3.0 MONITORING ASSUMPTIONS, APPROACH, HYPOTHESES, AND BENCHMARKS

This section uses information developed in RI/FS and EcoRA, and presented in Section 2 of this document, to develop a framework for the environmental monitoring program. First, this information is interpreted and presented as statements of the current understanding of Basin-wide processes, termed "working assumptions." Second, the approach used to formulate a Basin-wide monitoring plan that is robust, yet practical and cost-effective, is presented. Third, statistically testable monitoring hypotheses based on the monitoring objectives identified in Section 1 are presented. Finally, the ecological benchmarks that are identified in the ROD and used to measure progress of the remedy are presented.

3.1 CURRENT WORKING ASSUMPTIONS REGARDING BASIN OBSERVATIONS

As a basis for refinement of the conceptual site model during long-term monitoring, a number of working assumptions have been developed using the analyses performed during the RI, FS, EcoRA, and the Probabilistic Post-Remediation Metals Loading Tech Memo (EPA 2001e). These working assumptions are general enough to be observable on a Basin-wide scale and summarize an evolving understanding of Basin-wide processes. The working assumptions are summarized below and further explanation and rationale are provided in Table 3-1.

1. Metals concentrations in the Basin are generally decreasing with time.

2. River flow and metals concentrations (and therefore metals loading) are approximately log-normally distributed.

3. Location-dependent statistical correlations exist between metals concentrations and loads, hardness, and river discharge.

4. Dissolved zinc is an indicator for other dissolved metals.

5. Total lead is an indicator for total metals.

6. Surface water/groundwater interactions result in a net increase in dissolved metals loads in surface water.

7. The AWQC ratios (the ratio of concentration to AWQC) are less variable than measured concentration or calculated loading. Statistical evidence of a decreasing trend is stronger for AWQC ratios than for concentrations or loads (see Table 2-2). There is also evidence, based on the RI data set, that AWQC ratios are not correlated with discharge except at very high discharges and the variability

(as measured by the coefficient of variation) is less for AWQC ratios than for concentrations. AWQC ratios are federal criteria as of the signing of the ROD. Site-specific or other criteria can only be used as a basis if incorporated into the ROD by official amendment.

8. Portions of the Basin upstream from mining-related impacts support aquatic biota populations comparable to reference streams.

9. Ecological conditions are degraded in mining-impacted stream segments.

10. Ingestion of lead-contaminated soil and sediment is the injury pathway to migratory birds in the Basin.

11. Coeur d'Alene Lake is a partial sink for metals from the Coeur d'Alene River.

The assumptions of the conceptual model (CH2M Hill 2000) summarize the current understanding of processes in the Basin, and, as additional information is gathered, the assumptions of the model will be revised whenever necessary. The working assumptions of the model form the foundation for the hypotheses that will be tested by the long-term monitoring program. While the assumptions of the model have been developed to describe Basin-wide processes in terms of scientifically testable and reasonably quantifiable components, the long-term monitoring program does not directly focus on proving or disproving these assumptions.

3.2 MONITORING APPROACH AND PRINCIPLES

The BEMP is founded on several primary principles that are intended to enhance the practicality, robustness, and cost-effectiveness while maintaining adequate technical rigor and effectiveness. The principles are summarized in this section.

First, the BEMP is based on the remedy selected in the ROD. The ROD identifies benchmarks that include key indicators of ecological improvement representing the broad range of ecological conditions in the Basin. These key indicators were selected based on the results of the RI/FS (EPA 2001a and b), EcoRA (EPA 2001c), and supporting technical memoranda (EPA 2001e and f) and stakeholder input. These key indicators of environmental improvement are the focus of the monitoring program; they include:

- Dissolved and total metals and nutrients in surface water
- Metals in soil and sediment in riverine and riparian environments in the Upper Basin (Ninemile Creek, Pine Creek, and South Fork); in riverine, riparian, lacustrine, and palustrine environments in the Lower Basin; and depositional areas of the Spokane River

- Fish, macroinvertebrates, and aquatic habitat in riverine environments
- Songbirds, riparian vegetation, and invertebrates in riparian environments
- Waterfowl in wetland environments
- Waterfowl and fish in lake environments

The monitoring program uses parameters and sampling frequencies that are intended to be sensitive and responsive to the potential rates of relevant environmental changes in the Basin over the period of the remedy implementation. Given the large area of the Basin and the pace of remedy implementation over the 30-year timeframe, it is anticipated that relevant changes in environmental media will occur relatively slowly. Consequently, many parameters will be monitored at a relatively long interval (e.g., five or ten years). The monitoring program includes more frequent (e.g., several times per year, yearly, or event-triggered) sampling at key locations (e.g., South Fork near confluence with North Fork; Coeur d'Alene River near Coeur d'Alene Lake). These "sentinel" locations will provide data to fill any gaps on potential short-term trends or trend discontinuities that could be used to aid interpretation of data from the more comprehensive, but less frequent, sampling events and to help anticipate any developing changes in longer-term trends. This approach is anticipated to reduce the expense associated with sample collection and analysis while maintaining adequate monitoring effectiveness in terms of sensitivity and responsiveness.

