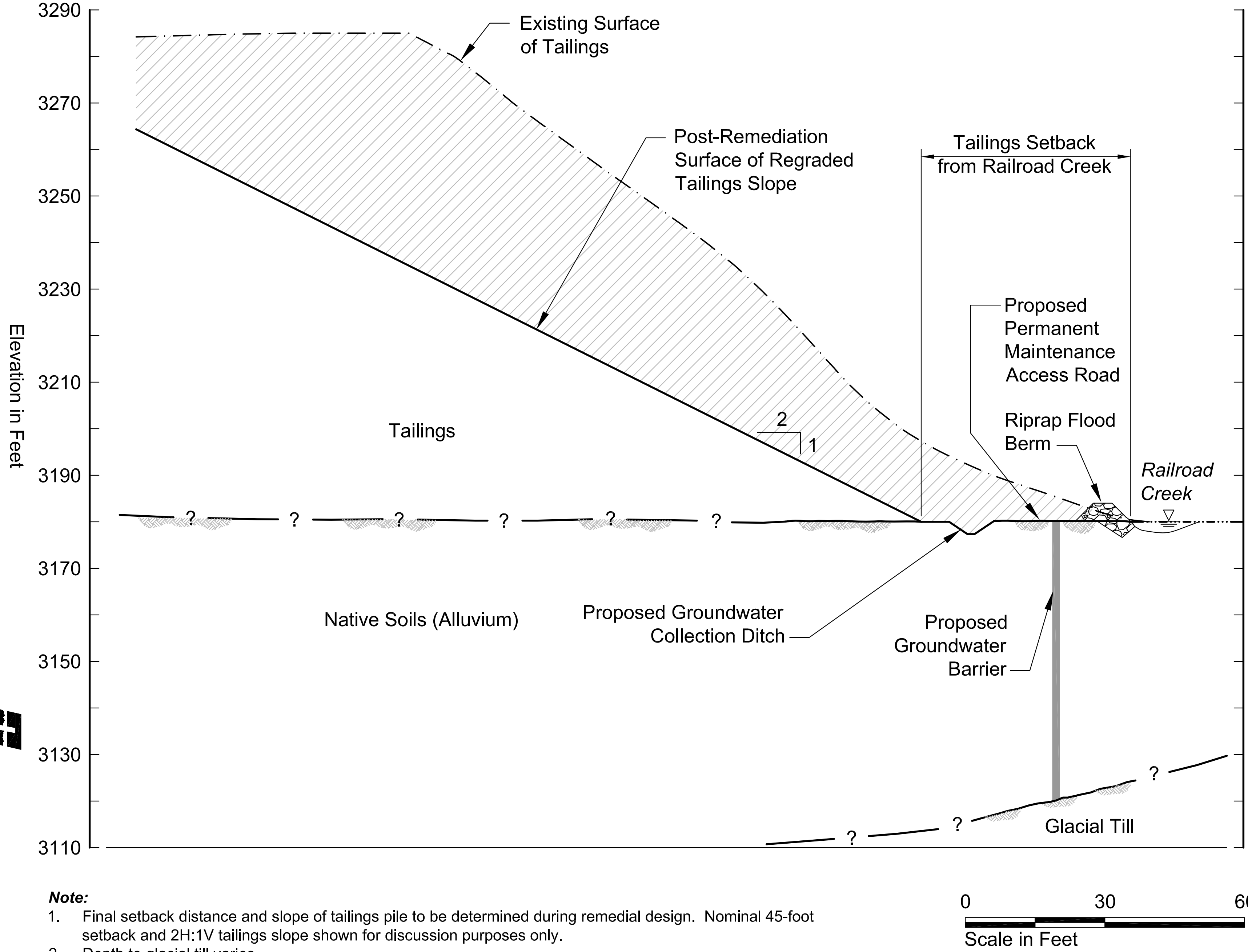
Figure D-4 ***5/5***
SFS - Appendix D

Schematic of Proposed Tailings Pile Regrading adjacent to Railroad Creek



Note:
1. Final setback distance and slope of tailings pile to be determined during remedial design. Nominal 45-foot setback and 2H:1V tailings slope shown for discussion purposes only.
2. Depth to glacial till varies.

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Figure D-5
SFS - Appendix D

SRN 8/30/07 476911-027.dwg Layout: Figure D-5 - Draft SFS - Appendix D

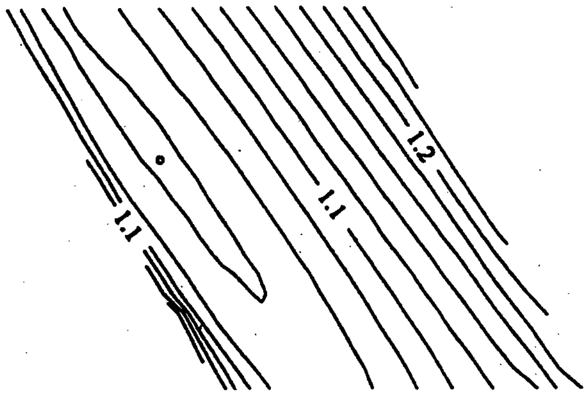
ATTACHMENT D-1
REFERENCED TABLES AND FIGURES FROM THE REMEDIAL INVESTIGATION

TABLE 4.2-3
SUMMARY OF CHARACTERISTICS AND EROSION POTENTIAL FOR TAILINGS PILES AND SLOPES
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Tailings Location	Reach	Approximate Length (ft)	Height Range (ft)	Average Slope Angle	Range in Slope Angle	Slope Setback	Slope Material	Condition of Grass Mats	Observed Erosion	Erosion Potential
Tailings Pile 1	1-A	225	5-10	> 33	30-60	No	No	None	Moderate	High
	$1\text{-}B_{west}$	175	30-65	26.9	25-75	Yes	Yes	None	Minor	Moderately Low
	$1\text{-}B_{east}$	175	50-65	35.9	25-75	Yes	Yes	None	Minor	Moderate
	1-C	200	60-65	40.2	25-80	No	Yes	None	Minor	Moderate
	1-D	300	65-70	40.2	30-85	No	Yes	None	Minor	Moderate
	1-E	210	68-72	32.4	25-75	-	No	None	Minor	Moderately Low
	1-F	160	55-75	30.2	15-75	-	-	None	Minor	-
Tailings Pile 2	2-As	210	50-80	30.2	20-90	-	Yes	None	Minor	Moderately Low
	2-An	225	80-110	31.3	20-60	No	No	Good	Moderate	Moderately High
	2-B	350	100-110	37.5	30-60	No	No	Fair	Moderate	High
	2-C	160	105-115	38.7	30-60	No	No	Poor	Extensive	High
	$2\text{-}D_{west}$	350	110-120	37.2	10-50	Yes	No	Good	Moderate	Moderate
	2-E	475	120-125	39.0	30-55	No	No	None	Moderate	Moderately High
	$2\text{-}F_{west}$	760	125-130	35.0	30-60	-	Yes	Good	Moderate	Moderately High
Tailings Pile 3	$2\text{-}F_{east}$		50-55	40.2	30-50	-	Yes	None	Moderate	Moderately High
	3-A	550	50-60	31.1	30-50	Yes	-	None	Minor	Moderate
	3-B	435	55-65	35.2	20-45	-	No	None	None	Moderately Low
	3-C	215	60-65	29.4	15-32	Yes	No	None	None	Low

Notes:
Average Slope - estimated from the top of the slope to the mean elevation of the bottom of the rip rap.
Range in Slope - the approximate range in slopes found vertically and laterally across the entire slope reach.
Slope Setback: "Yes" - the slope is setback sufficiently from the top of the rip-rap to allow for accumulation of talus at the angle of repose.
Slope Setback: "No" - the slope is not setback sufficiently from the top of the rip-rap to allow for accumulation of talus at the angle of repose.
Creek Setback: "Yes" - the main channel of the creek is setback significantly from the base of the rip-rap.
Creek Setback: "No" - the main channel of the creek is at the base of the rip-rap.
Present Erosion - see Table 4.2-3 (*Erosion Potential Ranking Criteria*)

.7693B65.CDR



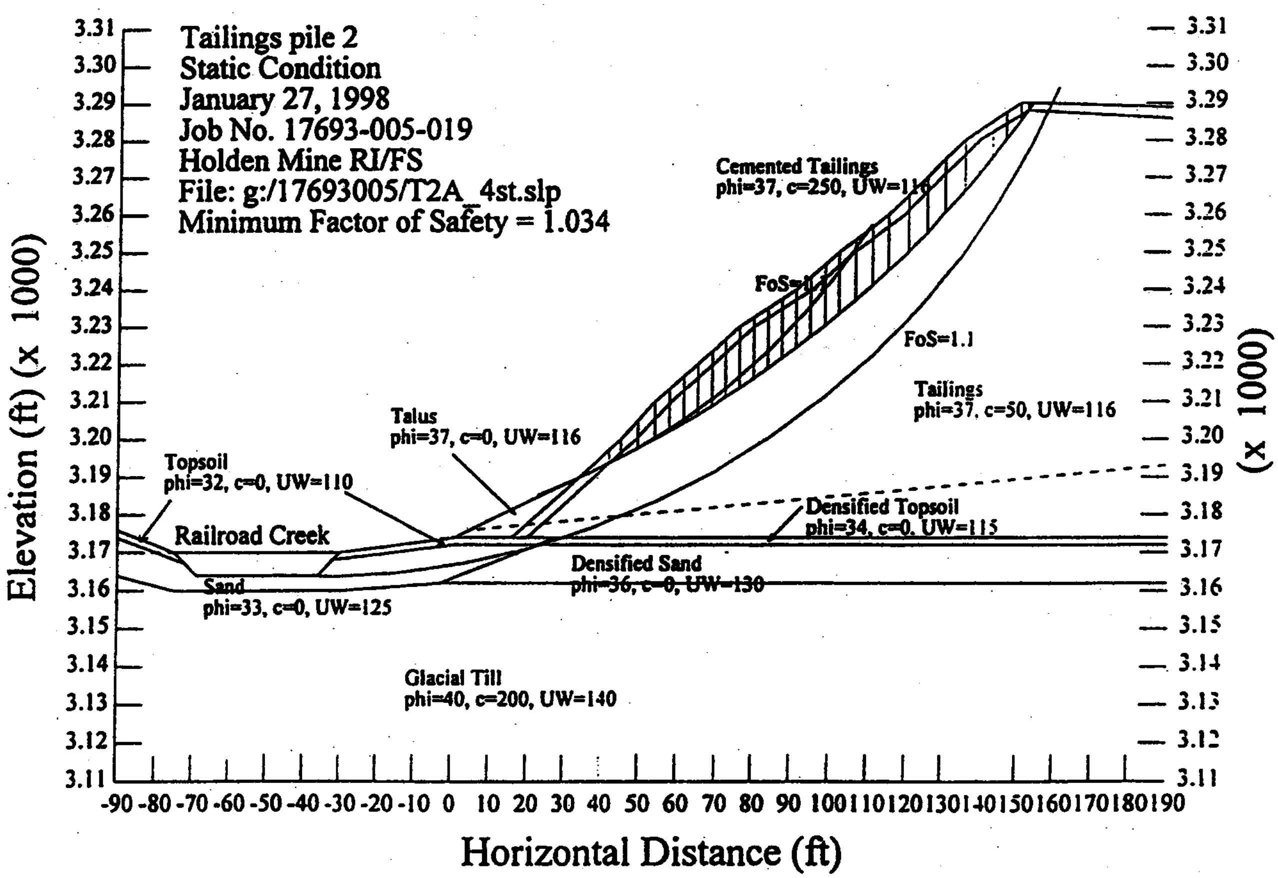


Figure 4.2-17
HOLDEN MINE SITE SLOPE STABILITY
CROSS SECTION C-C'
STATIC CONDITIONS

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

Job No. 17693-005-019

Holden Mine RI/FS
Draft Final RI Report

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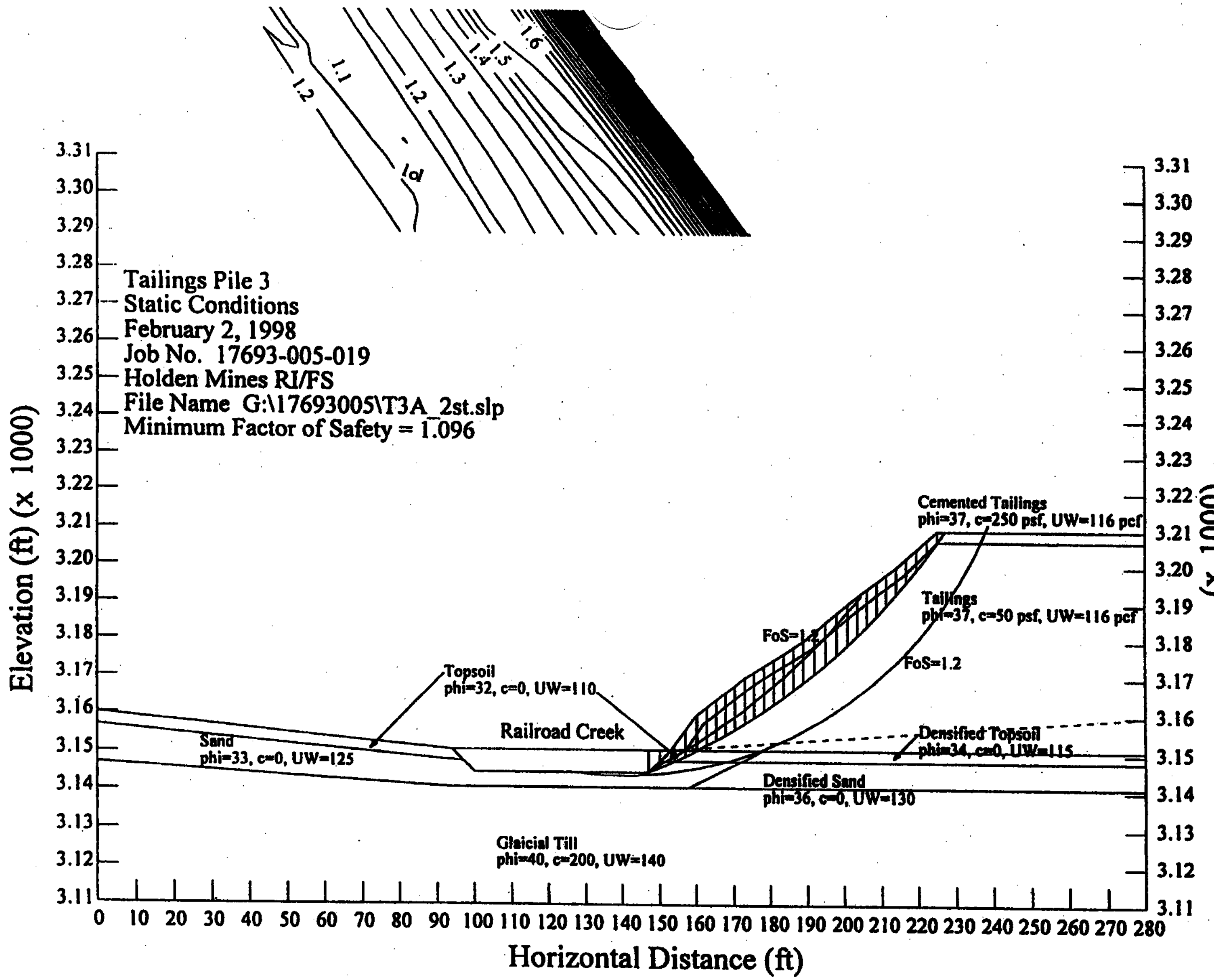

Figure 4.2-18
HOLDEN MINE SITE SLOPE STABILITY CROSS SECTION D-D' STATIC CONDITIONS

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

Job No. 17693-005-019

Holden Mine RI/FS
Draft Final RI Report

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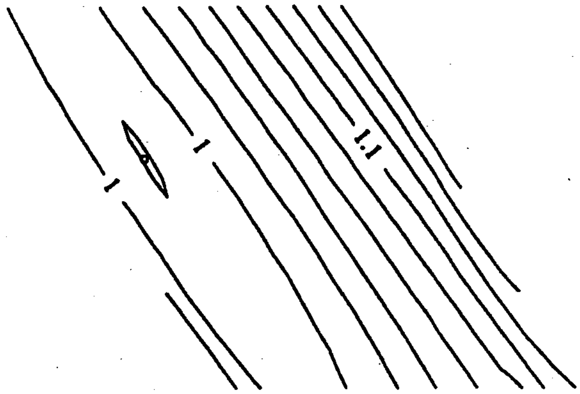

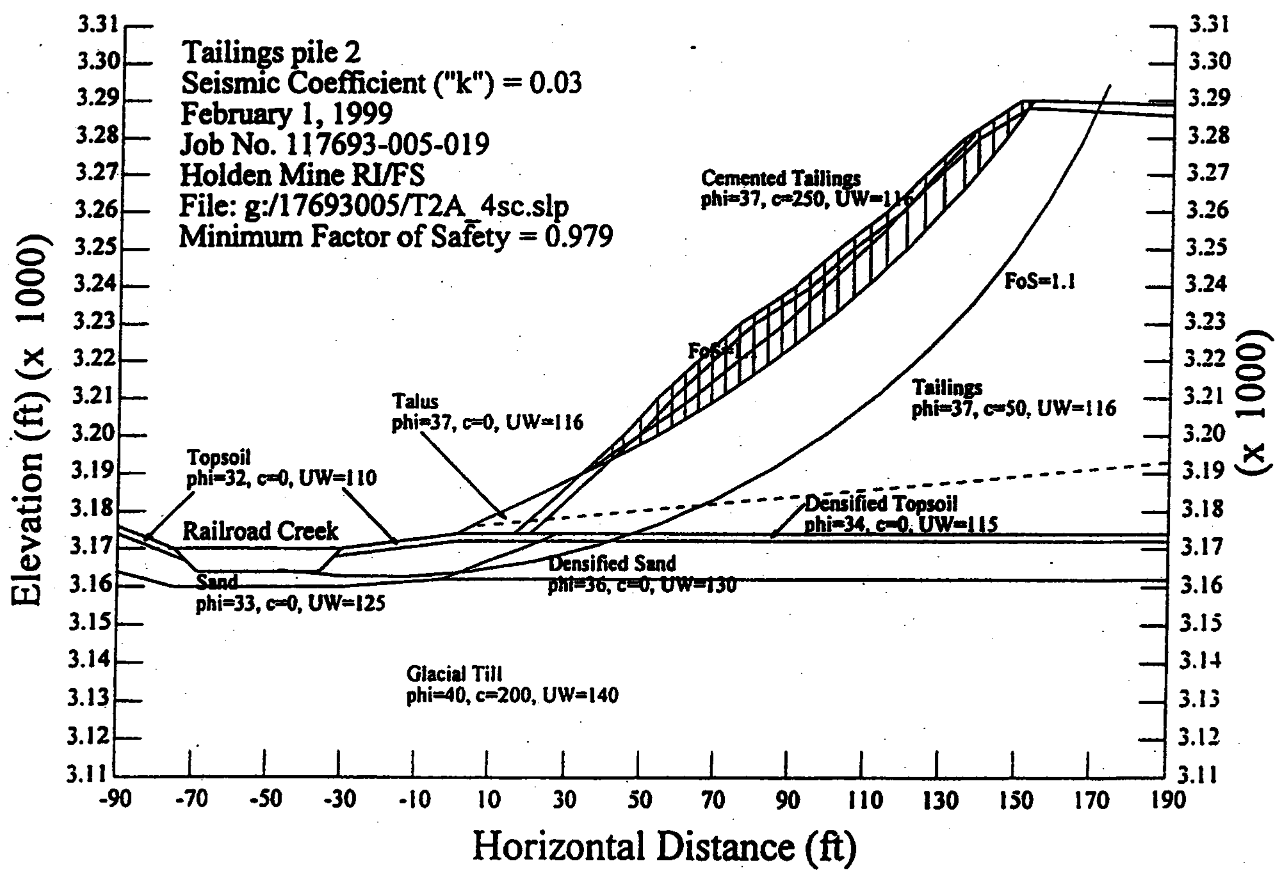

Figure 4.2-19

HOLDEN MINE SITE SLOPE STABILITY
CROSS SECTION C-C'
SEISMIC CONDITIONS

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Job No. 17693-005-019

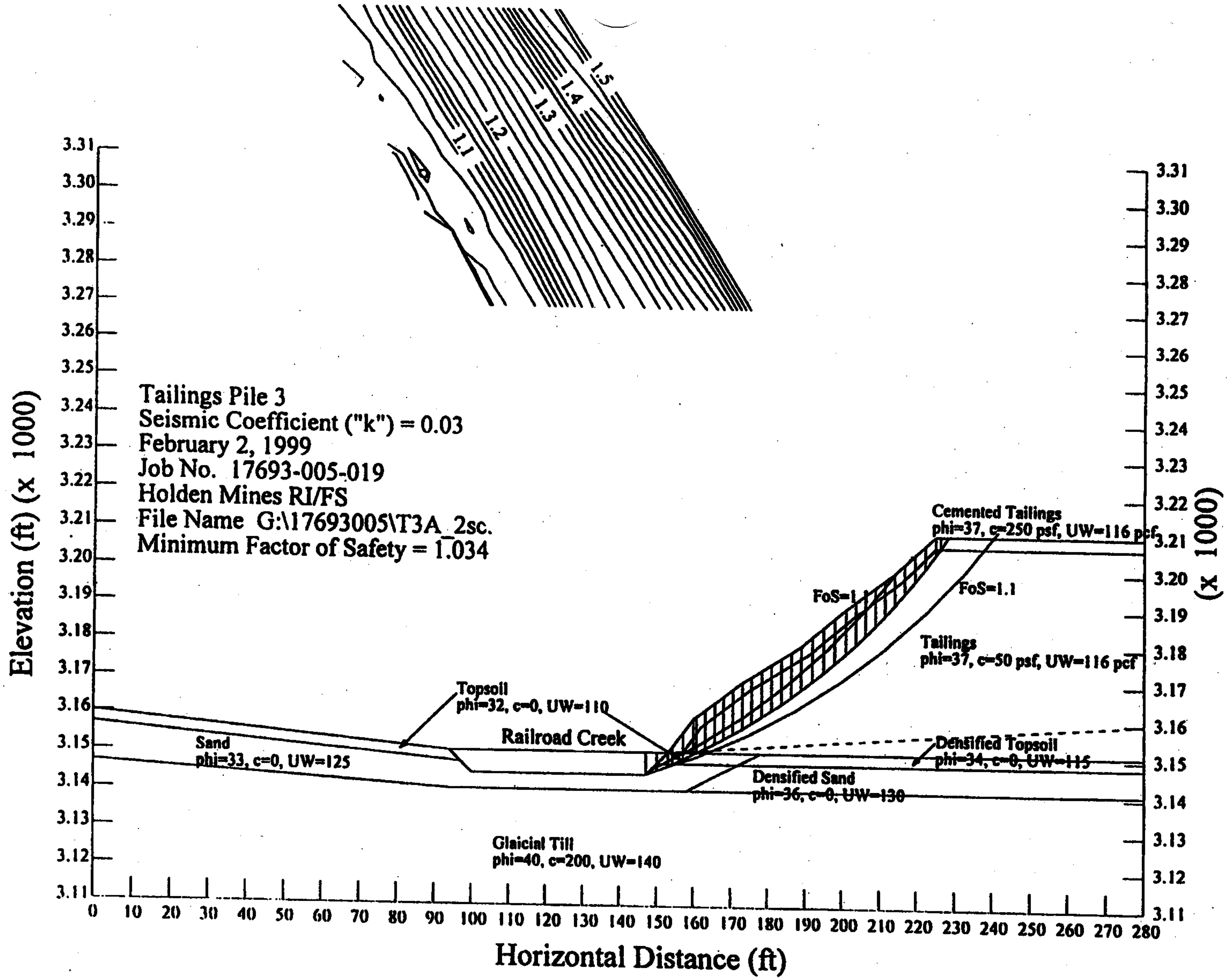
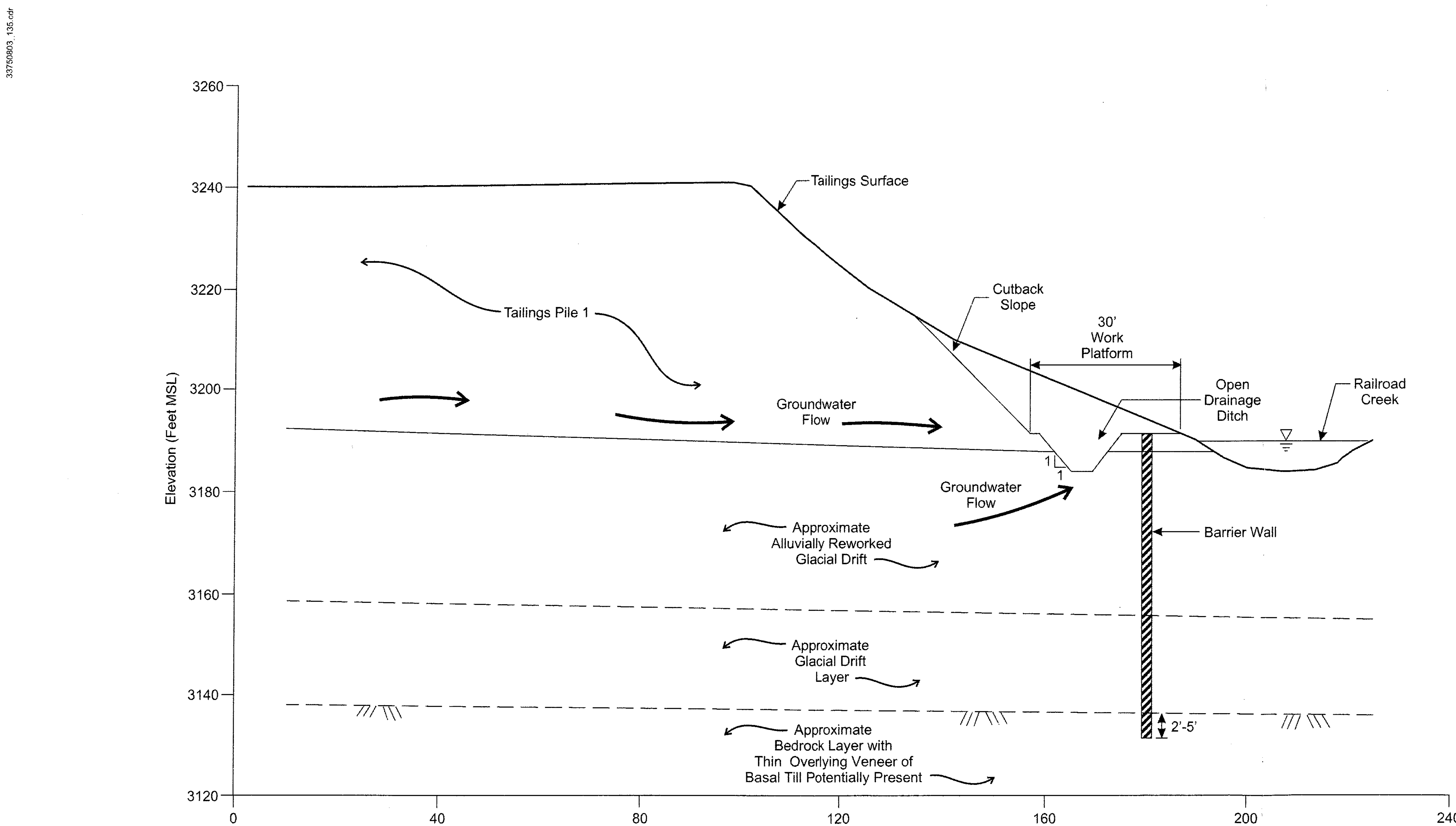


Figure 4.2-20
HOLDEN MINE SITE SLOPE STABILITY CROSS SECTION D-D' SEISMIC CONDITIONS

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

ATTACHMENT D-2
REFERENCED FIGURES FROM THE DRAFT FINAL FEASIBILITY STUDY

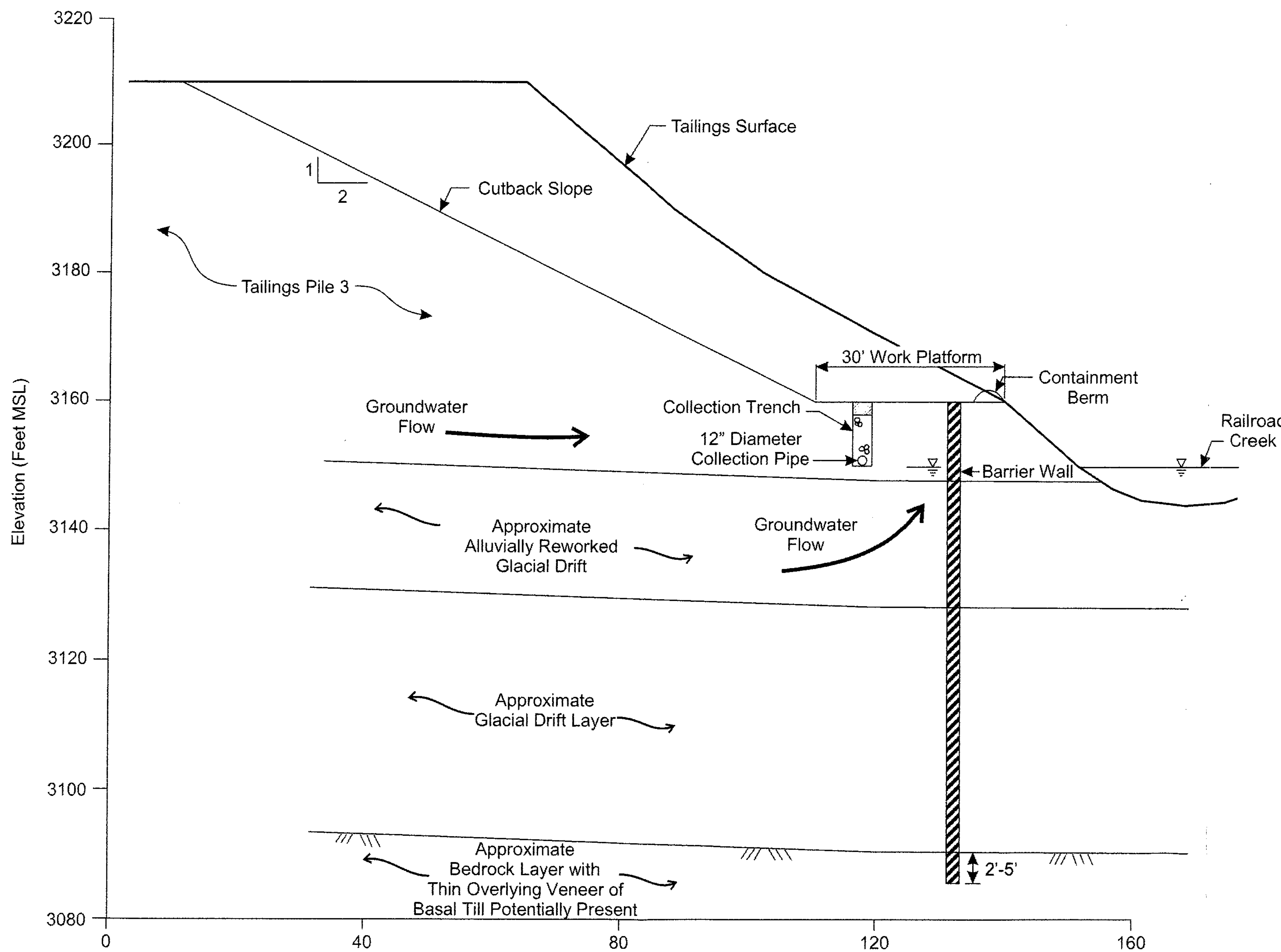


Job No. 33750803

Figure 6-17
Cross-Section 1-1A

URS

Holden Mine RI/FS
Draft Final FS Report
February 2004



Job No. 33750803

Figure 6-27
Cross-Section 3-3B

URS

Holden Mine RI/FS
Draft Final FS Report
February 2004

APPENDIX E
TERRESTRIAL ECOLOGICAL RISK ASSESSMENT ISSUES

APPENDIX E
TERRESTRIAL ECOLOGICAL RISK ASSESSMENT ISSUES

Executive Summary

CERCLA requires that remedial actions be protective of human health and the environment [40 CFR § 300.430(f)(1)(ii)(A)]. The discussion in this appendix focuses on the terrestrial environment. The Draft Remedial Investigation (DRI, Dames & Moore, 1999) for the Holden Mine Site (Site) provided an assessment of risk to human health and aquatic and terrestrial receptors. The DRI provides sufficient information to develop and evaluate remedial alternatives that are protective of human health. However, the DRI did not adequately address risk to aquatic and terrestrial receptors, as noted in comments by the Agencies (e.g., see Comments 2.1, 2.2b, 7.6, 7.7, 7.12, 9.2, 10.8; Forest Service 2001a).

The Agencies expected that deficiencies in the DRI would be addressed as part of the feasibility study [or in the Natural Resources Damage Assessment (NRDA) that Intalco was accomplishing concurrent with the DFFS]. Intalco proposed cleanup levels based on risk to aquatic and terrestrial receptors in the Draft Final Feasibility Study (DFFS, URS 2004). The Agencies modified findings in the DFFS related to aquatic risk (Forest Service 2007a), and noted that reports by the U.S. Fish and Wildlife Service (USFWS 2004, 2005, and 2007c) indicate that remedial alternatives that satisfy potential ARARs based on the National Recommended Water Quality Criteria (NWQC), would be protective of aquatic life. The Agencies also modified the DFFS to incorporate soil cleanup values based on MTCA Table 749-3 (Ecological Indicator Concentrations for Protection of Terrestrial Plants and Animals), which are protective of terrestrial receptors [WAC 173-340-7493(2)(a)(i)]. The Agencies modified the DFFS to indicate that additional terrestrial ecological risk assessment (ERA) will be needed during remedial design (RD) if other soil cleanup levels are to be used.[1]

The Agencies do not accept Intalco's contention that, "there is no risk to most animals, plants and soil biota throughout a majority of the Site and only a low potential risk to select plants, soil biota and wildlife in limited Site areas" (e.g., Section 3.1.8.3 of the DFFS, and elsewhere). There is no basis for this statement,

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[1] Results of additional terrestrial ERA may also show that changes in the proposed remedy would be protective, and if this is the case, the remedy could be modified through an Explanation of Significant Differences (ESD), or a Record of Decision (ROD) Amendment.

since Intalco failed to remedy deficiencies in the DRI (i.e., per the Agencies' Comments: 2.1, 2.2b, 7.6, 7.7, 7.12, 9.2, 10.8; Forest Service 2001a).

The Agencies require that cleanup of soils at the Site must be protective of potential terrestrial receptors as determined on the basis of a terrestrial ecological evaluation in accordance with EPA guidance (EPA 1997) and regulations established under Washington's Model Toxics Control Act (MTCA): WAC 173-340-7490(a)(iii) and WAC 173-340-7490(b). The proposed cleanup levels based on MTCA Table 749-3 are risk-based and, therefore, satisfy these requirements.

The Site does not qualify for an exclusion from a terrestrial ecological evaluation under MTCA [WAC 173-340-7491(1)]. Exclusion is allowed only for sites that meet one or more of the following criteria:

a) All contaminated soil is, or will be, below the point of compliance established under WAC 173-340-7490(4);
b) All contaminated soil is, or will be, covered by buildings, pavement, or other physical barriers that prevent exposure of plants or wildlife;
c) The site is related to, or connected to, less than 1.5 acres of undeveloped land [or other conditions described under WAC 173-340-7491(1)(c)(ii and iii)]; or
d) Concentrations of hazardous substances in soil do not exceed natural background levels.

The soil cleanup values proposed by Intalco[2] do not satisfy the EPA guidance (EPA 1997) and MTCA regulations [WAC 173-340-7490(a)(iii) and WAC 173-340-7490]. Review by the Agencies indicated that problems with the terrestrial ERA and derivation of Intalco's proposed soil cleanup levels makes it inappropriate to use this information as the basis for cleanup of soils at the Site. These problems include:

- Incomplete evaluation of potential constituents of concern (PCOCs);
- Reliance on the assertion that metals do not act synergistically;
- Inadequate characterization of potentially affected populations;
- Insufficient assessment of risk to plants;
- Incomplete assessment of terrestrial exposure pathways;
- Incomplete assessment of points of compliance; and
- Other problems with ecological evaluation procedures used by Intalco.

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[2] Intalco proposed soil cleanup levels in Appendix K of the DFFS and subsequently modified these in another document (URS 2005).

As a result of these problems, the Agencies used the MTCA terrestrial ecological screening values as proposed soil cleanup values in comparing remedial alternatives in the Supplemental Feasibility Study (SFS, Forest Service 2007b). However, additional terrestrial ERA is still needed to determine the extent of soil cleanup needed in some areas of the Site where existing soil concentrations exceed the ecological screening values presented in MTCA.

This appendix to the SFS discusses deficiencies in the terrestrial ERA prepared by Intalco. This appendix identifies the additional work that would be needed to address the problems identified above to determine: 1) whether soil cleanup values exceeding MTCA screening values would be protective; 2) what type of cover should be used to close the tailings and waste rock piles if the default cover specified in state regulations is not used; 3) the extent of soil cleanup needed in some areas of the Site; and 4) what site-specific point of compliance would be appropriate for soils.

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TABLE

APPENDIX E
TERRESTRIAL ECOLOGICAL RISK ASSESSMENT ISSUES

1.0 Introduction

This appendix identifies inadequacies with Intalco's evaluation of Site-related environmental effects on terrestrial ecological receptors, and discusses necessary actions to correct the identified concerns. Section 2 of this appendix provides an overview of the ecological risk assessment (ERA) presented in the Draft Remedial Investigation (DRI, Dames and Moore 1999), the Draft Final Feasibility Study (DFFS, URS 2004), and other supporting documents. Section 3 of this appendix provides Agency comments on the terrestrial part of Intalco's ERA and describes modifications needed to use it as the basis for determining proposed cleanup levels during remedial design (RD).

CERCLA requires that information on the risks to human health and the environment be used to support the development, evaluation, and selection of appropriate response alternatives [40 CFR § 300.430(d)(1)]. Under CERCLA, potential risks at the Site are assessed through analysis of a number of factors, including:

- "The general characteristics of the waste, including . . . concentration, toxicity, propensity to bioaccumulate, persistence and mobility" [40 CFR § 300.430(d)(2)(iii];
- "Actual and potential exposure pathways through environmental media" [40 CFR § 300.430(d)(2)(v)]; and
- "Other factors, such as sensitive populations, that pertain to the site or support the analysis of potential remedial action alternatives" [40 CFR § 300.430(d)(2)(vii)].

Guidance for completing ERAs on CERCLA sites is presented in EPA (1997). Washington's Model Toxics Control Act (MTCA, Chapter 173-340 WAC) a potential applicable or relevant and appropriate requirement (ARAR) under CERCLA, provides independent cleanup authority for the state of Washington and prescribes the conduct of a terrestrial ecological evaluation to assure that the selected remedy is protective [WAC 173-340-7490 through -7494]. Intalco presented an ERA in Chapter 7 of the DRI, which described risks to aquatic and terrestrial species at the Site. However, the ERA presented in the DRI was not intended to establish soil cleanup levels on the basis of terrestrial ecological risk (see first paragraph of Appendix K of the DFFS). Acceptance of the DRI by the Agencies (Forest Service 2002a) was part of a complex exchange of documents with comments and responses (e.g., Forest Service 2001a). The Agencies deferred resolution of several issues pertaining to the terrestrial receptors for resolution after the DRI. However, Intalco did not adequately address these issues in either the DFFS or the NRDA injury determination (URS 2002a; Forest Service 2002b). Intalco attempted to evaluate preliminary soil values protective of terrestrial ecological receptors in Appendix K of the DFFS. This evaluation was incomplete as discussed in Hart Crowser (2005a). Intalco's subsequent response (URS 2005) did not provide adequately supported cleanup levels or completely identify the areas where cleanup is needed, as discussed in this appendix.

As discussed in the SFS, Washington's MTCA is an ARAR for the Site under CERCLA. The State of Washington is also exerting its independent cleanup authority under MTCA. To set proposed soil cleanup levels for the Site; the ERA must comply with the Terrestrial Ecological Evaluation Procedure in MTCA [WAC 173-340-7490 through -7494].

The main focus of this appendix is to present the reasons why Intalco's ERA is inadequate to determine: 1) whether soil cleanup levels can be modified from the proposed values based on MTCA Table 749-3; and 2) the extent of soil cleanup in areas of the Site that exceed these values. The Agencies also note that Intalco's ERA did not provide an adequate basis to establish surface water and sediment cleanup levels for protection of aquatic receptors. Proposed cleanup levels for protection of aquatic receptors are based on the National Recommended Water Quality Criteria (NWQC) as addressed in comments on the DFFS (Forest Service 2007a) and reports prepared by the U.S. Fish and Wildlife Service (USFWS 2004, 2005, and 2007c). Comments on sediments are presented in comments on the DFFS (Forest Service 2007a), in the SFS, and in Section 4.0 of this appendix.

2.0 Overview of Intalco's Terrestrial Ecological Risk Assessment

This section discusses the information presented and omitted from the DRI terrestrial ERA, and use of this information in the DFFS and subsequent analyses prepared by Intalco. The additional information and analyses needed to complete the terrestrial ERA is discussed in Section 3.

According to the DRI, Intalco's ERA was based on ecological receptors of concern for the Site that were selected according to the guild concept. This means one animal with a particular feeding habitat represents similar animals with the same feeding habitat. This concept assumes that if the selected receptor is protected, the entire guild is protected.

2.1 Terrestrial Receptors of Concern

For the terrestrial environment, Intalco proposed some invertebrates, birds, and mammals as potential receptors of concern. In the DRI, Intalco provided estimates of doses for these terrestrial receptors:

- Mule Deer;
- Deer Mouse;
- Shrew;
- Robin;
- American Dipper;
- Little Brown Bat;
- Osprey;
- Mink; and
- Red-Tailed Hawk

For these receptors, Intalco estimated doses based on Site-specific soil concentrations for potential constituents of concern (PCOCs).

In the DRI, Intalco also evaluated hazards to plants in general and earthworms, based on published toxicity benchmarks. Intalco did not include any insects or amphibians as receptors.

2.2 Potential Exposure Pathways and Constituents of Concern

The primary PCOCs for the Site are metals released from the abandoned mine, mine-related tailings, and waste rock.[3] Metals released from the source areas come into contact with ecological receptors through surface water runoff, groundwater (including seeps), direct contact, and air transport of particulates. For surface water, the potential exposure pathways for terrestrial ecological receptors are ingestion, or dermal or respiratory contact. Soil and tailings exposure pathways include ingestion by animals or uptake by plants growing in these areas. Animals can also gain exposure to PCOCs via the food web by ingesting plants, aquatic organisms, fish, and small mammals.

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[3] Additional constituents of concern including total petroleum hydrocarbons (TPH) are present in limited areas of the Site and represent a relatively smaller part of the overall risk to terrestrial ecologic receptors. The Agencies anticipate that MTCA Method A levels would be used for cleanup of these areas. The risk associated with TPH and PCBs is not addressed further in this appendix.

Terrestrial receptors may also be exposed to groundwater by ingestion, or dermal or respiratory contact where groundwater discharges as seeps, e.g., in the wetland east of TP-3, although this pathway was not evaluated by Intalco. Inhalation exposure pathways were not considered in the ERA, as Intalco contends that these pathways were not well characterized for ecological receptors and could not be accurately quantified (DRI Pages 7-51 and 7-52).

To identify PCOCs in soils, Intalco compared soil and tailings data for the Site with background data[4] and the Oak Ridge National Laboratory toxicological benchmarks for plants and earthworms. In the DRI, Intalco did not include any measurements of metal concentrations in plants present at the Site, and relied on published algorithms to estimate metals uptake and bioavailibility.[5] The plant-herbivore exposure pathway was addressed for two terrestrial species—mule deer and deer mice. Where the 95 percent upper confidence limit (UCL) for concentrations in soils exceeded background values and/or toxicological benchmarks, Intalco identified the metal as a PCOC. Soil PCOCs identified in the ERA included cadmium, copper, lead, and zinc.

Intalco included consumption of surface water in calculating the PCOC dose for mule deer, deer mice, mink, shrew, red-tailed hawk, robin, and bat. Intalco identified surface water PCOCs when the 95 percent UCL for metals in surface

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[4] Intalco compared soil concentration on site with both a Site-specific calculated background concentration (based on the 90th percentile of 20 samples) that Intalco referred to as "area background" as well as published natural background values (Ecology 1994). MTCA defines Area Background as concentrations of hazardous substances that are consistently present in the vicinity of a site due to human activities unrelated to releases at the site; and Natural Background as the concentration consistently present in the environment that has not been influenced by localized human activities. Intalco calculated background based on samples collected within the Railroad Creek Watershed, but outside of areas they suspected to be affected by mine activities associated with the Howe Sound Company and the Holden Mine. Although referred to in the DRI as "area" background samples, Intalco's calculated background values should probably be more properly referred to as calculated natural background concentrations, to distinguish them from Ecology's reported natural background concentrations. MTCA does not require cleanup below natural background concentrations [WAC 173-340-740(5)(c) and WAC 173-340-700(6)(d)].

[5] In the DRI, Intalco estimated concentrations of metals in plants using "biota uptake algorithms" attributed (apparently incorrectly) to Efroymson et al. (1997). The Efroymson reference addresses toxicity, not bioaccumulation.

water exceeded the NWQC for aquatic life. Surface water PCOCs that Intalco identified in the DRI included cadmium, copper, lead, and zinc. Intalco did not further evaluate aluminum, arsenic, barium, beryllium, chromium, iron, mercury, manganese, nickel, and silver because concentrations in surface water were below federal criteria[6] or because toxicity benchmarks are not available to evaluate toxicity (Dames & Moore 1999).

Intalco estimated doses to the selected receptors based on Site-specific soil concentrations for PCOCs in Holden Village, the maintenance yard and lagoon areas; the wind-blown tailings area east of the Village; and the surface and subsurface of the tailings piles.[7]

Intalco did not calculate doses to plants or earthworms at the Site. Intalco assumed the soil concentrations to be the dose received by these receptors.

2.3 Preliminary Risk Assessment

Intalco evaluated risk for the various ecological receptor species at the Site by determining the hazard quotient (HQ). For most receptors, Intalco used the 95 percent UCL, highest value, or in some cases the median value concentration at the Site to estimate the dose concentration compared to the appropriate toxicity reference value (TRV) for each PCOC, to determine the HQ.[8] Intalco determined a total risk for each receptor by summing the HQ for each exposure pathway.

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[6] Although Intalco says the exclusion was based on "federal criteria" in Section 7.2.3.2 of the DRI, the section earlier refers to criteria from Chapter 173-201A WAC.

[7] In URS (2005), Intalco modified the evaluation of PCOCs to include only samples from Holden Village, the Wilderness Boundary Area, baseball field, and the Lower West Area.

[8] In Section 7.2.4.1 of the DRI, Intalco said, "worst case exposures using the UCL or highest value were used as a screening technique to determine if risk was feasible under more ecologically realistic median exposure scenarios." Intalco opined that free roaming receptors (i.e., not invertebrates or plants) would more realistically be exposed to a range of conditions, and that "exposure to median concentrations are more ecologically realistic and representative. Even for benthic invertebrates and plants, the median concentrations are more indicative of conditions experienced by plant and animal populations in the local environment." Intalco estimated HQ values using doses based on UCL and median value concentrations for dusky shrew, American robin, and plants.

In the ERA, Intalco described risk to ecological receptors based on definitions established by the British Columbia Ministry of the Environment, Land and Planning, and noted that neither EPA nor Ecology had provided specific guidance on interpretation of HQs at the time the ERA was completed. In the DRI, Intalco defined risks as follows:

- HQ < 1 indicates "a small potential risk of adverse effects;"

- 1 < HQ < 100 indicates an "intermediate-risk of adverse effects;" and

- HQ > 100 indicates a "high risk of adverse effects."

Where Intalco identified risk using the UCL evaluation (referred to in the DRI as the "worst case") exposure concentrations, Intalco revised the risk assessment using median exposure concentrations (referred to in the DRI as "more probable").

Intalco did not sum HQ values obtained for different PCOC metals because Intalco reported in the DRI that there is insufficient evidence that metals act synergistically, and some evidence that metals act antagonistically.[9]

Based on the approach described above, Intalco identified the following:

- Concentrations of cadmium, copper, lead, and zinc in Holden Village, the lagoon and maintenance yard areas, and the tailings piles exceed the referenced toxicological benchmarks for plants;[10]
- Concentrations of cadmium, lead, and zinc produce HQs for earthworms that range from 1 to 10 in some areas of the Site; and exceed 100 for copper;

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[9] Synergistically means that the adverse effects of two or more metals in combination are equal to or greater than the adverse effect of either metal acting alone; whereas antagonistically means that the adverse effect of one metal would cancel out the adverse effect of another metal. There is contradictory scientific evidence to support both phenomena (e.g., Youn-Joo An et al. 2004), and it is generally more protective to assume the effects are synergistic.

[10] The DRI also indicated copper concentrations in part of the Site are phytotoxic compared to concentrations at "other mine sites where plants are successfully growing," but the citation (Beyer et al. 1985) refers to smelter sites and Intalco did not provide any information that would support using these data as relevant to conditions at the Site.

- Concentrations of cadmium, lead, and zinc in soils in the lagoon and maintenance yard areas and the tailings produced HQ values for robins (representing other potential avian receptors) that range from 1 to 20.
- Finally, the HQ for mink and red-tailed hawk (representing receptors that consume small insectivore mammals) exposed to cadmium in subsurface tailings and soils in the lagoon area are in the range from 1 to 10. The HQ for dusky shrews exposed to cadmium in the same areas ranges from 20 to 30.

2.4 Subsequent Analyses Prepared by Intalco

In July 2001, the Agencies provided detailed comments on Intalco's DRI. The Agencies separated their comments into categories such as: "insufficient information provided or available," and "the Agencies do not concur with Intalco's response." The Agencies deferred resolution of a number of issues related to terrestrial ecological receptors to a later stage of the process when the Agencies accepted the DRI (Forest Service 2001a and 2002a).

In February 2004, Intalco submitted the DFFS, including Appendix K titled, "Evaluation of Preliminary Risk-Based Cleanup Levels for the Protection of Terrestrial Ecological Receptors at the Holden Mine Site." Intalco intended this analysis to provide the basis for establishing soil cleanup levels protective of plants at risk from exposure to copper; earthworms (representative of other invertebrates) at risk due to cadmium, copper, and zinc; and robins (representative of avian receptors) at risk due to lead at the Site. It appears that Intalco eliminated further consideration of risk to mink, red-tailed hawk, and dusky shrew by focusing on "normally expected conditions" rather than "worst case" exposures described in the DRI.

In the DFFS, Intalco proposed soil cleanup concentrations that ranged from concentrations that would produce an HQ less than 1 to values that produced potential risk. The adjustment of the TRV or dose values presented in the DRI was not clearly explained or supported in some cases. The DFFS Appendix K included a number of deficiencies, as described by the Agencies (Hart Crowser 2005a). Intalco's response to the Agencies' comments (URS 2005) did not completely address concerns raised by the Agencies, and in some cases raised new questions, as discussed in Section 3 of this appendix.

At the time the DRI was prepared, neither EPA nor Ecology had established ecologically based screening levels for soils. Subsequently, Ecology amended MTCA regulations to include Table 749-3, Ecological Indicator Soil Concentrations for Protection of Terrestrial Plants and Animals. Table 749-3 provides concentrations that are protective of terrestrial receptors [WAC 173-

340-7493(2)(a)(i)]. In responding to Agency comments on the DFFS Appendix K, Intalco compared soil concentrations to the MTCA screening values (URS 2005).

For the 2005 analysis, Intalco identified barium, copper, molybdenum, and zinc as soil PCOCs. Cadmium and lead were identified as PCOCs in the DRI, but were omitted in 2005 because Intalco's 2005 analysis only considered areas of the Site that Intalco said were "not currently addressed under any of the remedial alternatives." The 2005 analysis considered soil samples only from Holden Village, the Wilderness Boundary area, baseball field, and Lower West Area (LWA). Intalco subsequently eliminated barium and molybdenum as PCOCs based on further analysis, and proposed soil cleanup values only for copper and zinc (URS 2005).

3.0 Agency Comments on the Holden Mine Ecological Risk Assessment and Work Needed

There are a number of problems with using the DRI as the basis for setting proposed soil cleanup levels, as described in Sections 3.1 through 3.7 below. To provide a basis for setting soil cleanup levels, the ERA must comply with the Terrestrial Ecological Evaluation Procedure in MTCA [WAC 173-340-7490 through -7494] and Environmental Protection Agency (EPA) Ecological Risk Assessment Guidance for Superfund (1997).

The Agencies reject Intalco's incorrect assertion in Section 3.1.8.3 of the DFFS that the Site is exempt from establishing potential soil cleanup levels to protect terrestrial ecological receptors; as discussed in the Agency comments on the DFFS, Forest Service (2007a).

Further, because the terrestrial ERA prepared by Intalco is incomplete, the Agencies reject Intalco's conclusion in the DFFS that "*there is no risk to most animals, plants and soil biota throughout a majority of the Site and only a low potential risk to select plants, soil biota and wildlife in limited Site areas.*" There is no basis for this statement, since Intalco failed to remedy deficiencies in the DRI (i.e., per the Agencies' Comments 2.1, 2.2b, 7.6, 7.7, 7.12, 9.2, 10.8; Forest Service 2001a).

Specific comments on the terrestrial ERA and modifications necessary to use revised ERA to set final soil cleanup levels at the Site are discussed below. These comments are divided into seven general categories for convenience in discussion. However, work needed to address problems identified in one category may also be applicable to other categories.

3.1 Incomplete Evaluation of PCOCs

Based on the DRI and DFFS, Intalco identified cadmium, copper, lead, and zinc concentrations at the Site that would cause risk to terrestrial receptors. Intalco's reanalysis (URS 2005) concluded that soil cleanup need only address copper and zinc. The Agencies disagree. All soil constituents exceeding Ecology's default values for protection of terrestrial receptors require cleanup unless eliminated based on consideration of a terrestrial ERA satisfactory to the Agencies.

3.1.1 Problems with the Work To Date

In the DRI, Intalco screened PCOCs to select constituents of concern (COCs) based on comparison of soil sample results from different portions of the Site with published toxicity data for plants and earthworms, and background concentrations. Intalco used two types of background concentrations: published regional background concentrations (Ecology 1994) and calculated background concentrations that Intalco referred to as area background concentrations.

As a result of the comparison process, Intalco eliminated eleven metals (aluminum, arsenic, barium, beryllium, iron, manganese, mercury, nickel, selenium, silver, and thallium) as soil COCs.

- Based on Table 7.2.3-3A of the DRI, Intalco excluded arsenic because the calculated background concentration exceeded the measured on-Site concentration.

- Intalco excluded aluminum, barium, beryllium, iron, and manganese based on the absence of earthworm or plant toxicity data for comparison. Intalco excluded chromium based on the absence of applicable Cr^3 toxicity data. Intalco excluded mercury because the measured on-Site concentrations did not exceed the cited toxicity data.

- Intalco excluded nickel, in error. Measured concentrations in tailings exceeded Intalco's reported toxicity benchmark for plants, as shown in DRI Table 7.2.3-3A, which Intalco cited to support the exclusion.

- Intalco excluded silver in the DRI text, although measured concentrations in soil and tailings exceeded Intalco's reported toxicity benchmark for plants in DRI Table 7.2.3-3A. Intalco reported that silver was excluded because no "primary toxicity value" is available.

- Intalco gave no reason for excluding selenium and thallium. These metals were not shown in DRI Table 7.2.3-3A, which was cited to support the text.

- Finally, Intalco's DRI screening process did not address molybdenum or uranium, though these metals were detected on the Site and should have been considered.

Based on the DRI screening process, Intalco selected only the metals cadmium, copper, lead, and zinc as COCs.

As previously mentioned, the MTCA was amended, including the addition of Table 749-3, Ecological Indicator Soil Concentrations for Protection of Terrestrial Plants and Animals [WAC 173-340-900], subsequent to publication of the DRI. Table 749-3 provides a basis for eliminating hazardous substances from further evaluation. However, where concentrations on the Site exceed the values in Table 749-3, MTCA requires further evaluation to demonstrate that the hazardous substances do not pose a threat to ecological receptors at the Site, or in the absence of such a showing, remediation may be appropriate. Table E-1 shows DRI concentrations in soils from various parts of the Site compared to the calculated and published natural background values, and proposed cleanup levels based on MTCA Table 749-3.

A footnote at the bottom of MTCA Table 749-3 indicates that a hazardous substance with no soil value presented in the table shall have plant and soil biota indicator concentrations based on a literature survey conducted in accordance with WAC 173-340-7493(4). Methods that can be used for developing wildlife and plant indicator concentrations for a hazardous substance not listed in Table 749-3 (e.g., aluminum) are presented in MTCA Tables 749-4 and 749-5. Intalco has not provided such an analysis. Therefore, it is not clear whether Intalco's proposed cleanup levels (based on a limited number of constituents) would produce a remedy that is protective with respect to other constituents present at the Site.

Intalco revisited the PCOC screening (URS 2005) using soils data from some areas of the Site "where potential exposure pathways for terrestrial ecological receptors may remain following remedy implementation," i.e., areas that were not addressed by the DFFS Alternatives 2 through 8 (including subalternatives). The approach presented by Intalco in URS (2005) avoids developing proposed soil cleanup criteria for the parts of the Site that are notably contaminated (e.g., the mill, maintenance yard, lagoon area, tailings piles, etc. The result is there is no basis to determine whether a proposed cleanup action in these areas is protective, since these areas may contain constituents of concern that are not present in the less-contaminated areas that Intalco used for its analysis. The following table summarizes results of the analysis presented by Intalco (from Tables 1a through 1d, URS 2005).

Area	Approximate Area in Acres	Number of Soil Samples	Results
Holden Village[11]	10	15	95% UCL exceeded Intalco's calculated area background and the MTCA screening criteria for aluminum[12], copper, molybdenum[13], and zinc.
Wilderness Boundary	Indeterminate	2	95% UCL exceeded Intalco's calculated area background and the MTCA screening criteria for copper, molybdenum[13], and zinc.
Baseball Field	3.5	2	95% UCL exceeded Intalco's calculated area background and the MTCA screening criteria for copper and zinc.
Lower West Area	12	3	95% UCL exceeded Intalco's calculated area background and the MTCA screening criteria for arsenic, copper and zinc.[14]

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[11] Intalco reported different UCL values for several hazardous substances in the DRI and URS (2005). It is not clear which values are correct.

[12] Intalco excluded aluminum because the Site concentration was below Ecology's published background concentration, and lower than the EPA ecological soil screening level (Eco-SSL, see http://www.epa.gov/ecotox/ecossl/) or is non-toxic. EPA reports that the total aluminum concentration is not correlated with toxicity to plants or invertebrates, but that soluble aluminum sometimes is. The DRI did not include measurements of soluble aluminum, and Intalco has not provided any assessment to show whether soluble salts of aluminum are present and whether this is a problem.

[13] Intalco incorrectly excluded molybdenum, although the UCL exceeded the MTCA plant screening value, stating that "site soils are fully vegetated" and because Intalco did not identify any phytotoxicity field reports for molybdenum. Efroymson et al. (1997) and Chatterjee and Nautiyal (2001) suggest the evidence for phytotoxicity is mixed, and therefore, to be acceptable to the Agencies, Intalco must further evaluate the risk due to molybdenum.

[14] Intalco excluded arsenic, although the UCL exceeded the MTCA plant screening value based on "the lack of arsenic bearing minerals in the ore body." Intalco also referred to the natural occurrence of arsenic in background soils, although arsenic measured in the

Intalco's 2005 reanalysis did not include mercury or selenium, and did not include development of wildlife indicator concentrations for hazardous substances not listed in the MTCA Tables.

Intalco's 2005 reanalysis did not address the wind-blown tailings area that extends over approximately 70 acres east of Holden Village, and north and east of TP-2 and TP-3. Comparing the results provided in the DRI Table 7.2.3-3A for the wind-blown tailings area with the current MTCA ecological risk screening criteria indicates that the soil concentrations in the wind-blown tailings area exceeded Intalco's calculated background and one or more ecological screening criteria for barium, copper, lead, molybdenum, silver, and zinc.[15]

The Agencies initially accepted Intalco's contention that a new ERA conforming to the February 2001 MTCA amendments "would not produce substantially different results from the DRI" (Forest Service 2003). However, the analysis presented above shows that some constituents, which were screened out in the DRI, should have been analyzed as required under MTCA for the purpose of developing proposed cleanup levels.

The DFFS only considered cleanup levels for the four constituents of concern (cadmium, copper, lead, and zinc) identified in the DRI. Intalco subsequently used the 2005 analysis to eliminate cadmium and lead as constituents of concern, by only considering areas of the Site where there are low concentrations of these substances. The use of limited areas (rather than the Site as a whole) enabled Intalco to avoid developing proposed soils cleanup levels for areas of the Site that have concentrations of some constituents that exceed screening levels, but which are not present in the areas Intalco evaluated in 2005. As a result, Intalco's analysis does not show whether soil cleanup is needed in areas such as the wind-blown tailings area north of Railroad Creek, or the LWA. Soil cleanup in these areas is not addressed in any of the alternatives proposed by Intalco.

LWA exceeded both Intalco's calculated background and Ecology's published background concentration.

[15] Based on the small sample size, the reported 95% UCL values for the wind-blown tailings area are not statistically valid, e.g., the reported UCL value for zinc is greater than any individual sample value. Typically, in such cases Intalco substituted maximum values. Intalco did not take enough samples to quantify the nature and extent of the contamination in this area.

Intalco asserted (URS 2004 and 2005) that analysis of the tailings piles relative to soil cleanup levels is not needed. Intalco also said the state's limited purpose landfill regulations (Chapter 173-350 WAC) are potential ARARs. However, concentrations in the tailings exceed terrestrial ecological screening levels. Therefore, closure of the tailings must satisfy the final closure cover requirements for limited purpose landfills [WAC 173-350-400(3)(e)]. Or, the terrestrial ERA may be used to demonstrate that an alternative cover is protective of terrestrial receptors.[16] Specifically this would include protection of burrowing animals, invertebrates, plants with roots in the tailings, and animals that graze on such plants. Intalco notes (Section 7.1.2.1 of the DRI) that subsurface tailings samples were not used in the risk assessment because "there is no reasonably foreseeable exposure." Although Intalco presented soil concentrations for both surface and subsurface tailings (Table 7.2.3-3A of the DRI), it did not discuss the depth of the samples that were included in either category, and did not discuss the results relative to the point of compliance for protection of terrestrial ecological receptors.

Table E-1 shows the tailings exceed background concentrations and proposed cleanup levels for aluminum,[17] barium, cadmium, copper, lead, mercury, molybdenum, selenium, silver, thallium, and zinc.

3.1.2 Additional Work Needed

Intalco cannot exclude PCOCs by focusing on limited areas of the site "where potential exposure pathways for terrestrial ecological receptors may remain following remedy implementation," unless the DFFS specifically evaluates the efficacy of the alternatives in eliminating those potential pathways. Since the DFFS did not address the point of compliance for soils, and did not include the default cover for the tailings piles for most alternatives, cleanup levels need to be established for all constituents of concern, and the remedy must include all affected areas of the Site.

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[16] Provided, of course, that the alternative cover is also protective of human health.

[17] Although the aluminum concentrations in Table E-1 (based on MTCA Table 749-3) are for soluble salts, EPA (2003) reports that soils with pH values below 5.5 indicate aluminum may be soluble and, therefore, toxic. Intalco reported pH values below 5.5 are typical in the tailings piles (URS 2002b); thus conditions that produce aluminum toxicity may exist in the tailings.

To justify excluding PCOCs with concentrations that exceed the screening values (MTCA Table 749-3), requires additional analysis. PCOCs that require additional analysis would at least include aluminum, arsenic, barium, cadmium, copper, lead, mercury, molybdenum, selenium, silver, and zinc. Although Intalco's 2005 reanalysis proposed cleanup levels for cadmium, copper, lead, and zinc, this analysis was inadequate to justify any cleanup levels that exceed the values in MTCA Table 749-3. Therefore, these constituents would need to be included in the additional terrestrial ERA to support any different cleanup levels. Where indicator concentrations are not provided in MTCA Table 749-3, (e.g. the table does not include concentrations protective of soil biota or wildlife for aluminum and silver; and does not provide concentrations protective of soil biota for barium and molybdenum); additional assessment is required by footnote b of MTCA Table 749-3.

Proposed methods for closure of the tailings piles must be shown to be protective (i.e., address all issues such as the uptake of cadmium by plants and effect on browsing deer) unless the closure satisfies the presumptive cover requirements of WAC 173-350-400(3)(e)(ii).

Any decision to not clean up discrete areas of the Site (e.g., the wind-blown tailings area), must be based on a statistically valid number of samples.[18]

3.2 Reliance on the Assertion That Metals Do Not Act Synergistically

In the ERA, Intalco did not sum HQ values obtained for different PCOC metals because Intalco reported in the DRI that there is insufficient evidence that metals act synergistically, and some evidence that metals act antagonistically (Comment 7.12, Forest Service 2001a). However, some studies show that metal additivity does occur in some cases, and failure to sum HQ values may underestimate risks to terrestrial ecological receptors. When accepting the DRI, the Agencies deferred the issue of chemical interaction to the NRDA (Comment 7.12, Forest Service 2001a). Although the Agencies expected that Intalco would address chemical interaction as part of the NRDA process concurrent with the feasibility study, the results should also have been used in the risk assessment. However,

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[18] For example, the total number of samples combined for the ballfield, LWA, and the Wilderness Area boundary are substantially less than the minimum number MTCA requires (20) for determining statistically acceptable background concentrations [WAC 173-340-709(4)]. This is an insufficient number overall, especially since Intalco analyzed these areas separately (URS 2005).

Intalco did not adequately address this issue in either the injury determination (URS 2002a) or the DFFS.

3.2.1 Problems with the Work to Date

Potential risk to ecological receptors is complicated since some metals act antagonistically (interfering), additively (cumulatively), or through potentiation (strengthening). Metals that act antagonistically tend to compete with or displace toxic metals, whereas metals that act additively tend to accumulate and react with other metals. Metals that act through potentiation tend to have stronger effects in the presence of other metals. Unless soil conditions and site-specific data are presented to the contrary, additivity is generally assumed (Federal Register 1986). Intalco cites studies (see Comment 7.12, Forest Service 2001a) that support the idea that metal toxicity is not additive. However, these studies are based on aquatic receptors, not terrestrial receptors.

Some studies show that metal additivity occurs, with adverse affects such as species richness and community composition, at concentrations far below individual metal chronic values (e.g., Jonker et al. 2004 and Sharma et al. 1999). As described above in Section 2.0 of this appendix, Intalco refers to a HQ > 10 and <100 as an intermediate risk. However, the addition of two chemicals of intermediate risk does not necessarily produce a HQ of <100; and failure to sum HQ values is not a protective assumption.

In several cases, the reported individual HQs for PCOCs eliminated from further assessment exceed the level warranting further assessments. The error of omitting these constituents from the process of setting cleanup levels is compounded where multiple PCOCs (which may include COCs that were inappropriately screened out) may act synergistically.

3.2.2 Additional Work Needed

If it is to be used to establish cleanup levels and screen PCOCs, the terrestrial ERA needs to evaluate the effects of multiple constituents that individually yield a HQ >1, to clarify whether the combined HQ values pose a risk to ecological receptors in portions of the Site that would not otherwise be cleaned up. This approach is consistent with provisions of WAC 173-340-7493(7)(f)(iii).[19]

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[19] WAC 173-340-7493(7)(f)(iii) is potentially relevant and appropriate because the Site meets the criteria for conducting a site-specific terrestrial ecological evaluation [WAC 173-340-7491(2)(a). The Site is located on, or directly adjacent to, an area where

Metals have also been shown to act synergistically in some plant studies (Youn-Joo An et al. 2004). Synergistic effects on phytotoxicity also need to be considered in evaluating cleanup levels that exceed the indicator concentrations for plants in MTCA Table 749-3.

3.3 Inadequate Characterization of Potentially Affected Populations

Intalco based the proposed soil cleanup levels in part on exposure assumptions described as "normally expected conditions," but the information provided to assess the effects on wildlife and other potential receptors is incomplete. The Agencies accepted the DRI on the assumption that Intalco would provide additional information in areas identified as deficient in the Agencies' comments (Forest Service 2001a). In some cases Intalco has not provided this additional information, and this omission may affect implementation of the cleanup at the Site. For example, most of the alternatives include removal of soils with hazardous substances in the lagoon area; however, Intalco has not identified the extent to which wildlife use this area, or the depth or lateral extent of cleanup in this area (Comment 7.8, Forest Service 2001a). Another example involves uncertainty over the location and effects of ferricrete and flocculent deposition in Railroad Creek (Comment 10.8); Intalco did not address control of both physical and chemical pathways for most of the alternatives in the DFFS, and did not use this for distinguishing between remedial alternatives.

Additional on-Site observations and studies of wildlife usage at the Site would provide useful information for determining toxicological risks to wildlife, such as 1) which species are present at the Site, 2) how these species use the Site, and 3) their duration of exposure.

3.3.1 Problems with the Work to Date

Problems with characterization of potentially affected populations fall into four categories as discussed below.

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management or land use plans will maintain native vegetation (e.g., forestlands). In addition, the Site includes riparian and other areas designated as environmentally sensitive by the Forest Service (in accordance with the Wenatchee National Forest LRMP, see Forest Service 1990), and the Site is used by sensitive, threatened, and/or endangered species (USFWS 2007b).

3.3.1.1 There is Incomplete Information on Wildlife that may be Affected by the Cleanup

Intalco's terrestrial biota survey for the DRI was limited because it occurred during one week in the fall of 1997, and was very general (Comment 7.12, Forest Service 2001a). Intalco did not conduct a wildlife population study that would account for seasonal effects on population levels due to changes in the season. While surveys performed during the fall provide an opportunity to document migrating species in the area, breeding populations may be eliminated from consideration as receptors.

The Agencies also took issue with Intalco's statement in the DRI that surveys should only be required if ground-disturbing activities are proposed in areas of potential habitat. The Agencies believe that wildlife surveys need to be completed in all areas potentially impacted by releases, to identify areas that might need remedial action (Comment 2.2b, Forest Service 2001a).[20] In the DRI, Intalco states that Dames & Moore (1996) reported that U.S. Fish and Wildlife Service had determined "there are no listed or proposed threatened or endangered animal species in the Railroad Creek area." However, the U.S. Fish and Wildlife Service's Chelan County current species list documents gray wolf *(Canis lupus)*, showy stickseed *(Hackelia venusta)*, Wenatchee Mountain checker-mallow *(Sidalcea oregana* var. *calva)*, bald eagle *(Haliaeetus leucocephalus)*, bull trout *(Salvelinus confluentus)*, Canada lynx *(Lynx canadensis)*, grizzly bear *(Ursus arctos horribilis)*, marbled murrelet *(Brachyramphus marmoratus)*, northern spotted owl *(Strix occiddntalis caurina)*, and Ute ladies' tresses *(Spiranthes diluvialis)* as endangered or threatened (USFWS 2007b). Portions of Chelan County (which includes the Site) are also designated as critical habitat for northern spotted owl, Canada lynx, and checker-mallow (USFWS 2007b).

The USFWS has not ruled out the potential for bull trout in Railroad Creek (Kelly-Ringel 2004). In addition, the Forest Service survey data and reports identify paired spotted owls within the Railroad Creek valley, and suitable nesting habitat

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[20] Intalco responded by citing an Agencies' letter (Forest Service 2001b) that said the Agencies agreed the surveys are not required for completion of the Remedial Investigation process, and proposed completion of one set of surveys after selection of the remedy. Surveys by the Forest Service have been ongoing, and will need to be completed by the time of the ROD.

is present within the Holden project area (Lenz 2007).[21] The current Interagency Conservation Agreement documents the area as occupied habitat for lynx (Forest Service 2006). Railroad Creek valley lies within the North Cascades Grizzly Bear Ecosystem, a recovery territory (USFWS 1993). Bald eagles are documented within the area around the Lucerne Bar and Domke Lake (Lenz 2007). Foraging opportunities for bald eagles are anticipated to increase as water quality and habitat conditions for fisheries improve in Railroad Creek (Krupka 2007).

To avoid adverse effects of the cleanup action, wildlife surveys need to be performed in all areas potentially impacted. The floodplain downstream of the anticipated remediation may support sensitive, rare, threatened, or endangered species, such as *Spiranthes diluvialis*, which could be affected by the remedial action. While the USFWS generally does not require surveys under Section 7 of the Endangered Species Act, if no surveys are performed, occupancy at a site is assumed (Krupka 2007).

Based on the limited terrestrial surveys, the Agencies acceptance of the DRI was based, in part, on the expected future performance of additional on-site observations and studies (Comment 2.1, Forest Service 2001a), which have not been completed to date.

3.3.1.2 The ERA did not include some potentially significant receptors for the Site

Intalco did not include any amphibians as receptors. Intalco eliminated amphibians based on the statement in the DRI (Dames & Moore 1999) that available data indicate that amphibians are less sensitive than salmonid fish. Based on this statement, Intalco assumed that amphibians would be protected by the TRVs used for salmonids. However, amphibians, such as frogs or salamanders, are appropriate receptors for addressing concerns related to

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[21] The sources noted, (Dames & Moore 1996, Lenz 2007, USFWS 2007a) use terms such as “area,” “Railroad creek valley,” and “territory” to refer to the location where listed species may be present. While these terms are somewhat imprecise, all three sources were writing in the context of remediation at the Site; therefore, it is reasonable to assume that all the species discussed in this and related paragraphs may exist at the Site. Also, although the bald eagle was removed from the list of threatened or endangered species in 2007, it is still protected under the Bald and Golden Eagle Protection Act, so it was retained in this discussion.

groundwater and surface water interactions, as well as terrestrial habitat (e.g., in the wetland east of TP-3).

Intalco did not analyze a true terrestrial insectivore or an omnivore that could feed on potentially high metal foods, such as insects or fungi.

The Agencies' DRI comments also noted that the ERA omitted several guilds, such as small- to medium-sized herbivores, avian herbivores (e.g., blue grouse), and carnivores (e.g., coyote, cougar, or other rare but potentially present species) that eat species, such as grouse, hares and deer (Comment 7.8, Forest Service 2001a). The Agencies noted that additional studies are needed to provide adequate representation of these guilds.

In Table 7.2.2-4 of the DRI, Intalco identifies grasses and forbs as a receptor representing primary producers; however, Intalco did not provide an analysis of grasses and forbs in the DRI. In the DRI, Intalco provides a general discussion of plants but does not address specific plant species or vegetative types (e.g., forbs, grasses, shrubs, and trees), which serve as a significant source of food for certain species at different times of the year. For example, trees and shrubs are a primary source of food for mule deer during fall and winter, whereas grasses and herbs provide food during the spring and summer.

3.3.1.3 The ERA did not fully address effects on some receptors at the Site

Other problems with characterization of risk to potential receptors include:

- The analysis of risk to mule deer presented in Section 7.2.4 of the DRI is based on TRVs for cadmium, copper, lead, and zinc, provided in Table 7.2.3-4B of the DRI. An analysis based on lethal doses (TRVs) may not adequately address effects on reproduction and toxicity to soft-tissue organ (e.g., kidney). These areas of potential toxicity are of concern, particularly for cadmium. This concern is also applicable for the analysis of other receptors.

- In the DRI, Intalco analyzed deer mice as herbivores, even though Table 7.2.2-4 of the DRI identified deer mice as omnivores. Intalco cited results from a study by Beyer et al. (1985), which indicated that fruiting bodies (e.g., berries) and seeds had lower concentrations of metals than the leaves of four species of Pennsylvanian berries tested (DRI, Dames & Moore 1999). Intalco's analysis failed to consider seasonal preference of specific plant parts, such as seeds, which are a major food source during the fall and winter months (Lenz 2007). In addition, Intalco's analysis assumed a diet of 100 percent plant matter, when larvae and insects provide a major food source for deer mice during the spring and summer months. Thus the deer mice may not adequately represent other small mammals at the Site.

- Intalco compared toxicity benchmarks and TRVs to median values of soil concentrations rather than 95 percentile values, and made other adjustments to create what it referred to as "reasonable exposure scenarios." In some cases adjustments were made because data collected in the lagoon area and maintenance yard were too limited to enable a complete analysis (e.g., for mink, red-tailed hawk, dusky shrew, and robin).

- In the DFFS, Intalco did not use appropriate values from the wildlife exposure model in MTCA. For example, Table 7 of Appendix K utilizes a gut absorption factor of 1 for robins for cadmium, lead, and zinc. MTCA Table 749-5 provides default values of 20, 11.3, and 131, respectively. Intalco did not provide any justification for not using the default values.

3.3.2 Additional Work Needed—Potential Receptors

To rely on a terrestrial ERA to establish cleanup levels for the Site, additional work would be needed to address the problems described above. This additional work is outlined below.

3.3.2.1 Better characterization of wildlife that may be affected by the cleanup

RD needs to include additional on-site observations and studies of wildlife usage of the Site to evaluate existing toxicological risks to wildlife and the impact of remedy implementation on wildlife. To be acceptable to the Agencies, the studies must determine: 1) which species are present at the Site at different times of year, 2) how these species use the Site, and 3) their durations of exposure. The scope of characterization surveys would be determined during RD. These surveys need to be consistent with the baseline studies outlined in the Conceptual Monitoring Program (to evaluate effectiveness of the remedy), presented in Appendix H of the SFS.

Completion of acceptable surveys may enable selection of appropriate species that could then be used in an acceptable terrestrial ERA to modify the proposed cleanup levels (currently based on MTCA screening levels). Results of surveys are also needed to assure that the cleanup action adequately considers the protection of listed species and habitat within the project area.

3.3.2.2 Addition of potentially significant receptors for the Site

The ERA must include all potentially significant receptors for the Site. These include:

- Addition of an amphibian receptor to address concerns for the wetland areas where the terrestrial receptors are impacted by groundwater discharge;
- Addition of a terrestrial insectivore, and an omnivore likely to feed on potentially high metal foods;
- Guilds not represented in the ERA including small- to medium-sized herbivore, avian herbivores, and carnivores; and
- An analysis of the effect of metals on grasses and forbs that are primary sources of food for wildlife (see discussion below in Section 3.4).

3.3.2.3 Modify the ERA to fully address effects on receptors

The ERA must fully address the issues raised in Section 3.3.1.3, including:

- Effects on wildlife reproduction and toxicity to soft-tissue organs, (particularly for cadmium) for mule deer and other receptors.

- Seasonal preference and use of plant parts for all herbivorous and omnivorous receptors.

- Compare toxicity benchmarks and TRVs to the 95 percent UCL values as required by MTCA, rather than the median soil concentrations, or provide justification acceptable to the Agencies for use of median values. Provide references to support the selective modification of exposure scenarios for mink, red-tailed hawk, dusky shrew, and robin; or other justification acceptable to the Agencies for relying on limited data in the lagoon and maintenance yard areas.

- Use MTCA default values or provide a justification acceptable to the Agencies for using other values in the Wildlife Exposure Model.

3.4 Insufficient Assessment of Risk to Plants

The Agencies commented that the DRI provided insufficient detail to assess the appropriateness of comparing soil concentrations for the Site with the two other mine sites, where Intalco indicated plants were reported to be "growing successfully" (Hart Crowser 2005a). Further, the DRI provided no information to distinguish effects of toxicity on plants from other factors that may limit plant growth, such as lack of moisture or other "physical qualities of the substrate"

(DRI Section 7.2.4.1). MTCA requires characterizing existing or potential threats to terrestrial plants exposed to hazardous substances [WAC 173-340-7490(1)(a)(ii)].

3.4.1 Problems with the Work to Date

In the DRI, Intalco identified soil concentrations in Holden Village, the surface and subsurface of the tailings piles, the lagoon, and maintenance yard areas exceeding the reported TRV for plants. The TRV was based on the Oak Ridge National Laboratory (ORNL) plant toxicity benchmarks (Efroymson et al. 1997). Soils and tailings at the Site exceeded these benchmarks for several metals, including cadmium, copper, lead, nickel, silver, and zinc, see Table E-1.

Soil concentrations at the Site exceed screening level concentrations for plants shown in Table 749-3 of the MTCA regulations for aluminum, arsenic, barium, copper, lead, molybdenum, and zinc. Concentrations in tailings exceed the same screening level values for aluminum, barium, cadmium, copper, lead, mercury, nickel, silver, and zinc.

However, except for copper, Intalco concluded that there was no risk to plants from these metals, largely by comparing the concentrations measured on Site to soil concentrations reported for “other mine sites where plants were successfully growing” (Beyer et al. 1985). However, Intalco did not provide any information to assess the appropriateness of comparing Site soil concentrations with the other mines.

In the DRI, Intalco cites Forest Service studies at Holden, and in particular, Zabowski and Everett (1997) that indicate 1) the presence of extractable copper and zinc should not cause toxicity for plants; and 2) that concentrations of cadmium, copper, nickel, and zinc were not sufficient to cause adverse effects on alder or lupine. However, Intalco does not document the PCOC concentrations in soils and tailings that were studied (i.e., how these concentrations compare to the range of metals concentrations measured for the DRI). Also, Intalco does not discuss whether pore water concentrations in the soils or tailings are phytotoxic.

The very limited plant cover on the tailings piles, roughly 15 years after placement of the soil/gravel cover, strongly suggests phytotoxicity despite findings of the Zabowski and Everett (1997) study cited by Intalco in the DRI. It is untenable for Intalco to rely on the Zabowski and Everett study and to indicate that other habitat considerations, e.g., available moisture, may be limiting plant growth, without undertaking sufficient analyses to distinguish potential toxicity effects from other factors at the Site.

Washington's landfill closure regulations require a self-sustaining vegetative cover (as well as other performance requirements). Potential phytotoxicity of the tailings will need to be addressed in designing the cover to satisfy this requirement, especially if the cover does not conform to the presumptive final closure cover requirements [WAC 173-350-400(e)(ii)].

Finally, Intalco does not mention distressed vegetation in areas of stained soils that is observable in the wetland downgradient of seeps east of TP-3.

3.4.2 Additional Work Needed

The ERA must determine what soil cover and revegetation of the tailings and waste rock piles would be acceptable, if the final cover does not meet the presumptive closure requirements for limited purpose landfills.

An ERA is also required to support any cleanup levels different from the MTCA screening criteria for plants. This ERA will need to include further analysis to determine: 1) impacts on local species and community richness, and 2) whether areas of the Site can support the plant species present on comparable uncontaminated sites in the Railroad Creek drainage.

Reference to studies such as Zabowski and Everett (1997) needs to document the metal concentrations in the soils and tailings that were studied and determined not to cause toxicity to plants, and compare these to the range of concentrations measured at the Site. To be acceptable to the Agencies, an expanded terrestrial ERA would need to include analyses to distinguish toxicity effects from other factors that may limit plant growth on the tailings piles and other areas of the Site.

Further analysis is needed in other areas of the Site with metals concentrations above proposed cleanup levels, even though some of these areas are vegetated. To justify not taking active remedial measures in areas such as Holden Village and the wind-blown tailings area, the ERA needs to demonstrate plants are not adversely affected. Potential adverse effects that must be considered include effects on growth and species diversity.

