APPENDIX C

Input Used for Probabilistic Analysis

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ABBREVIATIONS AND ACRONYMS

BHSS	Bunker Hill Superfund Site
CDR	Coeur d'Alene River
cy	cubic yard
EPA	U.S. Environmental Protection Agency
FP	floodplain sediment
FS	feasibility study
HELP	hydrologic evaluation of landfill performance
LB	lower bound
lb/d	pound per day
lb/yr	pound per year
mg/kg	milligram per kilogram
NFCDR	North Fork Coeur d'Alene River
ppm	parts per million
PRB	permeable reactive barrier
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RLP	relative loading potential
SFCDR	South Fork Coeur d'Alene River
TCD	typical conceptual design
TMDL	total maximum daily load
tons/cy	tons per cubic yard
UB	upper bound
USGS	U.S. Geological Survey
yr	year

C.1.0 INTRODUCTION

This appendix provides supplementary documentation of pertinent input estimates (input) used in the probabilistic analysis that has not already been documented in previous sections and appendixes. The estimates are specific for dissolved zinc.

The inputs are estimates of true values that are uncertain because of natural variability and limited information. This uncertainty is formally accounted for by treating the estimates probabilistically, assuming that the estimation uncertainty followed lognormal distributions. The probabilistic approach used to characterize and process these estimates has been documented in the previous sections and appendices of this technical memorandum, which is emphasized as follows.

C.1.1 REFERENCE TO OTHER SECTIONS OF THIS TECHNICAL MEMORANDUM

The concepts and details underpinning the estimates made in this appendix have been presented in the main text and Appendices A and B. Because those concepts and details are not repeated here, the estimates presented in this appendix include by reference the discussion and details previously presented in this technical memorandum. The information presented in the remedial investigation (RI) and feasibility study (FS) (USEPA 2000a and 2000b) is also included here by reference.

C.1.2 OBJECTIVITY OF ESTIMATES

The estimates are objective within common standards of engineering practice and represent practical approximations of complex phenomena based on engineering interpretation and synthesis of available information. Measurement data are used where available. However, information is unavoidably limited, particularly regarding future conditions. Estimates are therefore necessarily conditional on assumptions and hypotheses, which require engineering and scientific judgment.

The estimates are scientifically sound and technically defensible within theoretical and practical limits of available information, which adequately supports the purpose of the analysis. Because of the need for professional judgment, the possibility of legitimate differences in professional opinion as to exactly how the available information is interpreted to make specific estimates cannot be precluded. Uniquely objective estimates that assure unanimous and unqualified acceptance are unrealistic ideals, particularly where viewpoints conflict. The goal of the probabilistic approach is to quantitatively incorporate, as objectively and explicitly as practical,

the uncertainty inherent in the estimates. It is also expected that estimates will be refined over time as new information or improved understandings or hypotheses evolve.

In particular, to the maximum extent practical, the same estimation approach, including explicit and implicit hypotheses and assumptions, was used for all remedial alternatives so as to maximize consistency among the alternatives given available information.

Estimates for Alternatives 5 and 6 were based on interpretation of information supplied to the U.S. Environmental Protection Agency (EPA) by the State of Idaho (Alternative 5) and the mining companies (Alternative 6), as documented in the FS (Part 3, Appendixes AA and AB, respectively). These estimates can be refined if additional, relevant information is made available to the EPA for consideration.

C.1.3 ESTIMATES REPRESENT AVERAGES THAT ARE LOCATION SPECIFIC

The estimates represent aggregate spatial and temporal averages. Temporal and source-by-source variations are thus implicit in the estimates. Although particular site-specific values could deviate substantially from the averages, these deviations do not invalidate the *aggregate* effects represented by the estimates. The mathematical basis for this conclusion is documented in Appendix B.

The estimates vary with location and depend on the monitoring location where loading and concentrations are being estimated. The estimates are currently limited to the areas of remedial actions documented in the FS, and do not include the Bunker Hill Superfund Site (BHSS). Estimates apply to the U.S. Geological Survey (USGS) monitoring locations SF271 on the South Fork Coeur d'Alene River (SFCDR) at Pinehurst and LC60 on the Coeur d'Alene River (CDR) at Harrison.

C.2.0 UPPER BASIN ANALYSIS INPUTS

Input estimates used in the analysis for the upper basin are discussed in this section. The discussion reflects an emphasis on the upper basin, which is the major source of dissolved zinc in basin surface waters, including the SFCDR at Pinehurst and the CDR at Harrison. For the purpose of the analysis, the upper basin ends at Pinehurst SF271 because that is the most downgradient location where loadings are measured and estimated in the upper basin. The approximately 280,000 cy of tailings-impacted floodplain sediments that occur in the SFCDR 100-year floodplain downstream of SF271 to the confluence with the North Fork Coeur d'Alene River (NFCDR) are included with the lower basin estimates, as discussed in Section 3.2 of the main text.

Estimation uncertainty was characterized by lognormal distributions defined by expected values and coefficients of variation. The lognormal distributions were estimated in two alternative ways; that is, either by (1) estimating probable upper and lower bounds (UB and LB) on the true (spatial-temporal) averages, from which expected values and coefficients of variation were calculated, or (2) by directly estimating expected values and coefficients of variation. The conceptual and mathematical details for this approach is documented in Appendix A, Section A.4.

Table C-1 summarizes the input for each of the five action alternatives, Alternatives 2 through 6. For each upper basin source type, these inputs include relative loading potentials (RLPs), total volumes, and remediated volumes. For remedial actions, these inputs include remedial effectiveness estimates. The following sections discuss and qualify the input estimates.

C.2.1 SOURCE TYPES

Source types represent aggregations or spatial-temporal averages of all upstream site-specific sources included in that source type. Upper basin source types included tailings-impacted floodplain sediments, which were subdivided into six classes; unimpounded tailings piles; impounded tailings piles at inactive facilities; impounded tailings piles at active facilities; waste rock piles in floodplains; waste rock piles in upland areas; and adit drainages. These source types represent an objective classification within the limits of available data.

The theory of source types is presented in Appendix B and generally discussed in the main body of the technical memorandum. To summarize, source types are statistically homogeneous within the limits of available data. Statistical homogeneity means that the probability distributions used to characterize source types have reasonably constant expected values and coefficients of variation on average over the volume and time of interest. Statistical homogeneity for volume

(space) was obtained by segregating individual sources into the common source types used in the analysis. Statistical homogeneity for time was obtained by making the time of interest one water year. Seasonal and shorter-term variations in the instantaneous loading are thus integrated out, removing time as a factor, as discussed in Appendix B.

C.2.2 SOURCE TYPE TOTAL VOLUMES

This section discusses the total source volume estimates for the source types used in the analysis. Estimates were based on interpretation of available information as discussed and documented in the FS (USEPA 2000b). This included information contained in Bureau of Land Management source areas and various other GIS coverages, aerial photos, and USGS floodplain maps, as well as the RI and other available reports and documents, including the mining companies plan (Werner 1999 and Wesche 1999 in Vol. 3 of USEPA 2000b).

Estimates of source type volumes, as summarized in Table C-1,[1] include both expected values and coefficients of variation for each source type. The source type total volumes (V_j) estimated and documented in the FS were expected values, $E[V_j]$. The uncertainty in the volumes estimates for the upper basin were assigned a coefficient of variation, $CV[V_j]$, consistent with the expected accuracy of the estimated volumes given the available data and estimation methods and assumptions, as documented in the FS.

For impacted floodplain sediments, waste rock, and unimpounded tailings a $CV[V_j]=0.30$ was estimated. A $CV[V_j]=0.20$ was estimated for impounded tailings because the volumes can be estimated more accurately than for the source types having $CV[V_j]=0.30$. Volumes for deeper floodplain sediments were a special case and handled somewhat differently as discussed in Section C.2.3.

The relationship between coefficients of variation and probable bounds is discussed in Appendix A and illustrated in Figure A-4. A $CV[V_j]=0.30$ relates to a 90 percent probable range from approximately 59 percent of the expected value (95 percent lower bound) to 155 percent on the expected value (95 percent upper bound). A $CV[V_j]=0.20$ relates to a 90 percent probable range from approximately 71 percent of the expected value (95 percent lower bound) to 136 percent on the expected value (95 percent upper bound).

[1] The approximately 280,000 cy of tailings-impacted floodplain sediments that occur in the SFCDR 100-year, floodplain downstream of SF271 to the confluence with the NFCDR is included with the lower basin estimates.

C.2.2.1 Unit Weights and Source Type Masses

Unit weights (( ) were used to convert source type volumes (cy) to source type masses (tons). All source types were assumed to have the same unit weight with E[( ]=1.5 tons/cy and CV[( ]=0.10. A CV[( ]=0.10 relates to a 90 percent probable range from approximately 84 percent of the expected value (95 percent lower bound) to 117 percent on the expected value (95 percent upper bound).

