MILLTOWN DAM REMOVAL PREDICTED SURFACE WATER QUALITY IMPACTS[1]

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Abstract. Milltown dam, located on the Clark Fork River just upstream of Missoula, Montana, is proposed for removal in the next few years. The potential impacts of dam-removal-induced scour of reservoir sediments on downstream surface water quality is of concern particularly since some of these sediments contain elevated metals concentrations. Therefore as part of the Milltown dam removal project, evaluation and management of sediment scour has been carefully considered in a predictive sense to provide time-based release and to, where possible, minimize the impacts on downstream surface water quality and beneficial uses. The computational model "HEC-6, Scour and Deposition in Rivers and Reservoirs" was used to analyze predicted sediment transport resulting from removal of Milltown Dam and to estimate the effectiveness of various Best Management Practices (BMPs) to reduce potential water quality impacts. The evaluation determined that staging reservoir drawdown to take advantage of dilution provided by high flows combined with using cofferdams and a bypass channel to isolate higher metals sediment from flowing water should adequately protect downstream water quality. However, a comprehensive monitoring plan will also be conducted to evaluate dam removal and other construction impacts on downstream water quality. The monitoring plan identifies warning levels for constituents of concern which, if exceeded, may trigger changes in monitoring frequency, operational controls or implementation of additional BMPs.

Additional Key Words: Dam Removal, Sediment Transport, Water Quality, BMPs

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Site Location and Description

The Milltown Reservoir was created in 1907 by the construction of the Milltown Dam at the confluence of the Clark Fork River (CFR) and the Blackfoot River (BFR). The Milltown Dam is located approximately 4 miles east of Missoula, Montana and is adjacent to the small, unincorporated communities of Milltown and Bonner (Fig. 1).

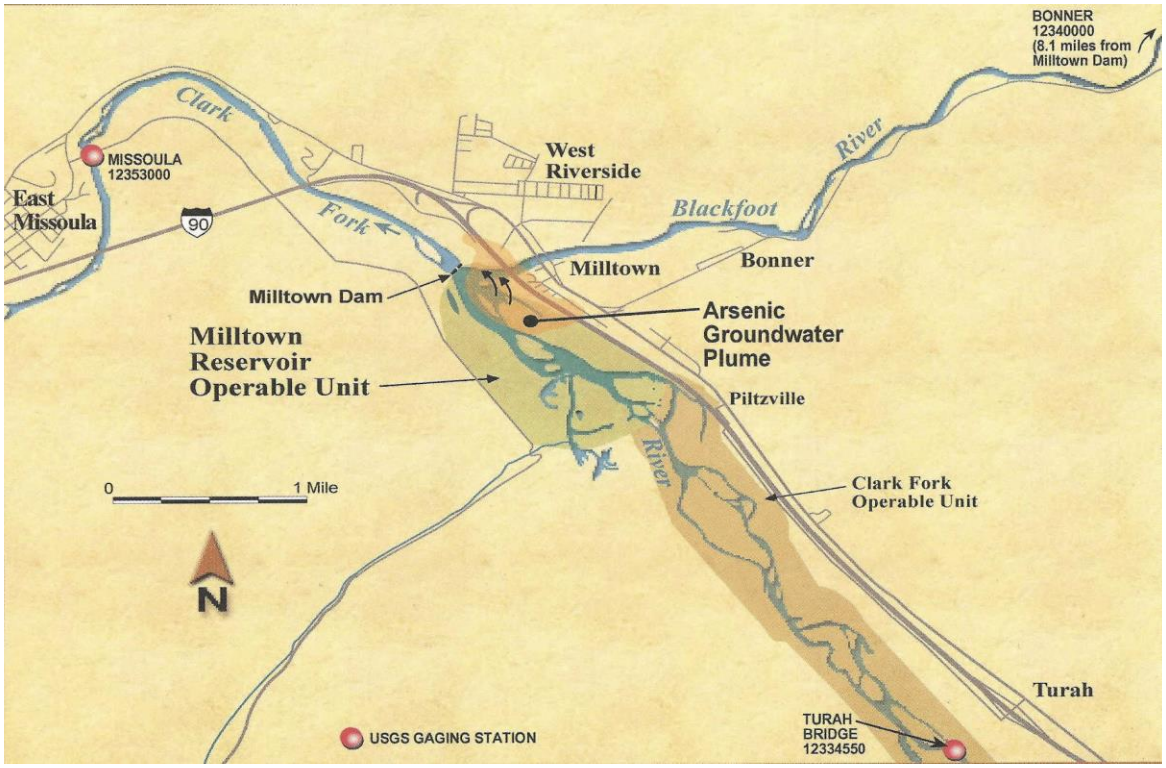

Figure 1. Project Location Map (EPA, 2004)

During the past century, mine wastes and natural sediment materials have washed downstream, creating some 7 million cubic yards (mcy) of sediment accumulation behind the Milltown Dam. Much of this material was deposited in 1908 when a major flood (estimated to coincide with a flow rate of approximately 48,000 cubic feet per second) resulted in overbank flows that washed tailings from the Cu mining operations in the Butte and Anaconda area approximately 100-miles upstream of Milltown (see Fig. 2).

The submerged environment within which these sediments resided caused an enhanced degree of solubility of As over time resulting in creation of a groundwater As plume. In addition, under certain conditions (i.e., reservoir drawdown, ice flow and some high flow events) net scour of reservoir sediments has resulted in short term increases in downstream Copper concentrations at USGS gauging station 12353000 (see Fig. 1 for gauging station location).

