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Focused Feasibility Study

Volume 2: TECHNICAL APPENDIXES

Reynolds Metals Company
TROUTDALE FACILITY

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APPENDIX A

Groundwater Modeling Evaluations

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Silt Unit Groundwater Elevation Data in South Plant Soil and Debris Areas

APPENDIX A

Groundwater Modeling Evaluations

A.1 Introduction

This appendix summarizes the groundwater modeling that was conducted to support evaluation of the groundwater options and sitewide remedial alternatives. For the purposes of this appendix, the term "time to compliance" is used to mean the time for groundwater concentrations to reduce to the maximum contaminant level (MCL) concentration. The modeling done in this appendix evaluates the time to achieve 4 mg/L MCL for fluoride. Whether or not the MCL will be the criterion for groundwater compliance at the site has not been determined.

The appendix contains the following sections:

- Section A.2—A description of groundwater Option GW-1 (production well optimization), including evaluation of its effectiveness at meeting the objective of containing groundwater onsite (that is, preventing offsite migration). This includes discussions of the minimum pumping rates of the production wells that would be required to meet this objective.
- Section A.3—A description of groundwater Option GW-2 (production well optimization with focused extraction), including evaluation of its effectiveness at meeting the objective of preventing migration of fluoride from the upper gray sand (UGS) to the intermediate zone (that is, to the production wells). This includes discussions of the minimum pumping rates of the production wells and the focused extraction wells that would be required to meet this objective.
- Section A.4—A description of groundwater Option GW-3 (production well optimization with enhanced focused extraction), which is similar to Option GW-2 but includes focused extraction in the UGS at south landfill and in the intermediate zone (in the northeast corner of Fairview Farms (near the southwestern corner of Company Lake). This discussion includes evaluation of the type of focused extraction well systems that would be required to meet the objective of restoring groundwater quality in these areas.
- Section A.5—A description of groundwater Option GW-4 (production well optimization with enhanced focused extraction and silt unit extraction), which is similar to Option GW-3 but includes extraction wells in the silt unit at south landfill and east potliner. This discussion includes evaluation of the type of silt unit extraction well system that would be required in these areas to meet the objective of reducing fluoride loading to the UGS.
- Section A.6—An analysis of the changes that would be anticipated in fluoride concentrations in the UGS, intermediate, and deep zones under each groundwater option. Specifically, the analysis evaluates the time that would be required for fluoride concentrations to decline to levels below the maximum contaminant level (MCL) and the

amount that the areal extent of the fluoride plume would be reduced within 5 years and 10 years of implementation of a given option.

- Section A.7—An analysis of the time that would be required for fluoride leaching in source areas (soil and debris areas and Company Lake) to decline to a level that would no longer cause silt unit groundwater concentrations to exceed the MCL.

The analyses of the groundwater options were conducted using the numerical groundwater flow model of the RMC-Troutdale site. The model is an 11-layer model that simulates groundwater flow in the unconsolidated deposits underlying the RMC-Troutdale site. The Columbia River forms the northern and eastern model boundaries, and the model extends as far west as the Blue Lake Aquifer and as far south as the southern limit of the regional Unconsolidated Sedimentary Aquifer (USA). Figure A-1 shows a schematic diagram of the model's layering, including the assignment of the RMC production wells, site monitoring wells, and surface water features to the different model layers. A detailed discussion of the design, construction, and calibration of the model is presented in *Technical Memorandum No. GW-20: Development of an Updated Hydrogeologic Conceptual Model and a Numerical Groundwater Flow Model at RMC-Troutdale* (CH2M HILL, June 25, 1999).

A.2 Groundwater Option GW-1 (Production Well Optimization)

Production well optimization (PWO) is the process of managing production well pumping in a manner that provides for the plant's water supply needs while preventing offsite migration of fluoride that is present in the intermediate and deep zones. PWO also is intended to prevent offsite migration of fluoride in the UGS that is the source of the fluoride plume in the intermediate and deep zones.[1] In addition, attainment of these objectives is constrained by the goal of keeping tap water quality at levels below the MCL (as has been the case historically).

Production well optimization addresses primarily the portion of the intermediate-zone and deep-zone fluoride plume that lies between the scrap yard and the production wells. Production well optimization does not seek to contain fluoride that currently migrates from Company Lake northward to the Columbia River. Fluoride migrating to the Columbia River from the north side of Company Lake does not present an unacceptable risk to human health or ecological receptors and does not significantly increase in-stream fluoride concentrations.[2]

Production well optimization differs from current management of the wellfield in the following respects:

- Pumping would occur continuously at or above a minimum rate required to contain the existing fluoride plume in the intermediate and deep zones. This rate would be contin-

[1] Specifically, fluoride that is present in the UGS beneath the scrap yard is the primary source of the fluoride plume in intermediate-zone groundwater (that is, production well pumping influences in this area have resulted in intermediate-zone fluoride concentrations exceeding MCLs). Fluoride that is present in the UGS beneath east potliner and south landfill does not appear to be a primary source of the intermediate-zone fluoride plume.

[2] For a more detailed discussion of these studies, refer to Section 3 and Appendix D of the *Draft Surface Water and Sediment Areas Addendum to the RI/FS Work Plan* (CH2M HILL, April 3, 1998).

ued even if plant demands were to decrease below this rate. Under present conditions, pumping is solely a function of plant demands.

- Specific wells would be operated on a long-term continual basis. Under present conditions, the use of individual wells is based on plant demand and other wellfield operating considerations, rather than on fluoride containment.

Production well optimization was evaluated with respect to the following two sets of wellfield pumping rates:

- **Historical long-term average production.** This condition was evaluated to describe the system's ability to meet the PWO objectives when the Troutdale plant is in a period of active aluminum production (involving use of the casthouse and at least some of the potlines).
- **Minimum production necessary to meet the PWO objectives.** This condition was evaluated to identify the wellfield pumping that would be required if the plant were to scale back production, as occurred during the mid-1990s.

A.2.1 Historical Pumping

The effect of historical long-term average pumping on fluoride capture and containment was evaluated with the flow model using three-dimensional particle tracking techniques.[3] Particle tracking was performed on a steady-state simulation of historical pumping conditions at the site. The historical pumping simulation used pumping rates and locations that represented plant operations from January 1990 through October 1991. During this period, the long-term average pumping rate was 1,800 gallons per minute (gpm) from wells PW03 (320 gpm), PW07 (580 gpm), PW08 (600 gpm), and PW10 (300 gpm).[4] Because this period represented a period of sustained plant activity (including operation of all five potlines at certain times), this simulation was assumed to consider the effects of the maximum historical pumping operations.

Figure A-2 shows a legend for maps that show the simulated three-dimensional movement of imaginary particles that were initiated in the model at the scrap yard, south landfill, east potliner, MW33, and Company Lake (see Figures A-3 through A-7). Each map shows the traces of particles that are initiated at various depths and locations in the model and tracked forward in time to delineate groundwater flow paths. The change in color along the length of a given particle trace illustrates the vertical movement of the particle through the groundwater system. The figures compare the particle traces with the current configuration of the fluoride plumes in groundwater, which are defined by concentrations exceeding the MCL. Specific observations and conclusions from the figures are as follows:

[3] This analysis of the historical pumping condition is also described in the *Groundwater Remedial Investigation Report* (CH2M HILL, June 1999) and *Technical Memorandum No. GW-20: Development of an Updated Hydrogeologic Conceptual Model and a Numerical Groundwater Flow Model at RMC-Troutdale* (CH2M HILL, June 25, 1999).

[4] Wells PW03 and PW07, which obtain groundwater from the upper portion of the regional Sand and Gravel Aquifer (SGA), were simulated as pumping from layer 9 of the model. PW08 obtains water from the deep zone and from the same interval as PW03 and PW07. Based on the screen lengths and aquifer permeabilities, it is estimated that 20 percent of the pumping at PW08 is obtained from the deep zone (model layer 7) and the remaining 80 percent is obtained from the upper SGA (model layer 9). Well PW10 pumps from the deep SGA (model layer 11).

- Figures A-3 and A-4 show the traces of particles that were initiated in the model at the top of the UGS and traced forward in time. Figure A-3 indicates that the production wells capture groundwater that is present in the UGS at the scrap yard. Particles initiated at the scrap yard were simulated to migrate to production well PW08. Figure A-4 shows that production wells PW07 and PW08 capture groundwater from south landfill and east potliner. The two figures together indicate that the existing fluoride plume in the intermediate zone conforms closely in shape to the particle traces initiated at the scrap yard, but not to the traces of particles initiated at south landfill and east potliner. This is consistent with the understanding that south landfill and east potliner are not primary contributors of fluoride to the intermediate zone.

- Figure A-5 shows that fluoride that is present in the intermediate and deep zones at MW33 migrates to PW08 under the historical pumping scenario. Groundwater at this location is captured by well PW08 because this well (unlike PW03, PW07, and PW10) has a portion of its perforated interval located within the deep zone (model layer 7).

- Figure A-6 shows the traces of particles that are initiated at the perimeter of Company Lake under the long-term average pumping scenario. The traces show that water from the pond recharges groundwater and that groundwater moves radially away from the pond. Particles initiated along the southern and eastern perimeters of the pond are captured by production wells PW03, PW07, and PW08. In contrast, particles initiated around the remainder of the pond are beyond the zone of influence of the production wells and, therefore, discharge to the Columbia River or the Sandy River bar (which extends into the Columbia River from the mouth of the Sandy River). As shown in Figure A-6, some of the particles that migrate northeast from Company Lake toward the Sandy River are pulled back toward the RMC production wells rather than discharging to the river.

A.2.2 Minimum Pumping

Analyses were performed to identify the minimum pumping rates that would be required to continue capturing the portion of the intermediate-zone and deep-zone fluoride that lies between the scrap yard and the production wells. Priority for the minimum pumping configuration was given to pumping PW07 and PW08 because these two wells are closest to the scrap yard. In addition, a portion of the open perforated interval of well PW08 lies in the deep zone, whereas other production wells have perforated intervals that lie exclusively in deeper portions of the aquifer.

Figure A-7 shows the traces of particles initiated at the scrap yard when only PW08 is pumping. The simulation was performed for a PW08 pumping rate of 600 gpm, which is the rate at which this well was pumped for the historical pumping simulation. Figure A-7 shows that particles initiated at the scrap yard migrate to the Sandy River and are not captured by PW08. This indicates that PW08 by itself may not be capable of sufficiently altering flow directions to allow for full containment of the fluoride plume lying north of the scrap yard. Figures A-8 and A-9 show traces for these same particles when production well PW07 is also operated at rates of 300 gpm (half the rate used in the historical pumping simulation) and 600 gpm (the full rate used in the historical pumping simulation). Figure A-8 shows that operation of PW07 at a rate of 300 gpm (along with operating PW08 at 600 gpm) is insufficient for fully containing the existing fluoride plume north of the scrap

yard. Specifically, Figure A-8 shows that several particles initiated in the western half of the scrap yard migrate to the Sandy River and not to the production wells. In Figure A-9, PW07 and PW08 operate at 600 gpm each, and particles initiated in the western half of the scrap yard eventually migrate to the production wells. This indicates that PW07 and PW08 need to operate at approximately 600 gpm each in order to contain the portion of the UGS fluoride plume that is contributing fluoride to the intermediate-zone fluoride plume.

A.2.3 Conclusions for Option GW-1

Conclusions from the analyses of production well optimization are:

1. The historical pumping condition is sufficient to contain the fluoride that is present in groundwater between the scrap yard and the production wells. Capture is performed primarily by production well PW08.
2. The historical pumping condition also contains a portion of the fluoride migrating from Company Lake. Fluoride migrating from the southern and eastern perimeters of Company Lake is captured by production wells PW03, PW07, and PW08. Fluoride migrating from the northern and western perimeters of Company Lake migrates toward the Columbia and Sandy Rivers.
3. Pumping only production well PW08 will not provide containment of fluoride that is present in the UGS at the scrap yard. Most (but not all) of the fluoride that is present in the intermediate zone at MW33 is captured by PW08 if PW08 is pumping on the order of 600 gpm.
4. Pumping both PW08 (at its full capacity of 600 gpm) and PW07 can provide containment of the western two-thirds of the scrap yard, which is the area encompassing the southern extent of the intermediate-zone fluoride plume. In order to contain this area, the pumping rate at both wells needs to be on the order of 600 gpm. Under this condition, the eastern third of the scrap yard and the entire area beneath east potliner are not captured by the production wells and instead migrate northeasterly toward the Sandy River.
5. Pumping PW08 at approximately 600 gpm and PW07 at approximately 300 gpm provides containment of the fluoride that is present in the intermediate zone at MW33.

A.3 Groundwater Option GW-2 (Production Well Optimization with Focused Extraction)

Groundwater Option GW-2 consists of adding focused extraction wells to Option GW-1. The additional wells would be in the UGS near the scrap yard. The primary objectives of focused extraction in this area are:

- Containment of constituents moving vertically out of the silt zone
- Containment and mass removal of constituents already within the UGS
- Prevention of constituent migration to the intermediate and deep zones (and to the RMC production wells)

- Flexibility in future production well operations

The following sections present an analysis of focused extraction, including a sensitivity analysis on the wellfield configuration that would be required to meet the objectives of groundwater Option GW-2.

A.3.1 Initial Analysis

The modeling analysis of the potential effectiveness of focused extraction and the wellfield design that would be required to meet the objectives was performed in a phased approach to identify the minimum number of wells and the lowest pumping rates that would provide containment. The containment objective specifically consisted of containing the UGS beneath the entire footprint of the scrap yard. The analysis was constrained by a desire to keep the total pumping rate of the focused extraction well system at 40 gpm or less so that pumped groundwater could be used in the wet electrostatic precipitator (wet ESP) process in the plant.

The analysis indicated that two wells, pumping approximately 20 gpm each, would be required to fully contain UGS groundwater beneath the entire footprint of the scrap yard. Figure A-10 shows groundwater elevation contours in the UGS for the two-well focused extraction system. The contours show cones of depression at each well, with the groundwater elevations calculated to be approximately 7.7 feet at each well. This elevation is approximately 4.2 feet below the static water level elevation in this unit (11.9 feet) and is approximately 10 feet above the base of the UGS [which lies at an approximate elevation of –2 feet (National Geodetic Vertical Datum (NGVD) at the scrap yard and east potliner]. The actual drawdown in the well is expected to be greater than the 4.2 feet predicted in the model simulation because of head losses across the well casing and also because the model node spacing [which is greater than the well diameter] causes the calculated groundwater level to be higher than would actually exist in the aquifer formation outside the well casing. However, the actual water level inside the well casing would likely be only a few feet below the level predicted by the model and would not likely be near the base of the UGS.

Figure A-11 shows the traces of particles that are initiated in the UGS along the entire perimeter of the scrap yard and east potliner for the two-well configuration for the focused extraction system. As shown in the figure, one well is located along the north side of the scrap yard and the other in the western portion of east potliner. The scrap yard well captures UGS groundwater from all but the eastern portion of the scrap yard. The east potliner well captures UGS groundwater beneath the eastern portion of the scrap yard and the entire footprint of east potliner. Figure A-12, which shows the 10-year capture zone of the two focused extraction wells, also shows the capture effectiveness of the two-well focused extraction system. As shown in Figure A-12, the capture zone of these wells includes the portions of the existing UGS fluoride plume that underlie both the scrap yard and east potliner, as well as areas outside of the plume.

A.3.2 Sensitivity Analysis

The principal uncertainty governing the conceptual design of the focused extraction system is the effect of the hydraulic conductivities in the UGS (model layer 3) and the upper portion of the intermediate zone (model layer 4) on the sustainable pumping rates of the focused

extraction wells and the area of the UGS that can be captured by each well. A sensitivity analysis was conducted to evaluate this uncertainty. The primary objective of the simulations was to evaluate the changes in particle traces that would arise for higher or lower hydraulic conductivities in these two model layers. The analysis examined changes in capture zone extent for a single focused extraction well and changes in particle movement into the intermediate and deep zone. The analysis consisted of four simulations with the following objectives:

- **Case 1: Raising the hydraulic conductivity in the UGS.** Simulations were performed by raising the hydraulic conductivity value from 35 to 50 ft/day in the UGS (layer 3). The value of 50 ft/day was selected because it is equal to values measured in other portions of the site (specifically at MW08-027, MW30-030, and MW33-033) and is half the value of two measurements (at MW09-030 and MW35-038) that are considered outliers. [See Table 1-3 in *Technical Memorandum No. GW-20: Development of an Updated Hydrogeologic Conceptual Model and a Numerical Groundwater Flow Model at RMC-Troutdale* (CH2M HILL, June 25, 1999).]

- **Case 2: Raising the hydraulic conductivity in the UGS and the upper portion of the intermediate zone.** This simulation modified Case 1 by raising the hydraulic conductivity value of layer 4 by a factor of 2 (from 75 to 150 ft/day). This value was selected because it is similar to the arithmetic mean of values measured during the sitewide aquifer testing program for the intermediate zone.

- **Case 3: Lowering the hydraulic conductivity in the UGS.** Simulations were performed by lowering the hydraulic conductivity value from 35 to 5 ft/day in the UGS (layer 3). A value of 5 ft/day was selected because it is the value used in the calibrated flow model for the UGS in the southwestern portion of the plant (including areas lying west of the scrap yard).

- **Case 4: Repeating Case 3 with pumping shifted into layer 4.** This simulation evaluated the idea of shifting pumping to layer 4 if the hydraulic conductivity of the UGS is sufficiently low to limit the effectiveness of the focused extraction well system. This simulation used the same hydraulic conductivity values as in Case 3.

The sensitivity runs were analyzed by comparing groundwater elevation contours and particle traces in each sensitivity run with those for the base-case simulation. The comparisons showed the following:

- **Case 1.** Figure A-13 compares UGS groundwater elevations in the base-case simulation and the Case 1 simulation. Figures A-14 through A-17 compare the particle traces. The figures show that the higher hydraulic conductivity causes little change to the system.

- **Case 2.** Figure A-18 compares UGS groundwater elevations, and Figures A-19 through A-22 compare the particle traces. The analysis indicates that two focused extraction wells pumping 20 gpm each are still capable of fully containing UGS groundwater beneath the scrap yard and east potliner.

- **Case 3.** The Case 3 analysis indicates that focused extraction wells will not be capable of pumping 20 gpm on a sustainable basis. This is shown in Figure A-23, which shows that

water levels in the aquifer formation outside the casings of each well will be on the order of –7 feet NGVD or lower, which is below the top of the UGS.

- **Case 4.** The Case 4 analysis indicates that shifting pumping from the UGS (model layer 3) to the upper portion of the intermediate zone (model layer 4) provides containment for much, but not all, of the UGS groundwater beneath the scrap yard and east potliner. For Case 4, groundwater is not captured by the focused extraction wells beneath the western portion of the scrap yard and the northern portion of east potliner. (See Figures A-24 through A-27.) In this simulation, the groundwater that is not captured by the focused extraction wells is captured by the production wells, which were simulated as pumping at their historical pumping rate. If the production wells pump at the minimum rate for production well optimization (600 gpm at PW07 and 600 gpm at PW08), then UGS groundwater in the northern portion of east potliner would not be contained. (See Figure A-9, which shows that UGS groundwater east of the western half of the scrap yard is not contained by the production wells.) In this situation, containment could potentially occur by adding an additional focused extraction well in the UGS and possibly pumping all three focused extraction wells at slightly lower rates.

A.3.3 Effect of Production Well Pumping on Performance of Focused Extraction Wells

Model simulations were performed to evaluate whether the pumping rates and locations for the production wells would affect the ability of the focused extraction system to contain groundwater in the UGS beneath the scrap yard and east potliner. Analyses were performed only for the base-case scenario, not the four sensitivity analyses discussed in Section A.3.2. An initial analysis was performed in which the production wells were not operating. This analysis indicated that UGS groundwater was still fully contained by the two-well focused extraction system. Consequently, the modeling analysis suggests that the performance of the focused extraction system (that is, containment of UGS groundwater beneath the scrap yard and east potliner) will be largely unaffected by the operation of the production wells.

A.3.4 Conclusions for Option GW-2

Conclusions from this analysis are:

1. A system consisting of two focused extraction wells each pumping 20 gpm can effectively contain groundwater beneath the entire footprint of the scrap yard. In addition, a two-well system is capable of capturing groundwater lying beneath the footprint of east potliner.

2. The two-well focused extraction system is expected to be effective at containing UGS groundwater beneath the scrap yard and east potliner regardless of the pumping schedule for the production wells.

3. Pumping the two focused extraction wells (at 20 gpm each) and production well PW08 (at 600 gpm) will not effectively contain the intermediate zone. Groundwater in areas just beyond the capture zone of the focused extraction wells will migrate to the Sandy River, rather than to PW08. A pumping scheme involving both PW08 and PW07 (such as described for Option GW-1) would likely be required in order to prevent migration of intermediate-zone fluoride to the Sandy River.

4. Modestly higher hydraulic conductivities (for example, on the order of 50 feet/day) in the UGS are not expected to adversely affect the performance of the focused extraction wells. Hydraulic conductivities on the order of 5 feet/day would require a greater number of wells at lower pumping rates in the UGS or completion of the focused extraction wells in the upper portion of the intermediate zone. These changes could potentially require higher total pumping rates in order to achieve containment of UGS groundwater beneath the entire footprint of the scrap yard and east potliner.

A.4 Groundwater Option GW-3 (Production Well Optimization with Enhanced Focused Extraction)

Groundwater Option GW-3 consists of Option GW-2 plus focused extraction from the UGS beneath the western portion of south landfill and focused extraction from the intermediate zone southwest of Company Lake.

A.4.1 Focused Extraction at South Landfill

The objective of performing focused extraction in the UGS at south landfill is to restore groundwater quality at the location of the localized fluoride plume along the western margin of south landfill. Aquifer test results and evaluations conducted with the numerical groundwater flow model indicate that the permeability of the UGS in the vicinity of south landfill may be lower (on the order of 5 feet/day) than in the vicinity of the scrap yard and east potliner (35 feet/day). Consequently, the pumping rate of 20 gpm at the scrap yard and east potliner focused extraction wells is not sustainable at the south landfill focused extraction well. Modeling evaluations indicate that a sustainable rate at south landfill is on the order of 5 gpm.

Figure A-28 shows the 10-year capture zone of a single focused extraction well pumping at 5 gpm from the UGS along the western portion of south landfill. The location of the focused extraction well was specified in the model to be the location of monitoring well MW47, which is within the zone of elevated fluoride concentrations in the UGS at south landfill. Figure A-28 shows that the focused extraction well is capable of capturing the entire portion of the UGS plume, as well as a larger area within the UGS (primarily to the west and north).

A.4.2 Focused Extraction at Company Lake

The objective of performing focused extraction in the intermediate zone southwest of Company Lake is to address the presence of elevated fluoride concentrations at this location, where a groundwater stagnation point exists when the production wells are operating. Figure A-29 shows groundwater elevation contours in the intermediate zone when the production wells are operating at their long-term historical average production rate (1,800 gpm). The contours in Figure A-29 show that a stagnation point exists within the large area covered by the yellow contour interval. The stagnation point results from the southerly groundwater flow direction from the southwestern corner of Company Lake, the northerly groundwater flow direction at Fairview Farms, and the action of the production wells. These three influences on groundwater flow patterns create a groundwater divide that extends in a southwesterly direction from the southwest corner of Company Lake. The influence of the production wells on the creation of this stagnation point is shown in

Figure A-30, which shows the groundwater elevation contours in the intermediate zone when the production wells are not operating. In Figure A-30, groundwater flow directions over a large area southwest of Company Lake are from the southeast to the northwest, and no broad stagnation point exists.

Model simulations were performed to evaluate the type of focused extraction pumping system that would be required when the production wells operate at their long-term historical average production rates. The simulations were run to identify the number of wells and their pumping rates that would be required to capture the closed fluoride concentration contour shown in Figure A-29. The analysis indicated that three wells pumping 15 gpm each would be required to fully capture intermediate-zone groundwater within this area. Figure A-31 shows the traces of particles traced backward in time for a 10-year period from the three wells. Two of the wells are located at the present locations of monitoring wells MW06 and MW31, and the third well is situated midway between MW06 and MW31. The traces show that the wells capture groundwater within and outside of this closed contour within a 10-year period. The traces also show that groundwater from the western portion of the southern perimeter of Company Lake is captured within a 10-year period.

A.4.3 Conclusions for Option GW-3

1. A single focused extraction well pumping approximately 5 gpm is capable of capturing fluoride in the UGS in the localized area along the western perimeter of south landfill.
2. Three wells pumping 15 gpm each would be required in order to capture fluoride in the intermediate zone southwest of Company Lake.

A.5 Groundwater Option GW-4 (Production Well Optimization with Enhanced Focused Extraction and Silt Unit Extraction)

Groundwater Option GW-4 consists of adding low-flow extraction from the silt unit to Option GW-3. Silt unit extraction was evaluated at south landfill and east potliner, where elevated fluoride concentrations are present in silt unit soil and groundwater and where the silt unit is greater than 10 feet thick. Silt unit extraction was not included at the scrap yard in this option because the silt is less than 10 feet thick and (according to soil sampling information) sampling data indicate that it contains low levels of fluoride in soils (compared with the overlying debris and surficial sand).

The objective of silt unit extraction is to prevent fluoride loading to the UGS from the silt unit beneath south landfill and east potliner. Modeling analyses were conducted to evaluate the spacing and pumping rates of a system consisting of well points at both south landfill and east potliner. The model was run to identify the system that would create an upward gradient within the lower portion of the silt unit without causing excessive drawdown in individual extraction wells. Before the analysis was conducted, the model was modified by tightening the node spacing to less than 10 feet (compared with a spacing of 50 feet in the original model) and subdividing the silt unit into three layers (rather than the two-layer representation used in the original model). Pumping was assumed to occur from the middle

layer (layer 2), which was assumed to have a thickness of between 5 and 10 feet. Pumping was not assigned to the lowest silt unit layer (layer 3 of the model) because of its proximity to the UGS, which could potentially cause greater capture of UGS groundwater than desired. At east potliner, extraction well locations were limited to areas situated outside the right-of-way of a high-pressure natural gas line, which is present along a southwest-northeast line in the middle of east potliner.

A.5.1 East Potliner

At east potliner, the horizontal hydraulic conductivity of layers 2 and 3 of the silt unit was set at 2.5 feet/day, which is five times higher than the value of 0.5 foot/day estimated to be typical of silt materials within the silt unit (from model calibration). This value was chosen because layers 2 and 3 of the silt unit consist of sandy silt and (in some borings) silty sand beneath east potliner. The vertical anisotropy (the ratio of horizontal to vertical hydraulic conductivity) was maintained at 100:1 in all three layers, which was the value established during model calibration.

The modeling analyses indicated that containment of east potliner groundwater in the silt unit (including beneath the right-of-way of the natural gas line) could be achieved by a system consisting of approximately 25 well points, each pumping 0.15 gpm (for a total of 3.75 gpm).

The total pumping rate of 3.75 gpm is equivalent to an infiltration rate of 20 inches/year over the 150,000-square-foot (ft^2) footprint of east potliner.[5] This indicates that the system is water-budget limited. That is, the feasible extraction rate for containing groundwater within the silt unit is governed by the long-term average annual precipitation infiltration rate. This is consistent with hydrogeologic interpretations, which indicate that vertical gradients within the silt unit under present site conditions are downward throughout the RMC-Troutdale site, with precipitation infiltration being the sole source of the water moving through the silt unit.

A.5.2 South Landfill

At south landfill, the target area for containment of silt unit groundwater was set equal to a 60,000-ft^2 area in the west-central portion of this soil and debris area. This area was selected because it is the only location at south landfill where fluoride migration to the base of the silt unit and into the UGS has been observed. As discussed in the *Groundwater Remedial Investigation Report* (CH2M HILL, June 1999), cross sections of the subsurface geology and fluoride concentrations at south landfill indicate that migration to the base of the silt unit is occurring at station GP49 and has resulted in the presence of fluoride above the MCL in the UGS at nearby station GP59. (See Figure 3-1 of the Focused Feasibility Study.)

The modeling analysis was performed using the horizontal hydraulic conductivity value of 0.5 foot/day for silt materials that was established from site data during calibration of the model. The vertical anisotropy was maintained at 100:1 in all three layers. The analysis indicated that at least 60 well points, and possibly as many as 75, would be required in order to contain the 60,000-ft^2 target area. Each well point would pump on the order of 0.05 to 0.1 gpm, for a total of between 3 and 7.5 gpm. Higher pumping rates at individual well

[5] Infiltration rate = 21 in/yr * 150,000 ft^2 * 7.48 gal/ft^3 * (1 ft / 12 in) * (1 yr / 365 days) * (1day / 1440 min) = 3.75 gpm.

points would not be sustainable if the horizontal hydraulic conductivity at each well point were 0.5 foot/day or lower. Pumping rates on the order of 0.05 gpm or lower could be required, depending on the permeability of the silt unit at each well point location.

As with east potliner, pumping of the silt unit at south landfill would be water-budget limited because the sole source of water to the silt unit is precipitation infiltration. As discussed below, only a portion of the precipitation infiltrating through the landfill migrates into the silt unit. The infiltration rate into the silt unit is estimated to be between 0.16 and 0.25 foot/year (between 1.9 and 3.0 inches/year) at south landfill, based on the low permeability of the silt unit in this area. For a 60,000-ft^2 area, this is equivalent to between 0.14 and 0.21 gpm.[6]

A.5.3 Conclusions for Option GW-4

1. At east potliner, a system of 25 well points, each pumping 0.15 gpm, could potentially prevent fluoride migration from the silt unit to the UGS.
2. At south landfill, a system of 60, and possibly 75, well points would be required in order to contain the target area containing elevated fluoride concentrations in the silt unit.
3. At both areas, the pumping rates from the well points would be limited by precipitation infiltration, which is the only significant source of water to the silt unit.

A.6 Effect of Groundwater Options on Fluoride Concentrations in Groundwater

Table A-1 summarizes the anticipated effects of the groundwater options on fluoride concentrations in each groundwater zone (the silt unit, UGS, intermediate, and deep zones). The anticipated effects are listed according to the remedial action objectives and metrics discussed in Section 4 of the Focused Feasibility Study. Because dredging of process residue at the bottom of Company Lake is expected to have a substantial influence on groundwater quality in the vicinity of the lake, Table A-1 presents the effectiveness of the groundwater options with and without dredging.

For each groundwater option, three-dimensional particle tracking was performed in the groundwater flow model to identify the portions of the fluoride plume where fluoride would be flushed out of the aquifer by lower concentration groundwater. In addition to identifying areas of flushing, the times required for concentrations to decline below the MCL in the UGS, intermediate, and deep zones were evaluated by considering the results of partitioning calculations conducted as part of the *Groundwater Remedial Investigation Report* (CH2M HILL, June 1999). The partitioning calculation specifically considered the potential for sorbed concentrations of fluoride in aquifer matrix soils to continue leaching fluoride to groundwater, thereby prolonging the time to compliance (that is, the time required for fluoride concentrations to drop below the MCL) in the UGS, the intermediate zone, and the deep zone.

[6] Infiltration rate = 1.9 in/yr * 150,000 ft^2 * 7.48 gal/ft^3 * (1 ft / 12 in) * (1 yr / 365 days) * (1day / 1440 min) = 0.14 gpm
= 3.0 in/yr * 150,000 ft^2 * 7.48 gal/ft^3 * (1 ft / 12 in) * (1 yr / 365 days) * (1day / 1440 min) = 0.21 gpm.

A.6.1 Option GW-1

Production well optimization will control fluoride migration but will not by itself substantially alter fluoride concentrations in areas where the fluoride plume is currently present. This is because the current configuration of the fluoride plume in the intermediate and deep zones is believed to be due in part to historical pumping of the RMC production wells. Production well optimization will allow continuation of the historical pattern of production well usage when the plant is operating at historical production levels, with the difference being that production wells PW07 and PW08 will be operated at long-term minimum rates of 600 gpm each, regardless of plant water demands. Consequently, fluoride concentration changes will occur only as follows:

- Concentration decreases could occur north of the production wells in the vicinity of Company Lake in the event that dredging of process residue at the bottom of the pond is performed. The impacts of this action on groundwater quality are discussed below in Section A.6.2 for groundwater Option GW-2. As discussed in Section A.6.2, groundwater in a substantial portion of the fluoride plume north of the production wells would be flushed with clean water within a 10-year period following dredging. Although it is possible that the soils forming the aquifer matrix could leach fluoride into the clean water, it is currently anticipated that this process will not substantially prolong the groundwater cleanup times over large areas surrounding Company Lake.
- For the portion of the fluoride plume situated south of the production wells:
  - Excavation of the debris in the northern half of the scrap yard may reduce fluoride concentrations in the UGS beneath and downgradient of the scrap yard in the near term (that is, 5 or 10 years). However, soil sampling data and transport calculations indicate that much longer periods of time (on the order of hundreds of years) may be required for the excavation to reduce fluoride concentrations in the UGS. This is because the surficial sand unit underlying the debris contains fluoride concentrations that are similar to those observed in the debris. The elevated concentrations in the surficial sand unit are sufficiently high to maintain aqueous-phase concentrations at current levels in the silt unit and therefore in the underlying UGS. Partitioning calculations described in Section A.7 below indicate that it is possible that concentration decreases in the UGS (and therefore in the intermediate and deep zones) will not occur for several hundred years.
  - Natural flushing of surficial debris and underlying soils would cause fluoride concentrations to decrease over time. However, partitioning calculations described in Section A.7 indicate that a concentration reduction might not occur for several hundred years or potentially over 1,000 years.

A.6.2 Option GW-2

Under Option GW-2, flushing of the fluoride plume in the UGS and intermediate zones in the south plant would occur primarily as the result of operation of the two UGS focused extraction wells. North of the production wells, flushing of the fluoride plume in the UGS and intermediate zones with lower concentration groundwater is expected to occur only if Company Lake dredging is performed. Option GW-2 will not affect the time to compliance in the silt unit.

A.6.2.1 Areas of Flushing

Areas where significant fluoride concentration improvements would be expected to occur within 5 and 10 years of implementation of Option GW-2 are shown in Figure A-32 for the UGS and Figure A-33 for the intermediate zone.[7] Figures A-32 and A-33 assume that Company Lake dredging is performed and removes the source of fluoride to groundwater around Company Lake. The figures also show conditions under continuous operation of the production wellfield at its long-term historical pumping rate of 1,800 gpm. (See Section A.2 for discussions of historical pumping and the minimum pumping that would be required under Option GW-1.) The figures show the following:

- In the south plant, changes in groundwater concentrations would occur from the combined action of the UGS focused extraction wells and the RMC production wells. Specific changes indicated by Figures A-32 and A-33 are:
  - The majority of the fluoride plume in the UGS would be captured by the two focused extraction wells within 5 years of implementation of focused extraction. No additional portions of the plume would be captured within 10 years.
  - The only portions of the UGS plume that would not be captured are areas that do not appear to be causing intermediate-zone fluoride concentrations to be above the MCL. This includes the elevated UGS concentrations in the western portion of south landfill and east of production well PW10.
  - The portions of the fluoride plume residing in the intermediate and deep zones would be partially captured within 5 years of implementation of Option GW-2. Capture of the entire portion of the intermediate-zone plume would require more than 5 years and would likely be accomplished within 10 years.
  - These results are independent of the selected option for the three soil and debris areas situated in the south plant (scrap yard, east potliner, and south landfill).
- North of the production wells, reductions in fluoride concentrations would occur in most (but not all) areas surrounding Company Lake as the result of leakage of low-concentration water from Company Lake to underlying groundwater following dredging. Figures A-32 and A-33 indicate the following:
  - Migration of low-concentration surface water into the underlying UGS would flush the portions of the UGS plume situated along the south side of the lake within the first 5 years after dredging is completed. Low-fluoride water would also move into the area containing the highest fluoride concentrations north of the lake in the UGS. During a 10-year period, the primary change in the UGS would be in the continued northward advancement of the low-fluoride water.
  - In the intermediate zone, a large area around the lake would be flushed by low-fluoride water within a 5-year period. The portion of the plume situated between

[7] The intermediate zone is considered an indicator of expected groundwater quality trends in the deep zone. The times required for water quality improvements in the deep zone are expected to be less than in the intermediate zone because fluoride is present at lower concentrations and in a smaller area in the deep zone. In addition, deep-zone fluoride is closer to the RMC production wells and will therefore be captured more quickly than intermediate-zone fluoride.

Company Lake and the production wells would not be flushed during the first 5 years but would be flushed within 10 years.

- The portion of the fluoride plume situated immediately southwest of Company Lake (primarily in the intermediate zone) would not be appreciably flushed during the first 5 to 10 years following dredging. This is because this area is located in a stagnation zone (a zone of extremely low groundwater velocities) that is present due to the combined effects of ambient groundwater flow, leakage from Company Lake, and pumping of the production wells. (See Section A.4.2 above.)

Figures A-34 and A-35 show the areas under Option GW-2 that would experience flushing if Company Lake dredging is not performed. Comparisons with Figures A-32 and A-33 indicate that the difference between the dredging and no-dredging conditions is the absence of flushing north of the production wells. Between the south plant soil and debris areas and the production wells, the flushing zones are the same in the two sets of figures because Company Lake dredging has no effect on groundwater flow patterns or on water quality south of the production wells.

A.6.2.2 Time to Compliance

For the UGS, the modeling analyses discussed in Section A.6.2.1 suggest that pumping from the focused extraction wells may cause fluoride concentrations in the south plant to decrease to levels below the MCL (4 mg/L) within a 5-year period. However, it is conceivable that concentrations could remain above the MCL in the UGS directly beneath certain portions of the scrap yard and east potliner because of the presence of elevated soil concentrations of fluoride. As discussed in Appendix G of the *Draft Groundwater Remedial Investigation Report* (CH2M HILL, June 1999), partitioning calculations indicate that soil concentrations are sufficiently high to theoretically sustain fluoride levels above the MCL in UGS groundwater beneath portions of these two soil and debris areas. However, because these calculations are based on soil and groundwater samples collected on a small scale (that is, at small-diameter boreholes), they may overestimate the degree to which fluoride concentrations would remain above the MCL on an areawide scale or at groundwater monitoring locations downgradient of these two soil and debris areas. Consequently, fluoride concentrations in the UGS may remain above the MCL for more than 5 years or could decline below the MCL within a few years of implementing focused extraction under groundwater Option GW-2. Also, the fluoride partitioning calculations indicate that if fluoride concentrations decline below the MCL as the result of pumping the focused extraction wells, then it is possible that concentrations could rise in the future above the MCL if desorption from site soils is significant in terms of concentration and the area over which leachable soil fluoride is present.

For the intermediate zone, partitioning calculations indicate that soil concentrations of fluoride are similar to background levels and would not be expected to sustain fluoride concentrations above the MCL in groundwater as the result of leaching. Consequently, the time to compliance in the intermediate zone is predicted to be the same as the groundwater flushing times presented in Figures A-32 through A-35. Specifically:

- Fluoride concentrations in the intermediate zone are anticipated to decline below the MCL south of the production wells within a 10-year period.

- Fluoride concentrations in the intermediate zone north of the production wells would decline below the MCL within a 10-year period if Company Lake dredging is performed. If dredging is not performed, then fluoride concentrations in this portion of the intermediate zone would not be expected to decline to levels below the MCL for several hundred years or perhaps over 1,000 years.
- Fluoride concentrations in the intermediate zone southwest of Company Lake would not be expected to decline below the MCL within a 10-year period for the reasons discussed in Section A.6.2.1.

A.6.3 Option GW-3

Under Option GW-3, flushing of the fluoride plume in the UGS and intermediate zones in the south plant would occur primarily as the result of operation of the three UGS focused extraction wells. North of the production wells, flushing of the fluoride plume in the UGS and intermediate zones with lower concentration groundwater is expected to occur only if Company Lake dredging is performed, even though Option GW-3 includes focused extraction in the intermediate zone southwest of Company Lake (where elevated fluoride concentrations are present). Option GW-3 will not affect the time to compliance in the silt unit.

A.6.3.1 Areas of Flushing

Areas where significant fluoride concentration improvements would be expected to occur within 5 and 10 years of implementation of Option GW-3 are shown in Figure A-36 for the UGS and Figure A-37 for the intermediate zone. Figures A-36 and A-37 assume that Company Lake dredging is performed and removes the source of fluoride to groundwater around Company Lake. The areas shown in these two figures are similar to the areas shown for Option GW-2 (see Figures A-32 and A-33). The primary differences are that Option GW-3 captures the following additional areas where fluoride is present above the MCL:

- The elevated fluoride in the UGS beneath the western portion of south landfill
- The elevated fluoride in the intermediate zone southwest of Company Lake

Figures A-38 and A-39 show the areas that would experience flushing under Option GW-3 if Company Lake dredging is not performed. Comparisons with Figures A-36 and A-37 indicate that the difference between the dredging and no-dredging conditions is the absence of flushing north of the production wells, except in the area that lies within the upgradient portions of the capture zones of the three focused extraction wells located southwest of Company Lake. Between the south plant soil and debris areas and the production wells, the flushing zones are the same in the two sets of figures because Company Lake dredging has no effect on groundwater flow patterns or on water quality south of the production wells.

A.6.3.2 Time to Compliance

For the UGS, the times to compliance for Options GW-2 and GW-3 are similar because the primary actions improving UGS groundwater quality are Company Lake dredging and focused extraction at the scrap yard and east potliner. The addition of focused extraction at south landfill as part of Option GW-3 does not appreciably change the time to compliance for the UGS on a sitewide basis because of the small size of the fluoride plume being

targeted for capture by the south landfill focused extraction well. Also, the UGS does not appear to contain sufficiently high fluoride in soil to prolong the time to compliance at south landfill. [See Appendix G of the *Groundwater Remedial Investigation Report* (CH2M HILL, June 1999).]

For the intermediate zone, the only difference between Options GW-2 and GW-3 is the accelerated decline in fluoride concentrations within the intermediate zone southwest of Company Lake under Option GW-3. The shorter time to compliance in this area under Option GW-3 is the result of focused extraction at this location.

A.6.4 Option GW-4

Compared with Option GW-3, the primary difference in the effectiveness of Option GW-4 is a potential reduction in the time to compliance within the silt unit. Option GW-4 will not reduce the times to compliance within the UGS, intermediate, or deep zones beyond the times that could be achieved with Option GW-3. In addition, it is conceivable that Option GW-4 will not appreciably improve the time to compliance within the silt unit because the time to compliance is governed by the infiltration rate through the silt unit. See Section A.7 for a detailed discussion of time to compliance in the silt unit under present site conditions and under various remedial options for silt unit soils.

A.7 Time to Compliance in the Silt Unit

Analytical calculations were conducted to estimate the times that might elapse before leaching rates from silt unit soils would drop sufficiently to reduce groundwater concentrations in the silt unit to levels below the MCL (4 mg/L). The analyses were conducted for present site conditions and following various remedial options. The analysis was conducted beneath two soil and debris areas in the south plant (scrap yard and south landfill), for soils beneath north landfill, and for the process residue and underlying sediments at Company Lake. Analyses were also conducted for east potliner, where debris removal actions have been completed. The total time required for leaching from the units overlying the UGS is referred to hereafter in Section A.7 as the time to compliance (TTC). The following subsections of this appendix present the objectives of the analysis, the technical approach that was used, the area-specific assumptions and methodologies that were employed, the TTC results, a sensitivity analysis of the Langmuir coefficients and the fraction of debris containing leachable fluoride, and analyses of the reductions in TTC values that would occur under various remedial action alternatives.

A.7.1 Objectives of TTC Analysis

The objectives of the analysis were:

- To identify the general time frames required for natural flushing to reduce shallow groundwater concentrations to the MCL within the silt unit.
- To evaluate relative contributions to the TTC from debris layers and each geologic unit situated beneath the soil and debris areas. In the south plant area, the analysis considered leaching from three units (the debris, the surficial sand and the underlying silt zone). At north landfill, the analysis considered leaching from the debris; the

underlying sands within the UGS were assumed to contain fluoride at background levels. At Company Lake, the analysis considered leaching from the process residue and underlying sediment.

- To assess the relative improvements in the time to compliance that could be expected under the following specific remedial alternatives for nongroundwater media:
  - Placement of permeable or impermeable caps on each soil and debris area
  - Excavation of debris
  - Dredging of process residue in Company Lake

A.7.2 Technical Approach for TTC Analysis

The approach for conceptualizing the leaching mechanisms and for calculating TTC values consisted of the following:

- Quantifying the mass of fluoride that is sorbed to the debris and underlying soils beneath each soil and debris area. Calculations of the total fluoride mass for the three soil and debris areas in the south plant are provided in Table A-2. Calculations of the total fluoride mass in the process residue and underlying sediments at Company Lake are provided in Table A-3. The quantification of leachable fluoride mass involved:
  - Quantifying the total fluoride mass in each layer.
  - Initially assuming that all fluoride mass present in the debris and process residue is leachable. This may overestimate the fraction of the debris that can leach fluoride and the time to compliance.
  - Subtracting out the background concentration (208 mg/kg).[8]
- Estimating precipitation infiltration rates and identifying the depth to groundwater. The attachment to this appendix presents groundwater elevation data and summaries of annual minimum and maximum groundwater elevations for monitoring wells situated near the scrap yard, east potliner, and south landfill.
- Selecting a solubility limit for the form of fluoride present in the debris at a given soil and debris area. The solubility limit was generally selected as the highest concentration of fluoride measured in groundwater within the silt unit.
- Selecting geotechnical parameters (dry bulk density and total porosity).
- Selecting partition coefficients that describe desorption of fluoride from debris and soils. Appendix G of the *Groundwater Remedial Investigation Report* (CH2M HILL, June 1999) discusses the theory of desorption processes and identifies desorption parameters from available literature that can be used to quantify desorption from soils at the Troutdale facility. As discussed in the appendix, fluoride desorption generally follows a Langmuir isotherm in most soils. Desorption is described by two coefficients: the Langmuir constant and the Langmuir adsorption capacity. Published values of these coefficients were identified for site soils by comparing measured and published values of the oxalate

[8] See *Technical Memorandum DS No. 12: Background Data Summary for RMC-Troutdale* (CH2M HILL, December 3, 1996).

extractable aluminum content, the soil pH, and the clay content. Tabulations of the coefficients for samples of the debris, the surficial sand, and the silt are presented in Appendix G of the *Groundwater Remedial Investigation Report*.

- Calculating pore volume flushing times from the following relationship:

  (Thickness) * (total porosity) * 1.3 / infiltration rate

  where the factor of 1.3 accounts for the lengthening of the pore water flushing time caused by contribution of fluoride from dead-end pores.

- Calculating the total leaching time from the relationship:

  TTC = Step 1 + Step 2

  where Step 1 is the time required for dissolved-phase fluoride concentrations to drop below the solubility limit and Step 2 is the remaining time required for leaching (via precipitation infiltration) to reduce the dissolved-phase concentration to the MCL. The Step 2 process follows an exponential decay pattern.

- Calculating the following four sets of TTC values, which assume these steps are all additive:

  - Debris TTC = $(\text{Step 1} + \text{Step 2})_{\text{debris}}$
  - Surficial TTC = $(\text{Step 1} + \text{Step 2})_{\text{surficial sand}}$
  - Silt TTC = $(\text{Step 1} + \text{Step 2})_{\text{silt}}$
  - Total TTC = Debris TTC + Sand TTC + Silt TTC

A.7.3 Area-Specific Assumptions and Calculation Methods

Specific assumptions and adjustments to the approach were made to adapt the calculations to the conditions at each soil and debris area. These are discussed below.

A.7.3.1 North Landfill

The following adjustments and assumptions were made at north landfill:

- The time-to-compliance analysis was conducted exclusively for the debris in north landfill. The thickness of the debris was assumed to be 9 feet.

- The fluoride mass was assumed to be uniformly distributed through the full thickness of the debris. The fluoride mass estimates (Table A-2) were calculated using concentration data from surficial samples of the debris.

- The depth to groundwater was set at 4 feet, which is the depth of the seasonal high water table. During seasonal high groundwater conditions, approximately half of the thickness of the debris is situated below the water table.

- The solubility limit was set equal to 14 mg/L, which is the highest groundwater concentration measured near north landfill during August 1997 (at monitoring well MW09-030).

- The Langmuir coefficients were assumed to be the same as those for the surficial sand soils at south landfill.

A listing of the input parameters for the TTC calculations at north landfill is provided in Table A-4, along with explanations of the definitions and derivation of each parameter value.

A.7.3.2 South Landfill

The following adjustments and assumptions were made at south landfill:

- The thickness of the soil profile was as follows:
  - Debris: 5 feet
  - Surficial sand: 8 feet
  - Silt: 25 feet
- The depth to groundwater was set at 0.2 foot because the seasonal high water table is often at ground surface during a given year.
- The precipitation infiltration rate through the debris and the surficial sand was set equal to 24 inches/year, which is approximately 65 percent of the 40 inches/year of precipitation recorded at Portland International Airport. This rate is 4 inches/year higher than the rate at the scrap yard because the debris in south landfill consists of bulky debris with large pores, whereas the debris in the scrap yard is more equivalent to a porous medium.
- A lower infiltration rate was used in the silt unit than in the debris and the surficial sand. The silt unit infiltration rate was calculated to be between 0.16 and 0.25 foot/year using vertical hydraulic conductivity and vertical gradient data, as well as mixing calculations that examined the infiltration rate necessary for groundwater at the base of the silt unit (measured at 414 mg/L at station GP49) to result in the lower concentrations measured in the UGS (61 mg/L at station GP59). This calculation is discussed in detail in Section 5.2.2.1.3 of the *Groundwater Remedial Investigation Report* (CH2M HILL, June 1999). A value of 0.16 foot/year was selected for the base-case TTC analysis because the use of a higher rate could potentially underestimate duration of time required for silt unit groundwater concentrations to drop below the MCL.
- Two sets of solubility limits were used, based on vertical trends in fluoride concentrations shown in cross sections. [See Figure 4-9 in the *Groundwater Remedial Investigation Report* (CH2M HILL, June 1999).] A solubility limit of 75 mg/L was used for the debris and surficial sand, based on pore water concentrations measured in the surficial sand at GP59 and GP60. A solubility limit of 1,100 mg/L was used in the silt based on measured pore water concentrations at GP59.

A listing of the input parameters for the TTC calculations at south landfill is provided in Table A-5, along with explanations of the definitions and derivation of each parameter value.

A.7.3.3 Scrap Yard

The following adjustments and assumptions were made at the scrap yard:

- Calculations were performed only for the northern half of the scrap yard, rather than the entire area. This was based on examination of cross-sectional views of soil fluoride concentrations. [See Figure 4-19 in the *Groundwater Remedial Investigation Report* (CH2M HILL, June 1999).] Soil sampling data presented in the cross sections indicate that sorbed-phase fluoride is present primarily in the northern half of the scrap yard.
- The thickness of the soil profile was as follows:
  - Debris: 2 feet
  - Surficial sand: 7 feet
  - Silt: 12 feet
- The depth to groundwater was set at 2 feet, which is the depth of the seasonal high water table. This depth corresponds to the depth of the contact between the debris and the underlying surficial sand.
- The precipitation infiltration rate was assumed to be 20 inches/year, which is approximately 55 percent of the average annual rainfall at the Portland International Airport weather station.
- The solubility limit was set equal to 110 mg/L, which is the highest groundwater concentration measured beneath the scrap yard (at MW13 and GP37).

A listing of the input parameters for the TTC calculations at the scrap yard are provided in Table A-6, along with explanations of the definitions and derivation of each parameter value.

A.7.3.4 Company Lake

The following adjustments and assumptions were made at Company Lake:

- The thickness of the soil profile was assumed to be as follows:
  - Process residue: 1.75 feet, based on a thickness contour map[9]
  - Sediment: 1 foot
- The time to compliance was adjusted upward to account for the fact that a downward vertical gradient from the lake to underlying groundwater exists during only a portion of each year. As discussed in the Section 3.3.2 of the *Groundwater Remedial Investigation Report* (CH2M HILL, June 1999), groundwater elevations are below the lake level during approximately 6 months of a typical year. The vertical leakage rate through the process residue and underlying sediments during these 6 months was estimated to be 0.26 foot/year, based on an assumed vertical gradient of 0.5 foot/foot and the measured vertical permeability in three core samples of the sediment (10^{-6} centimeters per second). [See *Technical Memorandum DS No. 17: Data Summary for the Wastewater Discharge Areas Addendum to the RI/FS, Part 1* (CH2M HILL, December 12, 1997).]
- The solubility limit was set equal to 25 mg/L, which is the highest groundwater concentration measured near Company Lake (at GP39).

[9] See Figure 4-4 in *Technical Memorandum DS No. 15: Company Lake Supplemental Data Summary* (CH2M HILL, March 26, 1997).

- The Langmuir coefficients were assumed to be the same as those for the surficial sand soils at south landfill.

A listing of the input parameters for the TTC calculations at Company Lake is provided in Table A-7, along with explanations of the definitions and derivation of each parameter value.

A.7.3.5 East Potliner

The following adjustments and assumptions were made at east potliner:

- The thickness of the soil profile was as follows:
  - Debris: 0 feet (because of debris excavation conducted as part of a 1995 early action)
  - Surficial sand: 4 feet
  - Silt: 30 feet, which includes silt, sandy silt, and silty sand horizons
- The depth to groundwater was set at 2 feet, which is the depth of the seasonal high water table and is the same depth as was used at the scrap yard.
- The precipitation infiltration rate was set at 20 inches/year, which was the value used at the scrap yard.
- The solubility limit was set equal to 600 mg/L, which is the highest groundwater concentration measured beneath east potliner (at GP66).

A listing of the input parameters for the TTC calculations at east potliner is provided in Table A-8, along with explanations of the definitions and derivation of each parameter value.

A.7.4 TTC Results

Table A-9 summarizes the results of the TTC calculations, using the nominal values of the Langmuir coefficients in each debris and soil horizon. The table shows that the TTC values are over 1,000 years at all locations except east potliner, where the TTC is estimated to be 500 years. At north landfill and Company Lake, the debris and process residue (respectively) contribute to the entire duration of the TTC values. At south landfill and east potliner, the TTC values are governed primarily by the sorbed fluoride concentrations in the silt unit. At the scrap yard, the TTC values arise from the presence of sorbed fluoride in the debris and the surficial sand, with less contribution from the silt unit.

A.7.5 Sensitivity Analysis (Langmuir Coefficients, Leachable Fraction of Fluoride)

The calculations that are the basis for the TTC values in Table A-9 may potentially overestimate the actual times required for groundwater in the silt unit to show fluoride concentrations below the MCL. This potential overestimation is the result of the following factors:

- All fluoride mass that is present above background concentrations is assumed to be fully leachable. For the debris in each soil and debris area and the process residue in

Company Lake, this assumption could potentially overestimate the actual leachable mass. The degree of overestimation could be small or could be substantial.

- The calculation methodology assumes that leaching of fluoride from debris and underlying layers occurs sequentially. For example, the calculations assume that leaching from the soils beneath the debris does not begin until fluoride concentrations in debris are sufficiently low that the pore water in the debris no longer exceeds the MCL. This could potentially overestimate actual TTC values because leaching could occur from a lower horizon at the same time that leaching occurs from a shallower horizon whenever the shallower horizon is no longer leaching fluoride at the solubility limit.
- Concurrently with the assumption of sequential leaching, the calculations define the time to compliance as the time required for pore water concentrations to drop to exactly 4 mg/L (the MCL). The TTC values may overestimate the time that would be required for concentrations in a monitoring well to decline to 4 mg/L. This is because the TTC values describe pore water concentrations adjacent to the soil. Actual bulk groundwater concentrations in the silt unit could potentially be lower than calculated pore water concentrations. This could occur if the pores adjacent to the soil sample are discontinuous (that is, are not part of a continuous pore network extending through the silt unit to the UGS). In addition, actual concentrations in groundwater samples could potentially be lower than pore water concentrations because of mixing effects that occur during purging and sampling of monitoring wells.[10]

In addition to the potential overestimation of TTC values inherent in the calculation methodology, uncertainties in the Langmuir coefficients could potentially cause errors in the TTC values. These uncertainties could result in overestimation or underestimation of the TTC values. Consequently, a sensitivity analysis was conducted to evaluate how much TTC values might vary due to uncertainties in the leachable mass estimates and the Langmuir coefficients. The analysis evaluated the following:

- Reduction of the fluoride mass that is available from 100 percent of the total mass estimates to 20 percent of the total mass estimates. The value of 20 percent was chosen to help illustrate the potential importance of this parameter.
- Use of lower and higher Langmuir coefficients than were used in the base-case analysis.

Table A-10 summarizes the results of the sensitivity analysis using the lower leachable fraction. The lower leachable fractions reduce the TTC values, but the reductions are generally on the order of only a few hundred years and do not change the time frames to much smaller periods of time (for example, years or a few decades). In addition, the 80 percent reduction in the leachable mass causes less than 80 percent reduction in the time to compliance at some locations. The ratio of the TTC values calculated for the sensitivity analysis versus the base-case analysis is approximately 0.20 at north landfill and Company Lake (indicating an 80 percent reduction in the TTC), 0.38 at the scrap yard, 0.64 at east potliner, and 0.88 at south landfill. The limited change in the TTC values at south landfill is due to the low permeability and high fluoride mass of the silt unit, which controls the TTC values more strongly than conditions in the debris and the surficial sand.

[10] Specifically, purging and sampling induces three-dimensional flow around the wells, which can cause mixing of groundwater zones containing elevated fluoride concentrations and groundwater zones containing lower levels of fluoride.

The analysis of the effect of different Langmuir coefficients (summarized in Table A-11) shows little change in the TTC values at north landfill and Company Lake and moderate change at the other locations. At each location, the general time frame (that is, hundreds or thousands of years) is unchanged, although east potliner shows values ranging from about 100 to nearly 1,000 years.

A.7.6 Effects of Remedial Options for Nongroundwater Media on TTC

Calculations were performed to identify the effect of various remedial options for debris and soils at the scrap yard, east potliner, south landfill, and north landfill, as well as for process residue at Company Lake. The following options were considered separately:

- North landfill
  - Capping with a multilayer, low-permeability cap with riprap cover (Option NLF-3)
  - Excavation of waste layer (Option NLF-4 and Alternative C)
- South landfill
  - Capping with a multilayer, low-permeability cap (Option SLF-3)
  - Excavation of waste layer (Option SLF-4 and Alternative C)
  - Excavation of waste layer and surficial sand (Option SLF-5)
- Scrap yard
  - Excavation of waste layer (Option SY-3 and Alternatives B and C)
  - Excavation of waste layer and surficial sand (Option SY-4)
- Company Lake
  - Capping with a permeable cap over process residue (which would not change the infiltration rate from the lake through the process residue and sediments into underlying groundwater) (Option CL-2 and Alternative A)
  - Dredging process residue (Option CL-3 and Alternatives B and C)

The TTC results and the percentage reductions in the TTC values under these remedial alternatives results are presented by soil and debris area in Tables A-12 through A-16. The analyses indicate the following:

- At north landfill (Table A-12):
  - A low-permeability cap would reduce the TTC values by about 20 percent. However, the total TTC could still be several thousand years if the sorbed fluoride mass below the seasonal high water table is similar to the mass above the seasonal high water table.
  - Removal of the debris could potentially reduce TTC values dramatically. Under this scenario, the TTC would be governed by the flushing time for fluoride in the vicinity of north landfill to migrate out of the aquifer system into the nearby rivers. This time period is estimated to be on the order of 20 years. However, current fluoride concentrations in groundwater do not pose an unacceptable risk to human health or

ecological receptors in the Columbia River. In addition, groundwater in the area between the river and the flood control dike is unlikely to be used in the future because this area lies within a floodplain.

- At south landfill (Table A-13):
  - A low-permeability cap would have no discernible effect on the TTC values because the seasonal high water table is situated within less than one-half foot of ground surface during a normal year.
  - Removal of the debris or both the debris and the surficial sands would reduce TTC values between 20 and 30 percent. However, the total TTC would still be on the order of a few thousand years because of the elevated sorbed fluoride concentrations in the silt unit soils and the low permeability of the silt unit.
- At the scrap yard (Table A-14):
  - Excavation of the waste layer would reduce the TTC values by 1,000 years. However, groundwater concentrations in deeper horizons of the silt would likely continue to exceed MCLs for several hundred years or more.
  - Excavation of the waste layer and surficial sand could potentially reduce the TTC values by 80 or 90 percent or more. However, because of the presence of fluoride in the silt horizon at the base of the silt unit, groundwater concentrations in deeper horizons of the silt could potentially continue to exceed MCLs for 75 years or more.
- At Company Lake (Table A-15):
  - A permeable cap would have no effect on the TTC values because the cap would be designed to allow continued migration of surface water to groundwater, with leaching of fluoride from the process residue.
  - Removal of the process residue and the upper 1 foot of sediment would reduce TTC values dramatically. Under this scenario, the TTC would be governed by the flushing time for fluoride in the vicinity of north landfill to migrate out of the aquifer system into the nearby rivers. This time period is estimated to be on the order of 20 years.

A.8 References

CH2M HILL. December 3, 1996. *Technical Memorandum DS No. 12: Background Data Summary for RMC-Troutdale.* Prepared for Reynolds Metals Company, Troutdale, Oregon.

_____. March 26, 1997. *Technical Memorandum DS No. 15: Company Lake Supplemental Data Summary.* Prepared for Reynolds Metals Company, Troutdale, Oregon.

_____. December 12, 1997. *Technical Memorandum DS No. 17: Data Summary for the Wastewater Discharge Areas Addendum to the RI/FS Work Plan, Part 1.* Prepared for Reynolds Metals Company, Troutdale, Oregon.

_____. December 15, 1997. *Technical Memorandum DS No. 16: Data Summary for the Soil and Debris Areas Addendum to the RI/FS Work Plan*. Prepared for Reynolds Metals Company, Troutdale, Oregon.

_____. June 1999. *Groundwater Remedial Investigation Report*. Prepared for Reynolds Metals Company, Troutdale, Oregon.

_____. June 25, 1999. *Technical Memorandum No. GW-20: Development of an Updated Hydrogeologic Conceptual Model and a Numerical Groundwater Flow Model at RMC-Troutdale*. Prepared for Reynolds Metals Company, Troutdale, Oregon.

Appendix A Tables

Table A-1
Summary of Effectiveness Metrics for Groundwater Options 1 Through 4

Remedial Action Objective	Metric	Option GW-1	Option GW-2	Option GW-3	Option GW-4
Reduce or control offsite migration of fluoride and other constituents of concern in groundwater	Percent of sitewide fluoride plume contained	100% (intermediate/deep, south plant) 50% (intermediate/deep, north plant) 50%-100% (UGS in south plant) [a] 50% (UGS at Company Lake)	100% (intermediate/deep, south plant) 50% (intermediate/deep, north plant) 100% (UGS in south plant) 50% (UGS at Company Lake)	100% (intermediate/deep, south plant) 50% (intermediate/deep, north plant) 100% (UGS in south plant) 50% (UGS at Company Lake) [b]	100% (intermediate/deep, south plant) 50% (intermediate/deep, north plant) 100% (UGS in south plant) 50% (UGS at Company Lake) [b]
Reduce mass loading of fluoride and other constituents of concern to groundwater in the intermediate and deep zones.	Prevent fluoride loading to the intermediate and deep zones (with Company Lake dredging)	No (SY, EPL) No (SLF) Yes (Company Lake)	Yes (SY, EPL) No (SLF) Yes (Company Lake)	Yes (SY, EPL) Yes (SLF) Yes (Company Lake)	Yes (SY, EPL) Yes (SLF) Yes (Company Lake)
	Time to MCLs in the intermediate and deep zones (with Company Lake dredging)	Several hundred years (south plant) 15 years (north and southeast of Company Lake) 50-100 years (southwest of Company Lake)	10 years (south plant) 15 years (north and southeast of Company Lake) 50-100 years (southwest of Company Lake)	10 years (south plant) 15 years (north and southeast of Company Lake) 10-15 years (southwest of Company Lake)	10 years (south plant) 15 years (north and southeast of Company Lake) 10-15 years (southwest of Company Lake)
	Percent reduction in size of intermediate/deep zone plume after 5 and 10 years (with Company Lake dredging)	South Plant: No reduction anticipated Company Lake: 60% (5 years) 80% (10 years)	South Plant: 60% (5 years) 100% (10 years) Company Lake: 60% (5 years) 80% (10 years)	South Plant: 60% (5 years) 100% (10 years) Company Lake: 70% (5 years) 90% (10 years)	South Plant: 60% (5 years) 100% (10 years) Company Lake: 70% (5 years) 90% (10 years)
	Prevent fluoride loading to the intermediate and deep zones (without Company Lake dredging)	No (all areas)	Yes (SY, EPL) No (SLF) No (Company Lake)	Yes (SY, EPL) Yes (SLF) No (Company Lake)	Yes (SY, EPL) Yes (SLF) No (Company Lake)
	Time to MCLs in the intermediate and deep zones (without Company Lake dredging)	Several hundred years (south plant) Several hundred years (Company Lake)	10 years (south plant) Several hundred years (Company Lake)	10 years (south plant) Several hundred years (Company Lake)	10 years (south plant) Several hundred years (Company Lake)
	Percent reduction in size of intermediate/deep zone plume after 5 and 10 years (without Company Lake dredging)	South Plant: No reduction anticipated Company Lake: No reduction anticipated	South Plant: 60% (5 years) 100% (10 years) Company Lake: No reduction anticipated	South Plant: 60% (5 years) 100% (10 years) Company Lake: No reduction anticipated	South Plant: 60% (5 years) 100% (10 years) Company Lake: No reduction anticipated
Reduce mass loading of fluoride and other constituents of concern to groundwater in the UGS.	Prevent fluoride loading to the UGS (with Company Lake dredging)	No (SY, EPL) No (SLF) Yes (Company Lake)	No (SY, EPL) No (SLF) Yes (Company Lake)	No (SY, EPL) No (SLF) Yes (Company Lake)	Yes (SY, EPL) Yes (SLF) Yes (Company Lake)
	Time to MCLs in the UGS (with Company Lake dredging)	Several hundred years [c] (SY, EPL) Several hundred years [d] (SLF) 15-20 years (Company Lake)	10 years (SY, EPL) [e] Several hundred years [d] (SLF) 15-20 years (Company Lake)	10 years (SY, EPL) [e] 5-10 years [e] (SLF) 15-20 years (Company Lake)	10 years (SY, EPL) [e, f] 5-10 years [e, f] (SLF) 15-20 years (Company Lake)

Table A-1 (continued)
Summary of Effectiveness Metrics for Groundwater Options 1 Through 4

Remedial Action Objective	Metric	Option GW-1	Option GW-2	Option GW-3	Option GW-4
	Percent reduction in size of UGS plume after 5 and 10 years (with Company Lake dredging)	South Plant: No reduction anticipated Company Lake: 50% (5 years) 70% (10 years)	South Plant: 90% (5 and 10 years) Company Lake: 50% (5 years) 70% (10 years)	South Plant: 95% (5 and 10 years) Company Lake: 50% (5 years) 70% (10 years)	South Plant: 95% (5 and 10 years) Company Lake: 50% (5 years) 70% (10 years)
	Prevent fluoride loading to the UGS (without Company Lake dredging)	No (SY, EPL) No (SLF) No (Company Lake)	No (SY, EPL) No (SLF) No (Company Lake)	No (SY, EPL) No (SLF) No (Company Lake)	Yes (SY, EPL) Yes (SLF) No (Company Lake)
	Time to MCLs in the UGS (without Company Lake dredging)	Several hundred years [c] (SY, EPL) Several hundred years [d] (SLF) Several hundred years (Company Lake)	10 years (SY, EPL) [e] Several hundred years [d] (SLF) Several hundred years (Company Lake)	10 years (SY, EPL) [e] 5-10 years [e] (SLF) Several hundred years (Company Lake)	10 years (SY, EPL) [e, f] 5-10 years [e, f] (SLF) Several hundred years (Company Lake)
	Percent reduction in size of UGS plume after 5 and 10 years (without Company Lake dredging)	South Plant: No reduction anticipated Company Lake: No reduction anticipated	South Plant: 90% (5 and 10 years) Company Lake: No reduction anticipated	South Plant: 95% (5 and 10 years) Company Lake: No reduction anticipated	South Plant: 95% (5 and 10 years) Company Lake: No reduction anticipated
Restore groundwater to beneficial use criteria.	Time to achievement of the MCL or ambient water quality criteria	Several hundred years [g] for the silt unit as discussed above for other units	Several hundred years [g] for the silt unit as discussed above for other units	Several hundred years [g] for the silt unit as discussed above for other units	Several hundred years [g] for the silt unit as discussed above for other units

(a) For Option 1, the percentage of the plume that is contained is dependent in part on the magnitude of pumping from the RMC production wells. For the minimum pumping rate of 1200 gpm, UGS groundwater beneath east potliner and the eastern portion of scrap yard is not contained by the production wells. In these areas, historical groundwater monitoring has not indicated that intermediate-zone fluoride concentrations exceed the MCL.
(b) Groundwater south of Company Lake is captured, but groundwater north of Company Lake is not captured.
(c) The time to achievement of the MCL may be shorter if debris is excavated at scrap yard.
(d) The time to achievement of the MCL may be shorter if debris is excavated at south landfill.
(e) If the focused extraction wells are shut down once fluoride concentrations in the UGS drop below the MCL, it is conceivable that concentrations could eventually rise at some later time to concentrations above the MCL. This is because the potential exists for the overlying silt unit soils to continue leaching fluoride into the UGS. A rise in UGS concentrations could also occur beneath and downgradient of scrap yard or south landfill if debris excavation is not performed.
(f) At east potliner and south landfill, implementation of Option 4 is expected to prevent fluoride concentrations from rising in the UGS to levels above the MCL after the UGS focused extraction wells are shut down.
(g) This time assumes that no actions are taken at the soil and debris areas. Times to achievement of the MCL may be reduced by certain remedial options for the soil and debris areas.

Table A-2
Total Sorbed Fluoride Mass Above Background Levels

A	B	C	D	E	F	G	H	I	J	K	L
Location	Strata	Average Thickness (ft)	Area (ft^2)	Volume (ft^3)	Dry Bulk Density (lb/ft^3)	Average Fluoride Concentration (mg/kg)	Total Fluoride Mass (kg)	Background Fluoride Concentration (mg/kg)	Average Fluoride Concentration Above Background (mg/kg)	Total Fluoride Mass Above Background (kg)	Fluoride Mass per ft Thickness (kg/ft)
South Landfill											
	Waste Material	5	263,000	1,315,000	100	12,500	746,000	***	12,500	746,000	149,200
	Underlying Sand	8	263,000	2,104,000	100	1,430	137,000	200	1,230	117,000	14,625
	Silt	25	263,000	6,575,000	80	630	150,000	200	430	103,000	4,120
	UGS to 45 ft bgs	5	263,000	1,315,000	100	260	16,000	200	60	3,600	720
Scrap Yard (North)											
(Sand further subdivided)	Waste Material	2	84,600	169,200	100	31,600	243,000	***	31,600	243,000	121,500
	Underlying Sand-Western Third	7	14,800	103,600	100	390	2,000	200	190	900	129
	Underlying Sand-Middle Third	7	34,800	243,600	100	13,000	144,000	200	12,800	142,000	20,286
	Underlying Sand-Eastern Third	7	35,000	245,000	100	12,900	143,000	200	12,700	141,000	20,143
	Silt	12	84,600	1,015,200	80	730	27,000	200	530	20,000	1,667
	UGS to 40 ft bgs	20	84,600	1,692,000	100	360	28,000	200	160	12,000	600
Scrap Yard (North)											
(Sand not subdivided)	Waste Material	2	84,600	169,200	100	31,600	243,000	***	31,600	243,000	121,500
	Underlying Sand	7	84,600	592,200	100	10,825	291,000	200	10,625	286,000	40,857
	Silt	12	84,600	1,015,200	80	730	27,000	200	530	20,000	1,667
	UGS to 40 ft bgs	20	84,600	1,692,000	100	360	28,000	200	160	12,000	600
Scrap Yard (South)											
	Waste Material	2	160,000	320,000	100	1,900	28,000	***	1,900	28,000	14,000
	Underlying Sand	5	160,000	800,000	100	255	9,000	200	55	2,000	400
	Silt	8	160,000	1,280,000	80	310	14,000	200	110	5,100	638
	UGS to 40 ft bgs	25	160,000	4,000,000	100	240	44,000	200	40	7,300	292
East Potliner											
	Underlying Sand	4	150,000	600,000	100	345	9,000	200	145	3,900	975
	Silt	30	150,000	4,500,000	80	1,150	188,000	200	950	155,000	5,167
	UGS to 40 ft bgs	6	150,000	900,000	100	590	24,000	200	390	16,000	2,667
North Landfill											
	Waste Material	9	100,000	900,000	100	4,860	199,000	***	4,860	199,000	22,111

NOTES:

Column H: Total Fluoride Mass, Kg = (Soil Volume, ft^3)*(Dry bulk density,lb/ft^3)*(0.454 Kg/lb.)*(F Concentration, mg/Kg)*(1 Kg F/ 1000000 mg F).

Column I: Background soil concentration was assumed to be 200 mg/kg. An entry of *** indicates that background soil concentrations were not subtracted from waste material concentrations.

Column K: Total Fluoride Mass Above Background = (Soil Volume, ft^3)*(Dry bulk density,lb/ft^3)*(0.454 Kg/lb.)*(Average F Conc. Above Background, mg/Kg)*(1 Kg F/ 1000000 mg F).

Column L: F Mass per ft thickness of strata = Column K /Column C.

Table A-3
Company Lake Concentration Data in Sediments and Process Residue

Sample Station	Depth	Medium	EPA Method 340.1/340.2 (mg/kg)	Average Concentration (mg/kg)
CL-SD005	0	Process residue	10,500	
CL-SD009	0	Process residue	19,000	
CL-SD011	0	Process residue	12,000	
CL-SD013	0	Process residue	13,000	
CL-SD018	0	Process residue	34,000	
CL-SD019	0	Process residue	21,000	
CL-SD020	0	Process residue	7,000	
CL-SD022	0	Process residue	8,100	
CL-SD024	0	Process residue	18,000	
CL-SD028	0	Process residue	25,000	
CL-SD032	0	Process residue	57,000	
CL-SD034	0	Process residue	50,000	
CL-SD037	0	Process residue	27,000	23,200
CL-SD005	1	Sediment	470	
CL-SD009	2	Sediment	410	
CL-SD011	2	Sediment	300	
CL-SD013	2.5	Sediment	670	
CL-SD016	1	Sediment	410	
CL-SD018	2	Sediment	400	
CL-SD019	3	Sediment	450	
CL-SD020	2.5	Sediment	470	
CL-SD022	3	Sediment	430	
CL-SD024	1.5	Sediment	630	
CL-SD028	3	Sediment	390	
CL-SD032	3	Sediment	400	
CL-SD034	2	Sediment	3,300	
CL-SD037	3.5	Sediment	480	658

Table A-4
Input Parameters for Silt Unit Time-to-Compliance Calculations at North Landfill

Variable	Value Unit	Source
Vertical Groundwater Inflow (Through Debris and Underlying UGS Sands)		
PDX rainfall	40 inches per year	NOAA PDX airport value cited in Conceptual Hydrogeologic Model report
Infiltration under present ground surface conditions	2.00 ft per year	Assume the water budget that is desorbing fluoride is equal to 60% of rainfall, unit conversion from inches per year. Same value as used at south landfill.
Existing conditions (cleanup time in debris and surficial sand)	2.00 ft per year	Assumes debris has high porosity and allows infiltration of nearly all precipitation. Based on field observations of no substantial ponding or runoff during rainfall events.
Cap (cleanup time below seasonal high water table)	2.00 ft per year	Based on rough average 5-ft seasonal water table fluctuation within the debris and on an assumed porosity of 0.6 for the debris. These conditions are also assumed to exist at South Landfill.
Remove debris (cleanup time in remaining soils)	2.00 ft per year	Assumed to be same as capping scenario because of sitewide seasonal water level changes in the surficial sands.
Depth to seasonal high water table	4 ft	Equals average elevation of top of debris (24 ft) minus average elevation of seasonal high water table (20 feet) at well MW21-012 during water years 1996-1998.
Horizontal Groundwater Flow (Through Submerged Debris and In Underlying UGS Sands)		
Travel time to discharge points under no-pumping scenario	12 years	Average time in run RMC2DB2, assuming an effective porosity of 0.20. See files RMC2DB2.#15 and RMC2DB2.#16.
UGS hydraulic conductivity	35 ft/day	Horizontal hydraulic conductivity used for the UGS north of the dike in the calibrated groundwater flow model.
Average flowpath length from NLF to discharge point	800 ft	Longest distance from NLF interior to edge of visible shoreline. Assume this accounts sufficiently for the variability due to NLF footprint and location of discharge points slightly beyond the shoreline.
Average hydraulic gradient along flowpath	0.00104 ft/ft	Back-calculated as flowpath length * effective porosity of 0.2 / (Kh * travel time * 365 days/yr)
UGS aquifer flowpath width	650 ft	Assume this is the southwest-to-northeast width of north landfill
Darcy velocity	13.3 ft/yr	Equals Kh * gradient
Darcy flux through debris below seasonal high water table	43,225 ft3/yr	Equals Darcy velocity * debris thickness below water table * flowpath width
Geotechnical Characteristics		
Debris dry bulk density	100 lbs/cubic ft	Assume this is the same as the assumed value at south landfill.
Debris dry bulk density	1.61 g/cm3	Unit conversion from lbs/ft^3
Debris total porosity	0.5 vol/vol	Assume this is the same as the assumed value at south landfill. This value is also assumed to be almost twice as high as the assumed value in scrap yard.
Debris bulk density / porosity ratio	3.21 kg/L	Calculated from dry bulk density and porosity values above. Conversion factor from g/cc to kg/L is (1 g/cc) * (1 kg / 1000 g) * (1 cc / mL) * (1000 mL / L) = 1
North Landfill Geographical Characteristics and Fluoride Mass Distribution		
Total F mass in debris material	198,580 kg	Equals area * thickness * dry bulk density * (0.454 kg/lb) * concentration * (1 Kg / 1000000 mg). Assumes all solid-phase debris is capable of leaching fluoride.
Average F concentration in debris	4,860 mg/kg	Column G of Table A-2. Can also be calculated as (F mass/volume)*(1/dry bulk density)*(2.2 lbs/kg)*(10^6 mg/kg)
Background soil F conc	200 mg/kg	From Table 1 of *Technical Memorandum DS No. 12: Background Data Summary* (CH2M HILL, December 3, 1996).
Entire North Landfill	100,000 ft2	Column D of Table A-2.
Debris thickness	9 ft	Column C of Table A-2.
Debris thickness below seasonal high water table	5 ft	Debris thickness minus estimated average value of seasonal high water table.
Total F mass in debris below seasonal high water table	110,322 kg	Total debris mass under current conditions * debris thickness below seasonal high water table / current debris thickness.
Max F groundwater concentration	14 mg/L	Assumed value for the solubility for the debris. Equals highest measured groundwater concentration near North Landfill during August 1997 (at well MW09-030).
Mass Removal At Solubility Limit of Debris (Applies to Debris Situated Above Water Table)		
Debris pore volume flushing time (above WT)	1.30 years	Years to remove one pore volume (debris thickness above water table * porosity * 1.3 / infiltration rate; [1.3 extra time factor accounts for dead-end pores])
Max removable F mass (one debris pore volume above WT)	79 kg flushed per pore volume	max gw conc. * area * debris thickness above water table * porosity * 28.32 L/ft^3 * 1 kg/10^6 mg (if no pores are dead-end)
Mass Removal At Solubility Limit of Debris (Applies to Debris Situated Below Water Table)		
Pore volume flushing time (debris below seasonal high WT)	5.78 years	(Debris area / aquifer flowpath width through landfill) * debris porosity / Darcy velocity through debris lying beneath seasonal high water table
Max removable F mass (one debris pore volume below WT)	99 kg flushed per pore volume	max gw conc. * area * debris thickness below water table * porosity * 28.32 L/ft3 * 1 kg/10^6 mg (if no pores are dead-end)
Langmuir Coefficients For Mass Removal Below Solubility Limit (Debris)		
Low Langmuir constant (K)	0.14 L/mg	For Hjelle soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with low K value (b)	1,025 mg/kg	For Hjelle soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Nominal Langmuir constant (K)	0.175 L/mg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with nominal K value (b)	1,900 mg/kg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
High Langmuir constant (K)	0.055 L/mg	For Ando soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with high K value (b)	5,510 mg/kg	For Ando soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)

Highlighted items are not applicable at North Landfill.

Table A-5
Input Parameters for Silt Unit Time-to-Compliance Calculations at South Landfill

Variable	Value	Unit	Source
Vertical Groundwater Inflow (Through Debris and Surficial Sand)			
PDX rainfall	40	inches per year	NOAA PDX airport value cited in Conceptual Hydrogeologic Model report
Infiltration under present ground surface conditions	2.00	ft per year	Assume the water budget that is desorbing fluoride is equal to 60% of rainfall, unit conversion from inches per year
Existing conditions (cleanup time in debris and surficial sand)	2.00	ft per year	Assumes debris has high porosity and allows infiltration of nearly all precipitation. Based on field observations of no substantial ponding or runoff during rainfall events.
Cap (cleanup time below seasonal high water table)	2.00	ft per year	Based on rough average 5-ft seasonal water table fluctuation within the debris and on an assumed porosity of 0.6 for the debris.
Remove debris (cleanup time in remaining debris and soils)	2.00	ft per year	Assumed to be same as capping scenario because of sitewide seasonal water level changes in the surficial sands.
Depth to seasonal high water table	0.20	ft	Average seasonal high water table depth (below ground surface) at well MW26-012 during period 1995-1998.
Depth to seasonal low water table	7.00	ft	Average seasonal low water table depth (below ground surface) at wells MW16-014 and MW26-012 during period 1995-1998.
Vertical Groundwater Inflow (Through Silt Unit)			
Vertical Hydraulic Conductivity	9.80E-08	cm/sec	Measurement using flexible wall permeameter on soil sample SL-SB61-017
Vertical Hydraulic Conductivity	2.78E-04	ft/day	Equals (cm/sec * 86400 sec/day) / (30.48 cm/ft)
Vertical Hydraulic Gradient	0.40	ft/ft	Highest average vertical gradient listed in Table 10 of August 1997 Quarterly Report. Measured at MW02 and MW25 well clusters (in Scrap Yard). No measurements available at SLF.
Existing conditions (cleanup time for materials below debris)	0.16	ft per year	Silt permeability control. Use 4 x 10-7 cm/sec Kv (0.0004 ft/yr) and 0.4 ft/ft vertical gradient. Equates to 0.3 ft vertical fluoride movement per year (for porosity of 0.4), or 15.5 feet in 50 years. Permeablity value is average of log10 values for SLF permeability test and higher of the two scrap yard permeability tests.
Cap (cleanup time for materials below debris)	0.16	ft per year	Assumed to be same as existing conditions because of silt unit permeability control on vertical migration of fluoride.
Remove debris (cleanup time for materials below debris)	0.16	ft per year	Assumed to be same as existing conditions because of silt unit permeability control on vertical migration of fluoride.
Geotechnical Characteristics			
Debris dry bulk density	100	lbs/cubic ft	Assume same as sand.
Debris dry bulk density	1.61	g/cm3	Unit conversion from lbs/ft^3
Surficial sand unit dry bulk density	100	lbs/cubic ft	Sand unit average sitewide. Dry density in sample SL-SB61-005 before falling head (fixed wall) permeability test was 99.5 lbs/ft^3.
Surficial sand unit dry bulk density	1.61	g/cm3	Unit conversion from lbs/ft^3
Silt unit dry bulk density	80	lbs/cubic ft	Silt unit average sitewide. Dry density in sample SL-SB61-017 before triaxial (flexible wall) back-pressure permeability test was 76.5 lbs/ft^3.
Silt unit dry bulk density	1.28	g/cm3	Unit conversion from lbs/ft^3
Debris total porosity	0.5	vol/vol	Assumed to be almost twice as high as value used for scrap yard.
Surficial sand total porosity	0.35	vol/vol	Sand unit average sitewide. Total porosity in sample SL-SB61-005 (after falling head fixed wall test) was 0.371
Silt unit total porosity	0.5	vol/vol	Silt unit average sitewide. Total porosity in sample SL-SB61-017 (after falling head fixed wall test) was 0.506
Debris bulk density / porosity ratio	3.21	kg/L	Calculated from dry bulk density and porosity values above. Conversion factor from g/cc tokg/L is (1 g/cc) * (1 kg / 1000 g) * (1 cc / mL) * (1000 mL / L) = 1
Surficial sand bulk density / porosity ratio	4.59	kg/L	Calculated from dry bulk density and porosity values above. Conversion factor from g/cc to kg/L is (1 g/cc) * (1 kg / 1000 g) * (1 cc / mL) * (1000 mL / L) = 1
Silt unit bulk density / porosity ratio	2.57	kg/L	Calculated from dry bulk density and porosity values above. Conversion factor from g/cc to kg/L is (1 g/cc) * (1 kg / 1000 g) * (1 cc / mL) * (1000 mL / L) = 1
South Landfill Geographical Characteristics and Fluoride Mass Distribution			
Total F mass in debris material	679,808	kg	Equals area * thickness * dry bulk density * (0.454 kg/lb) * concentration * (1 Kg / 1000000 mg).
Total F mass above background in surficial sand unit	107,029	kg	Equals area * thickness * dry bulk density * (0.454 kg/lb) * concentration * (1 Kg / 1000000 mg).
Total F mass above background in silt unit	93,542	kg	Equals area * thickness * dry bulk density * (0.454 kg/lb) * concentration * (1 Kg / 1000000 mg).
Average F concentration in debris	12,500	mg/kg	Column G of Table A-2. Can also be calculated as (F mass/volume)*(1/dry bulk density)*(2.2 lbs/kg)*(10^6 mg/kg)
Average F concentration in surficial sand (above background)	1,230	mg/kg	Column J of Table A-2. Includes samples at depth of 5 feet in soil borings SB10 and SB11.
Average F concentration in silt (above background)	430	mg/kg	Column J of Table A-2. Can also be calculated as (F mass/volume)*(1/dry bulk density)*(2.2 lbs/kg)*(10^6 mg/kg)
Background soil F conc	200	mg/kg	From Table 1 of *Technical Memorandum DS No. 12: Background Data Summary* (December 3, 1996).
Entire South Landfill	239,580	ft2	Column D of Table A-2.
Debris material thickness	5	ft	Column C of Table A-2.
Surficial sand thickness	8	ft	Column C of Table A-2.
Silt thickness	25	ft	Column C of Table A-2.
Debris thickness below seasonal high water table	4.80	ft	Debris thickness minus seasonal high water table measured near north-central portion of scrap yard (well MW02 in 1997).
Total F mass in debris below seasonal high water table	652,616	kg	Total debris mass under current conditions * debris thickness below seasonal high water table * / current debris thickness.
Surficial sand thickness below seasonal low water table	6.00	ft	Debris thickness + sand thickness - depth of seasonal low water table

Table A-5 (continued)
Input Parameters for Silt Unit Time-to-Compliance Calculations at South Landfill

Total F mass in surficial sand below seasonal low water table	80,272	kg	Total debris mass under current conditions * sand thickness below seasonal low water table / current sand thickness.
Mass Removal At Solubility Limit of Remaining Debris (Applies In Debris and Surficial Sand)			
Max F groundwater concentration	75	mg/L	Assumed value for the solubility for the debris in scrapyard. Equals highest measured groundwater concentration in SLF debris and sand during summer 1998 field program.
Debris pore volume flushing time	1.63	years	Years to remove one pore volume (debris thickness * porosity * 1.3 / infiltration rate; [1.3 extra time factor accounts for dead-end pores])
Surficial sand unit pore volume flushing time	1.82	years	Years to remove one pore volume (Surficial sand unit thickness * porosity * 1.3 / infiltration rate; [1.3 extra time factor accounts for dead-end pores])
Maximum removable F mass in one debris pore volume	1,272	kg flushed per pore volume	max gw conc. * area * debris thickness * porosity * 28.32 L/ft^3 * 1 kg/10^6 mg (if no pores are dead-end)
Maximum removable F mass in one surficial sand pore volume	1,425	kg flushed per pore volume	max gw conc. * area * surficial sand unit thickness * porosity * 28.32 L/ft^3 * 1 kg/10^6 mg (if no pores are dead-end)
Pore volume flushing time (debris below seasonal high WT)	1.56	years	Current debris pore flushing time * debris thickness below seasonal high water table / current debris thickness.
Max removable F mass (one debris pore volume below WT)	1,221	kg flushed per pore volume	Current kg debris flushed per pore volume * debris thickness below seasonal high water table / current debris thickness.
Pore volume flushing time (surficial sand below seasonal low WT)	1.37	years	Current sand pore flushing time * sand thickness below seasonal low water table / current sand thickness.
Max removable F mass (one sand pore volume below WT)	1,069	kg flushed per pore volume	Current kg sand flushed per pore volume * sand thickness below seasonal low water table / current sand thickness.
Mass Removal At Solubility Limit of Initially Leached Debris (Applies in Silt Unit)			
Max F groundwater concentration	1,100	mg/L	Equals the highest groundwater concentration measured in the silt unit during the summer 1998 field program (at depth 20 ft in GP59).
Silt unit pore volume flushing time	101.56	years	Years to remove one pore volume (silt thickness * porosity * 1.3 / vertical flow rate through silt; [1.3 extra time factor accounts for dead-end pores])
Maximum removable F mass in one silt pore volume	93,292	kg flushed per pore volume	max gw conc. * area * silt unit thickness * porosity * 28.32 L/ft3 * 1 kg/10^6 mg (if no pores are dead-end)
Langmuir Coefficients For Mass Removal Below Solubility Limit (Debris)			
Low Langmuir constant (K)	0.14	L/mg	For Hjelle soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with low K value (b)	1,025	mg/kg	For Hjelle soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Nominal Langmuir constant (K)	0.175	L/mg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with nominal K value (b)	1,900	mg/kg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
High Langmuir constant (K)	0.055	L/mg	For Ando soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with high K value (b)	5,510	mg/kg	For Ando soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Langmuir Coefficients For Mass Removal Below Solubility Limit (Surficial Sand)			
Low Langmuir constant (K)	0.247	L/mg	For Ipava soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with low K value (b)	149	mg/kg	For Ipava soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Nominal Langmuir constant (K)	0.3	L/mg	Similar to Cisne soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with nominal K value (b)	300	mg/kg	Average of Cisne and Hosmer soils described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
High Langmuir constant (K)	0.397	L/mg	For Seaton soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with high K value (b)	469	mg/kg	For Seaton soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Langmuir Coefficients For Mass Removal Below Solubility Limit (Silt)			
Low Langmuir constant (K)	0.142	L/mg	Hosmer soil
Adsorption capacity associated with low K value (b)	200	mg/kg	Hosmer soil
Nominal Langmuir constant (K)	0.247	L/mg	Molokai soil
Adsorption capacity associated with nominal K value (b)	400	mg/kg	Molokai soil
High Langmuir constant (K)	0.045	L/mg	Elliot soil
Adsorption capacity associated with high K value (b)	625	mg/kg	Elliot soil

Table A-6

Input Parameters for Silt Unit Time-to-Compliance Calculations for Northern Half of Scrap Yard

Variable	Value	Unit	Source
Vertical Groundwater Flux (Controlling Factor For Loading into UGS)			
PDX rainfall	40	inches per year	NOAA PDX airport value cited in Conceptual Hydrogeologic Model report
Infiltration under present ground surface conditions	1.67	ft per year	Calculated as 50% of rainfall, unit conversion from inches per year
Existing conditions (cleanup time in debris and soils)	1.70	ft per year	Assumes F flux is governed by estimated annual precipitation infiltration rate. Also equivalent to 0.2 porosity times rough average 8.5-ft seasonal water table fluctuation.
Cap (cleanup time below seasonal high water table)	1.70	ft per year	Based on rough average 8.5-ft seasonal water table fluctuation at MW02 and MW25 and on assumed porosity of 0.2. Assumed to apply only to depths greater than 2 feet bgs.
Remove debris (cleanup time in remaining debris and soils)	1.70	ft per year	Same as existing conditions because ground cover will be the same.
Depth to seasonal high water table	2.00	ft	Seasonal high water table depth (below ground surface) at well MW02-12 during period 1994-1998. (This depth occurred in 1997.)
Geotechnical Characteristics			
Debris dry bulk density	100	lbs/cubic ft	Assume same as surficial sand.
Debris dry bulk density	1.61	g/cm3	Unit conversion from lbs/ft^3
Surficial sand unit dry bulk density	100	lbs/cubic ft	Sitewide average value for surficial sand. Dry density in sample SY-SB10-005 before falling head (fixed wall) permeability test was 108.5 lbs/ft^3.
Surficial sand unit dry bulk density	1.61	g/cm3	Unit conversion from lbs/ft^3
Silt unit dry bulk density	80	lbs/cubic ft	Sitewide average value for silt unit. Dry density in sample SY-SB10-017 before triaxial (flexible wall) back-pressure permeability test was 81.6 lbs/ft^3.
Silt unit dry bulk density	1.28	g/cm3	Unit conversion from lbs/ft^3
Debris total porosity	0.3	vol/vol	Assume same as surficial sand.
Surficial sand total porosity	0.35	vol/vol	Sitewide average value for surficial sand. Total porosity in sample SY-SB10-005 (after falling head fixed wall test) was 0.3079
Silt unit total porosity	0.5	vol/vol	Sitewide average value for silt unit. Total porosities in samples SY-SB10-017 and SY-SB11-005 (after falling head fixed wall test) were 0.5081 and 0.5491
Debris bulk density / porosity ratio	5.35	kg/L	Calculated from dry bulk density and porosity values above. Conversion factor from g/cc to kg/L is (1 g/cc) * (1 kg / 1000 g) * (1 cc / mL) * (1000 mL / L) = 1
Surficial sand bulk density / porosity ratio	4.59	kg/L	Calculated from dry bulk density and porosity values above. Conversion factor from g/cc to kg/L is (1 g/cc) * (1 kg / 1000 g) * (1 cc / mL) * (1000 mL / L) = 1
Silt unit bulk density / porosity ratio	2.57	kg/L	Calculated from dry bulk density and porosity values above. Conversion factor from g/cc to kg/L is (1 g/cc) * (1 kg / 1000 g) * (1 cc / mL) * (1000 mL / L) = 1
Scrapyard Geographical Characteristics and Fluoride Mass Distribution			
Total F mass in debris material	242,741	kg	Equals area * thickness * dry bulk density * (0.454 kg/lb) * concentration * (1 Kg / 1000000 mg).
Total F mass above background in surficial sand unit	285,662	kg	Equals area * thickness * dry bulk density * (0.454 kg/lb) * concentration * (1 Kg / 1000000 mg).
Total F mass above background in silt unit	19,542	kg	Equals area * thickness * dry bulk density * (0.454 kg/lb) * concentration * (1 Kg / 1000000 mg).
Average F concentration in debris	31,600	mg/kg	Column G of Table A-2. Can also be calculated as (F mass/volume)*(1/dry bulk density)*(2.2 lbs/kg)*(10^6 mg/kg)
Average F concentration in Surficial sand (above background)	10,625	mg/kg	Column J of Table A-2. Includes samples at depth of 5 feet in soil borings SB10 and SB11.
Average F concentration in silt (above background)	530	mg/kg	Column J of Table A-2. Can also be calculated as (F mass/volume)*(1/dry bulk density)*(2.2 lbs/kg)*(10^6 mg/kg)
Background soil F conc	200	mg/kg	From Table 1 of *Technical Memorandum DS No, 12: Background Data Summary* (December 3, 1996).
North Half SY area	84,600	ft2	Column D of Table A-2.
Debris material thickness	2	ft	Column C of Table A-2.
Surficial sand thickness	7	ft	Column C of Table A-2.
Silt thickness	12	ft	Column C of Table A-2.
Debris thickness below seasonal high water table	0.00	ft	Debris thickness minus seasonal high water table measured near north-central portion of scrap yard (well MW02 in 1997).
Total F mass in debris below seasonal high water table	0.00	kg	Total debris mass under current conditions * debris thickness below seasonal high water table / current debris thickness.