3.5 Incomplete Assessment of Terrestrial Exposure Pathways

The ERA is not suitable for establishing soil cleanup levels because it does not adequately address the potential pathway of plant uptake of metals, or the effects on animals that browse on the plants.

3.5.1 Problems with the Work to Date

In the DRI, Intalco does not adequately address the potential effects on animals that browse on plant cover in areas of impacted soils. Intalco did not measure metal concentrations in plants at the Site. The Zabowski and Everett (1997) study cited in URS (2005) is not suitable for this purpose, as described later in Section 3.7.3.1. In the DRI, Intalco estimated concentrations of metals in plants using "biota uptake algorithms" attributed (apparently incorrectly) to Efroymson et al. (1997).[22]

In the DRI, Intalco evaluated risk to mule deer and deer mice browsing on the Site. The process used to calculate the dose to the animals grazing on plant cover is not described.

- The dosage prediction for mule deer from plants presented in DRI Table 7.2.3-12 and the dose prediction for deer mice in Table 7.2.3-13 apparently rely on the algorithms for plant bioaccumulation in Table 7.2.3-10, which implies that there is only one algorithm per metal for all plants. It is unclear what plant species is/are addressed by the algorithm, or whether this algorithm is consistent with MTCA [WAC 173-340-7493(3)(c)].[23] Since many terrestrial species ingest a variety of plants in different quantities and plants can bioaccumulate metals at different rates and levels, there may be potential effects on the browsing community pathway, and/or other receptors that were not, but should have been, addressed in the DRI.

- Bioaccumulation of metals in plant material, such as willow, influence browsing pathways. Plants that are able to tolerate and accumulate metals may also concentrate them, thus delivering higher doses to browsers. It is unclear whether the affect of bioaccumulation is addressed in the algorithm Intalco used in the DRI.

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[22] The Efroymson reference addresses toxicity, not bioaccumulation. In the DRI, Intalco notes that concentration of metals in plants and earthworms were estimated as shown in Table 7.2.3-6, but this table presents TRVs for the Little Brown Bat.

[23] Subsequently, in Appendix K of the DFFS, it appears that Intalco modified some of the Wildlife Exposure Model parameters (MTCA Default values) without justification. For example, the cadmium gut absorption factor that Intalco used for the robin is 1 (see Table 7 of DFFS, Appendix K) whereas MTCA uses a value of 20 (see MTCA Table 749-5).

To be acceptable to the Agencies, the terrestrial ERA pathways must include plant uptake (considering plant species that would be expected at the Site, depth of root penetration, and transport of metals to the surface) to determine availability of metals through direct plant consumption or cycling of metals in the litter layer into other plants and/or consumers. The terrestrial ERA must also consider tolerance, and sequestering, as well as consumption of the plant material by animals (browsing species and/or species that transport metals from inaccessible areas).

In the DRI, Intalco identifies earthworms as surrogate receptors for soil biota. In the DFFS, Intalco indicates that the majority of earthworm species assessed in literature review based analysis are exotic species, not native to the Pacific Northwest. The Agencies concur with the comment in URS (2005) that earthworms are an appropriate component of a terrestrial risk assessment. Intalco provided data for some earthworm species that may not be relevant to the Holden Site. Intalco could have overcome potential questions on relevance of the study it cited, if they had provided site-specific quantification of the dose to and response of soil biota using site-specific bioassays or site-specific bioavailibility studies.

In the DRI and DFFS, Intalco also noted that other conditions at the Site, such as soils with low organic matter content and low pH, might limit the establishment of earthworms, rather than toxicity effects. The DRI concluded that the lack of adequate habitat reduced the importance of earthworms as a receptor pathway in some parts of the Site. However, the Agencies note that all the proposed alternatives for cleanup include removal or capping of soils above cleanup levels in both the lagoon and maintenance yard areas. Therefore, the ERA needs to address potential effects on earthworms following implementation of the cleanup in these areas. Further, the ERA must consider areas with better existing terrestrial habitat, such as within Holden Village, the wind-blown tailings area, the wetland downgradient (east) of TP-3, and the ballfield.

Species that could or do occur at a site are ecologically relevant. While the URS literature review did not reveal documentation of native earthworms and adequate earthworm habitat, it is likely that both are present at the Site and could be adversely impacted by metal concentrations. This must be addressed in order to rely on a terrestrial ERA to set soil cleanup levels at values higher than the MTCA Screening levels.

In the DFFS, Intalco identifies the American robin as a surrogate receptor and the only wildlife species used to set cleanup levels. While the American robin eats earthworms, a variety of other species, including moles, frogs, snakes, fish species, shrew, and other birds, also prey on earthworms. Given the wide range of terrestrial species that use the Site for feeding, breeding, and shelter, Intalco's analysis of effects on the food chain limited to plant toxicity, earthworms, and robins, is not sufficient to set soil cleanup levels.

3.5.2 Additional Work Needed

Additional work is required to address the problems described above, before the terrestrial ERA can be relied on to establish cleanup levels for the Site.

- Seasonal preference and effects of consumption of plant parts on herbivorous receptors need to be addressed. The ERA must quantify the effects of metals uptake by plants at the Site, with focus on vegetative species consumed by all types of wildlife present or likely to use the Site. The ERA must address the potential effects on animals that browse on plant cover in areas of impacted soils (e.g., a willow/grouse pathway), using one of the methods allowed under MTCA [WAC 173-340-7493(3)]. These effects need to include plant uptake, tolerance, sequestering, and consumption.
- If the ERA relies on non-site-specific relationships, Intalco must justify use of the algorithm for plant bioaccumulation for the dose predictions for mule deer and deer mice. Non-site-specific references need to be specific to variations in plant materials ingested by terrestrial species at the Site.
- The ERA needs to examine the plant-animal receptor pathway, focusing on metals bioaccumulation in plant materials ingested by terrestrial species at the Site.
- The ERA needs to identify some means to assess effects on soil macroinvertebrates that do not rely on studies of exotic earthworm species that may not be relevant. The ERA needs to consider earthworms as a receptor pathway in areas that contain better terrestrial habitat, and not just the tailings piles, maintenance yard, and lagoon area.

3.6 Points of Compliance

In the DRI and the DFFS, Intalco did not discuss the point of compliance for soil cleanup. The standard point of compliance for soil cleanup is a depth of 15 feet, but MTCA allows a conditional point of compliance for soils to be based on protection of terrestrial ecological receptors [WAC 173-340-7490(4)]. Metal concentrations in the surface and subsurface portions of the tailings and waste rock piles need to be considered as sources of hazardous substances to plants, macroinvertebrates, and burrowing animals, as well as other receptors that feed on them. Closure of the tailings and waste rock piles needs to satisfy the presumptive closure requirements for limited purpose landfills, unless Intalco can show that the proposed closure is protective within the depth to a point of compliance acceptable to the Agencies [WAC 173-340-740(6) and WAC 173-340-7490(4)].

Concentrations in subsurface tailings that exceed potentially toxic levels were described in the DRI as "inaccessible" to terrestrial receptors under current exposure conditions. However, Intalco did not discuss the depth or other conditions that distinguished accessible (near-surface) and inaccessible soils or tailings. The Agencies have observed during numerous Site visits (including test pits, erosion repairs, etc), that conditions at the Site do not preclude burrowing animals or plant roots from contacting subsurface soils or tailings across the Site.

The point of compliance for soils is potentially relevant and appropriate for protection of terrestrial receptors exposed to tailings and waste rock, unless the tailings and waste rock piles are closed in accordance with the presumptive final closure cover requirements specified in WAC 173-350-400(3)(e)(ii). Soil cleanup levels must be achieved at the point of compliance for soils in all other areas of the Site.

3.6.1 Problems with the Work to Date

Intalco collected and analyzed surficial or near-surface samples of soils and tailings for the DRI. However, in many areas of the Site, Intalco did not analyze any soil samples deeper than 1 to 2 feet below the surface. For sites with institutional controls, MTCA allows a conditional point of compliance to be set at a depth of 6 feet, which is assumed to be below the biologically active zone. Ecology may approve a site-specific depth that is more appropriate for the Site, based on considerations listed in WAC 1730340-7490(4)(a).

Setting a point of compliance shallower than 6 feet at Holden would require additional work to characterize soils throughout the biologically active zone, and to show that the biologically active zone is less than 6 feet and could be expected to stay that way.

3.6.2 Additional Work Needed

The ERA needs to be modified if Intalco wishes to use it to seek a conditional point of compliance for soils that is less than 6 feet in depth, or less than 15 feet in any area where institutional controls are not provided. For purposes of the ROD, proposed cleanup levels must be achieved at the required point(s) of compliance. During RD, Intalco will have the opportunity to use the ERA to determine the depth and extent of soil cleanup, in accordance with requirements of WAC 173-340-7490(4)(a). Based on results of that analysis, the agencies may modify the remedy decision in the form of an ESD, or ROD

Amendment, depending on the extent of the modification. The new ERA should address risks to burrowing animals, soil macroinvertebrates, and plants; as well as the effect of deep-rooted plants as a metals uptake pathway to other terrestrial receptors.

3.7 Other Problems with Ecological Evaluation Procedures Used by Intalco

This section discusses several problems with the evaluation that Intalco used to develop or support proposed soil cleanup levels, and describes additional work needed to develop cleanup levels, other than the MTCA screening values, for protection of terrestrial receptors.

3.7.1 Selection of Values for the Lowest Observed Adverse Effect Level (LOAEL)

MTCA requires the lowest LOAEL be used to set TRVs [WAC 173-340-7493(4)]. Intalco did not use the lowest LOAEL for soil biota for any of the metals.

3.7.1.1 Problems with the Work to Date

The DFFS analysis selects screening values for effects on soil invertebrates using the 20th percentile of rank-ordered adverse effects concentrations, from published scientific literature.[24]

Intalco cited Suter et al. (2000) as a justification for its approach. Suter et al. indicates that the EC20 is considered to be the point where appreciable effects on a population might be seen, depending on population dynamics. The selection of the 20th percentile of data is not acceptable based on MTCA requirements. MTCA [WAC 173-340-7493(4)(a)] requires selection of the relevant LOAEL as a toxicity reference value or soil concentration that is protective. Selection of a TRV, as required under MTCA, would reduce the metals concentrations considered protective compared to the values selected by Intalco.

[24] The 20th percentile rank of the data is the concentration that results in an effect on 20 percent of the organisms in a test, and is also referred to as the effective concentration 20 percent (EC20).

3.7.1.2 Additional Work Needed

The TRVs need to be recalculated using the lowest relevant LOAELs for all metals, as required by MTCA.

3.7.2 Selection of Risk-Based Soil Values

As described in WAC 173-340-7493(3), MTCA allows several alternative approaches to a site-specific terrestrial ecological evaluation, including use of a literature survey of protective soil concentrations.

3.7.2.1 Problems with the Work to Date

The soil cleanup values proposed by Intalco for copper and zinc are substantially higher (by a factor of about 10 times) than values developed for comparable mining sites (CH2M Hill 2001). Intalco previously proposed cleanup levels, based in part on results of literature reviews. It is appropriate to consider the results of studies accomplished to develop soil cleanup levels for sites, such as the mines in the Coeur d'Alene region of Idaho. Analyses by others, where relevant, may be used to develop cleanup levels [WAC 173-340-7493(3)(a)].

URS and CH2M Hill, as consultants to EPA, proposed Preliminary Remediation Goals (PRG) for soil and wildlife for the Coeur d'Alene Basin. A National Academy of Science (NAS) review concluded that these PRGs were protective (CH2M Hill 2001). The Coeur d'Alene Basin PRGs for protection of terrestrial biota were 10 mg/kg for cadmium, 100 mg/kg for copper, and 106 mg/kg for zinc (EPA 2002). The approaches used to develop these values are consistent with MTCA procedures and screening values. In contrast, the soil cleanup values that Intalco proposed for the Site are 455 mg/kg for copper, and 1,122 mg/kg for zinc. Intalco did not find that cadmium was a COC in soils at the Site.

Any analysis that proposes alternative soil cleanup values at the Site should explain why such values differ from the Coeur D'Alene values, or risk-based values from other comparable sites.

3.7.2.2 Additional Work Needed

If proposed soil cleanup values exceed the MTCA ecological screening values, the terrestrial ecological evaluation should demonstrate, by using the methods of WAC 173-340-7493 or other Agencies-approved method, that the proposed levels are appropriate. While PRGs accepted by EPA at comparable sites may or may not be appropriate for the Site, there should be a clear justification of differences.

3.7.3 Bioavailibility of Metal Salts in Soil and Tailings

In the DRI, Intalco's assessment of bioavailibility of metals was incomplete and not well supported by technical literature.

3.7.3.1 Problems with the Work to Date

In the DRI, Intalco's Site evaluation did not specifically consider the form of metals in soils and tailings at the Site. Metals exist as various salts and in different oxidation states. The form or state can greatly influence the bioavailibility, toxicity, and transport of the metal.

In the DRI, Intalco assumed that relatively insoluble sulfide salts "probably form the bulk of the metal salts still found at the site" and reduced the calculated bioavailibility factor for soils ingested by wildlife. Intalco did not provide any basis for its conjecture that the form of metal in soils and tailings are the same as in the parent ore. However, Intalco did not consider that alteration of the oxidation state and form by mining activities and subsequent changes in conditions, such as chemical oxidation of sulfide minerals could increase bioavailibility of metals in soils or tailings compared to the original ore. To be accepted, Intalco's assumption must be supported by Site data or technical literature for studies under comparable conditions.

Total metal concentrations measured for the DRI are not good predictors of the bioavailibility fraction of the metal in the soil. Many different laboratory extraction techniques have been evaluated to determine a correlation between extractable metals and the bioavailibility fraction, but the results do not reliably predict availability of the metals to ecological receptors. Bioassays may provide an indication of bioavailibility and where these have been conducted, the best correlation of a laboratory metals extraction method to bioassays has been with a weak electrolyte solution such as $Ca(No_3)_2$; (Conder and Lanno 2000, Lebourg et al. 1998, and O'Connor 1988). However, bioassay results are not always consistent, and even electrolytic analyses are just correlations to toxic response and do not represent a direct quantification of bioavailability fractions.[25]

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[25] Results of bioassays may vary since adverse effects on organisms may depend on the rate of metals accumulation, not just the total amount of metals. MTCA allows several alternatives to bioassays for assessing protective soil concentrations [WAC 173-340-7493(3)].

In the DRI, Intalco cited a study by Zabowski and Everett (1997) as indicating that metals on the Site were not readily bioavailable. The Zabowski and Everett study on plant growth used the diethylene triamine pentaacetic acid (DTPA) extraction procedure. This procedure is designed to evaluate the free fraction of trace metals. It is not designed to evaluate high metal concentrations such as those present at the Site. DTPA extraction has shown only a weak correlation (r^2 = 0.39 to 0.68) with bioavailability and uptake, and the regression relationship is highly dependent on soil conditions (Conder and Lanno 2000). Thus, the results Intalco relied on do not provide a good indicator of bioavailibility.[26]

DTPA may become “saturated” (i.e., not extract any more metals) at high metal concentrations, thus yielding an incorrect low bioavailibility value for soils or tailings with relatively high metals contents. While the DTPA extraction may accurately measure low concentrations of metals in studies of plant nutrition, it not a good measure of the bioavailability of metals present at concentrations that may be toxic to plants and/or soil invertebrates.

Intalco has not identified a surrogate that would accurately evaluate bioavailibility of potentially toxic concentrations of metals in soils at the Site. In the absence of studies based on comparable conditions at other sites, bioassays are the best option for determining the bioavailibility of toxic metals in soil.

The TRVs used by Intalco in the DRI may underestimate metals toxicity on the Site. Some of the same factors that contribute to poor plant growth; low pH and low organic matter (Tan 1994) contribute to increased bioavailibility (Newman 1998). It is difficult to determine the causative factor when poor growing conditions occur at sites that also have elevated metal concentrations. Site conditions, such as low pH and low organic matter content, increase metals bioavailibility above concentrations reported in typical soil toxicity test conditions. Metal toxicity in soil and tailings at the Site may be exacerbated by otherwise poor soil conditions but this was not addressed in the ERA.

3.7.3.2 Additional Work Needed

If proposed soil cleanup values exceed the MTCA ecological screening values, the terrestrial ecological evaluation should re-evaluate the bioavailibility of metals. The analysis should use Agency-approved method(s) that conform to

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[26] MTCA includes a number of requirements for literature surveys [WAC 173-340-7493(4)] that are not satisfied by the Zabowski and Everett (1997) reference cited in the DRI.

WAC 173-340-7493(3) and are appropriate for the high metals concentrations present at the Site.

3.7.4 DRI Interpretation of Hazard Quotients

Intalco's interpretation of HQ values is not consistent with conventional risk assessment practices.

3.7.4.1 Problems with the Work to Date

An HQ value is an attempt to quantify the risk from non-carcinogens to humans or ecological receptors, based on the ratio of the exposure point concentration to a toxicity reference value. In general, a HQ of 1 or greater represents a potential risk to ecological receptors.

HQs are calculated using TRVs based on toxicological studies, which produce a dose response curve; as the dose increases, the response generally increases. The slope of the dose response curve varies greatly between chemicals. The curve of the dose response and an assessment of the summed effects on a particular organ system or metabolic function are needed to properly interpret the meaning of the HQ value.

Intalco reported that HQ > 1 and < 100 represented an intermediate risk and HQ < 1 represented a small potential risk. However, in conventional risk assessment practice, an HQ > 1 indicates a potential ecological effect, and the burden of proof shifts to the risk assessor to show that an adverse effect is not occurring (EPA 1997).

It is not acceptable to simply dismiss HQ values around 1 as a "low risk," not requiring a cleanup action. Intalco did not consider the slope of the dose response curve or other factors influencing the environmental impact of the HQs that are much greater than 1 (i.e., up to 30 as noted in Section 2.3 of this appendix). By using an inappropriate interpretation of the HQ, Intalco dismissed potential risk to ecological receptors, without conducting appropriate additional evaluations (EPA 1997).

3.7.4.2 Additional Work Needed

If proposed soil cleanup values exceed the MTCA ecological screening values, Intalco must accomplish appropriate analysis for HQ values > 1 as contemplated in EPA (1997), to establish appropriate cleanup values to protect terrestrial receptors.

3.7.5 Sampling and Analysis of Waste Rock

The estimated volume of waste rock piles at the Site is approximately 350,000 cubic yards. In the DRI, Intalco did not analyze the potential effects of the exposed waste rock piles, although seeps discharging below the waste rock piles exceed aquatic life protection criteria by factors ranging from ten to more than a thousand.

3.7.5.1 Problems with the Work to Date

In the DRI, Intalco did not include any sampling and analyses, or published data indicating whether the waste rock piles pose any potential risk to terrestrial ecological receptors, even though Intalco demonstrated in the DRI that these piles potentially adversely affect aquatic receptors.

The cleanup alternatives proposed by Intalco neither provided for capping all the waste rock piles nor considered other means of protecting terrestrial ecological receptors from exposure to the waste rock.[27]

3.7.5.2 Additional Work Needed

The selected remedy must close all waste rock piles in accordance with ARARs, and to be protective of potential ecological receptors. Depending on the remedy selected, this may require additional studies to determine the bioavailibility of metals in the waste rock piles to terrestrial receptors.

3.7.6 Soil Sampling and Analysis Required to Delineate the Extent of Soil Cleanup Required

Additional sampling and analysis of soils will be needed during RD or remedy implementation to delineate the soil cleanup required to protect terrestrial receptors.

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[27] Alternative 7 includes a partial cap for the main East and West Waste Rock Piles, and Alternative 8 includes consolidation of these waste rock piles into the tailings pile prior to capping. However, none of the alternatives addressed potential exposure of terrestrial receptors to the Honeymoon Heights Waste Rock Piles.

3.7.6.1 Problems with the Work to Date

The sampling and analysis of soils that Intalco conducted did not adequately delineate the extent of soil cleanup required. Additional soil sampling and analysis are needed to better characterize the extent of areas where cleanup must occur. Additional soil sampling and analysis are also needed to complete characterization of areas where some existing data indicate soil concentrations exceed proposed cleanup levels, but the data are not necessarily representative of the area as a whole.

Comparison of the new characterization results with cleanup levels would determine whether action is required, and what that action would be for the following areas:

- Wind-blown tailings area;[28] and
- Lower West Area (LWA).[29]

Additional sampling and analysis are also needed to determine the cleanup required in areas where visual observations indicate soils likely exceed proposed cleanup levels as a result of mining, erosion, or other contaminant transport processes, including:

- Ventilator portal detention area;
- Abandoned mill building;
- Area east of the Holden Village sauna and along the Copper Creek Diversion;
- Beneath and downslope of areas where tailings or waste rock are removed as part of the remedy;
- Area between Tailings Pile 1 and Tailings Pile 2; and
- Wetlands east of Tailings Pile 3.

Sampling and analysis are also needed to determine the remediation needed (removal or capping of soils above proposed cleanup levels) in areas with soils above proposed cleanup levels. It is anticipated that these areas will include:

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[28] Additional samples are needed in the wind-blown tailings area because Intalco analyzed only five soil samples within an area of about 70 acres.

[29] Additional samples are needed in the LWA because Intalco analyzed only three existing soil samples within an area of about 12 acres.

- Maintenance yard; and
- Lagoon area.

3.7.6.2 Additional Work Needed

Better data are needed to clarify whether the reported concentrations are representative (e.g., in the wind-blown tailings area). Additional characterization data during RD, and/or confirmation sampling and analysis during implementation of the remedy are needed to define limits of the cleanup action. Sampling and analysis must conform to an Agencies-approved work plan.

4.0 Notes on Sediments in Railroad Creek

As noted previously, the USFWS addressed problems with Intalco's analysis of risk to aquatic receptors based on surface water quality. Although not directly related to terrestrial ecological risk assessment issues that are discussed above, the following notes document the need for further Railroad Creek and Lake Chelan sediment quality assessment following elimination of sources of metals releases.

In the DRI, Intalco indicates that sediment PCOCs at the Site include arsenic, cadmium, copper, iron, manganese, nickel, silver, and zinc. In the ERA, Intalco compared metal concentrations in Railroad Creek sediment to the low effects range values (tenth percentile) reported for marine and estuarine sediment quality in a single study (Long et al. 1995). Intalco eliminated aluminum because Long et al. did not provide a value for comparison. While Intalco stated in the ERA that marine and estuarine sediment criteria were selected over freshwater sediment guidelines because the marine and estuarine guidelines are based on a much larger database, the Agencies note that the current regional freshwater sediment quality guidelines (Corps of Engineers et. al. 2006), prepared by a group of state and federal agencies (including Ecology and the EPA),[30] provide a more appropriate comparison. Also, Intalco did not address sediment values at the Lucerne Bar in the DRI because additional studies were ongoing at the time the DRI was published.

Metal concentrations of sediments in Railroad Creek exceed the 2003 freshwater sediment quality guidelines (FSQG) published by Ecology for

[30] The current freshwater sediment quality guidelines (Corps of Engineers et al. 2006) supersede the freshwater SQVs reported by Avocet (2003), which were summarized in the NRRB report (Hart Crowser 2005b).

aluminum, beryllium, cadmium, chromium, copper, iron, silver, and zinc. Metal concentrations of sediments at the Lucerne Bar in Lake Chelan (near the mouth of Railroad Creek) exceed FSQG for cadmium, copper, iron, and zinc.

Intalco conducted bioassays on Lucerne Bar sediment in 2001 and 2002. The 2001 results were inconclusive. The 2002 results identified minor adverse effects on aquatic organisms. Provided the remedial action eliminates the sediment sources, the Agencies believe these adverse effects are neither severe enough nor widely distributed enough to require an active sediment cleanup (Forest Service 2003). Following elimination of the sources of metals released into the creek, the removal of ferricrete, and the natural redistribution of sediments in the creek system, the Agencies contemplate additional tests to determine whether the proposed approach to sediment is protective of aquatic organisms.

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Table E-1 - Comparison of Background Concentrations and Proposed Cleanup Levels to Soil Concentrations on the Site

Hazardous Substance (Concentrations in mg/kg)	Reported Background Concentration (Ecology 1994)	Calculated Background Concentration	Proposed Soil Cleanup Level for Protection of Terrestrial Plants and Animals, based on MTCA Table 749-3 [b]			Soil Concentration [a]								
			Plants	Soil Biota	Wildlife	Holden Village [c,e]	Tailings Pile 1 [c]	Tailings Pile 2 [c]	Tailings Pile 3 [c]	Subsurface TP-1, TP-2 & TP-3 [c,d]	Wind-blown Tailings Area [c]	Wilderness Boundary [e]	Baseball Field [e]	Lower West Area [e]
Aluminum (soluble salts) [f]	33,400	20,900	50			22,400	**39,000**	**38,000**	**44,000**	16,800	21,900	17,500	20,300	16,500
Antimony			5											
Arsenic III					7									
Arsenic V	5.13	11.6	10	60	132	3.4	5.5	2.94	2.2	3.08	2.8	11.4	10.8	**22**
Barium		310	500		102	**380**	**860**	**1,060**	**687**	**864**	**388**	93.1	101	70.9
Beryllium	1.57	0.2	10			0.26	0.1	0.2	0.2	0.2	0.2	0.2	0.2	
Boron			0.5											
Bromine			10											
Cadmium	0.93	5.41	4	20	14	1.54	4.51	**10.90**	1	**147**	0.58	3.1	1.3	3.9
Chromium (total)			42	42	67	34.3	11.3	19.1	24	**62**	29	27.8	29.4	25.9
Cobalt			20											
Copper	26.5	57.4	100	50	217	**311**	**442**	**287**	**274**	**16,500**	**319**	**147**	**63**	**255**
Fluorine			200											
Iodine			4											
Lead	11	20.6	50	500	118	**61.4**	**118**	**83**	**77**	**91**	**62**	37	15	13
Lithium			35											
Manganese	1,100	1,420	1,100		1,500	627	470	430	458	315	280	455	537	401
Mercury, inorganic	0.05		0.3	0.1	5.5	0.08	**0.35**	**0.25**	**0.27**	**0.13**				
Mercury, organic					0.4									
Molybdenum			2		7	**5**	**28**	**25.9**	**28.7**	**22.4**	**31.7**	**2.4**	1	
Nickel	45.9	22.7	30	200	980	21.1	4	4.7	6.6	**52.2**	27.8	17	18	14
Selenium			1	70	0.3		**28**	**17.9**	**17.1**	**15.4**				
Silver		0.49	2			2	**3**	**2.5**	**2.6**	**3.8**	**2.8**	0.6	0.5	0.3
Technetium			0.2											
Thallium			1			0.35	**1.2**	0.74	0.86	**3**		0.6	0.6	
Tin			50											
Uranium			5							3		4	2	
Vanadium			2											
Zinc	78.7	253	86	200	360	246	238	**255**	**745**	**2,750**	**509**	**303**	129	**346**

Notes

a. Soil concentration shown for each area is 95th percentile upper confidence limit (UCL), or maximum value where sample population is too small or data distribution prevents UCL from being meaningful. All data from Dames & Moore (1999) or URS (2005), rounded to three significant figures.
b. Where value not shown, MTCA requires it be based on value determined in accordance with WAC 173-340-7493(4), notes for MTCA Table 749-3, and MTCA Tables 749-4 and 749-5.
c. Data from DRI (Dames & Moore 1999) Tables 7.2.2-1E, 7.2.2-1F, and 7.2.3-3A. Missing value not reported.
d. Subsurface sample data combined in DRI for the three tailings piles.
e. Values from URS (2005) where not reported in DRI. Note URS (2005) value that differs from DRI not shown.
f. Concentration on Site for total aluminum, concentration of soluble salts not addressed in DRI.
g. Bold value exceeds background concentrations and one or more proposed cleanup levels.

APPENDIX F
CONCEPTUAL DESIGN EVALUATION FOR COLLECTION, CONVEYANCE, AND TREATMENT OF IMPACTED GROUNDWATER

Conceptual Design Evaluation for Collection, Conveyance, and Treatment of Impacted Groundwater
Holden Mine Site
Chelan County, Washington

Prepared for
Forest Service

September, 2007
4769-11

APPENDIX F
CONCEPTUAL DESIGN EVALUATION FOR COLLECTION, CONVEYANCE, AND TREATMENT OF IMPACTED GROUNDWATER
HOLDEN MINE SITE
CHELAN COUNTY, WASHINGTON

EXECUTIVE SUMMARY

A significant contamination issue at the Holden Mine Site (Site) is the release of hazardous substances to groundwater from the mine workings, tailings piles, and waste rock piles. The groundwater then carries the contamination to Railroad Creek, where the hazardous substances adversely impact aquatic biota. Several remedial alternatives propose to remediate groundwater contamination at the Site to eliminate adverse surface water impacts by: 1) collecting the contaminated groundwater before it reaches the creek; 2) conveying the contaminated groundwater to a treatment facility; 3) treating the contaminated groundwater to remove the hazardous substances; and 4) discharging the treated water to Railroad Creek. This report evaluates the conceptual design for groundwater collection, conveyance, and treatment for Alternative 10. Alternative 10 has number of elements that are common to other alternatives. These include:

- Groundwater collection and conveyance to the treatment system;
- Anticipated performance of the treatment system;
- Operation and maintenance issues including iron fouling; and
- Sludge management.

A unique feature of Alternative 10 is a partially penetrating barrier (PPB) for groundwater containment that distinguishes it from other alternatives. The Agencies'[1] evaluation of the PPB is included in Section 4 and Attachments A and B of this report.

The Agencies used this conceptual design evaluation of Alternative 10 to assess Alternative 10 and other alternatives in the Supplemental Feasibility Study (SFS,

[1] The Agencies refers to the USDA Forest Service, Washington State Department of Ecology, and the U. S. Environmental Protection Agency acting jointly on this project.

Forest Service 2007).[2] This report provides a level of detail not included in the Draft Final Feasibility Study (DFFS, URS 2004a) for Alternatives 1 through 8, or for Intalco's Alternative 9 (URS 2005) that was developed following completion of the DFFS. The Agencies developed Alternative 11 to address areas where existing information does not show that Alternative 10 would satisfy requirements for a final remedy.

Alternatives 9, 10, and 11 have the same type of groundwater treatment system, and will face many of the same operational issues (e.g., effect of winter freezing on treatment system operations, long-term sludge management). Although Alternatives 9, 10, and 11 differ in the location and extent, and to some degree in the methods of collecting and conveying groundwater, the discussion herein provides a useful frame of reference for comparing these alternatives. As a result, the Agencies have not prepared stand-alone appendices to duplicate this conceptual evaluation for other alternatives. Rather, the Agencies have discussed the particular aspects of each alternative in the SFS, making reference to this report where appropriate.

This conceptual design evaluation was prepared as an engineering tool to help address design, construction, operation, and cost issues associated with groundwater treatment at the Site. Information presented herein was considered in assessing the primary balancing criteria for remedy selection under CERCLA [40 CFR 300 § 430(f)(1)(i)(B)].[3] While this report discusses engineering issues related to remedy selection criteria under CERCLA and MTCA, the actual criteria evaluations are presented in the SFS.

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[2] This report focuses on the collection, conveyance, and treatment of groundwater. This report does not address other aspects of Alternative 10 or other alternatives, such as closure of the tailings and waste rock piles.

[3] These CERCLA criteria include long-term effectiveness; reduction of toxicity, mobility, and volume of hazardous substances through treatment; short-term effectiveness; implementability; and cost of the alternatives. Information presented herein is also relevant to assessing some aspects of the MTCA remedy selection criteria [WAC 173-340-360], most notably the analyses related to determining whether an alternative uses permanent solutions to the maximum extent practicable [WAC 173-340-360(3)].

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APPENDIX F
CONCEPTUAL DESIGN EVALUATION FOR COLLECTION, CONVEYANCE, AND TREATMENT OF IMPACTED GROUNDWATER
HOLDEN MINE SITE
CHELAN COUNTY, WASHINGTON

1.0 INTRODUCTION

This report (Appendix F to the SFS) describes the conceptual design evaluation prepared for the groundwater collection, conveyance, and treatment components that are part of Alternative 10 for remediation of the former Holden Mine Site (Site). The Site location is shown on Figure F-1. Principal site features and components of Alternative 10 are shown on Figure F-2.

Alternative 10 was formerly identified as the Agencies' Proposed Remedy [APR]. The conceptual design evaluation for Alternative 10 was prepared to provide a basis for assessing feasibility; to address engineering issues associated with design, construction, and operation; and to support cost estimates. The Alternative 10 design evaluation and cost estimates provide a basis for better understanding other alternatives that are evaluated in the Supplemental Feasibility Study (SFS, Forest Service 2007).

This report begins with a description of the major features of the groundwater treatment system for Alternative 10. Briefly, groundwater (including surface seeps) will be collected via gravity flow in collection ditches along the south side of Railroad Creek, and conveyed to a treatment influent pump station, located east of Tailings Pile 3 (TP-3). Site water will be pH-adjusted in a one- or two-stage process to reduce solubility and enable precipitation to remove hazardous substances including aluminum, cadmium, copper, iron, lead, and zinc. Following pH adjustment, the influent water will be aerated to increase oxygen concentrations, oxidize soluble ferrous iron to less soluble ferric iron, and promote precipitation of iron and other metals. Treatment will generally be accomplished within large ponds, where metal hydroxide sludge will accumulate as settling occurs. The effluent water will be polished by sand filtration. Equilibration of the treated water with atmospheric carbon dioxide during sand filtration will decrease effluent pH and will likely satisfy National Pollution Discharge Elimination System (NPDES) discharge limits for pH. However, further pH adjustment prior to discharge and/or other treatment steps could be added to the basic process described above, if needed, to meet discharge criteria as discussed in this report.

Engineering considerations associated with each of the treatment system components are described in this report. Additional points addressed in this report include operational maintenance of the treatment system, estimation of the volume of water treatment sludge that would be produced, and issues affecting on-Site sludge disposal. Anticipated treatability and effluent concentrations are described based on a brief literature review of other treatment studies for acid mine drainage and acid rock drainage (AMD and ARD, respectively).[4] Detailed supporting analysis pertaining to Site hydrology, potential iron fouling associated with groundwater collection and treatment, performance of groundwater barriers, and treatment system effluent considerations are presented in Attachments A through D.

1.1 Background

The Site is located in the Railroad Creek valley on the eastern slopes of the Cascade Mountains in Washington State, approximately 11 miles upstream (west) of Lake Chelan. The Site is situated within the Wenatchee National Forest and is surrounded on three sides by the Glacier Peak Wilderness Area. Conditions at the Site are described in the Draft Remedial Investigation (DRI, Dames & Moore 1999). Groundwater is discharged into Railroad Creek, as baseflow, seeps, and drainage from the abandoned mine.[5] Groundwater discharging to Railroad Creek contains hazardous substances at concentrations exceeding criteria for protection of aquatic life. Measured concentrations of hazardous substances in groundwater vary over the course of the year and

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[4] Acid rock drainage (ARD) refers to acid drainage from exposed waste rock and tailings on the ground surface, whereas acid mine drainage (AMD) refers to acid drainage from the underground mine workings. ARD/AMD are generated from weathering (e.g., chemical oxidation) of sulfur- and iron-bearing materials exposed in the underground mine openings, waste rock piles, and tailings piles. This oxidation generates low pH (i.e., acidic) drainage with high concentrations of metals (EPA 2001).

[5] Seeps occur where groundwater flows to the land surface and becomes surface water. Thus, seeps are surface water expressions of groundwater, and hazardous substance concentrations measured in seeps are indicative of hazardous substance concentrations in the groundwater that is the source of the seep. Hereafter, when groundwater is discussed, it is implicit that groundwater includes seeps. Water from seeps may flow overland a short distance before entering Railroad Creek or reinfiltrating into the groundwater. Groundwater also enters Railroad Creek directly as baseflow through the bottom and sides of the stream channel.

seasonally[6] exceed acute[7] toxicity criteria by factors of up to 75 times for aluminum, 500 times for cadmium, 9,400 times for copper,[8] 3 times for lead, and 840 times for zinc. Measured concentrations of hazardous substances in groundwater seasonally exceed chronic toxicity criteria by factors of up to 640 times for aluminum, 2,200 times for cadmium, 9,400 times for copper, 520 times for iron, 83 times for lead, and 940 times for zinc. Sources of hazardous substances in Site groundwater include the releases from the mine, waste rock piles, tailings piles, and other areas impacted by mine operations, as discussed in the DRI.

Conceptual design evaluations are based on representative spring and fall flow conditions measured on the Site as part of the DRI. Intalco submitted a Draft Final Feasibility Study (DFFS; URS 2004a) in February 2004. The DFFS presents

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[6] Concentrations vary seasonally due primarily to the effect of spring snowmelt and runoff. Flow in Railroad Creek is generally low from late summer through winter; monthly average stream flow is below about 45,000 gallons per minute (gpm) at Lucerne. Peak flows in Railroad Creek occur during the months of May and June coinciding with snowmelt in the basin, with average monthly stream flow rates ranging from about 230,000 to 280,000 gpm at Lucerne. As used in this document and related documents, spring conditions refer to the May – July period approximately 90 days long when snowmelt causes relatively high groundwater levels, and relatively high flow conditions in Railroad Creek. Fall conditions represent the other 275 days per year (August – April) typified by lower groundwater levels and relatively low flows in Railroad Creek.

[7] Acute toxicity criteria identify concentrations of hazardous substances that are fatal to organisms exposed to these levels for a short period of time. Chronic toxicity criteria identify concentrations of hazardous substances that are fatal to organisms exposed to these levels for a long period of time. Chronic toxicity criteria are lower than acute toxicity criteria. Exceedances of acute toxicity criteria indicate a greater need for expediency in implementing remedial actions or the need for expedient implementation of interim actions because even short periods of exposure to these levels may be fatal. Post-remediation concentrations must generally be at or below chronic toxicity values to be protective.

[8] Comparisons to the surface water, aquatic life toxicity criteria for copper are based on background values of copper in surface water at the Site. To date, not enough information has been collected at the Site to establish the acute and chronic ecological toxicity criteria for copper in surface water. The surface water aquatic toxicity criterion for copper is discussed in more detail in the SFS.

and comparatively evaluates a range of eight remedial alternatives, and additional sub-alternatives, for the Site. Intalco proposed that the DFFS alternative designated 3b, be selected as the remedy for the Site. After detailed review of the alternatives presented in the DFFS, the Agencies determined that none of the DFFS alternatives would meet CERCLA and MTCA threshold criteria for selection of a permanent remedy. The Agencies proposed consideration of an interim cleanup action (Alternative 10, formerly referred to as the Agencies' Proposed Remedy [APR]) that incorporated elements of some of the DFFS alternatives (Hart Crowser 2005c).[9] Intalco subsequently presented another alternative, designated as Alternative 9 (URS 2005). Alternative 9 is similar to Alternative 3b but also includes collection and treatment of some TP-1 seeps and groundwater from four pumped wells located on TP-1. The Agencies have since developed Alternative 11, as discussed in the SFS.

Most of the alternatives considered include some collection and treatment of groundwater to reduce concentrations of metals in Railroad Creek. The purpose of the evaluation discussed in this report is to provide additional information needed for evaluation of alternatives. This evaluation is presented in the context of Alternative 10, but is relevant to the other alternatives that include collection and treatment of groundwater.

1.2 Organization of this Conceptual Design Report

The remainder of this report is organized as follows:

- Section 2 provides an overview of the main components of the Alternative 10 conceptual groundwater collection, conveyance, and treatment system;
- Section 3 describes the conceptual water treatment system components and operations;
- Section 4 describes collection and conveyance of groundwater for treatment;

[9] In evaluating alternatives for the Site, the Agencies considered an interim remedial action that would address some of the significant sources of contamination, but that would not be designed to meet all applicable, relevant, and appropriate cleanup standards. Such an interim action must not exacerbate site problems and must not interfere with the final remedy, and must be followed within a reasonable time by complete measures that attain ARARs. (55 Fed Reg 8747 March 8, 1990). An interim remedy would necessitate further investigation resulting in future delays in implementing the final response action, while creating uncertainties regarding protectiveness and implementation timeframes.

- Section 5 discusses design elements that the Agencies anticipate evaluating further during remedial design and/or after startup of the treatment system;
- Attachments A and B present additional detail on hydrologic modeling accomplished to evaluate the PPB for Alternative 10;[10]
- Attachment C summarizes some case history information on iron fouling at other active and abandoned mine sites; and
- Attachment D is a memorandum prepared for the Agencies that compares estimated treated water quality to discharge criteria and provides an estimate of the upper-bound dilution factor for a mixing zone allowed under Chapter 173-210A WAC.

2.0 SUMMARY OF THE ALTERNATIVE 10 GROUNDWATER REMEDIATION COMPONENTS

Clean up of the Site includes collection and treatment of groundwater that exceeds proposed cleanup levels, from the following sources:

- Shallow groundwater that would otherwise enter Railroad Creek or Copper Creek as baseflow;
- Groundwater that currently discharges from the Main 1500 Level Portal; and
- Groundwater that is expressed as seeps at the ground surface at a number of locations across the Site. Some of the seeps are seasonal or ephemeral, and flow only in the spring and early summer.

The constituents of concern at the Site include the following metals: aluminum, cadmium, copper, iron, lead, and zinc. Other constituents of concern (e.g., petroleum hydrocarbons) are associated with areas subject to source controls or other cleanup actions and, therefore, are not anticipated to require water treatment.

Alternative 10 includes a number of remedial elements related to collection, conveyance, and treatment of groundwater that is above proposed cleanup levels. These elements alone are not sufficient to clean up the Site, but would be combined with other components of Alternative 10 that are discussed in the SFS as part of a comprehensive remedy. Elements of Alternative 10 related to groundwater include the following.

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[10] Attachment A refers to the groundwater barrier as a partially penetrating cutoff (PPC) whereas the SFS and other documents generally refer to the same barrier as a partially penetrating barrier (PPB).

- Installation of hydrostatic bulkheads in the main 1500 Level and ventilator portals to contain and control flow from the mine. The mine drainage would be conveyed in a pipeline for treatment. The DFFS proposed an alternative of using equalization pond(s) outside the mine, rather than bulkheads to control flow, which would be further evaluated during remedial design (RD).

- Construction of a groundwater barrier wall/collection ditch system to reduce discharge of groundwater above proposed cleanup levels to Railroad Creek. For parts of the Site (e.g., the western portion of the Lower West Area (LWA) and the north side of TP-3), the barrier would also reduce seepage from portions of Railroad Creek that contributes to the flow of clean groundwater that becomes contaminated and would otherwise need to be collected for treatment.

- Treatment of collected water using pH adjustment and aeration to precipitate and settle out aluminum, cadmium, copper, iron, lead, and zinc, prior to effluent discharge to Railroad Creek.

- Disposal of precipitated metal hydroxide sludge in an on-Site landfill.

- Long-term operation and maintenance (O&M) of the water collection and treatment facilities.

As shown on Figure F-2, the proposed location for the Alternative 10 water treatment facility is east of TP-3 on the north side of Railroad Creek. Conceptual locations for the groundwater barrier walls and collection ditches are also shown on Figure F-2.

Alternative 10 would include collection of groundwater in the following areas:

- The LWA along Railroad Creek from the existing Main Portal discharge point into Railroad Creek, to the Copper Creek Diversion;

- North and east of TP-1; and

- North and east of TP-3.

Alternative 10 does not include collection and treatment of groundwater below part of TP-2 as part of the initial implementation of the remedy. Alternative 10 includes further evaluation of groundwater quality following regrading of the tailings piles and installation of monitoring wells along the north side of TP-2.

3.0 WATER TREATMENT SYSTEM CONCEPTUAL DESIGN EVALUATION

3.1 Anticipated Water Flow Rates and Contaminant Loadings

This section discusses assumptions used in sizing the water treatment system and evaluating performance requirements for Alternative 10.

Surface water and groundwater flows and concentrations at the Site vary seasonally in response to snowmelt runoff and infiltration that is expressed as seeps and baseflow into Railroad Creek and Copper Creek. For the purposes of this conceptual design evaluation and consistent with the DFFS, each calendar year is assumed to consist of a spring (high-flow) and a fall (low-flow) period for groundwater and surface water (see footnote 6).

Table F-1 and Figure F-3 provide estimated flow rates and metals concentrations during the spring and fall flow periods for the various sources from which water would be collected and routed to the Alternative 10 treatment system. Table F-2 lists proposed cleanup levels for the Site, based on ARARs and surface water background levels, as appropriate. Spring and fall flow rates and estimated concentrations for blended treatment system influent are also provided. These estimates are based on data collected for the DRI in 1997 or subsequently reported by Intalco (URS 2004b and 2006). Estimates for discharge from the main 1500 Level portal with hydrostatic bulkheads in place are based on the SRK analysis provided in Appendix E of the DFFS (URS 2004a).

The DFFS assumed that hydraulic bulkheads constructed in the mine at the 1500 Level, and potentially the 1100 Level, would reduce peak flows to improve treatability, but did not assume flow equalization over the entire year. For discussion purposes, the Alternative 10 treatment system evaluation uses the same approach; however, the feasibility and benefit of true flow equalization should be more fully evaluated as part of RD.

For the evaluation of Alternative 10, the combined flow from all sources contributing to the treatment system influent is estimated to average about 2,400 gallons per minute (gpm) during the spring period and about 430 gpm during the fall period. Total volume of water to be treated over the course of a year is estimated at about 480 million gallons.

Mass loadings of constituents of concern to the proposed treatment system are estimated as follows for the spring and fall flow periods.

Constituent of Concern	Estimated Treatment System Loading in Pounds per Day	
	Spring	Fall
Aluminum	330	56
Cadmium	0.66	0.19
Copper	92	24
Iron	1,200	670
Lead	0.15	0.017
Zinc	120	36

Although concentrations in the blended influent are expected to be lower during the spring period for most of the constituents of concern, contaminant loadings (on a mass rate basis) are higher than in the fall, because of the much higher flow volumes during the spring period of the year. The tailings piles are the primary sources of iron and aluminum to Railroad Creek, whereas surface water seeps and groundwater flows from the mine and waste rock piles in the western portion of the Site are the primary sources of copper, cadmium, and zinc. Lead is present at low concentrations in the majority of the aforementioned sources.

The conceptual design for sizing the Alternative 10 treatment pond system assumed a maximum water flow rate of 2,900 gpm, or 20 percent greater than the average estimated flow from all sources during the spring period. This 20 percent increase was included to account for potential stormwater or snowmelt entry into the collection system, and for potential limitations in the DRI data available for use in estimating source flows. This value needs to be further assessed during RD as discussed later in this report.

The conceptual design evaluation for performance of the treatment system was based on assumed treatment of all source flows that are captured and delivered to the treatment facility. Alternative 10 includes a partially penetrating barrier (PPB) to contain groundwater for collection. This PPB would allow some flow from the creek to enter the groundwater collection system during periods of relatively high creek flow. Based on existing modeling (presented in Attachment B to this report), the estimated amount of water from the creek that would enter the collection system due to flow under the PPB appears to be negligible relative to the overall flow being considered. More detailed analyses could assess this further, if a PPB were to be implemented.

The conceptual treatment system performance was analyzed using a mass loading analysis referred to as the Treatment Plant Model (TPM) that is discussed in Appendix A of the SFS. The TPM loading evaluation is based on the assumption that water chemistry does not change (e.g., oxygen levels do not increase sufficiently to reduce metals concentrations as the water is conveyed to the treatment system). This is a conservative basis to assess treatment system performance requirements, but may not represent real conditions in the groundwater collection and conveyance system. Therefore, the effect of oxygenation on water quality changes and sludge precipitation in the conveyance system were considered in the evaluation of operation and maintenance of the conveyance components.

These and other assumptions will need to be evaluated more completely during treatment system design.

3.2 Acid Mine Drainage Treatment Case Studies

Limited information on treatment of ARD and AMD was provided in the DFFS, including data from proprietary reports that could not be verified for applicability. Additional treatment system performance information was obtained from engineering literature, to aid in the evaluation of proposed treatment systems as discussed herein. The compiled information on treatment system performance at other sites with similar conditions was used to evaluate the following:

1) Treatment system effluent concentrations that may be achievable at Holden;

2) Costs for treatment system capital construction and operations;

3) Characteristics of sludge produced as a byproduct of treatment; and

4) Potential changes in treatment that could be implemented to improve treatment effectiveness, if needed to meet discharge criteria.

Intalco referred to "low energy" treatment systems in the DFFS, in contrast to "conventional systems" that are more energy intensive. The chemical basis for treatment (pH adjustment and precipitation of metal hydroxide sludges) is the same for both types of systems. Intalco prefers low energy systems that rely (for example) on flow-induced aeration rather than compressed air injection to oxygenate the water during treatment, and gravity settling rather than mechanically induced thickening or filtration to remove sludge, etc. Both types of technology are evaluated in this report. Reported experience indicates similar effluent metals concentrations can be achieved with either approach. However, most of the published information on low-energy systems is for sites with much lower treatment flow requirements compared to those at Holden, thus the reported experience may not represent results than can be achieved at Holden, see Table F-5. Therefore, the suitability of this approach will need to be further evaluated during RD. Minimizing treatment system energy requirements is particularly important at the Holden Mine Site due to its remote location, but some elements of conventional treatment systems may be required if the low-energy systems cannot achieve acceptable water quality.

The literature review considered both pilot- and full-scale case studies, where sufficient examples were available. Bench-scale studies were also considered for aluminum removal, since relatively little information was available for pilot- and full-scale systems for aluminum. Tables F-3 and F-4 summarize metals removal experience for conventional and low-energy systems, respectively. Figures F-4 through F-8 graphically compare influent versus effluent concentrations from the literature review for constituents of concern (except lead).[11]

Case study results, including effluent concentration ranges and removal efficiencies, are summarized in Table F-6. On average, aluminum and iron were removed more effectively by the low-energy systems, whereas cadmium, copper, and zinc were removed more effectively by the conventional systems.

Intalco used jar shaking tests for a limited bench-scale treatability study of portal discharge samples in June 2000. These preliminary tests provide additional data that can be used to predict treatment system effluent concentrations, as discussed in Section 3.4.

3.3 Proposed Water Treatment Train

Initially the Agencies considered a two-stage pH adjustment process, followed by settling to remove metal hydroxide precipitates, for Alternative 10. Subsequent evaluation of published engineering experience suggested a single-stage of pH adjustment might be equally effective, as discussed herein.

A conceptual process flow diagram for a proposed single-stage water treatment facility is depicted on Figure F-9. This treatment approach is based on the low-energy treatment technology proposed in the DFFS. Components of the conceptual treatment process include the following unit operations:

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[11] Results for lead are not shown in the referenced tables and figures, because only a single case study addressing lead removal in AMD/ARD was identified. Water treatment to remove lead is more typically accomplished in industrial settings. Based on principles of chemical engineering, the treatment approach Intalco and the Agencies are discussing for the Site is likely to remove lead along with other metals. However, the potential lead concentration in treated effluent at this Site cannot be predicted using the information used for the other constituents of concern, based on treatment at other mine sites.

- Flow equalization/stormwater detention;
- Chemical addition;
- Precipitation; and
- Polishing.

The unit operations that make up the proposed treatment train are described below.

The single-stage chemical precipitation process shown on Figure F-9 is consistent with most of the conventional treatment case studies summarized in Table F-3. However, a two-stage precipitation process (depicted on Figure F-10) could be used if needed to enhance removal of aluminum or other metals.[12]

The decision to use single-stage vs. a two-stage system could be made during RD based on treatability tests. Alternatively, a second stage of treatment could be added based on performance of the treatment system after start-up, if needed to improve effluent water quality.

Predicted effluent metals concentrations for the proposed treatment system are discussed in Section 3.4. The conceptual treatment train used for the design evaluation, presented below, is based on available, limited information. Treatability testing and more detailed evaluation of process options will need to be accomplished during RD, or possibly during start-up testing after construction of the treatment system. Further changes to the conceptual design described

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[12] The rationale for using two stages rather than one is based on different solubility characteristics for the constituents of concern. Dissolved cadmium and zinc require a relatively high pH for optimum removal, whereas aluminum is least soluble in the neutral pH range, and becomes more soluble at higher as well as lower pHs. A two-stage treatment system would raise the water pH to approximately 7 for optimum removal of aluminum in the first stage of treatment. The pH would then be raised further in the second stage for optimum removal of cadmium and zinc. Iron, which does not require as high a pH to precipitate as cadmium and zinc, would largely be removed in the first stage. The majority of copper removal is also expected to occur in the first stage, via co-precipitation with iron. Primary removal of cadmium and zinc, along with additional removal of copper and iron, would occur as pH is increased further in the second stage. The same final pH would be achieved in both types of systems,

below may be made based on the experience gained during the initial operation. Additional elements of treatment system design are discussed in Section 5.

3.3.1 Flow Equalization

Groundwater (including seeps) collected from the LWA and TP-1 perimeter would flow by gravity to the lowest elevation in this part of the Site, near the northeast corner of TP-1. Similarly seeps collected adjacent to TP-2, and groundwater and seeps collected adjacent to TP-3 would flow to the lowest elevation in this part of the Site, the southeast corner of TP-3. Copper Creek would be excluded from the groundwater and seep collection system for Alternative 10, based on current water quality.

Conveyance of collected groundwater and surface water is anticipated to include a combination of ditches (inside the groundwater containment area), and pipelines.[13] Ditch flow adjacent to the tailings pile slopes is anticipated to collect snowmelt and stormwater runoff from the regraded tailings pile slopes. Runoff and shallow subsurface seepage down tailings pile slopes (referred to as interflow) may contain metals above cleanup levels, particularly in the short term after implementation. Flow will likely be directed through one or more in-line or off-line stormwater detention/equalization basin(s) (basically a lined pond or vault), potentially located at the low points near TP-1 and TP-3 as determined during RD.

- An in-line or off-line detention basin provides temporary water storage capacity during storm events, to prevent overflows of untreated water to Railroad Creek. Detention basins typically include a high-flow by-pass or emergency spillway for extreme storm events.

- An equalization basin acts as a sump in which flows from the various water sources can mix prior to entering the treatment process, and releases flow at a more or less controlled rate to dampen fluctuations in discrete source flow rates, temperature, and constituent concentrations.

One or more equalization basins may be used to provide some stormwater detention capacity. Size and optimal location of the basins would be determined from a hydrologic evaluation during RD. These basins would

[13] Separate conveyance pipeline(s) would be needed to transmit the Main Portal drainage and potentially collected seepage from the Honeymoon Heights (SP-12 and SP-23) areas, due to differences in head and water quality.

typically be partially filled under normal operation, with the filled portion representing equalization capacity and the unfilled portion representing available stormwater detention capacity.

Stormwater detention and equalization requirements will need to be evaluated during RD. An initial analysis provided in the DFFS focused on variable flows from the mine, and did not fully consider the range in stormwater and snowmelt conditions that could occur when seepage from other areas of the Site is also collected for treatment.

Portal Discharge

For purposes of this conceptual evaluation, the Agencies assumed that hydraulic bulkheads would be constructed within the mine to provide some degree of flow equalization, as discussed in the DFFS. The DFFS also provided an estimate of the volume of an equalization pond (potentially located on TP-1 or in the LWA) as an alternative to in-mine detention. Intalco suggested that this be further evaluated during RD.

There are two potential drawbacks to in-mine detention.

- The cost of constructing hydraulic bulkheads underground is unknown, since Intalco has to date accomplished only limited observations of underground conditions; and

- Geochemical data collected from other mine sites indicate a short-term potential degradation of water quality in the mine drainage, as discussed in Appendix E of the DFFS.

However, there are also significant drawbacks to surface detention ponds for the mine drainage, including detention capacity limitations; collection of clean water due to snowmelt and precipitation; and the fact that a surface pond would not provide sufficient volume to mitigate the potential increase (short-term or long-term) in discharge flow that could occur following the anticipated future collapse of some of the near-surface underground workings. The DFFS did not discuss potential effects on treatment from collecting clean precipitation in a surface detention pond.

For purposes of this conceptual evaluation, Alternative 10 load included the effect of the short-term increase in dissolved metals concentrations in the portal discharge due to the bulkheads, based on Appendix E of the DFFS. Alternative 10 also assumes significant differences in spring and fall flow rates based on data presented in the DRI. For cost estimating purposes, Alternative 10 uses the same bulkhead construction cost assumed by Intalco in the DFFS.

Stormwater and Snowmelt Runoff

Stormwater and snowmelt runoff was not quantified for purposes of this conceptual evaluation of Alternative 10. Initial assessment indicated that existing moisture conditions in the tailings (i.e., due to prior precipitation) would significantly influence the volume of stormwater runoff from the regraded tailings pile slopes, as would potential for a rain-on-snow event noted by Intalco. A design analysis based on Holden Village's long-term precipitation records is needed during RD, to determine storm flow requirements (referred to as a surcharge) through the proposed treatment system, and deciding what would trigger a high-flow stormwater bypass.

For this conceptual design evaluation, the treatment system design capacity of Alternative 10 is sized to handle flows 20 percent greater than the average estimated spring high flow conditions. The appropriateness of a 20 percent surcharge capacity for storm flow during spring flow needs to be further evaluated during RD, along with surcharge capacity requirements during the low-flow season, when a portion of the treatment system is off-line for maintenance or sludge removal, as discussed later in this report.

3.3.2 Pumping and Gravity Flow

The treatment facility in Alternative 10 would be located east of TP-3, on the north side of Railroad Creek. This location has a number of advantages, as discussed in Forest Service (2005) and the SFS (Forest Service 2007).

Although the location north of Railroad Creek has advantages, pumping is required to convey the flow of water for treatment. An existing wetland to the east constrains the area available for treatment; therefore, the system cannot rely on gravity flow alone. Because of the wetland, pumping is either required to convey collected groundwater and seep flow through the treatment system, or alternatively, pumping could be used to lift the water upslope so that it can flow by gravity through the treatment system. The Agencies selected the latter approach for evaluation.

For this evaluation, the Agencies assumed a pump station would be located at the low point in the collection system near the northeast corner of TP-3, at an approximate elevation of 3,145 feet, to convey water to the treatment system inlet at an approximate elevation of 3,175 feet. Groundwater collected in the LWA and TP-1 areas could be conveyed by gravity flow in a pipeline to a pump station at the northeast corner of TP-3, or could be conveyed directly from the northeast corner of TP-1 at about 3,190 feet in elevation, to the treatment system inlet. The feasibility of relying solely on gravity flow to convey groundwater from the LWA and TP-1 to the treatment system will need to be further evaluated during RD when more accurate surveyed elevation data are available.

Pumping would not be needed for flow from the Main Portal and the Honeymoon Heights seeps (SP-12 and SP-23). These sources are at approximate elevations of 3,440 and 3,240 feet, respectively, which provides sufficient head for gravity flow directly to the treatment system inlet.[14] However, there may be benefits for treatment from combining the portal drainage with seepage from below the tailings piles and that should be evaluated during RD. For cost estimating purposes, the Agencies assume that all flow in Alternative 10 (including the 20 percent surcharge previously mentioned) would need to be pumped.

For conceptual design evaluation purposes, the following head loss requirements are assumed for different components of the treatment system, based on information reported in the engineering literature.

Treatment System Component	Typical Reported Head Loss in Feet
Gravity Flow Mixing Flume	5
Cascade Aeration Channel	10
Settling Ponds (~1 % of pond length, based on nominal dimensions noted below)	5
Granular Media Filters	10

The proposed treatment facility location slopes downward toward the south with a total vertical relief on the order of 35 feet. The ground surface elevation varies from about 3,140 feet by Railroad Creek, up to about 3,175 feet adjacent to the Holden-Lucerne Road. Thus, it appears that there will be ample head available to support gravity flow of water from the treatment system inlet through the treatment system.

Details of the treatment system pump station would be developed during RD. Typically such a facility would include a wet well or basin, a series of pumps that

[14] The Portal and Honeymoon Heights seeps together represent about 20 percent of the overall flow to the treatment system.

would turn on and off in series to accommodate changes in flow required, and primary and emergency backup sources of power. Typically a high-flow bypass would be included to accommodate extreme stormwater runoff conditions, as determined during RD.

3.3.3 pH Adjustment and Precipitation

The conceptual design for treatment by low-energy, chemically induced precipitation discussed in the DFFS and assumed for Alternative 10 includes alkaline chemical addition, mixing, aeration, and solid-liquid separation via gravity settling.

Alkaline Chemical Addition. An alkaline chemical, likely in the form of hydrated lime (calcium hydroxide), would be added to the collected AMD waters to raise the pH of the influent water stream to approximately 9.0. This pH level is proposed on a preliminary basis for effective precipitation of cadmium and zinc (Vachon et al. 1987) and could be accomplished in one or two stages, as discussed previously. The optimum pH, and the hydrated lime dosing requirement to achieve that pH, would need to be determined during RD through bench-scale treatability testing of water from the various Holden Mine sources combined in their anticipated proportions to simulate the treatment system influent.

The conceptual treatment system evaluation assumes that bulk hydrated lime would be stored on the Site in watertight, weatherproof storage bins or silos, sized to accommodate the anticipated chemical feed rate and frequency of re-supply to the Site. The storage/feed system will likely need to be heated in the winter to maintain the flowability of the hydrated lime. An automated feed system would be used to regulate the lime-dosing rate based on inflow rate, pH measurements, and possibly other variables.

The treatment system would likely include a secondary alkaline chemical feed system for use in the event of malfunction in the primary feeding system. The backup system could employ hydrated lime or possibly a different alkaline chemical. Advantages and disadvantages of the most commonly used chemicals are reviewed in Section 5.2.2.

Mixing. The primary goal of the mixing step in the proposed treatment system is to disperse the hydrated lime into the influent water stream to ensure efficient chemical usage. Added benefits of mixing, depending on the method selected, could include aeration of the influent stream and promotion of particle flocculation. Mixing options are categorized as follows:

- **Natural mixing** is an intrinsic part of a treatment system design. It involves mixing produced through turbulence generated within the liquid as it flows through the system. The creation of turbulence depends on the characteristics of the fluid as well as those of the conduit through which the fluid is flowing. Natural mixing does not require the use of any specialized equipment or an external energy source, but is generally less efficient compared to static or mechanical mixing.

- **Static mixing** is usually achieved by passing the flow through a static mixer. Static mixers are characterized by their lack of moving parts (Metcalf & Eddy 1991) and can take the form of a pipe or channel with physical features (e.g., baffles) that create turbulence as the water flows through. Static mixers employ the dissipation of the kinetic energy of the flowing liquid to facilitate mixing, so an external energy source is not required.

- **Mechanical mixing** is achieved by imparting energy to the liquid, typically through motor-driven impellers in a mixing tank. Mechanical mixing provides more complete mixing than natural or static methods, but it is also the most expensive of the three mixing options, as it requires specialized equipment and an external energy source.

For conceptual evaluation purposes, the Alternative 10 treatment system is assumed to rely on natural and static mixing, which is the same assumption used by Intalco (except for DFFS Alternatives 6a and 6b).

Aeration. Aeration involves the introduction and dissolution of oxygen into the influent water stream, primarily for the purpose of oxidizing dissolved ferrous iron (Fe^{2+}) to the less soluble ferric (Fe^{3+}) state (Escher et al. 1983). Ferrous iron is water soluble over a wide pH range, while ferric iron is soluble at pH less than 3.5 and becomes highly insoluble at pH greater than 3.5. Ferrous hydroxide precipitates significantly only under reducing conditions at levels greater than approximately pH 8 (Patterson 1985). As a result, effluent iron concentrations can be reduced at a lower pH by oxidizing iron to its ferric form to the maximum extent possible. In addition, ferric iron precipitation forms a more stable solid (Patterson 1985; Vachon et al. 1987), which aids in sludge handling and disposal.

The proposed treatment system would likely use cascade aeration, which uses gravity and the momentum of the flowing liquid to create turbulence and mixing with air. Some aeration is expected to occur in the collection and conveyance system, which is one reason why Alternative 10 primarily relies on open trenches for collection and conveyance of groundwater and seeps affected by the tailings piles. Typical options to enhance aeration include passing flow through open troughs with splash blocks, or over stair steps or falls. These options, such as some forms of static mixing, contain physical features that are designed to disrupt the liquid flow, inducing turbulence at the liquid-air interface. Mixing the collected groundwater with air promotes oxygen transfer needed for treatment.

Other methods that may be considered include mechanical aeration, which uses an external energy source to introduce air into the aqueous stream, addition of chemical oxidants, or incorporation of oxidizing biological reactions. At the conceptual design level, cascade aeration would seem to be preferred over these aeration methods for the proposed treatment system due to its simplicity of design and anticipated low cost. However, prediction of the efficiency of cascade aeration, and the potential need for other technology can be difficult to estimate until the system is operated at full-scale at site-specific operating conditions (Escher et al. 1983).

Solid-Liquid Separation. A major byproduct of ARD/AMD treatment by chemical precipitation is sludge comprised of metal hydroxide solids. The volume of sludge produced may be relatively large, depending on the treated water volume and characteristics. Sludge handling and disposal are major factors to consider in the design and operation of the treatment system.

The conceptual treatment system evaluation assumed that solid-liquid separation would be achieved via sedimentation in two parallel settling ponds, similar to the approach presented in the DFFS.

Settling pond sizing is primarily driven by sludge accumulation and anticipated annual sludge removal. Conceptual design parameters for the Alternative 10 treatment system evaluation are presented in Table F-8, based on published criteria for typical sedimentation basin design that are summarized in Table F-7. Pond size requirements are based on estimated sludge accumulation rates in the ponds for the first year of operations, and the annual volume is anticipated to decrease over time. The ponds are sized to accommodate 1 year of sludge accumulation between maintenance (sludge removal) events.

Rates of sludge accumulation in the treatment system as a whole are estimated based on precipitation of metals, assuming influent and effluent concentrations discussed in this report. Other constituents that are expected to contribute to sludge production are also considered, including sulfate, calcium, magnesium, manganese, total suspended solids (TSS), and lime. The following assumptions are made in incorporating these constituents into the sludge production estimate:

- At sulfate concentrations below 3,000 mg/L, sulfate precipitation was observed to be minimal in various case studies (MEND 1997; Vachon et al. 1987). Negligible sulfate precipitation was observed in the bench-scale treatability jar tests that Intalco conducted in June 2000 on a sample of water collected from the main 1500 Level portal. Based on these study results, 5 percent of influent sulfate was conservatively assumed to precipitate in the conceptual treatment system.

- Calcium is assumed to precipitate with the sulfate in the form of gypsum (hydrated calcium sulfate), based on a stoichiometric estimate.

- A conservative magnesium removal rate of 25 percent is assumed based on treatability studies conducted at an AMD site (Hilton 2005).

- The amount of manganese removal is assumed to achieve a discharge concentration of 0.1 mg/L.

- The amount of TSS removal is assumed to achieve a discharge concentration of 1 mg/L.

- Complete precipitation of dosed lime (as calcium hydroxide) is assumed.

Neutralization of AMD using lime produces sludge that is light, gelatinous, and very voluminous. During storage in the pond bottoms, the sludge will consolidate somewhat to an estimated 3 to 5 percent solids (EPA 1985). An average value of 4 percent solids was assumed in estimating annual sludge accumulation on a volumetric basis for the Alternative 10 evaluation. The treatment system ponds were sized based on the anticipated sludge volume up to a depth of 9 feet, plus a 3-foot allowance for clear water storage (including precipitation) above the sludge, and finally a 2-foot freeboard to provide additional margin against uncontrolled overflow. This estimated pond volume was compared to the volume needed to allow adequate settling time during spring high flow rates, and the sludge accumulation volume controlled the anticipated design. Based on the assumptions outlined above, the sludge accumulation rate in the settling ponds was estimated to be 5.8 million gallons per year.[15] Sludge accumulation in the remainder of the treatment facility (including the collection and conveyance components and the media filters used

[15] Due to source reduction, the sludge accumulation rate is estimated to decrease to 3.4 million gallons per year by the fiftieth year of operation. Average sludge production over 50 years is estimated at about 4.6 million gallons per year.

for the treatment polishing step) is assumed to be negligible in increasing the overall volume of sludge (although the effort to maintain these components via regular sludge removal was included in calculation of O&M costs).

The total wetted volume needed for the two settling ponds, based on required sludge storage capacity, is estimated at 11.7 million gallons. At a total pond depth of 14 feet (12-foot wetted depth), this volume would result in a total pond surface area of about 172,000 square feet (sf) (or about 3.9 acres).[16] As shown in Table F-8, this pond size exceeds the minimum size required for particle settling (i.e., the size needed to prevent carry-over of suspended solids in the settling pond overflow).

Maintenance of the ponds is discussed in Section 3.5.4.

Effluent from the settling ponds would pass through a polishing step prior to discharge to Railroad Creek.

3.3.4 Effluent Polishing

The primary goal of effluent polishing is removal of potential residual suspended solids from the treated water prior to discharge. For Alternative 10, two gravity-flow granular media filters operating in parallel were considered for the polishing step, based on the same approach used in the DFFS.

Granular media filtration can be an effective method for removal of particulate metals (Vachon et al. 1987). Water from the treatment system settling ponds would flow through the media filter basins prior to discharge. Each basin would contain a layer of granular filter medium (sand) underlain by a drainage system. Residual suspended solids would be filtered out at the sand bed surface as the water infiltrates downward through the bed. A weir on the filter discharge would likely be used to maintain a minimum head of water above the filter medium regardless of water flow rate. Based on a typical hydraulic loading of 0.5 gpm per square foot for a slow sand filter (Table F-7), and a maximum design flow rate of 4.2 million gallons per day, the total required filtration surface area is estimated at 5,800 sf (about 0.13 acre). For an assumed filter thickness of 4 feet, approximately 860 cubic yards of sand filter media would be required.

[16] This pond sizing assumes a pond length-to-width ratio of 4 to 1, and side walls sloped at a horizontal-to-vertical ratio of 2 to 1.

Following the polishing step, treated effluent would be discharged by gravity flow through one or more outfall(s) into Railroad Creek. The potential need to lower effluent pH prior to discharge is discussed in Section 3.4.4.

3.4 Anticipated Effluent Characteristics

Water treatment system effluent would be discharged to Railroad Creek in conformance with requirements of the National Pollution Discharge Elimination System (NPDES). Proposed surface water cleanup levels for the constituents of concern are shown in Table F-2. In addition to limits on allowable constituent of concern concentrations, the discharge will need to satisfy discharge limits for pH and TSS, which may also affect design and operation of the treatment system.

3.4.1 Constituents of Concern

Two sources of information were used to predict concentrations of the constituents of concern in the treatment system effluent:

- Results of the bench-scale treatability test that Intalco conducted during the FS on a water sample collected from the main 1500 Level portal; and

- The case studies discussed in Section 3.2.

The treatability study tested a number of chemical dosing agents and neutralization over a range of final pH values. Table F-9 summarizes test results for neutralization using hydrated lime to a final pH between 9.1 and 9.2. Estimated treatment system influent concentrations are also provided in the table for comparison. Note that concentrations of cadmium, copper, and zinc in the tested water samples were within the respective ranges of anticipated Alternative 10 influent concentrations, while the aluminum concentration was only marginally lower. The iron concentration, however, was some two orders of magnitude below the anticipated range required for the Alternative 10 treatment system influent. Lead concentrations were not measured in the treatability study.

The last column in Table F-9 shows removal efficiencies achieved in the Intalco treatability study under these specific test conditions. The result for iron (greater than 90.5 percent removal) is likely not very relevant, both because the iron concentration in the test water was not representative of anticipated treatment system influent, and because the detection limit for iron was only an order of magnitude less than the starting concentration. However, for the other constituents included in the study, observed removal efficiencies (ranging from 96.7 percent for cadmium to 99.9 percent for copper and zinc) provide a reasonable basis for predicting achievable effluent concentrations for the full-scale system. Actual removal efficiencies may be either higher or lower, for various reasons. For example, higher iron concentrations in the influent for Alternative 10 could result in higher removal efficiencies for the other constituents due to co-precipitation.

Table F-10 shows order-of-magnitude ranges of treated effluent concentrations, based on evaluation of the case studies shown on Figures F-4 through F-8. Estimated treatment system effluent concentrations based on the removal efficiencies observed in the treatability study are also provided in Table F-10, for comparison. In making this comparison, a number of the low-energy system case studies were eliminated because they were judged to be relatively inapplicable to the anticipated treatment system for the Holden Site.[17]

Effluent concentration predictions based on Intalco's treatability study results fall within the other case study order-of-magnitude ranges for cadmium, and below the respective case study ranges for aluminum, copper, and zinc. While Alternative 10 could achieve effluent water quality similar to the ranges from reported case studies, it is not clear whether a full-scale treatment system would produce results as good as Intalco's limited bench-scale tests.

Actual concentrations in the treatment system effluent can be affected by a number of factors, including influent concentration, complexity of the ARD/AMD matrix, influent flow variations, influent pH, temperature, precipitation, and rate of snow melt. The degree of influence of these factors on effluent concentrations can vary from one system to the next, and over time for any one system (due to changes in more than one variable). Therefore, effluent concentrations for the Site may not be well predicted by either theoretical methods or through empirical comparisons such as described above.

Accordingly, there is no guarantee that the Site treatment system can achieve cleanup levels with the type of technology described in the DFFS and presented herein for the Alternative 10 evaluation. Additional treatment system modifications such as those described in Section 5.0 may need to be implemented to achieve cleanup levels.

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[17] The following case histories were not included in developing the ranges shown in Table F-9: Silver Bow Creek/Butte Area Superfund Site and Whitworth No. 1, since these treatment systems used constructed wetlands; Success Mine, which used an organic apatite treatment media; and the Underground Coal Mine and Brewer Gold Mine, both of which used sulfate-reducing bacteria as part of treatment.

3.4.2 Mixing Zone Dilution Factor

Comparison of the potential cleanup levels with anticipated effluent concentrations suggests that a mixing zone would be required downstream of the treatment plant outfall. Attachment D includes a memorandum that discusses anticipated concentrations in the Alternative 10 effluent and presents preliminary calculations for an "upper-bound" dilution factor for a mixing zone within Railroad Creek. The allowable, upper-bound, mixing zone factor was determined in conformance with Chapter 173-201A WAC, as described in Attachment D.

Ecology may allow consideration of a "mixing zone" immediately downstream of the outlet, rather than requiring that surface water cleanup levels be achieved right at the discharge pipe outlet. Dilution occurs within the mixing zone, and the approved cleanup levels must be achieved at the end of that zone.

Attachment D estimates the potential upper-bound magnitude of the mixing zone dilution factor for the treatment plant discharge to Railroad Creek. An upper-bound dilution factor of 3.4 was derived from a simple dilution calculation (in lieu of mixing zone modeling), based on the requirement that a mixing zone not use more than 25 percent of the stream flow [WAC 173-201A-100(7)(a)(ii)]. A complete mixing zone analysis includes evaluating details of the outfall and specific stream flow conditions for the location of the proposed outfall, which would be developed during RD.

Table F-10 includes proposed surface water cleanup levels (from Table F-2) in the second column from the right. The right-hand column lists potentially allowable concentrations at the discharge pipe outlet assuming that a dilution factor of 3.4 is applicable as estimated in Attachment D. Effluent criteria at the discharge pipe outlet would likely need to fall within the concentration ranges bracketed by the values in these two columns to meet water quality criteria. This may require enhancing the treatment system as discussed in Section 6.1 of this report, or other changes in treatment technology. Comparing the anticipated treated effluent concentrations from the literature review with the proposed cleanup levels and potential allowable water quality criteria in Table F-10 leads to the following observations:

- Effluent water quality concentrations have a good chance of achieving potential ARARs for iron and lead (although the estimate for effluent lead is highly uncertain since it is based on the results of a single case study);

- Effluent water quality concentrations have a moderate chance of achieving potential ARARs for aluminum and zinc; and

- Effluent water quality concentrations are unlikely to achieve potential ARARs for cadmium and copper.

At this time no decisions have been made as to the location or number of outfall(s) that may be used for the treatment system. Location of the treatment system outfall, and the effluent rate relative to stream flow at any location may affect whether the discharge meets water quality criteria. Also, the water quality criteria may vary from one location to another, depending on parameters in Railroad Creek, such as hardness, and in the case of copper, dissolved organic carbon, and a number of other parameters. The location of outfall(s) will need to be further addressed as part of RD.

3.4.3 Suspended Solids

Granular media filters are very effective at removing TSS. Provided the polishing filters are properly designed and able to operate so there is no bypassing within the polishing step, the TSS of the effluent should be well below the typical NPDES discharge criterion for suspended solids.

3.4.4 Effluent pH

After the chemical addition step described above, water flowing into the settling ponds with an anticipated pH of 9.0 would exceed the pH range typically allowed under an NPDES permit. However, a decline in pH is expected as solids precipitate out of solution in the ponds, and dilution in the mixing zone will further lower the pH. The degree to which pH is likely to be lowered by the combination of these two mechanisms is difficult to predict. However, case study results suggest that a typical NPDES discharge limit of 8.0 to 8.5 (for example) would likely be achievable.

In the event that the pH at the end of the mixing zone exceeds the NPDES discharge criterion, an additional treatment step could be added after the polishing step to lower the pH of the effluent prior to discharge. This has been accomplished at a number of AMD sites; for example, water treatment at the Argo Tunnel site in Colorado includes carbon dioxide injection to lower the pH of the treated water prior to discharge.

3.5 Treatment Facility Operation and Maintenance Requirements

This section describes O&M aspects of the proposed Alternative 10 water treatment facility. The conceptual design for the system assumes year-round, full-time operation, with parallel solid-liquid separation unit operations. Since average system flows anticipated during the fall period are less than half those anticipated during the spring period (which the system is designed to handle), half of the solid-liquid separation capacity can be shut down for maintenance during the fall period while the entire fall flow volume is routed through the remaining half.

Discussion of O&M requirements includes the following:

- Pump station;
- Alkaline chemical addition;
- Mixing and aeration;
- Settling ponds;
- Granular media filters;
- Incidental solids deposition;
- Scale formation; and
- Estimated labor requirement for O&M.

3.5.1 Pump Station

O&M associated with the influent pump station (and with a potential stormwater detention/equalization basin) includes pump maintenance, solids deposition monitoring, and periodic sludge removal. The pump station wet well or basin should be compartmentalized so that portions can be isolated and drained for sludge removal without shutting down the entire treatment system. Similarly, individual pumps should be capable of being isolated for maintenance. Maintenance associated with solids deposition is discussed further in Section 3.5.6.

3.5.2 Alkaline Chemical Addition

The alkaline chemical addition system would require periodic monitoring and maintenance to assess and maintain proper functioning of the equipment. It is critical that the dry chemical flows freely and uniformly from the storage vessels to the feeder. Hydrated lime is a light, fluffy material that is prone to bridging and jamming, so careful attention to storage/feed system design is particularly important. Even a well designed system, however, is likely to experience problems, especially during cold weather, and the need for operator attention should be anticipated. One source of feeding system problems is the hygroscopic nature of hydrated lime (i.e., hydrated lime readily absorbs and retains moisture), which can be controlled with well-sealed storage units.

The cost estimate for Alternative 10 assumes that lime would be transported to the Site using specialized transport trucks that are barged up Lake Chelan. A typical lime transport truck is equipped with a pneumatic conveyance system, which allows for direct transfer of the dry chemical to the on-Site storage units. Lime delivery would occur mostly in the summer months, as road access to the Site could be difficult during winter. Assuming a typical delivery truck capacity of 25 tons, an estimated 26 truckloads of hydrated lime would need to be transported to the Site per year during the early years of operation (see Section 3.7 for estimated chemical consumption).

3.5.3 Mixing and Aeration

Natural mixing, static mixing, and cascade aeration are driven by the gravitational flow of the water stream. Elevation requirements to achieve gravity flow are summarized in Section 3.3.2, and energy required is discussed in Section 3.7. The mixing and aeration units can be designed to minimize sludge accumulation and/or fouling, to minimize operator attention. Maintenance typically involves periodic equipment inspection and periodic (typically annual) cleaning to address clogging caused by accumulation of solids. Cleaning may be required more frequently, as determined during inspection.

Use of mechanical mixers and/or aerators would likely require more frequent operator attention and result in higher operating costs.

3.5.4 Settling Ponds

For the purpose of this conceptual design evaluation, sludge would be removed from the two parallel settling ponds on an annual basis. After the period of high spring flows, the entire treatment system flow would be diverted to one settling pond to allow for sludge removal from the off-line pond while continuing treatment system operations. Flow would then be diverted to the clean pond to allow for cleaning of the other pond. Specific sludge removal methods, optimum cleanout frequency, and the potential for dewatering of sludge in off-line ponds prior to removal, as described in Section 5.2.4, would be assessed during RD. Sludge removed from the settling ponds would be conveyed via pipeline to a permanent sludge landfill, possibly through an intermediate sludge dewatering cell within the on-Site landfill area. Sludge management is discussed further in Section 3.6.

3.5.5 Granular Media Filters

The hydraulic conductivity of the granular media filters will decrease as solids accumulate on the filter beds. In single-layer granular media filters, solids accumulation typically occurs in the top section of the media bed (Clark and Pitt 1999). The clogging process can often be slowed by using multiple granular media layers of decreasing grain size with depth. In that case, however, solids removed from the water stream are distributed not just near the filter surface, but deeper into the media layers, and the cost of procuring and placing filter media is increased. Periodic backwashing is typically used to flush accumulated solids from the media and to restore filter capacity. Backwashing can be used to maintain filter capacity for single- as well as multiple-layer granular media filters. However, it is an equipment- and energy-intensive process that typically requires significant operator attention. Therefore, single-stage filters without backwash capability were evaluated for Alternative 10.

To restore the hydraulic conductivity of the filters, the surface layer of the granular media would periodically need to be scraped from the filter to expose new granular media, or be replaced with clean media. Alternatively, the overall filter layer thickness can be increased such that several maintenance removal events can be performed before new filter media must be added to restore total thickness.

For cost estimating purposes for Alternative 10, the surface layers of the two granular media filters would be removed on an annual basis during the fall flow period. Maintenance was assumed to be performed sequentially, with the entire treatment flow being diverted to first one filter and then on alternate years to the other, to allow for uninterrupted water treatment during maintenance. Water would be drained from the filter, and conventional equipment such as a backhoe would be used to scrape a layer of sand and sludge from the bed surface. Assuming an initial bed thickness of 4 feet, annual maintenance events, and an average of 6 inches of sand removed per event, complete sand replacement could likely be performed at approximately 5- or 6-year intervals. Replacement sand could initially be obtained from screened sand obtained from Dan's Camp during remedial construction. Over the longer term, sand could be imported.

3.5.6 Incidental Solids Deposition

Incidental deposition of solids (sludge) is an inherent maintenance issue in virtually all chemical precipitation systems. Although the Alternative 10 water treatment system will be designed for solids to settle and accumulate on the bottom of each settling pond (with residual removal on the granular media filters), solids will also likely accumulate to some degree in the other wetted areas of the collection/conveyance and treatment facility as well. Effects on the collection and conveyance components are discussed in Section 4.5. Effects on the treatment system are discussed below.

Solids deposition at the inlet pump station could clog pumps, decreasing their performance or even potentially causing pump failure. Deposition in a stormwater detention/equalization basin would reduce detention capacity and make the basin less effective at equalizing flow to the treatment system. Periodic monitoring of sludge accumulation in the pump station/basin, pump maintenance, and sludge removal at an appropriate frequency, will be important components of the treatment system O&M program.

Accumulation of solids could also adversely impact the mixing and aeration steps, which are anticipated to rely on static or gravitational processes. These processes are designed with physical features to agitate and create turbulence in the liquid flow to promote mixing and aeration. To the extent that these physical features become filled in with accumulated solids, their effectiveness would be progressively reduced. As with the inlet pump station, monitoring and managing sludge accumulation in these unit operations will be important to maintaining overall treatment system performance.

