5 Site Characteristics

5.1 Conceptual Model

The primary source of contaminants of concern in the Milltown Reservoir is the accumulated sediments from the upper Clark Fork River and headwater tributaries. The sediments consist of a mixture of clay, silt, sands, organic material, and residual historic mine tailings and wastes transported to, and deposited in, the reservoir over approximately 100 years. Secondary sources include contaminated surface water that exposed aquatic flora and fauna to arsenic and metals. Other secondary sources include surface water and suspended sediment transported from the Clark Fork River OU upstream.

The primary pathways by which contaminants move within and between media include sediments, groundwater, and surface water transmissions. Fate and transport of contaminants by these media are listed below and shown in Exhibit 2-5, *Conceptual Model: Cross-Section of Hydrogeological System and Geochemical Process in Milltown Reservoir.*

- **Reservoir Sediments**
  - Geochemical conditions induced by fluctuation of the reservoir pool level releases arsenic into the sediment pore water; reservoir head pressure and local groundwater flow patterns become the transporting mechanism.
  - Ice scour, high flows, and operational drawdowns liberate, and allow re-suspension by river water of contaminated sediment from the reservoir facilitating the transport of total and dissolved arsenic and metals downstream; aquatic flora and fauna exposed.
  - Contaminants are ingested by aquatic invertebrates or accumulated by plants and enter the food chain.
  - Sediment material coated with metal oxides, sulfides, and hydroxides—potential dissolution into the river water.
  - Dam failure would cause release of large quantities of contaminated sediments downstream.
- **Groundwater**
  - Sediment pore water and groundwater interaction.
  - Groundwater flow into the local aquifers.
  - Groundwater and surface water interaction.
- **Surface Water**
  - Surface water and sediment interaction.
  - High seasonal flows in the Clark Fork and Blackfoot Rivers erode reservoir sediment and re-suspend it for transport downstream.

- Reservoir drawdown also creates conditions that promote erosion of the in-place sediments and their subsequent transport downstream.

- **Biological resources**
  - Aquatic organisms and plants exposed through consumption of or exposure to contaminated sediments or ingestion or absorption of water. Periods of high flow induced by seasonal snow melt or storms represent mechanisms for downstream transport of contaminants.
  - Dermal contact with sediment by persons recreating at the reservoir or using sediment as an amendment for gardens, is a potential exposure mechanism.

- **Airborne Transmissions**
  - Dust entrainment by wind during drought conditions or extended reservoir drawdown; potential inhalation and ingestion of dust by residents.

The factors influencing the conceptual site model are discussed in more detail throughout this section. Primary exposure pathways for potential human health risk and ecological risk are presented in Exhibit 2-6, *Conceptual Model of Exposure Pathways.*

5.2 Site Overview

5.2.1 Site Size, Geography, and Topography

The MRSOU is located at the confluence of the Clark Fork and Blackfoot Rivers in Missoula County, Montana, as shown on Exhibit 2-7, *Photomap of Milltown Reservoir Site: Reservoir at Low Pool*. The reservoir was formed by the construction of Milltown Dam in 1907, and is located approximately 7 miles upstream of Missoula, Montana. The Milltown Dam is owned and operated as a hydroelectric generating facility by NorthWestern Corporation and is licensed and regulated by FERC. The current license is valid through December 31, 2006. The community of Milltown is located 1/2 mile east of the dam and powerhouse. The smaller community of Bonner borders Milltown to the northeast. The Stimson timber mill complex is just east of Milltown, adjacent to the Blackfoot River. The general residential area has a population of approximately 2,000 (Atlantic Richfield Company 1995). The site is bounded to the east and north by a major railroad, interstate highway with interchange, and local access roads.

Tailwaters of Milltown Dam

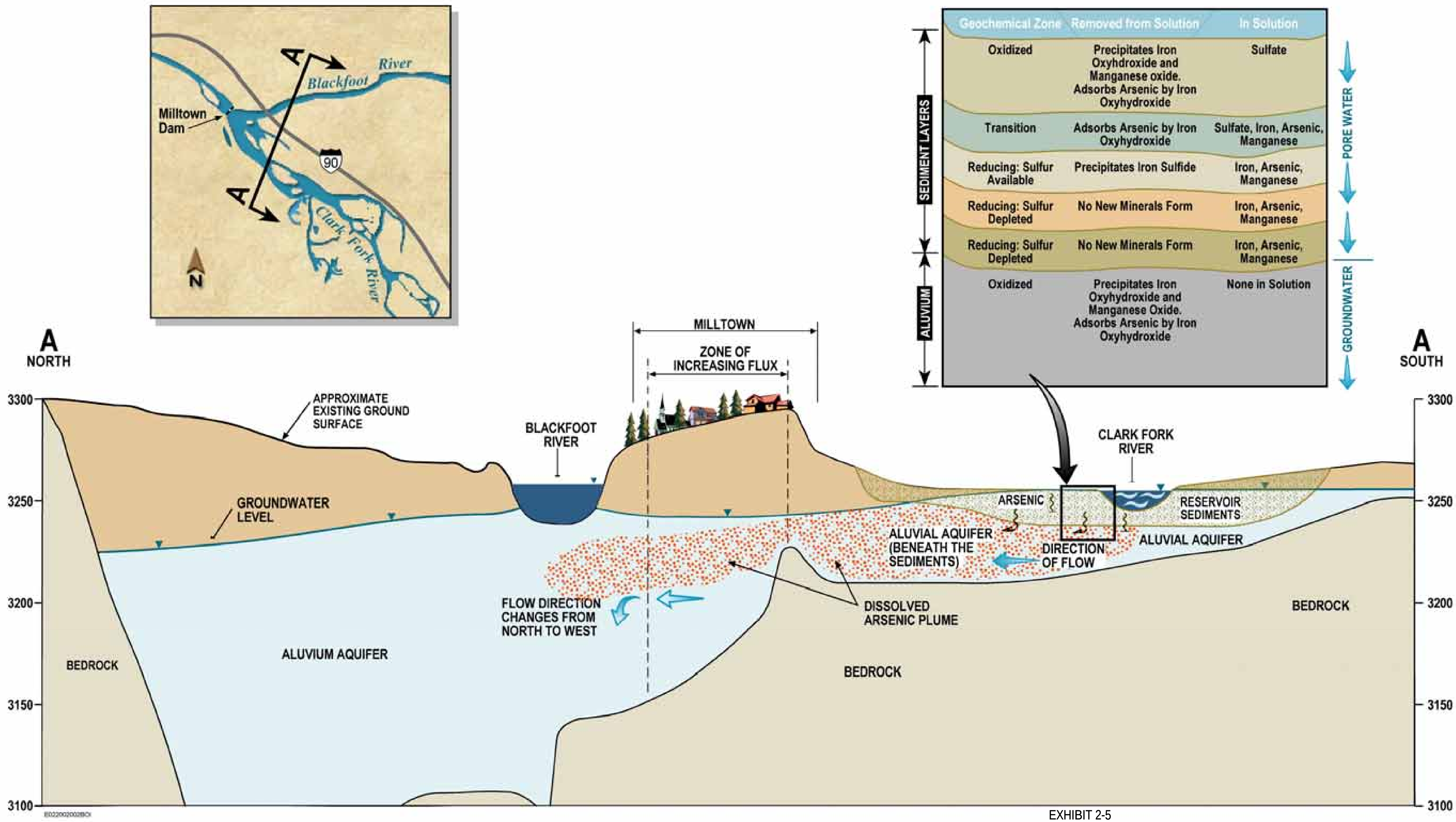

EXHIBIT 2-5
Conceptual Model: Cross-Section of Hydrogeological System and Geochemical Processes in Milltown Reservoir

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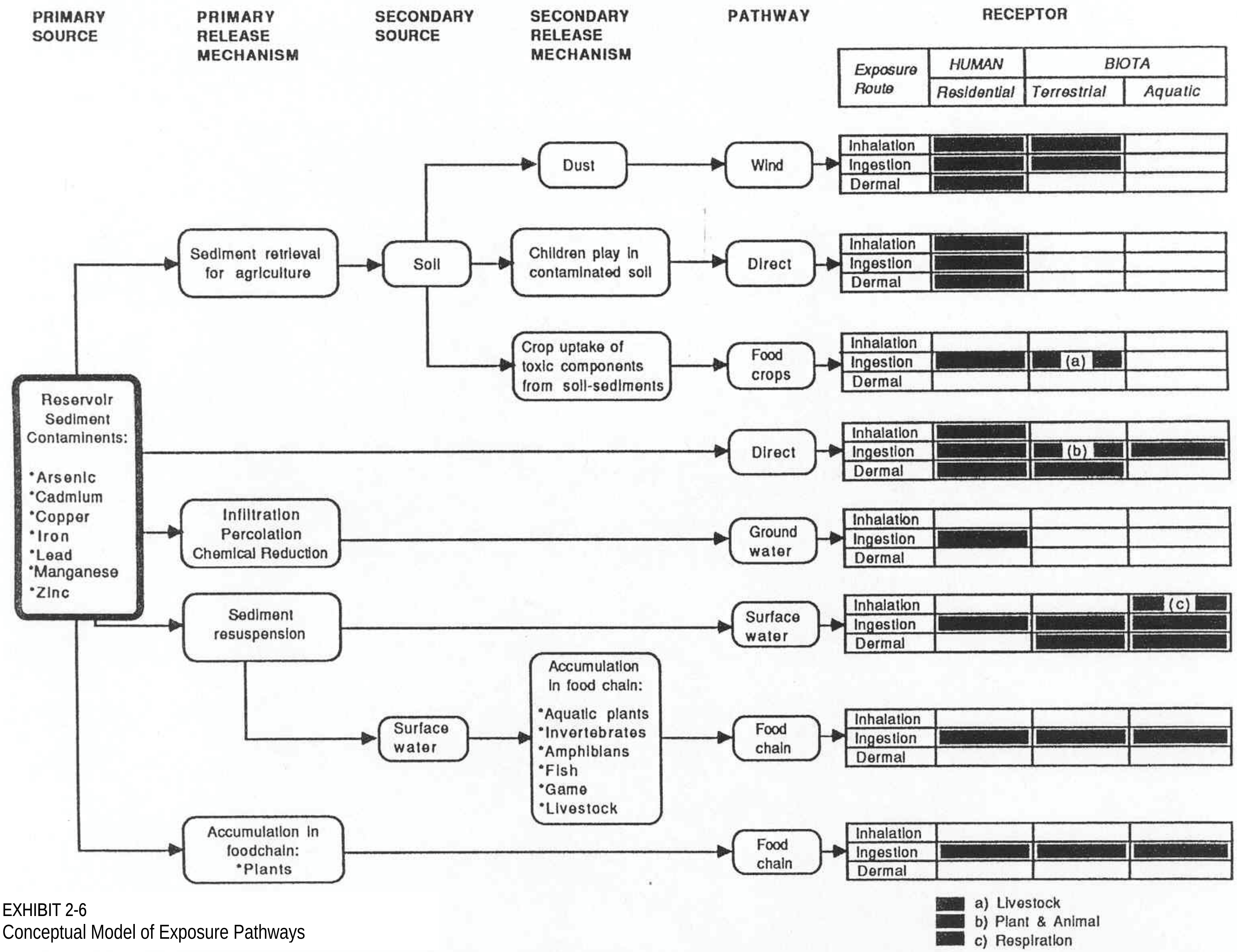

EXHIBIT 2-6
Conceptual Model of Exposure Pathways

The reservoir boundary is defined as the area inundated by the maximum pool elevation of 3263.5 feet above mean sea level (amsl), which is an area of about 540 acres. For *Feasibility Study* purposes, the reservoir was divided into two subsections: the upper reservoir and lower reservoir, with the dividing line at Duck Bridge (see Exhibit 2-7). The boundary extends approximately 2 miles up the Clark Fork Valley. The actual Superfund OU boundaries are larger and include both the reservoir sediment area, and the groundwater plume area, as shown on Exhibit 2-1, *Milltown Reservoir Sediments Operable Unit Map*. The OU also includes the temporary water supply facilities.