Table A-6 (continued)
Input Parameters for Silt Unit Time-to-Compliance Calculations for Northern Half of Scrap Yard

Mass Removal At Solubility Limit			
Max F groundwater concentration	110	mg/L	Assumed value for the solubility for the debris in scrapyard. Equals highest measured groundwater concentration (at GP37 and MW13).
Debris pore volume flushing time	0.47	years	Years to remove one pore volume (debris thickness * porosity * 1.3 / infiltration rate; [1.3 extra time factor accounts for dead-end pores])
Surficial sand unit pore volume flushing time	1.91	years	Years to remove one pore volume (Surficial sand unit thickness * porosity * 1.3 / infiltration rate; [1.3 extra time factor accounts for dead-end pores])
Silt unit pore volume flushing time	4.68	years	Years to remove one pore volume (silt thickness * porosity * 1.3 / infiltration rate; [1.3 extra time factor accounts for dead-end pores])
Maximum removable F mass in one debris pore volume	158	kg flushed per pore volume	max gw conc. * area * debris thickness * porosity * 28.32 L/ft^3 * 1 kg/10^6 mg (if no pores are dead-end)
Maximum removable F mass in one surficial sand pore volume	646	kg flushed per pore volume	max gw conc. * area * surficial sand unit thickness * porosity * 28.32 L/ft^3 * 1 kg/10^6 mg (if no pores are dead-end)
Maximum removable F mass in one silt pore volume	1,581	kg flushed per pore volume	max gw conc. * area * silt unit thickness * porosity * 28.32 L/ft^3 * 1 kg/10^6 mg (if no pores are dead-end)
Pore volume flushing time (debris below seasonal high WT)	0	years	Current debris pore flushing time * debris thickness below seasonal high water table / current debris thickness.
Max removable F mass (one debris pore volume below WT)	0	kg flushed per pore volume	Current kg debris flushed per pore volume * debris thickness below seasonal high water table / current debris thickness.
Langmuir Coefficients For Mass Removal Below Solubility Limit (Debris)			
Low Langmuir constant (K)	0.14	L/mg	For Hjelle soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with low K value (b)	1,025	mg/kg	For Hjelle soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Nominal Langmuir constant (K)	0.175	L/mg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with nominal K value (b)	1,900	mg/kg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
High Langmuir constant (K)	0.055	L/mg	For Ando soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with high K value (b)	5,510	mg/kg	For Ando soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Langmuir Coefficients For Mass Removal Below Solubility Limit (Surficial Sand)			
Low Langmuir constant (K)	0.044	L/mg	For Sagehill soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with low K value (b)	54	mg/kg	For Sagehill soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Nominal Langmuir constant (K)	0.07	L/mg	For Yolo soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with nominal K value (b)	172	mg/kg	For Yolo soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
High Langmuir constant (K)	0.175	L/mg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with high K value (b)	1,900	mg/kg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Langmuir Coefficients For Mass Removal Below Solubility Limit (Silt)			
Low Langmuir constant (K)	0.056	L/mg	For Panoche soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with low K value (b)	47	mg/kg	For Panoche soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Nominal Langmuir constant (K)	0.213	L/mg	For Muscatine soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with nominal K value (b)	358	mg/kg	For Muscatine soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
High Langmuir constant (K)	0.175	L/mg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with high K value (b)	1,900	mg/kg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)

Table A-7
Input Parameters for Silt Unit Time-To-Compliance Calculations at Company Lake

Variable	Value Unit	Source
Vertical Groundwater Inflow (Through Process Residue and Underlying Sediments)		
Vertical hydraulic gradient	0.5 ft/ft	Assumed value.
Vertical hydraulic conductivity	1.00E-06 cm/sec	Approximate average of vertical permeabilities measured for the native sediments. See Table 12 and pages 32-35 of *Technical Memorandum DS No. 17* (CH2M HILL, December 12, 1997).
Vertical hydraulic conductivity	2.83E-03 ft/day	Equals (cm/sec) * (86400 sec/day) / (30.48 cm/ft)
Number of months that vertical gradient is downwards	6 months	Estimated average from inspection of hydrographs contained in Figure 9 of *Technical Memorandum DS No. 18* (CH2M HILL, June 17, 1998).
Infiltration under downward vertical gradient	0.26 ft per year	Vertical gradient * vertical conductivity in ft/day * number of months when gradient is downwards * (365 days/yr) / (12 months/year)
Horizontal Groundwater Flow (In Underlying UGS Sands)		
Travel time to discharge points under no-pumping scenario	20 years	Average time in run RMC2DB2, assuming an effective porosity of 0.20. See files RMC2DB2.#03 and RMC2DB2.#04.
UGS hydraulic conductivity	35 ft/day	Horizontal hydraulic conductivity used for the UGS north of the dike in the calibrated groundwater flow model.
Average flowpath length from CoLake to discharge point	1500 ft	Longest distance from lake interior to edge of visible shoreline. Assume this accounts sufficiently for the variability of the lake shoreline and location of discharge points slightly beyond the shoreline.
Average horizontal hydraulic gradient along flowpath	0.00117 ft/ft	Back-calculated as flowpath length * effective porosity of 0.2 / (Kh * travel time * 365 days/yr)
UGS aquifer flowpath width	2000 ft	East-west width of lake
Darcy velocity	14.9 ft/yr	Equals Kh * horizontal gradient
Geotechnical Characteristics (Combined Process Residue + Fluoride-Bearing Sediments)		
PR dry bulk density	20 lbs/cubic ft	From CH2M HILL November 4, 1998 memo *RMC Troutdale, Company Lake Predesign: Task 4 Results*
PR dry bulk density	0.32 g/cm3	Unit conversion from lbs/ft^3
Sediment dry bulk density	78.2 lbs/cubic ft	From CH2M HILL November 4, 1998 memo *RMC Troutdale, Company Lake Predesign: Task 4 Results*
Sediment dry bulk density	1.26 g/cm3	Unit conversion from lbs/ft^3
PR total porosity	0.85 vol/vol	From CH2M HILL November 4, 1998 memo *RMC Troutdale, Company Lake Predesign: Task 4 Results*
Sediments total porosity	0.5 vol/vol	From CH2M HILL November 4, 1998 memo *RMC Troutdale, Company Lake Predesign: Task 4 Results*
PR bulk density / porosity ratio	0.38 kg/L	Calculated from dry bulk density and porosity values above. Conversion factor from g/cc to kg/L is (1 g/cc) * (1 kg / 1000 g) * (1 cc / mL) * (1000 mL / L) = 1
Sediments bulk density / porosity ratio	2.51 kg/L	Calculated from dry bulk density and porosity values above. Conversion factor from g/cc to kg/L is (1 g/cc) * (1 kg / 1000 g) * (1 cc / mL) * (1000 mL / L) = 1
Company Lake Geographical Characteristics and Fluoride Mass Distribution		
Total F mass in process residue	112,408 kg	Equals area * thickness * dry bulk density * (0.454 kg/lb) * concentration * (1 Kg / 1000000 mg)
Total F mass above background in sediment	4,871 kg	Equals area * thickness * dry bulk density * (0.454 kg/lb) * concentration * (1 Kg / 1000000 mg)
Average concentration in process residue	23,200 mg/kg	From Table A-3. Average of 13 samples collected during 1996. See *Technical Memorandum DS No. 15* (CH2M HILL, March 26, 1997).
Average Surficial sand concentration (above background)	450 mg/kg	From Table A-3. Average of 14 samples collected during 1996. See *Technical Memorandum DS No. 15* (CH2M HILL, March 26, 1997).
Background soil F conc	200 mg/kg	From Table 1 of *Technical Memorandum DS No. 12: Background Data Summary* (CH2M HILL, December 3, 1996).
70% of Company Lake area at stage 15.5 ft	304,920 ft2	Assume 70% of lake area contains process residue. Total lake acreage of 10 acres estimated from Table 2 of *Technical Memorandum DS No. 18* (CH2M HILL, June 17, 1998).
Thickness of PR	1.75 ft	Estimated from thickness contour map (Figure 4-4 of *Technical Memorandum DS No. 15* [CH2M HILL, March 26, 1997]).
Thickness of sediments	1 ft	Assumed value
Max F groundwater concentration	25 mg/L	Similar to concentration at GP39.
Mass Removal At Solubility Limit (Applies to Process Residue and Sediments)		
PR pore volume flushing time	7.48 years	Years to remove one pore volume (process residue thickness * porosity * 1.3 / infiltration rate; [1.3 extra time factor accounts for dead-end pores])
Sediments pore volume flushing time	2.51 years	Years to remove one pore volume (surficial sand unit thickness * porosity * 1.3 / infiltration rate; [1.3 extra time factor accounts for dead-end pores])
Max removable F mass (one PR pore volume)	321 kg flushed per pore volume	max gw conc. * area * process residue thickness * porosity * 28.32 L/ft^3 * 1 kg/10^6 mg (if no pores are dead-end)
Max removable F mass (one sediment pore volume)	108 kg flushed per pore volume	max gw conc. * area * surficial sand unit thickness * porosity * 28.32 L/ft^3 * 1 kg/10^6 mg (if no pores are dead-end)
Langmuir Coefficients For Mass Removal Below Solubility Limit (Process Residue)		
Low Langmuir constant (K)	0.14 L/mg	For Hjelle soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999). Assumed same as south landfill debris.
Adsorption capacity associated with low K value (b)	1,025 mg/kg	For Hjelle soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999). Assumed same as south landfill debris.
Nominal Langmuir constant (K)	0.175 L/mg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999). Assumed same as south landfill debris.
Adsorption capacity associated with nominal K value (b)	1,900 mg/kg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999). Assumed same as south landfill debris.
High Langmuir constant (K)	0.055 L/mg	For Ando soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999). Assumed same as south landfill debris.
Adsorption capacity associated with high K value (b)	5,510 mg/kg	For Ando soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999). Assumed same as south landfill debris.

Table A-8
Input Parameters for Silt Unit Time-to-Compliance Calculations at East Potliner

Variable	Value	Unit	Source
Vertical Groundwater Flux (Controlling Factor For Loading Into UGS)			
PDX rainfall	40	inches per year	NOAA PDX airport value cited in Conceptual Hydrogeologic Model report
Infiltration under present ground surface conditions	1.67	ft per year	Calculated as 50% of rainfall, unit conversion from inches per year
Existing conditions (cleanup time in debris and soils)	1.70	ft per year	Assumes F flux is governed by estimated annual precipitation infiltration rate. Also equivalent to 0.2 porosity times rough average 8.5-ft seasonal water table fluctuation.
Cap (cleanup time below seasonal high water table)	1.70	ft per year	Based on rough average 9-ft seasonal water table fluctuation at MW02 and MW25 and on assumed porosity of 0.2. Assumed to apply only to depths greater than 2 feet bgs.
Remove debris (cleanup time in remaining debris and soils)	1.70	ft per year	Same as existing conditions because ground cover will be the same.
Depth to seasonal high water table	2.00	ft	Seasonal high water table depth (below ground surface) at well MW02-12 during period 1994-1998. (This depth occurred in 1997.)
Geotechnical Characteristics			
Debris dry bulk density	100	lbs/cubic ft	Assume same as sand.
Debris dry bulk density	1.61	g/cm3	Unit conversion from lbs/ft^3
Surficial sand unit dry bulk density	100	lbs/cubic ft	Sand unit average sitewide. Dry density in sample SY-SB10-005 before falling head (fixed wall) permeability test was 108.5 lbs/ft^3.
Surficial sand unit dry bulk density	1.61	g/cm3	Unit conversion from lbs/ft^3
Silt unit dry bulk density	80	lbs/cubic ft	Silt unit average sitewide. Dry density in sample SY-SB10-017 before triaxial (flexible wall) back-pressure permeability test was 81.6 lbs/ft^3.
Silt unit dry bulk density	1.28	g/cm3	Unit conversion from lbs/ft^3
Debris total porosity	0.3	vol/vol	Assumed same as underlying sand
Surficial sand total porosity	0.35	vol/vol	Sand unit average sitewide. Total porosity in sample SY-SB10-005 (after falling head fixed wall test) was .3079
Silt unit total porosity	0.5	vol/vol	Silt unit average sitewide. Total porosities in samples SY-SB10-017 and SY-SB11-005 (after falling head fixed wall test) were .5081 and .5491
Debris bulk density / porosity ratio	5.35	kg/L	Calculated from dry bulk density and porosity values above. Conversion factor from g/cc to kg/L is (1 g/cc) * (1 kg / 1000 g) * (1 cc / mL) * (1000 mL / L) = 1
Surficial sand bulk density / porosity ratio	4.59	kg/L	Calculated from dry bulk density and porosity values above. Conversion factor from g/cc to kg/L is (1 g/cc) * (1 kg / 1000 g) * (1 cc / mL) * (1000 mL / L) = 1
Silt unit bulk density / porosity ratio	2.57	kg/L	Calculated from dry bulk density and porosity values above. Conversion factor from g/cc to kg/L is (1 g/cc) * (1 kg / 1000 g) * (1 cc / mL) * (1000 mL / L) = 1
Scrapyard Geographical Characteristics and Fluoride Mass Distribution			
Total F mass in debris material	0	kg	Equals area * thickness * dry bulk density * (0.454 kg/lb) * concentration * (1 Kg / 1000000 mg).
Total F mass above background in surficial sand unit	3,950	kg	Equals area * thickness * dry bulk density * (0.454 kg/lb) * concentration * (1 Kg / 1000000 mg).
Total F mass above background in silt unit	155,268	kg	Equals area * thickness * dry bulk density * (0.454 kg/lb) * concentration * (1 Kg / 1000000 mg).
Average F concentration in debris	0	mg/kg	Debris was excavated as part of an early action at east potliner during 1995 and 1996.
Average F concentration in surficial sand (above background)	145	mg/kg	Column J of Table A-2. Includes samples at depth of 5 feet in soil borings SB10 and SB11.
Average F concentration in silt (above background)	950	mg/kg	Column J of Table A-2. Can also be calculated as (F mass/volume)*(1/dry bulk density)*(2.2 lbs/kg)*(10^6 mg/kg)
Background soil F conc	200	mg/kg	From Table 1 of *Technical Memorandum DS No. 12: Background Data Summary* (CH2M HILL, December 3, 1996).
EPL area	150,000	ft2	Column D of Table A-2.
Debris material thickness	0	ft	Column C of Table A-2.
Surficial sand thickness	4	ft	Column C of Table A-2.
Silt thickness	30	ft	Column C of Table A-2.
Debris thickness below seasonal high water table	0.00	ft	Debris thickness minus seasonal high water table measured near north-central portion of Scrap Yard (well MW02 in 1997).
Total F mass in debris below seasonal high water table	0.00	kg	Total debris mass under current conditions * debris thickness below seasonal high water table / current debris thickness.

Table A-8 (continued)
Input Parameters for Silt Unit Time-to-Compliance Calculations at East Potliner

Mass Removal At Solubility Limit			
Max F groundwater concentration	600	mg/L	Assumed value for the solubility for the debris in EPL. Equals highest measured groundwater concentration (at GP66).
Debris pore volume flushing time	0.00	years	Years to remove one pore volume (debris thickness * porosity * 1.3 / infiltration rate; [1.3 extra time factor accounts for dead-end pores])
Surficial sand unit pore volume flushing time	1.09	years	Years to remove one pore volume (Surficial sand unit thickness * porosity * 1.3 / infiltration rate; [1.3 extra time factor accounts for dead-end pores])
Silt unit pore volume flushing time	11.70	years	Years to remove one pore volume (silt thickness * porosity * 1.3 / infiltration rate; [1.3 extra time factor accounts for dead-end pores])
Maximum removable F mass in one debris pore volume	0	kg flushed per pore volume	max gw conc. * area * debris thickness * porosity * 28.32 L/ft^3 * 1 kg/10^6 mg (if no pores are dead-end)
Maximum removable F mass in one surficial sand pore volume	3,568	kg flushed per pore volume	max gw conc. * area * surficial sand unit thickness * porosity * 28.32 L/ft^3 * 1 kg/10^6 mg (if no pores are dead-end)
Maximum removable F mass in one silt pore volume	38,232	kg flushed per pore volume	max gw conc. * area * silt unit thickness * porosity * 28.32 L/ft^3 * 1 kg/10^6 mg (if no pores are dead-end)
Pore volume flushing time (debris below seasonal high WT)	0	years	Current debris pore flushing time * debris thickness below seasonal high water table / current debris thickness.
Max removable F mass (one debris pore volume below WT)	0	kg flushed per pore volume	Current kg debris flushed per pore volume * debris thickness below seasonal high water table / current debris thickness.
Langmuir Coefficients For Mass Removal Below Solubility Limit (Debris)			
Low Langmuir constant (K)	0.14	L/mg	For Hjelle soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with low K value (b)	1,025	mg/kg	For Hjelle soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Nominal Langmuir constant (K)	0.175	L/mg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with nominal K value (b)	1,900	mg/kg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
High Langmuir constant (K)	0.055	L/mg	For Ando soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with high K value (b)	5,510	mg/kg	For Ando soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Langmuir Coefficients For Mass Removal Below Solubility Limit (Surficial Sand)			
Low Langmuir constant (K)	0.044	L/mg	For Sagehill soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with low K value (b)	54	mg/kg	For Sagehill soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Nominal Langmuir constant (K)	0.07	L/mg	For Yolo soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with nominal K value (b)	172	mg/kg	For Yolo soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
High Langmuir constant (K)	0.175	L/mg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with high K value (b)	1,900	mg/kg	For Jory soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Langmuir Coefficients For Mass Removal Below Solubility Limit (Silt)			
Low Langmuir constant (K)	0.158	L/mg	For Nysse soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with low K value (b)	42	mg/kg	For Nysse soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Nominal Langmuir constant (K)	0.142	L/mg	For Hosmer soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with nominal K value (b)	200	mg/kg	For Hosmer soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
High Langmuir constant (K)	0.038	L/mg	For Cisne soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)
Adsorption capacity associated with high K value (b)	493	mg/kg	For Cisne soil described in Appendix G of the *Draft Groundwater Remedial Investigation Report* (June 1999)

Table A-9
Summary of Time to Compliance for Subsurface Materials Situated Above the UGS

	Debris (years)	Surficial Sand (years)	Silt (years)	Total (years)
Scrap Yard				
Base Case (Debris and soil 100% leachable)	900	900	200	2,000
East Potliner				
Base Case (Soil 100% leachable)	0 (debris removed)	50	450	500
South Landfill				
Base Case (Debris and soil 100% leachable, 0.16 ft/yr silt unit infiltration rate)	1,200	200	4,200	5,600
North Landfill				
Base Case (Debris and soil 100% leachable)	7,500	---	---	7,500
Company Lake				
Base Case (Process residue and sediment 100% leachable)	2,700	---	Negligible in underlying sediments	2,700

Note: All listed time-to-compliance values are derived using nominal values of the Langmuir coefficients (which describe desorption of fluoride from debris and soils in each soil and debris area).

Table A-10
Summary of Sensitivity Analysis of Time to Compliance to Leachable Fraction

	Debris (years)	Surficial Sand (years)	Silt (years)	Total (years)
Scrap Yard				
Base Case (Debris and soil 100% leachable)	900	900	200	2,000
Sensitivity Run (Debris and surficial sand 20% leachable, silt 100% leachable)	350	200	200	750
East Potliner				
Base Case (Soil 100% leachable)	0 (debris removed)	50	450	500
Base Case (Surficial sand 20% leachable, silt 100% leachable)	0 (debris removed)	35	285	320
South Landfill				
Base Case (Debris and soil 100% leachable, 0.16 ft/yr silt unit infiltration rate)	1,300	200	4,200	5,700
Sensitivity Run (Debris.20% leachable, soil 100% leachable, 0.16 ft/yr silt unit infiltration rate)	600	200	4,200	5,000
North Landfill				
Base Case (Debris and soil 100% leachable)	7,500	---	---	7,500
Sensitivity Run (Debris 20% leachable, soil 100% leachable)	1,600	---	---	1,600
Company Lake				
Base Case (Process residue and soil 100% leachable)	2,700	---	Negligible in underlying sediments	2,700
Sensitivity Run (Process residue 20% leachable, soil 100% leachable)	600	---	Negligible in underlying sediments	600

Note: All listed time-to-compliance values are derived using nominal values of the Langmuir coefficients (which describe desorption of fluoride from debris and soils in each soil and debris area).

Table A-11
Summary of Sensitivity Analysis of Time to Compliance to the Langmuir Coefficients

	Debris (years)	Surficial Sand (years)	Silt (years)	Total (years)
Scrap Yard				
Sensitivity Run (Low Coefficients)	830	860	75	1,765
Base Case (Nominal Coefficients)	900	900	200	2,000
Sensitivity Run (High Coefficients)	1,250	1,400	0	2,650
East Potliner				
Sensitivity Run (Low Coefficients)	0	10	100	110
Base Case (Nominal Coefficients)	0	50	450	500
Sensitivity Run (High Coefficients)	0	390	480	870
South Landfill				
Sensitivity Run (Low Coefficients)	1,100	200	2,200	3,500
Base Case (Nominal Coefficients)	1,300	200	4,200	5,700
Sensitivity Run (High Coefficients)	1,900	200	5,300	7,400
North Landfill				
Sensitivity Run (Low Coefficients)	7,700	---	---	7,700
Base Case (Nominal Coefficients)	7,500	---	---	7,500
Sensitivity Run (High Coefficients)	7,900	---	---	7,900
Company Lake				
Sensitivity Run (Low Coefficients)	2,800	---	Negligible in underlying sediments	2,800
Base Case (Nominal Coefficients)	2,700	---	Negligible in underlying sediments	2,700
Sensitivity Run (High Coefficients)	2,700	---	Negligible in underlying sediments	2,700

Note: All listed time-to-compliance values are derived using 100 percent leachable fraction for fluoride in all debris and soil horizons.

Table A-12
Summary of Results for Silt Unit Time-to-Compliance Calculations at North Landfill

No Action (Results Correspond also to Options NLF-1 and NLF-2 and Alternatives A and B)

Low Adsorption Capacity (b)		Nominal Adsorption Capacity (b)		High Adsorption Capacity (b)	
Debris above WT time to drop below solubility (years)	1,245	Debris above WT time to drop below solubility (years)	1,045	Debris above WT time to drop below solubility (years)	732
Debris above WT time to drop below MCL (years)	182	Debris above WT time to drop below MCL (years)	337	Debris above WT time to drop below MCL (years)	768
Total time in debris above WT (years)	1,427 <--- Subtotal	Total time in debris above WT (years)	1,382 <--- Subtotal	Total time in debris above WT (years)	1,500 <--- Subtotal
Debris below WT time to drop below solubility (years)	5,537	Debris below WT time to drop below solubility (years)	4,648	Debris below WT time to drop below solubility (years)	3,259
Debris below WT time to drop below MCL (years)	740	Debris below WT time to drop below MCL (years)	1,296	Debris below WT time to drop below MCL (years)	3,071
Total time in debris below WT (years)	6,277 <--- Subtotal	Total time in debris below WT (years)	5,944 <--- Subtotal	Total time in debris below WT (years)	6,330 <--- Subtotal
Groundwater transport time for last pore vol	12 <--- Subtotal	Groundwater transport time for last pore vol	12 <--- Subtotal	Groundwater transport time for last pore vol	12 <--- Subtotal
Total time to drop below MCL (years)	**7,716 <--- Total**	**Total time to drop below MCL (years)**	**7,338 <--- Total**	**Total time to drop below MCL (years)**	**7,842 <--- Total**

Multilayer Low Permeability Cap With Rip Rap Cover (Option NLF-3)

Low Adsorption Capacity (b)		Nominal Adsorption Capacity (b)		High Adsorption Capacity (b)	
Debris above WT time to drop below solubility (years)	0	Debris above WT time to drop below solubility (years)	0	Debris above WT time to drop below solubility (years)	0
Debris above WT time to drop below MCL (years)	0	Debris above WT time to drop below MCL (years)	0	Debris above WT time to drop below MCL (years)	0
Total time in debris above WT (years)	0 <--- Subtotal	Total time in debris above WT (years)	0 <--- Subtotal	Total time in debris above WT (years)	0 <--- Subtotal
Debris below WT time to drop below solubility (years)	5,537	Debris below WT time to drop below solubility (years)	4,648	Debris below WT time to drop below solubility (years)	3,259
Debris below WT time to drop below MCL (years)	740	Debris below WT time to drop below MCL (years)	1,296	Debris below WT time to drop below MCL (years)	3,071
Total time in debris below WT (years)	6,277 <--- Subtotal	Total time in debris below WT (years)	5,944 <--- Subtotal	Total time in debris below WT (years)	6,330 <--- Subtotal
Groundwater transport time for last pore vol	12 <--- Subtotal	Groundwater transport time for last pore vol	12 <--- Subtotal	Groundwater transport time for last pore vol	12 <--- Subtotal
Total time to drop below MCL (years)	**6,289 <--- Total**	**Total time to drop below MCL (years)**	**5,956 <--- Total**	**Total time to drop below MCL (years)**	**6,342 <--- Total**

Excavation of Waste Layer (Option NLF-4 and Alternative C)

Low Adsorption Capacity (b)		Nominal Adsorption Capacity (b)		High Adsorption Capacity (b)	
Debris above WT time to drop below solubility (years)	0	Debris above WT time to drop below solubility (years)	0	Debris above WT time to drop below solubility (years)	0
Debris above WT time to drop below MCL (years)	0	Debris above WT time to drop below MCL (years)	0	Debris above WT time to drop below MCL (years)	0
Total time in debris above WT (years)	0 <--- Subtotal	Total time in debris above WT (years)	0 <--- Subtotal	Total time in debris above WT (years)	0 <--- Subtotal
Debris below WT time to drop below solubility (years)	0	Debris below WT time to drop below solubility (years)	0	Debris below WT time to drop below solubility (years)	0
Debris below WT time to drop below MCL (years)	0	Debris below WT time to drop below MCL (years)	0	Debris below WT time to drop below MCL (years)	0
Total time in debris below WT (years)	0 <--- Subtotal	Total time in debris below WT (years)	0 <--- Subtotal	Total time in debris below WT (years)	0 <--- Subtotal
Groundwater transport time for last pore vol	12 <--- Subtotal	Groundwater transport time for last pore vol	12 <--- Subtotal	Groundwater transport time for last pore vol	12 <--- Subtotal
Total time to drop below MCL (years)	**12 <--- Total**	**Total time to drop below MCL (years)**	**12 <--- Total**	**Total time to drop below MCL (years)**	**12 <--- Total**

Table A-12 (continued)
Summary of Results for Silt Unit Time-to-Compliance Calculations at North Landfill

Relative Improvement (Multilayer Low Permeability Cap Compared With No Action)

Low Adsorption Capacity (b)

Debris above WT time to drop below solubility (years)	100%
Debris above WT time to drop below MCL (years)	100%
Total time in debris above WT (years)	100% <--- Subtotal
Debris below WT time to drop below solubility (years)	0%
Debris below WT time to drop below MCL (years)	0%
Total time in debris below WT (years)	0% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**18% <--- Total**

Nominal Adsorption Capacity (b)

Debris above WT time to drop below solubility (years)	100%
Debris above WT time to drop below MCL (years)	100%
Total time in debris above WT (years)	100% <--- Subtotal
Debris below WT time to drop below solubility (years)	0%
Debris below WT time to drop below MCL (years)	0%
Total time in debris below WT (years)	0% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**19% <--- Total**

High Adsorption Capacity (b)

Debris above WT time to drop below solubility (years)	100%
Debris above WT time to drop below MCL (years)	100%
Total time in debris above WT (years)	100% <--- Subtotal
Debris below WT time to drop below solubility (years)	0%
Debris below WT time to drop below MCL (years)	0%
Total time in debris below WT (years)	0% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**19% <--- Total**

Relative Improvement (Excavation of Waste Layer Compared With No Action)

Low Adsorption Capacity (b)

Debris above WT time to drop below solubility (years)	100%
Debris above WT time to drop below MCL (years)	100%
Total time in debris above WT (years)	100% <--- Subtotal
Debris below WT time to drop below solubility (years)	100%
Debris below WT time to drop below MCL (years)	100%
Total time in debris below WT (years)	100% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**99.8% <--- Total**

Nominal Adsorption Capacity (b)

Debris above WT time to drop below solubility (years)	100%
Debris above WT time to drop below MCL (years)	100%
Total time in debris above WT (years)	100% <--- Subtotal
Debris below WT time to drop below solubility (years)	100%
Debris below WT time to drop below MCL (years)	100%
Total time in debris below WT (years)	100% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**99.8% <--- Total**

High Adsorption Capacity (b)

Debris above WT time to drop below solubility (years)	100%
Debris above WT time to drop below MCL (years)	100%
Total time in debris above WT (years)	100% <--- Subtotal
Debris below WT time to drop below solubility (years)	100%
Debris below WT time to drop below MCL (years)	100%
Total time in debris below WT (years)	100% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**99.8% <--- Total**

Relative Improvement (Excavation of Waste Layer Compared With Multilayer Low Permeability Cap)

Low Adsorption Capacity (b)

Debris above WT time to drop below solubility (years)	---
Debris above WT time to drop below MCL (years)	---
Total time in debris above WT (years)	--- <--- Subtotal
Debris below WT time to drop below solubility (years)	100%
Debris below WT time to drop below MCL (years)	100%
Total time in debris below WT (years)	100% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**99.8% <--- Total**

Nominal Adsorption Capacity (b)

Debris above WT time to drop below solubility (years)	---
Debris above WT time to drop below MCL (years)	---
Total time in debris above WT (years)	--- <--- Subtotal
Debris below WT time to drop below solubility (years)	100%
Debris below WT time to drop below MCL (years)	100%
Total time in debris below WT (years)	100% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**99.8% <--- Total**

High Adsorption Capacity (b)

Debris above WT time to drop below solubility (years)	---
Debris above WT time to drop below MCL (years)	---
Total time in debris above WT (years)	--- <--- Subtotal
Debris below WT time to drop below solubility (years)	100%
Debris below WT time to drop below MCL (years)	100%
Total time in debris below WT (years)	100% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**99.8% <--- Total**

Table A-13
Summary of Results for Silt Unit Time-to-Compliance Calculations at South Landfill

No Action (Results Correspond also to Options SLF-1 and SLF-2 and to Alternatives A and B)

Low Adsorption Capacity (b)		Nominal Adsorption Capacity (b)		High Adsorption Capacity (b)	
Debris time to drop below solubility (years)	803	Debris time to drop below solubility (years)	746	Debris time to drop below solubility (years)	560
Debris time to drop below MCL (years)	280	Debris time to drop below MCL (years)	505	Debris time to drop below MCL (years)	1,308
Total time to compliance in debris (years)	1,083 <--- Subtotal	Total time to compliance in debris (years)	1,251 <--- Subtotal	Total time to compliance in debris (years)	1,868 <--- Subtotal
Sand time to drop below solubility (years)	121	Sand time to drop below solubility (years)	105	Sand time to drop below solubility (years)	86
Sand time to drop below MCL (years)	53	Sand time to drop below MCL (years)	100	Sand time to drop below MCL (years)	138
Total time to compliance in sand (years)	174 <--- Subtotal	Total time to compliance in sand (years)	205 <--- Subtotal	Total time to compliance in sand (years)	224 <--- Subtotal
Silt time to drop below solubility (years)	55	Silt time to drop below solubility (years)	7	Silt time to drop below solubility (years)	0
Silt time to drop below MCL (years)	2,133	Silt time to drop below MCL (years)	4,164	Silt time to drop below MCL (years)	5,281
Total time to compliance in silt (years)	2,188 <--- Subtotal	Total time to compliance in silt (years)	4,171 <--- Subtotal	Total time to compliance in silt (years)	5,281 <--- Subtotal
Total time to drop below MCL (years)	**3,445 <--- Total**	**Total time to drop below MCL (years)**	**5,627 <--- Total**	**Total time to drop below MCL (years)**	**7,373 <--- Total**

Multilayer Low Permeability Cap (Option SLF-3)

Low Adsorption Capacity (b)		Nominal Adsorption Capacity (b)		High Adsorption Capacity (b)	
Debris time to drop below solubility (years)	771	Debris time to drop below solubility (years)	716	Debris time to drop below solubility (years)	538
Debris time to drop below MCL (years)	268	Debris time to drop below MCL (years)	485	Debris time to drop below MCL (years)	1,256
Total time to compliance in debris (years)	1,039 <--- Subtotal	Total time to compliance in debris (years)	1,201 <--- Subtotal	Total time to compliance in debris (years)	1,794 <--- Subtotal
Sand time to drop below solubility (years)	121	Sand time to drop below solubility (years)	105	Sand time to drop below solubility (years)	86
Sand time to drop below MCL (years)	53	Sand time to drop below MCL (years)	100	Sand time to drop below MCL (years)	138
Total time to compliance in sand (years)	174 <--- Subtotal	Total time to compliance in sand (years)	205 <--- Subtotal	Total time to compliance in sand (years)	224 <--- Subtotal
Silt time to drop below solubility (years)	55	Silt time to drop below solubility (years)	7	Silt time to drop below solubility (years)	0
Silt time to drop below MCL (years)	2,133	Silt time to drop below MCL (years)	4,164	Silt time to drop below MCL (years)	5,281
Total time to compliance in silt (years)	2,188 <--- Subtotal	Total time to compliance in silt (years)	4,171 <--- Subtotal	Total time to compliance in silt (years)	5,281 <--- Subtotal
Total time to drop below MCL (years)	**3,401 <--- Total**	**Total time to drop below MCL (years)**	**5,577 <--- Total**	**Total time to drop below MCL (years)**	**7,299 <--- Total**

Excavation of Waste Layer (Option SLF-4 and Alternative C)

Low Adsorption Capacity (b)		Nominal Adsorption Capacity (b)		High Adsorption Capacity (b)	
Debris time to drop below solubility (years)	0	Debris time to drop below solubility (years)	0	Debris time to drop below solubility (years)	0
Debris time to drop below MCL (years)	0	Debris time to drop below MCL (years)	0	Debris time to drop below MCL (years)	0
Total time to compliance in debris (years)	0 <--- Subtotal	Total time to compliance in debris (years)	0 <--- Subtotal	Total time to compliance in debris (years)	0 <--- Subtotal
Sand time to drop below solubility (years)	121	Sand time to drop below solubility (years)	105	Sand time to drop below solubility (years)	86
Sand time to drop below MCL (years)	53	Sand time to drop below MCL (years)	100	Sand time to drop below MCL (years)	138
Total time to compliance in sand (years)	174 <--- Subtotal	Total time to compliance in sand (years)	205 <--- Subtotal	Total time to compliance in sand (years)	224 <--- Subtotal
Silt time to drop below solubility (years)	55	Silt time to drop below solubility (years)	7	Silt time to drop below solubility (years)	0
Silt time to drop below MCL (years)	2,133	Silt time to drop below MCL (years)	4,164	Silt time to drop below MCL (years)	5,281
Total time to compliance in silt (years)	2,188 <--- Subtotal	Total time to compliance in silt (years)	4,171 <--- Subtotal	Total time to compliance in silt (years)	5,281 <--- Subtotal
Total time to drop below MCL (years)	**2,362 <--- Total**	**Total time to drop below MCL (years)**	**4,376 <--- Total**	**Total time to drop below MCL (years)**	**5,505 <--- Total**

Table A-13 (continued)
Summary of Results for Silt Unit Time-to-Compliance Calculations at South Landfill

Excavation of Waste Layer and Surficial Sand (Option SLF-5)

Low Adsorption Capacity (b)

Debris time to drop below solubility (years)	0
Debris time to drop below MCL (years)	0
Total time to compliance in debris (years)	0 <--- Subtotal
Sand time to drop below solubility (years)	91
Sand time to drop below MCL (years)	40
Total time to compliance in sand (years)	131 <--- Subtotal
Silt time to drop below solubility (years)	55
Silt time to drop below MCL (years)	2,133
Total time to compliance in silt (years)	2,188 <--- Subtotal
Total time to drop below MCL (years)	**2,319 <--- Total**

Nominal Adsorption Capacity (b)

Debris time to drop below solubility (years)	0
Debris time to drop below MCL (years)	0
Total time to compliance in debris (years)	0 <--- Subtotal
Sand time to drop below solubility (years)	79
Sand time to drop below MCL (years)	75
Total time to compliance in sand (years)	154 <--- Subtotal
Silt time to drop below solubility (years)	7
Silt time to drop below MCL (years)	4,164
Total time to compliance in silt (years)	4,171 <--- Subtotal
Total time to drop below MCL (years)	**4,325 <--- Total**

High Adsorption Capacity (b)

Debris time to drop below solubility (years)	0
Debris time to drop below MCL (years)	0
Total time to compliance in debris (years)	0 <--- Subtotal
Sand time to drop below solubility (years)	65
Sand time to drop below MCL (years)	104
Total time to compliance in sand (years)	169 <--- Subtotal
Silt time to drop below solubility (years)	0
Silt time to drop below MCL (years)	5,281
Total time to compliance in silt (years)	5,281 <--- Subtotal
Total time to drop below MCL (years)	**5,450 <--- Total**

Relative Improvement (Multilayer Low Permeability Cap Compared With No Action)

Low Adsorption Capacity (b)

Debris time to drop below solubility (years)	4%
Debris time to drop below MCL (years)	4%
Total time to compliance in debris (years)	4% <--- Subtotal
Sand time to drop below solubility (years)	0%
Sand time to drop below MCL (years)	0%
Total time to compliance in sand (years)	0% <--- Subtotal
Silt time to drop below solubility (years)	0%
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**1% <--- Total**

Nominal Adsorption Capacity (b)

Debris time to drop below solubility (years)	4%
Debris time to drop below MCL (years)	4%
Total time to compliance in debris (years)	4% <--- Subtotal
Sand time to drop below solubility (years)	0%
Sand time to drop below MCL (years)	0%
Total time to compliance in sand (years)	0% <--- Subtotal
Silt time to drop below solubility (years)	0%
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**1% <--- Total**

High Adsorption Capacity (b)

Debris time to drop below solubility (years)	4%
Debris time to drop below MCL (years)	4%
Total time to compliance in debris (years)	4% <--- Subtotal
Sand time to drop below solubility (years)	0%
Sand time to drop below MCL (years)	0%
Total time to compliance in sand (years)	0% <--- Subtotal
Silt time to drop below solubility (years)	---
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**1% <--- Total**

Relative Improvement (Excavation of Waste Layer Compared With No Action)

Low Adsorption Capacity (b)

Debris time to drop below solubility (years)	100%
Debris time to drop below MCL (years)	100%
Total time to compliance in debris (years)	100% <--- Subtotal
Sand time to drop below solubility (years)	0%
Sand time to drop below MCL (years)	0%
Total time to compliance in sand (years)	0% <--- Subtotal
Silt time to drop below solubility (years)	0%
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**31% <--- Total**

Nominal Adsorption Capacity (b)

Debris time to drop below solubility (years)	100%
Debris time to drop below MCL (years)	100%
Total time to compliance in debris (years)	100% <--- Subtotal
Sand time to drop below solubility (years)	0%
Sand time to drop below MCL (years)	0%
Total time to compliance in sand (years)	0% <--- Subtotal
Silt time to drop below solubility (years)	0%
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**22% <--- Total**

High Adsorption Capacity (b)

Debris time to drop below solubility (years)	100%
Debris time to drop below MCL (years)	100%
Total time to compliance in debris (years)	100% <--- Subtotal
Sand time to drop below solubility (years)	0%
Sand time to drop below MCL (years)	0%
Total time to compliance in sand (years)	0% <--- Subtotal
Silt time to drop below solubility (years)	---
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**25% <--- Total**

Table A-13 (continued)

Summary of Results for Silt Unit Time-to-Compliance Calculations at South Landfill

Relative Improvement (Excavation of Waste Layer and Surficial Sand Compared With No Action)

Low Adsorption Capacity (b)

Debris time to drop below solubility (years)	100%
Debris time to drop below MCL (years)	100%
Total time to compliance in debris (years)	100% <--- Subtotal
Sand time to drop below solubility (years)	25%
Sand time to drop below MCL (years)	25%
Total time to compliance in sand (years)	25% <--- Subtotal
Silt time to drop below solubility (years)	0%
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**33% <--- Total**

Nominal Adsorption Capacity (b)

Debris time to drop below solubility (years)	100%
Debris time to drop below MCL (years)	100%
Total time to compliance in debris (years)	100% <--- Subtotal
Sand time to drop below solubility (years)	25%
Sand time to drop below MCL (years)	25%
Total time to compliance in sand (years)	25% <--- Subtotal
Silt time to drop below solubility (years)	0%
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**23% <--- Total**

High Adsorption Capacity (b)

Debris time to drop below solubility (years)	100%
Debris time to drop below MCL (years)	100%
Total time to compliance in debris (years)	100% <--- Subtotal
Sand time to drop below solubility (years)	24%
Sand time to drop below MCL (years)	25%
Total time to compliance in sand (years)	25% <--- Subtotal
Silt time to drop below solubility (years)	#DIV/0!
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**26% <--- Total**

Table A-14
Summary of Results for Silt Unit Time-to-Compliance Calculations at Scrap Yard

No Action (Results Correspond also to Options SY-1, SY-2, and Alternative A)

Low Adsorption Capacity (b)		Nominal Adsorption Capacity (b)		High Adsorption Capacity (b)	
Debris time to drop below solubility (years)	697	Debris time to drop below solubility (years)	677	Debris time to drop below solubility (years)	611
Debris time to drop below MCL (years)	135	Debris time to drop below MCL (years)	241	Debris time to drop below MCL (years)	637
Total time to compliance in debris (years)	832 <--- Subtotal	Total time to compliance in debris (years)	918 <--- Subtotal	Total time to compliance in debris (years)	1,248 <--- Subtotal
Sand time to drop below solubility (years)	842	Sand time to drop below solubility (years)	833	Sand time to drop below solubility (years)	702
Sand time to drop below MCL (years)	19	Sand time to drop below MCL (years)	60	Sand time to drop below MCL (years)	678
Total time to compliance in sand (years)	861 <--- Subtotal	Total time to compliance in sand (years)	893 <--- Subtotal	Total time to compliance in sand (years)	1,380 <--- Subtotal
Silt time to drop below solubility (years)	53	Silt time to drop below solubility (years)	20	Silt time to drop below solubility (years)	0
Silt time to drop below MCL (years)	22	Silt time to drop below MCL (years)	173	Silt time to drop below MCL (years)	0
Total time to compliance in silt (years)	75 <--- Subtotal	Total time to compliance in silt (years)	193 <--- Subtotal	Total time to compliance in silt (years)	0 <--- Subtotal
Total time to drop below MCL (years)	**1,768 <--- Total**	**Total time to drop below MCL (years)**	**2,004 <--- Total**	**Total time to drop below MCL (years)**	**2,628 <--- Total**

Excavation of Waste Layer in North Area (Option SY-3 and Alternatives B and C)

Low Adsorption Capacity (b)		Nominal Adsorption Capacity (b)		High Adsorption Capacity (b)	
Debris time to drop below solubility (years)	0	Debris time to drop below solubility (years)	0	Debris time to drop below solubility (years)	0
Debris time to drop below MCL (years)	0	Debris time to drop below MCL (years)	0	Debris time to drop below MCL (years)	0
Total time to compliance in debris (years)	0 <--- Subtotal	Total time to compliance in debris (years)	0 <--- Subtotal	Total time to compliance in debris (years)	0 <--- Subtotal
Sand time to drop below solubility (years)	842	Sand time to drop below solubility (years)	833	Sand time to drop below solubility (years)	702
Sand time to drop below MCL (years)	19	Sand time to drop below MCL (years)	60	Sand time to drop below MCL (years)	678
Total time to compliance in sand (years)	861 <--- Subtotal	Total time to compliance in sand (years)	893 <--- Subtotal	Total time to compliance in sand (years)	1,380 <--- Subtotal
Silt time to drop below solubility (years)	53	Silt time to drop below solubility (years)	20	Silt time to drop below solubility (years)	0
Silt time to drop below MCL (years)	22	Silt time to drop below MCL (years)	173	Silt time to drop below MCL (years)	0
Total time to compliance in silt (years)	75 <--- Subtotal	Total time to compliance in silt (years)	193 <--- Subtotal	Total time to compliance in silt (years)	0 <--- Subtotal
Total time to drop below MCL (years)	**936 <--- Total**	**Total time to drop below MCL (years)**	**1,086 <--- Total**	**Total time to drop below MCL (years)**	**1,380 <--- Total**

Excavation of Waste Layer and Surficial Sand in North and South Areas (Option SY-4)

Low Adsorption Capacity (b)		Nominal Adsorption Capacity (b)		High Adsorption Capacity (b)	
Debris time to drop below solubility (years)	0	Debris time to drop below solubility (years)	0	Debris time to drop below solubility (years)	0
Debris time to drop below MCL (years)	0	Debris time to drop below MCL (years)	0	Debris time to drop below MCL (years)	0
Total time to compliance in debris (years)	0 <--- Subtotal	Total time to compliance in debris (years)	0 <--- Subtotal	Total time to compliance in debris (years)	0 <--- Subtotal
Sand time to drop below solubility (years)	0	Sand time to drop below solubility (years)	0	Sand time to drop below solubility (years)	0
Sand time to drop below MCL (years)	0	Sand time to drop below MCL (years)	0	Sand time to drop below MCL (years)	0
Total time to compliance in sand (years)	0 <--- Subtotal	Total time to compliance in sand (years)	0 <--- Subtotal	Total time to compliance in sand (years)	0 <--- Subtotal
Silt time to drop below solubility (years)	53	Silt time to drop below solubility (years)	20	Silt time to drop below solubility (years)	0
Silt time to drop below MCL (years)	22	Silt time to drop below MCL (years)	173	Silt time to drop below MCL (years)	0
Total time to compliance in silt (years)	75 <--- Subtotal	Total time to compliance in silt (years)	193 <--- Subtotal	Total time to compliance in silt (years)	0 <--- Subtotal
Total time to drop below MCL (years)	**75 <--- Total**	**Total time to drop below MCL (years)**	**193 <--- Total**	**Total time to drop below MCL (years)**	**0 <--- Total**

Table A-14 (continued)
Summary of Results for Silt Unit Time-to-Compliance Calculations at Scrap Yard

Relative Improvement (Excavation of Waste Layer in North Area Compared With No Action)

Low Adsorption Capacity (b)

Debris time to drop below solubility (years)	100%
Debris time to drop below MCL (years)	100%
Total time to compliance in debris (years)	100% <--- Subtotal
Sand time to drop below solubility (years)	0%
Sand time to drop below MCL (years)	0%
Total time to compliance in sand (years)	0% <--- Subtotal
Silt time to drop below solubility (years)	0%
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**47% <--- Total**

Nominal Adsorption Capacity (b)

Debris time to drop below solubility (years)	100%
Debris time to drop below MCL (years)	100%
Total time to compliance in debris (years)	100% <--- Subtotal
Sand time to drop below solubility (years)	0%
Sand time to drop below MCL (years)	0%
Total time to compliance in sand (years)	0% <--- Subtotal
Silt time to drop below solubility (years)	0%
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**46% <--- Total**

High Adsorption Capacity (b)

Debris time to drop below solubility (years)	100%
Debris time to drop below MCL (years)	100%
Total time to compliance in debris (years)	100% <--- Subtotal
Sand time to drop below solubility (years)	0%
Sand time to drop below MCL (years)	0%
Total time to compliance in sand (years)	0% <--- Subtotal
Silt time to drop below solubility (years)	---
Silt time to drop below MCL (years)	---
Total time to compliance in silt (years)	--- <--- Subtotal
Total time to drop below MCL (years)	**47% <--- Total**

Relative Improvement (Excavation of Waste Layer and Surficial Sand in North and South Areas Compared With No Action)

Low Adsorption Capacity (b)

Debris time to drop below solubility (years)	100%
Debris time to drop below MCL (years)	100%
Total time to compliance in debris (years)	100% <--- Subtotal
Sand time to drop below solubility (years)	100%
Sand time to drop below MCL (years)	100%
Total time to compliance in sand (years)	100% <--- Subtotal
Silt time to drop below solubility (years)	0%
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**96% <--- Total**

Nominal Adsorption Capacity (b)

Debris time to drop below solubility (years)	100%
Debris time to drop below MCL (years)	100%
Total time to compliance in debris (years)	100% <--- Subtotal
Sand time to drop below solubility (years)	100%
Sand time to drop below MCL (years)	100%
Total time to compliance in sand (years)	100% <--- Subtotal
Silt time to drop below solubility (years)	0%
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**90% <--- Total**

High Adsorption Capacity (b)

Debris time to drop below solubility (years)	100%
Debris time to drop below MCL (years)	100%
Total time to compliance in debris (years)	100% <--- Subtotal
Sand time to drop below solubility (years)	100%
Sand time to drop below MCL (years)	100%
Total time to compliance in sand (years)	100% <--- Subtotal
Silt time to drop below solubility (years)	---
Silt time to drop below MCL (years)	---
Total time to compliance in silt (years)	--- <--- Subtotal
Total time to drop below MCL (years)	**100% <--- Total**

Relative Improvement (Excavation of Waste Layer and Surficial Sand in North and South Areas Compared With Excavation of Waste Layer in North Area)

Low Adsorption Capacity (b)

Debris time to drop below solubility (years)	---
Debris time to drop below MCL (years)	---
Total time to compliance in debris (years)	--- <--- Subtotal
Sand time to drop below solubility (years)	100%
Sand time to drop below MCL (years)	100%
Total time to compliance in sand (years)	100% <--- Subtotal
Silt time to drop below solubility (years)	0%
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**92% <--- Total**

Nominal Adsorption Capacity (b)

Debris time to drop below solubility (years)	---
Debris time to drop below MCL (years)	---
Total time to compliance in debris (years)	--- <--- Subtotal
Sand time to drop below solubility (years)	100%
Sand time to drop below MCL (years)	100%
Total time to compliance in sand (years)	100% <--- Subtotal
Silt time to drop below solubility (years)	0%
Silt time to drop below MCL (years)	0%
Total time to compliance in silt (years)	0% <--- Subtotal
Total time to drop below MCL (years)	**82% <--- Total**

High Adsorption Capacity (b)

Debris time to drop below solubility (years)	---
Debris time to drop below MCL (years)	---
Total time to compliance in debris (years)	--- <--- Subtotal
Sand time to drop below solubility (years)	100%
Sand time to drop below MCL (years)	100%
Total time to compliance in sand (years)	100% <--- Subtotal
Silt time to drop below solubility (years)	---
Silt time to drop below MCL (years)	---
Total time to compliance in silt (years)	--- <--- Subtotal
Total time to drop below MCL (years)	**100% <--- Total**

Table A-15

Summary of Results for Silt Unit Time-to-Compliance Calculations at Company Lake

No Action (Results Correspond also to Option CL-1)

Low Adsorption Capacity (b)		Nominal Adsorption Capacity (b)		High Adsorption Capacity (b)	
PR time to drop below solubility (years)	2,527	PR time to drop below solubility (years)	2,442	PR time to drop below solubility (years)	2,257
PR time to drop below MCL (years)	135	PR time to drop below MCL (years)	232	PR time to drop below MCL (years)	419
Total time in PR (years)	2,662 <--- Subtotal	Total time in PR (years)	2,674 <--- Subtotal	Total time in PR (years)	2,676 <--- Subtotal
Sediments time to drop below solubility (years)	0	Sediments time to drop below solubility (years)	0	Sediments time to drop below solubility (years)	0
Sediments time to drop below MCL (years)	103	Sediments time to drop below MCL (years)	0	Sediments time to drop below MCL (years)	0
Total time in sediments (years)	103 <--- Subtotal	Total time in sediments (years)	0 <--- Subtotal	Total time in sediments (years)	0 <--- Subtotal
Groundwater transport time for last pore vol	20 <--- Subtotal	Groundwater transport time for last pore vol	20 <--- Subtotal	Groundwater transport time for last pore vol	20 <--- Subtotal
Total time to drop below MCL (years)	**2,785 <--- Total**	**Total time to drop below MCL (years)**	**2,694 <--- Total**	**Total time to drop below MCL (years)**	**2,696 <--- Total**

Permeable Cap Over Process Residue (Option CL-2 and Alternative A)

Low Adsorption Capacity (b)		Nominal Adsorption Capacity (b)		High Adsorption Capacity (b)	
PR time to drop below solubility (years)	2,527	PR time to drop below solubility (years)	2,442	PR time to drop below solubility (years)	2,257
PR time to drop below MCL (years)	135	PR time to drop below MCL (years)	232	PR time to drop below MCL (years)	419
Total time in PR (years)	2,662 <--- Subtotal	Total time in PR (years)	2,674 <--- Subtotal	Total time in PR (years)	2,676 <--- Subtotal
Sediments time to drop below solubility (years)	0	Sediments time to drop below solubility (years)	0	Sediments time to drop below solubility (years)	0
Sediments time to drop below MCL (years)	103	Sediments time to drop below MCL (years)	0	Sediments time to drop below MCL (years)	0
Total time in sediments (years)	103 <--- Subtotal	Total time in sediments (years)	0 <--- Subtotal	Total time in sediments (years)	0 <--- Subtotal
Groundwater transport time for last pore vol	20 <--- Subtotal	Groundwater transport time for last pore vol	20 <--- Subtotal	Groundwater transport time for last pore vol	20 <--- Subtotal
Total time to drop below MCL (years)	**2,785 <--- Total**	**Total time to drop below MCL (years)**	**2,694 <--- Total**	**Total time to drop below MCL (years)**	**2,696 <--- Total**

Dredging Process Residue (Option CL-3 and Alternatives B and C)

Low Adsorption Capacity (b)		Nominal Adsorption Capacity (b)		High Adsorption Capacity (b)	
PR time to drop below solubility (years)	0	PR time to drop below solubility (years)	0	PR time to drop below solubility (years)	0
PR time to drop below MCL (years)	0	PR time to drop below MCL (years)	0	PR time to drop below MCL (years)	0
Total time in PR (years)	0 <--- Subtotal	Total time in PR (years)	0 <--- Subtotal	Total time in PR (years)	0 <--- Subtotal
Sediments time to drop below solubility (years)	0	Sediments time to drop below solubility (years)	0	Sediments time to drop below solubility (years)	0
Sediments time to drop below MCL (years)	0	Sediments time to drop below MCL (years)	0	Sediments time to drop below MCL (years)	0
Total time in sediments (years)	0 <--- Subtotal	Total time in sediments (years)	0 <--- Subtotal	Total time in sediments (years)	0 <--- Subtotal
Groundwater transport time for last pore vol	20 <--- Subtotal	Groundwater transport time for last pore vol	20 <--- Subtotal	Groundwater transport time for last pore vol	20 <--- Subtotal
Total time to drop below MCL (years)	**20 <--- Total**	**Total time to drop below MCL (years)**	**20 <--- Total**	**Total time to drop below MCL (years)**	**20 <--- Total**

Table A-15 (continued)

Summary of Results for Silt Unit Time-to-Compliance Calculations at Company Lake

Relative Improvement (Permeable Cap Over Process Residue Compared with No Action)

Low Adsorption Capacity (b)

PR time to drop below solubility (years)	0%
PR time to drop below MCL (years)	0%
Total time in PR (years)	0% <--- Subtotal
Sediments time to drop below solubility (years)	0%
Sediments time to drop below MCL (years)	0%
Total time in sediments (years)	0% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**0% <--- Total**

Nominal Adsorption Capacity (b)

PR time to drop below solubility (years)	0%
PR time to drop below MCL (years)	0%
Total time in PR (years)	0% <--- Subtotal
Sediments time to drop below solubility (years)	0%
Sediments time to drop below MCL (years)	---
Total time in sediments (years)	0% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**0% <--- Total**

High Adsorption Capacity (b)

PR time to drop below solubility (years)	0%
PR time to drop below MCL (years)	0%
Total time in PR (years)	0% <--- Subtotal
Sediments time to drop below solubility (years)	0%
Sediments time to drop below MCL (years)	---
Total time in sediments (years)	0% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**0% <--- Total**

Relative Improvement (Dredging Process Residue Compared With No Action)

Low Adsorption Capacity (b)

PR time to drop below solubility (years)	100%
PR time to drop below MCL (years)	100%
Total time in PR (years)	100% <--- Subtotal
Sediments time to drop below solubility (years)	0%
Sediments time to drop below MCL (years)	100%
Total time in sediments (years)	100% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**99.3% <--- Total**

Nominal Adsorption Capacity (b)

PR time to drop below solubility (years)	100%
PR time to drop below MCL (years)	100%
Total time in PR (years)	100% <--- Subtotal
Sediments time to drop below solubility (years)	0%
Sediments time to drop below MCL (years)	---
Total time in sediments (years)	0% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**99.3% <--- Total**

High Adsorption Capacity (b)

PR time to drop below solubility (years)	100%
PR time to drop below MCL (years)	100%
Total time in PR (years)	100% <--- Subtotal
Sediments time to drop below solubility (years)	0%
Sediments time to drop below MCL (years)	---
Total time in sediments (years)	0% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**99.3% <--- Total**

Relative Improvement (Dredging Process Residue Compared With Permeable Cap Over Process Residue)

Low Adsorption Capacity (b)

PR time to drop below solubility (years)	---
PR time to drop below MCL (years)	---
Total time in PR (years)	--- <--- Subtotal
Sediments time to drop below solubility (years)	---
Sediments time to drop below MCL (years)	100%
Total time in sediments (years)	100% <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**99.3% <--- Total**

Nominal Adsorption Capacity (b)

PR time to drop below solubility (years)	---
PR time to drop below MCL (years)	---
Total time in PR (years)	--- <--- Subtotal
Sediments time to drop below solubility (years)	---
Sediments time to drop below MCL (years)	---
Total time in sediments (years)	--- <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**99.3% <--- Total**

High Adsorption Capacity (b)

PR time to drop below solubility (years)	---
PR time to drop below MCL (years)	---
Total time in PR (years)	--- <--- Subtotal
Sediments time to drop below solubility (years)	---
Sediments time to drop below MCL (years)	---
Total time in sediments (years)	--- <--- Subtotal
Groundwater transport time for last pore vol	0% <--- Subtotal
Total time to drop below MCL (years)	**99.3% <--- Total**

Appendix A Figures

Figure A-1
Layer Conceptualization for Site-Scale Groundwater Flow Model
Reynolds Metals Company (Troutdale, Oregon)

Layer	Surface Water	Production Wells	Monitoring Wells	Elevation (feet NGVD)	Depth (feet)	Thickness (feet)	Stratigraphy
1	Company Lake, Sandy River, and Columbia River			30 to 20	0 - 10	10	Silt
2				20 to 5	10 - 25	15	
3				5 to -20	25 - 50	25	UGS
4	Columbia River			-20 to -45	50 - 75	25	Intermediate Sand
5				-45 to -70	75 - 100	25	
6				-70 to -120	100 - 150	50	Deep Sand
7		PW05, PW08, PW18		-120 to -170	150 - 200	50	
8				-170 to -200	200 - 230	30	Deep USA/SGA
9		PW03, PW05, PW07, PW08, PW18, FF04, FF06		-200 to -230	230 - 260	30	
10				-230 to -410	260 - 440	180	
11		PW10		-410 to -530 and deeper	440 - 560 and deeper	120 feet and thicker	
							Older Rocks

Notes: South Ditch, West Drainage, and Salmon Creek reside in Layer 1.
The hatch pattern symbolizes the open intervals of production wells and monitoring wells.

Areas Where Fluoride Concentrations Currently Exceed MCLs:

UGS

Intermediate and Deep Zones

Particle Traces

Yellow	Silt Unit (Layer 1 of groundwater flow model)
Cyan	Silt Unit (Layer 2 of groundwater flow model)
Green	Upper Gray Sand (UGS) (Layer 3 of groundwater flow model)
Magenta	Intermediate Zone (Layer 4 of groundwater flow model)
White	Intermediate Zone (Layer 5 of groundwater flow model)
Dark Blue	Deep Zone (Layer 6 of groundwater flow model)
Dark Green	Deep Zone (Layer 7 of groundwater flow model)
Red	Deep Zone (Layer 8 of groundwater flow model)
Yellow	Deep Zone (Layer 9 of groundwater flow model)

Figure A-2
Color Codes for Particle-Tracking Diagrams
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

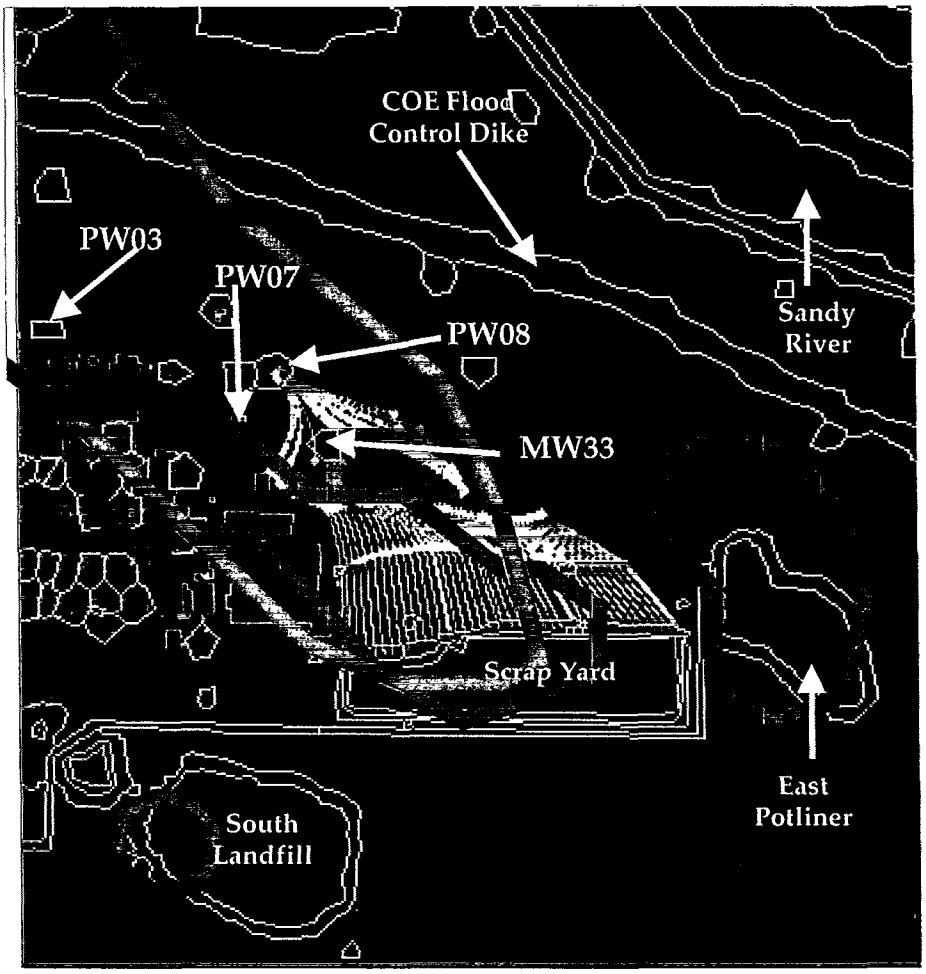


Figure A-3 shows imaginary particles that are initiated in the groundwater flow model and traced forward in time. The particles are placed at the top of the upper gray sand (UGS) along the northern boundary of the scrap yard soil and debris area. The figure shows particles moving from the UGS (green) into the intermediate zone (magenta and white), then into the deep zone (dark blue and dark green), where they are captured by production well PW08. Site features are outlined in white, and plant buildings are shown in red. The figure also shows the thick blue and red lines that outline areas where fluoride concentrations currently exceed the MCL (4 mg/L) in the UGS and intermediate zones, respectively.

Figure A-3
Groundwater Migration from the UGS at Scrap Yard Under
Long-Term Average Historical Pumping Rates from RMC Production Wells
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

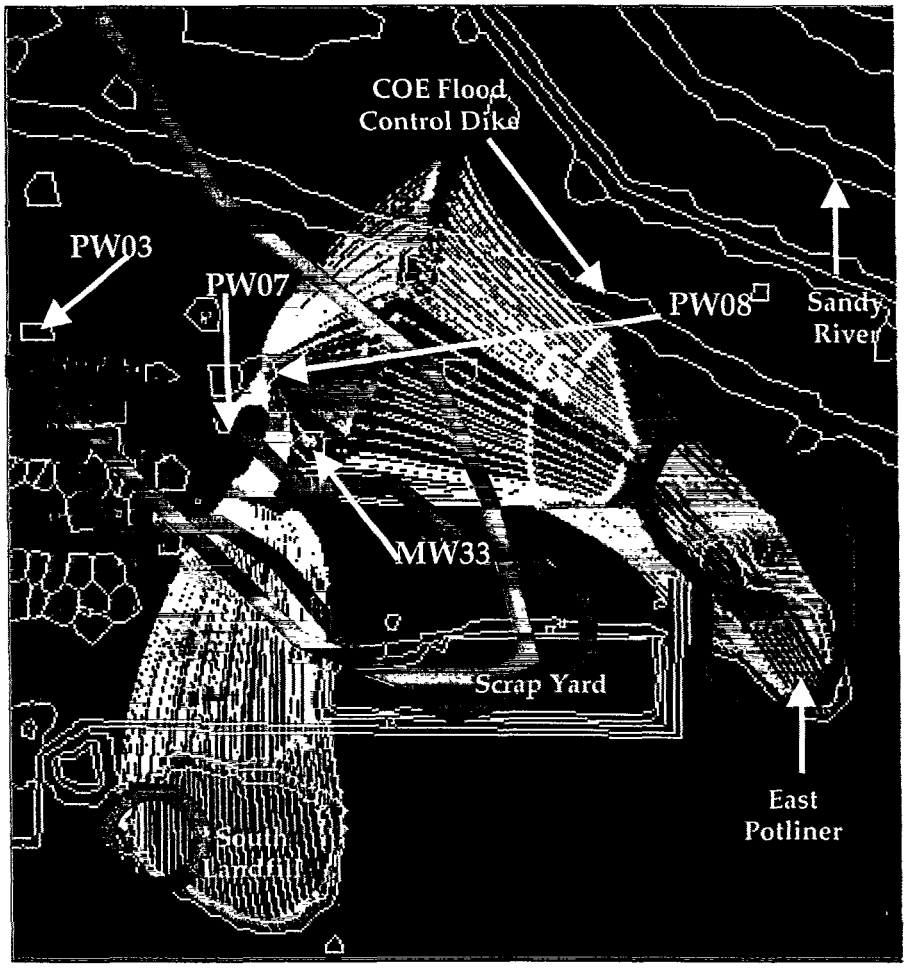


Figure A-4 is similar to Figure A-3, except that the particles are initiated along the perimeter of the south landfill and east potliner soil and debris areas. The particles are placed at the top of the upper gray sand (UGS) as in Figure A-3. Figure A-4 shows particles moving from the UGS (green) into the intermediate zone (magenta and white), then into the deep zone (dark blue, dark green, red, and yellow), where they are captured by production wells PW07 and PW08. The figure also shows the thick blue and red lines that outline areas where fluoride concentrations currently exceed the MCL (4 mg/L) in the UGS and intermediate zones, respectively.

Figure A-4
Groundwater Migration from the UGS at South Landfill and East Potliner Under Long-Term Average Historical Pumping Rates from RMC Production Wells
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

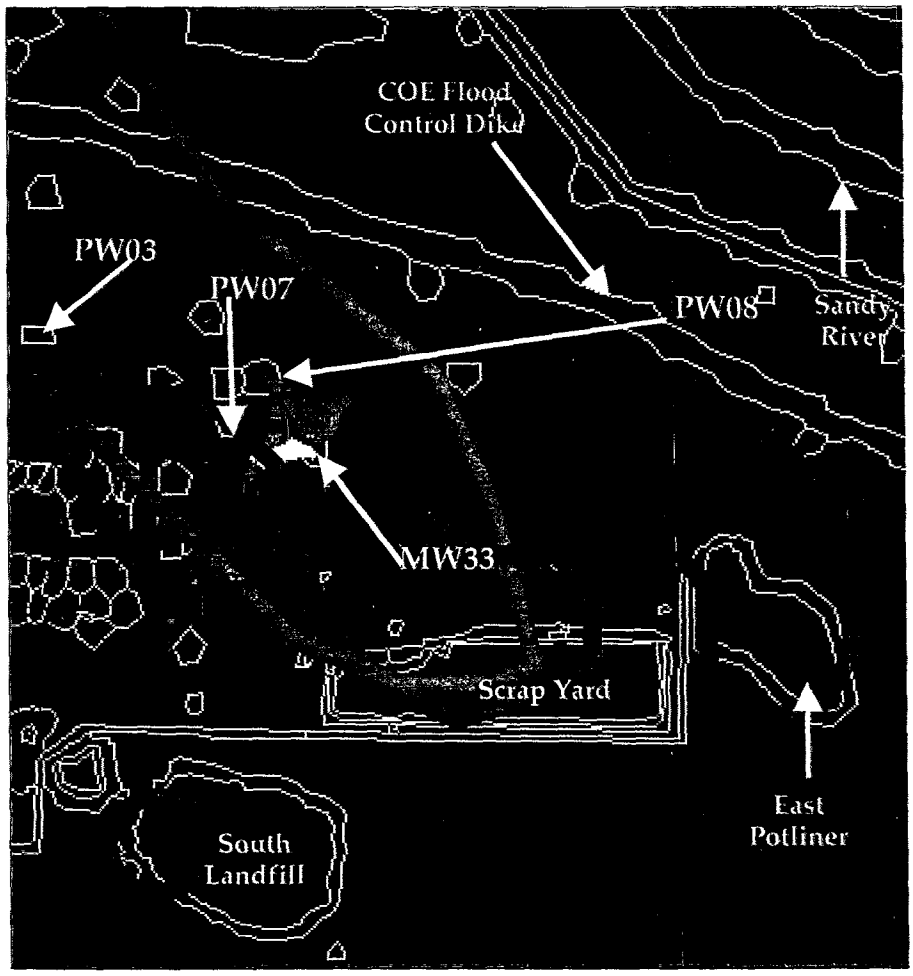


Figure A-5 is similar to Figure A-3, except that the particles are initiated at monitoring well MW33, which is the monitoring well closest to the RMC production wells. The particles are placed from the top of the intermediate zone (magenta and white) into the deep zone (dark blue and dark green) and are traced forward in time. Each particle is captured by production well PW08. The figure also shows the thick blue and red lines that outline areas where fluoride concentrations currently exceed the MCL (4 mg/L) in the UGS and intermediate zones, respectively.

Figure A-5
Groundwater Migration from MW33 Under Long-Term
Average Historical Pumping Rates from RMC Production Wells
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

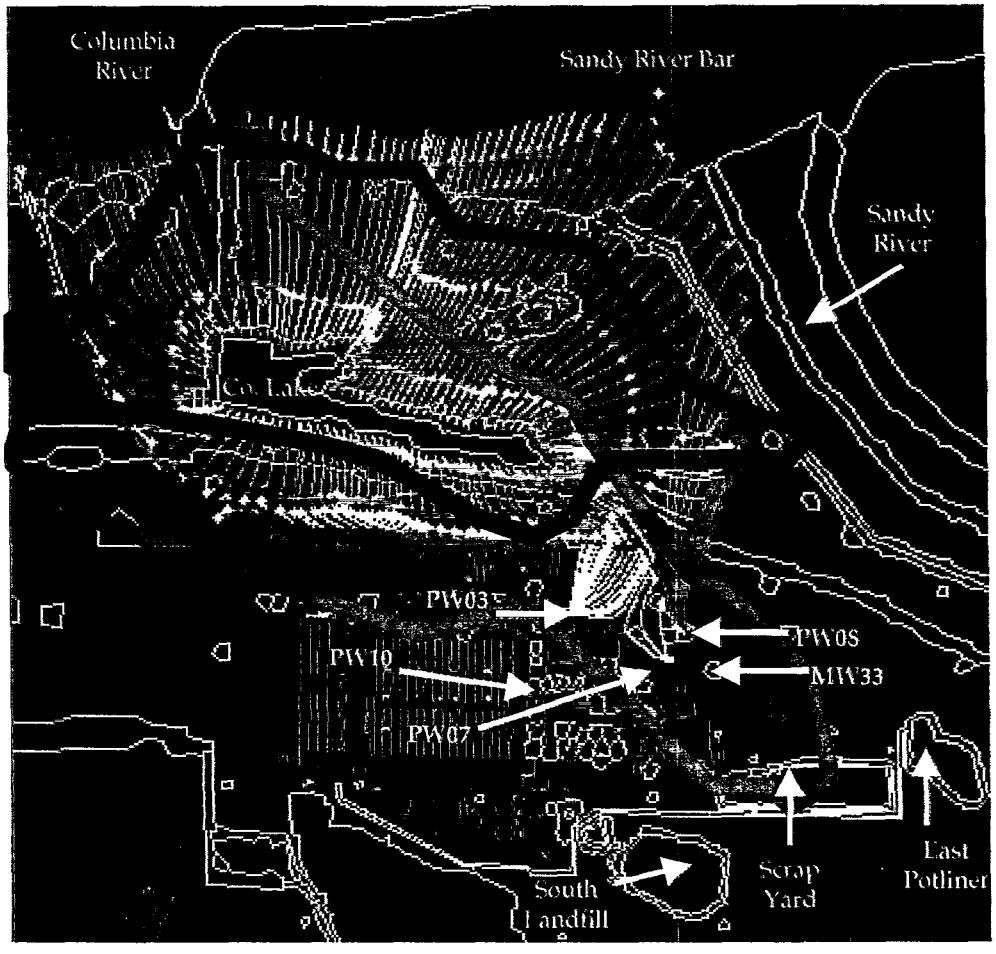


Figure A-6 shows particles initiated along the perimeter of Company Lake. The particles are initiated in the model at elevations corresponding to the elevation of process residue on the bed of Company Lake. The figure also shows a thick blue line outlining the area where fluoride concentrations around Company Lake currently exceed 4 mg/L in the UGS. The figure shows particles moving from the UGS (light blue and green) into the intermediate zone (magenta and white), then into the deep zone (dark blue, dark green, red, and yellow), where they are captured by production wells PW03, PW07, and PW08. Some particles moving toward the Sandy River migrate into the deep zone (dark blue and dark green), then migrate in a southwesterly direction and are captured by the production wells.

Figure A-6
Groundwater Migration from Company Lake Under
Long-Term Average Historical Pumping Rates from RMC Production Wells
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

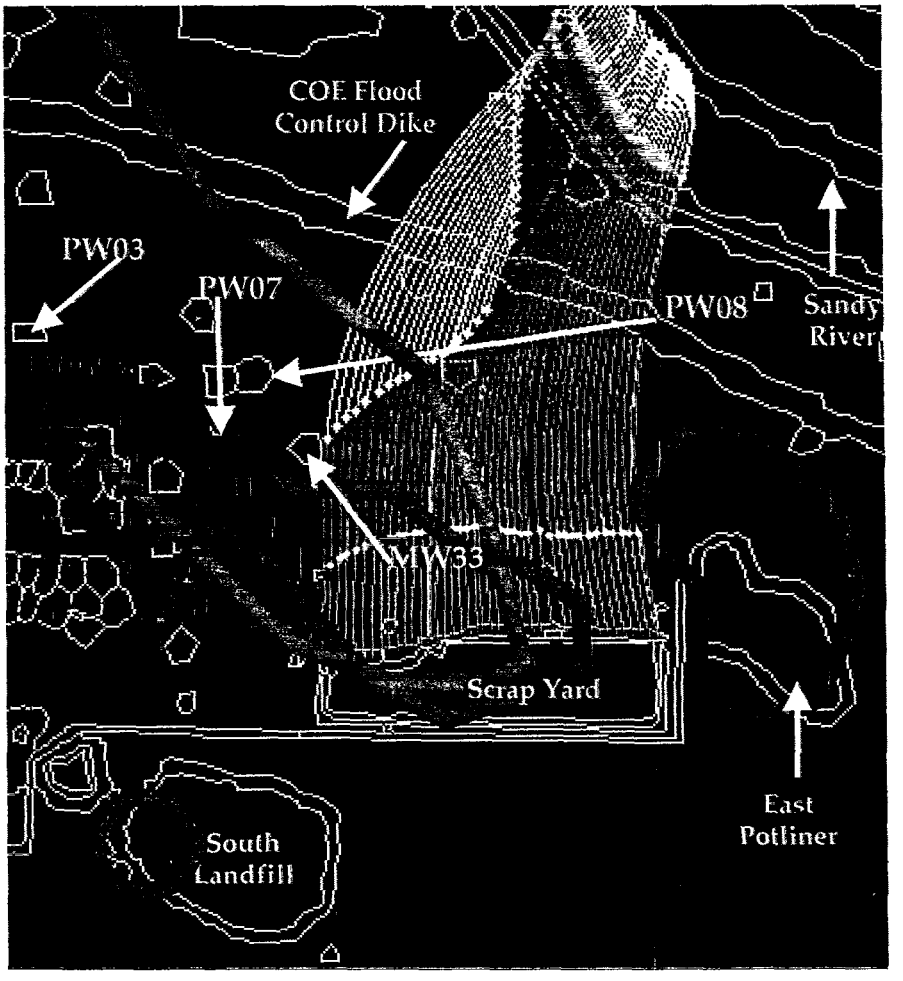


Figure A-7 shows the traces of particles that are initiated at the top of the UGS along the northern perimeter of Scrap Yard when PW08 is pumping at 600 gpm. Particles move from the UGS (green) to the Sandy River after first migrating into the upper and lower portions of the intermediate zone, which are shown in magenta and white, respectively. None of the particles are captured by production well PW08, which is the only well being pumped in this model simulation. The blue and red contour lines show the outlines of the UGS and intermediate zone fluoride plumes, respectively.

Figure A-7
Groundwater Migration from UGS at Scrap Yard For Pumping PW08 at 600 gpm
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

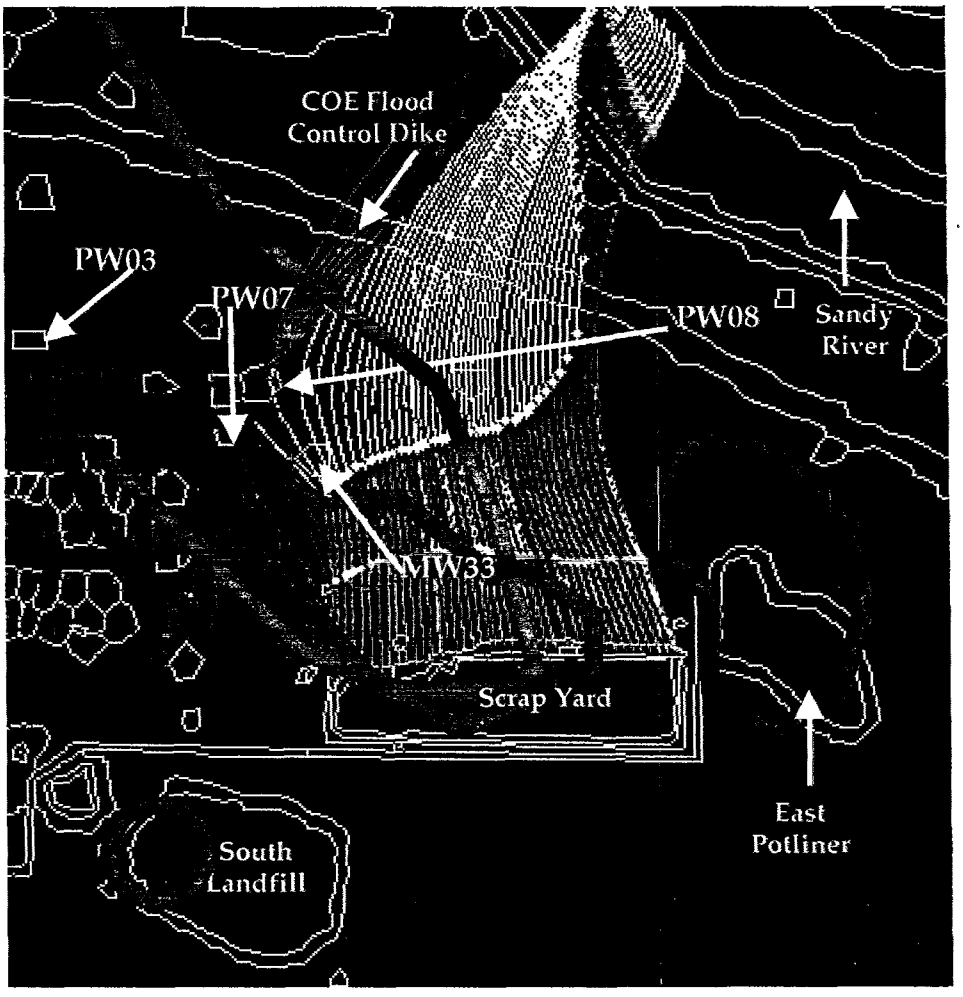


Figure A-8 shows the traces of particles that are initiated at the top of the UGS along the northern perimeter of Scrap Yard when PW07 is pumping at 300 gpm and PW08 is pumping at 600 gpm. Particles move from the UGS (green) to the Sandy River after first migrating into the upper and lower portions of the intermediate zone, which are shown in magenta and white, respectively. The only particles that are captured by the production wells are those initiated in the western-most portion of the scrap yard. However, these particles migrate nearly all the way to the Sandy River before being pulled back onsite by the production wells. The blue and red contour lines show the outlines of the UGS and intermediate zone fluoride plumes, respectively.

Figure A-8
Groundwater Migration from UGS at Scrap Yard For Pumping PW07 at 300 gpm and PW08 at 600 gpm
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

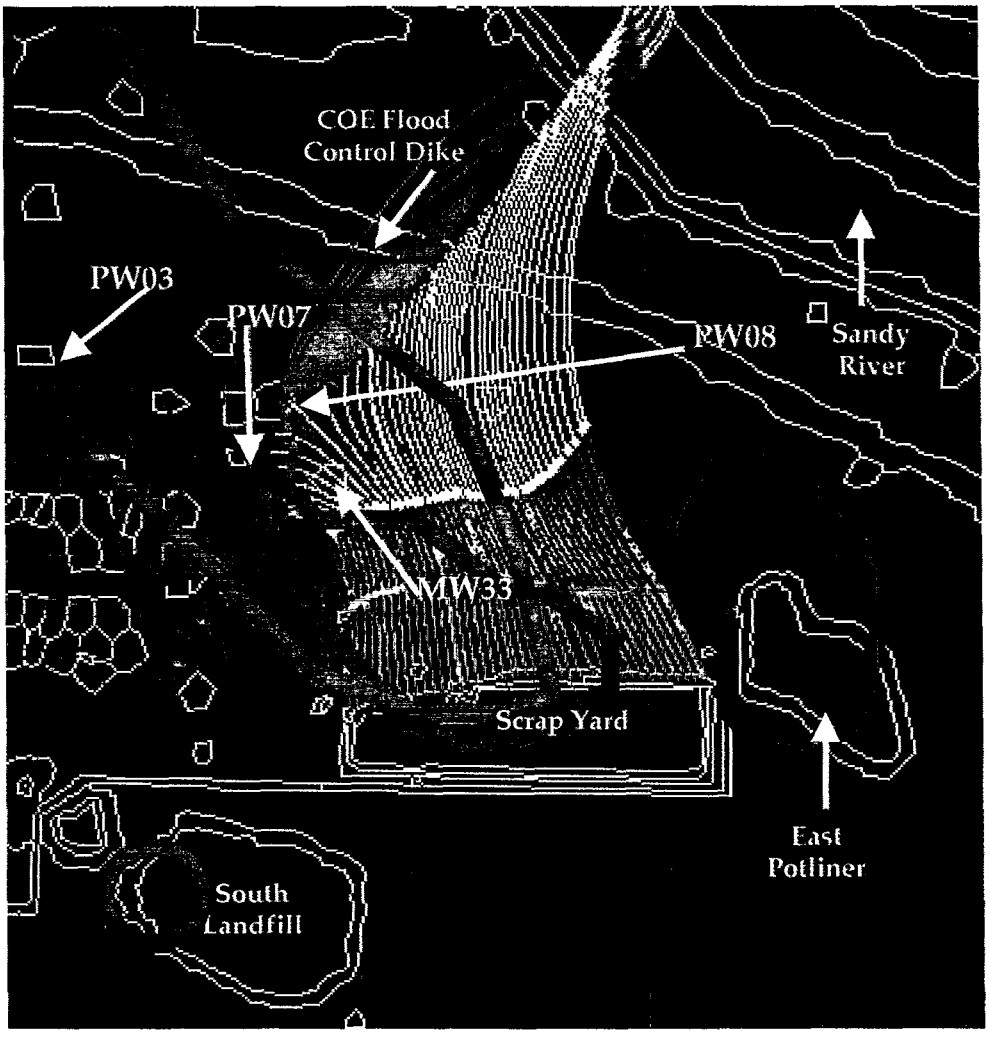


Figure A-9 shows the traces of particles that are initiated at the top of the UGS along the northern perimeter of Scrap Yard when PW07 and PW08 are pumping at 600 gpm each. The particle traces lying within the intermediate zone plume are contained by the production wells. Particles initiated along the northeastern perimeter of the scrap yard are outside the plume and migrate to the Sandy River after first migrating into the upper and lower portions of the intermediate zone, which are shown in magenta and white, respectively. The blue and red contour lines show the outlines of the UGS and intermediate zone fluoride plumes, respectively.

Figure A-9
Groundwater Migration from UGS at Scrap Yard For Pumping PW07 at 600 gpm and PW08 at 600 gpm
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

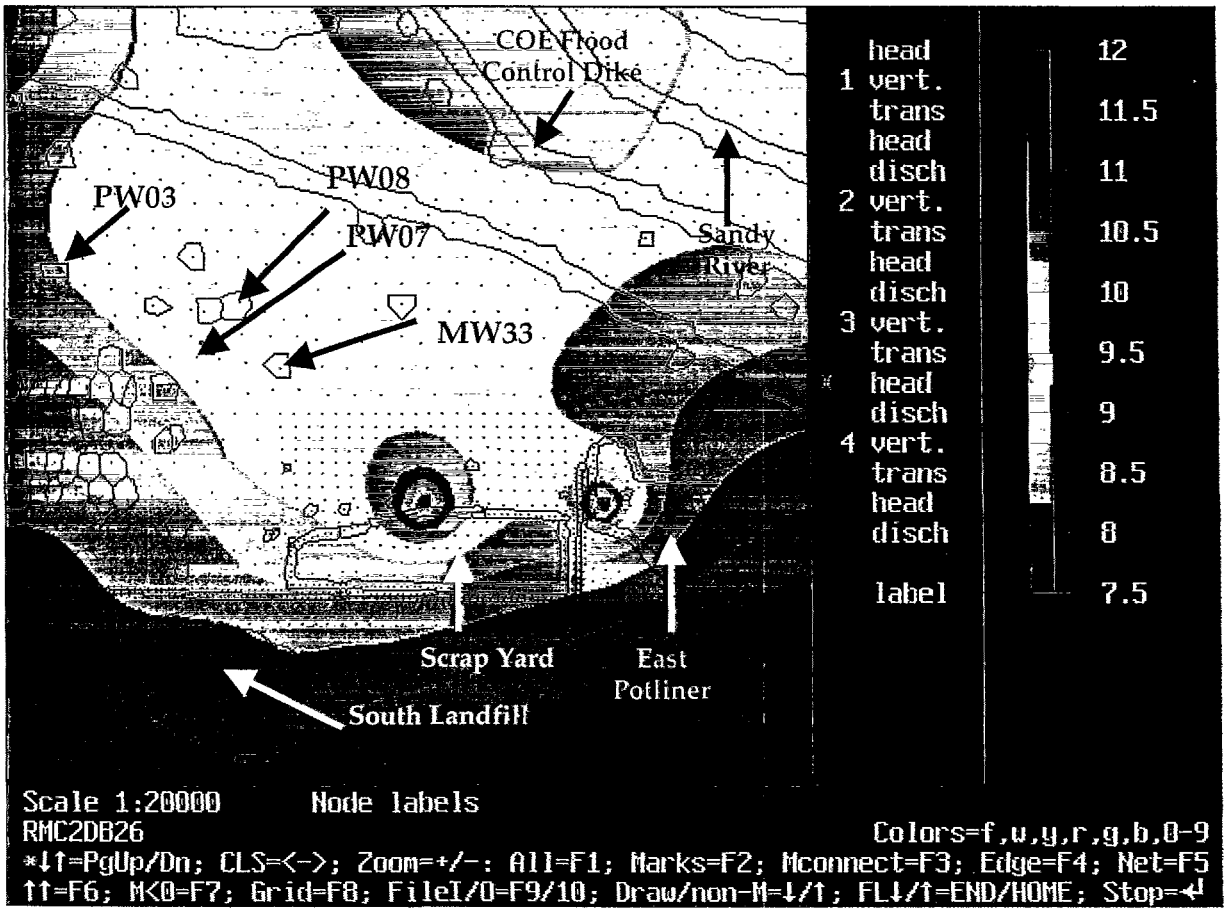


Figure A-10 is a groundwater elevation contour map in the UGS (layer 3 of the model) for the two-well focused extraction system at scrap yard and east potliner. The contour interval is 0.25 feet. The blue, black and red contours represent the highest groundwater elevations, and the green contours represent the lowest elevations. The map shows that drawdown cones are centered around each of the two focused extraction wells. In this simulation, the production wells are simulated at their long-term historical pumping rates (which total 1,800 gpm).

Figure A-10
UGS Groundwater Elevation Contour Map For the Two-Well Focused Extraction System
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

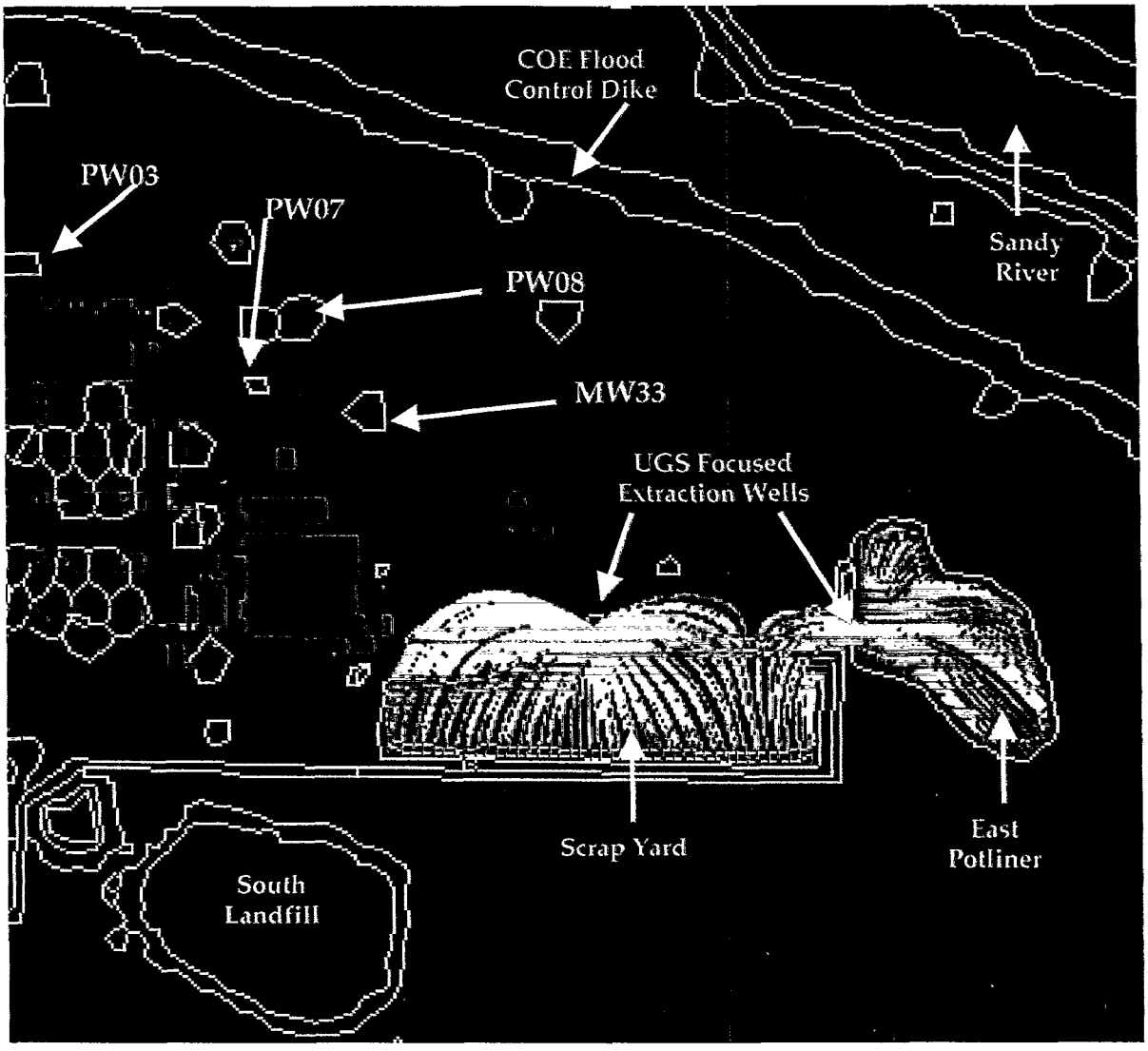


Figure A-11 shows the traces of particle that are initiated at the top of the UGS along the entire perimeters of scrap yard and east potliner for the simulation of two focused extraction wells. Particles move from the UGS (green) into the focused extraction well without entering the intermediate zone. None of the particles are captured by the production wells. Additional particle tracking showed that this result was unchanged if particles were initiated at the bottom of the UGS

Figure A-11
Groundwater Migration from the UGS Along the Perimeters of Scrap Yard and East Potliner For the Two-Well Focused Extraction System
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

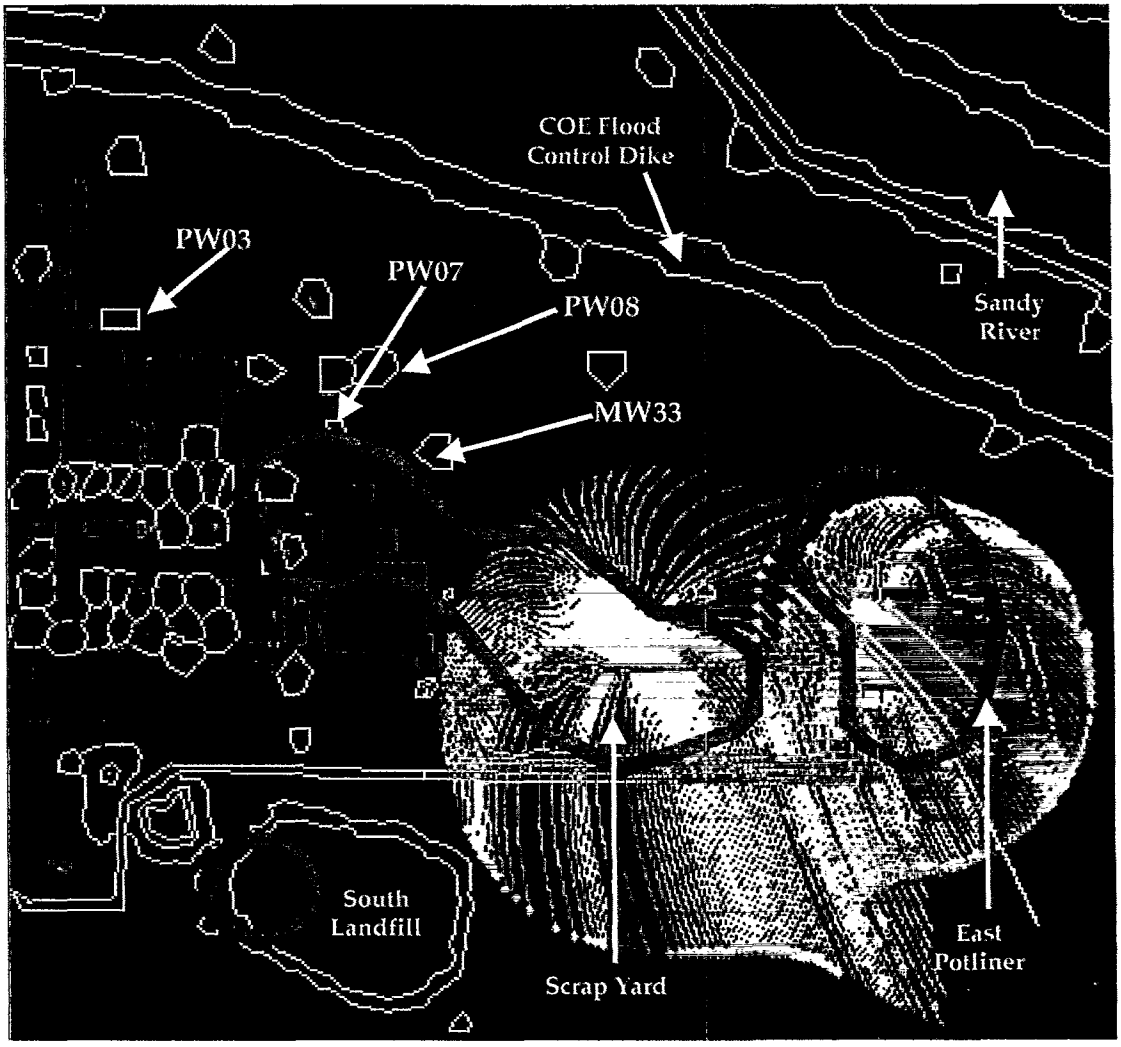
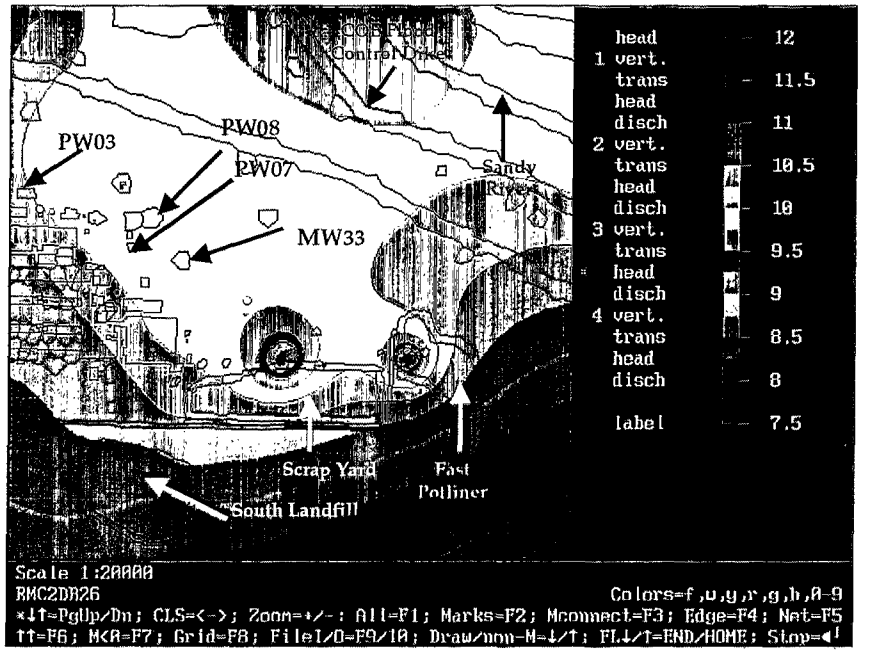


Figure A-12 shows reverse particle tracking from the two focused extraction wells. 100 particles are initiated at each well in the middle of Layer 3 (the UGS) and tracked backwards for 10 years. The green traces lie within the UGS, the cyan traces lie within the lower portion of the silt unit (layer 2 of the model), and the magenta and white traces lie within the upper and lower portions of the intermediate zone (model layers 4 and 5, respectively). The blue contour line shows the outline of the UGS fluoride plume.

Figure A-12
10-Year Capture Zone for Focused Extraction Wells
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study



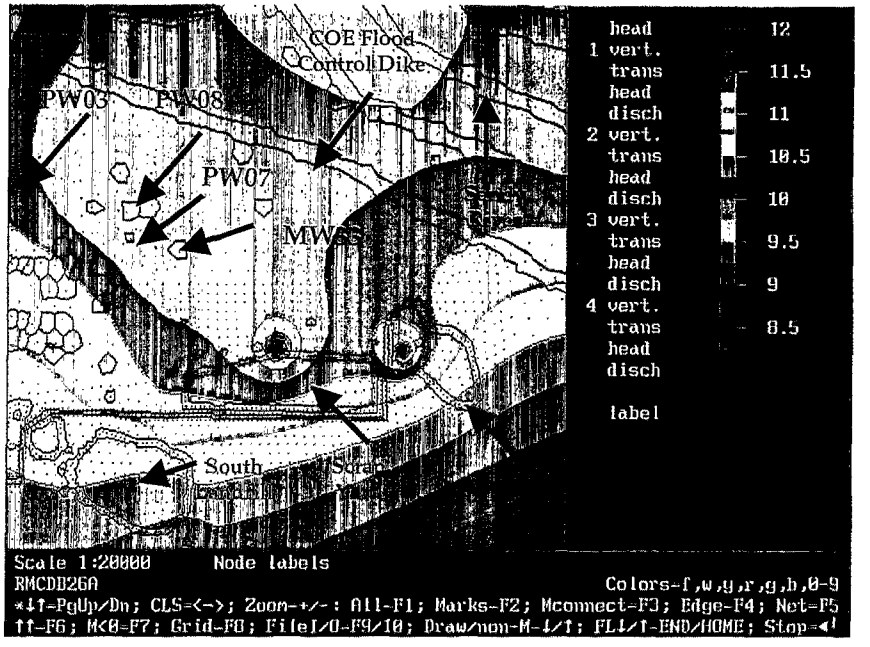
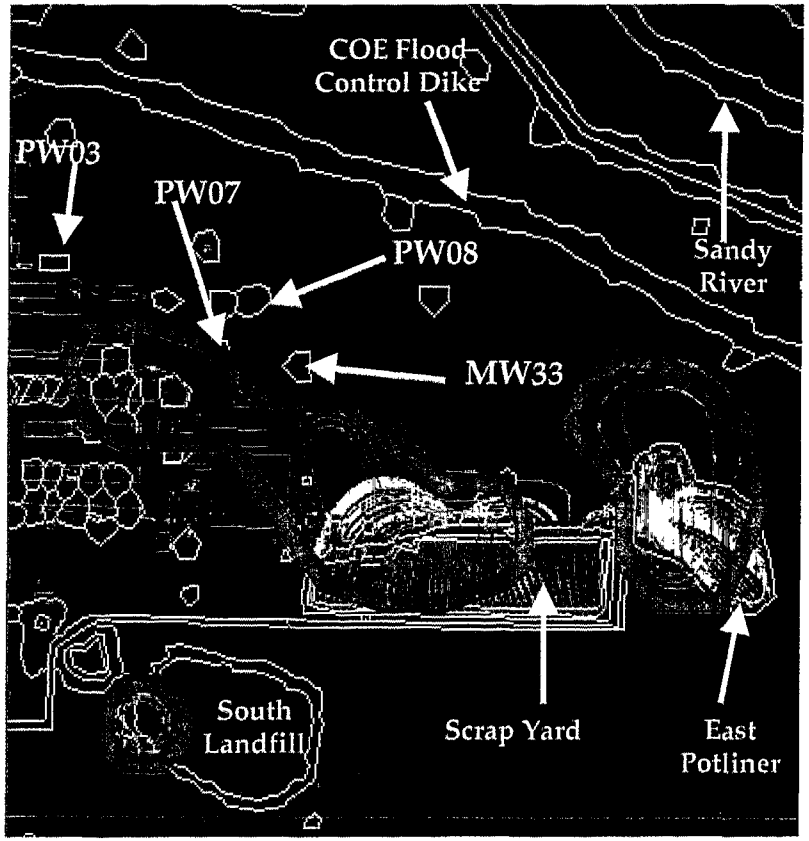


Figure A-13 shows groundwater elevation contour maps in the UGS (layer 3 of the model) for the two-well focused extraction system. The base case run (using a hydraulic conductivity value of 35 feet/day) is shown on the left and the sensitivity analysis (using a higher hydraulic conductivity value of 50 feet/day) is shown on the right. The contour interval is 0.25 feet. The higher hydraulic conductivity value produces less drawdown at the extraction wells, but cones of depression are still evident around the extraction wells in both figures.