Sludge accumulation is also anticipated to potentially affect valves, weirs, and any pipes or other areas where flow through the treatment system is constricted. This is a normal part of AMD treatment system operations and the adverse effects can be minimized though good engineering design practices and regular maintenance.

Regular maintenance is anticipated to consist of cleaning impacted facilities by power washing with a water jet, or a combined jet of compressed air and water. Pipe cleaning may be accomplished with a mechanical cleaning tool (that may incorporate these methods) referred to as “pipeline pigging.” A contractor can accomplish this with conventional equipment as needed.

3.5.7 Scale Formation

In addition to incidental solids deposition, scale formation, in the form of gypsum (hydrated calcium sulfate), can also occur in lime treatment systems treating AMD. The degree and characteristics of scale formation depend on the chemistry of the influent stream and can be correlated to sulfate concentrations. At sulfate concentrations below 3,000 mg/L, scale formation may be limited (Vachon et al. 1987). Also, solutions of low ionic strength in general tend not to form scale (MEND 1994). Both of these conditions are generally expected to apply to the anticipated blended treatment system influent for Alternative 10, so scale formation may be of relatively minor concern. However, if gypsum deposition does occur, it will generally need to be addressed with more aggressive mechanical removal methods other than a simple water jet. Formation of iron oxide scale is also a concern. A more detailed analysis of iron precipitate issues is provided in Attachment C, and will need to be evaluated during RD and/or after treatment system startup.

3.5.8 Estimated Labor Requirements for System Operation and Maintenance

Anticipated labor requirements associated with day-to-day operation and maintenance of the groundwater collection, conveyance, and treatment system can be categorized as follows:

- **System Operation/Monitoring.** Includes routine monitoring of system operating conditions and adjustments as needed to maintain effective treatment; delivery transfers of fuel and chemicals; identification and evaluation of conditions potentially requiring corrective action and/or maintenance; collection of routine water samples for chemical analysis; and inventory tracking and ordering of chemicals and supplies.

- **Equipment Maintenance.** Includes routine maintenance and as-needed replacement of mechanical/electrical equipment such as electrical generators, pumps, chemical feeders, compressors, motors, heaters, and site vehicles.

- **Project Management/Reporting.** Includes review and evaluation of system operating and monitoring data; treatment system troubleshooting and performance optimization; coordination and oversight of field staff; preparation of periodic progress reports; budgeting and cost tracking; and interface with regulatory agencies.

Labor requirements are expected to be relatively high during the initial startup phase, as system “bugs” are worked out and routine O&M procedures established. The cost estimate for Alternative 10 uses the same lump sum startup treatment system costs that were assumed in the DFFS. Actual startup costs will need to be further evaluated during RD.

After completion of the startup phase, longer term labor requirements for O&M were preliminarily estimated in terms of the following full time employee (FTE) labor equivalents:

Labor Category	FTE
System Operation/Monitoring	0.5
Equipment Maintenance	0.2
Project Management/Reporting	0.33

Maintenance tasks that are performed infrequently, such as settling pond sludge removal and granular media filter maintenance, were addressed separately in the cost estimate and are not included in the above estimates. Actual maintenance requirements can be better estimated based on actual system design and startup operations.

3.6 Sludge Handling and Disposal

As discussed in Section 3.3.3, the initial rate of sludge accumulation in the treatment facility is estimated at 5.8 million gallons per year, assuming the sludge has an average solids content of 4 percent. Sludge generation is expected to decrease over time, as the rate of metals release from the Site is reduced through source depletion, as predicted in the DFFS.

For the purpose of the conceptual design evaluation for Alternative 10, the sludge would be pumped annually to a landfill located on top of regraded TP-2. The two parallel settling ponds in the water treatment facility would be cleaned in sequence each year during low flow conditions, as previously described. Two scenarios have been considered:

1. The Agencies assumed dewatering in the sludge disposal landfill with recovery of free water for recirculation through the treatment system. The sludge could be pumped directly to a permanent disposal cell for dewatering by evaporation and consolidation. This approach would eliminate the cost of rehandling the sludge after initial drying.

2. Alternatively, the sludge could be pumped into an interim cell for initial dewatering followed by transfer to an on-Site landfill for permanent disposal.

The advantage of pumping the sludge to a temporary dewatering cell is that this could have a relatively large surface area to promote rapid evaporation in the late summer. The sludge could then be transferred to a landfill with a smaller footprint, to reduce the amount of sludge exposed to rewetting by winter precipitation.

The final sludge disposal facility would need to conform to state standards for limited purpose landfills [Chapter 173-350 WAC]. The Alternative 10 conceptual design approach assumes that the sludge would dry passively in the landfill (or dewatering cell) over a period of months during the summer season. Freezing in winter would also dewater the sludge, although moisture content of the surficial sludge would increase, especially during spring snowmelt. Over the long term, consolidation would further reduce the water content (increase the percent solids on a unit volume basis). As long as the sludge remains saturated, consolidation is a function of effective stress, not total stress within the sludge, thus the presence of a free water layer on top of the sludge does not slow the rate of consolidation.

For the Alternative 10 conceptual design evaluation, the Agencies conducted a consolidation analysis of sludge to assess preliminary sizing criteria. Estimated capital and replacement costs were developed, as described in SFS Appendix B, for a typical landfill cell that would receive a 50-year accumulation of sludge from the treatment facility. Landfill size was preliminarily estimated using consolidation analyses based on typical AMD sludge properties (Pedroni et al. 2006). The actual rate of sludge dewatering would need to be evaluated after startup of the treatment system.

The long-term stability of sludges similar to those anticipated at the Holden Mine Site was assessed on a preliminary basis. A literature review indicated that, for sludges recently generated from lime treatment of AMD, metals concentrations in leachate are typically low (Hart Crowser 2004). However, the propensity for metals to leach as a sludge ages is a complex function of many variables. Montana Tech of the University of Montana and MSE Technology Applications, Inc., conducted bench-scale studies to evaluate AMD sludge stability under different aging conditions (MTUM & MSE 2000). There is no long-term experience available to demonstrate sludge stored in a saturated (anaerobic) condition would remain chemically stable over many years. Therefore, at the conceptual design evaluation level, dewatering cells constructed in the TP-2 area would require a lining and leachate collection system to satisfy Chapter 173-350 WAC and assure that metals removed by treatment would not reenter the environment. Alternatively, the dewatering cells could potentially be constructed upgradient of a groundwater collection system (such as those proposed for TP-1 and TP-3), in which case a liner and leachate collection system might not be needed.

Granular filter media (sand) intermixed with particulate matter filtered from the treatment system effluent would also likely be disposed of in the on-Site sludge disposal landfill. This represents a minor volume of waste compared to the settling pond sludge. Assuming that a 6-inch depth of sand is removed annually from the media filters described above, the waste sand is estimated at 107 cubic yards per year, or about 0.4 percent of the annual sludge volume described above. The volume of treatment-derived sludge mixed with the sand is expected to be much less than that of the sand itself. This waste stream would have low water content, and would not require dewatering prior to disposal. It would be transported in trucks to the on-Site sludge landfill for disposal.

3.7 Chemical and Energy Consumption

Hydrated lime dosing rates are estimated from the calculated acidity to be removed in the chemical precipitation treatment step, based on the blended influent flow rates and metals concentrations provided in Table F-1. Concentrations of magnesium and sulfate provided in Table 6-4 of the DFFS are also considered. This estimate uses a lime demand of mass ratio of 1.1, [i.e. 1.1 kg of calcium hydroxide per 1.0 kg of acidity (represented as calcium carbonate)], assuming a neutralization efficiency of 70 percent (Escher et al. 1983). On this basis, the lime-dosing rate for chemical precipitation is estimated to average 1.3 and 3.2 tons per day (tpd) for fall and spring flow conditions, respectively. About 640 tons of hydrated lime would be consumed annually during the early years of operating the treatment facility.[18]

Lime dosing requirements will need to be more precisely determined during RD. Bench-scale treatability testing conducted during the RD should include water from the various Holden Mine sources combined in their anticipated proportions to simulate the treatment system influent.

Table F-11 provides estimated maximum annual energy requirements for O&M of the treatment facility, which are anticipated during the early years of system operation. Fifty-year averages for anticipated energy consumption associated with water and sludge pumping, storing and feeding lime, and other miscellaneous needs were used in developing cost estimates for Alternative 10.

Estimated energy requirements for pumping water into the treatment system assumed that impacted water from all sources would flow via gravity to the pump station near TP-3, and then would be pumped to a 30-foot higher elevation to allow gravity flow through the treatment system, as discussed in Section 3.3.2.

[18] Due to decreases in loading to the treatment system caused by source reduction, lime consumption is estimated to decrease to approximately 220 tons per year by the fiftieth year of operation. Average lime consumption over 50 years is estimated at 430 tons per year.

Pumping water is by far the largest source of energy consumption, estimated to account for approximately 62 percent of the total annual energy requirement. As an alternative to pumping water to enable gravity flow through the Alternative 10 treatment system, the Agencies considered a linear treatment system that would extend down the valley along Railroad Creek at a nominal gradient of 1.25 percent, corresponding to the gradient of Railroad Creek in this area. This alternative was considered by the Agencies, but rejected due to the extensive wetland disturbance that would be required for construction east of the proposed Alternative 10 treatment facility location.

The Alternative 10 cost estimate assumes hydrated lime storage in heated silos with vibratory feeders. This accounts for approximately 21 percent of the total energy requirement. Conceptual design to date has not included analysis of using waste heat generated from pumps to reduce the amount of energy required to keep the lime in a usable condition, but economies such as this should be further evaluated during RD.

The estimated total annual energy requirement of 211,000 kilowatt-hours (kW-hr) is equivalent to an average load of approximately 24 kilowatts (kW). For the preliminary cost estimate presented in the SFS Appendix B, diesel generators were assumed to provide electric power for Alternative 10. However, the use of locally generated hydroelectric power (e.g., from 10-Mile Creek) should be further assessed during RD.[19]

4.0 COLLECTION AND CONVEYANCE OF GROUNDWATER AND SEEPS FOR TREATMENT

Alternative 10 includes a groundwater barrier and collection system along Railroad Creek in the LWA, and adjacent to TP-1 and TP-3. Main components of the water collection and conveyance system include partially penetrating groundwater barrier walls, collection trenches, conveyance piping, and inverted siphons to cross Copper Creek and Railroad Creek. This section reviews

[19] There is also potential to generate a portion of the required power on the Site using water flow from the Main Portal to the treatment facility, as is being accomplished for remediation of the Britannia Mine (another Howe Sound property) in British Columbia. Preliminary estimates indicate that approximately 7 kW and 2.5 kW of power could be generated during the spring and fall flow periods, respectively, using a micro-generator. The economics of using the portal discharge for generating a portion of the power required to operate the treatment facility should be further evaluated during RD.

components of the collection and conveyance system as well as potential maintenance issues.

Two independent groundwater barrier and collection systems are proposed, as shown on Figure 2.

- The West Area system would include a PPB extending from the vicinity of P-5 (where the portal drainage presently enters Railroad Creek) east along Railroad Creek adjacent to TP-1, with a leg extending along the west side of Copper Creek. Total length would be about 3,800 feet.

- The East Area system would extend along the north side of TP-3 from about seep SP-4, with a leg extending along the east side of TP-3, a total of approximately 2,000 feet in length.

For the portion of the groundwater and seep collection system adjacent to the tailings piles, Alternative 10 would use open ditches for groundwater and seep collection. An open collection ditch was proposed for Alternative 10, rather than a perforated pipe buried in a gravel-filled trench (French drain), because of the ease with which sludge could be removed with a backhoe or vacuum truck, as needed over the life of the system.[20] The open trenches allow for easy access for maintenance using a backhoe or vacuum truck to clean out ferric hydroxide sludge that may be produced when groundwater rich in ferrous iron is exposed to oxygen in the atmosphere (iron fouling).[21]

In the LWA, Alternative 10 considered that groundwater collection might be accomplished with a French drain or a trench. Groundwater in the LWA has relatively low concentrations of iron (see Table F-1) and iron fouling is not anticipated to be as much of a potential problem as it may be downgradient of

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[20] After development of the APR (Alternative 10), Intalco proposed Alternative 9, which would use French drains for collection of seeps along TP-1, on the premise that iron fouling would not be a significant problem if such drains were located below the groundwater table. The Agencies note that if this premise is correct, there is no reason the same approach would not be effective for Alternative 10, and could be further considered as part of RD.

[21] The degree to which iron fouling would occur is hard to predict, as indicated by the range of experience at other sites, discussed in Attachment C. The iron-rich sludge that would accumulate in the collection ditches would otherwise discharge into Railroad Creek if groundwater containment and collection are not accomplished.

the tailings piles. However, there is a potentially significant amount of aluminum in groundwater in the LWA, and the potential for fouling with aluminum hydroxides needs to be further assessed during RD.

The collection ditches (or French drain, if used) would be located immediately upgradient of the groundwater barrier. Groundwater contained by the barrier wall would be collected and conveyed to the treatment plant. The ditches (or French drain) would intercept groundwater with metals concentrations above proposed cleanup levels that would otherwise discharge into Railroad Creek.

4.1 Partially Penetrating Barrier System

A schematic of the proposed PPB and collection trench layout for Alternative 10 is presented on Figure F-11. Alternative 10 uses a PPB wall as a potential cost-effective alternative to a fully penetrating cutoff that would be keyed into the underlying, relatively impermeable glacial till or bedrock. The PPB wall could be constructed using a soil-cement or cement-bentonite slurry. The concept includes regrading the tailings to provide space for construction of the barrier and collection trench and a permanent access road for maintenance of the collection system. The hydraulic analysis used for a proof of concept analysis for the PPB is described in a memo included as Attachment A. Attachment B discusses additional hydrologic modeling that was accomplished to further assess effectiveness of the approach. Details of the different components of the groundwater barrier wall, collection, and conveyance system as well as potential maintenance issues, are provided below.

4.1.1 Overview of Modeling Analysis to Assess PPB Effectiveness

With a barrier wall not keyed into till/bedrock, hydraulic interaction will occur between the river and groundwater discharging from the south side of the Site. The interaction, direction, and amount of flow depend on the head difference between the river and the south side groundwater.

A commercially available, commonly used groundwater model (The VADOSE/W Unsaturated Infiltration and Seepage Model) was used to evaluate the effectiveness of the PPB as discussed in Attachment A.

VADOSE/W is a powerful two-dimensional finite element tool for modeling the unsaturated soil conditions that exist within the Site tailings piles and the underlying alluvial aquifer, including modeling of infiltration and recharge that augment groundwater flow and seepage. This modeling approach was used to provide a preliminary assessment of the concept of the PPB because it is cost-effective and allows for inclusion of site-specific parameters in the analysis. A summary is provided below.

Model Geometry. For development of the two-dimensional model, a representative cross section from TP-1 was selected that had sufficient data available to support the modeling effort. Sufficient data included three wells along a cross section that intersected Railroad Creek, with a consistent record of water level measurements. The model was calibrated to simulate current conditions at the Site using input parameters such as hydraulic conductivity, infiltration, river stage, and side-valley (south) groundwater inflow. The PPB configuration, as shown on Figure F-11, was initially analyzed under four different scenarios for both spring and fall (eight scenarios total). For both spring and fall conditions, the collection trench depth and cutoff wall depth were varied. Similar to the DFFS loading analysis, the PPB model considered seasonal extremes in the groundwater and surface water regime, which is referred to as a steady state analysis. River stage was varied as part of a sensitivity analysis, discussed below, and provides a reasonable means of analyzing the variable stream conditions.

Effectiveness of the PPB. The modeling analysis indicated that the PPB enables collection of more than 80 percent of the groundwater that would otherwise enter Railroad Creek under a reasonable range of hydrologic conditions (river stage and groundwater elevation changes).

The analysis showed the effectiveness of the PPB and trench collection system is constrained:

- During high flow conditions in Railroad Creek, the groundwater collection system takes in some clean creek water; and

- Conversely, under low flow conditions in the creek, not all of the contaminated groundwater is collected.

While the probability of collecting some clean water from the creek is high, the model indicates that the amount that would be collected is very low. The amount of river water intercepted by the trench is predicted by the model to be low, due to the relative ease of preferential flow within the stream channel, which has much lower flow resistance compared to vertical seepage through the alluvial sediments. Relatively low vertical hydraulic conductivity of alluvial sediments and the length of the flow path under the wall is anticipated to reduce the amount of creek water intercepted by the collection system. Similarly there is preferential flow within the collection ditch on the south side of the barrier, compared to flow resistance within the sediments.

The Agencies' hydrologic analysis suggests that more than 80 percent of the groundwater that would otherwise enter Railroad Creek can be collected with a trench and a 10- to 30-foot-deep barrier wall. The model indicates that increased effectiveness in collecting groundwater can be achieved by deepening the collection trench (at a "cost" of collecting additional clean water during high creek flow periods), or by increasing the barrier wall depth.

Sensitivity Analysis. As part of the modeling effort, three different sensitivity analyses were performed. One analysis looked at the variability in hydraulic conductivity. The second looked at changing the depth of the PPB; and the third studied the effect of changing river stage on percentage of water capture.

The first analysis involved subdividing the aquifer into two zones in the cross section to fine tune the hydraulic conductivities applied to the different units. This sensitivity analysis looked at the spring and fall condition for a 2-foot-deep trench only. For both the fall and spring condition, the trench captured all groundwater from the south side of the creek as well as some creek water under high flow conditions. Comparing data from the model using the single hydraulic conductivity with these results showed that the flow in the trench increased by 15 to 20 percent. This analysis indicated that while percentage of groundwater capture varied slightly, overall collection of more than 80 percent of the groundwater was achieved even when flow through the aquifer was varied.

Differences in hydraulic conductivity do not seem to have much influence on effectiveness of the PPB. In discussions with the Agencies, Intalco commented that this analysis does not address the potential effect of preferential pathways that may exist in the subsurface, such as the old Railroad Creek channel in the West Area shown on Figure F-12. However, the difference between the model assumptions about hydraulic conductivity and more complex real conditions does not mean results of the model are invalid. It is also extremely unlikely that preferential flow pathways exist that would dip under a PPB, considering the geomorphic processes (glacial outwash, colluvial mass wasting, alluvial scour) that form the aquifer in the Railroad Creek valley. Finally, analyses presented by Intalco (URS 2004b, page 20) "indicate that groundwater recharging Railroad Creek is likely shallow groundwater, from the water table to approximately 10 feet below the water table" and, therefore, would likely be cutoff by the PPB.

Intalco has also noted that for some sections of Railroad Creek, the shallow trench collection system would be ineffective for reaches where Railroad Creek is losing water to recharge the aquifer. However, in these areas the PPB would reduce the amount of water from the creek that would otherwise flow into the contaminated portion of the aquifer and re-enter the creek downstream with higher concentrations of dissolved metals. Gaining and losing reaches of the creek are illustrated on Figure F-12, based on information presented in the DFFS.

The second type of sensitivity analysis considered the depth of the PPB to better understand the VADOSE/W model sensitivity to the depth of the barrier wall. The VADOSE/W model was run with the same cross section using a 2-foot-deep collection trench while varying the wall depth between 10 and 30 feet deep. Results are shown on Figure F-13.

For both the spring and fall analyses with this model configuration, greater than 95 percent of groundwater on the south side of Railroad Creek would be captured as well as some creek water. During the spring, there is a relatively linear trend that shows less creek water is captured by the system as depth of the barrier increases. The spring condition trend of increasing efficiency with barrier depth appears to extend all the way to the top of the underlying, relatively impermeable, glacial till. For the fall conditions, however, the effectiveness of the barrier becomes asymptotic at around a depth of 30 feet, suggesting that a deeper barrier would not provide much additional benefit (if any) in collecting groundwater that would otherwise flow into the creek during seasonal low water periods.

The third sensitivity analysis evaluated the effect of variations in river stage on groundwater collection efficiency. In this analysis, a 30-foot barrier wall was used, and the river stage varied over a range of 5 feet. Results of the model indicate that, under the range of groundwater and stream conditions analyzed, a PPB would provide significant containment of shallow groundwater discharges to the creek. Further analyses would be required to confirm these results for the range of conditions in all the areas where groundwater is discharging above proposed cleanup levels. The results of this sensitivity analysis are provided on Figure F-14, and are summarized below.

- For the **spring** analysis, under extreme high water (flood) conditions in Railroad Creek, 100 percent of groundwater that would otherwise flow into the creek from the south is captured. However, the trench would also capture some creek water due to seepage below the PPB. At peak flow stage in Railroad Creek, about 30 percent of the water flowing into the collection trench would be inflow from the creek (seepage below the PPB). {This proportion is calculated as follows, the model predicts the trench would collect 40 percent more flow (from the creek) compared to the entire flow of groundwater that would otherwise enter the creek. 40/140 = 30%}.

- Conversely, under **spring, low** flow conditions in the creek (possible, but unlikely to occur at the same time as when groundwater levels are at a high level) about 50 percent of the contaminated groundwater would be collected and about 50 percent would be lost to the creek.

- In the **fall** analysis, the trench flow was more sensitive to the river stage. Under high flow conditions in the fall, the trench flow is about 30 percent creek water for a high water level in the creek of only 3,192 feet in elevation.

- Under **fall**, **low** flow conditions (river stage elevation of 3,190 feet), about 50 percent of the contaminated groundwater would be collected and about 50 percent would be lost to the creek.

These model results indicate the collection effectiveness is sensitive to changes in creek flow as expressed by the river stage, relative to the elevation of the bottom of the collection trench. While the peak percentages lost or gained appear to be significant in magnitude, the seasonal extremes in creek flow occur infrequently and over relatively short durations. Effectiveness of the system depends not only on the expressed percentages of water collected or lost, but the frequency and duration of the corresponding river stage. This was addressed by the additional modeling presented in Attachment B and discussed in the next section.

4.1.2 Hydrograph Analysis of PPB

The modeling effort outlined above was for a steady state condition, meaning that two scenarios were used to depict the average spring and fall condition. Since the VADOSE/W analysis only considered seasonal extremes, a separate hydrograph-based analysis was conducted to better understand how collection efficiencies will change on a daily basis. Intalco has provided the Agencies with water level data that have been collected by their consultant, URS, at various monitoring wells and in Railroad Creek at station RC-4. Using the water level data from well MW-1 and Railroad Creek sampling station RC-4, a spreadsheet-type analysis was completed to assess the variability in collection efficiencies. Details, including equations and assumptions, are provided in Attachment B, and a summary is provided below.

Site water level data collected using a pressure transducer from well MW-1 covered a 287-day period for which data were also available from station RC-4. Data were from October 2003 through July 2004. The transducer data were typically recorded on an hourly basis or every 4 hours. Groundwater flux into Railroad Creek was calculated using these two data points (RC-4 and MW-1). A hydrograph of the two data sets is provided on Figure F-15.

Results of this groundwater flux calculation were used to estimate the percent capture for a 30-foot-deep PPB installed downgradient of well MW-1. The third sensitivity analysis from the VADOSE/W modeling effort described previously, where the river stage was varied, resulted in linear relationships between river stage and collection effectiveness. These linear relationships varied for spring and fall, as shown on Figure F-14. Assuming that a similar relationship would occur along other gaining stretches of the river if a 30-foot-deep PPB and trench collection system were installed, the time-varying capture effectiveness can be calculated using the river stage data and groundwater flux values previously calculated. Details of this analysis are presented in Attachment B.

The combined analyses demonstrate the applicability of the PPB for aquifer conditions at the Site.

Analysis based on the hydrograph record indicates that leakage of creek water past the PPB would not overwhelm the treatment system with clean water. The hydrograph analysis predicted that the amount of creek water collected by the Alternative 10 system is on the order of 1 to 2 percent of the volume of groundwater collected, or a total of about 2.1 million gallons per year, which is less than about a half percent of the total annual volume of water (480 million gallons) expected to be treated by Alternative 10.

Results of this analysis indicated for the conditions that were modeled, the PPB would capture about 88 and 85 percent for spring and fall conditions, respectively, or an annual average of about 86 percent of the groundwater flow that would otherwise enter Railroad Creek. (This quantity does not include the additional flow from discrete seeps that would also be collected under Alternative 10, or the discharge from the 1500 Level Portal.[22] The model indicates that the overall proportion of contaminated water that Alternative 10 would collect and treat is quite a bit more than 86 percent of the metals-laden groundwater that currently enters Railroad Creek.)

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[22] Seeps occur where groundwater flows to the land surface, thus, seeps are surface expressions of groundwater. Water from seeps may flow overland a short distance before entering Railroad Creek or reinfiltrating into the groundwater. Groundwater enters Railroad Creek directly as baseflow through the bottom and sides of the stream channel, as well as via discrete seep flow. This analysis considered groundwater baseflow at the modeled cross section, not including any discrete seep flow component. Elsewhere, however, when groundwater is discussed in the SFS or its appendices, it is generally implicit that groundwater includes seeps.

4.1.3 Summary of PPB Design Considerations

The analyses outlined above were used to provide a preliminary assessment of the barrier for the PPB system. More detailed engineering analyses would need to be accomplished during RD, to optimize depth of the trench relative to the hydraulic grade line of Railroad Creek, and to adjust the depth of the barrier locally to improve collection effectiveness. Final design of the PPB would require the development of a three-dimensional (3-D) groundwater model during RD. A 3-D analysis would account for additional aspects of the groundwater system at the Site such as discrete seeps, and provide better representation of groundwater-surface water interactions. Use of a 3-D groundwater model is well within the standard of practice for remediation of complex sites. The Agencies expect that a 3-D model would be used to design Alternative 10. The following design issues would need to be considered.

Collection Trench Depth

With the proposed PPB wall, proper construction of the collection trench relative to the annual range in river stage is a critical component of collection effectiveness. As the trench depth is increased below the head of the river, more river water would potentially be intercepted, thus increasing the overall flow to the treatment system. Conversely as the trench is made shallower relative to the river stage, less groundwater would be intercepted by the trench, which would increase the proportion of contaminated groundwater that could reach Railroad Creek. Optimal design depth of the trench would need to address the range in Site conditions and seasonally variable flow in Railroad Creek.

Depth of Completed Barrier Wall

Based on the preliminary analysis of the PPB wall (Attachments A and B), the completed depth of the wall impacts groundwater loss to the river and, conversely, water gain in the trench from Railroad Creek. The VADOSE/W modeling indicates that less river water would be collected as the barrier wall depth is increased, particularly for spring high flow conditions. The cost trade-off between barrier construction and treatment facility operating cost is an issue that should be addressed during RD.

Gaining and Losing Stream Segments

Along the Site, Railroad Creek has gaining and losing segments that vary based on stream stage and groundwater elevations. A losing segment is where water infiltrates into the ground recharging groundwater. A gaining segment is where groundwater discharges into the creek as baseflow. Figure F-12 provides a summary of these conditions for the spring and fall flow periods.

Along segments of the creek where there is a gaining condition, the purpose of the PPB is to intercept shallow groundwater discharging into Railroad Creek. This occurs in the upstream portion of the LWA and along TP-3. Where there is a losing condition, the PPB would reduce stream water from flowing below the tailings piles where the concentration of dissolved metals would increase before the water reenters Railroad Creek downstream.

There is no reason that the PPB needs to be a consistent depth all along its length. Optimal depth of the PPB for losing and gaining segments of the creek should be evaluated during RD.

4.2 Discrete Seep Collection

Alternative 10 includes collection of flow from discrete seeps SP-23, SP-23B, SP-12, SP-3, and SP-4, as well as incidental seep flow into the collection trenches. The water collected from discrete seeps would be conveyed to the treatment facility via pipeline and/or ditches.

Various seeps at the Site are ephemeral; they do not flow all year long, and may not flow consistently from one year to another. Collection of the seeps could be accomplished by constructing a catch basin that consists of an impervious barrier on the downgradient side, or potentially a pervious pipe in a gravel matrix to collect the seepage, as Intalco proposed for Alternative 9. Alternative 10 assumes discrete seep collection at each seep location; however, it is possible that a single linear catch basin could be used to collect multiple seeps in close proximity, e.g., SP-12. Since seep locations are likely to change over time, linear collection facilities would be more effective than point source collection.

4.3 Water Conveyance

Collected water would be conveyed to the treatment system via a combination of open trenches and buried pipes. Trenches would be used for conveyance in areas where the same trenches could be used for groundwater collection. A pipeline would likely be used along TP-2 where no groundwater collection is proposed as part of Alternative 10. To reduce risk of infiltration along an open ditch, groundwater discharged from the 1500 Level Portal and Honeymoon Heights seeps would be conveyed by pipeline all the way to the treatment plant.

Figure F-16 provides a hydraulic profile of Railroad Creek. The Railroad Creek profile is remarkably consistent across the Site, with a uniform gradient of about 1.25 percent, based on the topographic (LiDAR) map provided by Intalco. This profile illustrates that the valley provides sufficient hydraulic head to convey the collected water to a proposed pump station at TP-3 from which the water would be pumped to the treatment plant inlet.

The flow net analyses provided in the DFFS indicate that Railroad Creek has a losing condition in the fall months along a portion of TP-3. It is possible that collected water upgradient of TP-3 may re-infiltrate along TP-3 if groundwater levels under TP-3 are below water levels in the trench. However, the flow nets included in the DFFS indicate this water would be collected on the downstream (east) side of TP-3, where the barrier and collection system trends to the southwest along the toe of the pile (Figure F-2).

4.4 Stream Crossings

Two stream crossings would be necessary to convey collected water to the Alternative 10 treatment system, one where the water conveyance system crosses Copper Creek, and the other where the collected flows cross Railroad Creek to the stormwater detention/equalization basin northeast of TP-3.

Inverted siphons are proposed for both crossings. An inverted siphon is a pipe that would extend from the bottom of the trench elevation on one side of the creek, down under the bed of the creek, and up to the trench bottom on the opposite side of the creek.

Each creek crossing could include two or more pipes, since flow from the portal would typically be separated from flow in the open trenches. The pipes could be cross-connected, with valves to allow crossover, to facilitate pipe cleaning and other maintenance.

4.5 Groundwater Collection and Conveyance Maintenance Considerations

In addition to engineering issues associated with optimizing the PPB and trench collection system, the design of groundwater collection and conveyance components would need to consider maintenance issues. Possible factors that will impact collection and conveyance effectiveness include winter freeze-up, iron fouling, and seep migration. Proper maintenance can mitigate impacts on collection/conveyance effectiveness caused by such factors.

4.5.1 Winter Freeze-up

Intalco has suggested that winter conditions may adversely affect collection and conveyance of groundwater in two ways.

- Freezing of groundwater seeping into the open collection trench may lead to decreased collection efficiencies; and

- Low flows in the late fall and winter combined with freezing conditions and possible snow accumulations may lead to reduced conveyance capacity in the trench.

It is unclear whether ice formation in the trench is going to be a problem in winter. Hart Crowser has observed agricultural drainage trenches in eastern Washington where flow occurs below surficial ice crusts. Freezing of the seepage face on the base or side of the trench is not expected to be a problem as long as there is flowing water in the trench.

If winter freeze-up does occur, seep collection efficiency and trench flow capacity could decrease seasonally. This is not anticipated to be a problem, since the trench system would be sized for higher spring flows, i.e., flows would increase with the following spring melt.

Freeze-up concerns and excess runoff (rain-on-snow) can potentially be eliminated in the collection system segment located in the LWA by installing a French drain (i.e., buried perforated pipe) in lieu of an open collection trench, as previously discussed. Also, as previously mentioned, on-line or off-line detention could be provided to relieve potential flow increases due to precipitation or snowmelt.

4.5.2 Iron Fouling

Iron contamination emanating from the Site has long been identified as a problem within Railroad Creek.

Groundwater intercepted by the Alternative 10 trench collection system along the tailings piles is expected to have relatively high concentrations of dissolved iron (see Figure F-3). Iron can take different chemical forms, which can have an impact on different treatment scenarios. Iron has two oxidation states, ferrous (Fe^{2+}) and ferric (Fe^{3+}). Solubility of these species is affected by pH, oxidation-reduction conditions, and by the presence of other aqueous species. Ferrous iron is water soluble over a wide pH range, while ferric iron is soluble at pH less than 3.5 and becomes highly insoluble at pH greater than 3.5. When ferrous iron is oxidized to ferric iron, ferric hydroxides readily precipitate.

Ferricrete (cementation of the stream channel gravels with an iron oxide precipitate) is present in portions of Railroad Creek adjacent to the tailings piles. Iron-oxide precipitate (flocculent) has been observed in Railroad Creek from TP-1 to approximately 2 to 3 miles downstream of the Site. After the Alternative 10 groundwater collection system is installed, iron currently entering Railroad Creek as seepage below TP-1 and TP-3 would be intercepted, leading to iron deposits in the collection and conveyance system, which is referred to as "iron fouling."

Periodic inspection and maintenance of the trench and pipeline system will enable the operator to mitigate potential losses in collection and flow efficiencies due to iron fouling. In contrast to a French drain system, the open collection trench can be cleaned out with a backhoe and/or vacuum truck, as necessary, to maintain collection efficiency. A French drain could be maintained by water jetting, although the effectiveness of this may be limited as described in Attachment C. Alternative 10 conceptual design includes a maintenance road along the collection trench to provide access for equipment to maintain the trench. Iron deposits (floc or ferricrete) would periodically need to be removed and disposed of with the treatment facility sludge in an on-Site landfill, throughout the period of active remediation (more than 200 years).

Excavation of the trench bottom to remove iron deposits could change the trench bottom elevation relative to the hydraulic grade line along Railroad Creek. Changing the trench bottom elevation would have a corresponding effect on collection effectiveness as discussed in Section 4.1.3. This may be a problem especially if ferricrete builds up in the subsoil in the base of the trench and diminishes its capacity for seepage. Periodic maintenance may need to include regrading the collection trench beyond what is needed to simply remove the iron build-up.

Pipeline segments are proposed to convey water along the base of TP-2 and across Copper Creek and Railroad Creek. When necessary, these sections of pipeline will be cleaned out to remove accumulations of iron precipitate. Potential methods to clean pipelines include high pressure water jetting and mechanical cleaning referred to as "pipeline pigging."

A more detailed analysis of the iron precipitate issues is provided in Attachment C. A review of other mine sites that deal with maintaining collection and conveyance systems fouled by iron precipitates is included.

4.5.3 Seep Migration

Since seeps are simply expressions of groundwater, areas of seepage may migrate over the lifetime of the remedial action. This may occur due to iron precipitation (ferricrete formation) or for other reasons. Discrete seep collection systems will need to be monitored and modified as needed over time to assure continued collection of the contaminated groundwater.

5.0 ADDITIONAL ELEMENTS OF SYSTEM DESIGN

This section discusses elements of the Alternative 10 treatment system that go beyond the conceptual design assessment completed to date. These elements would be evaluated during RD and/or potentially after startup. The issues discussed herein are related to the general type of treatment system proposed (lime addition and sedimentation) and, therefore, are common elements that would need to be addressed for Alternative 10, as well as most other alternatives proposed for the Site.

5.1 Treatment System Effectiveness

From a “big picture” standpoint, the most fundamental design uncertainty relates to designing a treatment system that has the capability to achieve effluent discharge requirements. This depends on a complex interaction of variables, including influent flow rates; influent metals concentrations; treatment removal efficiencies; allowable mixing zone dilution; and surface water cleanup levels. Final design will require a thorough consideration of these variables and good engineering to produce the best functioning treatment system possible. An important component of RD will be treatability testing using water samples from the Site combined in appropriate proportions to simulate treatment system influent.

A detailed mixing zone analysis will need to be completed concurrent with design of the treatment facility outfall(s). The Agencies anticipate that a mixing zone analysis will evaluate treatment system performance requirements needed to meet proposed cleanup levels. Design of the treatment system will depend on results of the treatability studies as well as the mixing zone analysis. The final treatment system design may be different than described above, to meet discharge requirements. Design options discussed in the following section may increase metals removal efficiency, if this is required.

5.2 System Design Options

The following system design options are discussed in this section:

- Flow equalization at the main 1500 Level portal;
- Selection of acid-neutralizing chemical;
- Assisted flocculation; and
- Options associated with sludge handling.

5.2.1 Flow Equalization at the Main 1500 Level Portal

Flow equalization refers to providing a constant treatment system flow rate by dampening flow rate variations in the influent stream (Metcalf & Eddy 1991), to remedy problems caused by variations in flow. Equalization can stabilize and optimize performance of downstream system processes and can potentially reduce the size of downstream system facilities. At the Holden Site, flow equalization could potentially be provided with hydraulic bulkheads in the mine (partial or complete equalization) or by constructing a detention pond (for partial equalization) upgradient of the treatment facility.[23]

The DFFS includes analysis of a hydraulic bulkhead at the main 1500 Level portal to dampen spring and fall flow variations, but does not fully address the extent to which the bulkhead could be used for flow equalization. For example, it may be beneficial to contain a larger portion of the mine discharge in the spring, and treat it later in the year. This would enable treating groundwater flow (and a portion of the mine discharge) during the high spring peak period, and treating an increased proportion of the mine discharge during the remainder of the year when groundwater flow from the LWA and tailings piles has decreased. In addition to reducing the overall size of treatment system required, this approach may improve treatment efficiency and reduce the effluent mass of metal discharged from the treatment system due to the effects of co-precipitation.

Another approach to flow equalization for the groundwater and seep portion of the influent could involve constructing an in-line detention pond. However, size limitations for a pond would not enable complete equalization, and the area

[23] The treatment system would still need to handle seasonal changes in influent metals concentrations, with or without flow rate equalization.

required for the detention pond would increase the overall footprint of permanent remedial facilities. Even with a reduction in downstream treatment system size, the total required area of the collection and treatment system would likely be greater than using the underground mine for full, or partial, flow equalization.

5.2.2 Selection of Acid-Neutralizing Chemical

The precipitation process described in Section 3.3.3 would employ the addition of acid-neutralizing chemical to precipitate constituents of concern as metal hydroxides. As described by Escher et al. (1983), alkaline reagents used in treatment of AMD include:

- Quicklime (calcium oxide);
- Hydrated lime (calcium hydroxide);
- Limestone (calcium carbonate);
- Caustic soda (sodium hydroxide); and
- Soda ash (sodium carbonate).

Either quicklime or hydrated lime is considered to be most applicable for the treatment of AMD at the Site. Use of hydrated lime has been assumed in this conceptual design evaluation, but alternative chemicals may be further considered during detailed RD.

Quicklime is typically more economical than hydrated lime per ton of neutralizing chemical, but can potentially require the preparation of a slurry (i.e., slaking) prior to addition to the influent water stream (Patterson 1985). The disadvantages of quicklime include high capital cost for slaking equipment, the need for close operational control of the slaking process, and the hazard to personnel of possible chemical burns (Escher et al. 1983). However, quicklime, in pebble form, has been used in contemporary AMD treatment systems without slaking in some cases (Hilton 2005).

Hydrated lime has a number of benefits over quicklime. Dry hydrated lime does not require slaking and can be fed directly into the water stream to be treated. It also poses less of a chemical hazard to personnel. However, hydrated lime can bulk up and "bridge" in storage bins, requiring special agitation systems and operational supervision to maintain its flowability to prevent downtime in system operation (Patterson 1985). The capital costs associated with an agitation system for hydrated lime are typically less than those for a slaking system (Escher et al. 1983).

The use of **limestone** in treatment of AMD has been assessed in various studies. The bulk cost of limestone is typically much less than that of quicklime or hydrated lime. However, the use of limestone is limited due to slow reactivity, inability to raise pH much above 6, poor dissolution, poor effluent quality after treatment, and high transportation costs (Vachon et al. 1987).

Caustic soda has been employed in the treatment of low-flow, mildly acidic drainages in remote areas. It is usually purchased as a concentrated liquid (e.g., 50 percent concentration) to reduce shipping costs and prevent freezing of the solution during cold weather conditions. Benefits of caustic soda include high reactivity and production of good effluent quality. The use of caustic soda is limited due to its high cost, the hazards associated with its handling, and the production of voluminous sludge (Escher et al. 1983, MEND 1994).

Soda ash has been shown to produce an effluent of satisfactory discharge quality in treatment of acid mine drainages containing ferric iron (Escher et al. 1983). The sludges formed through soda ash neutralization generally settle well and compact to densities comparable to those obtained with quicklime and hydrated lime. However, the high cost associated with soda ash, and its limited availability, often make its use impractical.

Hydrated lime was selected for use in the conceptual design of the Site treatment system to formulate a conservative estimate. The acid-neutralizing chemical to be used in the final design should be assessed through bench-scale treatability testing of Holden AMD samples combined in their anticipated proportions to represent treatment system influent.

5.2.3 Assisted Flocculation

A flocculation step may be included to aid in solid-liquid separation. Flocculation is the process by which smaller solid particles coalesce to form a larger, faster settling solid mass or floc, to improve solids removal from the treated water stream.

- Flocculation can be assisted by the addition of mechanical energy to enhance particle collisions, either through mechanical mixing or by static mixing in a channel with over and under baffles to induce turbulent flow.

- Flocculation can be assisted also by the addition of chemicals that aid floc formation via chemical bonding. Iron salts and alum are commonly used, but would not be applicable at the Site, as iron and aluminum constitute two of the constituents to be removed. Polar, high-molecular weight polymers are also used in particle settling applications. According to Escher et al. (1987), anionic, low-charged, high-molecular weight polymers perform well in the treatment of AMD.

The cost versus benefit of a flocculation step should be further considered in the final design of the treatment system, and may include bench-scale treatability testing.

The employment of a flocculation step can improve particle settling and thus reduce loading on the granular media filters. However, mechanical flocculation requires the input of additional energy, which may limit its use at the Site. Static methods may be inconsistent in providing the correct amount of mixing for flocculation to occur, in that this mixing is dependent on flow conditions. Use of chemical flocculating agents poses the risk of release of these chemicals to area surface waters in the discharged effluent. Studies have shown that certain polymers used to aid flocculation can exhibit toxicity toward aquatic species (NICNAS 2000 and 2002). If a chemical flocculating agent is considered, spill prevention and potential environmental effects need to be assessed as part of RD.

5.2.4 Options Associated with Sludge Handling

The production of metal hydroxide solids is accompanied by the need to store, handle, and dispose of these solids. These solids take the form of sludge, which can vary in density depending on water chemistry, type of alkaline chemical added, type of precipitation process used, and other factors. With lower density sludges, the volume of sludge produced can be significant (MEND 1994). As a result, the treatment system's temporary sludge storage capacity (in the settling ponds), and the capacity of the final disposal facility (on-Site landfill) for the sludge, can be very large, leading to extensive land use (Vachon et al. 1987). The handling and disposal of the large quantity of solids produced also contributes significantly to the facility's O&M requirements.

Sludge Recycling

Sludge recycling is a waste-reducing process modification that can be effectively used in treating AMD. In a conventional chemical precipitation and sedimentation system, alkaline chemical is added directly to the influent stream to achieve a desired pH set point, with subsequent solids precipitation followed by clean effluent discharge. A treatment system with sludge recycling varies from a conventional system in that alkaline chemical is mixed with sludge recirculated from the sedimentation process prior to addition to the influent stream. Sludge recirculation from the sedimentation process originates typically from a mechanical clarifier with a sludge collection and pumping system.

Sludge recycling provides a number of benefits. It produces a denser sludge than the conventional chemical precipitation system, with solids contents in the range of approximately 15 to over 30 percent (MacDonald et al. 1989; MEND 1997; Zick et al. 1999). Higher solids content translates into lower sludge volume and reduces the required solids handling capacity of the treatment system. Sludge recycling also improves the efficiency of alkaline chemical utilization, resulting in a reduction of the quantity of chemical used. However, the cost-effectiveness of sludge recycling must be evaluated, since these cost reductions are offset by increased costs for specialized equipment, increased energy requirements, and increased operation and maintenance requirements associated with sludge recirculation.

Sludge Removal

The conceptual design of Alternative 10 assumes that the treatment system would include two parallel settling ponds as shown on Figures F-9 and F-10. Sludge removal from the ponds would take place annually, during low-flow conditions.

Design of the settling ponds could include drainage infrastructure installed beneath the ponds to promote sludge dewatering prior to removal. This could involve draining the off-line pond to allow the sludge to dewater *in situ* prior to removal. This drainage system could consist of perforated piping running through a drainage layer along the base of each settling pond. Control valves would be installed to shut off the drainage system when the pond was online. Leachate from the dewatering process could potentially be returned to the treatment system, disposed of through land application, or discharged to Railroad Creek if it met effluent discharge quality standards.

By draining an off-line pond, sludge solids content of up to 20 percent could potentially be attainable, depending on Site-specific operating conditions (Escher et al. 1983; MEND 1994). Sludge has been successfully pumped at up to 20 percent solids through short pipelines, and at up to 8 percent solids through long pipelines (greater than 10 miles in length; EPA 1979).

In the event that sludge consolidation is carried beyond the solids content where pumping is feasible, other removal methods would need to be considered. Sludge that cannot be pumped would likely be removed by loader from the drained off-line pond and transported to the on-Site landfill area by truck.

As an alternative to the approach described above, sludge could potentially be removed by hydraulic dredging, and the water content reduced by centrifuge or other mechanical means, and pumped or trucked to a disposal landfill. While this approach may seem more expensive due to the equipment needs and energy-intensive nature of mechanical dewatering, the effectiveness of drainage and natural drying for the particular climate conditions at the Site may make it cost-effective.

5.3 Cold Weather Effects on the Treatment System

Some of the Alternative 10 treatment system components (such as the chemical mixing and cascade aeration units) can be designed to produce enough agitation to prevent water freezing. However, freezing is a potential concern in the quiescent, low flow velocity unit operations, such as the settling ponds and media filters.

Pond freezing may or may not be a problem. If ice forms on the pond surface, it could potentially cause short-circuiting if the influent stream begins to flow over the ice surface toward the effluent point. To prevent this, adequate flow velocities would need to be maintained at the influent and effluent points of the settling ponds or the ponds could be designed with adequately submerged influent and effluent pipes. Increased velocity at the pond influent and effluent points could be achieved through the use of mixing baffles.

Other than the influent and effluent points, the remainder of the pond surface could be allowed to freeze over. This may actually be beneficial for solids removal, since the ice would provide a cover for the pond surface, minimizing wind effects and instilling more quiescent conditions within the pond that would aid in particle settling.

The extent of freezing impacts to the media filters will also need to be addressed during RD. By maintaining a minimum head of water above the filter medium, freezing on and within the granular media filter may be prevented. Preventing blockage or short-circuiting of the water stream may also be accomplished through a combination of insulation and adjusting the operation hydraulically by taking one unit off line to increase flow rate during the winter low-flow period.

Sub-freezing temperatures could potentially be a benefit to the sludge dewatering and drying process. The cycle of freezing and thawing of wet sludge frees water molecules, which can then freely drain from the sludge, potentially increasing the solids content of the sludge to approximately 20 to 30 percent (MEND 1994). However, this benefit is likely to be counteracted to some degree by snow accumulation and thawing on the sludge surface in the landfill.

Finally, low winter temperatures are likely to increase the difficulty of maintaining uniform delivery of acid-neutralizing chemicals, such as hydrated lime, which is subject to forming lumps and blocking feed systems. The Alternative 10 estimate was based on conventional technology including storage bin heaters, vibrators, and insulated enclosures. The possible use of waste heat from generators used for water pumping for the Alternative 10 treatment system, should be further evaluated to supplement or replace conventional silo heaters and vibrators.

6.0 REFERENCES FOR APPENDIX F

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Table F-1 - Anticipated Source Contributions and Alternative 10 Treatment System Influent Characteristics

Water Source[a]	Spring (90 days/year)							Fall (275 days/year)						
	Average Flow Rate in gpm[b]	Blended Concentration in mg/L						Average Flow Rate in gpm[b]	Blended Concentration in mg/L					
		Al	Cd	Cu	Fe	Pb	Zn		Al	Cd	Cu	Fe	Pb	Zn
Honeymoon Heights Seeps	257	6.9	0.04	6.1	0.01	0.008	4.6	No Flow	--	--	--	--	--	--
Discharge from Main 1500 Level Portal (with Hydrostatic Bulkheads in Place)[c]	261	17	0.10	12	2.0	0.003	21	87	17	0.10	12	2.0	0.003	21
Groundwater Downgradient of Lower West Area[d]	424	3.9	0.03	3.8	0.03	0.005	3.6	214	4.1	0.03	3.9	0.02	0.005	3.6
Groundwater Downgradient of Tailings Pile 1	285	44	0.02	1.0	242	0.020	6.3	105	23	0.01	0.48	522	0.001	3.8
Seeps SP-3 and SP-4	240	23	0.02	0.82	95	0.001	1.7	5	3.9	0.002	0.09	251	0.0025	0.61
Groundwater Downgradient of Tailings Pile 3[e]	940	1.3	0.0002	0.05	4.4	0.001	0.10	15	6.2	0.002	0.04	101	0.001	0.27
Treatment System Influent	**2410**	**11**	**0.02**	**2.8**	**40**	**0.005**	**4.3**	**430**	**11**	**0.04**	**4.5**	**130**	**0.004**	**7.0**

Notes

[a] See Figure 3 for source locations.

[b] Average flow rates and blended concentrations are based on data collected in 1997 (URS 2004a) except LWA, which is also based on URS (2006).

[c] Based on SRK analysis provided in Appendix E of the DFFS (URS 2004a).

[d] Includes sources seeps and flow tubes from P-5 (the main 1500 Level portal discharge into Railroad Creek) to the Copper Creek Diversion, see Hart Crowser (2005b).

[e] Includes seep SP-21.

Table F-2 - Proposed Surface Water Cleanup Levels

PCOC	Proposed Cleanup Level in ug/L [a]	Basis
Dissolved Metals		
Cadmium	0.07	Background [b]
Copper	1.06	Section 304 of the CWA (chronic) [d,f]
Lead	0.54	Background [b]
Zinc	17 [c]	Chapter 173-201A WAC (chronic) [e]
Total Metals		
Aluminum	144	Background [b]
Iron	1,000	Section 304 of the CWA (chronic) [d]

Notes:

[a] Proposed cleanup levels based on ARARs.

[b] Reported background concentration may not meet MTCA statistical criteria and may be adjusted prior to Record of Decision.

[c] Proposed cleanup level is hardness dependent; value shown is for a hardness of 12 mg/L as $CaCO_3$.

[d] Water quality criteria published under Section 304 of the Clean Water Act. EPA, National Recommended Water Quality Criteria.

[e] Chapter 173-201A WAC. Water Quality Standards for Surface Waters of the State of Washington.

[f] Proposed cleanup level for dissolved copper to be based on the Aquatic Life Ambient Freshwater Quality Criteria - Copper 2007 Revision or background concentration, whichever is higher. Value shown is background.

Table F-3 - Case Study Comparison of Metals Removal from Acid Mine Drainage: Conventional Systems

Name of Site, Location	**Gilt Edge Mine, South Dakota**				**Argo Tunnel, Colorado**		**Eagle Mine, Colorado**		**Leadville Mine Drainage Tunnel, Colorado**		**Brunswick Mine, New Brunswick**		**Britannia Mine, British Columbia**		**Bunker Hill Mine, Idaho**	
Treatment Scale	Pilot test		Pilot test		Full scale		Full scale		Full scale		Pilot test		Pilot test		Full scale & pilot test	
Period of Operation	42 days[f]		N/A		Eight months[f]		Eight years[f]		Six years[f]		Two weeks		Two months		1974 to present	
Description of Treatment Process	Batch test to simulate ponded acid rock drainage (i.e., pit lakes). Series of 200 L drums containing wasterock mixed with ViroMine™ reagent Acid-B™ to final concentrations of 10, 5, and 2% by weight.		Wasterock leachate trials, consisting of lined trench containing approx. 20 m^3 Sulfidic wasterock mixed with ViroMine™ reagent Acid-B™ to final concentration of 10% by weight. Leachate sampled monthly for water quality analysis.		Metals precipitated using sodium hydroxide. Polymer added in clarifier to enhance flocculation of hydroxide precipitates. Overflow from clarifier routed to gravity filter to remove any unsettled solids. Carbon dioxide then added to adjust pH of effluent before discharge.		Two-stage metal precipitation process using lime (calcium hydroxide) followed by sodium carbonate addition. An anionic polymer is used to assist flocculation during subsequent clarification. The pH of the clarifier overflow is adjusted prior to discharge.		Primary treatment process utilizes carbon dioxide stripping followed by precipitation and solid contact clarification using a 50% sodium hydroxide feed solution. Gravity filtration is used on the clarifier overflow to remove residual solids. The pH is then adjusted prior to discharge.		Cominco high-density sludge (HDS) process: Metal precipitation facilitated by contacting acid mine drainage with lime/recycled sludge slurry. Air sparged through the mixture for ferrous oxidation. Flocculation assisted by polymer addition, followed by clarification and discharge of clarified water.		HDS process pilot-scale study. Lime/recycled sludge mixture contacted with acid mine drainage to precipitate metal hydroxides. Air sparged through the mixture for ferrous oxidation. Flocculation assisted by polymer addition, and solids separated via gravity filtration, producing a clear effluent.		Full scale, low-density sludge (LDS) process: metal hydroxide precipitation with lime, with subsequent aeration, flocculation, and clarification. Clarified effluent flows to polishing pond and then to final discharge point. Clarifier effluent treated by pilot-scale multi-media filtration.	
Influent Flow Rate	batch test		N/A		150 to 550 gpm		400 gpm		1,600 gpm		30- to 90-minute retention		0.22 to 0.32 gpm		N/A	
Effluent Flow Rate	batch test		N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Influent Concentration	mg/L		control mg/L		mg/L		mg/L		mg/L		mg/L		dissolved mg/L		total mg/L[e]	
Cd	0.214		0.671		0.05 to 0.3		0.25		0.02		0.099		0.32		0.142	
Cu	27.3		31.25		4.0 to 7.0		1.08		N/A		0.219		40		N/A	
Zn	4.11		34.95		25 to 50		130		3.6		108		47		93	
Fe	N/A		N/A		75 to 200 (total)		320 (total)		1.4 (total)[c]		43.3 (total)		47		N/A	
Pb	N/A		N/A		N/A		N/A		N/A		N/A		N/A		0.58	
Al	N/A		N/A		15 to 35		N/A		N/A		15.9		45		N/A	
Effluent Concentration/ % Reduction	mg/L	%	mg/L	%	mg/L[b]	%	mg/L[b]	%	mg/L[d]	%	mg/L[k]	%	dissolved mg/L	%	avg. total mg/L	%
Cd	0.0153	92.9%	0.0004	99.9%	<0.003	>94.0%	<0.008	>96.8%	<0.0044	>78.0%	<0.0007	>99.3%	<0.002	>99.4%	0.0002	99.9%
Cu	0.016	99.9%	0.0129	>99.9%	<0.017	>99.6%	<0.15	>86.1%	N/A	N/A	<0.0004	>99.8%	<0.005	>99.9%	N/A	N/A
Zn	0.0219	99.5%	0.0292	99.9%	<0.125	>99.5%	<0.4	>99.7%	<0.127	>96.5%	<0.04	>99.9%	0.014	>99.9%	0.0224	>99.9%
Fe	N/A	N/A	N/A	N/A	<1.0 (total)	>98.7%	<9.8 (total)	>96.9%	<1.0 (total)[c]	>28.6%	<0.06 (total)	>99.9%	N/A	N/A	N/A	N/A
Pb	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00062	99.9%
Al	N/A	N/A	N/A	N/A	<1.0	>93.3%	N/A	N/A	N/A	N/A	0.796	95.0%	0.37	99.2%	N/A	N/A
Performance Goals	N/A		N/A		Discharge limits not specified.[b]		Discharge limits not specified.[b]		Discharge limits not specified.[b]		N/A		N/A		Cd 0.0005 mg/L Zn 0.05 mg/L Pb 0.003 mg/L	
Reference	Virotec (2003)				Willow and Braak (1999)		Willow and Braak (1999)		Willow and Braak (1999)		Zinck and Griffith (2000)		CEMI (2002)		CH2M Hill (2000)	

Table F-3 - Case Study Comparison of Metals Removal from Acid Mine Drainage: Conventional Systems

Name of Site, Location	Bunker Hill Mine, Idaho				Confidential, North America (Elbow Creek Site 1)		Confidential, North America (Elbow Creek Site 2)		Confidential, North America (Elbow Creek Site 3)		Wheal Jane Mine, Baldu, Cornwall, UK		Woolley , West Yorkshire, UK	
Treatment Scale	Full scale and pilot test				Full scale		Full scale		Full scale		N/A		N/A	
Period of Operation	1974 to present				1992 through 2001		Late 1980s to present		Late 1990s to present		2001 to present		2000 to present	
Description of Treatment Process	Full scale LDS process: metal hydroxide precipitation with lime, with subsequent aeration, flocculation, and clarification.		Pilot-scale multi-media filtration, preceded by LDS treatment process. LDS process effluent spiked with sludge from thickener underflow to simulate higher TSS concentrations expected during future plant operations as a HDS system.		Lime and recycled sludge neutralization in HDS system, followed by mechanical clarification.		Lime neutralization in HDS system followed by mechanical clarification and gravity sand filtration.		Lime neutralization with sludge recycle followed by mechanical clarification.		HDS system. Aeration. Clarification.		HDS system. Aeration. Settling ponds. Flow-through settling lagoons followed by aerobic wetland.	
Influent Flow Rate	N/A		N/A		3,800 gpm		5,000 to 15,000 gpm		1,000 gpm		4,000 gpm		2,600 gpm	
Effluent Flow Rate	N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Influent Concentration	dissolved mg/L[g]		dissolved mg/L[g]		dissolved mg/L[h]		total mg/L[i]		total mg/L[j]		mg/L		mg/L	
Cd	0.11		0.0024		0.075		2.7		N/A		0.056		N/A	
Cu	0.10		N/A		0.18		0.087		32		0.4		N/A	
Zn	75.7		1.44		40		265		13		44		N/A	
Fe	79.2		N/A		190		9.3		140		1.59		16	
Pb	N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Al	N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Effluent Concentration/ % Reduction	dissolved mg/L[g]	%	dissolved mg/L[g]	%	dissolved mg/L[h]	%	total mg/L[i]	%	total mg/L[j]	%	mg/L	%	mg/L	%
Cd	0.0003	99.7%	0.0002	91.7%	<0.002	>97.3%	0.003	99.9%	N/A	N/A	<0.001	>98.2%	N/A	N/A
Cu	N/A	N/A	0.049 (total)	N/A	0.008	95.6%	0.002	97.7%	0.07	99.8%	<0.1	>75.0%	N/A	N/A
Zn	0.065	>99.9%	0.028	98.1%	0.02	>99.9%	0.06	>99.9%	0.05	99.6%	0.4	99.1%	N/A	N/A
Fe	N/A	N/A	0.030 (total)	N/A	0.02	>99.9%	0.21	97.7%	0.19	99.9%	1.3	18.2%	0.3	98.1%
Pb	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Performance Goals	N/A		N/A		Reg. criteria (monthly avg.) Cu <0.15 mg/L Fe <0.6 mg/L Zn <0.3 mg/L		Reg. criteria (monthly avg.) Cd 0.002 mg/L Cu 0.015 mg/L Fe none Zn 0.12 mg/L		Reg. criteria (monthly avg.) Cu 0.1 mg/L Fe 50 mg/L Zn none		N/A		N/A	
Reference	URS Corporation (2004a)				URS Corporation (2004a)		URS Corporation (2004a)		URS Corporation (2004a)		URS Corporation (2004a)		URS Corporation (2004a)	

Table F-3 - Case Study Comparison of Metals Removal from Acid Mine Drainage: Conventional Systems

Name of Site, Location	Wedge Mine, Arizona		Les Mines Gallen, Ontario		Chester Mine, Mississippi		Brunswick Mining and Smelting Corp., Ltd., Site 12		Brunswick Mining and Smelting Corp., Ltd., Site 6		Waite-Amulet Mine, Noranda, Quebec		Geco Division, Manitouwadge, Ontario	
Treatment Scale	Full scale		Full scale		Full scale		Full scale		Full scale		Full scale		Full scale	
Period of Operation	N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Description of Treatment Process	Treatment of leachate. Lime precipitation with sludge settling ponds.		Treatment of AMD, HDS system. Lime precipitation with sludge recycling and clarifier.		Treatment of AMD. Lime precipitation with clarifier.		Treatment of AMD. Lime precipitation. Aeration to oxidize ferrous iron. Polymer added to aid settling. Plate-pack clarifier for solid-liquid separation.		Treatment of leachate. Lime precipitation. Solid-liquid separation in open pit. No aeration or polymer addition.		Treatment of leachate, HDS system. Lime precipitation with sludge recycling. Mechanical aeration to oxidize ferrous iron. Polymer added to aid settling. Plate-pack clarifier for solid-liquid separation. Clarifier overflow passes through polishing pond.		Treatment of AMD and leachate. Lime precipitation with aeration to oxidize ferrous iron. Polymer added to aid settling. Solid-liquid separation in clarifier. Overflow passes by gravity to holding tank prior to discharge to surface water.	
Influent Flow Rate	1,000 gpm		475 gpm		240 gpm		400 gpm		750 gpm		800 gpm		800 gpm	
Effluent Flow Rate	N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Influent Concentration	mg/L		mg/L		mg/L		total mg/L		total mg/L		yearly avg., total mg/L		yearly avg., total mg/L	
Cd	N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Cu	55		0.26		100		5 to 12		10 to 20		3.5		3.4	
Zn	580		530		100		1,700		300 to 500		20.7		120	
Fe	2,100		865		300		500 to 1,200		500 to 800		254		460	
Pb	N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Al	N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Effluent Concentration/ % Reduction	mg/L	%	mg/L	%	mg/L	%	total mg/L	%	total mg/L	%	yearly avg., total mg/L	%	yearly avg., total mg/L	%
Cd	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cu	0.24	99.6%	0.04	84.6%	0.01	>99.9%	0.01 to 0.1	>98.0%	0.2	>98.0%	0.02	99.4%	0.1	97.1%
Zn	0.58	99.9%	0.45	99.9%	0.09	99.9%	0.01 to 4	>99.8%	0.1 to 2.5	>99.2%	0.2	99.0%	0.4	99.7%
Fe	1.6	99.9%	0.75	99.9%	0.2	99.9%	0.01 to 4	>99.2%	0.2 to 4	>99.2%	1.4	99.4%	1.1	99.8%
Pb	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Performance Goals	N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Reference	Vachon et al. (1987)		Vachon et al. (1987)		Vachon et al. (1987)		Wasserlauf (1985)		Wasserlauf (1985)		Wasserlauf (1985)		Wasserlauf (1985)	

Table F-3 - Case Study Comparison of Metals Removal from Acid Mine Drainage: Conventional Systems

Name of Site, Location	**Westmin Mine, Vancouver Island**		**Inco Nolin Creek, Ontario**		**Cominco Mine**	
Treatment Scale	Full scale		Full scale		Full scale	
Period of Operation	N/A		N/A		N/A	
Description of Treatment Process	Treatment of leachate. Lime precipitation with solid-liquid separation in settling ponds.		Treatment of AMD and leachate, HDS system. Lime precipitation with solid-liquid separation in clarifier.		Treatment of AMD, HDS system. Lime precipitation with aeration. Solid-liquid separation in clarifier.	
Influent Flow Rate	10,500 gpm		6600 gpm		4800 gpm	
Effluent Flow Rate	N/A		N/A		N/A	
Influent Concentration	mg/L		mg/L		mg/L	
Cd	N/A		N/A		N/A	
Cu	6		6.7		0.15	
Zn	40		N/A		22 to 75	
Fe	2		35.6		250	
Pb	N/A		N/A		N/A	
Al	N/A		N/A		N/A	
Effluent Concentration/ % Reduction	mg/L	%	mg/L	%	mg/L	%
Cd	N/A	N/A	N/A	N/A	N/A	N/A
Cu	0.02	99.7%	0.02 to 0.6	>91.0%	0.05	66.7%
Zn	0.3	99.3%	N/A	N/A	<0.2	>99.1%
Fe	0.08	96.0%	0.3 to 3.4	>90.4%	<1.0	>99.6%
Pb	N/A	N/A	N/A	N/A	N/A	N/A
Al	N/A	N/A	N/A	N/A	N/A	N/A
Performance Goals	N/A		N/A		N/A	
Reference	Vachon et al. (1987)		Vachon et al. (1987)		Vachon et al. (1987)	

Notes:
a) Averaged over 7-month period.
b) 30-day average post-treatment discharge limit values. Treatment facility successfully achieves these values.
c) 30-day average.
d) Daily maximum post-treatment permit limit values. Treatment facility successfully achieves these values.
e) 3-week average.
f) Approximated period of operation; exact period of operation unavailable.
g) 4-day average.
h) Average data from 1992 - 2001 generated from over 4,500 data points for each parameter.
i) Average data from 1998 - 2001 generated from over 580 data points for each parameter.
j) Average data from 1999 - 2001 generated from over 4,100 data points for each parameter.
k) 2-week average.
N/A means not available.

Table F-4 - Case Study Comparison of Metals Removal from Acid Mine Drainage: Low-Energy Systems

Name of Site, Location	**Silver Bow Creek/Butte Area Superfund Site, Montana**											
Treatment Scale	Pilot test		Pilot test		Pilot test		Pilot test		Pilot test			
Period of Operation	Two years		Two years		Two years		Two years		20 months			
Description of Treatment Process	Treatability study to investigate use of constructed wetlands to treat groundwater with elevated metal concentrations. *Subsurface Wetland 1*: Horizontal flow, anaerobic, gravel substrate, no organics added.		Treatability study to investigate use of constructed wetlands to treat groundwater with elevated metal concentrations. *Subsurface Wetland 2*: Horizontal flow, anaerobic, gravel with 20% compost substrate.		Treatability study to investigate use of constructed wetlands to treat groundwater with elevated metal concentrations. *Subsurface Wetland 3*: Vertical, upward flow, anaerobic, gravel with 50% compost substrate.		Treatability study to investigate use of constructed wetlands to treat groundwater with elevated metal concentrations. *Subsurface Wetland 4*: Same as Subsurface Wetland 1, but half-size to decrease residence time.		Treatability study to investigate use of constructed wetlands to treat groundwater with elevated metal concentrations. *Surface Wetland 1*: From two sedimentation/ retention basins, influent enters three open water cells separated by two treatment walls. First treatment wall consists of highly permeable river rock. Second treatment wall consists of 90% river rock and 10% compost by volume. Serves as comparative baseline for Surface Wetland 2.			
Influent Flow Rate	5 gpm		5 gpm		5 gpm		5 gpm		50 to 150 gpm		50 to 150 gpm	
Effluent Flow Rate	N/A		N/A		N/A		N/A		N/A		N/A	
Influent Concentration	dissolved mg/L		dissolved mg/L		dissolved mg/L		dissolved mg/L		dissolved mg/L		acid soluble mg/L	
Cd	0.042		0.042		0.042		0.042		0.0394		0.0452	
Cu	0.188		0.188		0.188		0.188		0.3288		1.5355	
Zn	12.176		12.176		12.176		12.176		11.2729		13.6452	
Fe	N/A		N/A		N/A		N/A		N/A		N/A	
Al	N/A		N/A		N/A		N/A		N/A		N/A	
Effluent Concentration/ % Reduction	dissolved mg/L	%	dissolved mg/L	%	dissolved mg/L	%	dissolved mg/L	%	dissolved mg/L	%	acid soluble mg/L	%
Cd	0.001	97.6%	<0.001	>97.6%	<0.001	>97.6%	0.002	95.2%	0.025	36.5%	0.0252	44.2%
Cu	0.013	93.1%	0.012	93.6%	0.058	69.1%	0.014	92.6%	0.0847	74.2%	0.1408	90.8%
Zn	0.572	95.3%	0.361	97.0%	0.088	99.3%	3.347	72.5%	6.9952	37.9%	7.8583	42.4%
Fe	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Performance Goals	N/A		N/A		N/A		N/A		N/A		N/A	
Reference	McCarthy et al. (1999)											

Table F-4 - Case Study Comparison of Metals Removal from Acid Mine Drainage: Low-Energy Systems

Name of Site, Location	Silver Bow Creek/Butte Area Superfund Site, Montana (continued)				Success Mine, Idaho				Crystal Mine, Montana		Confidential, North America (Elbow Creek Site 4)	
Treatment Scale	Pilot test				Pilot test				Pilot test		Full scale	
Period of Operation	Four months				Nine months				Two years		Mid-1990s to present	
Description of Treatment Process	Treatability study to investigate use of constructed wetlands to treat groundwater with elevated metal concentrations. *Surface Wetland 2*: Influent water drawn from open water ponds or construction dewatering trenches. Same wetland layout as Surface Wetland 1 but incorporates lime addition prior to wetland treatment. For first month lime addition system consisted of mechanical water wheel lime addition machine. For remainder of study, lime addition system was changed to two slurry-mixing tanks and two metering pumps.				Demonstration project at a large floodplain tailings pile for testing viability of semi-passive groundwater treatment before discharge to surface water. Grout wall intercepts groundwater flow, which is directed via gravity drains to flow-through treatment vault containing organic apatite treatment media. Effluent then discharged to surface water.				Quicklime neutralization with AquaFix water-powered lime feeder, aeration using riprap channels, two settling ponds in series. Flow transferred through the system by gravity, with minimal system control or oversight.		Automated hydrated lime addition/mixing with flocculant addition and removal of suspended solids in two 3-million gallon, baffled settling ponds. Solids dredged from within ponds annually and disposed of in lined containment on site.	
Influent Flow Rate	125 gpm		125 gpm		3 to 101 gpm		3 to 101 gpm		20 to 100 gpm		200 to 6,000 gpm	
Effluent Flow Rate	N/A		N/A		Effluent "E" = 2.9 gpm		Effluent "W" = 2.2 gpm		N/A		N/A	
Influent Concentration	dissolved mg/L		acid soluble mg/L		total mg/L[a]		total mg/L[a]		avg. total mg/L		avg. total mg/L	
Cd	0.0344		0.0362		0.373		0.373		3.04		0.015	
Cu	0.2861		0.839		N/A		N/A		14.7		0.30	
Zn	9.4740		9.8493		55.6		55.6		65		0.90	
Fe	N/A		N/A		N/A		N/A		50		30.8	
Al	N/A		N/A		N/A		N/A		N/A		N/A	
Effluent Concentration/ % Reduction	dissolved mg/L	%	acid soluble mg/L	%	total mg/L	%	total mg/L	%	avg. total mg/L	%	avg. total mg/L	%
Cd	0.0015	95.6%	0.0022	93.9%	<0.002	>99.5%	<0.0005 to 0.058	84.5 to >99.8%	0.005	99.8%	0.0003	98.0%
Cu	0.022	92.3%	0.0356	95.8%	N/A	N/A	N/A	N/A	0.04	99.7%	0.004	98.7%
Zn	0.068	99.3%	0.2357	97.6%	0.151	99.7%	0.006 to 7.68	86.2 to >99.9%	0.4	99.4%	0.05	94.4%
Fe	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.02	>99.9%	0.29	99.1%
Al	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Performance Goals	N/A		N/A		To reduce concentrations of total and dissolved cadmium and zinc by 75% at treatment system outflow relative to system inflow.				N/A		N/A	
Reference	McCarthy et al. (1999)				Calabretta et al. (2004)				URS Corporation (2004a)		URS Corporation (2004a)	

Table F-4 - Case Study Comparison of Metals Removal from Acid Mine Drainage: Low-Energy Systems

Name of Site, Location	**Whitworth No. 1, South Wales, UK**		**Ynysarwed, South Wales, UK**		**St. Salvy Mine, France**		**Underground Coal Mine, Pennsylvania**		**Brewer Gold Mine, South Carolina**	
Treatment Scale	N/A		N/A		N/A		Pilot test		Pilot test	
Period of Operation	1995 to present		2000 to present		1997 to present		14 months		Approximately 18 months	
Description of Treatment Process	Two anaerobic wetland treatment cells. Two aerobic wetland treatment cells.		Lime neutralization. Mechanical aeration. Polymer addition. Clarification via lamellar settling. Aerobic wetland. Sludge dewatering via centrifugation.		Lime neutralization. Polymer addition. Clarification via lamellar settling. Polishing in anaerobic/aerobic wetland. Sludge dewatering via centrifugation.		Anaerobic sulfate reducing bacteria cell. Effluent feeds into aerobic polishing wetland. Discharge collects in a holding pond.		Two pilot-scale sulfate reducing bacteria cells.	
Influent Flow Rate	48 gpm		571 gpm		32 to 476 gpm		1.7 gpm		0.75 gpm	
Effluent Flow Rate	N/A		N/A		N/A		N/A		N/A	
Influent Concentration	mg/L		mg/L		mg/L		mg/L		mg/L	
Cd	N/A		N/A		0.4		N/A		N/A	
Cu	N/A		N/A		N/A		N/A		N/A	
Zn	N/A		N/A		72.8		N/A		N/A	
Fe	24.2		200		7.2		130		8 to 3,950	
Al	N/A		N/A		N/A		40[b]		60 (avg.); 4 to 220	
Effluent Concentration/ % Reduction	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%
Cd	N/A	N/A	N/A	N/A	0.002	99.5%	N/A	N/A	N/A	N/A
Cu	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zn	N/A	N/A	N/A	N/A	0.28	99.6%	N/A	N/A	N/A	N/A
Fe	4.3	82.2%	<1	>99.5%	0.43	94.0%	N/A	N/A	44	>98.9%
Al	N/A	N/A	N/A	N/A	N/A	N/A	<0.1	>99.8%	6	<97.3%
Performance Goals	N/A		N/A		N/A		N/A		N/A	
Reference	URS Corporation (2004a)		URS Corporation (2004a)		URS Corporation (2004a)		Gusek and Wildeman (2002)		Gusek and Wildeman (2002)	

Notes:
a) Averaged over 7-month period.
b) Maximum influent concentration during pilot testing period.
c) No low energy system case studies addressing lead (Pb) removal were reviewed.

Table F-5 - Comparison of Treatment System Flow Rates

Conventional Teatment Systems (From Table F-3)	
Name of Site, Location	**Influent Flow Rate in gpm**
Argo Tunnel, Colorado	150 to 550
Eagle Mine, Colorado	400
Leadville Mine Drainage Tunnel, Colorado	1,600
Britannia Mine, British Columbia	0.22 to 0.32
Confidential, North America (Elbow Creek Site 1)	3,800
Confidential, North America (Elbow Creek Site 2)	5,000 to 15,000
Confidential, North America (Elbow Creek Site 3)	1,000
Wheal Jane Mine, Baldu, Cornwall, UK	4,000
Woolley , West Yorkshire, UK	2,600
Wedge Mine, Arizona	1,000
Les Mines Gallen, Ontario	475
Chester Mine, Mississippi	240
Brunswick Mining and Smelting Corp., Ltd., Site 12	400
Brunswick Mining and Smelting Corp., Ltd., Site 6	750
Waite-Amulet Mine, Noranda, Quebec	800
Geco Division, Manitouwadge, Ontario	800
Westmin Mine, Vancouver Island	10,500
Inco Nolin Creek, Ontario	6,600
Cominco Mine	4,800

Low Energy Teatment Systems (From Table F-4)	
Name of Site, Location	**Influent Flow Rate in gpm**
Silver Bow Creek, Montana	5 to 150
Success Mine, Idaho	3 to 101
Crystal Mine, Montana	20 to 100
Confidential, North America (Elbow Creek Site 4)	200 to 6,000
Whitworth No. 1, South Wales, UK	48
Ynysarwed, South Wales, UK	571
St. Salvy Mine, France	32 to 476
Underground Coal Mine, Pennsylvania	1.7
Brewer Gold Mine, South Carolina	0.75

Estimated peak flow for Alterantive 10 is 2,440 gpm; for comparison peak anticipated flow for Alternative 9 is 1,240 gpm.

Table F-6 - Summary of Case Study Effluent Concentrations and Removal Efficiencies

PCOC	Range of Effluent Concentrations in ug/L		Removal Efficiencies[a]	
	Conventional Systems	Low-Energy Systems	Conventional Systems	Low-Energy Systems
Aluminum	370 to <1,000	<100 to 6,000	>93.3% to 99.2% Mean: 95.8%	<97.3% to >99.8% Mean: 98.5%
Cadmium	0.2 to 15.3	0.3 to 58	>78.0% to 99.9% Mean: 95.9%	>36.5% to >99.8% Mean: 88.5%
Copper	0.2 to 600	4 to 141	66.7% to >99.9% Mean: 94.4%	>69.1% to >99.7% Mean: 80.0%
Iron	10 to <9,800	20 to 44,000	18.2% to >99.9% Mean: 90.6%	>82.2% to >99.9% Mean: 95.6%
Lead	0.62	N/A	99.9%	N/A
Zinc	10 to 4,000	6 to 7,860	96.5% to >99.9% Mean: 99.4%	>37.9% to >99.9% Mean: 87.2%

N/A - No case studies reviewed for this PCOC.

Notes:
a) In calculating mean removal efficiencies, results reported as "greater than" or "less than" a value are assumed to be equal to that value.

Table F-7 - Standard Design Criteria for Sedimentation Basins and Filters

Sedimentation Basins		Overflow Rate in gal/ft^2-d	Hydraulic Retention Time in Hours	Tank Depth in Feet	Source
Primary Sedimentation Tanks Followed by Secondary Treatment					
	Average Flow	800 to 1200	1.5 to 2.5	10 to 15	M&E 1991
	Peak Flow	2000 to 3000	1.5 to 2.5		M&E 1991
Primary Sedimentation Tanks With Activated Sludge Return					
	Average Flow	600 to 800	1.5 to 2.5	10 to 15	M&E 1991
	Peak Flow	1200 to 1700	1.5 to 2.5		M&E 1991
Primary Sedimentation Tanks For Domestic Wastewater Treatment					
	Average Flow	800 to 1000	NA	NA	WPCF/ASCE 1977
Settling Basins Following Biological Fixed-Growth Treatment					
	Average Flow	500 to 700	NA	NA	WPCF/ASCE 1977
Horizontal Flow Sedimentation Tanks Conventional-Type Basin					
	Average Flow	736 to 1473	2 to 4	3 to 5	JMM 1985
Horizontal Flow Sedimentation Tanks For High-Rate Filters Without High-Rate Settler					
	Average Flow	1104 to 1841	1 to 2	3 to 5	JMM 1985
Horizontal Flow Sedimentation Tanks For High-Rate Filters With High-Rate Settler					
	Average Flow	2208 to 4418	0.1 to 0.42	3 to 5	JMM 1985
Clarifiers and Settling Ponds w/o Sludge Recycle					
	Flow NA	4.4 to 8.6 (a)	NA	NA	Vachon et al. 1987
Clarifiers w/ Sludge Recycle					
	Flow NA	393 to 2455	NA	NA	Vachon et al. 1987

Filters	Hydraulic Loading in gpm/ft^2	Depth of Media in Feet	Source
Slow Sand Filters	0.15 to 0.5	3 to 5	Corbitt 1990
Rapid Sand Filters	1 to 2.5	1.5 to 2.5	Corbitt 1990
High Rate Filters	3 to 15	NA	Corbitt 1990

Notes:
NA - Not Available
(a) Values are well below typical overflow rate range. Source of values requires further investigation as this information was not provided in detail by listed reference.

Table F-8 - Conceptual Design Parameters for Settling Ponds (Single Stage) and Filters

Settling Pond Parameters

Sizing Based on Particle Settling		**Two Parallel Ponds**
Maximum Overflow Rate	gpd/ft^2	500
Minimum Hydraulic Detention Time	min	120
Flow Rate	gpd	4,200,000
Minimum Water Volume for Settling	gallons	350,000
Minimum Water Depth	ft	3
Total Pond Surface Area	ft^2	15,600
Total Pond Wetted Depth	ft	12
Total Pond Wetted Volume	gallons	1,400,000
Sizing Based on Sludge Storage Capacity		
Total Sludge Capacity Required	gallons	5,790,000
Maximum Sludge Depth	ft	9
Minimum Water Depth	ft	3
Total Pond Depth	ft	14
Total (2 Ponds) Top Surface Area	ft^2	149,000
Total (2 Ponds) Volume	gallons	12,200,000
Minimum Water Volume (2 Ponds)	gallons	2,940,000
Flow Rate	gpd	4,200,000
Hydraulic Detention Time (at Minimum Water Volume)	min	1010

Granular Media Filter Parameters

Overflow Rate	gpm/ft^2	0.5
Flow Rate	gpd	4,200,000
Total Required Surface Area	ft^2	5,800
Depth of Media	ft	4

Notes:
The pond sizing calculations include the following assumptions:
Spring and fall flow and blended influent concentrations as discussed elesewhere in this report.
Effluent quality criteria would be achieved via chemical precipitation of dissolved metals and total suspended solids.
Dosed chemical would precipitate completely.
Minimum hydraulic detention time of 120 minutes for particle settling capacity.
Sludge volume required based on first year of operations, with solids content of 4%, sludge maximum depth of 9 feet, and storage capacity to accommodate 1 year of sludge accumulation between sludge removal events.
Settling pond length-to-width ratio of 4 to 1 with side walls sloped at a horizontal-to-vertical ratio of 2 to 1.

Table F-9 - Selected FS Treatability Study Results and Comparison with Alternative 10 Influent

	Anticipated Alt. 10 Influent Concentration in mg/L		Treatability Test Results(a)		
			Concentration in mg/L		Removal
PCOC	Spring	Fall	Initial(b)	Final	Efficiency
Aluminum	11	11	3.98	0.02 U	>99.5%
Cadmium	0.02	0.04	0.033	0.0011	96.7%
Copper	2.8	4.5	1.97	0.0014	99.9%
Iron	40	130	0.210	0.02 U	>90.5%
Lead	0.005	0.001	NA	NA	---
Zinc	4.3	7.0	6.65	0.008	99.9%

NA - Not analyzed.
U - Not detected at detection limit indicated.

Notes:
(a) Refer to Section 2.7 of the DFFS (URS 2004a) for more complete information on the treatability study. The results summarized in this table are for neutralization using hydrated lime (Test 1) to a final pH between 9.1 and 9.2 (Sample 3).
(b) The treatability test was conducted in June 2000 on a sample of water collected from the main 1500 Level portal discharge.

Table F-10 - Comparison of Treatment System Effluent Concentrations with Proposed Cleanup Levels and Potential Water Quality Criteria

Constituent of Concern	Anticipated Peak Concentration in Treatment System Effluent in ug/L		Proposed Surface Water Cleanup Level in ug/L(b)	Potential Allowable Effluent Water Quality Criteria (Based on 3.4 Mixing Zone Dilution Factor) in ug/L(c)
	Based on FS Treatability Study Results(a)	Order-of-Magnitude Range Based on Selected Case Study Results		
Aluminum	<70	100 to 1,000	144	490
Cadmium	1.3	0.3 to 3.0	0.07	0.24
Copper	5.0	10 to 100	1.06	3.6
Iron	<14,000(d)	200 to 2,000	1,000	3,400
Lead	NA(e)	0.1 to 1.0(f)	0.5	1.84
Zinc	7.5	30 to 300	17	58

NA - Not applicable.

Notes:

(a) Values shown based on the removal efficiencies shown in Table 8 applied to estimated Alternative 10 Fall influent concentrations (which exceed estimated Spring influent concentrations) to obtain anticipated peak effluent concentrations based on FS treatability study results.

(b) See Table F-2 for proposed surface water cleanup levels.

(c) As discussed in Section 3.4.2, preliminary evaluation of the potential magnitude of the mixing zone dilution factor yielded an upper-bound value of 3.4.

