US Army Corps of Engineers®
Portland District

SEDIMENT QUALITY REPORT

LIBBY RESERVOIR, LAKE KOOCANUSA
COLUMBIA RIVER BASIN
KOOTENAI RIVER, MONTANA

Libby Reservoir, Lake Koocanusa

Sediment Quality Report
August 2020

EXECUTIVE SUMMARY

The Kootenai River (spelled Kootenay in Canada) drains 49,987 square kilometers of the Pacific Northwest in the United States and Canada, of which 23,271 square kilometers are upstream of Libby Dam. The Kootenai(y) system is the second largest tributary of the Columbia River after the Snake River and enters the Columbia River in British Columbia just downstream of Lower Arrow Lake about 40 kilometers from the U.S.-Canada border. The hydrology of the Kootenai River has been modified by the construction of Libby Dam and the reservoir, Lake Koocanusa, resulting in an alteration of the natural flow regime, river geometry, river velocity, and water residence time. A consequence of the creation of Lake Koocanusa is that the sediment transport patterns of the Kootenai River system have been altered resulting in increased sedimentation in the reservoir.

Sediment contamination in the Kootenai River exists. From the 1950s through the 1980s, contaminants were introduced to the river from a variety of sources such as a phosphate fertilizer production plant, a kraft paper mill, municipal sewage outfalls, lead-zinc mining operations, and vermiculite mine discharges (U.S. Fish and Wildlife Service [USFWS] 1999). Although most sources of contamination were reduced or eliminated by the 1990s, contamination from coal mining operations in the Elk River watershed of British Columbia still exists (Jenni, Naftz, and Presser 2017). As such, the pollutants currently entering the Kootenai River have substantially decreased in the past 40 years. Yet, monitoring efforts in the Kootenai River ecosystem in Idaho and British Columbia have detected metals, PCBs and organochlorine pesticides in white sturgeon (Acipenser transmountanous) indicating that contaminants still persist in the sediments (Knudson 1994; Kruse 2008).

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ACRONYMS

Acronym	Description
$CaCO_3$	Calcium Carbonate
cms	Cubic Meters Per Second
Corps	U.S. Army Corps of Engineers
DDT	Dichlorodiphenyltrichloroethane
L/min	Liters Per Minute
LIBBOR	Water Quality Station at the U.S.-Canada Border
LIBFB	Water Quality Station at the Forebay
LIBTMC	Water Quality Station at Ten Mile Creek
MDEQ	Montana Department of Environmental Quality
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Liter
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
SEF	Sediment Evaluation Framework
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

SECTION 1 - INTRODUCTION

1.1 STUDY AREA

The Kootenai River (spelled Kootenay in Canada) drains 49,987 square kilometers of the Pacific Northwest in the United States and Canada, of which 23,271 square kilometers are upstream of Libby Dam. The Kootenai(y) system is the second largest tributary of the Columbia River after the Snake River and enters the Columbia River in British Columbia just downstream of Lower Arrow Lake about 40 kilometers from the U.S.-Canada border. The hydrology of the Kootenai River has been modified by the construction of Libby Dam and the reservoir, Lake Koocanusa, resulting in an alteration of the natural flow regime, river geometry, river velocity, and water residence time. A consequence of the creation of Lake Koocanusa is that the sediment transport patterns of the Kootenai River system have been altered resulting in increased sedimentation in the reservoir.

Sediment contamination in the Kootenai River exists. From the 1950s through the 1980s, contaminants were introduced to the river from a variety of sources such as a phosphate fertilizer production plant, a kraft paper mill, municipal sewage outfalls, lead-zinc mining operations, and vermiculite mine discharges (U.S. Fish and Wildlife Service [USFWS] 1999). Although most sources of contamination were reduced or eliminated by the 1990s, contamination from coal mining operations in the Elk River watershed of British Columbia still exists (Jenni, Naftz, and Presser 2017). As such, the pollutants currently entering the Kootenai River have substantially decreased in the past 40 years. Yet, monitoring efforts in the Kootenai River ecosystem in Idaho and British Columbia have detected metals, PCBs and organochlorine pesticides in white sturgeon (Acipenser transmountanous) indicating that contaminants still persist in the sediments (Knudson 1994; Kruse 2008).

A summary of historical sediment quality data collected in Lake Koocanusa and the Kootenai River downstream of Libby Dam will be presented.