Figure A-13
Case 1: Sensitivity of UGS Groundwater Elevations to Increased Hydraulic Conductivity in the UGS
(Focused Extraction at Scrap Yard and East Potliner)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study



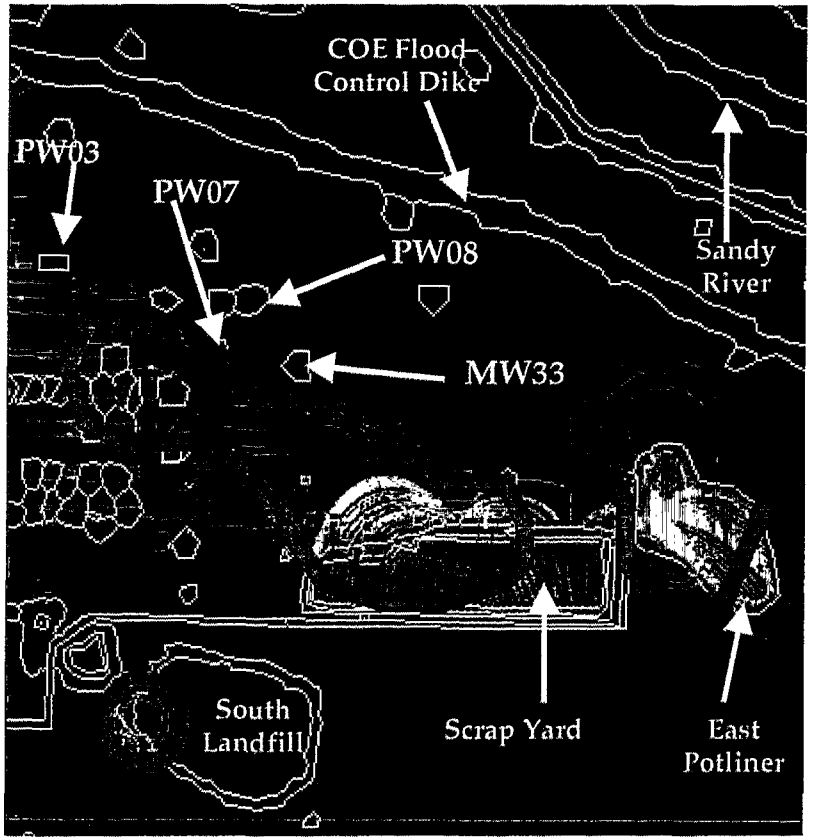
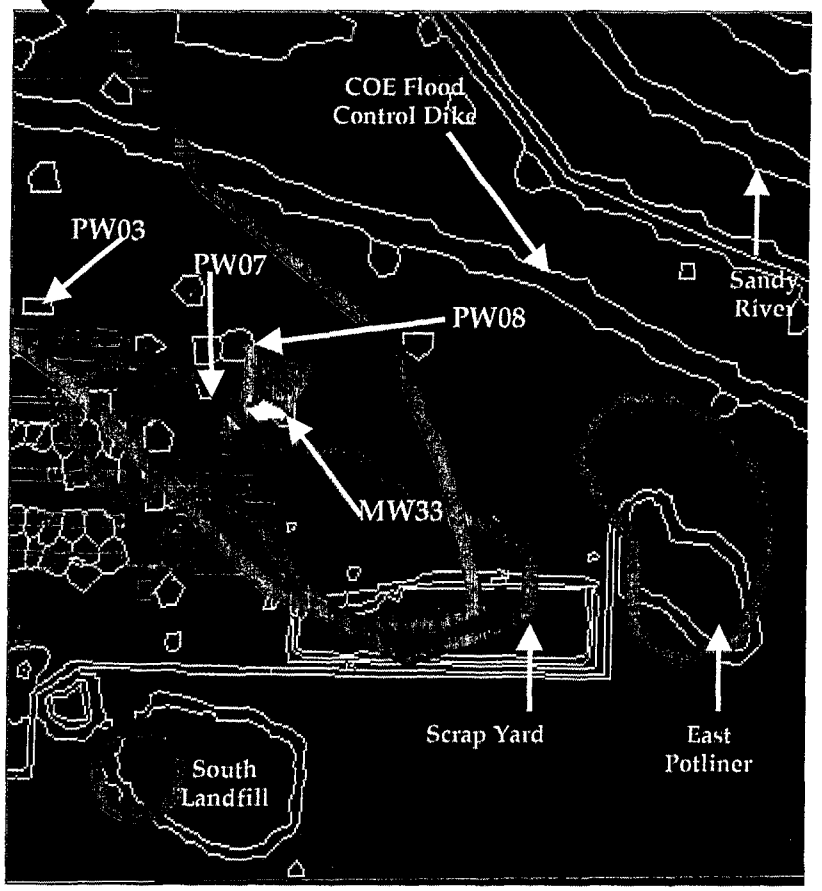


Figure A-14 shows the traces of particles that are initiated at the top of the UGS along the entire northern perimeter of Scrap Yard for the base case run (left) and the sensitivity run (right). For both simulations, particles along the western 2/3 of the perimeter move from the UGS (green) into the containment well without entering the intermediate zone. Particles along the eastern third of the perimeter move into the intermediate zone (magenta and white) and eventually the deep zone (dark blue and dark green) where they are captured by production well PW8. The thick blue lines are the outlines of the fluoride plume that is present in the UGS.

Figure A-14
Case 1: Sensitivity of Focused Extraction to Increased Hydraulic Conductivity in the UGS
(Particles Initiated at Scrap Yard and East Potliner)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study



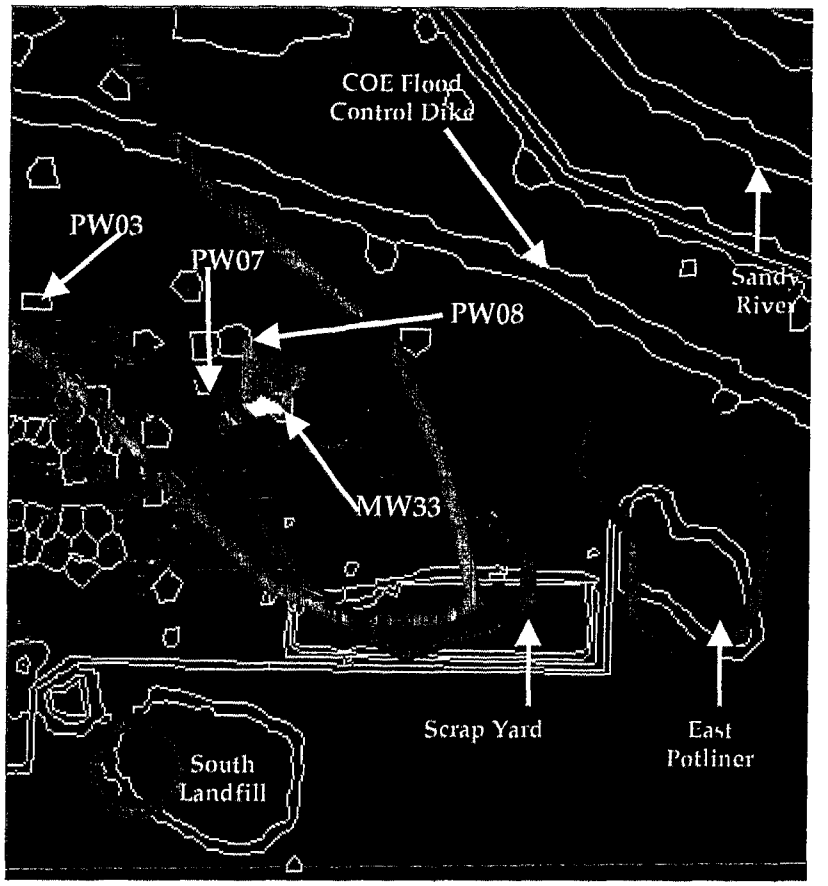


Figure A-15 shows the traces of particles that are initiated at MW33-095 at the top of the deep portion of the intermediate zone (model layer 5, shown in white). The base case run is shown on the left, and the sensitivity run is shown on the right. For both runs, migration is downward to the lower portion of the deep zone (dark green) and into well PW8. The thick blue lines are the outlines of the fluoride plume that is present in the UGS.

Figure A-15
Case 1: Sensitivity of Focused Extraction to Increased Hydraulic Conductivity in the UGS
(Particles Initiated at MW33-095)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

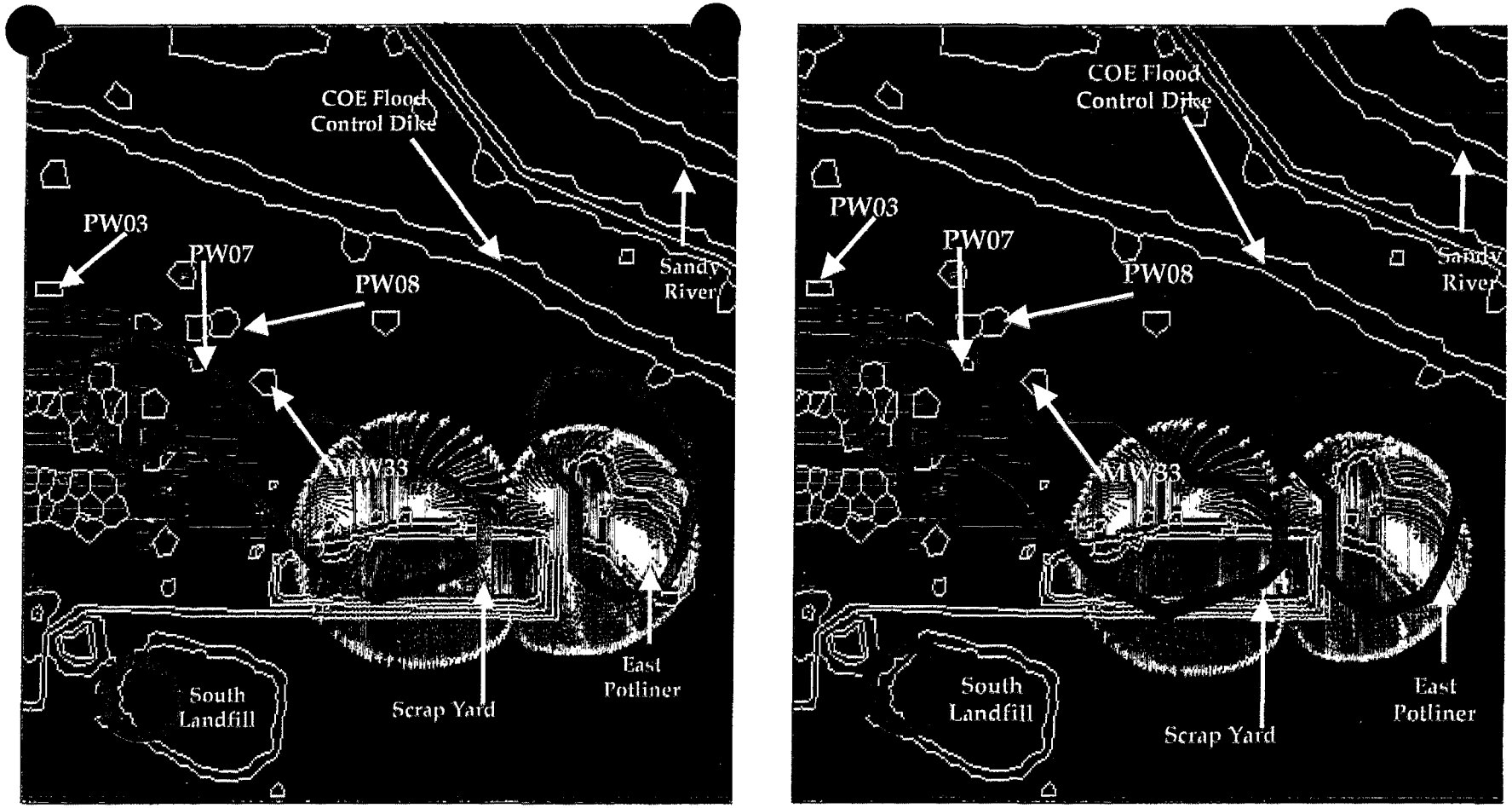


Figure A-16 shows the traces of particles that are tracked backwards in time from the scrap yard and east potliner focused extraction wells. 100 particles are initiated in the upper 1/4th of Layer 3 (the UGS) and tracked backwards for 10 years. The green traces lie within the UGS, the cyan traces lie within the lower portion of the silt unit (layer 2 of the model), and the yellow traces lie within the upper portion of the silt unit (model layer 1). The thick blue lines are the outlines of the fluoride plume that is present in the UGS.

Figure A-16
Case 1: Sensitivity of Focused Extraction to Increased Hydraulic Conductivity in the UGS
(10-Year Groundwater Capture Zone for Particles Initiated in the Upper ¼ of the UGS)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

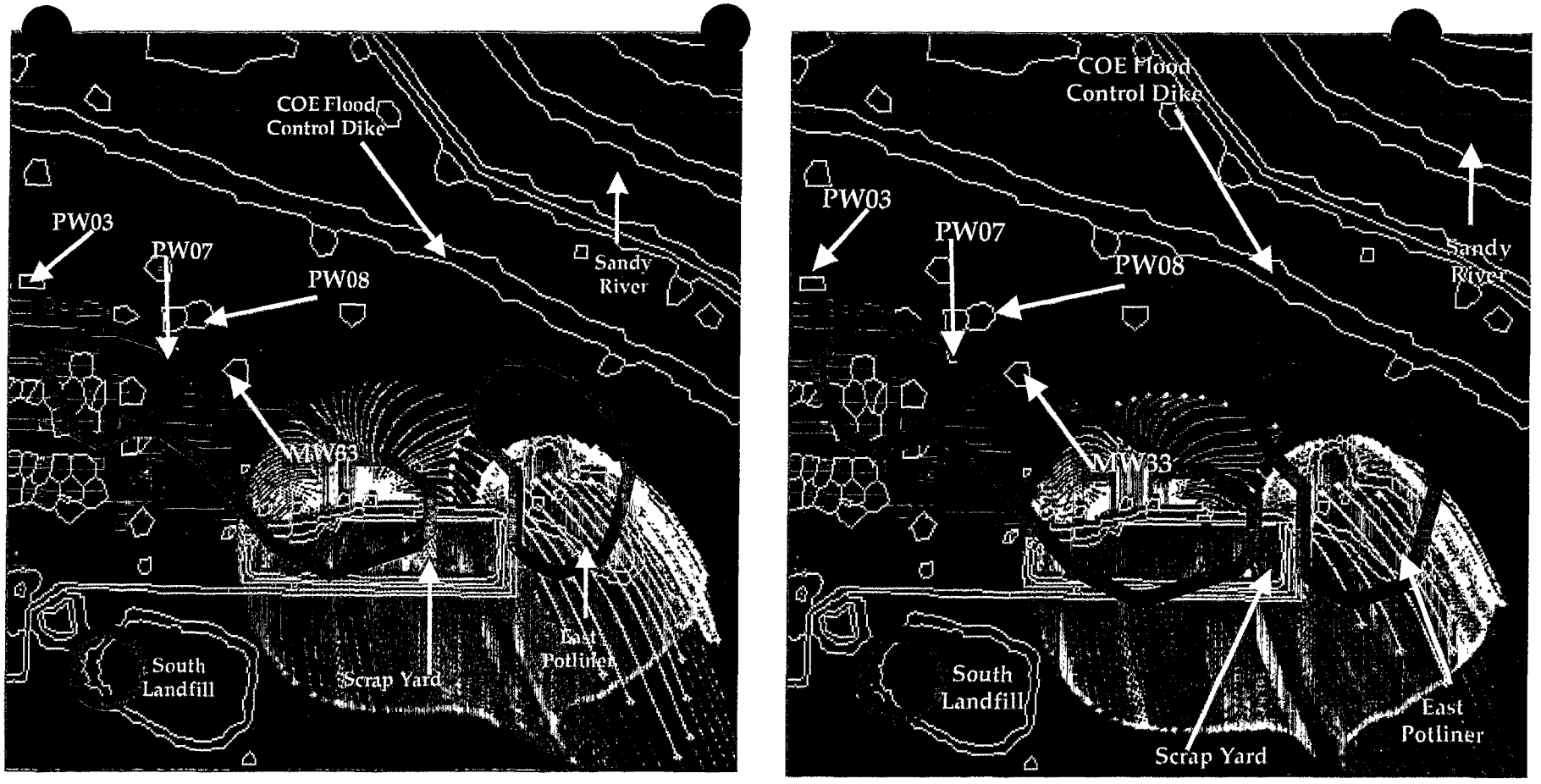
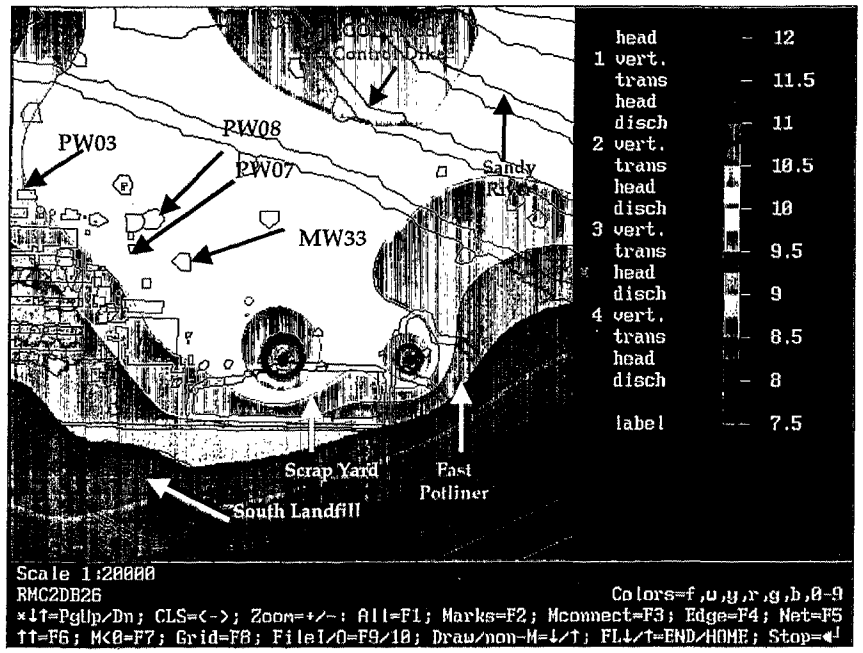


Figure A-17 shows the traces of particles that are tracked backwards in time from the scrap yard and east potliner focused extraction wells. 100 particles are initiated in the middle of Layer 3 (the UGS) and tracked backwards for 10 years. Most particles stay within the UGS (green traces) and are traced backwards into the silt unit (cyan and yellow traces). The particle traces show only minor differences between the two runs. The thick blue lines are the outlines of the fluoride plume that is present in the UGS.

Figure A-17
Case 1: Sensitivity of Focused Extraction to Increased Hydraulic Conductivity in the UGS
(10-Year Groundwater Capture Zone for Particles Initiated in the Middle of the UGS)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study



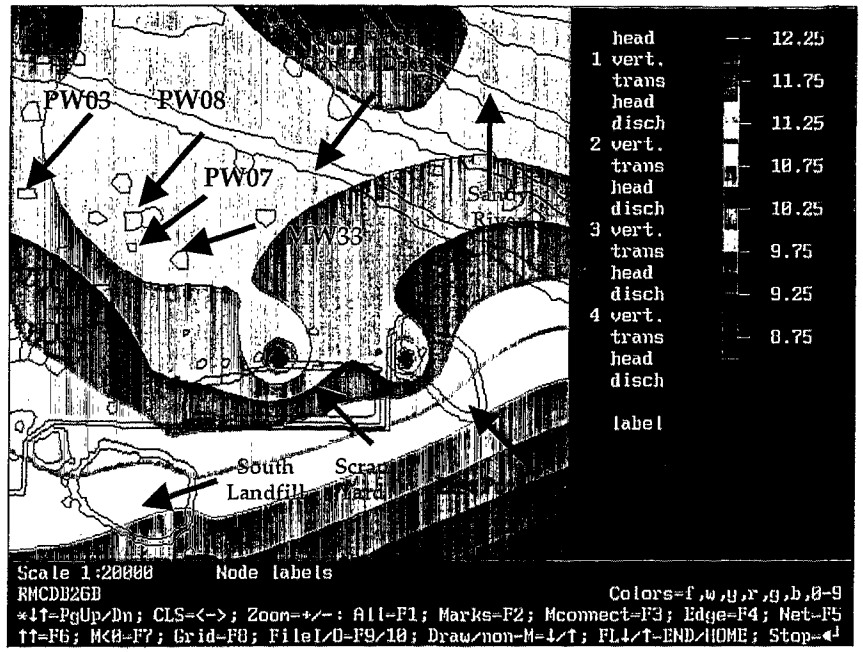
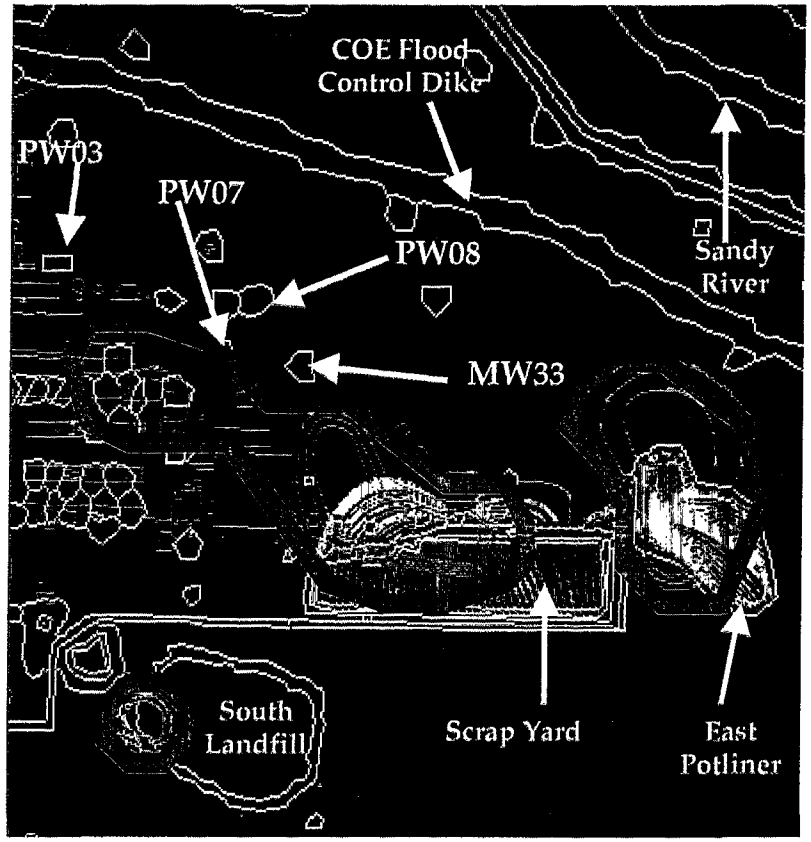


Figure A-18 shows groundwater elevation contour maps in the UGS (layer 3 of the model) for the two-well focused extraction system. The base case run (shown on the left) uses hydraulic conductivity values of 35 feet/day and 75 feet/day in the UGS and intermediate zones (respectively). The sensitivity run (shown on the right) use hydraulic conductivity values of 50 and 150 feet/day in the UGS and intermediate zones (respectively). The contour interval is 0.25 feet. The higher hydraulic conductivity values produce less drawdown at the extraction wells, but cones of depression are still evident around the extraction wells in both figures.

Figure A-18
Case 2: Sensitivity of UGS Groundwater Elevations to Increased Hydraulic Conductivity in the UGS and Intermediate Zone (Focused Extraction at Scrap Yard and East Potliner)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study



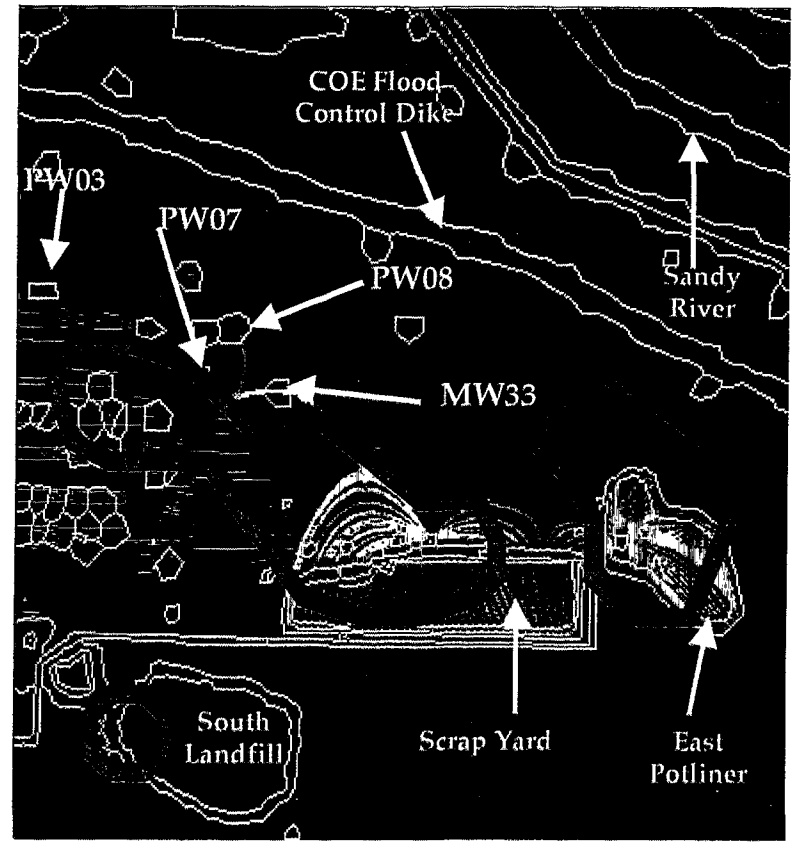
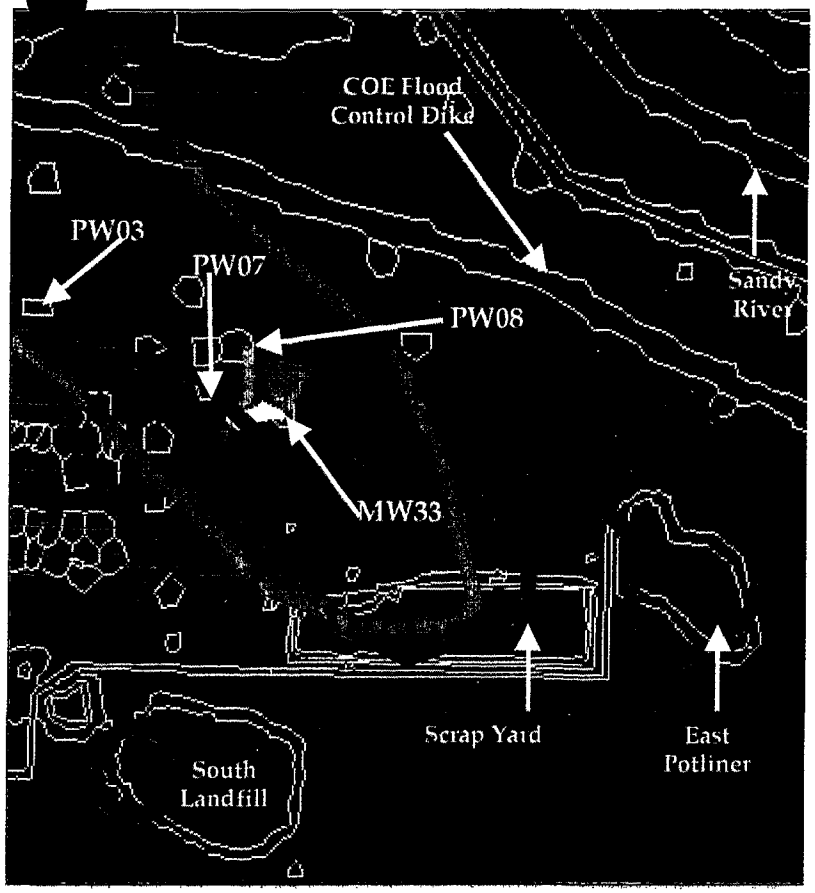


Figure A-19 shows the traces of particles that are initiated at the top of the UGS along the entire northern perimeter of Scrap Yard for the base case run (left) and the sensitivity run (right). For the sensitivity simulation, all but one particle initiated along the perimeter of scrap yard moves from the UGS (green) into the containment wells. One particle is not captured by the extraction wells, but is captured by PW08. The thick blue lines are the outlines of the fluoride plume that is present in the UGS.

Figure A-19
Case 2: Sensitivity of Focused Extraction to Increased Hydraulic Conductivity in the UGS and Intermediate Zones
(Particles Initiated at Scrap Yard and East Potliner)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study



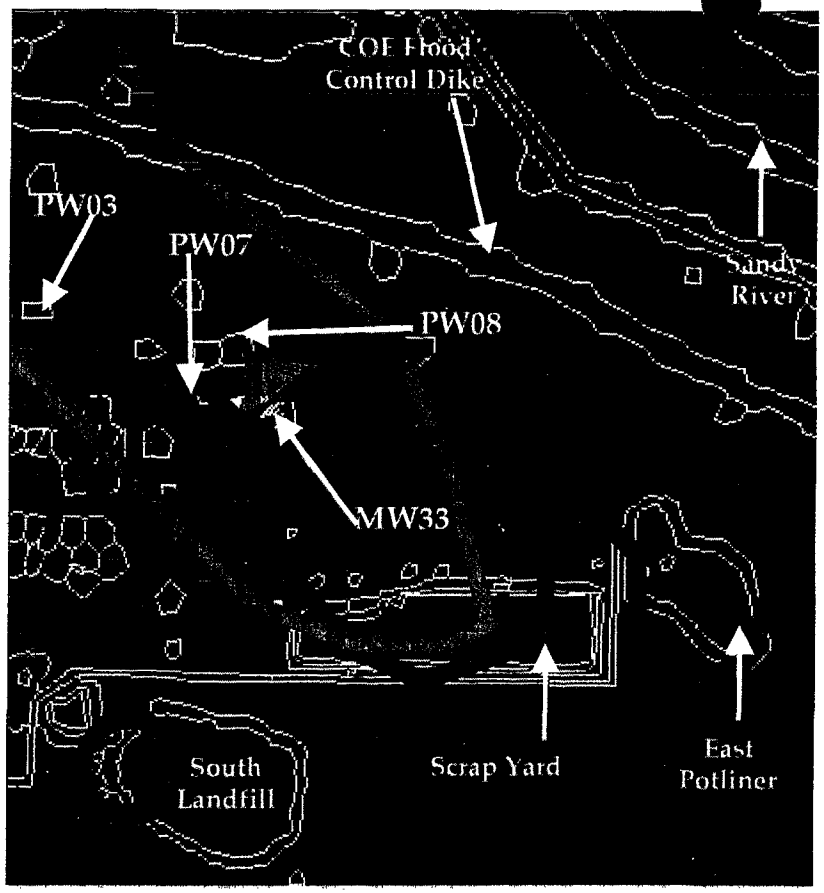
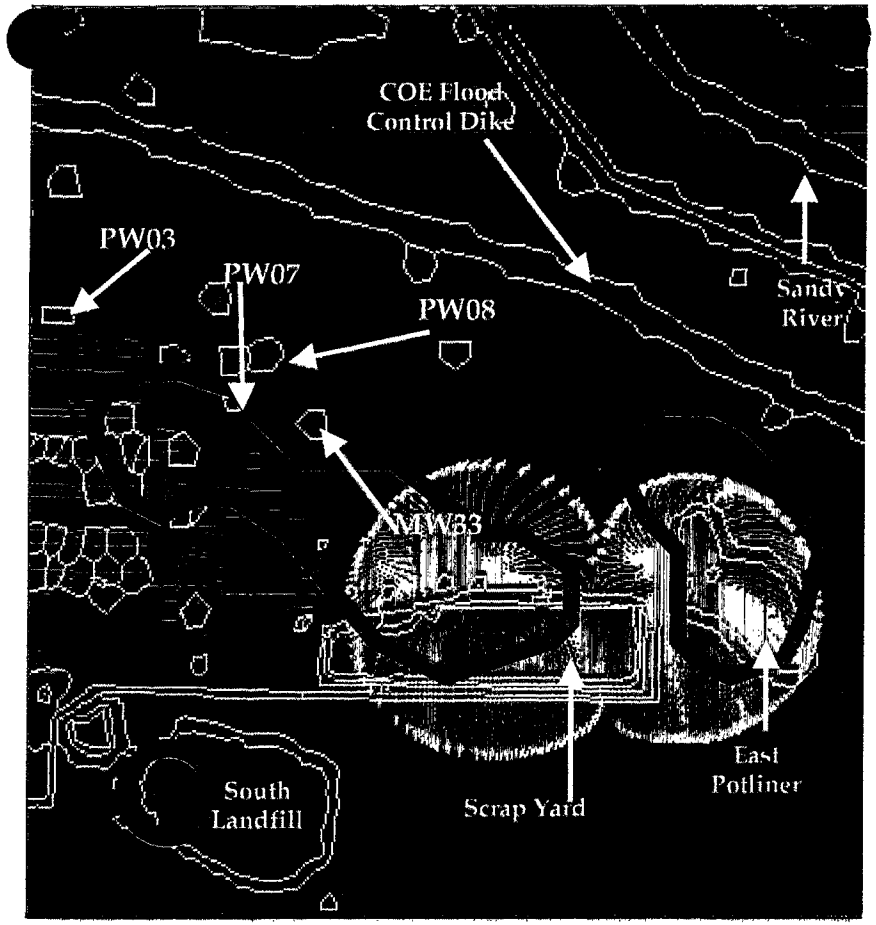


Figure A-20 shows the traces of particles that are initiated at MW33-095 at the top of the deep portion of the intermediate zone (model layer 5, shown in white). The base case run is shown on the left, and the sensitivity run is shown on the right. For both runs, migration is downward to the lower portion of the deep zone (dark green) and into well PW8. The thick blue lines are the outlines of the fluoride plume that is present in the UGS.

Figure A-20
Case 2: Sensitivity of Focused Extraction to Increased Hydraulic Conductivity in the UGS and Intermediate Zones
(Particles Initiated at MW33-095)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study



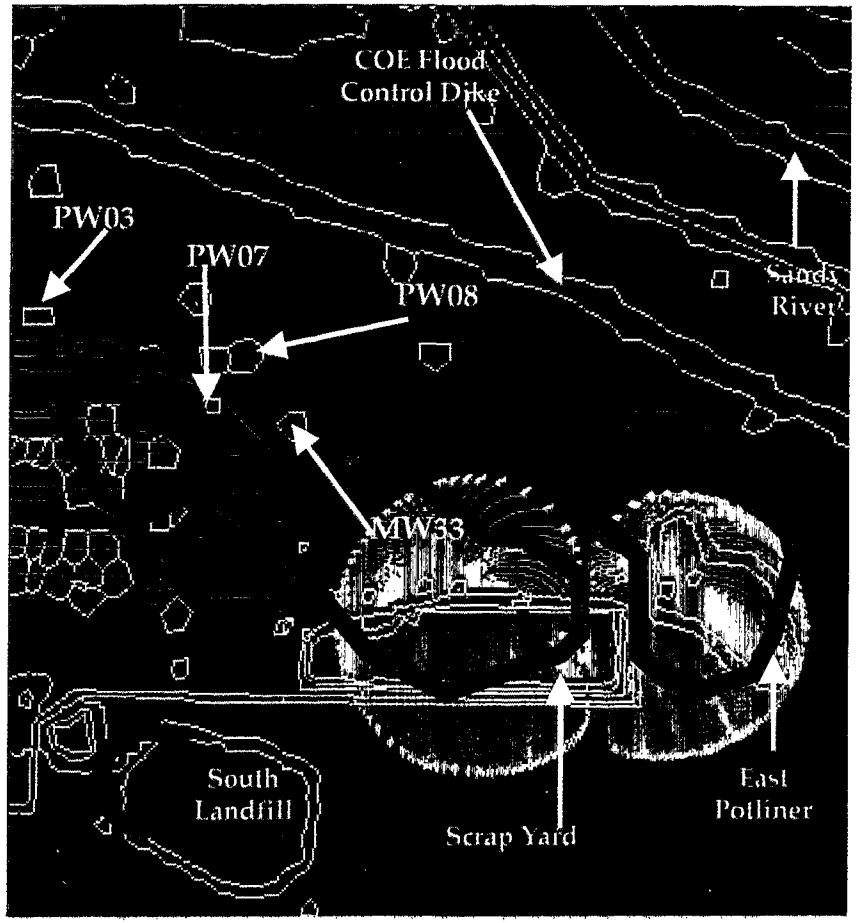
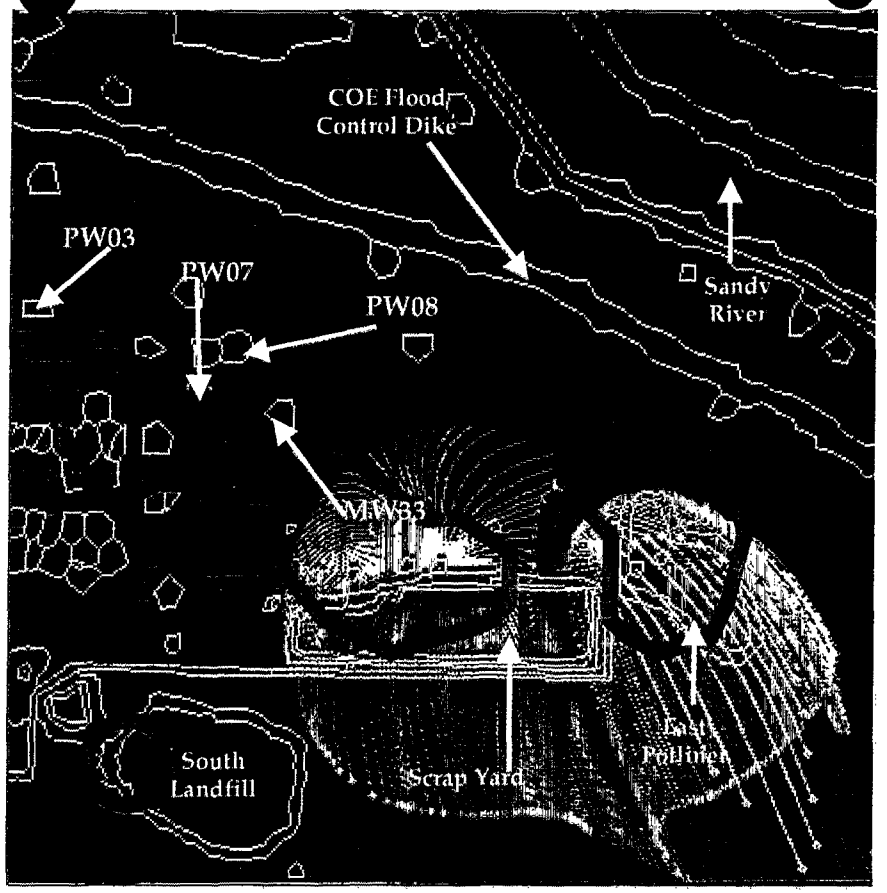


Figure A-21 shows the traces of particles that are tracked backwards in time from the scrap yard and east potliner focused extraction wells. 100 particles are initiated in the upper 1/4th of Layer 3 (the UGS) and tracked backwards for 10 years. The green traces lie within the UGS, the cyan traces lie within the lower portion of the silt unit (layer 2 of the model), and the yellow traces lie within the upper portion of the silt unit (model layer 1). The thick blue lines are the outlines of the fluoride plume that is present in the UGS.

Figure A-21
Case 2: Sensitivity of Focused Extraction to Increased Hydraulic Conductivity in the UGS and Intermediate Zones
(10-Year Groundwater Capture Zone for Particles Initiated in the Upper ¼ of the UGS)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study



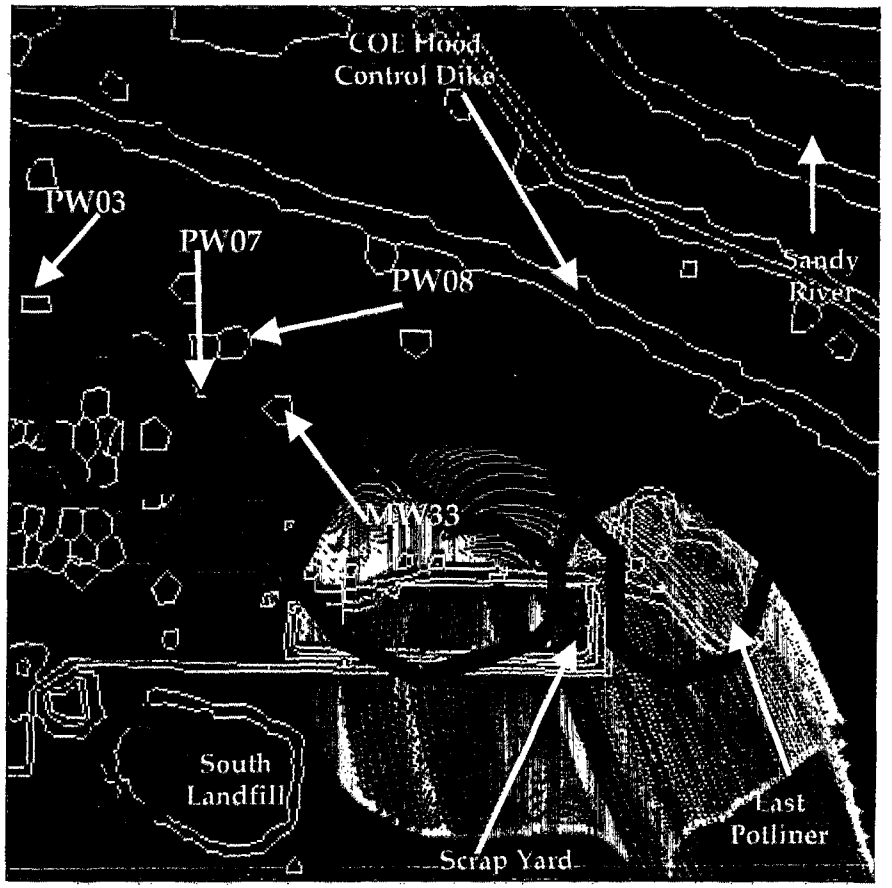
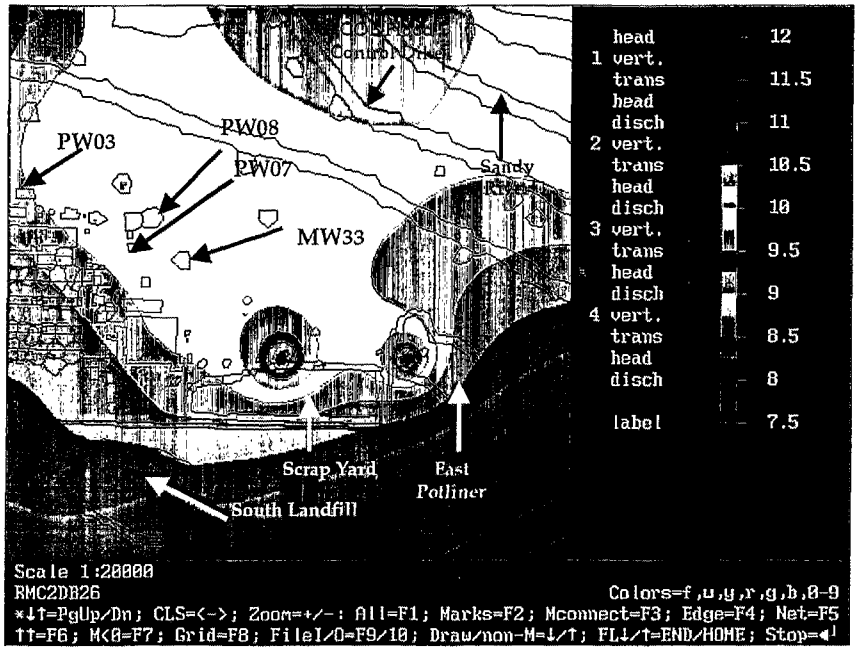


Figure A-22 shows the traces of particles that are tracked backwards in time from the scrap yard and east potliner focused extraction wells. 100 particles are initiated in the middle of Layer 3 (the UGS) and tracked backwards for 10 years. Most particles stay within the UGS (green traces). However, some particles are traced backwards into the upper portion of the intermediate zone (magenta traces), which indicates that groundwater is being obtained from both the UGS and the underlying intermediate zone. The particle traces show only minor differences between the two runs. The thick blue lines are the outlines of the fluoride plume that is present in the UGS.

Figure A-22
Case 2: Sensitivity of Focused Extraction to Increased Hydraulic Conductivity in the UGS and Intermediate Zones
(10-Year Groundwater Capture Zone for Particles Initiated in the Middle of the UGS)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study



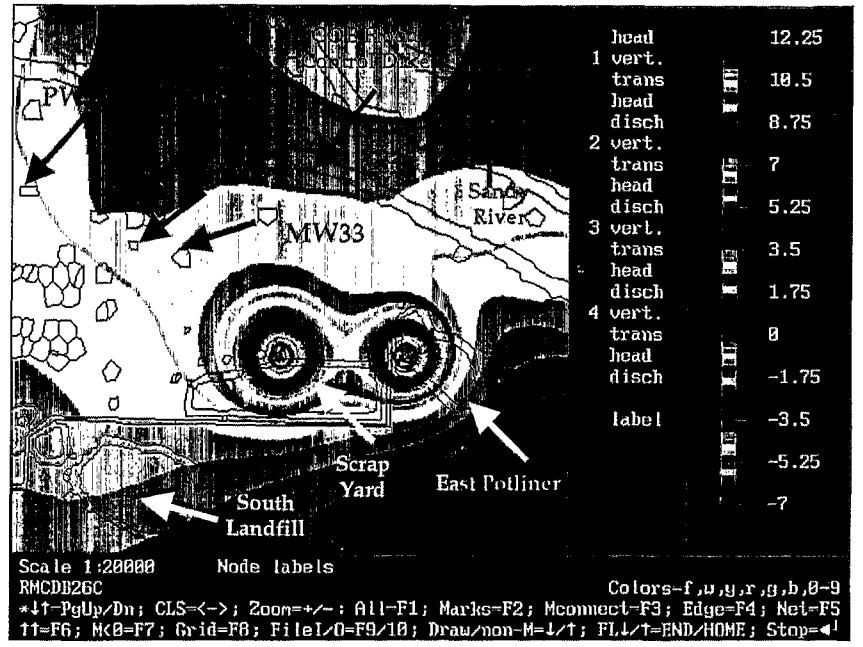
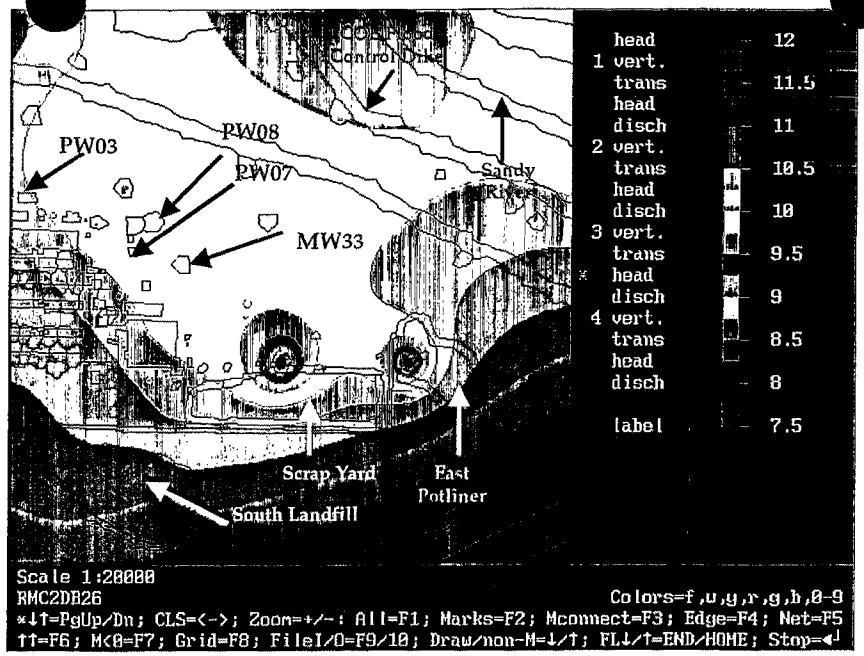


Figure A-23 shows groundwater elevation contour map in the UGS (layer 3 of the model) for the two-well focused extraction system. The base case run (shown on the left) uses a hydraulic conductivity value of 35 feet/day in the UGS. The sensitivity analysis (shown on the right) uses a hydraulic conductivity value of 5 feet/day in the UGS. The contour interval is 0.25 feet. The lower hydraulic conductivity value produces a substantial cone of depression around the extraction wells, with the water table at or below the top of the UGS (which is at elevation –5 feet NGVD).

Figure A-23
Case 3: Sensitivity of UGS Groundwater Elevations to Decreased Hydraulic Conductivity in the UGS
(Focused Extraction at Scrap Yard and East Potliner)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study



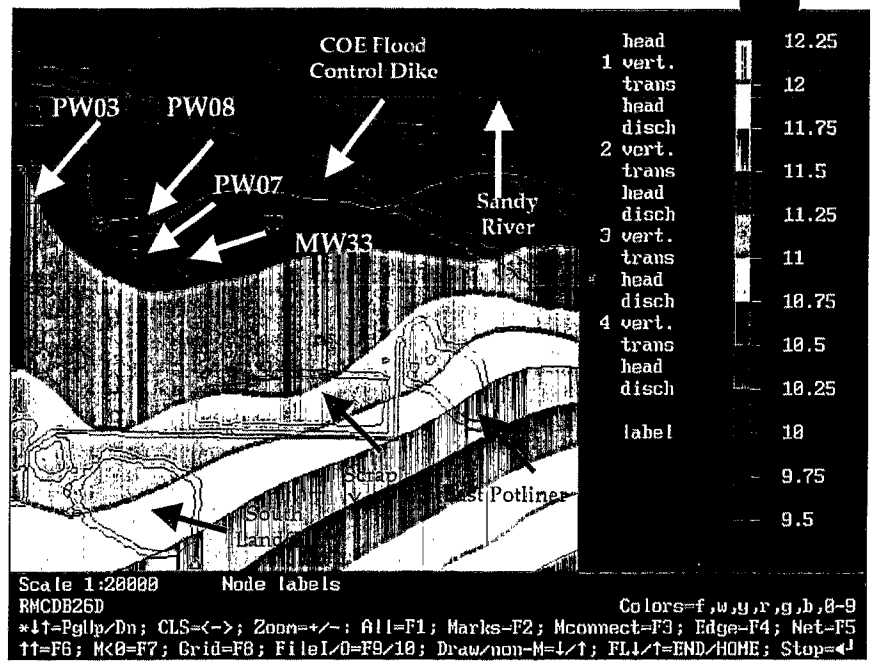
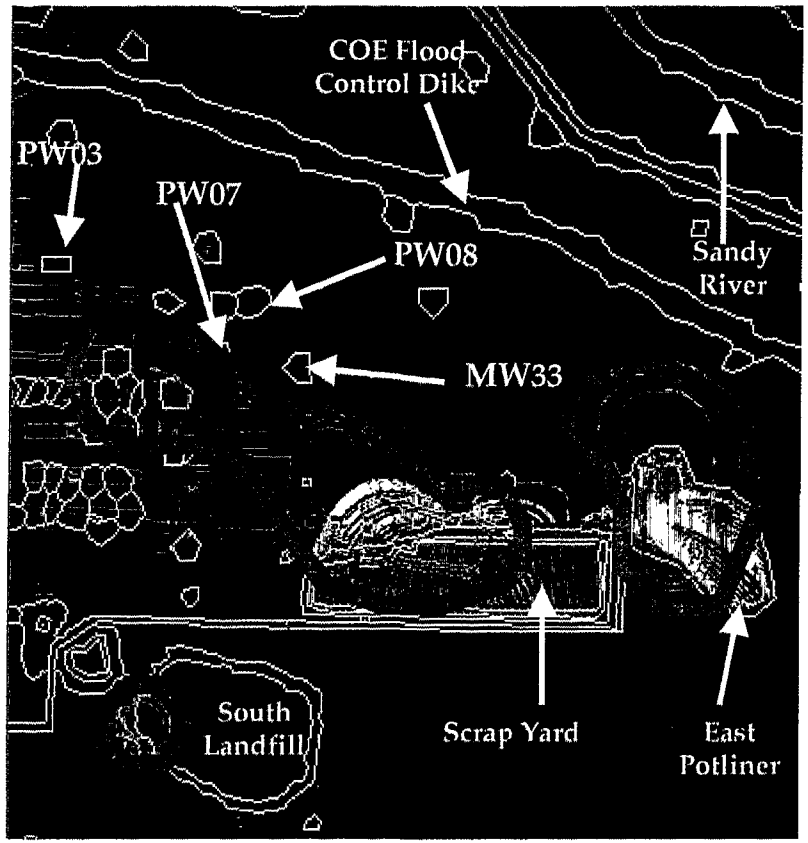


Figure A-24 shows groundwater elevation contour maps in the UGS (layer 3 of the model). These maps are the same as in Figure A-23, except the right-hand map shows UGS contours in the case where the focused extraction are deepened into the top of the intermediate zone (layer 4) because of low permeability in the UGS. The contour interval is 0.25 feet. The shifting of pumping into layer 4 removes the cone of depression in the UGS.

Figure A-24
Case 4: Sensitivity of UGS Groundwater Elevations to Decreased Hydraulic Conductivity in the UGS and to Shifting Pumping from the UGS into the Intermediate Zone
(Focused Extraction at Scrap Yard and East Potliner)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study



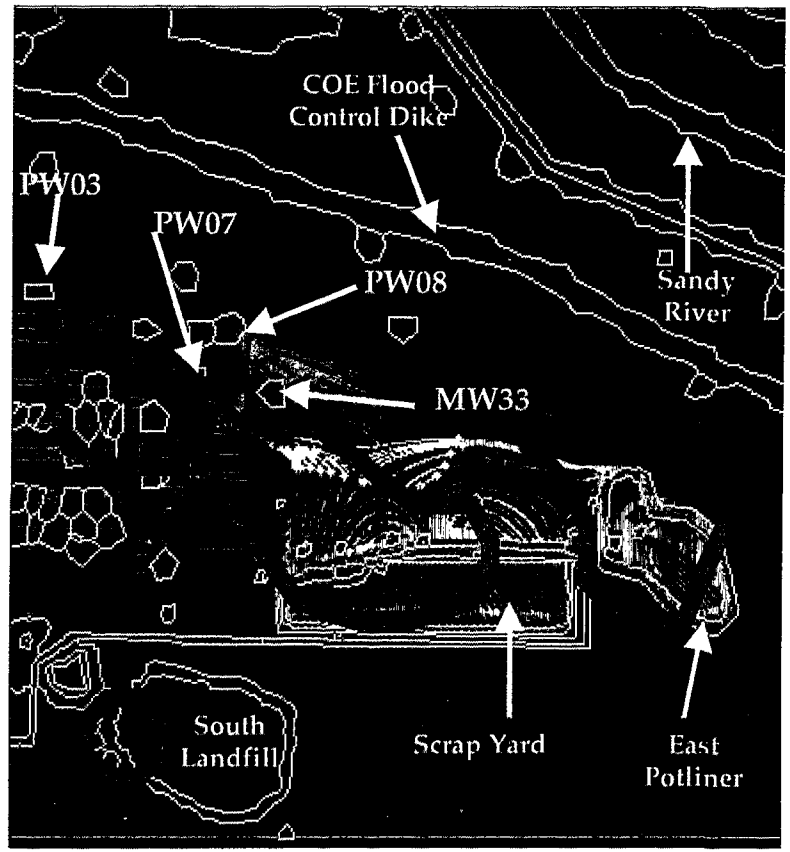
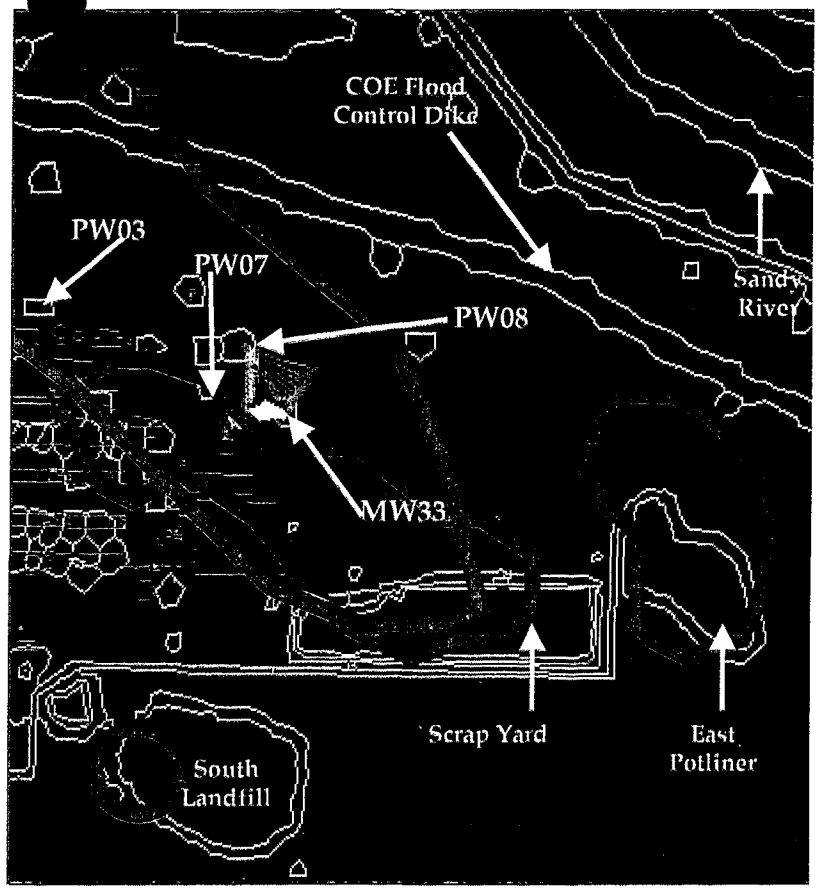


Figure A-25 shows the traces of particles that are initiated at the top of the UGS along the entire northern perimeter of Scrap Yard for the base case run (left) and the sensitivity run (right). For the sensitivity simulation, particles initiated along the western perimeter of scrap yard and the northern portion of east potliner move to production well PW08 rather than the focused extraction wells. The thick blue lines are the outlines of the fluoride plume that is present in the UGS.

Figure A-25
Case 4:
Sensitivity of Focused Extraction to Decreased Hydraulic Conductivity in the UGS and Shifting Pumping to the Intermediate Zone (Particles Initiated at Scrap Yard and East Potliner)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study



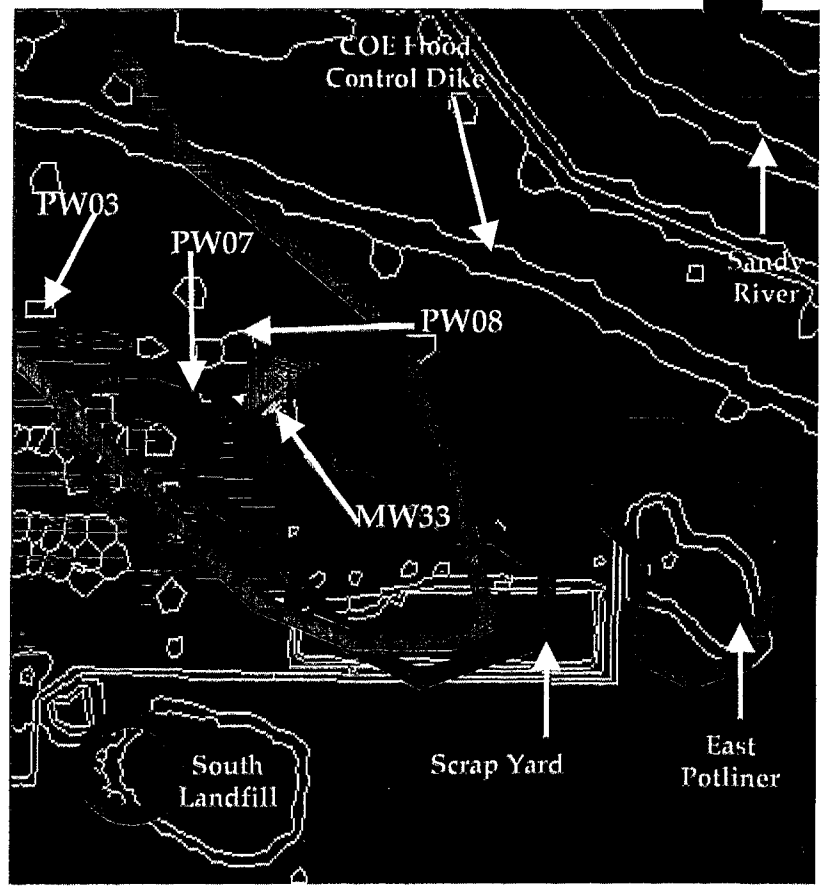


Figure A-26 shows the traces of particles that are initiated at MW33-095 at the top of the deep portion of the intermediate zone (model layer 5, shown in white). The base case run is shown on the left and the sensitivity run is shown on the right. For both runs, migration is to the open interval of well PW8 in model layer 7 (dark green). The thick blue and red lines are the outlines of the fluoride plumes that are present in the UGS and the intermediate zone, respectively.

Figure A-26
Case 4:
Sensitivity of Focused Extraction to Decreased Hydraulic Conductivity in the UGS and Shifting Pumping to the Intermediate Zone (Particles Initiated at MW33-095)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

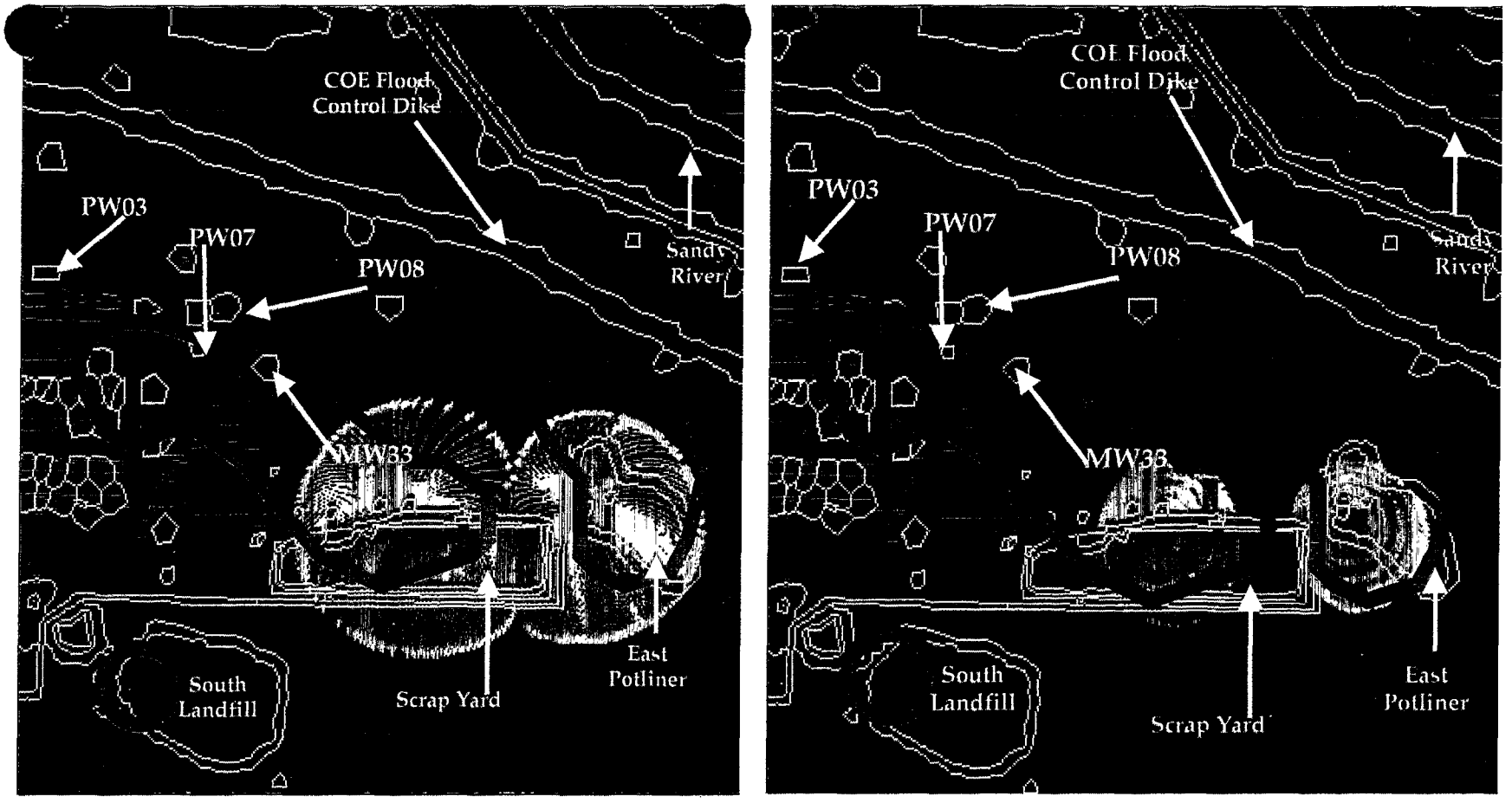


Figure A-27 shows the traces of particles that are tracked backwards in time from the scrap yard and east potliner focused extraction wells. 100 particles are initiated in the upper 1/4th of Layer 3 (the UGS) and tracked backwards for 10 years. The green traces lie within the UGS, the cyan traces lie within the lower portion of the silt unit (layer 2 of the model), and the yellow traces lie within the upper portion of the silt unit (model layer 1). The thick blue lines are the outlines of the fluoride plume that is present in the UGS.

Figure A-27
Case 4:
Sensitivity of Focused Extraction to Decreased Hydraulic Conductivity in the UGS and Shifting Pumping to the Intermediate Zone (10-Year Groundwater Capture Zone for Particles Initiated in the Upper ¼ of the UGS)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

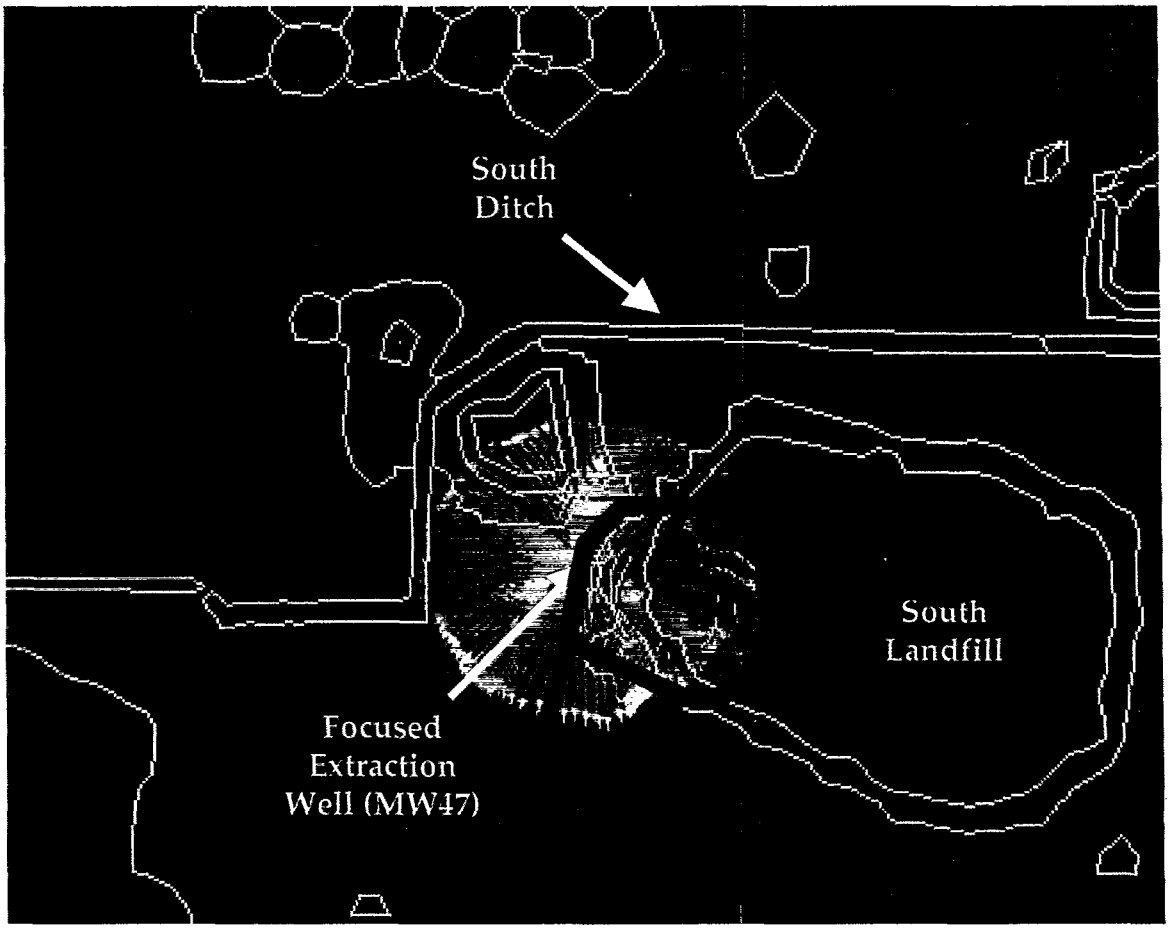


Figure A-28 shows reverse particle tracking from the south landfill focused extraction well under groundwater option 4. 100 particles are initiated at the well in the upper 15 percent of Layer 3 (the UGS) and tracked backwards for 10 years. The green traces lie within the UGS, and the cyan traces lie within the lower portion of the silt unit (layer 2 of the model). The blue contour line shows the outline of the UGS fluoride plume.

Figure A-28
10-Year Capture Zone for South Landfill Focused Extraction Well Under Groundwater Option 3
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

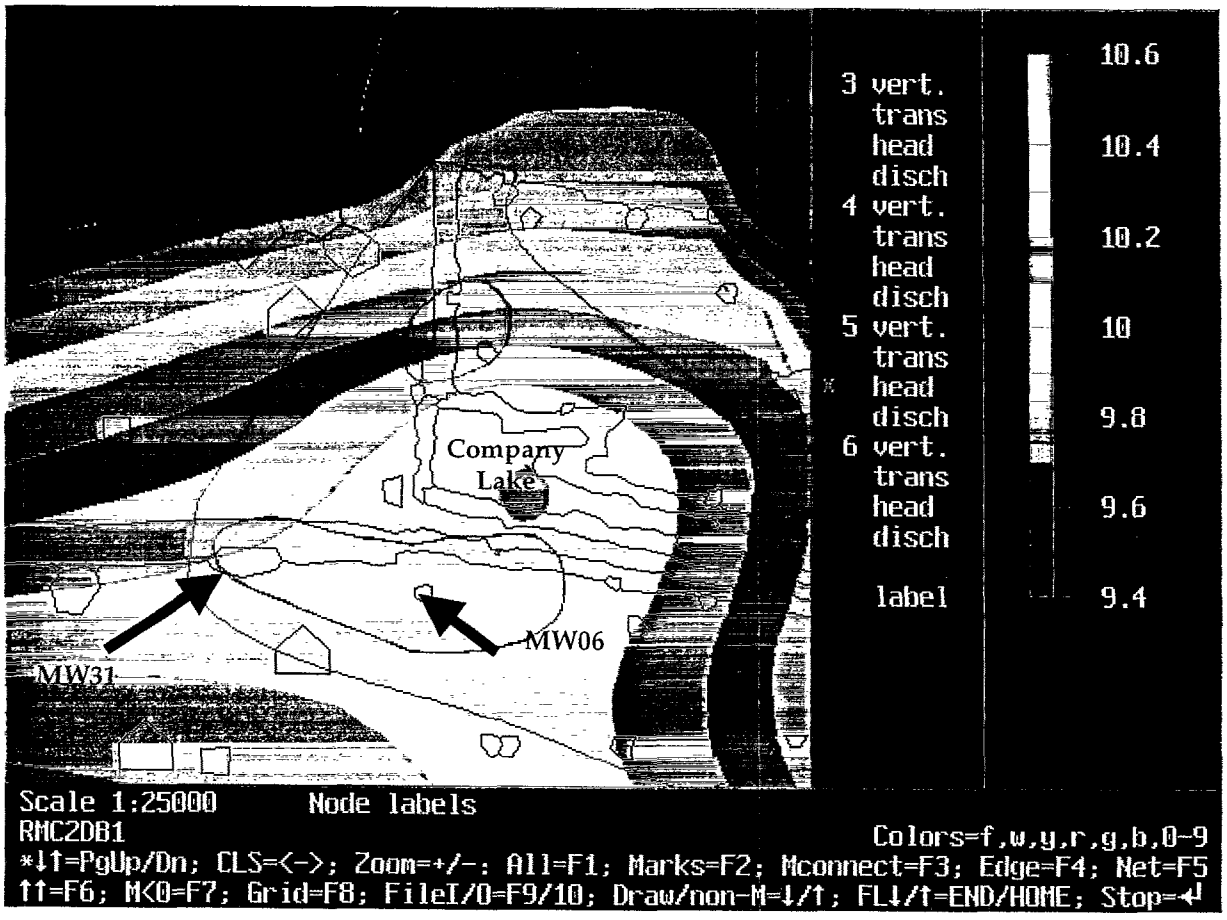


Figure A-29 shows groundwater elevation contours in the lower portion of the intermediate zone (layer 5 of the model) near Company Lake when the production wells are operating at their long-term historical average pumping rate (1,800 gpm). The contour interval is 0.1 feet. The brown, yellow, and green contours represent the highest groundwater elevations, and the gray and blue contours represent the lowest elevations. The highest elevations are in the southwest corner of the figure and beneath Company Lake. The broad area in yellow indicates a region of low groundwater velocities, including along the southwest corner of the lake. This coincides with the location of elevated fluoride concentrations in the intermediate zone, as indicated in red by the closed fluoride concentration contour. A stagnation point is present within this closed contour where groundwater from the southwestern corner of the lake is trying to move south while groundwater in the southern portion of Fairview Farms is trying to move north towards the lake.

Figure A-29
Groundwater Elevation Contour Map of the Intermediate Zone Near Company Lake (Under Long-Term Historical Production Well Operations)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

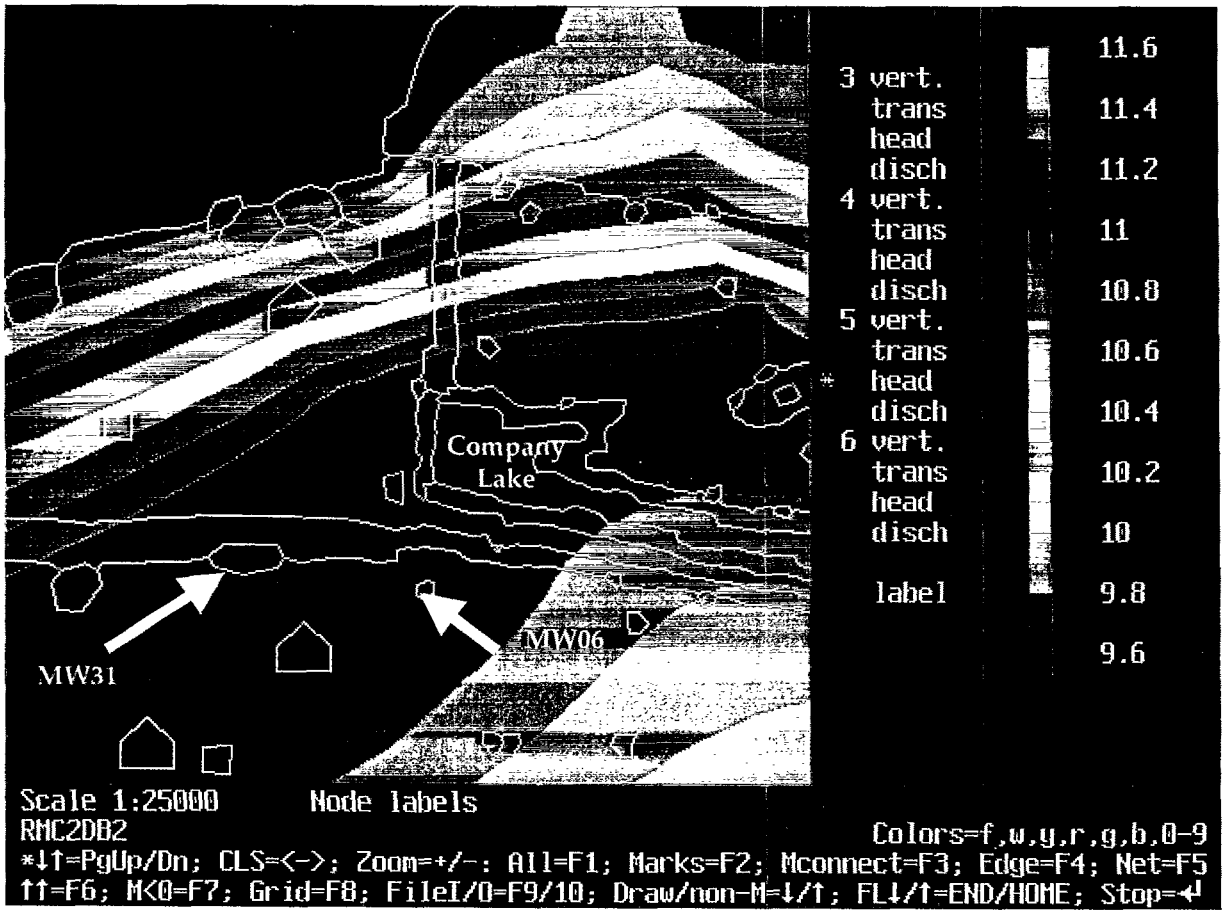


Figure A-30 shows groundwater elevation contours in the lower portion of the intermediate zone (layer 5 of the model) near Company Lake when the production wells are turned off for a sustained period of time. The contour interval is 0.1 feet. The highest elevations are in the southeast corner of the figure, and the lowest elevations are along the north side of the figure. The figure shows no evidence of a stagnation point in groundwater southwest of Company Lake, which was seen in the simulation of historical pumping. Wells MW06 and MW31 are cross-gradient of the lake.

Figure A-30
Groundwater Elevation Contour Map of the Intermediate Zone Near Company Lake
(Under A Sustained Period of No Pumping of the Production Wells)
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

Figure A-31 shows reverse particle tracking from three focused extraction wells located southwest of Company Lake. The wells are located in an area of elevated fluoride concentrations in the intermediate zone and are pumped from this zone. 50 particles are initiated at each well in the middle of Layer 5 (the lower portion of the intermediate zone) and tracked backwards for 10 years. The traces are dark blue in the upper portion of the deep zone (layer 6), white in the lower portion of the intermediate zone (layer 5), magenta in the upper portion of the intermediate zone (layer 4), green in the UGS (layer 3), and cyan and yellow traces lie within overlying portions of the UGS (layers 2 and 1, respectively). The red contour lines show the intermediate-zone fluoride plume. The enclosed contour in which the wells are situated is the area of highest fluoride concentrations in this zone near Company Lake.

Figure A-31
10-Year Capture Zone for Focused Extraction Wells Southwest of Company Lake
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

SRB COLOR2S.DWG
06-OCT-1999

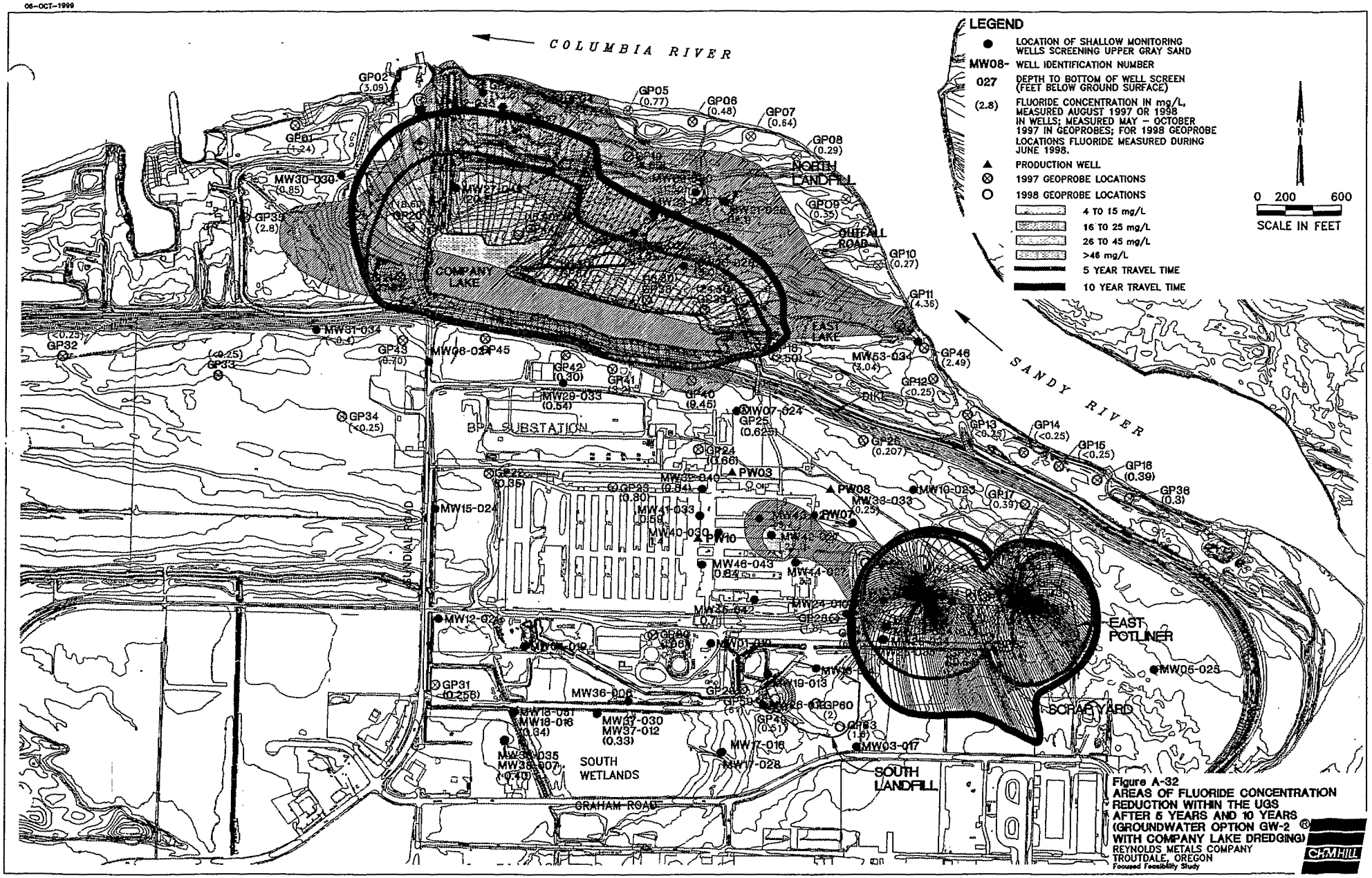


Figure A-32
AREAS OF FLUORIDE CONCENTRATION REDUCTION WITHIN THE UGS AFTER 5 YEARS AND 10 YEARS (GROUNDWATER OPTION GW-2 WITH COMPANY LAKE DREDGING)
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2MHILL

COLOR2S.DWG

SRB COLOR5S.DWG
06-OCT-1999

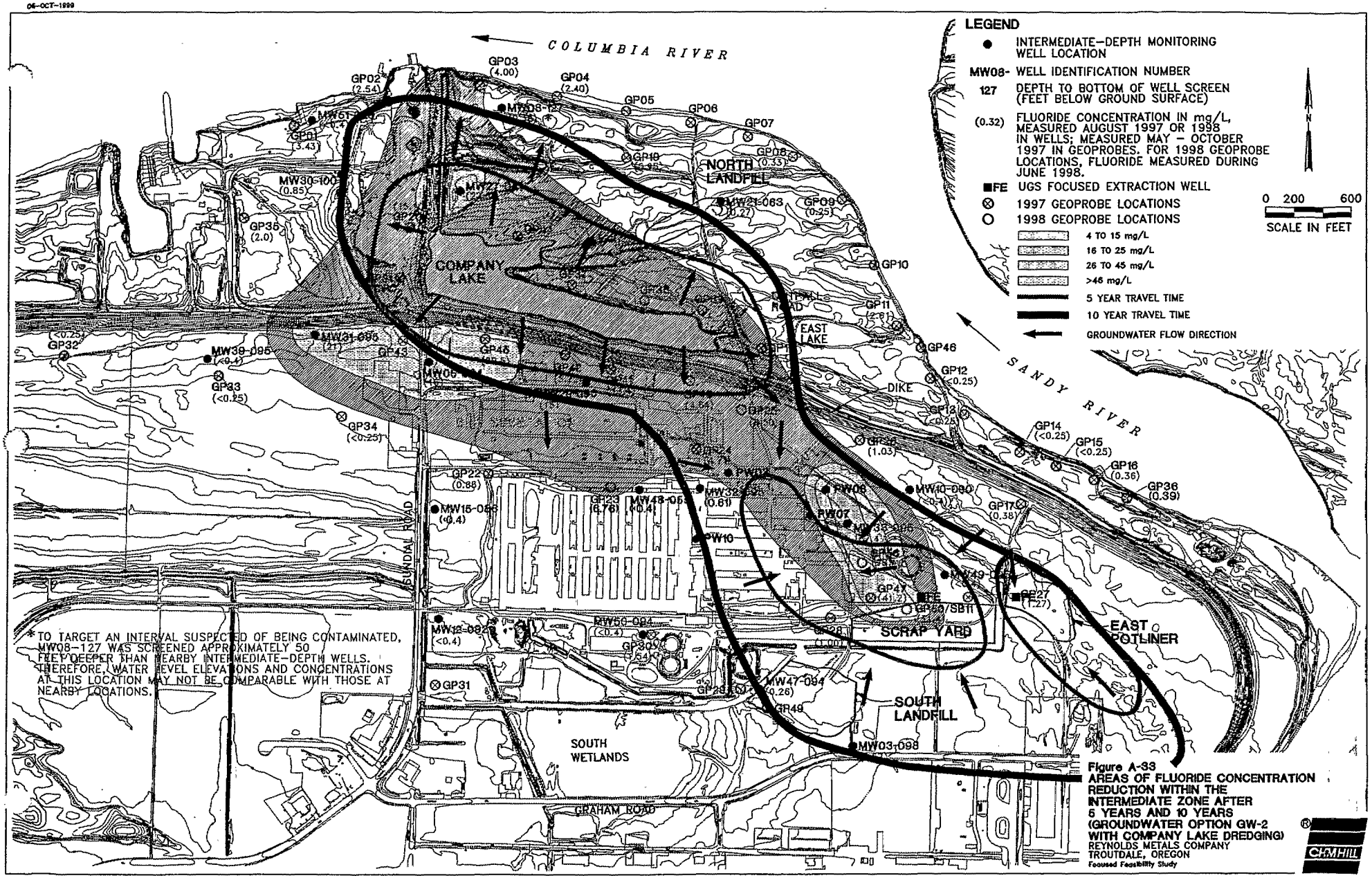


Figure A-33
AREAS OF FLUORIDE CONCENTRATION REDUCTION WITHIN THE INTERMEDIATE ZONE AFTER 5 YEARS AND 10 YEARS (GROUNDWATER OPTION GW-2 WITH COMPANY LAKE DREDGING)
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

COLOR5S.DWG

06-OCT-1999

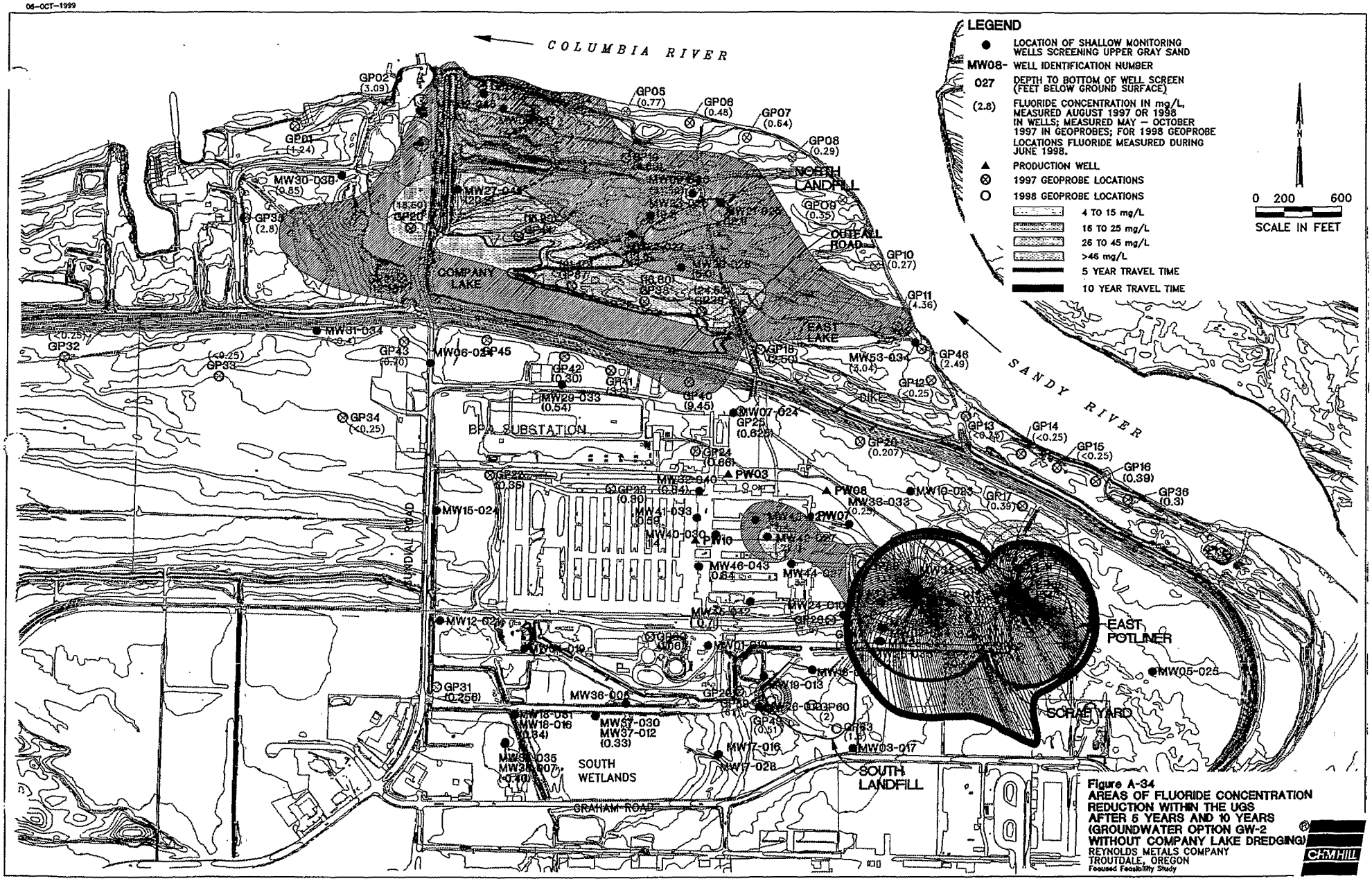


Figure A-34
AREAS OF FLUORIDE CONCENTRATION REDUCTION WITHIN THE UGS AFTER 5 YEARS AND 10 YEARS (GROUNDWATER OPTION GW-2 WITHOUT COMPANY LAKE DREDGING)
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

COLOR2T.DWG

SRB COLOR5T.DWG
08-OCT-1999

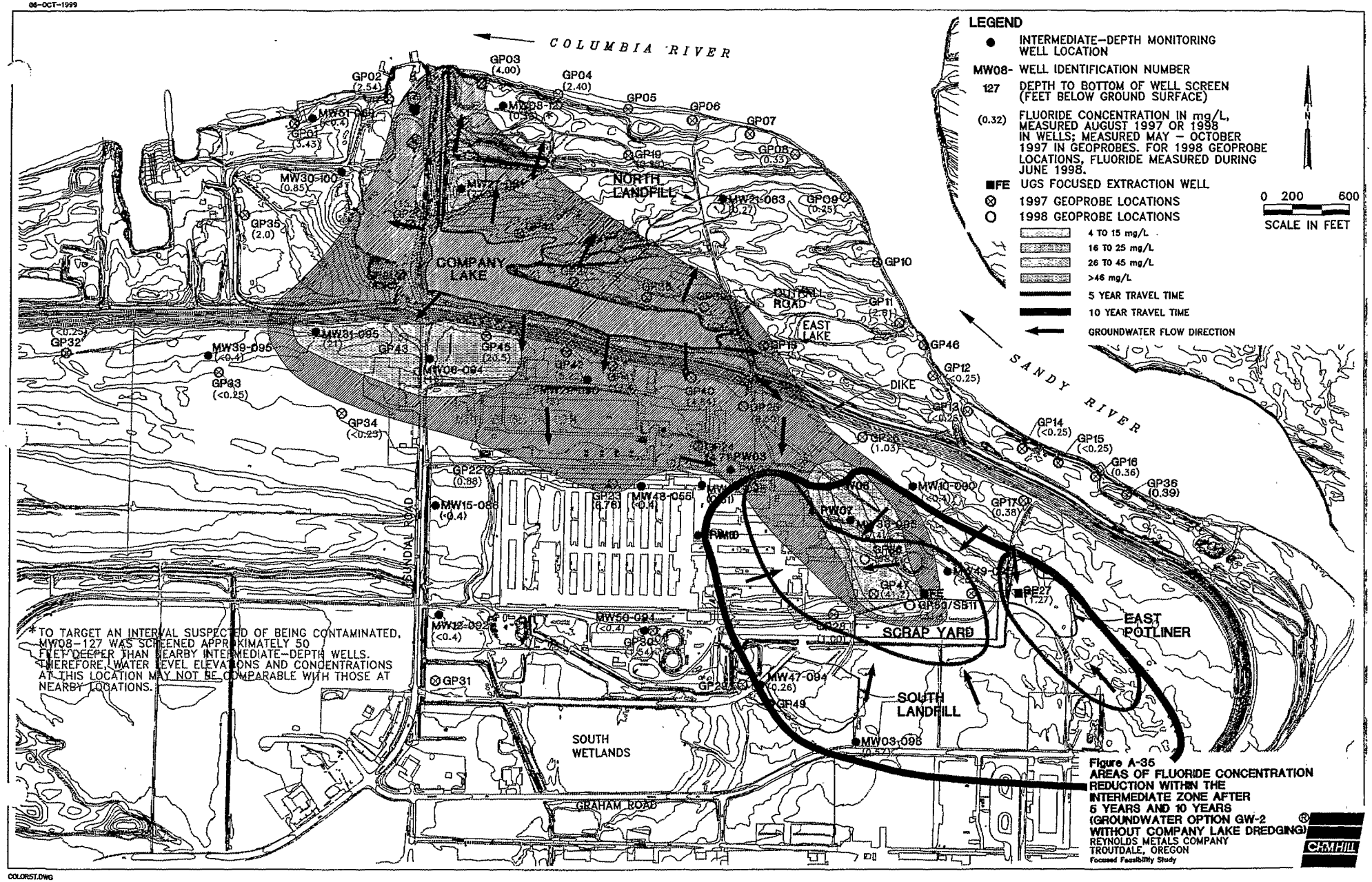


Figure A-35
AREAS OF FLUORIDE CONCENTRATION REDUCTION WITHIN THE INTERMEDIATE ZONE AFTER 5 YEARS AND 10 YEARS (GROUNDWATER OPTION GW-2 WITHOUT COMPANY LAKE DREDGING)
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

COLOR5T.DWG

SRB COLOR3V.DWG
05-OCT-1999

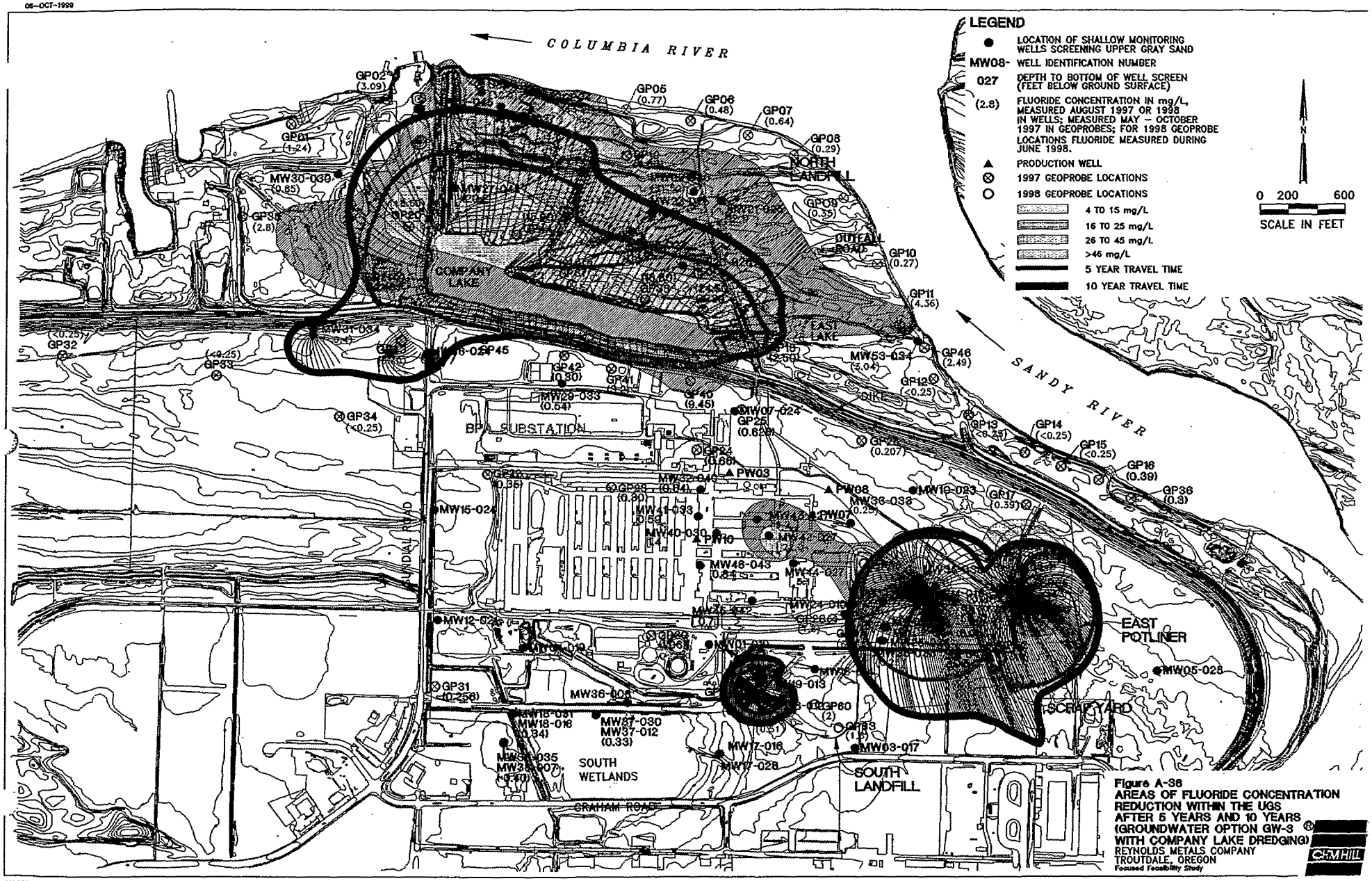


Figure A-36
AREAS OF FLUORIDE CONCENTRATION REDUCTION WITHIN THE UGS AFTER 5 YEARS AND 10 YEARS (GROUNDWATER OPTION GW-3 WITH COMPANY LAKE DREDGING)
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