(d) The iron concentration in the treatability study water sample was only an order-of-magnitude higher than the detection limit, and more than two orders-of-magnitude lower than the anticipated Alternative 10 Fall influent concentration. Consequently, the treatability study result for iron has limited usefulness in predicting effluent concentrations.

(e) Lead was not analyzed in the treatability study.

(f) The order-of-magnitude range for lead has a high uncertainty, as it is based on the results of a single case study.

Table F-11 - Estimated Annual Energy Requirements

Item	Annual Energy Requirement in kw-hr	Percent of Total
Water Pumping [a]	130,000	62%
Lime Storage/Feed Systems [b]	45,000	21%
Sludge Pumping [c]	10,000	5%
Other Miscellaneous Energy Requirements	26,000	12%
Total Energy Requirements	211,000	100%

Notes:
Estimated annual energy requirements are maximum values, anticipated during early years of operation. Fifty-year averages are used in cost estimation for Alternative 10.
a) Based on pumping 490 million gallons of water from the influent pump station near TP-3 to the chemical addition step at 30-foot higher elevation.
b) Assumes heated storage silos and vibratory feeders.
c) Based on pumping 5.7 million gallons of sludge containing 4 percent solids from settling ponds to top of Tailings Pile 2.

Vicinity Map

47691107-001-AB.cdr EAL 07/24/07

Note: Base map prepared from Microsoft Streets and Trips 2005.

WASHINGTON

N

0 7.5 15

Approximate Scale in Miles

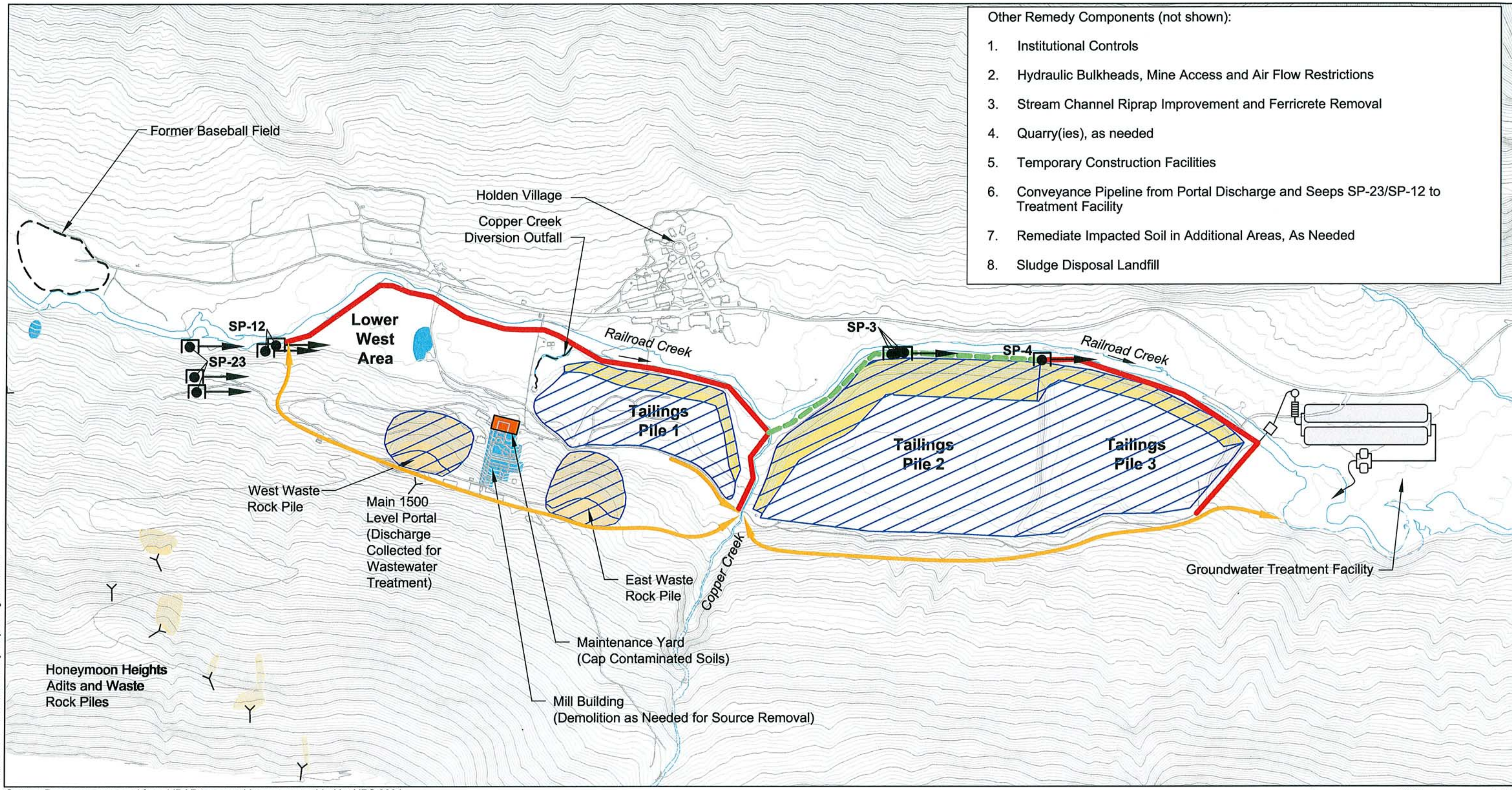
HARTCROWSER

4769-11 ***9/07***

Figure F-1

SFS Appendix F

Principal Components of Alternative 10



SRN 9/13/07 47691101-011.dwg Layout: Figure F-2 - SFS

Source: Base map prepared from LiDAR topographic survey provided by URS 2004

Capping Contanimated Soils

Regrade Tailings and Waste Rock Piles, and Cap with 1-foot of Soil

Move Toe of Tailings Pile Slopes away from Creek as Part of Regrading

Removal of Contaminated Soils

Waste Rock Piles (not regraded)

Potential Future Groundwater and Seep Collection

Groundwater and Seep Collection

Upgradient Runoff Diversion Swale

SP-12 Discrete Seep Collected for Treatment Location and Number

N

0 600 1,200

Scale in Feet

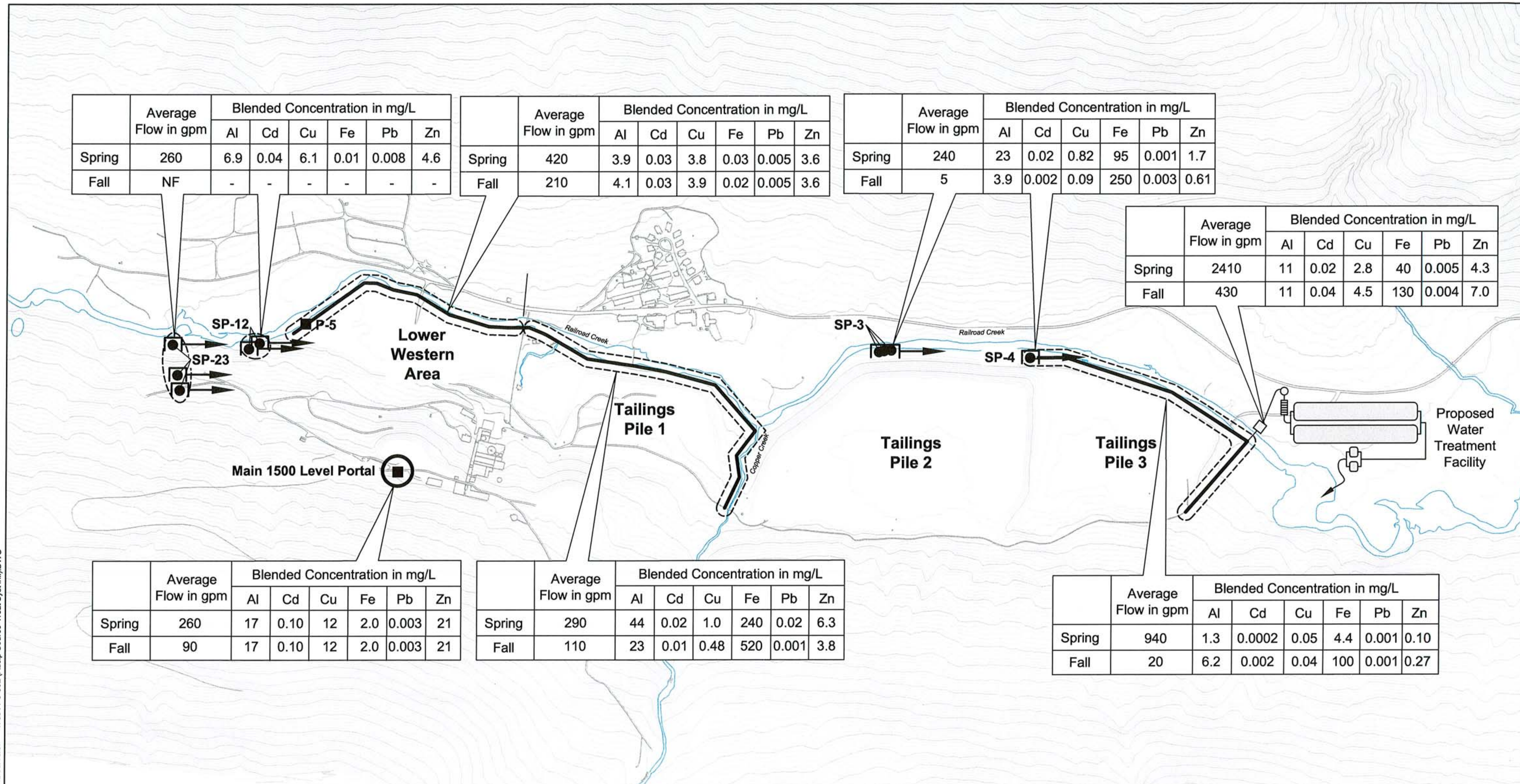
HARTCROWSER

4769-11 *9/07*

Figure F-2

SFS Appendix F

Anticipated Source Contributions and Treatment System Influent Characteristics



	Average Flow in gpm	Blended Concentration in mg/L					
		Al	Cd	Cu	Fe	Pb	Zn
Spring	260	6.9	0.04	6.1	0.01	0.008	4.6
Fall	NF	-	-	-	-	-	-

	Average Flow in gpm	Blended Concentration in mg/L					
		Al	Cd	Cu	Fe	Pb	Zn
Spring	420	3.9	0.03	3.8	0.03	0.005	3.6
Fall	210	4.1	0.03	3.9	0.02	0.005	3.6

	Average Flow in gpm	Blended Concentration in mg/L					
		Al	Cd	Cu	Fe	Pb	Zn
Spring	240	23	0.02	0.82	95	0.001	1.7
Fall	5	3.9	0.002	0.09	250	0.003	0.61

	Average Flow in gpm	Blended Concentration in mg/L					
		Al	Cd	Cu	Fe	Pb	Zn
Spring	2410	11	0.02	2.8	40	0.005	4.3
Fall	430	11	0.04	4.5	130	0.004	7.0

	Average Flow in gpm	Blended Concentration in mg/L					
		Al	Cd	Cu	Fe	Pb	Zn
Spring	260	17	0.10	12	2.0	0.003	21
Fall	90	17	0.10	12	2.0	0.003	21

	Average Flow in gpm	Blended Concentration in mg/L					
		Al	Cd	Cu	Fe	Pb	Zn
Spring	290	44	0.02	1.0	240	0.02	6.3
Fall	110	23	0.01	0.48	520	0.001	3.8

	Average Flow in gpm	Blended Concentration in mg/L					
		Al	Cd	Cu	Fe	Pb	Zn
Spring	940	1.3	0.0002	0.05	4.4	0.001	0.10
Fall	20	6.2	0.002	0.04	100	0.001	0.27

EAL 09/13/07 476911-3-002 (Aticip Source-Treat Syst Infl).DWG

● SP-4 Seep Sampling Location and Number

■ P-1 Portal Sampling Location and Number

Groundwater Collection

Discrete Seep Collection System

Notes:
1. NF = No Flow recorded for Fall 1997.
2. Average flow rates and blended concentrations are based on data collected in 1997.

N

0 600 1200
Scale in Feet

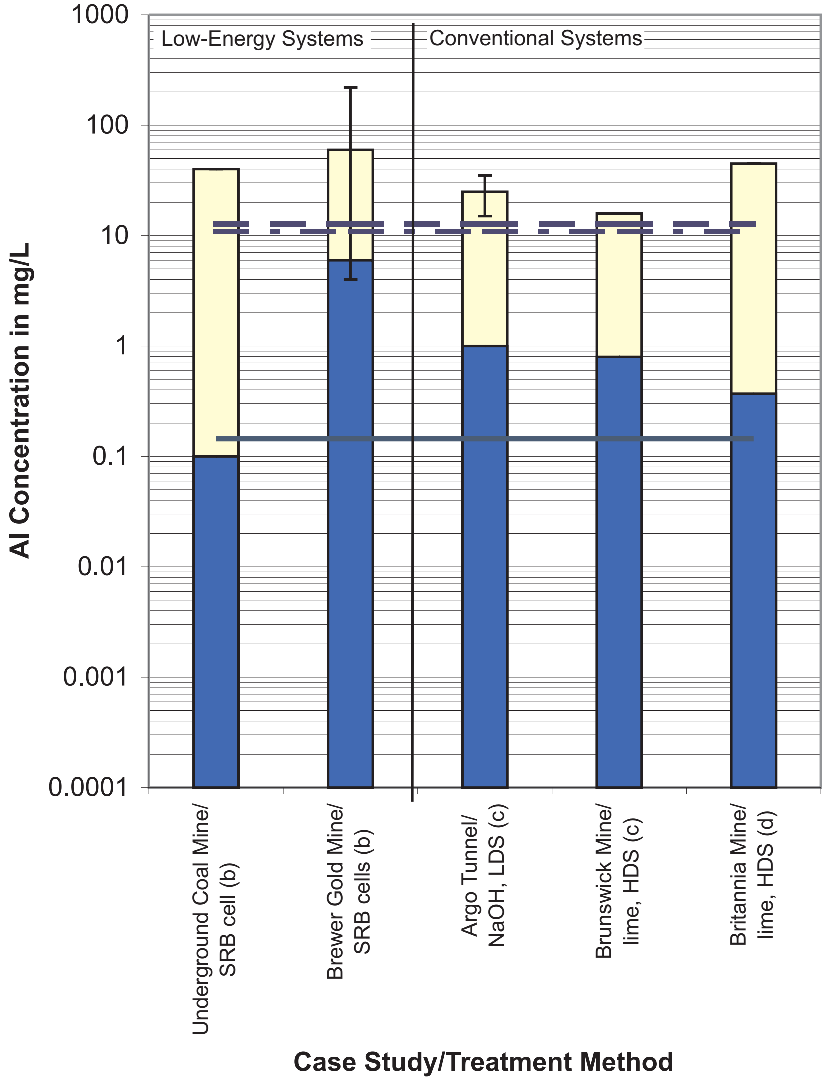
HARTCROWSER

4769-11 9/07

Figure F-3

SFS Appendix F

Case Study Comparison - Aluminum Removal

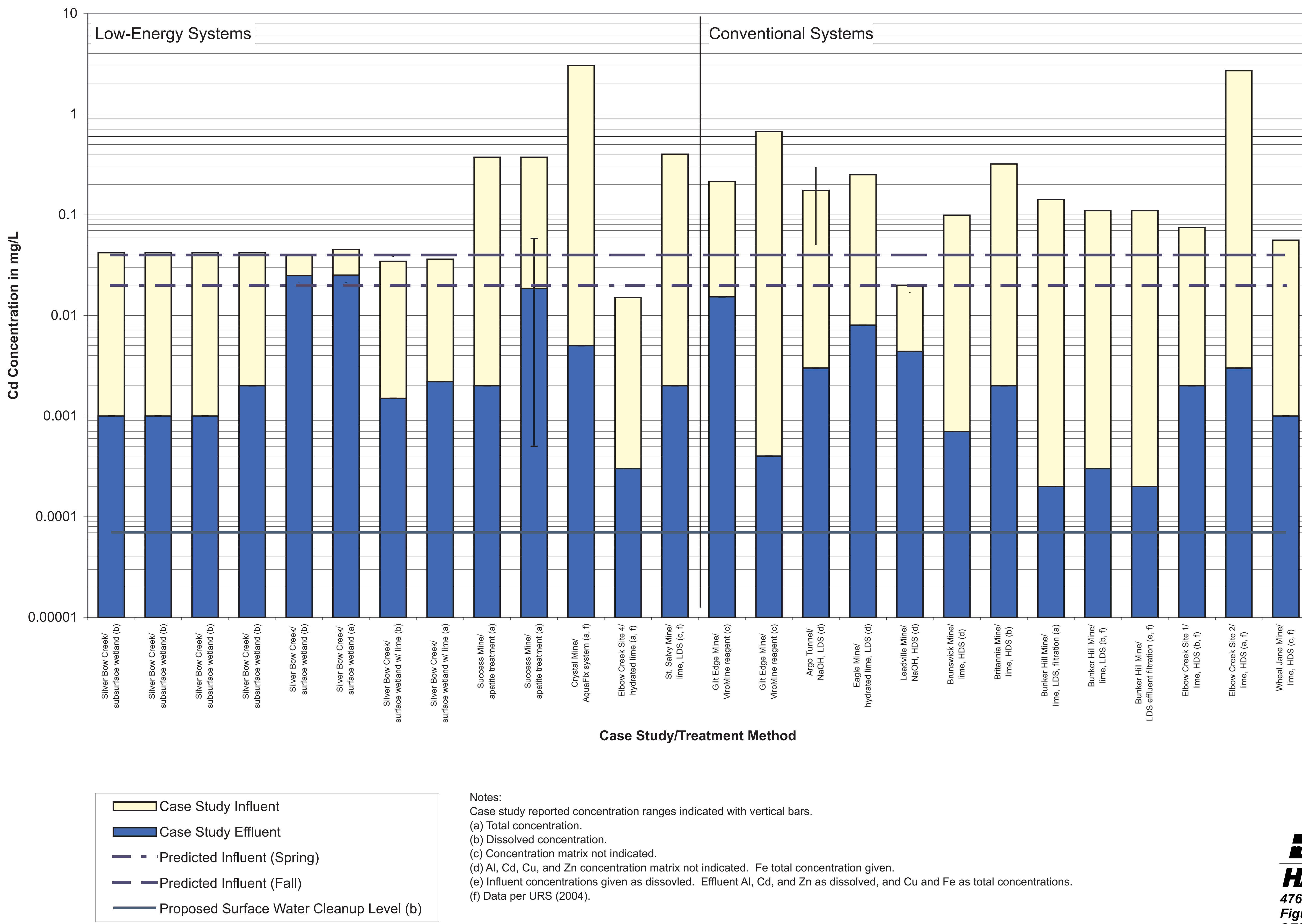


4769-11-4-002 (Alum Removal).cdr EAL 09/13/07

Case Study Influent
Case Study Effluent
Predicted Influent (Spring)
Predicted Influent (Fall)
Proposed Surface Water Cleanup Level (a)

Notes:
Study reported concentration ranges indicated with vertical bars.
(a) Total concentration.
(b) Concentration matrix not indicated.
(c) Al, Cd, Cu, Zn concentration matrix not indicated. Fe total concentration given.
(d) Dissolved concentration.

Case Study Comparison - Cadmium Removal

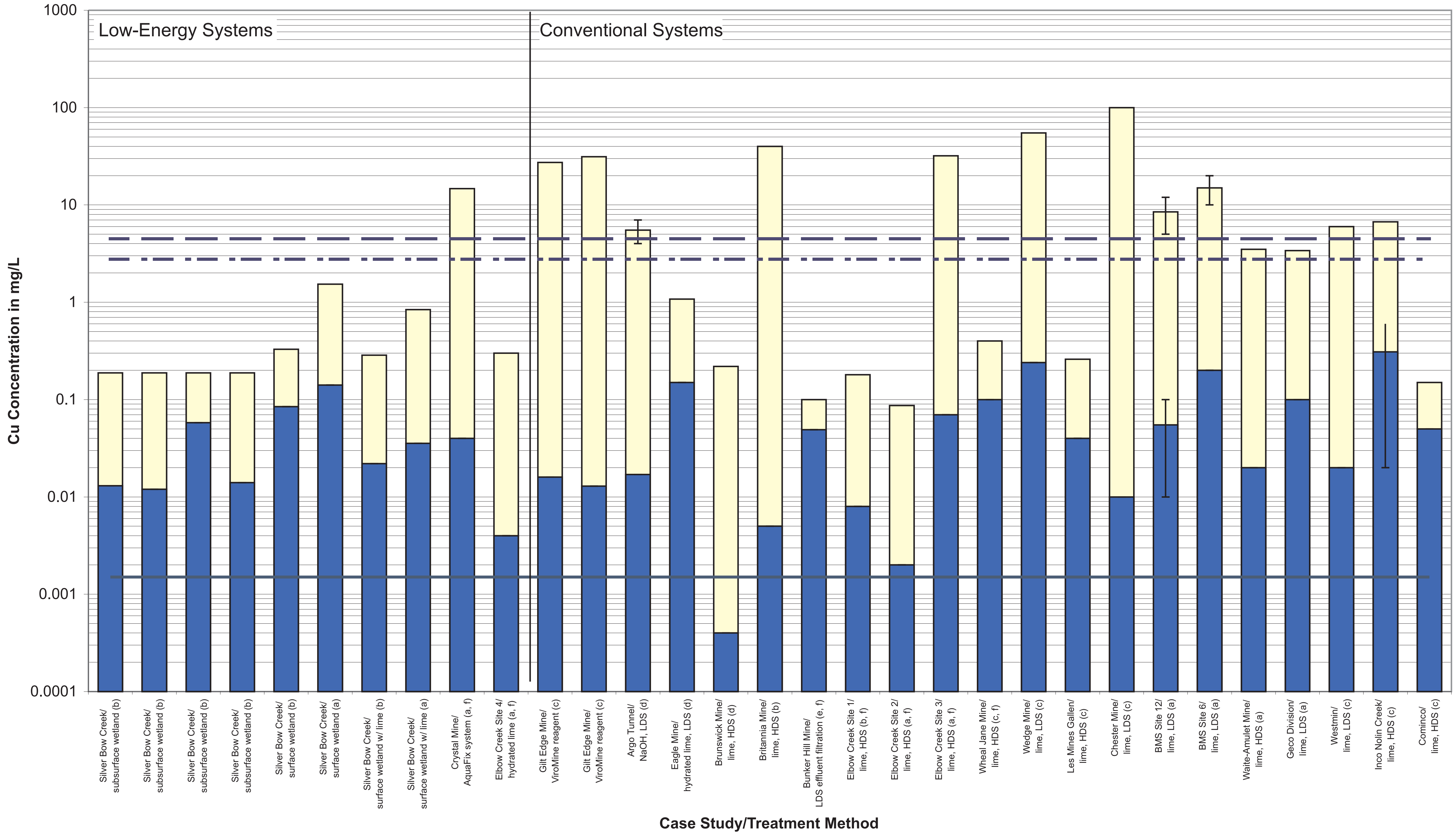


Notes:
Case study reported concentration ranges indicated with vertical bars.
(a) Total concentration.
(b) Dissolved concentration.
(c) Concentration matrix not indicated.
(d) Al, Cd, Cu, and Zn concentration matrix not indicated. Fe total concentration given.
(e) Influent concentrations given as dissovled. Effluent Al, Cd, and Zn as dissolved, and Cu and Fe as total concentrations.
(f) Data per URS (2004).

4769-11-5 thru 8-003 (Case Study).cdr EAL 09/13/07

HARTCROWSER
4769-11 9/07
Figure F-5
SFS Appendix F

Case Study Comparison - Copper Removal



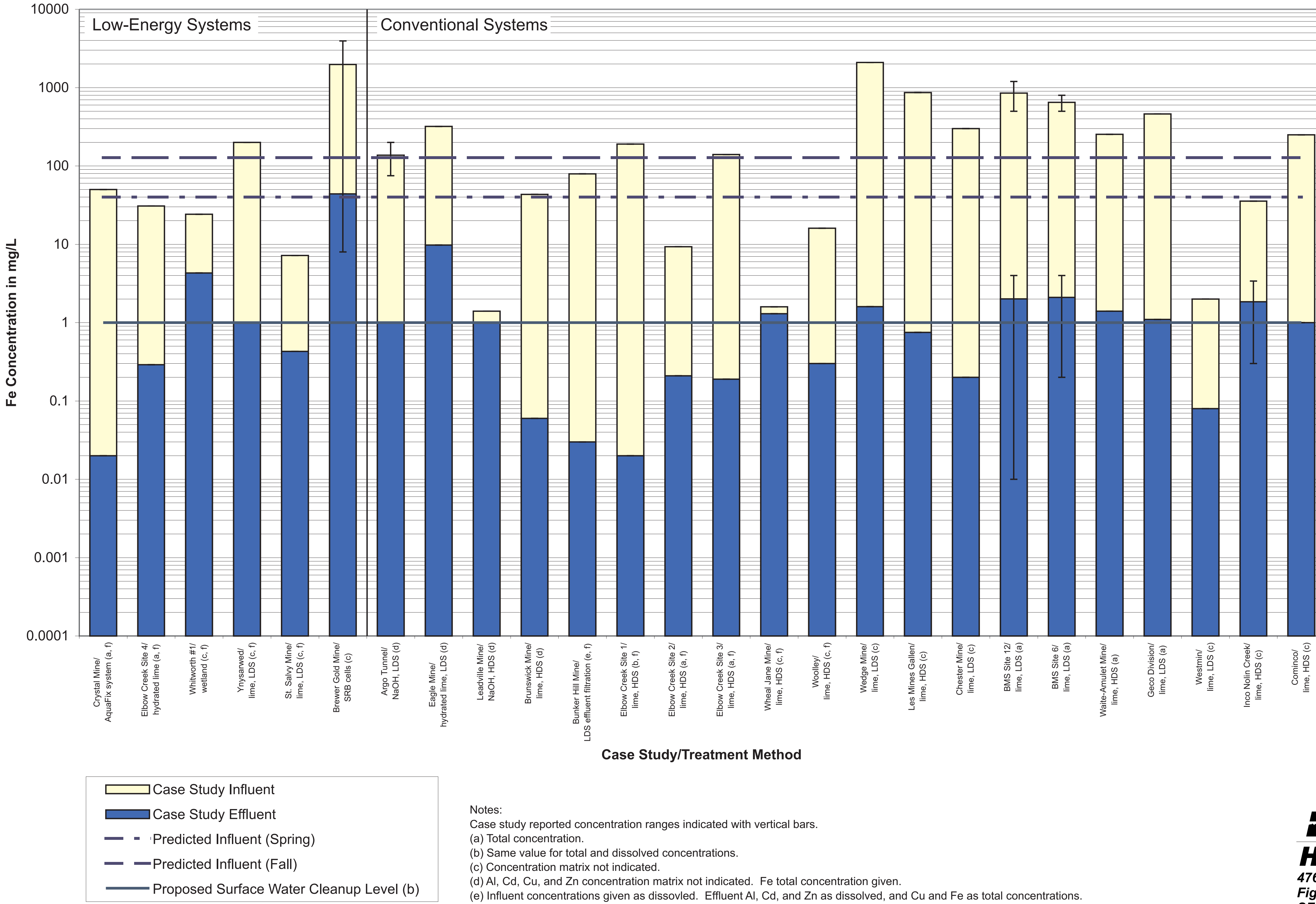
Case Study Influent
Case Study Effluent
Predicted Influent (Spring)
Predicted Influent (Fall)
Proposed Surface Water Cleanup Level (b)(g)

Notes:
Case study reported concentration ranges indicated with vertical bars.
(a) Total concentration.
(b) Dissolved concentration.
(c) Concentration matrix not indicated.
(d) Al, Cd, Cu, and Zn concentration matrix not indicated. Fe total concentration given.
(e) Influent concentrations given as dissolved. Effluent Al, Cd, and Zn as dissolved, and Cu and Fe as total concentrations.
(f) Data per URS (2004).
(g) Concentration based on equivalent hardness of 12 mg/L calcium carbonate and may vary.

4769-11 5 thru 8 (Case Study).cdr EAL 09/13/07

HARTCROWSER
4769-11 *9/07*
Figure F-6
SFS Appendix F

Case Study Comparison - Iron Removal

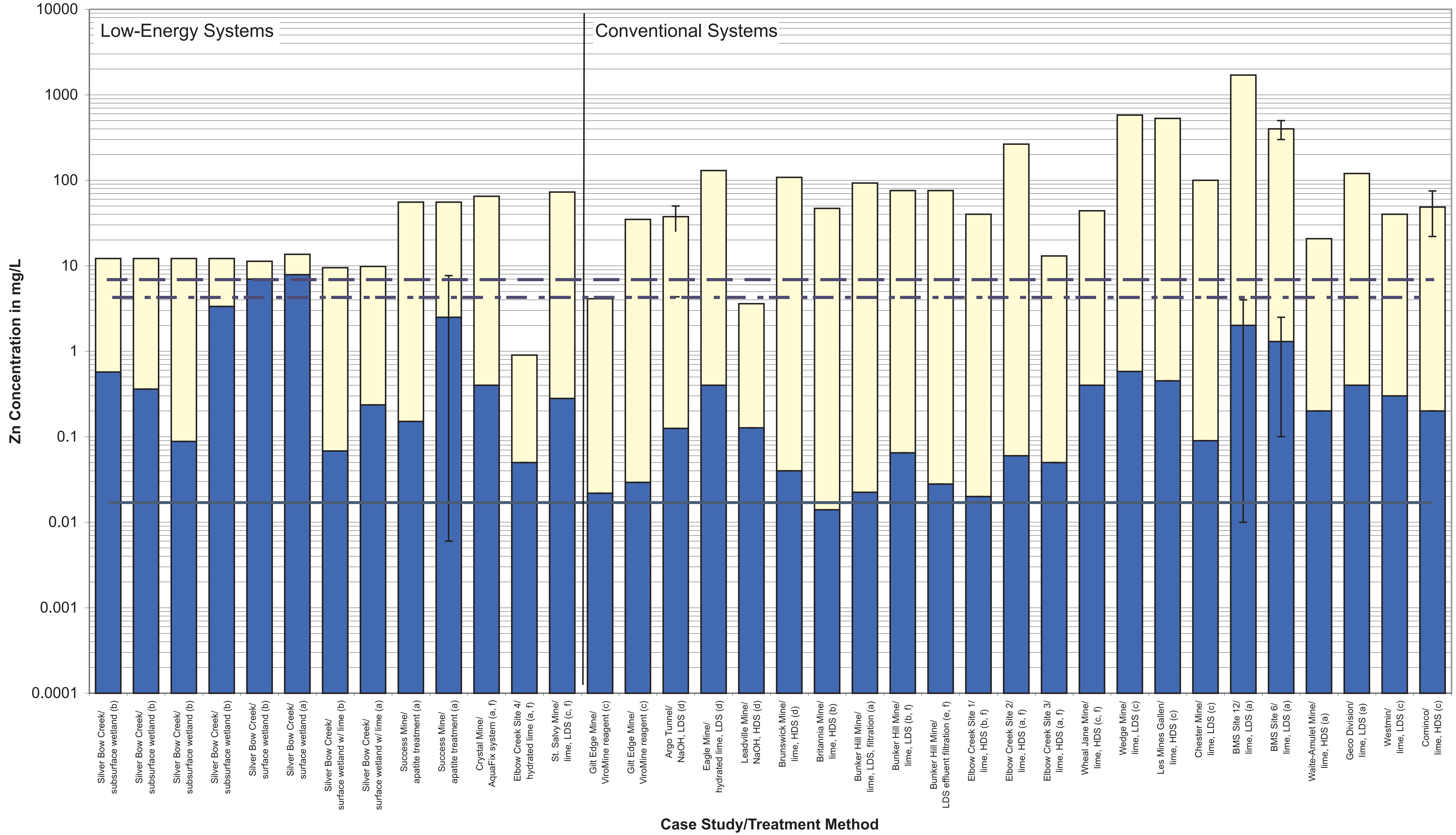


Notes:
Case study reported concentration ranges indicated with vertical bars.
(a) Total concentration.
(b) Same value for total and dissolved concentrations.
(c) Concentration matrix not indicated.
(d) Al, Cd, Cu, and Zn concentration matrix not indicated. Fe total concentration given.
(e) Influent concentrations given as dissovled. Effluent Al, Cd, and Zn as dissolved, and Cu and Fe as total concentrations.
(f) Data per URS (2004).

4769-11 5 thru 8 (Case Study).cdr EAL 09/13/07

HARTCROWSER
4769-11 9/07
Figure F-7
SFS Appendix F

Case Study Comparison - Zinc Removal



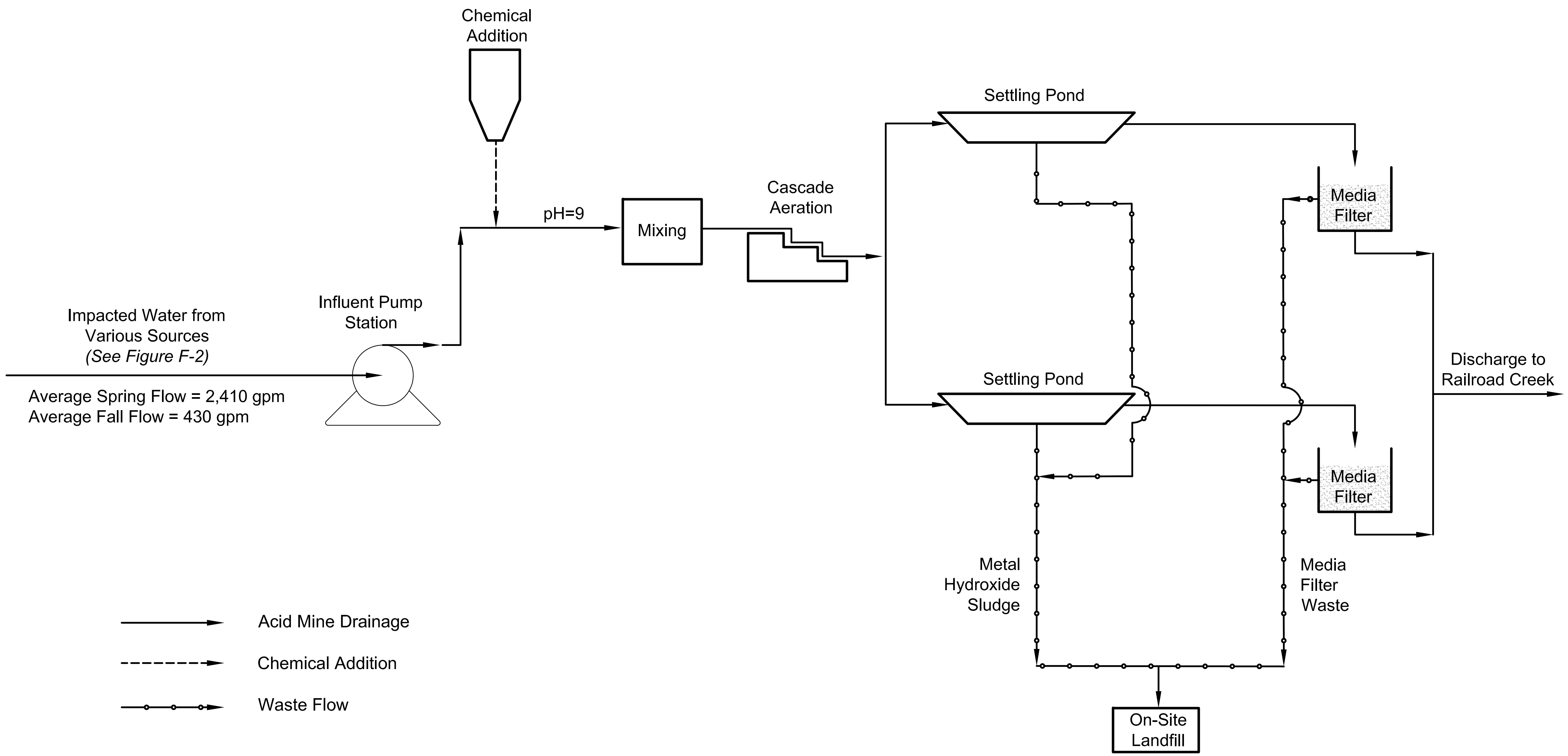
Case Study Influent
Case Study Effluent
Predicted Influent (Spring)
Predicted Influent (Fall)
Proposed Surface Water Cleanup Level (b)(g)

Notes:
Case study reported concentration ranges indicated with vertical bars.
(a) Total concentration.
(b) Dissolved concentration.
(c) Concentration matrix not indicated.
(d) Al, Cd, Cu, and Zn concentration matrix not indicated. Fe total concentration given.
(e) Influent concentrations given as dissolvled. Effluent Al, Cd, and Zn as dissolved, and Cu and Fe as total concentrations.
(f) Data per URS (2004).
(g) Concentration based on equivalent hardness of 12 mg/L calcium carbonate and may vary.

4769-11 5 thru 8 (Case Study).cdr EAL 09/13/07

HARTCROWSER
4769-11 9/07
Figure F-8
SFS Appendix F

Conceptual Process Flow Diagram for Water Treatment with Single-Stage Chemical Precipitation



EAL 09/13/07 476911-9-003 (Diagram - water treat).DWG

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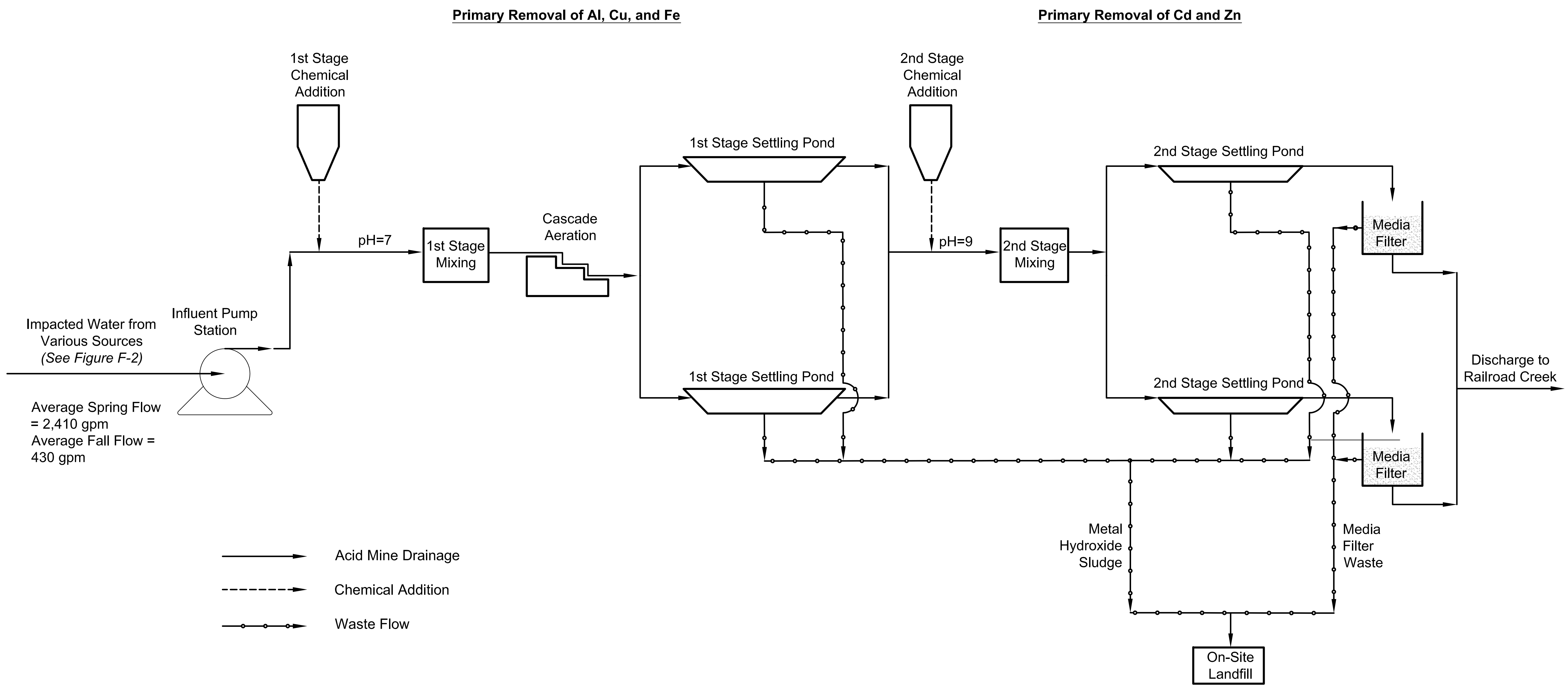
4769-11 *9/07*

Figure F-9

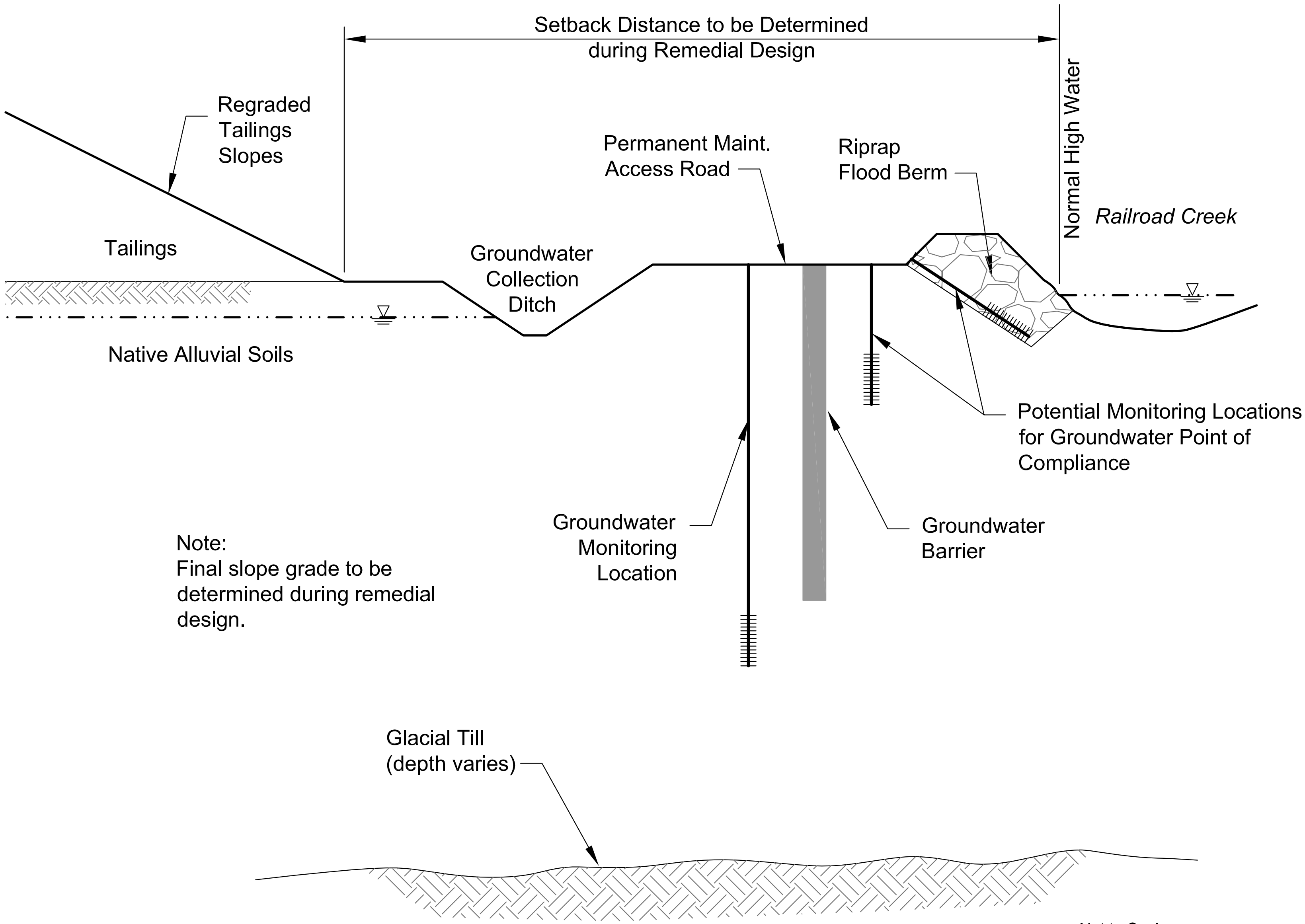
SFS Appendix F

Conceptual Process Flow Diagram for Water Treatment with Two-Stage Chemical Precipitation



EAL 09/13/07 476911-10-004 (Diagram - 2-stage).DWG

Schematic of Partially Penetrating Barrier and Groundwater Collection Ditch



Note:
Final slope grade to be determined during remedial design.

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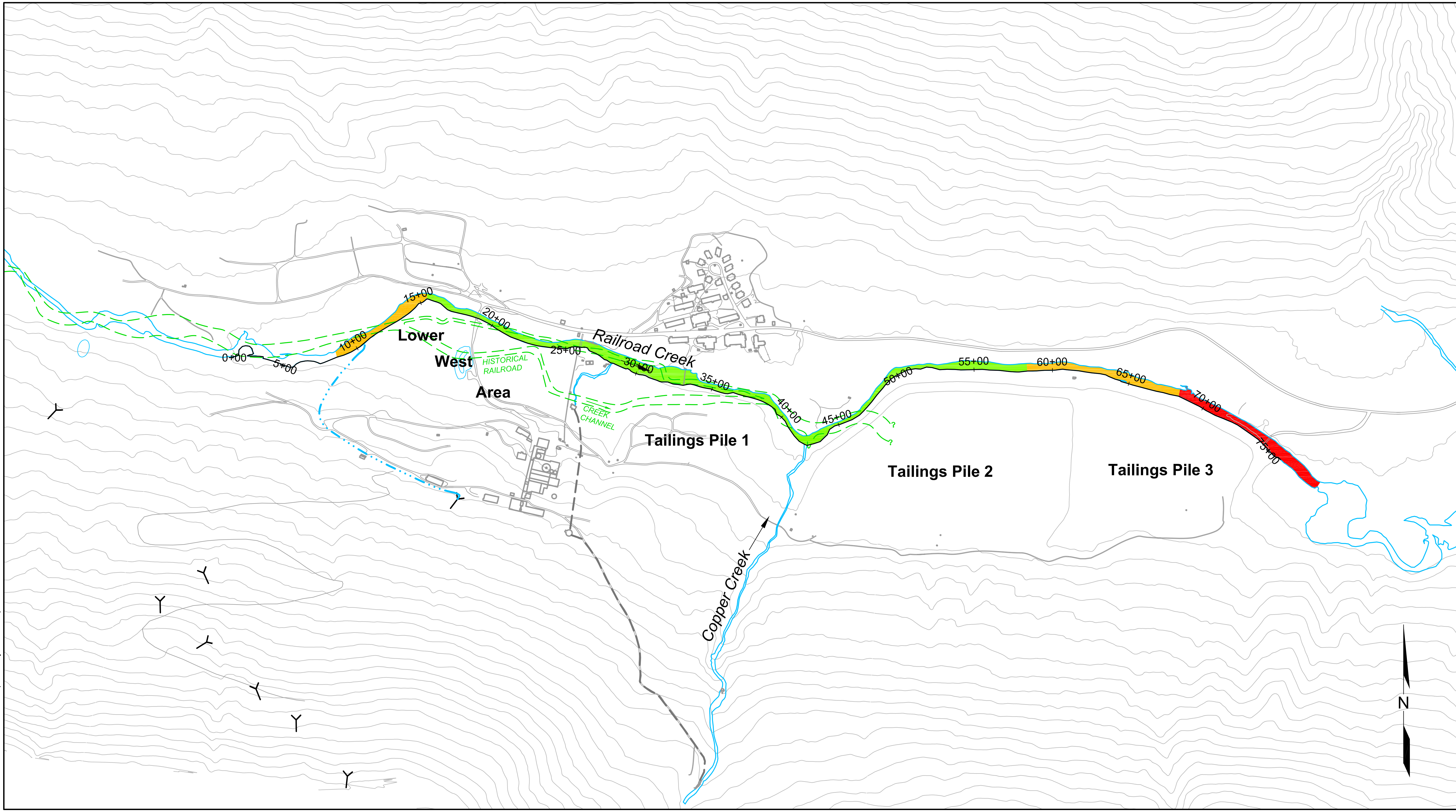
4769-11 **9/07**
Figure F-11
SFS Appendix F

EAL 09/13/07 476911-11-005 (Ditch Schematic).DWG

Summary of Gaining and Losing Conditions in Railroad Creek



476911-12-006(Summary Conditions).DWG

EAL 09/13/07

Source: Base map prepared from LiDAR topographic survey provided by URS, 2004

Notes:
1. The reference to South Bank "gaining" refers to groundwater base flow into creek along south bank of Railroad Creek. "Losing" refers to drainage of water from Railroad Creek channel into groundwater.
2. Determination of gaining versus losing based on well data from DRI (Dames & Moore 1999).

South Bank - Flat Gradient or Losing in Spring or Fall

South Bank - Gaining in Spring and Fall

South Bank - Gaining in Spring, Losing in Fall

0 600 1200

Scale in Feet

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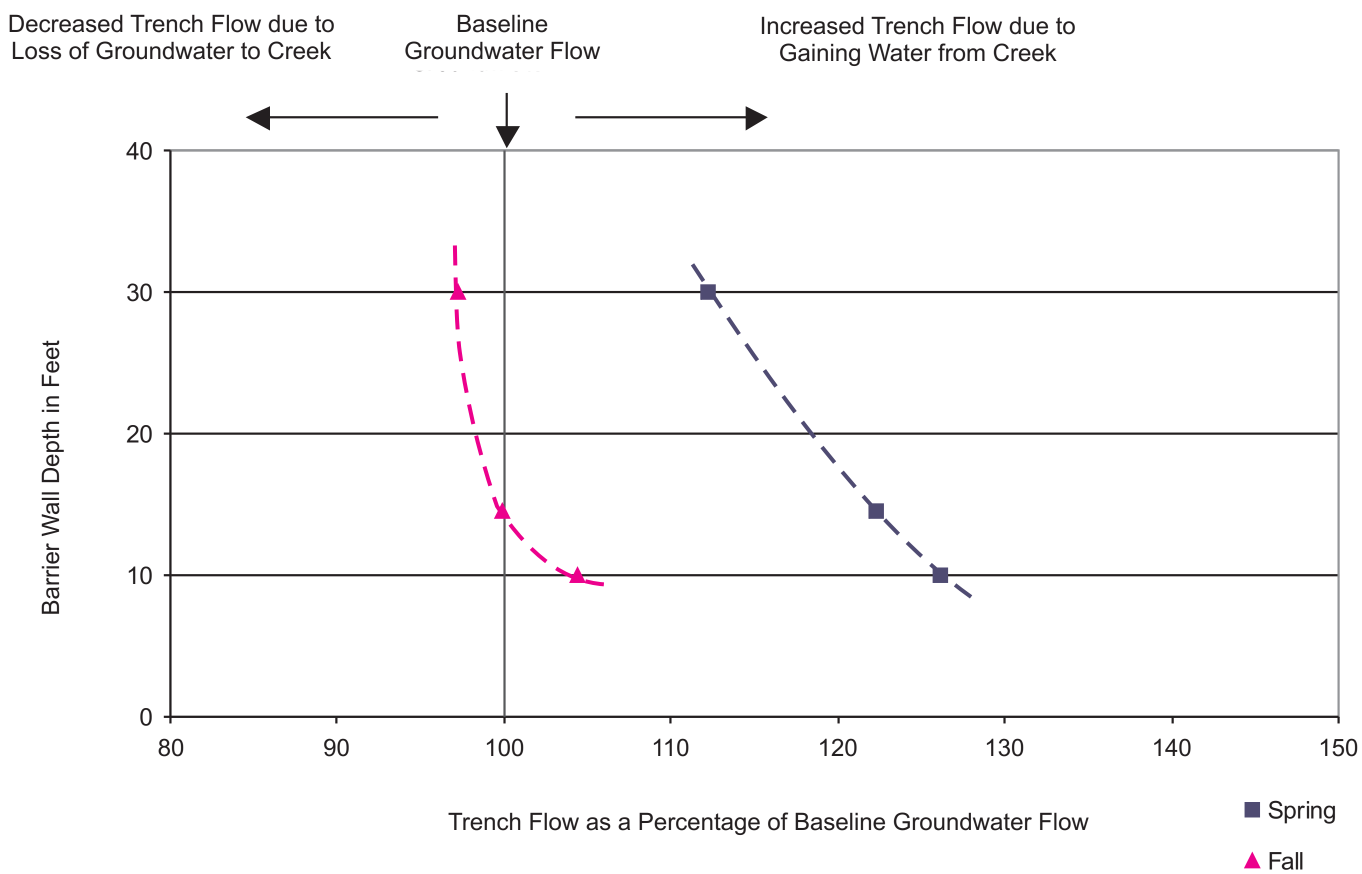
4769-11 *9/07*

Figure F-12

SFS Appendix F

Changes in Effectiveness for Various PPB Depths



Note:
Results shown for 2-foot-deep collection trench.
Trench Flow shown as a Percentage of Baseline Groundwater Flow.
100% trench flow means all of the baseline groundwater originating from the south is intercepted by the trench. Values greater than 100% indicate creek water flowing under the wall into the trench.
Values less than 100% indicate a loss of groundwater from south of the trench into the creek.
Analysis based on aquifer thickness of 55 feet.

476911AC-7-25-07 .cdr EAL 09/13/07

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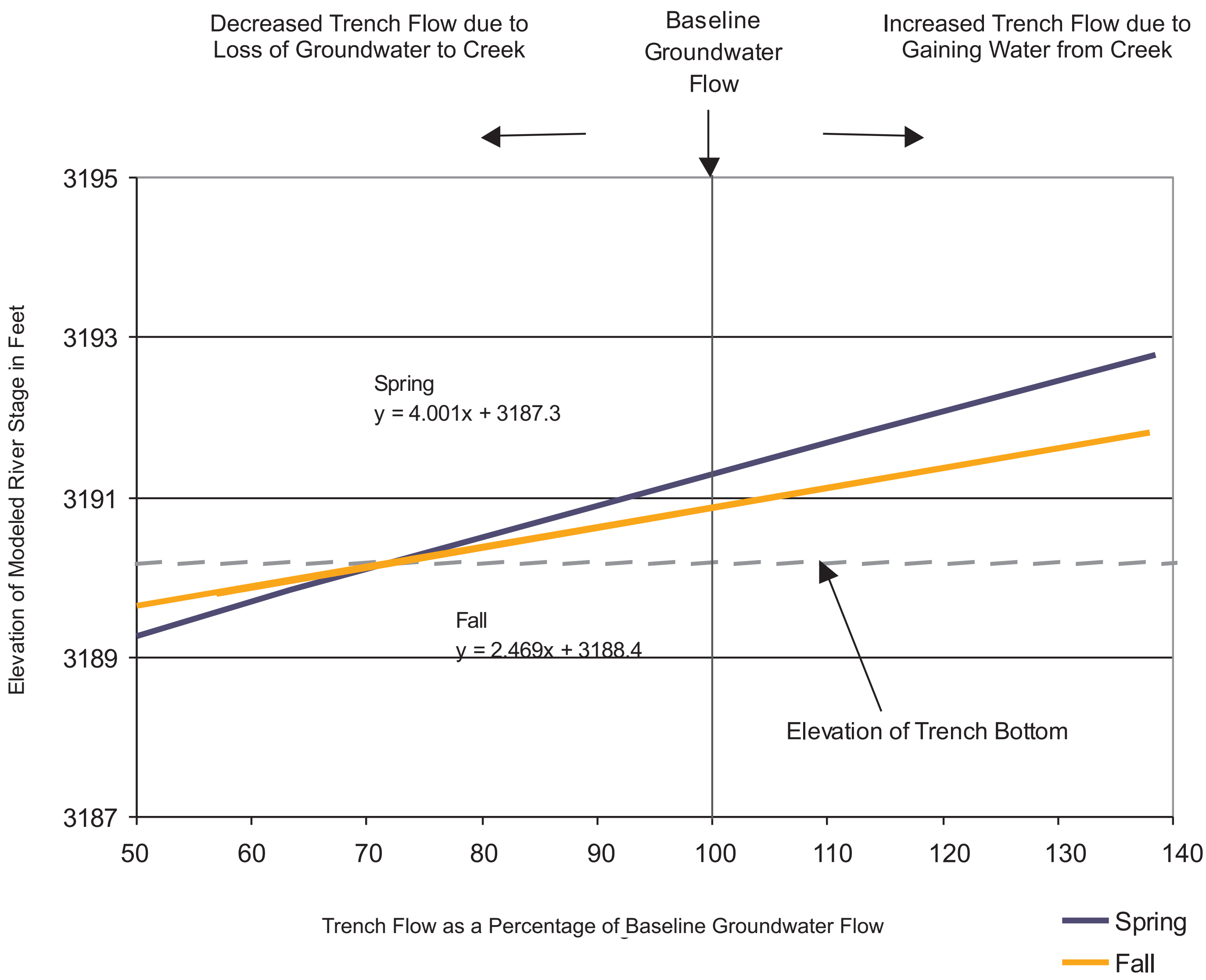
4769-11 ***9/07***
Figure F-13
SFS Appendix F

Changes in PPB Effectiveness for Variations in River Stage



Note: This figure depicts results of a representative analysis showing effect of varying river stage for a 30-foot barrier and 2-foot-deep collection trench.

476911AD-7-25-07.cdr EAL 09/13/07

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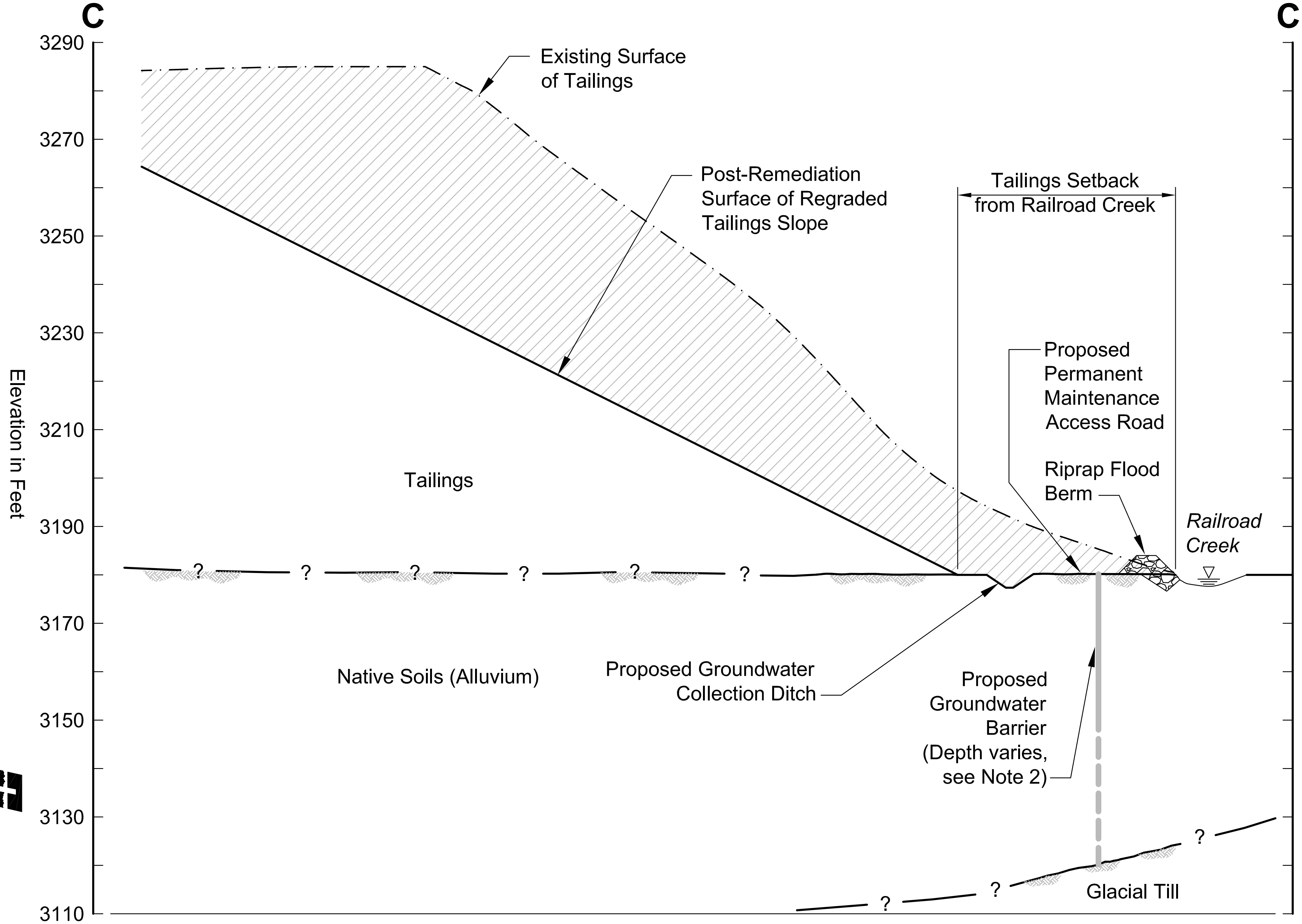
4769-11 9/07

Figure F-14

SFS Appendix F

Schematic of Proposed Tailings Pile Regrading adjacent to Railroad Creek for Alternatives 10 and 11



Note:

1. Final setback distance and slope of tailings pile to be determined during remedial design. Nominal 45-foot setback and 2H:1V tailings slope shown for discussion purposes only.
2. Depth of partially penetrating groundwater barrier for Alternative 10 assumed to be 30 feet, to be determined during remedial design. Groundwater barrier for Alternative 11 will extend into glacial till. Depth to glacial till varies.

0 30 60
Scale in Feet

HARTCROWSER
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Figure 15
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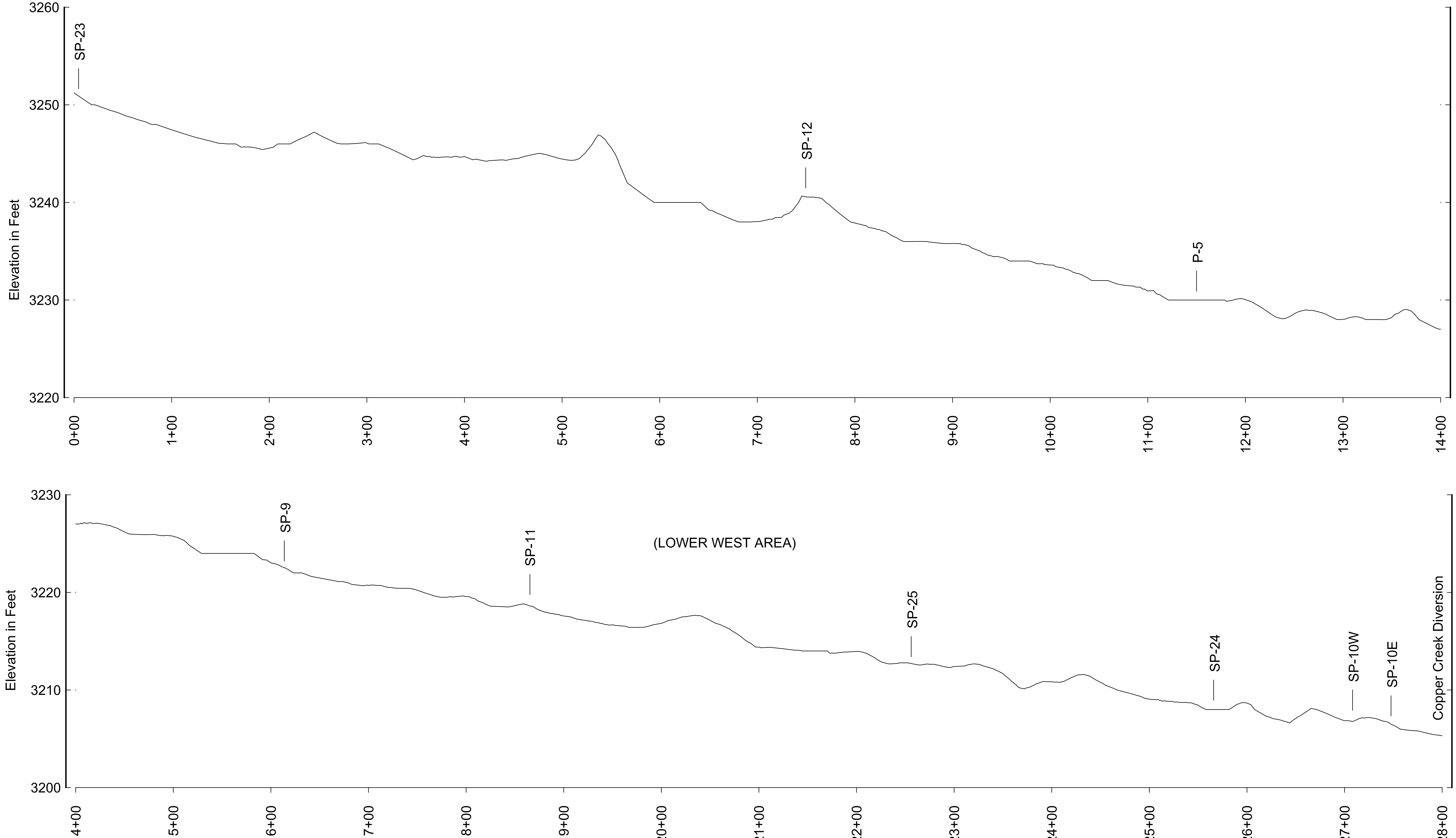
9/07

EAL 9/14/07 476911-024.dwg Layout: Figure 15 - SFS

Railroad Creek South Bank Profile



Horizontal Scale in Feet
0 100 200
0 10 20
Vertical Scale in Feet
Vertical Exaggeration x 10

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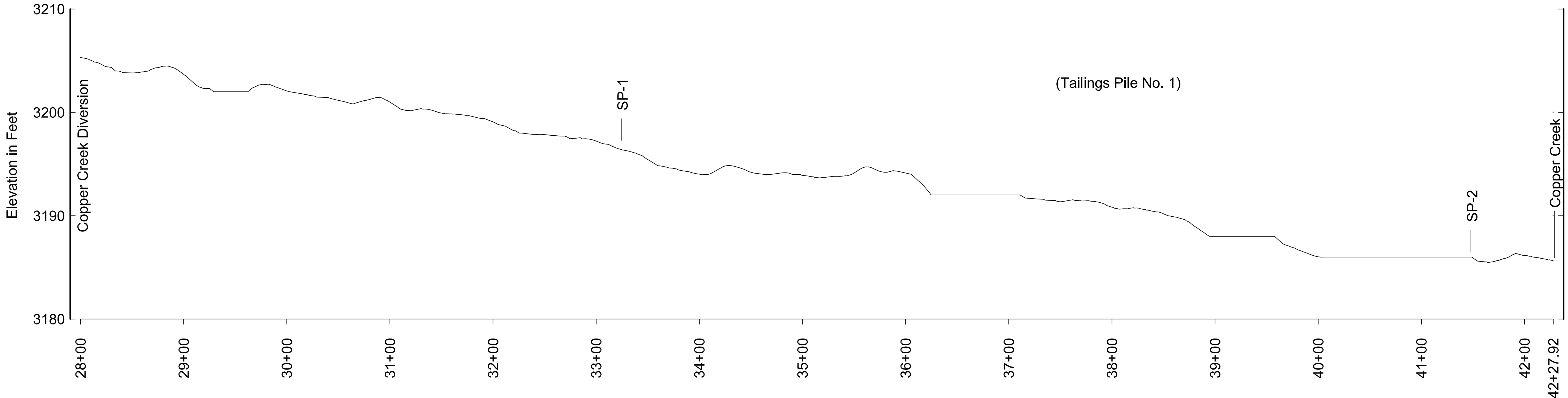
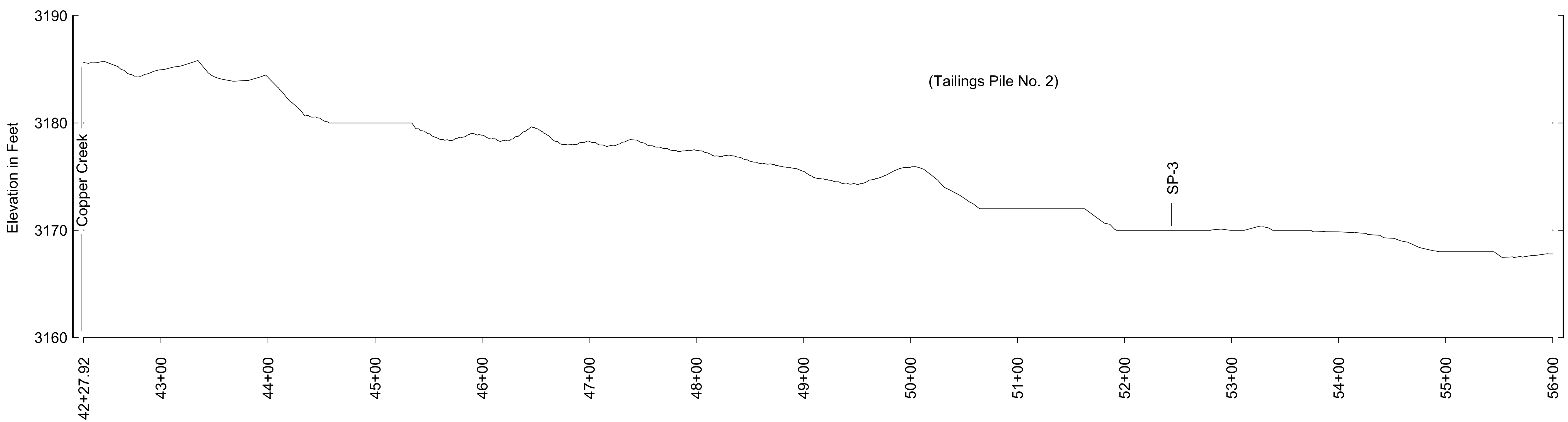
Figure F-16 *1/3*
SFS Appendix F

EAL 09/13/07 476911-16-007 (Railroad Profile).DWG

Railroad Creek South Bank Profile





Horizontal Scale in Feet
0 100 200
0 10 20
Vertical Scale in Feet
Vertical Exaggeration x 10

HARTCROWSER

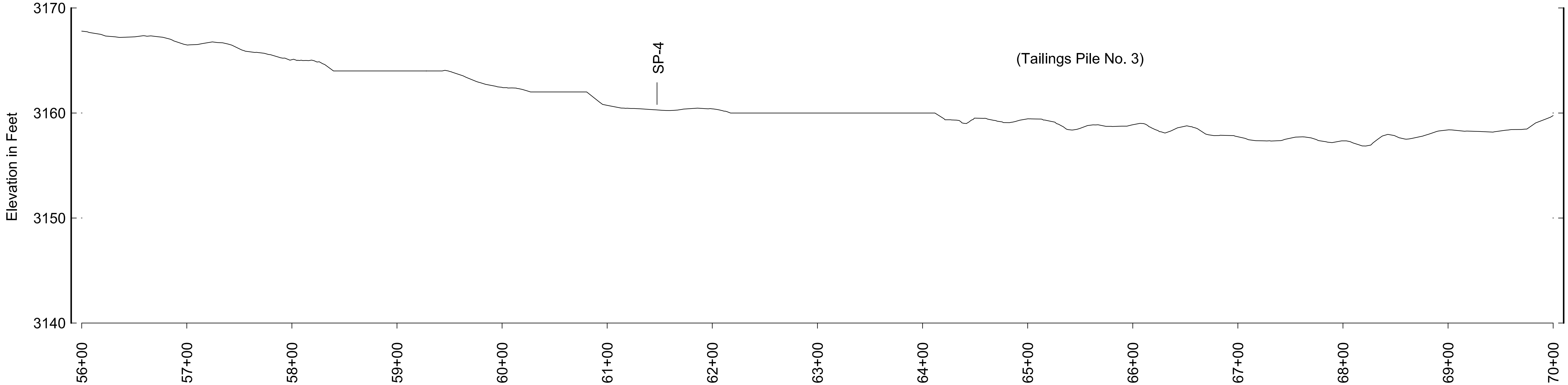
4769-11 ***9/07***

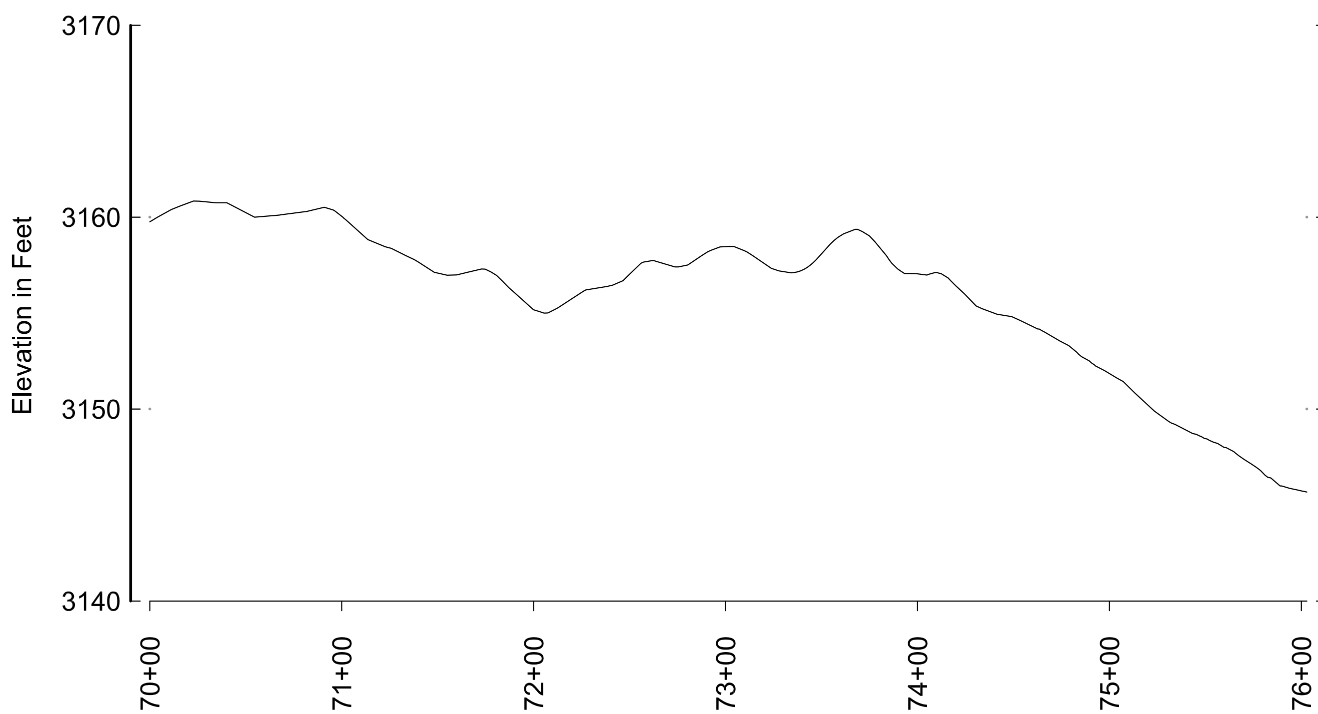
Figure F-16 ***2/3***

SFS Appendix F

EAL 09/13/07 476911 16 (Railroad Profile).DWG

Railroad Creek South Bank Profile





Horizontal Scale in Feet
0 100 200
0 10 20
Vertical Scale in Feet
Vertical Exaggeration x 10

HARTCROWSER
4769-11 9/07
Figure F-16 3/3
SFS Appendix F

EAL 09/13/07 476911 16 (Railroad Profile).DWG

ATTACHMENT A
RESULTS OF VADOSE/W SEEPAGE MODEL OF PARTIALLY PENETRATING CUTOFF
FEBRUARY 3, 2005, MEMORANDUM

MEMORANDUM

DATE: February 3, 2005

TO: Mr. Norman F. Day, USFS

FROM: Dana Cannon and Michael Kenrick, L.H.G., Hart Crowser

RE: **Results of VADOSE/W Seepage Model of Partially Penetrating Cutoff Holden Mine Tailings Piles, Washington**
4769-07

The hydrogeologic investigation performed by Intalco at the Holden Mine site in October 2003 (URS 2004a) indicated that the underlying bedrock and/or till in the area of the tailings piles are deeper than previously anticipated. Many of the alternatives considered in the Draft Final Feasibility Study (DFFS) (URS 2004b) included groundwater cutoff walls keyed into the underlying till or bedrock. With the increased depth of these formations, the installation of a fully penetrating cutoff wall became potentially challenging. Therefore, based on discussions with the Agencies, Hart Crowser created a 2-dimensional seepage model to investigate the effectiveness of a partially penetrating cutoff (PPC) for groundwater. A review of the model and results is provided in this memorandum.

GROUNDWATER MODELING OBJECTIVES

The scope of this work was to provide a preliminary analysis of the hydraulic performance of a partially penetrating wall (i.e., cutoff wall not keyed into till/bedrock). Whether the wall is engineered to be partially penetrating or complications during remedy implementation lead to a partially penetrating wall (e.g., encountering a boulder during trenching), evaluation of a PPC is important to evaluate the effectiveness of such incomplete wall configurations. The primary objectives of the groundwater modeling effort were to examine groundwater flow from Tailings Pile 1 toward Railroad Creek and to estimate the relative amount of water entering collection trenches from the south side as groundwater, or as groundwater augmented by the induced recharge of river water flowing under the wall to the trench. (This condition occurs if the collection trench is installed too deep relative to the adjacent creek.)

Anchorage
Denver
Edmonds
Philadelphia
Portland
Seattle

1910 Fairview Avenue East
Seattle, Washington 98102-3699
Fax 206.328.5581
Tel 206.324.9530

MODEL DESCRIPTION

The effectiveness of the PPC was evaluated using the VADOSE/W Unsaturated Infiltration and Seepage model (Geo-Slope International, Ltd 2004). This 2-dimensional finite element model is capable of representing infiltration, seepage, and groundwater flow in vertical cross section. VADOSE/W is a powerful tool for modeling the unsaturated soil conditions existing within the Holden Tailings Piles, including modeling of infiltration and recharge that augments groundwater flow and seepage.

For development of the 2-dimensional model, a representative cross section was selected that had sufficient data available to support the modeling effort. Tailings Pile 1 is well characterized and is an area the Agencies have designated as requiring remedial action. The cross section location we analyzed is close to Cross Section B-B' as illustrated on Figure 2-10 of the DFFS. Figure 1 provides the location of both the modeled and B-B' cross sections. As summarized in Section 2 and the flownet analysis in Appendix A of the DFFS, groundwater flow in the native materials underlying the tailings is toward Railroad Creek. Groundwater is thought to enter the piles and underlying native materials from the side valley to the south as well as from the west, parallel to Railroad Creek. Additionally, a portion of precipitation and snowmelt infiltrates the surface of the piles and percolates downward to recharge the water table.

MODEL ASSUMPTIONS

With any modeling, there are assumptions that are necessary to fit the variability of nature into a computer model. Since the purpose of this model was to provide a preliminary assessment of a PPC, a 2-dimensional model was chosen for this exercise. The cross section is oriented north/south through Tailings Pile 1. This orientation of the 2-dimensional model prevents inclusion of a down valley groundwater flow component (i.e., sub-parallel to the creek); however, it should be understood that this component of groundwater flow at the site may be considerable. While a 3-dimensional model may better address this component of uncertainty, insufficient hydrogeologic data are available for such a model. Furthermore, down valley groundwater flow would encounter sections of the proposed cutoff wall that are roughly perpendicular to this component of groundwater flow at the site (e.g., east of Tailings Piles 1 and 3).

Hydraulic conductivities measured in site wells completed in the native materials span from 0.0001 to 0.003 feet per second. This range in hydraulic conductivity is understandable given the depositional environment at the site; however, the variability produces a challenge for groundwater modeling. For modeling purposes, a mean hydraulic conductivity was chosen, with the variability in conductivities further assessed in the sensitivity analysis.

MODEL INPUT

A summary of the model input parameters are provided below and in Table 1.

Subsurface Geology

The first step in creating the model is building a representative cross section of the problem for investigation. The cross section was created for Tailings Pile 1 in the vicinity of seep SP-1. This section was chosen since three wells were located within 100 feet of the cross section, and Cross Section B-B' from the DFFS (see Figure 2-10 of the DFFS) was nearby, providing additional correlation with the site boring logs. The cross section location and the VADOSE/W-generated cross section are provided on Figures 1 and 2, respectively.

Based on the boring logs and Cross Section B-B' of the DFFS, the site stratigraphy can be generalized into three units: tailings, alluvium/reworked till (native material), and basal till/bedrock. The topographic surface for the cross section was created using the LiDAR-based map of the site. As shown on Figure 2, the tailings range from a maximum thickness of 55 to 75 feet and pinch out approximately 600 feet south of Railroad Creek. Underlying the tailings is the alluvium/reworked till; this unit is modeled to have a thickness of 55 feet along the center valley and narrows to a thickness of approximately 30 feet along the southern edge of the section. The contact between the native material and basal till/bedrock was assumed to be relatively impermeable and was modeled as a no flow boundary that forms the base of the modeled cross section.

Present site conditions were first modeled to develop the baseline case representing infiltration, recharge side-valley inflow, seepage, and groundwater flow to Railroad Creek beneath and through the base of the tailings pile, with the configuration as shown on Figure 2. Once the model was calibrated, the northern side of the cross section was modified where the tailings meet the river, as illustrated in the schematic shown on Figure 3. The tailings were cutback to have a 2 horizontal:1 vertical (2H:1V) slope and 45-foot setback from Railroad Creek. The 45-foot setback provides room for the PPC and collection trench as well as an access road for trench maintenance. The depths of both the cutoff wall and collection trench were modified to simulate flow conditions under spring and fall scenarios. It should be noted that the top of the tailings was not modified for the cutoff wall scenarios.

Hydraulic Conductivities

Glacially deposited materials have highly variable hydraulic conductivities. As previously discussed, it was necessary to make some assumptions on the heterogeneity of the materials to run this preliminary analysis of the PPC. The hydraulic conductivities used in the model were the average values provided in the flow net analysis of the DFFS (URS 2004b). For the main set of analyses, one value was applied to the tailings materials and a second to the underlying native materials (alluvium/glacial drift). As part of a model sensitivity analysis, the native material was further subdivided into two units. For this set of analyses, two separate hydraulic conductivities were applied to these units—alluvium and glacial drift.

Constant Head Boundary Condition

The influence of Railroad Creek on the groundwater flow system was applied using a constant-head boundary condition. A steady-state model was run for fall and spring conditions under which the constant head of the river was input at different elevations depending on the season. The constant head of the river was set at an elevation about 1 foot higher for spring conditions relative to fall conditions. Model elevations of the river, the trench, and wall elevations are summarized in Table 1.

Unit Flux Boundary Conditions

Infiltration

Infiltration from precipitation entering the tailings along the upper boundary was modeled using a unit flux boundary condition applied along the top surface of the tailings in the modeled cross section. The infiltration values chosen for the unit flux were determined based on model calibration, which is reviewed in more detail below. Two different infiltration values were applied for spring and fall scenarios to represent current and the regraded conditions. Infiltration values used in the model are summarized in Table 1.