C.2.3 RELATIVE LOADING POTENTIALS

The concept of relative loading potentials (RLPs) is discussed in Section 2.3 of the main text and Appendix B, Section B.2.2.1 and included in the following by reference. RLPs were estimated using the operational definition of RLPs with the most severely impacted floodplain sediments (FP) as a reference source type, such that RLP_{FP} =1. From Section B.2.2.1, for any source type j:

$$RLP_j = L_j / L_{FP} \text{ per unit volume of source type j and FP}$$
$$= V_{FP} / V_j \text{ per unit load of source type j and FP}$$

Although any source type could be used as the reference source type, the most severely impacted floodplain sediments was selected because it is expected to be the source type contributing the maximum zinc load per unit volume, on average. This expectation follows from these materials having relatively high zinc concentrations and mobility, high exposure to leaching from groundwater and surface water effects, and high exposure to erosion. The metals in tailings-impacted floodplain sediments can include metals in tailings that are dispersed within natural sediments, metals in lenses or strata of tailings buried or mixed within the sediments, and metals that have been transported to sediments from tailings, waste rock, adit discharges, or other mining-related sources. Note that tailings within floodplain sediments underlying tailings piles or impoundments are included with tailings-impacted floodplain sediments.

It is also important to recognize that the RLPs represent loads *per unit volume*, whereas total loads from a given source type must also include the source types volumes, as reflected in the equations documented in Section B.2.2.1. A source type with relatively high RLP may have a relatively small load contribution if the source type volume is small. Conversely, a source type with relatively low RLP may have a relatively high load contribution if the source type volume is large. The RLP estimates for the various source types were as follows.

Impounded Tailings

Impounded tailings in the upper basin were estimated to have an *average* true RLP of between 0.01 and 0.50 with 90 percent probability. There was a 5 percent probability that the true RLP

was less than 0.01 and a 5 percent probability that the true RLP was greater than 0.50, which resulted in E[RLP]=0.14 and CV[RLP]=1.76. Although there are differences between active and inactive tailings impoundments, as a practical approximation, the same values of relative loading potential were used for both active and inactive facilities. Impounded tailings do not include underlying floodplain material.

Unimpounded Tailings

Unimpounded tailings in the upper basin were estimated to have an *average* true RLP of between 0.10 and 1.0 with 90 percent probability. There was a 5 percent probability that the true RLP was less than 0.10 and a 5 percent probability that the true RLP was greater than 1.0, which resulted in E[RLP]=0.40 and CV[RLP]=0.80. Unimpounded tailings do not include underlying floodplain material.

Floodplain Waste Rock

Waste rock in floodplains of the upper basin was estimated to have an *average* true RLP of between 0.005 and 0.20 with 90 percent probability. There was a 5 percent probability that the true RLP was less than 0.005 and a 5 percent probability that the true RLP was greater than 0.20, which resulted in E[RLP]=0.06 and CV[RLP]=1.59. Waste rock does not include underlying floodplain material.

Upland Waste Rock

Upland waste rock was estimated to have an *average* true RLP of between 0.001 and 0.005 with 90 percent probability. There was a 5 percent probability that the true RLP was less than 0.001 and a 5 percent probability that the true RLP was greater than 0.005, which resulted in E[RLP]=0.003 and CV[RLP]=0.52.

Adits

The sum of all adit loadings (measured as dissolved zinc per day) was assigned a precise RLP of 1.0 and an "equivalent" volume of tailings-impacted sediments, V_{adits}, based on the proportion of upstream adit loading to the loading measured in the SFCDR at Pinehurst, A_L; that is:

$$V_{adits} = A_L/(1-A_L)*\Sigma(RLP*V)_{\text{solid source types}}$$

$$A_L = \text{Adit total load / Stream total loading, L}$$

An expected value for A_L was estimated as 0.07 based on a measured adit total load of approximately 100 lb/d and a stream loading of approximately 1,370 lb/d E[L] at SF271 Pinehurst absent loading from the BHSS). The net effect was that estimated average adit loading

(using RLPs) was identical to the measured average adit loading. An effective coefficient of variation of 0.30 was estimated for adit loading (i.e., CV[V]=0.30, where volume V, for adits, represents loading).

Tailings-Impacted Floodplain Sediments

As explained, the most severely impacted sediments were assigned an RLP=1.0. Impacted floodplain sediments identified as having less relative loading potential than the most severely impacted sediments received average RLPs of less than 1.0, corresponding to their expected relative contribution (on a per cubic yard basis). Tailings-impacted floodplain sediments were divided into several subclasses having successively decreasing relative loading potentials. The classes were correlated with the FS action alternatives, Alternatives 2 through 6, to help facilitate the analysis and comparison of the alternatives.

The expected value of the volumetric average RLP for impacted floodplain sediments was computed from the subclass RLPs discussed in the following paragraphs. This resulted in an expected value of E[RLP]=0.79. A coefficient of variation was assigned to the volumetric average RLP of CV[RLP]=0.30. Recall that a coefficient of variation of 0.30 relates to a 90 percent probable range from approximately 59 percent of the expected value (95 percent lower bound) to 155 percent of the expected value (95 percent upper bound), as shown in Figure A-4 in Appendix A.

Alternatives 5 and 6. The most severely impacted floodplain sediments, those having RLP=1.0, were assigned to the total sediments identified for removal by the State as part of their Alternative 5 (approximately 195,000 cy). The total sediments identified for removal by the mining companies as part of their Alternative 6 (approximately 170,000 cy) was also assigned RLP=1.

Alternative 2. The impacted sediment identified for removal under Alternative 2 (i.e., impacted sediments in the 100-year floodplain) and not included as part of Alternatives 5 or 6 was assigned an RLP=0.80. The volume of these RLP=0.80 sediments was approximated as the total sediment removal volume for Alternative 2[2] minus the combined sediment volumes for Alternatives 5 and 6. The RLP for impacted floodplain sediments below tailings impoundments ("discrete facilities") was assigned an RLP=1, reflecting the expectation that floodplain material directly below these facilities are likely to be "severely" impacted.

Alternative 3. The impacted sediment identified for removal under Alternative 3 and not included as part of Alternative 2 was assigned an RLP=0.70. The volume of these RLP=0.70 sediments was approximated as the total sediment removal volume for Alternative 3 minus the

[2] Includes 1,700,00 cy of excavated/repository-disposal material and 20,000 cy of excavate/cap material.

total sediment removal volume included in Alternative 2. The RLP for impacted floodplain sediments below tailings piles was assigned an RLP=1. The RLP for impacted floodplain sediments associated with hydraulic isolation applied to river reaches was assigned an RLP=0.80.

Alternative 4. The impacted sediment identified for removal under Alternative 4 and not included as part of Alternative 3 was assigned an RLP=0.60. The volume of these RLP=0.60 sediments was approximated as the total sediment removal volume for Alternative 4 minus the total sediment removal volume included in Alternative 3. The RLP for impacted floodplain sediments associated with hydraulic isolation applied to river reaches was assigned an RLP=0.80.

Deeper Impacted Floodplain Sediments

For the purpose of the analysis, this source type collectively represents potential zinc sources not subject to reduction by any potential remedial action documented in the FS. These deeper impacted sediments principally include aquifer materials below the depth of floodplain sediments identified in Table 1-1 of the main text as subject to potential remedial action. This source type also represents potential zinc sources associated with impacted material within floodplains that is not otherwise included in the draft FS volume estimates (e.g., road and former railroad embankments). In this regard, possible groundwater loading to streams through deep bedrock or from deeper parts of the alluvial system is also included. It is assumed that these collective, potential sources would not be reduced by the remedial actions identified in the draft FS.

The principal component of this collective source is believed to be historic mining-related zinc that has become sorbed, precipitated, or otherwise contained within deeper aquifer materials. This expectation is based on analysis and interpretation of information in the RI and the technical memorandum on background concentrations (USEPA 2001), reports by others (Paulson, Balderrama, and Zahl 1996), and various communications with the USGS (S. Box, USGS Spokane, Washington). Because of the general similarity in the source material and metal transport conditions, the deeper aquifer material was also used to characterize potential loading from the other floodplain sources, including the possible deep-groundwater sources

For the purpose of the analysis, a RLP for this collective source, RLP_{DS}, was approximated as proportional to the estimated volumetric average metal (zinc) concentrations in the deeper impacted sediments (C_{DS}) relative to the volumetric average concentration in the impacted sediments having an RLP=1 (C_S). That is:

$$RLP_{DS} = >C_{DS} / C_S$$

where, again, C_{DS} and C_S are volumetric average concentrations. Factor > depends on details of the C_{DS} and C_S estimates and allows RLP_{DS} to be other than directly proportional to C_{DS}/C_S. As a first approximation, >was set to unity, with E[>]=1 and CV[>]=0. This first approximation was considered reasonably consistent with the estimates of C_{DS} and C_S and the associated total volume represented by C_{DS}, as discussed in the following section. More refined analysis could modify these initial estimates.