SECTION 2 - SITE FEATURES AND HISTORY

2.1 PHYSICAL CHARACTERISTICS

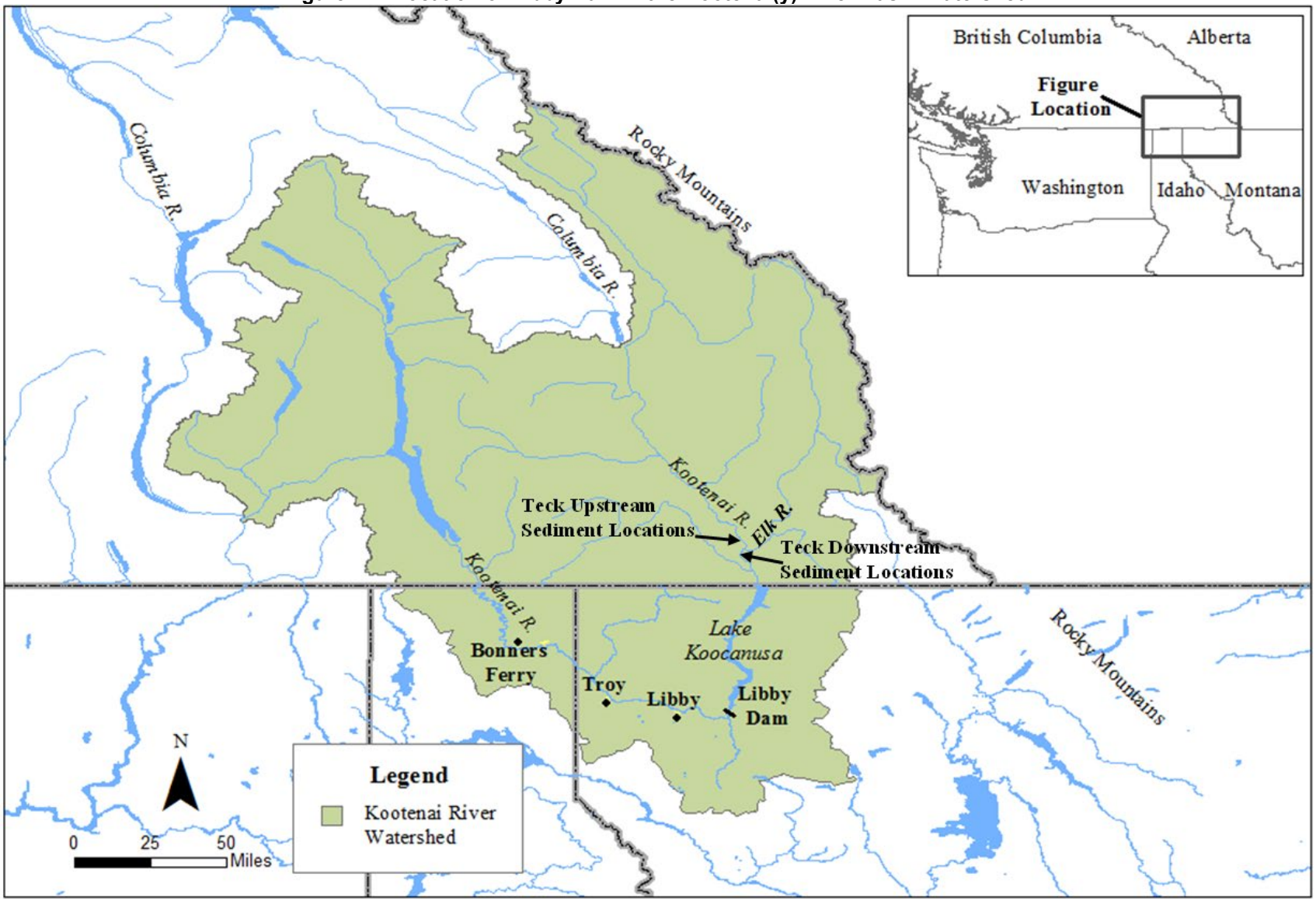
Libby Dam is located 29 kilometers northeast of Libby, Montana, at River Kilometer 357.1 of the Kootenai River (Figure 2-1). The dam's reservoir, Lake Koocanusa, is 145 kilometers long, extending 68 kilometers into British Columbia, Canada. The dam is a concrete gravity structure rising about 130 meters above bedrock with a top length of about 880 meters. The reservoir has a gross storage capacity of 7.24 million cubic kilometers, a mean depth of 38 meters, a maximum depth of 106 m at the forebay, and a mean water residence time of about 9 months. Normal full pool and minimum regulated reservoir elevations are 749.5 and 697.1[1] meters, respectively.

The headwaters of the Kootenai(y) River are in the Rocky Mountains of British Columbia in Kootenay National Park, about 70 kilometers east of Golden, British Columbia. The river flows south for about 120 kilometers through a steep, forested canyon until reaching Canal Flats, British Columbia. From Canal Flats to about 15 kilometers south of the Canadian border in Montana near the mouth of the Tobacco River, the river and lake are situated in the Rocky Mountain Trench, a relatively wide (approximately 10 kilometers) and flat valley. From the Tobacco River to Libby Dam, Lake Koocanusa is located in a steep and narrow canyon with a general north to south aspect. Downstream of Libby Dam, the Kootenai River flows to the south for about 4.8 kilometers to the mouth of the Fisher River and then to the northwest for about 114 kilometers to Bonners Ferry, Idaho, through a steep, forested canyon with an average slope of about 1 meter per kilometer. At Bonners Ferry, the river valley widens, and the river meanders to the north through a relatively flat section for about 75 kilometers to the U.S.-Canada border (Figure 2-1).

The Lake Koocanusa watershed is dominated by high, forested, northwest trending mountain ranges separated by narrow river valleys. Elevations range from about 640 meters immediately downstream of Libby Dam to more than 3,500 meters in the Rocky Mountains of British Columbia. The topography in the immediate Lake Koocanusa watershed is characterized by steep mountain slopes that plunge directly into the lake and relatively flat terraces that lie at intervals between the lake and the mountain slopes. The mountains rise as much as 400 meters per kilometer from the lake. Vegetation is dominated by ponderosa pine (Pinus ponderosa), Douglas-fir (Pseudotsuga menziesii), western larch (Larix occidentalis), western red cedar (Thuja plicata), western hemlock (Tsuga hererophylla), and lodgepole pine (Pinus contorta) (U.S. Department of Agriculture [USDA] 1995). The lake width ranges from about 0.9 kilometer at Libby Dam to about 4 kilometers near the U.S.-Canada border.

[1] All elevations in this Appendix are referenced to NGVD29 datum.

Figure 2-1. Location of Libby Dam in the Kootenai(y) River Basin Watershed



2.2 GEOLOGIC CHARACTERISTICS

The geology of the Kootenai River Valley varies from rocks of Precambrian age to consolidated and unconsolidated alluvial and glacial deposits of Quaternary age (Harrison et al. 1992). Bedrock consists largely of metasedimentary rocks of the Middle Proterozoic Belt Supergroup and limited exposures of Paleozoic, Mesozoic, and Tertiary strata. Harrison et al. (1992) estimated the bedrock to be about 14,630 meters thick. Unconsolidated and consolidated valley deposits consist of Holocene alluvial deposits, as well as Pleistocene glacial and fluvioglacial deposits and Pleistocene lakebed deposits. The alluvial and glacial deposits compose the principal water bearing units in the Kootenai River Valley (Boettcher and Wilke 1978).