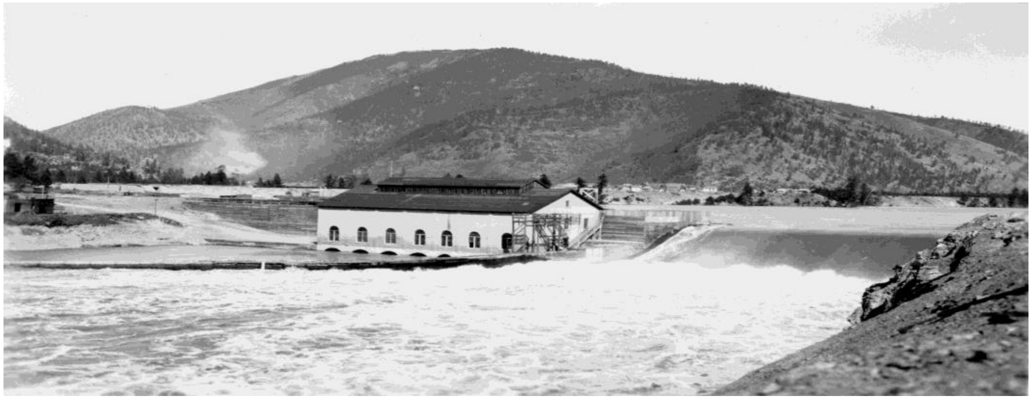

Figure 2. Later stages of the 1908 flood at the Milltown dam (Library of Congress)

As noted, an estimated 7 mcy of sediment have deposited within the reservoir area. These sediments were analyzed during the site's Remedial Investigation (Atlantic Richfield, 1995) and the results used to delineate five sediment accumulation areas (SAAs) as shown on Fig. 3. The principal area of impacted groundwater was also delineated. Based on the location of the impacts noted and the concentrations of metals within the sediments analyzed, the approximately 2.6 mcy of sediment within SAA I was identified for targeted removal.

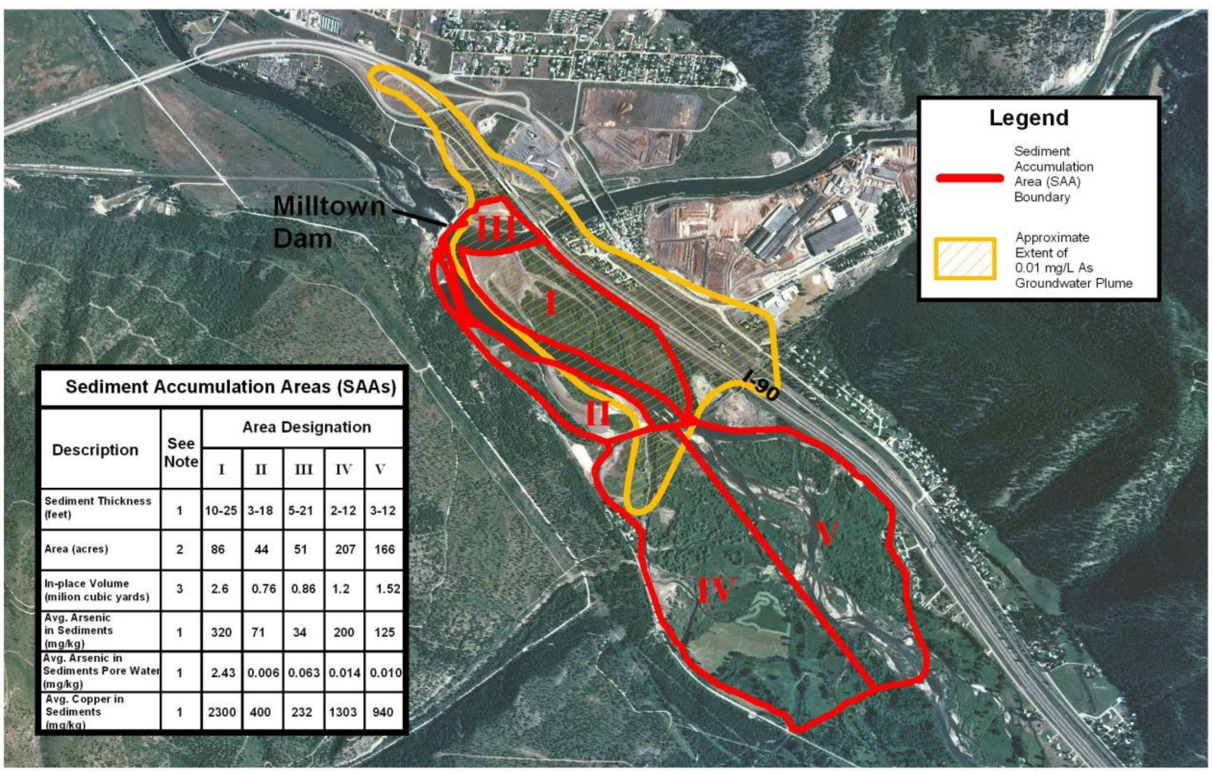

Figure 3. Sediment Accumulation Areas and Groundwater Arsenic Plume (Atlantic Richfield, 2002)

Cleanup Plan

A conceptual model of the Milltown Reservoir Site cleanup plan is provided on Fig. 4. The main elements of the cleanup plan are:

1. Protect sediments in existing CFR channel from dam-removal-induced scour by constructing a bypass channel and diverting CFR flows into it;
2. Remove the dam to lower reservoir water levels and thereby dewater the SAA I sediments to be removed;
3. Remove SAA I sediments in the dry and transport them by rail to Opportunity Ponds near Anaconda; and
4. Backfill and regrade the site, protect left-in-place sediment with higher metals concentrations from erosion, construct new river channels, and revegetate.