The estimate for the total volume potentially associated with this source type and concentration C_{DS} included deeper aquifer materials located directly below the areas mapped by USGS as impacted floodplain sediments. Based on interpretation of the data analysis documented in the background technical memorandum (USEPA 2001), the potential depths of these sediments were estimated to range up to approximately 15 feet. As explained previously, the volume also included impacted materials within floodplains not otherwise included in the draft FS volume estimates (e.g., roads and former railroad embankments). The total volume of material was approximated to range from between 4,000,000 cy and 20,000,000 cy with 90 percent probability. This resulted in E[V]=10,100,000 cy and CV[V]=0.52.

Concentrations C_{DS} and C_S used to estimate RLP_{DS} were based on interpretation of information obtained for floodplain sediments in the BHSS (USEPA 1997) and the technical memorandum on background concentrations in the basin (USEPA 2001), as explained in the following section. Also, because of the way C_{DS} and C_S were estimated, they would be positively correlated. A correlation coefficient of $p_{lnCsd,lnCs}$=0.5 was used to estimate RLP_{DS}; this represented a maximum entropy estimate for $p_{lnCsd,lnCs}$ uniformly distributed between 0.2 and 0.8, the expected limits of the correlation coefficient. The C_S estimate was also used to estimate all C_S-dependent variables in the analysis, as documented in Appendix B.

C.2.4 EFFECTIVE ZINC CONCENTRATIONS

Concentration C_{DS} was interpreted as the effective zinc concentration available for transport to surface water. As a first approximation, the true value of C_{DS} was estimated to be between 3,000 mg/kg and 274 mg/kg with 90 percent probability. This resulted in E[C_{DS}]=1,180 mg/kg zinc and CV[C_{DS}]=0.84. The 3,000 mg/kg 95 percent upper bound was numerically equated with the average zinc concentration in BHSS floodplain "alluvium" samples (that average was 2,847 mg/kg zinc for 100 samples [USEPA 1997, Table 2-1]).[3] The 274 mg/kg 95 percent lower bound was numerically equated with the 95th percentile background zinc concentration in upper basin sediments (USEPA 2001, Table 5-2).

[3] The BHSS samples are bulk concentrations based on unsieved samples and thus represent total zinc concentrations.

Concentration C_S (associated with zinc in RLP=1 sediments) was also interpreted as the effective zinc concentration available for transport to surface water. As a first approximation, the true value of C_S was estimated to be between 15,000 mg/kg and 3,000 mg/kg with 90 percent probability. This resulted in $E[C_S]$=7,560 mg/kg zinc and $CV[C_S]$=0.52. The 15,000 mg/kg 95 percent upper bound was numerically equated with the average zinc concentration in BHSS floodplain "tailings" samples (that average was 15,382 mg/kg zinc for 56 samples [USEPA 1997, Table 2-1]). The 3,000 mg/kg 95 percent lower bound was numerically equated with the average zinc concentration in BHSS floodplain "alluvium" samples (that average was 2,847 mg/kg zinc for 100 samples [USEPA 1997, Table 2-1]).[4]

The estimated 7,560-mg/kg expected value of C_S was somewhat less than the 9,748-mg/kg average zinc concentration found in BHSS floodplain samples identified as "tailings and alluvium" (n=87 [USEPA 1997, Table 2-1]). This appears reasonably consistent with the RLP=1 sediments being the most severely impacted floodplain sediments and the expectation that not all zinc (as measured by bulk concentrations) would be available for transport to surface water.

The same C_S-estimate was used to estimate all C_S-dependent variables in the analysis, as documented in Appendix B. This specifically included the estimate for TEM, the pre-remediation effective total zinc mass available for surface water loading.

It is also cautioned that equating *bounds* on the effective average zinc concentration inherent in the definitions of C_{DS} and C_S with average measured bulk zinc concentrations in BHSS floodplain samples represents practical approximations using available data, and should not be misinterpreted. First, the uncertain variables C_{DS} and C_S represent source material zinc that is available for transport, which is less than total or bulk zinc. Second, the true values of C_{DS} and C_S represent spatial averages over the upper basin, not just conditions in the BHSS. Third, the BHSS data were used to help estimate bounds on the estimates of the true values of C_S and C_{DS}; the BHSS data do not represent the true values of C_{DS} and C_S, which are uncertain.

C.2.5 REMEDIATED VOLUMES

Remediated volumes reflect the aggregate volume of each source type that would be remediated by specific remedial actions comprising a given alternative. These volumes were estimated from the individual sources and remedial actions comprising each remedial alternative, as documented in the FS. Symbolically, $V_{i,j}$ is the remediated volume of source type "j" being remediated by remedial action "i," including no action, for a given remedial alternative.

[4] The upper bound for C_{DS} was thus numerically equal to the lower bound for C_S.

Remediated volume estimates are summarized in Table C-1 for the upper basin, and include both expected values, $E[V_{i,j}]$, and coefficients of variation, $CV[V_{i,j}]$, for each remedial alternative. Note that the approximately 280,000 cy of tailings-impacted floodplain sediments that occur in the SFCDR 100-year floodplain downstream of SF271 to the confluence with the NFCDR was included with the lower basin, as discussed in Section 3.2 of the main text.

The remediated volumes documented in the FS were expected values, $E[V_{i,j}]$. The uncertainty in the estimates were assigned a coefficient of variation, $CV[V_{i,j}]$, equal to the $CV[V_j]$ for the source type total volumes. The $CV[V_{i,j}]$ were considered consistent with the expected accuracy of the estimated volumes given the available data and estimation methods and assumptions (as documented in the FS).

Each remediated volume $V_{i,j}$ was associated with a corresponding aggregate effectiveness of the remedial action, as measured by $R_{i,j}$, the remediation factor for remedial action "i" and source type "j." The $R_{i,j}$ estimates for each remedial alternative are discussed next.

C.2.6 REMEDIAL EFFECTIVENESS (REMEDIATION FACTOR) ESTIMATES

Remedial effectiveness is defined in terms of remediation factors, $R_{i,j}$, which are ratios of post-remediation loading to pre-remediation loading for remediated volumes volume $V_{i,j}$. The $R_{i,j}$ measure the reduction in metal loading from pre-remediation conditions to post-remediation conditions, following implementation of remedial action. Estimated for each source type and remedial action comprising each alternative, the $R_{i,j}$ estimates were based on spatial averages and aggregate effect of the specific remedial action on that source type. Effectiveness ($E_{i,j}$) and remediation factors $R_{i,j}$ are complements (i.e., $E_{i,j} + R_{i,j} = 1$), so that high effectiveness means a low remediation factor, and vice versa.

The remediation factor estimates are summarized in Table C-1 for the upper basin, and include both expected values, $E[R_{i,j}]$, and coefficients of variation, $CV[R_{i,j}]$, for each remedial alternative. The $E[R_{i,j}]$ and $CV[R_{i,j}]$ were calculated from estimates of the 95 percent upper bound (UB) and the 95 percent lower bound (LB) using the technique of Appendix A, Section A.4. The UB and LB estimates are presented in Table C-1.

The UB and LB $R_{i,j}$ estimates for Alternatives 2, 3, and 4 were based on engineering interpretation of the range of potential effectiveness for the typical conceptual designs (TCDs) used in the alternatives, as documented in the FS. These interpretations used qualitative engineering analysis, limited quantitative performance modeling, experience with similar remedial actions, and professional judgment. Professional judgment was used to set context and frame the interpretations, determine what questions to ask, and synthesize information to make the estimates. Experience with similar remedial actions generally considered how well actions

have performed in the past and included considerations inherent in the technology screening documented in FS Section 3. Qualitative engineering analysis was based on knowledge of scientific and engineering principles and construction limitations and used to consider how effective the TCDs are likely to be for the potential range of site-specific conditions. The analyses were qualitative except for hydrologic evaluation of land performance (HELP) analyses used to evaluate potential cover performance in terms of infiltration and percolation (Ridolfi 2000).

Estimates for Alternatives 5 and 6 were based on interpretation of information supplied to EPA by the State of Idaho (Alternative 5) and the mining companies (Alternative 6), as documented in the FS (Part 3, Appendixes AA and AB, respectively). The estimation approach used for Alternative 2, 3, and 4 was also used for Alternatives 5 and 6 to maximize consistency among the alternatives to the extent practical. These estimates can be refined if additional relevant information is made available to the EPA for consideration.