Fluvioglacial and glacial deposits overlie the Precambrian rocks. In general, the glacial deposits are composed primarily of broken and crushed Precambrian rocks that were deposited as till by the ice. The glacial deposits consist largely of poorly sorted boulders, gravel, sand, silt, and clay. Boettcher and Wilke (1978) estimated the thickness of these deposits to exceed 150 meters in the middle of the Libby Creek Valley. These authors noted that wells tapping these glacial deposits generally produce less than 115 liters per minute (L/min).

Lakebed deposits of clay, silt, and fine sand overlie the glacial deposit (Boettcher and Wilke 1978). Local deposits of gravel can be found at the top and base of these lakebed sediments. Lakebed deposits are known to yield little to no water because of their low permeability and because the formation has been drained due to downcutting of the Kootenai River. Estimated thickness of these deposits is more than 100 meters thick.

Alluvial deposits consist largely of relatively well-sorted and reworked silt, sand, gravel, and cobbles (Boettcher and Wilke 1978). Reworking separates the finer from the coarser materials leading to coarser materials being deposited in the stream channels and the finer materials being deposited along the edge. The alluvium has been unevenly deposited on top of the glacial deposits, leading to wide ranges in the alluvium thickness and grain size in the valley. Boettcher and Wilke (1978) estimate the thickness of the alluvium in the vicinity of the town of Libby to be 30 m locally, but the maximum thickness and shape of the alluvium in the Kootenai River Valley are unknown. Because of the coarse grained texture of the alluvium, these deposits are more permeable than the glacial deposits, yielding from less than 400 L/min to more than 1,800 L/min. The variable yields are due to the variable thickness of the alluvial deposits.

2.3 HYDROLOGIC CHARACTERISTICS

The climate of the study area is influenced by easterly moving weather systems from the Pacific Ocean. Winters are generally cloudy, cool, and wet, with November through March being the wettest months. Most of the snowpack in the mountains falls between November and April. Summers are typically warm and dry, with little rainfall occurring from June through September. The mean annual precipitation near Libby Dam is about 490 millimeters, while annual precipitation in the Rocky Mountains near the headwaters

can exceed 1,000 millimeters (USDA 1995). Annual snowfall in the watershed varies from about 1,000 millimeters in the valleys to an estimated 7,600 millimeters in some mountain areas.

Much of the annual runoff in the Kootenai River Valley occurs in spring with the snowmelt. The impoundment of the Kootenai River by Libby Dam in 1972 for flood control and hydroelectric power production altered the seasonal flow patterns of the river (Bonde and Bush 1982). The annual pre-impoundment runoff conditions for the Kootenai River at the town of Libby showed high flows from April through June time period, with relatively low runoff the rest of the year, especially in the dry late summer/fall period, and the cold winter periods (Bonde and Bush 1982). Average pre-impoundment (1912 to 1971) flows in the Kootenai River ranged from about 1,850 cubic meters per second (cms) in late May and early June to about 110 cms in January U.S. Geological Survey [USGS] 2003). Post-impoundment conditions (1972 to 2016) have resulted in retaining water in Lake Koocanusa during historical high-flow periods and discharging water during historical low-flow periods. Since the early 1990s, the U.S. Army Corps of Engineers (Corps) has increased spring discharge levels from Lake Koocanusa to benefit downstream white sturgeon survival. In general, the Kootenai River downstream of Lake Koocanusa experiences reduced flows for most of the year, with peak outflows of up to 750 cms in late May through June for sturgeon survival, and again in December for power production.

The primary source of inflow to Lake Koocanusa is the Kootenai River, where up to about 56 percent of the estimated inflow can be attributed to the gaged Kootenai River flows at Ft. Steele, British Columbia. The second largest tributary is the Elk River in British Columbia, which accounts for about 22 percent for the inflow. The Bull River in British Columbia is estimated to contribute about 11 percent of the inflow to Lake Koocanusa. The only gaged tributary of Lake Koocanusa in Montana is the Tobacco River, which contributes only 2 percent of the inflow. The remaining ungaged inflow to Lake Koocanusa accounts for about 9 percent of the total annual inflow.

2.4 SEDIMENT LOADINGS

Historic sediment sources to the Kootenai River were largely from the Purcell Mountains to the west and the erosion of glacial drift and remnant terraces in the river valley in the eastern watershed (Corps 2012). The suspended sediment carried by the Kootenai River varied seasonally, with almost all (about 95 percent) of the load being transported during the spring runoff months of May through July. Suspended sediment data collected in the Kootenai River by the Corps prior to the construction of Libby Dam (1968 to 1970) at a station located just downstream of the dam site had an average annual suspended sediment load of 1.426×10^9 kilograms (range from 4.291×10^8 to 2.428×10^9 kilograms per year) (Corps 2012). From 1968 to 1970, the Kootenai River below the Libby Dam site had a mean daily suspended sediment concentration of 132 milligrams per liter (mg/L), with a range of 1 to 1,200 mg/L. After construction of Libby Dam, the mean daily suspended sediment concentration dropped to 3 mg/L, with a range of 1 to 60 mg/L (WEST 1998).

Libby Dam has greatly influenced the sediment transport in the Kootenai River. Tetra Tech (2004) estimated that Lake Koocanusa had a sediment trap efficiency of 94 to 97 percent under average flow conditions. During peak flows in May and June, about 12 percent of the suspended sediment was estimated to pass through the dam. All bedload sediment is trapped by Lake Koocanusa. Tributaries downstream of Libby Dam continue to contribute suspended sediment to the Kootenai River. However, Tetra Tech (2004) estimated that the sediment transported by the river downstream into Idaho is only about 15 percent of its former load.