The BEMP will be integrated with remedial action effectiveness monitoring (e.g., the Box) and monitoring conducted under other programs (e.g., Lake Management Plan monitoring of Coeur d'Alene Lake and State of Idaho BURP monitoring). This approach is anticipated to reduce monitoring redundancy and enhance cost effectiveness.

Finally, it is anticipated the BEMP will evolve over the 30-year remedy implementation timeframe. The monitoring program assumes an adaptive management approach will be used to guide that evolution while maintaining a sound scientific and technical basis. The adaptive management approach emphasizes learning from experience and is tied to the statutory five-year reviews.

3.3 MONITORING HYPOTHESES

This section presents the hypotheses that will be tested during the long-term Basin-wide monitoring program. Practical, data-testable hypotheses were developed in order to answer specific questions related to Basin-wide conditions, including temporal trends and correlations between key monitoring parameters and stations. For this monitoring program the *null hypothesis* was selected to represent standard, base conditions while the *monitoring hypothesis* (or the alternative hypothesis) represents a change (typically a decrease) from base conditions. This places the burden of proof on demonstrating that conditions have changed, thereby rejecting the hypothesis that there has been no change. The hypotheses selected for testing under this Basin-wide monitoring plan therefore have a null hypothesis of "there is no change" vs. the to-be-tested monitoring hypothesis (alternative hypothesis) of "there is a change," typically "there is a decrease." Methods of evaluating the hypotheses are described in Section 6.

Specific monitoring hypotheses were developed based on the data needs identified in ROD Section 12.6. These nine hypotheses will become the focus of the Coeur d'Alene Basin environmental monitoring program:

1. **There is a decrease in dissolved zinc and/or cadmium concentrations in surface water** from the recent historic trend or pre-remediation condition.

2. **There is a decrease in particulate lead concentrations in the flood plain soils/sediment, levees, and riverbed sediments** from the recent historic trend or pre-remediation condition.

3. **There is a decrease in particulate lead loads and concentrations in surface water** from the recent historic trend or pre-remediation condition.

4. **There is a decrease in zinc AWQC ratios** (dissolved zinc concentration divided by AWQC for zinc) from the recent historic trend or pre-remediation condition. Cadmium will be tested as well. Note that AWQC ratios (using zinc as an indicator metal) is the metric used in the ROD to characterize surface water quality for ecological risk.

5. **There is an improvement in biotic benchmarks** from the recent historic trend or pre-remediation condition. Biotic benchmarks were established in the ROD (EPA 2002) and focus on indicators such as fish, songbirds, and waterfowl. Biological benchmark monitoring under the BEMP will evaluate improvements in biological resources on a habitat basis through the monitoring of habitat-specific indicators. The specific habitat indicators include:

   - Riverine habitat – aquatic macroinvertebrates, fish, aquatic habitat assessment
   - Lacustrine / palustrine habitat – waterfowl
   - Riparian habitat – songbirds, terrestrial macroinvertebrates, riparian vegetation

6. **There is a change in metals retention in Coeur d'Alene Lake** from the recent historic pre-remediation condition. The hypothesis of "there has been a statistically significant increase in metal retention in the lake based on the yearly net difference in outflow load minus inflow load" will be tested against a null hypothesis of no change. The hypothesis that retention has decreased also will be tested. That is, the hypothesis of "there has been a statistically significant

decrease in metal retention in the lake based on the yearly net difference in outflow load minus inflow load" will be tested against a null hypothesis of no change. The trend of retention over time will also be statistically analyzed.

7. **Implementation of the remedy has resulted in unwanted impacts to the system** such as recontamination, nutrient loading, excess sedimentation, etc. Specific, statistically testable hypotheses have yet to be determined for these factors. Recall that the monitoring hypothesis is representative of a deviation from base conditions. To evaluate any unwanted impacts to the system, post-remediation data (sedimentation, recontamination, nutrient loading etc.) would be evaluated against pre-remediation trends or conditions to determine whether or not there is sufficient evidence to reject the null hypothesis of "implementation of the remedy has NOT resulted in unwanted impacts to the system." This hypothesis is consistent with the approach of evaluating a monitoring hypothesis of *change* versus a null hypothesis of *no change*.

