LOADS OF SUSPENDED SEDIMENT AND SELECTED TRACE ELEMENTS IN THE CLARK FORK BASIN, MONTANA, BEFORE AND AFTER THE REMOVAL OF MILLTOWN DAM

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Abstract The former Milltown Reservoir, located on the Clark Fork of the Columbia River upstream from Missoula, Montana, was a National Priorities List Superfund site. After the 1907 construction of Milltown Dam, about 6.6 million cubic yards of sediments enriched in trace elements from historical mining operations were deposited in the reservoir. Milltown Dam was removed in March 2008, as part of remedial activities. In preparation for the removal of Milltown Dam, permanent drawdown of Milltown Reservoir began in June 2006.

Because of the large quantity of contaminated sediment that has been deposited in the former Milltown Reservoir, there was concern about scouring and transport of sediment and associated trace elements from the shallow reservoir, especially during high streamflow periods. To address this concern, the U.S. Environmental Protection Agency initiated a sampling program with the U.S. Geological Survey (USGS) in about 1985. The intensity of the sampling program was increased in 2006 to provide more detailed assessment of suspended-sediment and trace-element transport during dam-removal activities. The objectives of the sampling program were to estimate daily loads of suspended sediment and selected trace elements.

The annual mass balances (that is, the inflow loads minus the outflow loads) of suspended sediment and trace element loads within the project area (the historical Clark Fork channel and flood plain affected by impoundment of water behind Milltown Dam) were estimated for water years 1985–2009. Daily loads of suspended sediment were estimated by using daily sediment concentrations and daily mean streamflow measurements. Daily loads of unfiltered-recoverable arsenic, cadmium, copper, iron, lead, manganese, and zinc were estimated by using regression equations relating trace-element discharge determined from periodic sampling to either instantaneous streamflow or suspended-sediment discharge. The equations were applied to records of daily mean streamflow or daily suspended-sediment load to produce estimated daily trace-element loads.

During the 21-year period prior to the start of permanent drawdown in 2006, inflow loads of suspended sediment and most trace elements generally exceeded outflow loads indicating net gain or deposition in the project area. The 1985–2005 average net gain in the project area was 7,000 tons per year (tons/yr) for suspended sediment and 4.1 tons/yr for copper. However, in water years 1996 and 1997, when streamflow was substantially above average [170-180 percent of 1985–2009 mean annual streamflow of 2,600 cubic feet per second (ft^3/s)] there was net loss of suspended sediment and copper from the project area. In water year 1996, about 317,000 tons of suspended sediment were transported past Clark Fork above Missoula (a USGS gaging station just downstream from the project area), with about 52,000 tons (16 percent) contributed from the project area. Transport of copper in water year 1996 was about 105 tons with about 9 tons (9 percent) contributed from the project area. In water year 1997, about 445,000 tons of suspended

sediment were transported past Clark Fork above Missoula, with about 55,000 tons (12 percent) contributed from the project area. Transport of copper in water year 1997 was about 129 tons with about 5 tons (4 percent) contributed from the project area.

Consistent net loss of suspended sediment and trace elements from the project area began after the start of the permanent drawdown in June 2006 and continued through water year 2009. During water years 2006–07, which spanned most of the period between start of permanent drawdown and the breaching of Milltown Dam, the mean annual streamflow was about 2,460 ft^3/s (95 percent of the 1985–2009 mean annual streamflow). During water years 2006–07, an average of about 140,000 tons/yr of suspended sediment was transported past Clark Fork above Missoula, with about 78,000 tons/yr (54 percent) contributed from the project area. The average transport of copper during water years 2006–2007 was about 45 tons/yr with about 24 tons/yr (52 percent) contributed from the project area.

In water year 2008, most of the annual runoff occurred after the breaching of Milltown Dam in March and annual mean streamflow was 3,040 ft^3/s (120 percent of the 1985–2009 mean annual streamflow). In water year 2008, about 510,000 tons of suspended sediment were transported past Clark Fork above Missoula, with about 391,000 tons (77 percent) contributed from the project area. Copper transport in water year 2008 was about 188 tons with about 157 tons (84 percent) contributed from the project area. In water year 2009, the first full year after the breaching of Milltown Dam, annual mean streamflow was 3,560 ft^3/s (140 percent of the 1985–2009 mean annual streamflow). In water year 2009, about 221,000 tons of suspended sediment were transported past Clark Fork above Missoula, with about 76,000 tons (35 percent) contributed from the project area. Copper transport in water year 2009 was about 73 tons with about 30 tons (41 percent) contributed from the project area.

Thus, the loads of suspended sediment and copper transported past Clark Fork above Missoula were substantially smaller in water year 2009 than in water year 2008, even though streamflow was moderately larger. Furthermore, the relative contribution of suspended sediment and copper from the project area in water year 2009 was much less than in water year 2008 and also was less than during the period between the start of permanent drawdown and the breaching of the dam (2006–07).

During the period from the start of permanent drawdown in June 2006 through water year 2009, the cumulative load of suspended sediment transported past Clark Fork above Missoula was about 955,000 tons with about 622,000 tons (65 percent) contributed from the project area. Cumulative copper transport during this period was about 331 tons with about 232 tons (70 percent) contributed from the project area. Most of the cumulative load of both suspended sediment and copper contributed from the project area was transported during the first four months after the breaching of Milltown Dam.