COLOR3V.DWG

SRB COLOR5V.DWG
08-OCT-1998

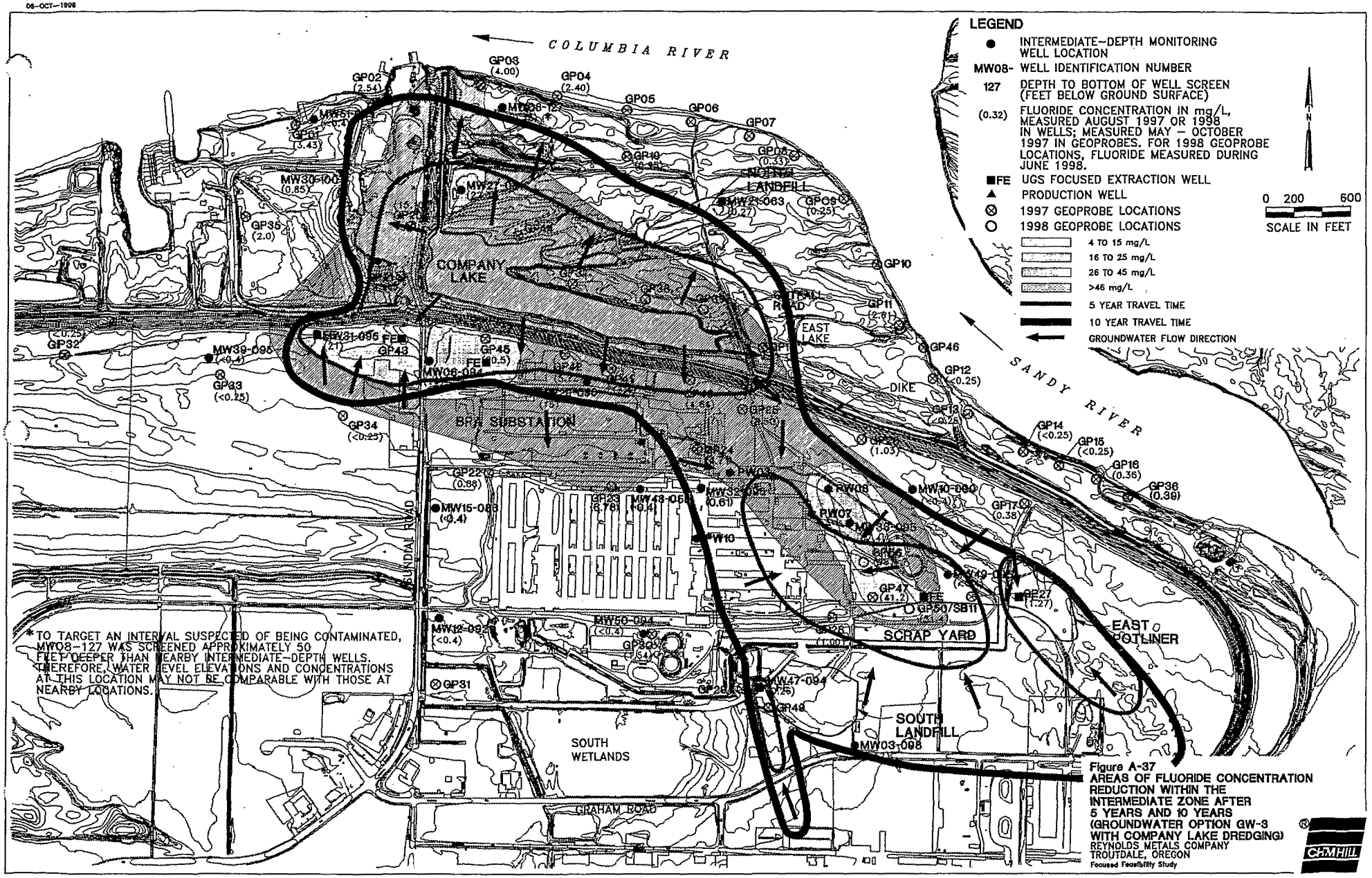


Figure A-37
AREAS OF FLUORIDE CONCENTRATION REDUCTION WITHIN THE INTERMEDIATE ZONE AFTER 5 YEARS AND 10 YEARS (GROUNDWATER OPTION GW-3 WITH COMPANY LAKE DREDGING)
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

COLOR5V.DWG

06-OCT-1999

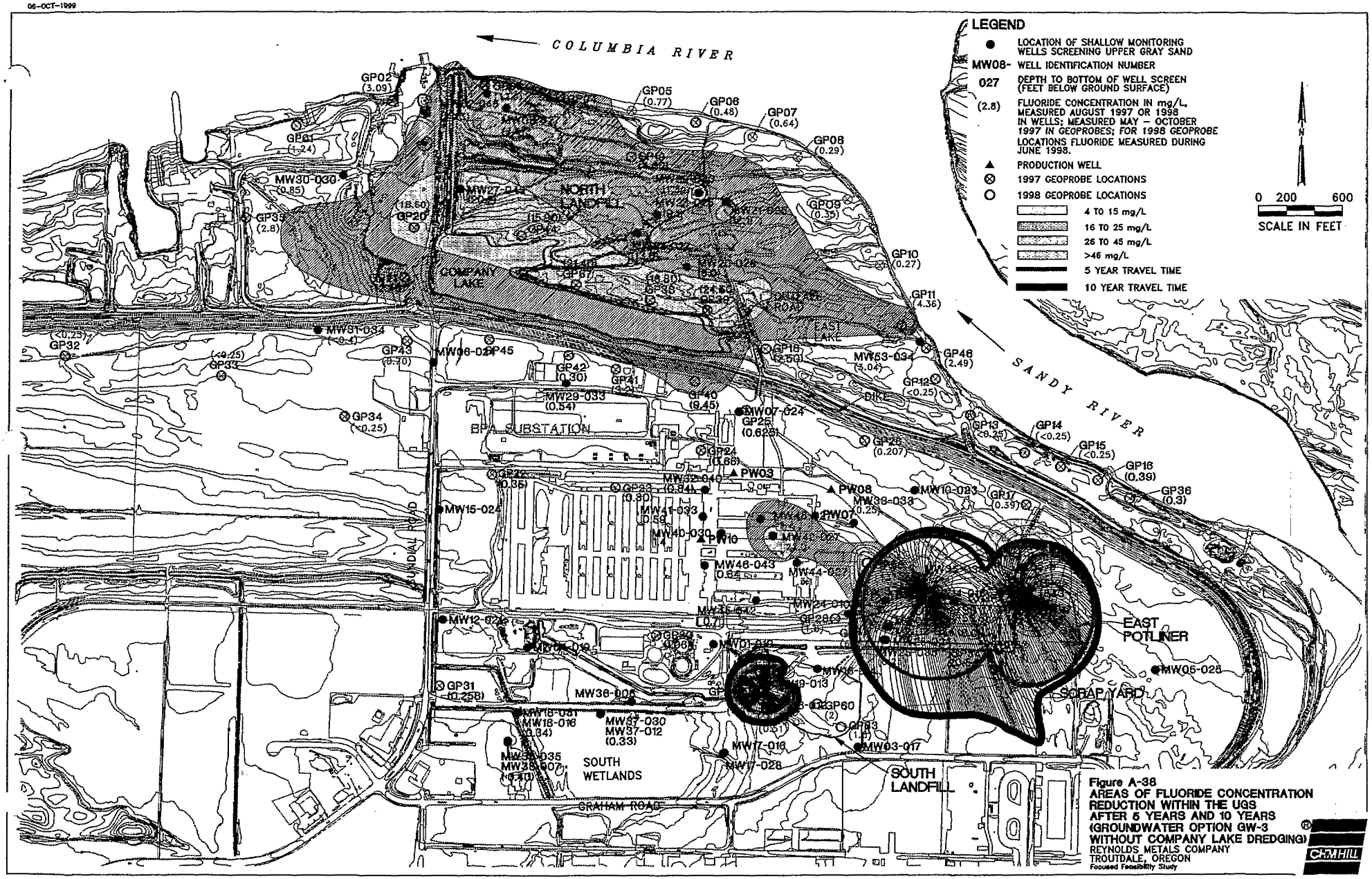


Figure A-38
AREAS OF FLUORIDE CONCENTRATION REDUCTION WITHIN THE UGS AFTER 5 YEARS AND 10 YEARS (GROUNDWATER OPTION GW-3 WITHOUT COMPANY LAKE DREDGING)
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2MHILL

COLOR2U.DWG

SRB COLOR5U.DWG
06-OCT-1999

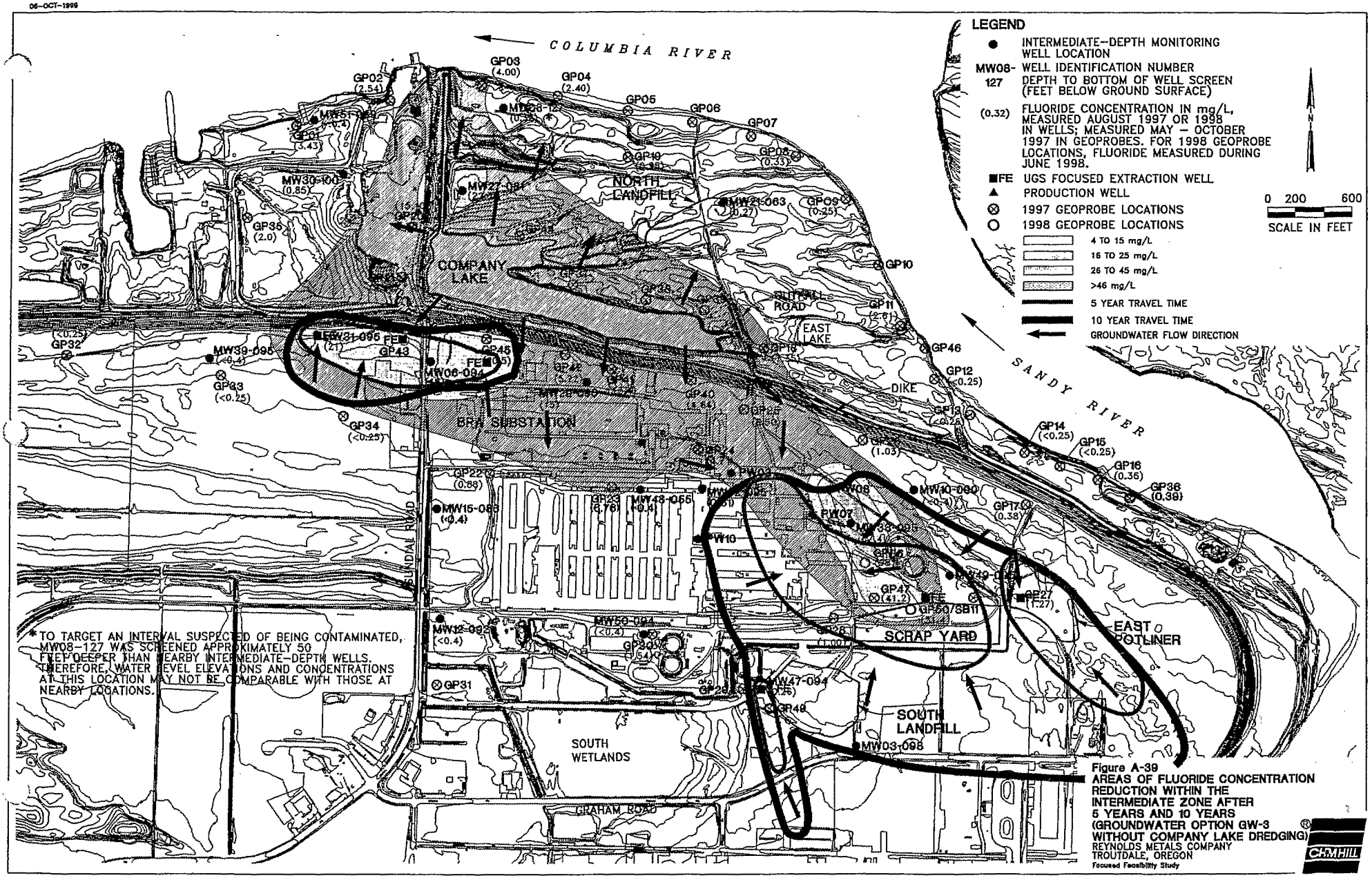


Figure A-39
AREAS OF FLUORIDE CONCENTRATION REDUCTION WITHIN THE INTERMEDIATE ZONE AFTER 5 YEARS AND 10 YEARS (GROUNDWATER OPTION GW-3 WITHOUT COMPANY LAKE DREDGING)
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

COLOR5U.DWG

ATTACHMENT TO APPENDIX A

Silt Unit Groundwater Elevation Data in South Plant Soil and Debris Areas

Silt Unit Groundwater Elevations: East Potliner, Scrap Yard, and South Landfill Areas
Reynolds Metals Company - Troutdale, Oregon

Well	Area	Date	Screened Interval (ft bgs)	MPE (feet)	GSE (feet)	Depth to Water (ft below MPE)	Depth to Water (ft bgs)	GW Elev (feet)	Yearly Max/Min Water Table (feet) By Well		Max / Min By Area (1994-1998) (Excluding MW03 and MW14)
East Potliner Area (No waste - previously removed)											
MW11-017	East Potliner	08/08/1994	7 to 17	31.61	29.50	13.22	11.11	18.39			
MW11-017		09/08/1994		31.61	29.50	14.21	12.10	17.40	1994 High WT: GW Elev	24.92	Does not apply to EPL,
MW11-017		10/07/1994		31.61	29.50	15.32	13.21	16.29	1994 Low WT: GW Elev	16.29	only one silt well.
MW11-017		10/28/1994		31.61	29.50	15.16	13.05	16.45	1994 High WT: Depth bgs	4.58	
MW11-017		12/13/1994		31.61	29.50	6.69	4.58	24.92	1994 Low WT: Depth bgs	13.21	
MW11-017		01/04/1995		31.61	29.50	6.41	4.30	25.20			
MW11-017		02/02/1995		31.61	29.50	4.54	2.43	27.07	1995 High WT: GW Elev	27.07	
MW11-017		02/17/1995		31.61	29.50	5.05	2.94	26.56	1995 Low WT: GW Elev	18.60	
MW11-017		03/01/1995		31.61	29.50	5.62	3.51	25.99	1995 High WT: Depth bgs	2.43	
MW11-017		04/04/1995		31.61	29.50	6.57	4.46	25.04	1995 Low WT: Depth bgs	13.21	
MW11-017		05/03/1995		31.61	29.50	5.72	3.61	25.89			
MW11-017		06/06/1995		31.61	29.50	6.67	4.56	24.94			
MW11-017		06/28/1995		31.61	29.50	7.30	5.19	24.31			
MW11-017		08/01/1995		31.61	29.50	9.18	7.07	22.43			
MW11-017		09/07/1995		31.61	29.50	11.88	9.77	19.73			
MW11-017		10/05/1995		31.61	29.50	13.01	10.90	18.60			
MW11-017		11/03/1995		31.61	29.50	10.24	8.13	21.37			
MW11-017		12/01/1995		31.61	29.50	5.02	2.91	26.59			
MW11-017		01/04/1996		31.61	29.50	5.05	2.94	26.56			
MW11-017		02/02/1996		31.61	29.50	5.98	3.87	25.63	1996 High WT: GW Elev	26.61	
MW11-017		03/01/1996		31.61	29.50	5.45	3.34	26.16	1996 Low WT: GW Elev	20.75	
MW11-017		04/01/1996		31.61	29.50	5.00	2.89	26.61	1996 High WT: Depth bgs	2.89	
MW11-017		05/08/1996		31.61	29.50	5.60	3.49	26.01	1996 Low WT: Depth bgs	8.75	
MW11-017		06/07/1996		31.61	29.50	5.90	3.79	25.71			
MW11-017		07/01/1996		31.61	29.50	6.96	4.85	24.65			
MW11-017		08/01/1996		31.61	29.50	8.95	6.84	22.66			
MW11-017		09/04/1996		31.61	29.50	10.86	8.75	20.75			
MW11-017		10/02/1996		31.61	29.50	10.77	8.66	20.84			
MW11-017		11/04/1996		31.61	29.50	8.98	6.87	22.63			
MW11-017		12/02/1996		31.61	29.50	6.68	4.57	24.93			
MW11-017		01/06/1997		31.61	29.50	4.65	2.54	26.96			
MW11-017		02/05/1997		31.61	29.50	5.23	3.12	26.38	1997 High WT: GW Elev	26.96	
MW11-017		02/28/1997		31.61	29.50	6.04	3.93	25.57	1997 Low WT: GW Elev	21.43	
MW11-017		03/11/1997		31.61	29.50	5.40	3.29	26.21	1997 High WT: Depth bgs	2.54	
MW11-017		04/04/1997		31.61	29.50	5.60	3.49	26.01	1997 Low WT: Depth bgs	8.07	
MW11-017		05/01/1997		31.61	29.50	5.32	3.21	26.29			
MW11-017		06/04/1997		31.61	29.50	5.94	3.83	25.67			
MW11-017		07/01/1997		31.61	29.50	6.44	4.33	25.17			
MW11-017		08/06/1997		31.61	29.50	7.74	5.63	23.87			
MW11-017		09/02/1997		31.61	29.50	9.31	7.20	22.30			
MW11-017		10/03/1997		31.61	29.50	10.18	8.07	21.43			
MW11-017		11/07/1997		31.61	29.50	8.71	6.60	22.90			
MW11-017		12/03/1997		31.61	29.50	8.04	5.93	23.57			
MW11-017		01/06/1998		31.61	29.50	7.10	4.99	24.51			
MW11-017		02/05/1998		31.61	29.50	5.67	3.56	25.94	1998 High WT: GW Elev	26.43	
MW11-017		03/04/1998		31.61	29.50	5.18	3.07	26.43	1998 Low WT: GW Elev	23.37	
MW11-017		05/04/1998		31.61	29.50	6.52	4.41	25.09	1998 High WT: Depth bgs	3.07	
MW11-017		08/04/1998		31.61	29.50	8.24	6.13	23.37	1998 Low WT: Depth bgs	6.13	

Silt Unit Groundwater Elevations: East Potliner, Scrap Yard, and South Landfill Areas
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Well	Area	Date	Screened Interval ((ft bgs)	MPE (feet)	GSE (feet)	Depth to Water (ft below MPE)	Depth to Water (ft bgs)	GW Elev (feet)	Yearly Max/Min Water Table (feet) By Well		Max / Min By Area (1994-1998) (Excluding MW03 and MW14)	
Scrap Yard Area (Waste Material depth approximately 2 feet deep)												
MW02-012	Scrap Yard	08/01/1995	7 to 12	31.10	28.30	13.52	10.72	17.58				
MW02-012		09/07/1995		31.10	28.30	14.82	12.02	16.28	1995 High WT: GW Elev	23.32	SY 1995 High WT GW Elev	24.19
MW02-012		10/05/1995		31.10	28.30	14.90	12.10	16.20	1995 Low WT: GW Elev	16.20	SY 1995 Low WT GW Elev	9.35
MW02-012		11/03/1995		31.10	28.30	13.26	10.46	17.84	1995 High WT: Depth bgs	4.98	SY 1995 High WT Depth bgs	4.31
MW02-012		12/01/1995		31.10	28.30	7.78	4.98	23.32	1995 Low WT: Depth bgs	12.10	SY 1995 Low WT Depth bgs	18.95
MW02-012		01/04/1996		31.10	28.30	8.64	5.84	22.46				
MW02-012		02/02/1996		31.10	28.30	7.68	4.88	23.42	1996 High WT: GW Elev	24.98	SY 1996 High WT GW Elev	24.98
MW02-012		03/01/1996		31.10	28.30	6.12	3.32	24.98	1996 Low WT: GW Elev	17.58	SY 1996 Low WT GW Elev	10.68
MW02-012		04/01/1996		31.10	28.30	9.33	6.53	21.77	1996 High WT: Depth bgs	3.32	SY 1996 High WT Depth bgs	3.17
MW02-012		05/06/1996		31.10	28.30	8.40	5.60	22.70	1996 Low WT: Depth bgs	10.72	SY 1996 Low WT Depth bgs	17.62
MW02-012		06/07/1996		31.10	28.30	8.32	5.52	22.78				
MW02-012		07/01/1996		31.10	28.30	10.29	7.49	20.81				
MW02-012		08/01/1996		31.10	28.30	12.40	9.60	18.70				
MW02-012		09/04/1996		31.10	28.30	13.52	10.72	17.58				
MW02-012		11/04/1996		31.10	28.30	11.48	8.68	19.62				
MW02-012		12/02/1996		31.10	28.30	8.10	5.30	23.00				
MW02-012		01/06/1997		31.10	28.30	4.80	2.00	26.30				
MW02-012		02/05/1997		31.10	28.30	6.40	3.60	24.70				
MW02-012		02/28/1997		31.10	28.30	9.11	6.31	21.99				
MW02-012		03/11/1997		31.10	28.30	8.29	5.49	22.81				
MW02-012		04/04/1997		31.10	28.30	8.07	5.27	23.03	1997 High WT: GW Elev	26.30	SY 1997 High WT GW Elev	26.30
MW02-012		05/01/1997		31.10	28.30	8.04	5.24	23.06	1997 Low WT: GW Elev	16.99	SY 1997 Low WT GW Elev	10.96
MW02-012		06/04/1997		31.10	28.30	7.93	5.13	23.17	1997 High WT: Depth bgs	2.00	SY 1997 High WT Depth bgs	2.00
MW02-012		07/01/1997		31.10	28.30	8.23	5.43	22.87	1997 Low WT: Depth bgs	11.31	SY 1997 Low WT Depth bgs	17.34
MW02-012		08/06/1997		31.10	28.30	11.94	9.14	19.16				
MW02-012		09/02/1997		31.10	28.30	13.03	10.23	18.07				
MW02-012		10/03/1997		31.10	28.30	14.11	11.31	16.99				
MW02-012		11/07/1997		31.10	28.30	11.97	9.17	19.13				
MW02-012		12/03/1997		31.10	28.30	11.50	8.70	19.60				
MW02-012		01/06/1998		31.10	28.30	10.93	8.13	20.17				
MW02-012		02/05/1998		31.10	28.30	9.29	6.49	21.81	1998 High WT: GW Elev	22.55	SY 1998 High WT GW Elev	23.08
MW02-012		03/04/1998		31.10	28.30	8.55	5.75	22.55	1998 Low WT: GW Elev	18.03	SY 1998 Low WT GW Elev	12.54
MW02-012		05/04/1998		31.10	28.30	11.86	9.06	19.24	1998 High WT: Depth bgs	5.75	SY 1998 High WT Depth bgs	4.22
MW02-012		08/04/1998		31.10	28.30	13.07	10.27	18.03	1998 Low WT: Depth bgs	10.27	SY 1998 Low WT Depth bgs	15.76
MW13-022	Scrap Yard	08/01/1995	17 to 22	30.88	28.30	18.25	15.67	12.63				
MW13-022		09/07/1995		30.88	28.30	20.52	17.94	10.36	1995 High WT: GW Elev	17.18		
MW13-022		10/05/1995		30.88	28.30	21.53	18.95	9.35	1995 Low WT: GW Elev	9.35		
MW13-022		11/03/1995		30.88	28.30	21.05	18.47	9.83	1995 High WT: Depth bgs	11.12		
MW13-022		12/01/1995		30.88	28.30	13.70	11.12	17.18	1995 Low WT: Depth bgs	18.95		
MW13-022		01/04/1996		30.88	28.30	11.68	9.10	19.20				
MW13-022		02/02/1996		30.88	28.30	10.08	7.50	20.80	1996 High WT: GW Elev	23.59		
MW13-022		03/01/1996		30.88	28.30	7.29	4.71	23.59	1996 Low WT: GW Elev	10.68		
MW13-022		04/01/1996		30.88	28.30	12.09	9.51	18.79	1996 High WT: Depth bgs	4.71		
MW13-022		05/06/1996		30.88	28.30	10.06	7.48	20.82	1996 Low WT: Depth bgs	17.62		
MW13-022		06/07/1996		30.88	28.30	9.46	6.88	21.42				
MW13-022		07/01/1996		30.88	28.30	12.25	9.67	18.63				
MW13-022		08/01/1996		30.88	28.30	16.42	13.84	14.46				
MW13-022		09/04/1996		30.88	28.30	18.85	16.27	12.03				
MW13-022		10/02/1996		30.88	28.30	20.20	17.62	10.68				
MW13-022		11/04/1996		30.88	28.30	19.81	17.23	11.07				
MW13-022		12/02/1996		30.88	28.30	12.10	9.52	18.78				
MW13-022		01/06/1997		30.88	28.30	5.65	3.07	25.23				
MW13-022		02/05/1997		30.88	28.30	7.82	5.24	23.06	1997 High WT: GW Elev	25.23		
MW13-022		02/28/1997		30.88	28.30	11.31	8.73	19.57	1997 Low WT: GW Elev	10.96		
MW13-022		03/11/1997		30.88	28.30	10.30	7.72	20.58	1997 High WT: Depth bgs	3.07		
MW13-022		04/04/1997		30.88	28.30	9.67	7.09	21.21	1997 Low WT: Depth bgs	17.34		
MW13-022		05/01/1997		30.88	28.30	8.51	5.93	22.37				
MW13-022		06/04/1997		30.88	28.30	8.11	5.53	22.77				
MW13-022		07/01/1997		30.88	28.30	9.45	6.87	21.43				
MW13-022		08/06/1997		30.88	28.30	15.55	12.97	15.33				
MW13-022		09/02/1997		30.88	28.30	17.82	15.24	13.06				
MW13-022		10/03/1997		30.88	28.30	19.92	17.34	10.96				
MW13-022		11/07/1997		30.88	28.30	18.80	16.22	12.08				
MW13-022		12/03/1997		30.88	28.30	18.10	15.52	12.78				
MW13-022		01/06/1998		30.88	28.30	17.00	14.42	13.88				
MW13-022		02/05/1998		30.88	28.30	12.70	10.12	18.18	1998 High WT: GW Elev	19.37		
MW13-022		03/04/1998		30.88	28.30	11.51	8.93	19.37	1998 Low WT: GW Elev	12.54		
MW13-022		05/04/1998		30.88	28.30	16.11	13.53	14.77	1998 High WT: Depth bgs	8.93		
MW13-022		08/04/1998		30.88	28.30	18.34	15.76	12.54	1998 Low WT: Depth bgs	28.30		

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Well	Area	Date	Screened Interval (ft bgs)	MPE (feet)	GSE (feet)	Depth to Water (ft below MPE)	Depth to Water (ft bgs)	GW Elev (feet)	Yearly Max/Min Water Table (feet) By Well		Max / Min By Area (1994-1998) (Excluding MW03 and MW14)
MW14-015	Scrap Yard	08/01/1995	5 to 15	30.88	28.30	7.80	5.22	23.08			
MW14-015		09/07/1995		30.88	28.30	8.66	6.08	22.22	1995 High WT: GW Elev	27.63	
MW14-015		10/05/1995		30.88	28.30	9.17	6.59	21.71	1995 Low WT: GW Elev	21.71	
MW14-015		11/03/1995		30.88	28.30	8.30	5.72	22.58	1995 High WT: Depth bgs	0.67	
MW14-015		12/01/1995		30.88	28.30	3.25	0.67	27.63	1995 Low WT: Depth bgs	6.59	
MW14-015		01/04/1996		30.88	28.30	3.94	1.36	26.94			
MW14-015		02/02/1996		30.88	28.30	4.33	1.75	26.55	1996 High WT: GW Elev	27.65	
MW14-015		03/01/1996		30.88	28.30	3.98	1.40	26.90	1996 Low WT: GW Elev	21.83	
MW14-015		04/01/1996		30.88	28.30	5.11	2.53	25.77	1996 High WT: Depth bgs	0.65	
MW14-015		05/06/1996		30.88	28.30	4.89	2.31	25.99	1996 Low WT: Depth bgs	6.47	
MW14-015		06/07/1996		30.88	28.30	5.20	2.62	25.68			
MW14-015		07/01/1996		30.88	28.30	6.42	3.84	24.46			
MW14-015		08/01/1996		30.88	28.30	7.65	5.07	23.23			
MW14-015		09/04/1996		30.88	28.30	8.58	6.00	22.30			
MW14-015		10/02/1996		30.88	28.30	9.05	6.47	21.83			
MW14-015		11/04/1996		30.88	28.30	7.63	5.05	23.25			
MW14-015		12/02/1996		30.88	28.30	3.23	0.65	27.65			
MW14-015		01/06/1997		30.88	28.30	2.85	0.27	28.03			
MW14-015		02/05/1997		30.88	28.30	3.56	0.98	27.32	1997 High WT: GW Elev	28.03	
MW14-015		02/28/1997		30.88	28.30	4.94	2.36	25.94	1997 Low WT: GW Elev	21.98	
MW14-015		03/11/1997		30.88	28.30	2.85	0.27	28.03	1997 High WT: Depth bgs	0.27	
MW14-015		04/04/1997		30.88	28.30	4.88	2.30	26.00	1997 Low WT: Depth bgs	6.32	
MW14-015		05/01/1997		30.88	28.30	4.55	1.97	26.33			
MW14-015		06/04/1997		30.88	28.30	8.73	6.15	22.15			
MW14-015		07/01/1997		30.88	28.30	6.11	3.53	24.77			
MW14-015		08/06/1997		30.88	28.30	7.41	4.83	23.47			
MW14-015		09/02/1997		30.88	28.30	8.24	5.66	22.64			
MW14-015		10/03/1997		30.88	28.30	8.90	6.32	21.98			
MW14-015		11/07/1997		30.88	28.30	7.64	5.06	23.24			
MW14-015		12/03/1997		30.88	28.30	6.99	4.41	23.89			
MW14-015		01/06/1998		30.88	28.30	5.75	3.17	25.13			
MW14-015		02/05/1998		30.88	28.30	4.49	1.91	26.39	1998 High WT: GW Elev	27.98	
MW14-015		03/04/1998		30.88	28.30	2.90	0.32	27.98	1998 Low WT: GW Elev	22.99	
MW14-015		05/04/1998		30.88	28.30	6.58	4.00	24.30	1998 High WT: Depth bgs	0.32	
MW14-015		08/04/1998		30.88	28.30	7.89	5.31	22.99	1998 Low WT: Depth bgs	5.31	
MW14-015		09/02/1998		30.88	28.30						
MW24-010	Scrap Yard	08/01/1995	5 to 10	30.13	27.30	9.93	7.10	20.20			
MW24-010		09/07/1995		30.13	27.30	10.68	7.85	19.45	1995 High WT: GW Elev	21.80	
MW24-010		10/05/1995		30.13	27.30	11.14	8.31	18.99	1995 Low WT: GW Elev	18.99	
MW24-010		11/03/1995		30.13	27.30	11.01	8.18	19.12	1995 High WT: Depth bgs	5.50	
MW24-010		12/01/1995		30.13	27.30	8.33	5.50	21.80	1995 Low WT: Depth bgs	8.31	
MW24-010		01/04/1996		30.13	27.30	7.25	4.42	22.88			
MW24-010		02/02/1996		30.13	27.30	6.74	3.91	23.39	1996 High WT: GW Elev	24.13	
MW24-010		03/01/1996		30.13	27.30	6.00	3.17	24.13	1996 Low WT: GW Elev	19.23	
MW24-010		04/01/1996		30.13	27.30	7.54	4.71	22.59	1996 High WT: Depth bgs	3.17	
MW24-010		05/06/1996		30.13	27.30	7.57	4.74	22.56	1996 Low WT. Depth bgs	8.07	
MW24-010		06/07/1996		30.13	27.30	7.66	4.83	22.47			
MW24-010		07/01/1996		30.13	27.30	8.55	5.72	21.58			
MW24-010		08/01/1996		30.13	27.30	9.62	6.79	20.51			
MW24-010		09/04/1996		30.13	27.30	10.46	7.63	19.67			
MW24-010		10/02/1996		30.13	27.30	10.90	8.07	19.23			
MW24-010		11/04/1996		30.13	27.30	10.34	7.51	19.79			
MW24-010		12/02/1996		30.13	27.30	7.38	4.55	22.75			
MW24-010		01/06/1997		30.13	27.30	4.87	2.04	25.26			
MW24-010		02/05/1997		30.13	27.30	5.96	3.13	24.17	1997 High WT: GW Elev	25.26	
MW24-010		02/28/1997		30.13	27.30	7.55	4.72	22.58	1997 Low WT: GW Elev	19.42	
MW24-010		03/11/1997		30.13	27.30	6.95	4.12	23.18	1997 High WT: Depth bgs	2.04	
MW24-010		04/04/1997		30.13	27.30	7.21	4.38	22.92	1997 Low WT: Depth bgs	7.88	
MW24-010		05/01/1997		30.13	27.30	7.50	4.67	22.63			
MW24-010		06/04/1997		30.13	27.30	7.66	4.83	22.47			
MW24-010		07/01/1997		30.13	27.30	7.77	4.94	22.36			
MW24-010		08/06/1997		30.13	27.30	9.37	6.54	20.76			
MW24-010		09/02/1997		30.13	27.30	10.13	7.30	20.00			
MW24-010		10/03/1997		30.13	27.30	10.71	7.88	19.42			
MW24-010		11/07/1997		30.13	27.30	10.32	7.49	19.81			
MW24-010		12/03/1997		30.13	27.30	9.88	7.05	20.25			
MW24-010		01/06/1998		30.13	27.30	9.23	6.40	20.90			
MW24-010		02/05/1998		30.13	27.30	7.72	4.89	22.41	1998 High WT: GW Elev	23.08	
MW24-010		03/04/1998		30.13	27.30	7.05	4.22	23.08	1998 Low WT: GW Elev	19.95	
MW24-010		05/04/1998		30.13	27.30	9.38	6.55	20.75	1998 High WT: Depth bgs	4.22	
MW24-010		08/04/1998		30.13	27.30	10.18	7.35	19.95	1998 Low WT: Depth bgs	7.35	

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Well	Area	Date	Screened Interval (ft bgs)	MPE (feet)	GSE (feet)	Depth to Water (ft below MPE)	Depth to Water (ft bgs)	GW Elev (feet)	Yearly Max/Min Water Table (feet) By Well		Max / Min By Area (1994-1998) (Excluding MW03 and MW14)
MW25-024	Scrap Yard	08/01/1995	13 to 23	31.14	28.50	13.27	10.63	17.87			
MW25-024		09/07/1995		31.14	28.50	15.90	13.26	15.24	1995 High WT: GW Elev	24.19	
MW25-024		10/05/1995		31.14	28.50	18.14	15.50	13.00	1995 Low WT: GW Elev	13.00	
MW25-024		11/03/1995		31.14	28.50	13.25	10.61	17.89	1995 High WT: Depth bgs	4.31	
MW25-024		12/01/1995		31.14	28.50	6.95	4.31	24.19	1995 Low WT: Depth bgs	15.50	
MW25-024		01/04/1996		31.14	28.50	9.05	6.41	22.09			
MW25-024		02/02/1996		31.14	28.50	8.48	5.84	22.66	1996 High WT: GW Elev	24.45	
MW25-024		03/01/1996		31.14	28.50	6.69	4.05	24.45	1996 Low WT: GW Elev	15.11	
MW25-024		04/01/1996		31.14	28.50	9.53	6.89	21.61	1996 High WT: Depth bgs	4.05	
MW25-024		05/06/1996		31.14	28.50	8.39	5.75	22.75	1996 Low WT: Depth bgs	13.39	
MW25-024		06/07/1996		31.14	28.50	8.06	5.42	23.08			
MW25-024		07/01/1996		31.14	28.50	9.85	7.21	21.29			
MW25-024		08/01/1996		31.14	28.50	12.15	9.51	18.99			
MW25-024		09/04/1996		31.14	28.50	13.95	11.31	17.19			
MW25-024		10/02/1996		31.14	28.50	16.03	13.39	15.11			
MW25-024		11/04/1996		31.14	28.50	12.77	10.13	18.37			
MW25-024		12/02/1996		31.14	28.50	8.45	5.81	22.69			
MW25-024		01/06/1997		31.14	28.50	4.90	2.26	26.24			
MW25-024		02/05/1997		31.14	28.50	6.71	4.07	24.43	1997 High WT: GW Elev	26.24	
MW25-024		02/28/1997		31.14	28.50	8.88	6.24	22.26	1997 Low WT: GW Elev	16.47	
MW25-024		03/11/1997		31.14	28.50	7.92	5.28	23.22	1997 High WT: Depth bgs	2.26	
MW25-024		04/04/1997		31.14	28.50	8.15	5.51	22.99	1997 Low WT: Depth bgs	12.03	
MW25-024		05/01/1997		31.14	28.50	7.61	4.97	23.53			
MW25-024		06/04/1997		31.14	28.50	7.63	4.99	23.51			
MW25-024		07/01/1997		31.14	28.50	8.48	5.84	22.66			
MW25-024		08/06/1997		31.14	28.50	11.58	8.94	19.56			
MW25-024		09/02/1997		31.14	28.50	12.94	10.30	18.20			
MW25-024		10/03/1997		31.14	28.50	14.67	12.03	16.47			
MW25-024		11/07/1997		31.14	28.50	12.03	9.39	19.11			
MW25-024		12/03/1997		31.14	28.50	11.60	8.96	19.54			
MW25-024		01/06/1998		31.14	28.50	10.90	8.26	20.24			
MW25-024		02/05/1998		31.14	28.50	9.26	6.62	21.88	1998 High WT: GW Elev	22.59	
MW25-024		03/04/1998		31.14	28.50	8.55	5.91	22.59	1998 Low WT: GW Elev	18.10	
MW25-024		05/04/1998		31.14	28.50	11.25	8.61	19.89	1998 High WT: Depth bgs	5.91	
MW25-024		08/04/1998		31.14	28.50	13.04	10.40	18.10	1998 Low WT: Depth bgs	10.40	
MW25-024		09/02/1998		31.14	28.50						

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Well	Area	Date	Screened Interval (ft bgs)	MPE (feet)	GSE (feet)	Depth to Water (ft below MPE)	Depth to Water (ft bgs)	GW Elev (feet)	Yearly Max/Min Water Table (feet) By Well		Max / Min By Area (1994-1998) (Excluding MW03 and MW14)	
South Landfill Area (Waste Material depth approximately 2- 3 feet with maximum depths of 6 to 7 feet)												
MW03-017	South Landfill	07/20/1994	9 to 17	29.69	27.40	7.28	4.99	22.41				
MW03-017		08/08/1994		29.69	27.40	7.76	5.47	21.93	1994 High WT: GW Elev	26.49	Does not apply.	
MW03-017		09/08/1994		29.69	27.40	8.13	5.84	21.56	1994 Low WT: GW Elev	20.90	Only one well present in 1994.	
MW03-017		10/07/1994		29.69	27.40	8.79	6.50	20.90	1994 High WT: Depth bgs	0.91		
MW03-017		10/28/1994		29.69	27.40	5.24	2.95	24.45	1994 Low WT: Depth bgs	6.50		
MW03-017		12/13/1994		29.69	27.40	3.20	0.91	26.49				
MW03-017		01/04/1995		29.69	27.40	3.52	1.23	26.17				
MW03-017		02/02/1995		29.69	27.40	1.91	-0.38	27.78	1995 High WT: GW Elev	27.85	SLF 1995 High WT GW Elev	23.70
MW03-017		02/17/1995		29.69	27.40	1.84	-0.45	27.85	1995 Low WT: GW Elev	22.99	SLF 1995 Low WT GW Elev	18.63
MW03-017		03/01/1995		29.69	27.40	3.00	0.71	26.69	1995 High WT: Depth bgs	-0.45	SLF 1995 High WT Depth bgs	0.20
MW03-017		04/04/1995		29.69	27.40	3.61	1.32	26.08	1995 Low WT: Depth bgs	4.41	SLF 1995 Low WT Depth bgs	6.72
MW03-017		05/03/1995		29.69	27.40	2.85	0.56	26.84				
MW03-017		06/06/1995		29.69	27.40	4.00	1.71	25.69				
MW03-017		06/28/1995		29.69	27.40	5.29	3.00	24.40				
MW03-017		08/01/1995		29.69	27.40	6.38	4.09	23.31				
MW03-017		09/07/1995		29.69	27.40	6.60	4.31	23.09				
MW03-017		10/05/1995		29.69	27.40	6.70	4.41	22.99				
MW03-017		11/03/1995		29.69	27.40	6.25	3.96	23.44				
MW03-017		12/01/1995		29.69	27.40	2.04	-0.25	27.65				
MW03-017		01/04/1996		29.69	27.40	2.59	0.30	27.10				
MW03-017		02/02/1996		29.69	27.40	3.14	0.85	26.55	1996 High WT: GW Elev	27.39	SLF 1996 High WT GW Elev	23.71
MW03-017		03/01/1996		29.69	27.40	2.58	0.29	27.11	1996 Low WT: GW Elev	22.65	SLF 1996 Low WT GW Elev	18.30
MW03-017		04/01/1996		29.69	27.40	2.43	0.14	27.26	1996 High WT: Depth bgs	0.01	SLF 1996 High WT Depth bgs	0.19
MW03-017		05/06/1996		29.69	27.40	3.41	1.12	26.28	1996 Low WT: Depth bgs	4.75	SLF 1996 Low WT Depth bgs	6.52
MW03-017		06/07/1996		29.69	27.40	3.94	1.65	25.75				
MW03-017		07/01/1996		29.69	27.40	4.81	2.52	24.88				
MW03-017		08/01/1996		29.69	27.40	6.07	3.78	23.62				
MW03-017		09/04/1996		29.69	27.40	6.96	4.67	22.73				
MW03-017		10/02/1996		29.69	27.40	7.04	4.75	22.65				
MW03-017		11/04/1996		29.69	27.40	5.15	2.86	24.54				
MW03-017		12/02/1996		29.69	27.40	2.30	0.01	27.39				
MW03-017		01/06/1997		29.69	27.40	2.02	-0.27	27.67				
MW03-017		02/05/1997		29.69	27.40	2.28	-0.01	27.41	1997 High WT: GW Elev	27.71	SLF 1997 High WT GW Elev	23.63
MW03-017		02/28/1997		29.69	27.40	2.77	0.48	26.92	1997 Low WT: GW Elev	23.38	SLF 1997 Low WT GW Elev	19.07
MW03-017		03/11/1997		29.69	27.40	1.98	-0.31	27.71	1997 High WT: Depth bgs	-0.31	SLF 1997 High WT Depth bgs	0.27
MW03-017		04/04/1997		29.69	27.40	3.19	0.90	26.50	1997 Low WT: Depth bgs	4.04	SLF 1997 Low WT Depth bgs	6.16
MW03-017		05/01/1997		29.69	27.40	2.73	0.44	26.96				
MW03-017		06/04/1997		29.69	27.40	3.31	1.02	26.38				
MW03-017		07/01/1997		29.69	27.40	3.77	1.48	25.92				
MW03-017		08/06/1997		29.69	27.40	5.97	3.68	23.72				
MW03-017		09/02/1997		29.69	27.40	6.33	4.04	23.36				
MW03-017		10/03/1997		29.69	27.40	6.20	3.91	23.49				
MW03-017		11/07/1997		29.69	27.40	5.04	2.75	24.65				
MW03-017		12/03/1997		29.69	27.40	4.66	2.37	25.03				
MW03-017		01/06/1998		29.69	27.40	3.18	0.89	26.51				
MW03-017		02/05/1998		29.69	27.40	2.71	0.42	26.98	1998 High WT: GW Elev	27.66	SLF 1998 High WT GW Elev	23.74
MW03-017		03/04/1998		29.69	27.40	2.03	-0.26	27.66	1998 Low WT: GW Elev	23.67	SLF 1998 Low WT GW Elev	19.65
MW03-017		05/04/1998		29.69	27.40	4.19	1.90	25.50	1998 High WT: Depth bgs	-0.26	SLF 1998 High WT Depth bgs	0.16
MW03-017		08/04/1998		29.69	27.40	6.02	3.73	23.67	1998 Low WT: Depth bgs	3.73	SLF 1998 Low WT Depth bgs	5.74
MW03-017		09/02/1998		29.69	27.40							

Silt Unit Groundwater Elevations: East Potliner, Scrap Yard, and South Landfill Areas
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Well	Area	Date	Screened Interval (ft bgs)	MPE (feet)	GSE (feet)	Depth to Water (ft below MPE)	Depth to Water (ft bgs)	GW Elev (feet)	Yearly Max/Min Water Table (feet) By Well		Max / Min By Area (1994-1998) (Excluding MW03 and MW14)
MW16-014	South Landfill	08/01/1995	6 to 14	28.91	26.70	8.29	6.08	20.62			
MW16-014		09/07/1995		28.91	26.70	8.72	6.51	20.19	1995 High WT: GW Elev	23.53	
MW16-014		10/05/1995		28.91	26.70	8.93	6.72	19.98	1995 Low WT: GW Elev	19.98	
MW16-014		11/03/1995		28.91	26.70	8.40	6.19	20.51	1995 High WT: Depth bgs	3.17	
MW16-014		12/01/1995		28.91	26.70	5.38	3.17	23.53	1995 Low WT: Depth bgs	6.72	
MW16-014		01/04/1996		28.91	26.70	6.62	4.41	22.29			
MW16-014		02/02/1996		28.91	26.70	6.53	4.32	22.38	1996 High WT: GW Elev	22.95	
MW16-014		03/01/1996		28.91	26.70	6.42	4.21	22.49	1996 Low WT: GW Elev	20.18	
MW16-014		04/01/1996		28.91	26.70	7.07	4.86	21.84	1996 High WT: Depth bgs	3.75	
MW16-014		05/06/1996		28.91	26.70	7.01	4.80	21.90	1996 Low WT: Depth bgs	6.52	
MW16-014		06/07/1996		28.91	26.70	7.08	4.87	21.83			
MW16-014		07/01/1996		28.91	26.70	7.52	5.31	21.39			
MW16-014		08/01/1996		28.91	26.70	8.12	5.91	20.79			
MW16-014		09/04/1996		28.91	26.70	8.62	6.41	20.29			
MW16-014		10/02/1996		28.91	26.70	8.73	6.52	20.18			
MW16-014		11/04/1996		28.91	26.70	7.65	5.44	21.26			
MW16-014		12/02/1996		28.91	26.70	5.96	3.75	22.95			
MW16-014		01/08/1997		28.91	26.70	5.45	3.24	23.46			
MW16-014		02/05/1997		28.91	26.70	5.88	3.67	23.03	1997 High WT: GW Elev	23.46	
MW16-014		02/28/1997		28.91	26.70	6.89	4.68	22.02	1997 Low WT: GW Elev	20.54	
MW16-014		03/11/1997		28.91	26.70	5.86	3.65	23.05	1997 High WT: Depth bgs	3.24	
MW16-014		04/04/1997		28.91	26.70	6.91	4.70	22.00	1997 Low WT: Depth bgs	6.16	
MW16-014		05/01/1997		28.91	26.70	6.66	4.45	22.25			
MW16-014		06/04/1997		28.91	26.70	7.31	5.10	21.60			
MW16-014		07/01/1997		28.91	26.70	7.46	5.25	21.45			
MW16-014		08/06/1997		28.91	26.70	7.87	5.66	21.04			
MW16-014		09/02/1997		28.91	26.70	8.23	6.02	20.68			
MW16-014		10/03/1997		28.91	26.70	8.37	6.16	20.54			
MW16-014		11/07/1997		28.91	26.70	7.61	5.40	21.30			
MW16-014		12/03/1997		28.91	26.70	7.31	5.10	21.60			
MW16-014		01/06/1998		28.91	26.70	6.75	4.54	22.16			
MW16-014		02/05/1998		28.91	26.70	6.62	4.41	22.29	1998 High WT: GW Elev	23.20	
MW16-014		03/04/1998		28.91	26.70	5.71	3.50	23.20	1998 Low WT: GW Elev	20.96	
MW16-014		05/04/1998		28.91	26.70	7.43	5.22	21.48	1998 High WT: Depth bgs	3.50	
MW16-014		08/04/1998		28.91	26.70	7.95	5.74	20.96	1998 Low WT: Depth bgs	5.74	
MW19-013	South Landfill	08/01/1995	8 to 13	27.10	24.80	8.10	5.80	19.00			
MW19-013		09/07/1995		27.10	24.80	8.25	5.95	18.85	1995 High WT: GW Elev	21.17	
MW19-013		10/05/1995		27.10	24.80	8.47	6.17	18.63	1995 Low WT: GW Elev	18.63	
MW19-013		11/03/1995		27.10	24.80	8.22	5.92	18.88	1995 High WT: Depth bgs	3.63	
MW19-013		12/01/1995		27.10	24.80	5.93	3.63	21.17	1995 Low WT: Depth bgs	6.17	
MW19-013		01/04/1996		27.10	24.80	7.04	4.74	20.06			
MW19-013		02/02/1996		27.10	24.80	6.94	4.64	20.16	1996 High WT: GW Elev	21.22	
MW19-013		03/01/1996		27.10	24.80	6.73	4.43	20.37	1996 Low WT: GW Elev	19.07	
MW19-013		04/01/1996		27.10	24.80	7.24	4.94	19.86	1996 High WT: Depth bgs	3.58	
MW19-013		05/08/1996		27.10	24.80	7.32	5.02	19.78	1996 Low WT: Depth bgs	5.73	
MW19-013		06/07/1996		27.10	24.80	7.17	4.87	19.93			
MW19-013		07/01/1996		27.10	24.80	7.50	5.20	19.60			
MW19-013		08/01/1996		27.10	24.80	7.84	5.54	19.26			
MW19-013		09/04/1996		27.10	24.80	8.03	5.73	19.07			
MW19-013		10/02/1996		27.10	24.80	7.86	5.56	19.24			
MW19-013		11/04/1996		27.10	24.80	7.30	5.00	19.80			
MW19-013		12/02/1996		27.10	24.80	5.88	3.58	21.22			
MW19-013		01/06/1997		27.10	24.80	5.43	3.13	21.67			
MW19-013		02/05/1997		27.10	24.80	5.92	3.62	21.18	1997 High WT: GW Elev	21.67	
MW19-013		02/28/1997		27.10	24.80	6.83	4.53	20.27	1997 Low WT: GW Elev	19.47	
MW19-013		03/11/1997		27.10	24.80	5.96	3.66	21.14	1997 High WT: Depth bgs	3.13	
MW19-013		04/04/1997		27.10	24.80	6.80	4.50	20.30	1997 Low WT: Depth bgs	5.33	
MW19-013		05/01/1997		27.10	24.80	6.65	4.35	20.45			
MW19-013		06/04/1997		27.10	24.80	7.09	4.79	20.01			
MW19-013		08/06/1997		27.10	24.80	7.45	5.15	19.65			
MW19-013		09/02/1997		27.10	24.80	7.63	5.33	19.47			
MW19-013		10/03/1997		27.10	24.80	7.57	5.27	19.53			
MW19-013		11/07/1997		27.10	24.80	7.07	4.77	20.03			
MW19-013		12/03/1997		27.10	24.80	6.87	4.57	20.23			
MW19-013		01/06/1998		27.10	24.80	6.28	3.98	20.82			
MW19-013		02/05/1998		27.10	24.80	6.30	4.00	20.80	1998 High WT: GW Elev	21.72	
MW19-013		03/04/1998		27.10	24.80	5.38	3.08	21.72	1998 Low WT: GW Elev	19.80	
MW19-013		05/04/1998		27.10	24.80	7.06	4.76	20.04	1998 High WT: Depth bgs	3.08	
MW19-013		08/04/1998		27.10	24.80	7.30	5.00	19.80	1998 Low WT: Depth bgs	5.00	

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Well	Area	Date	Screened Interval (ft bgs)	MPE (feet)	GSE (feet)	Depth to Water (ft below MPE)	Depth to Water (ft bgs)	GW Elev (feet)	Yearly Max/Min Water Table (feet) By Well		Max / Min By Area (1994-1998) (Excluding MW03 and MW14)
MW26-012	South Landfill	11/03/1995	7 to 12	26.26	23.90	5.54	3.18	20.72	1995 High WT: GW Elev	23.70	
MW26-012		12/01/1995		26.26	23.90	2.56	0.20	23.70	1995 Low WT: GW Elev	20.72	
MW26-012		01/04/1996		26.26	23.90	3.04	0.68	23.22			
MW26-012		02/02/1996		26.26	23.90	3.56	1.20	22.70	1996 High WT: GW Elev	23.71	
MW26-012		03/01/1996		26.26	23.90	3.42	1.06	22.84	1996 Low WT: GW Elev	18.30	
MW26-012		04/01/1996		26.26	23.90	3.25	0.89	23.01	1996 High WT: Depth bgs	0.19	
MW26-012		05/06/1996		26.26	23.90	3.68	1.32	22.58	1996 Low WT: Depth bgs	5.60	
MW26-012		06/07/1996		26.26	23.90	4.15	1.79	22.11			
MW26-012		07/01/1996		26.26	23.90	5.79	3.43	20.47			
MW26-012		08/01/1996		26.26	23.90	7.09	4.73	19.17			
MW26-012		09/04/1996		26.26	23.90	7.96	5.60	18.30			
MW26-012		10/02/1996		26.26	23.90	7.63	5.27	18.63			
MW26-012		11/04/1996		26.26	23.90	3.99	1.63	22.27			
MW26-012		12/02/1996		26.26	23.90	2.55	0.19	23.71			
MW26-012		01/06/1997		26.26	23.90	2.67	0.31	23.59			
MW26-012		02/05/1997		26.26	23.90	3.09	0.73	23.17	1997 High WT: GW Elev	23.63	
MW26-012		02/28/1997		26.26	23.90	3.38	1.02	22.88	1997 Low WT: GW Elev	19.07	
MW26-012		03/11/1997		26.26	23.90	2.63	0.27	23.63	1997 High WT: Depth bgs	0.27	
MW26-012		04/04/1997		26.26	23.90	3.69	1.33	22.57	1997 Low WT: Depth bgs	4.83	
MW26-012		05/01/1997		26.26	23.90	3.11	0.75	23.15			
MW26-012		06/04/1997		26.26	23.90	3.80	1.44	22.46			
MW26-012		07/01/1997		26.26	23.90	4.13	1.77	22.13			
MW26-012		08/06/1997		26.26	23.90	6.56	4.20	19.70			
MW26-012		09/02/1997		26.26	23.90	7.19	4.83	19.07			
MW26-012		10/03/1997		26.26	23.90	7.12	4.76	19.14			
MW26-012		11/07/1997		26.26	23.90	3.63	1.27	22.63			
MW26-012		12/03/1997		26.26	23.90	3.46	1.10	22.80			
MW26-012		01/06/1998		26.26	23.90	2.65	0.29	23.61			
MW26-012		02/05/1998		26.26	23.90	3.00	0.64	23.26	1998 High WT: GW Elev	23.74	
MW26-012		03/04/1998		26.26	23.90	2.52	0.16	23.74	1998 Low WT: GW Elev	2.52	
MW26-012		05/04/1998		26.26	23.90	4.34	1.98	21.92	1998 High WT: Depth bgs	0.16	
MW26-012		08/04/1998		26.26	23.90	6.61	4.25	19.65	1998 Low WT: Depth bgs	4.25	

Notes:
ft bgs = feet below ground surface.

APPENDIX B

ARARs Evaluation

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APPENDIX B

ARARs Evaluation

B.1 Introduction

This appendix presents an evaluation of applicable or relevant and appropriate regulatory requirements (ARARs) to support the Focused Feasibility Study (FFS) for the Reynolds Metals Company (RMC) facility in Troutdale, Oregon.

The identification of ARARs is an iterative process. The Remedial Investigation/Feasibility Study (RI/FS) Work Plan identified potential ARARs from the universe of regulations, requirements, and guidance that may be pertinent to actions to be taken at RMC, and included an initial assessment of whether the potential ARARs would be applicable, or relevant and appropriate, based on known site conditions and a broad matrix of potential soil and groundwater response actions (CH2M HILL, May 1996). Subsequent refinement of ARARs evaluations were included in media- or area-specific work plans. Final determination of ARARs will be presented in the record of decision for the site.

This appendix is organized into the following sections:

- Section 1: Introduction and Overview
- Section 2: Chemical-Specific ARARs
- Section 3: Location-Specific ARARs
- Section 4: Action-Specific ARARs

B.1.1 Overview of ARARs

Remedial actions at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites must attain, or justify the waiver of, any federal or more stringent state environmental standards, requirements, criteria, or limitations that are determined to be applicable or relevant and appropriate (ARAR) (CERCLA §121(d)).

- **Applicable** refers to those requirements under federal or state law that specifically address the situation at a CERCLA site and meet the legal prerequisites for application.

- **Relevant and appropriate** refers to those requirements that, while not applicable, address problems or situations sufficiently similar to the site's circumstances and are well suited to the conditions of the site.

In order to constitute an ARAR a requirement must also be:

- Substantive, not procedural or administrative
- Promulgated

Therefore, for onsite activities only the substantive provisions of requirements identified as ARARs in this analysis are considered ARARs. Offsite activities must comply with both substantive and administrative requirements. Policy and guidance issued by federal or state

governments are not legally binding and are not ARAR. However, such advisories or guidance may be useful and are "to be considered" (TBC) for onsite actions. TBCs are intended to complement the use of ARARs and may be used to establish removal action objectives in circumstances for which ARARs do not exist.

State requirements must meet additional criteria. To qualify as a state ARAR under the *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP) the requirement must be:

- More stringent than federal requirements
- Identified by the state in a timely manner
- Consistently applied

B.2 Chemical-Specific ARARs

Chemical-specific requirements are usually health- or risk-based numerical values or standards that establish the acceptable amount or concentration of a chemical in the ambient environment.

The potential federal and state chemical-specific ARARs by media are discussed in the following sections and summarized in the tables at the end of the appendix. Table B-1 lists potential chemical-specific ARARs.

B.2.1 Safe Drinking Water Act

The Safe Drinking Water Act establishes maximum levels of contaminants in public drinking water sources [42 United States Code (USC) § 300g-1)]. Maximum contaminant levels (MCLs) are enforceable limits for contaminants that "may have an adverse effect on the health of persons and which [are] known or anticipated to occur in public water systems" [42 USC§ 300g-1(b)(3)(A)]. Maximum contaminant level goals (MCLGs) are "set at the level at which no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety" [42 USC 300g-1(b)(4)].

The NCP states that MCLs and nonzero MCLGs are potentially relevant and appropriate during remediation of groundwater or surface waters that are current or potential sources of drinking water. Federal MCLs are relevant and appropriate for sources of drinking water at the RMC site. Constituents of concern for groundwater at RMC and corresponding MCLs are listed in Table B-2. State MCLs for these constituents are either not established or equal to federal MCLs (OAR 333-61). Federal MCLGs for these constituents are either equal to MCLs or zero.

B.2.2 Clean Water Act

EPA has established federal water quality criteria (WQC) under § 304 of the Clean Water Act. WQC are set for human health protection and for protection of aquatic life. CERCLA §121(d) requires WQC to be attained if relevant and appropriate to the circumstances of the site. Federal WQC form the basis of Oregon water quality standards.

WQC are relevant and appropriate at RMC for determining acceptable contaminant levels in the Columbia and Sandy Rivers, where there are surface water or groundwater pathways

that could contribute to contaminant levels in the rivers. As discussed in the FFS Section 2.1.2.2, as a result of mixing factors, concentrations of constituents of concern in groundwater discharging from the site to surface water do not exceed WQC. South Ditch and Company Lake are part of the wastewater treatment system permitted by the National Pollutant Discharge Elimination System (NPDES). Therefore, WQC are not relevant or appropriate for these areas. Discharges to the Columbia River through the RMC NPDES permit, including new discharges resulting from implementation of the remedial activities, are subject to WQC. These discharges are discussed under action-specific ARARs.

Federal Criteria Maximum Concentrations (CMC) (generally referred to as acute); Criteria Continuous Concentrations (CCC) (generally referred to as chronic); and more stringent state standards are presented in Table B-3 for groundwater COPCs.

Oregon's surface water quality protection program includes an anti-degradation policy to prevent unnecessary degradation from point and nonpoint sources of pollution. The policy is also intended to protect, maintain, and enhance existing surface water quality for existing beneficial uses (OAR 430-41-0026). This anti-degradation standard would also be applicable to the RMC facility. Beneficial uses for the Columbia and Sandy Rivers are presented in Table B-4 [OAR 340-41-445(p)].

B.2.3 Toxic Substance Control Act

The Toxic Substances Control Act (TSCA) regulates disposal, handling, and cleanup of material contaminated with polychlorinated biphenyls (PCBs) at concentrations of approximately 50 ppm or greater. TSCA includes anti-dilution provisions, which prohibit the dilution of PCBs to avoid the law's concentration-specific requirements. In some cases, the effect of the rule is to require PCBs below the 50 ppm threshold to be regulated on the presumption that they were diluted. EPA has clarified that in the context of selecting response action strategies and cleanup levels under CERCLA, EPA should evaluate the form and concentration of the PCB contamination "as found" at the site (EPA August 1990). PCBs have not been encountered at the north landfill, south landfill, scrap yard, Company Lake, or sitewide groundwater at concentrations that would trigger the applicability of TSCA. TSCA regulations for handling and disposing of PCB wastes would be applicable if such regulated wastes were encountered.

EPA Guidance on Remedial Action for Superfund Sites with PCB Contamination, OSWER Directive No. 9355.04-01 (EPA 1990) recommends cleanup levels of 10 to 25 ppm for industrial settings. These guidance levels have been incorporated in early actions taken at the RMC Troutdale site, and can serve as TBC standards for future actions.

B.2.4 RCRA Hazardous Waste Handling and Disposal Requirements

The Resource Conservation and Recovery Act (RCRA) regulates the handling and disposal of hazardous wastes from the point of generation through disposal. Oregon has adopted RCRA standards by reference and includes additional waste characterization procedures and waste codes (OAR 340-101). Toxicity, as defined by the Toxic Characteristic Leaching Procedure (TCLP) limits in 40 CFR 261.24, may be used to assess whether waste generated by remedial action activities should be classified as hazardous waste.

Consolidation of materials onsite within an area of concern at a CERCLA site is not considered waste generation. Therefore, RCRA waste characterization is not applicable or relevant to waste consolidation within the RMC site. Materials removed from the site that are determined to be hazardous wastes would be fully regulated. For those wastes removed from the site, both the substantive and administrative requirements for waste characterization, transportation, and disposal would be applicable.

B.2.5 Oregon Environmental Cleanup Law

The Oregon Environmental Cleanup Law, ORS 465.200 et seq., was patterned after CERCLA and the remedial measures required are very similar to those required by the NCP. Procedural aspects of the Oregon Environmental Cleanup Law would not be ARAR. Similar to CERCLA, the Oregon Cleanup Law includes a preference for treatment that is applied to "hotspots,", and a procedure for evaluating the feasibility of treatment. Because state standards are ARAR only to the extent that they are more stringent than federal standards and federal standards include preference for treatment for the entire site, the hotspot portion of the state rules in not ARAR.

Oregon Environmental Cleanup Law standards at ORS 465.315 and OAR 340-122-040 are applicable to the extent that they are more stringent than federal standards in the NCP. Under the Oregon cleanup process, the level of contaminants assumed to be protective of human health and the environment are an excess lifetime cancer risk of 10^{-6} for individual carcinogens, a cumulative excess lifetime cancer risk of 10^{-5}, and a hazard index of less than or equal to 1 for systemic toxicants with similar endpoints. For protection of ecological receptors, the acceptable level of risk is at the point before significant adverse impacts are expected to occur.

B.2.5.1 Stringency of State Requirement

Oregon's environmental cleanup statute at ORS 465.315 requires DEQ to select or approve a remedial action requiring treatment of hotspots to the extent feasible. Implementing regulations at OAR 340-122-090 provide the procedural steps for identifying hotspots through the state equivalent of a feasibility study. The state preference for treatment presents a substantive standard and its potential ARAR status is considered below. The implementing regulations, which detail the administrative process for incorporating the hotspot determination into the state equivalent feasibility study, are procedural. As noted above, procedural aspects of requirements are not ARAR and are not included in this analysis.

State requirements are considered in the ARARs process only to the extent they are more stringent than federal requirements. The Oregon preference for treatment is less stringent because it applies only to "hotspots" where the federal remedy selection process imposes a preference for treatment on all contamination above risk-based thresholds. The intent of the Oregon hotspot treatment preference is to require treatment only for the worst contamination (See *DEQ Final Guidance for Identification of Hot Spots, April 23, 1998, page 1.)*

DEQ evaluated the differences between state and federal approaches to cleanup regarding hotspots during the proposal of the hotspot regulations and made the following conclusion.

> "The federal program usually requires treatment of any contamination requiring cleanup. Oregon's new law does not follow the 'treatment at all costs' approach,

allowing more flexibility toward making reasonable site-specific determination." *Oregon Department of Environmental Quality, Memorandum to Interested and Affected Public, Attachment C, September 17, 1996, Re: Rulemaking Proposal and Rulemaking Statements-Environmental Cleanup Rules Mandated by 1995 Amendments to Environmental Cleanup Law.*

Because the state preference for treatment applies to only a limited portion of the cleanup site, the state hotspot rules are not more stringent than the federal remedy selection criteria and are not ARAR.

Equivalency of State Requirement. Even if the state hotspot treatment preference were considered ARAR, the federal remedy selection process in the NCP is equivalent to state process for identifying and evaluating the feasibility of treating hotspots and provides an equivalent outcome. EPA has stated that in such situations compliance with the federal requirements is sufficient.

"State requirements that are equivalent to but not more stringent than Federal requirements, are those that are identical to federal requirements i.e., (1) enacted verbatim; or (2) not identical to Federal requirements but are substantively equivalent i.e. that use the same or a different approach to achieve an identical result. In such situations by complying with the federal ARAR, the state requirements will have been adequately considered." (CERCLA Compliance with Other Laws Manual, Part II, EPA, August 1989 at p. 7-9.)

The state hotspot rule requires balancing of remedy selection criteria which mirror the remedy selection criteria of the NCP. Therefore, compliance with the NCP remedy selection process will adequately consider state concerns regarding hotspot treatment.

The state process for defining hotspots relies on an evaluation of several factors in the state equivalent of a feasibility study. Oregon defines hotspots at OAR 340-122-000:

> For groundwater or surface water, hazardous substances having a significant adverse effect on beneficial uses of water or waters to which the hazardous substances would be reasonably likely to migrate and for which treatment is reasonable likely to restore or protect such beneficial uses within a reasonable time, as determined in the feasibility study.
>
> For other media (for example, soil, debris, sediment, and sludges) if hazardous substances present a risk to human health or the environment exceeding the acceptable risk level, the extent to which the hazardous substances :
>
> - Are present in concentrations exceeding risk-based concentrations (generally, a lifetime excess cancer risk of 1 $x10^{-4}$ or a hazard quotient of 10 for non-carcinogens)
> - Are reasonable likely to migrate to such an extent that a hotspot would be created; or
> - Are not reliably contained, as determined in the feasibility study.

These definitions require that the hotspot determination be made in the context of the state feasibility study. The factors to be considered for hotspot determination are similar or identical to the remedy selection factors identified in the NCP. (40 CFR 300.430(e))

Under the NCP, remedies are selected based on nine criteria. (40 CFR 300.430(f)). These federal criteria define the preferred attributes of the selected remedy. The state preference for treatment of hotspots is satisfied by the evaluation performed under the federal criteria for reduction in toxicity, mobility, and volume through treatment (40 CFR 300.430(e)(9)(C)). This federal criteria addresses the degree to which the remedy employs recycling or treatment that reduces toxicity, mobility or volume including how treatment is used to address the principal threats posed by the site. Evaluation of the federal treatment criteria assesses the identical concerns of the state treatment preference.

The state preference for treatment is qualified. The results of the state feasibility study are used to assess whether treatment is likely to restore or protect such beneficial uses (of water) within a reasonable time frame or if contaminants can be "reliably contained." (OAR 340-122-115(31). The state feasibility study balances five factors including effectiveness in achieving protection; long-term reliability; implementability; short-term risk; and cost-reasonableness. Similarly, the federal program requires that the remedies balance five factors including; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; implementability; short-term effectiveness; and cost. These factors are compared in Table B-5.

Although not identically drafted, these factors are sufficiently similar to yield identical results for hotspots. For nonhotspots, the federal approach is more stringent as stated above. CERCLA does not require dual processes or evaluations to satisfy equivalent requirements that are met by federal requirements, and therefore the state hotspot rule is not included as an ARAR.

B.3 Location-Specific ARARs

Location-specific ARARs are those standards based on actions taken in specific locations. These may be ARAR for certain remedial actions or may apply only to certain portions of the site.

The potential federal and state location-specific ARARs for the RMC site are discussed in the following sections and summarized in Table B-6.

B.3.1 Wild and Scenic Rivers Act

The segment of the Sandy River adjacent to the RMC facility is designated as a recreational and scenic river under the Federal Wild and Scenic Rivers Act (16 USC §1271 et seq.) and Oregon Scenic Waterways Act. (ORS 390.805 et seq.). A federal agency may not assist the construction of a water resource project that would have a direct and adverse effect on free-flowing characteristics of a designated river or that would unreasonably diminish the scenic, recreational, and fish and wildlife values present in the river corridor. This standard would be applicable to remedial actions at the RMC site which could affect the river corridor.

B.3.2 Endangered Species and Migratory Bird Treaty Acts

The state and federal endangered species acts, ORS 496.012 and 16 USC§1351 et seq. and Migratory Bird Treaty Act, 16 USC §703 require protection for certain plant and animal species and their habitat. The RMC facility is adjacent to the Columbia River, which is habitat for documented threatened or endangered species in the area, as well as species that are proposed for listing. Federally listed Snake River fall Chinook salmon, spring Chinook salmon, and sockeye salmon migrate in the Columbia River. The Columbia River is also within the Pacific Flyway, a migration corridor, mostly for waterfowl, along the Pacific Ocean from Alaska to Mexico.

Requirements for consultation with US Fish and Wildlife and Oregon Fish and Wildlife would be applicable for response actions that could affect a protected species or its habitat. If so, that action must be avoided or appropriate mitigation measures taken. To make such a determination, a biological assessment that describes the nature and extent of potential impacts of the action must be prepared. After the assessment is completed, a biological opinion is prepared that states whether species are likely to be jeopardized.

B.3.3 National Archaeological and Historic Preservation Act

Cultural resources are protected under several federal and state programs. For the RMC site, the primary programs are the National Archaeological and Historic Preservation Act (16 USC §461 et seq.), Executive Order 11593, implementing regulations, and the state statute protecting archaeological sites (ORS 358.905). The State Historic Preservation Office (SHPO), in consultation with federal agencies, reviews projects under the National Historic Preservation Act.

SHPO has identified the RMC locale as an area with high probability for archaeological sites because of its proximity to the confluence of two rivers (personal communication, 1996). However, the areas have not been inventoried.

These standards may be applicable to remedial actions that include construction or excavation located in previously undisturbed areas. Consultation with SHPO may be needed to assess the specific activities planned and their potential for disruption of protected resources.

B.3.4 Siting Requirements for Waste Management Facilities

Federal regulations at 40 CFR 257.3 and 40 CFR Part 258 Subpart B, and state regulations at OAR 340-95-030 establish minimal siting criteria for solid waste landfills. These requirements include protection of ecological receptors and habitat, restrictions on disposal within a 100-year floodplain or wetlands, restrictions on construction near unstable geologic areas, and protection of sensitive hydrological environments. These requirements would be applicable to solid waste land disposal sites constructed as part of the remedial action.

These requirements may also be relevant and appropriate to containment of source areas inplace. The landfill siting requirements for floodplains in 40 CFR 258.11 and OAR 340-94-030 are considered relevant and appropriate to the inplace closure of north landfill. The regulations require that landfills located within a floodplain must be controlled to prevent

the washout of solid waste that may pose a hazard to human life, wildlife, or land or water resources.

B.3.5 Protection of Floodplains

At the RMC facility, the 100-year floodplain boundary is at approximate elevation 32 feet which generally follows the U.S. Army Corps of Engineer (COE) dike. The COE dike separates developed areas of the RMC Troutdale facility from the Columbia and Sandy Rivers. The north landfill and Company Lake are outboard of the dike and within the 100-year floodplain.

Encroachments in floodways and floodplains are regulated under state and federal programs including Executive Order 11988, entitled Floodplain Management (40 CFR 6 Appendix A). Generally, these programs enforce floodplain protection standards through a permit process. Under CERCLA, the permitting aspects would not be ARARs, but conformance with substantive floodplain protection standards may be relevant and appropriate for response actions that would alter or result in construction within a floodplain.

B.4 Action-Specific ARARs

Action-specific ARARs regulate the specific type of action or technology under consideration, or the management of regulated materials. The potential federal and state action-specific ARARs for the remedial actions being considered for the RMC Troutdale site are discussed in the following section and summarized in Table B-7.

B.4.1 Management of Solid Waste/Hazardous Waste/Toxic Waste

B.4.1.1 RCRA Requirements for Hazardous Wastes

Federal regulations promulgated under RCRA and corresponding state law provide standards for the handling and disposal of solid and hazardous waste. These regulations are applicable to remedial action activities that result in the generation of waste. The generation of waste under RCRA is determined by whether the waste would be hazardous or non-hazardous, and whether the waste would be moved outside the area of contamination (AOC).

Hazardous waste regulations 40 CFR Part 260 to 268 and OAR 340-100 to 340-106 establish procedures for identifying, handling, storing, transporting, and disposing of hazardous waste. Both substantive and the administrative aspects of these requirements are applicable if, as part of the remedial action, hazardous wastes are moved offsite.

Several of the remedial options being considered include the excavation or dredging of source areas. Excavation, dredging, processing, and consolidation of waste within the AOC is not considered waste generation. However, RCRA hazardous waste regulations would be applicable if the source area materials are moved outside the AOC, and the material is considered hazardous. In addition, hazardous waste regulations could be applicable to other remedial options being considered that would generate waste, such as treatment of groundwater, if the generated waste is hazardous and the waste would not remain onsite.

Important considerations for the determination of hazardous waste are dates of waste disposal, process by which waste was generated (listed waste), and concentrations of constituents detected. Spent potliner from primary aluminum reduction is a listed hazardous waste (K088); this listing was finalized on September 13, 1988. Spent potliner that has been generated at the RMC facility has been managed as a hazardous waste since 1983. As a result, spent potliner that may have been disposed onsite was disposed prior to the listing date in 1988. Remedial options that would excavate and move spent potliner from source areas to outside the AOC would be classified as the generation of a listed waste. As such, the listed waste would need to be accumulated, transported and disposed in compliance with hazardous waste regulations.

B.4.1.2 RCRA Land Disposal Restrictions

RCRA Land Disposal Restrictions (LDRs) restrict the land disposal of specific wastes unless treatment standards are met. Some treatment standards are technology-based and some are construction-based. LDRs are action-specific ARARs for remedial action activities that would include generation of specified hazardous waste, and movement outside the AOC for land disposal.

EPA has established LDRs for spent aluminum potliner (K088 waste) in 40 CFR 268.39. Spent potliner was disposed at the RMC facility prior to the effective date of the LDR and therefore, the LDR does not apply to the spent potliner in place. The LDR would, however, be applicable if spent potliner were excavated during remedial activities and moved outside the AOC. Spent potliner that would be moved outside the AOC as part of the remedial activities would need to attain specific treatment standards to comply with ARARs.

B.4.1.3 DOT Requirements for Transportation of Hazardous Waste

Transportation of hazardous materials is regulated by 49 CFR Parts 171 to 177. Requirements for transportation of hazardous materials include classification, proper packaging, properly labeling and placarding, inspection, proper loading and unloading techniques and required training. These requirements apply to hazardous wastes that are generated during remedial action activities and shipped offsite.

B.4.1.4 TSCA requirements for PCB-Containing Wastes

40 CFR Part 761 regulates the use and manufacture of toxic substances, as well as the storage and disposal of PCBs. The disposal restrictions for PCB-containing materials require that nonliquid PCBs at concentrations greater than 50 ppm in the form of contaminated soil or other debris be disposed of in a TSCA-approved incinerator or in a TSCA-approved chemical waste landfill or by a TSCA-approved alternative disposal method.

These regulations would be applicable to wastes generated by the remedial action activities that contain PCBs at concentrations of 50 ppm or more. To date, PCBs have not been identified at NLF, SLF, or SY in soil samples at concentrations greater than 50 ppm during the previous investigations.. However if PCB wastes were encountered during the excavation of these areas, the management of the PCB wastes would need to comply with the provisions of TSCA.

B.4.2 Closure of Waste Inplace/Onsite Waste Disposal

Federal and state regulations promulgated under RCRA governing land disposal units may be relevant and appropriate for remedial activities that involve closure of waste inplace (containment or capping of source areas), or for remedial activities that involve excavation of source areas and disposal in a new onsite landfill.

Substantive RCRA landfill requirements would be applicable to remedial activities if the waste is a regulated waste and either

1. The waste was initially treated, stored, or disposed after the effective date of the particular RCRA requirement, or
2. The remedial activity constitutes disposal as defined by RCRA.

For inplace containment options that would not disturb waste materials at NLF, SLF, SY, or CL, hazardous waste landfill closure requirements are not applicable because waste that is known to be a listed waste under RCRA was not disposed after the date it was listed. In addition, federal nonhazardous waste landfill closure requirements are not applicable because nonhazardous solid wastes were not disposed after 1991. State requirements for landfill closure which apply to facilities that received waste after January 1, 1980 may be considered relevant and appropriate and therefore ARARs for inplace containment options.

For remedial options that involve the disposal of wastes in a new onsite landfill, hazardous waste landfill regulations are not applicable because consolidation by disposal in an onsite landfill would not be considered hazardous waste disposal. Spent potliner or PCB-containing wastes encountered in the excavated source area materials would be removed from the waste stream and not disposed in the onsite landfill. Nonhazardous waste landfill regulations, however, are applicable to the onsite landfill because onsite disposal of excavated source area materials would be considered disposal of nonhazardous waste.

Nonhazardous waste landfill regulations include criteria for siting, operations, design, groundwater monitoring and corrective action, closure, and post-closure care. Table B-8 identifies those requirements that are ARARs for inplace closure options, and those requirements that are ARARs for source area excavation options. Requirements that are not applicable, and not relevant and appropriate, are not ARARs.

Landfill operation requirements would apply to alternatives in which a new nonhazardous waste landfill onsite would be constructed. Landfill operation requirements include procedures for excluding hazardous waste, specify cover material requirements, require run-on and runoff controls, require limitations on liquids, designate access requirements, and outline recordkeeping. Design criteria that would apply to a new nonhazardous waste landfill include a composite liner system, and a leachate collection system.

Groundwater monitoring and corrective action requirements that are applicable to a new onsite landfill, and relevant and appropriate for inplace closure of source areas, are designed to ensure that constituents entering the groundwater from a regulated unit do not exceed the concentration limits for contaminants of concern in the uppermost aquifer beyond the relevant point of compliance. Monitoring requirements include a detection monitoring program. If indicator concentrations from background and downgradient wells

show a statistically significant increase in indicator concentrations over background, assessment monitoring and implementation of corrective measures are required.

Landfill closure criteria primarily require that a final cover system be installed to minimize infiltration and erosion. Landfill closure regulations specify technical standards for the cover design, but allow alternative designs meeting performance standards. General performance standards for a cover design include: (1) provide long-term minimization of liquid migration through the closed landfill; (2) function with minimum maintenance; (3) promote drainage and minimizes cover erosion; (4) accommodate settling and cover subsidence; and (5) have a permeability less than or equal to the permeability of the bottom liner system or the natural subsoil present. Oregon closure regulations require specified cover depths, and final site face slopes, as appropriate based on site conditions.

Landfill closure regulations are applicable to a new onsite landfill, and may be relevant to options that would close source areas inplace (Oregon requirements). The performance standard for a cover system to minimize infiltration through use of a low-permeability layer in the cover system is not considered relevant and appropriate because of the seasonal high groundwater table being at or near the ground surface. Post-closure care regulations for landfills require maintaining the integrity and effectiveness of the final cover, including making repairs to the cover as necessary to correct the effects of settlement, subsidence, erosion, or other events, and preventing run-on and run-off from eroding or otherwise damaging the final cover. In addition, the leachate collection systems, and groundwater monitoring systems are to be operated and maintained throughout the post-closure period. The post-closure maintenance period is 30 years unless it can be demonstrated that a shorter or longer maintenance period is appropriate to protect human health and the environment.

Post-closure care regulations are applicable to the new onsite landfill, and may be relevant and appropriate to in-place closure options that would involve installation of a containment system. The operation and maintenance of leachate collection systems and landfill gas systems are not considered relevant and appropriate to the in-place closure of source areas.

B.4.3 Discharge of Wastewater

The CWA and DEQ rules regulate the discharge of pollutants to surface waters of the United States or the State of Oregon, permitted by the National Pollutant Discharge Elimination System (NPDES) program. Technology-based discharge limitations have been established for categories and classes of point sources of pollutants. Discharges of conventional pollutants (including oil and grease) must apply best conventional control technology (BCT). Discharges of any designated toxic pollutant [including lead, mercury, pesticides, and PAHs] must apply best available control technology (BACT) economically achievable. No categorical BCT/BACT standards exist for remedial response actions, so the technology-based discharge limitations must be determined on a case-specific basis by DEQ. On the basis of its "best professional judgment", DEQ sets numerical effluent discharge limits. These limits must meet the BCT/BACT requirements and be sufficiently stringent to ensure that water quality standards are not violated.

RMC currently has an NPDES permit for the discharge of wastewater to the Columbia River. Wastewater generated from the remedial activities is proposed to be discharged to

the Columbia River through either the same outfall, or a similarly placed outfall, authorized by the NPDES permit.

Wastewater that may be generated by the remedial activities may include water from production well and focused extraction of groundwater, groundwater dewatering for source removal activities, and dewatering of Company Lake sediments. Wastewater generated by these activities would be discharged through the existing outfall to the Columbia River as part of the NPDES permit. Treatment of extracted groundwater will be either through the existing industrial wastewater treatment system, or by a separate reverse osmosis or precipitation treatment system.

B.4.4 Discharge of Stormwater

The discharge of stormwater during construction (remedial activities) is regulated by the CWA and DEQ rules if the selected remedial alternative results in activities including clearing, grading, and excavation that disturb 5 acres or more. Requirements including monitoring and use of best management practices to control sedimentation and erosion.

B.4.5 Installation of Monitoring Wells

The Oregon Water Resources Department (OWRD) regulates the construction, alteration, abandonment, maintenance, and use of water wells and monitoring wells, or other holes, though which groundwater can become contaminated. These requirements in OAR 690 200 through 240 would apply to wells constructed, maintained, or abandoned as part of the remedial action. Wells that are constructed for obtaining water (such as focused extraction wells), or monitoring wells (such as for monitoring an onsite landfill) would need to comply with these requirements.

B.4.6 Extraction of Groundwater

Under ORS 537.110, water within the state from all sources of water supply belongs to the public (with minimal exceptions); therefore, those who want to use water must obtain a permit or water right from the OWRD. Four fundamental provisions are included in the statute:

1. A water right may be established only for beneficial uses
2. Prior appropriation defines the right to use water of a "first in time, first in right" priority basis
3. A water right is attached to the land where it is established.
4. A water right is valid as long as it is beneficially used at least once every 5 years

Response actions that appropriate or use surface water or groundwater require water rights. Permits to use groundwater may be issued only for the designated classified uses of a basin. Groundwater resources of the Sandy Basin are classified for commercial, group domestic, industrial, irrigation, mining, municipal, and statutory exempt groundwater uses (OAR 690-505-050).

RMC currently has water rights to use groundwater. Proposed remediation activities involving groundwater production well optimization would be performed under existing

water rights. Water rights for the focused extraction activities, between 50 and 112 gpm proposed, may be achieved within, or transferable from, RMC's existing water rights.

Appropriation of surface water may be interpreted for wells located near a river. The Columbia and Sandy Rivers are adjacent to the site, and groundwater is hydraulically connected. Wells within ¼ mile from a surface water source are presumed to be hydraulically connected. Extraction wells located near east potliner and scrap yard may be located within ¼ mile of the Sandy River.

Substantial groundwater interference with surface water is assumed if the groundwater appropriation is a horizontal distance less than ¼ mile from the surface water source; or (if the point of appropriation is a horizontal distance less than 1 mile from the surface water source) the rate of appropriation is greater than 5 cubic feet per second (cfs); or the rate of appropriation is greater than 1 percent of the pertinent adopted minimum perennial streamflow; or the groundwater appropriation continues for a period of 30 days, and would result in stream depletion greater than 25 percent of the rate of appropriation. Substantial interference with surface water is not anticipated for RMC remedial activities because the maximum groundwater extraction rate from the focused extraction would be 112 gpm (0.25 cfs) and the groundwater extraction from the production well optimization would be 1,800 gpm (2.7 cfs), which is within RMC's current water rights.

Appendix B Tables

Table B-1 Potential Chemical-Specific ARARs				
Requirement	**Prerequisite**	**Citation**	**ARAR Determination**	**Comments**
Safe Drinking Water Act, 42 USC 300f et seq.*				
National primary drinking water standards are health-based standards for public water systems and are expressed as MCLs.	Public water system.	40 CFR 141.11 - 40 CFR 141.12	Relevant and appropriate for sources of drinking water.	The NCP defines MCLs as relevant and appropriate for groundwater determined to be a current or potential source of drinking water. State MCLs for constituents of concern at RMC are either equal to Federal MCLs or not established. Federal MCLGs for these constituents are either zero or not established.
Clean Water Act, 33 USC 1251 et seq.*				
Surface water quality criteria.	Discharges to waters of the United States.	33 USC 1313; National Recommended Water Quality Criteria-Correction. EPA Document 822-Z_99-001, April 1999. OAR 340-41-482	Potentially relevant and appropriate	Relevant and appropriate for assessing the impact of non-permitted discharges on surface water quality. Where the state water quality standards are more stringent, they supersede the federal standards.
Resource Conservation and Recovery Act*				
Definition of RCRA hazardous waste	Waste generation.	OAR 340-101; 40 CFR 261	Potentially applicable	Requirements to perform a waste determination would be applicable to solid wastes removed from area of concern. If hazardous, wastes transported offsite, would be fully regulated under RCRA.

Table B-1 (continued) Potential Chemical-Specific ARARs				
Requirement	**Prerequisite**	**Citation**	**ARAR Determination**	**Comments**
Toxic Substances Control Act*				
Polychlorinated Biphenyls	Debris generated from cleanup of a release of PCBs before April 1978 and currently at a concentration ≥ 50ppm PCBs or from an original source in excess of 500 ppm beginning April 1978 or 50 ppm beginning July 1979.	40 CFR 761.50 40 CFR 761.61(b) & (c)	Not ARAR	PCB remediation wastes must be disposed of according to performance based or risk based disposal standards. Performance based disposal options for liquids include incineration (40 CFR 761.60(e)) or decontamination (40 CFR 761.79). For solids, disposal options include incineration or landfill in TSCA compliant facilities, or decontamination (40 CFR 761.79). Risk based disposal is permitted by EPA on a case-by-case based on "unreasonable risk to human health or the environment." PCBs have not been encountered at North Landfill, South landfill, Scrap Yard, Company Lake or in groundwater at concentrations that would trigger TSCA.
PCB spill cleanup policy.	All spills of PCBs at concentrations of 50 ppm or greater that are subject to decontamination requirements under TSCA.	40 CFR 761.120 through 761.139	Potential TBC	EPA has used the TSCA PCB Spill Policy as a basis for establishing guidance on cleanup levels for PCBs. EPA *Guidance on Remedial Action for Superfund Sites with PCB Contamination,* OSWER Directive No. 9355.4-01 (EPA, 1990) defines cleanup levels of 1 ppm for unrestricted or residential areas and 10 to 25 ppm for industrial settings. These cleanup levels are not ARARs for Superfund sites since they are not promulgated standards, but they are to-be-considered criteria (TBCs).

Table B-1 (continued)
Potential Chemical-Specific ARARs

Requirement	Prerequisite	Citation	ARAR Determination	Comments

*Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs for the convenience of readers. Listing the statutes and policies does not indicate that the statutes or policies in their entirety are potential ARARs. Only substantive requirements of the specific citations are considered potential ARARs.

Abbreviations:

ACLs–Alternate concentration limits
ARARs–Applicable or relevant and appropriate requirements
bgs–Below the ground surface
CAA–Clean Air Act
CERCLA–Comprehensive Environmental Response, Compensation, and Liability Act
CFR–Code of Federal Regulations
CWA–Clean Water Act
EPA–U.S. Environmental Protection Agency
FIFRA–Federal Insecticide, Fungicide, and Rodenticide Act
MCLs–Maximum contaminant levels
MCLGs–Maximum contaminant level goals
NAAQS–National Ambient Air Quality Standards (primary and secondary)
NCP–National Contingency Plan
OAR–Oregon Administrative Rule
PCB–Polychlorinated biphenyl
ppm–Parts per million
RMC–Reynolds Metals Company
RCRA–Resource Conservation and Recovery Act
SDWA–Safe Drinking Water Act
SMCLs–Secondary maximum contaminant levels
TBC–To be considered
TCLP–Toxicity characteristic leaching procedure
TSCA–Toxic Substances Control Act
USC–United States Code

Table B-2
Relevant and Appropriate MCLs (μg/L)

Inorganics		Volatile Organics	
Constituent	**MCL**	**Constituent**	**MCL**
Arsenic	50	11-DCE	7
Beryllium	4	PCE	5
Chromium	100		
Cyanide	200		
Fluoride	4,000		
Lead	15*		
Nickel	100**		

* Action level.
** Being remanded.

Table B-3
Relevant and Appropriate WQC (μg/L)

	Freshwater Aquatic Life		Human Health Consumption	
Constituent	**Acute CMC**	**Chronic CCC**	**Water and Organism**	**Organism**
Arsenic	340	150	0.0022 [s]	0.0175 [s]
Beryllium	-	-	6,800 [c]	117,000 [c]
Chromium	570 [t]/16 [h]	74 [t]/11 [h]	50 [h s]	-
Cyanide	22	5.2	200 [s]	220000
Fluoride	-	-	-	-
Lead	65	2.5	-	-
Nickel	470	52	13.4 [s]	100 [s]
11-DCE	-	-	0.057 [c]	3.2 [c]
PCE	-	-	0.8 [c]	8.85 [c]

- = Not established.
C = Based on carcinogenicity of 10^{-6} risk.
H = Hexavalent.
P = Pentavalent.
S = State Water Quality Criteria that is more stringent than Federal.
T = Trivalent.

Notes:
Nickel values are hardness dependent, 100 mg/L hardness used.
For complete qualifying information for values, see *National Recommended Water Quality Criteria-Correction*, EPA document 822-Z-99-001, April 1999.

Table B-4
Sandy Basin Beneficial Uses

Beneficial Uses[a]	Sandy River[b]	All Other Sandy River Tributaries	Columbia River (RM 86 to 120)[c]	Columbia River (RM 120 to 147)[c]
Public domestic water supply	X	X	X	X
Private domestic water supply	X	X	X	X
Industrial water supply	X	X	X	X
Irrigation	X	X	X	X
Livestock watering	X	X	X	X
Anadromous fish passage	X	X	X	X
Salmonid fish rearing	X	X	X	X
Salmonid fish spawning	X	X	X	
Resident fish and aquatic life	X	X	X	X
Wildlife and hunting	X	X	X	X
Fishing	X	X	X	X
Boating	X	X	X	X
Water contact recreation	X	X	X	X
Aesthetic quality	X	X	X	X
Hydro power	X	X	X	X
Commercial navigation and transportation			X	X

[a] These are potential beneficial uses. Current or reasonably likely beneficial uses in the locality of the Troutdale facility have not been determined.

[b] The Sandy River is water quality limited as follows: RM 0-25 is partially impaired for dissolved oxygen.

[c] The Columbia River is water quality limited as follows:
- RM 26-120 is partially impaired for pH.
- RM 120-203 is impaired for dioxin.

Abbreviations:
ARAR–Applicable or relevant and appropriate requirement.
RM–River mile.
Source: Oregon's 1992 305(b) report.

Table B-5
Comparison of Balancing Factors for Remedy Selection

Federal	Oregon
Reduction of toxicity, mobility, or volume through treatment	Effectiveness in achieving protection
Permanence and long-term effectiveness	Long-term reliability
Implementability	Implementability
Short-term effectiveness	Short-term risk
Cost	Cost-reasonableness

Table B-6 Location-Specific ARARs					
Location	**Requirement**	**Prerequisite**	**Citation**	**ARAR Determination**	**Comments**
Resource Conservation and Recovery Act Solid Waste Disposal Facilities and Practices*					
Landfill Siting Standards	Disposal facilities or practices are prohibited if they violate standards regarding: adverse modifications or effects on floodplain; endangered species surface waters; groundwater; food crops; air quality; safety or a sources of disease vectors.	Solid waste disposal facility or practices	40 CFR 257.3 40 CFR 258 Subpart B OAR 340-95-030	Applicable	Disposal facilities that do not meet specified criteria are prohibited under §4004 of Solid Waste Disposal Act and must eliminate health hazards and minimize potential health hazards. Standards are applicable to disposal sites that are part of the response site, and onsite disposal areas that received solid waste after the effective date of the regulations. Disposal facilities in floodplains "shall not result in washout of solid waste so as to pose a hazard to human life, wildlife, or land or water resources."
Executive Order 11988, Protection of Floodplains*					
Within floodplain	Actions taken should avoid adverse effects, minimize potential harm, and restore and preserve natural and beneficial values of floodplains	Action that will occur in a floodplain, i.e., lowlands, and relatively flat areas adjoining inland and coastal waters and other flood-prone areas	Executive Order 11988 (40 CFR 6 Appendix A)	Potentially applicable for response actions	A U.S. Army Corps of Engineers dike separates RMC from the Columbia and Sandy rivers. Some of the areas of concern are within the floodplain, and some are outside the floodplain. The 100-year floodplain boundary is at approximate Elevation 32, generally at the flood control dike. Source: FEMA Flood Insurance Study.

Table B-6 (continued) Location-Specific ARARs					
Location	**Requirement**	**Prerequisite**	**Citation**	**ARAR Determination**	**Comments**
National and State Archaeological and Historic Preservation Acts*					
Areas with protected cultural resources	Protection of cultural resources.	Alteration of terrain that threatens significant scientific, prehistoric, historic, or archaeological data	16 USC §461, Executive Order 11593, ORS 385.905	Potentially applicable for response actions	According to SHPO, there is a probability for archaeological sites such as summer villages to be present near the RMC facility because of confluence of two rivers. The area has not been surveyed. Consultation with SHPO may be needed to assess the response activities planned and their potential for disruption of protected resources.
Endangered Species Protection*					
Critical habitat of endangered or threatened species	Requires federal agencies to ensure that any action authorized, funded, or carried out by said agency will not jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of habitat critical to survival of the species.	Determination of effect upon endangered or threatened species or its habitat	16 USC 1536(a); ESA Section 7 (a) (2 ORS 635.100-0125	Potentially relevant and appropriate	There is a potential for protected species to occur in the project area. The federally listed Snake River fall Chinook salmon, spring Chinook salmon, and sockeye salmon are known to migrate through Columbia and Snake Rivers. Oregon's *Sensitive Species List* (OAR 635-100-0125 includes species in addition to federal lists. Review of proposed response action will be needed by EPA to determine if a biological opinion or formal consultation is needed. A biological assessment may be needed to assess potential for all reasonable and prudent alternative actions to conserve endangered or threatened species.

Table B-6 (continued)
Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Wild and Scenic Rivers Act*					
Within area affecting national wild, scenic, or recreational river	A federal agency may not assist, through grant loan, license, or other means, the construction of a water resources project that would have a direct effect on the free-flowing scenic and natural values for which a river was designated.	Action that may affect any of the rivers specified in Section 1276(a)	16 USC 1271 et seq.; Section 7(a)	Potentially applicable for response actions	The Sandy River is designated a scenic and recreational river. Because the RMC site is adjacent to a designated river, response actions are not permitted to have a direct and adverse effect on the characteristics for which the river was listed.
Migratory Bird Treaty Act of 1972*					
Migration corridor	Prohibition on any action that may result in taking of a migratory bird or their eggs, or nests.	Taking of migratory birds or their nests	16 USC Section 703	Potentially applicable for response actions	Columbia River is within the Pacific flyway, a migration corridor. All waterfowl species, neotropical migrants, and most other wild bird species are protected. Response actions are not permitted to cause taking of birds or nests.

Table B-6 (continued)
Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments

*Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs for the convenience of readers. Listing the statutes and policies does not indicate that the statutes or policies in their entirety are potential ARARs. Only substantive requirements of the specific citations are considered potential ARARs.

Abbreviations:
ARARs–Applicable or relevant and appropriate requirements
bgs–Below the ground surface
CERCLA–Comprehensive Environmental Response, Compensation, and Liability Act
CFR–Code of Federal Regulations
ESA–Endangered Species Act
FEMA–Federal Emergency Management Agency
MMPA–Marine Mammals Protection Act
NEPA–National Environmental Policy Act
RCRA–Resource Conservation and Recovery Act
RMC–Reynolds Metals Company
SHPO–State Historic Preservation Office
USC–United States Code
USFWS–U.S. Fish and Wildlife Service

Table B-7
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
Resource Conservation and Recovery Act, Hazardous Waste Management*						
Onsite waste generation, hazardous waste accumulation	Generation of hazardous waste. Person who generates waste is to determine whether that waste is hazardous. Generator may accumulate waste onsite for 90 days or less.	Generation, accumulation, storage, transportation of hazardous waste.	40 CFR 261; 40 CFR 262; OAR 340-100 through 340-103	3-5, 8,12, 15, 18		Applies to any operation in which waste is generated (e.g., excavated material). Waste is anticipated to be generated by options involving groundwater treatment; excavation of materials from north landfill, south landfill, and scrap yard; and dredging of Company Lake process residue. Any waste generated that is determined to be hazardous will be disposed offsite.
Placement of waste in land disposal unit	Attain land disposal treatment standards to comply with land ban restrictions. Land disposal bans may prohibit land disposal or require treatment before land disposal. The purpose of the land bans is to restrict the land disposal of specific wastes unless treatment standards are met. Requirements exist for generators and treatment, storage, and disposal facilities.	Placement of RCRA hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, underground mine or cave, or concrete vault or bunker intended for disposal purposes.	40 CFR 268 OAR 340-100	8, 12, 15		These regulations would be applicable to wastes generated by the action that are classified as land-banned wastes. Such wastes would not be disposed onsite, but would be transported offsite. Any offsite disposal would need to comply with the land disposal restrictions. Land-banned wastes that may be generated by remedial options include spent potliner and materials characterized as hazardous by the Toxic Characteristic Leaching Procedure (EPA Hazardous Waste numbers D004-D011).

Table B-7 (continued)
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
Closure and post-closure with hazardous waste in place	General performance standard requires elimination of the need for further maintenance and control; elimination of post-closure escape of hazardous wastes, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products; removal or decontamination of all waste residues and contaminated containment system components; and cleanup to health-based standards.	Land-based unit containing RCRA hazardous waste placed after the effective date of the requirements, or placed into another unit. Not applicable to material treated, stored, or disposed before the effective date of the requirements, or to material treated in situ or consolidated within the area of contamination.	40 CFR 264 OAR 340-100, OAR 340-104		7, 10, 14, 17	These requirements cover land units such as waste piles, surface impoundments, and landfills, used for disposal of hazardous waste. These requirements are not considered applicable to in-place closure options because most wastes were placed into north landfill, south landfill, and scrap yard prior to the effective date of the regulations (November 1980). Although some wastes were deposited at north landfill and scrap yard after 1980, no RCRA hazardous wastes are known to have been placed after 1980. Substantive portions of the requirements will be applied to the extent that they are relevant and appropriate to in-place closure at north landfill, south landfill, scrap yard, and Company Lake. Would not be applicable to new landfill because only nonhazardous waste would be disposed of in the new landfill.

Table B-7 (continued)
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
Hazardous waste landfill closure	Final cover must be designed and constructed to provide long-term minimization of migration of liquids through the closed landfill; function with minimum maintenance; promote drainage and minimize erosion or abrasion of the cover; accommodate settling and subsidence so that the cover's integrity is maintained; and have a permeability less than or equal to the permeability of any bottom liner or the natural subsoil present. Also requires maintenance of cover; continued operation of leachate collection system, and groundwater monitoring system; and maintenance of surveyed benchmarks.	Landfill containing RCRA hazardous waste placed after the effective date of the requirements, or placed into another unit. Not applicable to material treated, stored, or disposed before the effective date of the requirements.	40 CFR 264 Subpart N OAR 340-100, OAR 340-104		7, 10, 14, 17	Applies to units that dispose of hazardous wastes. Units newly constructed, replaced, or expanded must meet these requirements. These requirements are not considered applicable to inplace closure options because most wastes were placed into north landfill, south landfill, and scrap yard prior to the effective date of the regulations (November 1980). Although some wastes were deposited at north landfill and scrap yard after 1980, no RCRA hazardous wastes are known to have been placed after 1980. Substantive portions of these requirements will be applied to the extent that they are relevant and appropriate to in-place closure at north landfill, south landfill, scrap yard, and Company Lake. These requirements are not applicable to the new landfill because only nonhazardous waste would be disposed of at the new landfill.