8. **There has been progress toward achieving benchmarks of the selected remedy.** This "meta hypothesis" will consider the hypothesis testing results from monitoring hypotheses 1 through 7 together with results of hypothesis testing of the location-specific numeric ROD benchmarks for the selected remedy. Table 3-2 summarizes the location-specific numeric benchmarks from ROD Table 12.2-1. The numeric benchmarks that will be tested as part of monitoring hypotheses 8 are the zinc and cadmium AWQC ratios associated with fishery-tier benchmarks in Ninemile Creek, Pine Creek, and the SFCDR above Elizabeth Park; the 50% reduction in dissolved metal [zinc] load from Canyon Creek to SFCDR; and the 50% reduction in yearly lead load discharged to the Spokane River. For each of these location-specific numeric benchmarks, the monitoring (alternative) hypothesis will be that the benchmark has been achieved—tested against the conservative, presumptive null hypotheses that the benchmark has *not* been achieved. The BEMP will not test the numeric benchmarks for lead concentration reductions to 530 mg/kg in the Lower Basin wetland and lake sediments that are part of the selected remedy. These benchmarks will be tested as part of the effectiveness monitoring associated with the individual cleanup actions that are implemented (as part of the selected remedy) to achieve those benchmarks.

The monitoring hypotheses evaluate BEMP data against a null hypothesis (of no change) in terms of time-history *trends,* aggregated temporal *averages,* or *both*, depending on data characteristics and/or availability. In particular, where available data do not support an estimate of a trend, aggregated temporal averages will be used.

The "best available" baseline data that will be used in the analysis and testing of trends and averages (or other measures) represent the recent historic record that was used in the RI/FS and

ROD. The baseline data is summarized in Section 2.3. Note that the quantity and quality of the baseline data vary between parameters to be evaluated under the monitoring hypotheses. Baseline data analyses are included in Appendix C.

There is not a monitoring hypothesis addressing groundwater quality in the Basin. Groundwater is not specifically addressed under the ROD; however, groundwater monitoring will likely be an important component of remedial action-specific effectiveness monitoring at various locations throughout the Basin. As future remedial action effectiveness monitoring data become available, it may be possible to incorporate the data into a better understanding of groundwater processes within the Basin. Relative contributions or reductions in metals loading to the river or its tributaries may also be inferred from metals loading mass balances on specific reaches. Mass balance calculations using surface water monitoring data may also illustrate the relative effects of surface water/groundwater interactions in different areas within the Basin.

3.4 BENCHMARKS

The priority ecological actions included in the interim remedy were selected to achieve measurable ecological benchmarks, which are near-term objectives that will serve as landmarks and measurements to evaluate the progress of the remedy toward achievement of long-term goals (see Table 12.2-1 of the ROD, EPA 2002). The identification of benchmarks and prioritization of actions were based on knowledge gained during the RI/FS process and extensive consultations with governmental stakeholders with expertise in local environmental conditions and wildlife habitat. Key areas of focus included identification of benchmarks that would be achievable within the time period of the Selected Remedy, appropriate measures of success, and actions necessary to achieve the benchmarks. These discussions drew heavily on the large amount of environmental data collected over time (e.g., water quality data and fish surveys) and the extensive experience of stakeholders in the Basin. The benchmarks are shown on Table 3-2 of this document.

In the ROD, the selected remedy and the expected outcomes of remedy implementation are identified by geographic unit and media type (see ROD Section 12). The qualitative and quantitative measures of the expected outcomes are called benchmarks. Progress toward the benchmarks will be considered during five-year reviews as part of the long-term monitoring adaptive management framework, in which the performance expectations will be compared to the observed outcomes of the completed actions. The benchmarks are listed in Table 3-2.