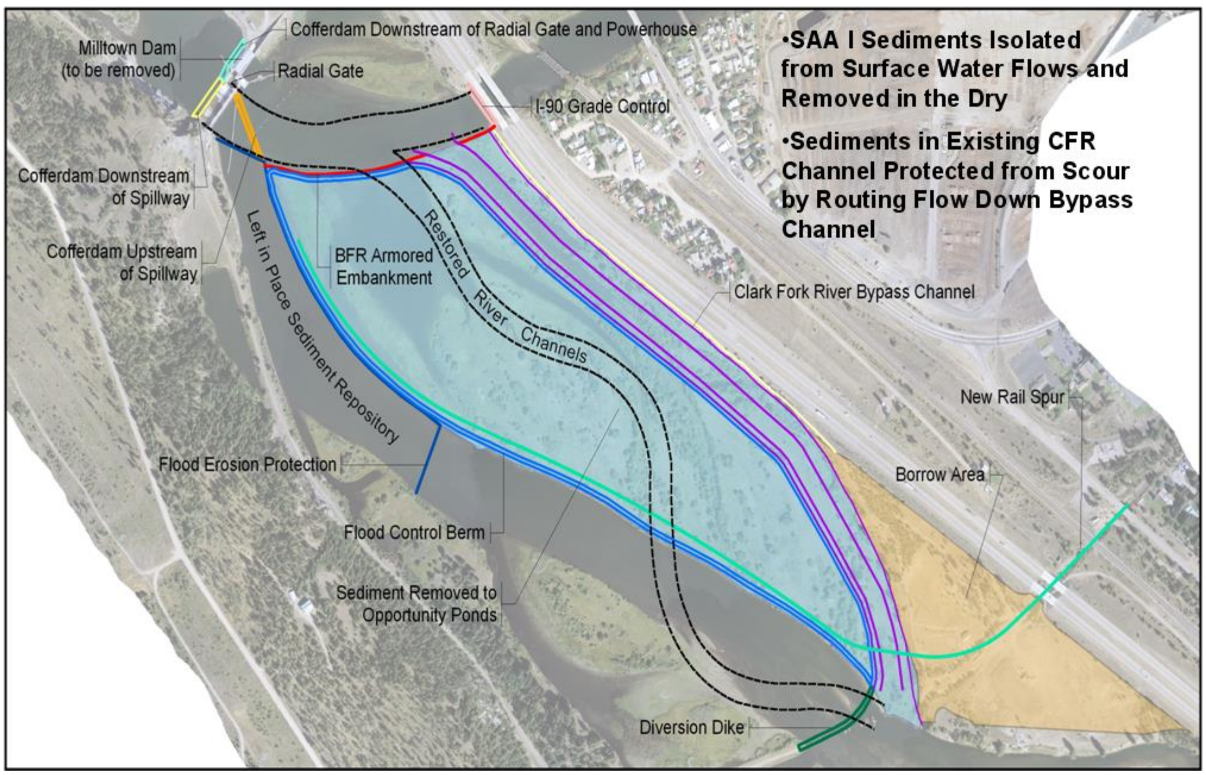

Figure 4. Conceptual Model of Clean-up Plan

The EPA has determined that the cleanup plan will provide: permanent long-term protection of public health and the environment; recovery of a drinking water aquifer in a reasonable amount of time; elimination of the potential for negative impacts to downstream aquatic life from contaminant release associated with ice scouring, floods and catastrophic events; and removing a fish passage impediment/returning the CFR to a free flowing state (EPA, 2004). However, the reservoir drawdown associated with dam removal has the potential to result in short-term increases in scour of reservoir sediment and associated increases in suspended sediment, Cu and As concentrations in the downstream surface water. Therefore a key element of the design is to predict the timing and amounts of scour and develop best management practices (BMPs) to mitigate scour-related impacts to downstream water quality. The applicable water quality criteria, along with the methodology and results of the scour mitigation design work are described in the following sections.

Applicable Compliance Criteria

Table 1 lists EPA's temporary surface water standards to be used during the construction implementation portion of the project. These temporary standards were established by EPA to protect human health and prevent acute impacts to the downstream fishery and bull trout with the proposed point of compliance set 2.8 miles downstream of Milltown Dam at the current USGS "Above Missoula" sampling station. The primary standards of concern are for concentrations of TSS and dissolved arsenic and copper. To provide added protectiveness EPA also identified an early warning limit set at 80% of the below standards where implementation of mitigative measures may be considered.

Table 1. Temporary Construction Related Water Quality Standards* (EPA, 2004)

Constituent	Concentration Standard	Duration
Cadmium-Acute AWQC	2 ug/L	Short-term (1 hour)
Copper-80% of the TRV (dissolved) (at hardness of 100 mg/L)	25 ug/L	Short-term (1 hour)
Zinc-Acute AWQC (dissolved)	117 ug/L	Short-term (1 hour)
Lead-Acute AWQC (dissolved) DWS	65 ug/L	Short-term (1 hour)
(dissolved)	15 ug/L	Long-term (30-day average)
Arsenic-Acute AWQC (dissolved)	340 ug/L	Short-term (1 hour)
DWS (dissolved)	10 ug/L	Long-term (30-day average)
Iron-AWQC (dissolved)	1,000 ug/L	Short-term (1 hour)
Total Suspended Solids (TSS)	550 mg/L	Short-term (day)
	170 mg/L	Mid-term (week)
	86 mg/L	Long-term (season)

*All hardness related AWQC values assume a hardness of 100 mg/L.
TRV = Toxicity Reference Value, used in proposed plan for the Clark Fork River Operable Unit.
AWQC = Federal Ambient Water Quality Criteria.
DWS = Federal Drinking Water Standard.