Table B-7 (continued)
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
U.S. Department of Transportation, 49 USC 1802 et seq.*						
Hazardous materials transportation	Requirements for transportation of hazardous materials: • Classify hazardous materials • Package hazardous materials properly • Mark, label, and placard shipments and vehicles properly • Inspect packages and vehicles used for shipment • Use proper loading and unloading techniques • Provide required training	Interstate carriers transporting hazardous waste and substances by motor vehicle.	49 CFR 171 through 173	3-5, 8, 12, 15, 18		Applies to hazardous wastes that are generated and managed by shipment offsite for disposal. The majority of the wastes to be generated by the remedial action options are anticipated to be characterized as nonhazardous and disposed of in a new onsite landfill. These regulations would be applicable to any wastes generated by the remedial action that are classified as hazardous and transported offsite.

Table B-7 (continued)
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
Resource Conservation and Recovery Act, Solid Waste Management*						
Solid waste disposal	A facility or practice shall not contaminate an underground drinking water source beyond the solid waste boundary or a court- or state-established alternative.	Solid waste disposal facility and practices.	40 CFR 257	8, 12, 15, 18	7, 10, 14, 17	These criteria are for use under RCRA in determining which solid waste disposal facilities and practices have a reasonable probability of posing adverse effects on health or the environment. Protects groundwater sources of drinking water against releases from solid waste disposal facilities. These requirements are potential ARARs for onsite disposal activities, for options that include waste excavation and disposal in a new onsite landfill, as well as options that include in-place closure of waste.
Solid waste landfill closure	Requires the final cover system be designed to minimize infiltration and erosion. Provides specific technical standards for cover design, but allows alternative cover designs if it is demonstrated that they achieve the same level of performance.	Placement of final covers.	40 CFR 258 Subpart F OAR 340-94	8, 12, 15, 18	7, 10, 14, 17	Federal rule applies to closure of solid waste landfills that received waste after 1991. Oregon rule applies to facilities that close after January 1, 1980. For RMC remedial action options, requirements may be relevant and appropriate to source areas closed inplace, and applicable to a new onsite landfill.

Table B-7 (continued)
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
Solid waste landfill post-closure care	Requires post-closure maintenance for a period of 30 years unless it can be demonstrated that a shorter or longer maintenance period is required. If it can be demonstrated that the site poses no threat to public health and safety, or to the environment, the post-closure maintenance period may be terminated.	Post-closure maintenance.	40 CFR 258 Subpart F OAR 340-94	8, 12, 15, 18	7, 10, 14, 17	Federal rule applies to closure of solid waste landfills closed after September 1993. Oregon rule applies to facilities that close after January 1, 1980. For RMC remedial action options, requirements may be relevant and appropriate to source areas closed in-place, and applicable to a new onsite landfill.
Solid waste landfill operation	Requires procedures for excluding hazardous waste, specifies cover material requirements, requires control of explosive gases, requires run-on and runoff controls, requires limitations on liquids, designates access requirements, and outlines recordkeeping.	Applicable to solid waste landfills that received waste after October 9, 1991.	40 CFR 258 Subpart C OAR 340-94	8, 12, 15, 18		Requirements are applicable to alternatives in which a new or expanded onsite solid waste landfill would be used.

Table B-7 (continued)
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
Solid waste landfill design criteria	Sets forth requirements for design of solid waste landfills. Requires: 1. A composite liner consisting of a minimum 30-mil flexible membrane liner and at least a 2-foot layer of compacted soils with a hydraulic conductivity of no more than 10^{-7} cm/sec 2. A leachate collection system 3. Run-on and runoff control systems capable of handling the peak discharge of a 25-year storm 4. Closure of each cell with a final cover after the last waste has been received	Applies to new solid waste landfills and lateral expansions.	40 CFR 258 Subpart D OAR 340-94	8, 12, 15, 18		Applies to alternatives in which a new or expanded onsite solid waste landfill would be used.

Table B-7 (continued)
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
Groundwater monitoring and corrective action	Sets forth requirements for groundwater monitoring and corrective action. Standards designed to ensure that constituents from regulated units do not exceed the concentration limit for contaminants of concern in the uppermost aquifer underlying the waste management area beyond the point of compliance.	Applies to solid waste landfills unless it can be demonstrated that there is no potential for migration of hazardous constituents to the uppermost aquifer.	40 CFR 258 Subpart E	8, 12, 15, 18	7, 10, 14, 17	Applicable to options in which a new or expanded onsite solid waste landfill would be used. Substantive requirements would be applied to inplace closure options to the extent they may be relevant and appropriate.
Clean Water Act*						
Discharge of treatment system effluent	Restore and maintain the chemical, physical, and biological integrity of the waters of the United States. Requires the establishment of guidelines and standards to control the direct or indirect discharge of pollutants.	Discharge to waters of the State of Oregon. Requires conformance with state-wide Water Quality Management Plan.	40 CFR 122 OAR 340-041	2, 3, 4, 5, 8, 12, 18		Applies to options that would extract and treat groundwater, or otherwise generate wastewater. Options 3, 4, and 5 would include focused extraction. Options 8 and 12 may include dewatering of excavations, and Option 18 will include dewatering of sediments. Wastewater generated by these options would be discharged through the existing outfall to the Columbia River in compliance with substantive water quality requirements.

Table B-7 (continued)
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
Discharge of storm water	Storm water associated with industrial activity that comes in direct contact with manufacturing processes or raw-material storage areas.	Stormwater discharges associated with industrial activity are the discharges from any conveyance that is used to collect and convey storm water directly related to manufacturing, processing, or raw-material storage areas at an industrial plant.	40 CFR 122	All soil		Industrial activities include construction activities for disturbances greater than 5 acres, landfills, and treatment, storage, and disposal facilities. Requirements include monitoring and use of best management practices. These requirements would be applicable for alternatives that would disturb areas greater than 5 acres, including construction of the new onsite landfill.
Dredging	Dredging must comply with Section 10 of the Rivers and Harbors Act and U. S. Army Corps of Engineers regulations.	Dredging in navigable waters of the United States.	33 USC 403; 33 CFR 320 to 330	18		Since Company Lake is part of the NPDES system, and not a navigable water of the state, this requirement is not an ARAR.
Toxic Substances Control Act*						
PCB-contaminated materials management	Storage, treatment, disposal and marking of PCB and PCB-containing items	Generation of PCBs at concentrations of 50 ppm or greater and PCB items with PCB concentrations of 50 ppm or greater.	40 CFR 761 OAE 340-110	8, 12, 15		PCBs have not been identified at NLF, SLF, or SY in soil samples at concentrations greater than 50 ppm during previous investigations. However, if encountered during remedial activities that involve excavation of source areas, PCB-containing wastes would have to be managed and disposed of in accordance with TSCA requirements.

Table B-7 (continued)
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
Clean Air Act*						
Emissions of particulate matter	Governs particulate emission standards other than specific emission standards. Defines special control areas (e.g., incorporated cities having a population of 4,000 or more).	Emission of particulates, including fugitive emissions.	OAR 340-021	All soil		Applies to activities that generate particulate emissions such as earth moving
Gaseous emissions	Sets forth the standards and requirements for gaseous emissions such as VOCs that contribute to the formation of photochemical oxidant, mainly ozone.	Emission of VOCs.	OAR 340-022	2-5		The groundwater contains only trace quantities of VOCs that might be released during removal or treatment activities. The RMC facility is located in the Portland-Vancouver Air Quality Maintenance Area. This requirement is not an ARAR.
Air pollution control	Specifies air pollution control rules for areas with unique air quality needs.	Activities located within Multnomah County. Activities conducted in the listed counties other than those for which specific industrial standards have been adopted.	OAR 340-030-400	7, 8, 10, 12, 14, 15, 17		Standards for particulate emissions, visible air emissions, and odors are addressed.
Oregon Water Resources Department*						
Water well construction and abandonment	Governs the construction and abandonment of water wells and other holes.	Any water well or other hole through which groundwater can become contaminated.	OAR 690-220	3-5		These requirements would apply to all water supply wells installed or abandoned as part of the response actions. Groundwater extraction wells would be installed for Options 3-5.

Table B-7 (continued)
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
Monitoring wells	Governs the construction and maintenance of monitoring wells and other holes.	Any wells or other holes drilled to allow groundwater quality determinations through which groundwater can become contaminated.	OAR 690-240	6-18		These requirements would apply to all monitoring wells installed or abandoned as part of the response actions. Groundwater monitoring wells would be used for all Options.
Water supply well construction, operation, and maintenance	Governs the construction and maintenance of water supply wells and other holes.	Applies to any wells constructed for the purpose of locating or obtaining water, with some exceptions, and to wells in which groundwater can become contaminated.	OAR 690-200 to 690-215	3-5 6-18		These requirements would apply to all water supply wells and other holes constructed, operated, and maintained as part of the response actions. Groundwater extraction wells would be used for Options 3-5. Groundwater monitoring wells would be used for all Options.

Table B-7 (continued)
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
Groundwater interference with surface water	Governs the use of groundwater where it is hydraulically connected to and the use interferes with surface waters.	Applies to wells that produce water from an unconfined or confined aquifer that is determined to be hydraulically connected to surface water. Wells within one-quarter mile from a surface water source that produce water from an unconfined aquifer are presumed to be hydraulically connected. Substantial interference occurs when the point of appropriation is a distance less than one-quarter mile away, or the rate of appropriation is greater than 5 cubic feet per second (cfs), or the rate of appropriation is greater than 1 percent of the minimum annual stream flow, or the groundwater appropriation continues for 30 days and would result in stream depletion of greater than 25 percent of the rate of appropriation.	OAR 690-09	2-5		Potentially an issue for any groundwater extraction conducted near a surface water body as part of response actions for the site. The Columbia and Sandy Rivers are adjacent to the site, and groundwater is hydraulically connected. Extraction wells located near east potliner and scrap yard may be located within ¼ mile of the Sandy River. Extraction wells located near Company Lake may be located within ¼ mile of the Columbia River. Substantial interference is not anticipated as the maximum groundwater extraction rate is less than 3 cfs.

Table B-7 (continued)
Potential Action-Specific ARARs

Sitewide Groundwater Options: (1) No action. (2) Production Well Optimization. (3) Production Well Optimization + Basic Focused Extraction. (4) Production Well Optimization + Enhanced Focused Extraction. (5) Production Well Optimization + High Level of Focused Extraction. **North Landfill Options:** (6) No further action. (7) Riprap cover. (8) Excavate waste layer. **South Landfill Options:** (9) No further action. (10) Soil + vegetation cap. (11) Fencing + signs. (12) Excavate waste layer. **Scrap Yard Options:** (13) No further action. (14) Gravel cap. (15) Excavate waste layer in north 1/2. **Company Lake Options:** (16) No further action. (17) Permeable cap. (18) Dredge process residue and mechanically dewater.

				ARAR Determination		
Action	**Requirement**	**Prerequisites**	**Citation**	**A**	**RA**	**Comments**
Groundwater appropriation	Requires that use of groundwater be approved through issuance of water rights by OWRD. Includes any water beneath the land surface regardless of the geological formation or structure in which the water stands, flows, percolates, or moves through.	Applies where groundwater is appropriated for beneficial use. Groundwater resources of the Sandy Basin are classified for commercial, group domestic industrial, irrigation, mining, municipal, and statutory-exempt groundwater uses.	ORS 537.110	3-5		RMC currently has water rights to use groundwater. The Oregon Water Resources Department would need to be consulted regarding any new wells used as part of a groundwater extraction and treatment option. Water rights for the extraction of 50 to 112 gpm through focused extraction may be transferable from RMC's existing water rights.

*Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs for the convenience of readers. Listing the statutes and policies does not indicate that the statutes or policies in their entirety are potential ARARs. Only substantive requirements of the specific citations are considered potential ARARs.

Abbreviations:
A–Applicable
ARAR–Applicable or relevant and appropriate requirement
CERCLA–Comprehensive Environmental Response, Compensation, and Liability Act
CFR–Code of Federal Regulations
cfs–cubic feet per second
CWA–Clean Water Act
EPA–U.S. Environmental Protection Agency
gpm–gallons per minute
OAR–Oregon Administrative Rule
ORS–Oregon Revised Statute
OWRD–Oregon Water Resources Department
PCBs–polychlorinated biphenyls
RA–Relevant and appropriate
RCRA–Resource Conservation and Recovery Act
RMC–Reynolds Metals Company
TSCA–Tosic Substances Control Act
USC–United States Code
VOC–volatile organic compound

Table B-8
Nonhazardous Waste Landfill Regulations as ARARs for RMC

RCRA Nonhazardous Waste Landfill Regulations	Options involving containment (closure of waste inplace) at NLF, SLF, SY, CL	Options involving source area excavation and disposal of waste in a new onsite landfill
Siting (40 CFR 258.10-258.15. OAR 340-94-030. OAR 340-95-010)	May be relevant and appropriate (1)	Applicable to new landfill
Operating (40 CFR 258.20-258.29. OAR 340-94-040. OAR 340-95-020)		Applicable to new landfill
Design (40 CFR 258.40. OAR 340-94-060. OAR 340-95-030)		Applicable to new landfill
Groundwater Monitoring and Corrective Action (40 CFR 258-50 –258.58. OAR 340-94-080. OAR 340-95-040)	May be relevant and appropriate	Applicable to new landfill
Closure (40 CFR 258.60. OAR 340-94-120. OAR 340-95-070)	May be relevant and appropriate (2)	Applicable to new landfill
Post-Closure Care (40 CFR 258.61. OAR 340-94-130. OAR 340-95-080)	May be relevant and appropriate (3)	Applicable to new landfill

(1) The siting requirements for floodplains in 40 CFR 258.11 and OAR 340-94-030 may be considered relevant and appropriate to actions at NLF. The regulations require that a landfill located within a floodplain must be controlled to prevent the washout of solid waste that may pose a hazard to human life, wildlife, or land or water resources. See discussion of floodplain restrictions under Location-Specific ARARs in Appendix B.

(2) Closure requirements in 40 CFR Part 258 apply to disposal facilities that received waste after 1991. OAR 340-95-070 applies to facilities that close after January 1, 1980. The closure requirements primarily pertain to the installation of a final cover system. A cover system may be relevant and appropriate to the source areas that are disposal areas. The performance standard for a cover system to minimize infiltration though a low-permeability layer is not considered relevant and appropriate because the seasonal high ground-water table is at or near the ground surface.

(3) The post-closure care provisions that require maintenance of the final cover system may be relevant and appropriate to in-place closure options. The post-closure care provisions that require operation and maintenance of leachate collection systems and landfill gas systems are not considered relevant and appropriate.

APPENDIX C

Cost Estimates for Remedial Options

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APPENDIX C

Cost Estimates for Remedial Options

Together, this appendix and Appendix D provide an estimate of remediation costs for the RMC-Troutdale Superfund site. Cost estimates are provided in this appendix for the remedial options (combinations of technologies) discussed in Section 4 of the Focused Feasibility Study (FFS).

Appendix D contains cost estimates for the remedial alternatives (combinations of options) discussed in Section 6 of the FFS.

As discussed in the FFS, remedial option costs were estimated for use in evaluating the options. Option cost data are combined with effectiveness evaluations in Section 4 of the FFS as a basis for deciding which options to use in developing the sitewide alternatives presented in Section 5 of the FFS.

The cost estimates developed for this appendix were originally created for an early action decisionmaking process initiated in October 1998 and completed in February 1999. In some cases, these costs represent a higher level of detail than would normally be provided in a feasibility study. Nevertheless, cost estimates presented in this appendix should not be considered as absolute amounts but rather in terms of relative cost, providing a comparative evaluation of options for each area of concern or medium. The design details provided for each option represent assumptions made in order to generate costs, and not final decisions for any option that might be implemented.

The cost estimates for the remedial options are considered to be order-of-magnitude with an intended accuracy of +50 percent and – 30 percent. The actual cost is expected to be no higher than 50 percent more than the estimate or 30 percent less than the estimate. Unit costs provided in this appendix are based on quotations from vendors, construction cost data, professional engineering judgment, and standard costing references. Final project costs will depend on actual labor and material costs, site conditions, competitive market conditions, final project scope, final project schedule, the firm(s) selected for engineering design and implementation, and other variable factors. Because of these factors, financial needs must be carefully reviewed before specific financial decisions are made or remedial action budgets are established.

The costs presented here are estimated, with 1998 as the base year.

Remedial option cost estimates are provided for the following areas and media:

- North landfill
- South landfill
- Scrap yard
- Company Lake
- Sitewide groundwater

The remedial option cost estimates compiled in this section include total capital costs, annual operation and maintenance (O&M) costs, and net present value (assuming a 30-year operating horizon). Net present value (NPV) is determined assuming constant future dollars and a 7 percent discount rate.

In order to evaluate the remedial options for each soil and debris area as independent actions in Section 4, the options are defined as assuming offsite disposal of excavated material. A contingency factor has been applied to costs that are affected by the volume of material to be excavated to allow for uncertainty in these quantities. The contingency factors applied are: north landfill, 50 percent; south landfill, 50 percent; and scrap yard, 25 percent. The costs affected include excavation, transportation, and offsite disposal. The cost table spreadsheets identify the contingency costs as separate line items.

Material quantity contingency factors are provided for waste transport and offsite disposal. Line items are included in the cost estimates to identify excavation, transport, and disposal of expected material quantities and the additional costs assigned for contingency volumes.

A summary of remedial option costs for north landfill, south landfill, scrap yard, and Company Lake is provided in Table C-1. A summary of groundwater option cost estimates is provided in Table C-2.

C.1 North Landfill

Five remedial options are evaluated for north landfill. Figure C-1 delineates the area of north landfill that is addressed in this cost estimate. North landfill is approximately 2.4 acres in areal extent.

C.1.1 North Landfill Option Descriptions and Assumptions

C.1.1.1 NLF–1: Institutional Controls

The institutional controls for NLF-1 include:

- Deed restrictions to limit the use of the area by possible future owners
- Access restrictions (fencing) and signage
- Use restrictions (limited to authorized plant personnel and site visitors)
- Level D personal protective equipment (PPE) for authorized RMC personnel and trench workers during possible excavation activities

C.1.1.2 NLF–2: Permeable Riprap Cover

This option includes deed restrictions and Level D PPE (see institutional controls above). Construction of the riprap cover consists of the following elements (see Figure C-2):

- Surface preparation, clearing and grubbing, and stripping
- Access roads
- Geotextile layer

- 12-inch-thick layer of 50-lb riprap

C.1.1.3 NLF–3: Multilayer Low-Permeability Cap

This option includes deed restrictions and Level D PPE (see institutional controls above). Construction of the low-permeability cap consists of the following elements (see Figure C-3):

- Surface preparation, clearing and grubbing, and stripping
- Access roads
- 12-inch-thick layer of compacted soil
- 40-mil flexible geomembrane
- Geonet layer
- Geotextile layer
- 12-inch-thick layer of compacted soil
- Geotextile layer
- 12-inch-thick layer of 50-lb riprap over the entire area

C.1.1.4 NLF–4: Excavation of Waste Layer

This option includes deed restrictions and Level D PPE (see institutional controls above). Excavation of the waste layer includes:

- Surface preparation, clearing and grubbing, and stripping
- Access roads
- Visual removal of waste layer; approximately 33,000 cubic yards (average thickness of 9 feet over entire area)
- Transport and offsite disposal of waste layer
- Backfill with 6 inches of clean topsoil
- Natural revegetation

C.1.1.5 NLF–5: Excavation of Waste Layer and Surficial Sand

This option includes deed restrictions and Level D PPE (see institutional controls above). Excavation of the waste layer and an additional 2 feet of surficial sand includes:

- Surface preparation, clearing and grubbing, and stripping
- Access roads
- Visual removal of waste layer; approximately 33,000 cubic yards (average thickness of 9 feet over entire area)
- Excavation of surficial sand; approximately 8,000 cubic yards

- Transport and offsite disposal of waste layer and surficial sand
- Backfill with 2.5 feet of clean topsoil (to same grade as option NLF-4)
- Natural revegetation

C.1.2 North Landfill Option Cost Estimates

Tables C-3 and C-4 provide the line item cost estimating assumptions and unit costs used for all soil and debris areas. Table C-5 provides the order-of-magnitude cost estimates for each north landfill remedial option. Costs are lowest for the institutional controls and capping options. Costs increase substantially for NLF-4 and NLF-5, which involve excavation and offsite waste disposal.

C.2 South Landfill

Five remedial options are evaluated for south landfill. Figure C-4 delineates the area of south landfill that is addressed in this cost estimate. South landfill is approximately 5.8 acres in areal extent.

C.2.1 South Landfill Option Descriptions and Assumptions

C.2.1.1 SLF–1: Institutional Controls

The institutional controls for SLF-1 include:

- Deed restrictions to limit the use of the area by possible future owners
- Access restrictions (fencing) and signage
- Use restrictions (limited to authorized plant personnel and site visitors)
- Level D PPE for authorized RMC personnel and trench workers during possible excavation activities

C.2.1.2 SLF–2: Permeable Soil Cap

This option includes deed restrictions and Level D PPE (see institutional controls above). Construction of the permeable soil cap consists of the following elements (see Figure C-5):

- Surface preparation, clearing and grubbing, and stripping
- Access roads
- 12-inch-thick permeable soil cap over waste layer
- 6 inches of topsoil
- Natural revegetation of capped area

C.2.1.3 SLF–3: Multilayer Low-Permeability Cap

This option includes deed restrictions and Level D PPE (see institutional controls above). Construction of the low permeability cap consists of the following elements (see Figure C-6):

- Surface preparation, clearing and grubbing, and stripping
- Access roads
- 12-inch-thick layer of compacted soil
- 40-mil flexible geomembrane liner
- Geonet layer
- Geotextile layer
- 12-inch-thick layer of compacted soil
- 6 inches of topsoil
- Natural revegetation of capped area

C.2.1.4 SLF–4: Excavation of Waste Layer

This option includes deed restrictions and Level D PPE (see institutional controls above). Excavation of the waste layer includes:

- Surface preparation, clearing and grubbing, and stripping
- Access roads
- Visual removal of waste layer; approximately 44,000 cubic yards (average thickness of 5 feet over 5.5 acres)
- Transport and offsite disposal of waste layer
- Backfill with 6 inches of clean topsoil
- Natural revegetation

C.2.1.5 SLF–5: Excavation of Waste Layer and Surficial Sand

This option includes deed restrictions and Level D PPE (see institutional controls above). Excavation of the waste layer and an additional 2 feet of surficial sand includes:

- Surface preparation, clearing and grubbing, and stripping
- Access roads
- Visual removal of waste layer; approximately 44,000 cubic yards (average thickness of 5 feet over 5.5. acres)
- Excavation of surficial sand; approximately 18,000 cubic yards
- Transport and offsite disposal of waste layer and surficial sand
- Backfill with 2.5 feet of clean topsoil (to same grade as option SLF-4)
- Natural revegetation

C.2.2 South Landfill Option Cost Estimates

Tables C-3 and C-4 provide the line item cost estimating assumptions and unit costs used for all soil and debris areas. Table C-6 provides the order-of-magnitude cost estimates for each south landfill remedial option. Costs are lowest for the institutional controls and capping options. Costs increase dramatically for SLF-4 and SLF-5, which involve excavation and offsite waste disposal.

C.3 Scrap Yard

Four remedial options are evaluated for the scrap yard. Figure C-7 delineates the area of the scrap yard that is addressed in this cost estimate.

C.3.1 Scrap Yard Option Descriptions and Assumptions

C.3.1.1 SY–1: Institutional Controls

The institutional controls considered for the scrap yard include:

- Deed restrictions to limit the use of the area by possible future owners
- Maintenance of the existing main plant area fencing
- Industrial use restrictions (limited access)
- Level D PPE for authorized RMC personnel, visitors, and trench workers

C.3.1.2 SY–2: Permeable Gravel Cap Over North Area

This option includes deed restrictions and Level D PPE (see institutional controls above). The areal extent of the north half of the scrap yard is approximately 2.1 acres. Construction of the permeable gravel cap consists of the following elements (see Figure C-8):

- Surface preparation, clearing and grubbing, and stripping
- Access roads
- 12-inch-thick layer of compacted gravel over the waste layer

C.3.1.3 SY–3: Excavation of Waste Layer in North Area

This option includes deed restrictions and Level D PPE (see institutional controls above). Excavation of the waste layer includes:

- Surface preparation, clearing and grubbing, and stripping
- Access roads
- Visual removal of waste layer in north area; approximately 6,000 cubic yards (average thickness of 2 feet over 2.1 acres)
- The scrap yard is currently as much as 2 feet above original grade. Excavation of waste material will return portions of the area to original grade. Clean gravel will be placed

and compacted in limited areas to bring the site to a relatively uniform grade and allow continued industrial use of the area.

C.3.1.4 SY–4: Excavation of Waste Layer in North Area and Additional Surficial Sand

This option includes deed restrictions and Level D PPE (see institutional controls above). Construction of this option involves excavation of the waste layer and additional surficial sand (up to 7 feet in depth) in the north-central and northeastern portions of the scrap yard, as indicated in Figure C-9. Specific construction elements include:

- Surface preparation, clearing and grubbing, and stripping
- Access roads
- Visual removal of the waste layer, approximately 6,000 cubic yards (average thickness of 2 feet over 2.1 acres)
- Excavation of additional surficial sand, approximately 18,000 cubic yards
- Transport and offsite disposal of the waste layer and surficial sand
- Backfill to original ground surface with clean topsoil

C.3.2 Scrap Yard Option Cost Estimates

Tables C-3 and C-4 provide the line item cost estimating assumptions and unit costs used for all soil and debris areas. Table C-7 provides the order-of-magnitude cost estimates for each scrap yard remedial option. Costs are lowest for the institutional controls and capping options. Costs increase dramatically for SY-3 and SY-4, which involve excavation and offsite disposal.

C.4 Company Lake

Three remedial options are evaluated for Company Lake. Figure C-10 delineates the area of Company Lake that is addressed in this cost estimate.

C.4.1 Company Lake Option Descriptions and Assumptions

C.4.1.1 CL–1: Institutional Controls

The institutional controls considered for Company Lake:

- Deed restrictions to limit use of the area by possible future owners
- Access restrictions: fencing and signage

C.4.1.2 CL–2: Permeable Cap Over Process Residue

This option includes deed restrictions as an institutional control. Construction of the permeable cap consists of the following elements (see Figure C-11):

- Surface preparation, clearing and grubbing, and stripping over 3.7 acres
- Access roads and ramp to pond

- Staging area
- Diversion system for NPDES process water discharge
- Removal of debris from outfall canal, pond perimeter, and pond bottom, approximately 3,100 cubic yards
- Placement of geotextile over approximately 20 acres of pond bottom and bank fringe
- Placement of 12-inch-thick layer of 1-inch gravel over 20 acres of pond bottom and bank fringe
- Placement of 12-inch-thick layer of 3-inch gravel over 20 acres of pond bottom and bank fringe

C.4.1.3 CL–3: Dredging Process Residue

This option includes deed restrictions as an institutional control. Dredging of process residue from Company Lake includes the following elements:

- Surface preparation, clearing and grubbing, and stripping over 3.7 acres
- Access roads and ramp to pond
- Staging area
- Diversion system for NPDES process water discharge
- Hydraulic dredging to remove an estimated 41,000 cubic yards of process residue and bottom sediments
- Mechanical dewatering of dredged material
- Stockpiling of dewatered material
- Transportation and offsite disposal of dredged material

C.4.2 Company Lake Option Cost Estimates

Tables C-8 and C-9 provide the line item cost estimating assumptions and unit costs used for Company Lake. Table C-10 provides the order-of-magnitude cost estimates for each Company Lake remedial option. Costs are lowest for the institutional controls and capping options. Costs increase substantially for Option CL-3, which involves dredging and offsite disposal.

Company Lake Option CL-3 assumes that all material is removed from the lake using a hydraulic dredge and is mechanically dewatered. If this option is selected, pilot testing of dredging and dewatering equipment will be required to determine whether this approach will work as assumed in this cost estimate.

C.5 Sitewide Groundwater

Four remedial options are evaluated for sitewide groundwater.

C.5.1 Sitewide Groundwater Option Descriptions and Assumptions

C.5.1.1 GW–1: Production Well Optimization

Implementation of production well optimization involves the following activities:

- Operation of existing production wells PW07 and PW08 (see Figure C-12)
- Pumping these wells at a rate sufficient to both meet plant demand [long-term average of 1,800 gallons per minute (gpm)] and contain the existing constituent plume currently present in the intermediate and deep groundwater zones

In the event of a long-term plant shutdown, when plant demand might drop below the minimum required to contain the intermediate- and deep-zone constituent plume, RMC would maintain operation of the production wells at the expected minimum required extraction rate of 600 gpm each (1,200 gpm total).

C.5.1.2 GW–2: Production Well Optimization with Focused Extraction

This option adds focused extraction to production well optimization (GW-1). Implementation of this option involves the following additional activities:

- Installation of two focused extraction wells in the upper gray sand (UGS) in the south plant locations shown in Figure C-13
- Pumping focused extraction wells at an estimated 20 gpm each
- Conveyance of water from the focused extraction wells to the wet electrostatic precipitator (ESP) for use as bleed stream makeup water
- Continued treatment of wet ESP bleed stream water (for removal of fluoride) in the plant industrial wastewater treatment system followed

A flow diagram showing the planned management of extracted groundwater in this option is provided in Figure C-14. In the event of a long-term plant shutdown, when bleed stream makeup water is not required, alternative treatment of groundwater removed by the focused extraction wells may be required.

C.5.1.3 GW–3: Production Well Optimization with Enhanced Focused Extraction

This option contains all the elements included in GW-2 and adds additional focused extraction in the north and south plant areas, as shown in Figure C-15. Implementation of this option involves the following activities, in addition to those described in GW-2:

- Installation of one new focused extraction well in the south plant UGS
- Installation of three additional intermediate-depth focused extraction wells in the north plant area

- Pumping each additional focused extraction well at an estimated 15 gpm each (60 gpm total)
- Conveyance of water from the four additional focused extraction wells to a new groundwater treatment system (to be located near the existing plant industrial wastewater treatment system)
- Treatment of extracted groundwater from the four additional wells using reverse osmosis, followed by treatment of the brine using calcium fluoride precipitation

The need for use of reverse osmosis as a groundwater treatment is indicated by a groundwater treatability study conducted in 1998 by RMC (see Appendix F). This study found that groundwater containing fluoride at concentrations of less than about 100 mg/L was not effectively treated by calcium fluoride precipitation, the technology used in the plant industrial wastewater treatment system and the most common system for removing fluoride in an industrial setting. If the extracted groundwater added in this option were discharged to the Columbia River without treatment, the additional fluoride mass (estimated at 22 pounds per day) would, during normal plant operations, cause RMC to violate its NPDES permit limitation for fluoride. To avoid this increase in fluoride discharge to the river, extracted groundwater would be treated using reverse osmosis to a concentrated brine of approximately 13 gpm and 117 mg/L fluoride. Fluoride would be removed from the brine stream by precipitation methods. A flow diagram showing the planned management of extracted groundwater in this option is provided in Figure C-16. A process flow diagram for calcium fluoride precipitation is provided in Figure C-17.

C.5.1.4 GW–4: Production Well Optimization with Enhanced Focused Extraction and Silt Unit Extraction

This option contains all the elements included in GW-3 and adds groundwater extraction from the silt units at the east potliner (EPL) and south landfill (SLF) areas as shown in Figure C-18. Groundwater extraction from EPL and SLF silts are added because these are locations where groundwater fluoride concentrations are elevated and the silt unit is greater than 10 feet thick. Silt unit extraction was not considered in the scrap yard because the silt is less than 10 feet thick and monitoring data indicate that it contains low levels of fluoride compared with the overlying waste and surficial sand. Implementation of this option involves the following activities, in addition to those described in GW-3:

- Installation of approximately 24 east potliner and 72 south landfill silt unit well points
- Installation of four 15-horsepower jet pumping units equipped with 24 ports each (three at south landfill and one at east potliner)
- Treatment of extracted groundwater (estimated at 11 gpm) using the calcium fluoride precipitation system described in GW-3

Groundwater modeling analyses were conducted to evaluate the spacing and pumping rates of the well point system. The model was run to identify a system that would create an upward vertical gradient in the lower portion of the silt unit without creating excessive drawdown in individual wells.

The modeling analyses indicated that containment of east potliner silt unit groundwater could be achieved by a system of approximately 25 well points each pumping 0.15 gpm (for a total of 3.75 gpm). A configuration of 24 well points was used for costing purposes. The total pumping rate of 3.75 gpm is equivalent to an infiltration rate of 20 inches per year over the 150,000-square-foot area. The actual feasible extraction rate is limited by the average annual precipitation infiltration rate, which is estimated to be less than 20 inches per year.

At the south landfill, a west-central portion (60,000 square feet) was selected because it is the only location at south landfill where fluoride migration to the base of the silt unit and into the UGS has been observed. Modeling analyses indicated that between 60 and 75 well points might be required to contain the target area. Each well point would pump at 0.1 gpm for a total of between 6 and 7.5 gpm. Pumping rates could be on the order of 0.05 gpm or lower, depending on the permeability of the silt unit at each well point location. As with east potliner, pumping of the silt unit in south landfill is limited by infiltration from precipitation.

The estimated fluoride concentration in extracted groundwater at these sites is 470 mg/L. Assuming an extraction rate of 11 gpm, if discharged to the Columbia River untreated, this would contribute approximately 62 pounds per day of additional fluoride. Because this added contribution would, during normal plant operations, cause RMC to violate its NPDES permit limitations for fluoride, treatment by calcium fluoride precipitation is required. A flow diagram showing the planned management of extracted groundwater in this option is provided in Figure C-19. A process flow diagram for calcium fluoride precipitation was previously provided in Figure C-17.

C.5.2 Sitewide Groundwater Option Cost Estimates

Table C-11 provides a summary of the sitewide groundwater treatment cost estimating assumptions. Tables C-12 through C-15 provide detailed cost estimates for each groundwater option. Costs are lowest for the groundwater options 1 and 2. Costs increase substantially for options GW-3 and GW-4 due to the addition of groundwater treatment.

Appendix C Tables

Table C-1 Cost Summary for Soil and Debris Areas and Company Lake Remedial Options			
Area	**Total Capital Cost**	**Annual O&M**	**Net Present Value (7% over 30 yr)**
North Landfill			
NLF-1	$70,850	$1,596	$90,655
NLF-2	$449,448	$19,979	$697,368
NLF-3	$909,550	$31,370	$1,298,827
NLF-4	$10,845,258	$5,054	$10,907,973
NLF-5	$14,110,878	$5,054	$14,173,593
South Landfill			
SLF-1	$80,750	$1,995	$105,506
SLF-2	$723,925	$24,307	$1,025,557
SLF-3	$1,697,986	$51,533	$2,337,459
SLF-4	$14,599,030	$4,306	$14,652,462
SLF-5	$21,212,643	$4,306	$21,266,074
Scrap Yard			
SY-1	$31,250	$0	$31,250
SY-2	$375,775	$17,820	$596,909
SY-3	$1,916,133	$6,703	$1,999,313
SY-4	$7,206,010	$6,703	$7,289,190
Company Lake			
CL-1	$229,250	$7,980	$328,274
CL-2	$5,111,090	$16,563	$5,316,626
CL-3	$10,817,288	$18,130	$10,864,866

Table C-2 Groundwater Option Cost Summary					
		O&M		Present Worth of	
Option	**Total Capital**	**Years 1-5**	**Years 6-30**	**O&M**	**NPV (7%, 30 yr)**
GW-1	$0	$128,000	$64,000	$1,056,591	$1,056,591
GW-2	$375,000	$150,934	$86,934	$1,388,197	$1,763,197
GW-3	$3,316,000	$297,140	$233,140	$3,502,210	$6,818,210
GW-4	$4,121,000	$477,813	$413,813	$6,114,586	$10,235,586

Table C-3
Soil and Debris Area Line Item Cost Estimating Assumptions

Item		Unit	Description
Capital Costs			
Institutional Controls			
1.1	Deed use restriction legal fees	lump sum	One lump sum for implementation of deed restrictions for each area.
1.2	Fencing	linear feet	Linear footage costs for fencing to restrict access to unauthorized personnel and trespassers for options NLF-1, SLF-1, and SY-1.
Site Preparation			
2.1-2.2	Clearing, grubbing, stripping, and surface preparation.	acres	Clearing, grubbing, and stripping costs for all capping and excavation options. The surface areas for each option are taken from various soil and debris area option cost tables. An additional 5% was added to the area for overlap.
2.3	Road construction gravel	linear feet	Linear footage costs for haul and access road construction.
Source Area Containment			
3.1	Geomembrane	square feet	One layer of geomembrane will be incorporated into the low-permeability cap in options NLF-3 and SLF-3. The surface areas for each option are taken from various soil and debris area option cost tables. An additional 5% was added to the area for overlap.
3.2	Geotextile	square feet	One layer of geotextile will be incorporated into the riprap cover for north landfill (NLF-2), two layers for the low-permeability cap at north landfill (NLF-3), and one layer for the low-permeability cap at south landfill (SLF-3). The surface areas for each option are taken from the NLF remedial option cost tables. An additional 5% was added to the area for overlap.
3.3	Geonet	square feet	One layer of geonet will be incorporated into the low-permeability caps at north landfill (NLF-3) and south landfill (SLF-3). Area taken from the NLF and SLF option cost tables. An additional 5% was added to the area for overlap.
3.4	Clean soil	tons	Tonnage of clean soil required for construction of low-permeability capping options NLF-3 and SLF-3 is calculated by multiplying the total thickness of soil layers in the low-permeability cap (36 inches) by the surface areas noted above. It is further assumed that the material will have a density of 1 ton/cubic yard.
3.5	Seeding	acres	The low-permeability cap for south landfill (SLF-3) will be seeded after construction. The area seeded will correspond to the area noted above. This includes the added 5% for overlap.
3.6	Soil cap	acres	The area of the south landfill soil cap (SLF-2) is provided in the SLF option cost table. Costs are calculated based on a cap thickness of 18 inches over the area noted above, and the unit cost of clean soil.
3.7	Gravel cap	acres	The area of the gravel cap over the north half of the scrap yard (SY-2) is taken from the scrap yard option cost table. An extra 5% was included for overlap.
3.8	Riprap cover	acres	The area of the riprap cover over north landfill (NLF-2 and NLF-3) is provided in the NLF option cost table. An extra 5% was included for overlap.
3.9	Drainage ditches	linear feet	Linear feet of ditches to provide proper site drainage for each area and option.

Table C-3, continued
Soil and Debris Area Line Item Cost Estimating Assumptions

Item		Unit	Description
Source Removal (Excavation, Transport, Disposal)			
4.1	Excavate solid waste	cubic yards	The volume of solid waste excavated for each area and option is taken from the NLF, SLF, and SY option cost tables. The volume is based on the calculated surface area and assumed depth of excavation.
4.2	Waste excavation volume contingency	cubic yards	Contingency provided for uncertainties in excavation volumes.
4.3	Waste characterization cost	lump sum	Lump sum cost for waste characterization after excavation.
4.4	Dewater excavation	lump sum	Lump sum cost for excavation below the water table.
4.5	Clean backfill	tons	NLF-4: 6 inches clean backfill NLF-5: 3.5 feet clean backfill SLF-5: 6 inches clean backfill SLF-5: 2.5 feet clean backfill SY-3: No backfill SY-4: 7 feet clean backfill northeast 2/3 Backfill volumes based on assumed thickness of backfill and area from the NLF, SLF, and SY option cost tables. These volumes are then multiplied by 1.5 tons/cubic yard of material.
4.6	Onsite short haul	cubic yards	Quantity of waste materials hauled to new onsite landfill (for remedial alternatives B and C, which include onsite landfill).
4.7	Onsite short haul volume contingency	cubic yards	Contingency provided for onsite haul cost based on potential changes in volume of waste excavated.
4.8	Offsite solid waste disposal weight	tons	Quantity of excavated waste to be disposed of at a licensed disposal facility.
4.9	Offsite solid waste disposal weight contingency	tons	Contingency for offsite disposal costs based on potential changes in volume of waste excavated.
4.10	Offsite waste transport weight	tons	Quantity of waste to be sent offsite based on volume of waste excavated.
4.11	Offsite waste transport weight contingency	tons	Contingency for offsite haul costs based on potential changes in volume of waste excavated.
Engineering, Oversight, Administrative Cost			
5.1	Engineering Design	7%	Engineering design is assumed to be 7% of the total capital cost for all options.
5.2	Waste Removal Documentation	3%	It is assumed that additional waste removal documentation costs will be required at 3% of the total capital cost for excavation options only.
5.3	Construction Management	5%	Construction management is assumed to be 5% of the total capital cost for all options.

Table C-3, continued
Soil and Debris Area Line Item Cost Estimating Assumptions

Item		Quantity	Description
5.4	Change Management	2%	Change management is assumed to be 2% of the total capital cost for all options.
5.5	Project Administration	2%	Project administration is assumed to be 2% of the total capital cost for all options.
5.6	Notice of Substantial Completion Report (CERCLA)	2%	Notice of Substantial Completion Report, which is required under CERCLA, is assumed to be 2% of the total capital costs for all options.
5.7	Permitting	lump sum	Lump sum permitting cost for implementation of remedial actions for each source area.
5.8	Contingency, Legal Fees, Taxes, Etc...	25%	Contingency, legal fees, and taxes are assumed to be 25% of the total capital costs for all options.
Operations and Maintenance Costs			
	Institutional Controls		
6.1	Fencing and Sign Maintenance	5%	Annual maintenance costs for fencing and signage are assumed to be 5% of original capital cost of fencing.
	Source Area Containment		
6.2	Road Maintenance (Gravel)	5%	Road gravel maintenance is assumed to be 5% of the original road-building cost. This is for grading and gravel addition for all options that require gravel access roads.
6.3	Low-Permeability Geomembrane Maintenance	10%	For low-permeability capping options, geomembrane maintenance is assumed to be 10% of the total capital cost of the geomembrane layer.
6.4	Soil Cap Maintenance	2%	Soil cap maintenance is assumed to be 5% of the original capital cost. This covers repairs to soil cover and vegetation (reseeding and mowing) for options SLF-2 and SLF-3.
6.5	Gravel cap maintenance	2%	Maintenance of the gravel cap for option SY-2 is assumed to be 2% of the original capital cost of gravel cap installation.
6.6	Riprap Cover Maintenance	2%	Riprap cover maintenance for options NLF-2 and NLF-3 is assumed to be 2% of the original capital cost of the riprap cover.
6.7	Ditch Maintenance	10%	Ditch maintenance is assumed to be 10% of the original capital cost of drainage ditch construction for all options that require ditches.
	Miscellaneous O&M Costs (Engineering, Oversight, and Administration)		
6.8	Engineering/ Administration Costs	8%	It is assumed that engineering and administration costs are 8% of the total O&M costs.
6.9	Contingency, Legal Fees, Taxes, Etc.	25%	Contingency, legal fees, and taxes are assumed to be 25% of the total O&M costs for this option.

Table C-4

Order of Magnitude Remedial Option Costs for North Landfill

OPTION NLF-1: Institutional Controls (Deed, Use, and Access Restrictions)

OPTION NLF-2: Construct a permeable riprap cover over waste layer. (geotextile, 12" thick rip-rap)

OPTION NLF-3: Construct low permeability cap (12-inches compacted soil, 40 mil FML, geonet, geotextile, and 12-inches soil, geotextile, and riprap)

OPTION NLF-4: Excavate waste material, backfill with clean soil, natural re-vegetation

OPTION NLF-5: Excavate waste material, 2 feet of underlying sands, backfill with clean soil, natural re-vegetation

Item		Unit	Unit Cost	NLF-1 Quantities	NLF-2 Quantities	NLF-3 Quantities	NLF-4 Quantities	NLF-5 Quantities	NLF-1 Cost	NLF-2 Cost	NLF-3 Cost	NLF-4 Cost	NLF-5 Cost
1 Institutional Controls													
1.1	Deed or Use Restriction Legal Fees	EA	$25,000	1	1	1	1	1	$25,000	$25,000	$25,000	$25,000	$25,000
1.2	Fencing	LF	$15.00	1,600					$24,000	$0	$0	$0	$0
2 Site Preparation													
2.1	Clearing, Grubbing, and Stripping	AC	$4,200		2.40	2.40	2.40	2.40	$0	$10,080	$10,080	$10,080	$10,080
2.2	Surface Preparation	AC	$800		2.40	2.40	2.40	2.40	$0	$1,920	$1,920	$1,920	$1,920
2.3	Road Construction-Gravel	LF	$35.00		1,600	1,600	1,600	1,600	$0	$56,000	$56,000	$56,000	$56,000
3 Source Area Containment Systems													
3.1	Geomembrane	SF	$0.43			105,000			$0	$0	$45,150	$0	$0
3.2	Geotextile	SF	$0.19		105,000	210,000			$0	$19,950	$39,900	$0	$0
3.3	Geonet	SF	$0.55			105,000			$0	$0	$57,750	$0	$0
3.4	Clean Soil	CY	$20.00			7,800			$0	$0	$156,000	$0	$0
3.5	Seeding	AC	$2,000						$0	$0	$0	$0	$0
3.6	Soil Cap	AC	$48,000						$0	$0	$0	$0	$0
3.7	Gravel Cap	AC	$40,000						$0	$0	$0	$0	$0
3.8	Riprap Cover	AC	$48,000		2.40	2.40			$0	$115,200	$115,200	$0	$0
3.9	Ditches	LF	$20.00		1,000	1,000	500	500	$0	$20,000	$20,000	$10,000	$10,000
4 Excavation, Transportation, and Disposal													
4.1	Excavate Solid Waste	CY	$15.00				33,000	41,000	$0	$0	$0	$495,000	$615,000
4.2	Contingency for excavation volume changes	CY	$15.00				16,500	20,500	$0	$0	$0	$247,500	$307,500
4.3	Additional Waste Characterization Costs	LS	$25,000					10	$0	$0	$0	$0	$250,000
4.4	De-water Excavation	LS	$40,000						$0	$0	$0	$0	$0
4.5	Clean Backfill	CY	$15.00				1,900	13,000	$0	$0	$0	$28,500	$195,000
4.6	On-site Short Haul	CY	$1.50						$0	$0	$0	$0	$0
4.7	Contingency for on-site short haul volume changes	CY	$1.50						$0	$0	$0	$0	$0
4.8	Off-Site Solid Waste Disposal	TON	$50.00				49,500	61,500	$0	$0	$0	$2,475,000	$3,075,000
4.9	Contingency for off-site disposal volume changes	TON	$50.00				24,750	30,750	$0	$0	$0	$1,237,500	$1,537,500
4.10	Off-Site Solid Waste Transport	TON	$25.00				49,500	61,500	$0	$0	$0	$1,237,500	$1,537,500
4.11	Contingency for off-site transport volume changes	TON	$25.00				24,750	30,750	$0	$0	$0	$618,750	$768,750
5 Capital Costs													
5.1	Contractor Markup (mob/demob, bond/ins., profit, overhead)	%	22%						$5,280	$49,093	$110,440	$1,411,905	$1,840,135
5.2	Engineering/Design	%	7%						$1,680	$15,621	$35,140	$449,243	$585,498
5.3	Waste Removal Documentation	%	3%						$0	$0	$0	$174,720	$228,615
5.4	Construction Management	%	5%						$1,200	$11,158	$25,100	$320,888	$418,213
5.5	Change Management	%	2%						$480	$4,463	$10,040	$128,355	$167,285
5.6	Project Administration	%	2%						$480	$4,463	$10,040	$128,355	$167,285
5.7	Notice of Substantial Completion Report (CERCLA)	%	2%						$480	$4,463	$10,040	$128,355	$167,285
5.8	Permitting	EA	$50,000		1	1	1	1	$0	$50,000	$50,000	$50,000	$50,000
5.9	Contingency, Legal Fees, Taxes, etc.	%	25%						$12,250	$62,038	$131,750	$1,610,688	$2,097,313
6. Operations and Maintenance Costs													
	Institutional Controls												
6.1	Fencing and Signs	%	5%						$1,200	$0	$0	$0	$0
	Source Area Containment Systems												
6.2	Road Maintenance-Gravel	%	5%						$0	$2,800	$2,800	$2,800	$2,800
6.3	Low Permeability Cap Maintenance	%	3%						$0	$0	$8,964	$0	$0
6.4	Soil Cap Maintenance	%	2%						$0	$0	$0	$0	$0
6.5	Gravel Cap Maintenance	%	2%						$0	$0	$0	$0	$0
6.6	Riprap Maintenance	%	2%						$0	$2,703	$2,304	$0	$0
6.7	Ditch Maintenance	%	10%						$0	$2,000	$2,000	$1,000	$1,000
6.8	Annual Monitoring and Reporting	EA	$10,000		1	1			$0	$10,000	$10,000	$0	$0
	Miscellaneous												
6.9	Engineering/Administration	%	8%						$96	$600	$1,285	$304	$304
6.10	Contingency, Legal Fees, Taxes, etc.	%	25%						$300	$1,976	$4,017	$950	$950
								Total Capital Cost	$70,850	$449,448	$909,550	$10,845,258	$14,110,878
								Annual O&M Cost	$1,596	$19,979	$31,370	$5,054	$5,054
								Present Value of O&M Costs (30 Year)	$19,805	$247,920	$389,277	$62,715	$62,715
								Total Net Present Value Cost	$90,655	$697,368	$1,298,827	$10,907,973	$14,173,593

Note: The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive marked conditions, final project scope, final schedule and other variable factors. As a results , the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

TABLE C-5

Order of Magnitude Remedial Option Costs for South Landfill

OPTION SLF-1: Institutional Controls (Deed, Use, and Access Restrictions)

OPTION SLF-2: Construct a permeable vegetated soil cap (18" thick clean soil) over waste layer

OPTION SLF-3: Construct low permeability cap (12-inches compacted soil, 40 mil FML, geonet, geotextile, and 18-inches soil, 6-inches topsoil, and vegetation)

OPTION SLF-4: Excavate waste layer, backfill with clean soil, natural re-vegetation

OPTION SLF-5: Excavate waste layer, 2 feet of the surficial sand unit, backfill with clean soil, natural re-vegetation

Item		Unit	Unit Cost	SLF-1 Quantities	SLF-2 Quantities	SLF-3 Quantities	SLF-4 Quantities	SLF-5 Quantities	SLF-1 Cost	SLF-2 Cost	SLF-3 Cost	SLF-4 Cost	SLF-5 Cost
1 Institutional Controls													
1.1	Deed or Use Restriction Legal Fees	EA	$25,000	1	1	1	1	1	$25,000	$25,000	$25,000	$25,000	$25,000
1.2	Fencing	LF	$15.00	2,000	0	0	0	0	$30,000	$0	$0	$0	$0
2 Site Preparation													
2.1	Clearing, Grubbing, and Stripping	AC	$4,200		5.75	5.75	5.75	5.75	$0	$24,150	$24,150	$24,150	$24,150
2.2	Surface Preparation	AC	$800		5.75	5.75	5.75	5.75	$0	$4,600	$4,600	$4,600	$4,600
2.3	Road Construction-Gravel	LF	$35.00		1,850	1,850	1,850	1,850	$0	$64,750	$64,750	$64,750	$64,750
3 Source Area Containment Systems													
3.1	Geomembrane	SF	$0.43			252,000			$0	$0	$108,360	$0	$0
3.2	Geotextile	SF	$0.19			252,000			$0	$0	$47,880	$0	$0
3.3	Geonet	SF	$0.55			252,000			$0	$0	$138,600	$0	$0
3.4	Clean Soil	CY	$20.00			28,000			$0	$0	$560,000	$0	$0
3.5	Seeding	AC	$2,000			5.75			$0	$0	$11,500	$0	$0
3.6	Soil Cap	AC	$48,000		5.75				$0	$276,000	$0	$0	$0
3.7	Gravel Cap	AC	$40,000						$0	$0	$0	$0	$0
3.8	Riprap Cover	AC	$48,000						$0	$0	$0	$0	$0
3.9	Ditches	LF	$20.00		1,000	1,000	0	0	$0	$20,000	$20,000	$0	$0
4 Excavation, Transportation, and Disposal													
4.1	Excavate Solid Waste	CY	$15.00				44,400	62,100	$0	$0	$0	$666,000	$931,500
4.2	Contingency for excavation volume changes	CY	$15.00				22,200	31,050	$0	$0	$0	$333,000	$465,750
4.3	Additional Waste Characterization Costs	LS	$25,000					10	$0	$0	$0	$0	$250,000
4.4	De-water Excavation	LS	$40,000					1	$0	$0	$0	$0	$40,000
4.5	Clean Backfill	CY	$15.00				4,400	22,100	$0	$0	$0	$66,000	$331,500
4.6	On-site Short Haul	CY	$1.50						$0	$0	$0	$0	$0
4.7	Contingency for on-site short haul volume changes	CY	$1.50						$0	$0	$0	$0	$0
4.8	Off-Site Solid Waste Disposal	TON	$50.00				66,600	93,150	$0	$0	$0	$3,330,000	$4,657,500
4.9	Contingency for off-site disposal volume changes	TON	$50.00				33,300	46,575	$0	$0	$0	$1,665,000	$2,328,750
4.10	Off-Site Solid Waste Transport	TON	$25.00				66,600	93,150	$0	$0	$0	$1,665,000	$2,328,750
4.11	Contingency for off-site transport volume changes	TON	$25.00				33,300	46,575	$0	$0	$0	$832,500	$1,164,375
5 Capital Costs													
5.1	Contractor Markup (mob/demob, bond/ins., profit, overhead)	%	22%						$6,600	$85,690	$215,565	$1,903,220	$2,770,158
5.2	Engineering/Design	%	7%						$2,100	$27,265	$68,589	$605,570	$881,414
5.3	Waste Removal Documentation	%	3%						$0	$0	$0	$260,280	$378,498.75
5.4	Construction Management	%	5%						$1,500	$19,475	$48,992	$432,550	$629,581
5.5	Change Management	%	2%						$600	$7,790	$19,597	$173,020	$251,833
5.6	Project Administration	%	2%						$600	$7,790	$19,597	$173,020	$251,833
5.7	Notice of Substantial Completion Report (CERCLA)	%	2%						$600	$7,790	$19,597	$156,370	$228,545
5.8	Permitting	EA	$50,000		1	1	1	1	$0	$50,000	$50,000	$50,000	$50,000
5.9	Contingency, Legal Fees, Taxes, etc.	%	25%						$13,750	$103,625	$251,210	$2,169,000	$3,154,156
6. Operations and Maintenance Costs													
	Institutional Controls												
6.1	Fencing and Signs	%	5%						$1,500	$0	$0	$0	$0
	Source Area Containment Systems												
6.2	Road Maintenance-Gravel	%	5%						$0	$3,238	$3,238	$3,237.50	$3,238
6.3	Low Permeability Cap Maintenance	%	3%						$0	$0	$25,990	$0	$0
6.4	Soil Cap Maintenance	%	2%						$0	$5,520	$0	$0	$0
6.5	Gravel Cap Maintenance	%	2%						$0	$0	$0	$0	$0
6.6	Riprap Maintenance	%	2%						$0	$0	$0	$0	$0
6.7	Ditch Maintenance	%	10%						$0	$2,000	$2,000	$0	$0
6.8	Annual Monitoring and Reporting	EA	$10,000		1	1			$0	$10,000	$10,000	$0	$0
	Miscellaneous												
6.9	Engineering/Administration	%	8%						$120	$861	$2,498	$259	$259
6.10	Contingency, Legal Fees, Taxes, etc.	%	25%						$375	$2,689	$7,807	$809	$809
								Total Capital Cost	$80,750	$723,925	$1,697,986	$14,599,030	$21,212,643
								Annual O&M Cost	$1,995	$24,307	$51,533	$4,306	$4,306
								Present Value of O&M Costs (30 Year)	$24,756	$301,632	$639,473	$53,432	$53,432
								Total Net Present Value Cost	$105,506	$1,025,557	$2,337,459	$14,652,462	$21,266,074

Note: The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive marked conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

TABLE C-6
Order of Magnitude Remedial Option Costs for Scrap Yard

OPTION SY-1: Institutional Controls (Deed, Use, and Access Restrictions)

OPTION SY-2: Construct a 12" thick permeable gravel cap over waste layer

OPTION SY-3: Excavate north scrap yard area waste layer. No further action for south scrap yard area.

OPTION SY-4: Excavate north scrap yard area waste layer, excavate middle and eastern third of the surficial sand unit, backfill with clean soil to same grade as Option SY-3. Note: It is assumed that the scrap yard is currently 2 ft. above original grade.

Item		Unit	Unit Cost	SY-1 Quantities	SY-2 Quantities	SY-3 Quantities	SY-4 Quantities	SY-1 Cost	SY-2 Cost	SY-3 Cost	SY-4 Cost
1 Institutional Controls											
1.1	Deed or Use Restriction Legal Fees	EA	$25,000	1	1	1	1	$25,000	$25,000	$25,000	$25,000
1.2	Fencing	LF	$15.00	0	0	0	0	$0	$0	$0	$0
2 Site Preparation											
2.1	Clearing, Grubbing, and Stripping	AC	$4,200		2.10	2.10	2.10	$0	$8,820	$8,820	$8,820
2.2	Surface Preparation	AC	$800		2.10	2.10	2.10	$0	$1,680	$1,680	$1,680
2.3	Road Construction-Gravel	LF	$35.00		2,400	2,400	2,400	$0	$84,000	$84,000	$84,000
3 Source Area Containment Systems											
3.1	Geomembrane	SF	$0.43					$0	$0	$0	$0
3.2	Geotextile	SF	$0.19					$0	$0	$0	$0
3.3	Geonet	SF	$0.55					$0	$0	$0	$0
3.4	Clean Soil	CY	$20.00					$0	$0	$0	$0
3.5	Seeding	AC	$2,000.00					$0	$0	$0	$0
3.6	Soil Cap	AC	$48,000					$0	$0	$0	$0
3.7	Gravel Cap	AC	$40,000		2.10	2.10	2.1	$0	$84,000	$42,000	$42,000
3.8	Riprap Cover	AC	$48,000					$0	$0	$0	$0
3.9	Ditches	LF	$20.00					$0	$0	$0	$0
4 Excavation, Transportation, and Disposal											
4.1	Excavate Solid Waste	CY	$15.00			6,000	24,000	$0	$0	$90,000	$360,000
4.2	Contingency for excavation volume changes	CY	$15.00			1,500	6,000	$0	$0	$22,500	$90,000
4.3	Additional Waste Characterization Costs	LS	$25,000				1	$0	$0	$0	$25,000
4.4	De-water Excavation	LS	$40,000					$0	$0	$0	$0
4.5	Clean Backfill	CY	$15.00			0	17,200	$0	$0	$0	$258,000
4.6	On-site Short Haul	CY	$1.50					$0	$0	$0	$0
4.7	Contingency for on-site short haul volume changes	CY	$1.50					$0	$0	$0	$0
4.8	Off-Site Solid Waste Disposal	TON	$50.00			9,000	36,000	$0	$0	$450,000	$1,800,000
4.9	Contingency for off-site disposal volume changes	TON	$50.00			2,250	9,000	$0	$0	$112,500	$450,000
4.10	Off-Site Solid Waste Transport	TON	$25.00			9,000	36,000	$0	$0	$225,000	$900,000
4.11	Contingency for off-site transport volume changes	TON	$25.00			2,250	9,000	$0	$0	$56,250	$225,000
5 Capital Costs											
5.1	Contractor Markup (mob/demob, bond/ins., profit, overhead)	%	22%					$0	$39,270	$240,405	$933,790
5.2	Engineering/Design	%	7%					$0	$12,495	$76,493	$297,115
5.3	Waste Removal Documentation	%	3%					$0	$0	$31,845	$121,335
5.4	Construction Management	%	5%					$0	$8,925	$54,638	$212,225
5.5	Change Management	%	2%					$0	$3,570	$21,855	$84,890
5.6	Project Administration	%	2%					$0	$3,570	$21,855	$84,890
5.7	Notice of Substantial Completion Report (CERCLA)	%	2%					$0	$3,570	$21,855	$84,890
5.8	Permitting	EA	$50,000		1	1	1	$0	$50,000	$50,000	$50,000
5.9	Contingency, Legal Fees, Taxes, etc.	%	25%					$6,250	$50,875	$279,438	$1,067,375
6. Operations and Maintenance Costs											
	Institutional Controls										
6.1	Fencing and Signs	%	5%					$0	$0	$0	$0
	Source Area Containment Systems										
6.2	Road Maintenance-Gravel	%	5%					$0	$4,200	$4,200	$4,200
6.3	Low Permeability Cap Maintenance	%	3%					$0	$0	$0	$0
6.4	Soil Cap Maintenance	%	2%					$0	$0	$0	$0
6.5	Gravel Cap Maintenance	%	2%					$0	$1,680	$840	$840
6.6	Riprap Maintenance	%	2%					$0	$0	$0	$0
6.7	Ditch Maintenance	%	10%					$0	$0	$0	$0
6.8	Annual Monitoring and Reporting	EA	$10,000		1			$0	$10,000	$0	$0
	Miscellaneous										
6.9	Engineering/Administration	%	8%					$0	$470.40	$403	$403
6.10	Contingency, Legal Fees, Taxes, etc.	%	25%					$0	$1,470.00	$1,260	$1,260
							Total Capital Cost	$31,250	$375,775	$1,916,133	$7,206,010
							Annual O&M Cost	$0	$17,820	$6,703	$6,703
							Present Value of O&M Costs (30 Year)	$0	$221,134	$83,180	$83,180
							Total Net Present Value Cost	$31,250	$596,909	$1,999,313	$7,289,190

Note: The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive marked conditions, final project scope, final schedule and other variable factors. As a results , the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table C-7
Company Lake Line Item Quantity Assumptions

Item		Unit	Description
Capital Costs			
1 Site Preparation			
1.1	Clearing, Grubbing, and Stripping	acres	Option CL-1: Negligible
			Option CL-2 Total 3.7 acres (includes edge of Company Lake, access road, lake access, and construction staging area from 1998 estimate).
			Option CL-3 Total: 6.4 acres • Edge of lake: (1.8 acres) • Road to outfall: (1.1 acres) • Lake access: negligible • Mechanical dewatering pad. Assume 2.6 acres based on Gould site scale-up. • Mechanical dewatering stockpile area. Assume 200 ft x 200 ft area (0.9 acre). • Gravel staging area. Assume staging done in area planned for dewatering pad (0 acres).
1.2	Surface Preparation	acres	Option CL-2, CL-3 Same areas as line 1.1.
1.3	Road Construction—Pavement	linear feet	Option CL-3 Assume 0.03 acre for Company Lake access; convert to linear feet assuming unit price applies to 10-foot-wide road (130 linear feet).
1.4	Road Construction—Gravel	linear feet	Option CL-2 Access road on north edge of lake (3,700 linear feet).
			Option CL-3 Assume road to outfall 3,200 linear feet less 25% credit for existing road (2,400 linear feet).
1.5	Fencing	linear feet	Total: 5,560 linear feet • Mechanical dewatering pad perimeter fencing (1,560 linear feet) • Stockpile perimeter fencing (800 linear feet) • Fence north side of lake along outfall road (3,200 linear feet).
1.6	Gravel Construction Staging Area	square feet	Gravel construction staging area. Assume 100' x 100' (10,000 square feet).
1.7	Paved Dewatering Pad and Stockpile Area	acres	Asphalt pavement (12-inch gravel and 4-inch asphalt-concrete). Assume 2.6-acre dewatering pad, 0.9-acre stockpile area.

Table C-7, continued
Company Lake Line Item Quantity Assumptions

	Item	Unit	Description
1.8	Water Access Ramp	square feet	Water access ramp. Assume 40 ft x 40 ft. Total = 1,600 square feet.
1.9	Install Electrical Hookup	each	Power to pumps, lights, and site general.
1.10	Install Mobile Decontamination Pad	each	Install decon pad. Assume 6-inch-thick, 900-square-foot reinforced concrete. Includes 1,000-gallon sump.
1.11	Decontamination, Demolition, Demobilization	lump sum	Decontamination, demolition, and demobilization. Assume partial tear-down of fencing, remove and dispose decon pad and sump. Total $10,000.
2 Divert NPDES and Relocate Pond Influent			
2.1	Temporary 12" HDPE Pipe	linear feet	Temporary HDPE piping to be installed predominantly on grade with minimal site prep. Bypass current outfall past Company Lake during dredging (1,800 linear feet) plus dedicated outfall from dredging operations (4,800 linear feet). Both pipes terminate at current outfall location.
2.2	12" Excavation and Backfill	linear feet	12-inch excavation and backfill. For relocated influent line to east end of Company Lake, use when lake is restored. Estimate 2,800 linear feet.
2.3	12" Steel Pipe	linear feet	12-inch steel pipe. See item 2.2.
2.4	Diffuser	each	Diffuser into Company Lake. Estimate $10,000. See item 2.2.
2.5	Decontamination, Demolition, Demobilization	linear feet	Decontamination, demolition, and demobilization. HDPE pipe removal. Assume 0.5 hr/12 ft section, $30/hr.
3 Source Area Containment Systems			
3.1	1" to 3" Stone	cubic yards	Option CL-2 Stone layer for permeable cap (53,860 cubic yards assuming 14-acre cap area and additional overlap on bank).
3.2	Geotextile	square feet	Option CL-2 Geotextile layer for permeable cap (872,000 square feet assuming 3 to 5 feet of overlap and additional material placed to 3 feet above high water line).
3.3	Seeding	acres	Option CL-2 Seeding of shoreline areas disturbed during cap construction (2.0 acres).
4 Site Drainage			
4.1	Ditches	linear feet	Option CL-3 Assume ditches at perimeter of 340' x 340' dewatering pad, and 200' x 200' stockpile area, 2,140 linear feet.
4.2	Catch Basins	each	Option CL-3 Assume one catch basin every 200 linear feet.

Table C-7, continued Company Lake Line Item Quantity Assumptions			
	Item	**Unit**	**Description**
5 Debris Survey and Removal			
	Miscellaneous		
5.1	Diver Debris Survey	days	Options CL-2, CL-3 Diver debris survey. Based on quotation from Advanced American Diving, assume 5-day survey.
5.2	Diver Debris Removal and Standby	days	Options CL-2, CL-3 Diver debris removal and standby. Assume hand picking, 3-person crew, hand tools, barge, 15 days based on Gould Lake data. Assume 5 additional days during dredging operations. Assume additional 5 days equivalent for standby time.
5.3	Debris Removal Mobilization	each	Options CL-2, CL-3 Diver debris removal mobilization. Assume one initial mobilization. Assume three additional mobilizations during dredging efforts. Assume 2 days equivalent cost per mobilization event.
6 Dredge-Specific Items (*Option CL-3 Only*)			
6.1	Silt Curtains	square feet	Silt curtains. Assume 1,000 linear feet with 10 ft average depth.
6.2	Water Service to Work Area—Piping	linear feet	Water service to work area piping. Assume 150 gpm @50 psi, 1,200-linear-foot pipe run from plant site.
6.3	Valve Connection	lump sum	Valve connection. Assume water main tie-in.
6.4	Effluent Pump and Sump	each	For discharging treated water through dedicated outfall to point of compliance. Assume one sump/tank, one primary pump plus one standby pump.
6.5	Decontamination, Demolition, Demobilization	lump sum	Silt curtain removal, decon, or disposal in landfill (negligible volume in landfill). Tear-down of effluent discharge piping. Decontamination of dredge, pumps, equipment. Demobilization of dredge and ancillary equipment, demobilization of pumps and other equipment.
	Mechanical Dewatering		
6.6	Equipment/Unit Price for Dewatering	cubic yards in place	Unit cost includes filter press or centrifuges and associated pumps and equipment, prescreening or grinding of sludge as required, sludge totes, skip/end loader, all necessary crane service to unload/load and otherwise move the dewatering and related equipment, project superintendent, dewatering technicians (2), labor to set up, move, and tear down the job, fuels/oils/lubricants necessary to complete the project, housing and subsistence for contractor personnel.
6.7	Decontamination, Demolition, Demobilization	lump sum	Water service disconnect.
6.8	Electrical Power	dollars per kilowatt-hour	Power. Assume 600 amps, 480 V, 12 hr/day, 6 day/wk, 18 wk/yr, $0.06/KWh. Total 373,000 kWh.

Table C-7, continued
Company Lake Line Item Quantity Assumptions

Item		Unit	Description
7 Excavation, Transportation, and Disposal			
Source Removal			
7.1	Hydraulically Dredge	cubic yards	Option CL-3 Remove sediments from Company Lake by dredging (37,915 cubic yards in situ). Assume process residue (PR) field survey, 14 survey points, previous calculation (27,000 cy PR). Assume 6-inch overcut into native soil (NS), contract limit for Four Seasons Gould Lake project, 15-acre pond bottom (12,000 cy NS). Less lake perimeter by excavator, item 8.3 (-1185 cy PR + NS). Dredge unit cost includes dredge, 1500 HDPE discharge line, all crane service to unload/load dredge and ancillary gear, project superintendent, dredge operators, cable/anchoring/harnessing, necessary support equipment, labor to set up/tear down/move dredge, fuels/oils/ lubricants, housing/subsistence for contractor personnel.
7.2	Excavate Solid Waste	cubic yards	Option CL-2, Option CL-3 Excavate outfall channel material (1850 cy) plus pond N,W,E perimeter material (1185 cy) plus debris (100 cy) to stockpile. Total 3,137 cubic yards.
7.3	Excavate Dry Sludge from Stockpile	cubic yards	Option CL-3 Assume in situ pond material volume = dried material volume in stockpile = 1185 cy perimeter material, 1852 cy channel material, 100 cy debris, 37915 cy dredged material. Total 41,052 cubic yards.
Transport and Disposal			
7.4	Onsite Short Haul	cubic yards	Onsite short haul volume for remedial alternative that includes an onsite landfill (not included in remedial option costs).
7.5	Offsite Solid Waste Transport	tons	Option CL-2 Assume quantity from line 7.2 multiplied by 1.5 tons/cubic yards.
			Option CL-3 Assume same as volume excavated from stockpile (including debris) from line 7.3 multiplied by 1.5 tons/cubic yard to convert to tonnage.
7.6	Offsite Solid Waste Disposal	tons	Option CL-2 Same as line 7.5.
			Option CL-3 Same as line 7.5.
8 Engineering, Oversight, and Administrative Costs			
8.1	Engineering/Design	%	Engineering design is assumed to be 7% of the total capital cost for all options.

Table C-7, continued
Company Lake Line Item Quantity Assumptions

	Item	Unit	Description
8.2	Waste Removal Documentation	%	It is assumed that additional waste removal documentation costs will be required at 3% of the total capital cost for excavation options only.
8.3	Construction Management	%	Construction management is assumed to be 5% of the total capital cost for all options.
8.4	Change Management	%	Change management is assumed to be 2% of the total capital cost for all options.
8.5	Project Administration	%	Project administration is assumed to be 2% of the total capital cost for all options.
8.6	Notice of Substantial Completion Report (CERCLA)	%	Notice of Substantial Completion Report, which is required under CERCLA, is assumed to be 2% of the total capital cost for all options.
8.7	Permitting	each	Lump sum permitting cost for implementation of remedial actions for each area of concern.
8.8	Contingency, Legal Fees, Taxes, etc.	%	Contingency, legal fees, and taxes are assumed to be 25% of the total capital cost for permeable cap options, and 35% for dredging option.
Operations and Maintenance Costs			
9 Annual O&M Capital Costs			
	Source Area Containment Systems		
9.1	Fencing Maintenance	%	Fencing maintenance is assumed to be 5 percent of original capital cost of installation annually.
9.2	Road Maintenance—Gravel	%	Road maintenance gravel is assumed to be 5% of capital cost of road construction.
9.3	Road Maintenance—Pavement	%	O&M costs for pavement maintenance are assumed to be 10% of paving capital costs.
9.4	Permeable Cap Maintenance	%	Annual O&M costs for permeable cap maintenance are assumed to be 2% of capital costs for construction of the cap.
	Site Drainage		
9.5	Ditch Maintenance	%	Annual O&M costs for drainage ditches are assumed to be 10% of the capital costs for construction of the ditches.
9.6	Catch Basin Maintenance	%	Annual O&M costs for drainage ditches are assumed to be 10% of the capital costs for construction of the catch basins.
	Miscellaneous O&M Costs (Engineering, Oversight, and Administration)		
9.7	Engineering/Administration	%	It is assumed that engineering and administration costs are 8% of the total O&M costs.
9.8, 9.9	Contingency, Legal Fees, Taxes, etc.	%	Contingency, legal fees, and taxes are assumed to be 25% of the total O&M costs for the permeable cap option, and 35% for the dredging option.

Table C-8
Company Lake Remedial Option Cost Estimates

Option CL-1: Institutional Controls.
Option CL-2: Construct permeable Cap over process residue.
Option CL-3: Hydraulically dredge process residue, mechanically dewater.

	Item	Unit	Unit Cost	Option CL-1 Quantity	Option CL-2 Quantity	Option CL-3 Quantity	Option CL-1 Cost	Option CL-2 Cost	Option CL-3 Cost
1 Institutional Controls									
1.1	Deed or Use Restriction Legal Fees	EA	$25,000	1	1	1	$25,000	$25,000	$25,000
1.2	Fencing	LF	$15	8,000	3,550	6,180	$120,000	$53,250	$92,700
2 Site Preparation									
2.1	Clearing, Grubbing, and Stripping	AC	$4,200		3.68	6.40	$0	$15,456	$26,880
2.2	**Surface Preparation**	AC	$800		3.68	6.40	$0	$2,944	$5,120
2.3	Road Construction-Pavement	LF	$51			130	$0	$0	$6,630
2.4	Road Construction-Gravel	LF	$35		3,700	2,400	$0	$129,500	$84,000
2.5	Gravel Construction Staging Area	SF	$1.75		10,000	10,000	$0	$17,500	$17,500
2.6	Dewatering Pad and Stockpile Area	AC	$130,000			3.5	$0	$0	$455,000
2.7	Water Access Ramp	SF	$6		1,600	1,600	$0	$9,600	$9,600
2.8	Install Electrical Hook-up	EA	$80,000		1	1	$0	$80,000	$80,000
2.9	Install Mobile Decon Pad	EA	$10,000		1	1	$0	$10,000	$10,000
2.10	Decontamination, demolition, demobilization	LS	$10,000			1			$10,000
2 Divert NPDES and Relocate Pond Influent									
2.1	Temporary 12" HDPE Pipe	LF	$40.00		6,660	6,660	$0	$266,400	$266,400
2.2	12" Excavation and Backfill	LF	$7.11		2,800	2,800	$0	$19,908	$19,908
2.3	12" Steel Pipe	LF	$66.00		2,800	2,800	$0	$184,800	$184,800
2.4	Diffuser	EA	$10,000		1	1	$0	$10,000	$10,000
2.5	Decontamination, demolition, demobilization	LF	$1.25		6,660	6,660	$0	$8,325	$8,325
3 Source Area Containment Systems									
3.1	1" to 3" Gravel	CY	$28.70		53,860		$0	$1,545,782	$0
3.2	Geotextile	SF	$0.19		872,690		$0	$165,811	$0
3.3	Seeding	AC	$2,000.00		2.00		$0	$4,000	$0
4 Site Drainage									
4.1	Ditches	LF	$20.00			2,140	$0	$0	$42,800
4.2	Catch Basins	EA	$1,750.00			12	$0	$0	$21,000
5 Debris Survey and Removal									
5.1	Diver Debris Survey	Day	$5,000.00		5	5	$0	$25,000	$25,000
5.2	Diver Debris Removal and Standby	Day	$2,500.00		25	25	$0	$62,500	$62,500
5.3	Debris Removal Mobilization	EA	$5,000.00			4	$0	$0	$20,000
6 Dredge Specific Items									
	Miscellaneous								
6.1	Silt Curtains	SF	$2.00			10000	$0	$0	$20,000
6.2	Water Service to Work Area - Piping	LF	$20.00			1200	$0	$0	$24,000
6.3	Valve, Connection	LS	$5,000.00			1	$0	$0	$5,000
6.4	Effluent Pump and Sump	EA	$30,000.00			1	$0	$0	$30,000
6.5	Decontamination, demolition, demobilization	LS	$25,000.00			0.5	$0	$0	$12,500
	Mechanical Dewatering								
6.6	Equipment/Unit price for dewatering	CYIP	$40.00			37915	$0	$0	$1,516,600
6.7	Decontamination, demolition, demobilization	LS	$50,000.00			1	$0	$0	$50,000
6.8	Electrical Power	$/kWh	$0.06			448000	$0	$0	$26,880
7 Excavation, Transportation, and Disposal									
	Excavation								
7.1	Hydraulically Dredge	CY	$14.00			37,915	$0	$0	$530,810
7.2	Excavate Solid Waste	CY	$22.00		3137	3137	$0	$69,014	$69,014
7.3	Excavate Dry Sludge from Stockpile	CY	$4.00			26,100	$0	$0	$104,400
	Transport and Disposal								
7.4	Onsite Short Haul	CY	$5.00		3137	3137	$0	$15,685	$15,685
7.5	Off-Site Solid Waste Transport	TON	$25.00		4706	29,600	$0	$117,638	$740,000
7.6	Off-Site Solid Waste Disposal	TON	$50.00		4706	29,600	$0	$235,275	$1,480,000
8 Capital Costs									
8.1	Contractor Markup (mob/demob, bond/ins., profit, overhead)	%	22%				$26,400	$670,645	$1,338,271
8.2	Engineering/Design	%	7%				$8,400	$213,387	$425,814
8.3	Waste Removal Documentation	%	3%				$0	$0	$88,197
8.4	Construction Management	%	5%				$6,000	$152,419	$304,153
8.5	Change Management	%	2%				$2,400	$60,968	$121,661
8.6	Project Administration	%	2%				$2,400	$60,968	$121,661
8.8	Notice of Substantial Completion Report (CERCLA)	%	2%				$2,400	$60,968	$121,661
8.8	Permitting	EA	$50,000		1	1	$0	$50,000	$50,000
8.9	Contingency, Legal Fees, Taxes, etc.	%	25%				$36,250	$768,347	$0
8.1	Contingency, Legal Fees, Taxes, etc.	%	35%				$0	$0	$2,137,818
9 Operations and Maintenance Cost									
	Institutional Controls								
9.1	Fencing and Signs	%	5%				$6,000	$2,663	$4,635
	Source Area Containment Systems								
9.2	Road Maintenance-Gravel	%	5%				$0	$6,475	$1,000
9.3	Road Maintenance-Pavement	%	10%				$0	$0	$663
9.4	Permeable Cap Maintenance	%	2%				$0	$3,316	$0
	Site Drainage								
9.5	Ditch Maintenance	%	10%				0	0	4280
9.6	Catch Basin Maintenance	%	10%				0	0	2100
	Miscellaneous								
9.7	Engineering/Administration	%	8%				$480	$996	$1,014
9.8	Contingency, Legal Fees, Taxes, etc.	%	25%				$1,500	$3,113	$0
9.9	Contingency, Legal Fees, Taxes, etc.	%	35%						$4,437
						Total Capital Cost	$229,250	$5,111,090	$10,817,288
						Annual O&M Cost	$7,980	$16,563	$18,130
						Present Value of O&M Costs (30 Year)	$99,024	$205,537	$47,578
						Total Net Present Value Cost	$328,274	$5,316,626	$10,864,866

Note: The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive marked conditions, final project scope, final schedule and other variable factors. As a results , the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

July 1999 Option Evaluation

Table C-9
Sitewide Groundwater Options

Option	Description	Added Well System	Flow Rate (GPM)	Comments on System and Flow	Approximate Fluoride Concentration (mg/L)	Comments on Concentration	Treatment	Wells	Pumps	Electrical	Well Drilling Spoils	Conveyance
No Action	No Action (current pumping)	Existing Production Wells	1200 gpm minimum, 1800 gpm long term average	Historical pumping under typical plant full operations	1.5	Similar to mean and 95% UCL for tap water concentration. Based on data collected three times per week (May 1998 to April 1999)						
GW-1	Production Well Optimization (PWO) (Managed Pumping)	Primarily PW07 & PW08	1200 gpm minimum, 1800 gpm long term average	Primary pumping is from PW07 & PW08 and possibly PW03 when greater flow rates area needed	1.5	Assume same as for no action, based on time-series analyses discussed in Appendix A of the FFS						
GW-2	PWO + Basic Focused Extraction (FE) at SY & EPL	2 FE wells (SY & EPL)	2 wells x 20 gpm/well = 40 gpm	Need to identify minimum flow for PWO system that still allows FE wells to contain UGS	75	Assume that SY FE well contains 50 mg/L and EPL FE wells contains 100 mg/L. Net mixed concentration is 75 mg/L.	In this option, the extracted GW is used for makeup water in the Wet ESP. No additional treatment is planned.	Two 8-inch dia Sch 80 PVC 50 ft deep UGS focused extraction wells, one each in the SY and EPL. Cost includes air rotary drilling, installation, development	Two 3/4 hp, 230 volt, 4-in dia. Submersible pumps with control boxes installed (each can pump up to 30 gpm)	Pump electrical feeds (2 @ $2750/ea)	Management of drummed soil cuttings, decon, and development water	Piping system to wet ESP
GW-3	PWO + Enhanced Focused Extraction (FE) at SY, EPL, SLF, and SW corner of Company Lake	3 wells SW of Company Lake	3 wells x 15 gpm/well = 45 gpm	Fewer wells at higher flow rate might not achieve same degree of capture as this 3 well system	15-20mg/L 1st year	Estimated from residential exposure analysis. Equals one third of monitoring well data.	In this option, the extracted GW is directed to RO then CaF2 Precipitation for treatment before discharge	Three 8-inch, Sch 80 PVC, 100 ft deep using air rotary drilling method including installation and development	Three 3/4 hp, 230 volt, 4-in diameter, submersible pumps with control boxes installed	Pump electrical feeds (2 @ $2750/ea)	Management of drummed soil cuttings, decon, and development water	Piping to GWTS includes: 900-feet 1 1/2-inch diameter HDPE; 100 feet 2-inch HDPE; 3,000 feet 3-inch dia. HDPE; 5 road undercrossings and 1 RR undercrossing.
		One well at SLF	10 gpm	Capture only localized area around GP59	61 mg/L startup, 20 mg/L in first year			One 8-inch, Sch 80, PVC well 50 ft deep with 10 ft screen. Using air rotary drilling method, including installation and development	One 3/4 hp, 230 volt, 4-in diameter, submersible pump with control box installed			2-inch HDPE piping to GWTS
GW-4	PWO + High Level Focused Extraction (Option 4 + Silt Unit FE at EPL and SLF)	Silt wells - 24 at EPL, 72 at SLF	3.6 gpm at EPL (24 x .15 = 3.6); 7.2 gpm at SLF (72 x .1 = 7.2); Total = 10.8 gpm	EPL area is ~ 172,000 ft2. Area of localized UGS plume at SLF is ~ 30,000 to 40,000 ft2	50 - 600 (EPL) 300 to 400 (SLF)	Range at EPL is from Geoprobe GP66 . GP65 range was 174 to 440 mg/L at EPL. Range at SLF is at GP49 .	Silt unit FE @ EPL and SLF directed to CaF2 precipitation for treatment	24 Silt wells at EPL, 25 feet deep; 72 silt wells at SLF, 25 ft deep; completed with hollow stem auger, 10-inch borehole, 2"Sch 80 PVC casing, 10 ft screen	Four vacuum pumps, 15 HP each, 3 for SLF and 1 for EPL	Pump electrical feeds (4 @ $2750/ea)	Management of drummed soil cuttings, decon, and development water	Piping to GWTS

NOTE: The above cost opinion does not include escalation,construction management, financing or O&M costs.The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final project schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table C-10 Option GW-1 Costs			
Cost Summary for Option GW-1			
	Capital	Year 1 O&M	Total First Year Costs
SITE PREPARATION	$ -	$ -	$ -
FOCUSED EXTRACTION SYSTEM	$ -	$ -	$ -
PERFORMANCE MONITORING	$ -	$ 128,000	$ 128,000
CONVEYANCE	$ -	$ -	$ -
TREATMENT	$ -	$ -	$ -
TOTAL	$ -	$ 128,000	**$ 130,000**

Table C-10, continued
Option GW-1 Costs
Capital Costs for Option GW-1

	Units	Unit Cost	Unit	Cost	*Subtotal*	Comments
SITE PREPARATION						
Clearing, grubbing and stripping	-	$4,200	AC	$0		
Surface preparation	-	$800	AC	$0		
Import fill	-	$15	TON	$0		
Road construction gravel	-	$28	LF	$0		
Fencing	-	$15	LF	$0		
Gravel construction staging area	-	$2	SF	$0		
Subtotal				$0		
Allowance		0%		$0		
Subtotal				$0		
Contingency		20%		$0		
Subtotal				$0		
Mobilization		10%		$0		
Construction Total				$0		
Engineering, Legal, Admin		25%		$0		
SUBTOTAL SITE PREPARATION				$0	*$ -*	No capital costs incurred by this option
FOCUSED EXTRACTION SYSTEM						
Wells	-	$10,089	LS	$0		
Pumps	-	$1,800	LS	$0		
Pump electrical feeds	-	$2,750	ea	$0		
Subtotal				$0		
Allowance		15%		$0		
Subtotal				$0		
Contingency		20%		$0		
Subtotal				$0		
Mobilization		10%		$0		
Construction Total				$0		
Engineering, Legal, Admin, Construction oversight		35%		$0		
SUBTOTAL FOCUSED EXTRACTION SYSTEM				$0	*$ -*	No capital costs incurred by this option
CONVEYANCE						
HDPE Pipelines	-	$0	LS	$0		
Subtotal				$0		
Allowance		10%		$0		
Subtotal				$0		
Contingency		20%		$0		
Subtotal				$0		
Mobilization		10%		$0		
Construction Total				$0		
Engineering, Legal, Admin		25%		$0		
SUBTOTAL CONVEYANCE				$0	*$ -*	No capital costs incurred by this option

Table C-10, continued
Option GW-1 Costs
Capital Costs for Option GW-1

	Units	Unit Cost	Unit	Cost	*Subtotal*	Comments
TREATMENT						
Reverse Osmosis and Pretreat						
RO System	-	$170,000	EA	$0		
Spare Parts	-	$20,000	LS	$0		
HCl Storage Tank;	-	$30,000		$0		
Raw water tank	-	$20,000	EA	$0		
Product Water tank	-	$20,000	LS	$0		
Bag filters	-	$2,000	EA	$0		
Concentrate tank	-	$15,000	EA	$0		
CaF2 Precipitation						
Precipitation System	-	$130,000	ea	$0		
Subtotal				$0		
	Assumed % of Total	Ratio % of Total		Cost		
Purchased Equipment	40	32%		$0		
Purchased Equipment Installation	9	7%		$0		
Instrumentation (installed)	7	6%		$0		
Piping (installed)	8	6%		$0		
Electrical (installed)	5	4%		$0		
Building (including services)	5	4%		$0		
Yard Improvements	2	2%		$0		
Service Facilities (installed)	15	12%		$0		
Land	1	1%		$0		
Engineering and Supervision	10	8%		$0		
Construction Expense	12	10%		$0		
Contractor's Fee	2	2%		$0		
Contingency	8	6%		$0		
SUBTOTAL TREATMENT	124	100%		$0	*$0*	No capital costs incurred by this option
TOTAL CONSTRUCTED COST ESTIMATE					$0	No capital costs incurred by this option

NOTE: The above cost opinion does not include escalation,construction management, financing, or O&M costs. The budget level cost opinion shown has been prepared for guidance in project evaluationat the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table C-10, continued
Option GW-1 Costs
Operations and Maintenance Costs for Option GW-1

		Year 1	Year 2	Year 3	Year 4	Year 5	Years 6 to 10 (5 yrs)	Years 11 to 25 (15 years)	Discount Rate Years 26 to 30 (5 years)	Comments
SITE PREPARATION										
	Extraction or pumping wells	8	8	8	8	8	8	8	8	
10%	Road Maintenance	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	10% of loaded capital cost. O&M proportionate to number of pumping wells each year presuming roads to wells no longer in service do not require maintenance.
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
FOCUSED EXTRACTION SYSTEMS										
	Total Flow Rate (gpm)	40	40	40	40	40	40	40	40	
	Power	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	6 cents per KWh, FT operation, assume 6 HP at yr 1, assume power costs proportionate to flow for subsequent years.
15%	Focused Extraction	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	O&M (15% of capital costs annually). Subsequent years proportionate to flow. Includes replacement costs.
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
PERFORMANCE MONITORING										
	Number of Wells Sampled	39	39	39	39	39	20	20	20	
	Performance Monitoring Cost	$128,000	$128,000	$128,000	$128,000	$128,000	$64,000	$64,000	$64,000	Includes sampling and analysis, reporting, water level monitoring, and basic monitoring well network maintenance costs. Sampling efforts are assumed to drop by 50% after 5 years.
	Subtotal	$128,000	$128,000	$128,000	$128,000	$128,000	$64,000	$64,000	$64,000	
CONVEYANCE										
	Total Flow Rate (gpm)	40	40	40	40	40	40	40	40	
	Power	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	6 cents per KWh, FT operation, assume 5 HP year 1. Assume power costs proportionate to flow rate in subsequent years.
	Extraction or pumping wells	8	8	8	8	8	8	8	8	
1.5%	Piping and Pumps	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	Painting, pipe supports, inspections. Assume costs proportionate to number of pumping wells each year.
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
TREATMENT										
	RO Influent Flow Rate (gpm)	-	-	-	-	-	-	-	-	
	RO and Pretreat	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
	Acid cost	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	30 lb/day 37% HCl*.15/lb (VWR quote)*365*320/50; proportionate to flow for subsequent years
	Anti scalant	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$5/day year 1. Proportionate to flow for subsequent years
10%	Long term replacement	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	Assume 10% of RO package cost for first year, flow proportioned thereafter.
	Ppt Influent Flow Rate (gpm)	-	-	-	-	-	-	-	-	
	CaF2 Power Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	6 cents per KWh, FT operation, assume 12 HP at year 1, power costs proportionate to flow for subsequent years
	Ppt Influent Mass Rate (ppd F)	-	-	-	-	-	-	-	-	
	CaF2 Precipitation	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	Costs proportionate to fluoride mass flow for years 2 to 30.
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
OUTFALL AND DIFFUSER										
	Effluent Monitoring Station	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	Inspections
TOTAL ANNUAL O&M COSTS		$ 128,000	$ 128,000	$ 128,000	$ 128,000	$ 128,000	$ 64,000	$ 64,000	$ 64,000	

NOTE: The above cost opinion is in November 1998 dollars and does not include escalation,construction management, financing or O&M costs.The budget level cost opinion shown has been prepared for guidance in project evaluationat the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table C-11 Option GW-2 Costs Cost Summary for Option GW-2			
	Capital	Year 1 O&M	Total First Year Costs
SITE PREPARATION	$ 134,805	$ 13,481	$ 148,286
FOCUSED EXTRACTION SYSTEM	$ 59,999	$ 6,743	$ 66,743
PERFORMANCE MONITORING	$ -	$ 128,000	$ 128,000
CONVEYANCE	$ 180,651	$ 2,710	$ 183,360
TREATMENT	$ -	$ -	$ -
TOTAL	$ 375,000	$ 150,934	**$ 530,000**

Table C-11, continued

Option GW-2 Costs

Capital Costs for Option GW-2

	Units	Unit Cost	Unit	Cost	Subtotal	Comments
SITE PREPARATION						Site prep associated with treatment system is reported under treatment costs
Clearing, grubbing and stripping	3.0	$4,200	AC	$12,600		Company Lake Focused Extraction (0.0) + East Potliner (0.5) + Scrap Yard (0.5) + South Landfill 0.0) + Conveyance (2.0)
Surface preparation	3.0	$800	AC	$2,400		Company Lake Focused Extraction (0.0) + East Potliner (0.5) + Scrap Yard (0.5) + South Landfill (0.0) + Conveyance (2.0)
Import fill	100	$15	TON	$1,500		Company Lake Focused Extraction (0) + East Potliner (50) + Scrap Yard (0) + South Landfill (0) + Conveyance (50)
Road construction gravel	900	$28	LF	$25,200		Company Lake Focused Extraction (0) + East Potliner (200) + Scrap Yard (200) + South Landfill (0) + Conveyance (500)
Fencing	2,000	$15	LF	$30,000		Company Lake Focused Extraction (0) + East Potliner (500) + Scrap Yard (500) + South Landfill (0) + Conveyance (1000)
Gravel construction staging area	5,000	$2	SF	$10,000		Assume single 50' x 100' area
Subtotal				$81,700		
Allowance		0%		$0		
Subtotal				$81,700		
Contingency		20%		$16,340		
Subtotal				$98,040		
Mobilization		10%		$9,804		
Construction Total				$107,844		
Engineering, Legal, Admin		25%		$26,961		
SUBTOTAL SITE PREPARATION				$134,805	*$ 134,805*	
FOCUSED EXTRACTION SYSTEM						
Wells	2	$10,089	LS	$20,178		Extraction Wells. (2) 8-inch dia. Sch 80 PVC focused extraction wells, 50 feet deep with 10 ft.screens using air rotary drilling methods in SY and EPL.
Pumps	2	$1,800	LS	$3,600		Eight 3/4 hp, 230 volt, 4-in.dia.submersible pump with control boxes installed
Pump electrical feeds	2	$2,750	*ea*	$5,500		*Assumes on grade installation, 150 feet of electrical line ($15/foot) per pump plus $500 electrical box and meter*
Subtotal				$29,278		
Allowance		15%		$4,392		Fittings, testing, startup, IDW Management of drummed soil cuttings, decon and development water
Subtotal				$33,670		
Contingency		20%		$6,734		
Subtotal				$40,404		
Mobilization		10%		$4,040		
Construction Total				$44,444		
Engineering, Legal, Admin, Construction oversight		35%		$15,555		
SUBTOTAL FOCUSED EXTRACTION SYSTEM				$59,999	*$ 59,999*	
CONVEYANCE						
HDPE Pipelines	1	$99,532	LS	$99,532		HDPE pipeline to Wet ESP.
Subtotal				$99,532		
Allowance		10%		$9,953		Fittings, testing, startup
Subtotal				$109,485		
Contingency		20%		$21,897		
Subtotal				$131,382		
Mobilization		10%		$13,138		General contractor's mob, bonds, insurance, temp facilities, demob, etc
Construction Total				$144,520		
Engineering, Legal, Admin		25%		$36,130		
SUBTOTAL CONVEYANCE				$180,651	*$ 180,651*	

Table C-11, continued

Option GW-2 Costs

Capital Costs for Option GW-2

	Units	Unit Cost	Unit	Cost	*Subtotal*	Comments
TREATMENT						
Reverse Osmosis and Pretreat						
RO System	-	$170,000	EA	$0		Two 30 gpm = 60 gpm, installed, with metering pumps, feed and high pressure pumps, and controls; Cost Curves
Spare Parts	-	$20,000	LS	$0		Allowance
HCl Storage Tank;	-	$30,000		$0		7200 gal, HDPE with secondary containment and earthquake tie-down
Raw water tank	-	$20,000	EA	$0		17000 gal
Product Water tank	-	$20,000	LS	$0		
Bag filters	-	$2,000	EA	$0		60 gpm
Concentrate tank	-	$15,000	EA	$0		10,000 gal
CaF2 Precipitation						
Precipitation System	-	$130,000	ea	$0		10 gpm per Dave Lee estimate.
Subtotal				$0		
	Assumed % of Total	Ratio % of Total		Cost		
Purchased Equipment	40	32%		$0		Assumed % of total from Peters and Timmerhaus, Plant Design and Economics for Chemical Engineers, 3rd Ed. P.164
Purchased Equipment Installation	9	7%		$0		
Instrumentation (installed)	7	6%		$0		
Piping (installed)	8	6%		$0		
Electrical (installed)	5	4%		$0		
Building (including services)	5	4%		$0		
Yard Improvements	2	2%		$0		
Service Facilities (installed)	15	12%		$0		
Land	1	1%		$0		
Engineering and Supervision	10	8%		$0		
Construction Expense	12	10%		$0		
Contractor's Fee	2	2%		$0		
Contingency	8	6%		$0		
SUBTOTAL TREATMENT	*124*	*100%*		*$0*	*$0*	Includes:instrumentation,piping, electrical, building, yard improvements, service facilities, land, engineering, supervision, construction *expense, contractor's fee, and services during construction*
TOTAL CONSTRUCTED COST ESTIMATE					**$375,000**	

NOTE: The above cost opinion does not include escalation,construction management, financing or O&M costs.The budget level cost opinion shown has been prepared for guidance in project evaluationat the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table C-11, continued

Option GW-2 Costs

Operations and Maintenance Costs for Option GW-2

		Year 1	Year 2	Year 3	Year 4	Year 5	Years 6 to 10 (5 yrs)	Years 11 to 25 (15 years)	Discount Rate Years 26 to 30 (5 years)	Comments
SITE PREPARATION										
	Extraction or pumping wells	8	8	8	8	8	8	8	8	
10%	Road Maintenance	$ 13,481	$ 13,481	$ 13,481	$ 13,481	$ 13,481	$ 13,481	$ 13,481	$ 13,481	10% of loaded capital cost. O&M proportionate to number of pumping wells each year presuming roads to wells no longer in service do not require maintenance.
	Subtotal	$ 13,481	$ 13,481	$ 13,481	$ 13,481	$ 13,481	$ 13,481	$ 13,481	$ 13,481	
FOCUSED EXTRACTION SYSTEMS										
	Total Flow Rate (gpm)	40	40	40	40	40	40	40	40	
	Power	$ 2,352	$ 2,352	$ 2,352	$ 2,352	$ 2,352	$ 2,352	$ 2,352	$ 2,352	6 cents per KWh, FT operation, assume 6 HP at yr 1, assume power costs proportionate to flow for subsequent years
15%	Focused Extraction	$ 4,392	$ 4,392	$ 4,392	$ 4,392	$ 4,392	$ 4,392	$ 4,392	$ 4,392	O&M (15% of capital costs annually). Subsequent years proportionate to flow. Includes replacement costs.
	Subtotal	$ 6,743	$ 6,743	$ 6,743	$ 6,743	$ 6,743	$ 6,743	$ 6,743	$ 6,743	
PERFORMANCE MONITORING										
	Number of Wells Sampled	39	39	39	39	39	20	20	20	
	Performance Monitoring Cost	$128,000	$128,000	$128,000	$128,000	$128,000	$64,000	$64,000	$64,000	Includes sampling and analysis, reporting, water level monitoring, and basic monitoring well network maintenance costs. Sampling efforts are assumed to drop by 50% after 5 years.
	Subtotal	$128,000	$128,000	$128,000	$128,000	$128,000	$64,000	$64,000	$64,000	
CONVEYANCE										
	Total Flow Rate (gpm)	40	40	40	40	40	40	40	40	
	Power	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	6 cents per KWh, FT operation, assume 5 HP year 1. Assume power costs proportionate to flow rate in subsequent years.
	Extraction or pumping wells	8	8	8	8	8	8	8	8	
1.5%	Piping and Pumps	$ 2,710	$ 2,710	$ 2,710	$ 2,710	$ 2,710	$ 2,710	$ 2,710	$ 2,710	Painting, pipe supports, inspections. Assume costs proportionate to number of pumping wells each year.
	Subtotal	$ 2,710	$ 2,710	$ 2,710	$ 2,710	$ 2,710	$ 2,710	$ 2,710	$ 2,710	
TREATMENT										
	RO Influent Flow Rate (gpm)	-	-	-	-	-	-	-	-	
	RO and Pretreat	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
	Acid cost	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	30 lb/day 37% HCl*.15/lb (VWR quote)*365*320/50, proportionate to flow for subsequent years
	Anti scalant	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$5/day year 1. Proportionate to flow for subsequent years
10%	Long term replacement	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	assume 10% of RO package cost for first year, flow proportioned thereafter.
	Ppt Influent Flow Rate (gpm)	-	-	-	-	-	-	-	-	
	CaF2 Power Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	6 cents per KWh, FT operation, assume 12 HP at year 1, power costs proportionate to flow for subsequent years
	Ppt Influent Mass Rate (ppd F)	-	-	-	-	-	-	-	-	
	CaF2 Precipitation	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	*Costs proportionate to fluoride mass flow for years 2 to 30.*
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
OUTFALL AND DIFFUSER										
	Effluent Monitoring Station	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	Inspections
TOTAL ANNUAL O&M COSTS		$ 150,934	$ 150,934	$ 150,934	$ 150,934	$ 150,934	$ 86,934	$ 86,934	$ 86,934	