The efficient trapping of suspended sediments in Lake Koocanusa has not substantially reduced its storage capacity. From 1972 to 1997, the reservoir capacity of Lake Koocanusa decreased by only 0.3 percent (WEST 1998). Nearly all the sediment deposition occurred in the upper 60 percent of the reservoir, largely in British Columbia. The lower 40 percent of the reservoir showed an increase in storage capacity during this time frame. During this time period, the Kootenai River downstream of Libby Dam was relatively stable (WEST 1998).

2.5 LAND USE

The Kootenai River watershed encompasses 49,987 square kilometers of southeastern British Columbia, northwestern Montana, and northern Idaho. The watershed is a sparsely populated mountainous area with a majority of the land in the basin being government owned or managed (Knudson 1994). In Montana, the Federal government owns approximately 72 percent of the land in the watershed, and in Idaho, the Federal government owns approximately 61 percent of the land in the watershed (Corps 2012). In British Columbia, the majority of land in the watershed is managed as Crown Land. The population centers in the British Columbia section of the watershed are concentrated near the confluence of the St. Mary River and Kootenay River, such as Cranbrook and Kimberley, and along the Elk River, such as Fernie, Sparwood, and Elkford. In Montana and Idaho, population centers are concentrated along the Kootenai River Valley downstream of Libby Dam and include the towns of Libby and Troy in Montana, and Bonners Ferry in Idaho (Corps 2012).

The economy of the watershed relies heavily on forest products, mining, hydropower, recreation (tourism), technology, and agriculture. In the past, timber and mining were the main drivers of employment in the region; however, recently tourism and recreation have become more important, as has government employment. In addition, the technology and electronics industry are becoming economically important in several British Columbia cities, such as Cranbrook and Kimberley (Corps 2012). Agriculture, although present in the region, is not considered to be a major economic industry.

2.6 CONTAMINANT SOURCES

Historical and current point source discharges of contaminants that may impact sediments in Lake Koocanusa and the Kootenai River exist in the watershed. Mining has been active in the watershed since the 1800s. Pacific Watershed Institute and Resources (1999) identified a variety of water and sediment quality impacts associated

with historic mining activities including heavy metal loadings, increased suspended sediments and turbidity, elevated nitrate levels, and increased selenium loadings. Actions have been taken to reduce the loading of contaminants from historic and active mines in the watershed, including treatment and recycling of waste rock and tailings pile runoff, and restoration of abandoned mines. Nonetheless, coal mining operations continue in the watershed in British Columbia. The impacts are discussed in greater detail in the following section.

Two major historical sources of contamination to the water and sediments were the Cominco Sullivan Mine and ammonium phosphate fertilizer plant near Kimberley, British Columbia, and the Crestbrook Forest Industries kraft pulp mill near Skookumchuck, British Columbia. The ammonia phosphate fertilizer plant began production in 1953 and discharged large quantities of phosphorus, fluoride, ammonia, and heavy metals into the St. Mary River, a major tributary to the Kootenay River in British Columbia. Levels of phosphorus and ammonia decreased in 1975 due to pollution abatement measures, and the plant closed in 1987. The Crestbrook pulp mill was one of the largest point sources of industrial wastewater to the river in the 1960s and 1970s. Pollution control efforts in the 1980s substantially improved effluent water quality (Woods 1982; Knudson 1994; Tetra Tech 2004)

The communities of Cranbrook, Kimberley, Fernie, Sparwood, and Elkford in British Columbia; Libby, Troy, and Eureka in Montana; and Bonners Ferry in Idaho continue to discharge secondary treated water to the Kootenai River. In addition to these larger point sources, there are numerous small community wastewater systems and individual septic systems.

2.7 COAL MINING IMPACTS

The Elk River originates in southeastern British Columbia and is a major tributary of the Kootenai River and Lake Koocanusa (see Figure 2-1). Historic and current coal mining in the watershed has degraded the sediment and water quality in the Elk River entering Lake Koocanusa. Coal mining and the corresponding waste rock spoils it generates has increased in the watershed as mining operations have expanded. Estimates of the total amount of coal produced from mining operations along the Elk and Fording Rivers has increased from about 2,800 million tonnes in 1997 to over 27,000 million tonnes in 2016, a tenfold increase (Teck Resources Limited [Teck] 2016). Hauer and Sexton (2013) reported elevated loadings of selenium, nitrate, and sulfate from the Elk River in British Columbia to Lake Koocanusa and the Kootenai River. Jenni, Naftz, and Presser (2017) determined that selenium loading to Lake Koocanusa from the Elk River increased fivefold between 1992 and 2012.

The increased loads of these elements from the Elk River pose a serious ecological threat to fish and aquatic birds in Lake Koocanusa. In particular, increased selenium loading is of concern because selenium can bioaccumulate in the food web and is toxic to fish and aquatic birds. In addition, the increased loadings of nitrate to Lake Koocanusa are of concern because nitrate is an essential nutrient for plant growth. Although the vast majority of lake water quality problems are associated with increased