Scour Predictive Modeling Methodology

For dam removal projects of sufficient scale to require consideration of active sediment management it is typical to develop a computational model capable of quantitatively analyzing sediment scour and transport under various hydraulic conditions and dam removal staging assumptions. Various numerical sediment transport models are available that can be tailored to predict fate and transport of sediment following dam removal. One model that is often chosen is the Corps of Engineers "HEC-6, Scour and Deposition in Rivers and Reservoirs". HEC-6 requires three groups of data for model computations: channel geometry, sediment characteristics and hydrology. Once the required input data has been obtained, the model is calibrated to best simulate existing site conditions before being used to predict the effect of dam removal. Although considerable time and information is required to develop a calibrated model, one of the advantages of the numerical models is that after being used to predict sediment fate and transport during, and following, dam removal under base conditions of no sediment management they can be updated relatively easily to evaluate the sensitivity of predicted sediment scour/transport to various sediment management options.

<u>Scour Mitigation BMPs Evaluated</u>

Planned BMPs for mitigating scour-related impacts to downstream water quality associated with removal of Milltown Dam can be divided into two general groups:

1. Implementing the drawdown in a series of steps staged over time; and
2. Isolating reservoir sediments from flowing surface water prior to dam removal.

These planned measures are detailed below.

<u>Stage reservoir drawdown over time</u>

This BMP does not try to prevent natural erosion of reservoir sediment but uses a staged reservoir drawdown approach (i.e., incremental dam breaching) in order to meter out sediment release over time. As shown on Fig. 5, to further protect downstream water quality the primary drawdown steps are timed to take advantage of dilution provided by seasonal high flows and coincide with times when downstream irrigators and recreational users are least effected. Under this approach, in Stage 1 the reservoir is drawn down about 10 feet by opening the dam's radial gate. In Stage 2, the reservoir is drawn down an additional approximately 7 feet by converting the powerhouse inlets to low level outlets. In Stage 3, the dam's spillway would be removed to lower the reservoir water level by a final drawdown of approximately 13 feet. During the first two stages of drawdown, the rate and degree of drawdown can be varied depending on water quality monitoring results. By controlling the rate and timing of sediment release this BMP is designed to meet concentration-based downstream water quality criteria to the greatest degree possible.

<u>Isolate Reservoir Sediments from Flowing Surface Water</u>

This BMP includes constructing an excavated channel to bypass CFR flows around reservoir sediments in the existing CFR channel along with using bank armoring, flood berms, dikes, cofferdams and channel bed grade controls to isolate higher metals concentration sediments from surface water flows prior to dam removal. Because the CFR flows are bypassed around the reservoir sediments, bank armoring and flood berm protection for the SAAI sediments is focused along the BFR channel. A conceptual layout of the planned sediment isolation BMPs is provided on Fig. 4.

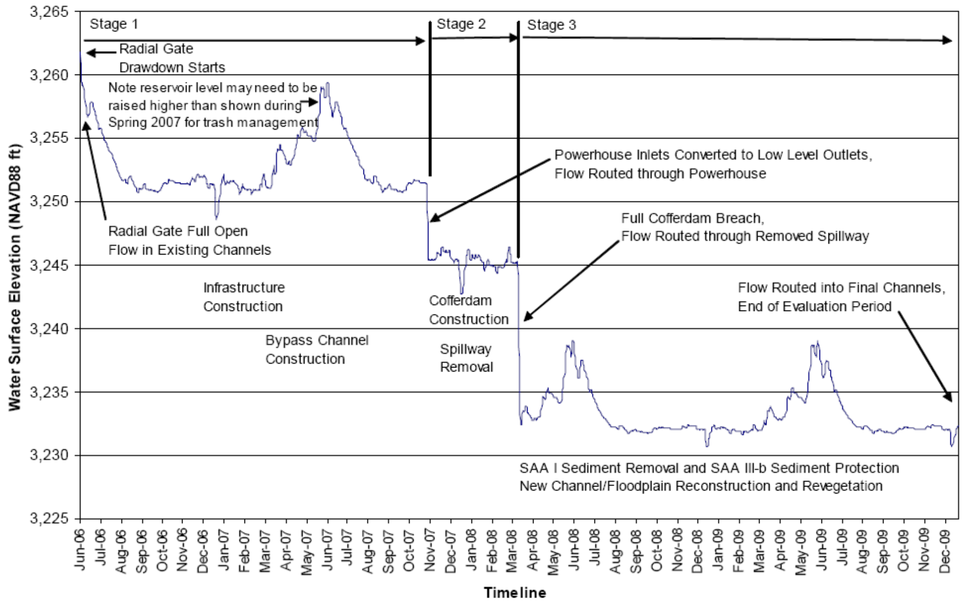

Figure 5. Staged Drawdown of Milltown Reservoir Water Surface (Envirocon, 2006)

Scour Modeling Results

HEC-6 modeling results for the predicted total amount of sediment, Cu, and As released from the reservoir over the entire approximately 4 year long dam and sediment removal construction period are shown on Table 2. For context these predicted total loads from scour of Milltown Reservoir sediment are compared to the contributions to the CFR from upstream and downstream sources (through Thompson Falls Reservoir) that would be expected over the same period. The staging of reservoir drawdown affects the rate/timing of sediment release and hence the predicted maximum concentrations but does not effect the total amount of scour. However, the planned BMPs that isolate much of the sediment from flowing surface water are predicted to be effective in limiting the total amount of reservoir sediment scour to approximately 300,000 tons compared to over 1,000,000 tons that would be anticipated without these BMPs (note the HEC-6 modeling also predict some additional scour of alluvium underlying the reservoir sediments but this material is low in metals and of large enough particle size that it is unlikely to add significantly to downstream Cu, As or total suspended sediment [TSS] loads). For comparison, about 592,000 tons of sediment currently moves through the reservoir during an average 4 year period, while 442,000 tons moved through the reservoir in a single high-flow year (1997) (USGS, 1998).

