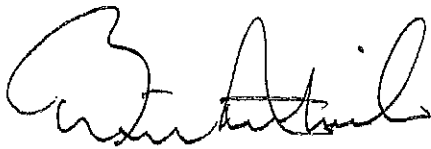


A Report Prepared For:
Clariant Corporation
4000 Monroe Road
Charlotte, North Carolina 28025

**FEASIBILITY STUDY
FORMER CLARIANT CORPORATION CHEMICAL PLANT
404 HENDRICKSON DRIVE
KALAMA, WASHINGTON
VCP #SWO492**

October 10, 2008



Brian Antonioli, P.E.
Project Engineer



Pamela J. Morrill, LHG
Project Manager



CDM

11811 N.E. 1st Street, Suite 201
Bellevue, Washington 98005
425/453-8383

CDM Project No. 5256.46525

Contents

Executive Summary	vii
Section 1 Introduction	
1.1 FFS Objectives.....	1-1
1.2 Report Organization.....	1-1
Section 2 Site Description and History	
2.1 Location and Description.....	2-1
2.2 Site Description and Land Use.....	2-1
2.3 Manufacturing Process History	2-2
2.4 Geologic Setting	2-3
2.4.1 Site Area Geologic Conditions	2-3
2.4.2 Site Area Hydrologic Conditions	2-3
2.4.3 Surface Water	2-3
Section 3 Summary of Previous Investigations/Interim Actions	
3.1 Summary of Investigations Completed	3-1
3.1.1 Contaminant Delineation	3-1
3.1.2 Soil Excavation Interim Action	3-2
3.1.3 Groundwater Extraction	3-2
3.1.4 Groundwater Monitoring	3-3
3.1.5 Site Conceptual Model.....	3-3
3.1.6 Screening Level Ecological Risk Assessment (SLERA)	3-4
3.1.7 Tidal Variations on Water Levels and Contaminant Concentrations	3-4
3.1.8 Establishment of Plume Boundary and Depth to Bedrock.....	3-5
Section 4 Cleanup Levels and Contaminant Distribution	
4.1 Regulatory Analysis	4-1
4.2 Points of Compliance.....	4-2
4.2.1 Soil.....	4-2
4.2.2 Groundwater	4-2
4.3 Cleanup Levels and Contaminant Distribution	4-3
4.3.1 Soil.....	4-4
4.3.2 Groundwater	4-5
4.3.3 Summary.....	4-6
Section 5 Remedial Goals and Objectives	5-1
Section 6 Development and Screening of Remedial Options	
6.1 General Response Actions, Technologies and Process Options.....	6-1

6.2 Screening of Remedial Technologies.....6-1

6.2.1 No Further Action.....6-2

6.2.2 Institutional Controls6-3

6.2.3 Monitored Natural Attenuation6-4

6.2.4 Stormwater Controls and Best Management Practices6-5

6.2.5 Containment.....6-6

6.2.6 In-Situ Treatment.....6-10

6.2.7 Groundwater Pump and Treat 6-11

6.2.8 Additional Soil Removal, Transport, and Disposal6-15

6.3 Initial Alternatives Screening Summary.....6-16

Section 7 Remedial Action Alternatives

7.1 Description of Remedial Action Alternatives7-1

7.1.1 Remedial Action Alternative 1 - Monitored Natural Attenuation, Stormwater Controls and Institutional Controls.....7-2

7.1.2 Remedial Action Alternative 2 - Impermeable Cap, Monitored Natural Attenuation, Stormwater Controls and Institutional Controls7-2

7.1.3 Remedial Action Alternative 3 - Additional Soil Removal, Neutralization Cap, Monitored Natural Attenuation, Stormwater Controls and Institutional Controls.....7-4

7.1.4 Remedial Action Alternative 4 - Slurry Wall, Impermeable Cap, Monitored Natural Attenuation, Stormwater Controls and Institutional Controls7-5

7.1.5 Remedial Action Alternative 5 - Additional Soil Removal, Hydraulic Barrier Pump and Treat, Monitored Natural Attenuation, Stormwater Controls and Institutional Controls7-6

7.2 Conceptual Level Cost Estimates7-8

7.3 Evaluation of Remedial Action Alternatives7-9

7.3.1 Method of Evaluation.....7-9

7.3.2 Comparison Evaluation7-10

7.3.3 Cost Disproportionate Analysis7-12

Section 8 Conclusions and Recommended Remedial Action8-1

Section 9 References9-1

Distribution

Tables

Figures

Appendices

Appendix A Summary RI Data

Appendix B Hydraulic Analysis

Appendix C Alternative Design Assumptions and Cost Estimates

Tables

Table 1	Development of Draft Cleanup Levels
Table 2	Identification of Potential Remedial Technologies
Table 3	Initial Screening of Potential Remedial Technologies
Table 4	Cost Estimate Summary
Table 5	Remedial Technologies Cost Disproportionate Analysis

Appendix A

Table A-1	Metals Concentrations - Settling Basin 1 and South End Settling Basin 2 Excavation Limit
Table A-2	Total Metals Concentrations - Settling Basin 2 Excavation Limits
Table A-3	Leachable Metals Concentrations in Settling Basins 1 and 2
Table A-4	Metals in Soil at Former Settling Basins 3 and 4
Table A-5	Metals in Soil Around the Manufacturing Plant Area
Table A-6	Total Metals Concentrations - Manufacturing Plant East and West Excavations
Table A-7	Groundwater Elevation Data
Table A-8	Groundwater Field-Measured Parameters
Table A-9	Zinc and Cadmium in Groundwater
Table A-10	Zinc and Hardness in River Water Samples
Table A-11	Mann-Kendall Trend Test Results

Appendix B

Table B-1	Land Cover Data for Impermeable Cap Scenario
Table B-2	Zinc Contributed by Each Segment of the Site July, 2005 Sampling Event

Appendix C

Cost Estimate Assumptions

Table C-1	Assumptions for Conceptual Design of Alternative 1
Table C-2	Assumptions for Conceptual Design of Alternative 2
Table C-3	Assumptions for Conceptual Design of Alternative 3
Table C-4	Assumptions for Conceptual Design of Alternative 4
Table C-5	Assumptions for Conceptual Design of Alternative 5
Table C-6	Cost Estimate for Alternative 1
Table C-7	Cost Estimate for Alternative 2
Table C-8	Cost Estimate for Alternative 3
Table C-9	Cost Estimate for Alternative 4
Table C-10	Cost Estimate for Alternative 5

Figures

- Figure 1 Vicinity Map
- Figure 2 Site Plan
- Figure 3 Groundwater Zinc and Cadmium Plume Delineation
- Figure 4 Alternative 1 - MNA
- Figure 5 Alternative 2 - Impermeable Cap
- Figure 6 Alternative 3 - Additional Soil Removal and Neutralization Cap
- Figure 7 Alternative 4 - Slurry Wall with Impermeable Cap
- Figure 8 Alternative 5 - Additional Soil Removal and Hydraulic Containment Pump and Treat

Appendix A

- Figure A-1 Vicinity Map
- Figure A-2 Excavation Sample Locations - Settling Basin 1 and South End Settling Basin 2
- Figure A-3 Excavation Sample Locations - Settling Basin 2
- Figure A-4 Exploration Locations in Former Settling Basins 3 and 4
- Figure A-5 Exploration Locations in the Manufacturing Plant Area
- Figure A-6 Excavation Sample Locations - Mfg. Plant West Excavation
- Figure A-7 Excavation Sample Locations - Mfg. Plant East Excavation

Appendix B

- Figure B-1 Groundwater Recharge Area
- Figure B-2 Impermeable Cap Area
- Figure B-3 Additional Soil Removal and Hydraulic Containment Pump and Treat

Executive Summary

This document presents the results of Camp Dresser & McKee Inc.'s (CDM) feasibility study (FS) for the former Clariant Chemical Plant in Kalama, Washington (site or subject property). This FS was performed to develop, evaluate, and provide recommendations for appropriate alternatives to remediate metals contamination associated with onsite manufacturing activities. CDM completed this FS on behalf of the prior owner of the site, Clariant Corporation (Clariant). In January 2003 Chemtrade Logistics assumed site ownership and conducts generally the same chemical manufacturing operations onsite. Investigation and cleanup of metals contamination is being conducted under Washington State Department of Ecology's (Ecology) Voluntary Cleanup Program (VCP). The site VCP number is SWO492.

The site is occupied by an active chemical processing plant that produces sodium hydrosulfite. It is situated adjacent to the Columbia River on land that was created from dredge spoils obtained from the Columbia River. These dredge spoils consist of poorly graded fine to medium grained sand. Bedrock underlies the site at depths of 24 feet to greater than 60 feet below ground surface (ft bgs). Groundwater occurs at approximately 20 to 25 ft bgs. There is a direct hydraulic connection to the Columbia River and tidal influences cause a wave-like effect on the groundwater flow underlying the site.

The southern portion of the site is occupied by the plant facilities. The northern portion of the site is undeveloped except for a paved access road. This area had once been occupied by a series of four settling basins, one of which (Settling Basin #2) had been used to dewater zinc carbonate sludge that had been generated by the manufacturing process. The marketable sludge was removed in 1989 and all of the settling basins were filled in 1989 under approval of Ecology. A Phase 1 and 2 environmental assessment (EA) completed for the site in November 2002 identified metals contamination, specifically zinc and cadmium in soil and groundwater. Between March 2003 and August 2003, CDM conducted a series of investigations to evaluate the nature and distribution of contamination. These investigations identified residual zinc carbonate sludge containing elevated zinc, cadmium, and lead concentrations and elevated zinc and cadmium concentrations in soil underlying Settling Basins #1 and #2 (SB #1 and SB #2). Elevated zinc and cadmium concentrations were identified in soil and groundwater within the manufacturing plant area. Two separate zinc plumes were identified in groundwater. One plume originates from SB #2. The second zinc plume originates from the plant area. In addition, a cadmium plume was identified within the plant area. The origin of the zinc and cadmium within the plant area has not been determined. Zinc concentrations in groundwater exceed surface water standards adjacent to the Columbia River; however, sampling of the river water itself adjacent to the site has not identified elevated zinc concentrations. Cadmium concentrations have attenuated to near surface water standards prior to reaching the river.

This FS included screening of multiple remedial technologies. Remedial technologies surviving the initial screening were assembled into five remedial alternatives listed below. The remedial alternatives were then evaluated in accordance with the Model Toxics Control Act.

Remedial Alternative	Technology Options
Alternative 1	Stormwater controls Institutional controls Site monitoring/MNA
Alternative 2	Impermeable cap Stormwater controls Institutional controls Site monitoring/MNA
Alternative 3	Additional soil removal Neutralization cap Stormwater controls Institutional controls Site monitoring/MNA
Alternative 4	Slurry wall Impermeable cap Stormwater controls Institutional controls Site monitoring/MNA
Alternative 5	Additional soil removal Hydraulic barrier pump and treat Stormwater controls Institutional controls Site monitoring/MNA

MNA - Monitored Natural Attenuation

At the conclusion of this FS it was determined that current technologies simply do not provide a long term solution that can achieve cleanup levels in a timely manner and at a reasonable cost for this site. The predominant reasons for this are: 1) the overwhelming hydraulic influence of the Columbia River on site groundwater; 2) the disproportionately low surface water standard for zinc; and 3) the depth of contaminated soils.

Alternative 5 is simply too costly to implement even if it could result in the achievement of surface water standards in a timely manner. Alternative 4 is similarly too costly to justify, especially considering that the hydraulic forces of the river would eventually cause failure of the slurry wall and require expensive repair/replacement.

Alternative 3 appears to provide the most cost effective reduction in contaminant concentrations. However, the net overall effects of this approach cannot be ascertained without at least implementing it in a pilot program. Based on this, CDM recommends implementing Alternative 3 in a phased approach. In this approach, the elements of additional soil removal, applying the neutralization cap in the area of

SB #2 only, and institutional controls would be implemented. The site would be monitored on a regular basis (i.e., semiannually). At the end of a 5 year period the effectiveness of these actions would be re-evaluated.

Section 1

Introduction

This document presents the results of Camp Dresser & McKee's (CDM) feasibility study (FS) for the former Clariant Chemical Plant in Kalama, Washington (site or subject property). The site location is shown on **Figure 1**. This FS was performed to develop, evaluate, and provide recommendations for appropriate alternatives to remediate metals contamination associated with onsite manufacturing activities. Camp Dresser & McKee Inc. (CDM) completed this FS on behalf of the prior owner of the site, Clariant Corporation (Clariant). In January 2003 Chemtrade Logistics assumed site ownership and conducts generally the same chemical manufacturing operations onsite. Investigation and cleanup of metals contamination is being conducted under Washington State Department of Ecology's (Ecology) Voluntary Cleanup Program (VCP). The site VCP number is SWO492.

1.1 FS Objectives

The objectives of this FS are summarized below:

- Develop remedial action objectives (RAOs) to achieve cleanup of the site.
- Screen potential remedial technologies to attain RAOs for the site.
- Combine remedial technologies, if necessary, to develop comprehensive remedial action alternatives.
- Develop conceptual level cost estimates for the implementation, operation, and maintenance of the remedial action alternatives.
- Recommend the most appropriate remedial action alternative program for implementation at the site.