Calibrated infiltration values were then reviewed based on average precipitation values for Holden Village, the results of the Hydraulic Evaluation of Landfill Performance (HELP) model provided in Appendix G of the DFFS, the Railroad Creek hydrograph (Figure 2-25 of the DFFS), and lower west area hydrographs (URS 8/23/04 presentation). Hydrographs were included in the review since much of the winter precipitation infiltrates the tailings during spring snowmelt. The final calibrated infiltration values input to the model correlated reasonably well with values from the HELP model.

It should be noted that VADOSE/W, similar to HELP, can be used to model infiltration and runoff; however, that was not the objective of this modeling effort. Additional climate data would be needed to better model runoff and infiltration using VADOSE/W and the work would have been somewhat redundant to the effort already put forth by URS using the HELP model.

Side-Valley Groundwater Flow

Based on the flow-net analyses, groundwater flow has a strong south to north component. This side valley component was adjusted during calibration to simulate the appropriate groundwater levels within the model based on water level measurements reported by URS. The unit flux boundary was set along a portion of the southern edge of the model within the native material unit.

Seepage Faces

VADOSE/W allows for nodes to be selected as seepage faces. Seepage nodes allow groundwater to exit the model, with internal review checks to ensure phreatic conditions (i.e., that the groundwater potential at the seepage face equals the elevation of the seepage face). These seepage nodes were used both in the base model and the cutoff wall models. For the base condition, seepage review nodes were set at the toe of the tailings comparable to the location of seep SP-1. For the cutoff wall models, the groundwater collection trench walls (including the base of the trench) were all set as seepage faces.

MODEL CALIBRATION

Monitoring wells TP1-2, TP1-3, and TP1-4 are within the modeled cross section alignment. These three wells are screened within the native material below the tailings. Groundwater elevation data from these wells (Dames & Moore 1999) were used to calibrate the model. A model of the current tailings pile configuration was run for spring and fall conditions. Figure 4 illustrates calibrated spring conditions for the modeled cross section.

Modeled groundwater elevations in wells TP1-3 and TP1-4 were within approximately 0.5 foot of the groundwater elevations measured at the site for spring and fall. Modeled groundwater elevations in well TP1-2 were lower in the model by approximately 2 feet for both spring and fall. In general, this degree of correspondence indicated pretty good correlation between the model and real world conditions. This disparity in groundwater elevations may be due to local variability in hydraulic conductivities at TP1-2. It should be noted that TP1-2 is located about 100 feet north of the cross section alignment, which may also account for this disparity.

MODEL RESULTS

VADOSE/W allows the user to define a *flux section* across which it calculates groundwater and seepage flow volumes. A flux section was specified within the model to compute the flow volumes into the collection trench and under the cutoff wall. The model was run under four different scenarios for spring and for fall (eight scenarios in all). For both spring and fall conditions, the collection trench depth and cutoff wall depth were varied. Trench depths were set approximately 2 and 2.5 feet below the toe of the regraded tailings. The two wall depths modeled were 15 and 30 feet below the toe of the regraded tailings. Results are summarized on Figure 5.

Trench flow results are given in percentages relative to the volume of south side groundwater occurring within the cross section (i.e., the baseline groundwater flow). Values less than 100 percent indicate a net loss of groundwater to the river. Values greater than 100 percent indicate an increase in flow to the collection trench relative to the baseline groundwater flow (i.e., river water flows under the cutoff wall into the collection trench). We used the groundwater flow volume from the tailings and underlying native materials as a baseline and expressed the additional flow from the creek as a percent of this groundwater flow.

Spring

During spring conditions, the constant head representing Railroad Creek was 1.6 and 2 feet above the base of the 2- and 2.5-foot-deep collection trench, respectively. Under all conditions, the trench collected all groundwater originating from the south side of the model (tailings side). However, the trench also gained water by induced recharge from Railroad Creek.

With a wall completed to a depth of 15 feet below the toe of the regraded tailings, the trench received between 26 and 42 percent additional water relative to the volume of baseline groundwater flow. Although increasing the depth of the wall to 30 feet improves the effectiveness of the collection system, some river water still enters the trench. With a 30-foot-deep wall, the trench was modeled to intercept 14 and 24 percent additional water relative to the volume of baseline groundwater flow.

Fall

With the fall condition, the constant head representing Railroad Creek was lowered by approximately 1 foot to account for the lower flow in the creek. With the lowering of the river stage to represent drier, lower flow conditions, the model results indicated that some groundwater would flow under the cutoff wall toward the river (i.e., loss in effectiveness).

Again both the trench and wall depths were varied for these analyses. For both scenarios with the 2-foot trench, approximately 3 percent of baseline groundwater from the south side of the model was lost to the creek with both the 15- and 30-foot depth cutoff walls. Increasing the depth of the trench to 2.5 feet results in a gain in the trench due to capture of river water. Model results indicated an additional 14 and 24 percent of collected water relative to baseline groundwater flow.

MODEL SENSITIVITY

Two parameters were varied to review the sensitivity of the model. In the results reviewed above, the relationship between the trench depth and the river stage was shown to be critical for collection efficiencies. Therefore, for one of the sensitivity analyses, the constant head representing the river stage was varied while trench depth was kept constant. Another parameter chosen for closer review was the hydraulic conductivity. As discussed in the **MODEL ASSUMPTIONS** section, the native deposits underlying the tailings were considered as one unit (i.e., having one hydraulic conductivity). We understand from site borings that hydraulic conductivity and the underlying geology can be quite variable. To analyze this variability, the alluvium/reworked glacial drift was split into two units having two different hydraulic conductivities. Results of both of these analyses are discussed below.

Varying River Stage

Using the spring scenario with a 2-foot collection trench and 30-foot cutoff wall, the river stage was varied at 1-foot increments to understand how variability in the relationship between river level and trench depth will impact groundwater collection effectiveness. The elevation of the constant head representing this section of Railroad Creek was varied from approximately 3189 to 3193 feet. The base of the collection trench was set at an elevation of 3190.2 feet, 2 feet below the toe of the tailings.

Figure 6 provides a graphed summary of the results. Again trench flows are given in percentages relative to the south side groundwater intercepted. Values less than 100 percent indicate a loss of groundwater to the river. Values greater than 100 percent indicate an increase in trench flow relative to the volume of groundwater intercepted (i.e., some induced recharge water from the river flows under the cutoff wall and enters trench). Modeled trench collection results ranged from approximately 50 to 140 percent of baseline groundwater flow. For the constant head representing the river 3191.3 feet, the trench was modeled to be 100 percent effective with no loss of groundwater to the river and no recharge of river water induced by the trench.

Varying Hydraulic Conductivity

Generalizations were made at the beginning of the analysis with respect to the hydraulic conductivity of the materials underlying the tailings. For this sensitivity analysis, the native material was subdivided into two units, alluvium and glacial drift. The cross section was modified such that the thicknesses were 10 feet for the alluvium and 45 feet for the glacial drift. The hydraulic conductivity applied to the alluvium was 0.001 ft/sec. The glacial drift was modeled using a hydraulic conductivity an order of magnitude lower at 0.0003 ft/sec. This relationship between the two units was based on a review of the range of conductivities available for the site, as provided in Appendix A of the DFFS.

The model was run for both the spring and fall conditions but only for the 2-foot-deep collection trench. As before, the depth of the trench is relative to an arbitrary datum, the toe of the tailings. Results are summarized on Figure 6. For both the fall and spring condition, the trench is capturing all groundwater from the south side of the creek as well as some creek water. Comparing data from the model using the single hydraulic conductivity with these newer results shows that the flow in the trench increases by 15 to 20 percent. The percentage increase in trench flow due to loss from the river is relative to the baseline groundwater flow from the south side of the model.

CONCLUSIONS

The purpose of this study was to consider whether a PPC should be considered during the remedial design phase of the Holden Mine site remediation. The analysis above indicates that the PPC is a possible option to reduce the cost of wall installation relative to a fully penetrating wall keyed into Till/Bedrock.

The modeling study has shown that proper construction of the collection trench relative to the river is a critical component of collection effectiveness. As the trench depth is increased below the head of the river, more river water is intercepted thus increasing the overall flow to the treatment system. Conversely as the trench is made shallower relative to the river stage, less groundwater is intercepted by the trench thus increasing the risk that a small amount of contaminated groundwater may reach Railroad Creek.

Given the variation of numerous modeled factors across the Holden site (e.g., tailings pile configuration, underlying topography, infiltration and seepage rates, hydraulic conductivities, river location, depth and bed conditions, etc.), the optimal design depth of the collection trench for the PPC will need to be a compromise that best addresses site conditions and seasonally variable flow in Railroad Creek. Monitoring of groundwater elevations at selected locations on either side of the PPC for a short period after construction would allow its effectiveness to be assessed in combination with monitoring of water quality trends, both in the groundwater and at the conditional point of compliance where groundwater enters surface water.

Please call if you have any questions.

Attachments:
Table 1 - Model Input Parameters
Figure 1 - Location of Modeled Cross Section
Figure 2 - VADOSE/W Modeled Cross Section
Figure 3 - Schematic of Groundwater Cutoff and Collection System
Figure 4 - Calibrated Spring Condition
Figure 5 - Modeled Effectiveness of a Partially Penetrating Cutoff Wall
Figure 6 - Summary of Sensitivity Analysis

REFERENCES

Dames & Moore, 1999. Draft Final Remedial Investigation Report, Holden Mine Site. Prepared for Alumet, Inc. by Dames and Moore, dated July 28, 1999.

URS, 2004a. Fall 2003 Hydrogeologic Investigation Data Transmittal, Holden Mine RI/FS. Prepared for Intalco by URS Corporation, dated March 29, 2004.

URS, 2004b. Draft Final Feasibility Study, Holden Mine Site. Prepared for Intalco by URS Corporation, dated February 19, 2004.

Table 1 - VADOSE/W Model Input Parameters

Hydraulic Conductivities [a]	
Tailings	0.00008 ft/sec
Native Material	0.001 ft/sec
Alluvium	0.001 ft/sec
Glacial Drift	0.0003 ft/sec
Trench Depths in Feet below Toe of Tailings Pile 1 [b]	
Shallow Trench	2
Deep Trench	2.5
Wall Depths Relative in Feet below Toe of Tailings Pile 1 [b]	
Shallow Wall	15
Deep Wall	30
Constant Head for Railroad Creek in Feet below Toe of Tailings Pile 1 [b]	
Spring	0.3
Fall	1.3
Infiltration Applied as a Unit Flux to the Tops of the Tailings Pile	
Spring (current conditions)	0.17 in/d
Fall (current conditions)	0.05 in/d
Spring (regraded)	0.02 in/d
Fall (regraded)	0.007 in/d

Notes

[a] Based on hydraulic conductivities provided in the flownet analysis (Attachment A-1 of the DFFS, URS 2004b).

[b] All depths are set from an arbitrary datum, assumed for this model as the toe of the regraded tailings pile.

Location of Modeled Cross Section

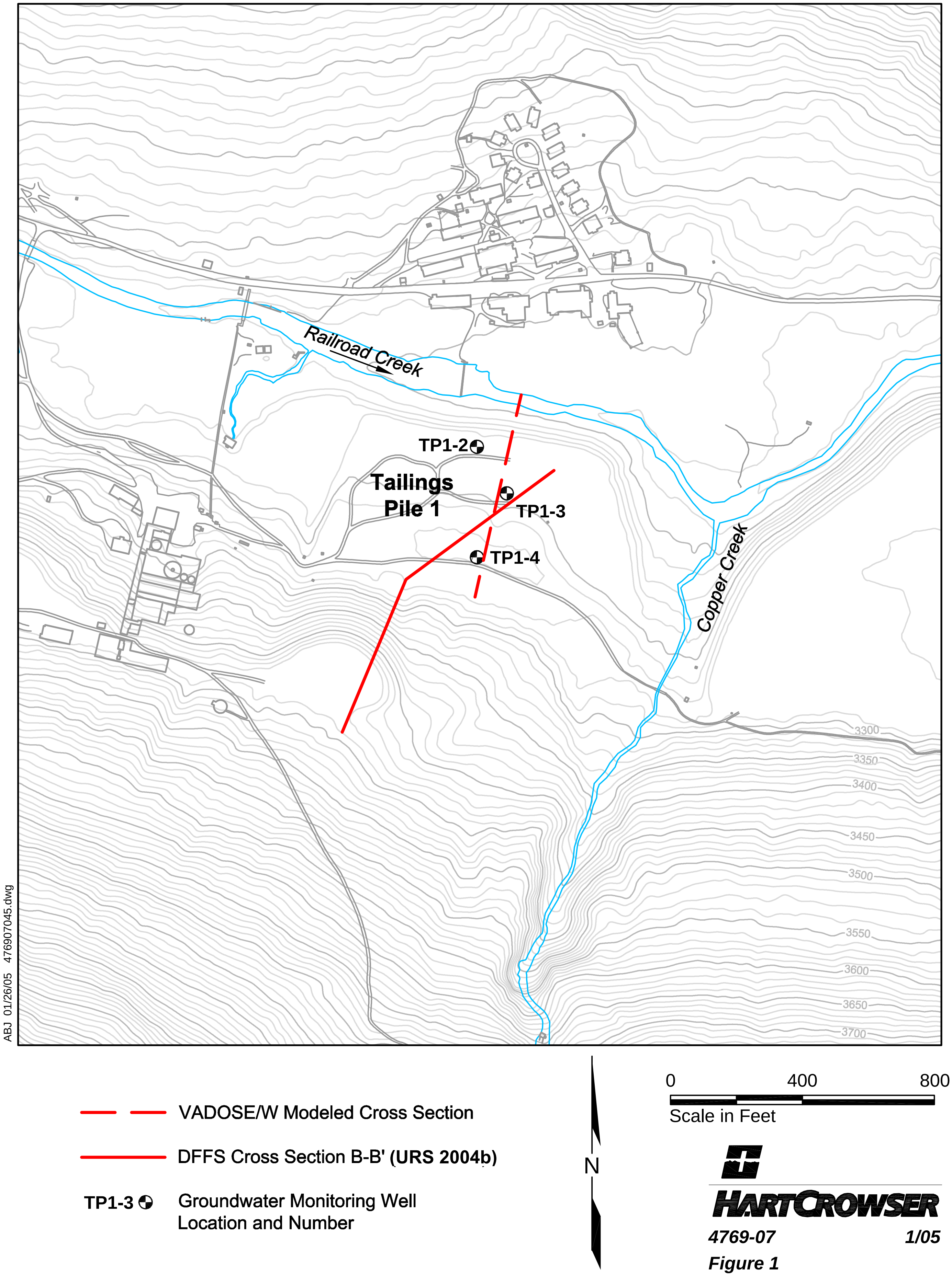


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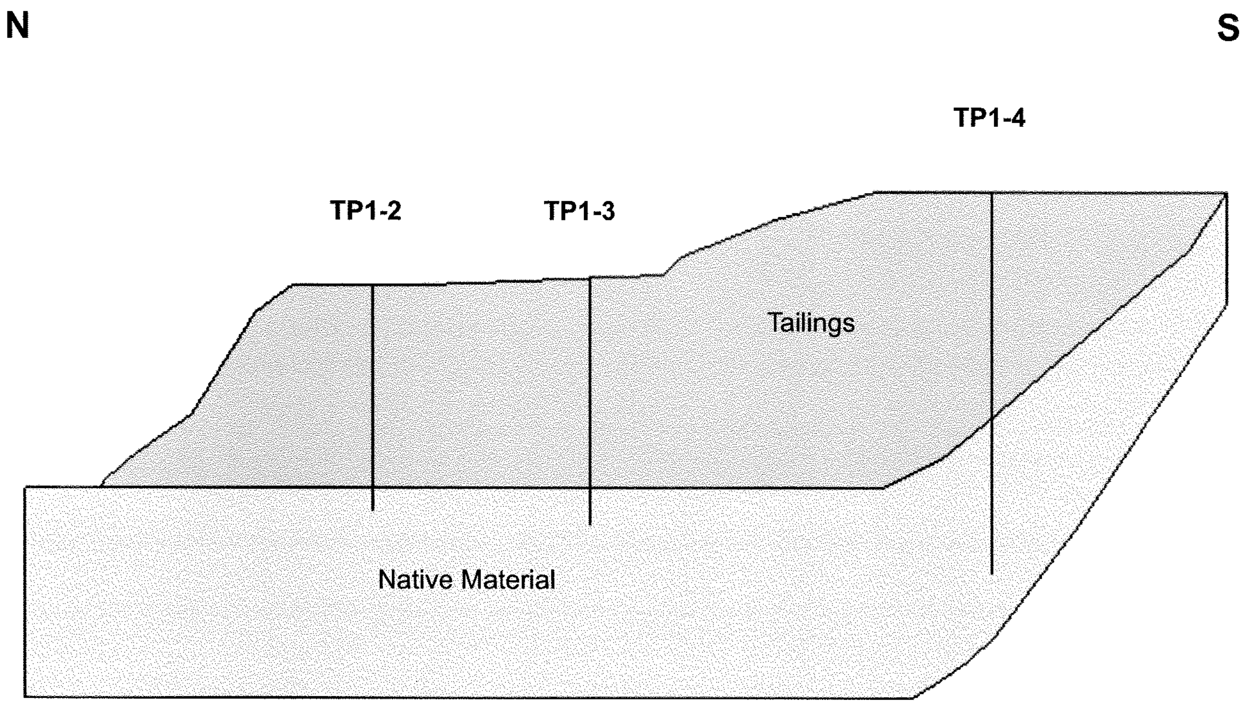
Figure 1

Vadose/W Modeled Cross Section



Vertical Exaggeration ~2.25

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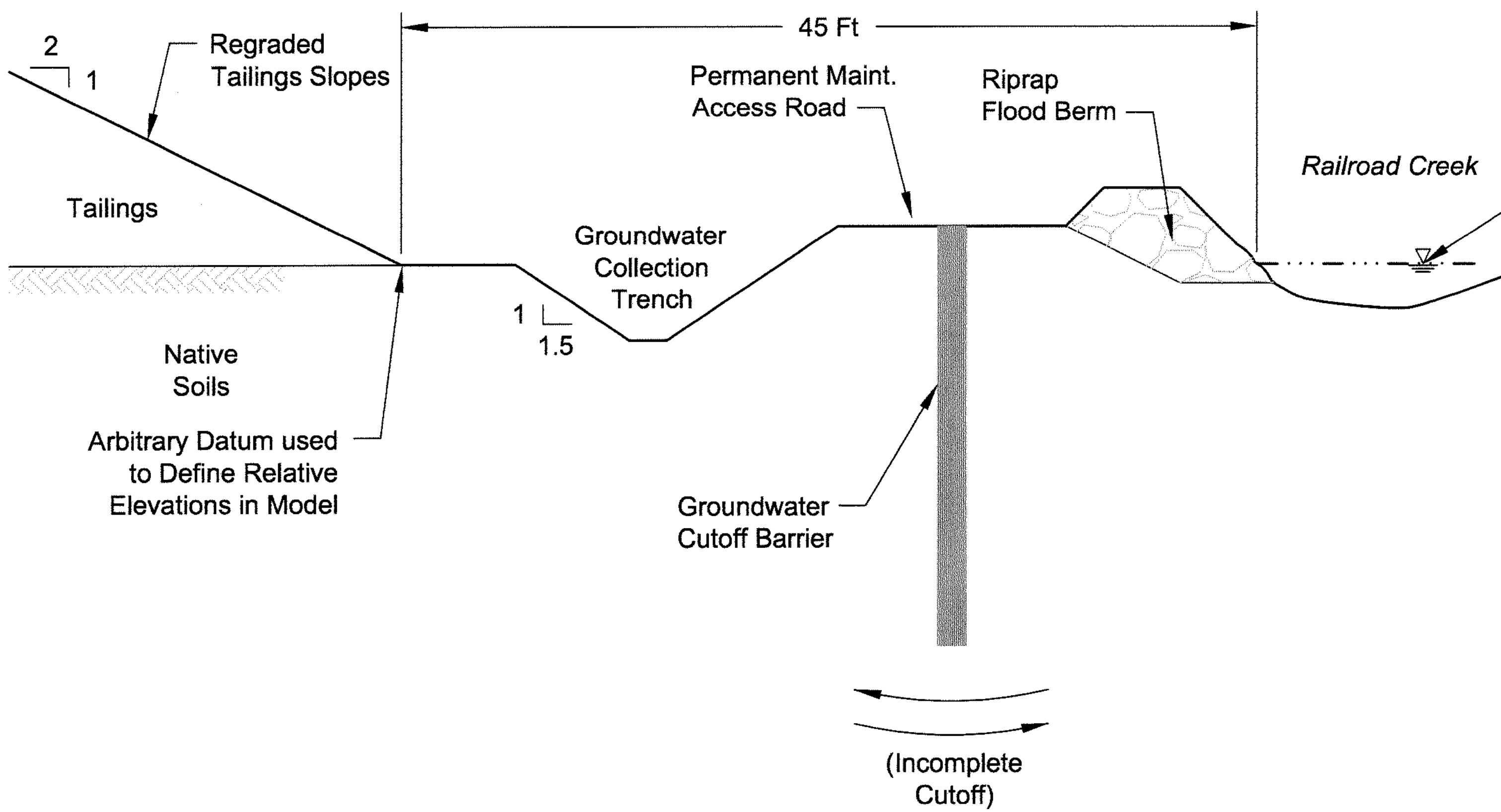
Figure 2

Schematic of Groundwater Cutoff and Collection System



Not to Scale

CAS 1/24/05 476907046.DWG

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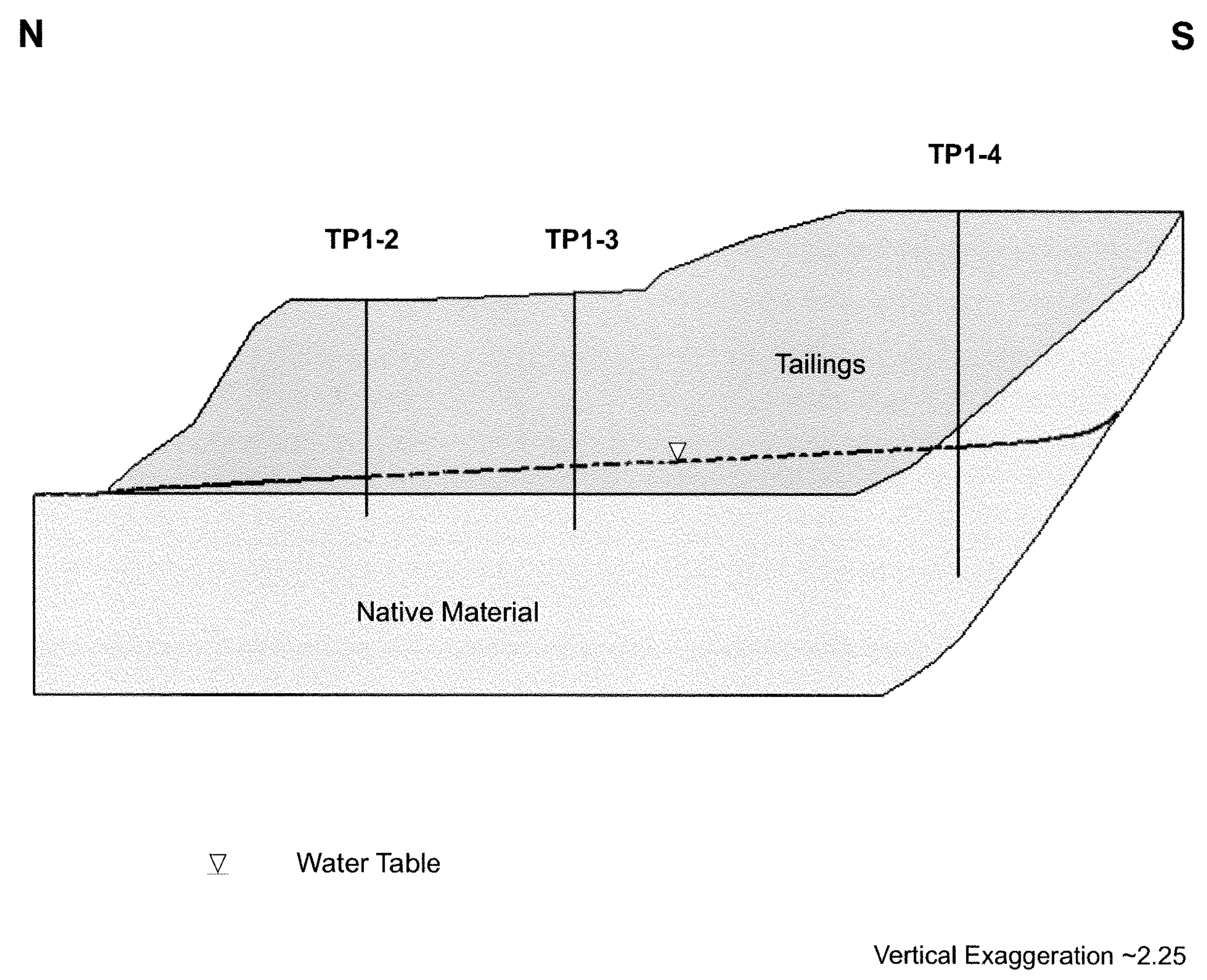
4769-07 1/05
Figure 3

Calibrated Spring Condition



476907AB.CDR CAS 2/2/05

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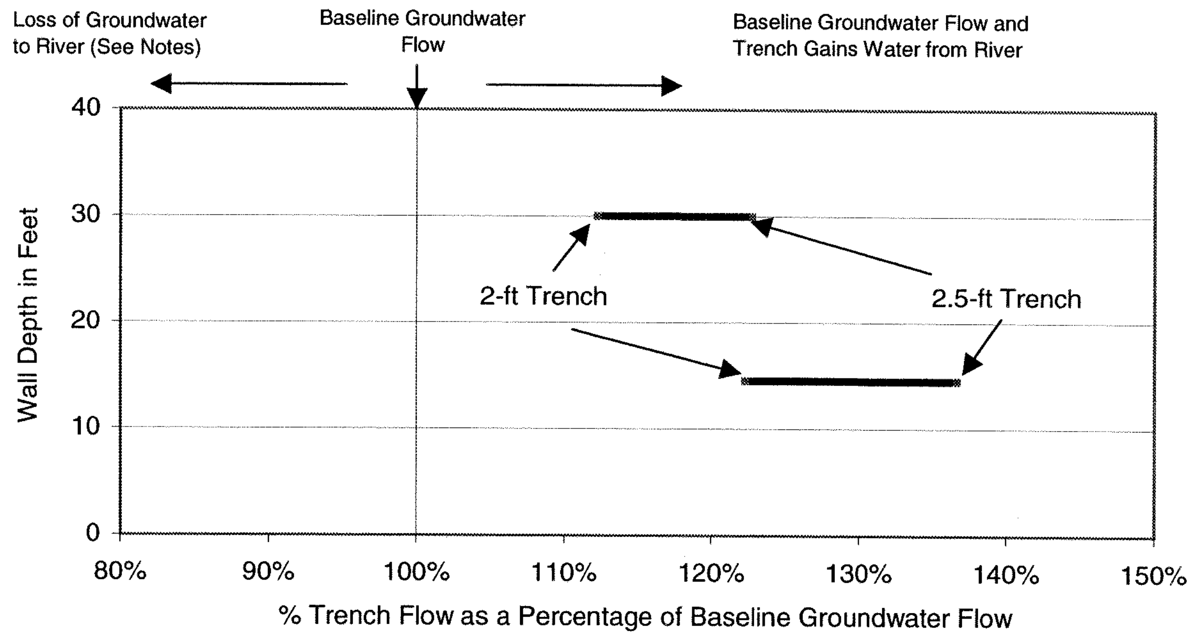
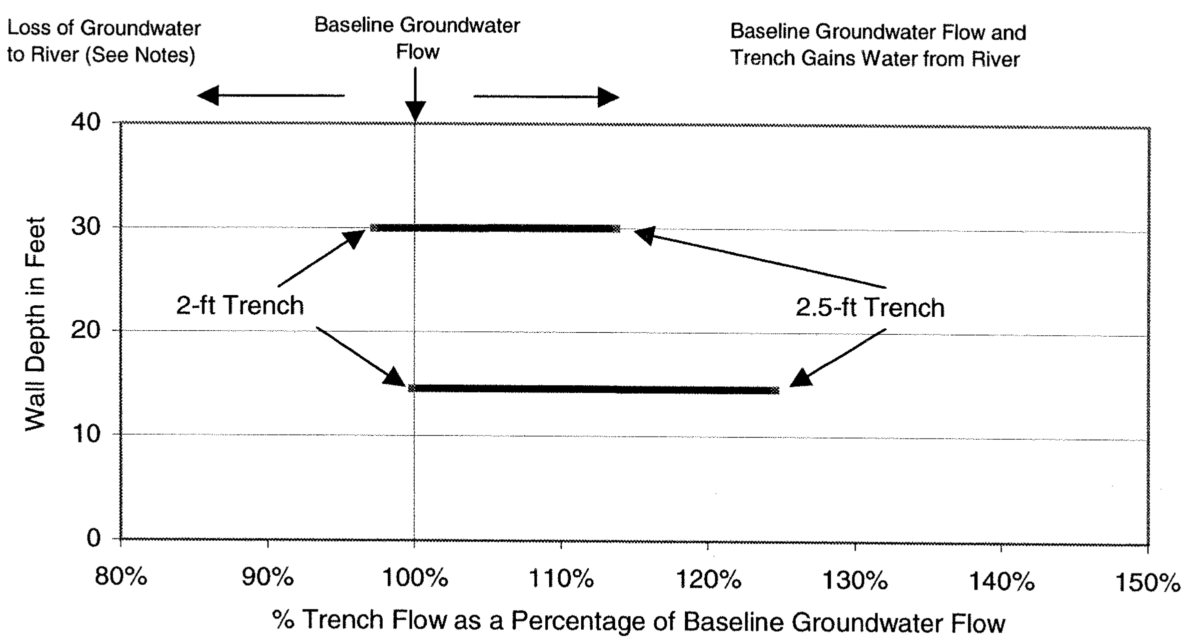
Figure 4

Modeled Effectiveness of a Partially Penetrating Cutoff Wall

Spring



Fall



Notes

Trench Flow as a Percentage of Baseline Groundwater Flow - 100% trench flow means all of the baseline groundwater originating from the south is intercepted by the trench. Values greater than 100% indicate river water flowing under wall into trench. Values less than 100% indicate a loss of south side groundwater under wall to river.

Based on assumed aquifer thickness of ~55 feet

Bar represents range of variation in flows for trench depths between 2 and 2.5 feet.

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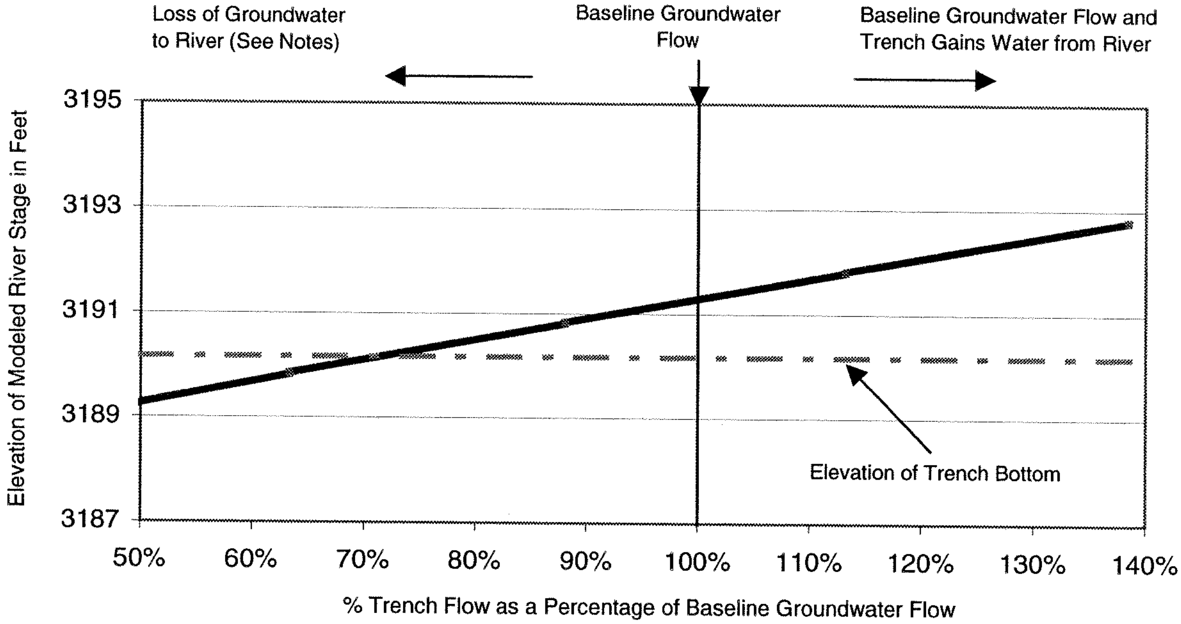
4769-07 *2/05*

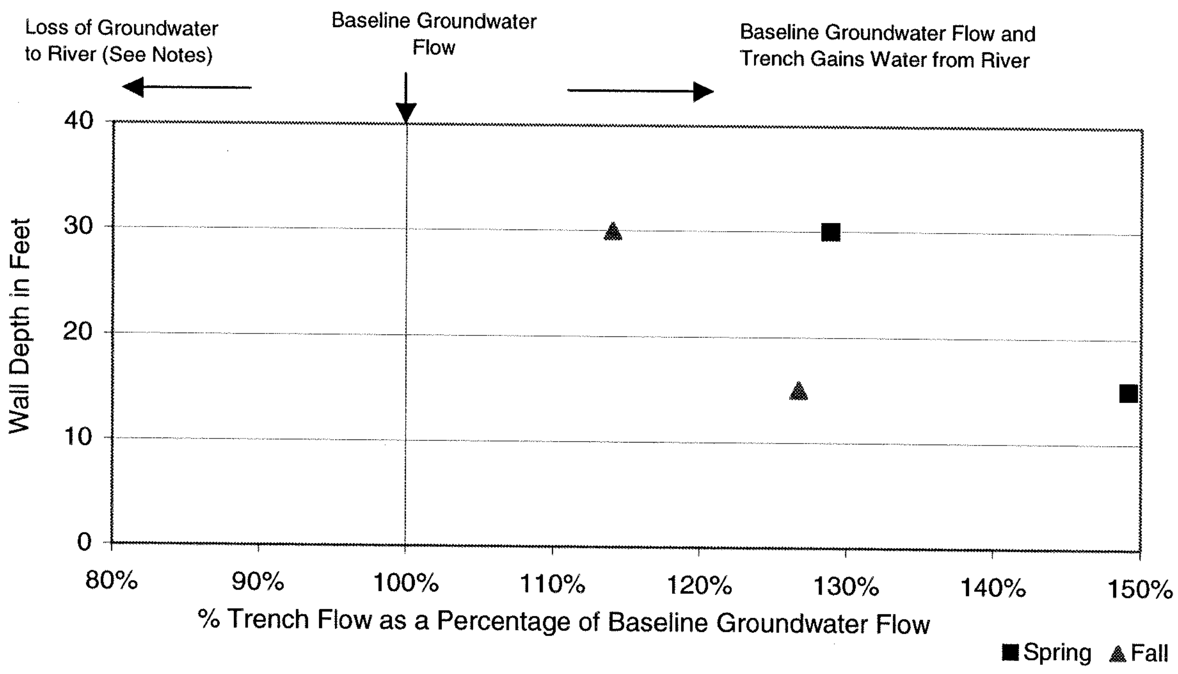
Figure 5

Summary of Sensitivity Analyses

Varying River Stage



Varying Hydraulic Conductivity [a]



Notes

Trench Flow as a Percentage of Baseline Groundwater Flow - 100% trench flow means all of the baseline groundwater originating from the south is intercepted by the trench. Values greater than 100% indicate river water flowing under wall into trench. Values less than 100% indicate a loss of south side groundwater under wall to river.

[a] This model was run for the case of a 2-foot depth collection trench.

ATTACHMENT B
RAILROAD CREEK HYDROGRAPH ANALYSIS

ATTACHMENT B
RAILROAD CREEK HYDROGRAPH ANALYSIS

Introduction

While the VADOSE/W analysis provided a sufficient preliminary assessment of the partially penetrating barrier (PPB), it also indicated that the effectiveness of the PPB would change due to the normal variations in river stage. The VADOSE/W modeling results (Attachment A) indicated that the effectiveness of the PPB varies as the amount of groundwater flow captured by the accompanying trench was directly influenced by the river stage relative to the collection trench depth.[1] A linear relationship was determined to exist between the PPB collection efficiency and river stage as shown on Figure F-14. As indicated on the figure, some water from Railroad Creek enters the groundwater collection ditch during high river stage conditions, and less groundwater is intercepted by the PPB as the river stage drops.

Intalco compiled a hydrograph of Railroad Creek stage heights on an hourly basis using a pressure transducer deployed at station RC-4. Using these data and the VADOSE/W modeling results, a hydrograph analysis was performed by Hart Crowser to study the likely variation in groundwater captured over time. The analysis discussed in this attachment uses the available hydrograph data to provide a more realistic estimate (compared to the simple model presented in Attachment A) of the volume of groundwater collected for treatment over time. The hydrograph model provides a basis for estimating changes in the amount of groundwater that is or is not collected, and the amount of creek water that is captured by the groundwater collection system as flow in the creek varies over time. Two different sets of calculations were performed as part of the hydrograph analysis outlined below: (1) percent groundwater capture for the trench, and (2) volume of water intercepted by the trench. The latter estimates of flow volumes were performed for each area where groundwater would be collected for Alternative 10 (i.e., Lower West Area [LWA], Tailings Pile 1 [TP-1], and Tailings Pile 3 [TP-3]). Groundwater flows from beneath TP-2 were excluded from this initial analysis, since Alternative 10 does not include collection of groundwater below TP-2.

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[1] The partially penetrating cutoff (PPC) referred to in Attachment A, is the same groundwater barrier referred to herein and in other documents as the partially penetrating barrier (PPB).

Calculating Groundwater Flux

Continuous records of contemporaneous water level data are available as hydrographs from well MW-1 and Railroad Creek station RC-4 (as illustrated on Figure F-15 of this report). To calculate groundwater flux entering Railroad Creek in this part of the LWA, it is assumed that the flux from the alluvial aquifer can be represented as unconfined aquifer flow based on the difference in elevations between the two water bodies (i.e., the shallow unconfined aquifer in the LWA, and Railroad Creek) represented by the hydrographs. The calculated groundwater flux discussed below was used to estimate the variability in the percentage of groundwater capture by the trench, as well as in the volume of creek water intercepted by the trench.

Dupuit Formula

Aquifer flux, q (in units of volume per foot of stream length) is calculated using Dupuit's formula, which is as follows for planar flow (Harr 1962; see reference list in main text of Appendix F):

$$q = K (H^2 - h^2) / 2 L$$

The input parameters are:

- **K = Hydraulic Conductivity of the Aquifer between MW-1 and Railroad Creek.** The hydraulic conductivity used in the analysis is 0.001 foot per second, which is the mean value of the native sediments as defined in the loading analysis of the DFFS.

- **H = Aquifer Head.** This can be calculated from the hydrograph for MW-1 if a base of aquifer (defined below) is assumed. The assumed base of aquifer elevation is subtracted from the water elevation recorded in well MW-1 to give the aquifer head.

- **h = Seepage Head at the Creek.** This represents the water level in the creek that controls the rate of groundwater discharge from the aquifer, and can be calculated from the hydrograph for RC-4 if a base of aquifer is assumed. To give a representative relationship between MW-1 and the stream hydrograph, 12 feet was initially added to the RC-4 data to represent a location in the creek opposite MW-1. This elevation adjustment was based on the topographic data and the LiDAR map provided by Intalco. The assumed base of aquifer elevation is subtracted from the adjusted water elevation for station RC-4 to give the seepage head. Note that the Dupuit formula ignores the development of any seepage face at the creek.

- **L = Distance between MW-1 and the Creek.** As measured in the approximate direction of groundwater flow, this distance is 110 feet.

- **Base of Aquifer Elevation.** For calculating the percent of water captured by the trench, this elevation was initially set at 3,210 feet. Setting the base of aquifer elevation at 3,210 feet results in average head values between 9 and 12 feet for the seepage and aquifer heads, which is comparable to the 10-foot aquifer thickness assumed in the DFFS flow net analysis. It should be noted that calculations of the percent capture are virtually insensitive to this parameter.

  For calculation of the trench flow volumes, the base of aquifer elevation was varied for the three different sets of calculations performed for the three areas that are contributing to groundwater collection—the LWA, TP-1, and TP-3. The base of aquifer elevation was adjusted until the flows generated in each calculation were comparable to the corresponding mean flows generated in the flow net analysis provided in Appendix A of the DFFS.

Water level data were recorded by Intalco at well MW-1 every 4 hours and at river station RC-4 data every hour from October 2003 through July 2004. For simplicity, flows were calculated for every hour, for the full available record of MW-1. Groundwater levels, which change more slowly than surface water levels, were assumed to be constant over each 4-hour increment of the hydrograph record.

The resulting record of generated groundwater flows was checked for consistency with the DFFS loading analysis by comparing the calculated spring versus fall fluxes. The change from fall to spring flow conditions was defined as the rising limb of the spring hydrograph on March 7, 2004. The contrast between spring and fall flows was based on the flow nets used to develop the loading analysis. Flow net calculations for the loading analysis indicate that the fall flow should be 61 percent of the spring flow. A small modification was therefore made to the streambed elevation adjustment made to the RC-4 data, to maintain this relationship in the hydrograph analysis. The streambed elevation adjustment was modified to 11.8 feet such that the average of all the fall hourly flows is 61 percent of the average of all the spring hourly flows calculated for the full hydrograph record.

Assumptions

There are several important assumptions in the hydrograph analysis, which are discussed below. The assumptions are consistent with hydrogeologic conditions in the Railroad Creek valley. The assumptions are necessary for the analysis to be completed using the limited information that is available from the RI/FS accomplished by Intalco. More complete information would change results of the analysis to some degree, but is not likely to change the general conclusions discussed in this attachment.

The overall calculation is a first order approximation that is inherently dependent on the assumptions underlying the Dupuit formula, some of which are not completely satisfied:

- **Flow between the aquifer and Railroad Creek is not at steady state,** as implied by the changing differences in groundwater and seepage head, flow is in fact varying continuously.

- **Flow between the aquifer and Railroad Creek is not entirely horizontal,** but includes components of vertical flow, which are ignored in this analysis.

- **Variation in aquifer thickness between MW-1 and Railroad Creek is ignored.**

- **Variation in seepage velocity with depth are ignored.** Flow velocity in the aquifer is assumed to be uniform with depth.

- **The presence of a low-permeability streambed in Railroad Creek** (e.g., the presence of ferricrete adjacent to TP-1) could also affect rates of exchange between surface water and groundwater; this has not been considered in the Hydrograph Analysis.

In addition, the following facets of groundwater flow are not considered explicitly, although it is likely that their effects are manifest within the hydrograph records:

- Flow in the capillary fringe;

- Lateral flow in the vadose zone above the capillary fringe;

- Contributions to and from bank storage;

- Leakage to and from the till and/or bedrock underlying the aquifer; and

- Changes in recharge and evaporation are assumed to be fully manifest in the hydrograph record.

The single most important assumption when calculating trench flows is that of uniform hydraulic conductivity in the aquifer, which is adopted from the DFFS loading analysis. Any variation in conductivity from that assumed in the loading analysis will result in a proportional deviation from the calculated flows and amounts of groundwater capture by the PPB system. Conductivity measurements for the RI/FS vary over 3 to 4 orders of magnitude depending on gradation and compaction of the sediments and the method of measurement used (e.g., see Table 4.4-3, Dames & Moore 1999), but a single value was selected for analysis (referred to as "best estimate" in URS 2004a). While changes in conductivity from one location to another would change the results of the analysis, use of the "best estimate" provides results that are representative of the overall range in conditions across the Site.

An equally significant assumption inherent to the Hydrograph Analysis is that historical variations in groundwater levels can be used in a predictive sense to assess the performance of the PPB. However, installation of the PPB would be accomplished expressly to disrupt groundwater flows and, therefore, is highly likely to impact groundwater levels, as will the diversion of groundwater flow into the capture trench. Changes in the existing flow system due to installation of Alternative 10 could be better assessed by advanced hydrologic modeling, provided sufficient data were available to support more advanced analysis. It should be noted that the Hydrograph Analysis uses data from a specific seasonal period (2003-04) to simulate capture flows, with overall flow rates normalized to be similar to mean spring and fall flows deduced from the DFFS Loading Analysis, which was in turn based on data from May and September 1997. No data are available to support the contention that flows in 1997 and 2003-04 are in fact comparable. More extensive data collection by Intalco would have improved our ability to analyze conditions following implementation of the remedy.

Calculating Groundwater Capture

The second sensitivity analysis from the VADOSE/W modeling effort, where the river stage was varied, resulted in a linear relationship between river stage and collection effectiveness. These linear relationships varied for spring and fall and are shown on Figure F-14. The original analyses as summarized in Attachment A only looked at the spring condition. Using the same method, a relationship between river stage and collection effectiveness was also determined for the fall condition. Note that the data shown on Figure F-14 illustrate the PPB modeling results, which are from a cross section downstream of Railroad Creek station RC-4 at an elevation approximately 15 feet lower. Assuming a similar relationship between river stage and collection effectiveness would occur along other gaining stretches of the Railroad Creek if a PPB and collection system were installed, a time-varying capture effectiveness and trench flow volumes can be calculated.

Generalized Calculations of Percent Capture

Focusing on the MW-1 to Railroad Creek flow path, relative percent capture estimates were calculated. The analysis of spring versus fall has been split with the appropriate linear relationship from Figure F-14 applied. The split between fall and spring was defined as the rising limb of the spring hydrograph on March 7, 2004, which results in 147 days of fall flows and 140 days of spring flows represented in the hydrograph analysis. (Note that inspection of the hydrograph does not support the assumption used in the DFFS that "spring" flow conditions represent actual flows about 90 days of the year, and that "fall" flow conditions represent actual flows about 275 days of the year. While the 90/275 assumption is used by the Agencies for analysis of remedy effectiveness to be consistent with the DFFS; the hydrograph analysis described in this attachment gives a more realistic estimate of the groundwater flow volume that will be captured for treatment).

Over the 287-day period of the analysis (the entire hydrograph record that is presently available), the average of the calculated groundwater capture rates is 86 percent, with an average of 83 percent in the fall and 89 percent in the spring.

These average values represent a weighted mean of the continually varying effect of changes in stream flow. Over the entire 287-day period that was analyzed, the collection efficiencies ranged between extreme values of 225 and 70 percent, where the extremes represent short duration periods of maximum and minimum water levels in Railroad Creek. Values less than 100 percent indicate a net loss of groundwater to the creek during relatively low water periods in the creek. Values greater than 100 percent indicate an increase in flow to the collection trench relative to the baseline groundwater flow (i.e., creek water flows under the barrier wall into the collection trench) during relatively high water periods in Railroad Creek.

Over the period that was analyzed, the analysis shows the PPB collection system would collect an overall average of 86 percent of the groundwater that would flow from the Site into Railroad Creek.

- During the "fall" the average was only 83 percent, and there were only 15 days when the collection trench is predicted to collect water from the creek. The 225 percent collection efficiency was part of the October 2003 storm event. During this 15-day period, the hydrograph had three peaks that were related to the initial storm event, stormwater runoff from up-basin, and then a second rain event. Out of 15 days, the collection efficiencies were greater than 100 percent for 7 days. There were no other occasions during the fall period that capture exceeded 100 percent for periods longer than 36 hours. Conversely, collection efficiencies dipped below 75 percent for less than 2 days over the 287-day period of the analysis.

- During the spring portion of the hydrograph, collection efficiencies range from 74 and 115 percent, and overall the analysis shows the trench would collect 89 percent of the contaminated groundwater that would otherwise flow into the trench during the "spring." Collection efficiencies exceed 100 percent for approximately 11 days during the spring.

The time-varying groundwater flux and the time-varying capture percentage were multiplied to give calculated capture flux per foot of trench with units of cubic feet per second. Since the record is hourly, this capture flux is then multiplied by 3,600, the number of seconds in one hour, to provide a groundwater capture volume per hour. A similar conversion of 3,600 is applied to time-varying groundwater flux to calculate the total groundwater flow volume. The captured volumes and groundwater flow volumes are then summed over each hour of the record to provide a total for the spring and fall periods of the record. These calculations yield similar capture percentages of 88 and 85 percent, respectively, for spring and fall.

Estimating Flow in the Collection Trench

While understanding the amount of fluctuation in the collection efficiencies is helpful, flow volumes are necessary to size the trench and treatment system. The flow net analysis from the DFFS does provide an estimate for groundwater flow that would be captured; however, with the PPB system, the hydrograph analysis provides a basis for estimating how much water from Railroad Creek would be drawn into the collection trench. The hydrograph at RC-4 was used to provide a preliminary estimate of this flow. It should be understood that this is a very rough estimate and a more robust modeling effort with a three-dimensional groundwater flow model is recommended to better estimate these values.

The analysis was performed for three of the source areas that are expected to have groundwater barrier and collection systems under Alternative 10: the LWA, TP-1, and TP-3. In the VADOSE/W analysis, the length of trench considered was 1 foot at one specific cross section. To estimate total flows, the VADOSE/W results are extrapolated over the "stream length" values used in the loading analysis. The stream length is the summed width of the flow tubes as measured at the Railroad Creek stream bank, as used in the DFFS loading analysis, for each source area.

The hydrograph record analyzed is 287 days in length, 140 days of spring and 147 days of fall. To calculate trench flow from groundwater for a full year, it was assumed that the remaining 78 days (365 minus 287 days) were fall conditions, and that flow was the average from the 147 days of available fall data.

Lower West Area

The LWA includes the length of Railroad Creek from the Portal drainage to the Copper Creek Diversion. Flow nets for this area were not included as part of the DFFS loading analysis; therefore, Hart Crowser drafted flow nets for spring and fall based on well data from the area (Hart Crowser 2005). The Base of Aquifer elevation was adjusted to 3,213 feet for discharge results to be similar to flow volumes calculated in the flow net analysis.

The analysis indicated that on an annual basis, the PPB trench in the LWA would collect 41 million gallons of groundwater. Based on the 287-day period of the hydrograph, the volume of creek water that would be intercepted by the trench was estimated to be 580,000 gallons per year, or about 1-1/2 percent of the contaminated groundwater that would be captured in this reach.

Tailings Pile 1

TP-1 includes the length of Railroad Creek from the Copper Creek Diversion to Copper Creek. The Base of Aquifer elevation was adjusted to 3,210 feet for discharge results to be similar to groundwater flow volumes calculated for the native materials beneath TP-1 in the DFFS flow net analysis.

The annual trench flow from the native materials beneath TP-1 was calculated to be 64 million gallons. Based on the hydrograph analysis, the volume of Railroad Creek water that would be intercepted by the trench over the course of a year was estimated to be 880,000 gallons, (about 1-1/2 percent of the contaminated groundwater that would be collected for treatment).

Tailings Pile 2

The RI/FS completed by Intalco did not include collection of any information on the quality of groundwater along the margin of TP-2 that is flowing into Railroad Creek. Groundwater flows from beneath TP-2 were excluded from this initial analysis since Alternative 10 does not include collection of groundwater below TP-2.

Tailings Pile 3

TP-3 includes the length of Railroad Creek from the approximately seep SP-4 to seep SP-21.

- During fall flow conditions, Railroad Creek is a losing stream along TP-3, where creek water is apparently recharging the aquifer beneath TP-3 and subsequently discharging to the east (where the groundwater apparently enters Railroad Creek in the vicinity of seeps SP-5 to SP-21).

- During spring flow conditions, a portion of Railroad Creek appears to be a gaining stream based on flow nets in the DFFS, and a portion appears to have a flat gradient, or even losing stream conditions.

While the VADOSE/W modeling results are for a gaining condition, these results were extrapolated to the TP-3 area to provide an estimate of the flow volumes that could enter the Alternative 10 trench. (This provides an apparent upper-bound estimate of trench flow that would be collected for treatment, since the PPB would reduce the amount of creek water that flows under TP-3 and accordingly the groundwater volume collected between SP-5 and SP-21 is expected to be reduced.)

For the TP-3 estimate, the Base of Aquifer elevation was adjusted to 3,215 feet for discharge results to be similar to groundwater flow volumes calculated in the DFFS for the groundwater discharging from the native materials beneath TP-3 into Railroad Creek.

If the VADOSE/W results are extrapolated to the TP-3 flow tubes, the annual trench flow from the native materials beneath TP-3 was estimated to be on the order of 35 million gallons. The amount of creek water collected might be on the order of 660,000 gallons over the course of a year, (slightly less than 2 percent of the collected groundwater).

Discussion

Intalco has raised concerns regarding the expected variations in collection efficiencies of the PPB. While there is no absolute requirement for collection efficiency, the Agencies expect that design of the PPB would be optimized to balance the amount of contaminated groundwater that is not collected, with the amount of creek water that is collected and, therefore, would need to be treated. The hydrograph analysis provides a basis for evaluating how the PPB design can reduce the amount of metals-laden groundwater discharged into Railroad Creek while minimizing the amount of relatively clean Railroad Creek water intercepted by the collection and conveyance system, considering normal flow variability in Railroad Creek.

The analyses described above indicate that Alternative 10, consisting of a nominal 30-foot-deep barrier and 2-foot-deep collection trench, would be effective in collecting an average of 86 percent of the contaminated groundwater that would otherwise seep into Railroad Creek as it flows across the Holden Mine Site.

For the range of creek flow conditions documented by the available hydrograph record (that includes the uncommon high-water conditions that occurred during the October 2003 flood), Alternative 10 is estimated to collect a volume of creek water corresponding to 1 to 2 percent of the groundwater that would be collected.

This analysis quantifies the effectiveness of the PPB at the Holden Mine Site for a realistic hydrograph scenario. The PPB is an effective means of reducing metals-laden groundwater from entering Railroad Creek.

The results of the second set of analyses indicate that the annual volume of groundwater intercepted by the trench (not including discrete seep collection) would be on the order of 140 million gallons. It should be noted that the calculations outlined above do not account for the range of uncertainty that exists for the hydraulic conductivity of the aquifer material. A more complete three-dimensional groundwater flow model would be necessary to provide a more reliable estimate of flow in the trench.

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ATTACHMENT C
REPORTED EXPERIENCE ON METHODS TO ADDRESS IRON FOULING ISSUES ASSOCIATED WITH AMD CONVEYANCE SYSTEMS

ATTACHMENT C
REPORTED EXPERIENCE ON METHODS TO ADDRESS IRON FOULING ISSUES ASSOCIATED WITH AMD CONVEYANCE SYSTEMS

Hart Crowser conducted a literature review and contacted EPA project managers of acid mine drainage (AMD) remediation sites to better understand how industry addresses iron fouling issues associated with conveyance of AMD with high iron content. Intalco also conducted a literature search of iron fouling associated with mining and other types of sites (BBL 2004). Results of both reviews are summarized below and in the attached annotated bibliography.

Iron fouling occurs when acidic mine waters drain from areas with ferrous sulfate minerals (primarily pyrite and marcasite), which oxidize to form ferric sulfate and then form iron hydroxides. Similar problems occur with formation of aluminum hydroxides for some sites (such as Holden).

The EPA list of hazardous substances includes ferrous sulfate, ferric sulfate, and aluminum sulfate (40 CFR Table 302.4). Based on the chemical processes described in the RI/FS, ferrous sulfate is released at the Site through the oxidation of pyrite into groundwater. Aluminum sulfate in groundwater results from the dissolution of alumino-silicates. Ferric sulfate may also be released into Railroad Creek if ferrous iron is converted to ferric iron within the mine or in groundwater downgradient of the waste rock and tailings piles.

Background: Iron (and Aluminum) in Mine Waters

Iron-rich mine drainage can take different chemical forms, which has a great impact on treatment requirements and strategy. Iron has two oxidation states, ferrous (Fe^{2+}) and ferric (Fe^{3+}). Solubility of these species is affected by pH, oxidation-reduction conditions, and by the presence of other aqueous species. In general, iron solubility can be summarized as follows:

- Ferrous iron is soluble in water over a wide range in pH; and
- Ferric iron is soluble at a pH less than 3.5 and becomes relatively insoluble when pH is greater than 3.5.

Ferrous iron (as ferrous sulfate) is generated by the oxidation of pyrite (Fe_2S) in tailings, waste rock, or within the abandoned mine by oxygen in air or dissolved in water, as shown in the following equation:

$$2FeS_{2(s)} + 7\,O_{2(g)} + 2H_2O_{(l)} \rightarrow 2Fe^{2+} + 4SO_4^{2-} + 4H^+_{(aq)}$$

The ferrous sulfate can be present on the surface of the pyrite or dissolved in groundwater in contact with the pyrite.

When low-oxygen or anoxic water containing ferrous iron comes in contact with oxygen, the ferrous iron is converted to ferric iron by the following equation:

$$4Fe^{2+}_{(aq)} + O_{2(g)} + 4H^+_{(aq)} \rightarrow 4Fe^{3+}_{(aq)} + 2H_2O_{(l)}$$

Certain bacteria can increase the rate of oxidation from ferrous to ferric iron. This reaction is also pH dependent, occurring slowly under acidic conditions and becoming faster as pH increases. It can take hours to reach equilibrium (USFWS 2005).

Once the dissolved ferric iron is generated, it will be rapidly converted to ferric hydroxide if the pH is high enough (greater than pH 3.5). The ferric hydroxide is insoluble and precipitates. This reaction is shown in the following equation:

$$Fe^{3+}_{(aq)} + 3H_2O_{(l)} \rightarrow FeOH_{3(s)} + 3H^+_{(aq)}$$

Iron precipitates in Railroad Creek are observed adjacent to and up to several miles downstream of the tailings piles, indicating that conversion of ferrous iron to ferric hydroxide occurs over some distance downstream (USFWS 2005).

Ferrous iron is highly toxic to aquatic organisms, which is why it is desirable to have this reaction occur as groundwater enters a seep collection trench, and not within Railroad Creek. Fine precipitates of ferric hydroxides, also referred to as iron flocculent, are also toxic to aquatic organisms, since fine precipitates can adhere to gills and lead to suffocation (USFWS 2005). However, it is the physical occurrence of this precipitate and its effect on groundwater collection and conveyance systems that is the focus of the discussion in this appendix.

It is the ferric form of iron that forms the orange/yellow precipitate ferricrete, a mineral conglomerate consisting of surficial sand and gravel cemented into a hard mass. The presence of ferricrete has been documented in areas adjacent to seeps SP-1, SP-2, and SP-3, which contain elevated concentrations of iron and flow directly to Railroad Creek (DFFS Section 2.5.3.2). The extent of ferricrete identified in the RI is shown on Figure 2-45 of the DFFS. Iron oxy-hydroxide precipitates (iron flocculent) were also observed adjacent to Tailings Pile 1 (TP-1) near station RC-9, which may be due to an upwelling of iron-rich groundwater in that area (DFFS Section 2.5.4.1), and in the main 1500 Level portal (DFFS URS Supporting Calculations 2.1.3).

Aluminum is released at the Site through the dissolution of alumino-silicates in the rock. Aluminum is highly soluble at pH 5 or lower and relatively insoluble from pH 5.5 to 9. Modeling results using MINTEQA2 in the DFFS determined that dissolved aluminum in the spring flush of the portal drainage consisted of the trivalent aluminum ion (Al^{3+}, approximately 50 percent) and aluminum sulfate ($AlSO_4^+$, approximately 30 percent), along with lesser amounts of AlF^{2+}, $AlOH^{2+}$, and $Al(SO_4)_2^-$. During the fall and summer, as the acidity of the portal drainage increases, the dominant dissolved aluminum species in the portal drainage is $Al(OH)_4^-$. Groundwater seepage from the tailings piles has aluminum species similar to that present in the portal drainage during the spring flush, dominated by the trivalent aluminum ion and aluminum sulfate (DFFS Appendix H).

Methods to Address Iron Fouling Issues

In general, methods used to address iron fouling issues in AMD conveyance systems can be divided into two categories: those which attempt to reduce the rate of conveyance system fouling; and those which facilitate conveyance system cleaning. These two categories are addressed separately below.

Methods to Reduce Conveyance System Fouling

Methods used to reduce the rate at which iron fouling occurs in conveyance systems include the following:

- Precipitation and removal of dissolved iron as a pretreatment step at the point of AMD collection (prior to conveyance);

- Maintaining anoxic conditions in the conveyance system;

- Adding phosphate-based dispersants prior to conveyance; and

- Maintaining high flow velocities in the conveyance system.

These methods are addresses separately in the following subsections.

Iron Precipitation/Removal Prior to Conveyance

One way to potentially reduce iron fouling in conveyance systems is to provide a pretreatment step for iron precipitation and removal upstream of the conveyance system.

At the Hilton Mine, the effective diameter of piping downstream of a dewatering system pump house decreased from 8 inches to approximately 4 inches over a

2.5-year period (Whitelock 1993). Initially, mine engineers considered creating an oxygen-depleted environment in the pump house. However, this was ruled out as too dangerous for mine personnel and difficult to maintain. Their solution was to add a pretreatment step in the mine, where the water is aerated using sprays and fans to promote precipitation of the iron. Then a scale inhibitor (Antiprex A) is added to keep residual iron in solution as the water is conveyed to the treatment plant. Iron sludge that accumulates in the pretreatment step is cleaned out and disposed of periodically.

This method of reducing conveyance system fouling is most applicable to sites where AMD emanates from a small number of distinct point sources. This is not the case at the Holden Site, where water from the tailings piles has the greatest potential for iron fouling. The tailings piles represent diffuse sources of AMD, in that water would need to be collected along the entire downgradient edge of the tailings piles. AMD from this type of source is not amenable to pretreatment prior to conveyance.

Maintaining Anoxic Conditions in Conveyance System

Since oxygen is needed to convert ferrous iron to the less soluble ferric form, iron fouling can potentially be reduced by maintaining anoxic conditions in the collection and conveyance system.

- Anoxic conditions have been maintained with some success by submerging an entire drain line in at least 1 to 4 feet of water. Water traps can be used at pipe outlets to reduce air inflow. However, water traps often collect sediment and are subject to plugging.

- An oxygen scavenger, such as sodium dithionite, could potentially be added to further reduce the potential for iron oxidation and accretion. Drawbacks of adding an oxygen scavenger include chemical cost, the need for special dosing equipment (at multiple point in the case of the Holden Site), and increased aeration requirements at the treatment plant. Also, pilot-scale testing indicates that oxygen scavengers are less effective when suspended particulate is present in the mine water (Dudeney et al. 2003).

The little dissolved oxygen data available from Holden Mine Site wells indicate that significant concentrations of oxygen already exist in the groundwater system. Thus, trying to maintain anoxic conditions at Holden does not appear to be feasible.

Adding Phosphate-Based Dispersant

Another chemical-based method for controlling iron fouling is the addition of phosphate-based dispersant. As with an oxygen scavenger, this would require special dosing equipment at multiple points, and the dispersant would have an associated chemical cost. In addition, a second chemical would need to be added at the front end of the treatment plant to reverse the effect of the dispersant so that iron precipitation and settling could be accomplished. Finally, during an upset condition, there is the potential to release phosphate, a nutrient that can promote algal growth, to Railroad Creek. For these reasons, use of phosphate-based dispersants at the Holden Site may not be practical.

Limestone-Lined Drains

AMD is sometimes treated using drains lined with limestone in gravel form. Dissolution of the limestone increases the pH of mine waters. A common problem that occurs with these drains is precipitate clogging the pores in the limestone gravel.

A study of sites using this treatment method indicate that engineering the drain with a 10 percent or greater slope helped reduce the precipitate accumulation in the pore spaces (Fripp et al. 2000). An evaluation at a mine site in Kentucky recommended a slope of 20 percent to maintain a high flushing rate (Carew et al. 2003).

Limestone-lined drains were eliminated in the DFFS (Section 5.2.1.3) as a viable treatment option for the Holden Site. It is not possible to maintain sufficiently steep gradients in the Holden conveyance system due to the relatively flat gradient (1.25 percent) along this section of Railroad Creek.

Methods to Facilitate Conveyance System Cleaning

Methods used to facilitate conveyance system cleaning include the following:

- Pressure washing/jetting;
- Acid washing;
- Pigging; and
- Open conveyance systems.

These methods are addresses separately in the following subsections.

Pressure Washing/Jetting

Routine pressure washing or jetting is used at some sites to maintain adequate drainage in pipes or lined conveyance systems where iron fouling is an issue. Sufficient access points must be provided into pipelines for such maintenance activities, and pipeline geometry must be simple between the access points (no sharp bends). A pipeline cleaned with high-pressure water jetting typically requires hatches for access every 100 meters (Dudeney et al. 2003). Pipelines that are not large enough for human entry are pressure washed with remotely operated equipment, referred to as a pipeline pig, which are discussed later in this attachment.

Pressure washing may be effective for fresh precipitates, but ineffective for aged precipitates that have become crystalline. When used to clean perforated drain lines associated with French drain-type systems, care must be taken to avoid destabilizing the materials around the drain line. In addition, pressure washing is not effective in removing precipitates that can accumulate in soil pore space outside the drain line.

This method of conveyance system cleaning is likely applicable to the Holden Site for the pipeline along Tailings Pile 2 (TP-2) and inverted siphon creek crossings. These conveyance pipelines are expected to be installed relatively near the ground surface, so providing access points for cleaning should be relatively straightforward. Depending on precipitate accumulation rates, pressure washing would likely be conducted annually or every other year.

Acid Washing

Acid washing is an alternative to pressure washing with simple water, to facilitate removal of iron precipitates. Low-pH fluids such as hydrochloric acid, sulfuric acid, sulfamic acids, and sulfur dioxide gas are used at some sites to dissolve iron deposits that coat pipes and associated conveyance system components.

Unlike simple pressure washing, acid washing can potentially be used to remove iron precipitates that accumulate outside a perforated drain line as well as within the piping system itself. However, there are significant materials handling and safety considerations associated with these corrosive chemicals. Conveyance system materials of construction must be compatible with the chemicals used. Waste liquids generated by the acid washing process must be neutralized prior to discharge.

This method of conveyance system cleaning is potentially applicable to the Holden Site. However, it is generally not effective enough to recommend use of French drain collection systems adjacent to the tailings piles.

Pigging

A pig is a bullet-shaped tool that is sent through a pipeline of similar diameter to remove precipitate build-up. Pressurized water is typically used to drive a pig through a pipeline at velocities of 1 to 2 meters per second, although some pigs can be advanced by a tow cable that is pulled between manholes. The pig may be equipped with high-pressure water jets and/or hydraulically actuated tools that remove precipitates in the pipe through mechanical abrasion.

Pigging requires regularly spaced access points along the pipe run, and pipeline geometry must be simple between the access points. Pigging is usually not an option for cleaning perforated drain lines, since pressurized water cannot be used to drive the pig within a French drain. Pipelines must be equipped with pig launchers and receivers. Pigging must be accomplished on a regular basis to prevent build-up of precipitates, since excess build-up of crystalline precipitates can prevent the passage of a pig, potentially leading to more costly maintenance measures.

This method of conveyance system cleaning is potentially applicable to the Holden Site.

Open Conveyance Systems

Open conveyance systems (e.g., open trenches) are an option when gravity flow is employed and site topography allows for system installation at relatively shallow depths. The primary benefits of an open conveyance system are ease of inspection and maintenance. Conventional equipment (e.g., backhoes) can be used to muck out and maintain flow through the system. Potential disadvantages associated with open conveyance systems include the following:

- Surface water may enter during storm events and periods of high snowmelt runoff, potentially introducing a significant sediment load into the conveyance/treatment systems and flooding the treatment system with uncontaminated water;
- During cold weather, water is more likely to freeze in an open trench than in a buried pipeline, potentially causing system blockages; and
- An open trench may be more prone to leakage than a closed pipe system.

At the Holden Site, open conveyance systems have been proposed as a component of Alternative 10, as well as the DFFS remedial alternatives that included seep and groundwater collection from the East Area (Alternatives 4c, 5c, 5d, 6a, and 6b). However, it is important to note that certain segments of the conveyance system will likely need to be “closed” regardless of the remedy ultimately selected. In the case of Alternative 10, for example, closed pipeline would presumably be required at points where collected water must be conveyed across Copper Creek and Railroad Creek. Closed pipelines would also likely be considered for conveying water collected from sources with relatively low iron content, such as the Honeymoon Heights seeps and LWA.

Discussion

Experience reported at other mine sites provides a basis for planning to address iron fouling issues for Alternative 10. There is no single solution to address iron fouling issues in AMD conveyance systems. Rather, a variety of methods have been implemented to control iron fouling on a case-by-case basis. For the Holden Site, use of open ditches for groundwater collection adjacent to the tailings piles is recommended. Control of conveyance system fouling in pipelines adjacent to TP-2, and at creek crossings, can be accomplished with regular use of a pipeline pig.

Although maintenance to control iron fouling does add to the cost of remediation, the experience reported at other mine sites show that this is not an uncommon or unworkable problem.

Annotated Bibliography on Control of Iron Fouling at Acid Mine Sites

Anderson, R.C., and B.G. Hansen, 1999. Mine Waste and Water Management at the Upper Blackfoot Mining Complex. Tailings and Mine Waste '99. Underground lead, zinc, and silver mining activities have led to AMD from adits and waste rock piles. Remediation included moving waste rock piles and passive treatment systems. The system used an anoxic limestone drain to pretreat waters followed by passively driven jet (venturi) pumps to aerate water leading to oxidation of ferrous iron. The pretreatment of the water and removal of iron floc before the water goes to wetlands for polishing was to increase the lifetime of the wetlands.

Burke, S., S. Banwart, A. Jarvis, A. England, and P. Younger, 2003. Up-scaling of Oxidation and Accretion Reactors: Engineering and Economic Considerations. Land Contamination and Reclamation Volume 11, No. 2, pp. 165-172. The technology reviewed in this paper is ochre accretion, surface-catalyzed oxidation of iron. This technology was developed as an alternative to

aerobic wetlands for waters with iron concentrations <5 mg/L. Mine water discharge is evenly discharged over a cascade of steps and into a brushwood filter allowing ochre accretion and reducing 82 percent of the dissolved iron. The authors state that the technology is more suitable for polishing rather than treatment of water with significant iron concentrations and they recommend waters be alkaline prior to treatment. The system also requires frequent maintenance due to the clogging effect of the iron.

Carew, M.B., L. Volk, and D. Wilson, ~2003. Acid Mine Drainage Characterization and Abatement in the Lower Rock Creek Watershed - McCreary County, Kentucky, www.surfacemining.ky.gov. Portal water had low pH and high concentrations of iron (103 kg/d) and aluminum (25 kg/d). Open limestone channels were used to treat the water but there were problems with precipitates settling and plugging pores of the drain. "Maintaining a high flushing rate through the limestone bed can minimize plugging of voids...Optimum performance is attained on slopes exceeding 20%, where precipitates are washed from limestone surfaces and kept in suspension by high velocities."

Cheong, Y.W., J-S Min, and K-S Kwon, 1998. Metal Removal Efficiencies of Substrates for Treating Acid Mine Drainage of the Dalsung Mine, South Korea. Journal of Geochemical Exploration, Volume 64, pp. 147-152. At the site AMD had high concentrations of Fe, Al, Mn, Zn, Cu, and S. A passive **pilot** reactor was tested using rice stalks, cow manure, and limestone. While there was removal of these metals with the treatment system, efficiencies dropped off over time. Also PVC pipes used to convey AMD clogged and solutions to the problem were deferred to further studies.

Costello, C, 2003. Acid Mine Drainage: Innovative Treatment Technologies. National Network of Environmental Studies Fellows for USEPA, Office of Solid Waste and Emergency Response. www.clu-in.org. One study used sulfate-reducing bacteria bioreactors for treatment of waters with low pH and elevated metals concentrations (specific metals not discussed). The article mentioned the "most notable obstacle to the success was when flow through the reactor ceased due to biofouling and consequent clogging. The problem was quickly addressed within a month." No specifics were mentioned. **Permeable Reactive Barriers (PRBs)** were also discussed. This treatment technology is considered to be a relatively new technology and the article mentions four common problems: 1) actual lifetimes are shorter than theoretical estimates due to the presence of other reactive substances in the environment; 2) Chemical reactions are slowed due to depletion of reactive component of the barrier; 3) Precipitation of secondary precipitate reduces reactive surface area; and 4) Physical clogging and preferential path flow.

Dey, M., P.J.K. Sadler, and K.P. Williams, 2003. A Novel Approach to Mine Water Treatment. Land Contamination and Reclamation, Volume 11, No. 2, pp. 253-258. A study at Cardiff University looked at pretreatment of mine water effluent with autocatalytic oxidation and ochre accretion, which was shown to remove over 90 percent of the dissolved iron. This is being developed as a replacement for pretreatment settlement lagoons to reduce the area needed for mine water treatment and address sludge disposal issues. The pilot-scale test was conducted at Taff Merthyr mine in South Wales where iron concentrations in water to be treated were 10 mg/L and waters were net-alkaline. The water was first aerated by cascade steps then conveyed to an intermediate bulk container containing a pea gravel filter media. A discharge pipe at the base of the container then conveyed the water to surface flow wetlands for final treatment.

Dudeney, B., O. Demin, and I. Tarasova, 2003. Control of Ochreous Deposits in Mine Water Treatment. Land Contamination and Reclamation Volume 11, No. 2, pp. 259-265. This article reviewed the various physical and chemical techniques used to control iron deposits in mine water conveyance and treatment systems. Standard methods include the following: jetting pipelines requiring hatchways along the pipeline for access; pigging in which pigs, composite foam scraper with a conical shape, are launched in pipelines and driven through the pipes under flows of 1 to 2 meters/second; and addition of phosphate-based dispersants. Systems cleaned via pigging and jetting require simple geometry. The article also discussed a pilot-scale test where water was dosed with sodium dithionite. Sodium dithionite scavenges oxygen thus precluding iron oxidation and accretion but mine water must be free of suspended particles. Problems with the reagent are price, special dosing equipment, and little impact on accretion or adsorption by suspended particles unless the water was overdosed.

Fripp, J., P.F. Ziemkiewicz, and H. Charkavorki, 2000. Acid Mine Drainage Treatment. www.wes.army.mil/el/emrrp/pdf/sr14.pdf. This article discusses clogging problems of open limestone drains due to metal sludge precipitation. Problem is lessened if slope is greater than 10 percent. Article also provided some equations to calculate iron sludge production used to calculate settling pond requirements. Using fall chemistry from SP-3, Fe sludge production was estimated at ~0.6 ft^3/day.

Gammons, C.H., W.J. Drury, and Y. Li, 2000. Seasonal Influence on Heavy Metal Attenuation in an Anaerobic Treatment Wetland, Butte, Montana, In Proc. 5th International Conf. Acid Rock Drainage, Denver, 2000, pp. 1159-1168. www.mtech.edu/ee/Academics/Research/ Heavy%20Metal%20Attenuation.pdf. The treatment system was installed to

address Zn, Cd, and Cu contamination. Based on 3 years of monitoring, zinc removal rates in winter by bacterial sulfate reduction was less compared to warmer months. This article contained no helpful information regarding iron sludge problems. Water entered the system oxidized and effluent was reduced.

Gansel, J, Plant Operator. Phone Conversations about Iron Fouling at Riverbank Army Ammunition Plant, December 2, 2004. Groundwater with moderate iron concentrations is treated via ion-exchange. A hard iron scale occasionally forms on the outside of pipes and inside the reactor, but overall is not a problem. No scaling occurs in the valves.

Holmes, M., R. Abel, and M. Scott. Phone Conversations about Iron Fouling at Central City/ClearCreek, January 28, 2005. Operation of Argo tunnel (treatment system) began in April 1998. The plant treats approximately 200 gallons per minute through addition of NaOH to increase the pH to 10. Alkaline addition of NaOH will be changed to lime in the near future. The pH is later reduced by bubbling CO_2 through the water. Process water is collected in a sump and pumped into the equalization basin to be recycled. Ms. Scott speculates that this recycling increases iron precipitation due to the addition of such high pH sludge. Iron maintenance is performed quarterly. Iron precipitate is flushed into the clarifier. This is a labor-intensive process requiring men with fire hoses and shovels. The pipe conveying the adit water is pigged every 2 years. Iron precipitate in this piping is generally a hard scale. Failure to look at basic chemistry through treatability studies caused a problem with sludge densification at the Central City site. Mr. Abel also noted that using a mini-filter press will provide a proxy for the actual filter press.

Jarvis, A., A. England, and S. Mee, 2003. Mine Water Treatment at Six Bells Colliery, South Wales: Problems and Solutions from Conception to Completion. Land Contamination and Reclamation, Volume 11, No. 2, pp. 153-160. Iron in mine effluent was primarily in the ferrous form; therefore, hydrogen peroxide was added to effectively oxidize water in a limited land area. During the first stage of the test, mine water was more acidic than anticipated; therefore, the water was further treated with caustic soda. Following this first flush, hydrogen peroxide was sufficient. While no iron issues were reported in this report, in their conclusions they advise to build into the design facilities for temporary active treatment, even if the long-term plan is for passive-only treatment. In the long-term, there may be variability in the quality of the mine discharge; therefore, the facility needs to be flexible wherever reasonably possible.

Mayer, K., EPA Site Manager. Phone Conversation about Iron Fouling at Leviathan Mine, November 8, 2004. Twelve acres of ponds collect the most contaminated flows. Water is conveyed via polyethylene pipes with flow control systems. It was difficult to install a new system and bring it on-line in one summer. Evaporation during the summer reduces the volume of water to treat, but is problematic because it concentrates acids, sulfate, and dissolved metals. Overflows occur during spring runoff, at period of highest contaminant dilution. The system operates only in summer months and fouling does not occur if water is flowing before and after lime treatment. System is run 24 hours per day and winter shutdown is the highly important to avoid fouling. Solar power is not reliable, but a windmill/diesel generator combination may be implemented; along with insulating pipes and the lime feed system, burying pipes, and switching from lime slurry to lime powder; to operate remotely year round.

Ordonex, A, J. Loredo, and F. Pendas, 2000. Treatment of Mine Drainage Water Using a Combined Passive System. ICARD 2000, Proceedings from the 5th International Conference on Acid Rock Drainage, Volume II, pp. 1121-1129. Influent waters had a concentration of 50 mg/L Fe, 190 mg/L Mn, and 50 mg/L Al. The treatment involved successive alkalinity producing system (SAPS), following by anoxic limestone drain (ALD), then cascade aeration to an anaerobic wetland. The organic layer in the SAPS device reduced the Fe and Al content of the water thus leading to greater/longer performance of the ALD. With less Fe in the water, armoring of the limestone is avoided. Since much of the Fe and Al were removed early in the treatment process, iron and aluminum hydroxides were not discussed as a problem.

Palestini, A, Remedial Project Manager. Phone Conversation about Iron Fouling at U.S. Titanium. November 10, 2004. Water is conveyed via pipes. Fouling mainly occurs in pipes and valves, so both are routinely replaced. Pipe is replaced at the discharge end and a pig is used to clean feed lines. A pipe-in-pipe system was developed, but not yet implemented, to make pipe replacement easier. Therefore, its effectiveness is not known.

Pitts, M.M., 1995. Fouling Mitigation in Aqueous Systems using Electrochemical Water Treatment. www.zetacorp.com/fouling_mitigation.shtml. This electrochemical water treatment was used to control iron oxidation deposition in a 4-mile stretch of pipeline conveying acid mine drainage. Water had iron concentrations greater than 500 ppm. Technology requires a power source.

Plewes, H.D. and T. McDonald, 1999. Investigation of Chemical Clogging of Drains at Inco's Central Area Tailings Dams. Tailings and Mine Waste '96, Balkema, Rotterdam. Toe drains in tailings dams have been clogged by chemical precipitates. Studies indicated that oxidation of Fe^{2+} was the primary contributor to the problem. Chemical precipitate did not form in saturated soils below the water table. Authors proposed submergence of the drain materials to preclude oxygen as a means to preventing the formation of the iron precipitates.

Pulles, W., 1992. Water Pollution: Its Management and Control in the South African Gold Mine Industry. Journal of the Mine Ventilation Society of South Africa, Volume 45(2), pp. 18-35. Article covers general water quality issues associated with mine industry. Mine water was not too high in iron. The article does mention iron scaling as a problem but nothing more. Overall the article was not very helpful.

USEPA, 1997. Citizen's Handbook to Address Contaminated Coal Mine Drainage. USEPA Publication, September 1997. While focused on coal mine drainages, this report provides a summary of different passive and active treatment technologies. Aluminum and iron hydroxide precipitates were mentioned as problems in many different scenarios such as limestone drains, aerobic and anaerobic wetlands, and diversion wells. In the case of the wetlands, maintenance or reconstruction were the primary solutions. In the case of diversion wells or limestone drains, velocity was the key. Keep the water moving so the precipitates stay in suspension and move through the system.

USGS, Chuck Cravotta, late-1990s. Evaluation of Limestone Treatment of Acidic Mine Drainage in Swatara Creek Basin, Schuylkill County, Pennsylvania. This article was about construction of anoxic limestone drains (ALD) for treatment of AMD. As it is anoxic, it is important to keep out oxygen thus preventing precipitation of iron hydroxide, which can armor limestone and clog the drain.

Whitelock, J. P., 1993. Underground Aquifer Dewatering and Water Handling within the Stratiform Zn-Pb-Ag Orebody at the Hilton Mine, Mount Isa, NW Queensland, International Mining Geology Conference, Kalgoorlie WA, 5-8 July 1993. Dewatering efforts were necessary to increase production at the mine. The iron-rich groundwater caused pipe scaling issues. The effective diameter of one pipe was reported to have been reduced from 200 mm to 112 mm over a 2.5-year period due to scaling (primarily Fe hydroxides and oxides). Initially mine engineers thought of creating an oxygen-depleted environment in the pump house. However, this was ruled out as too dangerous for mine personnel and difficult to maintain. Their solution was to create a pump station at depth in the mine where the water is aerated before being pumped to the surface. Sprays and fans aerate the water, promoting precipitation of the iron floc. Then a scale inhibitor (Antiprex A) is added to keep remaining Fe in solution while the water is pumped to the surface for further treatment. The iron sludge that accumulates in the pump station at depth is cleaned out and disposed of periodically.

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ATTACHMENT D
PRELIMINARY EVALUATION OF MAXIMUM DILUTION FACTOR
HOLDEN TREATMENT SYSTEM EFFLUENT

MEMORANDUM

DATE: April 11, 2006, Revised August 6, 2007

TO: Norman F. Day, USDA Forest Service,
Holden Mine Project Manager

FROM: Dave Heffner, P.E., and Michael Bailey, P.E.

RE: **Preliminary Evaluation of Maximum Dilution Factor**
Holden Treatment System Effluent
4769-07

As requested, Hart Crowser prepared a preliminary evaluation of the potential magnitude of the mixing zone dilution factor that might be allowed for the proposed groundwater treatment system discharge to Railroad Creek at the Holden Mine Site. Primary Washington State Department of Ecology (Ecology) documents referenced include the following:

- WAC 173-201A-100. Water Quality Standards for Surface Waters of the State of Washington, Part III – Antidegradation, Mixing Zones.

- Guidance for Conducting Mixing Zone Analyses.

Application criteria for mixing zones are also presented in WAC 173-201A-400.