In addition, because these BMPs preferentially protect the higher metals concentration sediments in the reservoir from scour, most of the material predicted to scour will be uncontaminated sediments from the BFR channel bottom with the remainder from the CFR arm of the reservoir that exhibit metals concentrations similar to upstream CFR channel sediments. Hence, the average concentration of arsenic and copper on the 300,000 tons of sediment predicted to be released from Milltown Reservoir is estimated to be only slightly higher than the sediment currently coming down the BFR and considerably lower than the sediment coming down the CFR from upstream. As shown on Table 2, after mixing with this upstream BFR and

CFR sediment and with additional sediment contributions from downstream sources the weighted average sediment Cu and As concentrations entering Thompson Falls Reservoir are not expected to be elevated compared to existing conditions.

Table 2. Milltown Dam Removal Scour Evaluation Results Estimated Copper and Arsenic Concentrations on TSS Entering Thompson Falls Reservoir (Envirocon, 2004)

Major Contributions to the Clark Fork River	Predicted Sediment Load over 4 Years (tons)	Average Copper Concentrations on TSS (mg/kg)	Average Arsenic Concentrations on TSS (mg/kg)
Blackfoot near Bonner	211,041	116	30
Clark Fork River at Turah	214,875	586	191
Milltown Reservoir Scour (Averaged over 4 years)	290,689	232	34
Bitterroot River near Missoula	1,262,136	26	2.6
Flathead River at Perma	514,940	25	5.4
Weighted Average Estimates for Thompson Falls Reservoir Input	2,493,681	106*	25*

*For comparison existing Thompson Falls Reservoir Sediment averages 108 mg/kg copper and 19.3 mg/kg arsenic (Johns and Moore, 1985)

From a water quality standpoint the timing and rate of sediment scour is more important than the total amounts of sediment released over the project duration because that is what effects downstream concentrations of TSS, Cu and As. Based on the results of modeled simulations the increase in downstream TSS and metals concentrations from breaching the dam are significantly dampened by a prior period of reservoir drawdown staged over a couple years (Envirocon, 2004). In addition, the predicted period of higher TSS and metals concentrations is reduced by sequencing the drawdown/dam breach steps to take advantage of the dilution capacity provided by high flows that typically occur on the CFR and BFR in May and June. Similarly, by taking several weeks to gradually lower reservoir water levels during each stage the peak predicted TSS and metals concentrations are predicted to be further reduced.

Taking advantage of this sequencing, modeling predicted peak total and dissolved metals concentrations during construction similar to what is currently observed during high flow events (see Fig. 6 and 7). No exceedances of dissolved metals temporary construction related water quality standards were predicted due to scour of reservoir sediments during any of the drawdown stages. As shown on Fig. 8 peak TSS concentrations were predicted (under some modeled flow scenarios) to potentially exceed the daily maximum TSS standard (550 mg/L) briefly after some drawdown steps but overall were expected to be well below this level for the vast majority of the construction period (i.e., > 99% of the time).

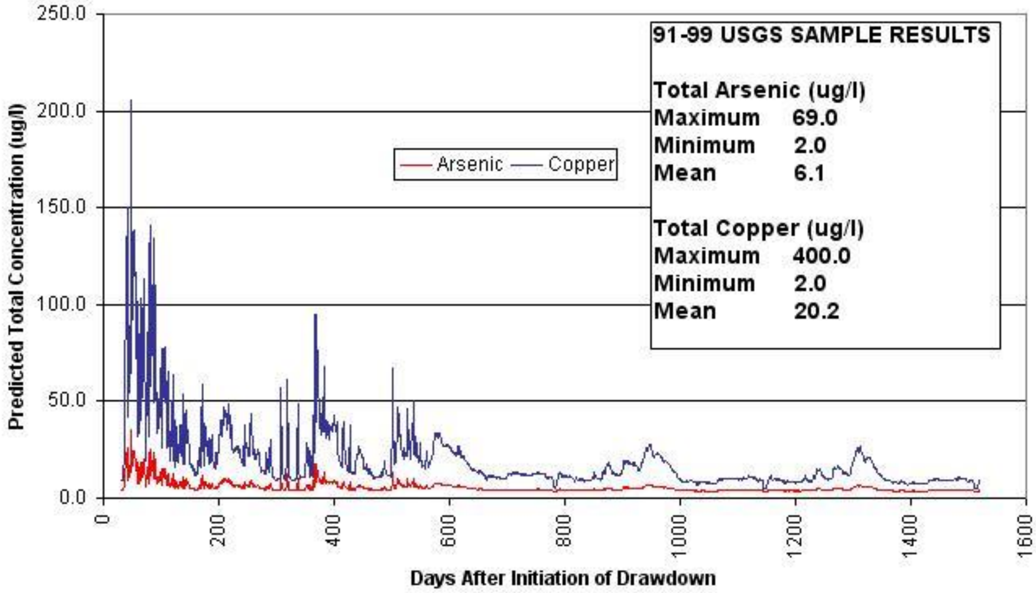

Figure 6. Predicted Total Metals Concentrations in Downstream Surface Water During Milltown Reservoir Remedial Action (Envirocon, 2004)