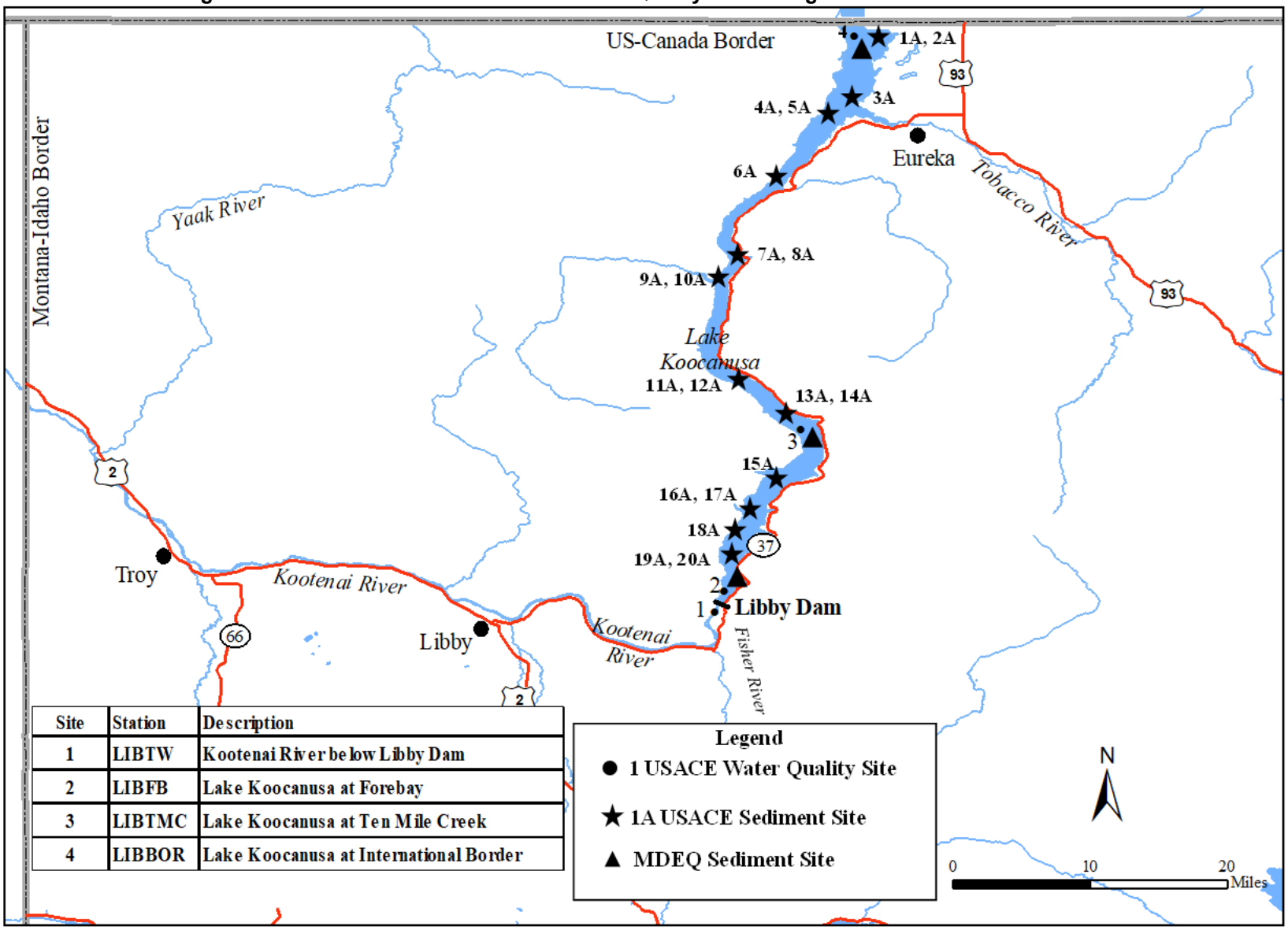
phosphorus loadings, there is concern that increased nitrogen loadings may also negatively impact the water quality of Lake Koocanusa by increasing algal growth, changing the species composition of the algae, altering zooplankton size and abundance, and altering the trophic status of the lake.

2.8 HISTORICAL SEDIMENT CHARACTERIZATION STUDIES

2.8.1 U.S. Army Corps of Engineers 1977 Study

The Corps Cold Regions Research and Engineering Laboratory collected 20 sediment samples in 1977 at 12 locations between the forebay and the U.S.-Canada border (Iskandar and Shukla 1981). In general, samples were collected from the reservoir thalweg, which ensured that each sample was being collected from a relatively deep reservoir location. Samples were collected at the long-term reservoir water quality stations (International Border-LIBBOR, Ten Mile Creek-LIBTMC, and Forebay-LIBFB), as well as at nine other locations spaced relatively evenly between the border and the forebay (Figure 2-2). Samples were collected using a stainless steel Ponar dredge sampler. Samples were analyzed for pH, calcium carbonate ($CaCO_3$), organic matter, particle size (except for sample 19A), total inorganic phosphorus, total organic phosphorus, and oxalate extractable iron, aluminum and phosphorus.

Figure 2-2. Locations of Sediment and Water Quality Monitoring Stations in Lake Koocanusa



Site	Station	Description
1	LIBTW	Kootenai River below Libby Dam
2	LIBFB	Lake Koocanusa at Forebay
3	LIBTMC	Lake Koocanusa at Ten Mile Creek
4	LIBBOR	Lake Koocanusa at International Border

2.8.2 Montana Department of Environmental Quality 2013 Study

The Montana Department of Environmental Quality (MDEQ) collected sediment samples in 2013 at three primary sites that were located in close proximity to the long-term reservoir water quality sites used by the USGS and Corps (Feldman and McNeil 2014). The International Border sampling site was located about 73.5 kilometers up reservoir from Libby Dam near water quality station LIBBOR at latitude 48.995556, longitude -115.178611. The Ten Mile Creek sampling site was located about 22.5 kilometers up reservoir from Libby Dam near water quality station LIBTMC at latitude 48.5850, longitude -115.231111. The forebay sampling station was located immediately up reservoir from Libby Dam near water quality station LIBFB at latitude 48.411944, longitude -115.309167. The general location for these samples are presented in Figure 2-2.

At each of the MDEQ sediment sampling sites, two types of sediment samples were collected. Shoreline soil samples were collected at least 5 meters above the annual high water mark, and benthic soil samples were collected from reservoir locations that remain permanently underwater. A statistical method was used to randomly choose eight sample locations for each type of sample. Sampling procedures followed those described in MDEQ (2013). Shoreline samples were collected with a PE or PVC trowel to a sampling depth that did not exceed 15 centimeters and passed through a 2-millimeter screen into a plastic tub or bucket where they were thoroughly mixed and consolidated. Benthic samples were collected with either a stainless steel Ekman or Ponar dredge sampler and thoroughly mixed and consolidated in a plastic tub or bucket. Samples were analyzed for pH, Eh (oxidation potential), and 10 different metals.