Steady-state "mixing zone" models are normally used to determine appropriate dilution factors. The Very Shallow Water (VSW) mixing zone model may be applicable to the Holden Site. The Ecology guidance document referenced above describes this model, then steps through the evaluation process for a real-life example – City of Sumner discharge to the White River. While VSW model inputs and results are discussed in detail, the limiting dilution factor for this example is ultimately derived from a simple dilution calculation, not a model result. As described below, we performed the same calculation for anticipated Holden conditions to estimate (on a preliminary basis) a maximum allowable dilution factor for the treatment system discharge to Railroad Creek.

The regulatory basis for the dilution calculation is WAC 173-201A-400(7)(a)(ii), which requires that mixing zones not utilize more than 25 percent of the total stream flow. The guidance document example used the 7Q10 flow rate, which is the lowest mean 7-day river flow rate with a 10-year recurrence interval. We estimated a 7Q10 flow rate of 11.7 cubic feet per second (cfs) for Railroad Creek at the proposed treatment system discharge location based on the following:

- Per the table on Page 269 of the USGS report, *Streamflow Statistics and Drainage-Basin Characteristics for the Southwestern and Eastern Regions, Washington, Volume II. Eastern Washington* (included in Appendix H of the Draft Final RI), the 7Q10 flow rate for Railroad Creek at Lucerne is 16.7 cfs.

- Per RI Table 4.3-5, the flow rate at Lucerne during low-flow months is 1.6 times the flow rate at Station RC-4 (upstream of Tailings Pile 1).

- Per RI Page 4-48, the flow rate at Station RC-2 (proposed treatment plant location) is about 12 percent higher than at Station RC-4.

Per WAC 173-201A-400(7)(a)(ii), up to 25 percent of this flow, or 2.93 cfs, can be included in the dilution calculation.

The other flow rate estimate needed for the dilution calculation is the "reasonable worst-case" effluent flow rate for the Holden treatment facility. We assumed that high spring flows need not be considered, since they would never coincide with the 7Q10 creek flow. Rather, we used 1.2 times the anticipated average fall flow rate, or 550 gpm (1.23 cfs) that corresponds to the combined flow for groundwater, seeps, and the portal drainage for Alternative 10.

A maximum dilution factor of 3.4 is then calculated from the equation,

$$DF_{max} = (Q_{amb} + Q_{eff})/ Q_{eff},$$

where:

Q_{eff} is the reasonable worst-case effluent flow rate (1.23 cfs); and

Q_{amb} is the creek flow available for dilution (2.93 cfs).

Note that while this calculation produced the limiting dilution factor in the guidance document example, the mixing zone model result may be lower for conditions at the Site, in which case the model-derived dilution factor would apply rather than the dilution factor estimated above. Also, a different maximum dilution factor could be obtained for any remedial alternative that treats and discharges more or less water than Alternative 10.

The table below applies a dilution factor of 3.4 to the proposed surface water cleanup levels at the Site, and compares those values with anticipated peak concentrations in the treatment system effluent. Cleanup levels could be different from those shown below, depending on location of the treatment system outfall.

Comparison of Proposed Surface Water Cleanup Levels

Potential Constituent of Concern	Lowest Potential Surface Water ARAR or Cleanup Level in ug/L(a)	Potential Allowable Effluent Water Quality Criteria (Based on 3.4 X Proposed Surface Water Cleanup Level) in ug/L	Anticipated Peak Concentrations in Treatment System Effluent in ug/L	
			Based on FS Treatability Study Results (URS 2004)	Order of Magnitude Range Based on Published Case Study Results (see Appendix F of SFS, Forest Service 2007)
Aluminum	144	490	<70	100 to 1,000
Cadmium	0.07	0.24	1.3	0.3 to 3.0
Copper	1.06	3.6	5	10 to 100
Iron	1,000	3,400	<14,000	200 to 2,000
Lead	0.54	1.84	Not analyzed.	0.1 to 1.0(b)
Zinc	17	58	7.5	30 to 300

(a) Proposed cleanup levels adjusted for background and/or hardness as applicable; see Hart Crowser (2005c). Cleanup levels are based on dissolved concentrations for cadmium, copper, lead, and zinc; total concentrations for aluminum and iron.
(b) Order of magnitude treatment range for lead is based on the results of a single case study.

Based on the above comparison, and assuming that a dilution factor of 3.4 will be allowed, it appears from this preliminary evaluation that compared to effluent water quality the published case study results:

- Effluent water quality concentrations at the Site have a good chance of meeting potential ARARs for iron and lead (although the estimate for effluent lead is highly uncertain since it is based on the results of a single case study);

- Effluent water quality concentrations at the Site have a moderate chance of meeting potential ARARs for aluminum and zinc; and

- Effluent water quality concentrations at the Site are unlikely to meet potential ARARs for cadmium, and may be problematic for copper.

For the cleanup levels shown above, the treatment system performance may need to be better than predicted from Intalco's jar tests and some of the published experience for other sites, to meet water quality criteria. The actual concentrations of cadmium (and potentially other metals) in the treated effluent could well be lower than indicated by the case study results depending on final design and operation of the treatment system. Conditions in Railroad Creek could produce mixing zone model results with a lower dilution factor than estimated above. Finally, water quality criteria for some constituents of concern will be affected by conditions (e.g., hardness, dissolved organic carbon, etc.) in Railroad Creek at the outfall location(s). The difficulty in achieving water quality criteria, therefore, will not be known until the treatment system design advances and characteristics of Railroad Creek are determined at the outfall location(s).

Please call if you have any questions.

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APPENDIX G
PRACTICABILITY ANALYSIS
HOLDEN MINE SITE
CHELAN COUNTY, WASHINGTON

APPENDIX G
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HOLDEN MINE SITE
CHELAN COUNTY, WASHINGTON

Executive Summary

Using the criteria of Washington's Model Toxics Control Act (MTCA), the analysis in this appendix principally evaluates the practicability of groundwater collection and treatment versus source depletion and natural attenuation[1] in three new alternatives (Alternatives 9, 10, and 11) that were developed after completion of the Draft Final Feasibility Study (DFFS, URS 2004a). In addition, this document examines other components of the alternatives as they relate to reducing the risk of releases to Railroad Creek. Alternative 8 from the DFFS is included to provide a point of comparison between the new alternatives and the alternatives that were included in the DFFS.

The four alternatives analyzed herein primarily differ in the extent to which they rely on active containment, collection, and treatment of groundwater that would otherwise enter Railroad Creek with concentrations of metals above aquatic life protection criteria. A key consideration in selecting a cleanup action under MTCA is whether active measures, such as the containment and collection for treatment of groundwater (including seeps), are practicable. If so, such active

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[1] Source depletion results from the chemical process of oxidizing sulfide minerals in rock within the underground mine, tailings, and waste rock. Oxidation of the sulfide minerals releases metals and produces acidic conditions that increase solubility of the metals in groundwater at the Site. This process is irreversible and over hundreds of years the available sulfide minerals will be "used up" and reduce the rate of ongoing release of acidic drainage and metals to groundwater. However, this change in the rate of release does nothing to mitigate the adverse effects of metals already or continuing to be released to the environment. In essence, relying on source depletion is a "no action" approach; which is similar to letting an oil drum leak on the premise that the release will stop when all the oil has left the drum.

Natural attenuation processes "include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater" (EPA 1999; a similar definition is presented in WAC 173-340-200). For metals at the Site, these natural attenuation processes may include dispersion, dilution, and sorption, although these processes have not been quantified in the DRI or the DFFS.

measures must be implemented in favor of reliance on passive measures, such as source depletion and natural attenuation.

MTCA defines “practicable” to mean “capable of being designed, constructed, and implemented in a reliable and effective manner including consideration of cost” [WAC 173-340-200]. The definition further provides that when considering cost, “an alternative shall not be considered practicable if the incremental costs of the alternative are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives” [WAC 173-340-200]. For the purposes of this analysis, the disproportionate cost analysis of WAC 173-340-360(3)(f) is used as a tool for evaluating the practicability of active groundwater collection and treatment measures, as well as other components related to reducing the risk of releases to Railroad Creek.

Using this analysis, this document concludes that the groundwater containment, collection, and treatment system placed along Railroad Creek in Alternative 11 would be more effective than the barrier and collection system proposed for the other alternatives. Alternative 11 would contain, collect, and treat all identified sources of groundwater above aquatic life protection criteria that would otherwise enter Railroad Creek. The greater the extent of a barrier wall system adjacent to Railroad Creek, the more effective it will be in preventing hazardous substances from entering the creek.

Alternative 11 includes moving the toe of the tailings piles away from Railroad and Copper Creeks, regrading the slopes to improve stability, and capping, to prevent the risk of releasing hazardous substances into the creeks.

By providing greater collection and containment of contaminated groundwater adjacent to Railroad Creek, Alternative 11 achieves a shorter restoration timeframe than either Alternatives 8, 9, or 10, with a unit cost for groundwater treatment and collection that is slightly less than for Alternative 10. There is also less uncertainty about the ability of Alternative 11 to achieve potential ARARs within a reasonable restoration timeframe. The unit cost for groundwater collection and treatment for Alternative 11 is less than for Alternatives 8 and 9. Alternative 11’s groundwater collection and treatment system is thus not disproportionately more costly than Alternative 10, or to the natural attenuation and source depletion processes relied upon by Alternatives 8 and 9.

Alternative 11 is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. Based on the analyses described in this appendix, Alternative 11 uses permanent solutions to the maximum extent practicable, and to a greater degree than the other alternatives.

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1.0 Introduction

A key consideration in selecting a cleanup action under Washington's Model Toxics Control Act (MTCA) is whether active measures, such as the containment and collection for treatment of groundwater baseflow and seeps, are practicable. If so, such active measures must be implemented in favor of reliance on passive measures, such as source depletion and natural attenuation.

Using the criteria of MTCA, this analysis principally evaluates the practicability of groundwater collection and treatment versus source depletion and natural attenuation[2] in three new alternatives (Alternatives 9, 10, and 11) that were developed after completion of the Draft Final Feasibility Study (DFFS, URS 2004a). This document also examines other components of the alternatives as they relate to reducing the risk of releases to Railroad Creek. Alternative 8 from the DFFS is also included in the analysis to provide a point of comparison between the new alternatives and the alternatives that were included in the DFFS. The four alternatives primarily differ in the extent to which they rely on active collection and treatment of groundwater that would otherwise enter Railroad Creek metals concentrations above aquatic life protection criteria.

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[2] Source depletion results from the chemical process of oxidizing sulfide minerals in rock within the underground mine, tailings, and waste rock. Oxidation of the sulfide minerals releases metals and produces acidic conditions that increase solubility of the metals in groundwater at the Site. This process is irreversible and over hundreds of years the available sulfide minerals will be "used up" and reduce the rate of ongoing release of acidic drainage and metals to groundwater. However, this change in the rate of release does nothing to mitigate the adverse effects of metals already or continuing to be released to the environment. In essence, relying on source depletion is a "no action" approach, that is similar to letting an oil drum leak on the premise that the release will stop when all oil has left the drum.

Natural attenuation processes "include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater" (EPA 1999; a similar definition is presented in WAC 173-340-200). For metals at the Site, these natural attenuation processes may include dispersion, dilution, and sorption, although these processes have not been quantified in the DRI or the DFFS.

2.0 Background

Intalco Aluminum Company (Intalco), a successor to Howe Sound Mining Company, has entered into an Administrative Order on Consent/Agreed Order issued by Agencies (the United States Department of Agriculture, Forest Service, referred to as the Lead Agency, United States Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology), (collectively referred to as the Agencies). This work is being completed under the authorities of the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and MTCA.

The primary environmental toxicity risks at the Site are elevated concentrations of aluminum, cadmium, copper, iron, lead, and zinc in the portal drainage, seeps, and groundwater baseflow that discharge to the Railroad Creek. Concentrations of metals including aluminum, cadmium, copper, and zinc in groundwater exceed human health criteria for drinking water by factors of up to 31.[3] In addition, there is damage to the aquatic habitat from the release of waters with elevated concentrations of ferric sulfates and other hazardous substances that precipitate as ferrous oxides to form iron floc and ferricrete in Railroad Creek. In addition, concentrations of metals in exposed tailings and soils in some parts of the Site exceed criteria for protection of human health for direct contact and ingestion.

To protect the aquatic environment in Railroad Creek and to meet proposed surface water cleanup levels, metals concentrations within the creek and in groundwater entering the creek must be reduced.

Under state law, the point of compliance for obtaining proposed surface water cleanup levels is the point or points where the hazardous substances are released to the creek [WAC 173-340-730(6)].[4,5]

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[3] Groundwater is currently used for drinking water at Lucerne downstream from the mine, but groundwater is not used for drinking water in other areas of the Site. Holden Village obtains its drinking water from Copper Creek upstream of the Site.

[4] The only exception to this is where a mixing zone is authorized, i.e., in accordance with Chapter 173-201A WAC. However, no mixing zone is allowed for groundwater discharges to surface water [WAC 173-340-730(6)(b)].

[5] Under federal law, the point of compliance is intended to protect receptors at the point of exposure. Thus the point of compliance for surface water depends on the designated beneficial use of the surface water. The following are the designated beneficial uses of

The standard point of compliance for groundwater under MTCA is throughout the Site, from the uppermost level of the saturated zone to the lowest depth that could potentially be affected. MTCA requires that groundwater cleanup levels be attained in all groundwater from the point of compliance to the outer boundary of the hazardous substance plume [WAC 173-340-720(8)]. MTCA allows a conditional point of compliance for groundwater for limited circumstances where it is not practicable to meet the cleanup level throughout the site within a reasonable restoration time frame.

The DFFS determined that it is not practicable to clean up groundwater throughout the Site within a reasonable restoration time frame. Thus, for contaminated groundwater entering the creek, a conditional point of compliance may be approved within the creek as close as technically possible to the point(s) where contaminated groundwater enters the creek, subject to certain specified conditions [see WAC 173-340-720(8)(d)(i)]. These conditions are satisfied to varying degrees by the different alternatives, as discussed in the SFS and within this appendix.

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surface water in Railroad Creek (per WAC 173-201A-600; the use categories are shown in parenthesis): aquatic life (salmonid spawning, rearing, migration, and core summer habitat), recreation (extraordinary primary contact), water supply (domestic, industrial, agricultural, and stock watering), and miscellaneous (wildlife habitat, harvesting, commerce and navigation, boating, and aesthetic values). In addition, because the Site is within a National Forest, and because Railroad Creek is a feeder stream to Lake Chelan, WAC 173-201A-600(1)(a) requires that Railroad Creek also to be protected for the designated uses of salmon and trout spawning, non-core rearing, and migration; and extraordinary primary contact recreation. Accordingly, cleanup levels for groundwater at the Site that enters Railroad Creek are based on protection of aquatic life.

Under CERCLA, the preamble to the final NCP [55 FR 8753] states that groundwater remediation levels should generally be attained throughout the contaminated plume, or at and beyond the edge of the waste management area when the waste is left in place. See also 53 FR 51426. While EPA acknowledges an alternative point of compliance may also be protective of public health and the environment under "site-specific circumstances," the preamble to the proposed NCP also states "EPA's policy is to attain ARARs...so as to ensure protection at all points of potential exposure" [53 FR 51440]. Under CERCLA, the alternative point of compliance for groundwater at this Site is based on the State of Washington's designated beneficial uses of the surface water, as set forth above. The points of potential exposure for the beneficial uses of surface water are at the groundwater-surface water interface. Achieving water quality criteria at the interface is necessary to protect benthic invertebrates, in addition to other aquatic life.

The DFFS described eight alternatives and a number of subalternatives for remediation of the Site. The DFFS compared these proposed alternatives to the CERCLA and MTCA selection criteria for a final remedy. The DFFS alternatives generally focused on collection and treatment of groundwater and surface water impacted by metals released from the mine, waste rock piles, and/or tailings piles. The DFFS alternatives also included varying degrees of source control to manage source materials and prevent the release of hazardous substances.[6]

Alternative 8 involves the use of consolidation and capping of the tailings and waste rock piles, combined with collection and treatment of impacted groundwater from a portion of the Site to prevent ongoing releases, and reliance on natural attenuation for the remainder of the Site. Because Alternative 8 takes a different remedial approach compared to many of the other DFFS alternatives and to Alternatives 9, 10, and 11, Alternative 8 has been retained for comparison purposes in this current practicability analysis; even through it was previously evaluated in the DFFS.

A detailed description of Alternative 8 is provided in the DFFS. Alternatives 9, 10, and 11 were developed after the DFFS was completed. Alternative 9 was developed by Intalco. Alternative 10 and Alternative 11 were developed by the Agencies. Descriptions of Alternatives 9, 10, and 11 are provided in the main text of the SFS, in Section 3.0.[7]

A key difference between Alternatives 8, 9, 10, and 11 is where and how impacted groundwater is collected for treatment to reduce metals concentrations in groundwater entering Railroad Creek. The alternatives all include collection and treatment of groundwater discharging from the mine portal and seeps downgradient of the portion of the Site referred to as

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[6] As used in this appendix, source controls refer to active measures taken to prevent the release of hazardous substances such as run-on diversion, waste consolidation, capping, removal, and treatment, or other engineered controls as defined in WAC 173-340-200.

[7] Alternative 10 was also described in the EPA NRRB Holden Mine Site Information Package (Hart Crowser 2005b), where it is referred to as the APR. As presented to the NRRB, the APR included potential contingent actions, primarily including the possibility of extending the barrier wall and collection system along Tailings Pile 2 (TP-2); the possible need to make the partially penetrating barrier a fully penetrating cutoff; and the potential need to improve the tailings and waste rock piles cover to satisfy the state regulations for closure of a limited purpose landfill. For the purpose of analyses in the SFS and this appendix, the Agencies have not assumed Alternative 10 would include implementation of any contingent actions that were part of the APR.

Honeymoon Heights. However, the alternatives differ significantly in the extent to which additional groundwater above proposed cleanup levels would be collected for treatment from other areas of the Site:

- Alternative 8 includes consolidation of Tailing Piles 1 and 3 (TP-1 and TP-3), and the main East and West Waste Rock Piles, onto the existing TP-2, and collection of impacted groundwater from below this consolidated waste pile using a barrier wall and groundwater collection system around the west, north, and east sides of the consolidated pile. Alternative 8 does not include collecting the Lower West Area (LWA) groundwater, or the impacted groundwater below the former TP-1 and TP-3 areas.

  Alternative 8 relies on natural attenuation over time in the LWA and in the former footprints of TP-1 and TP-3 after consolidation of the waste rock and tailings piles has occurred. In these areas, impacted groundwater would continue to flow into Railroad Creek after implementation of the remedy, and groundwater and seep concentrations would decrease slowly over time.

- Alternative 9 collects contaminated groundwater in the Upper West Area (UWA) of the Site using a barrier wall and groundwater collection system 450 to 750 feet upgradient from Railroad Creek. Alternative 9 also collects some groundwater from TP-1 using four groundwater extraction wells and a seep interception system. However, Alternative 9 does not collect groundwater in the LWA or along TP-2 and TP-3, and does not collect all the groundwater impacted by TP-1.

  Alternative 9 relies on upgradient controls, and natural attenuation processes over time, to clean up the LWA. It relies on upgradient controls and source depletion, and natural attenuation to clean up groundwater contaminated by TP-2 and TP-3. In these areas, as well as below a portion of TP-1, contaminated groundwater would continue to flow into Railroad Creek after implementation of the remedy, and groundwater and seep concentrations would decrease slowly over time.

- Alternative 10 uses a barrier wall to contain and collect groundwater adjacent to Railroad Creek in the LWA (i.e., downgradient of the UWA and on the downgradient side of the LWA) and along TP-1 and TP-3. The barrier wall is referred to as a partially penetrating barrier, since it would not fully penetrate the aquifer and is intended to contain the shallow groundwater that would otherwise enter Railroad Creek.[8]

- Alternative 11 collects groundwater adjacent to Railroad Creek along the entire length of the Site, including the LWA and TP-1, TP-2, and TP-3. It uses a fully penetrating barrier wall to contain and collect all the identified sources of groundwater that would otherwise enter Railroad Creek above the proposed cleanup levels.

The common elements and distinguishing features of each of these alternatives are discussed in more detail in the SFS.

Alternatives 8 and 9 are more dependent than Alternatives 10 or 11 on natural attenuation processes (dilution and adsorption), and in the case of Alternative 9, on source depletion as well as natural attenuation, to reduce metals concentrations in the creek over large portions of the Site. Particularly with respect to Alternative 9, Intalco maintains that reliance on these measures delivers similar benefits to Alternative 10 at a lesser cost (URS 2005a).

MTCA allows remedial actions to rely on passive processes such as source depletion and natural attenuation only under limited circumstances. MTCA has the following requirements:

- Groundwater cleanup actions that are non-permanent shall implement containment of contaminated groundwater "to the maximum extent practicable" [WAC 173-340-360(2)(c)(ii)(B)];[9]

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[8] A fully penetrating barrier could replace the partially penetrating barrier as a contingent part of the remedy, if necessary, but for purposes of the SFS, only the partially penetrating barrier was considered for Alternative 10. Alternative 10 also does not include a barrier adjacent to TP-2, but does include seep collection adjacent to TP-2 and monitoring to determine whether extending the groundwater containment and collection system between TP-2 and Railroad Creek would be necessary as part of the final cleanup action.

[9] MTCA includes provisions for both permanent and non-permanent groundwater cleanup actions [WAC 173-340-360(2)(c)]. A permanent groundwater cleanup action achieves groundwater cleanup levels throughout the Site, which is the standard point of compliance. A non-permanent groundwater cleanup action refers to remediation that would not achieve cleanup levels at the standard point of compliance, either because it is not practicable (as is the case at Holden) or it is determined by Ecology to not be in the public interest. The Agencies agree with Intalco that it is not practicable to meet the

- Natural attenuation may be appropriate only after source control (including removal and/or treatment of hazardous substances) has been conducted "to the maximum extent practicable" [WAC 173-340-370(7)];

- Cleanup actions shall not rely primarily on dilution and dispersion unless the incremental costs of any active remedial measures over the costs of dilution and dispersion grossly exceed the incremental degree of benefits of active remedial measures over the benefits of dilution and dispersion [WAC 173-340-360(2)(g)]; and

- For facilities adjacent to surface water, active measures will be taken to prevent/minimize releases to surface water via surface runoff and groundwater discharges in excess of cleanup levels. Dilution will not be the sole method for demonstrating compliance with cleanup levels in these instances [WAC 173-340-370(6)].

Thus, under MTCA, a key consideration is whether active measures, such as the proposed containment and collection of groundwater baseflow and seeps in Alternatives 10 and 11, are practicable. If so, such active measures must be implemented in favor of reliance on passive measures, such as source depletion and natural attenuation.

This appendix analyzes Alternatives 8, 9, 10, and 11 under the practicability criteria in MTCA. The document primarily examines the groundwater collection and treatment system used in Alternatives 10 and 11 versus the source depletion and natural attenuation processes proposed as components of Alternatives 8 and 9. In addition, this document examines other components of the four alternatives as they relate to reducing the risk of releases to Railroad Creek.

3.0 Practicability Analysis

MTCA defines "practicable" to mean "capable of being designed, constructed, and implemented in a reliable and effective manner including consideration of cost." When considering cost, "an alternative shall not be considered practicable if the incremental costs of the alternative are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives" [WAC 173-340-200].

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proposed groundwater cleanup levels throughout the Site within a reasonable time frame. A non-permanent groundwater cleanup action can thus be used, including establishing a conditional point of compliance where cleanup levels must be met.

The essence of this "practicability" concept is captured in a disproportionate cost analysis applied under MTCA to alternatives under consideration as final remedies. Under MTCA, this analysis compares the incremental costs and incremental benefits of cleanup alternatives that satisfy MTCA's threshold requirements for remedy selection.[10] The Agencies evaluation of the ability of Alternatives 9, 10, and 11 to meet threshold criteria is discussed in detail in the SFS. Alternative 8 was evaluated relative to the threshold criteria in the DFFS, and as discussed in the Agencies' comments on the DFFS.

The Agencies do not believe that Alternatives 8 and 9 would satisfy MTCA's threshold criteria to become eligible for remedy selection, for the reasons discussed in the Agency comments on the DFFS (Forest Service 2007a) and in the SFS (Forest Service 2007b). The Agencies further believe that additional information is needed before they can determine whether Alternative 10 could satisfy such threshold criteria, as discussed in the SFS. While Alternative 10 may be protective and satisfy ARARs, there is much greater certainty that Alternative 11 will satisfy the threshold criteria. The Agencies have concluded that a final cleanup action needs to include more than Alternative 10 to be protective and meet ARARs. Alternative 11 is the only alternative anticipated to fulfill MTCA's threshold criteria, as discussed in the SFS.

Since Alternative 11 is the only alternative that is expected to satisfy the threshold criteria, it is not necessary to evaluate Alternatives 8, 9, and 10, under the disproportionate cost analysis for the purpose of selecting a remedy. Nevertheless, in light of MTCA's requirements favoring active remedial measures where practicable,[11] the disproportionate cost analysis can serve as a tool for evaluating the practicability of active groundwater collection and treatment measures, as well as other components related to reducing the risk of releases to Railroad Creek.

Under WAC 173-340-360(3)(f), there are seven evaluation criteria to be compared in the disproportionate cost analysis. These criteria are:

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[10] The MTCA threshold criteria for remedy selection are that a cleanup action shall: 1) protect human health and the environment; 2) comply with cleanup standards; 3) comply with applicable state and federal laws; and 4) provide for compliance monitoring [WAC 173-340-360(2)(a)].

[11] These requirements are identified in Section 2.0 above; see WAC 173-340-360(2)(c)(ii)(B), WAC 173-340-370(7), WAC 173-340-360(2)(g), and WAC 173-340-370(6).

- Protectiveness;
- Permanence;
- Cost;
- Effectiveness over the long term;
- Management of short-term risks;
- Technical and administrative implementability; and
- Consideration of public concerns.

Completion of this analysis determines whether the incremental benefits of one alternative have disproportionate costs compared to a less permanent alternative. The costs are considered disproportionate to the benefits if the "incremental costs of the alternative over that of a lower cost alternative exceed the incremental degree of benefits achieved by the alternative over that of the other lower cost alternative" [WAC 173-340-360(3)(e)(i)].

The analysis presented in the DFFS uses a loading model as a basis for comparing the alternatives. As described in Appendix A of the SFS, the DFFS Model has certain limitations that affect its utility. Among these, the model does not represent conditions at the point(s) where contaminated groundwater enters Railroad Creek, which is the only location within Railroad Creek where a conditional point of compliance for groundwater cleanup could be established under MTCA [see WAC 173-340-720(8)9d)(i)].[12] Rather, the model evaluates metals concentrations in a fully mixed condition within the stream at a point downstream of most of the Site loading (designated as "RC-2"). Other problems with the DFFS Model include its reliance on assumed efficiency factors for

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[12] MTCA requires that a groundwater conditional point of compliance be as close as practicable to the source, not to exceed a point within surface water as close as technically possible to the point(s) where contaminated groundwater flows into surface water [see WAC 173-340-720(8)(c) and WAC 173-340-720(8)(d)(i)]. This also represents an acceptable alternative point of compliance for groundwater under CERCLA as discussed in footnote 3. Therefore, provided that the final remedy satisfies the MTCA requirements for a conditional point of compliance [WAC 173-340-720(8)(d)(i) (A) through (G)], the Agencies propose that Holden Mine's groundwater point of compliance be at the interface of contaminated groundwater and abutting surface water all across the Site (e.g., Railroad and Copper Creeks).

upgradient controls, assumptions related to collection and treatment efficiency, use of arbitrary adjustments referred to as unaccounted loads, and lack of empirical data to support assumed rates of source depletion and natural attenuation.

Of particular importance to this analysis, the DFFS Model contains unsupportable assumptions related to Alternatives 8 and 9 with respect to the rate of load reduction through passive processes in the LWA, after upgradient source controls are installed.[13] The model also suffers from a reliance on adjustments for unaccounted load that do not distinguish between the effects of measurement error, differences in timing of measurements, inflow from the north side of Railroad Creek (or differences in south side inflow from that assumed), or the effects of chemical and physical changes within the stream, such as sorption and precipitation. For further discussion of these limitations of the DFFS Model, see SFS Appendix A.

As a result of these limitations, two other methods are used in this analysis, for comparison of Alternatives 8 through 11.

- The volume of groundwater and seep flow exceeding proposed surface water cleanup levels that would be intercepted at the conditional points of compliance and treated, rather than flowing into Railroad Creek for each alternative; and

- The length of Railroad Creek (in linear feet of shoreline) that will be protected through the collection of groundwater that exceeds proposed cleanup levels at the conditional points of compliance rather than flowing into the creek.

According to MTCA [WAC 173-340-360(3)(e)(ii)(B)], where no permanent solution is evaluated, the alternative that provides the greatest degree of permanence shall be considered the baseline cleanup alternative for purposes of the comparison. Based on the extent of consolidation and closure of the tailings piles and main East and West Waste Rock Piles, and the associated groundwater collection and treatment, the Agencies consider Alternative 8 to be the most permanent of the DFFS alternatives. For this reason, the Agencies used Alternative 8 as the baseline alternative from the DFFS against which Alternatives

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[13] The Batch Flush Model, which is discussed in more detail in Appendix A of the SFS, as well as later in this appendix, predicts a much longer estimated time to achieve cleanup levels for different alternatives, compared to the assumption in the DFFS.

9, 10, and 11 were evaluated. The evaluation of Alternatives 8, 9, 10, and 11 against the seven criteria of the MTCA disproportionate cost analysis [WAC 173-340-360(3)(f)] follows.

3.1 Protectiveness

Protectiveness of human health and the environment is defined by MTCA [WAC 173-340-360(3)(f)(i)] to include:

- The degree to which existing risks are reduced;
- The time required to reduce risk and attain cleanup standards;
- On-site and off-site risks of implementation; and
- Improvement of the overall environmental quality.

3.1.1 Degree to Which Existing Risks are Reduced

Risks at the Site include risk to the aquatic environment that is directly related to the toxicity and quantity of hazardous substances being released, potential risk of mass release of tailings into the creek that could cause future aquatic impacts, and risks to terrestrial receptors resulting from exposed waste materials and impacted soils at the Site.

The primary environmental toxicity risks to the aquatic environment are the result of elevated concentrations of aluminum, cadmium, copper, iron, and zinc in Railroad Creek and in the portal drainage, seeps, and groundwater baseflow that discharge to the creek.[14] The release of waters with elevated concentrations of ferric sulfates that precipitate as ferrous oxides to form iron floc and ferricrete in Railroad Creek has caused damage to the aquatic habitat. Aquatic habitat within the creek may also be damaged through the precipitation of aluminum released in impacted groundwater.

[14] Additional hazardous substances that have groundwater concentrations above surface water protection criteria (e.g., lead) also pose a risk to aquatic life at and near the point of compliance, even though these substances did not have measured concentrations above criteria within the fully mixed stream channel (i.e., after dilution).

Tailings that are susceptible to erosion represent an additional source of metals to the creek, and erosion likely contributes to the overall exceedance of water quality criteria.

Another risk to the aquatic environment is the potential for mass instability of the tailings piles, which contain soluble metals including aluminum, cadmium, copper, iron, lead, and zinc. The DRI (Dames & Moore 1999) reports several instances of tailings pile instability leading to releases prior to the Forest Service interim actions in 1989-91. Erosion in October 2003 displaced an estimated 600 cubic yards (cy) of tailings, some portion of which was released into Railroad Creek. Additional stabilization was required in 2006 to prevent ongoing release of tailings due to continued erosion of TP-1.

The degree to which Alternatives 8 through 11 would reduce these existing risks is discussed below.

3.1.1.1 Reducing Risk by Reducing Toxicity in Railroad Creek

Reducing risk by reducing toxicity in Railroad Creek includes: 1) reducing the flow of sources above water quality criteria that discharge into the creek, and 2) reducing the length of the creek that is exposed to discharges above criteria.

The DFFS presented a method of quantifying the amount of groundwater that enters Railroad Creek as baseflow (i.e., not including flow from discrete seeps), referred to as a flow net analysis. The flow net analysis provides a way to estimate the quantity of groundwater flow for segments of the aquifer (referred to as flow tubes) that extend across the Site, during the spring and fall months.[15] The water quality in each flow tube is represented by concentrations measured in the nearest well or seep, or in some cases by averaging concentrations in adjacent wells or seeps.

Figures G-1 and G-3 show the location of flow tubes and the individual seeps that were identified in the DFFS as flowing into Railroad Creek. Average spring and fall groundwater and seep concentrations that discharge into Railroad Creek

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[15] As described in the DFFS and SFS, spring conditions refer to the May – July period approximately 90 days long when snowmelt causes relatively high groundwater levels, and relatively high flow conditions in Railroad Creek. Fall conditions represent the other 275 days per year (August – April) typified by lower groundwater levels and relatively low flows in Railroad Creek.

expressed as multiples of the proposed surface water cleanup levels (based on protection of aquatic life) are shown on Figures G-2 and G-4, respectively.

- The highest exceedances of cadmium, copper, and zinc occur in groundwater from the Honeymoon Heights area, the portal drainage, and the LWA, although spring groundwater baseflow concentrations associated with TP-1, and seeps associated with the three tailings piles are typically more than 100 times the proposed cleanup levels. Fall concentrations are typically lower than those in the spring for cadmium, copper, and zinc, but still range from about 5 to 75 times the proposed cleanup levels and in some areas exceed the proposed cleanup levels by factors of several hundred to more than 1,000. Figures G-1 and G-3 only show seeps and flow tubes that discharge directly into Railroad Creek; even higher metals concentrations were measured in groundwater within the tailings piles.

- The greatest proposed cleanup level exceedances for iron and aluminum occur in groundwater flow tubes and seeps associated with TP-1, where spring concentrations exceed proposed cleanup levels by factors of 50 to several hundred times. Spring concentrations in the west part of the Site, and fall concentrations overall, are variable for iron and aluminum but commonly range from about 2 to more than 100 times proposed cleanup levels.

The degree to which Alternatives 8 through 11 would reduce existing risks due to these sources is discussed below.

Reducing Risk by Reducing Flow of Sources above Water Quality Criteria that Discharge Directly into the Creek. Alternatives 8 through 11 each include comparable measures to collect and treat the portal drainage and Honeymoon Heights seeps. However, these alternatives differ significantly in the way they address other groundwater that discharges into Railroad Creek with concentrations above proposed cleanup criteria.

- Alternative 8 collects groundwater for treatment from below the consolidated tailings pile, but relies on natural attenuation to reduce concentrations in groundwater associated with the LWA or the TP-1 and TP-3 footprints.[16]

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[16] Appendix A of the SFS discusses an analysis called the Batch Flush Model that indicates natural attenuation would reduce metals concentrations in seeps and groundwater at a much slower rate than predicted in the DFFS. The Batch Flush Model

- Alternative 9 uses pumped wells and seep collection systems to prevent flow from seeps SP-1 and SP-2 associated with TP-1, and part of the groundwater impacted by TP-1 [i.e., spring flow tubes S4, S5, and part of S6; fall flow tubes S2 and at least part of S3 (URS 2005a)] from entering Railroad Creek, but relies on source depletion and natural attenuation to reduce concentrations in groundwater in the LWA, below TP-2 and TP-3, and part of TP-1.[17]

- Alternative 10 collects and treats groundwater from the LWA, TP-1, and TP-3, but relies on monitoring to determine whether additional containment, collection, and treatment are needed for groundwater impacted by TP-2. Alternative 10 also relies on a partially penetrating barrier, which may not be completely effective in reducing groundwater concentrations to achieve surface water protection criteria at the point of compliance.[18]

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was used to estimate the time required for groundwater to reach proposed cleanup levels adjacent to Railroad Creek following elimination of sources in the UWA, as proposed for Alternatives 8 and 9. The results varied from a period of decades to more than 200 years for different metals, before concentrations would be below levels that are protective of aquatic life. The results of one-such analysis are shown on Figure G-5 and discussed in Appendix A of the SFS.

[17] Appendix E of the DFFS describes available information on the anticipated rate of source depletion based on comparison of the Site to studies undertaken at other mine sites. The geochemical analysis in Appendix E of the DFFS calculates rates of source depletion and natural attenuation for the waste rock pile, tailings, and underground mine. Based on this analysis, oxygen diffusion through the fine-grained tailings may limit the rate of source depletion compared to the waste rock piles and Portal drainage. If the tailings were left as-is, the DFFS predicts that the metals load from the tailings should generally be no greater than current loads with the possible exception of short-term (next few decades) increases in copper and cadmium loads associated with TP-3, and zinc and aluminum loads associated with TP-2. Appendix E does not specifically address groundwater concentrations in this discussion, but the load referred to is the product of concentration multiplied by groundwater flow rate. The DFFS goes on to note "All future loadings beyond year 2100 are predicted to be lower than current conditions," i.e., if the tailings portion of the cleanup relies on source depletion and natural attenuation rather than active measures.

[18] A hydrograph-based model for the partially penetrating barrier suggests an average reduction in groundwater baseflow into Railroad Creek that varies from about 83 percent in the spring to 89 percent in the fall (see Attachment B of Appendix F to the SFS). Since Alternative 10 also eliminates seep discharge and the portal drainage, a

- Alternative 11 collects and treats groundwater that exceeds proposed cleanup levels and would otherwise discharge into Railroad Creek. Unlike Alternative 10, Alternative 11 relies on a fully penetrating barrier, and unlike Alternatives 8, 9, and 10, Alternative 11 provides collection and treatment for all the identified sources that discharge into Railroad Creek above aquatic protection criteria. The effectiveness of barrier walls to contain impacted groundwater has been demonstrated at dozens of sites, as discussed in Appendix C of the SFS.

Alternative 11 does more than the other three alternatives to reduce risk by reducing flows that exceed water quality criteria from entering Railroad Creek.

Even if groundwater containment and collection are imperfect in some areas (e.g., due to potential construction defects in the barrier, or seepage below the barrier if it was not adequately keyed into an underlying relatively impermeable stratum), the effect of reduced flow is to reduce the metals loading that enters Railroad Creek, with proportional reductions in concentrations and metals toxicity within the creek.

Finally, there is one other source of metals entering Railroad Creek that could increase risks to aquatic life, unless it is controlled by the proposed cleanup action. Forest Service reports indicate that in 1970, collapse of overburden within the mine dammed the mine drainage from the main 1500 Level portal, causing water to back up into the mine (Forest Service 1970a and 1970b). The impounded water breached the dam, eroded the West Waste Rock Pile, flowed through the Holden Village vehicle maintenance area and the lagoon, and discharged into Railroad Creek. A similar uncontrolled discharge could occur if the underground workings collapsed into the flooded portion of the mine. Under existing conditions there is some risk that such instability could lead to increased flow rates and/or decreased water quality of the main 1500 Level portal drainage, which could adversely impact water quality in Railroad Creek.[19]

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reduction of the groundwater discharge from TP-1, TP-3, and the LWA by more than 80 percent would immediately reduce metals concentrations within the creek, but the Agencies have concluded that at this time, there is not sufficient information available to show whether it would result in protective levels at the point of compliance, within a reasonable restoration time frame.

[19] The duration of surface water impacts following instability may be substantial, as evidenced by an underground collapse in the abandoned McDonald Mine in 2005 near Barton, Maryland. The McDonald Mine collapse is reported to have caused a seven-fold

In addition to a potential short-term surge, collapse of the underground workings could increase the amount of air and water flowing through the mine and result in potential long-term degradation of water quality. Alternatives 8, 9, 10, and 11 include installation of hydraulic barriers in the mine (in the main 1500 Level portal and the 1500 Level ventilator portal), which would protect the environment from at least the short-term effects of underground collapse. Since Alternatives 8 through 11 include these barriers, this is not a point of distinction in evaluating the degree to which existing risks are reduced, for this Practicability Analysis.

Reducing Risk by Reducing the Length of the Creek Subject to Discharges above Criteria. The DFFS Model estimated concentrations that Alternatives 2 through 8 would produce for fully mixed conditions in Railroad Creek. However, the effectiveness of each alternative needs to be considered at the points where groundwater discharges into the creek and the areas immediately adjacent where concentrations would exceed proposed cleanup levels. Concentrations downstream from the points of release will decrease because of the effects of dilution. MTCA does not allow a mixing zone for groundwater discharges above cleanup levels into surface water [WAC 173-340-720(8)(d)(i)(C)], thus all points where impacted groundwater is discharging from the Site into Railroad Creek need to be addressed by the remedy. Therefore, an alternative that addresses a greater proportion of the stream length where releases occur will be more protective of the aquatic environment than an alternative that addresses a lesser proportion of the stream.

The table below summarizes the relative lengths along Railroad Creek where each alternative would contain and collect groundwater above proposed cleanup levels before it discharges into Railroad Creek.

Alternative No.	Approximate Length of Creek Where Releases Occur, that Would Have Active Groundwater Collection in Feet
8	1,800
9	<1,000
10	4,500
11	6,400

increase in the rate of drainage, reduced pH, and increased metals concentration in the mine discharge that lasted more than 7 months (Fahrenthold 2006).

Figure G-8 shows the relative extent of groundwater collection that would be accomplished along the edge of Railroad Creek for each alternative. The alternatives collect groundwater above proposed cleanup levels along differing lengths of the creek. Only Alternative 11 includes collection of all the groundwater sources above proposed cleanup levels along the creek as shown on Figures G-1 through G-4.[20] Areas where active groundwater collection would be accomplished would have reduced concentrations of hazardous substances immediately following implementation of the remedy. Areas without active collection would have metals concentrations that slowly decline from existing concentrations over long periods as source depletion and natural attenuation occur.

Alternative 11 would reduce existing aquatic risks by reducing metals concentrations in sources that discharge into the Railroad Creek to a greater degree than Alternatives 8, 9, and 10. Alternative 11 addresses all the identified sources with active collection of groundwater (including seeps), rather than relying on natural attenuation and source depletion to gradually reduce concentrations over extended periods for significant portions of the Site.

3.1.1.2 Reducing Risk by Removal of Hazardous Substances

Another way of comparing the four alternatives is to examine the volume of groundwater exceeding proposed surface water cleanup levels that is intercepted adjacent to Railroad Creek (at the points of compliance as previously described), then treated. Collecting impacted groundwater directly adjacent to the creek has the benefit of immediately reducing metals concentrations within the creek and immediately reducing aquatic risks as well. Where source depletion and natural attenuation processes are relied on, impacted groundwater will continue to flow into the creek. As a result, metals concentrations decrease slowly over time (decades to hundreds of years), and aquatic risk will decrease slowly over time as well. The greater the volume of contaminated water collected adjacent to Railroad Creek for treatment, the more immediate and greater the reduction in aquatic risk at the Site.

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[20] This includes areas where Railroad Creek seasonally loses water, e.g., adjacent to TP-3 where fall flow tubes SL1, SL2, SL3, and potentially part of SL8, enable water to flow from the creek into the ground below the tailings, as shown on Figure G-3. This clean water currently becomes contaminated as it flows east, and would continue to do so under Alternative 9. However, the barrier proposed for Alternative 11, and possibly Alternative 10, would break this flow path and prevent discharge of impacted groundwater to Railroad Creek east of TP-3.

As the impacted groundwater enters Railroad Creek, these waters are mixed with Railroad Creek water from upstream of the Site, and the metals concentrations are diluted. Figure G-5 shows surface water concentrations in Railroad Creek compared to the proposed surface water cleanup levels. Although the sources are diluted, water in the creek (for fully mixed conditions) still has peak, fully mixed concentrations greater than 15 times the proposed cleanup level for copper, and 5 and 8 times proposed cleanup levels for zinc and cadmium adjacent to the Site, respectively. Under existing seasonal conditions, concentrations of metals exceed the proposed cleanup level along the length of Railroad Creek to near the outlet of Railroad Creek into Lake Chelan for cadmium (3 times), copper (7 times), and zinc (2 times). Total iron and aluminum concentrations in Railroad Creek adjacent to the Site seasonally exceed proposed cleanup levels by a factor of about 2. These high concentrations of metals have reduced populations of fish and aquatic macroinvertebrates in Railroad Creek adjacent to and downstream of the Site.

Of the four alternatives, Alternative 11 collects the largest volume of water above proposed cleanup levels, approximately 600 million gallons per year (MGY). Alternative 10 collects less groundwater annually, about 483 MGY, compared to Alternative 11, as Alternative 10 would implement a partially penetrating barrier wall and would not immediately collect TP-2 groundwater. Relying on source depletion and natural attenuation processes, in the LWA and in the former TP-1 and TP-3 footprints, Alternative 8 would only collect about 357 MGY of groundwater for treatment. Alternative 9 would collect the least amount of groundwater, about 324 MGY, and of this total, only about 126 MGY would be collected from the portal drainage, and seeps and flow tubes immediately adjacent to Railroad Creek.[21]

The collected volume of water that exceeds criteria before it enters the creek is a good direct indicator of reduced toxicity in Railroad Creek. Figures G-2 and G-4 indicate that all of the identified seeps and flow tubes have concentrations of one or more metals that exceed aquatic life criteria, throughout the year. The alternative that collects the largest volume of groundwater above proposed cleanup levels that would otherwise enter the creek is the alternative most protective of the aquatic environment. Alternative 11 does more to reduce risk by removal of hazardous substances in this way, than the other alternatives.

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[21] Most of the groundwater that Alternative 9 would collect for treatment is anticipated to come from the UWA barrier and collection system (about 198 MGY of about 324 MGY), and this would produce relatively less immediate benefit to Railroad Creek.

3.1.1.3 Reduction in Risk of Mass Release

Another aspect of the degree to which existing risks are reduced (the first element of the protectiveness criteria) is the degree to which each alternative reduces risk of a mass release of reactive tailings into Railroad Creek. Such a release could occur due to instability of the tailings piles, which could arise due to flooding or scour in Railroad Creek, uncontrolled erosion of the tailings pile slopes, earthquakes, or possibly due to a water surge caused by collapse of the underground mine workings. The DRI reports a tailings slope failure related to a 50-year flood event in 1948, and erosion- and scour-related stability problems have occurred in 2003 and 2006. In 1970, a surge of water from the mine was documented as a result of the collapse of overburden within the mine (Forest Service 1970a, 1970b, and 1970c).

The four alternatives differ in the way they address risk of tailings pile instability. This is an important aspect for comparing the alternatives since the three tailings piles are immediately adjacent to Railroad Creek, a meandering alpine stream. The peak stream flow measured at the east end of the tailings piles (sample location RC-2) during the RI was 370,000 gallons per minute (gpm; Table 2-3, URS 2004a). Copper Creek separates TP-1 from TP-2, and also has significant erosion potential, with a peak measured flow of 61,400 gpm. A meander in Copper Creek during October 2003 caused uncontrolled erosion that impacted an estimated 600 cy of tailings, of which an unknown amount of reactive tailings was released into the creek (Forest Service 2003). The same flood caused scour in Railroad Creek that undermined a portion of the riprap along the toe of TP-2.

The release of tailings into Railroad and/or Copper Creeks is likely to increase the concentration of total and dissolved metals, with consequent adverse impacts to aquatic life in Railroad Creek, and potentially in Lake Chelan.

While damage to the riprap and/or future meandering of either Railroad or Copper Creeks are sources of potential instability, erosion due to runoff and potential gully formation on the tailings pile slopes is another potential source. The DRI identified extensive existing erosion on a portion of the TP-2 slopes, and "moderately high" to "high" potential erosion on portions of the slopes of the three tailings piles. Subsequent site inspections since the DRI have shown that erosion is ongoing (Forest Service 2003 and 2006), and Intalco had to conduct significant erosion stabilization work in 2003 and 2006 on portions of TP-1.

Alternatives 8, 10, and 11 include regrading and moving the toe of the tailings piles away from Railroad and Copper Creeks, whereas Alternative 9 includes only regrading of slopes on TP-1 and TP-2 with no setback of the toe of slope of TP-1 or TP-2 from the creeks and no regrading or setback of the toe of the slope of TP-3. Thus, Alternative 9 provides significantly less reduction in risk of erosion or mass instability compared to the Alternatives 8, 10, or 11. Figure G-7 illustrates the effect of regrading and setback of the toe of the tailings for a representative cross section of TP-2.

Slope stability analyses accomplished for the DRI indicated that slopes of TP-2 and TP-3 had factors of safety between 1.0 and 1.1, which are barely stable. The DFFS reported that portions of the TP-1 slopes adjacent to Railroad Creek and the majority of TP-2 are "marginally stable" under normal conditions, and that the remainder of TP-1 slopes and TP-3 slopes are considered stable under both normal and earthquake conditions. The Agencies accomplished additional slope stability evaluations (see Appendix D of the SFS) and determined minimum factors of safety for the three tailings piles were below 1.0, and average factors of safety were often below 1.0 and rarely exceeded 1.1, except for a small portion of TP-1 that had acceptable factors of safety (greater than 1.3). For comparison, agencies such as the U.S. Army Corps of Engineers and Ecology generally require factors of safety of at least 1.3, or even 1.5, depending on the importance of the slope (Corps of Engineers 2000, Ecology 1993). The DRI presents figures that show minimum factors of safety for TP-2 and TP-3 under normal conditions range from 1.0 to 1.1. Intalco included regrading portions of the TP-1 and TP-2 slopes to improve stability for Alternative 9.[22] However, Alternative 9 did not include moving the toe of slope back from Railroad Creek, which is necessary to assure stability.

It is not enough that the tailings slopes be stable under normal conditions. Washington solid waste regulations require waste disposal facilities located in seismic impact zones be designed to resist (be stable under) the maximum horizontal acceleration for the site [WAC 173-350-400(3)]. These regulations are potentially relevant and appropriate requirements for closure of the tailings and waste rock piles.

Seismic impact zones are areas with a 10 percent or greater probability that the maximum horizontal acceleration will exceed 0.10 g in 250 years [WAC 173-350-100]. This criterion refers to an earthquake that has an average return period of 2,373 years. The US Geological Survey (2007) estimates that an

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[22] Results of analyses were reported for TP-3 in the DRI, but omitted from the DFFS. Although Intalco reported that portions of TP-3 slopes are steeper than the estimated angle of repose, and the minimum factor of safety under normal (not seismic) conditions was only 1.1, the DFFS recommended leaving the TP-3 slopes alone because they "appear to be stable" in their current configuration, and there is room for accumulation of slide debris between the base of the tailings slope and Railroad Creek.

earthquake with this return period at the Site would have an estimated peak horizontal acceleration of 0.20 g. In comparison, analyses for the DRI indicated an earthquake that produced a peak ground acceleration of only 0.05 g is large enough to cause a slope failure.

The DRI described results of the stability analyses as indicating the potential depth of slope failure is on the order of 10 to 15 feet. Thus, instability could introduce tailings with substantial quantities of leachable metals into Railroad and Copper Creeks. The DRI noted that the horizontal length of slope failures "is expected to range from less than 100 feet to more than several hundred feet." For perspective, a 200-foot-long slope failure on TP-3 would release approximately 3,000 cy of tailings into Railroad Creek. This is the equivalent of the contents of about 240 three-axle dump trucks. During an earthquake, several such failures could occur along the length of the tailings piles facing Railroad and Copper Creeks.

In addition to regrading to achieve stable slopes under both normal and seismic conditions, moving the toe of the tailings pile slopes back from the edge of the creek is necessary to permanently eliminate the risk of a mass release of tailings into either creek. As noted in the DRI and DFFS, erosion and/or removal of material at the toe of the tailings piles (e.g., by scour in the creek channel) would reduce the factors of safety even if the slopes were flattened to improve stability. Flattening the slopes would reduce risk of seismic instability or surficial erosion of the tailings piles, but would not address the risk of instability due to scour in Railroad Creek. Scour could undermine the riprap and/or flooding could overtop the riprap. Either type of failure could deposit significant volumes of tailings into the creek and release metals above proposed cleanup levels.

A shallow failure of the tailings would likely result in the release of tailings that have already oxidized, which may not have high concentrations of soluble metals. However, a deeper failure would introduce relatively unweathered tailings into the creek, which would rapidly oxidize and release high concentrations of total and dissolved metals.

- Test pits in the tailings piles encountered a surficial oxidized layer that extended to a depth of 2 to 3 feet in fine-grained tailings, and as deep as 7 feet in the coarser tailings along the perimeter of the piles (see Appendix E of the DFFS). The average pH of this layer was 4.0; acidic conditions such as this produce the maximum solubility of aluminum and copper, and also increase mobility of other metals that are present. Intalco sometimes refers to tailings within the oxidized layer as if they were no longer sources of metals release, but this is an inaccurate generalization. Once the sulfide minerals have been completely depleted by oxidation, pH should return to near-neutral conditions. This is not yet evident at Holden. Oxidation of the near-surface tailings may continue for decades or hundreds of years and continue to be a source of metals.

- Underlying the surficial oxidized layer is the "acidic layer" that ranged up to 15 feet thick in the fine-grained tailings at Holden, and is probably deeper in the coarse-grained tailings along the perimeter of the tailings piles. The average pH of this layer is 5.0. Within the acidic layer, some oxidation is ongoing, along with storage of some metals that have precipitated as acidic seepage from above encounters neutralizing minerals within this layer. These tailings are also reactive, and slope failure would expose these tailings to oxidation and release the stored metals.

Regrading the slopes and improving the existing deteriorated riprap alone, without relocation of the toe of the tailings pile slopes, would not eliminate the risk of mass release of the tailings piles into Railroad or Copper Creeks. As noted above, Alternative 9 provides significantly less reduction in risk of toe erosion or mass instability compared to the Alternatives 8, 10, or 11.

3.1.1.4 Reducing Risks to Terrestrial Receptors from Exposed Waste Materials and Impacted Soils

Alternatives 8 and 11 include closure of the tailings piles and the main East and West Waste Rock Piles with an impervious cap (a combination of 2 feet of soil and a geomembrane) that would satisfy the presumptive cover requirements in state standards for limited purpose landfills [WAC 173-350-400(3)(e)(ii)].[23] Properly maintained over time, this cap would be protective of human health and terrestrial receptors from direct contact with the tailings, and would eliminate seepage through the waste rock.

Alternative 10 includes closure of the tailings and main waste rock piles with a 1-foot-thick soil cover that would support vegetation for erosion protection. This alternative assumed that an ecological risk assessment would show the proposed cover is protective of terrestrial receptors, and that in combination with institutional controls, it would also protect human health from exposure to the

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[23] Note that only Alternative 11 addresses closure of the Honeymoon Heights Waste Rock Piles.

tailings. However, the proposed cap for Alternative 10 would need to be modified if further analysis does not show it is protective.[24]

Intalco's description of Alternative 9 did not address closure of the tailings piles (URS 2005). However, the cost estimate breakdown provided by URS indicated that Alternative 9 would include placement of topsoil and revegetation on 16 acres of regraded slopes, and that the remaining surface of the tailings piles would be revegetated but not capped in any way. Intalco did not discuss whether revegetating the existing sand and gravel cover on the tailings would be protective of terrestrial receptors, nor did it propose any ecological risk evaluation to assess this. The existing sand and gravel cover, placed by the Forest Service to control wind erosion in 1989-1991, is incomplete; areas of bare tailings are exposed on steep slopes and where the cover has eroded.

Based on the descriptions provided above, Alternative 9 is less protective of terrestrial receptors that the other alternatives because it does less to reduce risks related to exposed waste materials and impacted soils. Alternative 11 is more protective than the other alternatives because it does more to reduce risks related to exposed waste materials and impacted soils.

3.1.1.5 Summary of the Degree to Which Existing Risks are Reduced

In summary, Alternative 11 does more than the other alternatives to reduce existing risks by: reducing the concentrations of hazardous substances in Railroad Creek (reducing toxicity by reducing the length of creek exposed to such sources); removal of hazardous substances from groundwater that would otherwise enter the creek; and reducing the risk of a massive release of reactive tailings into Railroad and/or Copper Creeks. Alternative 11 also does more than the other alternatives to reduce risk of exposure of terrestrial receptors to hazardous substances.

3.1.2 Time Required to Reduce Risk and Achieve Cleanup Standards

The second element in determining the relative protectiveness of alternatives is the time required to reduce risk and achieve cleanup standards. As noted above, Alternative 11 will immediately reduce risk to the aquatic environment by

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[24] The proposed cap for Alternative 10 would also need to be modified if it was determined during remedial design to be insufficient to meet the performance requirements for closure of limited purpose landfills, [WAC 173-350-400(3)(e)(i)], which are potentially relevant and appropriate ARARs.

reducing metals concentrations in Railroad Creek along the entire length of the Site. Alternative 10 will also immediately reduce concentrations in Railroad Creek across most, but not all of the Site (monitoring would occur at TP-2 to determine whether groundwater should be collected from this tailings pile in the future). In contrast to Alternatives 10 and 11, Alternatives 8 and 9 rely on natural attenuation, and a combination of source depletion and natural attenuation, respectively, to reduce risk over time for significant parts of the Site.

The DFFS Model indicates aquatic toxicity risks would be substantially reduced after 50 years for Alternatives 8 and 9, but only for a fully mixed condition downstream of the Site and not at the points of compliance. Also, since the estimated rate of contaminant reduction in groundwater that Intalco assumed for the LWA is not supported by the EPA Batch Flush Model (see SFS Appendix A), the time to reach proposed cleanup levels for Alternatives 8 and 9 at the points of compliance would be much longer than assumed in the DFFS Model, on the order of decades or hundreds of years.

There are also significant limitations with the DFFS mass loading analysis, which makes its predictions of time to reach clean up levels unsuitable for use as the primary basis for selection of a remedy. These limitations are briefly summarized at the beginning of Section 3 of this appendix, and are discussed in detail in Appendix A of the SFS.

Alternatives 10 and 11 provide containment, collection, and treatment of groundwater immediately adjacent to the groundwater-surface water interface for large portions of the Site and the entire Site, respectively. As a result, Alternatives 10 and 11 require less time than Alternatives 8 and 9 to reduce risk to aquatic receptors at the conditional point of compliance. Alternative 11 would reduce aquatic risk in Railroad Creek faster than Alternative 10 as it collects TP-2 groundwater immediately after implementation and eliminates potential leakage underneath the partially penetrating barrier.

3.1.3 On-Site and Off-Site Risks of Implementation

The third element of evaluating relative protectiveness of remedial alternatives under MTCA is to assess the degree of risk both on and off site that arises from implementation of an alternative.

Implementation of any alternative brings with it short-term construction risks to the environment. These include the risk of a tailings release during regrading of the tailings next to Railroad Creek; risk of a bentonite or cement release while installing a barrier wall depending on the materials selected during RD; water quality degradation due to construction of hydraulic barriers in the underground mine; risk of sediment release during temporary stream crossings or construction of a groundwater containment and collection system; and potential adverse effects related to traffic, noise, and/or dust that might impact residents of Holden Village. Off-site risks associated with the four alternatives includes the risk of fuel spills or possibly a transportation accident involving lime for the treatment plant that could occur as these materials are delivered to the Site.

Construction-related impacts are not directly comparable for the different alternatives, since Alternatives 8, 9, and 10 would not be final remedies. The potential effects of implementing these alternatives as an interim remedy are described below, but the additional remedial work (and associated impacts) to complete the clean up to provide the same degree of protectiveness as Alternative 11 have not been identified to date.

3.1.3.1 Regrading Tailings

There is some risk of instability and sloughing of the tailings into Railroad Creek during regrading to improve slope stability. Alternative 8, 10, and 11 involve regrading larger volumes of tailings adjacent to Railroad Creek than Alternative 9, which would extend the time over which this risk is present, but not change the nature of the risk.

Stormwater runoff during regrading may also cause a release of tailings into Railroad Creek. The regrading work could be accomplished sequentially along the face of the tailings piles (moving east to west). This would allow soil cover to be placed over tailings that have already been regraded, concurrent with grading slopes further to the west. In this way, the area of unoxidized tailings that is exposed at any time could be minimized for each alternative, thus reducing the risk of stormwater runoff conveying exposed tailings into Railroad Creek. More important, Alternatives 10 and 11 both include installation of a runoff collection ditch alongside Railroad Creek, which would enable collection of runoff from the regraded slopes, and downstream detention and treatment of impacted stormwater in the new treatment facility (constructed prior to tailings regrading). For Alternative 8, the water treatment facility could not be constructed downstream of the tailings piles until after removal of TP-3. Thus stormwater detention and treatment would only be available during the later part of tailings regrading for Alternative 8.

This approach to protect against tailings release in stormwater runoff is not available under Alternative 9, since the toe of the tailings slope must be pulled back from the creek side to make room for a ditch. A DFFS analysis estimated that stormwater runoff from tailings exposed for a month would have a pH of about 2 and elevated concentrations of metals (especially zinc at around

3,500,000 ug/L; see Appendix E of the DFFS). Concentrations of metals in the runoff would increase if the tailings were exposed for a longer period before a storm.

For an assumed worst-case analysis (all the tailings exposed at the time of a 1-inch 24-hour storm), the DFFS estimated the mass of metals delivered to the creek would be 22 kilograms (kg) cadmium, 149 kg copper, 18,600 kg iron, and 93,200 kg zinc (according to Table 7-8 of the DFFS). Such a release would produce a plume toxic to aquatic life down Railroad Creek and possibly into Lake Chelan. Accordingly, the inability to collect and detain stormwater runoff during regrading is a major flaw in Alternative 9, somewhat less of a problem for Alternative 8 (i.e., TP-3), and not an issue for Alternatives 10 and 11.

For additional discussion on tailings pile regrading, see Appendix D of the SFS.

3.1.3.2 Groundwater Containment Barrier Wall Construction

Alternatives 8, 10, and 11 involve the placement of groundwater barrier walls adjacent to Railroad Creek, while the barrier wall for Alternative 9 is, at the least, several hundred feet upgradient from the creek. During construction of the barrier for Alternatives 8, 10, and 11, there is risk of a release to Railroad Creek of the bentonite and/or cement slurry that may be used for construction of the barrier. This risk is essentially non-existent for Alternative 9 due to the distance of the barrier wall from Railroad Creek. Potential risk of a bentonite or cement release can be minimized by good construction practices, including location of dry materials storage and mixing facilities away from the creek, good housekeeping to minimize spillage during slurry handling, and advance preparation of a spill management contingency plan.[25]

Alternatives 8, 9, and 11 include groundwater cutoff walls keyed into the underlying till or bedrock, while Alternative 10 includes a partially penetrating barrier. The depth of the barriers for Alternatives 8 and 11 range from about 55 to 80 feet below ground surface, whereas the depth of the barrier for Alternative 10 is estimated at 30 feet. Barrier wall depths for Alternative 9 are predicted to be approximately 15 to 20 feet deep. Although installation of the deeper barriers for Alternatives 8 and 11 is well within the depth of similar barriers

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[25] The DFFS proposed construction of barrier walls as soil-bentonite or cement-bentonite slurry trench walls. This approach is included for discussion and preliminary cost estimating purposes in these alternatives. The DFFS did not include an explicit evaluation of other types of groundwater barriers (e.g., secant soil mixing or jet grouting barriers); however, other alternatives could be evaluated during remedial design.

constructed at other sites, implementation of these cutoff walls would be somewhat more difficult and take longer compared to shallower barrier walls for Alternatives 9 or 10. Additionally, the length of the cutoff wall for Alternative 11 is longer than for Alternatives 8, 9, or 10. As a result, Alternative 11 would require a longer time for barrier construction adjacent to the creek, and thus has a greater risk of a construction accident releasing bentonite, cement, or sediment into Railroad Creek.

3.1.3.3 Underground Mine Work

The four alternatives include the installation of two hydraulic bulkheads within the main 1500 Level portal of the mine. However, Intalco proposed leaving open the option of installing a detention pond in lieu of mine bulkheads. Depending on results of analyses during remedial design, ponds could be used to provide some equalization of portal flow rates prior to treatment. However, it would not be practical to build ponds large enough to capture a surge in flow that could result in the event of a significant underground collapse, as reported at the McDonald Mine in Maryland (Fahrenthold 2006).

While the bulkheads are the preferred way to control the rate of drainage from the mine, the DFFS noted experience at other sites suggesting that bulkhead installation may degrade water quality over the short term by flooding areas where metal salts and/or exposed sulfide-bearing rock are not currently affected by mine drainage. The DFFS provides a basis for predicting the resulting water quality degradation at Holden, which would be addressed by treatment of the portal drainage. The effect of bulkhead construction is the same for Alternatives 8 through 11. Since the portal drainage would be collected for treatment under these four alternatives, this water quality degradation should not adversely impact water in Railroad Creek.

Work in the underground mine will also pose risks to workers that are different from other types of construction risks. For this work, adherence to the Mine Safety and Health Administration (MSHA) standard safety protocols would likely be required to reduce risks to workers.[26] The construction risk of underground work is the same for the four alternatives. Construction safety risk is more generally discussed in Section 3.5.1.

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[26] MSHA requirements are generally applicable only to active underground mining operations, but are frequently adopted as standards of practice for other underground construction work.

3.1.3.4 Risk of Sediment Release in Railroad Creek

Following regrading of the tailings piles, there is some additional potential risk of sediment release to Railroad or Copper Creeks due to excavation of groundwater and seep collection trenches adjacent to the creek for Alternatives 10 and 11, and to a lesser degree for Alternative 8. Alternative 9 does not involve construction of any groundwater collection trenches along Railroad Creek, but there is some risk of sediment release associated with installation of seep collection systems for SP-1 and SP-2, especially since there would not be any setback of TP-1 from the edge of Railroad Creek.

Alternatives 10 and 11 also include construction of two pipeline creek crossings, one across Copper Creek near the confluence with Railroad Creek, and one across Railroad Creek near the east end of TP-3. Alternative 8 would likely include a pipeline crossing Copper Creek to convey sludge from the west treatment facility to a sludge disposal facility on the consolidated tailings pile, but this is not mentioned in the DFFS. Intalco also does not mention any pipeline creek crossings for Alternative 9.

Conventional construction practices can mitigate risk of sediment release to the creeks due to construction of groundwater and seep collection systems, and pipeline creek crossings.

3.1.3.5 Risks to Local Community

Holden Village has raised concerns about the implementation of any remedy and the effect it will have on their community (Holden Village 2002, 2004, and 2005). These concerns include construction traffic and related exhaust emissions, noise, and dust.

The DFFS analyzes fuel consumption and resultant emissions during construction for Alternative 8, primarily related to regrading the tailings and waste rock piles. The following table extrapolates from that analysis to compare the alternatives, based on the relative volumes of regraded tailings and waste rock.

Alternative No.	Approximate Combined Volume of Regraded Tailings and Waste Rock in Cubic Yards	Estimated Fuel Consumption during Construction in Gallons	Estimated Vehicle Exhaust Emissions (Particulates, Carbon Dioxide, Hydrocarbons and Nitrogen Oxides) in Tons
8	3,900,000	700,000	360
9	250,000	45,000	23
10	740,000	133,000	68
11	790,000	142,000	73

The four alternatives probably would produce noise and dust to a similar degree as vehicle exhaust emissions, as indicated above. Alternative 9 would likely have the least noise and dust simply because it involves less remedial construction, followed by Alternatives 10 and 11; and Alternative 8 would likely produce the most noise and dust. Other potential impacts to Holden Village are discussed in Section 3.5.1 and elsewhere (URS 2005b and Forest Service 2005).

3.1.3.6 Risk of Fuel and Lime Spills

During construction, there is a risk of fuel spills both on and off the Site. In an assumed worst case scenario, an off-site spill could release the contents of a tanker truck (typically about 2,000 gallons) into Lake Chelan. The risk of this is proportional to the total quantity of fuel that would be used; the table above indicates that Alternative 8 would have the greatest risk, with Alternatives 10 and 11 having less, and Alternative 9 with the least risk of an off-site spill.

After treatment plant construction, there is some potential risk of spilling hydrated lime during transport to the Site or transfer from delivery trucks into on-site storage bins. Hydrated lime is a caustic chemical that can cause injury to humans and/or environmental damage if released in a spill. The degree of potential risk during treatment system operation is less for Alternatives 8 and 9 than for Alternatives 10 and 11, simply because these alternatives would not require as much lime since they do not treat as much water over time, as Alternatives 10 and 11.

3.1.3.7 Summary of On-Site and Off-Site Risks of Implementation

The four alternatives differ in the degree of on-site and off-site risks due to implementation, which is the third criterion used to assess protectiveness of the alternatives under MTCA.

In summary, Alternative 9 involves the least remedial activity to clean up the Site and, therefore, has lower risk of adverse impacts due to implementation. Generally Alternative 8 has the most potential to cause impacts to Railroad Creek during tailings regrading, consumes the most fuel, and has the greatest potential noise, dust, and traffic-related impacts to Holden Village residents. Alternatives 10 and 11 have the least potential to cause adverse impacts due to stormwater runoff during regrading of the tailings. However, Alternative 11 has the greatest potential to impact Railroad Creek during construction of the containment barrier wall, due to the length and depth of construction adjacent to the creek.

Construction-related impacts are not directly comparable for the different alternatives, since Alternatives 8, 9, and 10 would not be final remedies, and the degree of additional impacts to provide the same degree of protectiveness as Alternative 11 have not been identified to date.

3.1.4 Overall Improvement of Environmental Quality

The fourth component of assessing relative protectiveness of the different alternatives, as part of the disproportionate cost analysis, is the degree to which each alternative provides an overall improvement in environmental quality.

As discussed in detail in Section 3.1.1.1, the most immediate reduction in metals concentrations in Railroad Creek comes from Alternative 11's collection of groundwater that exceeds water quality criteria along the entire length of the Site. By collecting groundwater adjacent to Railroad Creek, at the conditional point of compliance, Alternative 11 relies less on natural attenuation and source depletion than would the other alternatives.

Alternative 10 collects most of the groundwater adjacent to Railroad Creek. This results in an immediate reduction in Railroad Creek's metals concentrations, but not to the same extent as Alternative 11. By collecting all the groundwater that exceeds proposed cleanup levels (see Figures G-2 and G-4), Alternative 11 results in a greater improvement in environmental quality. Alternative 8 would produce some immediate reduction in Railroad Creek metal concentrations as it collects groundwater along the length of the consolidated tailings pile. However, Alternative 8 relies on natural attenuation to reduce metals concentrations over time (decades to hundreds of years) in the creek in the LWA and in the former TP-1 and TP-3 areas. Alternative 9 would have the least amount of reduction in metals concentrations within the creek following implementation as it relies on source depletion and natural attenuation over large portions of the Site (i.e., the LWA, TP-2, TP-3, and part of the groundwater impacted by TP-1).

As previously noted, Alternatives 8 and 9 rely on natural attenuation, and a combination of source depletion and natural attenuation, respectively, as remedy components to a greater degree than Alternatives 10 and 11; thus Alternatives 8 and 9 will release more metals to surface water over time (decades to hundreds of years), resulting in a greater adverse impact to aquatic life compared to Alternatives 10 and 11.

Alternative 10 includes revegetation of the tops of the tailings and waste rock piles and there would be some terrestrial habitat improvement along the "riparian corridor" where the edges of the tailings piles are pulled back from Railroad Creek. Alternative 9 includes revegetation of the existing sand and gravel cover over the tailings piles, but does not provide cover or revegetation of the waste rock piles, nor would it improve any habitat along the south side of the creek.

Alternatives 8 and 11 would require animal and/or vegetation management on the regraded tailings and waste rock piles. This may be needed to prevent burrowing animals and/or establishment of trees and deep-rooted shrubs from damaging the geomembrane cap, or to control risk of metals uptake by plants. However, pending further ecological risk assessment, it is not clear whether the membrane cap could be eliminated from Alternative 11, or whether similar management would be needed for Alternative 10. Alternative 9 does not address potential risk to terrestrial receptors associated with the tailings and waste rock piles.

Additionally, Alternatives 10 and 11 include terrestrial ecological surveys to determine the extent of cleanup action required in other areas adjacent to the Site that exceed soil screening criteria, including the areas of visible accumulations of wind-blown tailings north and east of the mine, Holden Village, the baseball field, and the LWA. Alternatives 8 and 9 do not address these other areas with elevated metals concentrations.

In summary, Alternative 11 provides greater overall improvement of environmental quality than Alternative 10. Both of these alternatives provide greater overall improvement of environmental quality compared to Alternatives 8 or 9. Alternative 9 provides the least amount of overall environmental quality improvement.

3.1.5 Summary of the Relative Protectiveness of the Alternatives

Although each alternative has its own attributes, as discussed above, Alternatives 10 and 11 are more protective than Alternatives 8 and 9.

Alternatives 10 and 11 reduce existing aquatic risks to a greater degree than do Alternatives 8 and 9 by decreasing metals concentrations within Railroad Creek more quickly.

Alternative 11 would reduce risk and attain cleanup standards more quickly than the other alternatives, since Alternatives 8 and 9 rely to some degree on natural attenuation (and source depletion for Alternative 9), and the effectiveness of Alternative 10 cannot be completely determined on the basis of existing information. The on- and off-site risks for each alternative are not directly comparable, since Alternatives 8, 9, and 10 are not final cleanup actions, and the extent of additional impacts associated with expanding these alternatives to provide the same degree of protectiveness as Alternative 11 have not been determined.

Alternative 9 does not include any way to collect and treat stormwater runoff during tailings regrading, which is required to comply with state stormwater management standards for construction that are potentially relevant and appropriate to the cleanup action.

Overall, based on the criteria described above (reduction of existing risks, time required, and improvement of overall environmental quality) and considering the limits of available information on risks due to implementation, Alternative 11 is more protective compared to Alternatives 8, 9, and 10.

3.2 Permanence

The second element to be compared in the disproportionate cost analysis is the permanence of the remedy.

A "permanent cleanup action" achieves cleanup standards without further action at the site, such as long-term monitoring, maintenance, or institutional controls (WAC 173-340-200). In evaluating permanence, MTCA [WAC 173-340-360(3)(f)(ii)] looks at the degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances. Additionally, MTCA looks at how the alternative does the following:

- Destroys a hazardous substance;
- Reduces or eliminates hazardous substance releases and sources of releases;
- The degree of irreversibility of the waste treatment process; and
- The characteristics and quantity of the treatment residuals generated.

A comparison of the four alternatives based on these criteria is presented below.

3.2.1 Destruction of Hazardous Substances

None of the alternatives destroy hazardous substances.

3.2.2 Reduction or Elimination of Hazardous Substance Releases and Sources of Releases

The four alternatives each use some degree of engineered controls and treatment to reduce or eliminate hazardous substance releases at the Site.

3.2.2.1 Preventing or Reducing the Release of Hazardous Substances

The four alternatives include upgradient run-on diversions; removal of hazardous substances in the mill, lagoon, and ventilator portal detention areas; and capping of the maintenance yard soils.

Alternatives 8 and 11, and Alternative 10 to some degree, include consolidation and capping of the tailings and waste rock materials to reduce hazardous substance releases, which is not included in Alternative 9.

Consolidation and/or capping of the tailings and waste rock to varying degrees for Alternatives 8, 10, and 11 would reduce contact between these materials with air, surface water run-on, and infiltration. With less exposure to oxygen and water, the rate of metals release will decrease due to slower rates of oxidization and seepage to Railroad Creek. However, capping these materials does not permanently reduce metals toxicity or volume, and downgradient collection and treatment of impacted groundwater is still needed to achieve water quality criteria in Railroad Creek.

Alternatives 8 and 11 have an impermeable membrane over the tailings and at least some (Alternative 8) or all (Alternative 11) of the waste rock. Provided the caps are maintained, this will significantly reduce, but not wholly prevent, the ongoing release of hazardous substances from the tailings and waste rock. Both alternatives include a groundwater barrier and collection system around the tailings, since the base of the tailings would continue to be exposed to shallow groundwater and near-surface seepage and some release is likely to continue. However, Alternative 8 would not prevent groundwater contamination due to the Honeymoon Heights Waste Rock Piles.

3.2.2.2 Groundwater Collection and Treatment

The alternatives differ in the mass of metals that would be removed from the environment due to differences in where groundwater is collected from the Site and the volume of groundwater collected for treatment.

For Alternatives 9, 10, and 11, the primary way metals are kept from reaching Railroad Creek is through the collection and treatment of impacted groundwater, but the extent to which this is accomplished varies from one alternative to another.

- Alternative 8 does not collect and treat as much groundwater as Alternatives 10 and 11, since it entails consolidation and capping of the tailings piles and the waste rock piles. Alternative 8 relies on natural attenuation of the contaminated groundwater remaining in the former TP-1 and TP-3 footprints, and in the LWA.

- Alternative 9 does not include collection or treatment of groundwater impacted by TP-2 and TP-3, and some of the groundwater impacted by TP-1, relying rather on source depletion and natural attenuation in these areas. Alternative 9 collects groundwater with a barrier wall in the UWA, but would rely on natural attenuation to clean up groundwater in the LWA.

- Alternative 10 includes collection and treatment of groundwater in the LWA and below TP-1 and TP-3, but relies on the collection of additional groundwater data from TP-2 to determine whether groundwater from this portion of the Site requires collection and treatment.

- Alternative 11 collects all the identified sources of groundwater above proposed cleanup levels that would otherwise enter Railroad Creek.

The four alternatives differ in the degree to which they reduce hazardous substance releases via groundwater seepage to surface water. As noted earlier, each of the alternatives constitutes a non-permanent groundwater cleanup action under WAC 173-340-360(2)(c). (See the discussion in footnote 8). When such a non-permanent action is implemented, MTCA requires that:

> *Groundwater containment, including barriers or hydraulic control through groundwater pumping, or both, shall be implemented to the maximum extent practicable to avoid the lateral and vertical expansion of the groundwater volume affected by the hazardous substance* [WAC 173-340-360(2)(c)(ii)(B)].

Based on this requirement, an alternative that contains a greater proportion of the impacted groundwater at a site would be more permanent than another alternative, because it does more to avoid potential future lateral and vertical expansion of the plume. Therefore, Alternative 11 is more permanent than Alternatives 8, 9, and 10.

The disproportionate cost analysis requires weighing the incremental benefit vs. the incremental cost of two or more alternatives. This determines which is more permanent, or when two or more alternatives provide the same benefit, which is less costly [WAC 173-340-360(3)(e)(ii)]. Based on this analysis, Alternative 11 contains a greater proportion of the impacted groundwater than the other three alternatives and, therefore, provides more benefit. Alternative 11 would also cost less compared with Alternative 8 (see below). Alternative 10 would also contain a greater proportion of the impacted groundwater compared to Alternatives 8 or 9, and is intermediate in cost between these two alternatives.

Since all of the water contained in these alternatives is collected for treatment, the cost per gallon for collection and treatment (exclusive of other costs such as for tailings pile regrading) provides a measure of the unit or incremental cost of each alternative. The following estimated unit costs are derived from the present value of treatment plant operating costs over 50 years, divided by the volume of water that would be treated over 50 years, for each alternative.[27]

Alternative	Estimated Net Present Worth of O&M Cost for 50 Years	Estimated Annual Volume of Water Collected and Treated in Millions of Gallons	Unit Cost in $/Million Gallons over 50 Years
8	$8,350,000	357	$467
9	$6,410,000	324	$396
10	$8,980,000	483	$372
11	$11,000,000	600	$367

[27] Estimated O&M costs shown include capital replacement costs for groundwater containment, collection, conveyance, and treatment facilities, but not the capital cost for other remedy components. The net present worth of operations and maintenance costs for water collection and treatment is based on 50 years at a 7 percent discount rate, and does not include Site-wide environmental monitoring or Agency review and oversight.

These estimated costs are based on uniform assumptions for the four alternatives, based on cost estimates prepared by the Agencies, as discussed in Appendix B of the SFS.

This breakdown shows that the estimated unit cost for collection and treatment is lowest for Alternative 11, and somewhat higher for Alternative 10, and both these alternatives have a lower unit cost than Alternatives 8 and 9.

All of the groundwater that is collected for treatment is above proposed cleanup levels (based on protection of aquatic life) as shown on Figures G-2 and G-4.[28] Alternatives 8 and 9 would contain and collect considerably less groundwater for treatment than Alternatives 10 and 11, and at higher unit cost. Since Alternative 11 would contain (prevent the release of) about 22 percent more water that exceeds proposed cleanup levels, and thus produce greater environmental benefit, Alternative 11 is a more permanent remedy than Alternative 10.

3.2.2.3 Summary of the Reduction or Elimination of Hazardous Substance Releases and Sources of Releases

In summary, Alternative 11 does more to prevent or reduce the release of hazardous substances, and more to provide collection and treatment of groundwater above proposed cleanup levels, compared to the other alternatives. These criteria are the second part of evaluating permanence of the proposed cleanup action, in accordance with WAC 173-340-360(3)(f)(ii).

3.2.3 Irreversibility of the Waste Treatment Process

Water treated to remove metals will produce metal hydroxide sludge as a by-product of treatment. To assess the degree of irreversibility of the waste treatment process, the Agencies conducted a literature survey to assess sludge from multiple mine sites that had wastewater constituent and treatment technologies similar to what is expected at Holden (Hart Crowser 2004). These studies assessed sludge stability through leaching tests to assess potential for metals to be released and re-enter the environment. Reported results of leaching tests from various sludges indicate that metal concentrations in leachate are sometimes exceeded the proposed Holden surface water cleanup levels, or

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[28] This is true although Alternative 10 would collect a small volume of clean water from the creek during high flow events, as discussed in Attachment B of Appendix F of the SFS.

had detection limits above the proposed surface water criteria. While the sludge would contain most of the metals removed by treatment, water that drains from the sludge would include metals. The water that drains from the sludge would need to be managed to prevent release of metals to the environment. As a result, the Agencies anticipate that the sludge disposal landfill would need to be lined, or possibly might be unlined if located upgradient of a groundwater barrier and collection system, to protect surface water quality. Performance requirements for sludge disposal facility would need to be further evaluated during remedial design.

While the sludge would permanently contain the metals from the treated groundwater and prevent them from reaching Railroad Creek, any water produced from the sludge would need to be managed. The four alternatives include disposal of the sludge in an on-site landfill, which would need to conform to the standards for limited purpose landfills [Chapter 173-350 WAC].

3.2.4 Characteristics and Quantity of the Treatment Residuals Generated

The four alternatives would produce metals hydroxide sludge. Sludge from Alternatives 8, 10, and 11 would contain more iron than sludge from Alternative 9 (due to the difference in collection of groundwater impacted by the tailings piles), but generally sludges from the three alternatives would have similar physical characteristics. However, the volume of sludge produced by the four alternatives would differ substantially.

Over a period of 50 years, the estimated annual average volume of treatment facility sludge for Alternative 11 is about 31,000 cy, for Alternative 10 it is about 27,000 cy, for Alternative 9 it is about 18,000 cy, and for Alternative 8 it is about 20,000 cy. These estimates are based on an assumption that the sludge would have 4 percent solids content at the beginning of the annual dewatering stage of treatment. The volume of sludge produced annually is anticipated to decrease by about 60 percent in the first 50 years due to the estimated changes in mass loading used in the DFFS Model, and would continue to decrease at a much slower rate thereafter. Once the sludge is transferred from the treatment system to the landfill, its volume would further decrease based on consolidation, and potentially drying.

3.2.5 Summary of the Relative Permanence of the Alternatives

In summary, none of the alternatives involves destruction of hazardous substances, and the four alternatives are essentially the same relative to the irreversibility of the waste treatment processes. However the four alternatives can be distinguished by the criteria of reduction or elimination of hazardous substance releases, and the quantity of treatment residual produced.

- Alternative 11 will eliminate more hazardous substances than the other three alternatives. Alternatives 8 and 10 reduce or eliminate more hazardous substances than Alternative 9.

- Alternative 11 produces more sludge than the other alternatives, simply because it treats more water to remove metals above proposed cleanup criteria.