The potential for legitimate disagreement over the efficacy of various remedial technologies is recognized, given that the effectiveness estimates are predictions of hypothetical future conditions that are inherently uncertain and for which there is no actual measured data. The effectiveness estimates represent practical engineering approximations that were formulated probabilistically to formally account for the inherent uncertainty to the extent practical. Results of sensitivity analyses indicated that conclusions resulting from the estimates of post-remediation loading were not overly sensitive to credible variations in the effectiveness estimates. Overall, this effort to estimate effectiveness represented a practical limit on objectivity and supported the purpose of the FS.

The following discussion elucidates some of the logic and assumptions used to make the $R_{i,j}$ estimates documented in Table C-1. The FS can be consulted for details associated with the remedial actions.

C.2.6.1 Removals with Placement in Repositories

The lowest $R_{i,j}$ values were estimated for source removals with placement in engineered, high-performance regional repositories. These estimates reflected the expected near total, permanent isolation of the source material from surface water loading. Differences in the expected performance of regional repositories, as reflected in the TCDs associated with the alternatives, accounted for variations between alternatives. Relatively higher $R_{i,j}$ were estimated for source removals that relied on onsite or local repositories, which do not provide the same reliable degree of isolation as an engineered regional repository. Estimates were generally based on TCDs where available (Alternatives 2, 3, and 4).

C.2.6.2 Regrading and Covering/Capping Inplace

Relatively higher yet $R_{i,j}$ were estimated for source materials that were regraded and covered in place. Differences in the $R_{i,j}$ for these actions generally reflected, to the extent it could be interpreted, differences in the extent of regrading and the potential degree of permanent isolation afforded by the cover designs. Higher $R_{i,j}$ were estimated for covers that relied only on revegetation. Remedial actions that called for only limited regrading (e.g., toe stabilization) were estimated to have the highest $R_{i,j}$ because of the limited isolation of the source material to metal transport from surface water and groundwater effects. Implicit in the $R_{i,j}$ estimates was consideration of the potential degree of stabilization against erosion provided by bioengineering that was associated with the remedial action. Estimates were generally based on TCDs where available (Alternatives 2, 3, and 4).

C.2.6.3 Hydraulic Isolation

Hydraulic isolation is primarily used in Alternatives 3 and 4, and to a limited extent in Alternative 2. The purpose is to deal with major groundwater loading to streams from localized discrete sources (such as tailings impoundments) and broadly distributed source areas, including areas covered by existing development. For discrete sources, hydraulic isolation includes groundwater cutoff walls to control transport of metals in groundwater to surface water. It may be used to isolate localized areas of impacted sediments from upgradient groundwater flow that could leach metals to surface water via groundwater flow or to isolate collocated affected groundwater, which has already leached metals, from surface water. The Hecla Star tailings impoundments in Canyon Creek are an example where hydraulic isolations is used in Alternatives 2 and 3.

The hydraulic isolation used in Alternatives 3 and 4 also includes treatment of major groundwater loading to streams from broadly distributed source areas that are covered by existing development. These distributed source areas are not accessible to removal or amenable to effective capping. In these situations, the treatment could be active or passive, accomplished in situ using permeable reactive barriers (PRBs), or the like, in various possible configurations (including pond configurations like that in Alternative 3 for Canyon Creek). Done in situ, groundwater treatment does not require the actual isolation of groundwater from surface water, particularly for stream reaches. In these cases, it is the treatment of groundwater that provides the major load reduction from hydraulic isolation. Thus, hydraulic "isolation" is, more accurately, "isolation or treatment," where "treatment" is most appropriate for stream reaches, and "isolation" may be relatively more important for particular discrete sources.

Given the intent of hydraulic isolation, the $R_{i,j}$ estimates reflected an expectation of only partial effectiveness because of the inherently limited ability to isolate or treat impacted groundwater, as appropriate. In this regard, limitations on sealing the bottom of the isolation walls from

groundwater flow below the walls would not invalidate the intent of the remedial action. Because of the limitations of hydraulic isolation, higher $R_{i,j}$ (less effectiveness) were estimated for stream reaches than for localized discrete sources (such as tailings impoundments). Discrete sources can be surrounded with an areally continuous "isolation" wall, which would increase the effectiveness of both groundwater collection within the isolated area and the (partial) isolation of the area from upgradient groundwater. Stream reaches, on the other hand, cannot generally be surrounded and were therefore given higher $R_{i,j}$ estimates.

Specifically, the probable range of $R_{i,j}$ was estimated as 0.10 to 0.30 for discrete sources and 0.10 to 0.50 for stream reaches. These estimates also considered that the loading from the estimated 4,000,000 to 20,000,000 cubic yards of impacted deeper floodplain sediments, as discussed in Section C.2.3, would *not* be reduced by hydraulic isolation (or any other remedial action included in the alternatives). The estimates were predicated on the expectation that remedial design efforts would determine appropriate design and construction concepts and details for effective remedial action. Remedial design would not be limited to the TCDs used in the FS and could employ innovative approaches if and as appropriate.

C.2.6.4 Passive and Active Treatment

Estimates of $R_{i,j}$ for passive treatment of surface water, including adit drainages, based on apatite (or similar) treatment ranged from an upper bound of 0.30 to a lower bound of 0.02, yielding an expected value of 0.11 (89 percent effectiveness) and a coefficient of variation of 0.98. The lower bound estimate was partially based on laboratory column studies of Apatite WE showing a greater than 99 percent reduction of zinc (TerraGraphics 1998), but considering that field efficiencies are very likely to be lower. The lower range of estimates assumes that any actual implementation of passive treatment would be of a highly effective and reliable design.

The passive treatment included in Alternative 6 included surface water and mine water management that might be followed by wetland treatment, depending on results of the water management efforts. Because of relative vagueness and uncertainty associated with these efforts, a wide range of $R_{i,j}$ was assumed, with an upper bound of 0.80 and a lower bound of 0.02, yielding an expected value of 0.24 (76 percent effectiveness) and a coefficient of variation of 1.59.

Estimates of $R_{i,j}$ for active treatment of adit drainages or surface water ranged from an upper bound of 0.02 to a lower bound of 0.002, with an expected value of 0.008 (99 percent effectiveness) and a coefficient of variation of 0.80. This range is considered well within the current range of proven active treatment technology.

C.3.0 LOWER BASIN ANALYSIS INPUTS

This section documents the numeric input values used in the analysis of zinc loadings from the lower basin. Only remediation factor point estimates at time t=0 were made for the lower basin remedial alternatives. These R_0 point estimates were used with the approach discussed in Appendix B, Section B.3.3.3, to make probabilistic R(t) estimates, consistent with the probabilistic results from the upper basin. The discussion of the lower basin estimates is consistent with this approach.

The remedial alternatives developed for the lower basin were generally aimed at reducing total lead loads and concentrations, not zinc. The major source of total lead occurs downgradient of Cataldo LC50, where the vast majority of the remedial action is concentrated. Zinc reductions from remedial actions in the lower basin were, therefore, only applied to the zinc load from Cataldo to Harrison, estimated at approximately 248 lb/yr, as discussed in Section 3.2.

Table C-2 documents the inputs and resultant R_0 point estimates for each of the five action alternatives in the lower basin. The estimates only apply to the reach from Cataldo (LC50) to Harrison (LC60). For each lower basin source type, these inputs included RPLs, total volumes, and remediated volumes. For remedial actions, these inputs include remedial effectiveness estimates. The resulting R_0 point estimate for each alternative was made using the deterministic equations documented in Appendix B.

The following sections document or reference the input data used for the lower basin. Estimates from the upper basin, as discussed in Section C.2, that were also used for the lower basin are not repeated here but included by general reference.

C.3.1 SOURCE TYPES

Lower basin source types included riverbed sediments, riverbanks and levees, wetland sediments, lake sediments, upland ("other") floodplain sediments, and Cataldo dredge spoils at Mission Flats. Further discussion is included in the FS.

C.3.2 SOURCE TYPE TOTAL VOLUMES AND REMEDIATED VOLUMES

Estimates of total source volumes and remediated volumes were the same as those documented in the RI and FS. The source volumes were associated with a lead concentration threshold of 1,000 parts per million (ppm). Source volumes associated with lead concentrations of about 500 ppm are expected to be about 10 percent greater than the estimates in Table C-2. As discussed in Section 3.2.7, of the main text, each of the total source volumes (based on 1,000

ppm lead) was increased by 20 percent to account for potential additional zinc loading (lead and zinc are collocated in the affected sediments). This additional 20 percent source volume was also assumed to be unaffected by remedial action, as further discussed in the following Section C.3.4. More refined estimates of the zinc source volumes were not conducted because the zinc load from LC50 to LC60 is a small percentage of the total zinc load at Harrison (less than 10 percent).

C.3.3 RELATIVE LOADING POTENTIALS

RLPs for dissolved zinc from Cataldo to Harrison, as documented in Table C-2, were based on general principles and engineering interpretation of available information. It should be noted that more refined RLP estimates could result in changes to these initial estimates, which are considered tentative given the present uncertainties associated with zinc loading in the lower basin.