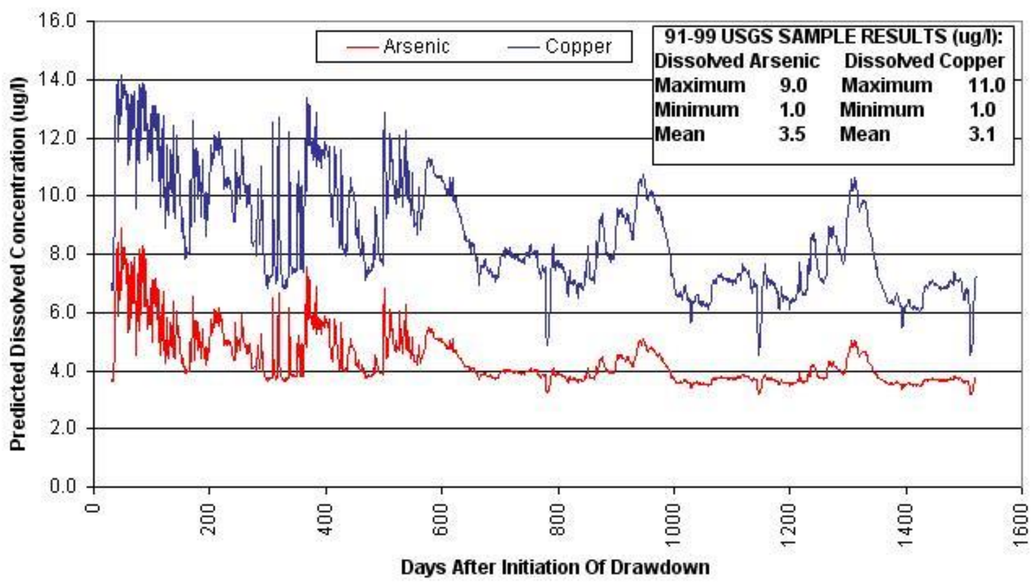

Figure 7. Predicted Dissolved Metals Concentrations in Downstream Surface Water During Milltown Reservoir Remedial Action (Envirocon, 2004)

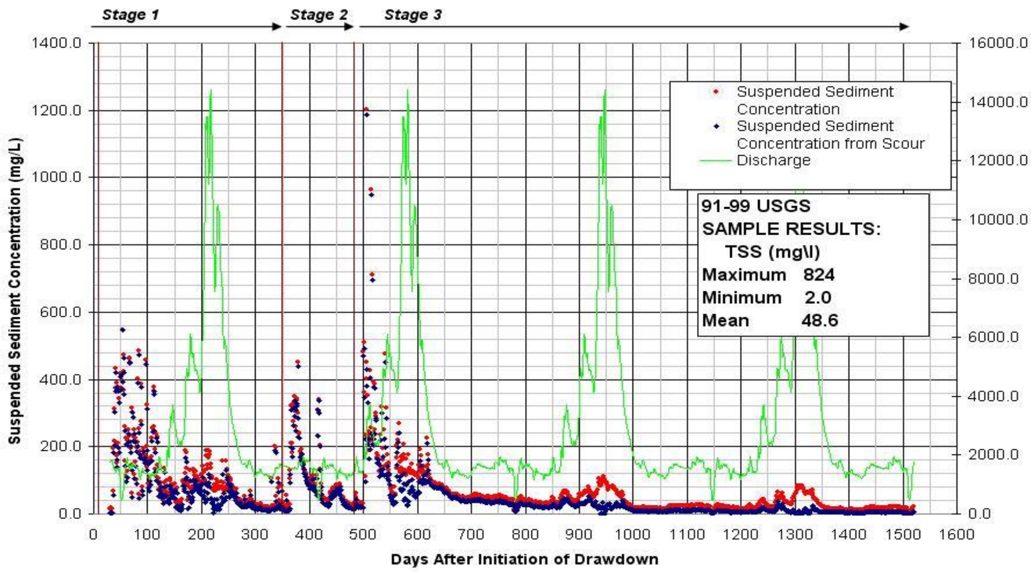

Figure 8. Predicted TSS Concentrations in Downstream Surface Water During Milltown Reservoir Remedial Action (Envirocon, 2004)

Monitoring Feedback System

Extensive monitoring of surface water, groundwater, aquatic biota and bed sediment will be conducted as part of the Milltown Reservoir Cleanup Plan. The planned surface water monitoring will be most applicable to evaluating the impacts of sediment scour. The primary objectives of the surface water monitoring are to:

- Measure the overall and cumulative effects of the construction activities on downstream surface water quality;
- Provide the analytical feedback system to trigger consideration of additional operational controls and BMPs;
- Provide information to determine if/when elevated downstream surface water dissolved arsenic concentrations justify increasing the frequency of well sampling to ensure that groundwater used for drinking water purposes does not exceed the arsenic standard; and
- Provide data to help assess the water quality and biological impact related to construction activities.

Upstream water quality, flow and biologic data are also necessary to characterize the surface water entering the construction area. These data can then be compared with similar data collected downstream of the site to determine the extent and magnitude of potential site construction activity impacts. Two proposed surface water quality sampling locations are located upstream of the Milltown reservoir and one is located downstream of the reservoir. All three sampling locations are currently used as CFR basin-wide surface water quality monitoring locations. The sampling locations are shown in Fig. 1.