5.2.2 Surface and Subsurface Features

Milltown is located in an alluvial valley in the northern Rocky Mountain region of Montana. Valley width ranges from 0.75 to 1.5 miles upstream from the dam. Local relief varies from a low of approximately 3250 feet above mean sea level in the valley to 6813 feet at Bonner Mountain.

This wide valley is underlain by Quaternary alluvial deposits and Precambrian meta-sediments. Valley alluvium consists of both laterally and vertically interbedded sand, gravel, and boulders with some clay lenses. This complex configuration of sediment deposits results from an apparent variation in the location of the Clark Fork channel over geologic time. This material is exposed on both sides of the Clark Fork River and underlies recent reservoir sediments near the Milltown Dam. Well drillers' geologic logs indicate that the alluvial deposits generally thicken north of the reservoir and reach a depth of 155 feet within the southern boundaries of the Stimson Mill.

Precambrian meta-sediments of the Belt Series underlie the valley alluvium. Argillite, quartzite, and limestone outcrop on Mount Sentinel, Bonner Mountain, and Sheep Mountain near Milltown. Several diabase sills and dikes intrude the metamorphosed sediments along the argillite-quartzite contact near the dam and on the slopes of Sheep Mountain.

5.3 Surface Water Hydrology

The Milltown Reservoir is considered a "run of the river" reservoir, meaning the flow rate of water leaving the reservoir to the lower Clark Fork River is equal to the flow rates of the Clark Fork and Blackfoot rivers entering the reservoir. Thus, actual water storage capacity of the reservoir is limited because of the accumulation of sediments behind the dam. The contribution of annual stream flow by the Blackfoot and Clark Fork rivers into the Milltown Reservoir was estimated from historic USGS stream flow records. Discharge records for the Blackfoot River near Bonner and the Clark Fork River above Missoula indicate the Blackfoot River contributes approximately 54 percent of the annual surface water discharge into the Milltown Reservoir, in spite of having a smaller drainage area.

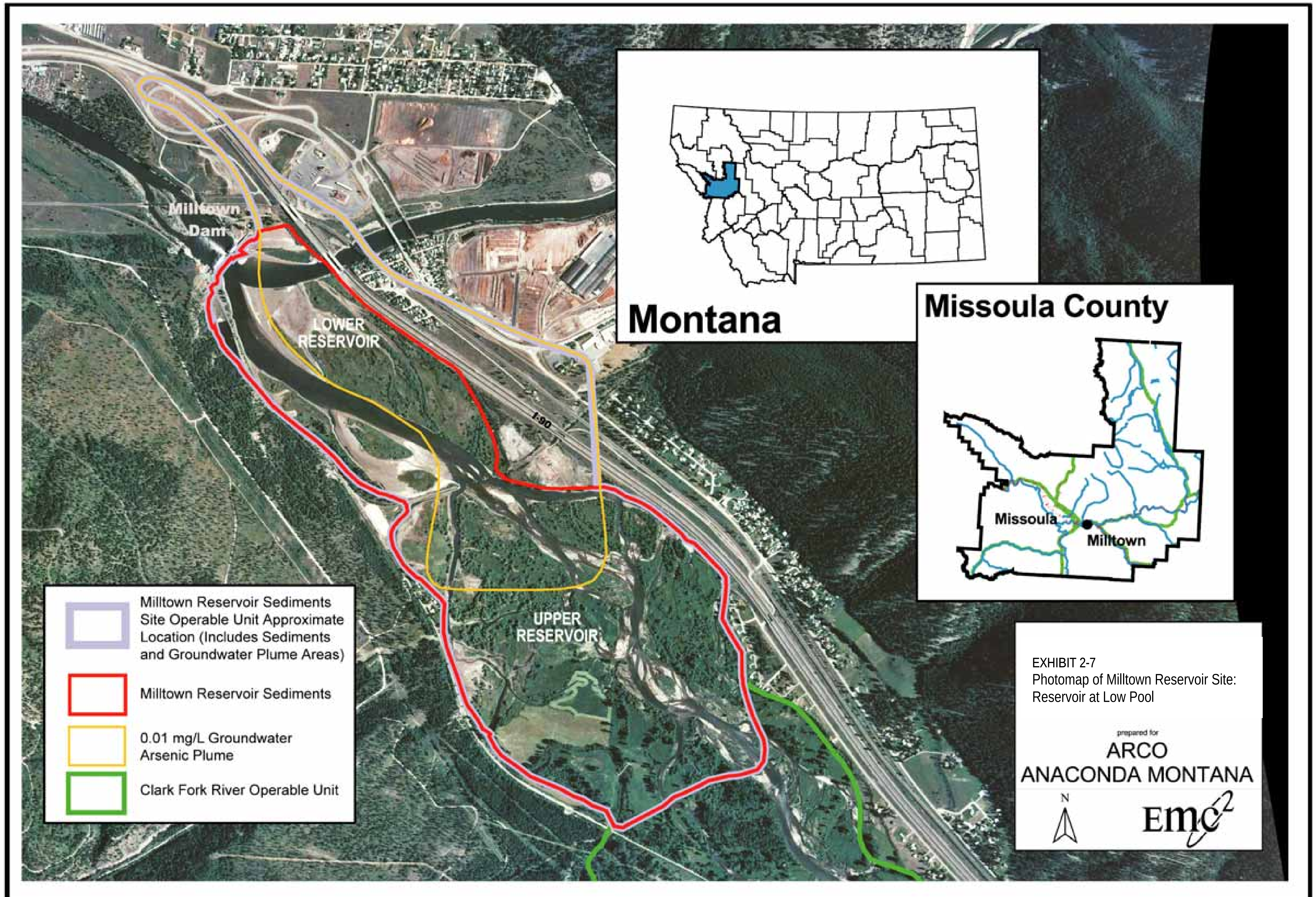

EXHIBIT 2-7
Photomap of Milltown Reservoir Site: Reservoir at Low Pool

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A 53-year average discharge for the Blackfoot River at the Bonner U.S. Geological Survey (USGS) Gauging Station is 1,619 cfs. Over the period of record, the maximum discharge in June 1964 was 19,200 cfs; the minimum in January 1950 was 200 cfs. The average annual spring flood at Bonner is 9,613 cfs; however, the 1997 spring flood event peaked at 16,200 cfs, as shown on Exhibit 2-8, *Surface Water Quality During Spring 1997 Flood Event for Clark Fork and Blackfoot Rivers*. (Longer-term surface water quality is discussed in greater detail in Section 5.5.2, *Surface Water Transport of Contaminants*.)

The average discharge for the Clark Fork River flow, measured 2.8 miles downstream of Milltown Dam at the USGS gaging station at East Missoula, is 2,973 cfs. Over the period of record from 1929 through 1997, the maximum discharge was 32,300 cfs measured in June 1975. Flows during the June 1997 runoff peaked at 26,300 cfs. Minimum flow was 340 cfs (Sept. 27, 1937). The 1908 flood (with an estimated peak of 48,000 cfs) lasted from May 25 to June 5, and resulted in the fluvial transport of large volumes of metals-enriched mine and mill wastes, soils, and sediments down the Clark Fork River. Much of this load was deposited behind the new Milltown Dam, which was completed the previous year, 1907, and set the stage for the conditions observed today. A Federal Emergency Management Agency (FEMA) study estimating the magnitude of potential flood events for the Clark Fork and Blackfoot rivers indicated the 1908 event had a reoccurrence period of slightly greater than 100 years (Atlantic Richfield Company 2001c).

In 1984, the USGS installed a gauging station on the Turah Bridge 3 miles upstream of the Milltown Reservoir on the Clark Fork River. The period of record of this location is less than the other gauging stations (20 years). Discharge records indicate that average flows for the Clark Fork River at this station are 1,223 cfs. The minimum flow was 219 cfs (Aug. 20, 1992) and the peak discharge for this period was 12,400 cfs, which occurred in February 1996. During the 1997 spring flood, flows at this station peaked at 9,870 cfs. This is the most recent flood recorded at this location. Water quality data and discharge for this flood event are presented on Exhibit 2-8, *Surface Water Quality During Spring 1997 Flood Event for Clark Fork and Blackfoot Rivers.*

An episodic event occurred in February 1996. An extended period of cold weather with temperatures of 30 to 40 degrees below zero created thick ice on the Clark Fork and Blackfoot Rivers near and upstream of Milltown. This was followed by a period of rapid warming with rainfall that melted the lower-elevation snowpack. This increased flows in the rivers and began breaking up the ice. As the newly released ice floated, numerous ice jams formed in both rivers. A large ice jam near Bonner caused the water to back up to 16 feet above flood level; as the ice began to move downstream it damaged bridges and other nearby structures. To protect Milltown Dam from ice damage, the operator removed the spillway stanchions and spill panels and opened the radial gate to pass the ice through the reservoir. These actions rapidly lowered the reservoir water level by about 8 feet, which placed the existing, thick reservoir ice cover directly on much of the previously submerged reservoir sediments. As the now-broken-up ice pack moved through the reservoir, pushed by increased upstream flows, the ice mechanically scoured large quantities of metals contaminated sediments. These sediments entered the reservoir water column, dramatically increasing its turbidity, and subsequently entered the lower Clark Fork River. During this event, mean daily flow measured downstream at the USGS gauge at East Missoula on February 9 reached 12,400 cfs, compared to normal seasonal flows of 1,800 to 2,000 cfs.