2.8.3 Teck Coal Limited 2014 to 2016 Study

Sediment samples were collected from 2014 to 2016 in the Canadian portion of Lake Koocanusa upstream and downstream of the Elk River confluence (Teck 2017). Sediment sampling focused on two transects, one located about 5 kilometers upstream of the Elk River confluence, and one located about 5 kilometers downstream (see Figure 2-1 for the general location of the Elk River confluence with Lake Koocanusa). Sediment was collected from five stations at each of the two transects in August of each of the three sampling years. Samples were collected using a stainless steel Petite Ponar sampler, and the top 3 centimeters of sediment was collected and composited into the sediment sample. Sediment samples were analyzed for pH, particle size and total organic carbon (TOC), as well as for selected chemicals such as polycyclic aromatic hydrocarbons (PAHs) and metals.

2.9 KOOTENAI RIVER IN IDAHO

2.9.1 USGS/Kootenai Tribe/Free Run Aquatic Research 2007 Study

The USGS, together with the Kootenai Tribe of Idaho and Free Run Aquatic Research, collected and analyzed sediment chemistry samples at up to 23 locations in the Idaho section of the Kootenai River about 100 kilometers downstream of Libby Dam in June

and July 2007 (Barton et al. 2012). Sediment cores intended for chemical analysis were collected in a 25-kilometer reach of the river near Bonners Ferry, Idaho, from about River Kilometer 232 to 257 (Figure 2-3 and Figure 2-4). Sampling procedures followed those described by the Corps Northwest Regional Sediment Evaluation Framework Manual (Corps 2006). Sediment cores were analyzed for pH, TOC, and grain size, as well as for selected chemicals such as organochlorine pesticides, PAHs, polychlorinated biphenyls (PCBs), metals, and asbestos.

Figure 2-3. Location of USGS Sediment Study Stations in the Kootenai River

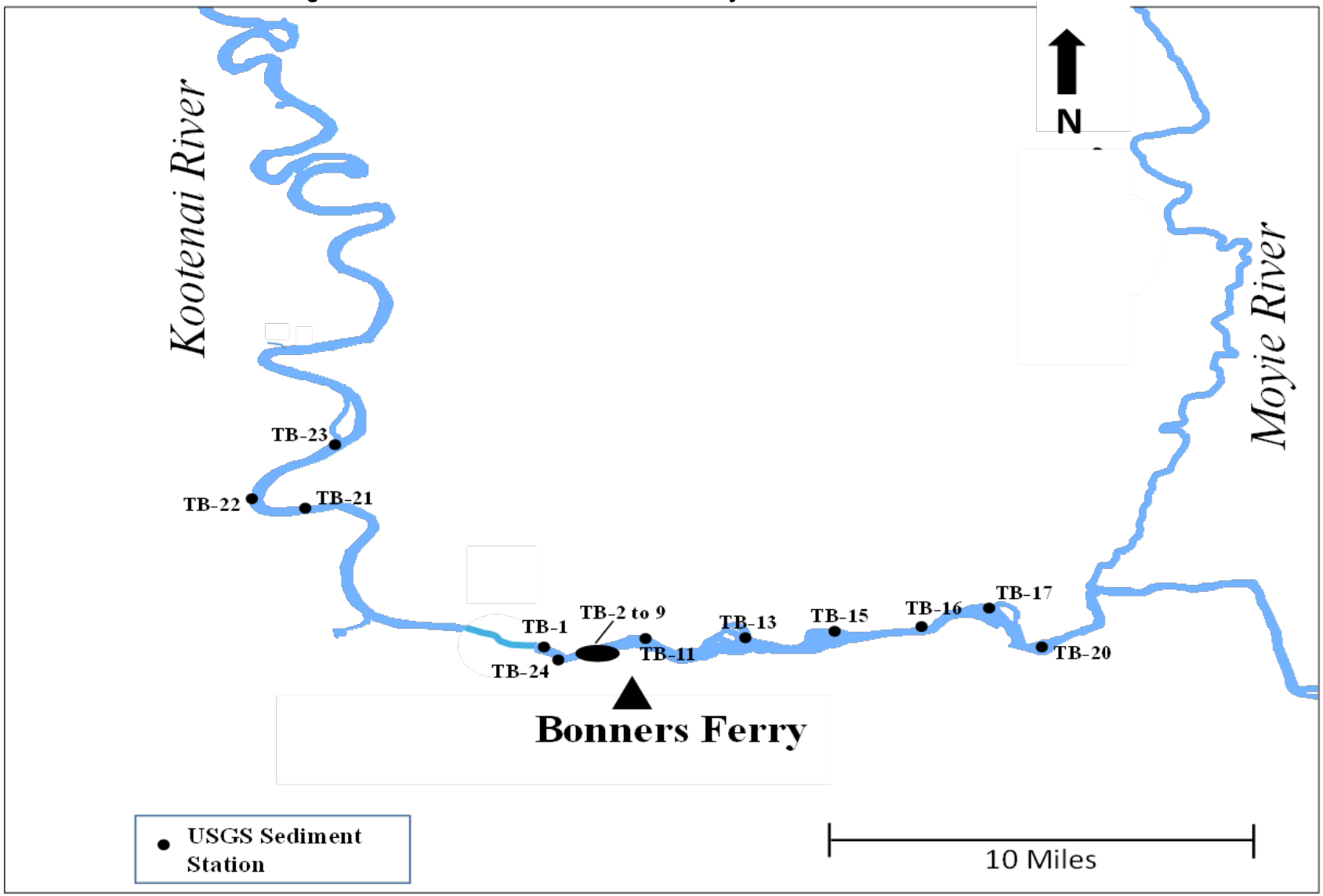
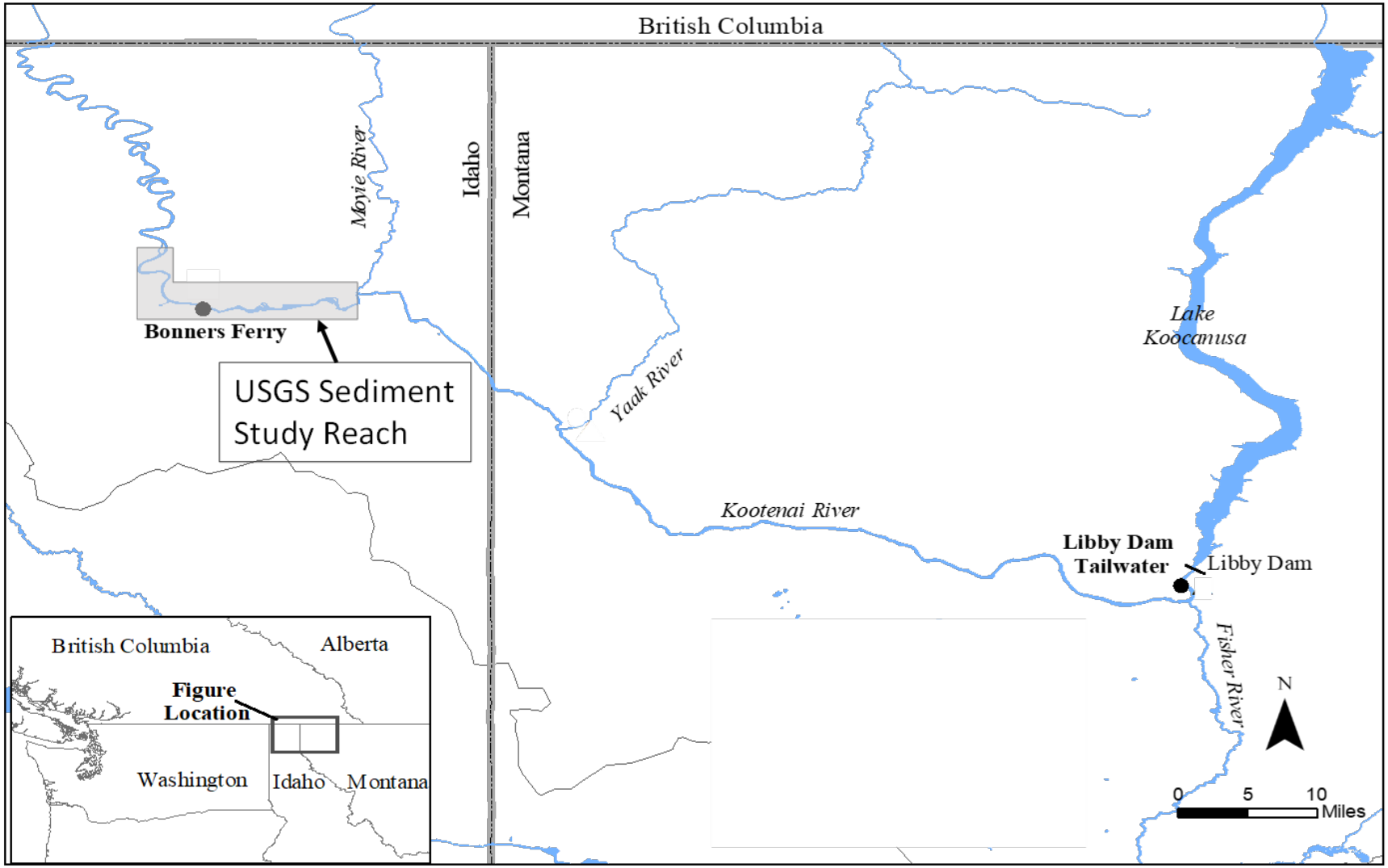