The highest RLP (1.0) was estimated for impacted sediments in riverbanks and levees. This estimate was based on the close physical proximity to the CDR and exposure to bank erosion as well as groundwater leaching.

A somewhat lower RLP of 0.70 was estimated for riverbed sediments because of generally reduced exposure to erosion. It was recognized that riverbed sediments could, however, have relatively increased loading from leaching and erosion associated with episodic flood events. The net effect of these episodic events over time could result in a higher RLP, potentially exceeding 1.0.

The RLP estimates for lake and wetland sediments were, respectively, 0.30 and 0.20. The estimates reflect the physical distance of lake and wetland sediments from the CDR, limited exposure to erosion, and expectation of a limited potential for groundwater transport because of shallow hydraulic gradients and the low hydraulic conductivity of the finer grained sediments.

The RLP estimates "other floodplain sediments," which consists primarily of upland sediments, was 0.10. The estimate considered the upland geography in terms of physical distance and elevation above the river and resultant limited exposure to erosion. A limited potential for groundwater transport is also expected because of shallow hydraulic gradients and low hydraulic conductivity of the upland sediments.

The estimated RLP for Cataldo dredge spoils at Mission Flats was 0.05. This low value was based on interpretation of available data that indicates limited potential for zinc transport from the dredge spoils to the CDR. Further discussion is presented in the FS.

C.3.4 REMEDIAL EFFECTIVENESS (REMEDIATION FACTOR) ESTIMATES

Estimates of remedial effectiveness for each remedial action $R_{i,j}$ were based on engineering interpretations generally consistent with the upper basin estimates. In particular, the lowest $R_{i,j}$ values were estimated for source removals with placement in engineered, high-performance regional repositories. As with the upper basin, these estimates assume the near total, permanent isolation of the source material from surface water loading.

As discussed in Section C.3.2, estimates of total source volumes (based on 1,000 ppm lead) were increased by 20 percent to account for potential additional zinc loading. These 20 percent volumes were assumed to be unaffected by remedial action. For source removals (by excavation and dredging), this assumption includes the expectation that not all source material would be removed because of likely inefficiencies associated with earthwork operations in river, lake, and wetland environments. Therefore, $R_{i,j}$ estimates for removals in the lower basin were not increased beyond the estimates for the upper basin, where earthwork is otherwise expected to be generally more efficient (on average, but also considering the unremediated source volumes included for the upper basin).

Estimated $R_{i,j}$ for remedial actions based on soil amendments (in-place chemical treatment) were based on interpretation of limited data and the assumption that applications would be "optimized" based on future advancements in the technology. More refined $R_{i,j}$ estimates for the lower basin remedial actions did not appear critical at this time because of the relatively limited zinc load from LC50 to LC60, approximately 248 pounds per day (lb/d) on average, less than 10 percent of the total zinc load at Harrison.

C.4.0 PRE-REMEDIATION ZINC LOAD AND LOAD CAPACITY ESTIMATES

Table C-3 summarizes the pre-remediation dissolved zinc loads and load capacities, based on total maximum daily load (TMDL) loading capacities (USEPA 2000c), used in the analysis. All loadings are dissolved zinc measured in lb/d. Except as noted, estimates are based on statistical analysis of historical data measured at identified stream monitoring locations in the basin. The historical data were collected from 1991 to 1999 and are reported in the RI. Very recent effects of remedial action in the basin, including the BHSS, are not reflected in these estimates based on historical data. Note that "average" and "expected value" are equivalent terminology.

C.4.1 ESTIMATES FOR PINEHURST SF271

Pre-remediation loading for the upper basin at Pinehurst SF271 without the BHSS was estimated as the sum of measured historical loading at Elizabeth Park SF268 and Pine Creek PC305. This resulted in an expected value of loading at SF271 of 1,374 lb/d without loading from the BHSS. The measured historic dissolved zinc loading at SF271 from all loads, including the BHSS, has an expected value of 2,921 lb/d. This indicates an historic loading of approximately 1,547 lb/d from the BHSS.

C.4.2 LOWER BASIN SOURCE AREAS AND LOAD ESTIMATES

Loading in the CDR at Harrison LC60 consists of the loading in the SFCDR at Pinehurst SF271 plus the sum of all loadings to the CDR downgradient of SF271 to LC60. The sum of loads from SF271 to LC60 was characterized by the following four source areas, which include the NFCDR and the lower basin (CSM Unit 3) from the confluence of the SFCDR and NFCDR (confluence) to Harrison; that is:

- SFCDR from Pinehurst SF271 to the confluence with the NFCDR
- NFCDR NF50 (Enaville)
- Lower Basin—CDR from the confluence to Cataldo LC50
- Lower Basin—CDR from Cataldo LC50 to Harrison LC60

Pre-remediation loadings from these four source areas were estimated from statistical analysis of historical data reported in the RI and information from the FS. The average total load from Pinehurst to Cataldo, 567 lb/d, was based on the average difference in loads between LC50 and SF271 for reasonably synoptic samplings (n=73). Similarly, the average total load from Cataldo to Harrison, 248 lb/d, was based on the average difference in loads between LC60 and LC50 for reasonably synoptic samplings (n=86). Estimated loads at LC60 assumed that the discharge

measured at LC50 was the same as that at LC60 (to eliminate potential discharge-measurement error at LC60). The estimated average load from the NFCDR, 243 lb/d, was estimated from lognormal analysis of USGS data, as will be reported in the final RI. Note that the coefficient of variation for each of these areas was very high (see Table C-3), indicating a very wide range of loadings over time, particularly between low flow and high flow periods.

Stream discharge and concentration data are not available to estimate the loads from SF271 to the confluence or from the confluence to LC50 because there is no monitoring station at the confluence. Therefore, the zinc loading from SF271 to the confluence was based on the estimated loading from approximately 280,000 cy of impacted floodplain sediments that has been identified along the SFCDR from SF271 to the confluence. The zinc load indirectly estimated for these sediments assumed an RLP=1 and resulted in an estimated 2.5 percent of the upper basin load at SF271 (not including the BHSS), or approximately 34 lb/d of zinc. The coefficient of variation of this loading is expected to be between approximately 0.5 and 1.0.

The average dissolved zinc load from the confluence to Cataldo was estimated as 290 lb/d by taking the 567 lb/d load between SF271 and LC50 and subtracting the 34 lb/d load from the sediments along the SFCDR and the 243 lb/d load from the NFCDR. This gave the total average zinc load along the CDR from the confluence to Harrison as 538 lb/d; that is: confluence to LC50 + LC50 to LC60 = 290 + 248 lb/d.

C.4.3 TOTAL AVERAGE ZINC LOAD

The total average dissolved zinc load from Pinehurst SF271 to Harrison LC60, including the NFCDR, was estimated at 815 lb/d; that is: SF271 to confluence + NFCDR + confluence to LC60 = 34 + 243 + 538 lb/d. The 815 lb/d average total load was consistent with the 860 lb/d average difference in loads between LC60 (using the LC50 discharge) and SF271 for reasonably synoptic samplings (n=60), which had a coefficient of variation of 1.86. The expected value of the dissolved zinc load at Harrison, including the BHSS, is therefore approximately 3,736 lb/d; that is: SF271 + SF271 to LC60 = 2,921 + 815 lb/d.

C.5.0 REFERENCES

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Table C-1

Basic Probabilistic Analysis Input Estimates for Upper Basin (to Pinehurst SF271) Remedial Alternatives—
Relative Loading Potentials (RLP), Remediated Volumes (V), and Remedial Action Effectiveness (Remediation Factors, R)

Source (Waste) Type (ST)j	RLP Relative Loading Potential E[RLPj] (cy FP/cy ST)	Source Type Volume E[Vj] (cy)	Relative Total Volume E[RLPjVj] (RLP cy)	Percentage Total Zn Load E[RLPjVj]/Sum	CV[RLPj]	Floodplain RLP Adjustments	E[RLP]
FP Sediments (FP)	0.795	6,820,000	5,419,000	54.1%	0.30	Alt 5 excavated volume	1.00
Deeper FP Sediments not removed	0.166	10,081,363	1,674,795	16.7%	0.71	Alt 6 excavated volume	1.00
Tailings, impounded in inactive facilities	0.143	3,700,000	530,592	5.3%	1.76	Alt 2 delta excavated volume	0.80
Tailings, impounded in active facilities	0.143	4,700,000	673,995	6.7%	1.76	Alt 3 delta excavated volume	0.70
Tailings, unimpounded	0.404	1,300,000	525,202	5.2%	0.80	Alt 4 delta excavated volume	0.60
Waste Rock, w/ loading potential	0.059	7,400,000	438,807	4.4%	1.59	Alt 2 HI discrete facilities	1.00
Waste Rock w/o loading potential	0.003	4,300,000	10,837	0.1%	0.52	Alt 3 HI delta discrete facilities	1.00
Adits: Equivalent FP Seds (RLP=1)	1.00		735,739	7.4%	0.00	Alt 4 HI discrete facilities	1.00
Adit Total Load/Total Loading w/o BHSS: 7.4%	Sums:	38,301,363	10,008,966	100.0%		Alt 3 and 4 river reaches	0.80
						Alt 2 excavate/cap	0.80