EXHIBIT 2-8
Surface Water Quality During Spring 1997 Flood Event for Clark Fork and Blackfoot Rivers

	Range	Average	DEQ[2] (WQB) Standard	DWS[4]	FAWQC[3]
Clark Fork River at Turah					
5/7/97 to 6/22/97: 18 sampling events					
Discharge (cfs)	3,840 – 9,870	7,934	N/A	N/A	N/A
Total Recoverable (ppb)[1]					
Arsenic	12 – 23	18	18	N/A	N/A
Cadmium	<1	<1	2/0.3	N/A	N/A
Copper	37 – 110	74	13/9	N/A	N/A
Lead	6 – 21	13	15	N/A	N/A
Zinc	60 – 210	131	119	N/A	N/A
Total Dissolved (ppb)					
Arsenic	6 – 13	8	N/A	10	340/150
Cadmium	<0.10 – 0.13	<0.10	N/A	5	2/0.25
Copper	5.3 – 20	12	N/A	1,300	13/9
Lead	<0.50 – 0.76	<0.50	N/A	15	82/3.2
Zinc	4.2 – 9.9	7	N/A	2,000	120/110
Total Suspended Solids (ppm)	64- 442	236	N/A	N/A	N/A
Blackfoot River at Bonner					
5/19/97 to 6/5/97: 3 sampling events					
Discharge (cfs)	5,130 – 13,400	10,110	N/A	N/A	N/A
Total Recoverable (ppb)[1]					
Arsenic	<1 - 3	3	18	N/A	N/A
Cadmium	<1	<1	2/0.3	N/A	N/A
Copper	3 - 34	15	13/9	N/A	N/A
Lead	<1 - 3	3	15	N/A	N/A
Zinc	<10	<10	119	N/A	N/A
Total Dissolved (ppb)					
Arsenic	1	1	N/A	10	340/150
Cadmium	<0.10	<0.10	N/A	5	2/0.25
Copper	1 – 2.2	1.7	N/A	1,300	18/12
Lead	<0.50	<0.50	N/A	15	82/3.2
Zinc	<3.0 – 3	<3.0	N/A	2,000	120/110
Total Suspended Solids (ppm)	23 – 212	131	N/A	N/A	N/A
Clark Fork River Above Missoula (East Missoula)					
5/13/97 to 6/22/97: 17 sampling events					
Discharge (cfs)	9,940 – 26,300	18,919	N/A	N/A	N/A
Total Recoverable (ppb)[1]					
Arsenic	6 – 14	9	18	N/A	N/A
Cadmium	<1	<1	2/0.3	N/A	N/A
Copper	22 - 63	39	13/9	N/A	N/A
Lead	3 – 14	8	15	N/A	N/A
Zinc	30 – 130	73	119	N/A	N/A
Total Dissolved (ppb)					
Arsenic	3 – 7	4	N/A	10	340/150
Cadmium	<0.10 – 0.12	0	N/A	5	2/0.25
Copper	4.4 – 7.8	6	N/A	1,300	13/9
Lead	<0.50	<0.50	N/A	15	82/3.2
Zinc	<3.0 – 8.3	6	N/A	2,000	120/110
Total Suspended Solids (ppm)	37 – 518	212	N/A	N/A	N/A

Notes:
[1] Values for arsenic are total concentration, values for cadmium, copper, lead and zinc are total recoverable concentration.
[2] Assumes 100 mg/l hardness.
cfs–cubic feet per second; ppb–parts per billion; N/A–Standard not applicable; #/# gives acute/chronic levels
Daily discharge values are calculated by multiplying instantaneous concentration by corresponding stream flow rate then converting to appropriate units. Data from USGS.
[3] Federal Ambient Water Quality Criteria, dissolved, Gold Book, Update 2002; first number is acute standard/second number is chronic standard.
[4] Federal Drinking Water Standard for Human Health, dissolved.

Water quality samples taken downstream over the course of this event indicated much larger concentrations of total and dissolved copper and other metals compared to any previously taken samples, as shown in Exhibit 2-9, *Surface Water Quality During February 1996 Ice Scour Event for Clark Fork River and Milltown Reservoir*. Based on these sample results, EPA directed Atlantic Richfield Company to undertake an additional *Focused Feasibility Study* for the Milltown site. This study was completed in June 2001.

5.4 Remedial Investigation Strategy

The MRSOU is a large, complex site. Data gathering concerning sources of contamination, pathways of migration, and impacts on receptors needed for the *Remedial Investigation* were triggered in the early 1980s with the discovery of arsenic in potable water supplied by several wells to Milltown residents and businesses. Preliminary investigations linked the source of the arsenic to the reservoir sediments, resulting in the installation of a replacement water supply. The complex interaction between the sediments, fluctuating reservoir pool elevations, and local groundwater flow patterns was the focus of numerous field investigations and water quality modeling through 1995. As part of the review process for data, EPA, in concert with DEQ and the Atlantic Richfield Company, established specific Data Quality Objectives (DQOs) for reviewing studies and qualifying existing data sets for incorporation into the overall understanding of site conditions, and ultimately formation of a conceptual model. Under EPA and DEQ direction (with the concurrence of other agencies), Atlantic Richfield Company and their consultants formulated work plans and sampling and analysis plans for subsequent investigations to fill data gaps and complete the characterization of environmental conditions. Pertinent studies and projects for all disciplines are cited in detail in the RI/FS documents.

5.5 Affected Media and Contaminant Types

As described in Section 5.1, *Conceptual Model*, the contaminants are found in media affected by mine wastes. The key media affected by contaminants in the MRSOU include the following:

- **Reservoir sediments:** The primary source of contaminants is the residual mine waste material mixed with sediment and impounded behind the Milltown Dam. As shown in the conceptual model (Exhibit 2-5), the primary pathway from the contaminated sediments to human receptors is through groundwater. Exposure may occur through dermal contact or ingestion. The primary mechanism for arsenic mobilization to pore water is the occurrence of arsenic associated with minerals that are unstable.

EXHIBIT 2-9
Surface Water Quality During February 1996 Ice Scour Event for Clark Fork River and Milltown Reservoir

					Total (ppb)				Dissolved (ppb)				
Sampler	**Location**	**Date**	**Time**	**Discharge (cfs)**	**Arsenic (ppb)**	**Cadmium (ppb)**	**Copper (ppb)**	**Zinc (ppb)**	**Arsenic (ppb)**	**Cadmium (ppb)**	**Copper (ppb)**	**Zinc (ppb)**	**TSS (ppm)**
USGS	CFR below Milltown Dam	2/9/96	9:30	9,080	69	5	400	1,100	9	<1	11	15	824
Missoula Co.	CFR below Milltown Dam	2/9/96	10:30	N/A	54	4	440	1,000	11	<1	<10	30	N/A
Missoula Co.	CFR below Milltown Dam	2/10/96	15:25	N/A	73	6	680	1,220	11	1	30	30	N/A
Missoula Co.	CFR below Milltown Dam	2/10/96	N/A	N/A	69	5	630	1,140	11	2	30	40	N/A
Missoula Co.	CFR below Milltown Dam	2/10/96	N/A	N/A	97	7	770	1,310	12	1	20	30	N/A
Missoula Co.	Milltown Reservoir	2/10/96	16:35	N/A	19	2	310	480	5	2	20	20	N/A
USGS	CFR at Turah Bridge	2/11/96	11:00	4340	23	<1	180	110	13	<0.1	11	22	100
DEQ[1] Water Quality Act Std. (WQB-7)					18	2/0.3	13/9	119	N/A	N/A	N/A	N/A	
FDWS									10	5	1,300	2,100	
FAWQC									340/150	2/0.25	14/9.3	120/120	

Notes:

1. Assumes 100 mg/l hardness.

Data from: USGS and Missoula City-County Health Department
CFR–Clark Fork River
cfs–cubic feet per second
ppb–parts per billion
ppm–parts per million
N/A–Not Available
TSS–Total Suspended Sediment
<–Indicates "non-detect" to the level indicated.
FDWS–Federal Drinking Water Standards
FAWQC–Federal Ambient Water Quality Standards (Gold Book 2002)
#/#–gives acute/chronic levels

Oxidation / reduction of contaminated sediment is the key contaminant dissolution mechanism, producing dissolved arsenic that can migrate from pore water and contaminate surface water and groundwater. Reservoir sediments can also be the source of dissolved and total metals, including copper. Sediment scour by high flows or ice can result in sediment entrainment in the water column and subsequent transport downstream. Aquatic flora and fauna can uptake contaminants directly from the sediment or through the water column.

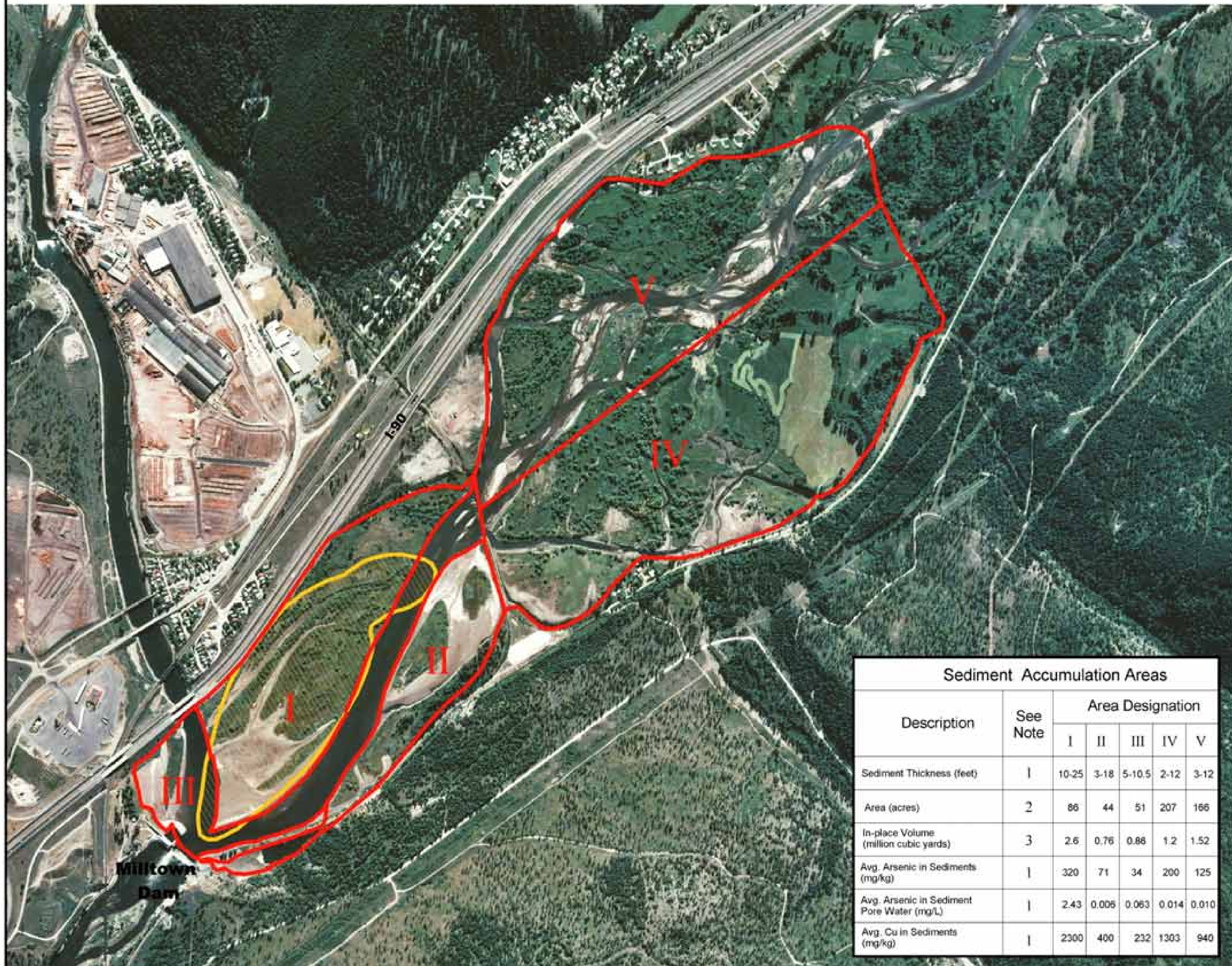
- **Groundwater:** Movement of arsenic contaminated groundwater into the local aquifer underlying the reservoir and adjacent valley has created a groundwater plume. Local wells in Milltown intercepted the plume resulting in an exposure risk through ingestion. Groundwater flow to surface water can also occur.
- **Surface water:** River water (surface water), as well as contaminated soils in the river, transports both dissolved and sediment-bound metals and arsenic. Inflow of contaminated groundwater can also increase levels of contamination in the surface water.
- **Biological resources:** Metals can be delivered to aquatic and terrestrial organisms from any of the contaminated media listed above. Organisms, including benthic macroinvertebrates, receive the contaminants through direct consumption of contaminated sediment or through absorption in water. These organisms are in turn part of the food chain—for example, macroinvertebrates are eaten by fish and, if contaminated, have been shown to potentially reduce growth of trout (Stratus 2002). Contaminant uptake in plants is a well-documented occurrence and could potentially be the source of problems for streambanks as demonstrated upstream in the Deer Lodge Valley. Spring runoff, floods, and ice scour events generate sediment that is detrimental to benthic macroinvertebrate populations, fish spawning success, other fish, and aquatic mechanisms.
- **Air resources:** Because of sustained moisture content, and various levels of existing vegetation located on the reservoir sediment delta, fugitive dust emanating from these areas during periods of drought or sustained drawdown is not significant and any resulting adverse air impacts are considered to be highly unlikely. Therefore, this air pathway is not of further concern except during remedial action construction.