1.2 Report Organization

The remaining sections of this report are organized as follows:

- Section 2 provides a description of the site and vicinity, including current land uses and geologic and hydrologic conditions. Historical land uses for site, as well as known and potential historical contaminant sources, are also presented.
- Section 3 provides a summary of previous environmental investigations conducted for the subject property.
- Section 4 provides a discussion of cleanup levels, contaminants of concern, and contaminant distribution.
- Section 5 establishes the site remedial goals and objectives.
- Section 6 includes an initial and secondary screening of remedial technologies applicable to the site.
- Section 7 provides an evaluation of five remedial alternatives developed for the site.
- Section 8 presents CDM's recommendations for site remediation.

Section 2

Site Description and History

2.1 Location and Setting

The site is located at 404 Hendrickson Drive, just south of the City of Kalama and north of Terminal 2, in the South Port area of the Port of Kalama. The site and vicinity are industrial, being located in the Port of Kalama industrial area. The site itself is not on Port-owned property. The Columbia River borders the west side of the site, Hendrickson Drive borders the east side of the site followed by a railroad line and then Highway 5. Dredge spoils are stockpiled on the Port of Kalama-owned property to the south. A river park is located to the north. Figure 1 shows the site location.

2.2 Site Description and Land Use

The property is approximately 6.7 acres in size and is relatively level throughout. Dredge spoils (sand) from the adjacent Columbia River were used to create the present land surface.

The site is occupied by an active chemical processing plant that produces sodium hydrosulfite. The site layout is shown on Figure 2. Facilities include an approximately 16,740-square-foot (sf) warehouse-type structure that is the manufacturing building. The building construction is structural steel column and beam framing with sheet metal siding and a concrete slab-on-grade foundation. This building houses the offices, dry material truck offloading, mechanic shop, dry raw material storage (i.e., during Clariant's ownership this included totes of granulated zinc, dry sodium hydrosulfite, pallets containing 50 pound bags of soda ash, and totes of sodium tripolyphosphate), zinc oxide baghouse, lab, and product manufacturing facilities (i.e., make tank room and formulation room).

Off the northwest side of the manufacturing building is a concrete secondary containment area. The chillers, wastewater tank, glycol, and dissolver tanks are located in this containment area. Electrical panels and an air compressor are located in a building addition off the west side of the manufacturing building to the south of this secondary containment area.

Just north of the manufacturing building is another metal building, about 900 sf in size, that houses the zinc oxide dryer. Liquid sodium hydrosulfite tanks are located in another concrete secondary containment area just north of the zinc oxide dryer building. Tank truck loading/unloading occurs just to the north of the sodium hydrosulfite tanks. North of this truck loading area are a caustic soda storage tank and two empty silos that formerly contained soda ash.

A railroad spur enters the site from the north end and extends along the east side of the facility structures. Just east of the railroad spur is a sulfur dioxide tank that rests on a concrete saddle. Between the railroad spur and sulfur dioxide tank is a small shed that houses a compressor.

A pump house is located adjacent to the west side of the property opposite the north end of the manufacturing building. A nitrogen tank system is located on a concrete pad east of the pump house and west of the electrical room.

Asphalt-paved parking is located at the south end of the manufacturing building. An asphalt-paved drive extends along the west side of the site. The north end of the facility, where the tank truck loading area and secondary containment areas with above ground storage tanks (ASTs) are located, is completely paved. A paved drive also extends from the northwest corner of the facility, curves toward the east, and exits the site through an electronic gate. Finally, the railroad spur, beginning at the truck loading drive on the north and extending along the east side of the plant warehouse to the entrance driveway on the south, is entirely paved.

From the north end of the manufacturing facility the property extends approximately another 800 feet. This is the area that formerly contained four settling basins as shown on **Figure 2**. Each settling basin was numbered 1 through 4 (SB #1 through SB #4) as shown on **Figure 2**. This area, which encompasses about 3.5 acres, is undeveloped except for the new asphalt drive described above and a Parshall flume through which noncontact cooling water is discharged to the Columbia River.

Some areas west and east of the manufacturing building are also unpaved as shown on **Figure 2**. An area south of the parking lot is also unpaved and unused. These areas tend to be sparsely vegetated with exposed sand at the surface.

2.3 Manufacturing Process History

The site was first developed in 1969 with the present facility. In the early day operation of the facility (approximately 1969-1973) zinc hydrosulfite was manufactured. From 1974 through the present day, the plant has been producing sodium hydrosulfite. Under the current manufacturing process zinc oxide is generated as a byproduct, which is sold for use as an additive during radial tire production. From approximately 1974 until the late 1970s or early 1980s, the process generated zinc carbonate sludge as a byproduct. This sludge was discharged to SB #2. Zinc carbonate sludge was apparently not discharged to SB #2 after 1984. SB #3 and SB #4 were never used. SB #1 received minor spillage of zinc carbonate sludge from the conveyance trough. The settling basins were closed in 1989 by removing the marketable zinc carbonate sludge from SB #2 and filling in the basins. Ecology approved of this closure method in a letter dated February 14, 1989.

One additional major change to the production process occurred with the discontinuance of cadmium sulfate solution. Prior to January 2004, cadmium sulfate was used as a catalyst, especially when lead impurities were present in the zinc. The use of this chemical had been reduced over the years until its eventual elimination from the process.

2.4 Geologic Setting

2.4.1 Site Area Geologic Conditions

The site lies within the Columbia River Basin and is underlain by alluvial river deposits and river dredge spoils. The site itself was created from dredge spoils derived from the Columbia River that consist primarily of gray to brown fine- to medium-grained sand with only a trace of silt underlie the entire site. The material sometimes contains minor gravel, coarse-grained sand, pumice-like volcanoclastic grains, and silt lenses. The dredge spoil thickness may be as much as 20 feet or more.

The river bank next to the west side of the site is protected by a solid layer of rip rap that extends from the top edge of the river bank to an undetermined depth below the water surface. There is no sediment along the riverbank; therefore, sediments are not a consideration applicable to the site.

Apparent bedrock underlies the dredge spoils. Close to the east side of the site near the plant building a brown to gray 2 to 8 foot thick silt layer has been observed on top of the bedrock and below the sand. In other areas the alluvial/fill sand appears to lie directly over the bedrock. The depth to bedrock ranges from 24 feet to greater than 60 feet. The bedrock dips downward toward the west and the south. Depth to bedrock at the north end of the site is approximately 24-28 feet, and along the east side of the site bedrock ranges between approximately 30-32 feet. The deepest exploration to date has been at piezometer location PZ15 (see Figure 2), located next to the fence line on the west side of the site opposite the southeast corner of the plant building, where bedrock was not encountered within the maximum explored depth of 60 feet.

2.4.2 Site Area Hydrologic Conditions

Groundwater occurs under water table conditions on top of the bedrock. Depth to groundwater varies seasonally and tidally, generally ranging between 20 and 26 feet below ground surface (ft bgs). There are some areas of the site (i.e., southeast and northeast corners) where the bedrock is apparently higher than the water table. Tidal water level monitoring has demonstrated the direct communication between the river and groundwater at this site. Generally, the groundwater flow direction is toward the Columbia River (west); however, the tidal action in the river creates a wave-like effect on the groundwater, which likely results in semi-stagnant conditions toward the center of the site.

2.4.3 Surface Water

Based on the flat topography, soil type, and paved conditions on the site there is very little stormwater runoff onto or off of the site. Unpaved areas have a very high infiltration rate due to the sandy nature of the surface and subsurface soils. The runoff from certain paved portions of the site that have a high likelihood of chemical contamination (i.e., zinc oxide loading area, the railroad spur, and secondary containment areas) is captured and discharged to storage tanks where it is used and incorporated into the manufactured product.

Until recently, runoff from the paved area to the west of the plant facility discharged to a small infiltration pond at the southwest corner of former SB#1 (see **Figure 2**). It is our understanding that this stormwater is also now entirely captured and used as manufacturing process water.

Section 3

Summary of Previous Investigations/ Interim Actions

3.1 Summary of Investigations Completed

The initial discovery/investigation of this site occurred when CDM completed a Phase 1 and 2 environmental assessment (EA) in November 2002 (CDM, 2002). The Phase 2 EA identified cadmium, lead, and zinc in site soils and cadmium and zinc in groundwater at concentrations that require additional investigation and remedial actions in accordance with the Model Toxics Control Act (MTCA). Since that time, several additional investigations and interim remedial actions have been completed in an effort to define and delineate the types, source, and extent of contamination, refine our understanding of the subsurface lithology, and to remove source areas of contamination. These investigations and interim remedial actions are summarized in the following sections. **Appendix A** includes analytical summary tables and figures showing exploration locations. The soil data and exploration locations presented in **Appendix A** are pertinent to current conditions following interim actions (e.g., soil analytical data and test pit locations in excavated portions of the settling basins are not presented).

3.1.1 Contaminant Delineation

Between March 2003 and August 2003, CDM conducted a series of investigations to evaluate the nature and distribution of contamination identified during the Phase 2 EA (CDM, 2004a). These investigations included installing and sampling nine vertical piezometers throughout the site (PZ1 through PZ9), installing and sampling two angle monitoring wells adjacent to/under the Columbia River (AB1 and AB2), excavating 24 test pits, and driving 12 temporary test holes to collect soil and/or water samples (W6 -W12; DPT-1 -DPT-5). Results of these studies indicated the following:

Soils

- Settling Basin #1 soils contained elevated concentrations of zinc and cadmium to a depth of approximately 7 ft bgs. The SB #1 fill soils contained scattered pockets of zinc carbonate sludge, but no indication that it was ever used to settle out zinc containing solids.
- Settling Basin #2 soils contained a thin layer of zinc carbonate sludge beginning at a depth of 4 to 6 ft bgs. The zinc carbonate sludge layer contained high concentrations of zinc, cadmium and lead. Below this sludge layer, zinc-contaminated soils apparently extend into groundwater to a depth of 25 feet or more.
- Soils in Settling Basin #3 and Settling Basin #4 did not appear to be adversely impacted and there was no indication of their prior use as settling basins.

- Surficial soils within the plant area contained elevated zinc concentrations primarily as a result of surface deposition from daily manufacturing activities. Surface soil cadmium exceedances were sporadic within the plant area. Cadmium was identified in subsurface soils near the groundwater interface, which appears to be primarily caused by groundwater transport.

Groundwater

- Groundwater is impacted with zinc and cadmium. Significant lead impacts were not identified.
- Not practicably excavatable (>15 ft bgs) residual zinc-contaminated soils below SB #2 are an ongoing source of zinc contamination to groundwater.
- Within the plant area there appears to be two separate sources of zinc and cadmium, which are distinct from the SB #2 zinc plume. The origin of zinc and cadmium are not known.
- Zinc concentrations in groundwater exceed surface water standards in monitoring wells closest to the river.
- The cadmium plume appeared to be limited to the plant area.

3.1.2 Soil Excavation Interim Action

In September and October 2003, Clariant excavated and disposed of 15,856 tons of soil (CDM, 2004b). Some of these soils were stabilized prior to offsite transport. SB #1 was excavated to an average depth of 7 ft bgs. SB #2 was excavated to an average depth of 15.2 ft bgs. The only contaminated soils that were not excavated from the settling basins were under the asphalt-paved road that extends through SB #1 and SB #2. Surficial soils were excavated from the east and west sides of the plant to an average depth of 1.5 ft bgs. Contaminated soils under the railroad spur were not excavated; however, this area was later paved over. With the exceptions of the soils under the road and railroad spur, remaining soils do not exceed standards based on human health risk. Also, soils in the area to the north of the plant (i.e., former settling basins) do not exceed limits based on protection of terrestrial ecological standards.

3.1.3 Groundwater Extraction

In December 2003, two extraction wells were installed within the plant, next to the secondary containment area, in an effort to clean up the cadmium plume (CDM, 2004c). Within a matter of months, iron oxide bacteria were found to be causing an accumulation of iron oxide sludge in the pumps (CDM, 2004d). The pumps repeatedly clogged from the sludge accumulation within a few weeks after cleaning. At first only one pump was affected, but a few months later the second pump incurred the same problem. By July 2004 the entire system was shut off as there was no reasonable way to both maintain the low flow rate and keep the system free from biofouling.

3.1.4 Groundwater Monitoring

In January 2004, a two year program of quarterly monitoring was implemented in an effort to evaluate normal variation in contaminant concentrations as well as the impact of removing source soils (CDM, 2004c; CDM, 2004e; CDM, 2004f; CDM, 2004g; CDM, 2005a; CDM, 2005b; CDM 2006a). No substantive conclusions could be made at the end of the second year of groundwater monitoring as significant variations in zinc and cadmium concentrations were observed throughout this period. While some increasing or decreasing trends were observed at individual wells, the trends appeared to be statistically significant at only a few locations.

3.1.5 Site Conceptual Model

In November 2005, CDM completed a site conceptual model of the hydrogeologic and geochemical conditions at the site that control the potential mobilization and transport of zinc and cadmium from residual and secondary sources of contamination (CDM, 2005c). The results of this evaluation are summarized as follows.

Cadmium Source and Distribution

- The most likely source of cadmium in groundwater is from cadmium sulfate, which historically had been used on the site.
- Based on the estimated mass of cadmium in the aquifer, natural attenuation by adsorption onto soil is likely limiting the size of the cadmium plume.

Zinc Sources and Distribution

- Residual zinc concentrations in soil at SB #1 have little impact on groundwater. Based on zinc concentrations in stormwater runoff, zinc that is present in groundwater in this area may be largely attributed to stormwater infiltration, rather than from the residual zinc concentrations present in the soil.
- Residual zinc concentrations at SB #2 below a depth of 15 feet, and residual sludge that underlies the paved road, are currently acting as a continuing source of contamination to groundwater. Under present circumstances infiltrating rainwater, which is slightly acidic, appears to be enhancing mobilization of the zinc.
- Groundwater geochemistry data are suggestive of a release of sodium hydrosulfite within the plant area. However, average zinc concentrations in the finished sodium hydrosulfite solution do not appear to be high enough to explain the high zinc concentrations noted in groundwater. The data indicates potential releases from equipment associated with the waste water tank (i.e., the sump or underground piping).
- Zinc concentrations in river water samples are low, even in river samples collected adjacent to groundwater wells that have high zinc concentrations.