		Remediated Volumes, E[Vj]					E[Rij] for Remedial Actions				
		Alternative					Alternative				
Source Type and Remedial Action	Unit	2	3	4	5	6	2	3	4	5	6
Floodplain Sediments											
Total sediment volume	cy	6,820,000	6,820,000	6,820,000	6,820,000	6,820,000					
Excavation/disposal in repository	RLP cy	1,209,000	1,909,000	2,749,000	195,000	170,000	0.05	0.01	0.01	0.05	0.11
Excavate/cap	RLP cy	16,000	0	0	0	0	0.11				
Hydraulic isolation at discrete facilities	RLP cy	310,000	1,630,000	1,350,000	0	0	0.18	0.18	0.18		
Hydraulic isolation of stream reaches	RLP cy	0	1,108,000	1,320,000	0	0		0.25	0.25		
No action	RLP cy	3,900,000	772,000	0	5,224,000	5,249,000	1.00	1.00	1.00	1.00	1.00
Potential Deeper Affected Sed	RLP cy	1,674,795	1,674,795	1,674,795	1,674,795	1,674,795	1.00	1.00	1.00	1.00	1.00
Tailings: Impounded, Inactive Facilities											
Total materials	cy	3,700,000	3,700,000	3,700,000	3,700,000	3,700,000					
Cover/revegetate (Alt 6)	cy	0	0	0	0	2,900,000					0.46
Cap (Alt 5)	cy	0	0	0	2,400,000	0				0.05	
Cap + HI (Alts 2,3)	cy	2,100,000	2,200,000	0	0	0	0.03	0.03			
Cap Only(Alts 2,3)	cy	1,000,000	1,451,000	0	0	0	0.05	0.05			
Excavation/disposal in repository	cy	0	49,000	3,700,000	163,000	0		0.01	0.01	0.05	
No action	cy	600,000	0	0	1,137,000	800,000	1.00			1.00	1.00
Tailings: Impounded, Active Facilities											
Total materials	cy	6,000,000	6,000,000	6,000,000	6,000,000	6,000,000					
No action & no loading potential (Galena)	cy	1,300,000	1,300,000	1,300,000	1,300,000	1,300,000					
Total materials w/ loading potential	cy	4,700,000	4,700,000	4,700,000	4,700,000	4,700,000					
Hydraulic isolation	cy	0	4,000,000	4,700,000	0	0		0.22	0.22		
No action w/loading potential	cy	4,700,000	700,000	0	4,700,000	4,700,000	1.00	1.00	1.00	1.00	1.00
Tailings: Unimpounded											
Total materials	cy	1,300,000	1,300,000	1,300,000	1,300,000	1,300,000					
Cover/revegetate	cy	0	0	0	80,000	600,000				0.46	0.46
Cap	cy	330,000	20,000	0	36,000	0	0.05	0.05		0.05	
Excavation/disposal in repository	cy	40,000	840,000	860,000	103,000	43,000	0.05	0.01	0.01	0.05	0.11
Hydraulic isolation	cy	360,000	0	0	0	0	0.22				
No Action (at active facilities)	cy	570,000	440,000	440,000	1,081,000	657,000	1.00	1.00	1.00	1.00	1.00
Waste Rock: w/Loading Potential											
Total materials	cy	6,400,000	6,400,000	6,400,000	6,400,000	6,400,000					
Stabilize toe	cy	1,000,000	0	0	10,000	0	0.85			0.85	
Regrade/cover	cy	4,200,000	470,000	230,000	1,100,000	780,000	0.46	0.46	0.46	0.46	0.46
Cap	cy	400,000	3,900,000	20,000	27,000	0	0.05	0.05	0.05	0.05	
Excavation/disposal in repository	cy	0	1,700,000	5,900,000	19,000	0		0.01	0.01	0.05	
Pull back toe/revegetate	cy	0	0	0	0	3,700,000					0.80
Regrade/vegetate	cy	0	0	0	1,000,000	840,000				0.80	0.80
Regrade/bioengr streambank w/o reveg	cy	0	0	0	380,000	0				0.80	
No action	cy	800,000	330,000	250,000	3,864,000	1,080,000	1.00	1.00	1.00	1.00	1.00
Waste Rock: upland, Little Loading Potential											
Total materials	cy	4,300,000	4,300,000	4,300,000	4,300,000	4,300,000					
Regrade/cover	cy	0	900,000	3,600,000	5,000	14,000		0.46	0.46	0.46	0.46
No action	cy	4,300,000	3,400,000	700,000	4,295,000	4,286,000	1.00	1.00	1.00	1.00	1.00
Waste Rock: w/Loading Potential (at Active Facilities)											
Total materials	cy	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000					
No action	cy	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1.00	1.00	1.00	1.00	1.00
Adit Drainage											
Total load	#Zn/d	101	101	101	101	101					
Passive Load Treatment	#Zn/d	84	15	12	91	65	0.11	0.11	0.11	0.11	0.24
Active Load Treatment	#Zn/d	0	86	89	0	0		0.01	0.01		
Load No Treatment	#Zn/d	17	0	0	10	36	1.00	1.00	1.00	1.00	1.00

Table C-1 (Continued)
Basic Probabilistic Analysis Input Estimates for Upper Basin (to Pinehurst SF271) Remedial Alternatives—
Relative Loading Potentials (RLP), Remediated Volumes (V), and Remedial Action Effectiveness (Remediation Factors, R)

	CV[Rij] for Remedial Actions					CV[Vj] for Remedial Actions				
	Alternative					Alternative				
Source Type and Remedial Action	**2**	**3**	**4**	**5**	**6**	**2**	**3**	**4**	**5**	**6**
Floodplain Sediments										
Excavation/disposal in repository	0.52	1.76	1.76	0.52	0.44	0.30	0.30	0.30	0.30	0.30
Excavate/cap	0.44					0.30				
Hydraulic isolation at discrete facilities	0.34	0.34	0.34			0.30	0.30	0.30		
Hydraulic isolation of stream reaches		0.52	0.52				0.30	0.30		
No action	0.00	0.00		0.00	0.00	0.30	0.30		0.30	0.30
Potential Deeper Affected Sed	0.00	0.00	0.00	0.00	0.00	0.52	0.52	0.52	0.52	0.52
Tailings: Impounded, Inactive Facilities										
Cover/revegetate (Alt 6)					0.34					0.20
Cap (Alt 5)				0.52					0.20	
Cap + HI (Alts 2,3)	0.70	0.70				0.20	0.20			
Cap Only(Alts 2,3)	0.52	0.52				0.20	0.20			
Excavation/disposal in repository		1.76	1.76	0.52			0.20	0.20	0.20	
No action	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.20	0.20
Tailings: Impounded, Active Facilities										
Hydraulic isolation		0.44	0.44				0.20	0.20		
No action w/ loading potential	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.20	0.20
Tailings: Unimpounded										
Cover/revegetate				0.34	0.34				0.30	0.30
Cap	0.52	0.52		0.52		0.30	0.30		0.30	
Excavation/disposal in repository	0.52	1.76	1.76	0.52	0.44	0.30	0.30	0.30	0.30	0.30
Hydraulic isolation	0.44					0.30				
No Action (at active facilities)	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.30	0.30
Waste Rock: w/Loading Potential										
Stabilize toe	0.04			0.04		0.30			0.30	
Regrade/cover	0.34	0.34	0.34	0.34	0.34	0.30	0.30	0.30	0.30	0.30
Cap	0.52	0.52	0.52	0.52		0.30	0.30	0.30	0.30	
Excavation/disposal in repository		1.76	1.76	0.52			0.30	0.30	0.30	
Pull back toe/revegetate					0.08					0.30
Regrade/vegetate				0.08	0.08				0.30	0.30
Regrade/bioengr streambank w/o reveg				0.08					0.30	
No action	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.30	0.30
Waste Rock: Upland, Little Loading Potential										
Regrade/cover		0.34	0.34	0.34	0.34		0.30	0.30	0.30	0.30
No action	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.30	0.30
Waste Rock: w/Loading Potential (at Active Facilities)										
No action	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.30	0.30
Adit Drainage										
Passive Load Treatment	0.98	0.98	0.98	0.98	1.59	0.30	0.30	0.30	0.30	0.30
Active Load Treatment		0.80	0.80				0.30	0.30		
Load No Treatment	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.30	0.30