Figure 2-4. Location of USGS Sediment Study Reach in the Kootenai River



2.10 CONTAMINANTS OF CONCERN

Many pollutants tend to be associated with particles that settle out onto bottom sediments. At great enough concentrations, these compounds may be harmful to benthic organisms and may bioaccumulate in fish and other aquatic organisms. Sediment samples in Lake Koocanusa have been analyzed for nutrients and metals (Iskandar and Shukla 1981; Feldman and McNeil 2014; Teck 2017). Sediment samples from the Kootenai River in Idaho have been analyzed for metals, organochlorine pesticides, PAHs, PCBs, and asbestos (Barton et al. 2012).

2.10.1 Metals

Metals of concern include arsenic, antimony, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, and zinc. Sources of these metals exist upstream and downstream of Libby Dam from historical mining and smelter activities in the watershed. Elevated concentrations of metals can be toxic to benthic and aquatic organisms and bioaccumulate.

2.10.2 Nutrients

Nutrients of concern that are found in sediments include phosphorus and nitrogen compounds, including ammonia. Elevated concentrations of phosphorus and nitrogen compounds in sediments may be an indication of an upstream source of these nutrients to the ecosystem. Additionally, elevated phosphorus concentrations may result in increased algal growth leading to eutrophication or nutrient enrichment of surface waters. High ammonia concentrations in sediments can be toxic to benthic organisms

2.10.3 Organochlorine Pesticides

Organochlorine pesticides are chlorinated hydrocarbons used extensively as pesticides from the 1940s through the 1970s. Most organochlorine pesticides are no longer sold in the United States. However, many of these pesticides are extremely persistent in the environment. Pesticides, such as DDT (Dichlorodiphenyltrichloroethane)), that were banned years ago are still found in the environment. Since the early 1970s, organochlorine pesticides, such as DDT, have been shown to be harmful to aquatic invertebrates, fish, birds, and mammals (USGS 1996).