- Based on the site conceptual model, an area weighted average of zinc concentrations across the site's boundary, the estimated maximum zinc loading to the Columbia River during an average rainfall year is no more than 11 pounds per day. This estimate is very conservative since it is based on a 31 acre recharge area (the plant site is 6.7 acres), does not take into consideration evapotranspiration from highly vegetated recharge areas and does not consider the daily gradient reversal of groundwater flow from tidal fluctuations in the Columbia River. A more realistic average daily loading of zinc to the river would be in the range of 25 to 50 percent of this estimate, or about 3 to 6 pounds per day. An updated hydraulic analysis is provided in **Appendix B**.
- The Columbia River carries an estimated load of 10,425 pounds of zinc per day (lb/day). Adding as much as 11 lb/day zinc would raise the zinc concentration in the river by an estimated 0.013 micrograms per liter ($\mu\text{g/L}$). Therefore, the flux of zinc from the site to this river is negligible.

3.1.6 Screening Level Ecological Risk Assessment (SLERA)

CDM also completed a SLERA in November 2005 to evaluate ecological pathways and site-related risks (CDM, 2005d). Results of the SLERA indicate that concentrations of dissolved zinc in the Columbia River just upstream of, and adjacent to, the site do not exceed or even approach concentrations at which important native aquatic biota are likely to experience adverse sublethal effects, or the site-specific chronic criterion for dissolved zinc based on Columbia River hardness from samples collected adjacent to the site. In addition, measured concentrations of dissolved zinc are well below concentrations associated with severe, acute effects in freshwater invertebrates and fish. Based on available data, adverse acute or chronic effects in resident or migratory fish and benthic aquatic invertebrates in the Columbia River from site-related contamination are not expected.

3.1.7 Tidal Variations on Water Levels and Contaminant Concentrations

CDM noted significant tidal influence on the groundwater across most of the site and recommended conducting an investigation of the variation of contaminant concentrations in selected wells due to tidal variation. In the summer of 2006, CDM conducted continuous water level monitoring and high and low tide sampling of selected wells near the river (CDM, 2006b). Additionally, the detection limit for cadmium was lowered to further determine if cadmium concentrations exceed surface water standards at sample locations near the river. The results of this investigation demonstrated the direct communication between the river and the groundwater. The wave-like effect on the groundwater table from the tides effectively results in semi-stagnant conditions further inland within the site. Zinc concentrations showed wide variation between high and low tides with no apparent consistency. With the lowered detection limits (previously $2 \mu\text{g/L}$), cadmium was detected in wells located near the river at concentrations ranging between 0.3 and $1.2 \mu\text{g/L}$.

3.1.8 Establishment of Plume Boundary and Depth to Bedrock

In February 2007, CDM conducted additional assessment along the north and south sides of the zinc plume in an effort to: 1) establish the north-south boundaries of the plume limits, and 2) to determine the depth to bedrock (CDM, 2007). Information on the depth to bedrock was considered important for the evaluation of a semi-permeable reactive barrier. This investigation did successfully define the north and south plume limits. The investigation confirmed that the bedrock surface dips generally downward from north to south along the western side of the site. At the north end of the plume the bedrock surface occurs at 55 ft bgs. At the south end of the plume bedrock was not encountered within the 60 ft exploration depth.

Section 4

Cleanup Levels and Contaminant Distribution

4.1 Regulatory Analysis

MTCA administered by Ecology (Washington Administrative Code [WAC] 173-340) establishes cleanup levels at contaminated sites. A cleanup level is the concentration a particular hazardous substance is considered a threat to human health or the environment. Points of compliance designate the location at a site where the cleanup must be met.

Under MTCA, cleanup levels that are protective of human health may be established under Method A, B, or C, as applicable. Method A provides tables of cleanup levels for 25 to 30 of the most common hazardous substances found in soil and groundwater. Method A cleanup levels are available for both unrestricted and industrial land uses. Cleanup levels under Method B are based upon unrestrictive land uses and are established using applicable state and federal laws and risk-based concentrations calculated using the equations specified in the regulations. Method C is similar to Method B, but cleanup levels are based on less stringent exposure assumptions and the lifetime cancer risk for carcinogens is set at 1 in 100,000 instead of 1 in 1,000,000. Use of Method C is limited to industrial sites where Method A or B cleanup levels are lower than technically possible, or when attainment of those levels may result in a significantly greater overall threat to human health and the environment. Method C requires that all practical methods of treatment have been used and institutional controls are in place. Natural background concentrations and the practical quantitation limit (PQL) are also considered when establishing Method A, B, or C cleanup levels.

In addition to the consideration for human health impacts, Methods A and B must account for potential terrestrial or aquatic ecological impacts unless it can be demonstrated that such impacts are not a concern at the site. Under Method C, only the impacts on wildlife must be considered when conducting the terrestrial ecological evaluation. Table 749-1 in MTCA provides a simplified terrestrial ecological evaluation to be used in evaluating whether or not potential terrestrial ecological concerns must be evaluated for a given site. The north end of the site is approximately 3.5 acres in size, and a substantial amount of undeveloped land exists within 500 feet of the site. Based on these current conditions and the apparent attraction for wildlife, terrestrial ecological concerns are considered applicable to the northern portion of the site. Terrestrial ecological concerns are not considered applicable on the southern portion of the site where there are manufacturing facilities and activities.

Because of the site's proximity to the Columbia river, surface water quality standards must also be considered when establishing cleanup levels. Method A surface water

quality standards generally refer back to the water quality standards in WAC 173-201A. Method B and C values based on human health protection can be calculated from standard calculations in MTCA. Determination of environmental effects on aquatic life may be determined from a literature search or whole effluent toxicity test (WET) (bioassay testing). Bioassay testing was not conducted for this site. CDM's SLERA provided an evaluation of the aquatic ecological risk to ecological receptor from dissolved zinc. Although the SLERA did not identify an imminent threat to aquatic resources from zinc discharges and, in reality the zinc discharges are negligible compared to what the Columbia River naturally carries on a daily basis, zinc concentrations in groundwater do not meet surface water standards at monitoring wells close to the river.

4.2 Points of Compliance

4.2.1 Soil

Under the terrestrial ecological evaluation procedures of MTCA, WAC 173-340-7490(4)(b) and human exposure via direct contact (WAC 173-340-740(6)(d)), the standard point of compliance for soil is 15 ft bgs. An institutional control is not necessary if soil contamination is deeper than this since it is considered that this depth represents a reasonable estimate of the maximum depth at which soil could be excavated and distributed to the surface. For sites with soil contamination at shallower depths, Ecology may grant a site-specific conditional point of compliance as long as institutional controls (i.e., restrictive covenant) are implemented. For cleanup levels based on terrestrial ecological protection only, Ecology generally accepts a conditional point of compliance below the biologically active soil zone, which is typically assumed to extend to a depth of 6 feet.

4.2.1
Soil
15 ft bgs
6 ft bgs

4.2.2 Groundwater

The point of compliance is the point or points where the groundwater cleanup levels have been established. The standard point of compliance is throughout the site, both vertically and horizontally throughout the aquifer. A conditional point of compliance may be used where it can be demonstrated that it is not practical to meet the cleanup level throughout the site. A conditional point of compliance cannot exceed the property boundary except under three specific situations. One of these situations includes properties, such as the subject property, which abut surface water. Ecology may approve of a conditional point of compliance that is located within the surface water as close as technically possible to the point or points where the groundwater flows into the surface water subject to the following conditions.

- 1) Contaminated groundwater is entering the surface water and will continue to do so after implementation of the selected cleanup action.
- 2) It is not practicable to meet the cleanup standard 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 is not allowed.
- 4) Groundwater discharges shall be provided with all known available and reasonable methods of treatment prior to discharge to the surface waters.
- 5) Groundwater discharges shall not result in exceedances of sediment quality standards.
- 6) Groundwater and surface water monitoring shall be conducted to assess the long-term performance of the selected cleanup action, including potential bioaccumulation problems resulting from surface water concentrations below method detection limits.
- 7) A notice of the proposal shall be mailed to the natural resources trustees, the Washington State Department of Natural Resources, and the United States Army Corps of Engineers.

4.3 Cleanup Levels and Contaminant Distribution

Table 1 summarizes cleanup levels for zinc and cadmium relevant to the site, based on protection of the various receptors of concern. During the initial RI work, lead and copper had been analyzed in some soil and groundwater samples. However, lead was only an issue when the zinc carbonate sludge was present (which is now all removed) and copper concentrations were never found to be substantially elevated. Therefore, these metals were dropped from further analyses. The following summarizes the most stringent cleanup levels applicable for site contaminants of concern.

Soil

Direct Contact Pathway - Settling Basins: For the direct contact pathway, the ecological indicator concentration of 360 milligrams per kilogram (mg/kg) for zinc is applicable to a depth of at least 6 ft bgs. Between 6 and 15 ft bgs, the direct contact human health (ingestion) concentration of 24,000 mg/kg is applicable. For cadmium, the Method A soil cleanup level of 2 mg/kg is the lowest applicable soil cleanup level.

Direct Contact Pathway - Plant Area: Direct contact human health standards to a depth of 15 ft bgs are considered applicable (24,000 mg/kg for zinc and 2 mg/kg for cadmium).

Groundwater Protection - Zinc and cadmium soil cleanup levels considered protective of groundwater have not been developed under MTCA. Previously, Ecology's Cleanup Level and Risk Calculation (CLARC) tables contained Method B soil cleanup levels that were considered protective of groundwater. These values were 6,200 mg/kg for zinc and 7.5 mg/kg for cadmium. However, as leachable analyses of site soils at the base of SB #2 suggest, these concentrations are not low enough to be sufficiently protective of groundwater.

Groundwater

Within the site, groundwater cleanup levels based on Maximum Contaminant Levels (5,000 µg/L for zinc and 5 µg/L for cadmium) are applicable. However, because of the direct communication between site groundwater and the surface water, beyond the property line a surface water standard is applicable according to MTCA (WAC 173-340-720(1)(c)). The lowest applicable surface water standards are 66 µg/L for zinc and 0.7 µg/L for cadmium. These values are calculated from the current surface water regulations (WAC 173-201A, modified November 20, 2006) using the Columbia River average hardness value of 58 milligrams per liter [mg/L]).

Summary tables of all groundwater data are contained in **Appendix A**. The following sections summarize site conditions with respect to these cleanup levels.

4.3.1 Soil

Summary tables of all soil data representing existing conditions are included as **Tables A-1 through A-6** in **Appendix A**. Based on the studies and interim actions completed to date, the following summarizes our understanding of the distribution of zinc and cadmium in site soils.

- In SB #1 soils that exceed terrestrial ecological-based cleanup levels, with the exception of soils underneath the asphalt-paved road, have been removed to a minimum depth of 6 ft bgs. Soils below this depth do not exceed direct contact human health-based standards. At the base of the excavation, zinc concentrations range from 27 to 410 mg/kg and cadmium is undetected. Leachable zinc concentrations at the base of the excavation range from <0.1 mg/L to 6.9 mg/L.
- In SB #2 soils that exceed terrestrial ecological and direct contact human health-based cleanup levels, with the exception of soils underneath the asphalt-paved road, have been removed to a depth of at least 10 ft bgs. In the southeast corner of the former SB #2 only, soils between 10 and 15 ft bgs may sometimes exceed the terrestrial ecological soil cleanup level for zinc, but do not exceed MTCA Method A or B soil cleanup levels for cadmium or zinc based on human health risks. At the base of the excavation zinc concentrations range from 990 to 6,200 mg/kg and cadmium is undetected. Leachable zinc concentrations range between 26 and 200 mg/L at the base of the excavation.
- In SB #3 and SB #4 cadmium is undetected and zinc concentrations are all well below the terrestrial ecological cleanup level, except for one 5 ft sample that contained 376 mg/kg.
- Zinc in soils underlying the manufacturing plant area does not exceed the direct contact human health-based soil cleanup levels. Zinc concentrations in surficial soils range to as much as 2,330 mg/kg. Out of 100 samples analyzed in this area, the median zinc concentration is 420 mg/kg.

Zinc

- In SB #1 residual soil zinc concentrations appear to have a low impact to groundwater. Based on zinc concentrations in stormwater runoff, the relatively low groundwater zinc concentrations in this area may be largely attributed to stormwater infiltration.
- In SB #2, even after removal of the majority of source soils, there is an ongoing source of zinc contamination to groundwater. Infiltrating acidic rainwater is dissolving residual zinc that had previously leached from the zinc carbonate sludge into vadose soils below the bottom of the excavation and is causing continued downward mobilization of zinc. An increasing trend in zinc concentrations downgradient of SB #2 is likely caused by the removal action completed in October 2003 of the zinc carbonate sludge layer, which had provided some alkaline buffer to counter the leaching effect of acidic rain water. Very high zinc concentrations next to the road suggest that that the road as a cap is not effectively reducing contaminant loading.
- In the plant area groundwater geochemistry and soil data are suggestive of a historic and/or continuing release of sodium hydrosulfite. No specific source area has been identified from soils data.
- Along the property line and adjacent to the river, zinc concentrations in groundwater exceed the acute fresh water aquatic standard. However, zinc concentrations in the river water adjacent to the site are all low. There is no difference between samples collected next to the plant, upstream or downstream of the plant.