The remedial actions defined in the Selected Remedy, when implemented, will have beneficial mitigative and corrective effects on the affected media.

5.5.1 Reservoir Sediment—Geomorphology and Characterization

Following construction of the Milltown Dam in 1907, metals enriched sediments transported by the Blackfoot and Clark Fork rivers began to deposit in the newly created reservoir. Investigation of the reservoir sediments has included monitoring wells with well-water sampling and chemical analysis, core sampling and chemical analysis, a cone penetrometer survey, cross sectional surveys, sediment pore water sampling and analysis, sequential extraction and mineralogical analyses, and aerial photo interpretation. Many additional monitoring wells were also installed and sampled in areas outside the reservoir sediments in strategic locations to better define the plume and local hydrogeology. Results of these many investigations are summarized as follows:

- **Contaminant concentrations within the reservoir sediments are highly variable with location and depth and are inversely proportional to particle size.** Average copper concentrations ranged from 83 mg/kg in sand sized sediment to over 5,000 mg/kg in silt/clay sized sediment (Atlantic Richfield Company 1995). As shown on Exhibit 2-10, *Source Characterization for Sediment Accumulation Areas 1-5, MRSOU,* average sediment copper and arsenic concentrations are highest in Area 1 and lowest in Area 3. Dissolved concentrations of arsenic in pore water are highest in Area 1 but are also elevated in Area 3 with lesser concentrations in Areas 4, 5, and 2, respectively.
- **Historical maps, aerial photo interpretation, and sediment stratigraphy indicate that the historic Clark Fork River channel passed through Area 1** (a portion of the backwater area discussed earlier in this section) and was mostly filled in 1908 with upstream sediments containing historic mining and milling wastes. These historic wastes contained greater concentrations of metals and arsenic than what was generated in later years. As the historic channel filled, it forced the active channel to move over time to the south and west. This hypothesis is supported by the fact that the greater volume of sediments containing the highest contaminant concentrations and greater sediment thicknesses are found in Area 1, and by the fact that the aerial photographs indicate that the reservoir sediments, particularly in Area 1, have been fairly stable in planform during the last 50 years.
- **The total volume of contaminated reservoir sediments for all five areas was earlier estimated at 6.6 million in-place cubic yards** (Atlantic Richfield Company 1995). The greatest volume of finer grained sediments with the highest levels of contamination is contained in Area 1.
- **Comparison of cross-section surveys indicate that both of the river channels within the lower reservoir have changed little during the last 20 years.** Small variations in channel depths during this period indicate that in years with lower average flows, some deposition of in-stream sediment occurs. In years where higher average flows occur, some scour occurs in the river channels. This demonstrates, along with extensive water quality data, that the reservoir is, and has been for the last 20 years, essentially in "dynamic equilibrium" with regard to sediment deposition and scour.
- **Sediment has filled the reservoir to capacity and USGS concludes** (Lambing 1998) **that the reservoir is in a long-term dynamic equilibrium with the incoming sediment load.** The average annual suspended sediment load reaching Milltown Reservoir for the period 1991 through 1997 was 142,000 tons/year, with an average of 148,000 tons/year leaving the reservoir. However, during the low flow years of 1991 through 1995, the reservoir actually accumulated an average of 13,000 tons/year of suspended sediments (about 65,000 tons total). In 1996 and 1997 (two high flow years), a total of about 107,000 tons were scoured from the reservoir. In the low flow years since 1997 (1998 through 2001), the reservoir has again accumulated sediments.



Sediment Accumulation Areas						
Description	See Note	Area Designation				
		I	II	III	IV	V
Sediment Thickness (feet)	1	10-25	3-18	5-10.5	2-12	3-12
Area (acres)	2	86	44	51	207	166
In-place Volume (million cubic yards)	3	2.6	0.76	0.86	1.2	1.52
Avg. Arsenic in Sediments (mg/kg)	1	320	71	34	200	125
Avg. Arsenic in Sediment Pore Water (mg/L)	1	2.43	0.006	0.063	0.014	0.010
Avg. Cu in Sediments (mg/kg)	1	2300	400	232	1303	940

Legend

Approximate Sediment Accumulation Area Boundary

Sediment Pore Water Arsenic >0.1 mg/L (Approximate **Source Sediment Area** for alluvial aquifer 0.02 mg/L arsenic plume)

Notes:

1. Information obtained from Final Draft Milltown Remedial Investigation Report (prepared by Titan Environmental Corporation for ARCO, February 1995)
2. Accumulation Area acreage determined using tools in ArcView v. 3.2.
3. Accumulation Area volume information obtained from presentation materials at Clark Fork Basin Symposium 2000 (April14-16) based on Harding Lawson's total reservoir estimate of 6.6 million cubic yards (HLA, 1997). More recent cross section data suggests current sediment volumes may more than estimated by HLA (AERL, 1998c).
4. Extents of Source Characterization Sediment Accumulation Areas I-V shown in this figure were modified from Figure ES-3 of the Final Draft Remedial investigation Report. Modifications include exclusion of areas outside the FEMA 100 yr floodplain. Upstream boundary based on approximate extent of area inundated by a maximum pool elevation of 3263.5 feet above MSL.

EXHIBIT 2-10
Source Characterization for Sediment Accumulation Areas 1-5, MRSOU

prepared for
ARCO
ANACONDA MONTANA

N
EMC²

Scale
500 0 500 1000 feet

Date: 09/20/01
Map Number: CFS1-2

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5.5.2 Surface Water Transport of Contaminants

Water quality data from the Clark Fork and Blackfoot rivers near the Milltown Reservoir have been collected for many years by USGS, DEQ, NorthWestern Corporation, Atlantic Richfield Company, FWP, and others. The USGS data set is the most comprehensive, includes total and dissolved metals concentrations, and was collected at numerous times per year. The water quality summary statistics for locations upstream and downstream of the reservoir are found in Exhibit 2-11, *Summary Statistics for USGS Surface Water Quality Data from Sampling Stations Near Milltown Reservoir*, and indicates that water quality, in general, has been acceptable, with the exception of copper and arsenic exceedances of standards. Suspended sediment sampling has also been conducted frequently. The USGS found that total suspended solids (TSS) can be highly correlated to total recoverable concentrations of copper in the surface water.

In addition, during the *Remedial Investigation* (Atlantic Richfield Company 1995), a HEC-6 computer model was run to predict sediment deposition, scour, and transport through Milltown Reservoir for the following scenarios: long-term deposition and various high flow events (up to a 100-year return interval). The results indicated that during low flow years, net sediment deposition occurs in the reservoir. For average flow years, sediment still tends to be deposited, but during high flow years and flood events sediment is consistently scoured from the reservoir. Actual USGS data and observations agree with these modeling results.

Conceptual models for likely events that may cause surface water quality impacts downstream were developed from previously described data/observations and are as follows.

5.5.2.1 Development of Conceptual Models of Events that May Cause Downstream Surface Water Quality Impacts

Surface water quality downstream of Milltown Reservoir can be affected by influent contaminant concentrations originating upstream and passing through the reservoir, as well as by residual metals-enriched sediments released or scoured from the reservoir itself. Several conceptual models were developed to illustrate the primary conditions likely to influence deposition or scour of sediments in the reservoir:

- During low flow periods with the reservoir at normal pool elevation, hydraulic conditions can favor incoming sediment deposition and accumulation (see Exhibit 2-12a, *Conceptual Model—Schematic of Sediment Accumulation During Low Flow Periods*). Impairment of downstream water quality is rarely an issue under these circumstances.
- In contrast, hydraulic conditions that trigger and induce sediment scour from the reservoir have significant potential to adversely affect water quality downstream:
  - Typical late spring snowmelt runoff, other high flow events (greater than 16,000 cfs), or ice scour from shallow portions of the reservoir during normal pool levels (see Exhibit 2-12b, *Conceptual Model—Schematic of Sediment Scouring During High Flow Events*).
  - Operational practices such as rapid and substantial lowering of reservoir pool levels to facilitate maintenance on the dam or to protect the structure from damage by thick ice flows (see Exhibit 2-12c, *Conceptual Model—Schematic of Reservoir Draw Down During Ice Event*).

If the dam were ever to fail, catastrophic environmental effects would occur as the sediments were released.