Table C-1 (Continued)
Basic Probabilistic Analysis Input Estimates for Upper Basin (to Pinehurst SF271) Remedial Alternatives—
Relative Loading Potentials (RLP), Remediated Volumes (V), and Remedial Action Effectiveness (Remediation Factors, R)

	95% Upper Bound (UB) and 95% Lower Bound (LB) Rij Estimates Used to Estimate E[Rij] and CV[Rij]									
	Alt. 2		Alt. 3		Alt. 4		Alt. 5		Alt. 6	
Source Type and Remedial Action	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB
Floodplain Sediments										
Excavation/disposal in repository	0.02	0.10	0.001	0.05	0.00	0.05	0.02	0.10	0.05	0.20
Excavate/cap	0.05	0.20								
Hydraulic isolation at discrete facilities	0.10	0.30	0.10	0.30	0.10	0.30				
Hydraulic isolation of stream reaches			0.10	0.50	0.10	0.50				
Tailings: Impounded, Inactive Facilities										
Cover/revegetate (Alt 6)									0.25	0.75
Cap (Alt 5)							0.02	0.10		
Cap + HI (Alts 2,3)	0.01	0.08	0.01	0.08						
Cap Only(Alts 2,3)	0.02	0.10	0.02	0.10						
Excavation/disposal in repository			0.00	0.05	0.00	0.05	0.02	0.10		
Tailings: Impounded, Active Facilities										
Hydraulic isolation			0.10	0.40	0.10	0.40				
Tailings: Unimpounded										
Cover/revegetate							0.25	0.75	0.25	0.75
Cap	0.02	0.10	0.02	0.10			0.02	0.10		
Excavation/disposal in repository	0.02	0.10	0.00	0.05	0.00	0.05	0.02	0.10	0.05	0.20
Hydraulic isolation	0.10	0.40								
Waste Rock: w/Loading Potential										
Stabilize toe	0.80	0.90					0.80	0.90		
Regrade/cover	0.25	0.75	0.25	0.75	0.25	0.75	0.25	0.75	0.25	0.75
Cap	0.02	0.10	0.02	0.10	0.02	0.10	0.02	0.10		
Excavation/disposal in repository			0.00	0.05	0.00	0.05	0.02	0.10		
Pull back toe/revegetate									0.70	0.90
Regrade/vegetate							0.70	0.90	0.70	0.90
Regrade/bioengr streambank w/o reveg							0.70	0.90		
Waste Rock: Upland, Little Loading Potential										
Regrade/cover			0.25	0.75	0.25	0.75	0.25	0.75	0.25	0.75
Adit Drainage										
Passive Load Treatment	0.02	0.30	0.02	0.30	0.02	0.30	0.02	0.30	0.02	0.80
Active Load Treatment			0.002	0.02	0.002	0.02				

	Upper and Lower Bounds on RLP Estimates*				
Source Type j	95%UB	95%LB	E[RLPj]	CV[RLPj]	RLP Notes
Resultant FP Sediments	1.23	0.47	0.795	0.30	CV used for RLP uncertainty for FP sediments w/ RLP<1
Deeper FP Sediments not removed	0.39	0.05	0.166	0.71	Values based on [Zn] estiamtes
Tailings, impounded in inactive facilities	0.50	0.01	0.143	1.76	UB and LB used to estiamte E[RLP] and CV[RLP]
Tailings, impounded in active facilities	0.50	0.01	0.143	1.76	UB and LB used to estiamte E[RLP] and CV[RLP]
Tailings, unimpounded	1.00	0.10	0.404	0.80	UB and LB used to estiamte E[RLP] and CV[RLP]
Waste Rock, w/loading potential	0.20	0.01	0.059	1.59	UB and LB used to estiamte E[RLP] and CV[RLP]
Waste Rock w/o loading potential	0.01	0.00	0.003	0.52	UB and LB used to estiamte E[RLP] and CV[RLP]
Adit total load/total loading	1.00	1.00	1.000	0.00	Values based on equating adit loads to RLP=1

* Source Type RLPs represent volumetric averages; therefore, localized areas can be higher or lower, but are expected to average out within this range.

	Remedial Alternative					
Summary of Selected Results for Time t=0	1	2	3	4	5	6
Estimated Remediation Factor at t=0, Ro						
Expected Value E[Ro]:	1.00	0.71	0.37	0.28	0.86	0.90
Coefficient of Variation CV[Ro]:	0.00	0.15	0.44	0.56	0.06	0.05
Estimated Loading Contribution by Source Type						
Floodplain Sediments	71%	79%	84%	84%	79%	77%
Tailings: Impounded, inactive facilities	5%	1%	1%	0%	2%	3%
Tailings: Impounded, active facilities	7%	9%	6%	5%	8%	7%
Tailings: Unimpounded	5%	4%	5%	7%	5%	4%
Waste Rock: w/ loading potential	4%	3%	1%	1%	4%	3%
Waste Rock: Upland--little loading potential	0.1%	0.2%	0.3%	0.2%	0.1%	0.1%
Waste Rock: w/ loading potential (at active facilities)	1%	1%	2%	2%	1%	1%
Adit Drainage6	7.4%	2%	0%	1%	1%	4%
Sum:	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Estimated Zinc Load (SF271 w/o BHSS) lb/d, Fo						
Expected Value E[Fo]:	1,374	924	439	319	1,163	1,214
Coefficient of Variation CV[Fo]:	0.78	0.69	0.66	0.69	0.73	0.74
Estimated zinc load by Source Type						
Floodplain Sediments	974	733	371	267	919	932
Tailings: Impounded, inactive facilities	73	13	3	1	24	41
Tailings: Impounded, active facilities	93	87	27	17	90	90
Tailings: Unimpounded	72	35	22	21	60	51
Waste Rock: w/ loading potential	52	27	6	3	43	40
Waste Rock: Upland--little loading potential	1	1	1	1	1	1
Waste Rock: w/ loading potential (at active facilities)	8	8	7	7	8	8
Adit Drainage6	101	20	2	2	17	50
Sum:	**1,374**	**924**	**439**	**319**	**1,163**	**1,214**
Estimated half-life, t1/2 yrs:						
Expected Value E[t1/2]:	337	337	337	337	337	337
Coefficient of Variation CV[t1/2]:	0.74	0.74	0.74	0.74	0.74	0.74

Table C-2
Lower Basin Cataldo (LC50) to Harrison (LC60)—Estimates of Relative Loading Potentials (RLPs), Remediated Volumes (Vij), Remediation Factors (Rij), and R Point Estimates at t=0 for Alternatives

Source Type (ST)	Estimated Relative Loading Potential (RLP) E[RLP] (cy ST/cy FP)	ST Volume (a) (cy)	Total Volume (a) Relative (cy)	Relative to River	% Total
Riverbed Sediments*	**0.70**	21,120,000	14,784,000	1.00	66%
Banks and Levees*	**1.00**	2,160,000	2,160,000	0.15	10%
Wetland Sediments	**0.20**	7,128,000	1,425,600	0.10	6%
Lake Sediments	**0.30**	7,080,000	2,124,000	0.14	9%
Other Floodplain Sediments*	**0.10**	12,240,000	1,224,000	0.08	5%
Cataldo/MF Dredge Spoils	**0.05**	16,320,000	816,000	0.06	4%
"Unidentified Sediments"	**same as ST**				
*Floodplain (FP) Sediments	**Sums:**	**66,048,000**	**22,533,600**	**1.52**	**100%**