The first upstream surface water quality sampling location is the CFR at Turah Bridge station with the USGS identification number 12334550. The second upstream surface water quality sampling location is the BFR near Bonner station with the USGS identification number 12340000. The downstream surface water quality sampling location and point of compliance for remedial action surface water quality is the CFR above Missoula station with USGS identification number 12340500. This gaging station is located 2.8 miles downstream of Milltown Dam. This compliance point monitoring location will allow direct comparison to historic water quality data.

Selection of two sampling locations immediately upstream of the reservoir, one on the BFR and one on the CFR, allows identification of the quality of the surface water entering the reservoir. Comparing the flow-weighted upstream water quality results to the downstream results provides a measure of the impact RA construction activities are having on the river downstream of the reservoir.

The frequency of surface water monitoring and the parameters to be monitored were developed following the Superfund Data Quality Objectives analysis process. From that analysis two sampling Regimes (1 and 2, see Fig. 9 and 10) were developed, each triggered by the analytical results of the surface water samples. Figure 9 shows the flow chart for Regime 1 sampling. In Regime 1 weekly grab samples will be collected from all three stations. Dissolved oxygen, pH, temperature and hardness will be measured in the field during sample collection at all three monitoring stations. These weekly samples will be analyzed for TSS, and dissolved and total recoverable arsenic and the following metals:

- cadmium;
- copper;
- iron;
- zinc; and
- lead.

Additionally, total nitrate nitrogen, nitrite nitrogen and phosphate will be determined on a monthly frequency but only at the CFR above Missoula monitoring station. A maximum 4-day turnaround will be provided for the results of all samples analyzed under Regime 1. If any of the analytes exceed the warning levels shown on Fig. 9 for samples collected at CFR above Missoula, Regime 2 will be added to Regime 1 and both Regimes will be followed. Otherwise Regime 1 will continue to be followed.

Additionally, if the exceedance occurs and TSS or any of the dissolved metals and arsenic is deemed to have been added by remedial action construction activities then additional BMPs and other operational controls to manage TSS or dissolved metals and arsenic will be evaluated

Figure 10 shows the flow chart for Regime 2 sampling. In Regime 2 daily grab samples will be collected at all three monitoring stations and analyzed for TSS and the dissolved As and Cu. One-day turnaround will be provided for the results of all samples analyzed under Regime 2. Also, dissolved oxygen, pH, temperature and hardness will be measured in the field during sample collection.

If the TSS, dissolved arsenic or dissolved copper concentrations exceed the warning limits found on Fig. 9 and TSS, dissolved As or dissolved Cu is deemed to have been added by remedial action construction activities then additional BMPs and other operational controls to manage TSS or dissolved copper or dissolved arsenic will be evaluated for implementation. If the warning limits are not exceeded, Regime 1 sampling only will resume after seven consecutive days of Regime 2 sampling without exceedance of the warning limits at the CFR above Missoula station.