EXHIBIT 2-11
Summary Statistics for USGS Surface Water Quality Data from Sampling Stations Near Milltown Reservoir

	Total Metals (µg/l)					Dissolved Metals (µg/l)				
	Arsenic	**Cadmium**	**Copper**	**Lead**	**Zinc**	**Arsenic**	**Cadmium**	**Copper**	**Lead**	**Zinc**
Clark Fork River at Turah Bridge (USGS gaging station 12334550) 1985 – 1992										
Sample Number	42	42	41	42	42	42	42	42	42	42
Mean	13.1	0.9	67.1	16.2	126.5	6.3	0.5	6.2	1.7	10.3
Median	8	0.5	30	8.5	50	5	0.5	5	1	8
Minimum	5	0.5	3	0.5	5	4	0.5	2	0.5	1.5
Maximum	110	4	500	100	1100	17	1	25	7	39
Lower Quartile	7	0.5	14	3.25	32.5	5	0.5	3	0.5	5
Upper Quartile	11	1	56	18.25	87.5	7	0.5	7	2.5	12.75
Std. Dev.	18.4	0.8	118.7	22.9	254.4	2.6	0.1	5.0	1.5	8.2
1993 – 1997										
Sample Number	42	42	42	39	42	42	42	42	39	42
Mean	11.0	0.5	36.8	6.4	55.7	6.7	0.1	6.0	0.3	6.7
Median	9	0.5	22.5	5	40	6	0.05	5	0.25	6
Minimum	5	0.5	3	0.5	5	4	0.05	2	0.25	1.5
Maximum	33	1	180	33	270	13	0.1	19	0.9	22
Lower Quartile	7	0.5	12	2	20	5	0.05	3	0.25	4.25
Upper Quartile	14	0.5	48.25	8.5	70	7	0.05	7	0.25	8
Std. Dev.	5.9	0.1	39.8	7.0	52.3	2.2	0.0	3.9	0.1	4.1
DEQ[1] Water Quality Act Std. (WQB-7)	18	2/0.3	13/9	15	120					
FDWS						10	5	1,300	15	2,000
FAWQC						340/150	2/0.25	14/9.3	82/3.2	120/120

EXHIBIT 2-11
Summary Statistics for USGS Surface Water Quality Data from Sampling Stations Near Milltown Reservoir

	Total Metals (µg/l)					Dissolved Metals (µg/l)				
	Arsenic	**Cadmium**	**Copper**	**Lead**	**Zinc**	**Arsenic**	**Cadmium**	**Copper**	**Lead**	**Zinc**
Blackfoot River near Bonner (USGS gaging station 12340000) 1985 – 1992										
Sample Number	34	34	33	34	34	34	34	34	34	34
Mean	1.2	0.7	10.3	7.1	14.9	0.8	0.5	2.5	1.9	5.0
Median	1	0.5	8	5	10	0.5	0.5	2	1.25	3
Minimum	0.5	0.5	0.5	0.5	5	0.5	0.5	0.5	0.5	1.5
Maximum	3	2	34	20	60	2	1	6	8	15
Lower Quartile	1	0.5	6	2	5	0.5	0.5	1	0.5	1.5
Upper Quartile	1	0.5	12	13.25	20	1	0.5	3	2.5	7
Std. Dev.	0.6	0.4	7.5	6.1	13.7	0.4	0.1	1.5	1.9	4.0
1993 – 1997										
Sample Number	25	25	25	23	25	25	25	25	23	25
Mean	1.4	0.5	6.0	2.2	7.2	0.8	0.1	1.4	0.3	2.1
Median	1	0.5	3	0.5	5	1	0.05	0.5	0.25	1.5
Minimum	0.5	0.5	0.5	0.5	5	0.5	0.05	0.5	0.25	1.5
Maximum	4	0.5	34	25	40	2	0.1	7	2	6
Lower Quartile	0.5	0.5	1	0.5	5	0.5	0.05	0.5	0.25	1.5
Upper Quartile	2	0.5	8	2	5	1	0.05	2	0.25	1.5
Std. Dev.	1.0	0.0	8.7	5.0	7.5	0.4	0.0	1.6	0.4	1.3
DEQ[1] Water Quality Act Std. (WQB-7)	18	2/0.3	13/9	15	120					
FDWS						10	5	1,300	15	2,000
FAWQC						340/150	2/0.25	14/9.3	82/3.2	120/120

EXHIBIT 2-11
Summary Statistics for USGS Surface Water Quality Data from Sampling Stations Near Milltown Reservoir

	Total Metals (µg/l)					Dissolved Metals (µg/l)				
	Arsenic	**Cadmium**	**Copper**	**Lead**	**Zinc**	**Arsenic**	**Cadmium**	**Copper**	**Lead**	**Zinc**
Clark Fork River above Missoula (USGS gaging station 12340500) 1989 – 1992										
Sample Number	20	20	19	20	20	20	20	20	20	20
Mean	3.6	0.5	9.7	3.1	17.5	2.7	0.5	2.5	0.6	5.5
Median	3.5	0.5	8	2	10	3	0.5	2	0.5	4
Minimum	2	0.5	2	0.5	5	1	0.5	1	0.5	1.5
Maximum	6	0.5	31	11	60	4	0.5	6	1	16
Lower Quartile	2.75	0.5	4.5	1	10	2	0.5	2	0.5	1.5
Upper Quartile	4	0.5	10.5	3.5	22.5	3	0.5	3	0.625	8
Std. Dev.	1.4	0.0	7.7	3.1	14.3	0.8	0.0	1.2	0.2	4.3
1993 – 1997										
Sample Number	42	42	42	38	42	42	42	42	38	42
Mean	7.3	0.6	26.3	5.1	54.9	3.8	0.1	3.6	0.3	4.4
Median	5	0.5	10.5	2	20	3	0.05	3	0.25	3.5
Minimum	3	0.5	4	0.5	5	2	0.05	2	0.25	1.5
Maximum	69	5	400	78	1100	9	0.1	11	1.2	15
Lower Quartile	4	0.5	7	1	10	3	0.05	2	0.25	1.5
Upper Quartile	7	0.5	21.5	4	37.5	4	0.05	4	0.25	6.75
Std. Dev.	10.2	0.7	61.9	12.7	167.7	1.6	0.0	2.3	0.2	3.4
DEQ[1] Water Quality Act Std. (WQB-7)	18	2/0.3	13/9	15	120					

EXHIBIT 2-11
Summary Statistics for USGS Surface Water Quality Data from Sampling Stations Near Milltown Reservoir

	Total Metals (µg/l)					Dissolved Metals (µg/l)				
	Arsenic	Cadmium	Copper	Lead	Zinc	Arsenic	Cadmium	Copper	Lead	Zinc
FDWS						10	5	1,300	15	2,000
FAWQC						340/150	2/0.25	14/9.3	82/3.2	120/1120

Notes:
1. Assumes 100 mg/l hardness.

Values reported as below detection were used at half the detection limit for statistical analysis.
Data from USGS for the period 1985 through 1997 for Clark Fork River at Turah and the Blackfoot River near Bonner.
Data from USGS for the period 1989 through 1997 for Clark Fork River above Missoula.
FDWS–Federal Drinking Water Standards
FAWQC–Federal Ambient Water Quality Criteria (Gold Book 2002) – first number is Acute Standard/second number is Chronic Standard
#/#–gives acute/chronic levels

5.5.3 Groundwater

Sediments containing arsenic and other metals related to upstream mining activities began to accumulate in the reservoir shortly after the Milltown Dam was built. Studies completed to date have identified the accumulated reservoir sediments as the primary source of arsenic loading to the alluvial aquifer beneath and downgradient of the reservoir. As shown on Exhibit 2-13, *Area of Groundwater Exceeding Federal Water Quality Arsenic Standard*, the 0.01 mg/l (milligram per liter) arsenic concentration contour extends to the north and east under portions of Milltown and northwest of the Blackfoot River, an area about 325 acres. The new Federal drinking water standard of 0.01 mg/l is reflected in these boundaries.

Also shown is the extensive well network developed to monitor groundwater. As noted earlier in Exhibit 2-10, *Source Characterization for Sediment Accumulation Areas 1-5, MRSOU*, the reservoir sediment pore waters exceeding 0.1 mg per liter (ten times higher than the standard) extend throughout most of Area 1 in the reservoir itself. A summary of dissolved arsenic concentrations for these wells are shown in Exhibit 2-14, *Dissolved Arsenic Concentrations in Alluvial Aquifer and Bedrock Wells; 1990 to 2000*.

5.5.3.1 Conceptual Model of Hydrogeologic System

Geochemical conditions within the reservoir sediments have resulted in mobilization of arsenic contained in the sediments. Arsenic is mobilized from the sediments to the sediment pore water and, ultimately, to the alluvial aquifer (groundwater) as a result of geochemical and hydrogeological conditions in the sediments. Once in the groundwater, arsenic concentrations decrease rapidly because of dilution and geochemical reactions that remove arsenic from solution. The reservoir sediments are the primary source of arsenic to the alluvial aquifer; however, only a portion of the sediments contribute to arsenic exceedances in the alluvial aquifer. Pore water arsenic concentrations in portions of the sediments outside of Area 1 are commonly below the new Federal standard of 0.01 mg/l.

Additionally, pore water concentrations need to be significantly higher than 0.01 mg/l arsenic to result in arsenic exceedances in the alluvial aquifer, because of dilution and geochemical reactions that attenuate arsenic concentrations along the flow path from the sediments to the alluvial aquifer. The conceptual hydrogeologic model was shown earlier in Exhibit 2-5, *Conceptual Model: Cross-Section of Hydrogeological System and Geochemical Processes in Milltown Reservoir*.

5.5.3.2 Nature and Extent of Arsenic

Arsenic is associated with different minerals in the reservoir sediments. Arsenic mobilization from the sediments depends on mineral association and geochemical conditions. The results of laboratory tests indicate that approximately 10 percent of the total arsenic in the sediments is adsorbed to iron oxyhydroxides. Iron oxyhydroxides are stable under oxidizing conditions but unstable under reducing conditions. A large portion of the sediments are in a reducing zone, resulting in the potential mobilization of arsenic from oxyhydroxides in this zone.