(a) Includes "unidentified" volumes

Source Type and Remedial Action	Unit	Remediated Volumes: Remedial Alternative 2	3	4	5	6	Remediation Factors, R, for Zinc Loading: Estimated Rij for Remedial Actions: Remedial Alternative 2	3	4	5	6
Riverbed Sediment											
Total Volume	cy	**17,600,000**	**17,600,000**	**17,600,000**	**17,600,000**	**17,600,000**					
Dredge and dispose in repository	cy	0	17,300,000	17,600,000	350,000	0	0.01	0.01	0.01	0.01	0.01
Alt 5 Hydraulic capping; clean sed feed											
No Action Volume	cy	17,600,000	300,000	0	17,250,000	17,600,000	1.00	1.00	1.00	1.00	1.00
Unidentified Volume (no action R=1)*	cy	3,520,000	3,520,000	3,520,000	3,520,000	3,520,000	1.00	1.00	1.00	1.00	1.00
*accounts for added Zn vol											
Total Volume + Unidentified Volume	cy	21,120,000	21,120,000	21,120,000	21,120,000	21,120,000					
Banks & Levees (Bank wedges)											
Total Volume	cy	**1,800,000**	**1,800,000**	**1,800,000**	**1,800,000**	**1,800,000**					
Removal; dispose in regional repository	cy	610,000	1,800,000	1,800,000	176,000	26,900	0.01	0.01	0.01	0.01	0.01
Alt 5: Cap/const levee	cy				90,000					0.95	
Stabilize removal areas											
Reveg FP area disturbed by removal											
No Action Volume	cy	1,190,000	0	0	1,534,000	1,773,100	1.00	1.00	1.00	1.00	1.00
Unidentified Volume (no action R=1)*	cy	360,000	360,000	360,000	360,000	360,000	1.00	1.00	1.00	1.00	1.00
*accounts for added Zn vol											
Total Volume + Unidentified Volume	cy	2,160,000	2,160,000	2,160,000	2,160,000	2,160,000					
Wetland (Palustrine) Sediments											
Total Volume	cy	**5,940,000**	**5,940,000**	**5,940,000**	**5,940,000**	**5,940,000**					
Total Area	acre	4,880	4,880	4,880	4,880	4,880					
Dredge (strip/remove); disposal in regional reposit	cy	80,700	435,700	5,940,000	163,000	0	0.01	0.01	0.01	0.01	0.01
Alt 5: Various measures TBD	cy				5,777,000					0.80	
Cap--remediated volume	cy	845,963	2,965,131				0.99	0.99			
Cap--remediated area	acre	695	2,436								
Soil amendments -- remediated area	acre	0	0		0	98					
Soil amendments--remed. vol. based on area	cy	0	0		0	118,800	Unused action				
No Action Volume	cy	5,013,337	2,539,169	0	0	5,821,200	1.00	1.00	1.00	1.00	1.00
Unidentified Volume (no action R=1)*	cy	1,188,000	1,188,000	1,188,000	1,188,000	1,188,000	1.00	1.00	1.00	1.00	1.00
*accounts for added Zn vol											
Total Volume + Unidentified Volume	cy	7,128,000	7,128,000	7,128,000	7,128,000	7,128,000					
Lake (Lacustrine) Sediments											
Total Volume	cy	**5,900,000**	**5,900,000**	**5,900,000**	**5,900,000**	**5,900,000**					
Total Area	acres	4,630	4,630	4,630	4,630	4,630					
Dredge; disposal in local repository	cy	66,900	571,400	5,600,000	0	0	0.01	0.01	0.01	0.01	0.01
Alt 5: Various measures TBD	cy				5,900,000					0.39	
Soil amendments -- remediated area	acres	0	0		0	93					
Soil amendments--remed. vol. based on area	cy	0	0		0	118,000	unused action				
No Action Volume	cy	5,833,100	5,328,600	300,000	0	5,782,000	1.00	1.00	1.00	1.00	1.00
Unidentified Volume (no action R=1)*	cy	1,180,000	1,180,000	1,180,000	1,180,000	1,180,000	1.00	1.00	1.00	1.00	1.00
*accounts for added Zn vol											
Total Volume + Unidentified Volume	cy	7,080,000	7,080,000	7,080,000	7,080,000	7,080,000					
Other Flooplain Areas											
Total Volume	cy	**10,200,000**	**10,200,000**	**10,200,000**	**10,200,000**	**10,200,000**					
Total Area	acres	3,500	3,500	3,500	3,500	3,500					
Dredge; disposal at regional repository	cy	50,000	231,000	8,400,000	50,000	0	0.01	0.01	0.01	0.01	0.01
Soil amendments -- remediated area	acres	131	884		750	70					
Soil amendments--remed. vol. based on area	cy	379,900	2,517,885		2,175,000	204,000	0.39	0.39	0.39	0.39	0.39
No Action Volume	cy	9,770,100	7,451,115	1,800,000	7,975,000	9,996,000	1.00	1.00	1.00	1.00	1.00
Unidentified Volume (no action R=1)*	cy	2,040,000	2,040,000	2,040,000	2,040,000	2,040,000	1.00	1.00	1.00	1.00	1.00
*accounts for added Zn vol											
Total Volume + Unidentified Volume	cy	12,240,000	12,240,000	12,240,000	12,240,000	12,240,000					
Cataldo/Mission Flats Dredge Spoils											
Total Volume	cy	**13,600,000**	**13,600,000**	**13,600,000**	**13,600,000**	**13,600,000**					
Volume under I-90	cy	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000					
Removal; disposal in regional repository	cy	0	0	10,900,000	150,000	25,000	0.01	0.01	0.01	0.01	0.01
Hydraulic Barrier (Alt 2:PRB; Alts3,4:WT)	cy	10,900,000	10,900,000	0	10,750,000		0.3	0.2		0.5	
Soil amend/cap (effect included w/HB)	acres	678	678		100						
Capped by I-90	cy	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	0.3	0.2	1.00	0.5	1.00
No Action Volume	cy	0	0	0	0	10,875,000	1.00	1.00	1.00	1.00	1.00
Unidentified Volume (no action R=1)*	cy	2,720,000	2,720,000	2,720,000	2,720,000	2,720,000	1.00	1.00	1.00	1.00	1.00
*accounts for added Zn vol											
Total Volume + Unidentified Volume	cy	16,320,000	16,320,000	16,320,000	16,320,000	16,320,000					

Table C-2 (Continued)
Lower Basin Cataldo (LC50) to Harrison (LC60)—Estimates of Relative Loading Potentials (RLPs), Remediated Volumes (Vij), Remediation Factors (Rij), and R Point Estimates at t=0 for Alternatives

RESULTS LC50 to LC60: Aggregate R Point Estimates (time t=0) for each Remedial Alternative						
	Remedial Alternative					
	1	2	3	4	5	6
Remediation Factor for Lower Basin LC50 to LC60: Ro						
Point Estimate Ro:	1.00	0.09	0.30	0.19	0.86	0.94
	Percent (%) Total Relative Loadings TRL by Source Type					
Source Type:						
Riverbed Sediment	66%	73%	42%	60%	75%	70%
Banks & Levees (Bank wedges)	10%	8%	6^%	9^%	10%	10%
Wetland (Palustrine) Sediments	6%	1%	4%	5%	1%	1%
Lake (Lacustrine) Sediments	9%	10%	29%	11%	5%	10%
Other Flooplain Areas	5%	6%	16%	9%	6%	6%
Cataldo/Mission Flats Dredge Spoils	4%	2%	4%	6%	2%	4%
Sum:	100%	100%	100%	100%	100%	100%
Estimated Post-remediation Dissolved Zinc Load LC50 to LC60 at time t=0 - Point Estimates (lb/d)						
Total:	248	223	74	48	213	234
Source Type:						
Riverbed Sediment	163	163	31	28	160	163
Banks & Levees (Bank wedges)	24	17	4	4	22	23
Wetland (Palustrine) Sediments	16	3	3	3	3	3
Lake (Lacustrine) Sediments	23	23	22	5	11	23
Other Flooplain Areas	13	13	12	4	12	13
Cataldo/Mission Flats Dredge Spoils	9	4	3	3	5	9
Sum:	248	223	74	48	213	234

Table C-3
Pre-remediation Zinc Loadings and TMDL Loading Capacities Used in Analysis

	Dissolved Zinc Pre-remediation Load, L (lb/d)		TMDL Loading Capacity, C_L	
USGS Monitoring Station	**E[L]**	**CV[L]**	**E[C_L]**	**CV[C_L]**
SF220 Mullan	35	0.70		
SF228 Wallace=UpperSF	89	1.20		
CC288 Canyon Creek (CC)	556	0.67	11.7	0.74
NM305 Ninemile (NM)	275	0.92	4.4	0.79
SF239 Silverton	1,111	0.80		
SF249Osburn	877	0.77		
SF259 BigCreek	1,201	0.85		
SF268 Elizabeth Park (EP)	1,284	0.69		
PC305 Pine Creek (PC)	90	2.93	30.0	1.13
SF271 Pinehurst (PH)	2,921	0.60	136.8	0.58
Upper Basin to SF271 w/o BHSS	1,374	0.78		
BHSS	1,547	0.55		
NF50 North Fork (NFCDR)	243	3.03		
SF271 to LC50 synoptic delta:	567	1.54		
SF271 to Confluence	34	Not used		
Confluence to LC50	290	Not used		
LC50 to LC60 synoptic delta w/LC50 Q's	248	5.13		
SF271 to LC60 synoptic delta (not used)	860	1.86		
Lower Basin PH to Harrison	572	2.49		
Lower Basin PH to Harrison w/ NFCDR	815	2.21		
LC60 Harrison*	3,736	0.77	497.2	1.00
* = SF271+ Synoptic(SF71 to LC50 + LC50 to LC60):				
LC60 w/o BHSS	2,189	1.06		

Notes:
Based on analysis of historical measured data
lb/d - pound per day
TMDL - total maximum daily load
USGS - U.S. Geological Society