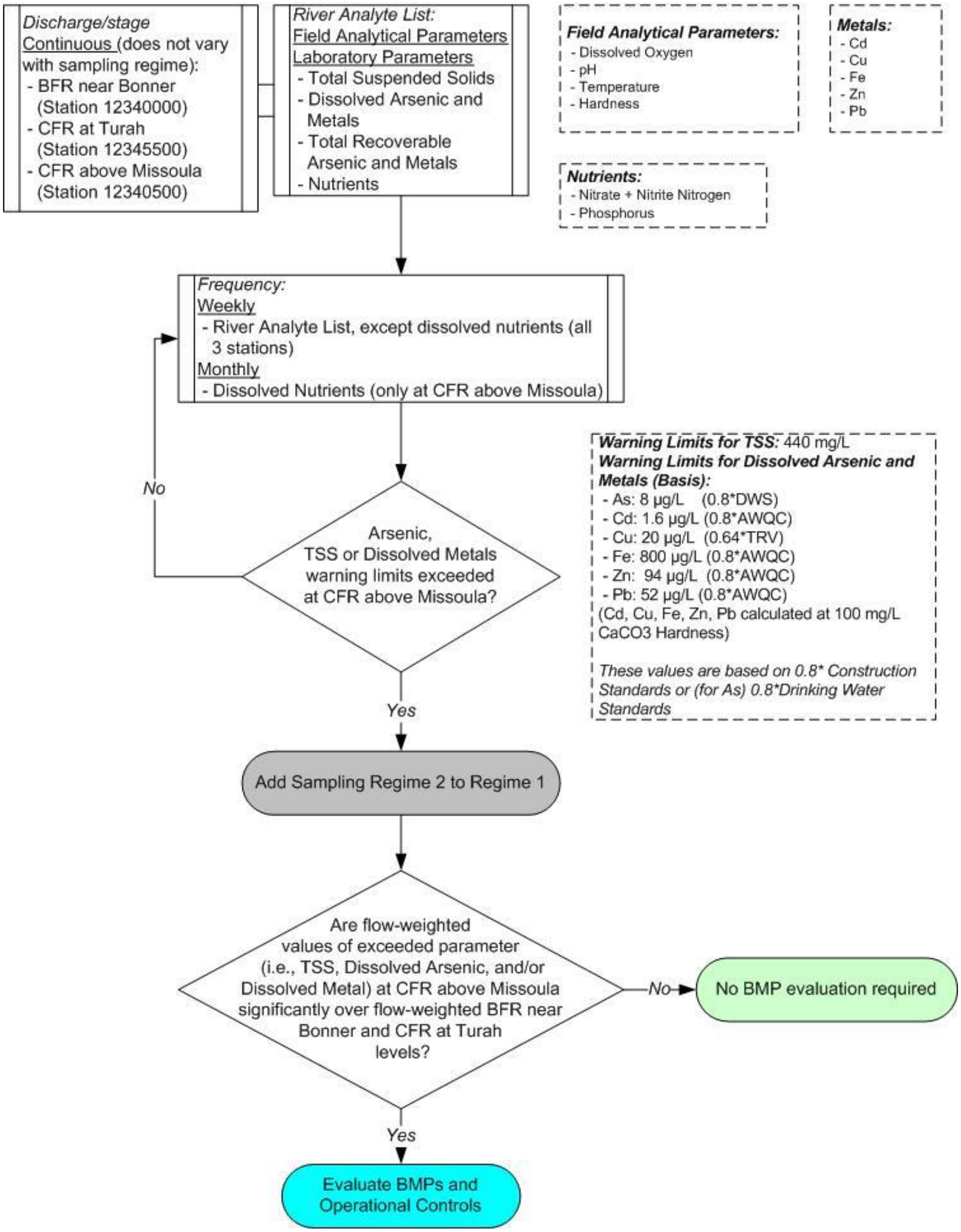

Figure 9. Regime 1 Surface Water Sampling

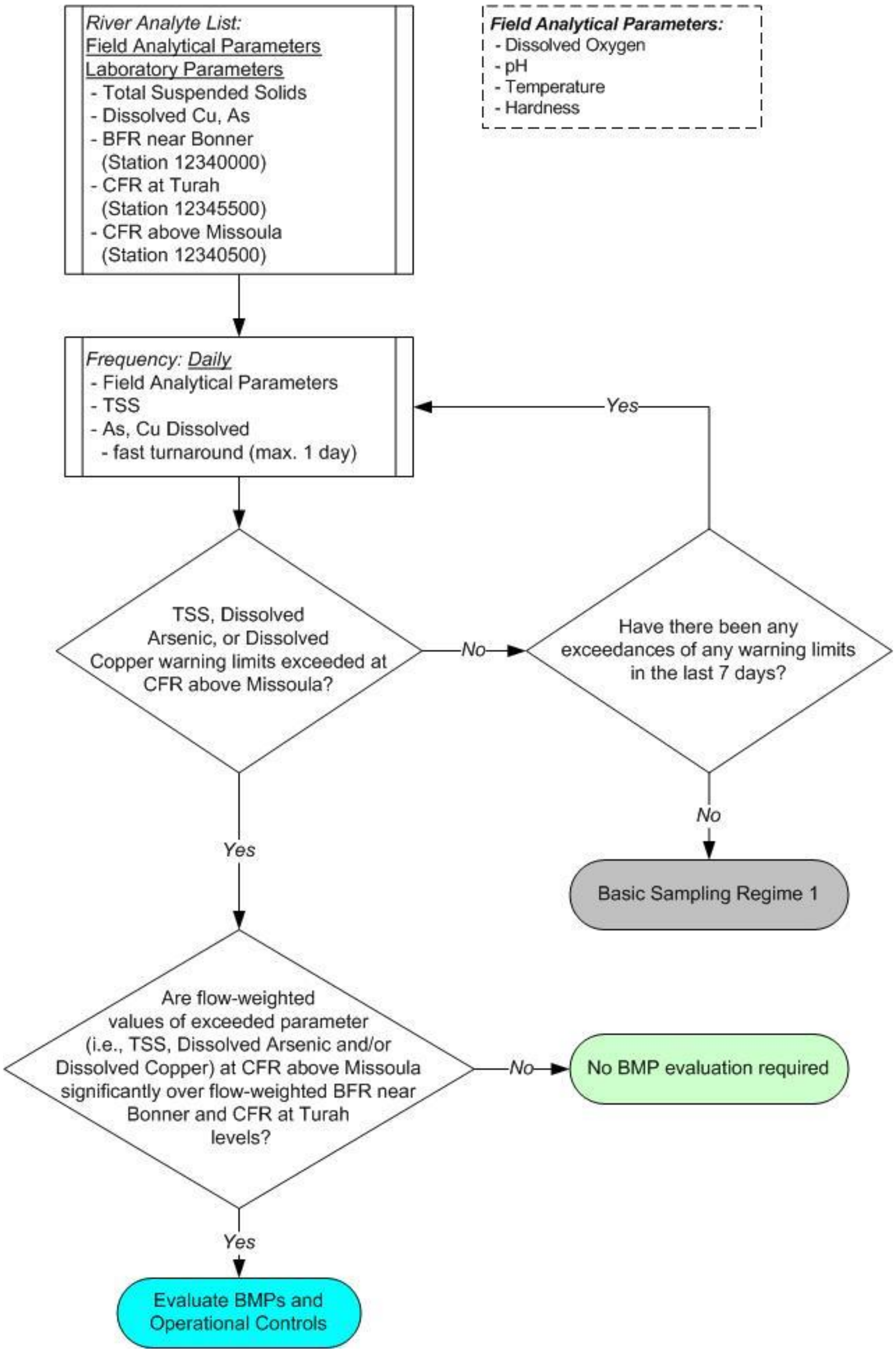

Figure 10. Regime 2 Surface Water Sampling

Use of Monitoring Results for Adjusting Operational Controls and BMPs

The cleanup plan design includes development of detailed contingency plans for how operational controls and BMPs could be adjusted or enhanced based on monitoring results. Specific to addressing scour-related impacts to downstream water quality the contingency plans focus on modifying the rate or amount of drawdown.

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