NOTE: The above cost opinion is in November 1998 dollars and does not include escalation,construction management, financing or O&M costs.The budget level cost opinion shown has been prepared for guidance in project evaluationat the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table C-12 Option GW-3 Costs Cost Summary for Option GW-3			
	Capital	Year 1 O&M	Total First Year Costs
SITE PREPARATION	$ 426,608	$ 42,661	$ 469,268
FOCUSED EXTRACTION SYSTEM	$ 230,546	$ 20,402	$ 250,949
PERFORMANCE MONITORING	$ -	$ 128,000	$ 128,000
CONVEYANCE	$ 473,715	$ 7,106	$ 480,821
TREATMENT	$ 2,185,500	$ 98,971	$ 2,284,471
TOTAL	$ 3,316,000	$ 297,140	**$ 3,610,000**

Table C-12, continued

Option GW-3 Costs

Capital Costs for Option GW-3

	Units	Unit Cost	Unit	Cost	Subtotal	Comments
SITE PREPARATION						Site prep associated with treatment system is reported under Treatment System costs
Clearing, grubbing and stripping	12.0	$4,200	AC	$50,400		Company Lake Focused Extraction (2.0) + East Potliner (0.5) + Scrap Yard (0.5) + South Landfill (7.0) + Conveyance (2.0)
Surface preparation	8.5	$800	AC	$6,800		Company Lake Focused Extraction (1.5) + East Potliner (0.5) + Scrap Yard (0.5) + South Landfill (4.0) + Conveyance (2.0)
Import fill	2,100	$15	TON	$31,500		Company Lake Focused Extraction (750) + East Potliner (50) + Scrap Yard (0) + South Landfill (1250) + Conveyance (50)
Road construction gravel	3,700	$28	LF	$103,600		Company Lake Focused Extraction (1800) + East Potliner (200) + Scrap Yard (200) + South Landfill (1000) + Conveyance (500)
Fencing	3,750	$15	LF	$56,250		Company Lake Focused Extraction (250) + East Potliner (500) + Scrap Yard (500) + South Landfill (1500) + Conveyance (1000)
Gravel construction staging area	5,000	$2	SF	$10,000		Assume single 50' x 100' area
Subtotal				$258,550		
Allowance		0%		$0		
Subtotal				$258,550		
Contingency		20%		$51,710		
Subtotal				$310,260		
Mobilization		10%		$31,026		
Construction Total				$341,286		
Engineering, Legal, Admin		25%		$85,322		
SUBTOTAL SITE PREPARATION				$426,608	$ 426,608	
FOCUSED EXTRACTION SYSTEM						
Wells	2	$10,000	LS	$20,000		Extraction Wells. (2) 8-inch dia. Sch 80 PVC focused extraction wells, 50 feet deep with 10 ft.screens using air rotary drilling methods in SY and EPL.
Wells	3	*$18,400*	*LS*	*$55,200*		Extraction Wells. (3) 8-inch dia. Sch 80 PVC focused extraction wells, 100 feet deep with 10 ft.screens using air rotary drilling methods SW of *Company Lake.*
Wells	1	$10,000	LS	$10,000		Extraction Wells. (1) 8-inch dia. Sch 80 PVC focused extraction well, 50 feet deep with 10 ft.screens using air rotary drilling methods in SLF.
Pumps	6	$1,800	LS	$10,800		Six 3/4 hp, 230 volt, 4-in.dia.submersible pump with control boxes installed
Pump electrical feeds	6	$2,750	ea	$16,500		Assumes on grade installation, 150 feet of electrical line ($15/foot) per pump plus $500 electrical box and meter
Subtotal				$112,500		
Allowance		15%		$16,875		Fittings, testing, startup, IDW Management of drummed soil cuttings, decon and development water
Subtotal				$129,375		
Contingency		20%		$25,875		
Subtotal				$155,250		
Mobilization		10%		$15,525		
Construction Total				$170,775		
Engineering, Legal, Admin, Construction oversight		35%		$59,771		
SUBTOTAL FOCUSED EXTRACTION SYSTEM				$230,546	$ 230,546	
CONVEYANCE						
HDPE Pipelines	1	$65,000	EA	$65,000		HDPE pipeline to Wet ESP.
HDPE Pipelines	1	*$196,000*	EA	$196,000		*HDPE pipelines to RO and Package treatment plant, to be installed on grade, on sand bed, and anchored.*
Subtotal				$261,000		
Allowance		10%		$26,100		Fittings, testing, startup
Subtotal				$287,100		
Contingency		20%		$57,420		
Subtotal				$344,520		
Mobilization		10%		$34,452		*General contractor's mob, bonds, insurance, temp facilities, demob, etc*
Construction Total				$378,972		
Engineering, Legal, Admin		25%		$94,743		
SUBTOTAL CONVEYANCE				$473,715	$ 473,715	

Table C-12, continued

Option GW-3 Costs

Capital Costs for Option GW-3

	Units	Unit Cost	Unit	Cost	*Subtotal*	Comments
TREATMENT						
Reverse Osmosis and Pretreat						
RO System	2	$160,000	EA	$320,000		Two 30 gpm = 60 gpm, installed, with metering pumps, feed and high pressure pumps, and controls; Cost Curves (York,Nov.1998)
Spare Parts	2	$20,000	LS	$40,000		Allowance
HCl Storage Tank;	2	$30,000		$60,000		7,200 gal, HDPE with secondary containment and earthquake tie-down
Raw water tank	2	$20,000	EA	$40,000		17,000 gal
Product Water tank	2	$20,000	LS	$40,000		
Bag filters	4	$2,000	EA	$8,000		*60 gpm*
Concentrate tank	2	$15,000	EA	$30,000		10,000 gal
						538000
CaF2 Precipitation						
Precipitation System	1	$167,000	ea	$167,000		15 gpm system estimated using 10 gpm per Dave Lee estimate ($130,900) and 6/10ths rule.
Subtotal				$705,000		
	Assumed % of Total	Ratio % of Total		Cost		
Purchased Equipment	40	32%		*$705,000*		*Assumed % of total from Peters and Timmerhaus, Plant Design and Economics for Chemical Engineers, 3rd Ed. P.164*
Purchased Equipment Installation	9	7%		$158,625		
Instrumentation (installed)	7	6%		$123,375		
Piping (installed)	8	6%		$141,000		
Electrical (installed)	5	4%		$88,125		
Building (including services)	5	4%		$88,125		
Yard Improvements	2	2%		$35,250		
Service Facilities (installed)	15	12%		$264,375		
Land	1	1%		$17,625		
Engineering and Supervision	10	8%		$176,250		
Construction Expense	12	10%		$211,500		
Contractor's Fee	2	2%		$35,250		
Contingency	8	6%		$141,000		
SUBTOTAL TREATMENT	124	100%		$2,185,500	*$2,185,500*	Includes:instrumentation,piping, electrical, building, yard improvements, service facilities, land, engineering, supervision, construction expense, contractor's fee, and services during construction
TOTAL CONSTRUCTED COST ESTIMATE					**$3,300,000**	

NOTE: The above cost opinion does not include escalation,construction management, financing or O&M costs.The budget level cost opinion shown has been prepared for guidance in project evaluationat the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table C-12, continued

Option GW-3 Costs

Operation and Maintenance Costs for Option GW-3

Discount Rate

		Year 1	Year 2	Year 3	Year 4	Year 5	Years 6 to 10 (5 yrs)	Years 11 to 25 (15 years)	Years 26 to 30 (5 years)	Comments
SITE PREPARATION										
	Extraction or pumping wells	12	12	12	12	12	12	12	12	
10%	Road Maintenance	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	10% of loaded capital cost. O&M proportionate to number of pumping wells each year presuming roads to wells no longer in service do not require maintenance.
	Subtotal	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	
FOCUSED EXTRACTION SYSTEMS										
	Total Flow Rate (gpm)	100	100	100	100	100	100	100	100	
	Power	$ 3,527	$ 3,527	$ 3,527	$ 3,527	$ 3,527	$ 3,527	$ 3,527	$ 3,527	6 cents per KWh, FT operation, assume 9 HP at yr 1, assume power costs proportionate to flow for subsequent years
15%	Focused Extraction	$ 16,875	$ 16,875	$ 16,875	$ 16,875	$ 16,875	$ 16,875	$ 16,875	$ 16,875	O&M (15% of capital costs annually). Subsequent years proportionate to flow. Includes replacement costs.
	Subtotal	$ 20,402	$ 20,402	$ 20,402	$ 20,402	$ 20,402	$ 20,402	$ 20,402	$ 20,402	
PERFORMANCE MONITORING										
	Number of Wells Sampled	39	39	39	39	39	20	20	20	
	Performance Monitoring Cost	$128,000	$128,000	$128,000	$128,000	$128,000	$64,000	$64,000	$64,000	Includes sampling and analysis, reporting, water level monitoring, and basic monitoring well network maintenance costs. Sampling efforts are assumed to drop by 50% after 5 years.
	Subtotal	$128,000	$128,000	$128,000	$128,000	$128,000	$64,000	$64,000	$64,000	
CONVEYANCE										
	Total Flow Rate (gpm)	100	100	100	100	100	100	100	100	
	Power for conveyance	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	6 cents per KWh, FT operation, assume 0 HP year 1. Assume power costs proportionate to flow rate in subsequent years. Assume no additional pumping is required.
	Extraction or pumping wells	12	12	12	12	12	12	12	12	
1.5%	Piping and Pumps	$ 7,106	$ 7,106	$ 7,106	$ 7,106	$ 7,106	$ 7,106	$ 7,106	$ 7,106	Painting, pipe supports, inspections. Assume costs proportionate to number of pumping wells each year.
	Subtotal	$ 7,106	$ 7,106	$ 7,106	$ 7,106	$ 7,106	$ 7,106	$ 7,106	$ 7,106	
TREATMENT										
	RO Influent Flow Rate (gpm)	55	55	55	55	55	55	55	55	
	RO and Pretreat	$ 83,390	$ 83,390	$ 83,390	$ 83,390	$ 83,390	$ 83,390	$ 83,390	$ 83,390	Assume 5% of capital cost. includes labor, constant flow rate of 60 gpm for system life (30 yrs). O&M proportionate to influent flow rate subsequent to year 1.
	Acid cost	$ 8,580	$ 8,580	$ 8,580	$ 8,580	$ 8,580	$ 8,580	$ 8,580	$ 8,580	30 lb/day 37% HCl*.15/lb (VWR quote)*365*320/50; proportionate to flow for subsequent years
	Anti scalant	$ 1,825	$ 1,825	$ 1,825	$ 1,825	$ 1,825	$ 1,825	$ 1,825	$ 1,825	$5/day year 1. Proportionate to flow for subsequent years
10%	Long term replacement	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	assume 10% of RO package cost for first year, flow proportioned thereafter.
	Ppt Influent Flow Rate (gpm)	15	15	15	15	15	15	15	15	
	CaF2 Power Costs	$ 1,176	$ 1,176	$ 1,176	$ 1,176	$ 1,176	$ 1,176	$ 1,176	$ 1,176	6 cents per KWh, FT operation, assume 3 HP at year 1, power costs proportionate to flow for subsequent years
	Ppt Influent Mass Rate (ppd F)	18	18	18	18	18	18	18	18	
	CaF2 Precipitation	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	Costs proportionate to fluoride mass flow for years 2 to 30.
	Subtotal	$ 98,971	$ 98,971	$ 98,971	$ 98,971	$ 98,971	$ 98,971	$ 98,971	$ 98,971	
OUTFALL AND DIFFUSER										
	Effluent Monitoring Station	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	Inspections
TOTAL ANNUAL O&M COSTS		$ 297,140	$ 297,140	$ 297,140	$ 297,140	$ 297,140	$ 233,140	$ 233,140	$ 233,140	

NOTE: The above cost opinion is in November 1998 dollars and does not include escalation,construction management, financing or O&M costs.The budget level cost opinion shown has been prepared for guidance in project evaluationat the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table C-13 Option GW-4 Costs Cost Summary for Option GW-4			
	Capital	Year 1 O&M	Total First Year Costs
SITE PREPARATION	$ 426,608	$ 42,661	$ 469,268
FOCUSED EXTRACTION SYSTEM	$ 357,603	$ 21,578	$ 379,181
PERFORMANCE MONITORING	$ -	$ 128,000	$ 128,000
CONVEYANCE	$ 609,840	$ 14,466	$ 624,306
TREATMENT	$ 2,726,760	$ 269,868	$ 2,996,628
TOTAL	$ 4,121,000	$ 476,573	**$ 4,600,000**

Table C-13, continued
Option GW-4 Costs
Capital Costs for Option GW-4

	Units	Unit Cost	Unit	Cost	Subtotal	Comments
SITE PREPARATION						Site prep associated with treatment system is reported under treatment costs
Clearing, grubbing and stripping	12.0	$4,200	AC	$50,400		Company Lake Focused Extraction (2.0) + East Potliner (0.5) + Scrap Yard (0.5) + South Landfill (7.0) + Conveyance (2.0)
Surface preparation	8.5	$800	AC	$6,800		Company Lake Focused Extraction (1.5) + East Potliner (0.5) + Scrap Yard (0.5) + South Landfill (4.0) + Conveyance (2.0)
Import fill	2,100	$15	TON	$31,500		Company Lake Focused Extraction (750) + East Potliner (50) + Scrap Yard (0) + South Landfill (1250) + Conveyance (50)
Road construction gravel	3,700	$28	LF	$103,600		Company Lake Focused Extraction (1800) + East Potliner (200) + Scrap Yard (200) + South Landfill (1000) + Conveyance (500)
Fencing	3,750	$15	LF	$56,250		Company Lake Focused Extraction (250) + East Potliner (500) + Scrap Yard (500) + South Landfill (1500) + Conveyance (1000)
Gravel construction staging area	5,000	$2	SF	$10,000		Assume single 50' x 100' area
Subtotal				$258,550		
Allowance		0%		$0		
Subtotal				$258,550		
Contingency		20%		$51,710		
Subtotal				$310,260		
Mobilization		10%		$31,026		
Construction Total				$341,286		
Engineering, Legal, Admin		25%		$85,322		
SUBTOTAL SITE PREPARATION				$426,608	$ 426,608	
FOCUSED EXTRACTION SYSTEM						
Wells	2	$10,000	LS	$20,000		Extraction Wells. (2) 8-inch dia. Sch 80 PVC focused extraction wells, 50 feet deep with 10 ft.screens using air rotary drilling methods in SY and EPL.
Wells	3	$18,400	LS	$55,200		Extraction Wells. (3) 8-inch dia. Sch 80 PVC focused extraction wells, 100 feet deep with 10 ft.screens using air rotary drilling methods SW of Company Lake.
Wells	1	$10,000	LS	$10,000		Extraction Wells. (1) 8-inch dia. Sch 80 PVC focused extraction well, 50 feet deep with 10 ft.screens using air rotary drilling methods in SLF.
						Multiple Well Points Cost
Pumps	6	$1,800	LS	$10,800		Six 3/4 hp, 230 volt, 4-in.dia.submersible pump with control boxes installed
						Vacuum extraction system
Pump electrical feeds	6	$2,750	ea	$16,500		Assumes on grade installation, 150 feet of electrical line ($15/foot) per pump plus $500 electrical box and meter
Subtotal				$112,500		
Silt Wells	1	$62,000	LS	$62,000		Well field construction at silt units, extraction wells (96) 2-in diameter, Sch 80 pvc, 25 ft deep, with 10 ft screens, using hollow stem auger drilling method, per D.Mustonen
Subtotal				$174,500		
Allowance		15%		$26,175		Fittings, testing, startup, IDW Management of drummed soil cuttings, decon and development water
Subtotal				$200,675		
Contingency		20%		$40,135		
Subtotal				$240,810		
Mobilization		10%		$24,081		
Construction Total				$264,891		
Engineering, Legal, Admin, Construction oversight		35%		$92,712		
SUBTOTAL FOCUSED EXTRACTION SYSTEM				$357,603	$ 357,603	
CONVEYANCE						
HDPE Pipelines	1	$65,000	EA	$65,000		HDPE pipeline to Wet ESP.
HDPE Pipelines	1	$196,000	EA	$196,000		HDPE pipelines to RO and Package treatment plant, to be installed on grade, on sand bed, and anchored.
HDPE Pipelines	1	$75,000	EA	$75,000		HDPE Pipelines from wellheads to CaF2 precipitation, silt wells, 1 1/2 inch, per D. Mustonen
Subtotal				$336,000		
Allowance		10%		$33,600		Fittings, testing, startup
Subtotal				$369,600		
Contingency		20%		$73,920		Contingency
Subtotal				$443,520		
Mobilization		10%		$44,352		General contractor's mob, bonds, insurance, temp facilities, demob, etc
Construction Total				$487,872		
Engineering, Legal, Admin		25%		$121,968		
SUBTOTAL CONVEYANCE				$609,840	$ 609,840	

Table C-13, continued
Option GW-4 Costs
Capital Costs for Option GW-4

	Units	Unit Cost	Unit	Cost	*Subtotal*	Comments
TREATMENT						
Reverse Osmosis and Pretreat						
RO System	2	$160,000	EA	$320,000		Two 30 gpm = 60 gpm, installed, with metering pumps, feed and high pressure pumps, and controls; cost curves
Spare Parts	2	$20,000	LS	$40,000		Allowance
HCl Storage Tank;	2	*$30,000*		$60,000		*7200 gal, HDPE with secondary containment and earthquake tie-down*
Raw water tank	2	$20,000	EA	$40,000		17000 gal
Product Water tank	2	$20,000	LS	$40,000		
Bag filters	4	$2,000	EA	$8,000		60 gpm
Concentrate tank	2	$15,000	EA	$30,000		10,000 gal
CaCl2 Precipitation						$538,000
Precipitation System	1	$227,000	ea	$227,000		25 gpm system estimated using 10 gpm per Dave Lee estimate ($130,900) and 6/10ths rule.
Silt Wells Groundwater Extraction						
Econopump, 24 port Jet pump				$80,000		
Vacuum gauges				$5,280		
Sampling ports				$13,440		
Well seal				$2,880		
Pump control panel				$11,000		
Discharge flow meter				$2,000		$114,600
Subtotal				$879,600		
	Assumed % of Total	Ratio % of Total		Cost		
Purchased Equipment	40	32%		$879,600		Assumed % of total from Peters and Timmerhaus, Plant Design and Economics for Chemical Engineers, 3rd Ed. P.164
Purchased Equipment Installation	9	7%		$197,910		
Instrumentation (installed)	7	6%		$153,930		
Piping (installed)	8	6%		$175,920		
Electrical (installed)	5	4%		$109,950		
Building (including services)	5	4%		$109,950		
Yard Improvements	2	2%		$43,980		
Service Facilities (installed)	15	12%		$329,850		
Land	1	1%		$21,990		
Engineering and Supervision	10	8%		$219,900		
Construction Expense	12	10%		$263,880		
Contractor's Fee	2	2%		$43,980		
Contingency	8	6%		$175,920		
SUBTOTAL TREATMENT	124	100%		$2,726,760	*$2,726,760*	Includes:instrumentation,piping, electrical, building, yard improvements, service facilities, land, engineering, supervision, construction expense, contractor's fee, and services during construction
TOTAL CONSTRUCTED COST ESTIMATE					$4,121,000	

NOTE: The above cost opinion does not include escalation,construction management, financing or O&M costs.The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table C-13, continued
Option GW-4 Costs
Operations and Maintenance Costs for Option GW-4

		Year 1	Year 2	Year 3	Year 4	Year 5	Years 6 to 10 (5 yrs)	Years 11 to 25 (15 years)	Discount Rate Years 26 to 30 (5 years)	Comments
SITE PREPARATION										
	Extraction or pumping wells	26	26	26	26	26	26	26	26	
10%	Road Maintenance	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	10% of loaded capital cost. O&M proportionate to number of pumping wells each year presuming roads to wells no longer in service do not require maintenance.
	Subtotal	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	$ 42,661	
FOCUSED EXTRACTION SYSTEMS										
	Total Flow Rate (gpm)	110	110	110	110	110	110	110	110	
	Power	$ 4,703	$ 4,703	$ 4,703	$ 4,703	$ 4,703	$ 4,703	$ 4,703	$ 4,703	6 cents per KWh, FT operation, assume 12 HP at yr 1, assume power costs proportionate to flow for subsequent years
15%	Focused Extraction	$ 16,875	$ 16,875	$ 16,875	$ 16,875	$ 16,875	$ 16,875	$ 16,875	$ 16,875	O&M (15% of capital costs annually). Subsequent years proportionate to flow. Includes replacement costs.
	Subtotal	$ 21,578	$ 21,578	$ 21,578	$ 21,578	$ 21,578	$ 21,578	$ 21,578	$ 21,578	
PERFORMANCE MONITORING										
	Number of Wells Sampled	39	39	39	39	39	20	20	20	
	Performance Monitoring Cost	$128,000	$128,000	$128,000	$128,000	$128,000	$64,000	$64,000	$64,000	Includes sampling and analysis, reporting, water level monitoring, and basic monitoring well network maintenance costs. Sampling efforts are assumed to drop by 50% after 5 years.
	Subtotal	$128,000	$128,000	$128,000	$128,000	$128,000	$64,000	$64,000	$64,000	
WELLFIELD										
2%	O&M	$ 1,240	$ 1,240	$ 1,240	$ 1,240	$ 1,240	$ 1,240	$ 1,240	$ 1,240	
	Subtotal	$ 1,240	$ 1,240	$ 1,240	$ 1,240	$ 1,240	$ 1,240	$ 1,240	$ 1,240	
CONVEYANCE										
	Total Flow Rate (gpm)	110	110	110	110	110	110	110	110	
	Power	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	Six cents per KWh, FT operation, assume 0 HP year 1. Assume power costs proportionate to flow rate in subsequent years. Assume no additional pumping in required.
	Extraction or pumping wells	26	26	26	26	26	26	26	26	
1.5%	Piping and Pumps	$ 9,148	$ 9,148	$ 9,148	$ 9,148	$ 9,148	$ 9,148	$ 9,148	$ 9,148	Painting, pipe supports, inspections. Assume costs proportionate to number of pumping wells each year.
	Silt Extraction - Power	$ 1,568	$ 1,568	$ 1,568	$ 1,568	$ 1,568	$ 1,568	$ 1,568	$ 1,568	Silt wells, 4 HP
5.0%	O&M	$ 3,750	$ 3,750	$ 3,750	$ 3,750	$ 3,750	$ 3,750	$ 3,750	$ 3,750	Silt wells, (5% of equipment cost annually)
	Subtotal	$ 14,466	$ 14,466	$ 14,466	$ 14,466	$ 14,466	$ 14,466	$ 14,466	$ 14,466	
TREATMENT										
	RO Influent Flow Rate (gpm)	55	55	55	55	55	55	55	55	
	RO and Pretreat	$ 84,760	$ 84,760	$ 84,760	$ 84,760	$ 84,760	$ 84,760	$ 84,760	$ 84,760	Includes labor, constant flow rate of 50 gpm for system life (30 yrs). O&M proportionate to influent flow rate subsequent to year 1.
	Acid cost	$ 8,580	$ 8,580	$ 8,580	$ 8,580	$ 8,580	$ 8,580	$ 8,580	$ 8,580	30 lb/day 37% HCl*.15/lb (VWR quote)*365*320/50, proportionate to flow for subsequent years
	Anti scalant	$ 1,825	$ 1,825	$ 1,825	$ 1,825	$ 1,825	$ 1,825	$ 1,825	$ 1,825	$5/day year 1. Proportionate to flow for subsequent years
10%	Long term replacement	$ 32,000	$ 32,000	$ 32,000	$ 32,000	$ 32,000	$ 32,000	$ 32,000	$ 32,000	Assume 10% of RO package cost for first year, flow proportioned thereafter.
	Ppt Influent Flow Rate (gpm)	25	25	25	25	25	25	25	25	
	CaCl2 Power Costs	$ 4,703	$ 4,703	$ 4,703	$ 4,703	$ 4,703	$ 4,703	$ 4,703	$ 4,703	6 cents per KWh, FT operation, assume 12 HP at year 1, power costs proportionate to flow for subsequent years
	Ppt Influent Mass Rate (ppd F)	79	79	79	79	79	79	79	79	
	CaCl2 Precipitation	$ 138,000	$ 138,000	$ 138,000	$ 138,000	$ 138,000	$ 138,000	$ 138,000	$ 138,000	Costs proportionate to fluoride mass flow for years 2-30.
	Subtotal	$ 269,868	$ 269,868	$ 269,868	$ 269,868	$ 269,868	$ 269,868	$ 269,868	$ 269,868	
OUTFALL AND DIFFUSER										
	Effluent Monitoring Station	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	Inspections
TOTAL ANNUAL O&M COSTS		$ 477,813	$ 477,813	$ 477,813	$ 477,813	$ 477,813	$ 413,813	$ 413,813	$ 413,813	

NOTE: The above cost opinion does not include escalation,construction management, financing or O&M costs.The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Appendix C Figures

19-AUG-1999

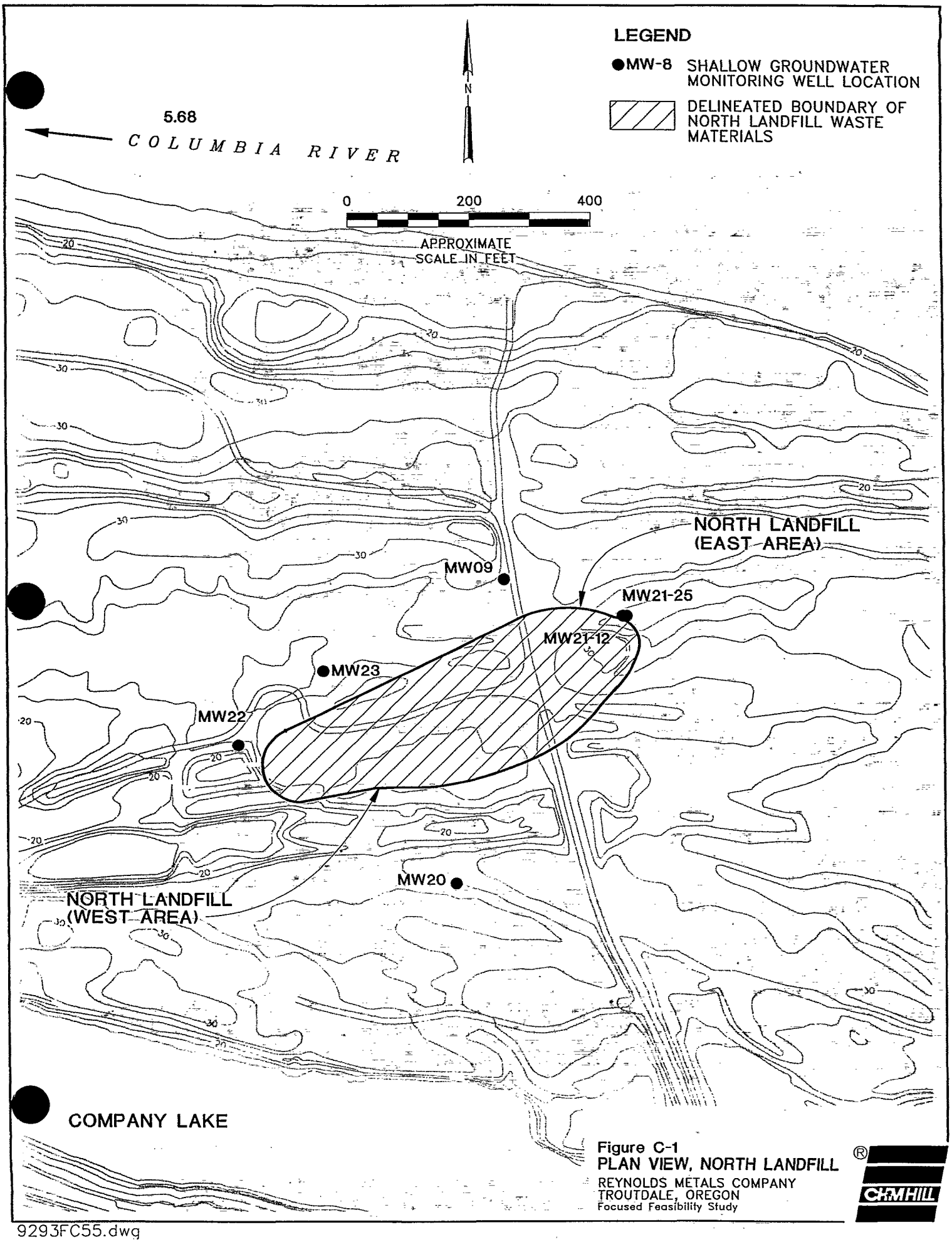

Figure C-1
PLAN VIEW, NORTH LANDFILL
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

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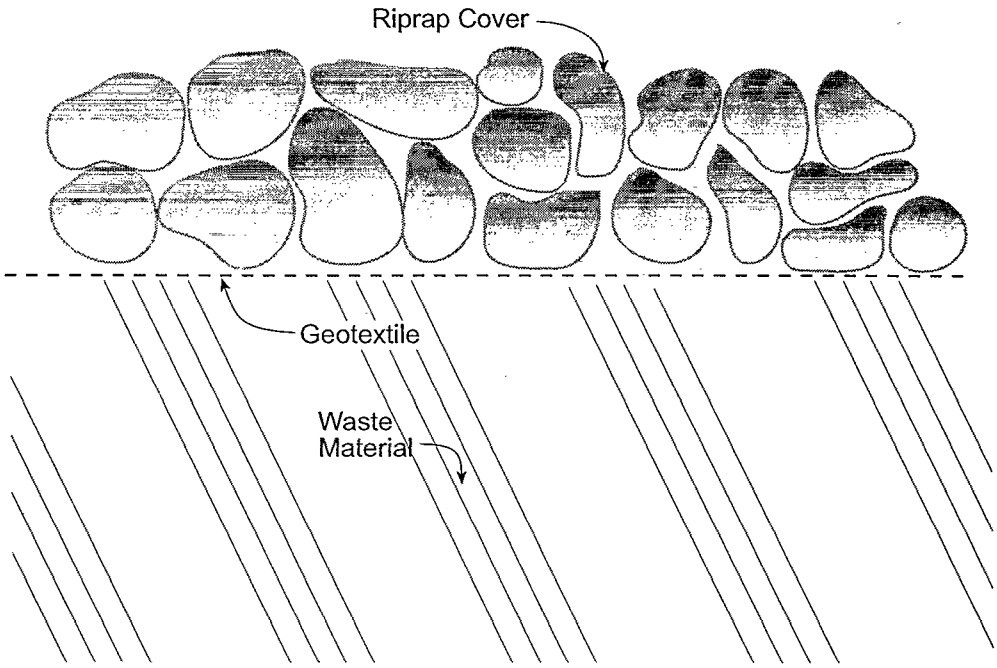

Figure C-2
North Landfill
Permeable
Riprap Cover

Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

CH2MHILL

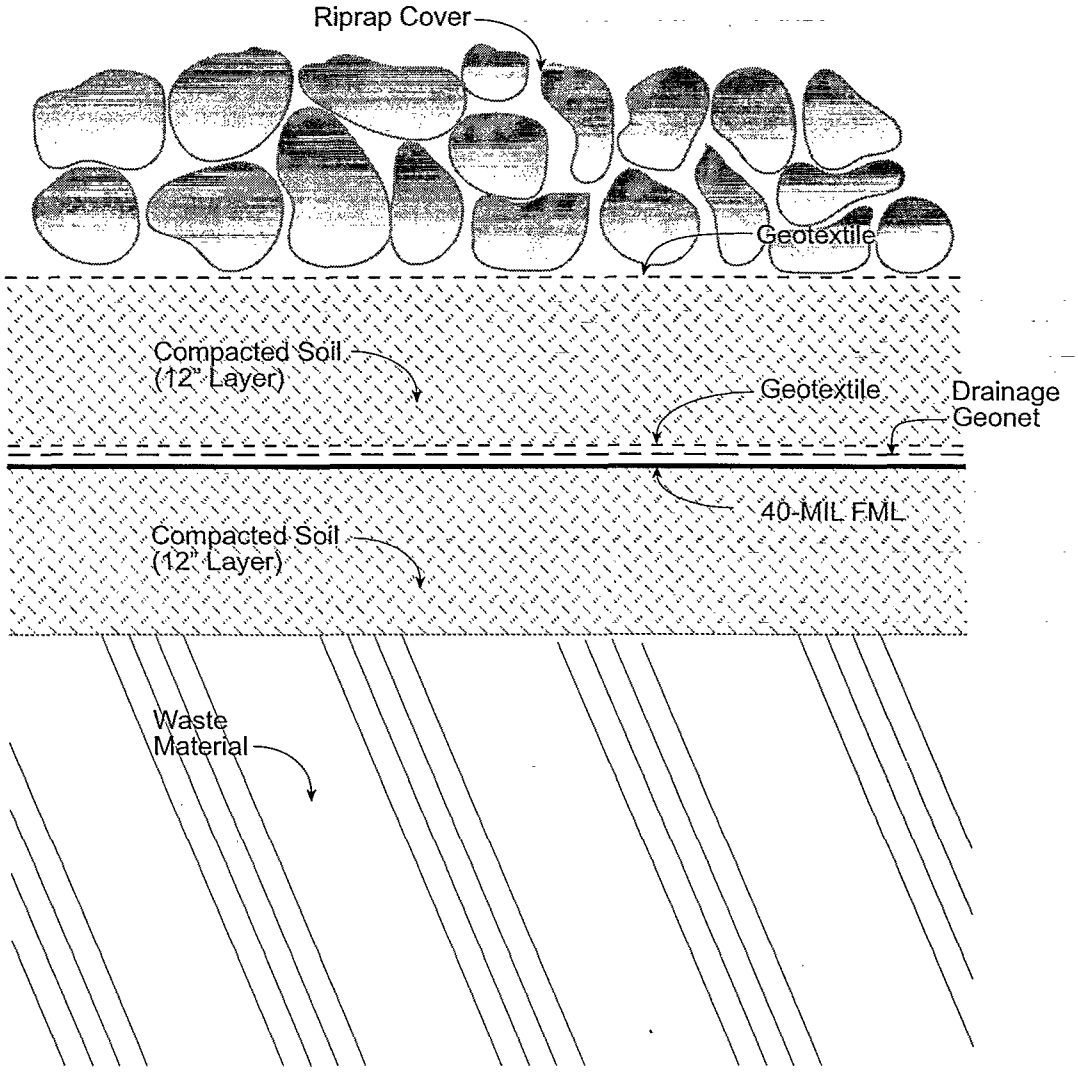

Figure C-3
North Landfill Multilayer Low-Permeability Cap
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

CH2MHILL

12-Oct-1999

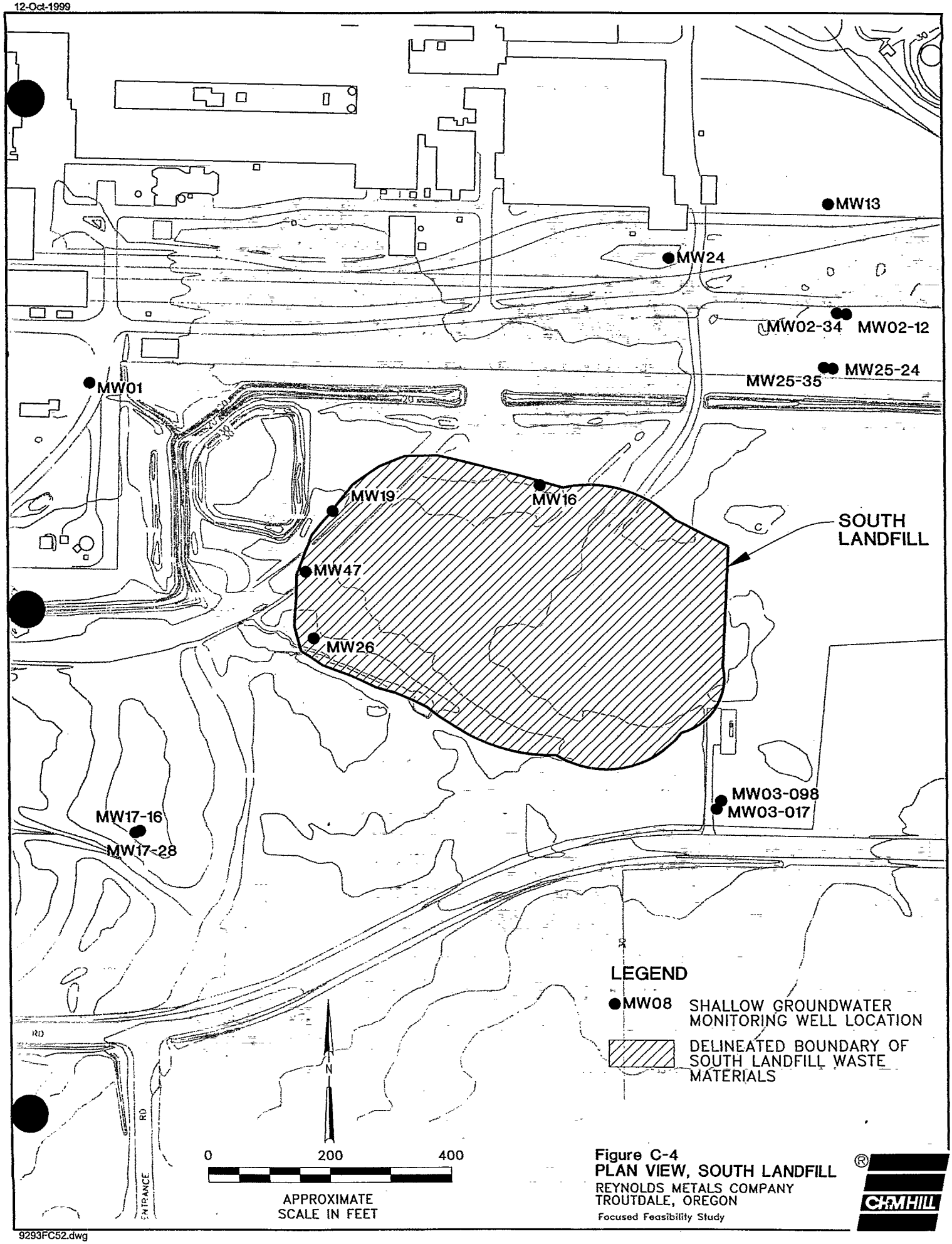

Figure C-4
PLAN VIEW, SOUTH LANDFILL
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2MHILL

9293FC52.dwg

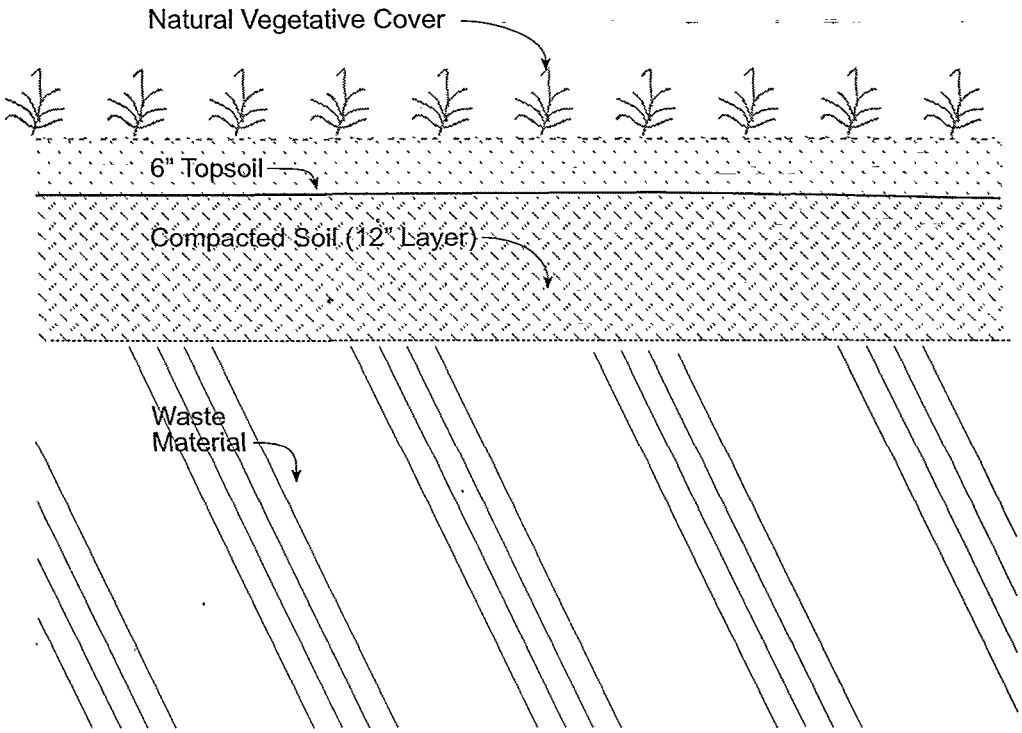

Figure C-5
South Landfill
Permeable Soil Cap

Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

CH2MHILL

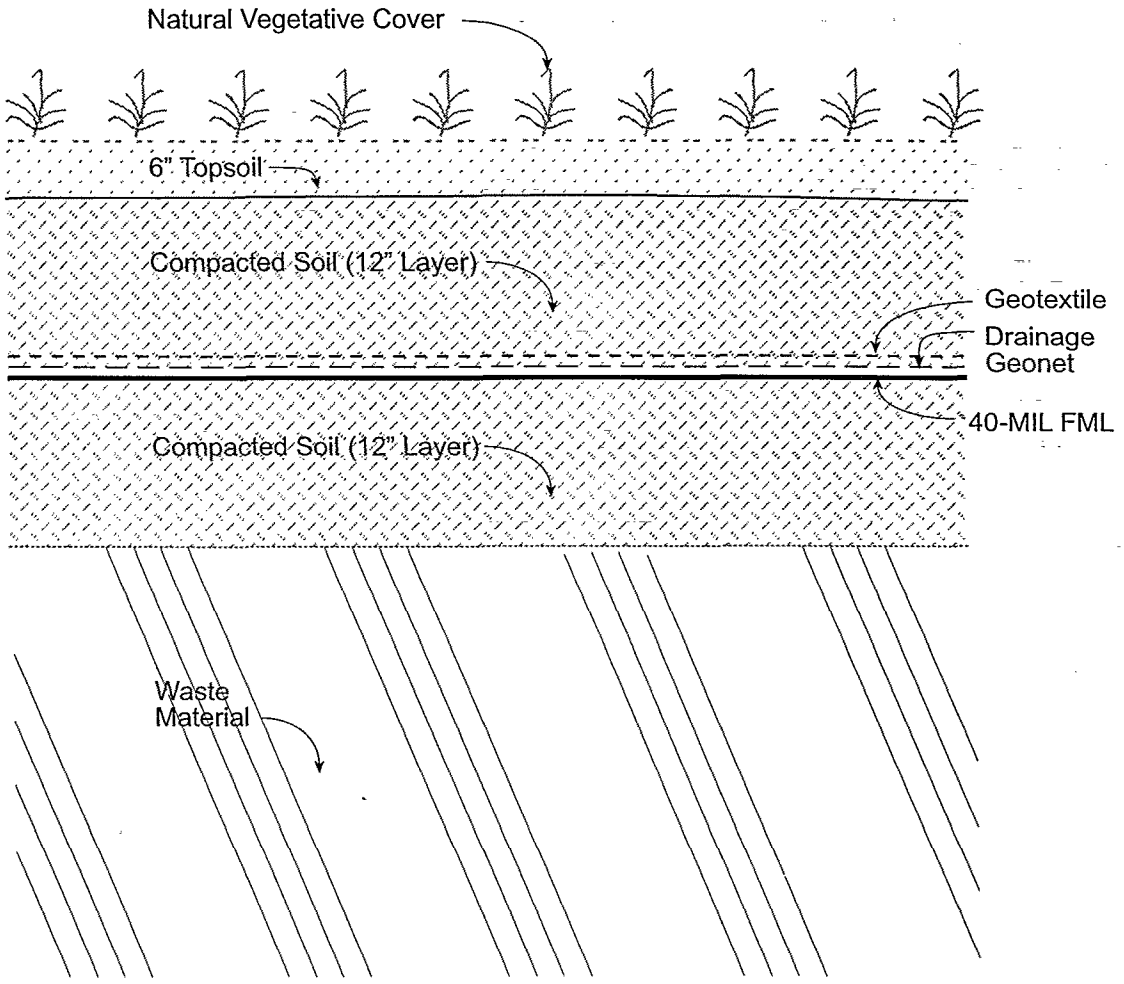

Figure C-6
South Landfill Multilayer Low-Permeability Cap
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

CH2MHILL

12-Oct-1999

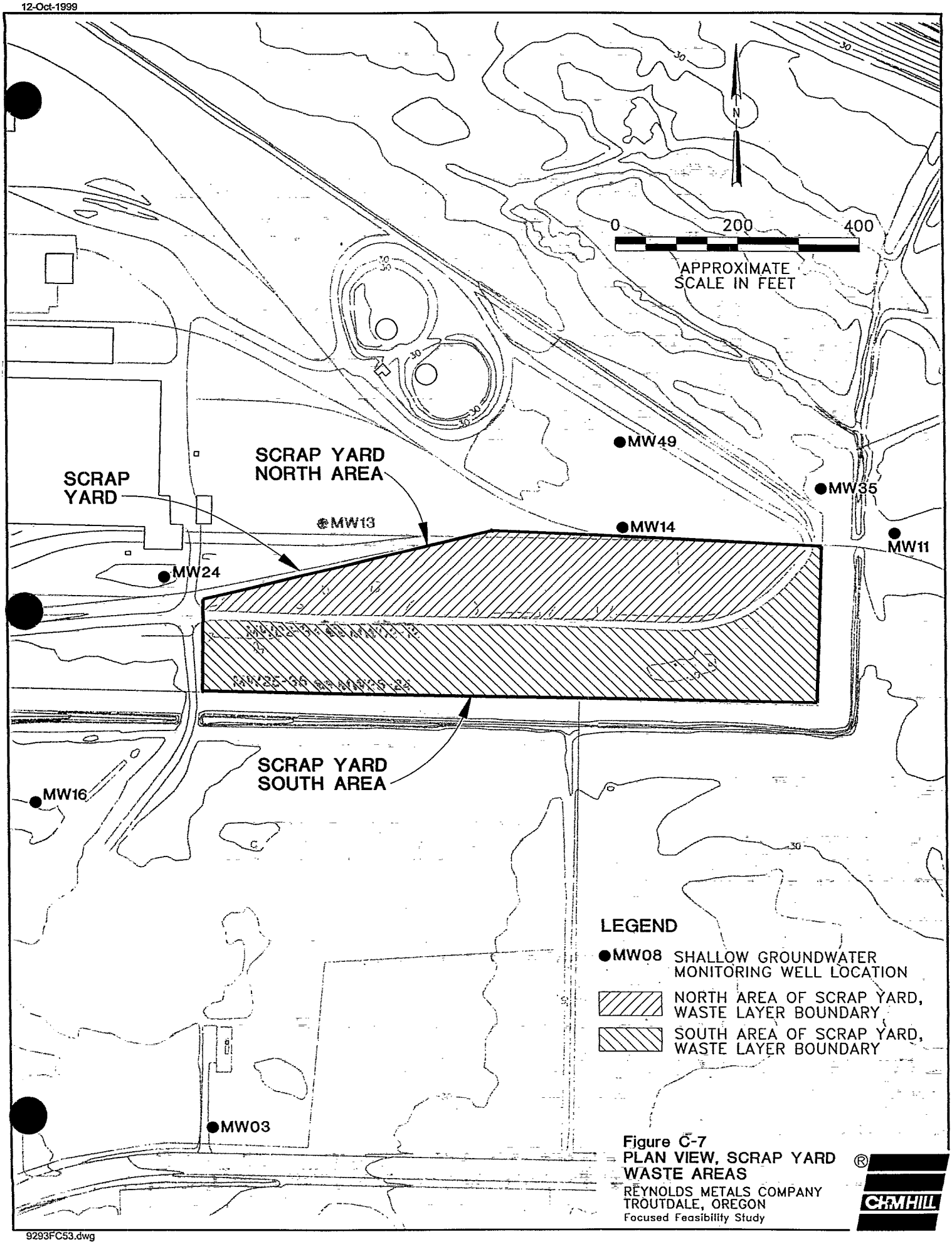

Figure C-7
PLAN VIEW, SCRAP YARD WASTE AREAS
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

9293FC53.dwg

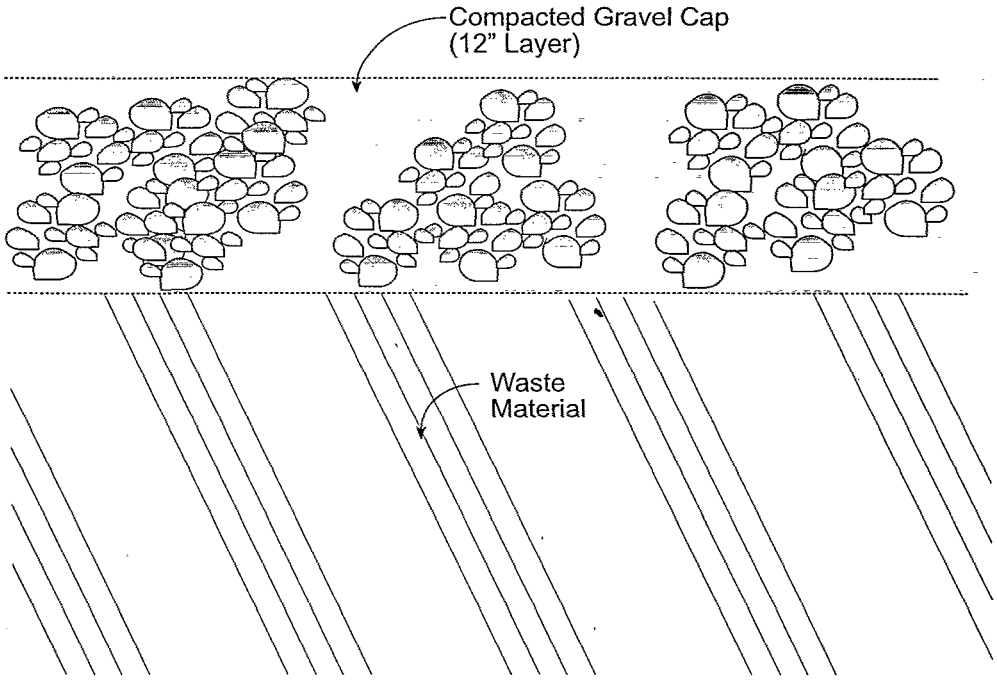

Figure C-8
Scrap Yard
Permeable Gravel Cap

Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

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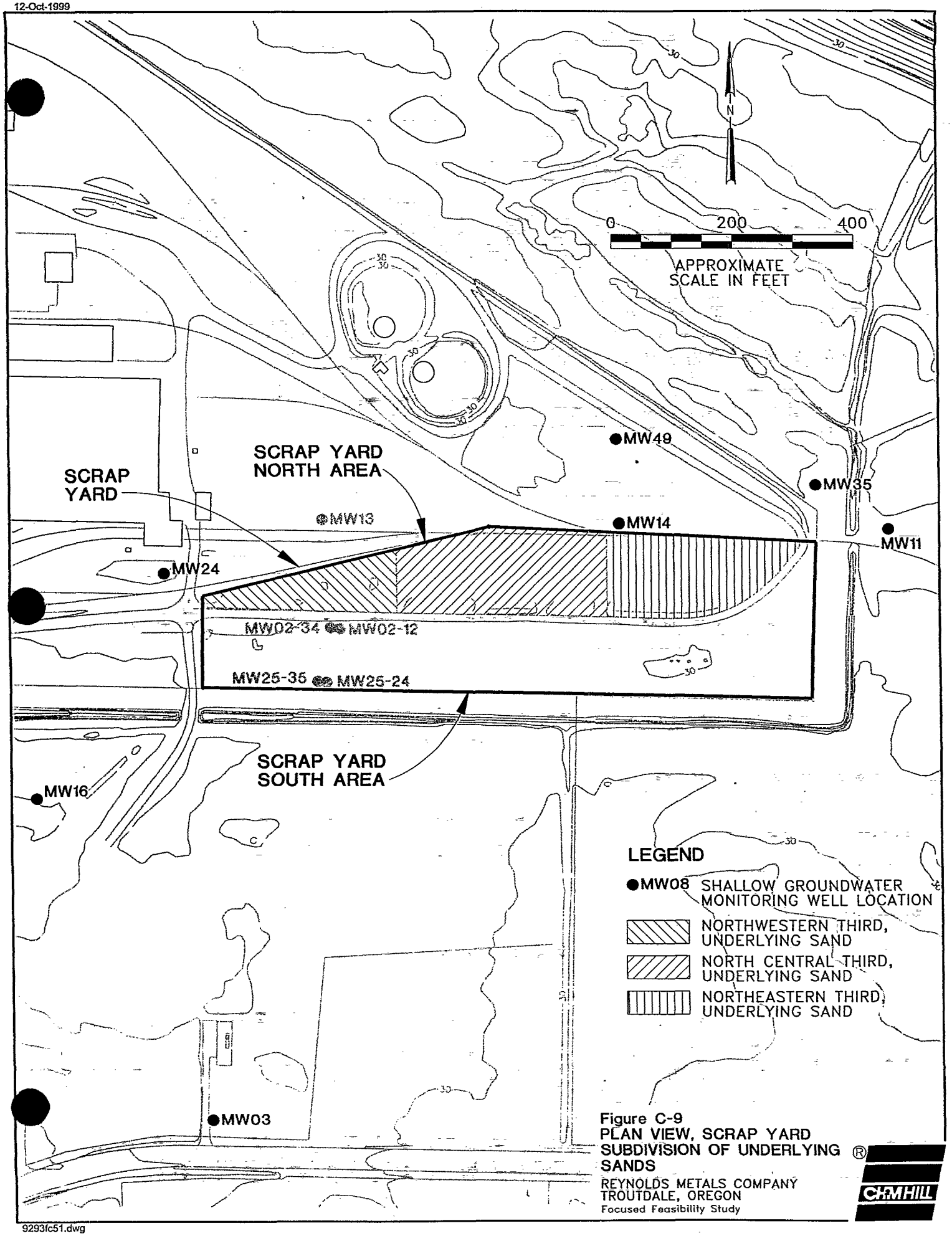

Figure C-9
PLAN VIEW, SCRAP YARD SUBDIVISION OF UNDERLYING SANDS
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

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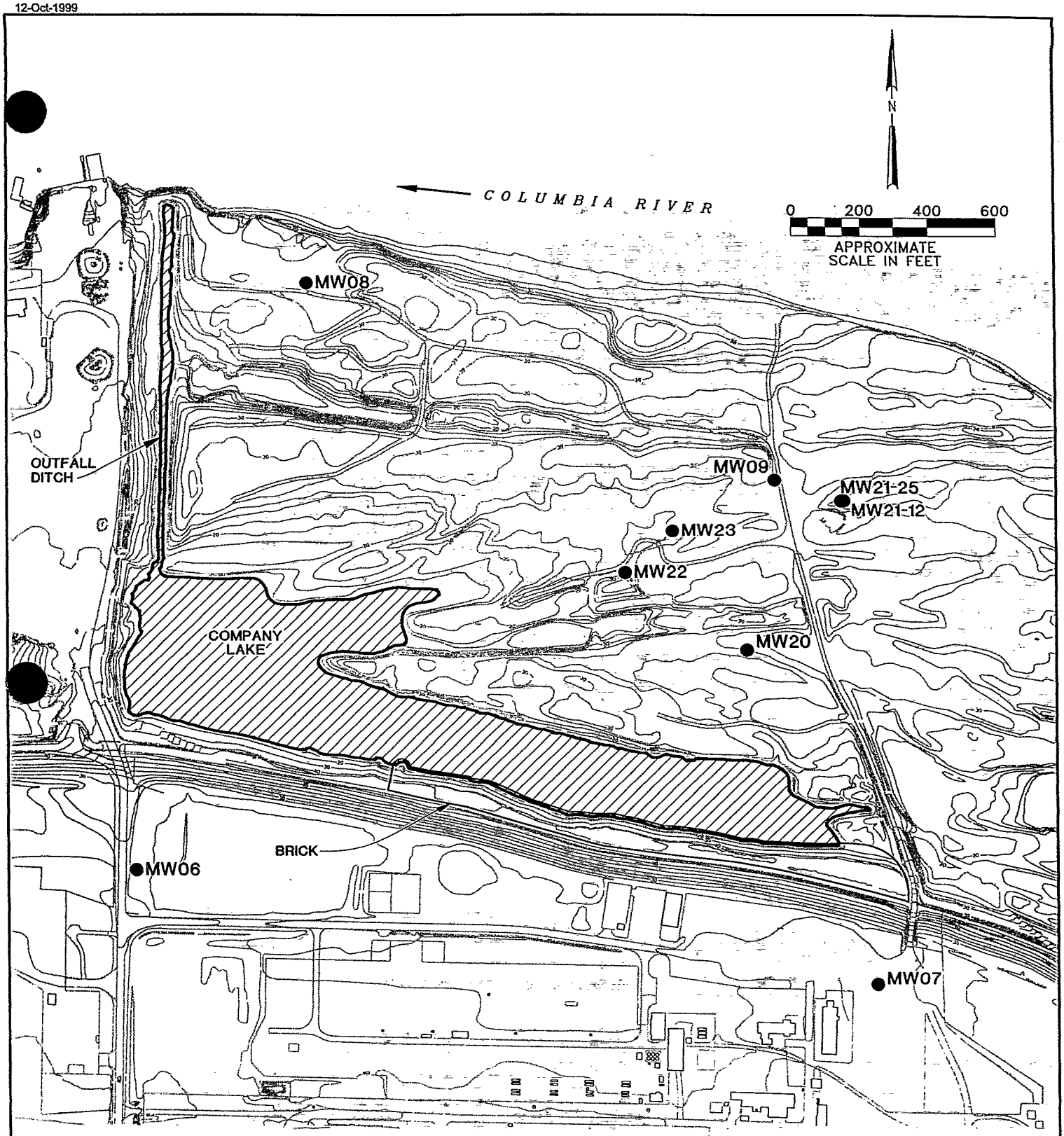

LEGEND

MW-8 SHALLOW GROUNDWATER MONITORING WELL LOCATION

COMPANY LAKE AND OUTFALL DITCH AREAS

Figure C-10
PLAN VIEW, COMPANY LAKE
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

9293fc54.dwg

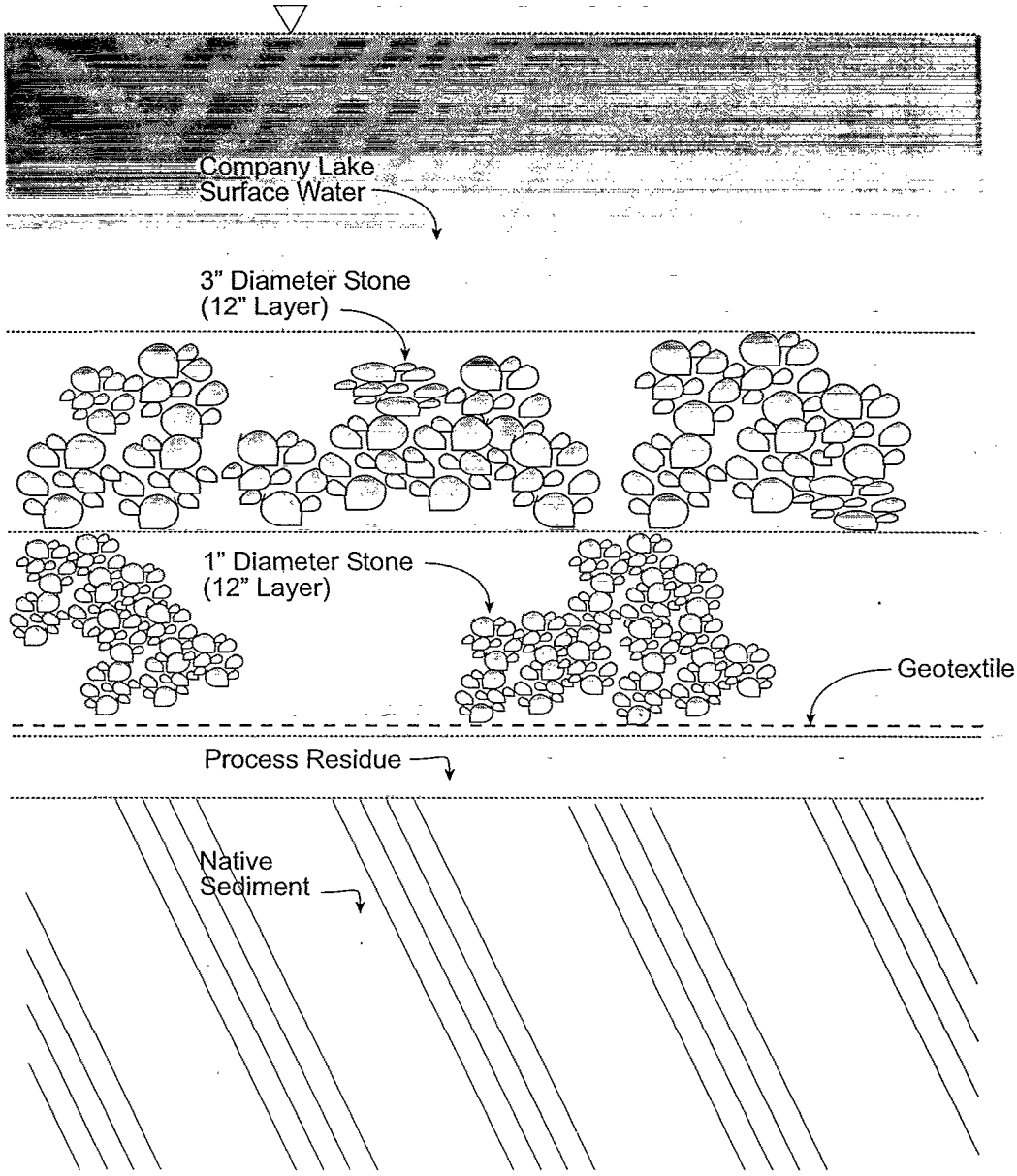

Figure C-11
Company Lake Permeable Cap
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

CH2MHILL

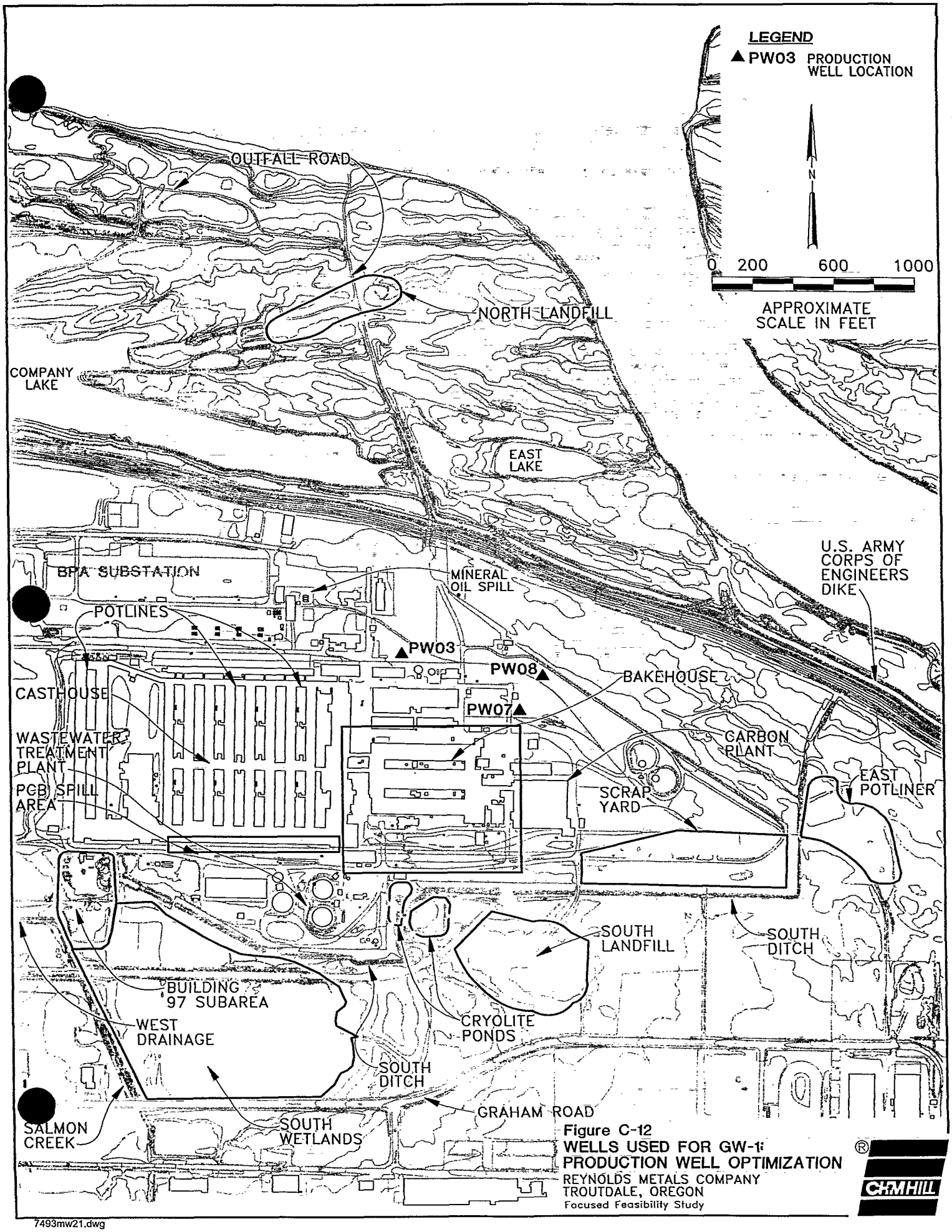

Figure C-12
WELLS USED FOR GW-1:
PRODUCTION WELL OPTIMIZATION
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

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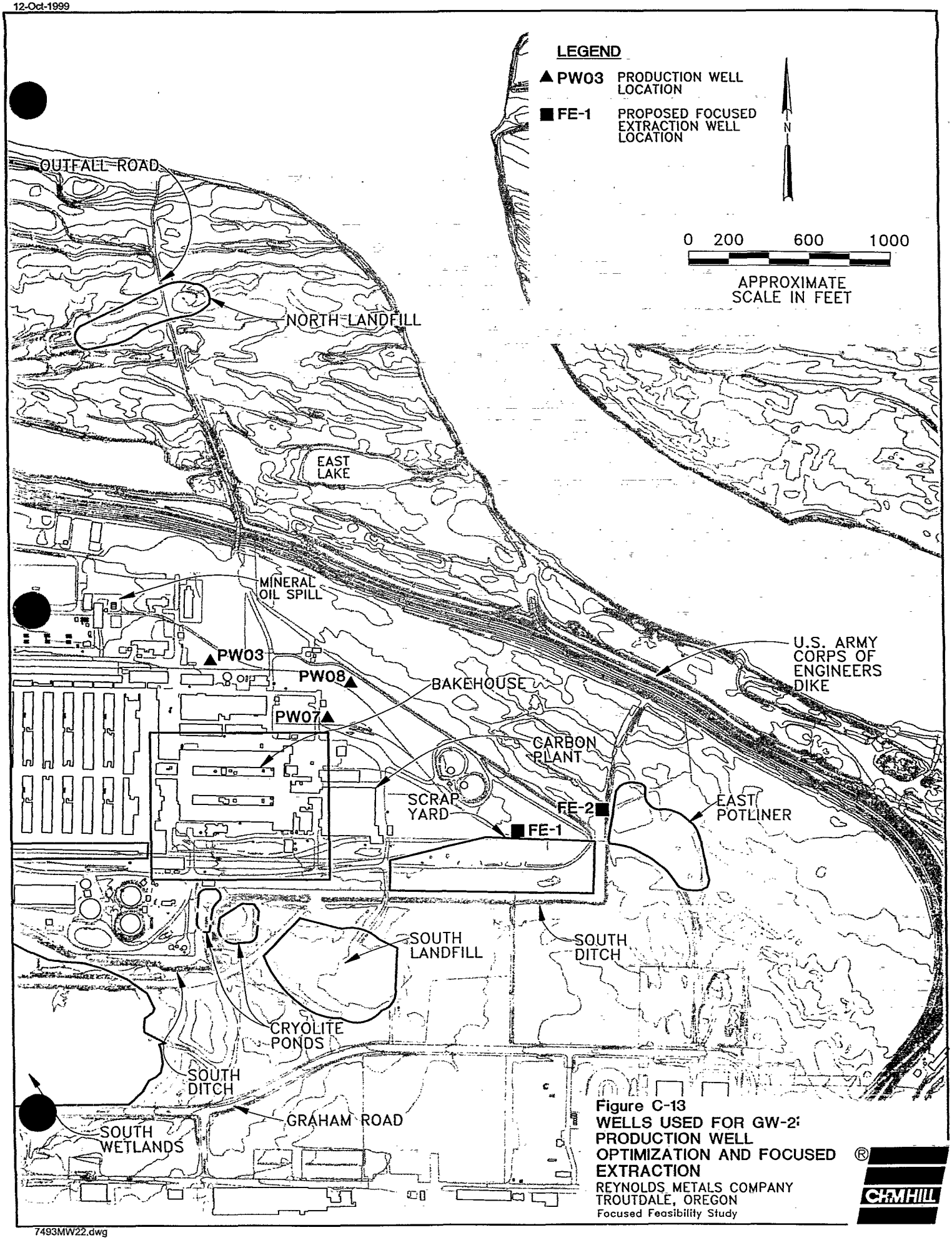
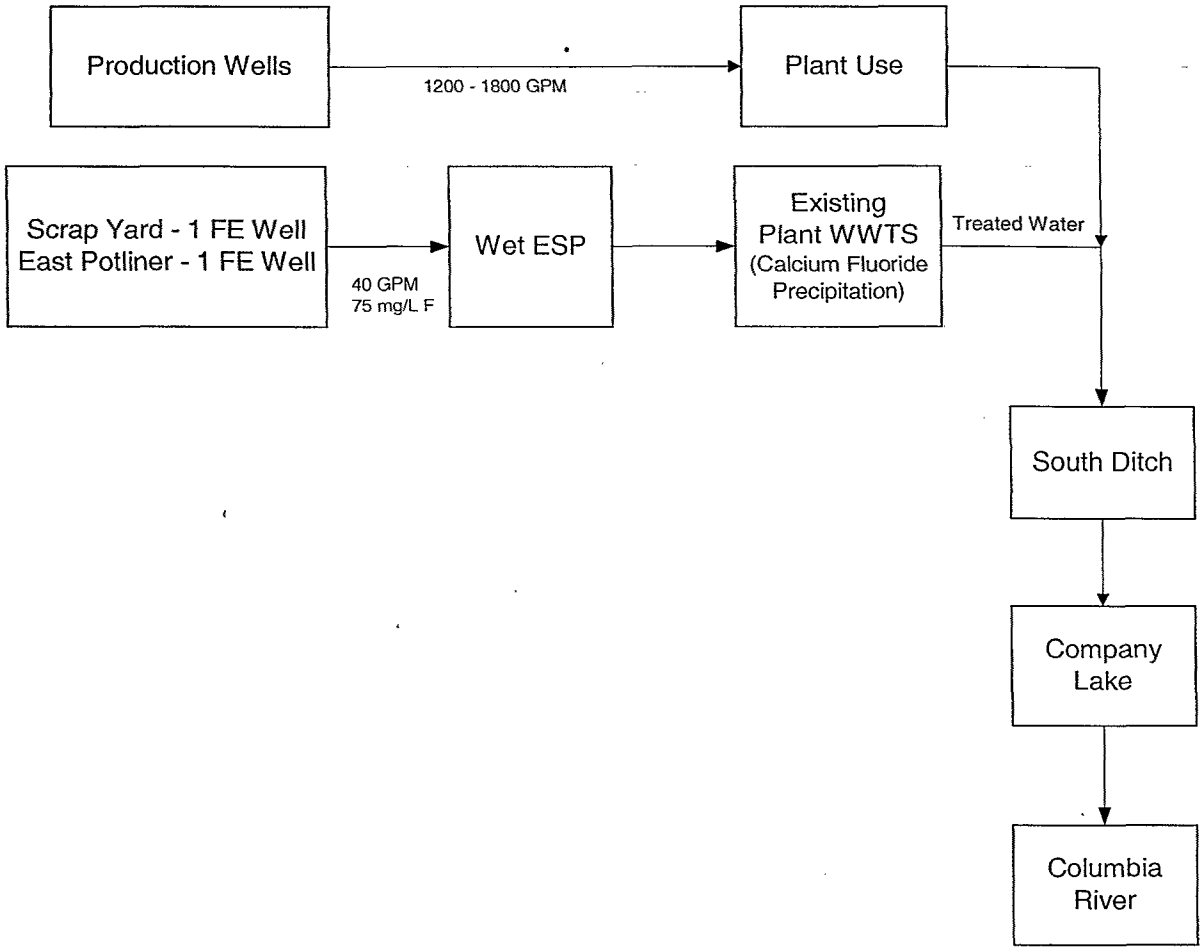


Figure C-13
WELLS USED FOR GW-2:
PRODUCTION WELL OPTIMIZATION AND FOCUSED EXTRACTION
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

7493MW22.dwg

Figure C-14 - Extracted Groundwater Treatment Flow Diagram for GW-2



Note: 1. Flows are estimated and concentrations are at startup. Not intended as a mass balance.
2. Flows may change after implementation and concentrations will decrease.
3. Calcium fluoride solids removal not shown.

12-Oct-1999

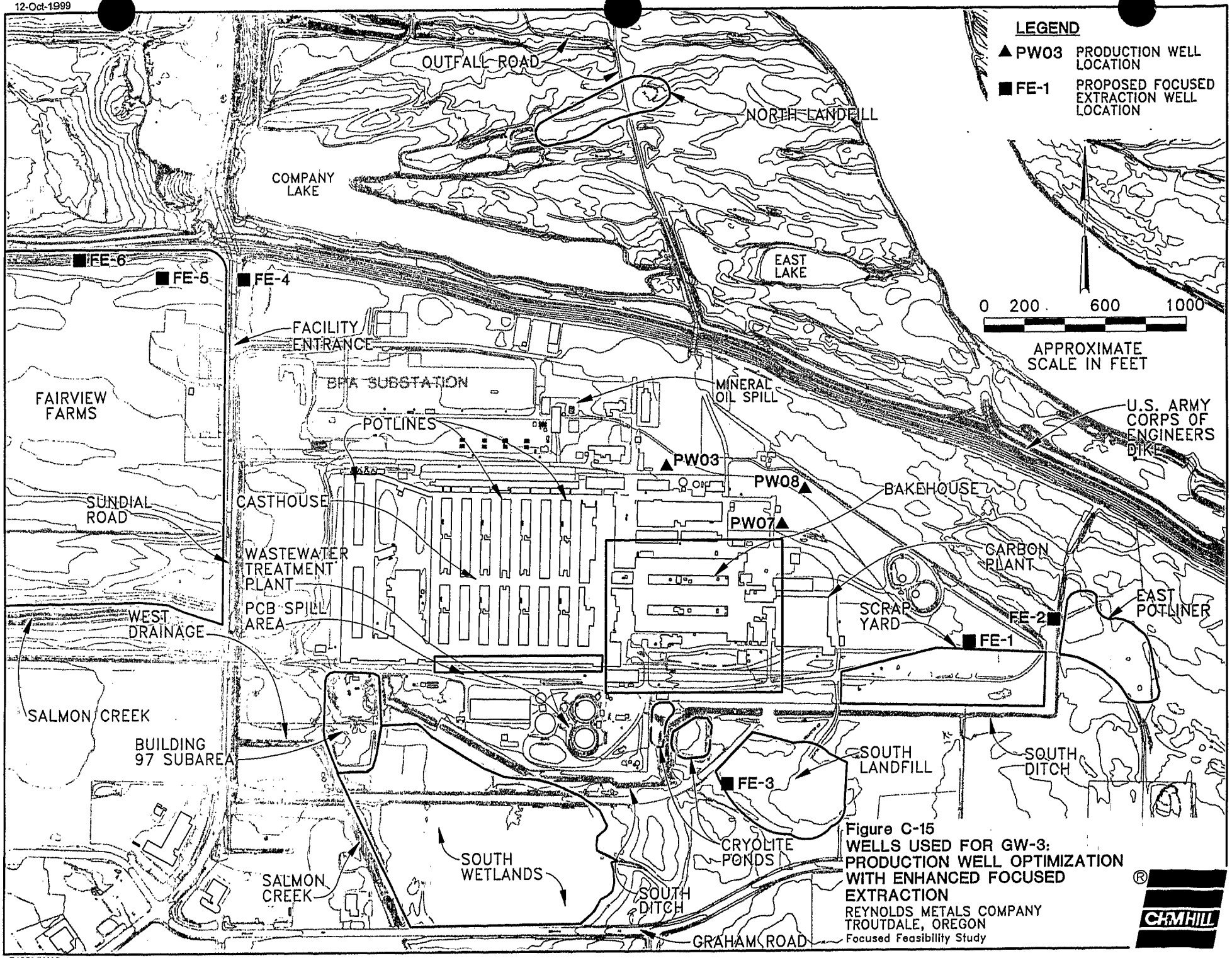
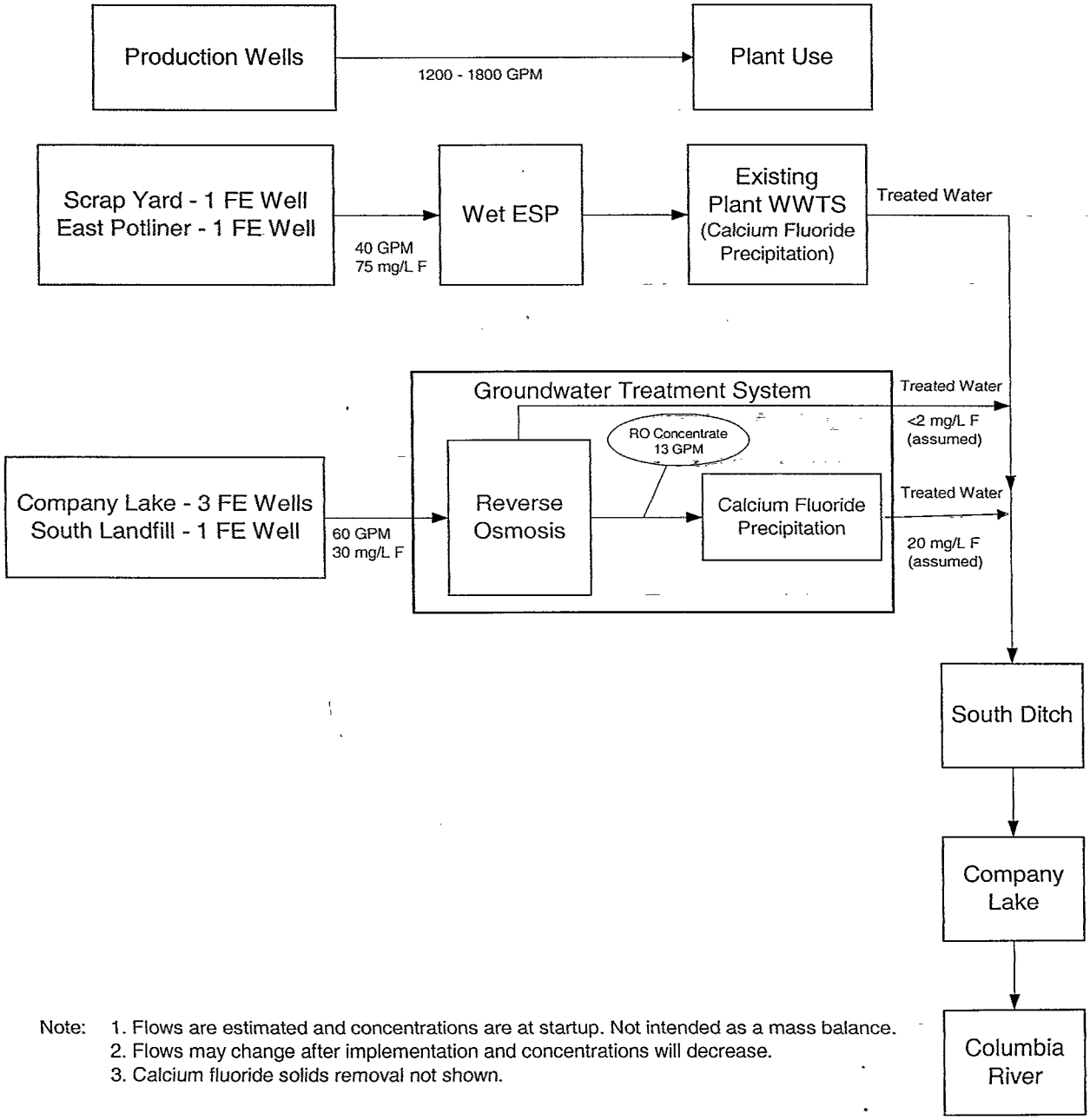


Figure C-15
WELLS USED FOR GW-3: PRODUCTION WELL OPTIMIZATION WITH ENHANCED FOCUSED EXTRACTION
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

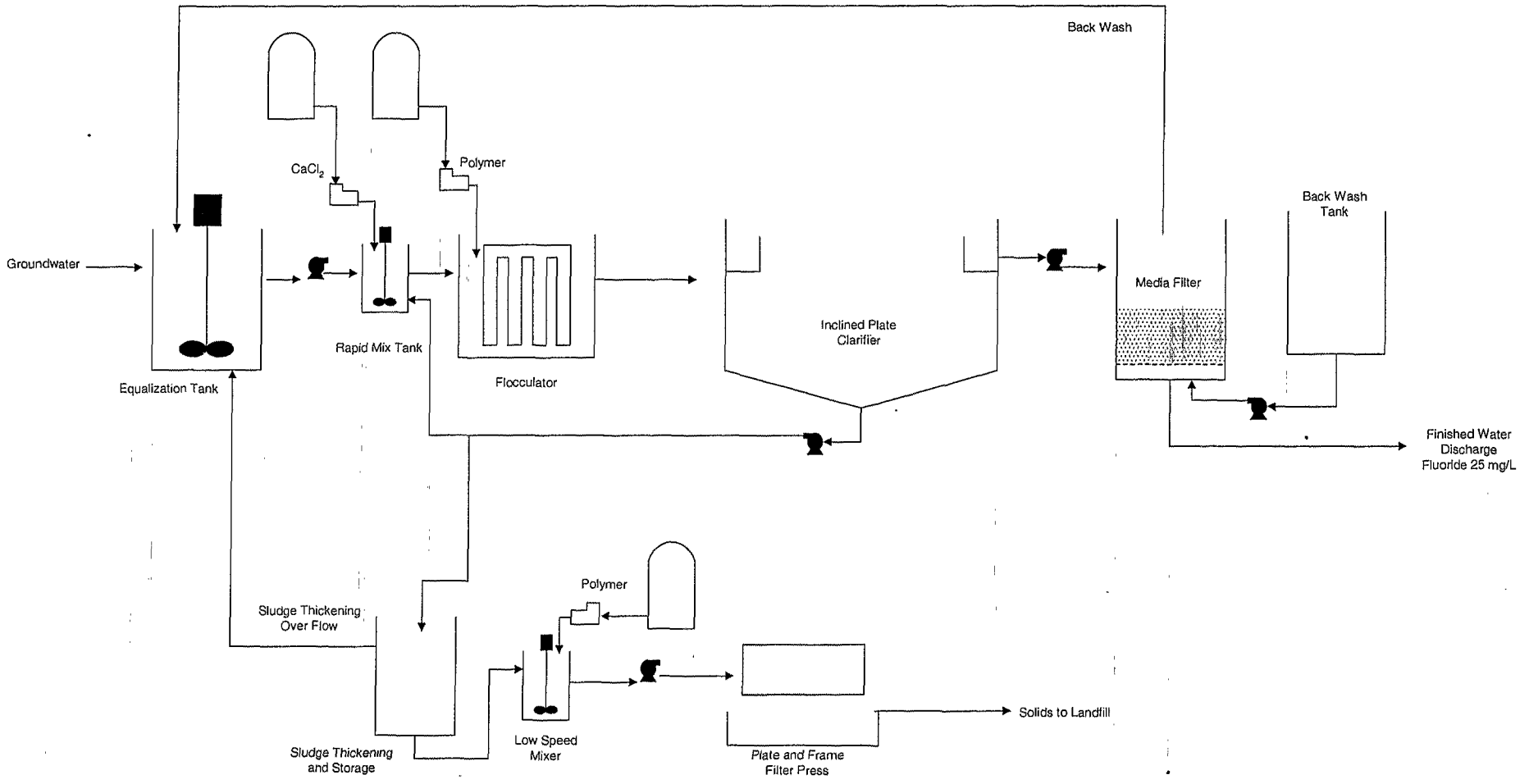
7493MW19.dwg

Figure C-16 - Extracted Groundwater Treatment Flow Diagram for GW-3



Note: 1. Flows are estimated and concentrations are at startup. Not intended as a mass balance.
2. Flows may change after implementation and concentrations will decrease.
3. Calcium fluoride solids removal not shown.

Figure C-17: Process Flow Diagram for Calcium Fluoride Precipitation



12-Oct-1999

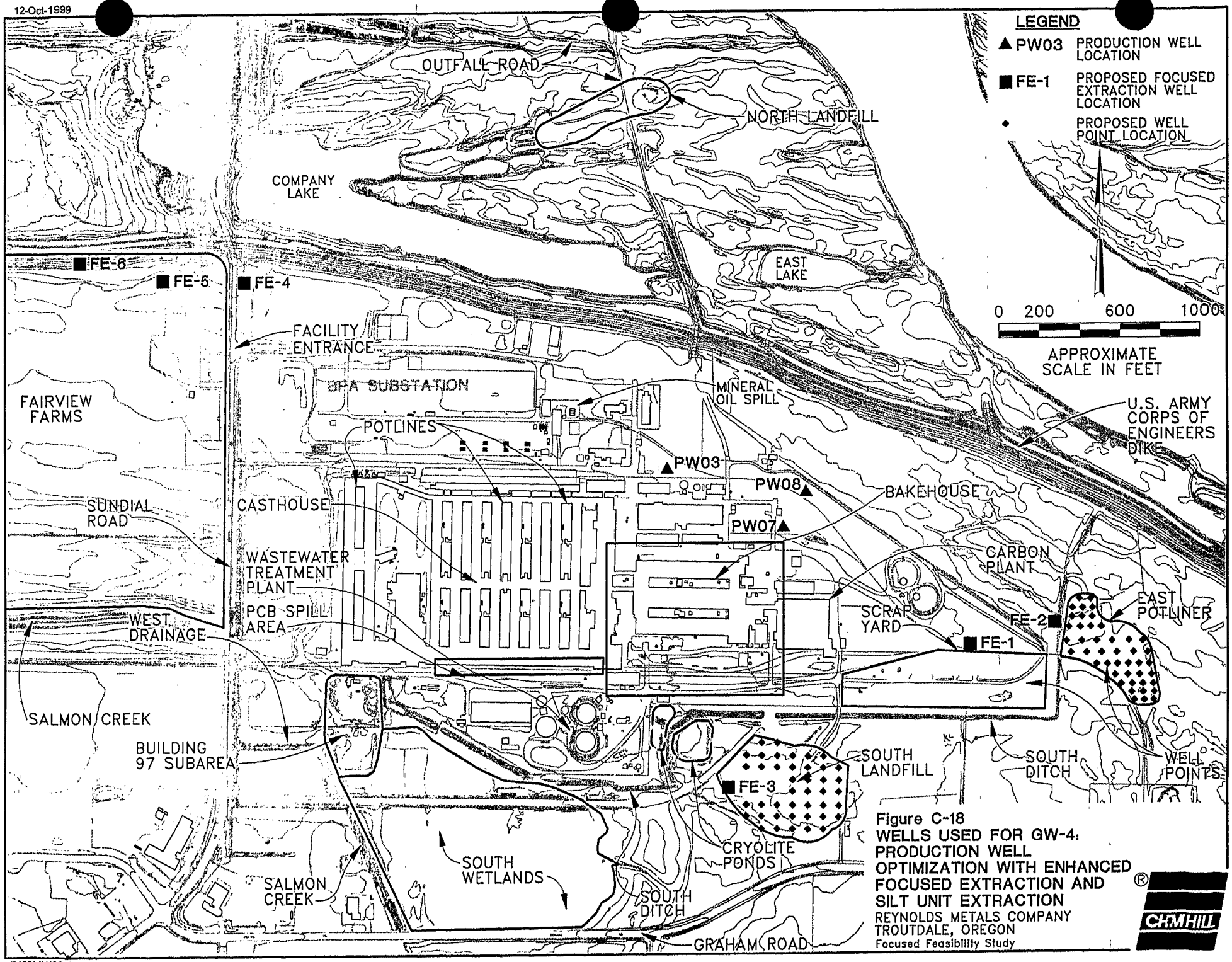
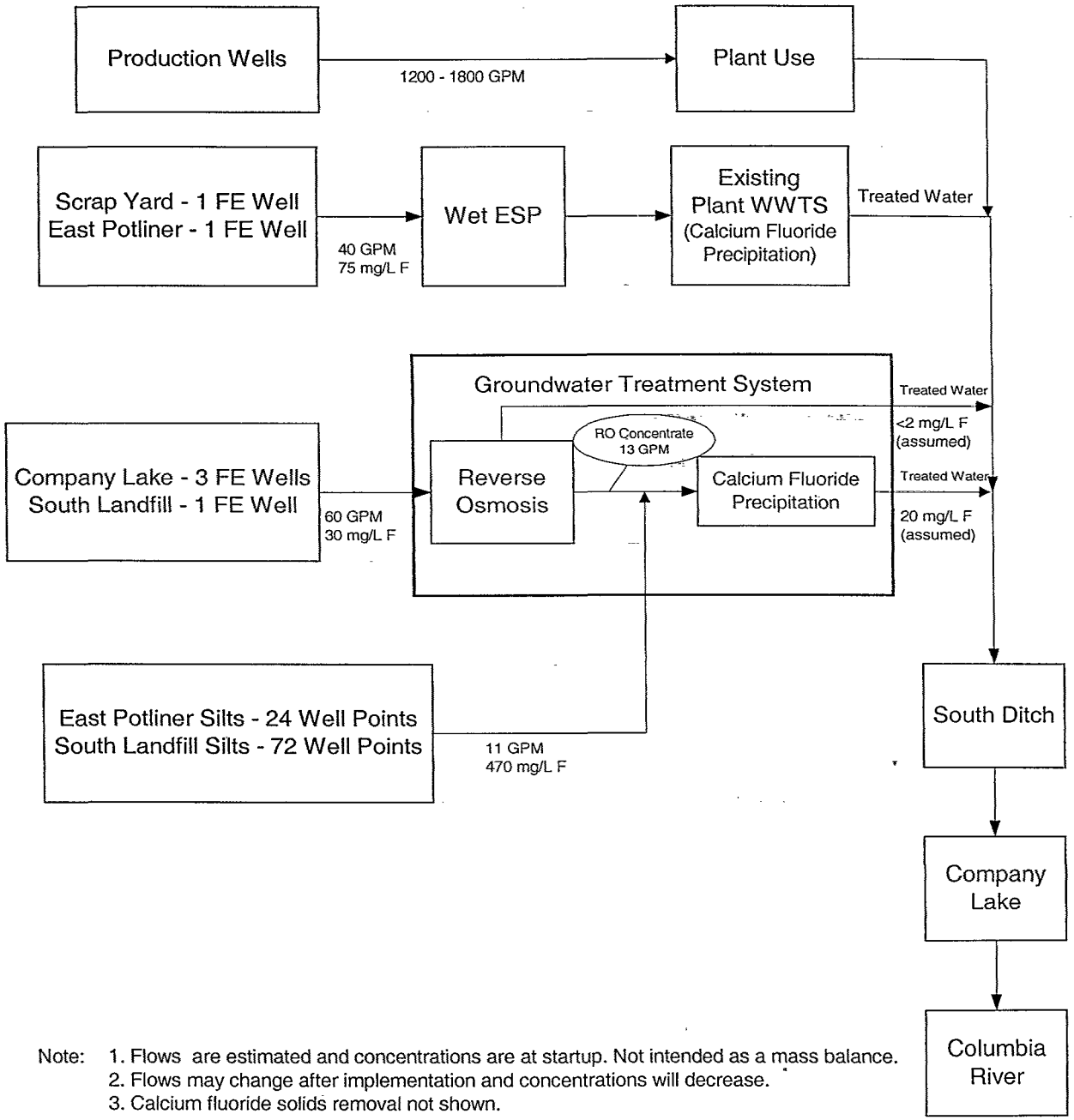


Figure C-18
WELLS USED FOR GW-4: PRODUCTION WELL OPTIMIZATION WITH ENHANCED FOCUSED EXTRACTION AND SILT UNIT EXTRACTION
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

7493MW20.dwg

Figure C-19 - Extracted Groundwater Treatment Flow Diagram for GW-4



Note: 1. Flows are estimated and concentrations are at startup. Not intended as a mass balance.
2. Flows may change after implementation and concentrations will decrease.
3. Calcium fluoride solids removal not shown.

APPENDIX D

Cost Estimates for Remedial Alternatives

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APPENDIX D

Cost Estimates for Remedial Alternatives

The cost estimates developed for this appendix were originally created for an early action decisionmaking process initiated in October 1998 and completed in February 1999. In some cases, these costs represent a higher level of detail than would normally be provided in a feasibility study. Nevertheless, cost estimates presented in this appendix should not be considered as absolute amounts but rather in terms of relative cost, providing a comparative evaluation of costs for each alternative. The design details provided for each alternative are assumptions made in order to generate costs, and not final decisions for any alternative that might be implemented.

The cost estimates for the remedial alternatives are considered to be order of magnitude with an intended accuracy of +50 percent and – 30 percent. The actual cost is expected to be no higher than 50 percent more than the estimate or 30 percent less than the estimate. Unit costs provided in this appendix are based on quotations from vendors, construction costs data, professional engineering judgment, and standard costing references. Final project costs will depend on actual labor and material costs, site conditions, competitive market conditions, final project scope, final project schedule, the firm(s) selected for engineering design and implementation, and other variable factors. Because of these factors, financial needs must be carefully reviewed before specific financial decisions are made or remedial action budgets are established.

The costs presented here are estimated, with 1998 as the base year.

Remedial alternative cost estimates are provided for Alternatives A, B, and C (as discussed in Section 6 of the Focused Feasibility Study). Cost summaries for remedial alternatives A, B, and C are provided in Tables D-1 through D-3. Tables D-4 through D-7 provide order-of-magnitude cost estimates for the options called out in each alternative. Costs for the onsite landfill are provided in Tables D-8 and D-9 and are discussed further in the next section.

A key difference between the cost estimates for individual *options* and the corresponding element in a sitewide *alternative* is the assumption made for each with regard to disposal of excavated material. As explained in Section C.1 in Appendix C of the FFS, offsite landfill disposal was assumed for individual options so that they could be evaluated and compared as independent actions. For sitewide alternatives, which combine options, this assumption is no longer required, and onsite landfill disposal replaces offsite disposal in Alternatives B and C. (Alternative A does not include excavation.) The same contingencies that were applied to offsite disposal costs, to account for uncertainty in the quantities to be excavated, are also applied to onsite disposal costs for the alternatives: north landfill, 50 percent; south landfill, 50 percent; scrap yard, 25 percent.

A related difference in the presentation of the two sets of cost estimates (that is, for options and for alternatives) is that for the individual options, the cost of disposal is included with each individual land unit option. For the sitewide alternatives, the cost of disposal is not included with the cost of the action for each land unit. The cost of an onsite landfill, for all

included with the cost of the action for each land unit. The cost of an onsite landfill, for all the affected land units, has been estimated separately and is presented in separate tables for Alternatives B and C, as explained in Section D.1, below.

The costs of some options consequently appear to be much less when they are presented as part of a sitewide alternative than when presented as an individual action. Some of this difference is real: the cost of offsite disposal is actually much higher than that of onsite disposal. However, the difference in the cost tables is primarily because the onsite disposal costs are presented in another table. [For instance, in Table C-5 (in Appendix C of the FFS), option NLF-4, presented as an individual action option, has a total cost of $9.5 million; in Table D-4, NLF-4, presented as part of a sitewide alternative, shows a total cost of $1.5 million.]

With these exceptions, the costs for the options are not changed when they are included in a sitewide alternative.

Groundwater costs for the alternatives remain the same as estimated for the options analysis. These costs were previously provided in Appendix C of the FFS.

The remedial alternative cost estimates are presented using two cost calculations: net present value (NPV) and as-spent dollars. The NPV measure includes initial capital expenditures (in 1998 dollars) and annual O&M costs over a 30-year period. Net present value is determined assuming constant future dollars and a 7 percent discount rate. The calculation of as-spent dollars is discussed in Section D.2, below.

D.1 Onsite Landfill Cost Estimate

An onsite landfill is assumed to be used in Alternatives B and C for disposal of excavated solid waste. The onsite landfill was not considered for Alternative A since minimal waste disposal is required for this alternative. The capacity of the onsite landfill is assumed to be 52,000 cubic yards for Alternative B and 170,000 cubic yards for Alternative C. The proposed location of the onsite landfill is to the east of the east potliner area, as shown in Figure D-1.

Conceptual design criteria were used for the purposes of this order-of-magnitude cost estimate. The design criteria for the onsite landfill are as follows:

- Site access: gravel road around the perimeter
- Institutional controls: perimeter fencing
- Site drainage: perimeter drainage ditches with outlet to South Ditch
- Elevation: above grade because of seasonal high groundwater tables
- Cell configuration: rectangular
- Side slopes: 4 horizontal to 1 vertical
- Cover slope: 5 percent
- Maximum fill height: 30 feet (not including cap and cover slope)

- Bottom liner type: multi-layer geomembrane with drainage and leachate collection (see Figure D-2 for conceptual liner cross section)
- Cap type: multilayer geomembrane (see Figure D-3 for conceptual cross section of the cap)

Table D-8 provides line item cost estimating assumptions and unit costs used for the onsite landfill estimate. Table D-9 provides the estimated capital, annual O&M, and NPV costs for the Alternative B and C landfills.

D.2 As-Spent Dollar Cost Estimates

The actual cash flow that RMC expects to spend on remedy implementation is estimated in as-spent dollars. In effect, this measure provides a roll-up of non-discounted costs as they are spent over a 30-year period. As-spent dollars are calculated assuming a 4 percent inflation rate for operational costs and a 6 percent inflation rate for capital costs. The as-spent dollar analysis also assumes that all remedies are constructed in the year 2000. Tables D-10 through D-12 provide the as-spent dollars analyses for Alternatives A, B, and C.

Appendix D Tables

Table D-1
Cost Summary for Remedial Alternative A

Option #	Total Capital	Annual O+M	NPV (7% for 30 years)	As-spent Dollars
NLF-2	$449,448	$19,979	$697,368	
SLF-2	$723,925	$24,307	$1,025,557	
SY-2	$375,775	$17,820	$596,909	
CL-2	$4,528,784	$16,563	$4,734,320	
GW-1[1]	$0	$128,000	$1,056,591	
OSLF[2]	NA	NA	NA	
Total	$6,077,931	$206,670	**$8,110,746**	$17,741,375

NA = not applicable

1. Costs are in 1998 dollars. Annual performance monitoring costs for groundwater options are $128,000 annually for the first 5 years of operation and are assumed to drop by 50 percent for the remainder of the 30-year life.

2. An onsite landfill (OSLF) does not apply to this option because no material will be excavated

Table D-2
Cost Summary for Remedial Alternative B

Option #	Total Capital	Annual O+M	NPV (7% for 30 years)	As-spent Dollars
NLF-2	$449,448	$19,979	$697,368	
SLF-1	$80,750	$1,995	$105,506	
SY-3	$500,320	$6,703	$583,500	
CL-3	$7,070,059	$18,130	$7,117,637	
GW-2[1]	$375,000	$150,934	$1,763,197	
OSLF-B	$1,987,172	$30,838	$2,369,841	
Total	$10,462,748	$228,579	**$12,637,049**	$21,681,948

NA = not applicable

1. Costs are in 1998 dollars. Annual performance monitoring costs for groundwater options are $128,000 annually for the first 5 years of operation and are assumed to drop by 50 percent for the remainder of the 30 year life.