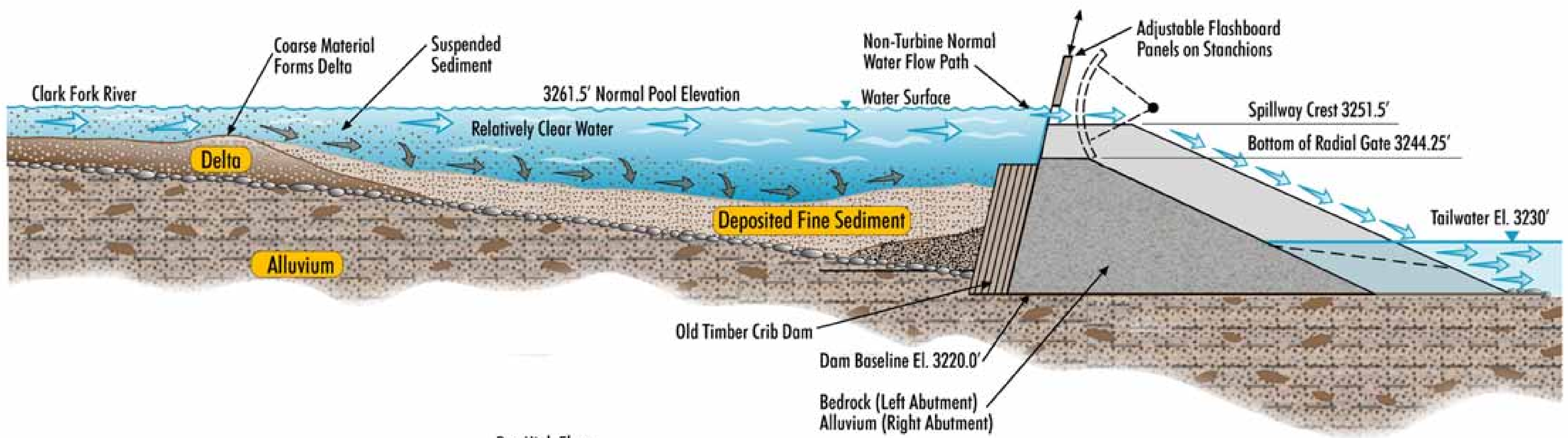


EXHIBIT 2-12a
Conceptual Model—Schematic of Sediment Accumulation During Low Flow Periods

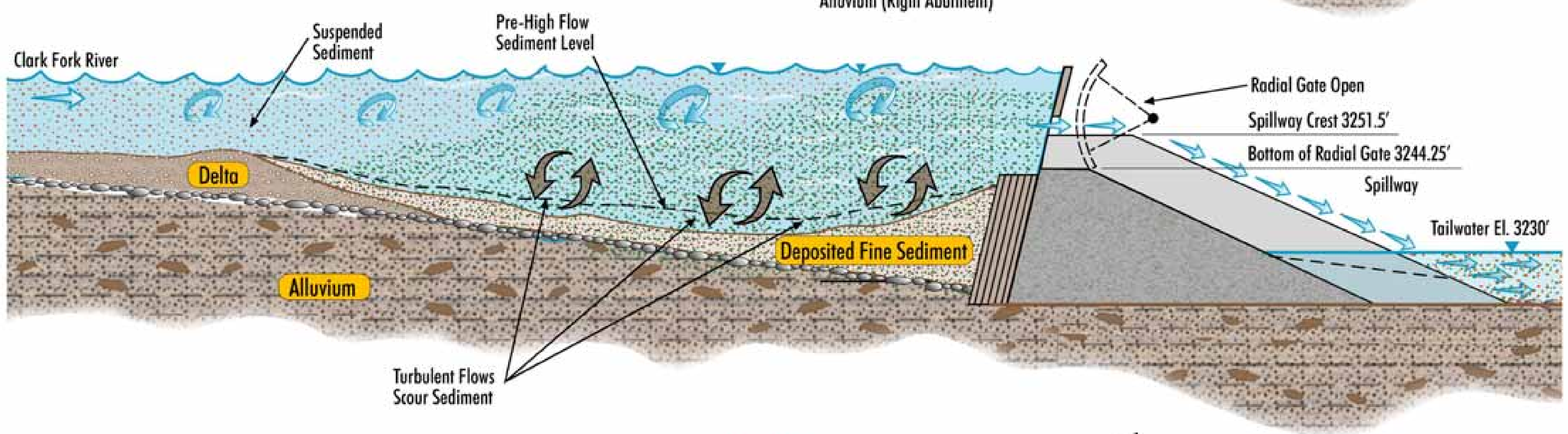


EXHIBIT 2-12b
Conceptual Model—Schematic of Sediment Scouring During High Flow Events

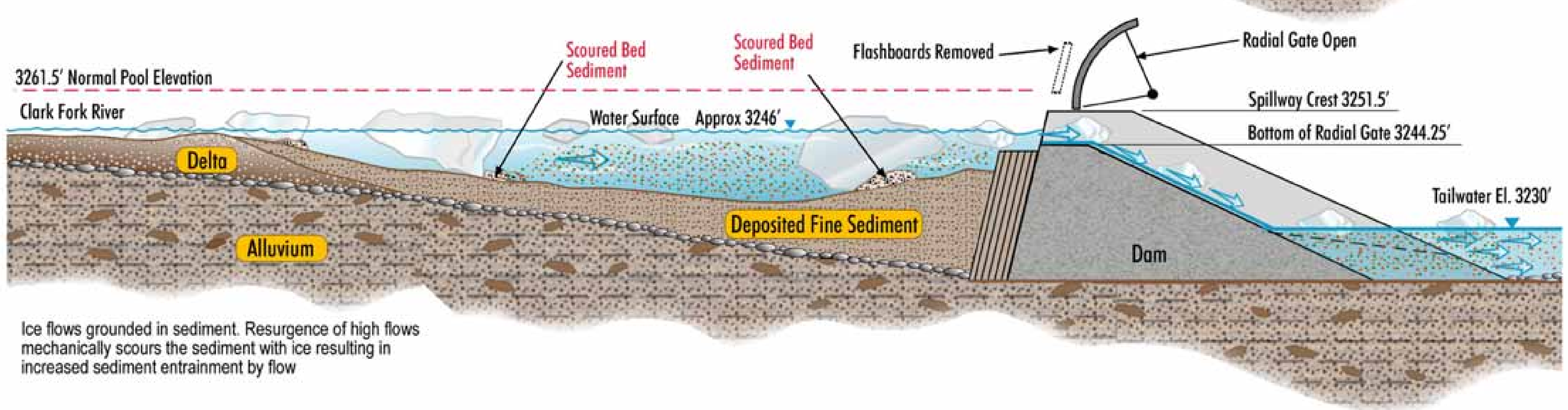


EXHIBIT 2-12c
Conceptual Model—Schematic of Reservoir Draw Down During Ice Event

Legend

Domestic Well

Monitoring Well

As <= 0.01 mg/L

As > 0.01 mg/L

0.020 As Concentration (mg/L) 2000-2001 Survey

0.020 As Concentration (mg/L) 1992 Survey

0.020 As Concentration (mg/L) 1991 Survey

ND Not detected

Approximate Area of Groundwater Exceeding the New Federal Standard of 0.01 mg/L Dissolved Arsenic Concentration (Approximately 325 acres in extent)

This portion of the plume boundary is inferred from the survey data and the known groundwater flow

Notes:

1. 2000-2001 Survey data was obtained from Land & Water Consulting, Inc. March 2001, December 2000 Groundwater Monitoring Event Data Summary Report.
2. For those wells not surveyed in 2000-2001, 1991-1992 data is presented from Final Draft Remedial Investigation Report – Milltown Reservoir Operable Unit, prepared for ARCO by Titan Environmental Corporation, Feb. 1995.

EXHIBIT 2-13
Area of Groundwater Exceeding Federal Water Quality Arsenic Standard

prepared for

ARCO
ANACONDA MONTANA

Scale

600 0 600 1200 feet

Date: 07/23/02

Map Number: Plume 10ppb

EXHIBIT 2-14
Dissolved Arsenic Concentrations (ppm) in Alluvial Aquifer and Bedrock Wells: Monitoring between 1990 to 2001

Well No.	Dates Sampled	Number of Samples	Maximum	Minimum	Standard Deviation	Mean
Upgradient Area						
35	1990-1991	2	0.0000	<0.0020	0.00	0.0000
36	1990-1991	2	0.0000	<0.0020	0.00	0.0000
110A	1990-1991, 1996-2003	14	0.0060	<0.0020	0.00	0.0017
110B	1990-1991, 1996-2003	15	**0.0180**	0.0050	0.00	**0.0133**
902	1990-1991	2	**0.0210**	**0.0100**	0.01	**0.0155**
918	1991	1	**0.0160**	**0.0160**	-	**0.0160**
2	1996-2001	10	**0.0130**	0.0030	0.00	0.0096
DA42	2000-2003	6	**0.0120**	0.0080	0.00	0.0095
BS	2000-2003	6	0.0020	<0.0020	0.00	0.0005
DB7	2000-2003	6	0.0030	<0.0020	0.00	0.0005
Upland Disposal Area						
910A	1990-1991	2	0.0000	<0.0020	0.00	0.0000
910B	1990	1	0.0050	0.0050	-	0.0050
911A	1990-1991	2	0.0030	<0.0020	0.00	0.0015
911B	1990-1991	2	0.0000	<0.0020	0.00	0.0000
912	1990-1991	2	0.0000	<0.0020	0.00	0.0000
913A	1990-1991	2	0.0000	<0.0020	0.00	0.0000
913B	1991	1	0.0000	<0.0020	-	0.0000
Arsenic Plume Area						
100A*	1990-1992	4	**1.2500**	**1.0100**	0.10	**1.1275**
100B	1990-1992	4	**1.4800**	**1.2600**	0.11	**1.3725**
101B	1990-1992	4	**1.0700**	**0.9410**	0.06	**0.9903**
102A	1990-1992	4	**0.8740**	**0.8050**	0.03	**0.8340**
102B	1990-1992	4	**1.0700**	**0.8060**	0.13	**0.9288**
103A	1991, 1997-2002	12	**0.2200**	**0.0120**	0.06	**0.0923**
103B	1990-1992, 1995-2002	18	**0.2300**	**0.0420**	0.05	**0.0896**
107A*	1997-2002	10	**0.7160**	**0.2140**	0.17	**0.5380**
107B*	1990-1992	4	0.0050	<0.0020	0.00	**0.0025**
107C*	1990-1992, 1995-2001	16	**1.4500**	**0.0880**	0.42	**0.7865**
901	1990-1992	4	**0.4150**	**0.3200**	0.04	**0.3785**
903	1990-1992	4	**0.6120**	**0.3790**	0.11	**0.4865**
904	1990-1992	4	**0.9920**	**0.2340**	0.32	**0.5938**
905	1990-1992, 2001	5	**0.6270**	**0.1580**	0.20	**0.2920**
908	1990-1992	4	**0.2910**	**0.0160**	0.11	**0.1465**
909A	1990-1992	4	**0.1870**	**0.0900**	0.04	**0.1295**
909B	1990-1992	4	0.0030	<0.0020	0.00	0.0015
917A	1991-1992, 1995-2002	17	**0.3400**	0.0010	0.12	**0.1322**
917B	1991-1992, 1995-2002	17	**0.2800**	0.0050	0.08	**0.1032**
HLA-1	1990-1992	4	**0.1510**	**0.0770**	0.03	**0.1233**
HLA-2	1990-1992, 1995-2003	19	**0.1050**	0.0030	0.03	**0.0517**
M-17	1990-1992	4	**0.0760**	**0.0430**	0.01	**0.0595**
11	1995-2003	13	**0.0330**	**0.0170**	0.01	**0.0244**
Northern Hydraulic Boundary Area						
99A	1990-1991, 1995-2003	17	0.0070	<0.0050	0.00	0.0024
99B	1990-1991, 1995-2003	17	0.0060	<0.0050	0.00	0.0020
99C	1995-2003	15	0.0050	<0.0050	0.00	0.0023
104A*	1990-1991, 1996-2003	15	**0.0160**	0.0060	0.00	**0.0102**
104B*	1990-1991, 1996-2002	14	**0.0150**	0.0070	0.00	**0.0123**
105A	1990-1991, 1996-2003	15	0.0080	0.0020	0.00	0.0050