Cadmium

- The cadmium plume is concentrated around the secondary containment area located off the northwest side of the building.
- Cadmium concentrations in groundwater at the property line and adjacent to the river sometimes minimally exceed the acute fresh water aquatic standard.

4.3.3 Summary

Residual zinc and cadmium concentrations in soil pose virtually no threat to human health and the environment from direct exposure. Nearly all soils exceeding direct exposure based cleanup levels have either been removed or are currently capped. However, residual zinc and cadmium concentrations continue to provide an ongoing source of contamination to groundwater.

Zinc and cadmium concentrations in groundwater exceed Method A/B standards and surface water standards (although cadmium exceedances of surface water standards are sporadic and minimal). The site is on city water and the groundwater is not a source of drinking water. Therefore, groundwater poses no imminent threat to human health. The river itself shows no apparent impact from elevated zinc or cadmium concentrations.

Section 5

Remedial Goals and Objectives

The overall goals for any proposed remedy at this site are to:

- Protect human health and the environment.
- Comply with all applicable regulations.
- Obtain a “No Further Action” status for the site.

The following remedial action objectives have been developed to meet these overall goals.

Remedial Action Objective #1 - Mitigate Off-Site Migration of Groundwater that Exceeds Surface Water Standards. Mitigating the offsite migration of zinc, and to a much lesser extent cadmium, (i.e., achieving surface water standards at the property boundary) is the primary remedial action objective (RAO) for this site.

Remedial Action Objective #2 - Mitigate Onsite Groundwater Exceeding Cleanup Levels. Groundwater cleanup levels applicable to the site are based on drinking water standards.

Remedial Action Objective #3 - Mitigate Soils that Exceed Direct Exposure Cleanup Levels. The interim action has achieved this RAO for most of the site. Currently, some soils within a depth of 15 feet from ground surface exceed direct exposure standards. However, almost all of these soils are currently capped.

Remedial Action Objective #4 - Mitigate Soils that Act as a Continuing Source of Groundwater Contamination. Zinc and/or cadmium in much of the soils in RAO#3 and in some deeper soils leach at concentrations that are not protective of groundwater/surface water.

Section 6

Development and Screening of Remedial Options

This section documents the initial steps involved in developing and screening remediation options for contaminated groundwater at the site. This section also identifies general response actions and screens viable technology types that will remediate contaminated groundwater and soil and attain the RAOs identified in Section 5. Finally, this section summarizes the remedial technologies that will be carried forward into the detailed description of selected technology alternatives (Section 7).

6.1 General Response Actions, Technologies and Process Options

General response actions are broad classes of actions that may satisfy RAOs for the site. General response action categories for the site are assembled based on the nature and extent of contamination, as described in Section 4. General response actions considered applicable to the metals contamination found at the site include treatment, containment, excavation, extraction, disposal, institutional controls, or a combination of these categories. The eight general response actions include the following:

- No Further Action
- Institutional Controls
- Monitored Natural Attenuation
- Storm Water Controls
- Containment
- In-situ Treatment
- Pump and Treat
- Excavation and Off-site Disposal

Specific remedial technologies and process options potentially applicable to the site have also been identified within the general response actions listed above. These technologies are summarized in **Table 2**. The following sections further describe these technologies and discuss and evaluate each and its applicability to metals contamination in soil and groundwater at the Clariant site.

6.2 Screening of Remedial Technologies

This section screens the identified potential technology types for remediation of contaminated soil and groundwater at the Clariant site. **Table 3** provides a summary of this evaluation and screening process. Screening and evaluation of remedial technologies and related process options are based on the type, distribution, and volume of contaminants found in soil and groundwater at the site and on the RAOs

discussed in Section 5. Technology types are identified for each general response action. One or more process options are identified for each technology and each is reviewed against site-specific conditions and evaluated based on three preliminary criteria: effectiveness, implementability, and relative cost. The basis for applying each of these three criteria in the evaluation of individual technology process option is described below.

Effectiveness Evaluation. This evaluation focused on the potential effectiveness of each process option in remediating the contaminated soil and groundwater and in meeting the RAOs. Specific information considered included types and levels of contamination, the volume and areal extent of contaminated soil and groundwater, and the time to achieve remediation goals. Each process option was classified as being effective, limited, or not effective.

Implementability Evaluation. This evaluation rated the relative degree of technical implementability and feasibility of implementing the process option. Aspects considered included any substantive requirements of potential permits for actions, availability of treatment, storage and disposal services, and the availability of necessary equipment and skilled workers to implement the technology. The implementability of each process option was classified as easy, moderately difficult, difficult, or not implementable.

Cost Evaluation. The cost evaluation was based on engineering judgment, and each process option was evaluated in relation to other process options of the same technology type. Both capital and operating costs were considered. The cost of each process option was classified as low, moderate, high or very high.

The following sections further describe and summarize the screening results for each general response action.

6.2.1 No Further Action

No Further Action implies that no remedial action will be conducted on the site. The site is allowed to continue in its current state, and no future actions are conducted to remove or remediate the contamination. No access restrictions are put into place, and no deed restrictions are placed on the site. The no action response provides a baseline for comparison to the other remedial response actions.

Effectiveness. The No Further Action option is not effective in remediating the contaminated soil and groundwater and in meeting the RAOs.

Implementability. The No Further Action option is easy to implement technically, because it does not require any actions to be taken. Administrative implementability is not evaluated in this FS.

Cost. There are no construction or operations and maintenance costs associated with the No Further Action option because no actions are taken and no site monitoring is conducted.

Screening Summary. The No Further Action option will not achieve RAOs and is not acceptable under MTCA so it is not retained.

6.2.2 Institutional Controls

Institutional controls are nonengineering measures, such as administrative or legal controls, that help minimize the potential for human exposure to contamination and/or protect the integrity of a remedy by limiting land or resource use. Washington defines institutional controls under WAC 173-340-440 as measures undertaken to limit or prohibit activities that may interfere with the integrity of an interim action or cleanup action or that may result in exposure to hazardous substances at a site. These institutional controls may include:

- Physical measures such as fences.
- Use restrictions such as limitations on the use of property or resources, or requirements that cleanup action occur if existing structures or pavement are disturbed or removed.
- Maintenance requirements for engineered controls such as the inspection and repair of monitoring wells, treatment systems, caps or ground water barrier systems.
- Educational programs such as signs, postings, public notices, health advisories, mailings, and similar measures that educate the public and/or employees about site contamination and ways to limit exposure.
- Financial assurances.

Examples of institutional controls that may be applicable to metals contamination at the site include land use controls and groundwater use restrictions. Institutional controls could also include health and safety policies and procedures to limit exposure to soil contaminants during construction activities.

Effectiveness: Institutional controls can be effective at managing human exposure to contaminated soil and groundwater (RAOs # 2 and #3); however, they do nothing to reduce existing contaminant concentrations. The effectiveness of institutional controls depends on the mechanisms used and the durability of the institutional control. The need for human actions to implement and maintain the controls make them less reliable than engineering controls. Overall, institutional controls are considered to have limited effectiveness.

Implementability: Institutional controls are typically easy to implement.

Cost: Institutional controls are low cost.

Screening Summary: Institutional controls could achieve RAOs #2 and #3, and can improve overall protectiveness when used in conjunction with other remedies. Therefore, institutional controls are retained.

6.2.3 Monitored Natural Attenuation

Monitored natural attenuation (MNA) refers to the reliance on natural attenuation processes to achieve site-specific remedial objectives within a timeframe that is reasonable compared with that offered by other more active methods (EPA, 1999). The processes, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes for metals include dispersion; dilution; sorption; and the chemical or biological stabilization or transformation of contaminants. Ecology expects that natural attenuation of hazardous substances may be appropriate at sites where:

- Source control (including removal and/or treatment of hazardous substances) has been conducted to the maximum extent practicable;
- Leaving contaminants onsite during the restoration time frame does not pose an unacceptable threat to human health or the environment;
- There is evidence that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site; and
- Appropriate monitoring requirements are conducted to ensure that the natural attenuation process is taking place and that human health and the environment are protected.

Effectiveness: The effectiveness of MNA at the site depends on site conditions such as source strength and persistence, soil and groundwater chemistry, pH, temperature, microbial activity, and oxidation-reduction coupling. Natural attenuation processes appear to be effectively limiting migration of cadmium contamination in groundwater in portions of the site (Section 3), but is less effective in limiting migration of zinc.

Implementability: Implementation of MNA as a remediation technology entails a comprehensive groundwater monitoring program to provide data to evaluate attenuation rates and to monitor plume extent. A monitoring well network exists at the site to adequately monitor natural attenuation. Equipment and methods to sample and analyze groundwater are readily available. Monitored natural attenuation is easy to implement.

Cost: Costs to implement and maintain a groundwater monitoring program to monitor natural attenuation are low to high, depending upon the number of wells sampled, the frequency of sampling, and the duration of sampling.

Screening Summary: Monitored natural attenuation alone may achieve surface water RAO #1 for cadmium, but not for zinc, within a reasonable timeframe. MNA is typically used as a follow-up to other more aggressive remediation efforts such as the interim remedial action completed in October 2003. It is retained for consideration.

6.2.4 Stormwater Controls and Best Management Practices

Stormwater controls and best management practices (BMPs) include a variety of engineering methods to manage stormwater to reduce potential releases of contaminants from the site. Common stormwater control elements include effective run-on and runoff controls. Run-on control ditches divert upgradient surface water flow around and away from the area. Runoff control ditches convey water away from source areas and any transported sediments to facility stormwater retention and treatment systems. BMPs would be used to minimize the release of metals from chemicals, products and materials at the facility. These practices include spill prevention, control and countermeasures, leak detection and minimization, safe work practices, clean product production and handling procedures, and timely maintenance.

Potential run-on to the site is currently prevented by Hendrickson Drive and railroad track embankments east of the site. Overland flow either infiltrates at these embankments or is diverted to the north or south of the site along these embankments. Precipitation that falls directly within the site is collected and controlled by existing stormwater features. Chemtrade has recently made improvements to its stormwater control system at the site. Reportedly, this includes completing pavement over all areas potentially impacted by contaminants associated with manufacturing activities and collection and use of the stormwater runoff from these areas as manufacturing process water. CDM, however, has not been advised of the complete details regarding this system. Stormwater associated with non-manufacturing areas is assumed to be unimpacted.

Effectiveness: Stormwater controls and best management practices at the site are expected to be effective at preventing off-site releases of contaminated stormwater and sediment and reducing the amount of stormwater infiltrating through source areas to groundwater. This is expected to result in a small reduction in zinc and cadmium flux to the river; however this reduction is not expected to meet RAOs. BMPs would minimize or eliminate addition of metals to site soil and groundwater.

Implementability: Stormwater controls and BMPs can be easily implemented at the site.

Cost: Costs to implement and maintain stormwater controls and BMPs are low. It is expected that Chemtrade will implement stormwater controls and BMPs as a part of its normal operations.

Screening Summary: Stormwater controls and BMPs alone are not expected to achieve RAOs; however, they do provide some benefit by managing and reducing

stormwater infiltration in the source areas. Therefore, these options are retained and will be considered in conjunction with other options to form cleanup alternatives.

6.2.5 Containment

Containment actions control or reduce migration of the contaminated materials into the surrounding environment. They can also be used to isolate contaminated soil or groundwater to reduce the possibility of exposure by direct contact. These actions may involve the use of physical barriers to block a contaminant migration pathway such as a soil-to-groundwater pathway. Containment actions for contaminated groundwater typically include physical barriers or hydraulic gradient controls. Phytoextraction can also be useful for hydraulic containment. This includes planting of deep rooted shrubs or trees within the contaminated groundwater area to uptake metals-contaminated water. The metals are then stored in the plant tissues. Plants are periodically harvested and disposed off-site.

6.2.5.1 Horizontal Barriers

For the site, a horizontal barrier or cap could be used to reduce precipitation infiltration through contaminated soil and potentially to prevent recharge to groundwater in source areas. An impermeable cap over contaminated soil areas could be constructed of clay, asphalt, concrete, or by using synthetic liners such as polyvinyl chloride or polyethylene. Some areas of the site are currently capped by paved parking lots/driveways and building foundations. The integrity of existing parking lots or building surface covers is unknown, but these surfaces all appear to be structurally good. Stormwater runoff from these impermeable areas (buildings and paved areas) is managed by the facility stormwater system. Runoff from newly capped areas would be allowed to infiltrate through adjacent areas or to be directed to existing surface water drainages.

Effectiveness: Horizontal barriers or caps at the site could significantly reduce migration of contaminants from soil to groundwater due to infiltration of precipitation (RAO #4). In addition, a cap would provide a barrier to human exposure to contaminated soil and groundwater (RAO #2 and RAO #3). However, source soils remaining within the saturated and capillary zones would remain and would continue to affect groundwater. Total groundwater flux to the river would be reduced by the cap but RAO #1 for the river is not expected to be met by the cap alone. The overall effect of a cap in the source areas and is ranked with moderate effectiveness.

Implementability: Capping is considered a standard construction practice and easily implemented. Equipment and construction methods associated with capping are readily available, and design methods and requirements are well understood.

Cost: A single-layer cap for the site source areas would have a moderate cost to construct and low maintenance cost.

Screening Summary: Containment with a cap could provide protection of human health and reduction in zinc loading to the river and is retained for use with other technologies in site-wide remediation strategy.