Table 3-1
Conceptual Model Working Assumptions

Working Assumption	Explanation and Rationale	Reference
1. Metals concentrations are generally decreasing with time.	Natural attenuation, source depletion and previous and ongoing remediation activities within the Basin contribute to the trend of generally decreasing metals concentrations in surface water, groundwater and soil/sediment.	EPA 2001e 7/9/02 Basin-Wide LTM Meeting
2. River discharge and metals concentrations (and therefore metals loading) are approximately lognormally distributed.	The lognormal distribution is a pattern commonly found in the natural world. Lognormal distributions "fit" the available measurements of stream flows and metal concentrations and loadings in the Basin.	RI Part 1 Section 5.0 RI Part 2 EPA 2001e
3. Location-dependent statistical correlations exist between metals concentrations and loads, hardness, and discharge.	Dissolved metal concentrations *decrease* but dissolved metal loading *increases* during high flows. Total metal concentrations increase during high flows. This is primarily due to increased sediment/particulate content during high flows. Linear regression between ln (flow) and hardness performed using available data; allows prediction of hardness values given flow.	RI Parts 2 through 6 RI Parts 2 through 6 Woods (2000b) TMDL Appendix I (EPA and IDEQ 2000) EPA 2001e
4. Dissolved zinc is an indicator for other dissolved metals.	There is generally a positive correlation between dissolved zinc concentrations and dissolved concentrations of the other 8 COC metals in the upper and midgradient watersheds. Also, Zinc is the most ubiquitous of the COC metals. Dissolved zinc occurs at much higher concentrations the dissolved cadmium and lead. Zinc is relatively mobile.	RI Part 2, Section 4.0 EPA 2001e, Section 1.4
5. Total lead is an indicator for other total metals.	There is a positive correlation pattern between total lead concentrations and total metals concentrations in the upper and midgradient watersheds.	RI Part 2, Section 4.0
6. Surface water/groundwater interactions result in a net increase in dissolved metals loads in surface water in the Basin.	In general, where rivers widen into floodplains there is a tendency for surface water to discharge to groundwater. Conversely, in areas where the river channel narrows groundwater tends to discharge metals to surface water, principally in the dissolved phase. Metals concentrations in groundwater are generally higher than in surface water at a given location.	RI Part 1 Section 3.0
7. AWQC ratios (ratio of concentration to AWQC) are less variable than C or L	AWQC ratios have less noise and are more reliable than concentration or loading data. AWQC ratios not correlated w/ discharge (Q) except at high Q ($Q>\sim 2*Q_{AVERAGE}$)	7/9/02 Basin-Wide LTM Meeting

Table 3-1 (Continued)
Conceptual Model Working Assumptions

Working Assumption	Explanation and Rationale	Reference
8. Portions of the Basin upstream from mining-related impacts support aquatic biota populations comparable to reference streams.	Habitat structure and diversity in Basin areas upstream from mining are comparable to conditions in reference streams. Macroinvertebrate abundance and diversity in these areas are comparable to or exceed those in reference streams. Fish populations in these areas are primarily composed of native species with multiple year classes present, and abundance approaches or exceeds reference benchmarks (<0.1 fish/meter^2)	EcoRA Section 2.3.3 EcoRA Appendix K Maret and MacCoy (2002)
9. Richness and population abundance of fish species and benthic macroinvertebrate taxa are reduced in mining-affected stream segments.	Ambient water quality criteria are commonly exceeded for cadmium, lead and zinc in mining-affected stream segments. Habitat conditions for aquatic species are poor due to stream channelization, lack of riparian vegetation, and alteration of stream-bottom substrates in mining-affected stream segments.	EcoRA Section 2.3.3 Stratus 2000 NAWQA Data. including Maret and MacCoy (2002)
10. Ingestion of lead-contaminated soil and sediment is the injury pathway to migratory birds in the Basin.	In the Basin, lead poisoning (primarily due to ingestion of contaminated sediments) is responsible for an estimated 96 percent of the total tundra swan mortality, compared to 20 to 30 percent (primarily due to ingestion of lead shot) at the Pacific flyway and national level.	EcoRA Stratus 2000
11. Coeur d'Alene Lake is currently a sink for metals from the Coeur d'Alene River.	Mass balance calculations (Woods 2000a) indicate that more metals enter Coeur d'Alene Lake on an annual basis from the Coeur d'Alene River than exit the lake to the Spokane River. This assessment is consistent with the current understanding of the trophic status of the lake.	RI Part 1 Section 3.0 RI Part 5

Notes:
AWQC ratio = ratio of concentration to ambient water quality criteria
C = concentration
COC = chemical of concern
EcoRA = ecological risk assessment
L = load
Ln =- natural logarithm
LTM = long-term monitoring
NAWQA = National Water Quality Assessment
Q = discharge
RI = risk assessment
TMDL = total maximum daily load