EXHIBIT 2-14
Dissolved Arsenic Concentrations (ppm) in Alluvial Aquifer and Bedrock Wells: Monitoring between 1990 to 2001

Well No.	Dates Sampled	Number of Samples	Maximum	Minimum	Standard Deviation	Mean
105B	1990-1991, 1996-2003	15	0.0050	<0.0020	0.00	0.0019
105C	1990-1991, 1996-2003	15	**0.0130**	<0.0020	0.00	0.0065
106A	1990-1991	2	0.0000	<0.0020	0.00	0.0000
106B	1990-1991	2	0.0000	<0.0020	0.00	0.0000
106C	1990-1991	2	0.0000	<0.0020	0.00	0.0000
108A	1990-1991, 1996-2003	15	0.0060	<0.0020	0.00	0.0016
108B	1990-1991, 1996-2003	15	0.0060	<0.0020	0.00	0.0018
109A	1990	1	0.0000	<0.0030	-	0.0000
109B	1990-1991	2	0.0040	<0.0020	0.00	0.0020
111A	1990-1991, 1997, 2001-2003	8	**0.5400**	<0.0020	0.19	**0.0684**
111B	1990-1991, 2001-2003	7	0.0020	<0.0020	0.00	0.0009
906	1990-1991, 1995-2000	13	**0.4000**	<0.0030	0.13	**0.1444**
914	1990-1991	2	0.0000	<0.0020	0.00	0.0000
915A	1990-1992, 1995-2003	19	**0.0270**	<0.0020	0.01	0.0066
916A	1991-1992, 1997-2003	15	0.0050	<0.0010	0.00	0.0019
916B	1991-1992, 1997-2003	15	0.0060	<0.0010	0.00	0.0023
G	1996-2003	13	**0.0270**	<0.0005	0.01	0.0074
J	1996-2003	13	0.0070	0.0020	0.00	0.0044
Downgradient Area						
907	1990-1992, 1995-2001	16	0.0040	<0.0020	0.00	0.0011
919A	1991-1992, 1996-2003	16	0.0040	<0.0020	0.00	0.0025
919B	1991-1992, 1996-2003	16	0.0080	<0.0020	0.00	0.0027
919C	1991-1992, 1996-2003	16	0.0080	<0.0020	0.00	0.0033
920	1991-1992, 1995-2001	15	**0.0280**	<0.0005	0.01	0.0058
921A	1991-1992, 1995-2003	18	0.0090	<0.0020	0.00	0.0053
921B	1991-1992, 1995-2003	17	**0.0270**	<0.0020	0.01	0.0029
922A	1991-1992, 1995-2003	17	0.0050	0.0000	0.00	0.0030
922B	1991-1992, 1995-2003	17	**0.0150**	0.0030	0.00	**0.0113**
922C	1991-1992, 1995-2003	17	**0.0150**	0.0070	0.00	**0.0125**
922D	1995-2003	15	**0.0150**	0.0090	0.00	**0.0133**
923A	1991-1992, 1995-2003	17	0.0090	<0.0005	0.00	0.0047
923B	1991-1992, 1995-2003	17	0.0080	<0.0005	0.00	0.0058
923C	1995-2003	15	**0.0110**	0.0030	0.00	0.0078
AC	1991-1992	2	0.0000	<0.0010	0.00	0.0000
HB	1991-1992	2	0.0050	0.0040	0.00	0.0045
MW-3	1995-1996	2	0.0000	<0.0005	0.00	0.0000
MW-6	1995-1996	2	0.0000	<0.0005	0.00	0.0000
MW-7	1995-2003	15	0.0080	0.0030	0.00	0.0042
HG-27	1995-2003	14	0.0030	<0.0005	0.00	0.0009
A4	1995-2001	11	0.0040	<0.0005	0.00	0.0018
DA21	2000-2003	5	0.0050	0.0020	0.00	0.0032
DA20	2000-2003	6	0.0030	<0.0020	0.00	0.0008
DA39	2000	1	0.0060	0.0060	-	0.0060
DB35	2000-2001	2	0.0030	0.0020	0.00	0.0025
DB39	2000-2003	6	0.0050	0.0020	0.00	0.0040

Notes:
*Bedrock well
Red, bold text indicates that the concentration is at or above the Federal standard of 0.01 ppm for dissolved arsenic.
A less-than symbol (<) indicates that the concentration is less than the laboratory limits of detection.

The largest percentage of arsenic is bound within residual minerals, primarily sulfides. In contrast to oxyhydroxides, sulfides are stable under reducing conditions, but unstable under oxidizing conditions. However, mobilization of arsenic from residual minerals located in the oxidized portion of sediments is limited. This is because the arsenic concentration in oxidized water is kept low by adsorption onto oxyhydroxides. Approximately 0.3 percent of the total arsenic in the sediment samples—pore water and solid sediment material combined—is present as dissolved arsenic. Arsenic pore water concentrations average 2.4 mg/l in the reservoir sediments immediately upstream of the dam and southeast of Milltown. In this area, sediment accumulations are deep and characterized by high total arsenic concentrations. In other areas, sediments are thinner or composed predominantly of coarse-grained sediments. These thinner or coarse-grained sediment areas have much lower average pore water arsenic concentrations and are not considered to contribute to the arsenic concentration exceedances observed in the Milltown alluvial aquifer.

5.5.3.3 Fate and Transport of Arsenic

Arsenic enters groundwater via movement of pore water through the reservoir sediments and to the alluvial aquifer, which is in direct contact with the sediments. The primary arsenic transport route is groundwater flow in a northeastern direction toward Milltown. The groundwater flow is bounded on the southwest by the “no-flow” boundary of the bedrock outcrop and to the west by the dam, which cause the flow within the alluvial aquifer to bend sharply around the dam and then to the west. Exhibit 2-15, *Alluvial Aquifer Potentiometric Surface Map*, indicates the direction of groundwater flow.

5.5.3.4 Arsenic Depletion from Reservoir Sediments

Arsenic can be mobilized from the sediments depending on mineral association and geochemical conditions, which gradually depletes the source of arsenic. Assuming the geochemical zones continue to be stable, the mass of arsenic available to enter the pore water was calculated to be approximately 430 tons. Based on flux estimates through the reservoir sediments, the arsenic loading rate to the alluvial aquifer has been estimated to be from 2 to 20 pounds per day. At this rate, assuming no addition of available arsenic from deposition of additional sediments from upstream or change in extent of geochemical zones, it will take between 200 and 2,000 years to deplete the arsenic source. This approximation assumes linear mobilization of arsenic from minerals in the sediment to the pore water. Realistically, pore water concentrations will decrease gradually over time, resulting in a longer time for arsenic depletion but with lower concentrations.

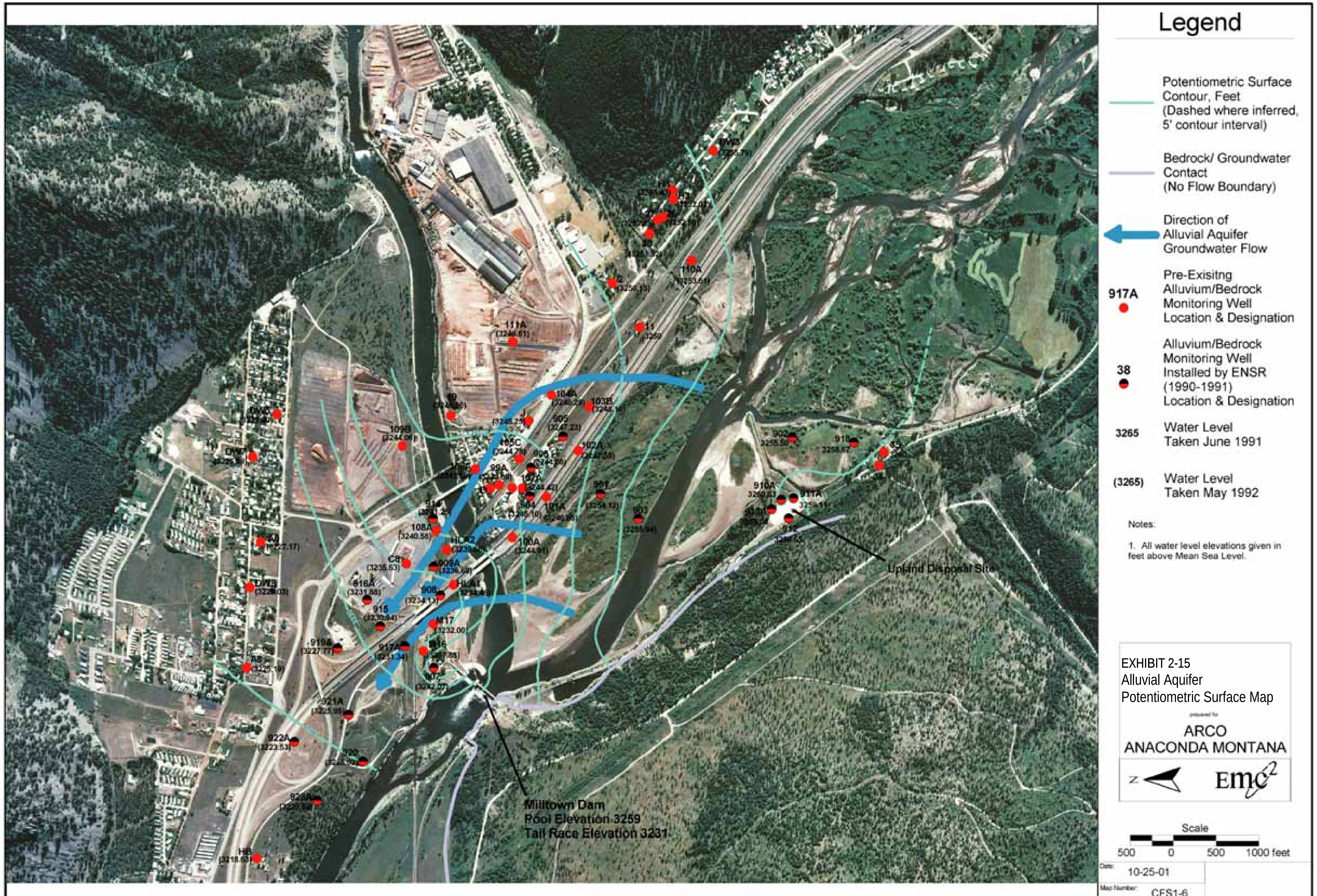
5.5.3.5 Arsenic Migration

A downward hydraulic gradient through the reservoir sediments is the primary mechanism for arsenic introduction into the alluvial aquifer. Alluvial water quality data indicates that the downgradient extent of elevated arsenic concentrations in the groundwater is limited by dilution and adsorption mechanisms that reduce arsenic concentrations. Arsenic from the reservoir sediments is diluted by the large alluvial groundwater flow by a factor of five as the water leaving the reservoir sediments mixes with the shallow aquifer beneath the sediments. Dilution is also important along the boundaries of the area with arsenic concentrations in groundwater exceeding 0.01 mg/l, decreasing concentrations by gradual mixing of the pore water with the alluvial aquifer. Adsorption also affects the extent of the arsenic in groundwater by removing arsenic from solution along the flow path through geochemical processes. In particular, adsorption to iron oxyhydroxides would be expected under the less reducing conditions present in the alluvial aquifer. A mass balance flow tube analysis completed as part of the *Remedial Investigation* suggested that adsorption could be a significant mechanism for reducing groundwater arsenic concentrations to low levels, particularly in the downgradient portion of the area. The natural mechanisms of dilution and adsorption, which provide a control on the extent of arsenic migration, will continue to operate. Significant changes in oxidation conditions or flow in the alluvial aquifer are unlikely because of the site location at the convergence of two rivers, which provides a constant, massive flow of oxidized water.