6.2.5.2 Vertical Barriers

Physical containment methods to isolate groundwater at the site could include vertical physical barriers including sheet piling and cutoff walls or curtains. These types of physical barriers could be used in conjunction with in-situ treatment walls or gates commonly referred to as permeable reactive barriers (see Section 6.2.6). The physical barrier technology evaluated for the Clariant site is slurry wall. Most slurry walls are constructed of a soil, bentonite, and water mixture. The bentonite slurry is used primarily for wall stabilization during trench excavation. A soil-bentonite backfill material is then placed into the trench (displacing the slurry) to create the cutoff wall. Walls of this composition provide a barrier with low permeability (typically 10^{-7} centimeters per second) and chemical resistance at low cost. Other wall compositions, such as cement/bentonite, pozzolan/bentonite, attapulgite, organically modified bentonite, or slurry/geomembrane composite, may be used if greater structural strength is required or if chemical incompatibilities between bentonite and site contaminants exist.

Slurry walls are typically placed at depths up to 100 feet and are generally 2 to 4 feet in thickness. Installation depths over 100 ft are implementable using clam shell bucket excavation, but the cost per unit area of wall increases by about a factor of three. The most effective application of the slurry wall for site remediation or pollution control is to base (or key) the slurry wall 2 to 3 feet into a low permeability layer such as clay or bedrock. This "keying-in" provides for an effective foundation with minimum leakage potential. An alternate configuration for slurry wall installation is a "hanging" wall in which the wall projects into the groundwater table to block the movement of lower density or floating contaminants such as oils, fuels, or gases. Hanging walls are used less frequently than keyed-in walls.

The following table presents a summary of the typical parameters for a soil-bentonite slurry wall in comparison with other backfill materials (Andromalos and Fisher, 2001). Other critical factors include acceptability of site soil for use in backfill, trench stability, chemical compatibility, available work area, water availability, longevity, and availability of off-site backfill materials (if required).

Slurry Wall Backfill Material Properties

Backfill Material	Permeability (cm/sec)	UCS (psi)	Density (pcf)	Cost (\$/sf)	Comment
Soil-Bentonite	1×10^{-7}	0	100-130	3-6	Requires min. 15% fines
Soil-Attipulgite	1×10^{-7}	0	100-130	3-6	For saline environments
Soil-Cement-Bentonite	5×10^{-7}	50	95-120	5-10	Typically remote mix
Cement-Bentonite	1×10^{-7}	25	70-75	6-12	Self-hardening slurry
Slag cement-Bentonite	5×10^{-7}	100	69-72	6-12	Self-hardening slurry
Impermix™	1×10^{-9}	100	69-72	8-16	Self-hardening slurry
Composite w/liner	1×10^{-10}	N/A	N/A	7-14	Depth Limitations

Notes:

cm/sec centimeters per second
 UCS uniform compressive strength
 Psi pounds per square inch
 Pcf pounds per cubic foot
 \$/sf dollars per square foot

Effectiveness: For a vertical groundwater barrier to be effective at the site, it would need to adequately reduce the rate of water flowing through contaminated soils. This may require keying the barrier into the top of the bedrock that underlies the alluvial aquifer. The bedrock surface underlying portions of the site may contain undulations that could prove problematic to sealing and pilot studies are recommended to further evaluate this issue. Also, a vertical barrier may need to encircle the source area to reduce any groundwater flow around the barrier, or be combined with groundwater pump and treat system if located only along the downgradient edge of the site. Finally, the effect of the river fluctuations on a slurry barrier wall is not known. Considering the direct hydraulic connectivity to the river, the constant tidal fluctuations and seasonal freshets are likely to weaken the wall. Effective containment of groundwater at the source areas by vertical physical barriers could significantly reduce zinc flux to the river and achieve RAO #1. Containment by itself would not remediate source areas, and soil and groundwater within the source areas would remain contaminated.

Implementability: Groundwater containment can be difficult to achieve; however, these actions have been successfully implemented at other similar sites. A slurry wall depth of between 35 and 65 feet at the Clariant site is well within the normal range for excavation equipment used for constructing slurry walls. Groundwater containment using a vertical barrier such as a slurry wall is ranked as moderately difficult to implement.

Cost: Vertical groundwater barrier using a slurry wall at the site would have a high cost to construct. Maintenance costs of vertical groundwater barriers are considered low.

Screening Summary: Vertical groundwater containment using a slurry wall could achieve RAO #1 and is retained as a potentially viable and effective alternative.

6.2.5.3 Hydraulic Barrier

Groundwater containment can also be achieved through the use of hydraulic barriers. Phytoextraction can be used to establish a hydraulic barrier through plant root uptake of shallow groundwater. More typically, hydraulic containment includes the use of pumping wells, french drains, or extraction trenches to create hydraulic sinks that would collect contaminated groundwater and reduce further migration. Hydraulic containment would require water treatment prior to on- or off-site disposal or reinjection (see Section 6.2.7 for additional discussion of pump-and-treat technologies).

Effectiveness: Except near the river edge, site groundwater depths are generally over 25 feet which is greater than the typical rooting depth of plants and trees used for phytoextraction. Zinc uptake by plants could be expected at the river edge; however, effectiveness is likely limited due to tidal fluctuations and river water influence. Hydraulic containment via conventional extraction methods is expected to be effective at reducing migration of zinc and cadmium contaminants in groundwater, but does not provide remediation for contaminated soil in source areas. This technology would effectively reduce zinc loading to the river, but achievement of RAO #1 is uncertain. Tidal fluctuations and reverse groundwater gradients caused by river influences could limit effectiveness. Some reduction in source area contaminant mass would be achieved by this approach since hydraulic containment requires the removal of contaminated groundwater; however, containment by itself would not remediate source areas to achieve groundwater standards in a reasonable timeframe.

Implementability: Phytoextraction would be difficult to establish at the river edge due to the large riprap. Equipment and construction methods associated with conventional hydraulic containment are readily available, and design methods and requirements are well understood. Pump and treat systems can be difficult to maintain and existing site extraction wells are prone to fouling. Hydraulic containment is lost when components fail or are shut down for maintenance. However, groundwater containment at the site is not expected to pose any insurmountable difficulties; these actions have been successfully implemented at other, similar sites. Maintenance of extraction well systems can be difficult depending upon site-specific conditions and potential fouling. Therefore, hydraulic containment is ranked as moderately difficult to implement.

Cost: Groundwater containment at the site would have a moderate cost to construct and a moderate to high cost to operate and maintain.

Screening Summary: Phytoextraction is not retained due to limited effectiveness and implementation difficulties posed by riprap at the river edge. While it is uncertain if conventional hydraulic containment would achieve RAO #1, it is retained and will be considered further as part of a pump-and-treat alternative.

6.2.6 In-Situ Treatment

In-situ treatment consists of actions that treat contaminants in place. In-situ treatment of metals in contaminated soil or groundwater generally includes methods to separate and remove contaminants or to stabilize contaminants in place. Methods of in-situ chemical treatment generally involve adding agents to the subsurface (via wells or treatment walls) that facilitate chemical stabilization. The types of in-situ degradation most frequently used with metals include neutralization and precipitation. Neutralization of metals at the site would make use of carbonate-based reagents and precipitation may be brought about using sulfur-based reagents, sulfate reducing bacteria, ferrous iron or nano-scale zero valent iron. A cap composed of crushed limestone would be one method of passive neutralization where precipitation infiltrating through the cap would carry neutralization capacity to subsurface soil and groundwater.

Another form of in-situ treatment uses permeable treatment walls or gates also known as permeable reactive barriers. A permeable reactive barrier to treat metals found at the Clariant site would most likely use zero valent iron or an ion exchange resin or zeolite. Contaminated groundwater comes into contact with the wall, which is permeable, and a chemical reaction removes dissolved metals from groundwater. The walls are placed in the subsurface across the natural flow path of the contaminant plume. They can be combined with impermeable flow barriers in a "funnel and gate" arrangement in which flow is directed through the treatment walls or gates.

In-situ solidification or stabilization involves physical mixing or pumping of cement, fly ash, or grout into the contaminated soil to limit the leachability of the material. Vitrification solidifies the soil matrix by high temperatures created using electric current. In-situ treatment methods to separate and remove contaminants include soil flushing or electrokinetic separation. Soil flushing involves introduction of mixtures of water, acids, chemical surfactants, or cosolvents into the subsurface to strip or dissolve contaminants and then remove them through groundwater extraction. Electrokinetic separation uses electricity to separate and collect metals at electrodes.

Effectiveness: The effectiveness of in-situ treatment options at the site is difficult to predict due to the dynamic nature of groundwater geochemistry caused by tidal influences. Geochemical conditions initially established by in-situ neutralization, precipitation or a permeable reactive barrier may be difficult to maintain because the influence of river water during high tide events may largely negate or reverse treatment effects. Pilot studies would be required to better predict treatment effectiveness of these techniques. Other options such as in-situ soil flushing and electrokinetic separation are largely unproven. Due to these uncertainties, these options are considered to have only limited effectiveness at reaching RAOs. In-situ

solidification is expected to be moderately to highly effective and would be only minimally affected by tidal influences.

Implementability: In-situ treatment is considered to moderately difficult to implement for those options such as in-situ flushing and neutralization that would require injection of reagents into the groundwater. A neutralization cap would be easy to implement. A permeable reactive barrier along the downgradient side of the site is expected to be moderately difficult to construct. In-situ solidification and electrokinetic separation are considered difficult to implement due to treatment depth, saturated conditions, and interferences with plant infrastructure in portions of the site.

Cost: The cost of in-situ treatment varies with the specific technology. A neutralization cap is expected to have a low to moderate cost. In-situ neutralization and precipitation through injection are expected to have moderate capital costs and high O&M costs since long-term repeat treatments are assumed. The cost of in-situ soil flushing and solidification are considered high to very high and the cost for in-situ electrokinetic separation is considered very high. The cost of a permeable reactive barrier is expected to be high to very high.

Screening Summary: Due to the high degree of uncertainty associated with most of the in-situ treatment options in attaining RAOs, only a neutralization cap is retained for further evaluation as a representative in-situ treatment technology.

6.2.7 Groundwater Pump and Treat

Collection, treatment, and discharge (pump and treat) are used to reduce groundwater contaminant levels more rapidly than plume containment or monitored natural attenuation in addition to preventing further plume migration. An extraction system is used to remove contaminated groundwater from the affected aquifer. This step is followed by treatment, if required, and discharge or reinjection of treated water back into the aquifer. Extraction can be achieved by using pumping wells, French drains, or extraction trenches. Pumping may be continuous or pulsed to remove contaminants after they have been given time to desorb from the aquifer material and equilibrate with groundwater. Above-ground treatment may involve physical and chemical processes such as adsorption/absorption, ion exchange, membrane filtration, precipitation/coagulation, or evaporation depending on the physical and chemical properties of the contaminants. Discharge options at the site include discharge to a holding tank where it is then used as manufacturing process water, groundwater reinjection, or discharge to surface water.

Pump and treat expands on the hydraulic barrier option described in Section 6.2.5.3 by providing for treatment and discharge of the extracted groundwater.

6.2.7.1 Extraction Wells and Collection Trenches

Two types of collection technologies are considered applicable to the site source areas: extraction wells and collection trenches. Small-diameter (2- to 6-inch) wells are the

most common method of extracting contaminated groundwater and could be used in all areas of the site. Extraction wells are typically emplaced vertically into the aquifer with a well screen and pump placed below the water table. Design of the extraction wells, including spacing, would be based on aquifer characteristics such as hydraulic gradient and hydraulic conductivity. Computer modeling may be used to predict required well spacing and pumping rate, but pilot testing is recommended to further define system design parameters. Extraction wells could be designed to remove water from specific depths within the aquifer or from across the entire saturated thickness. Collection trenches or horizontal wells could also be used at the site, where depths to the base of the aquifer are generally less than 60 feet. The collection trench would typically be constructed as a gravel-filled trench emplaced below the water table containing perforated pipe connected to a collection sump and pump. Collection trenches may also serve as a hydraulic barrier and can be more effective than vertical extraction wells at preventing off-site migration of contamination.

Effectiveness: Extraction wells are considered effective for intercepting and extracting groundwater; collection trenches are considered effective for shallow formations. **Appendix B** presents an assessment of one pump-and-treat option to contain and remediate groundwater at the site. The assessment found that pump-and-treat could be effective at preventing off-site migration of contaminated groundwater through hydraulic containment. These results suggest that pump-and-treat technology could be effective at meeting RAO #1 for the river; however, it is uncertain if full containment could be achieved due to tidal fluctuations and reverse groundwater gradients caused by river influences. Pilot studies would be necessary to determine overall effectiveness. Pump and treat would also be effective at removing zinc and cadmium from groundwater; however, the timeframe to reach groundwater standards is uncertain.

Implementability: Extraction wells are easy to construct and are a very well-tested and widely available technology. Collection trenches are considered moderately difficult to implement due to trenching depths.

Cost: Extraction wells, collection trenches, and pumping capital and maintenance costs are considered low to moderate and depend on the number of wells or trenches that must be installed and the length of operation.

Screening Summary: Pump-and-treat scenarios using extraction wells and collection trenches are effective methods for containing and treating groundwater but it is unknown if RAOs for groundwater or the river could be met within a reasonable timeframe. However, the technologies are retained and will be considered further in conjunction with treatment and discharge options.