Table 3-2
Ecological Benchmarks of the Selected Remedy

Area		Benchmark
Upper Basin		**Reduce potential for recontamination of downstream remedies and reduce metals load to Coeur d'Alene Lake and the Spokane River** Reduce metals and nutrient loads from groundwater to the South Fork
Canyon Creek		**Reduce metals toxicity to downstream aquatic receptors** Reduce dissolved metals load discharging to the South Fork by at least 50% Reduce particulate lead and sediment loading during high flows
Ninemile Creek	East Fork headwaters to above Success	**Improve conditions to allow natural reestablishment of a salmonid fishery** Tier 2 to 3+ fishery (see fishery tier definitions at end of table). Reestablish fishery in 1.7 miles of 13 miles of streams in the Basin that are devoid of fish. Reduce dissolved metals concentrations to less than 7 times chronic AWQC with mitigation of mining impacts on riverine areas. Protect riverine and riparian receptors Mitigate mining impacts on riparian areas along 1.7 miles of stream. Risks to riparian receptors will be mitigated using removal and replacement with clean soil or capping with clean soil to isolate contaminants and reduce or eliminate exposure pathways.
	East Fork above Success to confluence	**Improve conditions to allow natural reestablishment of a migratory corridor for adult and juvenile fish** Tier 1 fishery. Reduce dissolved metals concentrations to less than 20 times acute AWQC.
	Mainstem Ninemile Creek.	**Improve conditions to allow natural reestablishment of an adult salmonid fishery** Tier 1 fishery. Reduce dissolved metals concentrations to less than 20 times acute AWQC.
Pine Creek		**Improve conditions to allow natural increases in salmonid populations and improve spawning and rearing** Tier 3+ fishery. Protect riverine and riparian receptors Mitigate mining impacts on riparian areas at locations of hot spot removal/capping. Risks to riparian receptors will be mitigated using removal and replacement with clean soil or capping with clean soil to isolate contaminants and reduce or eliminate exposure pathways.
South Fork (above Elizabeth Park)		**Improve conditions to support a higher fish density** Tier 2+ to 3+ fishery at >0.1 fish/square meter Initial protection of riverine and riparian receptors Mitigate mining impacts on riparian areas at locations of hot spot removal/capping. Risks to riparian receptors will be mitigated using removal and replacement with clean soil or capping with clean soil to isolate contaminants and reduce or eliminate exposure pathways.
South Fork (Elizabeth Park to confluence including the Bunker Hill Box)		**Reduce metals loading to surface water**

Table 3-2 (Continued)
Ecological Benchmarks of the Selected Remedy

Area	Benchmark
Lower Basin Stream Banks and Beds, including the Harrison Delta (Riparian and Riverine)	**Reduce particulate lead loading in the river** Reduce lead load entering into Lake Coeur d'Alene and the Spokane River, with emphasis on peak discharge events. Estimated reduction in high-flow load needed is at least 50% to reduce year-round lead concentrations to below chronic AWQC in the Spokane River. Reduce soil toxicity for songbirds, small mammals, and riparian plants Mitigate risks to riparian receptors along 33.4 miles of river by removing contaminated bank wedges from a 30-foot wide zone (122 acres). Remove contaminated bank wedges and cap with clean topsoil to enhance vegetation establishment and isolate contaminants from receptors.
Lower Basin Floodplain	**Wetlands: Reduce sediment toxicity and waterfowl mortality** Increase feeding area with lead concentration <530 mg/kg by 1,169 acres (of a total of 5,829 wetland acres with lead exceeding 530 mg/kg). Potentially increase feeding area by an additional 1,500 acres through conversion of agricultural land. Lakes: Reduce sediment toxicity to diving ducks, dabbling ducks, and warm- and cold-water fishes Reduce lead concentration in whole brown bullhead fish (as an indicator species) by remediating 1,859 of 5,979 acres of lake with lead exceeding 530 mg/kg. Riparian: Reduce soil toxicity for riparian receptors

Source: EPA 2002, Table 12.2-1 of the ROD

Fishery Tier definitions:
Tier 0: No migrating or resident fish observed.
Tier 1: Presence of migrating fish only, no fish observed during resident fish surveys (expected to be achieved at concentrations below 20x acute AWQC).
Tier 2: Presence of resident salmonids (trout) of any species, sculpin absent (expected to be achieved at concentrations from 7x to 10x chronic AWQC).
Tier 3: Presence of 3 or more year classes of resident salmonids, including young of the year (YOY), sculpin absent (expected to be achieved at concentrations between 3x and 7x chronic AWQC).
Tier 4: Presence of 3 or more year classes of resident salmonids, including YOY, and sculpin (expected to be achieved at concentrations between 1x and 3x chronic AWQC).
Tier 5: Presence of 5 salmonid age classes, including YOY, sculpin, and bull trout. Fauna dominated by native species at high densities (0.1 to >0.3 fish/m^2) (least impacted watersheds with concentrations <1x chronic AWQC).
+ presence of adult trout (>150mm).
Note: For the definitions of fisheries tiers, AWQC are equal to the EPA-approved State of Idaho water quality standards for cadmium and zinc. The concentration ranges are unaffected by the 2001 update to the cadmium criteria.