Table D-3
Cost Summary for Remedial Alternative C

Option #	Total Capital	Annual O+M	NPV (7% for 30 years)	As-spent Dollars
NLF-4	$1,508,320	$5,054	$1,571,035	
SLF-4	$2,028,280	$4,306	$2,081,712	
SY-3	$500,320	$6,703	$583,500	
CL-3	$7,070,059	$18,130	$7,117,637	
GW-3[1]	$3,316,000	$297,140	$6,818,210	
OSLF-C	$4,772,553	$84,881	$5,825,841	
Total	$19,195,532	$416,213	**$23,997,935**	$43,665,924

NA = not applicable

1. Costs are in 1998 dollars. Annual performance monitoring costs for groundwater options are $128,000 annually for the first 5 years of operation and are assumed to drop by 50 percent for the remainder of the 30 year life.

Table D-4

Order-of-Magnitude Remedial Alternative Costs for North Landfill [a]

OPTION NLF-1: Institutional Controls (Deed, Use, and Access Restrictions)

OPTION NLF-2: Construct a permeable riprap cover over waste layer. (geotextile, 12" thick rip-rap)

OPTION NLF-3: Construct low permeability cap (12-inches compacted soil, 40 mil FML, geonet, geotextile, and 12-inches soil, geotextile, and riprap)

OPTION NLF-4: Excavate waste material, backfill with clean soil, natural re-vegetation

OPTION NLF-5: Excavate waste material, 2 feet of underlying sands, backfill with clean soil, natural re-vegetation

	Item	Unit	Unit Cost	NLF-2 Quantities	NLF-4 Quantities	NLF-2 Cost	NLF-4 Cost
1 Institutional Controls							
1.1	Deed or Use Restriction Legal Fees	EA	$25,000	1	1	$25,000	$25,000
1.2	Fencing	LF	$15.00			$0	$0
2 Site Preparation							
2.1	Clearing, Grubbing, and Stripping	AC	$4,200	2.40	2.40	$10,080	$10,080
2.2	Surface Preparation	AC	$800	2.40	2.40	$1,920	$1,920
2.3	Road Construction-Gravel	LF	$35.00	1,600	1,600	$56,000	$56,000
3 Source Area Containment Systems							
3.1	Geomembrane	SF	$0.43			$0	$0
3.2	Geotextile	SF	$0.19	105,000		$19,950	$0
3.3	Geonet	SF	$0.55			$0	$0
3.4	Clean Soil	CY	$20.00			$0	$0
3.5	Seeding	AC	$2,000			$0	$0
3.6	Soil Cap	AC	$48,000			$0	$0
3.7	Gravel Cap	AC	$40,000			$0	$0
3.8	Riprap Cover	AC	$48,000	2.40		$115,200	$0
3.9	Ditches	LF	$20.00	1,000	500	$20,000	$10,000
4 Excavation, Transportation, and Disposal							
4.1	Excavate Solid Waste	CY	$15.00		33,000	$0	$495,000
4.2	Contingency for excavation volume changes	CY	$15.00		16,500	$0	$247,500
4.3	Additional Waste Characterization Costs	LS	$25,000			$0	$0
4.4	De-water Excavation	LS	$40,000			$0	$0
4.5	Clean Backfill	CY	$15.00		1,900	$0	$28,500
4.6	On-site Short Haul	CY	$1.50			$0	$0
5 Capital Costs							
5.1	Contractor Markup (mob/demob, bond/ins., profit, overhead)	%	22%			$49,093	$186,780
5.2	Engineering/Design	%	7%			$15,621	$59,430
5.3	Waste Removal Documentation	%	3%			$0	$26,220
5.4	Construction Management	%	5%			$11,158	$42,450
5.5	Change Management	%	2%			$4,463	$16,980
5.6	Project Administration	%	2%			$4,463	$16,980
5.7	Notice of Substantial Completion Report (CERCLA)	%	2%			$4,463	$16,980
5.8	Permitting	EA	$50,000	1	1	$50,000	$50,000
5.9	Contingency, Legal Fees, Taxes, etc.	%	25%			$82,038	$218,500
6. Operations and Maintenance Costs							
	Institutional Controls						
6.1	Fencing and Signs	%	5%			$0	$0
	Source Area Containment Systems						
6.2	Road Maintenance-Gravel	%	5%			$2,800	$2,800
6.3	Low Permeability Cap Maintenance	%	3%			$0	$0
6.4	Soil Cap Maintenance	%	2%			$0	$0
6.5	Gravel Cap Maintenance	%	2%			$0	$0
6.6	Riprap Maintenance	%	2%			$2,703	$0
6.7	Ditch Maintenance	%	10%			$2,000	$1,000
6.8	Annual Monitoring and Reporting	EA	$10,000	1		$10,000	$0
	Miscellaneous						
6.9	Engineering/Administration	%	8%			$800	$304
6.10	Contingency, Legal Fees, Taxes, etc.	%	25%			$1,876	$950
					Total Capital Cost	$449,448	$1,508,320
					Annual O&M Cost	$19,979	$5,054
					Present Value of O&M Costs (30 Year)	$247,920	$62,715
					Total Net Present Value Cost	$697,368	$1,571,035

Note: The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

[a] See text for an explanation of the difference between the costs of the options presented here as part of a sitewide alternative and the costs for the same options presented as individual actions.

TABLE D-5

Order-of-Magnitude Remedial Alternative Costs for South Landfill*

OPTION SLF-1: Institutional Controls (Deed,Use, and Access Restrictions)

OPTION SLF-2: Construct a permeable vegetated soil cap (18" thick clean soil) over waste layer

OPTION SLF-3: Construct low permeability cap (12-inches compacted soil, 40 mil FML, geonet, geotextile, and 18-inches soil, 6-inches topsoil, and vegetation)

OPTION SLF-4: Excavate waste layer, backfill with clean soil, natural re-vegetation

OPTION SLF-5: Excavate waste layer, 2 feet of the surficial sand unit, backfill with clean soil, natural re-vegetation

Item		Unit	Unit Cost	SLF-1 Quantities	SLF-2 Quantities	SLF-4 Quantities	SLF-1 Cost	SLF-2 Cost	SLF-4 Cost
1 Institutional Controls									
1.1	Deed or Use Restriction Legal Fees	EA	$25,000	1	1	1	$25,000	$25,000	$25,000
1.2	Fencing	LF	$15.00	2,000	0	0	$30,000	$0	$0
2 Site Preparation									
2.1	Clearing, Grubbing, and Stripping	AC	$4,200		5.75	5.75	$0	$24,150	$24,150
2.2	Surface Preparation	AC	$800		5.75	5.75	$0	$4,600	$4,600
2.3	Road Construction-Gravel	LF	$35.00		1,850	1,850	$0	$64,750	$64,750
3 Source Area Containment Systems									
3.1	Geomembrane	SF	$0.43				$0	$0	$0
3.2	Geotextile	SF	$0.19				$0	$0	$0
3.3	Geonet	SF	$0.55				$0	$0	$0
3.4	Clean Soil	CY	$20.00				$0	$0	$0
3.5	Seeding	AC	$2,000				$0	$0	$0
3.6	Soil Cap	AC	$48,000		5.75		$0	$276,000	$0
3.7	Gravel Cap	AC	$40,000				$0	$0	$0
3.8	Riprap Cover	AC	$48,000				$0	$0	$0
3.9	Ditches	LF	$20.00		1,000	0	$0	$20,000	$0
4 Excavation, Transportation, and Disposal									
4.1	Excavate Solid Waste	CY	$15.00			44,400	$0	$0	$666,000
4.2	Contingency for excavation volume changes	CY	$15.00			22,200	$0	$0	$333,000
4.3	Additional Waste Characterization Costs	LS	$25,000				$0	$0	$0
4.4	De-water Excavation	LS	$40,000				$0	$0	$0
4.5	Clean Backfill	CY	$15.00			4,400	$0	$0	$66,000
4.6	On-site Short Haul	CY	$1.50				$0	$0	$0
4.7	Contingency for on-site short haul volume changes	CY	$1.50				$0	$0	$0
5 Capital Costs									
5.1	Contractor Markup (mob/demob bond/ins., profit, overhead)	%	22%				$6,600	$85,690	$254,870
5.2	Engineering/Design	%	7%				$2,100	$27,265	$81,095
5.3	Waste Removal Documentation	%	3%				$0	$0	$35,505
5.4	Construction Management	%	5%				$1,500	$19,475	$57,925
5.5	Change Management	%	2%				$600	$7,790	$23,170
5.6	Project Administration	%	2%				$600	$7,790	$23,170
5.7	Notice of Substantial Completion Report (CERCLA)	%	2%				$600	$7,790	$23,170
5.8	Permitting	EA	$50,000		1	1	$0	$50,000	$50,000
5.9	Contingency, Legal Fees, Taxes, etc.	%	25%				$13,750	$103,625	$295,675
6. Operations and Maintenance Costs									
	Institutional Controls								
6.1	Fencing and Signs	%	5%				$1,500	$0	$0
	Source Area Containment Systems								
6.2	Road Maintenance-Gravel	%	5%				$0	$3,238	$3,238
6.3	Low Permeability Cap Maintenance	%	3%				$0	$0	$0
6.4	Soil Cap Maintenance	%	2%				$0	$5,520	$0
6.5	Gravel Cap Maintenance	%	2%				$0	$0	$0
6.6	Riprap Maintenance	%	2%				$0	$0	$0
6.7	Ditch Maintenance	%	10%				$0	$2,000	$0
6.8	Annual Monitoring and Reporting	EA	$10,000		1		$0	$10,000	$0
	Miscellaneous								
6.9	Engineering/Administration	%	8%				$120	$861	$259
6.10	Contingency, Legal Fees, Taxes, etc	%	25%				$375	$2,689	$809
						Total Capital Cost	$80,750	$723,925	$2,026,280
						Annual O&M Cost	$1,995	$24,307	$4,306
						Present Value of O&M Costs (30 Year)	$24,756	$301,632	$53,432
						Total Net Present Value Cost	$105,506	$1,025,557	$2,081,712

Note: The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

* See text for an explanation of the difference between the costs of the options presented here as part of a sitewide alternative and the costs for the same options presented as individual actions.

TABLE D-6
Order-of-Magnitude Remedial Alternative Costs for Scrap Yard[a]

OPTION SY-1: Institutional Controls (Deed, Use, and Access Restrictions)

OPTION SY-2: Construct a 12" thick permeable gravel cap over waste layer

OPTION SY-3: Excavate north scrap yard area waste layer. No further action for south scrap yard area.

OPTION SY-4: Excavate north scrap yard area waste layer, excavate middle and eastern third of the surficial sand unit, backfill with clean soil to same grade as Option SY-3. Note: It is assumed that the scrap yard is currently 2 ft. above original grade.

Item		Unit	Unit Cost	SY-2 Quantities	SY-3 Quantities	SY-2 Cost	SY-3 Cost
1 Institutional Controls							
1.1	Deed or Use Restriction Legal Fees	EA	$25,000	1	1	$25,000	$25,000
1.2	Fencing	LF	$15.00	0	0	$0	$0
2 Site Preparation							
2.1	Clearing, Grubbing, and Stripping	AC	$4,200	2.10	2.10	$8,820	$8,820
2.2	Surface Preparation	AC	$800	2.10	2.10	$1,680	$1,680
2.3	Road Construction-Gravel	LF	$35.00	2,400	2,400	$84,000	$84,000
3 Source Area Containment Systems							
3.1	Geomembrane	SF	$0.43			$0	$0
3.2	Geotextile	SF	$0.19			$0	$0
3.3	Geonet	SF	$0.55			$0	$0
3.4	Clean Soil	CY	$20.00			$0	$0
3.5	Seeding	AC	$2,000.00			$0	$0
3.6	Soil Cap	AC	$48,000			$0	$0
3.7	Gravel Cap	AC	$40,000	2.10	2.10	$84,000	$42,000
3.8	Riprap Cover	AC	$48,000			$0	$0
3.9	Ditches	LF	$20.00			$0	$0
4 Excavation, Transportation, and Disposal							
4.1	Excavate Solid Waste	CY	$15.00		6,000	$0	$90,000
4.2	Contingency for excavation volume changes	CY	$15.00		1,500	$0	$22,500
4.3	Additional Waste Characterization Costs	LS	$25,000			$0	$0
4.4	De-water Excavation	LS	$40,000			$0	$0
4.5	Clean Backfill	CY	$15.00		0	$0	$0
4.6	On-site Short Haul	CY	$1.50			$0	$0
4.7	Contingency for on-site short haul volume changes	CY	$1.50			$0	$0
5 Capital Costs							
5.1	Contractor Markup (mob/demob, bond/ins., profit, overhead)	%	22%			$39,270	$54,780
5.2	Engineering/Design	%	7%			$12,495	$17,430
5.3	Waste Removal Documentation	%	3%			$0	$8,220
5.4	Construction Management	%	5%			$8,925	$12,450
5.5	Change Management	%	2%			$3,570	$4,980
5.6	Project Administration	%	2%			$3,570	$4,980
5.7	Notice of Substantial Completion Report (CERCLA)	%	2%			$3,570	$4,980
5.8	Permitting	EA	$50,000	1	1	$50,000	$50,000
5.9	Contingency, Legal Fees, Taxes, etc.	%	25%			$50,875	$68,500
6. Operations and Maintenance Costs							
	Institutional Controls						
6.1	Fencing and Signs	%	5%			$0	$0
	Source Area Containment Systems						
6.2	Road Maintenance-Gravel	%	5%			$4,200	$4,200
6.3	Low Permeability Cap Maintenance	%	3%			$0	$0
6.4	Soil Cap Maintenance	%	2%			$0	$0
6.5	Gravel Cap Maintenance	%	2%			$1,680	$840
6.6	Riprap Maintenance	%	2%			$0	$0
6.7	Ditch Maintenance	%	10%			$0	$0
6.8	Annual Monitoring and Reporting	EA	$10,000	1		$10,000	$0
	Miscellaneous						
6.9	Engineering/Administration	%	8%			$470.40	$403
6.10	Contingency, Legal Fees, Taxes, etc.	%	25%			$1,470.00	$1,260
					Total Capital Cost	$375,775	$500,320
					Annual O&M Cost	$17,820	$6,703
					Present Value of O&M Costs (30 Year)	$221,134	$83,180
					Total Net Present Value Cost	$596,909	$583,500

Note: The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

[a] See text for an explanation of the difference between the costs of the options presented here as part of a sitewide alternative and the costs for the same options presented as individual actions.

Table D-7
Company Lake Remedial Alternative Cost Estimates[a]

Option CL-1: Institutional Controls.
Option CL-2: Construct Permeable Cap over process residue.
Option CL-3: Hydraulically Dredge Process Residue, mechanically dewater.

	Item	Unit	Unit Cost	Option CL-2 Quantity	Option CL-3 Quantity	Option CL-2 Cost	Option CL-3 Cost
1 Institutional Controls							
1.1	Deed or Use Restriction Legal Fees	EA	$25,000	1	1	$25,000	$25,000
1.2	Fencing	LF	$15	3,550	6,180	$53,250	$92,700
2 Site Preparation							
2.1	Clearing, Grubbing, and Stripping	AC	$4,200	3.68	6.40	$15,456	$26,880
2.2	Surface Preparation	AC	$800	3.68	6.40	$2,944	$5,120
2.3	Road Construction-Pavement	LF	$51		130	$0	$6,630
2.4	Road Construction-Gravel	LF	$35	3,700	2,400	$129,500	$84,000
2.5	Gravel Construction Staging Area	SF	$1.75	10,000	10,000	$17,500	$17,500
2.6	Dewatering Pad and Stockpile Area	AC	$130,000		3.5	$0	$455,000
2.7	Water Access Ramp	SF	$6	1,600	1,600	$9,600	$9,600
2.8	Install Electrical Hook-up	EA	$80,000	1	1	$80,000	$80,000
2.9	Install Mobile Decon Pad	EA	$10,000	1	1	$10,000	$10,000
2.10	Decontamination, demolition, demobilization	LS	$10,000		1		$10,000
2 Divert NPDES and Relocate Pond Influent							
2.1	Temporary 12" HDPE Pipe	LF	$40.00	6,660	6,660	$266,400	$266,400
2.2	12" Excavation and Backfill	LF	$7.11	2,800	2,800	$19,908	$19,908
2.3	12" Steel Pipe	LF	$66.00	2,800	2,800	$184,800	$184,800
2.4	Diffuser	EA	$10,000	1	1	$10,000	$10,000
2.5	Decontamination, demolition, demobilization	LF	$1.25	6,660	6,660	$8,325	$8,325
3 Source Area Containment Systems							
3.1	1" to 3" Gravel	CY	$28.70	53,860		$1,545,782	$0
3.2	Geotextile	SF	$0.19	872,690		$165,811	$0
3.3	Seeding	AC	$2,000.00	2.00		$4,000	$0
4 Site Drainage							
4.1	Ditches	LF	$20.00		2,140	$0	$42,800
4.2	Catch Basins	EA	$1,750.00		12	$0	$21,000
5 Debris Survey and Removal							
5.1	Diver Debris Survey	Day	$5,000.00	5	5	$25,000	$25,000
5.2	Diver Debris Removal and Standby	Day	$2,500.00	25	25	$62,500	$62,500
5.3	Debris Removal Mobilization	EA	$5,000.00		4	$0	$20,000
6 Dredge Specific Items							
	Miscellaneous						
6.1	Silt Curtains	SF	$2.00		10000	$0	$20,000
6.2	Water Service to Work Area - Piping	LF	$20.00		1200	$0	$24,000
6.3	Valve, Connection	LS	$5,000.00		1	$0	$5,000
6.4	Effluent Pump and Sump	EA	$30,000.00		1	$0	$30,000
6.5	Decontamination, demolition, demobilization	LS	$25,000.00		0.5	$0	$12,500
	Mechanical Dewatering						
6.6	Equipment/Unit price for dewatering	CYIP	$40.00		37915	$0	$1,516,600
6.7	Decontamination, demolition, demobilization	LS	$50,000.00		1	$0	$50,000
6.8	Electrical Power	$/kWh	$0.06		448000	$0	$26,880
7 Excavation, Transportation, and Disposal							
	Excavation						
7.1	Hydraulically Dredge	CY	$14.00		37,915	$0	$530,810
7.2	Excavate Solid Waste	CY	$22.00	3137	3137	$69,014	$69,014
7.3	Excavate Dry Sludge from Stockpile	CY	$4.00		26,100	$0	$104,400
	Transport and Disposal						
7.4	Onsite Short Haul	CY	$5.00	3137	26,100	$15,685	$130,500
8 Capital Costs							
8.1	Contractor Markup (mob/demob, bond/ins., profit, overhead)	%	22%			$593,005	$875,131
8.2	Engineering/Design	%	7%			$188,683	$278,451
8.3	Waste Removal Documentation	%	3%			$0	$25,042
8.4	Construction Management	%	5%			$134,774	$198,893
8.5	Change Management	%	2%			$53,910	$79,557
8.6	Project Administration	%	2%			$53,910	$79,557
8.8	Notice of Substantial Completion Report (CERCLA)	%	2%			$53,910	$79,557
8.8	Permitting	EA	$50,000	1	1	$50,000	$50,000
8.9	Contingency, Legal Fees, Taxes, etc.	%	25%			$680,119	$0
8.1	Contingency, Legal Fees, Taxes, etc.	%	35%			$0	$1,401,003
9 Operations and Maintenance Cost							
	Institutional Controls						
9.1	Fencing and Signs	%	5%			$2,663	$4,835
	Source Area Containment Systems						
9.2	Road Maintenance-Gravel	%	5%			$6,475	$1,000
9.3	Road Maintenance-Pavement	%	10%			$0	$663
9.4	Permeable Cap Maintenance	%	2%			$3,316	$0
	Site Drainage						
9.5	Ditch Maintenance	%	10%			0	4280
9.6	Catch Basin Maintenance	%	10%			0	2100
	Miscellaneous						
9.7	Engineering/Administration	%	8%			$996	$1,014
9.8	Contingency, Legal Fees, Taxes, etc.	%	25%			$3,113	$0
9.9	Contingency, Legal Fees, Taxes, etc.	%	35%				$4,437
					Total Capital Cost	$4,528,784	$7,070,089
					Annual O&M Cost	$16,563	$18,130
					Present Value of O&M Costs (30 Year)	$205,537	$47,578
					Total Net Present Value Cost	$4,734,320	$7,117,637

Note: The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

[a] See text for an explanation of the difference between the costs of the options presented here as part of a sitewide alternative and the costs for the same options presented as individual actions.

Table D-8
Line Item Quantity Assumptions for the Onsite Landfill Cost Estimates

Item		Unit	Description
1 Institutional Controls			
1.1	Deed or Use Restriction Legal Fees	each	Cost to implement deed restrictions to limit use of property by future owners of onsite landfill area.
1.2	Fencing	linear feet	Landfill perimeter fencing to restrict access to onsite landfill area.
2 Site Preparation			
2.1	Clearing, Grubbing, and Stripping	acres	Clearing, grubbing, and stripping costs over footprint of onsite landfill.
2.2	Surface Preparation	acres	Surface preparation over footprint of onsite landfill.
2.3	Import Fill	tons	Import fill required to grade site prior to construction.
2.4	Road Construction-Gravel	linear feet	Gravel to construct an access road around perimeter of landfill and 500 additional feet of access road to connect to existing road system.
2.5	Ditches	linear feet	Drainage ditches around perimeter of landfill and a 500-foot ditch connecting to South Ditch.
3 Landfill Containment Systems (Liner and Cap; see Figures D-2 and D-3 for details)			
3.1	Landfill Liner (GCL)	square feet	Geosynthetic clay liner (1 layer in liner).
3.2	Geomembrane (FML)	square feet	Geomembrane used in cap and liner (2 layers in liner, 1 layer in cap).
3.3	Drainage Sand	cubic yards	Drainage sand used in liner drainage layer.
3.4	Drainage-Gravel	cubic yards	Drainage gravel used in liner drainage layer.
3.5	Drainage-Pipe	feet	Drainage pipe used in liner drainage layer.
3.6	Geotextile	square feet	Geotextile layers in liner and cap (3 layers in liner, 1 layer in cap).
3.7	Geonet	square feet	Geonet used in cap (1 layer).
3.8	Clean Soil	tons	Clean soil used in cap (2 layers).
3.9	Seeding	acres	Seeding costs over landfill surface area.
3.10	Pump Station	each	One pump station to transfer leachate to RMC water treatment plant.
3.11	Piping to RMC Treatment Plant	linear feet	Conveyance piping from landfill to RMC water treatment plant.

Table D-8, continued
Line Item Quantity Assumptions for the Onsite Landfill Cost Estimates

Item		Unit	Description
4 Capital Costs			
4.1	Engineering/Design	%	Engineering design is assumed to be 7% of the total capital cost for all options.
4.2	Construction Management	%	Construction management is assumed to be 5% of the total capital cost for all options.
4.3	Change Management	%	Change management is assumed to be 2% of the total capital cost for all options.
4.4	Project Administration	%	Project administration is assumed to be 2% of the total capital cost for all options.
4.5	Notice of Substantial Completion Report (CERCLA)	%	Notice of Substantial Completion Report, which is required under CERCLA, is assumed to be 2% of the total capital costs for all options.
4.6	Permitting	each	Lump sum permitting cost for implementation of remedial actions for each area of concern.
4.7	Contingency, Legal Fees, Taxes, etc.	%	Contingency, legal fees, and taxes are assumed to be 25% of the total capital costs for all options.
5 Operations and Maintenance Costs			
5.1	Overall Landfill Operations and Maintenance Costs	each	Assumed to be $10,000 per acre annually, based on CH2M HILL experience
6 Miscellaneous O&M Costs (Engineering, Oversight, and Administration)			
6.1	Engineering/Administration	%	It is assumed that engineering and administration costs are 8% of the total O&M costs.
6.2	Contingency, Legal Fees, Taxes, etc.	%	Contingency, legal fees, and taxes are assumed to be 25% of the total O&M costs for this option.

Table D-9
Order-of-Magnitude Onsite Landfill Cost Estimates

Alternative B Onsite Landfill: 33,000 cubic yards capacity
Alternative C Onsite Landfill:152,000 cubic yards capacity

Item	Unit	Unit Cost	Landfill B Quantity	Landfill C Quantity	Landfill B Cost	Landfill C Cost
1 Institutional Controls						
1.1 Deed or Use Restriction Legal Fees	EA	$25,000	1	1	$25,000	$25,000
1.2 Fencing	LF	$15.00	1,398	2,320	$20,975	$34,799
2 Site Preparation						
2.1 Clearing, Grubbing, and Stripping	AC	$4,200	2.3	6.4	$9,738	$26,804
2.2 Surface Preparation	AC	$800	2.3	6.4	$1,855	$5,106
2.3 Import Fill	Ton	$15.00	11,593	31,910	$173,898	$478,650
2.4 Road Construction-Gravel	LF	$35.00	1,898	2,820	$66,442	$98,698
2.5 Ditches	LF	$20.00	1,898	2,820	$37,967	$56,399
3 Source Area Containment Systems						
3.1 Landfill Liner-GCL	SF	$0.46	109,000	297,000	$50,140	$136,620
3.2 Geomembrane	SF	$0.43	329,000	900,000	$141,470	$387,000
3.3 Drainage Sand	CY	$19.40	3,700	10,000	$71,780	$194,000
3.4 Drainage-Gravel	CY	$28.70	3,700	10,000	$106,190	$287,000
3.5 Drainage-Pipe	FT	$10.80	1,739	4,787	$18,781	$51,694
3.6 Geotextile	SF	$0.19	398,000	1,088,000	$75,620	$206,720
3.7 Geonet	SF	$0.55	101,000	278,000	$55,550	$152,900
3.8 Clean Soil	TON	$20.00	11,200	30,900	$224,000	$618,000
3.9 Seeding	AC	$2,000	2.3	6.4	$4,637	$12,764
3.10 Pump Station	EA	$40,000	1	1	$40,000	$40,000
3.11 Piping to RMC Treatment Plant	LF	$25.00	2,000	2,000	$50,000	$50,000
4 Capital Costs						
4.1 Contractor Markup (mob/demob, bond/ins., profit, overhead)	%	22%			$258,290	$629,674
4.2 Engineering/Design	%	7%			$82,183	$200,351
4.3 Construction Management	%	5%			$58,702	$143,108
4.4 Change Management	%	2%			$23,481	$57,243
4.5 Project Administration	%	2%			$23,481	$57,243
4.6 Notice of Substantial Completion Report (CERCLA)	%	2%			$23,481	$57,243
4.7 Permitting	EA	$50,000	1	1	$50,000	$50,000
4.8 Contingency, Legal Fees, Taxes, etc.	%	25%			$293,511	$715,538
5 Operations and Maintenance Costs						
5.1 Overall Landfill Operations and Maintenance Costs	EA	$10,000			$23,186	$63,820
5.2 Engineering/Administration	%	8%			$1,855	$5,106
5.3 Contingency, Legal Fees, Taxes, etc.	%	25%			$5,797	$15,955
				Total Capital Cost	**$1,987,172**	**$4,772,553**
				Annual O&M Cost	**$30,838**	**$84,881**
				Present Value of O&M Costs (30 Year)	$382,669	$1,053,287
				Total Net Present Value Cost	**$2,369,841**	**$5,825,841**

Note: The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table D-10
Summary of As-Spent Costs for Remedial Alternative A

Capital Cost Escalation	6 percent/Year
O&M Cost Escalation	4 percent/year

Source Areas		TOTAL	As Spent	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
North Landfill	Capital		$504,999	$0	$0	$0	$504,999	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option NLF-2	O&M		$1,282,042	$0	$0	$0	$21,609	$22,474	$23,373	$24,307	$25,280	$26,291	$27,343	$28,436	$29,574	$30,757	$31,987	$33,266	$34,597
	TOTAL	$1,787,042																	
South Landfill	Capital		$813,402	$0	$0	$0	$813,402	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option SLF-2	O&M		$2,941,993	$0	$0	$0	$49,588	$51,572	$53,635	$55,780	$58,011	$60,332	$62,745	$65,255	$67,865	$70,580	$73,403	$76,339	$79,393
	TOTAL	$3,755,395																	
Scrap Yard	Capital		$422,221	$0	$0	$0	$422,221	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option SY-2	O&M		$1,143,527	$0	$0	$0	$19,275	$20,046	$20,847	$21,681	$22,548	$23,450	$24,388	$25,364	$26,379	$27,434	$28,531	$29,672	$30,859
	TOTAL	$1,565,747																	
Company Lake	Capital		$5,088,542	$0	$0	$0	$5,088,542	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option CL-2	O&M		$1,062,869	$0	$0	$0	$17,915	$18,632	$19,377	$20,152	$20,958	$21,796	$22,668	$23,575	$24,518	$25,499	$26,519	$27,579	$28,683
	TOTAL	$6,151,410																	
Onsite Landfill																			
Not applicable																			
Sitewide Groundwater	Capital		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option GW-1	O&M		$4,481,781	$0	$0	$0	$138,445	$143,983	$149,742	$155,732	$161,961	$84,219.63	$87,588	$91,092	$94,736	$98,525	$102,466	$106,565	$110,827
	TOTAL	$4,481,781																	
	Grand TOTALS	$17,741,375	$17,741,375	$0	$0	$0	$7,075,996	$256,705	$266,973	$277,652	$288,759	$216,089	$224,733	$233,722	$243,071	$252,794	$262,906	$273,422	$284,359
Summary	Remedy Capital	$6,829,164																	
	Remedy O&M	$10,912,211																	
	Onsite Landfill Capital	$0																	
	Onsite Landfill O&M	$0																	
	TOTAL	$17,741,375																	

Table D-10
Summary of As-spent Costs for Remedial Alternative A

Capital Cost Escalation	6 percent/Year
O&M Cost Escalation	4 percent/year

Source Areas		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
North Landfill	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option NLF-2	O&M	$35,981	$37,420	$38,917	$40,474	$42,093	$43,776	$45,527	$47,349	$49,243	$51,212	$53,261	$55,391	$57,607	$59;911	$62,308	$64,800	$67,392	$70,087
	TOTAL																		
South Landfill	*Capital*	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option SLF-2	O&M	$82,568	$85,871	$89,306	$92,878	$96,593	$100,457	$104,475	$108,654	$113,000	$117,520	$122,221	$127,110	$132,194	$137,482	$142,981	$148,701	$154,649	$160,835
	TOTAL																		
Scrap Yard	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option SY-2	O&M	$32,094	$33,377	$34,712	$36,101	$37,545	$39,047	$40,609	$42,233	$43,922	$45,679	$47,506	$49,407	$51,383	$53,438	$55,576	$57,799	$60,111	$62,515
	TOTAL																		
Company Lake	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option CL-2	O&M	$29,830	$31,023	$32,264	$33,555	$34,897	$36,293	$37,744	$39,254	$40,824	$42,457	$44,155	$45,922	$47,759	$49,669	$51,656	$53,722	$55,871	$58,106
	TOTAL																		
Onsite Landfill																			
Not applicable																			
Sitewide Groundwater	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option GW-1	O&M	$115,260	$119,871	$124,666	$129,652	$134,838	$140,232	$145,841	$151,675	$157,742	$164,051	$170,614	$177,438	$184,536	$191,917	$199,594	$207,577	$215,881	$224,516
	TOTAL																		
	Grand TOTALS	$295,733	$307,562	$319,865	$332,659	$345,966	$359,804	$374,197	$389,164	$404,731	$420,920	$437,757	$455,267	$473,478	$492,417	$512,114	$532,598	$553,902	$576,058

Table D-11
Summary of As-spent Costs for Remedial Alternative B

Capital Cost Escalation	6 percent/year
O&M Cost Escalation	4 percent/year

Source Areas		TOTAL	As Spent	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
North Landfill	Capital		$504,999	$0	$0	$0	$504,999	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option NLF-2	O&M		$1,282,042	$0	$0	$0	$21,609	$22,474	$23,373	$24,307	$25,280	$26,291	$27,343	$28,436	$29,574	$30,757	$31,987	$33,266	$34,597
	TOTAL	$1,787,042																	
South Landfill	Capital		$90,731	$0	$0	$0	$90,731	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option SLF-1	O&M		$241,519	$0	$0	$0	$4,071	$4,234	$4,403	$4,579	$4,762	$4,953	$5,151	$5,357	$5,571	$5,794	$6,026	$6,267	$6,518
	TOTAL	$332,249																	
Scrap Yard	Capital		$562,160	$0	$0	$0	$562,160	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option SY-3	O&M		$430,141	$0	$0	$0	$7,250	$7,540	$7,842	$8,155	$8,482	$8,821	$9,174	$9,541	$9,922	$10,319	$10,732	$11,161	$11,608
	TOTAL	$992,301																	
Company Lake	Capital		$7,943,918	$0	$0	$0	$7,943,918	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option CL-3	O&M		$40,002	$0	$0	$0	$19,609	$20,393	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	TOTAL	$7,983,920																	
Onsite Landfill	Capital		$2,232,786	$0	$0	$0	$2,232,786	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
OSLF-B	O&M		$1,978,855	$0	$0	$0	$33,354	$34,688	$36,076	$37,519	$39,020	$40,581	$42,204	$43,892	$45,648	$47,474	$49,373	$51,347	$53,401
	TOTAL	$4,211,641																	
Sitewide Groundwater	Capital		$421,350	$0	$0	$0	$421,350	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option GW-2	O&M		$5,953,445	$0	$0	$0	$163,250	$169,780	$176,571	$183,634	$190,980	$114,399.21	$118,975	$123,734	$128,684	$133,831	$139,184	$144,752	$150,542
	TOTAL	$6,374,795																	
	Grand TOTALS	$21,681,948	$21,681,948	$0	$0	$0	$12,005,088	$259,110	$248,265	$258,195	$268,523	$195,045	$202,846	$210,960	$219,399	$228,175	$237,302	$246,794	$256,665
Summary	Remedy Capital	$9,523,158																	
	Remedy O&M	$7,947,149																	
	Onsite Landfill Capital	$2,232,786																	
	Onsite Landfill O&M	$1,978,855																	
	TOTAL	$21,681,948																	

Table D-11
Summary of As-Spent Costs for Remedial Alternative B

Capital Cost Escalation	6 percent/year
O&M Cost Escalation	4 percent/year

Source Areas		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
North Landfill	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option NLF-2	O&M	$35,981	$37,420	$38,917	$40,474	$42,093	$43,776	$45,527	$47,349	$49,243	$51,212	$53,261	$55,391	$57,607	$59,911	$62,308	$64,800	$67,392	$70,087
	TOTAL																		
South Landfill	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option SLF-1	O&M	$6,778	$7,049	$7,331	$7,625	$7,930	$8,247	$8,577	$8,920	$9,277	$9,648	$10,034	$10,435	$10,852	$11,286	$11,738	$12,207	$12,696	$13,203
	TOTAL																		
Scrap Yard	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option SY-3	O&M	$12,072	$12,555	$13,057	$13,579	$14,123	$14,688	$15,275	$15,886	$16,521	$17,182	$17,870	$18,584	$19,328	$20,101	$20,905	$21,741	$22,611	$23,515
	TOTAL																		
Company Lake	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option CL-3	O&M	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	TOTAL																		
Onsite Landfill	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
OSLF-B	O&M	$55,537	$57,759	$60,069	$62,472	$64,971	$67,570	$70,272	$73,083	$76,007	$79,047	$82,209	$85,497	$88,917	$92,474	$96,173	$100,020	$104,020	$108,181
	TOTAL																		
Sitewide Groundwater	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option GW-2	O&M	$156,563	$162,826	$169,339	$176,112	$183,157	$190,483	$198,102	$206,027	$214,268	$222,838	$231,752	$241,022	$250,663	$260,689	$271,117	$281,962	$293,240	$304,970
	TOTAL																		
	Grand TOTALS	$266,932	$277,609	$288,714	$300,262	$312,273	$324,764	$337,754	$351,264	$365,315	$379,927	$395,125	$410,930	$427,367	$444,461	$462,240	$480,729	$499,959	$519,957

Table D-12
Summary of As-Spent Costs for Remedial Alternative C

Capital Cost Escalation	*6 percent /year*
O&M Cost Escalation	4 percent /year

Source Areas		TOTAL	As Spent	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
North Landfill	Capital		$1,694,748	$0	$0	$0	$1,694,748	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option NLF-4	O&M		$324,313	$0	$0	$0	$5,466	$5,685	$5,912	$6,149	$6,395	$6,651	$6,917	$7,193	$7,481	$7,780	$8,092	$8,415	$8,752
	TOTAL	$2,019,061																	
South Landfill	Capital		$2,278,975	$0	$0	$0	$2,278,975	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option SLF-4	O&M		$521,203	$0	$0	$0	$8,785	$9,136	$9,502	$9,882	$10,277	$10,688	$11,116	$11,561	$12,023	$12,504	$13,004	$13,524	$14,065
	TOTAL	$2,800,179																	
Scrap Yard	Capital		$562,160	$0	$0	$0	$562,160	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option SY-3	O&M		$430,141	$0	$0	$0	$7,250	$7,540	$7,842	$8,155	$8,482	$8,821	$9,174	$9,541	$9,922	$10,319	$10,732	$11,161	$11,608
	TOTAL	$992,301																	
Company Lake	Capital		$7,943,918	$0	$0	$0	$7,943,918	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option CL-3	O&M		$40,002	$0	$0	$0	$19,609	$20,393	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	TOTAL	$7,983,920																	
Onsite Landfill	Capital		$5,362,441	$0	$0	$0	$5,362,441	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
OSLF-C	O&M		$5,446,750	$0	$0	$0	$91,807	$95,479	$99,298	$103,270	$107,401	$111,697	$116,165	$120,812	$125,644	$130,670	$135,897	$141,332	$146,986
	TOTAL	$10,809,190																	
Sitewide Groundwater	Capital		$3,725,858	$0	$0	$0	$3,725,858	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option GW-3	O&M		$15,335,414	$0	$0	$0	$321,387	$334,242	$347,612	$361,516	$375,977	$306,796.34	$319,068	$331,831	$345,104	$358,908	$373,265	$388,195	$403,723
	TOTAL	$19,061,272																	
	Grand TOTALS	$43,665,924	$43,665,924	$0	$0	$0	$22,022,404	$472,476	$470,166	$488,973	$508,532	$444,653	$462,440	$480,937	$500,175	$520,182	$540,989	$562,629	$585,134
Summary	Remedy Capital	$16,205,659																	
	Remedy O&M	$16,651,074																	
	Onsite Landfill Capital	$5,362,441																	
	Onsite Landfill O&M	$5,446,750																	
	TOTAL	$43,665,924																	

Table D-12
Summary of As-spent Costs for Remedial Alternative C

Capital Cost Escalation	6 percent /year
O&M Cost Escalation	4 percent /year

Source Areas		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
North Landfill	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option NLF-4	O&M	$9,102	$9,466	$9,845	$10,238	$10,648	$11,074	$11,517	$11,978	$12,457	$12,955	$13,473	$14,012	$14,573	$15,155	$15,762	$16,392	$17,048	$17,730
	TOTAL																		
South Landfill	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option SLF-4	O&M	$14,628	$15,213	$15,821	$16,454	$17,112	$17,797	$18,509	$19,249	$20,019	$20,820	$21,653	$22,519	$23,420	$24,356	$25,331	$26,344	$27,398	$28,493
	TOTAL																		
Scrap Yard	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option SY-3	O&M	$12,072	$12,555	$13,057	$13,579	$14,123	$14,688	$15,275	$15,886	$16,521	$17,182	$17,870	$18,584	$19,328	$20,101	$20,905	$21,741	$22,611	$23,515
	TOTAL																		
Company Lake	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option CL-3	O&M	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	TOTAL																		
Onsite Landfill	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
OSLF-C	O&M	$152,865	$158,980	$165,339	$171,953	$178,831	$185,984	$193,423	$201,160	$209,207	$217,575	$226,278	$235,329	$244,742	$254,532	$264,713	$275,302	$286,314	$297,766
	TOTAL																		
Sitewide Groundwater	Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Option GW-3	O&M	$419,672	$436,667	$454,134	$472,299	$491,191	$510,838	$531,272	$552,523	$574,624	$597,609	$621,513	$646,374	$672,229	$699,118	$727,082	$756,166	$786,412	$817,869
	TOTAL																		
	Grand TOTALS	$608,539	$632,881	$658,196	$684,524	$711,905	$740,381	$769,996	$800,796	$832,828	$866,141	$900,786	$936,818	$974,291	$1,013,262	$1,053,793	$1,095,944	$1,139,782	$1,185,373

Appendix D Figures

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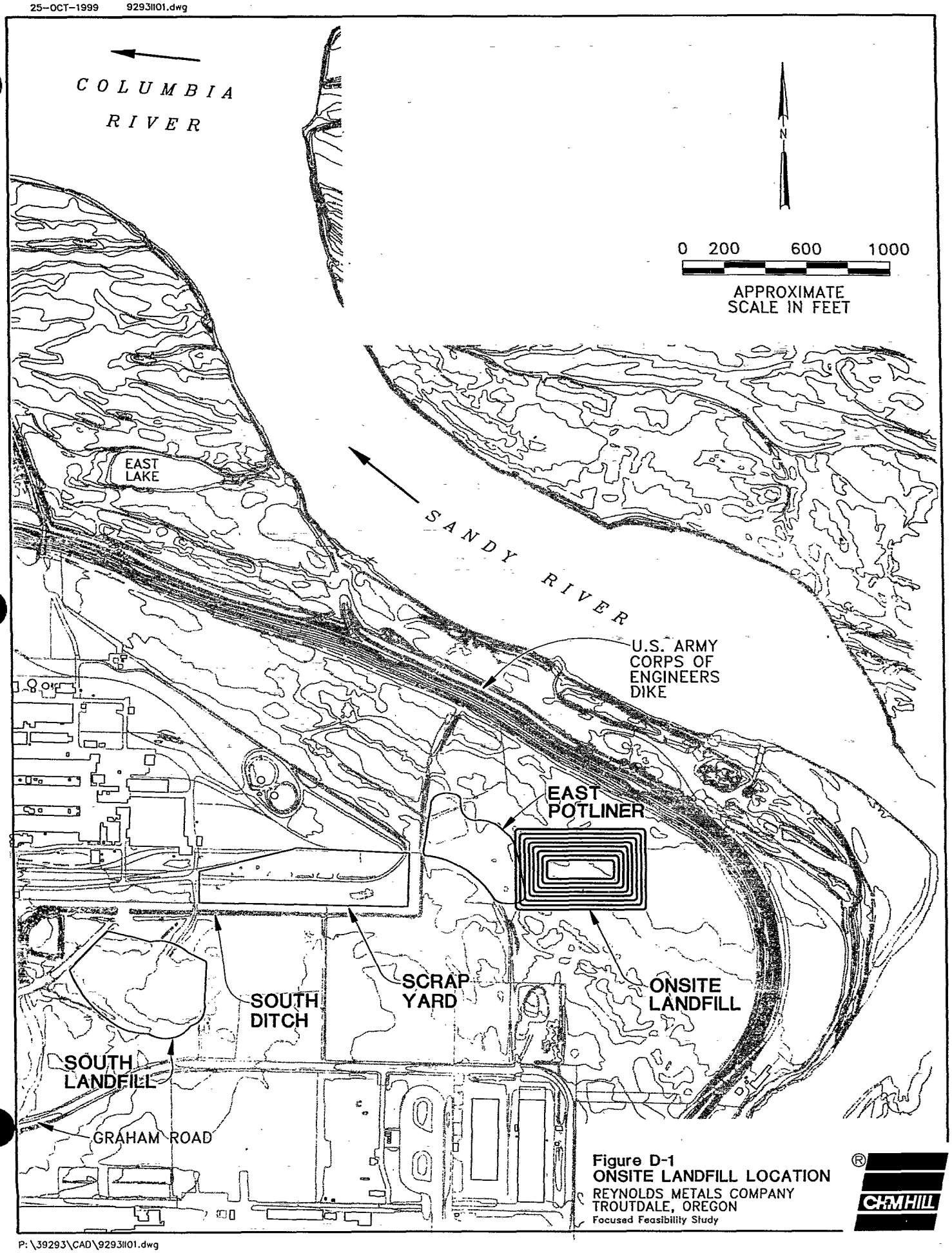

Figure D-1
ONSITE LANDFILL LOCATION
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

CH2M HILL

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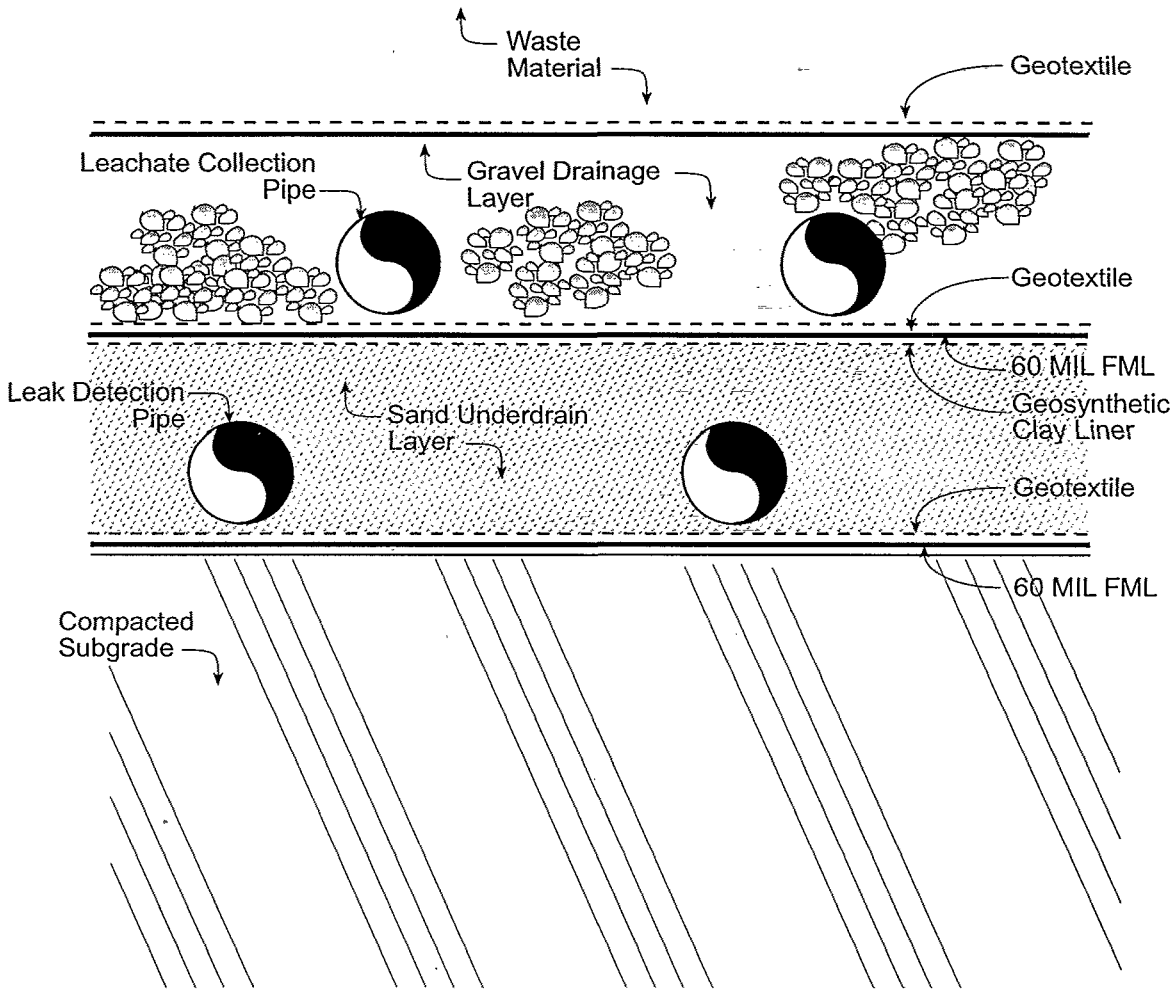

Figure D-2
Onsite Landfill Liner
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

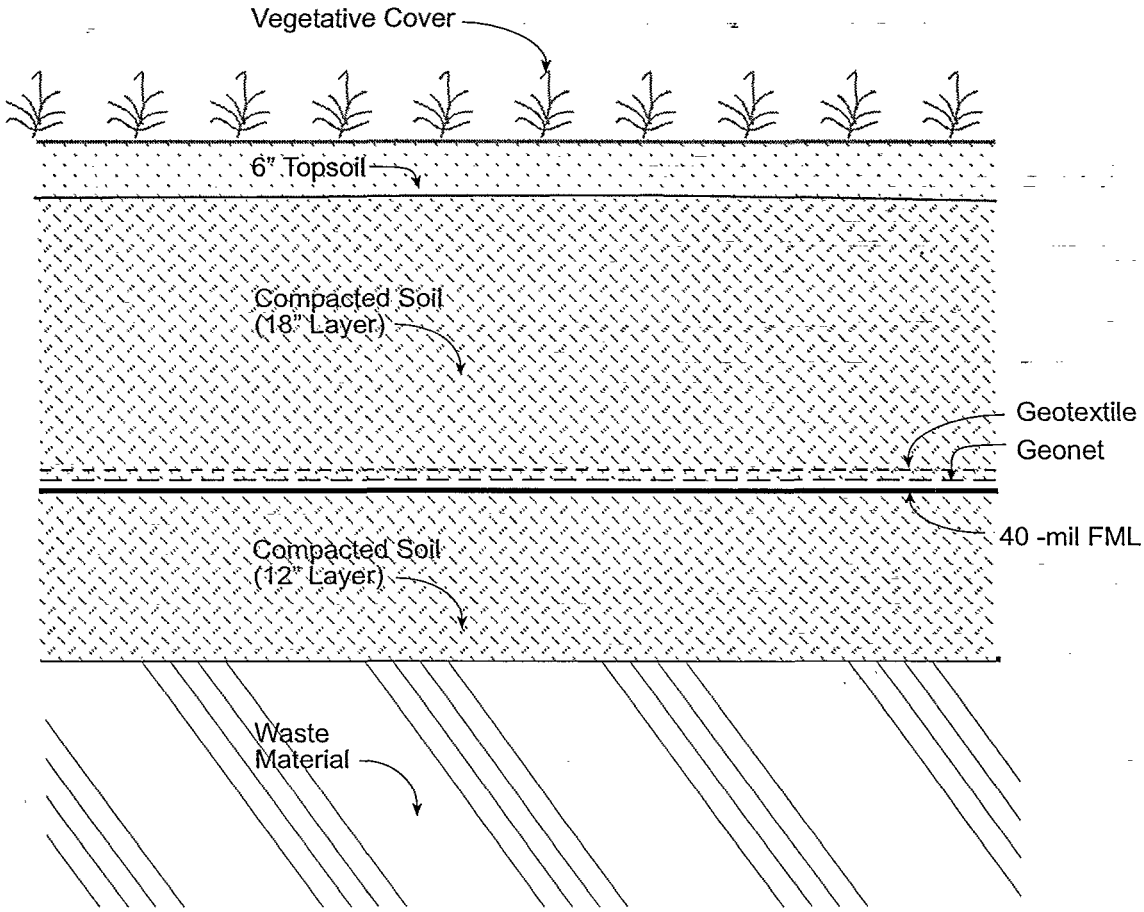

Figure D-3
Onsite Landfill Cap
Reynolds Metals Company
Troutdale, Oregon
Focused Feasibility Study

APPENDIX E

Fluoride Mass Calculations

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APPENDIX E

Fluoride Mass Calculations

This appendix provides a conceptual evaluation of the distribution of soil fluoride mass in north landfill, south landfill, scrap yard, and east potliner. Estimates of the fluoride mass contained in each soil and debris area and their corresponding geologic strata can be found in Table E-1. The following sections describe how the fluoride mass distribution was estimated from the parameters listed below.

- Strata type
- Average strata thickness
- Surface area
- Volume of material in strata
- Dry bulk density of material in strata
- Average total soil fluoride concentration in strata

E.1 Strata Type

The soil fluoride mass distribution was subdivided by subsurface strata for north landfill, south landfill, scrap yard, and east potliner where data were available. These subsurface strata are identified in the conceptual geologic cross sections provided in Section 4 of the *Groundwater Remedial Investigation Report, Volume II* (CH2M HILL, June 1999).

The scrap yard area was further subdivided based on historical usage of the property. The scrap yard is subdivided by an access road that crossed the area from east to west. The northern portion of the scrap yard was historically used for bulk materials storage, while the southern half of the area was typically used for industrial process equipment and scrap material storage.

Considering the difference in historical usage of the individual scrap yard areas, distributions of fluoride and other constituents of concern would also expected to vary across the area. Furthermore, fluoride concentrations in the northwestern third of the scrap yard are substantially lower than those found in the northeastern two-thirds of the surficial sand unit. For this reason, the surficial sand unit in the north half of scrap yard have been further subdivided into a western third, middle third, and eastern third. For further comparison, Table E-1 includes a comparison of fluoride distributions with the surficial sand unit considered as a whole to the relative distribution with the underlying sand further subdivided.

Limited data is available for the soil fluoride mass distribution at north landfill. Only soil fluoride mass in the waste materials of the landfill is considered in Table E-1 due to this limitation.

E.2 Average Strata Thickness

The average thickness of each of the subsurface strata was estimated from the conceptual geologic cross sections provided in Section 4 of the *Groundwater Remedial Investigation Report, Volume II* (CH2M HILL, June 1999). The cross sections were used to determine the average thickness that is most representative of each strata. These cross sections are based on test pit wall logs, monitor well geologic logs, and geoprobe geologic logs.

E.3 Surface Area

The surface area of each of the soil and debris areas was calculated from the most current site plan view maps. These maps area based on survey data.

E.4 Volume of Material in Strata

The volume of material in located in each strata within the delineated boundaries of each soil and debris area are calculated using the surface area and thickness of each strata. The volumes are reported in Table E-1.

E.5 Dry Bulk Density of Material in Strata

The dry bulk density of materials found in each strata are estimated by typical values based on soil type. The dry bulk densities assumed for each material are provided in Table E-1.

E.6 Average Total Soil Fluoride Concentration in Strata

The average soil fluoride concentrations were calculated by correlating analytical data, sample depths, and the conceptual geologic cross sections. Analytical data were grouped according to subsurface strata type and location. Average soil fluoride concentrations for each area and strata are presented in

Only analytical data with similar analytical methods were used to calculate average soil fluoride concentrations. For example, total fluoride data were used in the calculation, whereas soluble fluoride data were omitted. The analytical data used were primarily from surface soil and geoprobe samples. Table E-2 provides documentation of where the analytical soil fluoride data can be found.

E.7 Total Fluoride Mass Calculations

The total mass of soil fluoride was calculated using the following formula:

$$\text{Soil Volume}(ft^3) \times \text{Dry Bulk Density}(lb\ soil/ft^3 soil) \times \frac{0.454\ kg\ soil}{lb\ soil} \times \frac{mg\ Fluoride}{kg\ soil} \times \frac{1\ kg\ Fluoride}{10^6\ mg\ Fluoride}$$

Finally, Table E-1 provides a percentage distribution of fluoride mass for each soil and debris area broken down by subsurface strata.

Appendix E Tables

Table E-1
Total Soil Fluoride Mass Calculations for Soil and Debris Areas
Reynolds Metals Company, Troutdale, Oregon

A	B	C	D	E	F	G	H	I	J	K
Location	Strata	Average Thickness	Area	Area	Volume	Volume	Dry Bulk Density	Average Fluoride Concentration	Total Fluoride Mass	% of Total Fluoride Mass in Strata
		(ft)	(ft^2)	(acres)	(ft^3)	(yd^3)	(lb/ft^3)	(mg/Kg)	(Kg)	
South Landfill										
	Waste Material	5	240,000	5.5	1,200,000	44,400	100	12,500	681,000	71
	Surficial Sand	8	240,000	5.5	1,920,000	71,100	100	1,430	125,000	13
	Silt	25	240,000	5.5	6,000,000	220,000	80	630	137,000	14
	UGS to 45 bgs	5	240,000	5.5	1,200,000	44,400	100	260	14,200	1
Scrap Yard (North) (Sand further subdivided)	Waste Material	2	84,600	1.9	169,000	6,260	100	31,600	242,000	41
	Surficial Sand-Western Third	7	14,800	0.3	104,000	3,850	100	390	1,840	0
	Surficial Sand-Middle Third	7	34,800	0.8	244,000	9,040	100	13,000	144,000	25
	Surficial Sand-Eastern Third	7	35,000	0.8	245,000	9,070	100	12,900	143,490	24
	Silt	12	84,600	1.9	1,020,000	37,800	80	730	27,000	5
	UGS to 40 bgs	20	84,600	1.9	1,690,000	62,600	100	360	27,600	5
Scrap Yard (North) (Sand not subdivided)	Waste Material	2	84,600	1.9	169,000	6,260	100	31,600	242,000	41
	Surficial Sand	7	84,600	1.9	592,200	21,930	100	10,825	291,040	50
	Silt	12	84,600	1.9	1,020,000	37,800	80	730	27,000	5
	UGS to 40 bgs	20	84,600	1.9	1,690,000	62,600	100	360	27,600	5
Scrap Yard (South)										
	Waste Material	2	160,000	3.7	320,000	11,900	100	1,900	27,600	29
	Surficial Sand	5	160,000	3.7	800,000	29,600	100	255	9,300	10
	Silt	8	160,000	3.7	1,280,000	47,400	80	310	14,400	15
	UGS to 40 bgs	25	160,000	3.7	4,000,000	148,000	100	240	43,600	46
East Potliner										
	Surficial Sand	4	150,000	3.4	600,000	22,200	100	345	9,400	4
	Silt	30	150,000	3.4	4,500,000	167,000	80	1,150	188,000	85
	UGS to 40 bgs	6	150,000	3.4	900,000	33,300	100	590	24,100	11
North Landfill										
	Waste Material	9	100,000	2.3	900,000	33,300	100	4,860	199,000	

NOTE: Column H--Dry bulk density values for sand and silt are from laboratory tests conducted on samples collected at south landfill, scrap yard, and east potliner during the summer 1998 field program. Values in waste are assumed to be the same as in sand.

NOTE: Column I--Average soil concentrations in waste material are for soil borings and Geoprobes installed during the summer 1998 field program plus surface samples collected during 1997.

NOTE: Column J--Total Fluoride Mass, Kg = (Soil Volume, Ft^3)*(Dry bulk density,lb/ft^3)*(0.454 Kg/lb.)*(F Concentration, mg/Kg)*(1 Kg F/ 1,000,000 mg F).

Table E-2
Data References for Soil Fluoride Distribution Calculation
Reynolds Metals Company, Troutdale, Oregon

Location	Strata	Data Type	References
South Landfill	Waste Material	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
		1997 Surface Soil Transect Composite Samples	CH2M HILL. *Data Summary for the Soil and Debris Areas Addendum to the RI/FS Work Plan* (Section 3.2, Table 3-3). Dec. 15, 1997.
	Underlying Sand	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
	Silt	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
	UGS to 45 bgs	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
Scrap Yard (North)	Waste Material	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
		1995 Discrete Surface Soil Samples	CH2M HILL. *Draft Current Situation Summary* (Section 3.4.2.2, Table SY-1). April 5, 1996.
	Underlying Sand-Western Third	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
	Underlying Sand-Middle Third	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
	Underlying Sand-Eastern Third	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
	Silt	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
	UGS to 40 bgs	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
Scrap Yard (South)	Waste Material	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
		1998 Geoprobe Samples, 1995 Discrete Surface Soil Samples	CH2M HILL. *Draft Current Situation Summary* (Section 3.4.2.2, Table SY-1). April 5, 1996.
	Underlying Sand	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
	Silt	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
	UGS to 40 bgs	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
East Potliner	Underlying Sand		
		1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
	Silt	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
	UGS to 40 ft. bgs.	1998 Geoprobe Samples	CH2M HILL. *Groundwater Remedial Investigation Report, Volume III, Appendix B.* June 1999.
North Landfill	Waste Material	1997 Surface Soil Transect Composite Samples	CH2MHILL. *Data Summary for the Soil and Debris Areas Addendum to the RI/FS Work Plan* (Section 2, Table 2-3). Dec. 15, 1997.

APPENDIX F

Technical Memorandum No. GW-19: Evaluation of the Minimum Effective Influent Concentration (MEIC) for Fluoride Treatment

Evaluation of the Minimum Effective Influent Concentration (MEIC) for Fluoride Treatment

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DATE: February 3, 1999

1. Purpose of Technical Memorandum

This technical memorandum outlines an approach to identifying those areas of groundwater at the Reynolds Metals Company (RMC) site in Troutdale, Oregon, that have fluoride concentrations which are not sufficiently elevated to make extraction and treatment for fluoride removal a viable option. If RMC and EPA can agree on an approximate minimum groundwater concentration for extraction and treatment to be feasible, it will allow future discussions of this approach to focus only on areas that exceed this concentration. For areas that exceed this minimum concentration, extraction and treatment will continue to be one of the options evaluated, while for areas that do not exceed this concentration, extraction and treatment can be screened out.

2. Introduction

Fluoride is present in groundwater at the Troutdale facility. If groundwater is extracted to reduce the amount of fluoride in the aquifer, the extracted groundwater may require physical and chemical treatment to reduce the fluoride concentration before discharge. On the basis of a screening of groundwater treatment technologies in late 1997, RMC believes that the addition of calcium chloride for precipitation of calcium fluoride would likely be the most cost-effective fluoride reduction method.[1]

The theoretical concentration of fluoride that can be reached with this method is 8 milligrams per liter (mg/L), based on the solubility of calcium fluoride in water (16 mg/L.) The concentration that can be achieved on an actual sample of groundwater tested in the laboratory may be higher than the theoretical concentration because of interference by other

[1] See *Draft Memorandum GW No. 12: Screening of Groundwater Treatment Technology Options* (CH2M HILL, May 29, 1998).

constituents present. The practical effluent concentration of fluoride that can be achieved in an industrial setting is higher than the concentration that can be achieved in a laboratory setting. These differences are one of the subjects of this technical memorandum.

In order for a treatment system to be cost effective, the fluoride concentration in the influent must be sufficiently higher than the concentration in the effluent, following treatment. The smaller the difference between these two concentrations, the higher the cost per pound of fluoride removed. This technical memorandum addresses how large this difference (the "treatment differential") must be for the system to be cost effective.

An effective groundwater extraction and treatment system would also depend on the hydrogeologic setting; for instance, on whether sufficient well yields are possible. Hydrogeologic factors are outside the scope of this technical memorandum. For areas that exceed the minimum concentration for extraction/treatment, hydrogeologic factors will be an additional consideration for evaluating this approach.

3. Purpose of Evaluation

The purpose of the evaluation presented here is to propose a minimum concentration of fluoride for groundwater to be considered for a pump-and-treat approach. That is, groundwater with fluoride concentrations below this minimum level will not be further evaluated for pump and treat. For groundwater with concentrations above this minimum level, pump and treat will be evaluated further along with other potential approaches, such as containment.

The concentration proposed in this technical memorandum is an approximation of the actual minimum that might be cost-effectively treated in an optimally designed treatment system. The actual minimum would need to be determined by a pilot study and system operation. This technical memorandum is based on limited treatability bench testing and on information in the technical literature. It provides a reasonable basis for an approximation of the areas at the site for which pump and treat is not a viable option. Identification of these areas will allow RMC and the agencies to narrow the focus to more critical areas.

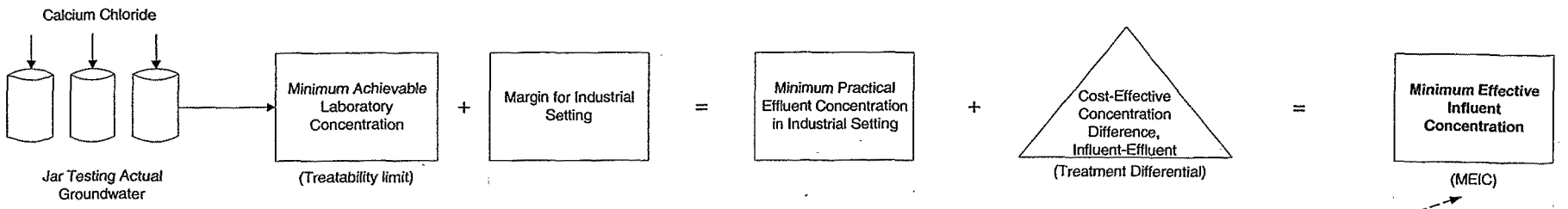
4. Definition of Minimum Effective Influent Concentration

Figure 1 defines the minimum effective influent concentration (MEIC), which must be the same as the minimum concentration in extracted groundwater that is to be treated. As shown in Figure 1:

MEIC (mg/L) = Treatability limit (mg/L) +
Margin for industrial setting (mg/L) +
Treatment differential across treatment system (mg/L)

The treatability limit is based on the bench testing performed in summer 1998. It is described in detail in the Attachment to this technical memorandum and summarized below in Section 5.

Definition of Minimum Effective Influent Concentration



Flow of Groundwater

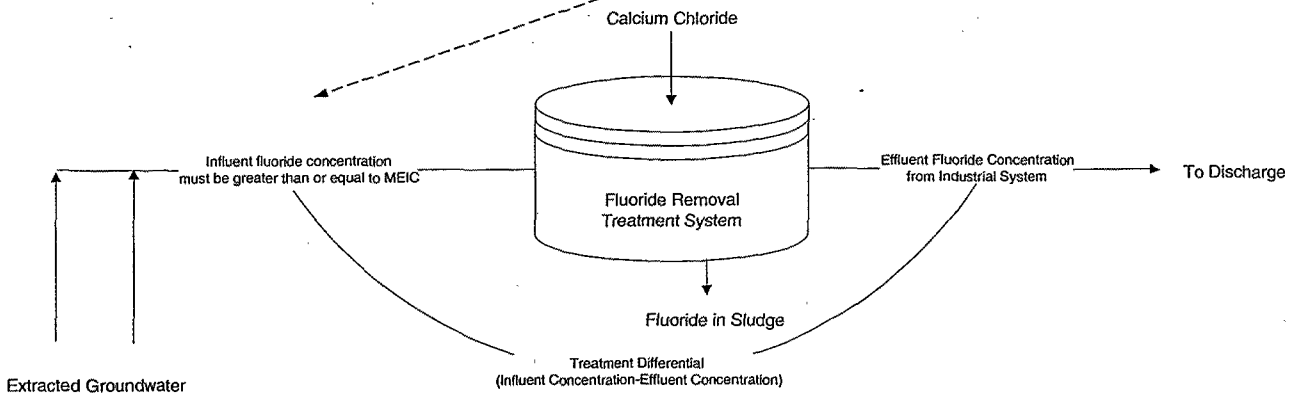


Figure 1

Flow Chart for Definition of Minimum Effective Influent Concentration

PDX18096.VSD

The margin for an industrial setting is the difference between the fluoride concentrations that can be achieved under laboratory conditions and those that can be achieved in an industrial setting, as discussed in Section 6.

The treatment differential across the treatment system required for the system to be cost effective is discussed in Section 7.

5. Bench Testing Results

Treatability testing was performed on groundwater extracted from the Troutdale site at a variety of fluoride concentrations, locations, and depths, as shown in Table 1. The samples were analyzed for fluoride, aluminum, calcium, iron, magnesium, manganese, total dissolved solids (TDS), conductivity, and pH. (Sample GP59-020 was analyzed only for fluoride, calcium, conductivity, and pH.) Fluoride concentrations in the samples ranged from 21 to 1,030 mg/L.

Table 1
Groundwater Samples

Well or Geoprobe ID	Site Area	Lithologic Zone	Actual Initial Fluoride Concentration [mg/L]
MW11-017 [a]	East Potliner	Silt	399
MW13-022	Scrap Yard	Silt	134
MW19-013	South Landfill	Silt	87.1
MW26-012	South Landfill	Silt	108
MW33-095	Scrap Yard	Intermediate Sand	93.4
GP56-055	Scrap Yard	Upper Gray Sand	150
GP59-020	South Landfill	Silt	1,060
GP59-045	South Landfill	Upper Gray Sand	49.4
GP66-040	East Potliner	Upper Gray Sand	21.4

[a] The number before the hyphen is the well or Geoprobe identifier; the number following the hyphen is the approximate depth of the sample.

The "best" conditions for reducing the fluoride concentration were determined by varying pH, retention time, calcium chloride dosage, polymer addition, and solids recycling. These parameters were varied one at a time while the others were held constant for a limited number of the available samples. The most effective values for all the parameters were then used in combination on all the samples.[2]

[2] This simplified approach was considered appropriate for the level of accuracy required to support the main purpose of this study: identification of areas at the plant for which pump and treat would be clearly inappropriate. Actual design of a treatment system would warrant further testing. For example, the longest testing time in this series was 2 hours, whereas a longer

Fluoride removals ranged from essentially zero to 98 percent (see Table 2). The most striking result was the correlation between the initial fluoride concentration and fluoride removal efficiency. For samples with initial concentrations above 100 mg/L (ranging from 103 to 1,060 mg/L), the average removal efficiency was 87 percent (ranging from 74 to 98 percent). Fluoride concentrations post-treatment for these samples averaged 19 mg/L (ranging from 6.7 to 35.4 mg/L).

Table 2
Fluoride Treatment Results [a]

Sample Number	Initial mg/L F	Following Treatment mg/L F	Removal Efficiency (%)
MW11-017	399	6.7	98.3
MW11-017	397	10.4	97.4
MW11-017 [b]	187	11.3	94.0
MW11-017 [b]	75.5	75.5	0.0
MW13-022	134	18.6	86.1
MW19-013	87.1	69.7	20.0
MW19-013	88.3	70.4	20.3
MW26-012	108	27.6	74.4
MW26-012	103	17.5	83.0
MW33-095	93.4	12.4	86.7
MW33-095	91.6	38.5	58
MW33-095	91.6	89.7	2.1
MW33-095	91.6	87.1	4.9
MW33-095	94.9	90.9	4.2
GP56-055	150	17.6	88.3
GP56-055	142	28.8	79.7
GP59-020	1,060	35.4	96.7
GP59-045	49.4	48.6	1.6
GP66-040	21.5	21.5	0.0

[a] For a Ca/F mole ratio of 2.0.
[b] Diluted with deionized water.

retention time might be more effective as well as cost-effective. Also, the relationships between the parameters were not explored to establish whether any particular combinations were synergistic.

For samples with initial concentrations below 90 mg/L (ranging from 22 to 88 mg/L), the removal efficiency ranged from essentially zero to 20 percent.[3]

The correlation between initial concentration and removal efficiency was tested by diluting one of the samples that had a high initial concentration and treating the diluted solution. MW11-017 had an initial fluoride concentration of approximately 395 mg/L, which was reduced by treatment to approximately 20 mg/L. After dilution (with deionized water) to approximately 200 mg/L, it was reduced by treatment to 11 mg/L; but after dilution to 75 mg/L, treatment did not reduce the concentration at all.[4]

These results suggest that groundwater with fluoride concentrations of less than approximately 90 to 100 mg/L may not provide sufficient fluoride for precipitation sites to occur.[5] No conclusive cause-and-effect relationship has been established, so extrapolation to all groundwater at the site without confirmation should be considered with caution. However, if it were shown that groundwater with concentrations below 90 to 100 mg/L could not be reduced to lower fluoride concentrations, then 90 to 100 mg/L would be the cutoff for consideration of pump and treat rather than the MEIC as defined in Section 3, because the MEIC as defined in Section 3 is expected to be below 90 to 100 mg/L.

To reiterate, the purpose of this technical memorandum is to propose a fluoride concentration that both the U.S. Environmental Protection Agency (EPA) and RMC can accept as representing areas of the site for which pump and treat is not a viable option. The definition of the MEIC presented in Section 3 may result in a lower concentration than 90 to 100 mg/L. Consequently, the best response for groundwater with concentrations between the MEIC and 90 mg/L may remain in question, but both EPA and RMC should be able to agree that groundwater below the MEIC (as defined in Section 3) is too low to treat cost effectively. Meanwhile, consideration of what response is appropriate for groundwater above 90 mg/L and between the MEIC and 90 mg/L can continue.

6. Margin for an Industrial Setting

A margin needs to be allowed for the difference between the fluoride concentrations that can be achieved in a laboratory setting and those that can be achieved in an industrial wastewater treatment plant.

This margin was estimated by consideration of two types of factors: the differences in the physical equipment used, and the increased variability in the influent conditions in an actual industrial setting.

In the first category are the following factors:

---

[3] Sample MW33-095 had an initial concentration of approximately 92 mg/L and the removal efficiencies were erratic and not reproducible (ranging from 2 to 87 percent).

[4] Similarly, sample GP59-020 had an initial concentration of approximately 1,000 mg/L and was treated with a removal efficiency of 97 percent. However, a sample from the same Geoprobe but at a different depth, GP59-045, with an initial concentration of 49 mg/L, was essentially untreatable (removal efficiency 1.6 percent). However, these samples were separated by approximately 25 feet in the aquifer and, consequently, may have other chemical differences that affect their treatability.

[5] The possibility that the problem was being caused by other constituents was considered, but no correlation was apparent between the initial concentration of other constituents and treatment efficiency.

- Mixing effectiveness—The ability of a continuous-flow stirred tank reactor to achieve ideal, complete, mixing
- Short-circuiting or bypass in a continuous stirred tank reactor—This is an estimate of the influent that enters the reactor and leaves untreated, because of short circuiting or spending less than the "mean residence time" required for the reaction to occur satisfactorily.
- Change from batch reactor (laboratory setting) to a continuous reactor—A batch reactor is expected to have higher treatment efficiency because the entire influent spends sufficient and identical time (equal to the average residence time) for satisfactory reaction to occur. Continuous flow reactors are not usually able to provide this degree of uniformity.

For a general discussion of the effect of these factors, see *Elements of Chemical Reaction Engineering*, H. Scott Fogler (Prentice Hall International Series in the Physical and Chemical Engineering Sciences, 2d Edition, 1992), Chapter 13.

The factors in the second category are site-specific and include:

- Fluctuations in influent fluoride and calcium (the two constituents most significantly affecting treatability) ion concentration—This is the concentration variability of reactants in the influent stream. The thermodynamics and kinetics of the reaction are directly dependent on the concentration of the reactants entering the reactor.
- Variations in influent water quality—Parameters such as pH, temperature, ionic strength, metals, etc., have a significant effect on the treatment obtained.
- Fluctuations in influent flow rate—Equipment for a treatment system must be sized for the maximum flow expected. If the number of wells to be pumped and/or the flow rate from each well changes significantly during the life of the project, residence times will increase or decrease. Flow variation may also affect the functioning and operation of the treatment equipment.

Some of these factors, for example pH, can be more easily controlled than others, such as the influent concentrations of fluoride and other constituents.

Table 3 summarizes the approximate effects of the six factors described above. The allowance listed for each factor represents the amount of inefficiency that the factor can reasonably be expected to introduce. A small allowance is listed for each of the first three factors, based on judgment. The remaining three factors are site specific and are based on our familiarity with conditions at the Troutdale facility.

Table 3 Margin for Industrial Setting	
Factor	**Allowance**
Mixing effectiveness	5%
Short-circuiting or bypass	10%
Change from batch to continuous reactor	5%
Fluctuations in the influent fluoride and calcium ion concentration	15%
Variations in influent water quality	10%
Fluctuations in influent flow rates	5%
Total Margin for Industrial Setting	**50%**

7. Cost-Effective Treatment Differential

To determine a cost-effective treatment differential, costs were estimated for three flow rates (100, 150, and 200 gallons per minute) and four influent fluoride concentrations (50, 80, 110, and 140 mg/L). The costs were based on an outlet concentration of 45 mg/L fluoride. Table 4 shows the cost comparison for these flow rates and concentrations.

Figure 2 is a series of three graphs showing net present value per pound of fluoride (NPV/lb F) removed versus the treatment differential. The treatment differential is defined as the influent concentration minus the effluent concentration in mg/L fluoride.

Figure 2. Cost-Effective Treatment Differential Determination

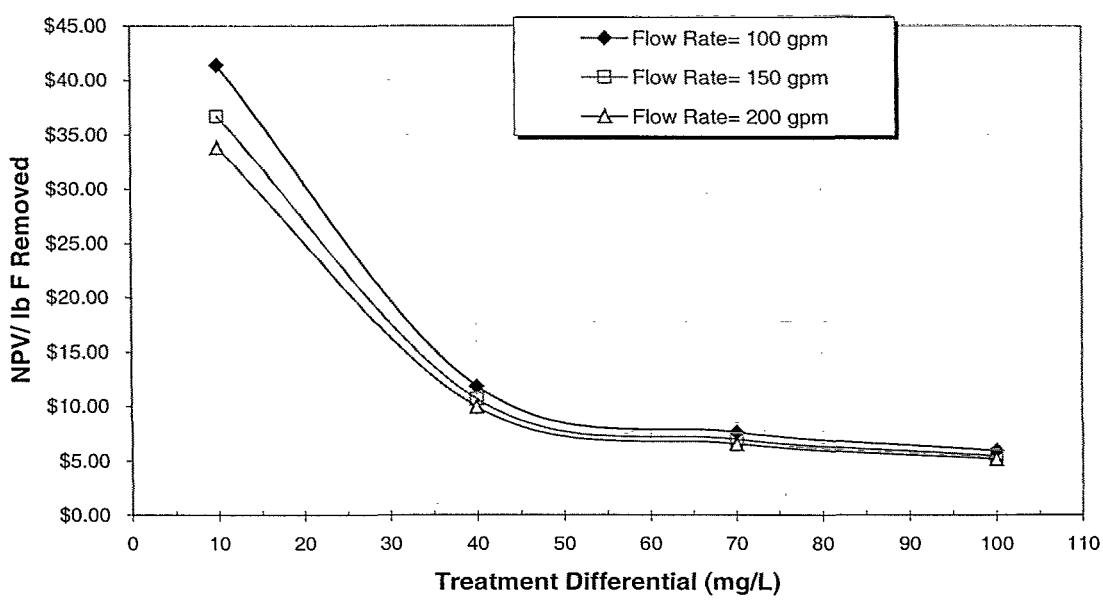


Table 4
Cost Comparison for Fluoride Removal Treatment with Varying Flowrates and Initial Fluoride Concentrations

Flow Rate (gpm)	Capital Cost [a]	Annual O&M Costs[b] (Excluding Chemical and Sludge Disposal Costs)	Influent Fluoride Concentration (mg/L)	Effluent Fluoride Concentration [d] (mg/L)	Treatment Efficiency	Treatment Differential (mg/L)	lb of Fluoride Removed per year (lb F/yr)	Annual Chemical and Sludge Disposal Costs	Net Present Value (NPV[e]) (10 yr, 4%)	Net Present Value (NPV[e]) (10 yr, 4%) per lb F Removed
100	$973,797	$48,690	50	40	20%	10	4,377	$54,723	$1,812,555	$41.41
100	$973,797	$48,690	80	40	50%	40	17,507	$87,005	$2,074,393	$11.85
100	$973,797	$48,690	110	40	64%	70	30,637	$119,288	$2,336,231	$7.63
100	$973,797	$48,690	140	40	71%	100	43,767	$151,570	$2,598,068	$5.94
150	$1,242,004	$62,100	50	40	20%	10	6,565	$82,084	$2,411,454	$36.73
150	$1,242,004	$62,100	80	40	50%	40	26,260	$130,508	$2,804,210	$10.68
150	$1,242,004	$62,100	110	40	64%	70	45,955	$178,932	$3,196,967	$6.96
150	$1,242,004	$62,100	140	40	71%	100	65,650	$227,356	$3,589,724	$5.47
200	$1,476,000	$73,800	50	40	20%	10	8,753	$109,445	$2,962,266	$33.84
200	$1,476,000	$73,800	80	40	50%	40	35,013	$174,011	$3,485,942	$9.96
200	$1,476,000	$73,800	110	40	64%	70	61,273	$238,576	$4,009,617	$6.54
200	$1,476,000	$73,800	140	40	71%	100	87,533	$303,141	$4,533,293	$5.18

[a] Capital costs were estimated based on order-of-magnitude estimates prepared for a 200-gpm system and scaled down for the 100- and 150-gpm systems using the "6/10ths rule": cost of equip. a = cost of equip. b x (capac. equip. a/capac. equip. b)$^{0.6}$. See *Plant Design and Economics for Chemical Engineers* . Peters, M.S. and Timmerhaus, K.D. (McGraw-Hill, 1968), p. 106.

[b] Annual O&M costs excluding chemical and sludge disposal costs were assumed to be 5% of capital costs

[c] Annual chemical and sludge disposal costs were estmated from detailed calculations with Ca/F mole ratio of 2 and chemical costs obtained from vendors.

[d] Derived from the treatability limit of 20 to 30 mg/L plus a margin for industrial setting of 10 to 15 mg/L = 30 to 45 mg/L.

[e] Net present value; calculated for 10 years at a 4 percent rate of return.

As shown in Figure 2, as the treatment differential increases, the NPV/lb F removed decreases to a minimum of approximately $5.00. At a treatment differential between 40 and 50 mg/L, the slopes of the curves change sharply. These curves show that, at treatment differentials below 40 to 50 mg/L, the NPV per pound of fluoride removed rapidly increases. For the 100-gallons-per-minute (gpm) system, the NPV/ lb F removed is about $7.50 at a treatment differential of 50 mg/L and is nearly tripled ($20) at a treatment differential of 30 mg/L. However, for all three capacities, the cost curves take a sharp upward turn as the treatment differential becomes less than approximately 45 mg/L.

Therefore, a treatment differential of between 40 and 50 mg/L appears to be a reasonable minimum.

8. Summary and Conclusions

The components of the MEIC as defined in Section 3 are:

- Treatability limit (Section 4) = 20 to 30 mg/L
- Margin for industrial setting (Section 5) = 10 to 15 mg/L
- Cost-effective treatment differential (Section 6) = 40 to 50 mg/L

As explained in Section 3 and Figure 1, the MEIC is the sum of these components and therefore falls within the range of 70 to 90 mg/L.

The implications of this evaluation for the Troutdale site are as follows:

- For groundwater with concentrations of fluoride less than 70 mg/L, extraction and treatment for fluoride removal is not an option to be considered further.
- For groundwater with concentrations of fluoride greater than 90 mg/L, extraction and treatment for fluoride removal is an option that can be considered along with other approaches, such as containment.
- For groundwater with concentrations of fluoride between 70 and 90 mg/L, further investigation would be required for extraction and fluoride treatment to be considered feasible.

Figures 3, 4, 5, and 6 illustrate the areas of the site where the groundwater concentrations of fluoride are between 70 and 90 mg/L and those areas where fluoride concentrations exceed 90 mg/L.

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01-DEC-1998

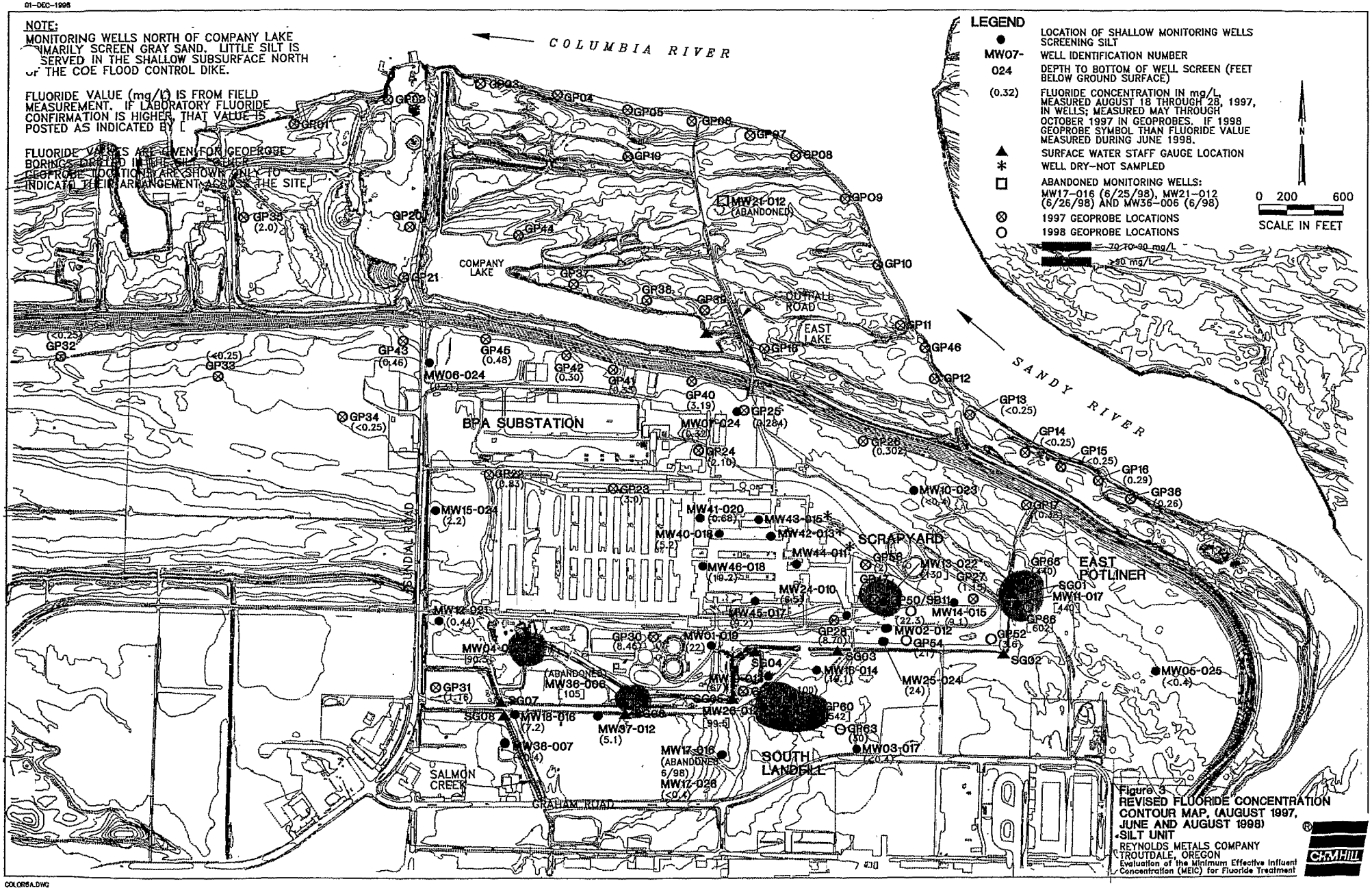
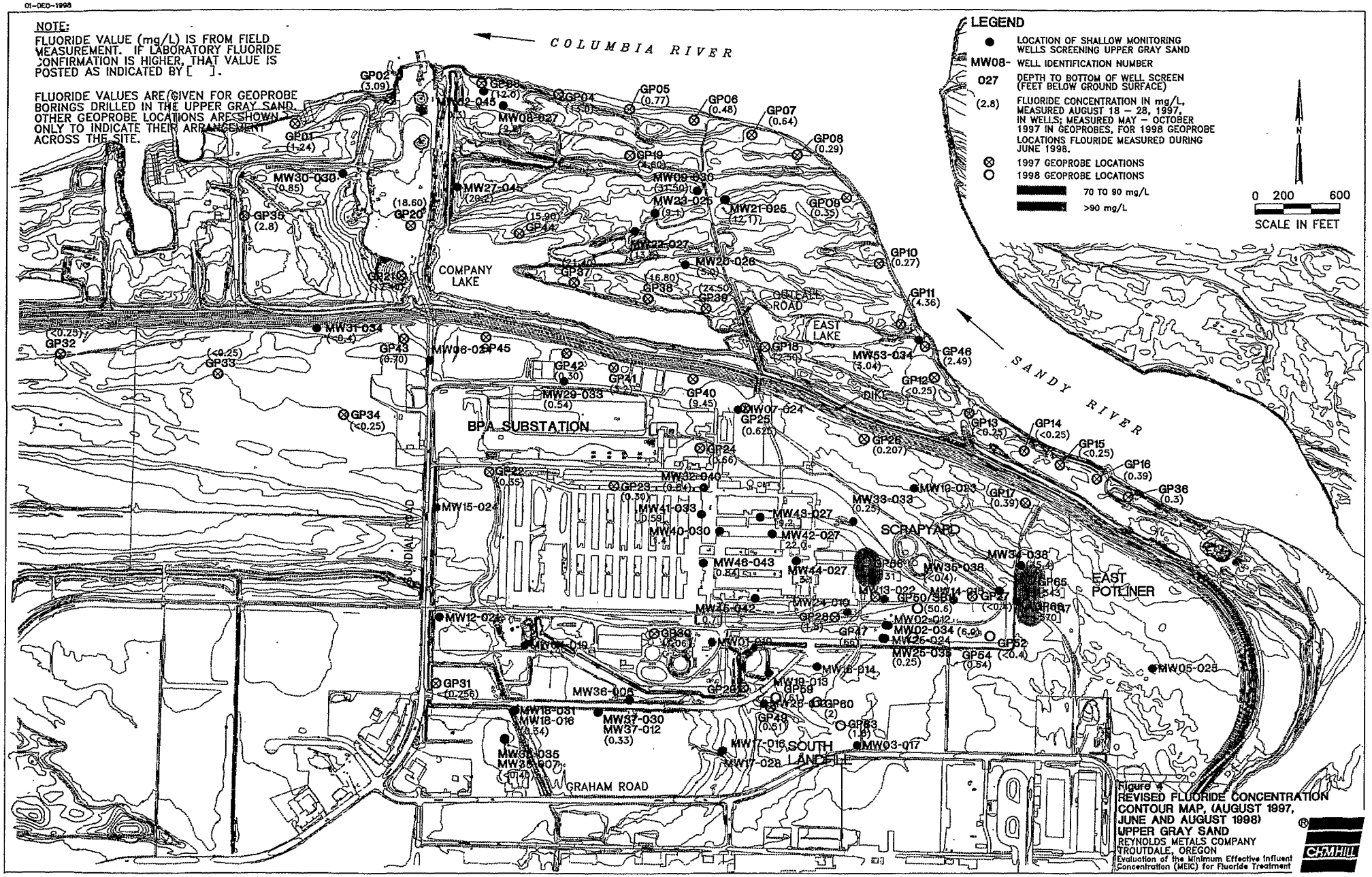


Figure 3
REVISED FLUORIDE CONCENTRATION CONTOUR MAP, (AUGUST 1997, JUNE AND AUGUST 1998)
•SILT UNIT
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Evaluation of the Minimum Effective Influent Concentration (MEIC) for Fluoride Treatment

CH2M HILL

COLOR6A.DWG

SRB COLOR2A.DWG
01-DEC-1998



COLOR2A.DWG

SRB COLOR5A.DWG
02-SEPT-1997

NOTE:
INTERMEDIATE-DEPTH MONITORING WELLS ARE GENERALLY SCREENED IN GRAY UNCONSOLIDATED SAND 80 TO 100 FEET BELOW GROUND SURFACE.

FLUORIDE VALUE (mg/L) IS FROM FIELD MEASUREMENT. IF LABORATORY FLUORIDE CONFIRMATION IS HIGHER, THAT VALUE IS POSTED AS INDICATED BY [ ].

FLUORIDE VALUES ARE GIVEN FOR GEOPROBE BORINGS DRILLED IN INTERMEDIATE-DEPTH SAND. OTHER GEOPROBE LOCATIONS ARE SHOWN ONLY TO INDICATE THEIR ARRANGEMENT ACROSS THE SITE.

*TO TARGET AN INTERVAL SUSPECTED OF BEING CONTAMINATED, MW08-127 WAS SCREENED APPROXIMATELY 50 FEET DEEPER THAN NEARBY INTERMEDIATE-DEPTH WELLS. THEREFORE, WATER LEVEL ELEVATIONS AND CONCENTRATIONS AT THIS LOCATION MAY NOT BE COMPARABLE WITH THOSE AT NEARBY LOCATIONS.

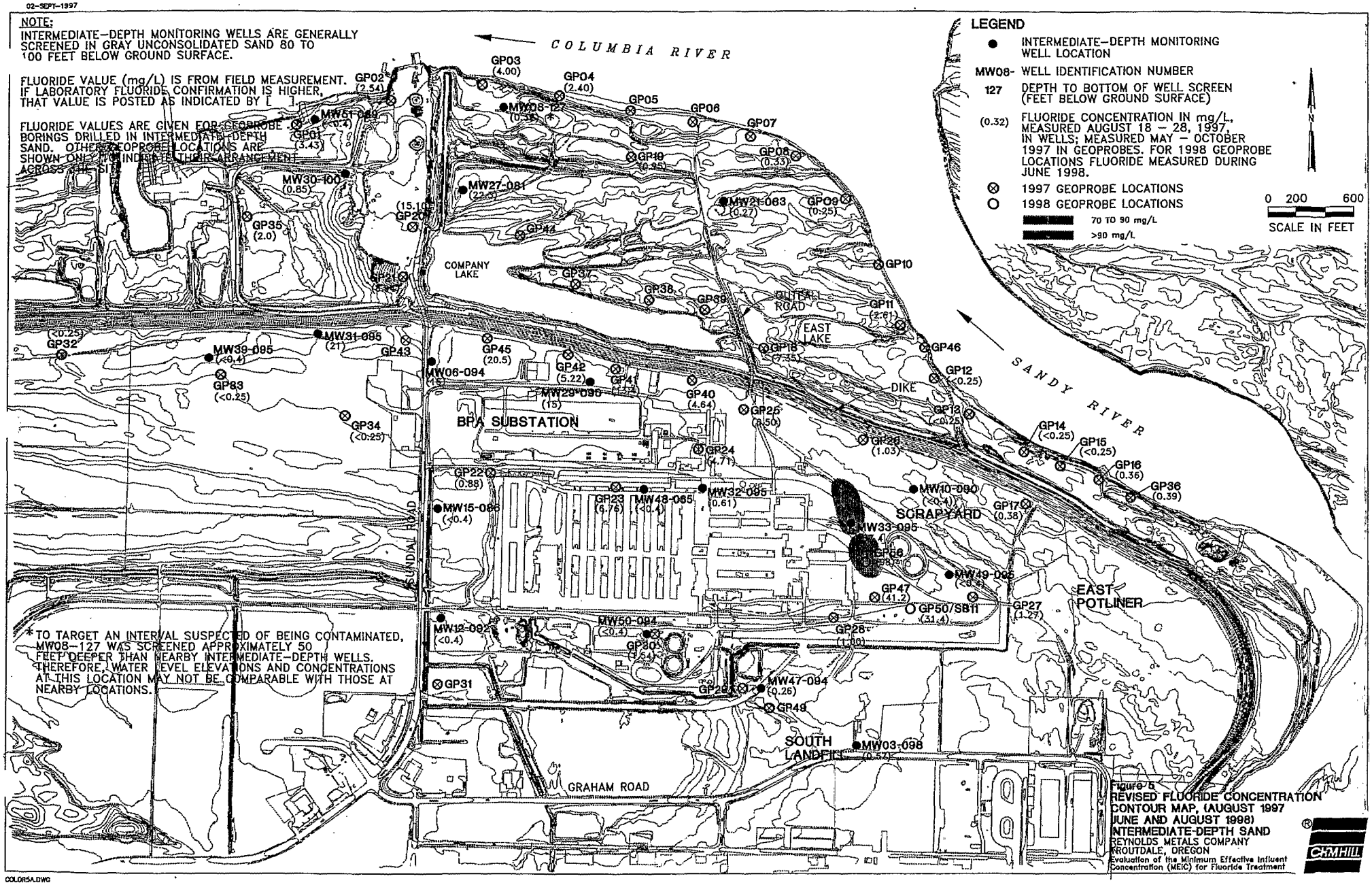


Figure 5
REVISED FLUORIDE CONCENTRATION CONTOUR MAP, (AUGUST 1997 JUNE AND AUGUST 1998) INTERMEDIATE-DEPTH SAND
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Evaluation of the Minimum Effective Influent Concentration (MEIC) for Fluoride Treatment

CH2MHILL

COLOR5A.DWG

SRB COLOR4E.DWG
08-DEC-1997

NOTE:
DEEP MONITORING WELLS ARE SCREENED 150 TO
'80 FEET BELOW GROUND SURFACE. SCREENED MATERIALS
.RE PRIMARILY GRAY SAND TO THE SOUTH, SAND AND GRAVEL
TO THE NORTH.

FLUORIDE VALUE (mg/L) IS FROM FIELD MEASUREMENT. IF
LABORATORY FLUORIDE CONFIRMATION IS HIGHER, THAT
VALUE IS POSTED AS INDICATED BY

FLUORIDE VALUES ARE GIVEN FOR GEOPROBE
BORINGS DRILLED IN THE DEEP SAND. OTHER
GEOPROBE LOCATIONS ARE SHOWN ONLY TO INDICATE
THEIR ARRANGEMENT ACROSS THE SITE.

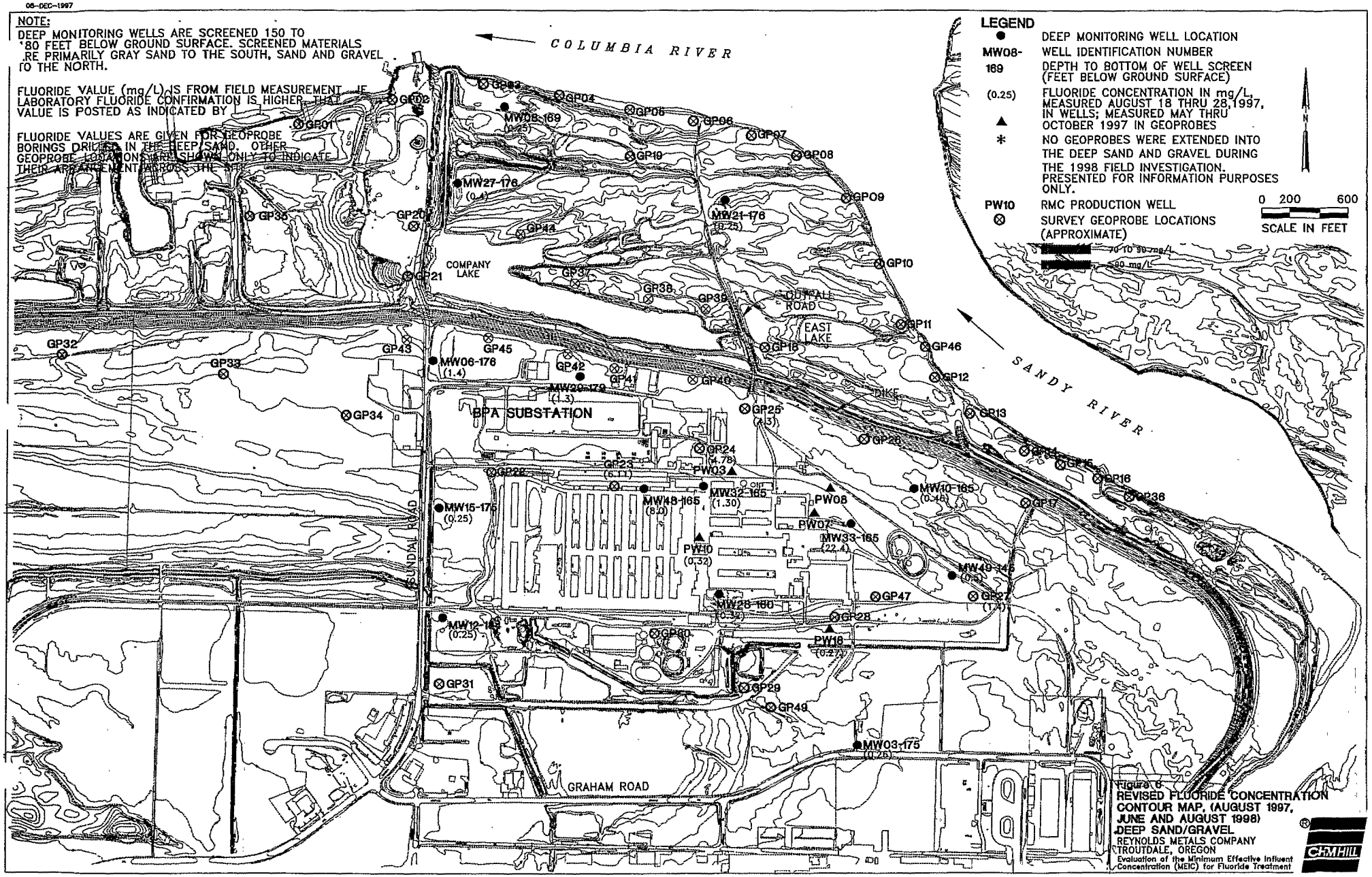


Figure 6
REVISED FLUORIDE CONCENTRATION CONTOUR MAP, (AUGUST 1997, JUNE AND AUGUST 1998) DEEP SAND/GRAVEL
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Evaluation of the Minimum Effective Influent Concentration (MEIC) for Fluoride Treatment

CH2M HILL

APPENDIX F ATTACHMENT A

Technical Memorandum: RMC Groundwater Treatability Study Lab Testing Summary

PDX180A7.DOC

TECHNICAL MEMORANDUM CH2MHILL

RMC Groundwater Treatability Study Lab Testing Summary

PREPARED FOR: RMC Project Team

PREPARED BY: Gary Hickman/CVO

DATE: October 12, 1998

1. Introduction

A groundwater treatability study has been performed in support of the Engineering Evaluation/Cost Analysis (EE/CA) for the Reynolds Metals Company (RMC) site in Troutdale, Oregon. Laboratory testing was conducted to evaluate fluoride removal from groundwater samples by precipitation with calcium chloride. All treatability testing was performed at CH2M HILL's laboratory in Corvallis, Oregon.