6.2.7.2 Physical/Chemical Treatment of Extracted Groundwater

Adsorption: Adsorption treatment involves pumping groundwater through a series of vessels that contain material that adsorbs the contaminants. Numerous types of adsorption media are available and include activated carbon, activated alumina,

forage sponge, lignin adsorption, sorption clays, and synthetic resins. The material may be either removed and regenerated or disposed of and replaced with new material, depending on the specific material, when the concentrations of contaminants in the effluent from the adsorbed material exceed a target level.

Ion Exchange: Ion exchange removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from materials that contain ionic functional groups that attach to exchangeable ions. Resins can be regenerated for re-use after the capacity of the resin has been exhausted.

Precipitation, Coagulation, and Flocculation: Precipitation has been a primary method for treating metals in industrial wastewater and has also been proven successful in treating groundwater that contains metals. In groundwater treatment applications, the metal precipitation process is often used as a pretreatment for other treatment technologies such as microfiltration. In the precipitation process, coagulation and flocculation are used to increase particle size through aggregation and, therefore, the efficiency of the process. After the coagulants have increased particle size, flocculation is used to promote contact between the particles.

Membrane Technologies: Membrane technologies can include microfiltration, reverse osmosis, electrodialysis, or pervaporation. Reverse osmosis and microfiltration is the process of pushing a solution through a filter that traps solute on one side and allows the solvent to pass through to the other side. This process is best known for its use in desalination, but has been routinely applied for metals treatment. Electrodialysis is a physical method for removing ionic contaminants. Contaminated water is exposed to an electric current as it passes through a semi-permeable membrane. This action separates the contaminant ions from groundwater and surface water.

Evaporation Ponds: Extracted groundwater can also be discharged to lined ponds and allowed to evaporate. Periodically, the ponds would be dried and sludge removed and disposed. This technology has limited effectiveness at the site because of the wet and cool climate and the site area available for evaporation ponds is not sufficient for this purpose. This option is not retained.

Effectiveness: As can be seen by the descriptions above, there are numerous treatment technologies that could be effective for removing zinc and cadmium from groundwater at the site. For this FS, a treatment method using precipitation/coagulation/flocculation and membrane filtration is likely the most effective treatment approach. Bench or pilot studies would be necessary to select the most appropriate treatment train. It is expected that treatment would meet applicable discharge limits for groundwater or surface water. As mentioned in Section 6.2.7.1, pump-and-treat would be effective at preventing off-site migration of contaminated groundwater through hydraulic containment or when used in conjunction with slurry wall containment. It is uncertain if pump-and-treat technology would meet RAO #1

for the river. Pump and treat would be effective at removing zinc and cadmium from groundwater; however, the timeframe to reach groundwater standards is uncertain.

Implementability: Precipitation/coagulation/flocculation and membrane filtration are readily available technologies and would be easy to construct and implement at the Clariant site. Sufficient space is available on-site for facilities and infrastructure.

Cost: Treatment using precipitation/coagulation/flocculation and membrane filtration is considered to have high capital and operation and maintenance (O&M) costs.

Screening Summary: All identified treatment technologies except for evaporation ponds are retained as potential options. The most appropriate technology or combination of technologies would be selected after bench or pilot studies. Pump-and-treat scenarios using precipitation/coagulation/flocculation and membrane filtration are retained for further evaluation as a representative treatment technology. Precipitation/coagulation/flocculation and membrane filtration are expected to be effective; however, it is unknown if RAOs for the river or groundwater could be met within a reasonable timeframe. The technology will be considered further as an alternative in conjunction with treatment and discharge options.

6.2.7.3 Discharge of Treated Groundwater

Injection Wells or Trenches: ReInjection of treated water into the aquifer would require that the water be treated to levels that comply with site cleanup levels, which would ultimately mean meeting surface water standards due to the proximity of the river. ReInjection can increase the hydraulic gradient in the aquifer and therefore the effectiveness of downgradient extraction wells or collection trenches. However, at the site, reInjection would likely be conducted in areas that would not affect the groundwater being treated. The volume of treated water that could be reInjected using infiltration trenches or an infiltration gallery, however, would be limited by available land area. A treated flow rate of about 22 gallons per minute could be accommodated by infiltration trenches based on an estimated available area at the site of 1 acre (the former settling basin #3 and #4 area) and a percolation rate of 0.8 gallon per square foot per day. ReInjection to the aquifer will be retained in conjunction with extraction and treatment options.

Discharge to Surface Water: Discharge to surface waters would require the water meet surface water quality standards. The volume of treated water discharged in this manner is not expected to have any limitations. Discharge to surface water will be retained in conjunction with extraction and treatment options.

Other Discharge Options: Treated water is sometimes discharged to a publicly owned treatment works (POTW), on-site stormwater system, or an on-site waste water treatment system. No access to POTW is available to the site and no waste water treatment system capable of receiving treated water exists. CDM understands that the existing stormwater system is being updated to discharge collected water to

the plant process water system, but this system does not currently have the capacity to accept all the additional water that would be generated by the pump and treat system as currently conceptualized. Therefore, these options are not retained.

Effectiveness: Discharge of treated water to groundwater or surface water appears to be a viable and effective alternative for the elimination of treated water from the site. Treatment options producing less than 22 gallons per minute are assumed to use injection wells or trenches. Treatment options producing more than 22 gallons per minute are assumed to use surface water discharge.

Implementability: Both discharge of treated water to groundwater and discharge to surface water are easy to implement. Both options would require permitting from Ecology.

Cost: The capital cost of reinjection is considered to be low to moderate, depending on the size and number of injection wells or trenches. The O&M costs would be similar to that of pump and treat. The cost of surface water discharge is considered low as little infrastructure would be required.

Screening Summary: Pump-and-treat scenarios using groundwater and surface water discharge options will be considered further as alternatives in conjunction with extraction and treatment.

6.2.8 Additional Soil Removal, Transport, and Disposal

This action involves removal of additional source material followed by transportation, treatment and disposal. This option would remove source material from beneath a portion of the facility access road in the area of former Settling Basin #2, adjacent to areas excavated previously. Source materials would be excavated using conventional earth-moving equipment such as front-end loaders and hydraulic excavators. No buildings or other structures are located in this area so no shoring, sheet piling, or other specialized techniques would be necessary. Excavation would be to the approximate depth of previous excavations in this area, which are about 6 to 15 feet below ground surface. No saturated materials would be encountered at this depth. Dust suppression during excavation may be necessary. Removed source material would be transported to off-site disposal in trucks. It is assumed that the same disposal facility used during previous removal actions would be used for the additional soil removal.

Effectiveness: Excavation and removal of additional contaminated soil would result in removal of approximately 3,700 cubic yards of soil containing about 14,900 pounds of zinc and is expected to achieve RAO #3. This option would meet RAO #4 except for deeper soil below about 15 feet bgs. Therefore, removal of this mass is expected to have a limited effect on overall groundwater zinc concentrations over the short term. However, this removal is expected to shorten the timeframe needed for groundwater zinc concentrations to reach standards through MNA. Due to the uncertainties with reaching all RAOs, this alternative is considered to have only moderate effectiveness.

Implementability: Excavation and removal of additional contaminated soil is considered to be easy to implement at the site to excavation depths of approximately 15 feet bgs. Excavation becomes more difficult near building foundations and other infrastructure. Excavation deeper than 15 feet and within saturated areas is considered difficult.

Cost: Excavation and removal of contaminated soil is expected to have a moderate to high cost.

Screening Summary: Excavation and removal of contaminated soil and disposal at an off-site facility is expected to meet RAOs for shallow soil; however, it is not expected to achieve RAOs in groundwater or surface water. However, this option could remove a large mass of zinc from the site and is expected to reduce contaminant concentrations in groundwater (and related flux to the river) over the long term. This option will be retained and further evaluated as an alternative and may be used in conjunction with other alternatives.

6.3 Initial Alternatives Screening Summary

The technologies that were retained for further consideration in this FS include:

- No Further Action
- Institutional Controls
 - Land use restrictions, groundwater use restrictions, and site administrative procedures
- Monitored Natural Attenuation
- Stormwater Controls and Best Management Practices
- Containment
 - Horizontal barrier (surface cap)
 - Vertical barrier (slurry wall)
- In Situ Treatment
 - Neutralization cap
- Groundwater Pump and Treat
 - Extraction wells
 - Precipitation/coagulation/flocculation and membrane filtration
 - On-site discharge to surface water or groundwater
- Additional Soil Removal
 - Excavation and off-site disposal

Section 7

Remedial Action Alternatives

In this section, the technology process options that were retained, as discussed in Section 6, are assembled into remedial action alternatives. Each alternative conceptual design is presented along with an evaluation of its ability to meet RAOs and estimates of capital and O&M costs. The remedial alternatives are then compared against each other using evaluation criteria developed by Ecology.

7.1 Description of Remedial Action Alternatives

Five remedial alternatives have been assembled using retained technology options. These five remedial alternatives are summarized in the table below and are described in more detail in this section. Although additional combinations of technology options are possible, the alternatives presented here are considered to represent a reasonable range of approaches and costs.

Remedial Alternative	Technology Options
Alternative 1	Stormwater controls Institutional controls Site monitoring/MNA
Alternative 2	Impermeable cap Stormwater controls Institutional controls Site monitoring/MNA
Alternative 3	Additional soil removal Neutralization cap Stormwater controls Institutional controls Site monitoring/MNA
Alternative 4	Slurry wall Impermeable cap Stormwater controls Institutional controls Site monitoring/MNA
Alternative 5	Additional soil removal Hydraulic barrier pump and treat Stormwater controls Institutional controls Site monitoring/MNA

7.1.1 Remedial Action Alternative 1 – Monitored Natural Attenuation, Stormwater Controls and Institutional Controls

Under this alternative monitored natural attenuation (MNA), stormwater controls and institutional controls would be implemented at the site to address RAOs. Preliminary design assumptions for this alternative are specified in **Appendix C, Table C-1** and existing monitoring wells used for sampling under this alternative are shown on **Figure 4**. Under this alternative it is assumed that all necessary stormwater controls related to facility operations are or will be implemented by Chemtrade and infiltration of precipitation runoff from existing impermeable areas (buildings, pads, paved areas, etc.) is prevented.

7.1.1.1 Evaluation of RAOs under Remedial Action Alternative 1

RAO#1 - Manage Off-Site Migration of Groundwater that Exceeds Surface Water Standards. This alternative does nothing to reduce the discharge of groundwater that exceeds surface water standards into the river. However, MNA and stormwater controls would provide some reduction in groundwater metals concentrations and flux to the river over time.

RAO #2 – Manage Onsite Groundwater Exceeding Cleanup Levels. Groundwater at and near the site is not currently used as a drinking water source and a restrictive covenant would ensure that potential human exposures do not occur in the future.

RAO #3 - Manage Soils that Exceed Direct Exposure Cleanup Levels. Some soil onsite within a depth of 15 feet from ground surface exceeds cleanup standards. This soil is currently paved over. Current and likely future land use of the site is industrial. Institutional controls in the form of existing access controls (pavement and fences) and restrictive covenants would ensure the protection of human exposure in the event of a land use change or subsurface work that may result in disturbance of these soils.

RAO #4 - Manage Soils that Act as a Continuing Source of Groundwater Contamination. Stormwater controls implemented by Chemtrade under this alternative would minimize additional new contaminant source material as a result of ongoing manufacturing activities.

7.1.2 Remedial Action Alternative 2 – Impermeable Cap, Monitored Natural Attenuation, Stormwater Controls and Institutional Controls

Under this alternative an impermeable cap, stormwater controls, site monitoring/MNA and institutional controls would be implemented at the site to address RAOs. Preliminary design assumptions for this alternative are specified in **Appendix C, Table C-2**. Conceptual design capping areas for this alternative are shown in **Figure 5**.

The conceptual design for the cap includes adding asphalt pavement so that the entire area of the site extending from the parking lot to the south to the south end of former SB #3 on the north is paved. Some interference with facility utilities and rail spur may be encountered and the cap would be constructed to the extent feasible in these areas. The cap would be constructed in a way that would preserve existing ground topography in these areas. Approximately 12 inches of existing soil would be removed in the areas to be capped. This material is assumed to be uncontaminated clean soil and gravel. This material would be placed and graded onsite outside of the capping areas. Excavated areas would be graded for drainage, backfilled with approximately 6 inches of base course material, and compacted. Bituminous asphaltic pavement would then be placed in two 3-inch thick layers to form a 6-inch thick asphalt cap. Stormwater runoff control/infiltration ditches would be constructed along the downgradient edges of the paved areas to control and allow infiltration of runoff water. Additional stormwater controls, site monitoring/MNA, and institutional controls would be implemented at the site as described in Section 7.1.1.

7.1.2.1 Evaluation of RAOs under Remedial Action Alternative 2

RAO #1 - Manage Off-Site Migration of Groundwater that Exceeds Surface Water Standards. This alternative will reduce the contaminated groundwater flux to the river by limiting surface water infiltration, but would not achieve surface water standards.

RAO #2 - Manage Onsite Groundwater Exceeding Cleanup Levels. Emplacement of a restrictive covenant would ensure that potential human exposures do not occur in the future.

RAO #3 - Manage Soils that Exceed Direct Exposure Cleanup Levels. Similar to Alternative 1, institutional controls in the form of existing access controls (pavement and fences) and restrictive covenants would ensure the protection of human exposure in the event of a land use change or subsurface work that may result in disturbance of these soils. The asphalt cap would further restrict access to subsurface soils beneath SB #2.