In addition to considering the total volume of metals impacted water that would be collected for treatment, it is important to consider where the reduction or elimination of hazardous substance releases occurs at the Site. While Alternative 9 would collect groundwater in the UWA that have higher metals concentrations than LWA groundwater, this would not produce the same immediate reduction in concentration of metals entering the creek as would collection of seeps and baseflow in the LWA. Thus, Alternative 9 would not produce an immediate decrease in the aquatic toxicity risk within Railroad Creek. The following table indicates the relative effectiveness of the alternatives in collecting and treating groundwater that would otherwise directly enter Railroad Creek.

Alternative No.	Estimated Total Annual Volume of Water Collected for Treatment in MGY[29]	Estimated Annual Volume of Water Collected that Would Otherwise Directly Enter Railroad Creek in MGY
8	357	357
9	324	126
10	483	483
11	600	600

The primary difference for Alternative 9 compared to the other alternatives is that most of the groundwater collected by Alternative 9 is from the UWA, which does not directly enter Railroad Creek. Some of the UWA groundwater flows through the LWA to enter Railroad Creek, but the remainder would flow down

[29] The estimates shown are based on seep and flow tube volumes, and collection efficiency factors as presented in the DFFS and SFS. These values do not include incidental collection of stormwater runoff, or for Alternative 10, seepage from the creek during high flow conditions as discussed in Attachment B of Appendix F of the SFS.

the Railroad Creek valley as a groundwater plume. However, Alternative 11 would collect all of the flow from the UWA, the LWA, and the tailings piles.

3.3 Cost

MTCA states that the cost to implement the alternative includes the cost of construction, the net present value of any long-term costs, and the agency oversight costs that are cost recoverable [WAC 173-340-360(3)(f)(iii)]. The long-term costs include operation and maintenance costs, monitoring costs, equipment replacement costs, and the cost of maintaining institutional controls. Where waste treatment technologies are involved, the pretreatment, analytical, labor, and waste management costs are also to be included. MTCA requires that the design life of the cleanup action be estimated and the cost of replacement or repair of major elements included in this cost estimate.

The DFFS provided a cost estimate for Alternative 8. The estimate provided in the DFFS included a breakdown of capital costs; recurring costs for operations, maintenance, and monitoring, plus a 50 percent contingency, as shown below.

Alternative	8
Capital Costs	$70,458,200
Annual O&M	$391,000
O&M Present Value	$4,848,400
Estimated Total without Contingency	$75,310,000
Total with +50% Contingency Per DFFS	$112,960,000

The DFFS cost estimates did not provide the same level of detail suggested in guidance developed by the U.S. Army Corps of Engineers and EPA (EPA 2000). The Agencies had concerns with the DFFS estimates, including the following:

- The DFFS did not include a clear definition of what was included in various line items;
- Some of the unit costs used in the DFFS differed significantly from what would be expected for comparable construction;
- The DFFS did not provide supporting information for many of the cost items, and correspondence from Intalco reported relying on engineering judgment for significant costs;
- The DFFS applied a 50 percent contingency to all alternatives, arbitrarily magnifying the difference between the alternatives; and

- The total cost in the DFFS breakdown for each alternative included a value for net present value of the recurring costs with a 7 percent discount rate. However, the period of analysis was not indicated and apparently varied from one line item to another.

Intalco also provided a cost estimate for Alternative 9 (URS 2005a). Intalco's cost estimate included a breakdown of capital costs; long-term operations, maintenance, and monitoring costs; and a 30 percent contingency (instead of the 50 percent contingency noted above), as shown in the table below. Intalco did not provide any breakdown or explanation of its assumptions for long-term operation and maintenance costs.

Alternative	9
Capital Costs	$21,680,000
Long-Term Operations and Maintenance Costs (7% discount rate)	$6,216,000
Estimated Total without Contingency	$27,896,000
Total with +30% Contingency	$36,265,000

Some of the same Agencies concerns noted above for the DFFS cost estimates also are applicable to the cost estimate for Alternative 9.

The Agencies prepared cost estimates for Alternatives 8, 9, 10, and 11, to provide a common basis for comparison and documentation of assumptions for these four alternatives. These estimates are presented in Appendix B of the SFS. Intalco does not accept the Agencies cost estimates for Alternative 10 and has provided its own estimate (URS 2005a).

The Agencies' cost estimates (rounded to three significant figures) for the four alternatives are summarized below. Potential contingent costs are not included in the following breakdown, but are discussed in Appendix B of the SFS.

	Alternative 8	Alternative 9	Alternative 10	Alternative 11
Total Estimated Capital Cost	$98,200,000	$22,600,000	$37,000,000	$65,500,000
NPV of Annual Operations, Maintenance and Maintenance Costs (50 years @ 7%)	$17,500,000	$15,600,000	$18,100,000	$20,200,000
Total Estimated Cost	$116,000,000	$38,200,000	$55,100,000	$85,800,000

For alternatives that satisfy the threshold requirements and appear comparable in performance, MTCA uses a "disproportionate cost analysis" to determine whether a proposed remedy uses permanent solutions to the maximum extent practicable. The disproportionate cost analysis is only applicable to comparing alternatives that meet the threshold requirements for selection of a final remedy. Alternative 11 is the only alternative expected to fulfill MTCA's threshold criteria, as discussed in detail in the SFS.[30] However, the disproportionate cost analysis can nevertheless be used in this analysis to: 1) evaluate which alternative among Alternatives 8, 9, 10, and 11 most fully satisfies the MTCA requirements for selection of a permanent remedy; and 2) evaluate the practicability of Alternatives 10 and 11's groundwater collection and treatment system in relation to Alternatives 8 and 9's greater reliance on natural attenuation and source depletion processes.

Under MTCA, costs are disproportionate to benefits if the incremental costs of the alternative over that of a lower cost alternative exceed the incremental degree of benefits achieved by the alternative over that of the other lower cost alternative. Where two or more alternatives are equal in benefits, the less costly alternative can be selected, provided the other requirements for selection of a cleanup action are met.[31] The remainder of this section discusses the incremental benefit of the alternatives relative to their costs.

Intalco (2006) has commented (regarding Alternative 10) that there is no benefit to reducing the mass of metals entering the creek if surface water meets proposed ARARs, but this is incorrect for the following reasons.[32]

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[30] Another problem with the disproportionate cost analysis of dissimilar alternatives (i.e., comparing an alternative that meets the threshold criteria with an alternative that does not) is that the estimated costs are for the alternatives as proposed. These do not include the additional costs that would be incurred to make an interim cleanup action as protective as a final cleanup action.

[31] CERCLA also allows cost to be considered in selecting a remedy, but only as part of balancing, or comparing alternatives that have been demonstrated to be protective and ARAR-compliant.

[32] In its Concise Explanatory Statement for the 2001 MTCA Cleanup Regulation amendments, Ecology addressed why dilution and the use of mixing zone in surface water is not allowed for demonstrating compliance when a conditional point of compliance for groundwater is located within surface water:

> The reasons for not allowing the use of dilution zones (mixing zones under the rule amendments) were stated in the 1991 Responsiveness Summary as follows:

- All of the seeps and flow tubes identified as discharging to Railroad Creek contain concentrations of one or more metals above aquatic life protection criteria throughout the year, as shown on Figures G-2 and G-4;
- Since the DFFS Model does not predict that water in the creek will meet ARARs for some decades, reducing the mass of metals entering the creek will reduce concentrations to ultimately achieve proposed ARARs;
- The faster the reduction in metals entering the creek, the more quickly ARARs will be achieved; and
- Reducing the mass of metals benefits aquatic life, thereby improving protectiveness, which is also a threshold criterion under CERCLA.

Under MTCA, "Cleanup actions shall not rely primarily on dilution and dispersion unless the incremental costs of any active remedial measures over the costs of dilution and dispersion grossly exceed the incremental degree of benefits of active remedial measures over the benefits of dilution and dispersion" [WAC 173-340-360(2)(g)]. Moreover, MTCA allows selection of a less costly alternative only if it provides the same environmental benefits as a more costly

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> Ecology believes that the use of surface water "mixing" or "dilution" zones for ground water discharges from contaminated sites is inappropriate. We believe it would be inappropriate to allow such mixing zones at contaminated sites for the following reasons:
>
> > It is generally technically possible to eliminate groundwater discharges to surface waters through the use of cutoff walls and/or groundwater pumping;
> >
> > There appears to be no direct public benefit that will result from the approval of a dilution zone; and
> >
> > Groundwater discharges are very difficult to measure and quantify due to the heterogeneous nature of groundwater flow systems and the interface with the surface water body.
>
> 1991 RS, Chapter XVIII, Issue #9, p. 221. Also, it should be noted that groundwater discharges to surface water are unique in that the discharge seeps out of the bank or through the bottom sediments into the surface water body. These are very sensitive zones with an abundance of aquatic life with the potential to be exposed to contamination before dilution can occur.

Concise Explanatory Statement for the Amendments to the Model Toxics Control Act Cleanup Regulation, Chapter 173-340 WAC (February 12, 2001), Response to Comment GQ 10.3.6, pp. 181-182.

alternative, and only if the less expensive alternative satisfies all the other criteria for remedy selection.

Models used to assess the effects of cleanup at the Site are discussed in Appendix A of the SFS. None of the available models can predict the improvement in water quality at the anticipated conditional point of compliance for groundwater all across the Site, for each alternative. Therefore, the relative reduction in volume of groundwater entering the creek above proposed cleanup levels for each alternative has been used as a surrogate for reduction in metals concentrations, reduction in aquatic toxicity, and improvement in habitat. The incremental cost and incremental benefit of each alternative (based on the ratio of the volume of water collected and treated to the estimated cost of groundwater collection and treatment, as presented above in Section 3.2.2.2) shows that Alternative 11 does not have a cost disproportionate to its benefit, as compared to the other alternatives.

Alternative 11 provides active remedial measures (groundwater containment and collection for treatment) at unit costs that are not disproportionate to the amount of collection and containment provided by Alternatives 8 and 9, both of which rely on source depletion and natural attenuation for significant portions of the Site. Alternative 11 has a slightly higher unit cost (6 percent) for groundwater collection and treatment compared to Alternative 10. However, this is offset by the relatively greater volume (22 percent) of water above proposed cleanup levels that would be collected and treated. It is also offset by the greater assurance that Alternative 11 will achieve water quality criteria in Railroad Creek (considering the difference at TP-2 and the fully penetrating vs. partially penetrating barrier).

Since Alternative 9 does not provide the same environmental benefits as Alternative 10 or 11, let alone meet the threshold criteria, Alternative 9 cannot be selected on the basis of cost. Alternative 8 is the most expensive remedy, yet does not provide the same degree of environmental benefits as Alternatives 10 or 11. Although Alternative 10 is less expensive than Alternative 11, Alternative 11 addresses all sources of releases above proposed cleanup levels from the Site into Railroad Creek. Thus, Alternative 11 would provide a greater environmental benefit compared to Alternative 10 or any other alternative.

3.4 Effectiveness over the Long Term

Long-term effectiveness includes:

- The degree of certainty that an alternative will be successful;

- The reliability of the alternative over the period of time hazardous substances are expected to remain on site at concentrations that exceed cleanup levels;

- The magnitude of risk remaining after implementation of the remedy; and

- The effectiveness of controls that are required for managing the residues or remaining waste [WAC 173-340-360(3)(f)(iv)].

3.4.1 Degree of Certainty for Success

The degree of certainty that the remedy will be successful over the long term varies between alternatives, and is not 100 percent certain for any of them.

Alternative 10 relies on collection of groundwater in ditches that would extend along a partially penetrating groundwater barrier. Alternative 11 also proposes use of ditches for groundwater and seep collection (extending along a fully penetrating groundwater barrier). Water from the ditches in Alternatives 10 and 11 would flow by gravity to a low point at the northeast corner of TP-3 and then be pumped into the treatment system.[33]

Alternative 8 uses a similar combination of groundwater barrier (fully penetrating) and a groundwater collection drain around the consolidated tailings and waste rock pile, combined with an impermeable cap over the tailings and waste rock and upgradient diversion of run-on. The DFFS assumes that collected groundwater from the west part of the Site would flow by gravity to a treatment facility in the lagoon area, and groundwater collected around the perimeter of the consolidated pile would flow by gravity to a treatment facility east of the pile.

The potential exists that iron fouling will occur in the collection and conveyance ditches for Alternatives 8, 10, and 11. (Similarly iron floc and ferricrete forms in Railroad Creek under present conditions and would continue as part of Alternative 9). However, the ditches are accessible for maintenance and can be cleaned out with a backhoe. Intalco has also suggested that the system would be ineffective if ice dams block flow in the ditch during winter months, but subsurface drains (as proposed for Alternatives 4b, 5b and 8), could be used to

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[33] Although collection and conveyance ditches are proposed for both Alternatives 10 and 11, further assessment during remedial design might show it would be feasible to use a buried perforated pipe collection system as proposed for seep collection in Alternative 9 and the tailings pile drain in Alternative 8, or even to cover the ditches.

mitigate potential freezing, although this could increase potential maintenance difficulty for iron fouling. The issues of iron fouling and freezing need to be further addressed as part of remedial design for any alternative.

The biggest limitation on the degree of success of Alternative 9 is that it does not address ongoing sources of metals discharge to Railroad Creek for significant portions of the Site. In contrast to gravity flow of groundwater into a collection ditch or drain, Alternative 9 relies on pumped wells to collect groundwater below a portion of TP-1 (but does not address groundwater below the remainder of the tailings piles). Intalco expects that iron-fouling problems will be manageable if the well screens, pump intakes, and perforated pipe collection systems (for seeps) are kept submerged to prevent air entry. Alternative 9 could reduce risk of problems with winter freezing by burial of water conveyance pipelines below the depth of anticipated frost.

Freezing may impact the effectiveness of the groundwater treatment system and, therefore, the certainty of success for the four alternatives, to about the same degree. The four alternatives have very similar pH adjustment and precipitation-based treatment systems. The potential effects of freezing are further discussed in Appendix F of the SFS.

Another area where there is less than complete certainty of success for both Alternatives 9 and 10 involves the potential for collection of water from Railroad Creek into the treatment system.

- Alternative 10's proposed partially penetrating barrier along the edge of Railroad Creek would allow some creek water to flow into the collection system during high water conditions when the creek elevation exceeds the adjacent groundwater elevation. The analysis presented in Attachment B to Appendix F of the SFS indicates there is a high probability this will happen, but a relatively low consequence since the annual volume of clean water collected will be on the order of only 1 to 2 percent of the volume of contaminated groundwater collected.

- There is a similar risk that the pumped wells proposed for Alternative 9 would draw in creek water. The rate of pumping, and perhaps the number of pumped wells, would need to be monitored and adjusted to limit this. In the absence of pumping tests and detailed hydrologic analysis, the effectiveness of Alternative 9 is uncertain. Pumping may need to be adjusted to avoid collecting clean water from the creek, which could also constrain the amount of contaminated groundwater that could be intercepted. This may vary seasonally, however, there is not sufficient information presently available to quantify this potential problem.

In contrast, Alternatives 8 and 11 have greater certainty that they will not unnecessarily collect clean water for treatment. However, Alternative 8 does not collect impacted groundwater from much of the Site, so it would not achieve proposed cleanup levels within a reasonable restoration time frame.

Intalco has pointed out that further analysis of Alternative 10's partially penetrating barrier may indicate that it would not be as successful at groundwater collection at the conditional point of compliance as a fully penetrating barrier such as proposed for Alternatives 8 and 11. This could be evaluated further during remedial design, but even a partial barrier would have a higher degree of effectiveness in the areas where it is installed compared to areas where no barrier and collection system would be installed for Alternatives 8 or 9.

Finally, the upper barrier wall in Alternative 9 may not be effective in reducing metals released into Railroad Creek through the LWA, and the Alternative 8 source removal actions in the UWA may not be effective. In either case a barrier wall along Railroad Creek may need to be constructed in the LWA at a future time to ensure protectiveness for Alternatives 8 or 9.

In summary, Alternative 11 provides the greatest degree of certainty that it will achieve the requirements for a successful permanent remedy, compared to Alternatives 8, 9, or 10.

3.4.2 Reliability over Time

The DFFS geochemical evaluation of the Holden Mine Site prepared by SRK Consulting (see Appendix E of URS 2004a) predicted that weathering processes that cause acid mine drainage and release of metals above proposed cleanup criteria will continue for thousands of years. Using SRK's estimated rate of source depletion in the DFFS Model indicates seasonal concentrations of various metals in Railroad Creek would remain above aquatic protection criteria for 50 to 450 years (different periods for different metals) if no action were taken to clean up the Site. To prevent releases above proposed cleanup levels, the remedy must operate reliably over this time frame. Although Holden is not dissimilar to other remediation sites, there are few examples of industrial processes that have been maintained this long. As a result, there is considerable question as to the reliability of any remedy over the time required to clean up this Site.

The potential for iron fouling of well screens and seep collection systems may reduce the effectiveness of these components over time. Collection systems that are accessible and simple to maintain, such as the open ditches proposed for Alternatives 10 and 11, are more likely to be reliable than the proposed French drains and pumped wells of Alternatives 8 and 9.[34] However, this should be further assessed as part of remedial design and/or based on operating experience following implementation of the remedy.

Other maintenance and operation requirements for the water collection and treatment systems are likely to be similar for the four alternatives, since all use the same method of treatment (acid neutralization and precipitation). The estimated cost for operation and maintenance of the Alternative 11 treatment system will exceed Alternative 10 on a total dollars basis, since maintenance and operation costs are proportional to the volume of water treated. Similarly, Alternative 10's estimated cost for operation and maintenance of the treatment system will exceed those for Alternative 8. Alternative 9 would have the lowest treatment system operation and maintenance cost, because it involves the least infrastructure to collect and treat the least amount of groundwater compared to the other alternatives.

Greater amounts of sludge will be produced by Alternative 11 compared to Alternatives 8, 9, and 10 for the same reason; more water is treated and more metals are prevented from entering the surface water environment under Alternative 11.

Alternatives 8 and 11 include an impermeable cap over the tailings pile(s). This cap must be maintained over the lifetime of the remedy to maintain its predicted effectiveness.

Alternative 9 does not include stability improvements to the waste rock piles and part of the tailings piles, thus stability of these waste dumps would be less reliable over time, and risk of a massive tailings release into Railroad Creek would be much greater than the other alternatives.

As a guide for assessing the relative degree of long-term effectiveness, MTCA states that the following types of cleanup components may be used, in descending order of preference:

- Reuse or recycling;

[34] A French drain is a type of groundwater collection system that typically consists of a perforated pipe installed in a trench that extends below the groundwater level and is backfilled with gravel. French drains intercept and divert groundwater by gravity flow.

- Destruction or detoxification;
- Immobilization or solidification;
- On-site or off-site disposal in an engineered, lined, and monitored facility;
- On-site isolation or containment with attendant engineering controls; and
- Institutional controls and monitoring.

These components are discussed below for each of the four alternatives.

3.4.2.1 Reuse or Recycling

None of the four alternatives include any significant reusing or recycling of materials at the Site.

3.4.2.2 Destruction or Detoxification

Detoxification of metals in groundwater through collection and treatment is included to some degree in each of the four alternatives. Alternative 11 provides the greatest volume of groundwater collected and treated (detoxified) compared to the other three alternatives. Alternative 11 treats approximately 600 MGY of groundwater, while Alternative 10 treats about 490 MGY, Alternative 8 treats about 360 MGY, and Alternative 9 treats about 325 MGY.

Each of the alternatives uses a groundwater treatment process involving lime addition to reduce acidity and precipitation to reduce concentrations of aluminum, cadmium, copper, iron, lead, and zinc. Treatment will produce metal hydroxide sludge, with the metals in a less toxic form than prior to treatment. Alternative 11 is anticipated to produce the largest volume of sludge, about 5.2 MGY (31,000 cy) per year, on average over the first 50 years of remediation. For comparison, Alternative 10 is anticipated to produce an annual average volume of about 4.6 MGY (27,000 cy) of sludge, Alternative 9 approximately 3.1 MGY (18,000 cy), and Alternative 8 approximately 3.4 MGY (20,000 cy).[35] The higher relative amount of sludge produced by Alternative 11 is due to its greater

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[35] The annual volume of sludge used in this comparison is based on an assumed solids concentration of 4 percent, which is the estimated concentration in a treatment system pond at the time that pond is taken off line for dewatering and sludge transfer to the landfill, as discussed in Appendix F of the SFS. Actual percent solids at this stage of treatment could vary.

volume of water treated and greater mass of metals removed compared to Alternatives 8, 9, and 10, because the additional source waters collected for treatment have metals that exceed aquatic life protection criteria and would otherwise enter Railroad Creek.

3.4.2.3 Immobilization or Solidification

Metals removed from groundwater through the treatment process for each of the alternatives become part of a sludge. Sludge stability is indicated by results of leaching tests to assess potential for metals to be released and re-enter the environment. Reported results of leaching tests from sludge from other mine sites indicate that metal concentrations in the leachate are typically well below those needed to protect groundwater at the Holden Site (Hart Crowser 2004). So long as the sludge is managed in an appropriately designed landfill, the metals are prevented from reaching Railroad Creek.

Based on the relative volume (and mass) of metal hydroxide sludges produced, Alternative 11 immobilizes a larger volume of metals than the other three alternatives.

3.4.2.4 On-Site or Off-Site Disposal

Based on available information, no wastes would be removed from the Site for off-site disposal under any of the proposed remedies. Experience on other abandoned mine sites indicates that residual processing wastes that fail state-only Dangerous Waste criteria could be encountered during clean up of the abandoned Holden mill building. If this occurs, the Agencies would determine whether such wastes could be stabilized and disposed of on the Site, or removed to an off-site landfill.

The four alternatives include consolidation of on-site materials from implementing the remedy (e.g., impacted soil removed from various locations across the Site, debris, and metal precipitates from the mine). These materials would be consolidated with tailings prior to closure of the tailings piles for Alternatives 8, 10, and 11. Presumably, the same could be accomplished in a limited purpose landfill constructed on site for Alternative 9.

3.4.2.5 On-Site Isolation or Containment

Alternative 11 provides the most complete on-site isolation of hazardous substances compared to the other four alternatives. Alternative 8 does more to provide on-site isolation of the tailings and waste rock than Alternatives 9 or 10, but does not isolate the impacted plume of groundwater in the LWA or under TP-1 and TP-3.

Alternatives 8 and 9 use a fully penetrating barrier wall for containment of contaminated groundwater for a portion of the Site, but rely on source control, natural attenuation, and/or source depletion processes for cleanup of groundwater over significant areas. In contrast, Alternative 11 would contain all the sources of impacted groundwater that discharge into the creek using a fully penetrating barrier wall and collection system adjacent to Railroad Creek. Alternative 10 would significantly contain most sources of impacted groundwater, but not to the same extent as Alternative 11. Alternative 10 does include plans for monitoring to determine whether the partially penetrating barrier and groundwater collection system should be extended along TP-2 as part of the final remedy, and whether the partially penetrating barrier is effective enough to be part of the final remedy.

Where a permanent remedy to achieve cleanup levels at the standard point(s) of compliance is not practicable, MTCA allows a conditional point of compliance for groundwater, subject to various conditions. Among these conditions [WAC 173-340-720(d)(i)] is the requirement that groundwater containment, including barriers or hydraulic control through groundwater pumping, or both, be implemented to the maximum extent practicable to avoid lateral and vertical expansion of the groundwater volume affected by the hazardous substance. Alternative 11 provides containment to a greater degree than do Alternatives 8, 9 and 10, and thus more fully satisfies the requirements for a conditional point of compliance. Similarly, Alternative 10 more fully satisfies the requirements for a conditional point of compliance in comparison to Alternatives 8 or 9.

3.4.2.6 Institutional Controls and Monitoring

The need for institutional controls is the same for the four alternatives, since none of them will eliminate groundwater metals concentrations above proposed cleanup levels, or eliminate the presence of hazardous substances (tailings and waste rock) at the Site.

The Agencies have developed a conceptual monitoring plan as part of Alternatives 10 and 11, which is presented in Appendix H of the SFS. Intalco has proposed deferring development of monitoring plans for Alternatives 8 and 9 until remedial design. It is likely that monitoring requirements for another alternative would be similar to the approach taken in Alternatives 10 and 11, but with additional monitoring needed in areas that rely on natural attenuation for clean up such as the LWA under Alternative 8 or 9; or on source depletion and natural attenuation such as TP-2 and TP-3, and part of TP-1 under Alternative 9.

3.4.2.7 Summary for Reliability over Time

Alternative 11 provides a greater degree of long-term effectiveness or reliability than the other three alternatives, based on the preferences given in WAC 173-340-360(3)(f)(iv).

3.4.3 Magnitude of Risks Remaining after Implementation

MTCA considers the magnitude of risks remaining after implementation as the third of four criteria for assessing long-term effectiveness of remedial alternatives.

The four alternatives differ significantly in the magnitude of risk remaining after implementation. The table presented in Section 3.1.1.1 shows that Alternative 9 would address less than 15 percent of the length of the creek where metals in groundwater are discharging above aquatic life protection criteria, compared to Alternative 11 that addresses all the source areas that discharge directly into the creek. Alternative 8 addresses about 30 percent of the creek length, and Alternative 10 about 70 percent. A lower percentage for source reduction indicates a correspondingly larger magnitude of releases that would continue after implementation of each alternative. The relative extent of each alternative in intercepting impacted groundwater that would otherwise directly enter Railroad Creek is illustrated on Figure G-8.

- Alternative 8 provides source control to limit potential for future releases from the consolidated tailings and waste rock, and includes collection of groundwater from below the consolidated pile. The DFFS load reduction model for Alternative 8 assumes that source removal would eliminate 80 to 90 percent of the metals loading to Railroad Creek from the LWA and below the current location of TP-1, but relies on natural attenuation to mitigate groundwater discharges to surface water from these areas and below TP-3. However, the Batch Flush Model described in Appendix A of the SFS shows that Intalco's assumed rate of load reduction for the LWA is not credible. (Groundwater below TP-2 would be contained and treated.)

- Alternative 9 would use containment and collection for groundwater in the UWA and a portion of groundwater below TP-1, but relies on source depletion and natural attenuation to mitigate groundwater discharges below the remainder of TP-1 and all of TP-2 and TP-3, and natural attenuation in the LWA. As noted above, the Batch Flush Model described in Appendix A of the SFS shows that Intalco's assumed rate of load reduction for the LWA due to the UWA barrier, is not credible.

- Alternative 10 provides containment and treatment for most of the impacted groundwater on the Site, with groundwater monitoring at TP-2 to determine whether groundwater from this tailings pile should be collected in the future. In the meantime, Alternative 10 would rely on source depletion and natural attenuation to mitigate groundwater discharges from TP-2.

- Alternative 11 provides containment, collection, and treatment for all sources of groundwater above proposed cleanup levels that would otherwise enter Railroad Creek, and monitoring to assure effectiveness of the remedy.

None of the four alternatives would clean up the groundwater on the Site within a reasonable restoration time frame and, therefore, each would need to rely on institutional controls to protect human health. The alternatives rely to varying degrees on the integrity of constructed caps, groundwater barriers, and treatment systems to protect human health and the environment. However, because both Alternatives 10 and 11 rely to a greater degree on active containment measures, Alternatives 10 and 11 are less reliant on natural attenuation and source depletion to protect surface water compared to Alternatives 8 and 9. Alternative 11 provides more active containment measures compared with Alternative 10. Thus, Alternative 11 would leave the least residual risk after implementation, compared to the other alternatives.

3.4.4 Effectiveness of Controls Required for Managing Residuals

MTCA's fourth criterion for assessing long-term effectiveness considers the effectiveness of the controls that would be required for managing treatment residues (e.g., impacted soils and other hazardous substances generated during remediation, and sludge from long-term wastewater treatment plant operations) that will remain on site after implementation.

The four alternatives are relatively similar in some regards: each would involve consolidation and on-site disposal of about the same amount of materials (e.g., debris from necessary mill demolition to remove contaminated soils and mineral processing residuals); each would involve excavation of about the same amount of contaminated soils to remediate the lagoon, ventilator portal detention area, etc.; and the water treatment facility for each of these alternatives would produce a metal hydroxide sludge for disposal.

Additional soil clean up may be required in the other areas (e.g., the LWA, the baseball field, areas within Holden Village, and the area of observed wind-blown tailings deposition east of the Village) that are apparently less impacted but still have metal concentrations above the proposed soil cleanup levels. Alternatives

10 and 11 include additional evaluation of risks associated with these other areas to determine whether additional soil clean up is needed. Alternatives 8 and 9 do not include any clean up in these areas, nor do these alternatives include any additional monitoring or risk evaluation.

The alternatives differ in the relative amount of sludge that would be produced.[36] The engineering management controls required for treatment plant operation and sludge disposal are similar for all the alternatives, although the size of the facilities and the amount of labor required to implement these controls would vary. The landfill performance criteria and other controls required for managing the residual sludge are the same for the four alternatives, even if the volume of sludge is not.

Alternatives 8 and 11 would require more engineering and management controls to maintain the tailings and waste rock pile cover(s), compared to Alternatives 9 and 10. Alternative 9 would not satisfy the state landfill closure requirements, which are potentially relevant and appropriate requirements as discussed in the SFS.

Considered on the whole, the four alternatives would require substantially similar engineering and management controls to manage treatment residues and hazardous substances left on site following implementation of the remedy. The alternatives differ primarily in the amount of sludge that will require handling, which is a function of the volume of metals removed from groundwater before it enters Railroad Creek. Alternative 11 would generate the largest volume of sludge because it treats the largest amount of water that is above aquatic life protection criteria and would otherwise directly enter the creek.

3.4.5 Summary of Effectiveness over the Long Term

The MTCA criteria for long-term effectiveness include: a) the degree of certainty that an alternative will be successful; b) reliability of the alternative over the period of time that hazardous substances will remain on site; c) the magnitude of risk remaining after implementation of the remedy; and d) the effectiveness of controls required to manage residues and remaining wastes left on the site. Based on consideration of these criteria, Alternative 11 provides greater long-term effectiveness than the other alternatives.

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[36] The amount of sludge produced is related to the volume of water that is collected and treated, as well as the amount of metals in the water.

3.5 Management of Short-Term Risks

Short-term risk management under MTCA [WAC 173-340-360(3)(f)(v)] includes the following:

- The risk to human health and the environment associated with the alternative during construction and implementation; and

- The effectiveness of the measures that will be taken to manage such risks.

During construction and initial implementation of the cleanup action there will be short-term risks that potentially affect both human health and the environment. Potential construction impacts for the four alternatives evaluated include:

1. Risk of a tailings release to Railroad or Copper Creeks during regrading;
2. Potential risk of bentonite or cement releases to the creeks during barrier wall construction, depending on the materials selected;
3. Risks associated with construction of hydraulic barriers in the underground mine;
4. Risk of sediment release to the creeks resulting from construction of groundwater and seep collection components, and temporary stream crossings;
5. Construction vehicle emissions, noise, and dust;
6. Risk of fuel and lime spills;
7. Risk of mass release of tailings from flood-induced instability;
8. Conventional construction safety risks;
9. Vehicle traffic safety risks; and
10. Risk of surface water quality exceedances after startup of the treatment plant.

The first seven of the issues listed above have already been discussed above in Section 3.1.3. Additional issues related to health and safety risks for workers and Holden Village residents, and management of risks to the environment are discussed below.

3.5.1 Short-Term Human Health Risk

Short-term human health risks due to remedy implementation at the Holden Site are primarily focused on construction safety, including traffic, and longer term risks associated with operation of the treatment facility. Table G-1 compares short-term human health risks from construction and presumed mitigation for Alternatives 8, 9, 10, and 11.

Human health and safety risks to construction workers from remedy implementation, include mine hazards previously discussed, construction traffic, open excavations for pipelines, and heavy equipment operations for regrading, barrier wall construction, treatment plant construction, exposure to soils with elevated concentrations of petroleum hydrocarbons and other hazardous substances, noise and dust exposure, and demolition of the derelict mill structure. The nature of these risks is consistent between the four alternatives, although the duration and number of workers exposed varies significantly, from Alternative 9 (the least) to Alternative 10, then to Alternative 11, and lastly to Alternative 8 (which is anticipated to have the greatest number of workers and longest duration of construction). For construction workers, the risk of worker injury increases with the overall level of construction required by the alternative.

Mitigation for the four alternatives would be based on conformance with state and federal construction safety standards [Chapter 296-155 WAC and 29 CFR Part 1926] and HAZWOPER standards [Chapter 296-62 WAC and 29 CFR Part 1910], and relevant and appropriate parts of MSHA safety standards for underground construction work [30 CFR Part 57].

Construction health and safety impacts to Holden Village residents and other members of the public (e.g., users of National Forest land in the vicinity) primarily consist of construction traffic safety issues, since it is unlikely there would be significant health risk due to exposure to vehicle emissions or dust for any alternative.

During construction, the contractor is expected to take measures to protect the public from trespass in construction areas. Traffic on the Lucerne-Holden Road during construction will increase compared to before and after remediation, and after remediation there will be somewhat more traffic than pre-construction to accommodate long-term delivery requirements for fuel and lime for the treatment system.[37] Generally, Alternative 9 will have the least traffic during and after construction. Alternative 10 will have less traffic during construction and less long-term traffic after construction is complete compared to Alternative 11, due to lower fuel and lime consumption requirements. Similarly, Alternative 8 will have greater construction traffic compared to both Alternatives 10 and 11, but will have less long-term traffic than Alternatives 10 and 11.

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[37] Even if electrical power for treatment facility operations is provided by hydroelectric generation, some fuel will be needed for equipment used to maintain the diversion swales and groundwater collection ditches, etc.

During construction, traffic through Holden Village can be avoided by use of a bridge across Railroad Creek at the east end of TP-3, which would enable traffic to access the south side of Railroad Creek without going through the Village. Figure G-6 is a map showing anticipated remedy construction impact areas. The Agencies expect that all traffic to construction staging area(s) and a potential temporary construction workers camp west of Holden Village could also be routed across a new bridge by TP-3, south of the tailings piles and then across the existing Holden Village vehicle bridge, so that there is no increase in construction traffic through the Village for any of the remedial alternatives.

Routing for traffic to supply fuel and lime to the treatment plant following startup would vary depending on the remedial alternative selected. Intalco has proposed that the treatment facility for Alternative 9, and one of the two treatment facilities for Alternative 8 would be located in the LWA, northwest of the abandoned mill. The other treatment facility location proposed by Intalco for Alternative 8 would be in the area currently occupied by TP-3. Intalco has suggested that the new bridge to be constructed east of TP-3 would not be a permanent fixture (URS 2005b), but no decision has been reached by the Agencies. If the new bridge by TP-3 is left after construction, it could provide access for fuel and lime delivery to the Alternative 8 and 9 treatment facility locations without increasing traffic through Holden Village.

Access for fuel and lime delivery to the Alternatives 10 and 11 treatment facility would not be through the Village, because the treatment facility for these alternatives is proposed to be located east of the Village.

3.5.2 Short-Term Environmental Risk

Short-term risks to the environment associated with implementation of the remedy were discussed in Section 3.1.3 as part of the discussion of protectiveness.[38] Table G-2 compares short-term environmental risks from construction and presumed mitigation for Alternatives 8, 9, 10, and 11.

In general, Alternative 9 appears to have less on- and off-Site risk during implementation than Alternatives 8, 10, or 11, because it involves less construction activity and, specifically, less construction activity immediately adjacent to Railroad Creek. However, Alternative 9 does not accomplish the same reduction in metals toxicity in Railroad Creek as Alternatives 8, 10, or 11.

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[38] These include risk of a tailings release during regrading; risk of bentonite or cement releases during barrier wall construction; risk of sediment release to the creeks; construction vehicle emissions, noise, and dust; and risk of fuel spills.

Therefore, the apparent lower risk of implementation is not significant in the MTCA disproportionate cost analysis.

Other environmental risks that would, or may, arise from initial implementation of the alternatives are the risk of water quality exceedances of proposed cleanup levels in Railroad Creek during startup of the treatment plant(s). Alternative 8 includes two treatment facilities, whereas Alternatives 9, 10, and 11 each only have one treatment facility, so there is some increased complexity in operation of the Alternative 8 treatment system during startup, and associated risk of effluent water quality problems resulting from this.

3.5.3 Summary of Management of Short-term Risks

In summary, Alternative 9 has relatively less risks to human health and the environment due to implementation, because it involves the least remedial activity to clean up the Site. Alternative 8 has the most potential to cause impacts to Railroad Creek during tailings regrading, consumes the most fuel, and has the greatest potential noise, dust, and traffic-related impacts to Holden Village residents, simply because it involves the greatest amount of remedial construction. However, construction-related impacts are not directly comparable for the different alternatives, since Alternatives 8 and 9, and possibly Alternative 10, would not be final remedies, and the degree of additional impacts to provide the same degree of protectiveness as Alternative 11 have not been identified to date.

Much of the discussion of short-term risks was provided in Section 3.1.3. As noted in Section 3.5.1, the four alternatives involve the same kinds of short-term risks to humans, and risk mitigation (conventional construction site health and safety practices, traffic management, etc.) are essentially the same for each alternative.

Many of the short-term environmental risks due to remedy implementation are similar from one alternative to another, but there are differences. In each case the significant differences involve a tradeoff between short-term risks during construction to achieve greater long-term (essentially permanent) benefits of the remedy. For example:

- Alternatives 8, 10, and 11 would produce a greater short-term risk of tailings releases during regrading, but much less risk of instability impacting the creeks over the long-term, compared to Alternative 9.

- Alternative 11 would produce more short-term risk of barrier construction impacting the creeks compared to the other alternatives, but would provide groundwater containment and collection for treatment of a much greater volume of groundwater that would otherwise enter the creeks above concentrations that are protective of aquatic life.

In summary, the degree of short-term risk is related to the amount of construction accomplished to clean up the Site. However, since Alternatives 8, 9, and 10 would not be permanent remedies, a direct comparison with the amount of construction proposed for Alternative 11 is inappropriate. Since the same risk management techniques are available for each alternative, the degree of short-term risk associated with Alternative 11 is no greater than the other alternatives and overall may be less.

3.6 Technical and Administrative Implementability

Each alternative under consideration has various technical and administrative issues that impact its ability to be implemented. The implementability issues to be considered under MTCA [WAC 173-340-360(3)(f)(vi)] include:

- Whether the alternative is technically feasible;
- The availability of the necessary off-site facilities, services, and materials;
- Administrative and regulatory requirements;
- Scheduling;
- Size;
- Complexity;
- Monitoring requirements;
- Access for construction operations and monitoring; and
- Integration with existing facility operations and other current or potential remedial actions.

3.6.1 Technical Feasibility

Each of the alternatives can be technically implemented. The main issues that affect technical implementation are related to installation of the groundwater containment and operation of the associated collection systems, and the maintenance of the groundwater collection system over time. Groundwater treatment is similar for the four alternatives. The alternatives differ in location and number of treatment facilities, but mainly in the volume of water and sludge that would be handled.

3.6.1.1 Groundwater Containment Systems

The DFFS described use of cement-bentonite and soil-bentonite groundwater barriers. This type of barrier has been constructed by the "slurry trench" method since the 1960s, in a wide range of different soils types. Slurry trench construction technology is well suited to subsurface conditions at the Site that include glacial and alluvial soils with boulders, but other types of barriers such as secant walls constructed by soil mixing or jet grouting may be further considered during remedial design. Barrier wall systems are frequently used for groundwater containment and waste isolation, and may be considered "best available technology" for this type of application, as discussed in Appendix C of the SFS.

Construction of the groundwater containment for each of the alternatives is technically feasible, despite their differences in location and geometry. There are a number of specialty contractors with experience in this type of construction. Duration of barrier construction from one alternative to another is directly related to length and depth of the barrier.

- Construction of the Alternative 8 groundwater barrier wall will extend 55 to 80 feet below ground surface (depending on the depth of underlying glacial till or bedrock) over a length of about 3,600 feet. However, cutoff walls at this depth have frequently been constructed at other sites.

- Construction of the barrier for Alternative 9 is anticipated to be less difficult compared to the other alternatives. This barrier would be only 15 to 20 feet in depth and about 2,500 feet in length, since it is intended to affect only a limited portion of the groundwater moving across the Site.

- The partially penetrating barrier for Alternative 10 is also relatively shallow; its depth is anticipated to average about 30 feet, depending on final design. The barrier for Alternative 10 is anticipated to be about 5,900 feet in length, since it is intended to improve surface water across most of the Site.

- Construction of the Alternative 11 groundwater barrier wall would be the most technically challenging of the four alternatives although cutoff walls of this depth have frequently been constructed at other sites. The Alternative 11 barrier wall would extend about 35 to 80 feet below ground surface (depending on the depth of underlying glacial till or bedrock along the length of the Site) and over a length of about 8,300 feet.

Intalco has questioned whether Alternative 10 is technically implementable. Specifically, Intalco questions effectiveness of the barrier, since it would not fully penetrate the saturated alluvium overlying the less permeable glacial till and bedrock as would the barrier walls for Alternatives 8, 9, and 11. However, partially penetrating barriers are used as part of groundwater clean up at other sites, and modeling indicates that a partially penetrating barrier would overall be more than 80 percent effective in preventing contaminated groundwater from entering Railroad Creek (see Attachment B to Appendix F of the SFS). Under seasonal low water conditions, some creek water would enter the groundwater collection ditch and be conveyed to the treatment system, but this is estimated to add less than 2 percent to the volume of contaminated groundwater that is collected. Further discussion of the effectiveness of barrier walls is included in Appendix C of the SFS.

The DFFS suggests that fully penetrating barriers and groundwater would have a 90 percent collection efficiency in the UWA but only 80 percent adjacent to the tailings piles. The DFFS suggested this 10 percent reduction in collection efficiency would occur due to iron precipitation in the collection system; however, no data or experience were cited to support this assumption. Also, the DFFS did not discuss whether regular maintenance of the collection system would eliminate this potential decrease in collection efficiency.

The four pumped wells included in Alternative 9 can technically be implemented, but are not sufficient to achieve ARARs or prevent discharge of impacted groundwater into Railroad Creek. Intalco proposed limited goals: removal of a portion of the impacted groundwater below TP-1, at a rate of 60 gpm. However, the four wells proposed by Intalco have the potential to draw in creek water. To limit this withdrawal of creek water, the rate of pumping, and perhaps the number of pumped wells, would need to be monitored and adjusted to accommodate seasonal changes, which would further reduce the likelihood that Alternative 9 would achieve ARARs. Limiting the number of wells or pumping rate would reduce the amount of contaminated groundwater from TP-1 that could potentially be collected for treatment. Final implementation of Alternative 9, therefore, would require more than the four wells proposed by Intalco to be protective and meet ARARs.

3.6.1.2 The Duration and Complexity of Maintaining the Groundwater Collection Systems

Maintenance of the groundwater collection systems would be quite different for the four alternatives. Maintenance of the groundwater collection system is anticipated to be required for the entire duration of the remedy, estimated to be on the order of hundreds of years.

Alternative 8 uses a French drain (a perforated pipe in a trench backfilled with gravel) along the upgradient side of the barrier wall, for collection of groundwater. Alternative 9 would use a similar system for the UWA barrier and seep collection systems. The perforated pipe is subject to clogging due to inflow of sediment and potential chemical precipitation (e.g., fouling by iron or aluminum hydroxides), but flow can be maintained by periodic use of a pipe-cleaning tool (referred to as a "pig").

Iron fouling is anticipated to be a problem for the French drain in Alternative 8 that extends around the consolidated tailings pile, and for the seep collection drains in Alternative 9. Intalco indicates the degree of fouling can be minimized or avoided by keeping the perforated pipes continuously below the groundwater level, to avoid entry of air that would enable conversion of dissolved ferrous iron to ferric iron sludge within the drain. Similarly, Intalco has suggested that iron fouling of the pumped wells in TP-1 for Alternative 9 can be minimized or avoided by proper well installation; and by controlling pumping rates to avoid groundwater drawdown that would expose the well screens to air, and by avoiding pumping relatively oxygen-rich creek water into the wells (URS 2006).

Experience at other sites indicates that iron fouling is a major concern, and it is unclear whether Intalco's approach is viable, see SFS Appendix F and URS (2004b). Monitoring would be needed if either Alternative 8 (French drain) or 9 (pumped wells and French drains for seep collection) is implemented, to determine whether these approaches are viable as a permanent remedy. For Alternative 9, the rate of pumping could need to be limited to control drawdown to reduce iron fouling. Pilot testing would be needed to determine the magnitude of groundwater collection, and whether there was any consequent surface water quality improvement.

In contrast, Alternatives 10 and 11 would collect groundwater in open ditches, which would provide ready access for removal of iron or aluminum sludges if sludge build-up is a maintenance issue. Alternatives 10 and 11 have only limited lengths of pipe (e.g., across Railroad and Copper Creeks, and within the treatment system) that would require use of a cleanout pig for maintenance.

Intalco has suggested that winter maintenance of the ditches used in Alternatives 10 and 11 would be a problem if they became frozen and ice dams caused release of contaminated groundwater into Railroad Creek. No information is available at the Site to indicate whether flow in collection ditches would continue below a surficial ice crust, or whether ice dams would impede flow and be a problem. Also, there is potential for replacing the open trenches with submerged drains (as proposed for the Alternative 9 seep collection) or wood plank covers that have been used for railway ditches.

Maintenance of the treatment system components is anticipated to be similar for the four alternatives. Problems may occur with chemical addition and mixing in winter weather, operation of media filters under freezing conditions, and sludge disposal. Generally the maintenance to mitigate treatment system problems becomes more difficult for alternatives that have larger water treatment volume requirements. However, a system with higher winter flow rates (e.g., Alternative 11) may be less susceptible to freezing than systems with lower flow rates. Maintenance needs would also be greater for Alternative 8, which includes two treatment plants. The treatment system for Alternative 11 would handle approximately 600 MGY, while Alternative 10 would handle about 483 MGY, Alternative 8 would handle about 357 MGY, and Alternative 9 would handle about 324 MGY.

3.6.1.3 Feasibility of Treatment

The feasibility of groundwater treatment is similar for the four alternatives, as they each rely on acid neutralization and precipitation to remove metals, and produce metal hydroxide sludge. The alternatives differ in location, but the main difference is the volume of water and sludge that would be handled.

The differences in location, and volume of water and sludge, affect the energy required for each alternative. No commercial electrical supply is available at Holden. Holden Village has no excess generating capacity from its hydroelectric system. Each of the remedy alternatives would rely on generators using imported fuel or possibly a new hydroelectric energy source, to provide electricity for necessary pumping, freeze protection, etc.

More energy is required to collect and treat all the impacted groundwater at the Site, than for only a portion of the impacted groundwater. Alternatives 8 and 9 would use less energy for treatment; as they rely mainly on gravity flow, although Alternative 9 includes pumping from wells and TP-1 seeps. The treatment facility in the west portion of the Site would be located downgradient from the main groundwater collection areas. Alternative 8 includes treatment in the east portion of the Site, and the DFFS is unclear what pumping would be required. Alternatives 10 and 11 would have treatment facilities located on the north side of Railroad Creek and, therefore, a substantial portion of water flowing into the treatment facility would need to be pumped. Sludge would need to be pumped for the four alternatives.

3.6.1.4 Summary of Technical Feasibility

The groundwater containment system proposed for Alternative 11 is technically feasible, and is well within the standard of practice used at other sites, as discussed in Appendix C of the SFS. So too is the containment proposed for Alternatives 8 and 9. There is not presently available information to address some of the questions Intalco raised about the effectiveness of the partially penetrating barrier for Alternative 10.

Groundwater collection proposed for the four alternatives is technically feasible, subject to the maintenance required to control the effects of iron fouling. Iron fouling may limit effectiveness of the Alternative 8 French drain, and the French drain and pumped wells proposed for Alternative 9. In contrast, the open ditch collection systems proposed for Alternatives 10 and 11 are easier to maintain to remove iron fouling, but potentially more subject to winter freezing.

The technical feasibility of operating and maintaining the treatment system; considering duration and complexity of the cleanup action, is similar for all alternatives. Alternatives 8 through 11 use the same pH adjustment and precipitation-based treatment technology, and face the same constraints presented by remote site operations. The main difference is the volume of water and sludge that would be handled under Alternative 11 and the associated energy requirements, since this alternative does more to address groundwater above proposed cleanup levels, compared to the other alternatives.

In summary, there is no reason to conclude that one alternative is less feasible than the others.

3.6.2 Availability of Off-Site Facilities, Services, and Materials

The availability of off-site facilities, services, and materials is not anticipated to be a factor in selection of, or successful implementation of, any of the alternatives.

- The Agencies anticipate that there will be construction firms and vendors willing to do this work and that the firms bidding for this work will be experienced in the technologies required for each alternative.

- None of the alternatives is adversely impacted by the need to work in a remote geographic location. Necessary equipment would be able to be moved to the Site for the four alternatives. Construction equipment and material would be brought to the Site via barges from Chelan.

- The technologies required for each of the components in the four alternatives are known and proven technologies.

3.6.3 Administrative and Regulatory Requirements

The alternatives differ in the degree to which they satisfy administrative and regulatory requirements, as was discussed in detail for Alternatives 9, 10, and 11 in the SFS. Similar issues are relevant for Alternative 8, as described below.

The main issues that affect administrative implementation for the four alternatives are:

- Ability to satisfy requirements for a groundwater conditional point of compliance; and

- Compliance with potential ARARs.

These issues are discussed below.

3.6.3.1 Ability to Satisfy Requirements for a Conditional Point of Compliance

The MTCA standard point of compliance for groundwater is throughout the saturated zone, all across the Site. The DFFS concluded that there is no practical approach to achieve potential groundwater ARARs throughout the Site. Therefore, Ecology may approve conditional points of compliance that are a) protective of surface water, and b) as close as practicable to the source of hazardous substances. While it should be as close as practicable to the sources, the approved conditional points of compliance may be located no farther within surface water than as close as technically possible to the point or points where groundwater flows into surface water, subject to the requirements of WAC 173-340-720(8)(d)(i).

For Ecology to approve conditional points of compliance at the groundwater surface water interface, there are seven conditions that must be met.

1. *It has been demonstrated that the contaminated groundwater is entering the surface water and will continue to enter the surface water even after implementation of the selected cleanup action.*

Alternatives 8, 9, and 10 would not address all sources of contaminated groundwater that enters Railroad Creek. Alternative 11 would address all identified sources, and will greatly reduce the volume of contaminated groundwater entering Railroad Creek. Unless the barrier is perfect (which is unlikely), there would still be some potential release of contaminated groundwater past the barrier that may enter the creek.

2. *It has been demonstrated that it is not practicable to meet the cleanup level at a point within the groundwater before entering the surface water, within a reasonable restoration time frame.*

   The DFFS asserted that it is not practicable to meet proposed groundwater cleanup levels at a point within groundwater before entering surface water, within a reasonable restoration time frame. There is no basis to reach a different conclusion for Alternatives 9 or 10. However, the Alternative 11 barrier may enable groundwater to reach cleanup levels between the barrier and the groundwater surface water interface within a reasonable restoration time frame. Since it uses the best technology available (see SFS Appendix C), if Alternative 11 does not produce this result, then it would demonstrate that it is not practicable to meet the cleanup level at a point within the groundwater before entering the surface water, within a reasonable restoration time frame.

3. *Use of a mixing zone to demonstrate compliance with surface water cleanup levels shall not be allowed.*

   Alternative 11 does not rely on a mixing zone to demonstrate compliance with surface water cleanup levels. Use of a mixing zone is implicit in the DFFS Model that Intalco used for evaluation of alternatives, but is not allowed under MTCA.

4. *Groundwater discharges will be provided with all known available and reasonable methods of treatment (AKART) before being released to surface waters.*

   AKART is an acronym for all known, available, and reasonable methods of treatment.[39] For conditions at the Site, groundwater containment and collection are necessary precursors to treatment.

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[39] All Known, Available, and Reasonable Methods of Treatment, is the definition provided in the MTCA regulations [e.g., WAC 173-340-200 (within the definition of "All

Alternative 11 would collect and treat all the sources of groundwater that exceeds proposed cleanup levels. This comprehensive collection for treatment constitutes AKART.

Alternatives 8, 9, and 10 do not include barrier walls and groundwater collection from all sources. It is possible to collect these waters for treatment, using readily available off-the shelf barrier wall technology as discussed in Appendix C of the SFS. It is also reasonable to collect the groundwater that exceeds aquatic life protection criteria. Since Alternatives 8, 9, and 10 do not provide collection for treatment of *all* sources of impacted groundwater above proposed cleanup levels that would otherwise enter the creek; they do not meet the requirement for AKART.

Alternative 11 would immediately reduce the discharge of metals in groundwater baseflow to Railroad Creek by installing a barrier and collection system along the Railroad and Copper Creeks. Alternatives 8, 9, and 10 do not include this degree of available and reasonable treatment. Collection of groundwater for treatment is necessary based on conditions at the Site. By reducing the flow of metals-impacted groundwater into Railroad Creek, Alternative 11 does not rely on source depletion or natural attenuation to achieve proposed surface water cleanup levels, as do the other alternatives.

5. *Groundwater discharges will not result in violations of sediment quality values.*

   Existing sediment quality is more likely to improve following implementation of Alternative 11 than any other alternative, since Alternative 11 would address all identified sources of groundwater above proposed cleanup levels that discharge into Railroad Creek. Following implementation of the cleanup action to remove the sources of metals discharge, sediment quality is anticipated to improve due to the natural channel erosion and transport associated with high velocity alpine streams such as Railroad and Copper Creeks.

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practicable methods of treatment"); WAC 173-340-720(8)(d)]. Note that other state regulations use AKART to refer to All Known, Available, and Reasonable Methods of Prevention, Control, and Treatment [e.g., WAC 173-201A-020], and this definition is also applicable to the Site.

Sediment quality would be assessed following implementation to determine whether any additional cleanup action was required, as described in the SFS and the conceptual monitoring program presented in Appendix H of the SFS.

6. *Groundwater and surface water monitoring will be conducted to assess the long-term performance of the selected cleanup action.*

   Each of the alternatives includes groundwater and surface water monitoring after implementation of the remedy. However, Alternative 9 does not readily enable groundwater monitoring along the portion of Railroad Creek that abuts the toe of the tailings piles. Regrading the tailings pile slopes for Alternative 9 decreases the steepness of some of the slopes, but does not pull back the tailings piles from Railroad Creek. For Alternative 9, there is no room available between the tailings piles and the creek to install monitoring wells in close proximity to the conditional point of compliance, as there is with Alternatives 8, 10, and 11.

7. *Before approving the conditional point of compliance, a notice of proposal will be sent to the natural resource trustees, the Washington State Department of Natural Resource (DNR), and the US Army Corps of Engineers.*

   This specific requirement of sending a notice of proposal to approve a conditional point of compliance could be equally satisfied by any of the alternatives. The Agencies anticipate that such a notice would be sent at about the same time the Proposed Plan is issued for public comment.

In summary, Alternative 11 meets the MTCA criteria for a conditional point of compliance for groundwater. Alternatives 8, 9, and 10 do not constitute AKART, and thus a conditional point of compliance could not be approved for these alternatives.

3.6.3.2 Compliance with Potential ARARs

The degree to which Alternatives 9, 10, and 11 would satisfy potential ARARs is discussed in the SFS, and the degree to which Alternative 8 would satisfy potential ARARs is discussed in the DFFS. A summary of the four alternatives is provided below.

- Alternative 8 would not be protective of the environment, since it would not eliminate releases to surface water that cause exceedance of aquatic life protection criteria. The proposed cleanup levels are based on potential ARARs for surface water and groundwater discharging to surface water at the Site are the National Recommended Water Quality Criteria aquatic life chronic toxicity criteria, and the Washington State Water Quality Standards for Surface Water aquatic life chronic toxicity criteria, or background, whichever is greater.

The proposed cleanup level is based on the potential ARARs for soil at the Site are Washington State MTCA soil cleanup criteria for the protection of terrestrial organisms, and protection of groundwater and surface water or background, whichever is greater. Alternative 8 would not address ecological risk to other areas of the Site that have been impacted by releases from the mine, including Holden Village and the wind-blown tailings area.

The potential ARARs for waste rock and tailings at the Site are the Washington State Solid Waste Handling Standards. Alternative 8 would not address closure of the Honeymoon Heights Waste Rock Piles as required by this potential ARAR.

- Alternative 9 would not be protective of human health since it would not address tailings that exceed allowable concentrations for dermal contact and ingestion.

  Alternative 9 would not be protective of the environment, since it would not eliminate releases to surface water that cause exceedance of aquatic life protection criteria.

  Alternative 9 would not address ecological risk to other areas of the Site that have been impacted by releases from the mine, including Holden Village and the wind-blown tailings area.

  Alternative 9 would not address closure of the waste rock and tailings piles as required by this potential ARAR.

- Alternative 10 may not be protective of the environment, since it would not eliminate releases to surface water that cause exceedance of aquatic life protection criteria. At this time, there is insufficient information to show whether Alternative 10 would achieve proposed cleanup levels in a reasonable restoration time frame. Alternative 10 could be implemented as an interim remedy, and additional analyses might show Alternative 10 would satisfy the requirements for a final remedy or that additional actions could be needed to satisfy requirements for a final remedy.

  Alternative 10 would be protective of human health since it would address closure of tailings that exceed allowable concentrations for dermal contact and ingestion. Alternative 10 includes an ecological risk assessment to determine whether the proposed tailings pile cover would be adequately protective of potential terrestrial receptors.

Alternative 10 would address ecological risk to other areas of the Site that have been impacted by releases from the mine, including Holden Village and the wind-blown tailings area.

Alternative 10 would not address closure of the Honeymoon Heights Waste Rock Piles as required by the Washington State Solid Waste Handling Standards that are a potential ARAR.

- Alternative 11 is anticipated to comply with all potential ARARs under federal environmental laws and state environmental or facility siting laws.

  Alternative 11 is anticipated to satisfy potential ARARs for surface water and groundwater discharging to surface water at the Site, which are the National Recommended Water Quality Criteria aquatic life chronic toxicity criteria, and the Washington State Water Quality Standards for Surface Water aquatic life chronic toxicity criteria, by collecting for treatment all the identified sources of groundwater above aquatic life criteria that discharge into Railroad Creek.

  The potential ARARs for soil, waste rock, and tailings at the Site are Washington State MTCA soil cleanup criteria for the protection of terrestrial organisms, and protection of groundwater and surface water. Alternative 11 includes completion of additional terrestrial ecological risk assessment to determine final soil cleanup requirements that would be protective of terrestrial receptors. Alternative 11 would provide downgradient containment to protect groundwater from wastes and impacted soils left on the Site.

  The Washington State Solid Waste Handling Standards for closure of limited purpose landfills is a potential ARAR for the tailings and waste rock piles. Alternative 11 includes closure of all the tailings and waste rock piles in accordance with this potential ARAR.

3.6.3.3 Summary of Administrative and Regulatory Requirements

The primary issues associated with whether an alternative satisfies administrative and regulatory requirements at the Site, involve whether the alternative satisfies MTCA requirements for a conditional point of compliance; and whether an alternative is anticipated to satisfy potential ARARs. As discussed in Sections

3.6.3.1 and 3.6.3.2, Alternative 11 satisfies these administrative and regulatory requirements to become a final remedy, better than do Alternatives 8, 9, or 10.

3.6.4 Scheduling

Scheduling for design and construction is not anticipated to be a factor for selection of any of the four alternatives.

Design, including baseline monitoring is anticipated to take 1 to 2 years for any of these alternatives.

Construction of Alternative 9 is anticipated to require two construction seasons (each season roughly 5 to 6 months duration), while Alternatives 10 and 11 would likely require three construction seasons. Alternative 8, because of the significantly larger volume of earthwork, would likely require double shifts to be accomplished in 3 years, or possibly could extend into four construction seasons.

3.6.5 Size and Complexity

Alternative 9 has less regrading and involves collection of groundwater from a smaller portion of the Site, so implementation is less complex than Alternatives 8, 10, or 11. Alternative 8 is larger and more complex than the other alternatives because it involves significantly more earthwork and construction of two treatment facilities rather than one. Alternative 11 is larger and more complex than Alternative 10, because of the longer and deeper barrier wall used for Alternative 11.

While Alternative 11 is not the smallest or least complex alternative, its size and complexity are not disproportionate to the degree of clean up accomplished. Alternative 11 is the only alternative that could be implemented as a final cleanup action for the Site, based on presently available information. The size and complexity of implementing Alternative 11 are well within the range of cleanup actions accomplished at other sites.

3.6.6 Monitoring Requirements

Alternatives 10 and 11 include a conceptual monitoring plan developed by the Agencies. It is reasonable and readily implementable. Intalco has proposed deferring development of monitoring plans for Alternatives 8 and 9 until remedial design.

The Agencies anticipate that generally similar performance objectives would be required for monitoring any remedy selected, but expect that details of the monitoring would vary for the four alternatives, to determine compliance, effectiveness, and protectiveness of the remedy. While the monitoring objectives would be relatively similar, more monitoring activity is anticipated to be required for Alternatives 8, 9, and 10, compared to Alternative 11, since Alternatives 8, 9, and 10 would not be final cleanup actions and additional monitoring would be required to determine their effectiveness and the potential need for augmentation.

3.6.7 Access for Construction Operations and Monitoring

Access to the overall Site for construction is the same for the four alternatives. The Agencies anticipate that materials and supplies would be barged up Lake Chelan to Lucerne, and a temporary construction camp would be established for the duration of construction. Remedial work would probably be seasonal. Summer time construction traffic on the Lucerne-Holden Road would need to accommodate Holden Village traffic and other users of the National Forest.

Alternatives 8, 10, and 11 include regrading to set back the toe of the tailings pile slopes a sufficient distance to enable remedial construction, and thus would provide permanent access for monitoring and maintenance of remedial components (e.g., groundwater monitoring; tailings pile slopes and cover; groundwater and seep collection ditch; and riprap) alongside Railroad and Copper Creeks.

By excavating and regrading the tailings from east to west, Alternatives 10 and 11 will enable a stormwater collection ditch to be advanced concurrent with the earthwork. This will enable collection and conveyance of metals-laden stormwater runoff from the construction area for treatment prior to discharge into Railroad Creek.

Alternative 9 does not include pulling the tailings back from Railroad Creek, and thus does not enable sequential regrading to advance a stormwater collection ditch that could be used to collect stormwater runoff during tailings pile regrading. There is no provision in Alternative 9 for stormwater detention or treatment downgradient of construction disturbance areas during the tailings pile regrading, despite the analysis in the DFFS that predicted the assumed worst case runoff from a 1-inch 24-hour storm could discharge cadmium, copper, iron, and zinc into Railroad Creek at concentrations more than four orders of magnitude (10,000 x) above the proposed ARARs (see Table 7-8 of the DFFS).

Alternative 8 also does not include provision for detention and treatment of stormwater runoff during tailings regrading, although it appears that a detention and treatment facility could be constructed after removal of TP-3, to provide stormwater management during subsequent regrading of TP-2 and relocation of TP-1. By locating the downstream water treatment facility for Alternative 8 within the footprint of TP-3, rather than north of the creek as in Alternatives 10 and 11, Intalco has eliminated use of the permanent water treatment facility during relocation of TP-3, which would involve excavating more than 1,000,000 cy of reactive tailings.

The four alternatives include comparable access for monitoring across most of the Site, except that Alternative 9 does not include access for monitoring downgradient of the tailings piles at the groundwater-surface water interface. As a result, groundwater compliance for Alternative 9 would need to be determined by monitoring in wells located within the tailings piles and extrapolation of groundwater quality downgradient of these wells.

3.6.8 Integration with Existing Facility Operations and Other Current or Potential Remedial Actions

The four alternatives can be integrated with remedial work previously accomplished. This could include potential reuse of some existing observation wells for groundwater monitoring; reuse of some existing riprap installed along Railroad and Copper Creeks; and construction access for installation of hydraulic bulkheads through the 1500 Level mine portal that was reopened in 2000.

Alternative 11 could be implemented as a final cleanup action. Implementation of Alternatives 8, 9, or 10 as an interim action could require integration of future cleanup actions to augment and complete the remedy.

The four alternatives can be modified during the design phase if further analysis indicates improvements can be made in achieving the cleanup action sooner, more reliably, or more cost-effectively.

3.6.9 Summary of Technical and Administrative Feasibility

In summary, the four alternatives are technically feasible, although the specific issues and attributes of each alternative are different. The four alternatives have comparable ability to use off-Site resources. Scheduling, size, and complexity of the alternatives do not indicate any one is more or less technically or administratively feasible.

Alternative 11 is more able to satisfy administrative and regulatory requirements than Alternatives 8, 9, or 10.

Although objectives of monitoring are similar for all alternatives, specific monitoring elements for Alternative 11 are better defined than for Alternatives 8, 9, and 10, since the degree to which additional monitoring would be needed to assess the protectiveness of an interim remedy is not yet defined. Alternatives 8, 10, and 11 have better access for monitoring downgradient of the tailings than does Alternative 9, and Intalco did not develop a conceptual monitoring plan for Alternatives 8 or 9.

Finally, Alternatives 8, 9, and 10 will likely need to be supplemented to varying degrees by future potential remedial measures, whereas Alternative 11 is anticipated to satisfy requirements for a final cleanup action. Alternative 11 is the only alternative that would address all the identified sources of groundwater that enter Railroad Creek with metals concentrations above aquatic life protection criteria.

As a result of combining these factors, Alternative 11 is more readily able to be implemented as a final remedy compared to Alternatives 8, 9, or 10.

3.7 Consideration of Public Concerns

The final evaluation criterion used to determine whether a proposed remedial alternative uses permanent solutions to the maximum extent practicable is consideration of public concerns. Since none of the alternatives have been presented for public comment, this criterion is not evaluated in this document.

4.0 Summary and Conclusions

The groundwater containment, collection, and treatment system placed along Railroad Creek in Alternative 11 would be more effective than the barrier and collection system proposed for the other alternatives. Alternative 11 would contain, collect, and treat all identified sources of groundwater above aquatic life protection criteria that would otherwise enter Railroad Creek. The greater the extent of a barrier wall system adjacent to Railroad Creek, the more effective it will be in preventing hazardous substances from entering the creek.

Alternative 11 includes moving the toe of the tailings piles away from Railroad and Copper Creeks, regrading the slopes to improve stability, and capping, to prevent the risk of releasing hazardous substances into the creeks.

By providing greater collection and containment of contaminated groundwater adjacent to Railroad Creek, Alternative 11 achieves a shorter restoration timeframe than Alternatives 8, 9, or 10, with a unit cost for groundwater treatment and collection that is less than for other alternatives. Alternative 11's active groundwater collection and treatment system is not disproportionately more costly than Alternatives 8, 9, or 10, which rely on natural attenuation and source depletion processes.

Alternative 11 is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. Based on the analyses described in this appendix, Alternative 11 uses permanent solutions to the maximum extent practicable, and to a greater degree than the other alternatives.

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Table G-1 - Short-Term Human Health Risk - Alternative Comparison

Potential Impacts	Alternative 8	Alternative 9	Alternative 10	Alternative 11
Vehicle Traffic Risk	Worker or Holden resident/visitor injury. The duration and number of vehicles required for implementation would be greater than Alt. 9, 10, and 11.	Worker or Holden resident/visitor injury. The duration and number of vehicles required for implementation would be less than Alts. 8, 10, and 11.	Worker or Holden resident/visitor injury. The duration and number of vehicles required for implementation would be greater than Alt. 9, but less than Alt. 8 and 11.	Worker or Holden resident/visitor injury. The duration and number of vehicles required for implementation would be greater than Alts. 9 and 10, but less than Alt. 8.
Mitigation	Minimize traffic through Holden Village, develop construction traffic control plan for Lucerne-Holden Road.			
Excavations/Regrading Risk	Worker injury. Volume of tailings pile and waste rock regrading is 4,150,000 cubic yards. Increased risk due to increased duration of work compared to Alt. 9, 10, and 11.	Worker injury. Volume of tailings pile regrading is 250,000 cubic yards. Barrier wall construction over 2,500 linear feet. Reduced risk due to shorter work duration compared to Alts. 8, 10, and 11.	Worker injury. Volume of tailings pile and waste rock regrading is 740,000 cubic yards. Barrier wall construction over 5,870 linear feet. Increased risk due to increased duration of work compared to Alt. 9, reduced compared to Alt. 8 and 11.	Worker injury. Volume of tailings pile and waste rock regrading is 790,000 cubic yards. Barrier wall construction over 7,700 linear feet. Increased risk due to increased duration of work compared to Alts. 9 and 10, but less than Alt. 8.
Mitigation	Adherence to applicable OSHA and WISHA regulations. Constructions workers required to have HAZWOPER training.			
Mine Work Risk	Worker injury. Mine actions the same for Alternatives 8, 9, 10, and 11.			
Mitigation	Adherence to appropriate MSHA standards.			
Treatment Plant Construction Risk	Worker injury. Two treatment plants will be constructed for this alternative. Increased risk to workers due to increased construction duration compared to the other three alternatives.	Worker injury. One treatment plant constructed in Alternatives 9, 10, and 11.		
Mitigation	Adherence to appropriate OSHA and WISHA regulations.			
Noise and Dust Concerns No Risk Anticipated	Possible effects on workers and Holden residents/ visitors. Noise duration from construction increased compared to Alt. 9, 10, and 11. Greater potential for dust generation compared to Alt. 9, 10, and 11, due to consolidation of tailings and waste rock.	Possible effects on workers and Holden residents/ visitors. Noise duration from construction less than Alts. 8, 10, and 11. Less potential for dust generation compared to Alts. 8, 10, and 11, due to limited regrading of tailings.	Possible effects on workers and Holden residents/ visitors. Noise duration from construction increased compared to Alt. 9, but less than Alt. 8 and 11. Similar potential for dust generation compared to Alt. 11, due to same regrading area; greater potential for generation than Alt. 9, but less than Alt. 8.	Possible effects on workers and Holden residents/ visitors. Noise duration from construction increased compared to Alts. 9 and 10. Similar potential for dust generation compared to Alt. 10, due to same regrading area; greater potential for generation than Alt. 9, but less than Alt. 8.
Mitigation	Best Management Practices to limit dust generation. Adherence to applicable OSHA and WISHA regulations, including HAZWOPER.			

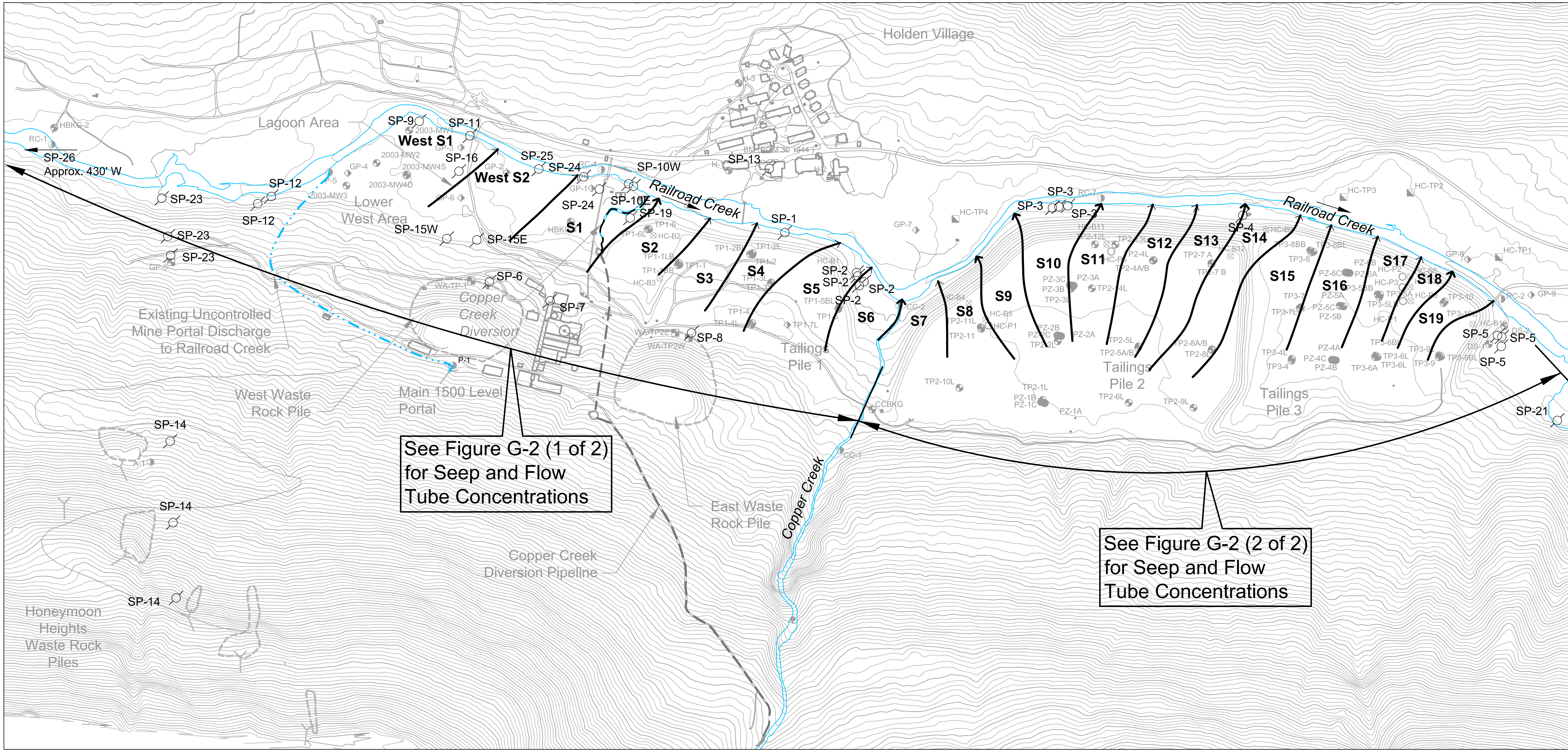
Table G-2 - Short-Term Environmental Risk - Alternative Comparison

Potential Impacts	Alternative 8	Alternative 9	Alternative 10	Alternative 11
Tailings Regrading Risk	Dust generation, potential tailings release into Railroad Creek, and potential for short-term water quality degradation due to impacted runoff for the three alternatives.			
	Volume of tailings pile and waste rock regrading is 4,150,000 cubic yards. Risk increased compared to Alt. 9, 10, and 11.	Volume of tailings pile regrading is 250,000 cubic yards. Less risk compared to Alts. 8, 10, and 11.	Volume of tailings pile and waste rock regrading is 740,000 cubic yards. Greater risk compared to Alt. 9. Same risk as Alt. 11, but less than Alt. 8.	Volume of tailings pile and waste rock regrading is 740,000 cubic yards. Greater risk compared to Alt. 9. Same risk as Alt. 10, but less than Alt. 8.
Mitigation	Treatment of stormwater runoff during regrading of TP-3 would require temporary treatment facility outside the area needed for other remedial construction. Runoff from regrading TP-2 and TP-1 could be accomplished with groundwater treatment facility.	No apparent option to collect and treat stormwater runoff impacted by tailings regrading.	The groundwater treatment facility could treat impacted runoff.	The groundwater treatment facility could treat impacted runoff.
	For all alternatives stormwater pollution prevention could include diversion of surface water run-on; use of silt fences or temporary berms; spraying mist to prevent dust; and concurrent placement of soil cover with regrading.			
Groundwater Barrier and Collection System Installation Risk	Potential release of construction materials (e.g., cement, bentonite), contaminated soil, or runoff into Railroad Creek. Barrier wall construction over approximately 2,000 linear feet adjacent to the creek. Risk increased compared to Alt. 9.	Potential release of construction materials (e.g., cement, bentonite), contaminated soil, or runoff into Railroad Creek. Groundwater extraction and seep interception system construction next to creek on Tailings Pile 1. Less risk compared to Alts. 10 and 11.	Potential release of construction materials (e.g., cement, bentonite), contaminated soil, or runoff into Railroad Creek. Barrier wall construction over approximately 5,870 linear feet adjacent to the creek. Greater risk compared to Alt. 9, less compared to Alt. 11.	Potential release of construction materials (e.g., cement, bentonite), contaminated soil, or runoff into Railroad Creek. Barrier wall construction over approximately 7,700 linear feet adjacent to the creek. Greater risk compared to Alts. 9 and 10.
Mitigation	The groundwater treatment facility could treat impacted runoff for all alternatives.			
	For all alternatives stormwater pollution prevention could include diversion of surface water run-on; use of silt fences or temporary berms; and construction of temporary sedimentation basins.			
Groundwater Conveyance System (Stream Crossings) Installation Risk	One potential pipeline stream crossing. Potential release from construction equipment working in creek (e.g., fuel spill, hydraulic fluid), or sediment into Railroad Creek. Risk of release increased compared to Alt. 9.	Groundwater conveyance not required over creeks for Alt. 9. No ferricrete removal so no risk associated with construction equipment working in creek.	Two pipeline stream crossings. Potential release from construction equipment working in creek (e.g., fuel spill, hydraulic fluid), or sediment into Railroad Creek. Risk of release increased compared to Alt. 9.	Two pipeline stream crossings. Potential release from construction equipment working in creek (e.g., fuel spill, hydraulic fluid), or sediment into Railroad Creek. Risk of release increased compared to Alt. 9.
Mitigation	Diversion of surface water; use of silt fences; temporary spill booms; SWPPP implementation.	No mitigation required for this item.	Diversion of surface water; use of silt fences; temporary spill booms; SWPPP implementation.	

Table G-2 - Short-Term Environmental Risk - Alternative Comparison

Potential Impacts	Alternative 8	Alternative 9	Alternative 10	Alternative 11
Fuel Delivery and Usage Risk	Potential for fuel spills and exhaust emissions, related to construction equipment and vehicles. Due to longer construction duration, increased risk for Alt. 8 compared to Alt. 9, 10, and 11.	Potential for fuel spills and exhaust emissions related to construction equipment and vehicles. Due to shorter construction duration, decreased risk for Alt. 9 compared to Alts. 8, 10, and 11.	Potential for fuel spills and exhaust emissions related to construction equipment and vehicles. Due to longer construction duration, increased risk for Alt. 10 compared to Alt. 9, but less than Alt. 8 and 11.	Potential for fuel spills and exhaust emissions related to construction equipment and vehicles. Due to longer construction duration, increased risk for Alt. 11 compared to Alts. 9 and 10, but less than Alt. 8.
Mitigation	Adhere to Washington State regulations regarding storage, transportation, and dispensing of fuel; including a contingency plan in case a release occurs.			
Surface Water Quality/Wastewater Production Risk	Potential for wastewater release to Railroad Creek. Due to longer construction duration, increased risk for Alt. 8 compared to Alt. 9, 10, and 11.	Potential for wastewater release to Railroad Creek. Less risk for Alt. 9 compared to Alts. 8, 10, and 11.	Potential for wastewater release to Railroad Creek. Due to longer construction duration, increased risk for Alt. 10 compared to Alt. 9. Less risk for Alt. 10 compared to Alt. 8 and 11.	Potential for wastewater release to Railroad Creek. Due to longer construction duration, increased risk for Alt. 11 compared to Alts. 9 and 10, but less than Alt. 8.
Mitigation	Obtain a Washington State wastewater discharge permit and comply with the state's wastewater discharge regulations.			
Net Gain (Loss) of Forest Habitat Risk	Some forest habitat lost during construction of the Lower West Area treatment facility. One of the treatment facilities for Alt. 8 is located in the Lower West Area, adjacent to Railroad Creek. Loss would include mature riparian forest considered to have high habitat value. East area treatment facility for Alt. 8 would be located in the area of former Tailings Pile 3.	Some forest habitat lost during construction of the treatment facility in the Lower West Area, adjacent to Railroad Creek. Loss would include mature riparian forest considered to have high habitat value.	Some forest habitat loss due to construction of the treatment facility. Treatment facility located downstream of tailings piles on the northern side of Railroad Creek.	Some forest habitat loss due to construction of the treatment facility. Treatment facility located downstream of tailings piles on the northern side of Railroad Creek.
Mitigation	Minimize treatment facility footprint within wooded area west of lagoon, and maximize treatment facility footprint in the east area with less habitat impacts.	Minimize treatment facility footprint within wooded area west of lagoon.	Minimize treatment facility footprint.	Minimize treatment facility footprint.

Seeps and Flow Tubes that Discharge into Railroad Creek for Spring Conditions



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Approximate Exploration Location

- Monitoring Well
- Boring
- Test Pit
- Percolation Test
- Surface Water Sample
- Waste Rock Pile

→ Inferred Groundwater Flow Path

S4 Flow Tube Designation

SP-25 Seep Location and Designation

Notes: Seep and flow tube locations and designations from URS, 2004a and Hart Crowser, 2005a.

Groundwater flow and concentrations vary seasonally due primarily to the effect of snowmelt and runoff. As used in the SFS and related documents, spring conditions refer to the May to June period approximately 90 days long when snowmelt causes relatively high groundwater levels. See text for additional discussions.