5.5.3.6 Source Area for Groundwater Arsenic Plume

Arsenic concentrations in the sediment pore water decrease rapidly upon entering the alluvial aquifer as a result of dilution and adsorption processes. For this reason, sediment pore water arsenic concentrations significantly higher than the new Federal Drinking Water Standard (FDWS) of 0.01 mg/l are required to represent a significant source contributing to arsenic exceedances in the alluvial aquifer. For the purpose of the RI/FS evaluations, sediments with pore water arsenic concentrations sufficiently elevated to potentially cause exceedances of arsenic standards in the alluvial aquifer are called source sediments. The source sediment area was delineated using pore water concentrations at least five times higher than the existing 0.018 mg/l Montana Numeric Water Quality Standard for arsenic, or 0.1 mg/l. The factor of five was derived to represent the initial dilution-related reduction in arsenic concentrations that is thought to occur as the sediment pore water mixes with the underlying alluvial aquifer. The initial dilution-related reduction, assuming complete mixing of waters, was estimated by comparing the 200,000 cubic feet per day vertical pore water flux through the sediments with the 1,000,000 cubic feet per day flux flowing in the shallow alluvial aquifer underneath the sediments (a potential 1-to-5 reduction ratio). Arsenic concentrations are further reduced along the flow path as the shallow alluvial aquifer flow mixes with the larger deep alluvial aquifer flow beneath and downgradient of Milltown and as adsorption removes arsenic from solution. However, to be conservative, only the initial approximately five-fold dilution reduction is assumed for delineating the source sediment area.

The source sediments occupy that portion of reservoir located immediately southwest of Milltown and compose the majority of Area 1 and a small part of Area 3. The estimated volume of source sediments responsible for the plume is 2 to 3 million cubic yards (mcy). The delineated source sediment area contains the thickest deposits of fine-grained silts and clays. Sediments located further upstream are generally thinner, coarser-grained, and have lower total arsenic and much lower pore water arsenic concentrations.


Legend
Potentiometric Surface Contour, Feet (Dashed where inferred, 5' contour interval)
Bedrock/ Groundwater Contact (No Flow Boundary)
Direction of Alluvial Aquifer Groundwater Flow
917A
Pre-Exisitng Alluvium/Bedrock Monitoring Well Location & Designation
38
Alluvium/Bedrock Monitoring Well Installed by ENSR (1990-1991) Location & Designation
3265
Water Level Taken June 1991
(3265)
Water Level Taken May 1992
Notes:
1. All water level elevations given in feet above Mean Sea Level.
Upland Disposal Site
Milltown Dam
Pool Elevation 3259
Tail Race Elevation 3231
EXHIBIT 2-15
Alluvial Aquifer
Potentiometric Surface Map
ARCO
ANACONDA MONTANA
Scale
500 0 500 1000 feet
10-25-01
CFS1-6

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5.6 Biological Resources

5.6.1 Wetlands

Wetlands throughout the reservoir area were delineated by USFWS during summer 1990 (USFWS 1991). A total of 297 acres of jurisdictional wetland, 125 acres of shallow water habitat, and 45 acres of deep-water habitat were identified under normal operating pool levels. A high diversity of wetland habitat types is distributed in a complex mosaic over the site. Palustrine wetlands were dominant. Willow, water birch, and mountain alder dominate the scrub-shrub wetlands. Common understory plants included redtop bentgrass, beaked sedge, Baltic rush, common tansy, and field horsetail. Balsam poplar trees occur in scattered groves in the upper reservoir area. Emergent wetlands were mainly dominated by cattail and hardstem bulrush. Aquatic beds were dominated by pondweed and small duckweed.

5.6.2 Fisheries and Macroinvertebrates

Fisheries resources in the Milltown section of the Clark Fork River, including the reservoir, have been monitored since 1979. Salmonids are present, with rainbow and brown trout as the dominant species. Rainbow trout are more common below the dam, as are large-scale and longnose suckers, mountain whitefish, northern pikeminnow, longnose dace, and sculpins. In contrast, brown trout are more abundant in the Clark Fork River just above the reservoir. Bull trout, cutthroat trout, and brook trout have also been identified in the Clark Fork River drainage. The shallow and weedy backwater of the reservoir also provides good spawning and rearing habitat for a healthy population of northern pike (*Esox lucius*). These pike are a nuisance fish and are detrimental to trout species. Northern pike are predators of trout and other fishes, and are detrimental to recreational and native fish populations.

DEQ has conducted benthic macroinvertebrate surveys annually since 1986. These are considered an indicator of water quality. At the Clark Fork River USGS Turah Bridge station, upstream of Milltown Dam, bio-integrity was non-impaired in 2003. Slight metals pollution was indicated at this site in 1986, 1990, and 1997. The Blackfoot River site has been one of the healthiest sites in the study area. Slight impairment was detected from 1986 through 1989 and was attributed to reduced sediment transport and drought. High flows during 1997 slightly impacted the Blackfoot River site. Below Milltown Dam, bio-integrity was slightly impaired in 2003, although not corroborated with organic or metal sensitive metrics. The population metrics used indicate no metals pollution had been observed since 1990, although nutrient-organic pollution has been evident, as indicated in the benthic macroinvertebrate studies.

EPA, through USGS, has conducted macroinvertebrate sampling since 1986 to evaluate the ecological impacts of mine wastes and the linkage between metal loads in the aquatic system, biological exposure, and impacts on community structure. Data from the Clark Fork at Turah (above Milltown) and the above Missoula site (below Milltown) indicate that macroinvertebrates have accumulated higher levels of copper, lead, and zinc from the Clark Fork River water and sediment than the reference site located on Rock Creek.

5.6.3 Wildlife

The reservoir area provides habitat for a variety of wildlife species. Big game species include white-tailed deer and elk. Small fur bearers include beaver, muskrat, and an occasional mink. Small mammals include meadow voles, house mice, deer mice, and the masked shrew. USFWS conducted bird surveys at the reservoir in 1990. Active breeders that use the area throughout the year include waterfowl, such as grebes, herons, swans, ducks, cormorants, and mergansers; raptors such as hawks, eagles, osprey, and kestrels; and song birds and other bird species, such as doves, pheasants, hummingbirds, and woodpeckers.

5.6.4 Threatened and Endangered Species

Bald eagles and bull trout occur in the reservoir area and are the key threatened and endangered species of concern. Bald eagles historically are present and are frequently seen along the Clark Fork River. Bull trout migration through this area, which is considered important for protection of the species in the Clark Fork River, is presently blocked by the Milltown Dam. During spawning season, some of the bull trout that gather below the dam are captured by netting, transported upstream of the dam, and released. From 1998 to 2002, three to eleven bull trout per year were captured and transported through this program.

5.7 Important Cultural and Historical Features

EPA and FERC, both of whom were involved in the selection and approval of Milltown Project activities, conclude that the National Historic Preservation Act (NHPA) applies to the Milltown Project activities. The following describes an approach that will be used at the MRSOU to investigate cultural and historic resources in compliance with National Historic Preservation Act and the Montana State Historic Preservation Office (SHPO) requirements:

- Atlantic Richfield Company, as required by EPA, completed an historical assessment and inventory of the area. Additionally, FERC conducted historical assessment activities under prior FERC related actions at the site. Together, these assessments recommended the Milltown Dam eligible for the NRHP as an historic district. The contributing elements of the district are the dam, powerhouse, divider block, right abutment, and three houses with their shed and garages lying north of the dam.

- As part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process, both the State and EPA conducted an analysis of alternatives to avoid the destruction of the Milltown Dam. Initially, EPA conducted a lengthy and detailed alternative analysis through a series of three *Feasibility Studies*, as described in Section 2, *Site History and Enforcement Activities*. These studies considered a range of cleanup alternatives at the MRSOU that included leaving the dam in place and the area relatively undisturbed, to removal of the in-stream dam only, to removal of the dam and related structures such as the powerhouse, divider block, and right abutment. The *Feasibility Study* process included extensive public involvement and historical resources coordination, and described the effects of alternatives on those resources. All three *Feasibility Studies*, as well as EPA's *Original Proposed Plan* (April 2003) and the *Revised Proposed Plan* (May 2004), were subject to public comment. EPA's *Proposed Plan* called for the removal of the in-stream dam and related sediments, under EPA's CERCLA remedial authority. In May 2003, the State released its DCRP under its CERCLA authority as lead natural resource trustee for natural resource restoration. This plan complemented EPA's plan and utilized EPA's prior alternatives analysis, and added additional cleanup requirements such as the removal of the right abutment, divider block, and powerhouse—all necessary to meet the restoration requirements of CERCLA. In response to public comment on the *Original Proposed Plan*, and in response to the overwhelmingly favorable public comment on the State's restoration plan, EPA issued a *Revised Proposed Plan* in May 2004. That plan modified EPA's cleanup plans for the sediment, recognized the State's DCRP plan, and described how the two plans could be completed at the same time. After consideration of public comment, the State finalized its DCRP and responded to public comments, including detailed responses to comments on the powerhouse removal and its historical features.

- The combined analysis by the two entities with responsibility for CERCLA action at the Milltown Site is that the Milltown Dam Complex must be removed to satisfy the statutory mandates of CERCLA. Public comment was solicited on these actions and fully considered by the agencies.
- The EPA assessment also identified aboriginal sites used by the CSKT as potentially eligible for NHPA protection. EPA has worked with the CSKT to map and evaluate these sites. A comprehensive list of all eligible or listed resources affected by the project is being compiled. EPA and the State believe that harm to these sites can be avoided through the careful design of the reconstruction and revegetation activities for the Milltown Project. If avoidance cannot occur after further and detailed engineering work occurs, EPA and the State will work with the CSKT to identify appropriate mitigation activities.
- EPA and FERC, in coordination with DOI, will work with the CSKT and SHPO to complete a Memorandum of Agreement for the Milltown Project to describe the avoidance and mitigation decisions, procedures for addressing sites if avoidance cannot occur, and procedures for protecting undiscovered protected resources at the Milltown Site. EPA and FERC, in coordination with DOI, will also develop a Historical Preservation and Mitigation Plan to describe the required mitigation efforts for the resources at the site which cannot be avoided during site cleanup—most notably the Milltown Dam Complex structures.

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