RAO #4 - Manage Soils that Act as a Continuing Source of Groundwater Contamination. Beyond the stormwater controls, this alternative reduces metals leaching from soil to groundwater by eliminating water infiltration through construction of an impermeable cap. Theoretically, by reducing the leaching potential of residual contaminants in site soils zinc concentrations in groundwater will be reduced. However, attainment of groundwater cleanup levels may or may not be realized in a shorter time frame than for Alternative 1 since the leaching potential will have been reduced.

7.1.3 Remedial Action Alternative 3 – Additional Soil Removal, Neutralization Cap, Monitored Natural Attenuation, Stormwater Controls and Institutional Controls

Under this alternative additional soil removal, a neutralization cap, stormwater controls, site monitoring/MNA and institutional controls would be implemented at the site to address RAOs. Preliminary design assumptions for this alternative are specified in **Appendix C, Table C-3**. Conceptual design soil removal and capping areas for this alternative are shown in **Figure 6**.

Additional soil removal would consist of excavation of contaminated soil beneath the access road area over former SB #2. During previous removal actions at the site, contaminated soil was excavated from portions of former SB #1 and SB #2, but not from the area beneath the access road. Asphalt pavement on the road surface would be removed and disposed off-site. Adjacent clean soil would be excavated to provide access to contaminated soil. Contaminated soil would then be excavated from the area to the approximate depth of previous excavations (up to 15 ft bgs) and the excavation would be advanced laterally to meet the limits of previous excavations.

Approximately 3,700 cubic yards of soil containing an estimated 14,900 pounds of zinc would be removed. Source materials would be excavated using conventional earth-moving equipment such as front-end loaders and hydraulic excavators. No buildings or other structures are located in this area so no shoring, sheet piling, or other specialized techniques would be necessary. No saturated materials would be encountered at this depth. Dust suppression during excavation may be necessary. Removed source material would be transported to an off-site disposal facility in trucks. It is assumed that the same disposal facility used during previous removal actions would be used for this soil removal. Excavation areas would be backfilled to approximate original grade using off-site borrow material, and the paved road surfaces would be restored in their approximate original areas.

A neutralization cap would be constructed in the areas shown on **Figure 6**. This includes all areas in and around the site where precipitation can currently infiltrate the ground surface and excludes all plant building areas, concrete pads, paved parking lots, and paved access roads. Some interference with facility utilities and rail spur may be encountered and the cap would be constructed to the extent feasible in these areas. The cap would be constructed in a way that would preserve existing ground topography in these areas. Approximately 30 inches of existing soil would be removed in the capped areas. This material is assumed to be uncontaminated clean sand. This material would be reused for surface cover as part of this alternative. Excess material is assumed to be placed and graded elsewhere on-site. Excavated areas would be backfilled with approximately 24 inches of a buffering material (such as crushed limestone). Limestone is assumed to be obtained from a source within 15 miles of the site. Backfilled limestone and the surface cover would not be compacted in order to retain a high permeability of the material.

Stormwater controls, site monitoring/MNA, and institutional controls would be implemented at the site as described in Section 7.1.1.

7.1.3.1 Evaluation of RAOs under Remedial Action Alternative 3

RAO #1 - Manage Off-Site Migration of Groundwater that Exceeds Surface Water Standards. Additional soil removal and the neutralization cap may show a significant reduction in groundwater metals concentrations and flux to the river. However, groundwater migrating off-site and entering the river would likely continue to exceed surface water standards for a long period of time.

RAO #2 - Manage Onsite Groundwater Exceeding Cleanup Levels. Additional soil removal and reducing the leaching potential of residual contaminants in site soils will likely result in achieving the zinc groundwater cleanup levels in a reasonable time frame, but cadmium concentrations will still likely exceed groundwater cleanup levels for years to come. However, as for Alternatives 1 and 2, emplacement of a restrictive covenant would ensure that potential human exposures do not occur in the future.

RAO #3 - Manage Soils that Exceed Direct Exposure Cleanup Levels. By removing all remaining soil with metals exceeding site cleanup levels to a depth of 15 ft bgs human risks from exposure to surface and near-surface soil are eliminated.

RAO #4 - Manage Soils that Act as a Continuing Source of Groundwater Contamination. Beyond the stormwater controls, the additional soil removal would significantly reduce the volume of soil available as a continuing source to groundwater contamination and the neutralization cap would reduce metals leaching from soil to groundwater by precipitation.

7.1.4 Remedial Action Alternative 4 - Slurry Wall, Impermeable Cap, Monitored Natural Attenuation, Stormwater Controls and Institutional Controls

Under this alternative a slurry wall, impermeable cap, stormwater controls, site monitoring/MNA and institutional controls would be implemented at the site to address RAOs. Preliminary design assumptions for this alternative are specified in **Appendix C, Table C-4**. Conceptual design soil removal and hydraulic barrier pump and treat for this alternative are shown in **Figure 7**.

An impermeable cap would extend across the same areas as described for Alternative 2. A slurry wall would then be constructed around the area of contaminated groundwater, essentially surrounding this portion of the aquifer on all sides. The slurry wall would effectively isolate contaminated site groundwater from interaction with upgradient groundwater and the river. The slurry wall would extend a total length of approximately 2,285 linear feet. The slurry wall would be located around the periphery of plant buildings and infrastructure to avoid interferences during construction to the extent feasible. The slurry wall is estimated to be 3 feet wide and would be keyed approximately 2 feet into bedrock, found between 35 and 65 feet

below ground surface in this area. An average slurry wall height of 50 feet is assumed for costing purposes. The slurry wall is estimated to contain 114,250 face square feet.

The slurry wall would be constructed by excavating a trench to bedrock. A 5% bentonite in water slurry would be mixed in basins constructed on-site and placed into the excavated trench for wall stabilization. A soil-bentonite backfill material would then be placed into the trench (displacing the slurry) to create the cutoff wall. The wall would have a design permeability of 10^{-7} centimeters per second and would have good chemical resistance.

Stormwater controls, site monitoring/MNA, and institutional controls would be implemented at the site as described in Section 7.1.1.

7.1.4.1 Evaluation of RAOs under Remedial Action Alternative 4

RAO #1 - Manage Off-Site Migration of Groundwater that Exceeds Surface Water Standards. The slurry wall and impermeable cap could effectively eliminate the discharge of metals to the river. However, some groundwater with metals concentrations above surface water standards could still reach the river due to normal leakage at low tides and barrier imperfections.

RAO #2 - Manage Onsite Groundwater Exceeding Cleanup Levels. This alternative relies on emplacement of a restrictive covenant to ensure the protection of potential human exposure.

RAO#3 - Manage Soils that Exceed Direct Exposure Cleanup Levels. Similar to Alternative 1, institutional controls in the form of existing access controls (pavement and fences) and restrictive covenants would ensure the protection of human exposure in the event of a land use change or subsurface work that may result in disturbance of these soils.

RAO #4 - Manage Soils that Act as a Continuing Source of Groundwater Contamination. This alternative reduces metals leaching from soil to groundwater by eliminating water infiltration through construction of an impermeable cap.

7.1.5 Remedial Action Alternative 5 - Additional Soil Removal, Hydraulic Barrier Pump and Treat, Monitored Natural Attenuation, Stormwater Controls and Institutional Controls

Under this alternative additional soil removal, a hydraulic barrier pump and treat system, stormwater controls, site monitoring/MNA and institutional controls would be implemented at the site to address RAOs. Preliminary design assumptions for this alternative are specified in **Appendix C, Table C-5**. Conceptual design soil removal and hydraulic barrier pump and treat for this alternative are shown in **Figure 8**.

Additional soil removal would consist of excavation of contaminated soil in the access road area near former SB #2 in the same manner as described for Alternative 3.

Following soil excavation, a hydraulic barrier pump and treat system would be installed to prevent impacted site groundwater from flowing into the river. The pump and treat system would consist of a network of extraction wells constructed in a manner to achieve containment of the groundwater plume at the property boundary. Collected groundwater would be pumped to a central treatment system, treated to surface water discharge standards, and then directly discharged to the river. CDM's conceptual design calls for the installation of extraction wells within and paralleling the facility property boundary adjacent to the river as shown on **Figure 8**. Groundwater recovered from the extraction wells would be transported to the treatment site by a single PVC collection line and treated water would be transported to the Columbia River for discharge as shown on **Figure 8**. The location of the treatment plant shown on **Figure 8** is approximate and could be adjusted to accommodate facility operations or avoid infrastructure or utilities.

Hydraulic capture of contaminated groundwater is assumed to require extraction of 120 gallons per minute (gpm) from 8 extraction wells (average of 15 gpm from each well) with an assumed well depth of 40 ft bgs. The average groundwater flux across the impacted area near the river edge (approximately 920 feet) is estimated to be 51 gpm based on the hydraulic analysis presented in **Appendix B**. However, groundwater flux varies with semi-diurnal tidal fluctuations in the river, and the maximum groundwater flux is expected to be approximately 96 gpm across the same impacted area. The estimated maximum flux of 96 gpm was calculated using Darcy's Law ($Q=KAI$), with a hydraulic conductivity (K) of 250 ft/day, a cross-sectional area (A) of 18,400 ft², and a hydraulic gradient of 0.004 (I). Treatment plant influent chemistry will vary depending upon tides. The highest concentrations of metals would be treated at low tide when the resultant water quality is from the combination of 90 gpm site-derived flow and 30 gpm flow derived from the Columbia River. Pump and treat pilot testing and additional hydrogeologic studies would be necessary to better define the number of wells and pumping rates required to achieve containment.

Treatment plant influent zinc concentration at low tide is estimated at 6.68 mg/L, based on an area weighted average zinc concentration in groundwater of 8.86 mg/L and an average zinc concentration in the river of 12 µg/L. These contaminants are straightforward to remove using a variety of treatment approaches. For the purpose of this evaluation, a caustic precipitation and microfiltration system was used for cost estimating. The primary contaminants targeted in the treatment process (zinc and cadmium) are efficiently removed with hydroxide precipitation at a pH of about 9 to 10. The use of a microfiltration skid permits the treatment process to be simplified by removing metals in one treatment step. Sludges would be processed through a filter press and periodically removed for off-site disposal. Waste sludges are assumed to be non-hazardous based on CDM's experience at other sites. Pilot studies would be necessary to further refine the treatment approach and confirm sludge characteristics.

Stormwater controls, site monitoring/MNA, and institutional controls would be implemented at the site as described in Section 7.1.1.

7.1.5.1 Evaluation of RAOs under Remedial Action Alternative 5

RAO #1 - Manage Off-Site Migration of Groundwater that Exceeds Surface Water Standards. The hydraulic barrier pump and treat system would significantly reduce metals flux to the river. However, some groundwater with metals concentrations above surface water standards could still reach due to barrier imperfections and during system shutdowns. Groundwater metals concentrations would be expected to decrease over time; however the timeframe for these concentrations to decrease to surface water standards is not known.

RAO #2 - Manage Onsite Groundwater Exceeding Cleanup Levels. Additional soil removal and actively pumping and treating groundwater will likely result in achieving the zinc groundwater cleanup levels in a reasonable timeframe, but cadmium concentrations will still likely exceed groundwater cleanup levels for many years. However, as for the other alternatives, emplacement of a restrictive covenant would ensure that potential human exposures do not occur in the future.

RAO #3 - Manage Soils that Exceed Direct Exposure Cleanup Levels. By removing all remaining soil with metals exceeding site cleanup levels to a depth of 15 feet below ground surface, human risks from exposure to surface and near-surface soil are eliminated.

RAO #4 - Manage Soils that Act as a Continuing Source of Groundwater Contamination. The additional soil removal significantly reduces the volume of soil available as a continuing source to groundwater contamination and reduces metals leaching from soil to groundwater. Stormwater controls under this alternative would also reduce to amount of water infiltration in areas with contaminated soil, thereby reducing the amount of metals leaching from these soils to groundwater.

7.2 Conceptual Level Cost Estimates

This section discusses CDM's conceptual level cost estimates for the three remedial action alternatives. Table 4 presents the cost estimate summary for the alternatives. The totals of these estimated costs are as follows:

Remedial Action Alternative 1	\$ 576,000
Remedial Action Alternative 2	\$ 1,858,000
Remedial Action Alternative 3	\$ 2,569,000
Remedial Action Alternative 4	\$ 4,125,000
Remedial Action Alternative 5	\$13,272,000

General assumptions for the conceptual level cost estimates shown on **Table 4** are as follows:

- Future capital costs and ongoing costs are presented in net present value terms with a 5% discount rate.
- All costs are rounded to the nearest 1,000 dollars.
- All construction costs include a construction fee (contractor overhead, profit, and business and occupation tax) of 20%.
- All construction items include 8.6% sales tax.
- Initial and future capital costs assume engineering cost at 15% of the total and project management costs at 12% of the total. Ongoing monitoring and maintenance costs assume no engineering costs and project management costs at 12% of the total.
- All costs include a contingency of 15%
- The duration of each alternative, including construction and/or long-term monitoring totals 30 years.

Tables C-1 through C-5 in Appendix C provide alternative-specific assumptions used in preparing the cost estimates. Tables C-6 through C-10 in Appendix C provide detailed costs breakdowns of the five remedial action alternatives.

7.3 Evaluation of Remedial Action Alternatives

7.3.1 Method of Evaluation

Chapter 173-340-360(2) of MTCA requires that all cleanup action alternatives meet certain minimum requirements as listed below.