N

0 500 1000

Scale in Feet

HARTCROWSER

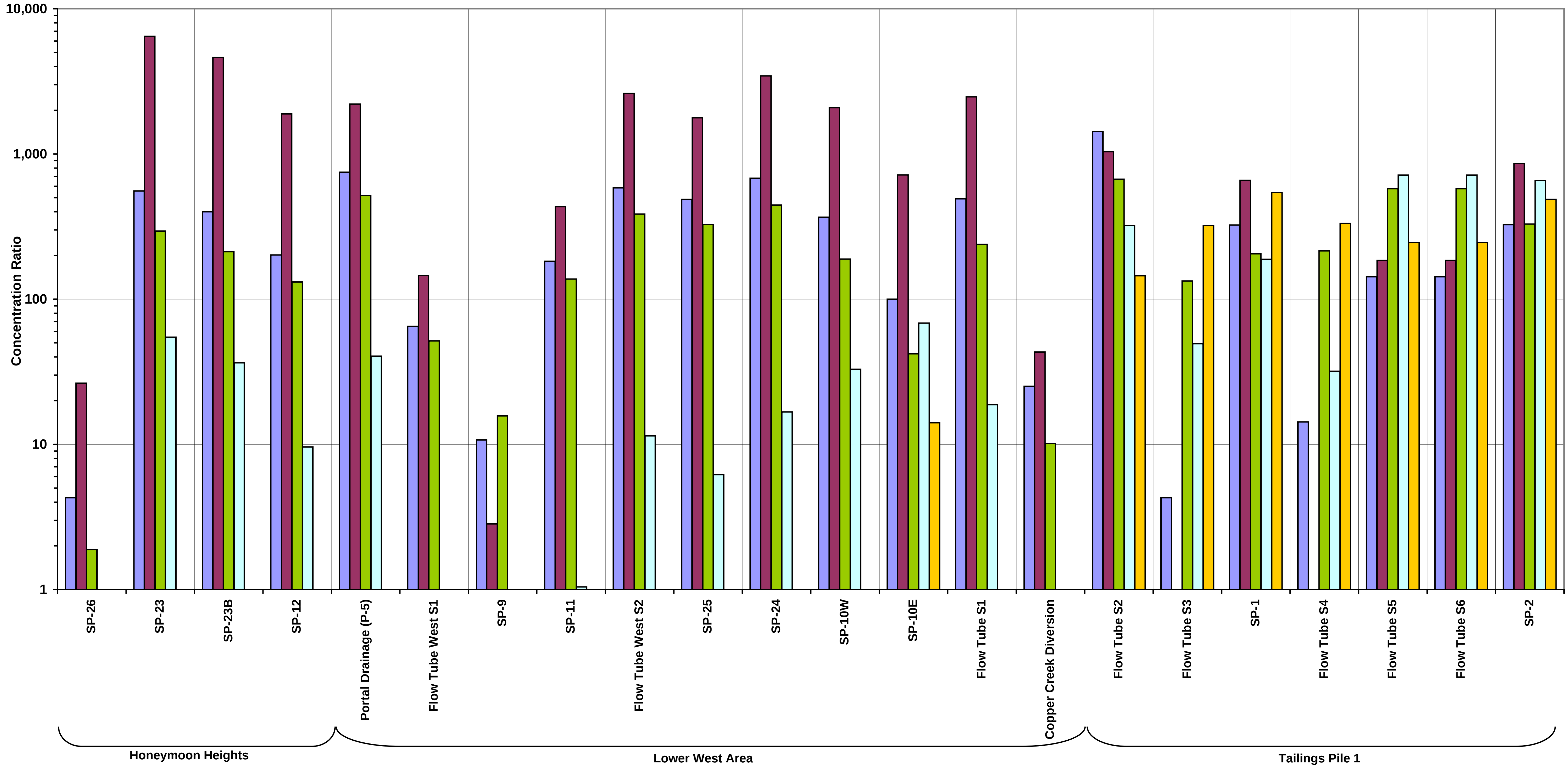
4769-11 ***9/07***

Figure G-1

SFS - Appendix G

Ratio of Groundwater (Including Seep) Concentrations to Proposed Cleanup Levels - Spring

Sources Discharging into Railroad Creek from West to East



Notes

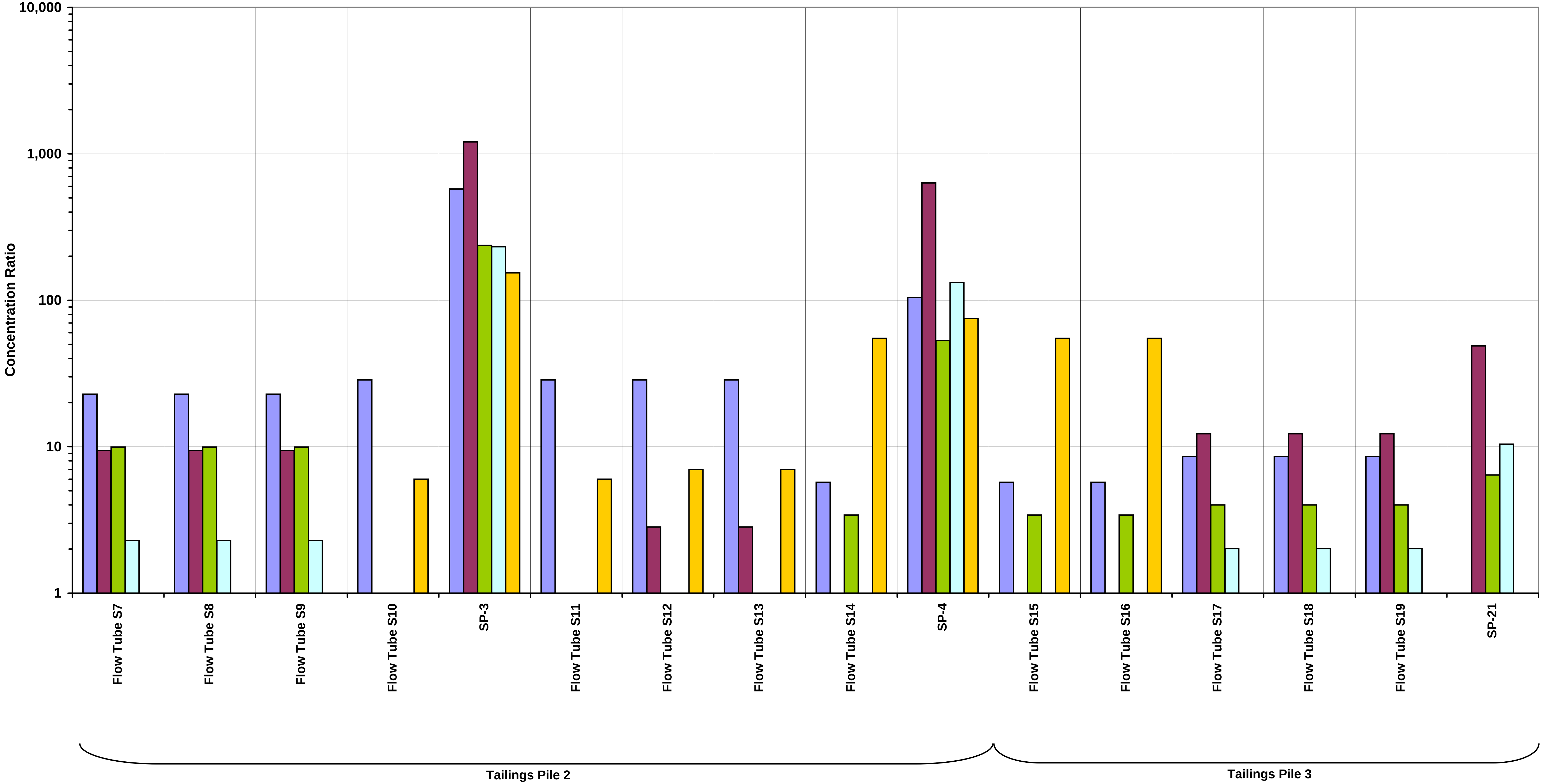
1. Plot shows the ratio of metal concentrations to proposed cleanup levels in Railroad Creek, for seeps and flow tubes that discharge into the creek.
2. Groundwater and seep concentrations are from URS 2004a, except concentrations for Flow Tubes West S1 and West S2 are based on data from URS 2006 and URS 2004a using the same method as described in URS 2004a.
3. See Figure G-1 for location of seeps and flow tubes.

Figure 8 9 Holden Conc Ratios 080707.xls - Spring Figure G-2

HARTCROWSER

4769-11 *9/07*
Figure G-2 *1/2*
SFS - Appendix G

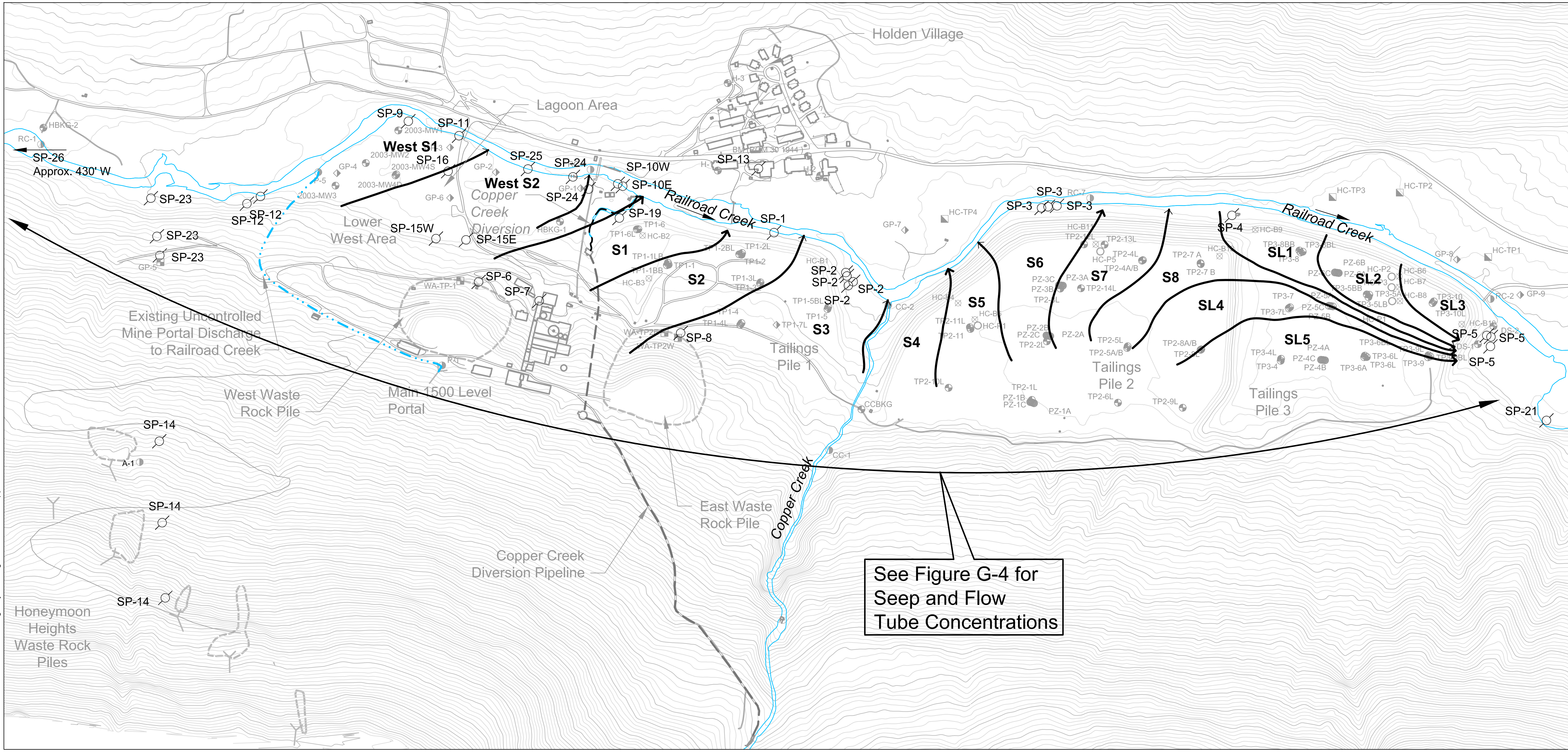
Ratio of Groundwater (Including Seep) Concentrations to Proposed Cleanup Levels - Spring
Sources Discharging into Railroad Creek from West to East



Notes

1. Plot shows the ratio of metal concentrations to proposed cleanup levels in Railroad Creek, for seeps and flow tubes that discharge into the creek.
2. Groundwater and seep concentrations are from URS 2004a, except concentrations for Flow Tubes West S1 and West S2 are based on data from URS 2006 and URS 2004a using the same method as described in URS 2004a.
3. See Figure G-1 for location of seeps and flow tubes.

Seeps and Flow Tubes that Discharge into Railroad Creek for Fall Conditions



Approximate Exploration Location

- Monitoring Well
- Boring
- Test Pit
- Percolation Test
- Surface Water Sample
- Waste Rock Pile

- Inferred Groundwater Flow Path
- **S4** Flow Tube Designation
- SP-25 Seep Location and Designation

Note: Seep and flow tube locations and designations from URS, 2004a and Hart Crowser, 2005.

Groundwater flow and concentration vary seasonlly due primarily to the effect of snowmelt and runoff. As used in the SFS and rlated documents, fall flow conditions are assumed to be representative of all low flow seasons (i.e., July through April). See text for additional discussion.

N

0 500 1000
Scale in Feet

HARTCROWSER

4769-11 *9/07*

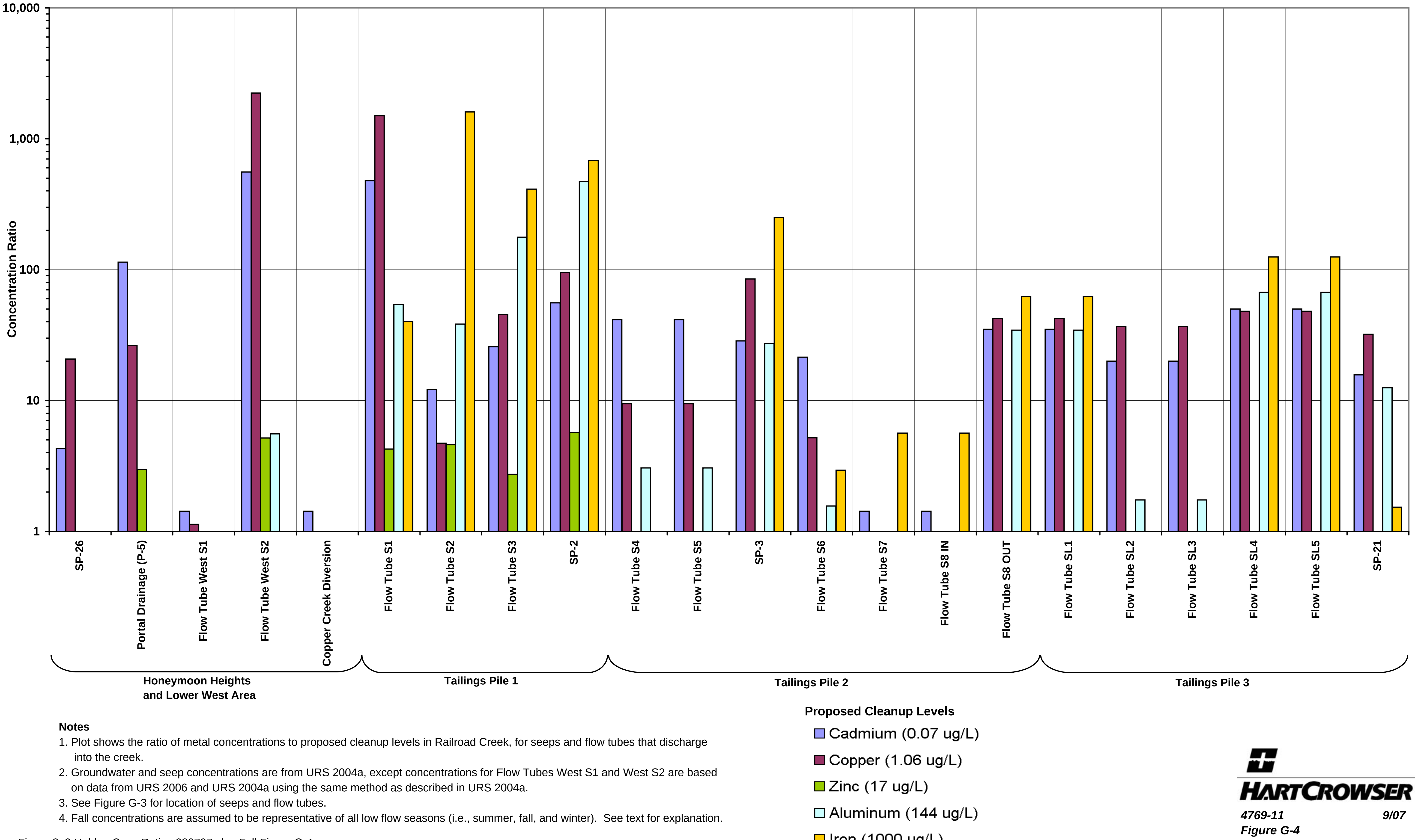
Figure G-3

SFS - Appendix G

EAL 09/14/07 47691101-013.dwg Layout: Figure G-3 - SFS - Appendix G

Ratio of Groundwater (Including Seep) Concentrations to Proposed Cleanup Levels - Fall

Sources Discharging into Railroad Creek from West to East



Notes

1. Plot shows the ratio of metal concentrations to proposed cleanup levels in Railroad Creek, for seeps and flow tubes that discharge into the creek.
2. Groundwater and seep concentrations are from URS 2004a, except concentrations for Flow Tubes West S1 and West S2 are based on data from URS 2006 and URS 2004a using the same method as described in URS 2004a.
3. See Figure G-3 for location of seeps and flow tubes.
4. Fall concentrations are assumed to be representative of all low flow seasons (i.e., summer, fall, and winter). See text for explanation.

Figure 8 9 Holden Conc Ratios 080707.xls - Fall Figure G-4

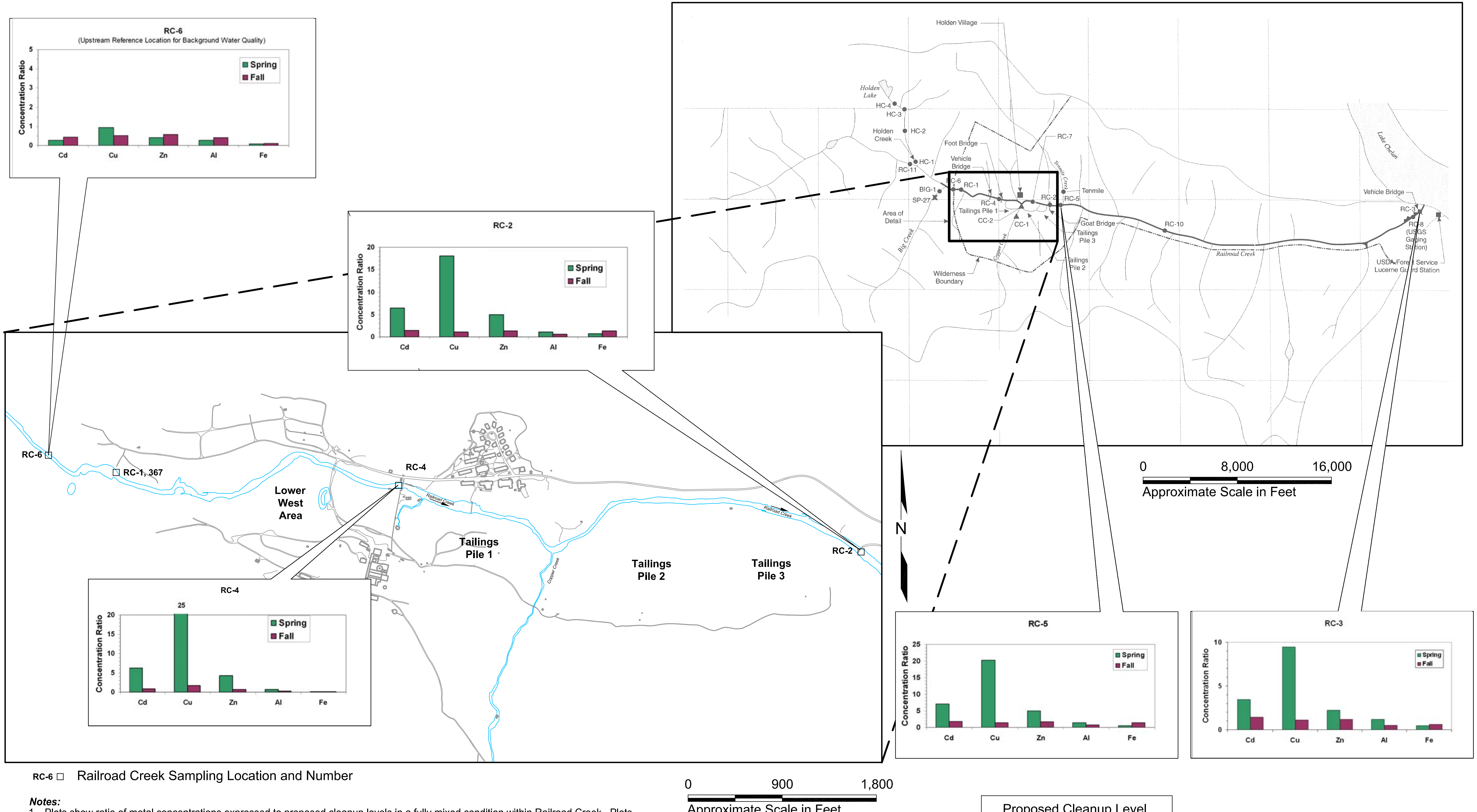
HARTCROWSER

4769-11 *9/07*

Figure G-4

SFS - Appendix G

Ratio of Surface Water Concentrations to Proposed Cleanup Levels



EAL 9/14/07 47691107-017.dwg Layout: Figure G-5 - SFS - Appendix G

Notes:

1. Plots show ratio of metal concentrations expressed to proposed cleanup levels in a fully mixed condition within Railroad Creek. Plots do not reflect metal concentrations at the point within Railroad Creek where a conditional point of compliance could be established under MTCA. Metals concentration at the point of compliance will be higher than in the fully mixed stream.
2. Proposed cleanup levels are based on lowest proposed cleanup level (including correction for hardness based on 12 mg/L CaCO3, where applicable) or background, whichever is greater. Proposed cleanup level for dissolved copper based on background concentration, pending further analysis.
3. Railroad Creek surface water metal data are from May 1997 and September 1997.
4. Dissolved concentrations of Cd, Cu, and Zn and total concentrations of Al and Fe were compared to proposed cleanup levels.
5. Small scale base map prepared from Draft Final Feasibility Study, URS 2004a. Large scale base map prepared from LIDAR topographic survey provided by URS 2004.
6. Fall concentrations are assumed to be representative of all low flow seasons (i.e., summer, fall, and winter). See text for explanation.

Proposed Cleanup Level in ug/L (See Note 2)	
Dissolved Cd	0.07
Dissolved Cu	1.06
Dissolved Zn	17
Total Al	144
Total Fe	1000

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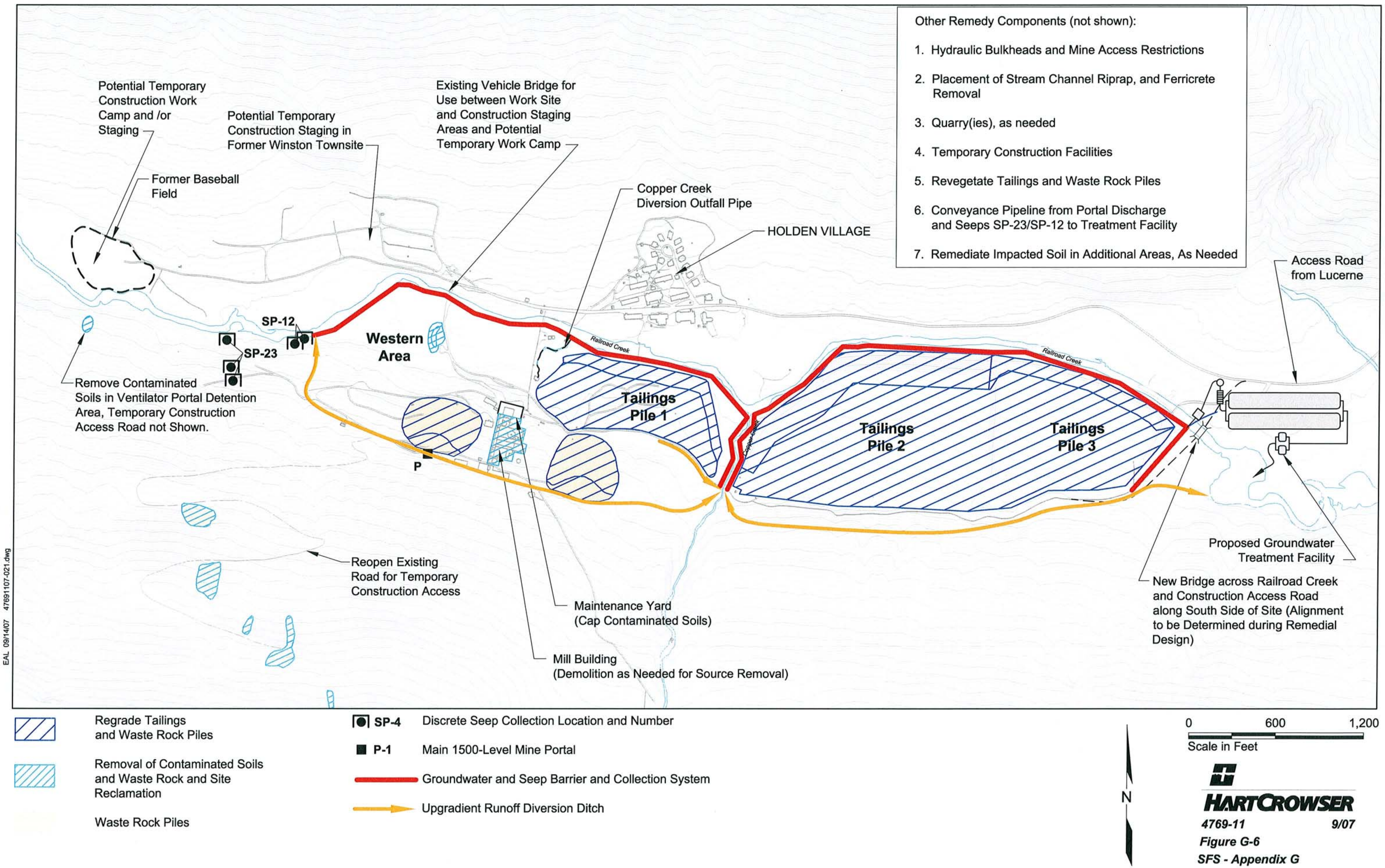
4769-11 *9/07*

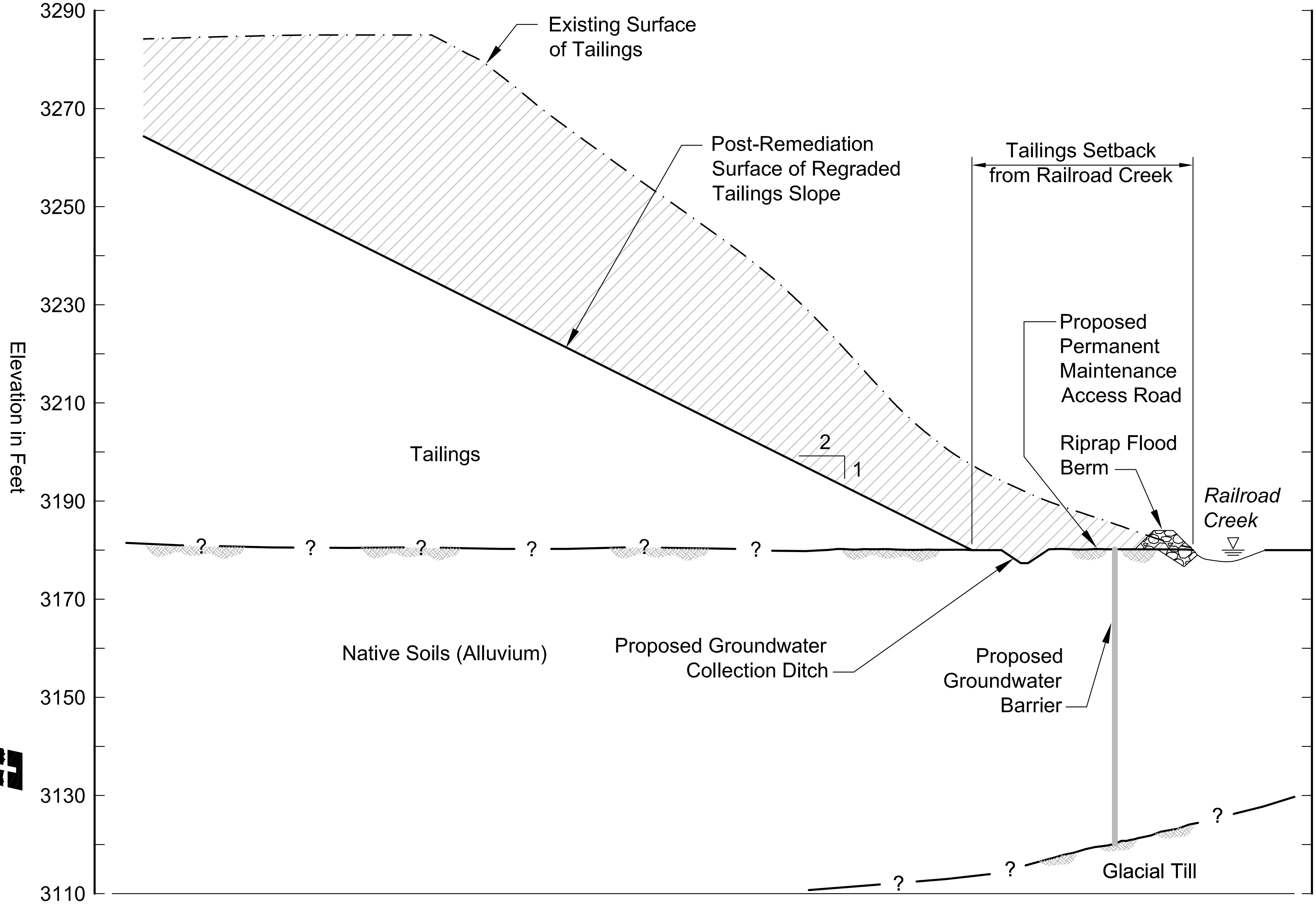
Figure G-5

SFS - Appendix G

Anticipated Remedy Construction Impact Areas



Schematic of Proposed Tailings Pile Regrading adjacent to Railroad Creek for Alternative 11



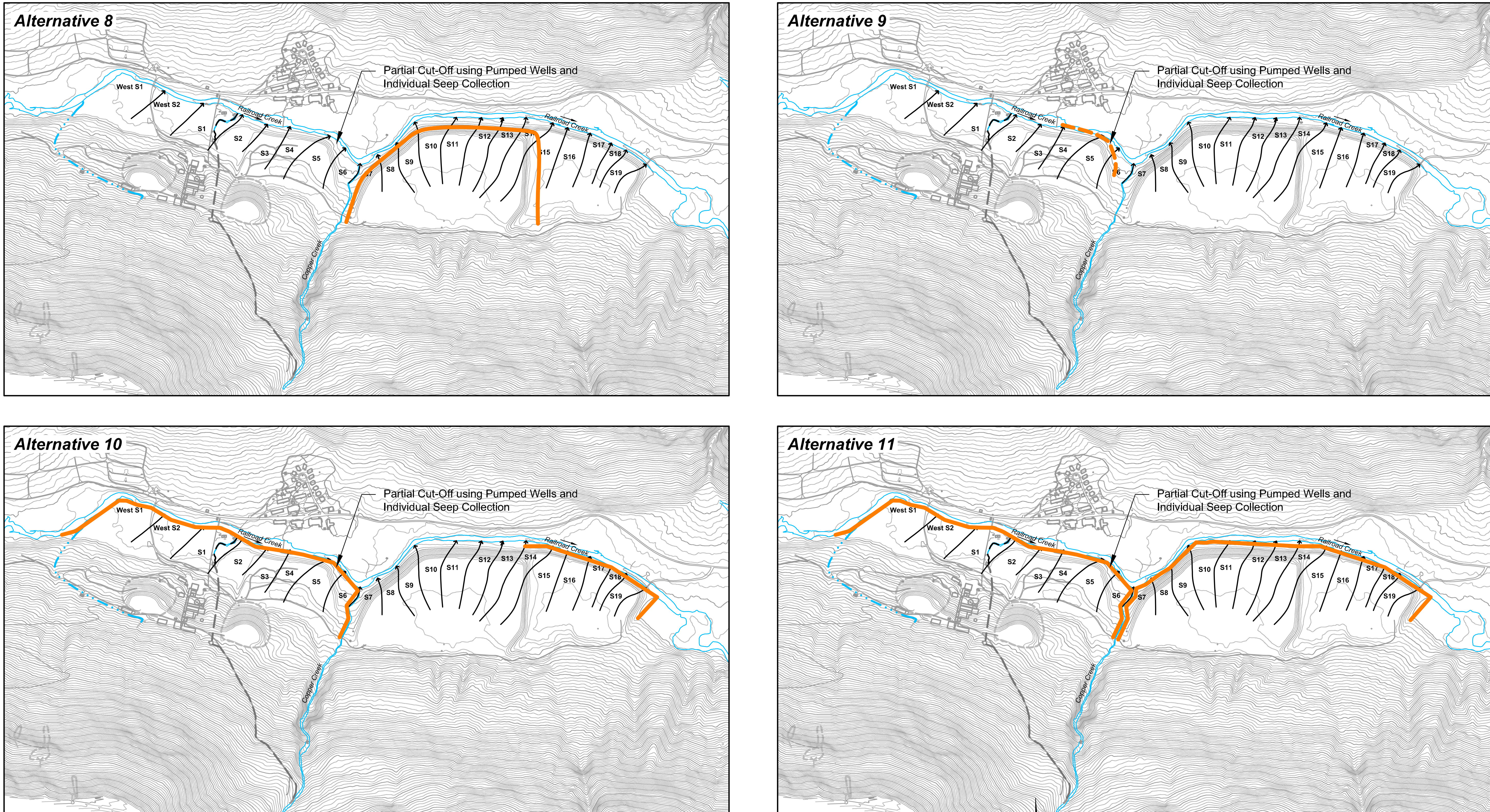
Note:

1. Final setback distance and slope of tailings pile to be determined during remedial design. Nominal 45-foot setback and 2H:1V tailings slope shown for discussion purposes only.
2. Depth to glacial till varies.

EAL 9/18/07 476911-029.dwg Layout: Figure G-7 - SFS - Appendix G

HARTCROWSER
4769-11 9/07
Figure G-7
SFS - Appendix G

Portion of Groundwater Entering Railroad Creek that will be Directly Cut-off by Alternatives 8, 9, 10, and 11 (Spring Conditions)



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Source: Base map prepared from LiDAR topographic survey provided by URS 2004

Extent of groundwater containment and collection along Railroad Creek

Note: Flow tube limits are different for fall flow conditions but the extent of groundwater containment and collection is similar. Extent of groundwater collection of Honeymoon Heights seeps and portal discharge not shown.

N

0 1000 2000
Scale in Feet

HARTCROWSER

4769-11 *9/07*

Figure G-8

SFS - Appendix G

APPENDIX H
CONCEPTUAL MONITORING PROGRAM

MEMORANDUM

DATE: March 10, 2005 (revised April 23, 2007)

TO: Mr. Norman Day, U.S. Forest Service

FROM: Michael Bailey, PE, Hart Crowser, Inc.; Erin Breckel, Floyd | Snider; and Dana Cannon, Aspect Consulting

RE: **Conceptual Monitoring Program for Holden Mine Site**
4769-11

This memorandum describes the Conceptual Monitoring Program that would be implemented as part of the proposed cleanup action to eliminate the release of hazardous substances at the former Holden Mine Site (Site). Cleanup of the Site is required by the federal Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Section 117(a) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR § 300.430(f)(2); as well as the State of Washington's independent authority under the Model Toxics Control Act (MTCA, Chapter 70.105D RCW and the regulations promulgated thereunder at Chapter 173-340 WAC).

This Conceptual Monitoring Program was prepared as part of developing and evaluating cleanup alternatives on behalf of the United States Department of Agriculture Forest Service (Forest Service), acting with the United States Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology). These agencies are collectively referred to as "the Agencies." Proposed cleanup levels are discussed in the Supplemental Feasibility Study (SFS, Forest Service 2007).

This Conceptual Monitoring Program provides a framework for discussion with Intalco and the public of the components that are expected to be in the final Monitoring Plan. The Conceptual Monitoring Program provides the basis for developing a Monitoring Plan, including a Sampling and Analysis Plan (SAP) and Quality Assurance Plan (QAP), that would be approved by the Agencies during remedial design (RD). This Conceptual Monitoring Program discusses how on-site monitoring would address the following items: documentation of baseline conditions and compliance monitoring; monitoring for remedy protectiveness; monitoring for remedy effectiveness; and operation and maintenance monitoring. The media to be monitored include surface water, groundwater, sediment, soil, terrestrial and aquatic biota and habitat, and performance of the remedy components.

Elements of this Conceptual Monitoring Program are summarized in Table H-1. Conceptual monitoring locations are shown on Figures H-1 and H-2; final monitoring locations would be determined by the Agencies during RD and specified in the SAP.

IMPLEMENTATION OF THE MONITORING PLAN

The Agencies intend that monitoring begin during RD to provide a representative measure of baseline conditions that can subsequently be used to assess protectiveness and effectiveness of the cleanup action. The approved Monitoring Plan would be reviewed every 5 years after implementation of the cleanup action, or at other times as needed. Potential future changes in monitoring, which could include provisions for reduction and eventual termination of monitoring, would be based on performance of the remedy. Interpretation of monitoring results and any changes in the approved Monitoring Plan would need to include acceptable statistical measures.[1] The Agencies expect that operation and maintenance of the remedy would continue for more than 200 years, as discussed in the SFS. Some monitoring would continue as long as the remedy is being implemented; however, the Agencies expect that some monitoring could be reduced in frequency and scope, and eventually eliminated, upon demonstration that the remedy is protective of human health and the environment.

PURPOSE OF MONITORING

The purpose and scope of the Conceptual Monitoring Program can be divided into these four categories:

- **Compliance Monitoring.** This monitoring occurs at the points of compliance necessary to assess whether soil and water quality achieves cleanup levels following implementation of the remedy. Points of compliance for soil, groundwater, and surface water are discussed in the SFS.

- **Monitoring for Remedy Protectiveness.** The cleanup action must be protective of human health and the environment [WAC 173-340-360(2)(a)(i), and 40 CFR § 300.430(e)(9)(iii)(A)]. Monitoring to assess protectiveness is particularly relevant since the proposed remedy relies to

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[1] For example, the frequency of some monitoring may need to be modified over time based on scatter in the data collected.

some degree on containment, and hazardous materials will remain in on-site soils, mine wastes, and groundwater following implementation.

- **Monitoring for Remedy Effectiveness.** Monitoring for remedy effectiveness is intended to assess whether components of the cleanup action, such as the groundwater barrier and collection system, conveyance, and treatment facility components, are effectively meeting their respective design objectives for the remedy. Monitoring for effectiveness of the remedy is closely related to operations and maintenance monitoring that is discussed below.

- **Operation and Maintenance Monitoring.** Operation and maintenance of the remedy will be needed on an ongoing basis, for a period on the order of hundreds of years. Monitoring the water collection and treatment system includes checking whether mechanical and hydraulic components are operating effectively, that maintenance is accomplished as needed, and that the system achieves its purpose. Maintenance monitoring also includes assessing performance of an on-site landfill for disposal of sludge from groundwater treatment, and whether earthwork accomplished as part of the remedy remain stable over time.

CONCEPTUAL SURFACE WATER MONITORING

Surface water sampling for the cleanup action at the Site has two principal components: to monitor water quality in Railroad Creek and Copper Creek as it crosses the Site, and additional specific monitoring to document performance of the water treatment system. Conceptual surface water sampling locations within the Site are illustrated on Figure H-1.

Standard field parameters (i.e., pH, temperature, specific conductance, turbidity, oxidation-reduction potential (ORP), and dissolved oxygen) would be measured during surface water sampling events. Samples submitted for analysis of constituents of concern would be analyzed for total aluminum and iron, and dissolved cadmium, copper, lead, and zinc. Additional laboratory analyses would include alkalinity (as $CaCO_3$), chloride, dissolved organic carbon (DOC), calcium, hardness (as $CaCO_3$), magnesium, potassium, sodium, and sulfate. The SAP would need to include measures to field filter samples as they are collected, and use of appropriate preservatives to obtain reliable results for dissolved metals analysis. Sampling is anticipated to begin during the RD phase to allow for sufficient collection of baseline monitoring results.

In addition to the sampling and analyses outlined below, continuous flow monitoring would be necessary for at least one location in Railroad Creek adjacent to the Site. The location is likely to be in the vicinity of the prior flow gaging station near RC-4 or possibly near the proposed treatment facility outfall, and is subject to approval by the Agencies.

Railroad Creek and Copper Creek

The purpose of Railroad Creek sampling and analysis is to measure effectiveness of the cleanup action. Monitoring in Railroad and Copper Creeks will also be used to assess whether any changes in Site conditions degrade water quality.

Data discussed in the DFFS indicate that concentrations of some metals of concern in Railroad Creek are greatest just before peak spring flow conditions of approximately 800 cubic feet per second (cfs). A spring surface water sampling event should occur as soon as safely possible after the peak spring flow conditions and correspond with the schedule for biological aquatic monitoring.

A fall sampling event represents normal baseflow conditions in Railroad Creek over about 9 months of the year, when average flows in the river are approximately 60 cfs. Since fall conditions represent average concentrations for most of the year, sampling after a fall rain event should be avoided for results to represent baseflow conditions.

Surface water samples are anticipated to be collected in Railroad and Copper Creeks to evaluate compliance and protectiveness at the following locations:

- Railroad Creek upstream of the site (RC-6);
- Copper Creek upstream of site (CC-1);
- Railroad Creek immediately upstream of confluence with Copper Creek (new sampling location, RC-X); and
- Railroad Creek downstream of site (RC-5, RC-10, and RC-3).

Surface water samples are anticipated to be collected four times a year (approximately three times during "fall" conditions and once during spring conditions, as described above). More frequent samples will be collected at RC-6 as needed to provide background samples for assessing performance of the water treatment system, as described below.[2]

Treatment Facility

Surface water monitoring is also needed to verify performance of the proposed water treatment facility that would be located northeast of Tailings Pile 3. Compliance monitoring for the treatment

[2] The frequency of sampling upstream of the site is also anticipated to follow pending EPA guidance on implementation of the 2007 copper criterion (EPA 2007), as discussed in the SFS.

facility discharge would conform to the substantive requirements of an NPDES permit, and the concepts provided below.

Surface water samples for monitoring treatment facility discharges would likely be collected at four locations: Railroad Creek upstream of Site (RC-6), treatment facility influent, effluent discharge, and the downstream edge of a mixing zone within Railroad Creek, if a mixing zone is approved.

Samples would be analyzed for the metals of concern, (total aluminum and iron, and dissolved cadmium, copper, lead, and zinc), alkalinity (as $CaCO_3$), calcium, chloride, DOC, hardness as $CaCO_3$, magnesium, potassium, sodium, sulfate, and field parameters.

Samples are anticipated to be collected monthly for the first 2 years that the treatment facility is in operation. This initial period of monthly sampling and analysis is especially critical for understanding seasonal variability in treatment effectiveness. Monthly monitoring may need to extend more than the first 2 years if the treatment system is not consistently effective, and/or if the treatment facility is modified.

After the first 2 years of operation, the Agencies may approve a tiered reduction in treatment facility monitoring based on facility performance. Monitoring for metals of concern could be reduced in frequency, and/or monitoring the treatment system might be based on field parameters in lieu of metals analyses provided initial results demonstrate that surrogate monitoring is an adequate indicator of treatment effectiveness. Data excursions would require more frequent monitoring and/or metals analyses (not surrogates), until consistent, effective treatment performance is demonstrated.

CONCEPTUAL GROUNDWATER MONITORING

Groundwater monitoring at the Site has three principal components: monitoring water quality at the points of compliance; monitoring wells to document changes in groundwater quality across the Site; and monitoring in wells downgradient of the Site to determine whether containment is effective.

The sample locations and frequency described below are intended to illustrate the approach for discussion. Conceptual groundwater and groundwater-surface water interface sampling locations within the Site are illustrated on Figure H-2.

Standard field parameters (i.e., depth to groundwater, pH, temperature, specific conductance, turbidity, ORP, and dissolved oxygen) would be measured during groundwater sampling events. Samples submitted for analysis of metals of concern would be analyzed for dissolved cadmium, copper, lead, and zinc, and total aluminum and iron. The samples would also be analyzed for hardness (as $CaCO_3$), as well as sulfate and calcium to track changes in metals release rates. The sampling and analysis plan would need to include measures to field filter samples and use of appropriate preservatives to obtain reliable results for dissolved metals analysis. Sampling would begin during the RD phase to enable collection of sufficient baseline information; and as soon as possible in the wells that are installed as part of the remedy (e.g., following tailings pile regrading).

Points of Compliance

For the proposed cleanup action, the Agencies anticipate that the groundwater-surface water interface along Railroad Creek represents the points of compliance for groundwater as discussed in the SFS and in conformance with WAC 173-340-720(8)(d)(i). Monitoring to determine conditions at the points of compliance would be accomplished with wells as close as practical to the creek [see WAC 173-340-720(8)(e)(i)]. This is consistent with the appropriate point of compliance for groundwater for this Site under CERCLA absent MTCA. Sampling within Railroad Creek at the point of compliance cannot exceed the groundwater-surface water interface. Compliance could theoretically be measured with an interface probe in the stream channel gravels if that is shown to produce acceptable, quality data. A schematic of a possible interface sampling location acceptable to the Agencies is provided on Figure H-3.

Groundwater samples would be collected from monitoring well(s) adjacent to Railroad Creek, or possibly from an interface sampler in stream bank gravels at these conceptual locations:

- Between seeps SP-9 and SP-24;
- Between seeps SP-10 West and SP-1;
- Near seep SP-2;
- Between Copper Creek and seep SP-3;
- Between seeps SP-3 and SP-4;
- Between seep SP-4 and the downstream edge of Tailings Pile 3; and
- Near downstream edge of Tailings Pile 3.

Monitoring would also be accomplished at seeps SP-26 and SP-21, which are outside the proposed groundwater containment area. Additional containment and collection for treatment may be required in these areas if groundwater does not achieve proposed cleanup levels following initial remedy implementation. Sampling at the points of compliance would be conducted quarterly following remedy implementation.

Monitoring Well Sampling

Quarterly monitoring well sampling would occur in March, June, September, and November/ December, in the wells described below.

Background

Existing well HV-3, located in Holden Village, would likely be sampled to represent background conditions for the Site. Sampling would begin 2 years prior to implementation, to document baseline data.

Downgradient of Honeymoon Heights

Two new wells would be installed downgradient of the Honeymoon Heights Waste Rock Piles, to monitor effectiveness of collecting seeps SP-12 and SP-23 in eliminating releases to Railroad Creek from this portion of the Site. Sampling would begin 2 years prior to implementation, to gather baseline data.

Lower West Area and Tailings Pile 1 Barrier and Collection System

The proposed cleanup action includes a groundwater barrier and collection system that extends around the Lower West Area (LWA) and Tailings Pile 1, which is the area along Railroad Creek that generally extends from the existing mine drainage discharge (designated as sampling location P-5) to Copper Creek. (The proposed cleanup action, referred to as Alternative 11, is described in more detail and shown on figures in the SFS). Groundwater monitoring would be conducted within and downgradient of the LWA/Tailings Pile 1 barrier to determine changes in groundwater quality and effectiveness of the containment and collection system.

Conceptually, three wells would be installed at locations along Railroad Creek upgradient and downgradient of the groundwater barrier, with the downgradient monitoring points possibly including monitoring locations at the points of compliance.

Tailings Piles 2 and 3 Barrier and Collection System

The proposed cleanup action includes a groundwater barrier and collection system that extends around Tailings Piles 2 and 3, from Copper Creek to wrap around the east end Tailings Pile 3. Design of the barrier would be developed during RD to avoid collection of seepage from Copper Creek. Groundwater monitoring would be conducted within and downgradient of Tailings Piles 2 and 3 to determine changes in groundwater quality and the effectiveness of the Tailings Piles 2 and 3 groundwater barrier and collection system.

New wells would be installed after regrading the tailings along Railroad Creek, to monitor groundwater flowing into Railroad Creek from below the tailings piles. Potential locations, as shown on Figure H-3, include:

- A well located between Copper Creek and seep SP-3 by the northern edge of Tailings Pile 2;
- A well located on the northern edge of Tailings Pile 2, between seeps SP-3 and SP-4;
- A well located between seep SP-4 and the downstream edge of Tailings Pile 3; and
- A well located adjacent to Railroad Creek at the downstream edge of Tailings Pile 3. The existing wells DS-1 or DS-2 may be suitable for monitoring after installation of the groundwater barrier at the downstream edge of Tailings Pile 3.

These four new wells may be collocated with monitoring locations for the groundwater-surface water interface.

Downstream of Site

Wells DS-1, DS-2, DS-3S/D, DS-4S/D, and DS-5 at the downstream edge of the Site would be monitored for compliance reasons. The S/D nomenclature refers to shallow and deep well pairs. Analytical results would be compared to surface water cleanup levels.

Wells DS-1 and DS-2 would be replaced or supplemented with new wells if these existing wells are not located downgradient of the proposed Tailings Pile 3 groundwater barrier and collection system. Also, wells DS-3S/D and/or DS-4S/D may need to be relocated to accommodate the water treatment facilities.

Groundwater monitoring downgradient of the treatment facility is necessary to confirm that water potentially infiltrating from the treatment ponds conforms to state Waste Discharge Permit requirements and to assess performance of the treatment ponds. This would likely be accomplished by installing one new shallow well and one pair of shallow/deep wells to replace DS-3S/D.

Mine Discharge and Groundwater Collection Ditch

Groundwater collection and conveyance systems are proposed as part of the cleanup action, extending along Railroad Creek from the LWA to Tailings Pile 3. This system may include ditches as proposed for Alternatives 10 and 11 or buried trench drains as described for seep collection in Alternatives 8 and 9, or possibly a combination of the two approaches. Water quality and performance of the groundwater collection and conveyance systems would need to be periodically monitored to assess effectiveness and potential maintenance needs.

Water that currently flows from the main 1500 Level mine portal, and collected flow from seeps SP-12 and SP-23, and possibly other collected groundwater and seeps, would be conveyed to the treatment facility via pipeline. The pipeline(s) would need to be periodically inspected to assess potential maintenance needs.

Flow rate, specific conductance, and pH of water in the conveyance systems would likely be monitored at the time that samples are collected from adjacent groundwater monitoring wells and at the groundwater-surface water interface. Monitoring would also include visually assessing the conveyance systems for potential iron fouling or other obstructions, as discussed in the Maintenance and Operations Monitoring section below.

BIOLOGIC MONITORING

The goal of biologic monitoring is twofold 1) to assess whether the remedy is enabling consistent, statistically significant improvements in habitat, biodiversity, and species abundance as a result of controlling the release of hazardous substances; and 2) to determine whether the remedy is protective even though hazardous materials would remain on the Site after implementation of the remedy. Trends indicating improvement in biologic parameters relative to reference sampling locations could be used to demonstrate protectiveness of the cleanup action, or conversely might indicate the need for further remedial action.

Baseline monitoring prior to implementing the cleanup action would be necessary to support analysis of post-remediation monitoring. It should be noted that baseline sampling might need to be supplemented if it occurs during atypical low or high runoff conditions, which could affect inputs of metals to the creek. Lower runoff is also likely to affect plant growth and wildlife populations directly.

Aquatic Monitoring

Conceptually, the aquatic monitoring would target biological indicators to measure the recovery of Railroad Creek macroinvertebrate community, fish abundance and ecology, and fish tissue chemistry. Data would be reviewed every 5 years to assess the effectiveness of the remedy and to determine whether continued monitoring would be necessary. More frequent reviews could also be accomplished, but may reflect short-term variations that are dissimilar to longer term trends.

Aquatic monitoring would typically be accomplished as soon after peak spring flow as safely possible, and consistent from year to year based on the hydrograph. Spring flush is the time with high metal concentrations and toxicity, but the river cannot be safely sampled. Fall sampling is when some metal concentrations are lowest, potentially biasing results. Sampling would likely include 1 to 2 years of baseline monitoring prior to the beginning of remediation. After implementation of the cleanup action, sampling for macroinvertebrates and fish would conceptually be accomplished every year for 5 years, and thereafter, depending on results.

Macroinvertebrate Monitoring

Macroinvertebrates are indicators of contaminant exposure and river channel conditions. Communities are relatively sensitive to changes in habitat and metals toxicity (community-wide effects), but many macroinvertebrate species are relatively insensitive to metal toxicity. Sampling protocols such as the Washington State Department of Ecology, Benthic Macroinvertebrate Biological Monitoring Protocols (BMBMP, Ecology 2001) and Biological Assessment of Small Streams in the Coastal Range Ecosystem and the Yakima River Basin (BASS, Merritt et al. 1999) would likely be followed, and could be adapted as needed (e.g., it may not be possible to sample 500 individual benthos at some locations). Sampling methods would be quantitative (e.g., Hess sampler, Surber sampler, modified D-frame kicknet) to allow for calculation of number of organisms per unit area.

Sample location identification would be based on stream habitat characteristics and access. Ideally the locations selected would be similar to locations previously sampled during remedial investigations for macroinvertebrates and/or for other monitoring parameters outlined in this Conceptual Monitoring Program. The sample locations and frequency described below are intended to illustrate the approach for discussion.

- **Reference Samples.** Reference samples would likely be collected at three locations in Railroad Creek upstream of the Site. Additional reference samples in other area watersheds could also be collected if upstream reference locations do not adequately compare to downstream assessment reaches.

- **Adjacent to Site.** Six macroinvertebrate locations would likely be located in Railroad Creek adjacent to and immediately downgradient of the Site. Stratified random sampling within a block design in the tailings area would likely be employed. For example, three riffles may be selected on the right bank and three riffles on the left bank to determine the effects of containment and potential leakage of contaminated groundwater plumes on macroinvertebrates.

- **Downstream of Site.** Three macroinvertebrate sampling locations would likely be established downstream of the Site, beyond the area with visible accumulations of iron flocculent.

Fish Monitoring

Salmonids and sculpin are known to be sensitive organisms to toxicity from the metals of concern (copper, cadmium, zinc, aluminum, and iron). Fish are transient and have been shown to actively avoid toxic metal concentrations, but nevertheless, need to be monitored because of their sensitivity and importance to the ecosystem. Species diversity is expected to be low, but age/size distributions within species would indicate reproduction, rearing, and long-term survival in a recovered system.

Sampling (i.e., snorkeling) would likely follow methods from Peterson et al. (2002). In addition, fish tissue residues would conceptually be monitored for copper, cadmium, and zinc. Tissue residues show the integration of metal exposure over time and are a measure of changes in mean metal exposure and bioavailability. Liver tissues could be monitored since this is the tissue that stores excess metals following metals exposure. The sample locations and frequency described below are intended to illustrate the approach for discussion.

- **Reference Samples.** Three reference locations would likely be selected upstream of the Site, in reaches similar to those for macroinvertebrates. One additional reference sample within another area watershed may be collected if adequate reference reaches are not available upstream of the Site.

- **Adjacent to Site.** Two sampling locations would likely be located adjacent to the mine area.

- **Downstream of Site.** Three sampling locations would likely be generally collocated at downstream macroinvertebrate stations.

The fish sampling locations are referred to as “similar to” or “generally collocated with” the macroinvertebrate sampling locations, because macroinvertebrate samples are collected in riffles, while fish sampling units should be collected in representative riffle and pool habitats. If the macroinvertebrate sample is collected in a long riffle, it may be necessary to go upstream or downstream a short distance to include pool habitats for fish sampling.

Habitat/Physical Parameters

Monitoring habitat/physical parameters is necessary to enable appropriate fish and macroinvertebrate population comparisons. General parameters to be monitored include pool-riffle ratio and percent cover for fish. BMBMP and BASS habitat parameters would be monitored such as average current velocity, maximum depth, wetted width, stream gradient, substrate composition, stream complexity, and shade at mid-channel. Metals-related parameters would also be noted during monitoring such as substrate embeddedness, ferricrete concretion and iron staining, and percent substrate covered with iron flocculent. The sample locations and frequency described below are intended to illustrate the approach for discussion.

- **Reference Samples.** Three reference locations would likely be selected upstream of the Site, in reaches similar to those for macroinvertebrates.
- **Adjacent to Site.** Two sampling locations would likely be located adjacent to the mine area.
- **Downstream of Site.** Three sampling locations would likely be located downstream of the Site.

Terrestrial Monitoring

The goal of terrestrial monitoring is to verify remedy protectiveness and success of revegetation.[3] The sample locations and frequency described below are intended to illustrate the approach for discussion.

Monitoring would include habitat/physical parameters, bio-indicators, and possibly metals-related parameters. Sampling and analysis would be accomplished every other year beginning 1 year following implementation of the cleanup action. Sampling and analysis would also include 1 to 2 years of baseline monitoring prior to beginning remediation. One to three sampling events per year are anticipated, as discussed below.

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[3] This section does not address the additional monitoring anticipated during RD as part of an ecological risk assessment (ERA) to determine the extent of soil cleanup in areas impacted by releases from the site that have soil concentrations above ecological screening values. See the SFS and Appendix E of the SFS for further discussion of the proposed ERA.

Habitat/Physical Parameters

The goal of the habitat monitoring is to track remedy effectiveness and/or address areas where additional remediation is needed (e.g., replanting) following elimination of the release of hazardous substances from the Site. Monitoring would focus on vegetation recovery and survival. Sampling protocols may generally follow those outlined in the following materials: WD(F)W Field Procedures for Characterization of Riparian Management Zones and Upland Management Areas with Respect to Wildlife Habitat (WDW 1990); Methods for Evaluating Riparian Habitats with Applications to Management (INT GTR-221, 1987); Classification and Management of Aquatic, Riparian, and Wetland Sites on the National Forests of Eastern Washington: Series Description (PNW GTR-593, 2004); or Line Intercept Vegetation Sampling (e.g., Kent and Coker 1992). It should be noted that the sampling protocols provided in these materials may be outdated and the most current and effective methodology available at the time monitoring begins should be used.

Sampling would likely occur in July and would be timed to capture and adequately identify herbaceous species during bloom period and record cover at maximum growth.

- **Reference Samples.** Two pairs of macroplots would likely be located upstream of the Site, one pair located where there is floodplain interaction, the second where the channel is at least somewhat confined. Plot pairs would be split such that one macroplot in each pair would be located on the north and south sides of creek.

- **Adjacent to Site.** Three to five plot pairs would likely be located adjacent to or within the reclaimed mine and tailings pile areas. Plot pairs would be split such that one macroplot in each pair would be on the north and south sides of the creek.

- **Wetland Downstream of Tailings Pile 3.** One to two paired macroplots would likely be monitored. Alternatively, a line/point intercept method may be used if more appropriate to monitor recovery in this sedge-dominated area.

Bio-Indicators

Bio-indicator monitoring would provide a measure of success for the remedy and potential need for additional clean up in areas impacted by releases from the Site. Bio-indicators selected for monitoring should include species representative of different ecological groups. Indicator species included in this Conceptual Monitoring Program are songbirds, ruffed grouse, and beavers, and are based on the Wenatchee Land Resource Management Plan (LRMP) (Forest Service 1990, as amended by the NWFP in 1994, 2001, 2004, and 2007). The selected indicator species may change. The bio-indicators listed below are currently placeholders; e.g., monitoring for amphibians could also potentially be added.

The sample locations and frequency described below are intended to illustrate the approach for discussion. Sampling would be conducted for 2 baseline years, and then every other year after implementation of the cleanup action.

Songbirds

Surveys would likely occur between May 15 and June 30, and could be timed to occur along with the ruffed grouse surveys (discussed below). Point count locations would be located at least 150 meters apart and in approximately the center of the riparian zone as measured from the edge of the creek to the edge of the riparian vegetation or the road. At a minimum, locations would be located in each of the vegetation sampling macroplots. Point counts would be conducted three times per survey at each location.

Ruffed Grouse

Drumming surveys or nest searches would likely be accomplished in late April or May at locations approximately 1 mile apart or alternatively, included in point count locations.

Beaver

Monitoring for beaver would consist of qualitative observation of the presence or absence, and recording any locations where presence is observed. This would likely be conducted during point counts or vegetation surveys.

Metals-Related Parameters

As discussed in the Proposed Plan and the SFS, Site soils will be cleaned up to the proposed cleanup levels, unless it is determined by the Agencies that other levels would be protective of terrestrial receptors based on additional ERA. Sampling for metals-related parameters may be focused on potential metals uptake from surface water and soils. Bioassay of potential forage would be used to determine the potential for metal ingestion, as a relevant indicator of impacts to deer, grouse, beaver, and/or other species as determined from the ERA. Based on the ecological risk assessment, additional soil monitoring or other remedial measures may be necessary in Holden Village, the baseball field, or areas with visible or reported accumulations of wind-blown tailings north and east of the mine.

Monitoring would conceptually occur in the winter/early spring and in July. Sampling would consist of collecting leaf and growing twig tip samples during vegetation monitoring at macroplot locations. Bud samples would need to be collected in winter/early spring. Samples would be collected from creek side vegetation that may be withdrawing water directly from the creek; in the wetland east of TP-3; and in other areas where there is evidence of wind-blown tailings deposition, evidence of stressed vegetation, or in areas where contaminated soils have been excavated, replaced, and replanted. Final determination of sample type location and the metals that would be analyzed for would depend on the additional ERA to be completed during RD.

SEDIMENT MONITORING

State freshwater sediment criteria are under review and may be promulgated before the Site remedy is determined to be final. Sediment sample analytical results available to date for the Railroad Creek valley indicate some exceedances of potential sediment cleanup levels. Sampling and analysis would be used to determine whether the proposed cleanup action would need to be expanded to address sediment quality at some future time, and in conjunction with other data, to assess the effectiveness of controlling releases from the Site on the macroinvertebrate population in Railroad Creek.

Sediment samples would conceptually be collected in pools corresponding to the fish sampling locations within Railroad Creek. Sampling and analysis would potentially be accomplished to document baseline conditions prior to implementation of the cleanup action, and in the first, fifth, and tenth years following implementation.

OPERATIONS AND MAINTENANCE MONITORING

This monitoring conceptually includes regular observation to verify performance of components constructed as part of the cleanup action, including: 1) groundwater collection, conveyance, and treatment components; 2) surface water diversion swales; 3) tailings, waste rock, and sludge landfill containment slopes; 4) soil and geomembrane cap on the tailings and waste rock piles; and 5) channel and bank stability where Railroad and Copper Creeks cross the Site.

The sample locations and frequency described below are intended to illustrate a general approach for discussion. Details of maintenance and operations monitoring would be determined during RD and/or may be modified based on performance of the system.

Groundwater Collection, Conveyance, and Treatment Components

Groundwater collection and conveyance systems would be monitored visually at least once a month to check for potential flow problems such as erosion, iron fouling, or accumulations of sediment or debris. Inlets for seep collection, and the inlet and outlet for conveyance pipelines, and the pipelines across Railroad and Copper Creeks would be observed to verify the absence of blockages that might lead to overflows.

During startup, the treatment system should be inspected each day, potentially increasing to weekly observations during regular operation. The purpose of regular treatment system operation inspection is to verify that chemical addition is occurring as intended, and that there are no flow blockages in the system.

Additional observations should be accomplished on an as-needed basis after especially heavy rainfall events, and during periods of high spring snowmelt and runoff.

Surface Water Diversion Swales

Surface water diversion swales on the reclaimed tailings piles and upgradient (south) of the Site would be monitored visually at least once a month to check for potential flow problems, such as erosion, and accumulations of sediment or debris. Monitoring frequency may be able to be reduced upon approval by the Agencies when revegetation of the reclaimed tailings and waste rock piles has reached a stable self-sustaining condition.

Additional observations should be accomplished after especially heavy rainfall events, and during periods of high spring snowmelt and runoff.

Geomembrane Cap on Waste Rock and Tailings Piles

The Proposed Plan includes caps on the waste rock and tailings piles to meet the presumptive closure requirements for limited purpose landfills [WAC 173-350-400(3)(e)(ii)] unless Intalco can demonstrate during RD that other methods are as protective. The presumptive requirements include a geomembrane cap with 2-foot soil cover. Following remedy implementation, monitoring will be needed so that plants that may develop deep roots can be controlled by spraying, so that the geomembrane is not damaged.

Tailings, Waste Rock, and Landfill Containment Berm Slopes

Slopes for the reclaimed tailings and waste rock piles, and the containment berms for the on-site sludge landfill should be observed visually at least twice annually, after spring runoff and early in the fall. Fall reconnaissance should be in September, to allow sufficient time for any maintenance action needed to stabilize slopes prior to winter.

Once vegetation is well established on reclaimed slopes, the frequency of observations may be decreased upon approval by the Agencies, provided there are no indications of locally unstable areas.

Channel and Bank Stability for Railroad and Copper Creeks

Channel and bank stability should be visually assessed at least once per year in the late spring or early summer and, as needed, after flood events. The purpose of this monitoring is to enable timely maintenance to prevent erosion or scour from impacting the groundwater barrier and collection system, and to assure stability of the reclaimed tailings piles nearest to the creeks.

REFERENCES FOR APPENDIX H

Ecology 2001. Benthic Macroinvertebrate Biological Monitoring Protocols for Rivers and Streams: 2001 Revision.

INT GTR-221 1987. Methods for Evaluating Riparian Habitats with Applications to Management.

Kent, M. and P. Coker 1992. Vegetation Description and Analysis: A Practical Approach. John Wiley & Sons: New York.

EPA 2007. Aquatic Life Ambient Freshwater Quality Criteria - Copper. EPA-822-R-07-001. February 2007.

Forest Service 1990. Land and Resource Management Plan for Wenatchee National Forest as amended by the Pacific Northwest Forest Plan (1994) and subsequent amendments of that Plan (2001 and 2004).

Forest Service 2007. Supplemental Feasibility Study, Holden Mine Site, Chelan County, Washington. September 2007.

Merritt, G.D., B. Dickes, and J.S. White 1999. Biological Assessment of Small Streams in the Coastal Range Ecosystem and the Yakima River Basin (BASS). Washington State Department of Ecology, Publication. No. 99-302.

Peterson, J., J. Dunham, P. Howell, S. Bonar, and R. Thurow 2002. Interim Protocol for Determining Bull Trout Presence. Western Division of the American Fisheries Society.

PNW GTR-593 2004. Classification and Management of Aquatic, Riparian, and Wetland Sites on the National Forests of Eastern Washington: Series Description.

WDW 1990. WD(F)W Field Procedures for Characterization of Riparian Management Zones and Upland Management Areas with respect to Wildlife Habitat.

Attachments

Table H-1	Summary of Conceptual Monitoring for Holden Mine Site Cleanup
Figure H-1	Proposed Surface Water Sampling Location Plan
Figure H-2	Proposed Groundwater and Groundwater-Surface Water Interface Sampling Location Plan
Figure H-3	Schematic of Groundwater-Surface Water Interface Sampling

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Table H-1 - Summary of Conceptual Monitoring for Holden Mine Site Cleanup

Type of Monitoring / Media	Frequency of Monitoring						Primary Purpose(s) of Monitoring	Secondary Purpose(s) of Monitoring
	Two Baseline Years	Years after Implementation of Interim Cleanup Action						
		Year 1	Year 2	Year 3	Year 4	Year 5		
Surface Water								
Railroad Creek RC-X (near confluence with Copper Creek), and at RC-5, RC-10, and RC-3	4 events / year @ 4 locations	4 events / year @ 4 locations	4 events / year @ 4 locations	4 events / year @ 4 locations	4 events / year @ 4 locations	4 events / year @ 4 locations	Protectiveness	Effectiveness
Railroad Creek at RC-6 and Copper Creek at CC-1	4 events / year @ 2 locations	Monthly @ RC-6 and 4 events / year @ CC-1	Monthly @ RC-6 and 4 events / year @ CC-1	4 events / year @ 2 locations	4 events / year @ 2 locations	4 events / year @ 2 locations	Compliance (comparison points for downstream locations)	Protectiveness (comparison points for downstream locations)
Treatment Facility (influent pipe (I), effluent pipe (E) and downstream edge of mixing zone, if a mixing zone is approved)		Monthly @ 3 locations	Monthly @ 3 locations	4 events / year @ 3 locations	4 events / year @ 3 locations	4 events / year @ 3 locations	Compliance	
Groundwater								
GW-SW Interface		4 events / year @ 7 locations	4 events / year @ 7 locations	4 events / year @ 7 locations	4 events / year @ 7 locations	4 events / year @ 7 locations	Compliance	Effectiveness
Background Monitoring Well (HV-3)	4 events / year @ 1 location	4 events / year @ 1 location	4 events / year @ 1 location	4 events / year @ 1 location	4 events / year @ 1 location	4 events / year @ 1 location	Compliance (comparison point for other groundwater locations)	
Monitoring Wells Downgradient of Honeymoon Heights	4 events / year @ 2 locations	4 events / year @ 2 locations	4 events / year @ 2 locations	4 events / year @ 2 locations	4 events / year @ 2 locations	4 events / year @ 2 locations	Effectiveness	
Lower West Area and TP-1 Monitoring Wells (Wells potentially collocated with GW-SW interface sampling locations)		4 events / year @ 3 locations	4 events / year @ 3 locations	4 events / year @ 3 locations	4 events / year @ 3 locations	4 events / year @ 3 locations	Compliance and/or Effectiveness (possibly comparison points for adjacent GW-SW interface monitoring points)	

Table H-1 - Summary of Conceptual Monitoring for Holden Mine Site Cleanup

Type of Monitoring / Media	Frequency of Monitoring						Primary Purpose(s) of Monitoring	Secondary Purpose(s) of Monitoring
	Two Baseline Years	Years after Implementation of Interim Cleanup Action						
		Year 1	Year 2	Year 3	Year 4	Year 5		
TP-2 and TP-3 Monitoring Wells (Wells potentially collocated with GW-SW interface sampling locations)		4 events / year @ 4 locations	4 events / year @ 4 locations	4 events / year @ 4 locations	4 events / year @ 4 locations	4 events / year @ 4 locations	Compliance and/or Effectiveness (possibly comparison points for adjacent GW-SW interface monitoring points)	
Monitoring Wells Downstream of Site (may include replacement wells downgradient of treatment system)		4 events / year @ 8 locations	4 events / year @ 8 locations	4 events / year @ 8 locations	4 events / year @ 8 locations	4 events / year @ 8 locations	Compliance and Effectiveness	
Mine Discharge and Groundwater Collection Trench		4 events / year	4 events / year	4 events / year	4 events / year	4 events / year	Effectiveness (comparison points for monitoring wells and adjacent GW-SW interface monitoring points)	
Biologic Monitoring - Aquatic Benthic Macroinvertebrates	1 event / year @ 12 locations	1 event / year @ 12 locations	1 event / year @ 12 locations	1 event / year @ 12 locations	1 event / year @ 12 locations	1 event / year @ 12 locations	Protectiveness and Effectiveness	
Fish	1 event / year @ 8 locations	1 event / year @ 8 locations	1 event / year @ 8 locations	1 event / year @ 8 locations	1 event / year @ 8 locations	1 event / year @ 8 locations	Protectiveness and Effectiveness	
Habitat/Physical Parameters	1 event / year @ 8 locations	1 event / year @ 8 locations	1 event / year @ 8 locations	1 event / year @ 8 locations	1 event / year @ 8 locations	1 event / year @ 8 locations	Protectiveness and Effectiveness (use to compare locations where benthos and fish are monitored).	

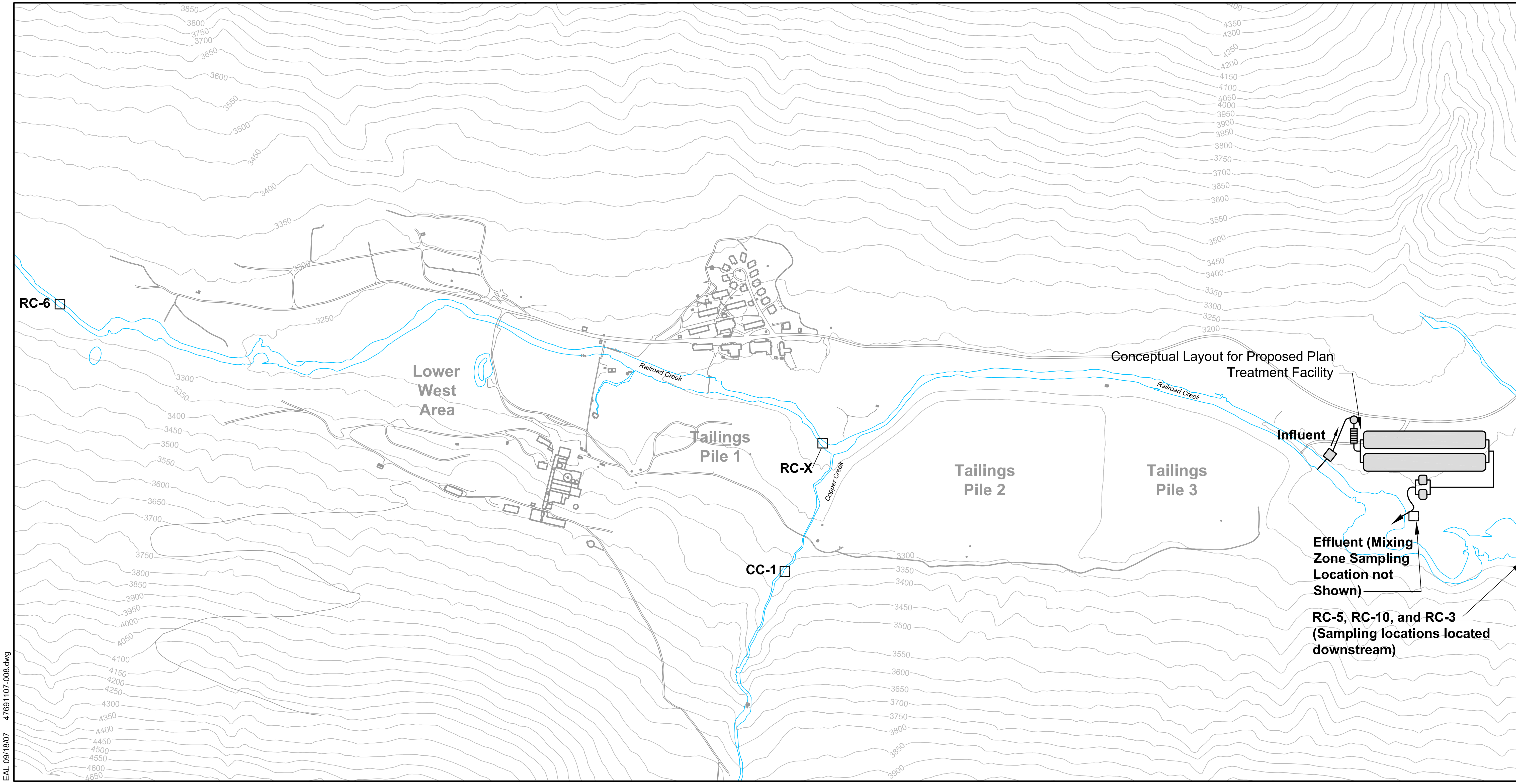
Table H-1 - Summary of Conceptual Monitoring for Holden Mine Site Cleanup

Type of Monitoring / Media	Frequency of Monitoring						Primary Purpose(s) of Monitoring	Secondary Purpose(s) of Monitoring
	Two Baseline Years	Years after Implementation of Interim Cleanup Action						
		Year 1	Year 2	Year 3	Year 4	Year 5		
Biologic Monitoring - Terrestrial Habitat/Physical Parameters	1 event / year @ 6 to 9 paired locations	1 event / year @ 6 to 9 paired locations		1 event / year @ 6 to 9 paired locations		1 event / year @ 6 to 9 paired locations	Protectiveness and Effectiveness	
Bio-Indicators	3 events / year for 2 years	3 events / year		3 events / year		3 events / year	Protectiveness and Effectiveness	
Metals-Related Parameters	2 events / year @ 6 to 9 paired locations	2 events / year @ 6 to 9 paired locations		2 events / year @ 6 to 9 paired locations		2 events / year @ 6 to 9 paired locations	Protectiveness	
Sediment	1 event @ 8 locations	1 event / year @ 8 locations				1 event / year @ 8 locations	Compliance	Effectiveness
Maintenance and Operations Monitoring Groundwater Collection and Conveyance System		Weekly to monthly, and as needed after high runoff events					Effectiveness	
Surface Water Diversion Swales		Monthly, may be reduced after vegetation reaches stable self-sustaining condition.					Effectiveness	
Stability of Disturbed Areas		Spring and early fall.					Effectiveness	
Revegetation Success		1 event / year		1 event / year		1 event / year	Effectiveness	
Creek Channel and Bank Stability		Annually, and as needed after flood events					Effectiveness	

Note:

1. Monitoring location and frequency are provided for discussion purposes and may be changed by the Agencies based on final design or performance of the remedy.
2. Long-term monitoring requirements (more than five years after implementation) would be determined based on observation of results and as needed to assure protectiveness and effectiveness of the cleanup action.

Conceptual Surface Water Sampling Location Plan



☐ **RC-6** Surface Water Sampling Location and Number

0 600 1200
Scale in Feet

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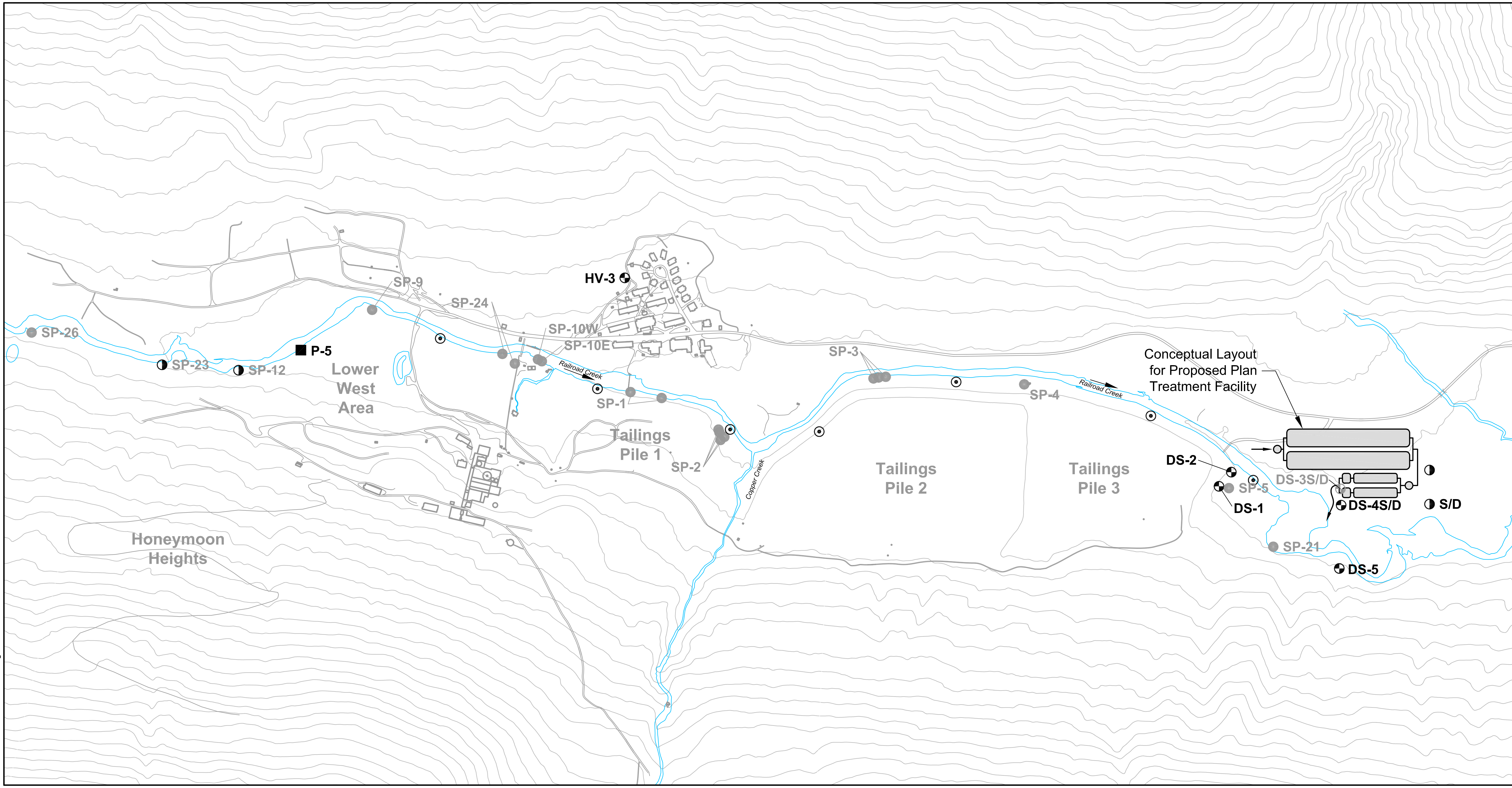
Figure H-1

SFS Appendix H

Conceptual Groundwater and Groundwater-Surface Water Interface Sampling Location Plan



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HV-3 Existing Monitoring Well Location and Number

Potential Monitoring Well Location

SP-26 Seep Location and Number

P-5 Surface Water Monitoring Location and Number

Potential Groundwater and Groundwater-Surface Water Interface Sampling Location (May Include Interface Sample Paired with Well)

Note: Existing monitoring wells DS-3S/D will likely be abandoned, and replaced downstream of the proposed treatment facility.

N

0 600 1200

Scale in Feet

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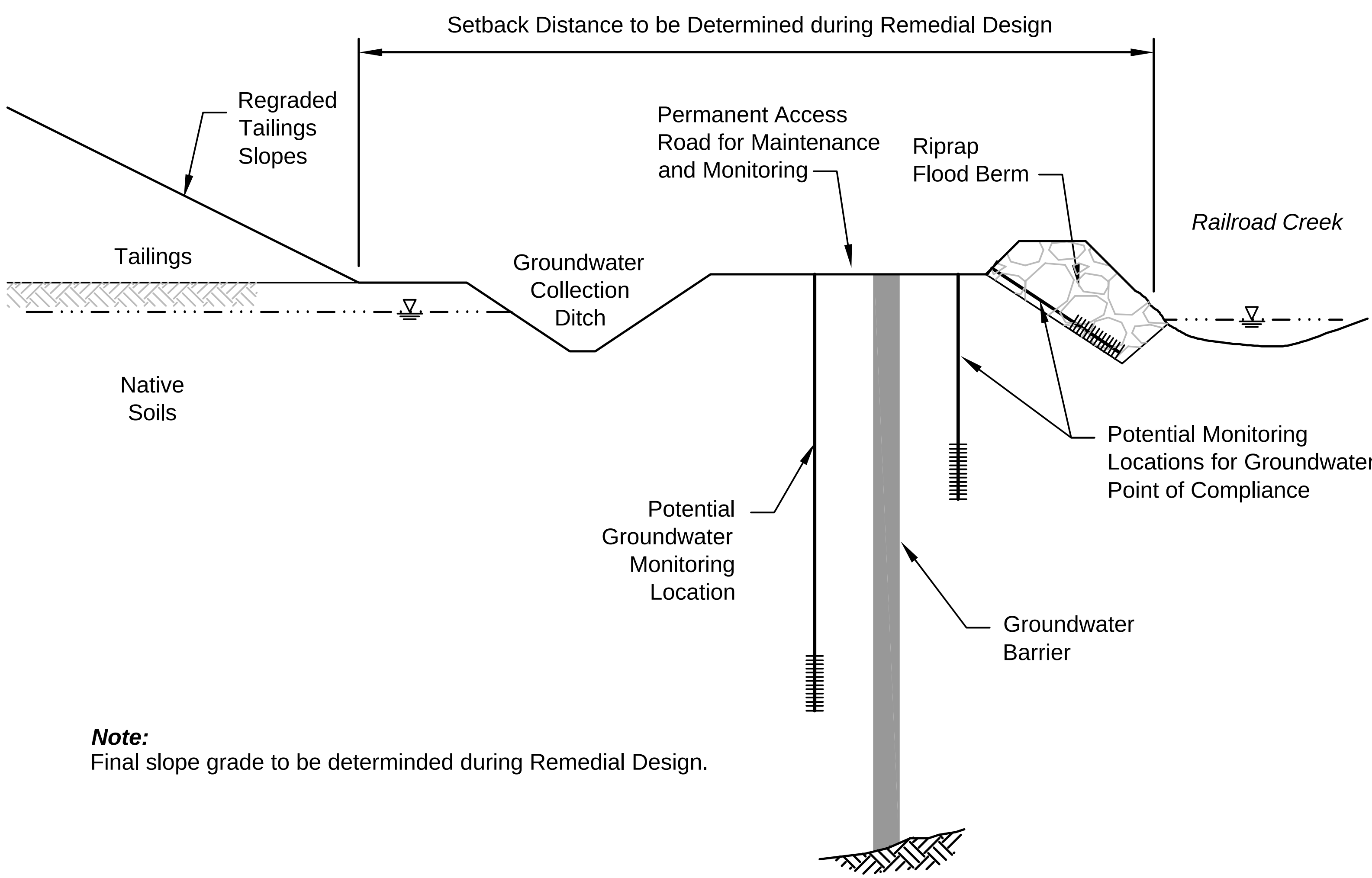
Figure H-2

SFS Appendix H

Conceptual Cross Section of Tailings Pile Setback from Railroad Creek



Note:
Final slope grade to be determinded during Remedial Design.

Not to Scale

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Figure H-3

SFS Appendix H