The overall purpose of this treatability study was to determine what portions of the site have fluoride concentrations sufficiently low that a pump-and-treat approach to groundwater remediation is not considered suitable, and will not be evaluated further. For the remaining portions of the site, pump and treat will be compared with other options.

On the basis of technology screening performed during late 1997 and summarized in *Memorandum GW No. 12: Screening of Groundwater Treatment Technology Options* (CH2M HILL, May 29, 1998), fluoride precipitation as calcium fluoride was the only treatment method tested in this study.

The laboratory testing objectives and approach are outlined below:

1. Identify a single set of "best" process operating conditions for fluoride treatment. The purpose of choosing a standard set of conditions is that it is likely that groundwater from a number of extraction wells would be treated in a single treatment system at the site. The "best" conditions were determined by varying operating parameters during bench-scale treatment of selected groundwater samples, and identifying the parameter values that produced, in general, the highest degree of fluoride removal. (Note: The set of conditions identified in the lab may or may not prove to be the optimum conditions for full-scale operation. Pilot- or full-scale trials are needed to determine optimum full-scale treatment conditions.)

2. Determine the practical concentration limit for fluoride in treated effluent. Each groundwater sample was treated individually in the laboratory using the standardized set of "best" operating parameters (identified in No. 1 above), and the effluent fluoride

concentration was measured. The measured value was assumed to be indicative of the achievable removal efficiency and the practical effluent fluoride concentration limit for treatment of groundwater extracted from that well.

3. Estimate treatment costs based on the lab testing results. Then combine the treatability results and cost estimates to indicate what fluoride concentrations in groundwater are too low to be cost-effectively reduced by ex-situ treatment.

This technical memorandum describes the lab testing portion of the treatability study, described in items 1 and 2 above.

2. Materials and Methods

Eight groundwater samples (the first eight listed in Table 1) were used initially in this treatability study. Five monitoring well (MW) and three Geoprobe (GP) samples were collected in late June and early July 1998, respectively. These wells and Geoprobe locations were selected to obtain a range of fluoride concentrations, indicated as "Target Fluoride Range" in Table 1. Upon receipt at the laboratory, the samples were analyzed for dissolved fluoride (EPA Method 300.0), dissolved aluminum, calcium, iron, magnesium, and manganese (EPA Method 200.7), total dissolved solids (TDS) (EPA Method 160.6), specific conductance (EPA Method 120.1), and pH (EPA Method 150.1). A ninth sample, GP59-020, was included in follow-up testing at the end of this study. Sample GP59-020 (also collected in June 1988) was analyzed only for dissolved fluoride, dissolved calcium, and conductivity.

Table 1
Groundwater Samples

Well ID	Site Area	Lithologic Zone	Target Fluoride Range (mg/L)	Measured Initial Fluoride Conc. (mg/L)
MW11-017	East Potliner	Silt	200-400	392
MW13-022	Scrap Yard	Silt	100-200	134
MW19-013	South Landfill	Silt	40-100	87.1
MW26-012	South Landfill	Silt	100-200	108
MW33-095	Scrap Yard	Intermediate Sand	100-200	93.4
GP56-055	Scrap Yard	Upper Gray Sand	100-200	150
GP59-045	South Landfill	Upper Gray Sand	40-100	49.8
GP66-040	East Potliner	Upper Gray Sand	20-40	21.4
GP59-020	South Landfill	Silt		1,030

The treatment method evaluated in the laboratory was fluoride precipitation as calcium fluoride, CaF_2. Calcium was provided by adding calcium chloride ($CaCl_2$) to the groundwater. The stoichiometric requirement for CaF_2 precipitation is 1 mole of calcium to

2 moles of fluoride, or a 0.5 Ca/F mole ratio. Calcium doses higher than the stoichiometric requirement often are necessary to achieve high fluoride treatment efficiencies. The theoretical minimum concentration of fluoride that can be achieved by this treatment process is about 8 mg/L, based on the solubility of CaF_2 in water of 16 mg/L. In practice, the level of fluoride achieved by this method in industry depends on several factors and ranges from around 20 to 50 mg/L.

This study employed standard jar test procedures. Batch precipitation tests were conducted in beakers mixed by a multiple-position, jar-stirring apparatus. Initially, five test series were designed to investigate the effects of five process variables: pH, reaction time, $CaCl_2$ dose, polymer addition, and solids recycling. Table 2 summarizes the test conditions, and the testing procedure used in each test series is described in more detail in Attachment A.

Table 2
Test Conditions

Test Series	Parameter Varied	Parameter Values	Samples Tested
1	pH Reaction time	7, 8, 9 pH 0.5, 1, 2 hours	MW11, MW26, GP56
2	$CaCl_2$ dose	Values ranging from 0.5 to 5.0 Ca/F mole ratio	MW11, MW19, MW26, MW33, GP56
3	Polymer[a] addition	0, 0.5, 1.0, 2.5 mg/L	MW11, GP56
4	Solids recycling	0, 500, 1,000 mg/L	MW33, GP56
5	None; used values selected in Test Series 1-4	pH 7 Reaction time = 1 hour $CaCl_2$ dose = 2 mole ratio Polymer dose = 0.5 mg/L No solids recycle	All eight original samples: MW11, MW13, MW19, MW26, MW33, GP56, GP59-045, GP66
6	Fluoride concentration	Same as Test Series 5	MW11, MW11 (200 mg F/L)[b], MW11 (75 mg F/L)[b], GP59-020, MW33-095

[a] Betz-Dearborn PolyFloc AP1110 (the polymer currently used in the fluoride treatment system at the site).
[b] Samples diluted with deionized water to specified target fluoride concentrations.

After Test Series 1-5 were completed, a sixth series of tests was conducted to further investigate the observed relationship between initial fluoride concentration and fluoride precipitation treatment effectiveness. The MW11-017 sample (approximately 395 mg F/L) and two dilutions of this sample in deionized water (targeting 200 and 75 mg F/L) were treated. An additional groundwater sample, GP59-020, was obtained from CH2M HILL's Redding, California, lab (where it had been sent for analysis) and treated. A dissolved fluoride concentration of 1,030 mg/L was measured in sample GP59-020, compared with only 50 mg/L in the GP59-045 sample used previously in this study. These two GP59 samples were obtained from the same Geoprobe location but from 20-foot and 45-foot depths, respectively. Finally, treatment of MW33-095 was repeated in an attempt to reproduce/verify earlier test results for that sample (which exhibited poor agreement).

These Test Series 6 experiments all used the same treatment conditions as Test Series 5 (shown under "Parameter Values" in Table 2).

3. Results and Discussion

The results of sample characterization analyses and Test Series 1-6 are presented and discussed in the subsections below. The results of all treatability tests performed are summarized in Attachment B.

3.1 Sample Characterization

Table 3 shows the untreated sample characterization results. Sample color ranged from light amber to brown. Dissolved fluoride concentrations ranged from roughly 20 to 400 mg/L, except for GP59-020, which contained approximately 1,000 mg/L. Dissolved fluoride concentrations measured at the beginning and end of the study showed good agreement. The GP59-045 sample was somewhat unusual in terms of its relatively high concentrations of dissolved calcium (98 mg/L), magnesium (60 mg/L), and manganese (3.5 mg/L).

3.2 Test Series 1—pH and Reaction Time

Table 4 shows the results from Test Series 1, in which pH and reaction time were varied. Observations are given below:

- For sample MW11, all conditions tested worked well (i.e., achieved fluoride removal efficiencies >93 percent),μ and neither pH nor reaction time variations had a dramatic effect on fluoride precipitation. Nevertheless, pH values of 7-8 and reaction times of 1-2 hours (hr) appeared to yield marginally better performance, and the highest fluoride removal was obtained at pH 7 and 1-hr reaction time.
- For sample MW26, no combination of pH and reaction time was effective for fluoride precipitation.
- For sample GP56, the highest fluoride removal was achieved at pH 7 and 1-hr reaction time.

On the basis of these results, pH 7 (or at least 7-8) and 1-hr reaction time were chosen as the "best" values of those parameters for use in subsequent fluoride treatability testing.

3.3 Test Series 2—Calcium Chloride Dose

Table 5 shows the results of Test Series 2, in which the calcium chloride dose was varied. Three sets of tests were conducted in sequence, because of the poor fluoride treatment achieved in some of the early tests. The results are discussed below:

- In the first set of tests, using $CaCl_2$ doses of 0.5-1 Ca/F mole ratio, excellent fluoride treatment was achieved for the groundwater from MW11 (>95 percent at doses ≥0.75 Ca/F mole ratio), fair treatment was achieved for GP56 (66 percent at a 1 Ca/F mole ratio), and little or no treatment was achieved for MW26.

Table 3
Groundwater Sample Characterization Data

Parameter	Units	Sample ID								
		MW11-017	MW13-022	MW19-013	MW26-012	MW33-095	GP56-055	GP59-045	GP59-020	GP66-040
Fluoride, dissolved[a]	mg/L	392	134	87.1	108	93.4	150	49.8	1,030	21.4
Fluoride, dissolved[b]	mg/L	397	134	88.3	103	91.6	142	49.4	1,060	21.5
Aluminum, dissolved	µg/L	3,000	2,680	6,190	4,740	665	1,050	529	nm	292
Calcium, dissolved	µg/L	14,300	2,420	2,840	1,480	6,420	2,960	98,000	58,600	7,960
Iron, dissolved	µg/L	4,890	2,310	2,270	2,540	4,540	3,800	2,070	nm	544
Magnesium, dissolved	µg/L	1,720	610	1,480	881	5,310	524	60,300	nm	6,510
Manganese, dissolved	µg/L	433	22.0	134	48.0	170	34.7	3,460	nm	315
Total dissolved solids (TDS)	mg/L	1,270	508	534	591	392	950	1,960	nm	370
Conductivity	µmho/cm	2,130	948	949	1,120	704	1,270	2,960	7,850	346
pH	pH units	8.67	7.64	7.16	7.33	7.31	9.49	7.67	nm	7.60

[a] Measured at beginning of study.
[b] Measured at end of study.
nm = not measured.

Table 4 Test Series 1 Results						
Sample ID	pH[a]	$CaCl_2$ Dose (Ca/F mole ratio)	Reaction Time (hr)	Fluoride Concentration (mg/L)		Removal Efficiency (%)
				Initial	Final	
MW11-017	7	0.6	0.5	392	21.4	94.5
MW11-017	7	0.6	1	392	19.1	95.1
MW11-017	7	0.6	2	392	19.3	95.1
MW11-017	8	0.6	0.5	392	23.1	94.1
MW11-017	8	0.6	1	392	21.2	94.6
MW11-017	8	0.6	2	392	21.0	94.6
MW11-017	9	0.6	0.5	392	27.2	93.1
MW11-017	9	0.6	1	392	24.7	93.7
MW11-017	9	0.6	2	392	23.2	94.1
MW26-012	7	0.6	0.5	108	98.6	8.7
MW26-012	7	0.6	1	108	102	5.6
MW26-012	7	0.6	2	108	93.9	13.1
MW26-012	8	0.6	0.5	108	95.5	11.6
MW26-012	8	0.6	1	108	99.2	8.1
MW26-012	8	0.6	2	108	101	6.5
MW26-012	9	0.6	0.5	108	90.5	16.2
MW26-012	9	0.6	1	108	98.4	8.9
MW26-012	9	0.6	2	108	104	3.7
GP56-055	7	0.6	0.5	150	47.1	68.6
GP56-055	7	0.6	1	150	27.7	81.5
GP56-055	7	0.6	2	150	39.8	73.5
GP56-055	8	0.6	0.5	150	40.1	73.3
GP56-055	8	0.6	1	150	35.9	76.1
GP56-055	8	0.6	2	150	53.0	64.7
GP56-055	9	0.6	0.5	150	68.3	54.5
GP56-055	9	0.6	1	150	36.4	75.7
GP56-055	9	0.6	2	150	63.0	58.0

[a] pH adjusted with H_2SO_4

Table 5 Test Series 2 Results						
Sample ID	pH [a]	$CaCl_2$ Dose (Ca/F mole ratio)	Reaction Time (hr)	Fluoride Concentration (mg/L)		Removal Efficiency (%)
				Initial	Final	
MW11-017	7	0.5	1	392	37.1	90.5
MW11-017	7	0.6	1	392	19.8	94.9
MW11-017	7	0.75	1	392	12.8	96.7
MW11-017	7	1.0	1	392	9.4	97.6
MW26-012	7	0.5	1	108	104	3.7
MW26-012	7	0.6	1	108	104	3.7
MW26-012	7	0.75	1	108	102	5.6
MW26-012	7	1.0	1	108	94.3	12.7
GP56-055	7	0.5	1	150	133	11.3
GP56-055	7	0.6	1	150	75.0	50.0
GP56-055	7	0.75	1	150	88.7	40.9
GP56-055	7	1.0	1	150	50.4	66.4
MW19-013	7	0.6	1	87.1	91.5	-5.1
MW19-013	7	1	1	87.1	88.9	-2.1
MW19-013	7	2	1	87.1	77.8	10.7
MW26-012	7	1.5	1	108	89.2	17.4
MW26-012	7	2	1	108	88.2	18.3
MW26-012	7	3	1	108	105	2.8
MW33-095	7	0.6	1	93.4	90.1	3.5
MW33-095	7	1	1	93.4	97.7	-4.6
MW33-095	7	2	1	93.4	95.4	-2.1
MW19-013	7.16[b]	1	1	87.1	78.1	10.3
MW19-013	7.16[b]	2	1	87.1	69.7	20.0
MW19-013	7.16[b]	5	1	87.1	33.1	62.0
MW26-012	7.33[b]	1	1	108	58.7	45.6
MW26-012	7.33[b]	2	1	108	27.6	74.4
MW26-012	7.33[b]	5	1	108	48.9	54.7

[a] pH adjusted with H_2SO_4, except where noted otherwise.

[b] pH not adjusted.

- In the second set of tests, higher $CaCl_2$ doses (1.5-3) failed to substantially improve treatment of MW26 groundwater. Also, virtually no fluoride was precipitated from the MW19 or MW33 groundwater samples at $CaCl_2$ doses of 0.6-2 Ca/F mole ratio.
- In the first two sets of tests, a solid precipitate formed in all of the tests—even when no reduction in dissolved fluoride occurred. It was assumed that calcium was the cationic part of the precipitate, and sulfate was identified as the possible anionic part of the precipitating salt. On the basis of this supposition, the third set of tests was conducted without adjusting the sample pH, to avoid adding sulfate to the groundwater. In this case, samples with a natural pH close to 7 were used; in later tests HCl was substituted for H_2SO_4 for pH adjustment.
- In the third set of tests, fluoride removal efficiency in MW26 was good (74 percent) at a $CaCl_2$ dose of 2 Ca/F mole ratio but lower (55 percent) at a $CaCl_2$ dose of 5 Ca/F mole ratio. In contrast, fluoride removal efficiency in MW19 was poor (20 percent) at the 2 Ca/F mole ratio dose but fair (62 percent) at a $CaCl_2$ dose of 5 Ca/F mole ratio.

These results indicated that sulfate (added as H_2SO_4 for pH adjustment) interfered with fluoride precipitation in some of the groundwater samples. A $CaCl_2$ dose of 2 Ca/F mole ratio was chosen as the generalized "best" value for use in subsequent fluoride treatability testing. It should be noted that this would be considered a very high dose in industrial practice, representing four times the stoichiometric amount of calcium required for precipitation of CaF_2. This excess would also increase the total dissolved solids in a treatment system effluent.

3.4 Test Series 3—Polymer Addition

The effects of polymer addition and dose were evaluated visually. No analyses were conducted because the anionic polymer used (Betz-Dearborn PolyFloc AP1110) was expected to enhance settling but not to cause precipitation of fluoride from the aqueous phase to the solid phase and, thus, not to affect the dissolved fluoride concentration.

Both polymer doses (1 and 2.5 mg/L) resulted in the formation of large flocs, rapid settling, and a clear supernatant. The 1 mg/L polymer dose appeared to create better settling characteristics than the 2.5 mg/L dose, and it seemed that an even lower dose might be adequate. A polymer dose of 0.5 mg/L was used in the next test series and worked as well as 1 or 2.5 mg/L, so the 0.5 mg/L polymer dose was chosen as the "best" value for use in subsequent fluoride treatability testing.

3.5 Test Series 4—Solids Recycling

Table 6 shows the results from Test Series 4, in which recycling of two concentrations of CaF_2 solids was simulated. Recycling solids did not improve fluoride removal, compared with the control test with no recycling, in either of the two groundwater samples tested. Consequently, no solids recycling was chosen as the "best" value for use in subsequent fluoride treatability testing. (Note: These results should not be interpreted to mean that solids recycling would not be beneficial in full-scale treatment. In addition to potentially improving fluoride precipitation, solids recycling has the potential of reducing the chemical dose and reaction time requirements.)

Table 6
Test Series 4 Results

Sample ID	pH	$CaCl_2$ Dose (Ca/F mole ratio)	Polymer Dose (mg/L)	Recycled Solids (mg/L)	Reaction Time (hr)	Fluoride Concentration (mg/L) Initial	Fluoride Concentration (mg/L) Final	Removal Efficiency (%)
MW33-095	7.31[a]	2	0.5	0	1	93.4	12.4	86.7
MW33-095	7.31[a]	2	0.5	500	1	93.4	47.3	49.4
MW33-095	7.31[a]	2	0.5	1,000	1	93.4	43.1	53.9
GP56-055	7[b]	2	0.5	0	1	150	17.6	88.3
GP56-055	7[b]	2	0.5	500	1	150	22.5	85.0
GP56-055	7[b]	2	0.5	1,000	1	150	38.5	74.3

[a] pH not adjusted.
[b] pH adjusted with HCl.

3.6 Test Series 5—"Best" Standardized Conditions

Table 7 shows the results of Test Series 5, in which the "best" standardized test conditions were used. The "best" standardized test conditions are the values of pH, reaction time, $CaCl_2$ dose, polymer dose, and solids recycling chosen in Test Series 1-4 because they yielded, in general, the highest levels of fluoride removal. Also included in Table 7 are data from test runs conducted in other test series using treatment conditions similar to the "best" standardized conditions (for example, using a slightly different pH or $CaCl_2$ or polymer dose).

Table 7
"Best" Standardized Treatment Conditions Results

Sample ID	pH [a]	$CaCl_2$ Dose (Ca/F mole ratio)	Polymer Dose (mg/L)	Recycled Solids (mg/L)	Reaction Time (hr)	Fluoride Concentration (mg/L) Initial	Fluoride Concentration (mg/L) Final	Removal Efficiency (%)
MW11-017	7[b]	1	0	0	1	392	9.4	97.6
*	7	2	0.5	0	1	397	10.4	97.4
MW13-022 *	7	2	0.5	0	1	134	18.6	86.1
MW19-013	7.16[c]	2	0	0	1	87.1	69.7	20.0
*	7	2	0.5	0	1	88.3	70.4	20.3
MW26-012	7.33[c]	2	0	0	1	108	27.6	74.4
*	7	2	0.5	0	1	103	17.5	83.0
MW33-095	7.31[c]	2	0	0	1	93.4	12.4	86.7
*	7	2	0.5	0	1	91.6	38.5	58.0
*	7.31[c]	2	0.5	0	1	91.6	89.7	2.1
*	7	2	0.5	0	1	91.6	87.1	4.9
GP56-055	7	2	0	0	1	150	17.6	88.3
*	7	2	0.5	0	1	142	28.8	79.7
GP59-045 *	7	2	0.5	0	1	49.4	48.6	1.6
GP66-040 *	7	2	0.5	0	1	21.5	23.0	-7.0

[a] pH adjusted with HCl except where noted otherwise.
[b] pH adjusted with H_2SO_4.
[c] pH not adjusted.
* Indicates Test Series 5 results.

Observations on the data are given below:

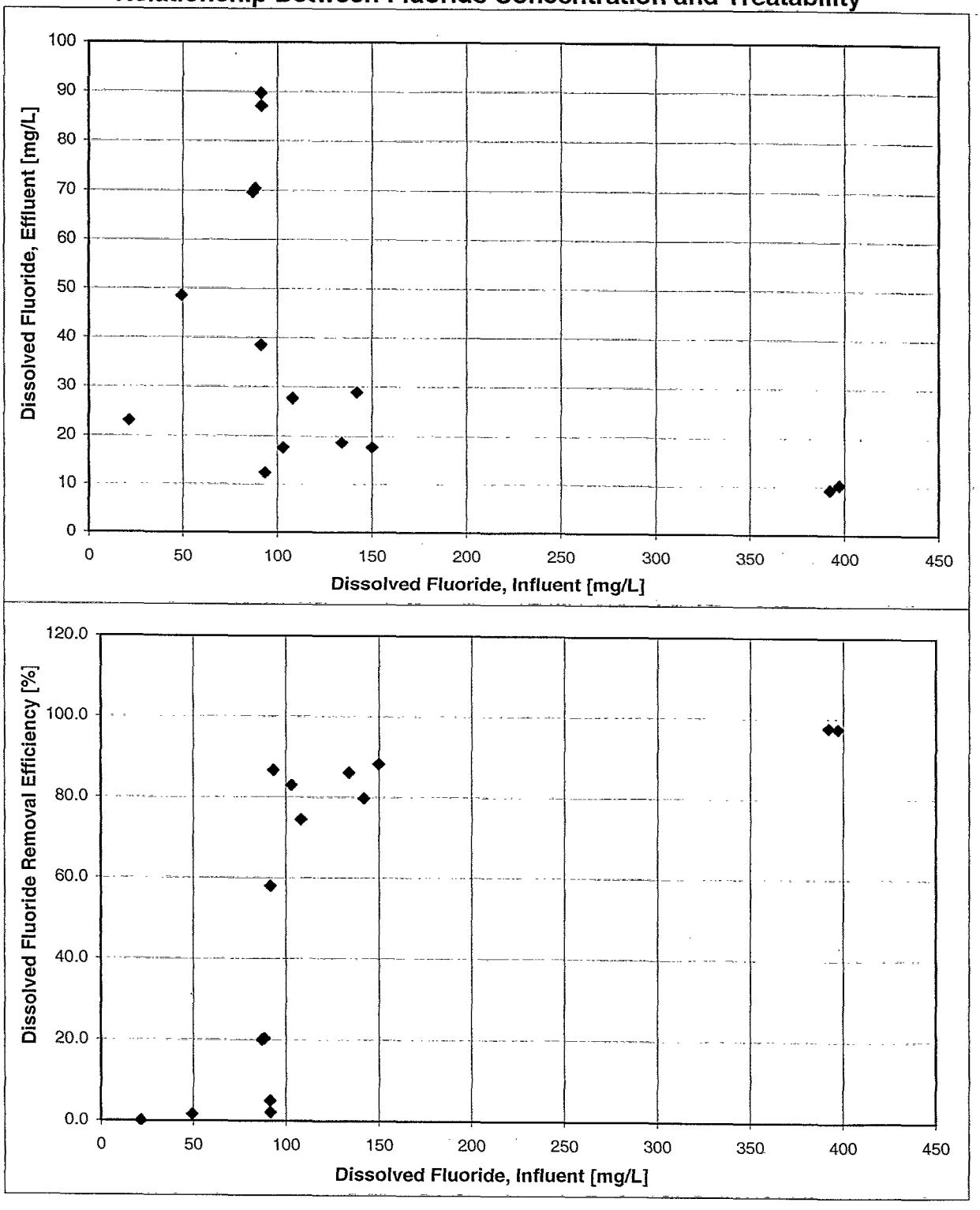
- Reasonably effective fluoride removal was achieved using the "best" standardized treatment conditions in four of eight groundwater samples tested (MW11, MW13, MW26, and GP56). The effluent fluoride concentrations for these treatments were roughly 10 to 30 mg/L, and the fluoride removal efficiency ranged from 74 to 98 percent.
- Fluoride treatment was ineffective for three of eight groundwater samples tested (MW19, GP59-045, GP66). Fluoride removal efficiency was virtually zero for the two Geoprobe samples, but this was not too surprising considering their low fluoride concentrations before treatment (approximately 50 and 21 mg/L). Fluoride removal efficiency was only 20 percent for MW19 under the "best" standardized treatment conditions. (A fluoride removal efficiency of 62 percent had been achieved for MW19 in Test Series 2 using a 5 Ca/F mole ratio $CaCl_2$ dose, but, at 10 times the stoichiometric requirement, this was considered an unreasonably high dosage.)
- Fluoride treatment was inconsistent for one of the groundwater samples (MW33-095). The fluoride treatment efficiency measured in the first test under Test Series 5 (58 percent) was not as high as the efficiency in a similar test under Test Series 4 (87 percent). Consequently, both of these tests were repeated, and this time treatment was ineffective (2.1 and 4.9 percent fluoride removal efficiency). A follow-up test on MW33-095 conducted under Test Series 6 confirmed the poor treatability of this sample (4.2 percent). These data indicate that fluoride treatability deteriorated over time, suggesting a chemical change in the sample, but no ready explanation for the treatment variability is apparent. Without further testing on a freshly collected sample, the potential for effectively treating this groundwater would have to be considered low.

Using the data from Table 7, effluent fluoride concentration and fluoride removal efficiency are plotted versus influent fluoride concentration in Figure 1. This figure illustrates the observed relationship between fluoride treatability and initial fluoride concentration. Groundwater samples with a fluoride concentration greater than about 100 mg/L were much more treatable than samples containing less than 100 mg/L of fluoride. Although this relationship appears to hold for the samples tested, it is not clear whether this is a cause-and-effect relationship or just coincidental and a function of some other factor such as water chemistry, fluoride source, etc. Therefore, caution should be exercised in concluding that <u>any</u> groundwater with fluoride <100 mg/L is untreatable and that <u>any</u> groundwater with fluoride >100 mg/L is treatable. Further testing to investigate the treatability-concentration relationship was performed in Test Series 6 (discussed below).

Figure 2 shows plots of fluoride removal efficiency versus the site area where groundwater samples were obtained and sample depth [using data from Test Series 5 (and 4.9 percent for MW33)]. No consistent relationship is apparent in these plots.

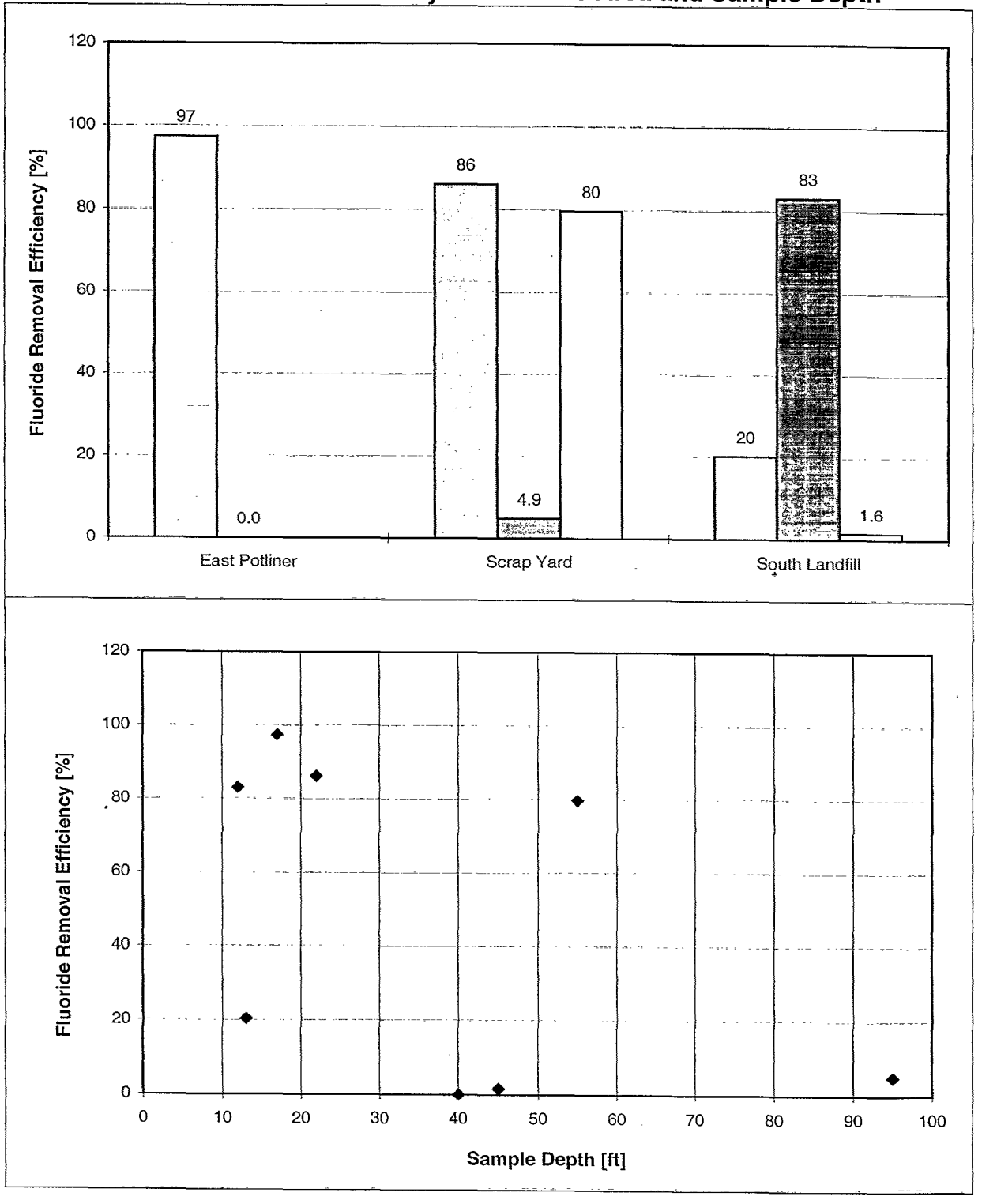
Table 8 shows effluent solids and conductivity data for Test Series 5. Effluent TSS (total suspended solids) concentration was relatively high in the GP56 sample and, to a lesser extent, in the MW26 and GP59-045 samples. Although effluent TSS is an indicator of solids settleability, elevated TSS in these lab tests is not necessarily indicative of poor settling because a few large clumps of floating solids in a small sample aliquot can skew the TSS

Figure 1
Relationship Between Fluoride Concentration and Treatability



Pdx1807e.xls/Fig1

Figure 2
Fluoride Removal Efficiency Versus Site Area and Sample Depth



Pdx1807e.xls/Fig2

measurement upwards. Based on visual inspection, all of the samples appeared to settle reasonably well, especially with polymer addition. Effluent TDS (total dissolved solids) and specific conductivity levels (Table 8) were substantially higher than influent levels (Table 3). These increases can be attributed largely to the excess $CaCl_2$ and pH adjustment chemicals added to the samples. The MW11 effluent had the highest effluent TDS and conductivity because that sample contained by far the most fluoride and therefore received the highest $CaCl_2$ dose.

Table 8
Test Series 5 Effluent Solids and Conductivity Data

Sample ID	TSS (mg/L)	TDS (mg/L)	Conductivity (μmho/cm)
MW11-017	26	5,170	7,280
MW13-022	11	2,490	3,020
MW19-013	40	2,270	3,170
MW26-012	73	2,200	3,420
MW33-095	24	2,930	2,440
GP56-055	208	3,240	3,800
GP59-045	60	2,600	3,670
GP66-040	14	3,310	4,150

3.7 Test Series 6 (Follow-up Testing)—Initial Fluoride Concentration

Table 9 shows the Test Series 6 results. The MW11 sample was tested "as received" (dissolved fluoride ≅ 395 mg/L) and after dilution with deionized water to approximately 200 and 75 mg F/L. Interestingly, the two higher concentrations were treated effectively but the lower concentration was not. The GP59-020 groundwater sample (dissolved fluoride ≅ 1,000 mg/L) was treated effectively (removal efficiency = 97 percent), whereas the GP59-045 sample, with a much lower fluoride concentration (dissolved fluoride ≅ 49.4 mg/L), was found to be untreatable in Test Series 5 (removal efficiency = 1.6 percent). These results support the observed relationship between fluoride treatment effectiveness and initial fluoride concentration discussed above. However, they do not conclusively establish a cause-and-effect relationship, so extrapolation of this relationship to other wells at the site is not recommended without confirmation. Figure 3 is a plot of efficiency versus initial concentration including the Test Series 6 data.

Table 9
Test Series 6 Results

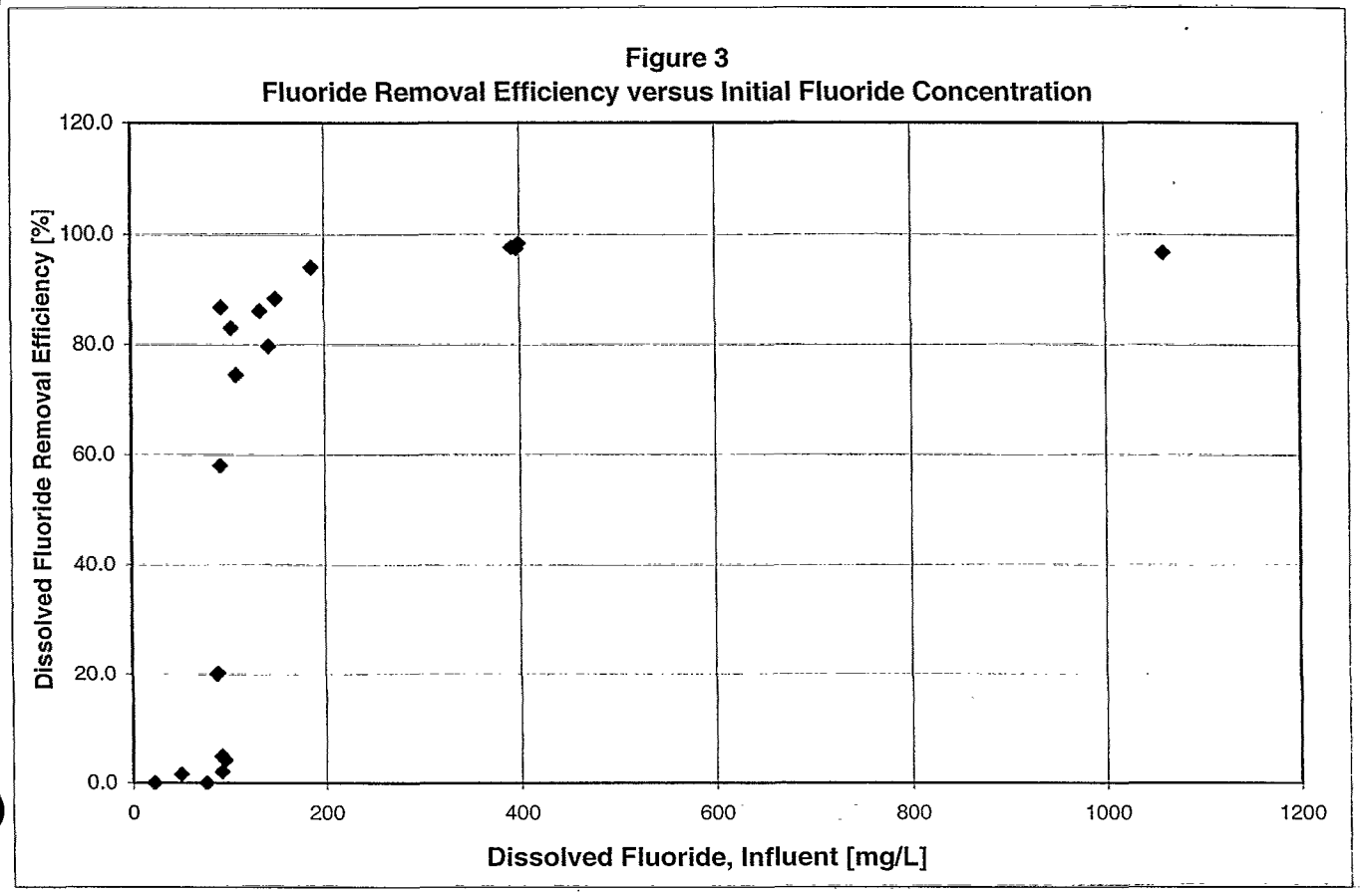
Sample ID	pH [a]	$CaCl_2$ Dose (Ca/F mole ratio)	Polymer Dose (mg/L)	Recycled Solids (mg/L)	Reaction Time (hr)	Fluoride Concentration (mg/L)		Removal Efficiency (%)
						Initial	Final	
MW11-017 (395 mg F/L)	7	2	0.5	0	1	399	6.73	98.3
MW11-017 (200 mg F/L)	7	2	0.5	0	1	187	11.3	94.0
MW11-017 (75 mg F/L)	7	2	0.5	0	1	75.5	76.6	-1.5
MW33-095	7	2	0.5	0	1	94.9	90.9	4.2
GP59-020	7	2	0.5	0	1	1,060	35.4	96.7

[a] pH adjusted with HCl.

4. Summary and Conclusions

The laboratory testing results support the following conclusions:

- The "best" standardized treatment conditions identified in this laboratory study were: pH = 7; reaction time = 1 hour; $CaCl_2$ dose = 2 Ca/F mole ratio; polymer dose = 0.5 mg/L; and no solids recycle.
- Sulfate addition (as sulfuric acid for pH adjustment) interfered with fluoride precipitation in some of the samples tested.
- Fluoride treatability was reasonably effective for five out of nine groundwater samples tested (including the additional sample, GP59-020, evaluated in Test Series 6), ineffective for three out of nine groundwater samples, and inconsistent for one groundwater sample.
- For the samples that were effectively treated, effluent dissolved fluoride concentrations of 7 to 35 mg/L were achieved, representing removal efficiencies of 74 to 98 percent. For the samples that were not effectively treated, fluoride removal efficiency was often around 0 to 5 percent (i.e., no treatment). Effluent dissolved fluoride concentrations for those samples not effectively treated ranged from 22 to 90 mg/L.
- Groundwater samples containing > 100 mg F/L tended to be treatable for fluoride removal, and samples containing < 100 mg F/L tended to be untreatable, under the treatment conditions tested. Whether these results represent a causal relationship and can be extended to other groundwater at the site is unknown.
- No consistent relationship was evident between fluoride treatability and either site area or sample depth.



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APPENDIX F ATTACHMENT B

Test Procedures

APPENDIX F ATTACHMENT B

Test Series 1 - pH and Reaction Time

Test Conditions

	pH	$CaCl_2$ Dose (Ca/F mole ratio)	Polymer Dose (mg/L)	Recycled Solids (mg/L)	Reaction Time (hr)
MW11-017	7, 8, 9	0.6	0	0	0.5, 1, 2
MW26-012	7, 8, 9	0.6	0	0	0.5, 1, 2
GP56-055	7, 8, 9	0.6	0	0	0.5, 1, 2

Procedure:

1. Transfer 500-milliliter (mL) sample aliquots to beakers; rapid mix
2. Adjust pH to target value - 7, 8, or 9 - using H_2SO_4 or NaOH
3. Add $CaCl_2$ dose
4. Re-adjust pH to target value (fine tune)
5. Rapid mix for 30 seconds (s) longer, then reduce mixing speed
6. Slow mix for target reaction time - 30, 60, or 120 minutes (min)
7. Collect samples for analysis, filter through 0.45-µm membrane filter, and "quench" reaction in filtrates by adjusting to pH 5 with HCl
8. Analyze effluent samples for dissolved fluoride

Test Series 2 - $CaCl_2$ Dose

Test Conditions

Sample	pH	$CaCl_2$ Dose (Ca/F mole ratio)	Polymer Dose (mg/L)	Recycled Solids (mg/L)	Reaction Time (hr)
MW11-017	7	0.5, 0.6, 0.75, 1	0	0	1
MW26-012	7	0.5, 0.6, 0.75, 1	0	0	1
GP56-055	7	0.5, 0.6, 0.75, 1	0	0	1
MW26-012	7	1.5, 2, 3	0	0	1
MW19-013	7	0.6, 1, 2	0	0	1
MW33-095	7	0.6, 1, 2	0	0	1
MW26-012	7.33*	1, 2, 5	0	0	1
MW19-013	7.16*	1, 2, 5	0	0	1

* pH not adjusted. In Test Series 1 and the first two parts of Test Series 2, pH was adjusted with H_2SO_4. In the last part of Test Series 2, pH was not adjusted. In subsequent testing, pH was either not adjusted or adjusted with HCl to avoid adding sulfate to the samples.

Procedure:

1. Transfer 500-mL sample aliquots to beakers; rapid mix
2. Adjust to pH 7*
3. Add target $CaCl_2$ dose; rapid mix for 30 s longer, then reduce mixing speed
4. Slow mix for 1-hr reaction time
5. Collect samples for analysis, filter through 0.45-µm membrane filter, and "quench" reaction in filtrates by adjusting to pH 5 with HCl
6. Analyze effluent samples for dissolved fluoride

Test Series 3 - Polymer Addition

Test Conditions

Sample	pH	$CaCl_2$ Dose (Ca/F mole ratio)	Polymer Dose (mg/L)	Recycled Solids (mg/L)	Reaction Time (hr)
MW11-017	7	2	0, 1, 2.5	0	1
GP56-055	7.16*	2	0, 1, 2.5	0	1

*pH not adjusted

Procedure:

1. Transfer 500-mL sample aliquots to beakers; rapid mix
2. Adjust pH of MW11 to 7; do not adjust pH of GP56
3. Add target $CaCl_2$ dose
4. Add polymer doses; rapid mix for 30 s longer, then reduce mixing speed
5. Slow mix for 1-hr reaction time
6. Observe floc formation and settling; record observations (no sampling/analysis for this test series)

Test Series 4 - Solids Recycle

Test Conditions

Sample	pH	$CaCl_2$ Dose (Ca/F mole ratio)	Polymer Dose (mg/L)	Recycled Solids (mg/L)	Reaction Time (hr)
GP56-055	7*	2	0.5	0, 500, 1,000	1
MW33-095	7.31**	2	0.5	0, 500, 1,000	1

* pH adjusted with HCl **pH not adjusted

Procedure:

1. Make CaF_2 solids for recycling using MW11 sample:
   - Treat 1.5 L by lowering pH to 8 with HCl, adding $CaCl_2$ dose of 1 Ca/F mole ratio, polymer dose of 0.5 mg/L, and slow mixing for 1 hr
   - Allow to settle and decant supernatant, retaining the solids

- Calculate CaF_2 solids concentration assuming 100 percent fluoride precipitation

2. Transfer 500-mL sample aliquots to beakers (two for each sample to conduct the 0 and 500 mg/L solids recycle tests); rapid mix
3. Add target solids recycle dose (either none or 500 mg/L)
4. Adjust pH of GP56 to 7 with HCl; do not adjust pH of MW33
5. Add $CaCl_2$ dose
6. Add polymer dose; rapid mix for 30 s longer, then reduce mixing speed
7. Slow mix for 1-hr reaction time
8. Allow to settle, collect supernatant samples for fluoride analysis; filter and quench filtrates
9. Decant remaining supernatant from the 500 mg/L recycled solids test beaker, retaining the sludge; use these beakers with the sludge for the 1,000 mg/L solids recycle tests
10. Refill the beakers with 500 mL of the respective samples, and add another 500 mg/L of solids (for a total of 1,000 mg/L plus whatever precipitated in the first test)
11. Adjust pH, add $CaCl_2$ and polymer doses, slow mix for 1 hr, and collect samples for analysis as above

Test Series 5 - "Best" Standardized Conditions

Test Conditions

Sample	pH	$CaCl_2$ Dose (Ca/F mole ratio)	Polymer Dose (mg/L)	Recycled Solids (mg/L)	Reaction Time (hr)
MW11-017	7	2	0.5	0	1
MW13-022	7	2	0.5	0	1
MW19-013	7	2	0.5	0	1
MW26-012	7	2	0.5	0	1
MW33-095	7	2	0.5	0	1
GP56-055	7	2	0.5	0	1
GP59-045	7	2	0.5	0	1
GP66-040	7	2	0.5	0	1
MW33-095	7*	2	0.5	0	1
MW33-095	7.31**	2	0.5	0	1

* pH adjusted with HCl **pH not adjusted

Procedure:

1. Transfer 500-mL sample aliquots to beakers; rapid mix
2. Adjust pH to 7 with HCl (except for last test)
3. Add target $CaCl_2$ dose
4. Add polymer dose, rapid mix for 30 s longer, then reduce mixing speed
5. Slow mix for 1-hr reaction time
6. Turn off stirrer and allow floc to settle

7. Collect supernatant samples for analysis; filter and quench samples to be analyzed for fluoride

Test Series 6 (Follow-up Testing) - Initial Fluoride Concentration

Test Conditions

Sample	pH	$CaCl_2$ Dose (Ca/F mole ratio)	Polymer Dose (mg/L)	Recycled Solids (mg/L)	Reaction Time (hr)
MW11-017 (as-received, 399 mg F/L)	7	2	0.5	0	1
MW11-017 (diluted to 187 mg F/L)	7	2	0.5	0	1
MW11-017 (diluted to 75.5 mg F/L)	7	2	0.5	0	1
MW33-095 (94.5 mg F/L)	7	2	0.5	0	1
GP59-020 (1,060 mg F/L)	7	2	0.5	0	1

Procedure:

1. Make dilutions of MW11 sample in deionized water assuming an initial fluoride concentration of 395 mg/L. Transfer 1-L sample aliquots to beakers, except use a 100-mL aliquot for GP59-020 because the available sample volume is limited. Rapid mix
2. Adjust to pH 7 using HCl
3. Add target $CaCl_2$ dose, add polymer dose, rapid mix for 30 s longer, then reduce mixing speed. Assume initial fluoride concentration = 1,030 mg/L for GP59-020.
4. Slow mix for 1-hr reaction time
5. Collect samples for analysis, filter through 0.45-µm membrane filter, and "quench" reaction in filtrates by adjusting to pH 5 with HCl
6. Analyze influent and effluent samples for dissolved fluoride, and GP59-020 influent for conductivity and calcium

APPENDIX F ATTACHMENT C

Data Summary

RMC Groundwater Treatability Study
Data Summary

Sample	Test Date	pH	$CaCl_2$ Dose (Ca/F mole ratio)	Polymer Dose (mg/L)	Recycled Solids (mg/L)	Reaction Time (hr)	Fluoride Concentration (mg/L) Initial	Fluoride Concentration (mg/L) Final	Removal Efficiency (%)	Comments
MW11-017	9-Jul	7	0.6	0	0	0.5	392	21.4	94.5	Best dose = 0.75-2
		7	0.6	0	0	1	392	19.1	95.1	
		7	0.6	0	0	2	392	19.3	95.1	
		8	0.6	0	0	0.5	392	23.1	94.1	
		8	0.6	0	0	1	392	21.2	94.6	
		8	0.6	0	0	2	392	21.0	94.6	
		9	0.6	0	0	0.5	392	27.2	93.1	
		9	0.6	0	0	1	392	24.7	93.7	
		9	0.6	0	0	2	392	23.2	94.1	
	14-Jul	7	0.5	0	0	1	392	37.1	90.5	
		7	0.6	0	0	1	392	19.8	94.9	
		7	0.75	0	0	1	392	12.8	96.7	*
		7	1	0	0	1	392	9.40	97.6	*
	5-Aug	7[b]	2	0.5	0	1	397	10.4	97.4	*
	9-Sep	7[b]	2	0.5	0	1	399	6.73	98.3	*
MW11(200)[c]		7[b]	2	0.5	0	1	187	11.3	94.0	
MW11(75)[c]		7[b]	2	0.5	0	1	75.5	76.6	-1.5	
MW13-022	5-Aug	7[b]	2	0.5	0	1	134	18.6	86.1	* Best dose = 2 (or less ??)
MW19-013	17-Jul	7	0.6	0	0	1	87.1	91.5	-5.1	Best dose = 5
		7	1	0	0	1	87.1	88.9	-2.1	SO4 interference not clear
		7	2	0	0	1	87.1	77.8	10.7	
	23-Jul	7.16[a]	1	0	0	1	87.1	78.1	10.3	
		7.16[a]	2	0	0	1	87.1	69.7	20.0	
		7.16[a]	5	0	0	1	87.1	33.1	62.0	*
	5-Aug	7[b]	2	0.5	0	1	88.3	70.4	20.3	
MW26-012	9-Jul	7	0.6	0	0	0.5	108	98.6	8.7	Best dose = 2 (5 not as good)
		7	0.6	0	0	1	108	102	5.6	SO4 interference indicated
		7	0.6	0	0	2	108	93.9	13.1	
		8	0.6	0	0	0.5	108	95.5	11.6	
		8	0.6	0	0	1	108	99.2	8.1	
		8	0.6	0	0	2	108	101	6.5	

RMC Groundwater Treatability Study
Data Summary

Sample	Test Date	pH	$CaCl_2$ Dose (Ca/F mole ratio)	Polymer Dose (mg/L)	Recycled Solids (mg/L)	Reaction Time (hr)	Fluoride Concentration (mg/L) Initial	Fluoride Concentration (mg/L) Final	Removal Efficiency (%)	Comments
		9	0.6	0	0	0.5	108	90.5	16.2	
		9	0.6	0	0	1	108	98.4	8.9	
		9	0.6	0	0	2	108	104	3.7	
	14-Jul	7	0.5	0	0	1	108	104	3.7	
		7	0.6	0	0	1	108	104	3.7	
		7	0.75	0	0	1	108	102	5.6	
		7	1	0	0	1	108	94.3	12.7	
	17-Jul	7	1.5	0	0	1	108	89.2	17.4	
		7	2	0	0	1	108	88.2	18.3	
		7	3	0	0	1	108	105	2.8	
	23-Jul	7.33[a]	1	0	0	1	108	58.7	45.6	
		7.33[a]	2	0	0	1	108	27.6	74.4	*
		7.33[a]	5	0	0	1	108	48.9	54.7	
	5-Aug	7[b]	2	0.5	0	1	103	17.5	83.0	*
MW33-095	17-Jul	7	0.6	0	0	1	93.4	90.1	3.5	Best dose = 2 (or less ??)
		7	1	0	0	1	93.4	97.7	-4.6	SO4 interference indicated
		7	2	0	0	1	93.4	95.4	-2.1	Recycle-no improvement
	30-Jul	7.31[a]	2	0.5	0	1	93.4	12.4	86.7	*
		7.31[a]	2	0.5	500	1	93.4	47.3	49.4	
		7.31[a]	2	0.5	1000	1	93.4	43.1	53.9	
	5-Aug	7[b]	2	0.5	0	1	91.6	38.5	58.0	
	13-Jul	7.31[a]	2	0.5	0	1	91.6	89.7	2.1	Does not agree with earlier test
		7[b]	2	0.5	0	1	91.6	87.1	4.9	Does not agree with earlier test
	9-Sep	7[b]	2	0.5	0	1	94.9	90.9	4.2	
GP56-055	9-Jul	7	0.6	0	0	0.5	150	47.1	68.6	Best dose=2 (or less ??)
		7	0.6	0	0	1	150	27.7	81.5	SO4 interference indicated
		7	0.6	0	0	2	150	39.8	73.5	Recycle-no improvement
		8	0.6	0	0	0.5	150	40.1	73.3	
		8	0.6	0	0	1	150	35.9	76.1	
		8	0.6	0	0	2	150	53.0	64.7	
		9	0.6	0	0	0.5	150	68.3	54.5	

RMC Groundwater Treatability Study
Data Summary

Sample	Test Date	pH	$CaCl_2$ Dose (Ca/F mole ratio)	Polymer Dose (mg/L)	Recycled Solids (mg/L)	Reaction Time (hr)	Fluoride Concentration (mg/L) Initial	Fluoride Concentration (mg/L) Final	Removal Efficiency (%)	Comments
		9	0.6	0	0	1	150	36.4	75.7	
		9	0.6	0	0	2	150	63.0	58.0	
	14-Jul	7	0.5	0	0	1	150	133	11.3	
		7	0.6	0	0	1	150	75	50.0	
		7	0.75	0	0	1	150	88.7	40.9	
		7	1	0	0	1	150	50.4	66.4	
	30-Jul	7[b]	2	0.5	0	1	150	17.6	88.3	*
		7[b]	2	0.5	500	1	150	22.5	85.0	*
		7[b]	2	0.5	1000	1	150	38.5	74.3	
	5-Aug	7[b]	2	0.5	0	1	142	28.8	79.7	*
GP59-045	6-Aug	7[b]	2	0.5	0	1	49.4	48.6	1.6	Dose of 2 not effective
GP59-020	9-Sep	7[b]	2	0.5	0	1	1,060	35.4	96.7	*
GP66-040	7-Aug	7[b]	2	0.5	0	1	21.5	23.0	-7.0	Dose of 2 not effective

[a] pH not adjusted
[b] pH adjusted with HCl
[c] MW11-017 sample diluted with DI water to indicated fluoride concentration

APPENDIX G

Performance Monitoring Plan and Conceptual Contingency Plan

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Table

G-1 Sitewide Remedial Action Objectives and Metrics

APPENDIX G

Performance Monitoring Plan and Conceptual Contingency Plan

This conceptual groundwater monitoring program includes two parts: a performance monitoring plan (PMP) and a conceptual contingency plan. The PMP will be implemented after final approval of this plan is received from the U.S. Environmental Protection Agency (EPA) and the Oregon Department of Environmental Quality (DEQ) and the components of the remedial action are in place. The objective of the PMP is to provide the necessary data to evaluate the effectiveness of the groundwater remedial action and determine if the remedial action objectives are being met. Results of the PMP will be evaluated on an annual basis, and future modifications to the program will be proposed to reflect the conditions observed at the site.

The conceptual contingency plan describes what steps will be taken if performance measures are not achieved within the agreed-upon duration, as described in this program. A detailed groundwater monitoring program will be developed following completion of the Record of Decision (ROD).

G.1 Performance Monitoring Plan

This section describes the key elements of the PMP that Reynolds Metals Company will implement at the Troutdale facility under the conditions of the ROD as negotiated with EPA. The proposed PMP is based on the predicted performance of the recommended groundwater alternative. A detailed discussion of the predicted performance is provided in Appendix A of the FFS.

G.1.1 Sitewide Groundwater Remedial Action Objectives and Metrics

The effectiveness of the recommended groundwater remedial action, production well optimization with focused extraction, is measured by its ability to meet the remedial action objectives (RAOs) presented in the next subsections and in Table G-1. Metrics are used to evaluate the achievement of each RAO.

G.1.1.1 RAO 1

The first RAO is to reduce or control offsite migration of the fluoride plume and other COPCs in groundwater. The proposed metric to measure this is fluoride concentrations in offsite groundwater.

Groundwater model simulations predict that production well optimization with focused extraction will contain 100 percent of the south plant intermediate- and deep-zone groundwater plume, 50 percent of the north plant intermediate- and deep-zone plume, 100 percent of the south plant upper gray sand (UGS) plume, and 50 percent of the north plant UGS plume.

Additionally, existing offsite groundwater fluoride concentrations are expected to decline rapidly as a result of the Company Lake dredging action called for in the recommended alternative. As discussed in Appendix A, Section A.6.2, following removal of process residue from Company Lake, groundwater in a substantial portion of the area occupied by the fluoride plume north of the dike (including the offsite areas) will be flushed with clean water within a ten year period. Although it is possible that the soil forming the aquifer matrix could leach fluoride into the clean water, it is currently anticipated that this process will not substantially prolong the groundwater cleanup times north and west of Company Lake.

Demonstration of compliance with this metric will involve plotting fluoride time concentration trends for selected UGS, intermediate-, and deep-zone groundwater monitoring wells. Groundwater elevation data will also be collected during sampling to prepare water level contour maps for evaluating the impact of production well optimization and focused extraction of groundwater in the UGS, intermediate, and deep zones throughout the plant. Water level contour mapping will be used to assess the net inward flow towards the pumping centers over the predicted area of the fluoride plume.

G.1.1.2 RAO 2

The second RAO is to reduce mass loading of fluoride and other COPCs to groundwater in the UGS, intermediate, and deep zones. The proposed metrics to evaluate this RAO are fluoride concentrations in the UGS, intermediate, and deep zones and the size of the UGS intermediate- and deep-zone plumes after 5 and 10 years.

Metric 1. Groundwater model simulations predict that production well optimization with focused extraction will result in measurable reductions in groundwater fluoride concentrations throughout most of the affected area in relatively short time periods. In most of north and south plant, the intermediate and deep groundwater zones are expected to achieve the 4 mg/L maximum contaminant level (MCL) for fluoride within 15 years. In the south plant UGS, groundwater fluoride concentrations are expected to reduce to the MCL within 5 to 10 years over 90 percent of the area. At Company Lake, the UGS is expected to achieve MCLs over 70 percent of the affected area within about 10 years.

The portion of the fluoride plume located southwest of Company Lake (primarily in the intermediate zone) would not be appreciably affected by dredging in Company Lake or production well optimization. This area is located in a zone of low groundwater velocities that is present due to the combined effects of ambient groundwater flow, leakage from Company Lake, and pumping of the production wells. It is expected that concentrations in this zone may require between 50 and 100 years to reduce to the MCL.

Demonstration of compliance with this metric will be made by plotting fluoride time-concentration plots for selected UGS, intermediate-, and deep-zone monitoring wells. Groundwater elevation data will also be collected during sampling to prepare water level contour maps for evaluating the impact of production well optimization on groundwater in the UGS, intermediate, and deep zones around the plant. The locations and frequency of monitoring are discussed later in this appendix.

Metric 2. Groundwater model simulations predict the following percent reduction in the intermediate and deep zone fluoride plume size following the implementation of the preferred remedial alternative:

- South Plant—60 percent in 5 years and 100 percent in 10 years
- Company Lake—60 percent in 5 years and 80 percent in 10 years

Water quality sampling data at selected monitoring wells will be used to assess the effectiveness of the preferred alternative in meeting this RAO. Success at reducing the size of the fluoride plume in the intermediate and deep zones will be illustrated by declining fluoride concentrations within, and specifically at the periphery of, the plume. Demonstration of compliance with this metric will be made by plotting planar fluoride concentration contour maps and time-concentration trends for selected UGS, intermediate-, and deep-zone monitoring wells. The locations and frequency of monitoring are discussed later in this appendix.

G.1.1.3 RAO 3

The third RAO is time to restore groundwater to beneficial use criteria. The proposed metric to measure this consists of groundwater quality data collected throughout the plant. For areas of the plant south of the dike, time to achieve MCLs was discussed above. Methods for measuring compliance with this metric were also discussed above.

For areas north of the dike, the beneficial use metric is ambient water quality in the rivers. Evaluations completed as part of the site remedial investigation have shown no current detectable impact on river water quality as a result of groundwater migration from the site to the rivers. The beneficial use criteria for groundwater discharging to the rivers are, therefore, already met.

G.1.2 Groundwater Monitoring

G.1.2.1 Frequency

Water Level Monitoring. Groundwater level monitoring will be performed on a quarterly basis for the first year. Based on first year results, a decision will be made whether to continue with quarterly water level measurements or go to a wet/dry (semiannual) program thereafter.

Water Quality Monitoring. Water quality will be monitored quarterly for one full year following completion of all of the remedial actions. Time-concentration trends will be reviewed to assess whether groundwater concentrations at the monitoring wells are increasing, decreasing, or remaining stable, and whether results are similar to performance predictions discussed previously in this section. Following a review of the first year data, a decision will be made whether to continue with quarterly sampling or move to semiannual sample collection.

G.1.2.2 Monitoring Well Networks

The groundwater monitoring networks for both water level monitoring and water quality monitoring will consist of sufficient wells to evaluate the effectiveness of the groundwater remedial action and to assess compliance with the performance standards.

Water Level Monitoring Well Network. During the first full year of operation of the groundwater remedial action, water level data will be collected from all available monitoring wells and pumping wells on the site. Surface water levels will also be measured quarterly at eight staff gauges in the South Ditch, West Drainage, Salmon Creek, Company Lake, and the Columbia River.

Following a review of the first year data, the water level monitoring program could be reduced. A reduced monitoring well network would focus on water level data collected from operating production wells, focused extraction wells, and selected monitoring wells. Location criteria for selecting the monitoring wells include:

- Monitoring wells located within the individual high concentration fluoride plumes associated with the soil and debris areas (within the UGS)
- Monitoring wells located within the lower concentration sitewide fluoride plume (within the intermediate zone)
- Monitoring wells located at the edges of the fluoride plumes

Water Quality Monitoring Well Network. The proposed water quality monitoring network would consist of production wells (PW07 and PW08), focused extraction wells (FE-1 and FE-2), and selected supplemental wells. The same location criteria used for selecting water level monitoring wells (described in the section above titled Water Level Monitoring Well Network) would be applied to selecting supplemental water quality monitoring wells.

G.1.2.3 Constituents

The predominant constituent of potential concern in groundwater at the site is fluoride because of its distribution and presence above the maximum contaminant level, which is 4 mg/L. Other than fluoride, only a few constituents have exceeded the MCL: amenable cyanide, six metals, and two volatile organic compounds. With few exceptions, all of these constituents exceeding the MCL are co-located with fluoride. Consequently, fluoride has been monitored since 1994 as an indicator parameter to assess potential impacts to groundwater at the RMC site.

A tiered risk assessment, performed for the final baseline risk assessment, confirmed that fluoride is the only constituent of concern in groundwater at the RMC site. This evaluation is documented in the *Draft Baseline Risk Assessment* (CH2M HILL, July 1999). On the basis of this evidence, fluoride will be the only parameter used to evaluate the performance and effectiveness of the groundwater remedial action.

A selective-ion fluoride probe will be used to measure fluoride in the field at all well locations during implementation of the PMP. Groundwater samples for laboratory fluoride analysis (by EPA Method 300.0) will also be collected at well locations exhibiting relatively high fluoride concentrations (for instance MW11-017, MW13-022, MW26-012, and MW33-095) because the field probe is generally less accurate at concentrations greater than 100 mg/L.

G.1.3 Performance Period

Initial remediation time-to-compliance estimates indicate that reducing the fluoride concentrations in groundwater to the beneficial use criteria will be a long-term process. Therefore, a 5-year initial performance period is proposed to provide adequate time to observe and document the actual effectiveness of the remedial action.

If fluoride concentrations fall below the remedial goal during this monitoring period, and the concentration is confirmed through four consecutive sampling events, fluoride monitoring at that location will cease. Should the current fluoride distribution change such that there is an increased risk to human health and/or the environment, actions to be specified in the Conceptual Contingency Plan will be implemented.

G.1.4 Performance Evaluation

This performance evaluation has two main elements: evaluating remedial action effectiveness and evaluating progress toward achieving the groundwater remedial action objectives.

As described in *Methods for Evaluating the Attainment of Cleanup Standards, Volume 2: Groundwater* (EPA, 1992), two decisions must be made when stopping corrective action: (1) whether groundwater quality has improved to the point where extraction can be terminated; and (2) determining whether the groundwater remedial goal has been attained. This subsection addresses the first of these two decisions. The approach for making the second decision will be proposed by RMC in the future after considering the site-specific data distribution present after treatment is terminated.

Annually, during performance monitoring, groundwater quality data obtained at the selected monitoring wells will be compared against the agreed-upon remedial goals. The comparison will be made separately for each zone (UGS, intermediate, and deep) by calculating the arithmetic mean of the concentration of fluoride at selected monitoring wells against its remedial goal. A simple arithmetic mean calculation approach is proposed as a preliminary step for assessing compliance to defer use of a more labor-intensive statistical approach until it appears likely that the facility will comply with its remedial goals. When the mean of performance monitoring well concentrations for fluoride appears to meet the remedial goal, or if other factors suggest that it may be appropriate to terminate extraction, a statistical technique that is suitable for the distribution of data existing at the time of apparent compliance will be used to document whether extraction can, in fact, be terminated.

Data reduction will be conducted by trend evaluation of concentration over time, using regression techniques (for a parametric data distribution) or the Cox or Kendall techniques (for a nonparametric data distribution). If it is determined at the time of analysis that the proposed techniques are inappropriate for the data distribution, or if alternate data analysis methods are available for assessing compliance with the remedial goals, alternate methods may be proposed to EPA and DEQ.

G.1.5 Reporting

Annual reports will be submitted to EPA and DEQ and will include:

- A brief summary of the number of wells sampled, the dates during which sampling events were conducted, and a discussion of any problems encountered or modifications made to the program during a particular sampling event (1-3 pages)
- A summary table of validated water quality monitoring results collected during the year compared to remedial goals
- A summary table of the quarterly water level elevation measurements
- Water level elevation contour maps for each quarter
- A table summarizing vertical gradients
- Selected analytical data time-series concentration plots (where necessary to reflect data of interest)
- A comparison of the post action fluoride distribution with the 1999 fluoride concentration contour maps to evaluate plume configuration changes and temporal concentration changes near source areas
- Compliance with remedial action objectives
- Compliance with performance standards during the year and responses taken if compliance was not demonstrated

The annual report will be submitted to EPA and DEQ within 90 days after receipt of validated 4th-quarter analytical results.

G.2 Conceptual Contingency Plan

Following implementation of the preferred remedial alternative, RMC will initiate groundwater monitoring as outlined earlier in this appendix. During the first year of operating the preferred remedial alternative, RMC will collect water level and water quality data in order to evaluate the effectiveness of the remedial alternative in meeting the performance metrics for each RAO. RMC proposes to complete the first year of performance monitoring before developing specific contingency actions. The objective of this conceptual contingency plan is to describe the approach for implementing contingency actions and develop some general types of response actions that will be considered should the performance metrics not have been met.

At the end of the first year of performance monitoring, following the review of the data, RMC will ascertain which of the performance metrics are not being met and which of the remedial alternative components (for example, focused groundwater extraction wells) are not performing as predicted. With this information, specific response actions can be developed, tailored specifically to the remedial alternative components that are not in compliance. In general, response actions will only be implemented based on statistically significant trends in the performance monitoring data. RMC will submit to EPA a

performance evaluation technical memorandum based on a review of the first year of monitoring data within 90 days of receiving and compiling the last quarterly data set (water levels and water quality data).

If deemed appropriate, groundwater will be resampled and the data re-evaluated to confirm that the observed water quality trend is statistically significant and/or that the hydraulic capture zone analyses are representative.

Following confirmation of the groundwater monitoring results, a decision will be made whether to:

- Continue performance monitoring
- Adjust the performance monitoring program and gather additional data
- Modify pumping rates at the production or focused extraction wells

If modification of pumping rates is not possible, the need for additional action will be evaluated. If additional action is deemed necessary, a schedule and timeframe mutually agreeable to RMC and EPA will be developed.

Appendix G Table

Table G-1
Sitewide Remedial Action Objectives and Metrics

Remedial Action Objective	Metric
1 - Reduce or control offsite migration of the fluoride plume and other constituents of potential concern (COPCs) in groundwater.	1 - Fluoride concentrations in offsite groundwater.
2 - Reduce mass loading of fluoride and other COPCs to groundwater in the UGS, intermediate, and deep zones.	1 - Fluoride concentrations in the UGS, intermediate, and deep zones. 2 - Size of UGS, intermediate-, and deep-zone plume after 5 and 10 years.
3 - Restore groundwater to beneficial use criteria.	1 – Maximum contaminant levels or concentrations that protect ambient water quality criteria (AWQC) at the rivers.

APPENDIX H

Memorandum: South Landfill and East Potliner Silt Unit Groundwater Drainage Trench Evaluation

South Landfill and East Potliner Silt Unit Groundwater Drainage Trench Evaluation

TO: Reynolds Metals Company
Focused Feasibility Study File

FROM: Todd Dye

DATE: September 9, 1999

The purpose of this memorandum is to evaluate the cost of implementing groundwater drainage trenches in the silt unit of south landfill and east potliner. The following sections provide discussion on the conceptual design of the drainage trench system, implementation, and an order-of-magnitude cost estimate.

Conceptual Trench Design

The silt unit groundwater drainage trenches at south landfill and east potliner are conceptually similar. Figure H-1 shows the proposed trench alignments for both areas. The purpose of the silt trenches in both areas is to capture groundwater in the silt unit currently exhibiting relatively high concentrations of fluoride and to reduce or prevent vertical migration of fluoride and other constituents from the silt to the upper gray sand (UGS). It is envisioned that the silt trenches would be employed only in a groundwater option that already included capture of the existing plumes in the UGS through focused extraction wells.

Predesign Investigation

Prior to the start of trench construction, a predesign investigation would be conducted to further define the lithology along the trench alignments. A cone penetrometer would be used to collect the required predesign data. A cone penetrometer would be advanced every 50 feet along the trench alignments in south landfill and east potliner. It is necessary to verify the interface between the silt unit and the underlying, more permeable UGS. The bottom of the trench must be completed within the silt (and with a sufficient buffer of silt separating the trench from the UGS) to prevent groundwater from the UGS from entering the trench. This is especially of concern in areas where the silt unit gradually transitions into the UGS.

Trench Construction

Prior to trench construction, the contractor will clear, grub, strip, and re-grade along the alignment of the trench. The trench can be excavated using a clamshell and biodegradable slurry shoring with construction methods similar to those used for constructing a conventional, impermeable slurry wall. Figure H-2 is a conceptual cross section of the

drainage trenches. Trenches would be installed to a total depth of 25 feet below the ground surface (bgs), depending upon the results of the predesign study. Trench width is assumed to be 1 foot, to minimize the amount of material excavated. A mixture of well-graded sand and gravel will be backfilled through the biodegradable slurry using a tremie line. This mixture constitutes the drainage layer, which will extend from the maximum depth of the trench to within 3 feet of ground surface. The final 3 feet of trench will be backfilled with clay after installation of extraction and conveyance systems.

The proposed trench alignment consists of approximately 550 feet of trenches at south landfill and approximately 1,300 feet of trenches at east potliner. The trenches will be constructed in parallel segments, to enhance hydraulic capture.

Well Point Extraction System

A well point extraction system will be used to extract groundwater from the drainage layer within the trench. After the trench is installed and the slurry has solidified, a series of 2-inch well points will be installed using a hollow-stem auger drilling method. The well points will be installed within the trench alignment and screened in the bottom 10 feet of the drainage layer. The well points will be spaced at 100 feet or a minimum of two well points per individual trench, whichever is greater. Approximately eight well points will be installed in south landfill and 14 in east potliner. Once the slurry polymer has biodegraded, the extraction well points will be developed.

Groundwater Vacuum Extraction System

One 15-horsepower, multi-port jet pump will be used to extract groundwater under vacuum from the well points in each area. Each jet pumping unit will be fitted with a pump control panel, flowmeter, and 1-horsepower transfer pump. Groundwater will be extracted from each well point via individual suction piping and conveyed to the jet-pumping unit through the existing trench alignment. Each well will be fitted with a well seal and vacuum gauge to allow a variable pumping rate for each well point. The 1-horsepower transfer pump will be used to convey the extracted groundwater to the RMC wastewater treatment plant.

Groundwater Conveyance Pipeline

An abovegrade, 1.5-inch, high-density polyethylene (HDPE) pipeline fitted with anchor blocks and thrust restraining devices will be used to convey extracted groundwater from the discharge of the jet-pumping units to the RMC wastewater treatment plant, where it will be discharged under atmospheric pressure. The abovegrade pipeline will be jacked under road and rail crossings where necessary.

The east potliner extraction system will be conveyed between the scrap yard and South Ditch for approximately 1,900 feet, where it will be connected with the south landfill conveyance system (see Figure H-1). From this point, the combined flows from east potliner and south landfill will be conveyed an additional 750 feet to the RMC wastewater treatment plant.

Construction-Derived Waste

Several types of waste materials are expected during the construction process:

- Biodegradable slurry
- Excavated soils
- Groundwater collected in trench alignment during construction
- Soil cuttings from well point installation

Disposal costs for the biodegradable slurry displaced by the placement of the sand/gravel backfill are assumed to be included in the unit cost for trench construction.

It is assumed that any materials excavated during trench construction will be disposed of in an onsite landfill. The actual disposal costs for the onsite landfill are not included in this estimate, but hauling costs for transporting the materials to the onsite landfill are included. It is likely that excavated materials from the silt unit would require dewatering prior to landfill. Dewatering costs are not included in this estimate.

The volume of materials to be dewatered depends somewhat on the groundwater elevation at the time of excavation, and on the type of material encountered. However, the silt unit is below the seasonal low groundwater table. Groundwater that is collected in the trench during construction will be used to hydrate the biodegradable slurry, and therefore will not require disposal.

Disposal costs for soil cuttings produced during well point installation are included with capital costs for well point installation.

Groundwater Treatment

Groundwater treatment is assumed to be identical in flow rate and fluoride concentration to that assumed for the groundwater extraction well field option, and therefore is not included in this estimate. If the trench alignment is placed too close to the interface between the silt and the UGS, or if the silt unit gradually transitions into the UGS, flow from the more permeable UGS could enter the trench. Depending on the degree to which this occurs, flow rates could increase and fluoride concentration could decrease. Increasing the volume of flow consequently increases treatment costs. If the fluoride concentrations decrease below the minimum effective influent concentration (MEIC) concentration (see Appendix F of the Focused Feasibility Study), a reverse osmosis treatment system would be required to treat the extracted groundwater prior to calcium fluoride precipitation. This scenario could increase the groundwater treatment costs substantially. These potential costs are not included in this estimate. Construction of multiple trench sections at each source area minimizes this problem, since a construction error at one trench would not affect the others. If, over time, one or more trenches exhibited characteristics of UGS infiltration, the individual trenches could be taken off-line.

Order-of-Magnitude Cost Estimates

Order-of-magnitude cost estimates are provided in Tables H-1 though H-8.

Table H-1 provides a cost breakdown of the conveyance pipeline from east potliner to south landfill.

Table H-2 provides a cost breakdown of the conveyance pipeline from south landfill to the RMC wastewater treatment plant.

Table H-3 provides a capital cost estimate for the south landfill well point system, groundwater vacuum extraction system, and the conveyance costs from Table H-2.

Table H-4 presents a breakdown of annual operations and maintenance costs for the south landfill well point system, vacuum extraction system, and conveyance piping.

Table H-5 provides a capital cost estimate for the east potliner well point system, groundwater vacuum extraction system, and the conveyance costs from Table H-1.

Table H-6 presents a breakdown of annual operations and maintenance costs for the east potliner well point system, vacuum extraction system, and conveyance piping.

Table H-7 includes the cost rollup of the previous six tables, and a capital cost estimate for construction of the trench system.

Table H-8 presents the basis of each line item cost used in Table H-7.

Conclusions

The overall cost of the silt drainage trenches for south landfill and east potliner is $2,800,548.

Appendix H Tables

Table H-1
East Potliner to South Landfill Conveyance Piping

DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL	LABOR/EQUIPMENT UNIT HOURS	LABOR/EQUIPMENT UNIT COST	LABOR/EQUIPMENT TOTAL	TOTAL UNIT COST	TOTAL COST	COMMENTS
1 1/2" HDPE Pipe										
1 1/2" HDPE pipe @ grade	*2,600*	*LF*	*0.70*	*1,820*	*0.008*	*1.97*	*5,113*	*2.67*	*$6,933*	*1000'/day*
Sand bed	2,600	LF	1.20	3,120	0.020	8.24	21,433	9.44	$24,553	asm 4"th & 2'w - either exc & haul or edge boards & above grade
Anchor block	260	EA	25.00	6,500	0.250	103.04	26,791	128.04	$33,291	asm 1'x1'x1' with pipe anchor
Undercrossings										
Railroad undercrossing	0	LF	100.00	0	0.000	0.00	0	100.00	$0	12" casing - subcontract including mob & demob
Pipeline undercrossing	100	LF	75.00	7,500	0.000	0.00	0	75.00	$7,500	12" casing - subcontract including mob & demob - thinner wall
Bore & receiving pits, etc.	1	LS	0.00	0	0.000	10,000.00	10,000	10,000.00	$10,000	allow $/undercrossing to excavate, backfill, etc
SUBTOTAL									**$82,278**	

ASSUMPTIONS:

- 1.5" HDPE pipe used for all applications under 20 gpm.
- Assume piping cost include connection, valves, hardware, etc. to connect system extraction systems and treatment system.
- Costs include material, labor, and equipment.
- Cost of undercrossing natural gas pipeline included.

Table H-2
South Landfill to RMC Wastewater Treatment Plant Conveyance

DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL	LABOR/EQUIPMENT UNIT HOURS	LABOR/EQUIPMENT UNIT COST	LABOR/EQUIPMENT TOTAL	TOTAL UNIT COST	TOTAL COST	COMMENTS
1 1/2" HDPE Pipe										
1 1/2" HDPE pipe @ grade	*1,300*	*LF*	*0.70*	*910*	*0.008*	*1.97*	*2,556*	*2.67*	*$3,466*	*1000'/day*
Sand bed	1,300	LF	1.20	1,560	0.020	8.24	10,717	9.44	$12,277	asm 4"th & 2'w - either exc & haul or edge boards & above grade
Anchor block	130	EA	25.00	3,250	0.250	103.04	13,396	128.04	$16,646	asm 1'x1'x1' with pipe anchor
Undercrossings										
Railroad undercrossing	0	LF	100.00	0	0.000	0.00	0	100.00	$0	12" casing - subcontract including mob & demob
Road undercrossings	0	LF	75.00	0	0.000	0.00	0	75.00	$0	12" casing - subcontract including mob & demob - thinner wall
Bore & receiving pits, etc.	0	LS	0.00	0	0.000	10,000.00	0	10,000.00	$0	allow $/undercrossing to excavate, backfill, etc
SUBTOTAL									**$32,389**	

ASSUMPTIONS:

- 1.5" HDPE pipe used for all applications under 20 gpm.
- Assume piping cost include connection, valves, hardware, etc. to connect system extraction systems and treatment system.
- Costs include material, labor, and equipment.

Table H-3

Well Point System, Extraction System, and Conveyance System Capital Costs for South Landfill Silt Drains

	Units	Unit Cost	Unit	Cost	Subtotal	Comments
Well Point Construction						
2 Inch Well Points	8	$650	LS	$5,200		Extraction Wells. (8) 2-inch dia. Sch 80 PVC extraction wells, 25 feet deep with 10 ft. screens, based on Geotech Price Quote. Assume 1 well per 100 feet of trench alignment (or 2 per individual trench whichever is greater)
Subtotal				$5,200		
Allowance		15%		$780		IDW Management of drummed soil cuttings, decon and development water
Subtotal				$5,980		
SUBTOTAL Wellpoint Construction				$5,980	$ 5,980	
Groundwater Conveyance Pipeline						
Conveyance to WWTP	1	$32,389		$32,389		1.5 inch HDPE pipeline south landfill extraction system to RMC WWTP
Subtotal				$32,389		
Allowance		10%		$3,239		fittings, testing, startup
SUBTOTAL CONVEYANCE				$35,628	$ 35,628	
Groundwater Extraction						
Econopump, 24 port Jet Pump	1	$20,000	EA	$20,000		15HP jet pump motor, supplied with 1 HP transfer pump, Steel skid mount
Vacuum gauges	8	$55	EA	$440		Allowance
Sampling Ports	8	$140	EA	$1,120		7200 gal, HDPE with secondary containment and earthquake tie-dowr
Well Seal	8	$30	EA	$240		17000 gal
Pump Control Panel	1	$2,750	LS	$2,750		NEMA 4 enclosure, motor starters, pressure switch time delay, level control relays, alarm lamp
Discharge flow meter	1	$500	EA	$500		
Subtotal				$25,050		
	Assumed % of Total	Ratio % of Total		Cost		
Purchased Equipment	40	40%		$25,050		Assumed % of total from Peters and Timmerhaus, Plant Design and Economics for Chemical Engineers, 3rd Ed. P.164
Purchased Equipment Installation	9	9%		$5,636		
Piping (installed)	8	8%		$5,010		
Electrical (installed)	5	5%		$3,131		
Building (including services)	5	5%		$3,131		
Yard Improvements	2	2%		$1,253		
Engineering and Supervision	10	10%		$6,263		
Construction Expense	12	12%		$7,515		
Contractor's Fee	2	2%		$1,253		
Contingency	8	8%		$5,010		
SUBTOTAL Extraction	101	100%		$63,251	$63,251	Includes: instrumentation, piping, electrical, building, yard improvements, engineering, supervision, construction expense, contractor's fee, and services during construction
TOTAL CONSTRUCTED COST ESTIMATE					**$104,859**	

NOTE: The above cost opinion does not include construction management, financing, or O&M costs. The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table H-4
Annual Operation and Maintenance Costs for Well Point, Extraction, and Conveyance Systems at South Landfill

System	Item	Annual O+M	Comments	Energy Costs
Well Point System				
	Power	$ -		No energy costs directly associated with well points
2%	Operation and Maintenance	$ 120	O&M (2% of equipment costs annually).	
	Subtotal	$ 120		
Groundwater Conveyance System				Energy Costs for Transfer Pumps
	Power	$ 392	6 cents per KWh, FT operation, assume 4 HP at yr 1	# HP Total HP Hr/Yr HP-Hr/Yr KWh-Yr
5%	Operation and Maintenance	$ 1,781	O&M (5% of equipment costs annually).	1 1 1 8,760 8,760 6,532
	Subtotal	$ 2,173		
Groundwater Extraction Systems				Energy Costs for Extraction System
	Power	$ 5,879	6 cents per KWh, FT operation, assume 60 HP at yr 1	# HP Total HP Hr/Yr HP-Hr/Yr KWh-Yr
15%	Operation and Maintenance	$ 3,758	O&M (15% of equipment costs annually).	1 15 15 8,760 131,400 97,985
	Subtotal	$ 9,637		

NOTE: The above cost opinion does not include construction management, financing, or O&M costs. The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table H-5

Well Point System, Extraction System, and Conveyance System Capital Costs for East Potliner Silt Drains

	Units	Unit Cost	Unit	Cost	Subtotal	Comments
Well Point Construction						
						Extraction Wells. (14) 2-inch dia. Sch 80 PVC extraction wells, 25 feet deep with 10 ft. screens, based on Geotech Price Quote.
2 Inch Well Points	14	$100	LS	$1,400		Assume 1 well per 100 feet of trench alignment (or 2 per individual trench, whichever is greater)
Subtotal				$1,400		
Allowance		15%		*$210*		*IDW Management of drummed soil cuttings, decon, and development water*
Subtotal				$1,610		
SUBTOTAL Wellpoint Construction				$1,610	*$ 1,610*	
Groundwater Conveyance Pipeline						
Conveyance to WWTP	1	$32,389		$82,278		1.5-inch HDPE pipeline from east potliner to connection with south landfill extraction system
Subtotal				$82,278		
Allowance		10%		$8,228		fittings, testing, startup
SUBTOTAL CONVEYANCE				$90,505	*$ 90,505*	
Groundwater Extraction						
Econopump, 24 port Jet Pump	1	$20,000	EA	$20,000		15HP jet pump motor, supplied with 1 HP transfer pump, steel skid mount
Vacuum gauges	14	$55	EA	$770		Allowance
Sampling Ports	14	$140	EA	$1,960		7200 gal, HDPE with secondary containment and earthquake tie-down
Well Seal	14	$30	EA	$420		17000 gal
Pump Control Panel	1	$2,750	LS	$2,750		NEMA 4 enclosure, motor starters, pressure switch time delay, level control relays, alarm lamp
Discharge flow meter	1	$500	EA	$500		
Subtotal				$26,400		
	Assumed % of Total	Ratio % of Total		Cost		
Purchased Equipment	40	40%		$26,400		Assumed % of total from Peters and Timmerhaus, *Plant Design and Economics for Chemical Engineers*, 3rd ed., p.164
Purchased Equipment Installation	9	9%		$5,940		
Piping (installed)	8	8%		$5,280		
Electrical (installed)	5	5%		$3,300		
Building (including services)	5	5%		$3,300		
Yard Improvements	2	2%		$1,320		
Engineering and Supervision	10	10%		$6,600		
Construction Expense	12	12%		$7,920		
Contractor's Fee	2	2%		$1,320		
Contingency	8	8%		$5,280		
SUBTOTAL Extraction	101	100%		$66,660	*$66,660*	*Includes: instrumentation, piping, electrical, building, yard improvements, engineering, supervision, construction expense,* contractor's fee, and services during construction
TOTAL CONSTRUCTED COST ESTIMATE					**$158,775**	

NOTE: The above cost opinion does not include construction management, financing, or O&M costs. The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table H-6
Annual Operation and Maintenance Costs for Well Point, Extraction, and Conveyance Systems at South Landfill

System	Item	Annual O+M	Comments	Energy Costs
Well Point System				
	Power	$ -		No energy costs directly associated with well points
2%	Operation and Maintenance	$ 32	O&M (2% of equipment costs annually).	
	Subtotal	$ 32		
Groundwater Conveyance System				Energy Costs for Transfer Pumps
	Power	$ 392	6 cents per KWh, FT operation, assume 4 HP at yr 1	# . HP Total HP Hr/Yr HP-Hr/Yr KWh-Yr
5%	Operation and Maintenance	$ 4,525	O&M (5% of equipment costs annually).	1 1 1 8,760 8,760 6,532
	Subtotal	$ 4,917		
Groundwater Extraction Systems				Energy Costs for Extraction System
	Power	$ 5,879	6 cents per KWh, FT operation, assume 60 HP at yr 1	# HP Total HP Hr/Yr HP-Hr/Yr KWh-Yr
15%	Operation and Maintenance	$ 3,960	O&M (15% of equipment costs annually).	1 15 15 8,760 131,400 97,985
	Subtotal	$ 9,839		

NOTE: The above cost opinion does not include construction management, financing, or O&M costs. The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. *The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule, and other variable factors.* As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table H-7

Order-of-Magnitude Silt Drainage Trench Cost Estimates

South Landfill Trench Drains (550 LF by 25 ft. Depth, 22 ft drainage layer thickness, 3 ft clay backfill, Yield = 1 gpm)
East Potliner Trench Drains (1300 LF by 25 ft. Depth, 22 ft drainage layer thickness, 3 ft clay backfill, Yield = 5 gpm)

Item	Unit	Unit Cost	SLF Quantity	EPL Quantity	SLF Cost	EPL Cost
1 Institutional Controls						
1.1 Deed or Use Restriction Legal Fees	EA	$25,000	1	1	$25,000	$25,000
1.2 Fencing (around well trench and conveyance areas)	LF	15	1,050	2,050	$15,750	$30,750
2 Site Preparation						
2.1 Clearing, Grubbing, and Stripping	AC	$4,200	0.9	1.8	$3,780	$7,560
2.2 Surface Preparation	AC	$800	0.9	1.8	$720	$1,440
3. Trench Construction Costs						
3.1 Cone Penetrometer Testing	LS	$7,390	50%	50%	$3,695	$3,695
3.2 Trenching mob/demob	LS	$15,000	50%	50%	$7,500	$7,500
3.3 Biodegradable Slurry Trenching	SF	20	13,750	32,500	$275,000	$650,000
3.4 Drainage Sand	CY	19.4	225	530	$4,365	$10,282
3.5 Drainage Gravel	CY	28.7	225	530	$6,458	$15,211
3.6 Clay Backfill	CY	20	60	145	$1,200	$2,900
4. Groundwater Well Point System, Pumping, Conveyance (See attached Capital Cost Tables)	LS				$104,859	$158,775
5. Investigation Derived Waste Disposal						
5.1 Onsite Short Haul of excavated soils	CY	15	510	1,200	$7,650	$18,000
4 Capital Costs						
4.1 Engineering/Design	%	7%			$31,918	$65,178
4.2 Construction Management	%	5%			$22,799	$46,556
4.3 Change Management	%	2%			$9,120	$18,622
4.4 Project Administration	%	2%			$9,120	$18,622
4.5 Notice of Substantial Completion Report (CERCLA)	%	2%			$9,120	$18,622
4.6 Permitting	EA	$50,000			$25,000	$25,000
4.7 Contingency, Legal Fees, Taxes, etc.	%	25%			$113,994	$232,778
5 Annual Operations and Maintenance Cost						
5.1 Trench Maintenance	%	2%			$5,964	$13,792
5.2 Well point maintenance	%	2%			$120	$32
5.3 Conveyance system operation and maintenance	%	5%			$2,173	$4,917
5.4 Extraction system operation and maintenance	%	15%			$9,637	$9,839
5.5 Engineering/Administration	%	8%			$1,432	$2,286
5.6 Contingency, Legal Fees, Taxes, etc.	%	25%			$4,473	$7,145
		Total Capital Cost			$677,046	$1,356,492
		Annual O&M Cost			$23,799	$38,012
		Present Value of O&M Costs (30 Year)			$295,321	$471,689
		Total Net Present Value Cost			$972,367	$1,828,181
		Combined Total Net Present Value			$2,800,548	

Note: The budget level cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table H-8

Basis for Order-of-Magnitude Cost Silt Trench Cost Estimates

Item	Unit	Unit Cost	Source	Comment
1. Institutional Controls				
1.1 Deed or Use Restriction Legal Fees	EA	25,000	Peters	Permitting costs for trenching action
1.2 Fencing (around well trench and conveyance areas)	LF	15.00	Peters	Trench area containment fencing
2. Site Preparation				
2.1 Clearing, Grubbing, and Stripping	AC	4,200	Dave Dailer and Means 8/97	Site preparation along trench alignment
2.2 Surface Preparation	AC	800	Dave Dailer and Means 8/97	Site preparation along trench alignment
3. Trench Construction Costs				
3.1 Cone Penetrometer Testing	LS	$7,390	Geotech Exploration Quote 9/16/99	Cone penetrometer survey to characterize silt/UGS interface(assume 1 boring/50 ft, 30 ft. deep)
3.2 Trenching mob/demob	LS	$15,000	Adjusted from Contractor quote from similar Oregon project	Trenching contractor mobilization and demobilization costs
3.3 Biodegradable Slurry Trenching	SF	$20.00	Adjusted from Contractor quote from similar Oregon project	Trench excavation using biodegradable slurry shoring
3.4 Drainage Sand	CY	$19.40	Dave Dailer and Means 8/97	Placement of drainage material though biodegradable slurry (assume 1/2 volume of 22 ft x 1ft drainage layer)
3.5 Drainage Gravel	CY	$28.70	Dave Dailer and Means 8/97	Placement of drainage material though biodegradable slurry (assume 1/2 volume of 22 ft x 1ft drainage layer)
3.6 Clay Backfill	CY	$20.00	Dave Dailer and Means 8/97 (assume same as clean soil)	Placement of a 3 foot deep layer of clay backfill in trench
4. Groundwater Well Point System, Pumping, Conveyance	LS		Adjusted from contractor quotes for well points and pumps	Assumes, 1 well point per 100 feet of trench alignment, vacuum extraction system, and conveyance to RMC WWTP
5. Investigation Derived Waste Disposal				
5.1 Onsite Short Haul of excavated soils	CY	15.00	Peters: estimated	Onsite short haul of excavated material to an onsite landfill
6. Capital Costs				
6.1 Engineering/Design	%	7%	Randy Pratt and Cindy Dahl Estimate, 11/98	
6.2 Construction Management	%	5%	Randy Pratt and Cindy Dahl Estimate, 11/98	
6.3 Change Management	%	2%	Randy Pratt and Cindy Dahl Estimate, 11/98	
6.4 Project Administration	%	2%	Randy Pratt and Cindy Dahl Estimate, 11/98	
6.5 Notice of Substantial Completion Report (CERCLA)	%	2%	Randy Pratt and Cindy Dahl Estimate, 11/98	
6.6 Permitting	EA	$50,000	Peters	
6.7 Contingency, Legal Fees, Taxes, etc.	%	25%		
7. Annual Operations and Maintenance Cost				
7.1 Trench Maintenance	%	2%		Maintenance and repair of trench as a percentage of original capital cost
7.2 Well point maintenance	%	2%		Maintenance and repair of well points as a percentage of original capital cost
7.3 Conveyance system operation and maintenance	%	5%		Maintenance and repair of conveyance piping as a percentage of original capital cost
7.4 Extraction system operation and maintenance	%	15%		Maintenance and repair of vacuum extraction system as a percentage of original capital cost
7.5 Engineering/Administration	%	8%		Annual operation and maintenance engineering oversight and administrative costs
7.6 Contingency, Legal Fees, Taxes, etc.	%	25%		Annual operation and maintenance contingency

Appendix H Figures

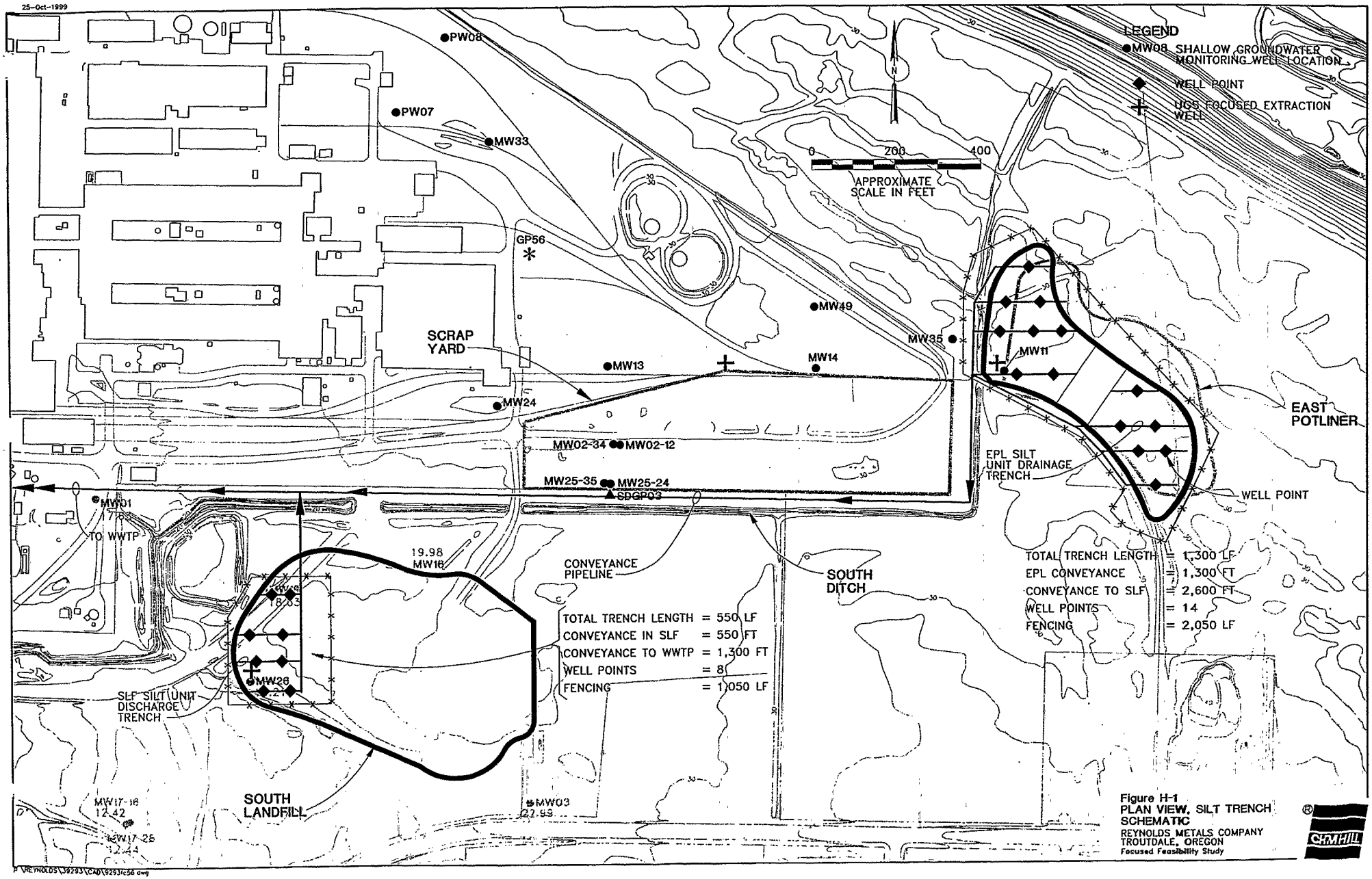

Figure H-1
PLAN VIEW, SILT TRENCH SCHEMATIC
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Focused Feasibility Study

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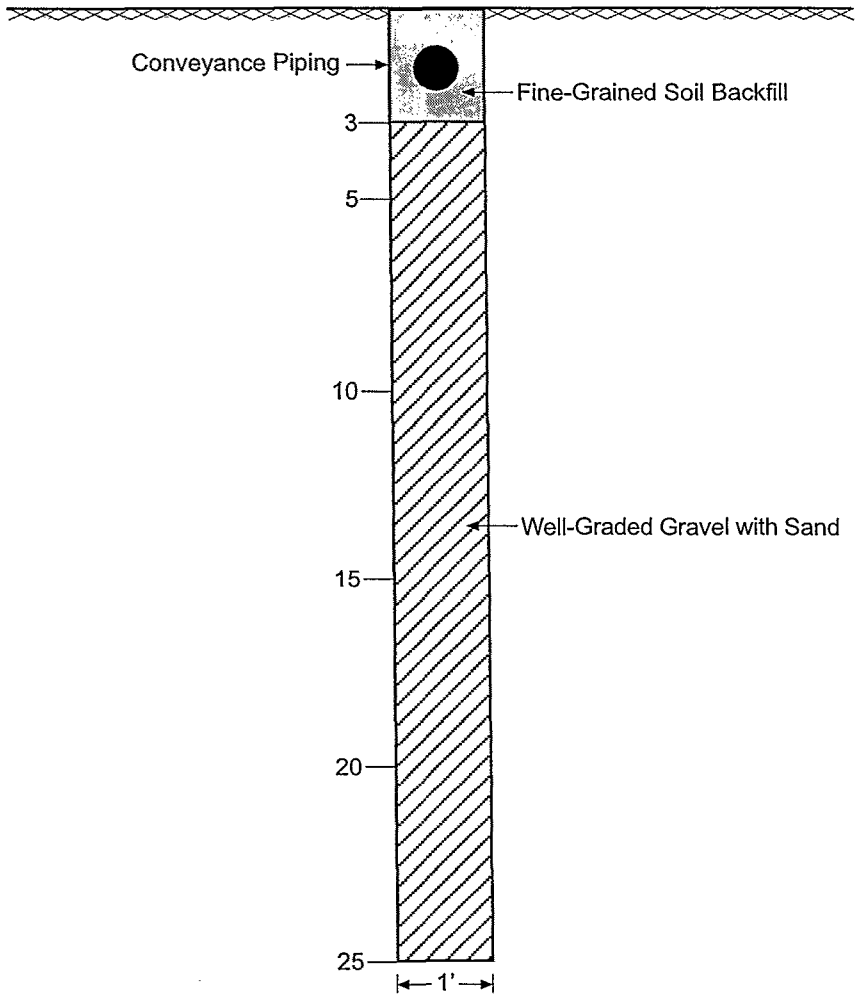

TRENCH SPECIFICATIONS	
Depth:	25'
Thickness of Drainage Layer:	22'
Backfill (Fine-Grained Soil):	3'
Width:	1'

Figure H-2

SILT DRAINAGE TRENCH CONCEPTUAL CROSS SECTION

REYNOLDS METALS COMPANY, TROUTDALE, OREGON
Focused Feasibility Study