1. **Protecting Human Health and the Environment:** This includes an evaluation of the degree to which existing risks are reduced, of the time required to reduce risks and attain cleanup levels, of on-site and off-site impacts resulting from the alternative, of the degree to which the alternative may perform to a higher level than the cleanup standards, and of overall improvement of environmental quality.
2. **Compliance with Cleanup Standards:** This includes an evaluation of the cleanup alternative and its ability to meet or exceed cleanup levels established in accordance with MTCA requirements.
3. **Compliance with Applicable State and Federal Laws:** Cleanup actions must comply with existing state or federal laws. All applicable or relevant and appropriate requirements (ARARs) that may apply to implementation of the

alternatives must be identified and satisfied. If a given law cannot be satisfied, it may be possible to obtain a waiver.

4. **Compliance Monitoring:** The cleanup action must provide for monitoring to verify that the cleanup action achieves cleanup or other performance standards and that it remains effective over time.
5. **Using Permanent Solutions to the Maximum Extent Practicable:** Permanent solutions are actions in which cleanup standards can be met without further action being required, such as monitoring or institutional controls. To select the most practicable permanent solution from the alternatives requires conducting a disproportionate cost analysis. This analysis involves comparing the cost and benefits of alternatives and selecting the alternative whose incremental costs are not disproportionate to the incremental benefits. A cost disproportionate analysis is presented in Section 7.3.3.
6. **Providing a Reasonable Restoration Time Frame:** This includes an evaluation of each alternative with respect to the time required to complete cleanup actions. To meet this MTCA requirement, a cleanup action shall provide a reasonable restoration time considering several factors. These factors include potential risks posed to human health and the environment, practicability of achieving restoration in a shorter time, current use of the site, future use of the site, costs associated with using alternatives with shorter restoration times, and others.
7. **Consider Public Concerns:** Whether the community has concerns regarding the alternative and if so, the extent to which the alternative addresses those concerns.

7.3.2 Comparison Evaluation

Protecting Human Health and the Environment: Alternatives 2 through 5 provide a similar level of protection for human health and the environment for onsite contaminants. Residual contaminated soils will either be removed or managed by capping and emplacement of a restrictive covenant. Current and likely future land use is industrial. The site is supplied by municipal water and there is no current or expected future use of onsite groundwater as a source of drinking water; therefore, the potential for direct exposure to contaminated groundwater is negligible. Alternatives 3 through 5 would provide the largest reduction in mass loading of zinc to the river. However, currently, no surface water standards are exceeded in the river and, based on CDM's screening level ecological risk assessment, no adverse acute or chronic effects in resident or migratory fish and benthic aquatic invertebrates in the Columbia River from site-related contamination are expected (CDM, 2005d). Similarly, CDM's site conceptual model showed that the flux of zinc from the site to the Columbia River was negligible when compared to the zinc load the river is already carrying (CDM, 2005c).

Compliance with Cleanup Standards: It is not expected that any of the alternatives will achieve all of the site cleanup standards within a reasonable time frame (see

below), but obviously some will achieve a greater degree of compliance than others. Alternatives 3 and 5 will achieve soil cleanup levels based on direct exposure and may achieve onsite groundwater cleanup levels in a reasonable time frame for zinc. However, none of the alternatives will likely achieve the surface water standard for zinc. Alternative 4 would likely achieve the greatest reduction in zinc and metals concentrations at the property boundary and within the shortest timeframe. Alternative 5 may achieve similar results to that of Alternative 4 with respect to controlling offsite contaminant migration. However, groundwater pump and treatment systems typically have frequent “down” times. Also, the tidal fluctuations and seasonal freshets of the river will require significant variations in the pumping rate of the system to achieve adequate hydraulic control.

Compliance with Applicable State and Federal Laws: MTCA, the primary ARAR for this site, should be met with any of the alternatives. However, at a minimum, Alternatives 1 through 3 will require approval of a conditional point of compliance. The need for a conditional point of compliance for Alternatives 4 and 5 will depend upon the effectiveness of these two alternatives (i.e., success in achieving zinc concentrations less than 66 µg/L at the property boundary). Alternative 4 is most likely to achieve this standard. The conditions required to obtain a conditional point of compliance were outlined in Section 4.4.2.

Alternatives 2 through 5 will have additional ARARs associated with construction activities (i.e., grading permit). Alternative 5 will require an NPDES permit for discharge of treated water to the river.

Compliance Monitoring: Compliance monitoring requirements would be met with a regular groundwater monitoring program for all of the alternatives.

Using Permanent Solutions to the Maximum Extent Practicable: In essence, all of these alternatives except Alternative 4 can provide a “permanent” solution through the eventual natural attenuation of site contaminants. For Alternative 2, while the contaminant loading to the river should be lessened on a daily basis, the cap will essentially cause the zinc to remain in site soils longer. The soil removal technologies of Alternatives 3 and 5 will remove a large quantity of mass; however, it has been demonstrated that removal of contaminated soils alone will not achieve cleanup standards in a timely manner. The neutralization cap will only serve to immobilize and the slurry wall will only contain site contaminants and the long-term life of these technologies are not fully predictable. At some point, the neutralization cap will become “used up” and zinc concentrations may rebound; however, the removal of contaminant mass during soil excavation may offset this. Similarly, it is anticipated that the tidal and seasonal fluctuations of the river will cause the slurry wall to prematurely degrade as compared to a similar wall installed in an inland property. The pump and treatment system of Alternative 5 would provide the only physical removal of zinc and cadmium from groundwater; however, the effectiveness of the removal will be substantially reduced because of the amount of water that the river will concurrently contribute.

Providing a Reasonable Restoration Time Frame: It is not expected that any of these alternatives would result in complete restoration, to the effect that all cleanup levels (soil, groundwater, surface water) would be met throughout the site and such that compliance monitoring and facility maintenance, if applicable, would no longer be required within a reasonable time frame (i.e., less than 30 years). The alternatives primarily differ by the degree of contaminant reduction and period of time over which the reduction will occur.

Consider Public Concerns: As indicated above, Alternatives 1 through 3 will require a notice to the natural resource trustees, Washington State Department of Natural Resources, and the U.S. Army Corps of Engineers prior to approval of a conditional point of compliance. It is uncertain at this time whether a conditional point of compliance would be required for Alternatives 4 and 5. Obviously, one would expect that the natural resource agencies will favor remedial methods that are likely to provide the most immediate and significant contaminant reduction. The Corps of Engineers may have some concern over the installation of a slurry wall adjacent to the river. The NPDES permit required for discharges of treated water to the river will also incur scrutiny by Ecology.

7.3.3 Cost Disproportionate Analysis

MTCA Section 173-340-360(3) outlines the method for conducting a cost disproportionate analysis. The objective is to determine whether costs are disproportionate to benefits of the incremental cost of the alternative over that of the lower cost alternative.

Table 5 lists the evaluation criteria and provides a numeric ranking from 1 to 5 for each criterion for each alternative. The criteria of protectiveness, permanence, and consideration of public concerns were discussed above in Section 7.3.2. In consideration of protectiveness, Alternatives 4 and 5 were ranked the highest since they will provide the most immediate overall reduction in zinc concentrations at the property boundary. For the criteria of permanence, Alternative 5 was ranked the highest since it provides for source material removal and removal of contaminants from groundwater. Alternative 4 was ranked second highest because it also provides for a substantial amount of source material removal. Alternative 4 was ranked the lowest since it is a containment technology and the river will likely compromise its integrity in time. In consideration of public concerns, all were ranked equally except for Alternative 1. It was felt that the natural resource protection agencies may tend to favor Alternatives 4 and 5, but that the Corp of Engineers may tend to favor Alternatives 2 and 3. None of the agencies are likely to favor Alternative 1 since it relies almost entirely on MNA.

Four additional criteria are evaluated in the cost disproportionate analysis: cost, effectiveness over the long term, management of short term risks, and technical and administrative implementability. The criteria of cost and technical/administrative implementability were weighted using multipliers of 3 and 2, respectively as practically speaking, if the liable party cannot afford to implement the remedial

alternative, or if the alternative is very difficult to implement, then all other criteria are inconsequential. Evaluation of the technical and administrative implementability required balancing the complexity of implementing a particular alternative against the expected level of administrative requirements. For effectiveness over the long term the alternatives were ranked according to the guidance in Section 173-340-360(3)(f)(iv). For management of short term risks, those alternatives that required a substantial amount of construction were ranked lower than those that did not.

For each alternative the numeric rankings were summed and the total was divided by the number of criteria (7). At the conclusion of the cost disproportionate analysis Alternative 5 with a score of 3.4 ranked well below all other alternatives. The estimated cost of this alternative at over \$13 million dollars is more than double that of any of the other alternatives. Alternative 4 ranked second lowest with a score of 3.9. The high cost, level of difficulty in implementing this technology, and uncertainty regarding its permanence all contributed to the lower ranking of this alternative. Alternatives 1 and 2 tied with a score of 4.4. Neither technology showed a particular strong benefit in any category. Alternative 3 ranked the highest with a score of 5.0. This alternative, while not given the highest ranking for any of the criteria, seems to provide the best balance of cost and contaminant reduction.

Section 8

Conclusions and Recommended Remedial Action

Current technologies simply do not provide a long term solution that can achieve cleanup levels in a timely manner and at a reasonable cost for this site. The predominant reasons for this are: 1) the overwhelming hydraulic influence of the Columbia River on site groundwater; 2) the disproportionately low surface water standard for zinc; and 3) the depth of contaminated soils.

Alternative 5 is simply too costly to implement even if it could result in the achievement of surface water standards. Alternative 4 is similarly too costly to justify, especially considering the uncertainty in the length of time until the hydraulic forces of the river would cause the need for expensive repair/replacement.

Alternative 3 appears to provide the most cost effective reduction in contaminant concentrations. However, the net overall effects of this approach cannot be ascertained without at least implementing it in a pilot program. Based on this, CDM recommends implementing Alternative 3 in a phased approach. In this approach, the elements of additional soil removal, applying the neutralization cap in the area of SB #2 only, and institutional controls would be applied immediately. The site would be monitored on a regular basis (i.e., semiannually). At the end of a 5 year period the effectiveness of these actions would be re-evaluated.

Section 9

References

Andromalos, Kenneth B., P.E. and Fisher, Michael J. 2001. Design and Control of Slurry Wall Backfill Mixes for Groundwater Containment.

CDM, 2002. Phase 1 and 2 Environmental Assessment, Clariant Corporation Chemical Plant 404 Hendrickson Drive, Kalama, Washington. Prepared by CDM November 19, 2002.

CDM, 2004a. Contaminant Delineation Former Clariant Corporation Chemical Plant 404 Hendrickson Drive, Kalama, Washington. VCP #SWO492. Prepared by CDM, March 3, 2004.

CDM, 2004b. Soil Excavation Summary Report. Former Clariant Corporation Chemical Plant 404 Hendrickson drive, Kalama, Washington. VCP #SWO492. Prepared by CDM, March 3, 2004.

CDM, 2004c. Winter 2004 Quarter - Groundwater Monitoring Former Clariant Corporation Chemical Plant, Kalama, Washington. Prepared by CDM, March 24, 2004.

CDM, 2004d. Letter, Evaluation of the Cadmium Plume, Former Clariant Plant, 404 Hendrickson Drive, Kalama, Washington. VCP #SWO492. Prepared by CDM, August 17, 2004.

CDM, 2004e. Spring 2004-2nd Quarter - Groundwater Monitoring Former Clariant Corporation Chemical Plant, Kalama, Washington. Prepared by CDM, July 9, 2004.

CDM, 2004f. Summer 2004 - 3rd Quarter - Groundwater Monitoring Former Clariant Corporation Chemical Plant, Kalama, Washington. Prepared by CDM, October 18, 2004.

CDM, 2004g. Fall 2004 - 4th Quarter - Groundwater Monitoring Former Clariant Corporation Chemical Plant, Kalama, Washington. Prepared by CDM, December 3, 2004.

CDM, 2005a. Winter 2005 - 5th Quarter - Groundwater Monitoring Former Clariant Corporation Chemical Plant, Kalama, Washington. Prepared by CDM, April 14, 2005.

CDM, 2005b. Spring/Summer 2005 - 6th and 7th Quarters. Groundwater Monitoring. Former Clariant Corporation Chemical Plant, Kalama, Washington. VCP #SWO492 Prepared by CDM, September 2, 2005.

CDM, 2005c. Site Conceptual Model for Zinc and Cadmium in Groundwater at the Former Clariant Corporation Chemical Plant, 404 Hendrickson Drive, Kalama, Washington, VCP #SWO492. Prepared by CDM, November 30, 2005.

CDM, 2005d. Screening Level Ecological Risk Assessment, Former Clariant Corporation Chemical Plant, 404 Hendrickson Drive, Kalama, Washington, VCP #SWO492. Prepared by CDM, November 30, 2005.

CDM, 2006a. Fall 2005 - 8th Quarter. Groundwater Monitoring. Former Clariant Corporation Chemical Plant, Kalama, Washington. VCP #SWO492 Prepared by CDM, January 3, 2006.

CDM, 2006b. Summer 2006, Groundwater Monitoring. Former Clariant Corporation Chemical Plant, Kalama, Washington. VCP #SWO492 Prepared by CDM, September 29, 2006.

CDM, 2007. Piezometer Installation and Groundwater Sampling Report - February 2007, Former Clariant Corporation Chemical Plant, Kalama, Washington. VCP #SWO492 Prepared by CDM, April 12, 2007.

EPA 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. OSWER Directive 9200.4-17P. April.

Distribution

4 Copies

Clariant Corporation
4000 Monroe Road
Charlotte, North Carolina 28025

Attention: Mr. Bill Grier
Mr. Ron Walton

Quality Assurance / Technical Review by:



Don Clabaugh, P.E.
Principal Engineer