2.10.4 Polychorinated biphenyls (PCBs)

PCBs were developed in the 1940s and used in the manufacturing of transformers, capacitors, and many other heat transfer devices. 1n 1979, their manufacture and import was banned in the United States due to evidence that the chemical compounds were toxic to humans and animals, were persistent in the environment, and tended to bioaccumulate. PCBs are mixtures of different congeners of chlorobiphenyls. Consequently, many forms of PCBs exist and are generally referred to by their commercial mixture names called Aroclors (U.S. Environmental Protection Agency [EPA] 2012).

2.10.5 Polycyclic aromatic hydrocarbons (PAHs)

PAHs are a class of organic compounds that contain two or more fused aromatic (benzene) rings that can be toxic to aquatic biota at elevated concentrations. PAHs are often classified into two groups based on their molecular structure: Low Molecular Weight and High Molecular Weight. PAHs occur naturally in coal, crude oil, and gasoline. Sources of PAHs to the environment are largely a product of the incomplete combustion of coal, oil, gas, wood, and garbage. Numerous potential sources of PAHs exist in the environment including vehicles, power plants, home heating, and coal-tar asphalt sealants. Emissions of PAHs are largely atmospheric, and atmospheric deposition is considered to be a major pathway to the aquatic environment (EPA 2013).

2.10.6 Asbestos

Asbestos is a term for six naturally occurring fibrous mineral substances that are highly resistant to heat, electricity, and chemical corrosion. These minerals include amosite, chrysotile, crocidolite, tremolite, actinolite, and anthophyllite. Asbestos contamination in the Kootenai River watershed has occurred due to mining of vermiculite that was contaminated with asbestos fibers, largely tremolite. Asbestos was widely used in spray-applied surfaces for fireproofing/insulating, pipe insulation, and other insulating materials until the mid-1970s when the EPA banned asbestos from these products because of their link to mesothelioma, lung cancer, and other chronic respiratory conditions. Asbestos is not completely banned from use in the United States, and the EPA currently regulates the use of asbestos in many products as long as it accounts for less than 1 percent of the product.

2.11 EXISTING 303(D) AND TMDLS

Lake Koocanusa was identified by the MDEQ as water quality impaired and not fully supporting aquatic life in the MDEQ 2016 Integrated Report (MDEQ 2018). Consequently, Lake Koocanusa was included in the 2016 MDEQ Clean Water Act 303(d) list category 5 for flow alterations and selenium. The 303(d) Category 5 list is defined by the EPA as waters with one or more beneficial uses being impaired or threatened, and a total daily maximum load (TMDL) is required to address the impairment or threat. For Lake Koocanusa, a TMDL is needed for selenium but is not applicable for flow alteration.

The Kootenai River was identified by MDEQ as water quality impaired in the 2016 Integrated Report, and the river was included in the 303(d) Category 5 list for flow alterations and water temperature. A TMDL is currently being developed for water temperature. A TMDL is not applicable for flow alteration in the river.

2.12 FRESHWATER SEDIMENT SCREENING LEVELS

The Pacific Northwest Sediment Evaluation Framework (SEF) manual provides a regional framework for assessing, characterizing, and evaluating sediments in the Pacific Northwest (Northwest Regional Sediment Evaluation Team Agencies 2016). The SEF developed freshwater sediment quality guidelines for evaluating sediment chemical

analytical results based on screening levels and bioaccumulation criteria. It serves as an implementation manual for the *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S.—Testing Manual* (Inland Testing Manual) (1998) produced by the U.S. Environmental Protection Agency (EPA) and the Corps for satisfying Clean Water Act testing requirements. Although the SEF was produced specifically for the evaluation of dredged materials for unconfined aquatic placement, the framework is also used for evaluating non-navigational projects and for anti-degradation evaluations.

SECTION 3 - SEDIMENT QUALITY

3.1 LAKE KOOCANUSA SEDIMENTS

3.1.1 Conventional

Table 3-1 shows the results for grain size, percent calcium carbonate, pH, and TOC for Lake Koocanusa sediment samples collected in 1977 at 12 different locations in the U.S. portion of the reservoir (Figure 2-2). Data collected in the 1970s showed that the sediments in the lake were calcareous, with $CaCO_3$ concentrations ranging from 6.3 to 24.7 percent (i.e., 63,000 to 247,000 milligrams per kilogram [mg/kg]). The pH of the sediments was near neutral (range of 6.7 to 7.2), and the organic matter content was low, ranging from 0.47 to 2.3 percent with a mean of 1.08 percent (Iskandar and Shukla 1981). In general, grain size analysis indicated that sediments were dominated by silt and clays (range of 52 to 96 percent), with sand comprising 4 to 48 percent. The authors concluded that the composition of the sediments in 1977 likely reflected the composition of the native material in the original riverbed and surrounding watershed with little influence from in-reservoir processes such as deposition of suspended sediments and organic matter from phytoplankton and zooplankton.

Table 3-1. Sediment Physical and Chemical Properties Collected in Lake Koocanusa by the U.S. Army Corps of Engineers in 1977

Sample Number	pH	$CaCO_3$ (%)	Org. Matter (%)	Sand (%)	Silt (%)	Clay (%)	Texture
1A	6.9	20.0	0.47	48	36	16	Loam
2A	6.7	18.6	1.17	14	66	20	Silty Loam
3A	6.8	21.5	0.80	20	62	18	Silty Loam
4A	6.9	26.9	1.20	10	61	29	Silt Clay Loam
5A	7	27.4	0.50	38	47	15	Loam
6A	6.9	23.5	1.06	8	48	44	Silty Loam
7A	6.9	17.1	0.90	34	38	28	Clay Loam
8A	7.1	20.0	1.05	26	38	36	Clay Loam
9A	6.95	14.2	1.27	18	48	34	Silt Clay Loam
10A	6.9	23.0	1.09	8	52	40	Silty Clay
11A	6.95	18.6	1.48	12	50	42	Silty Clay
12A	6.75	17.1	2.30	16	44	40	Silty Clay
13A	7.2	12.7	1.15	6	52	42	Silty Clay
14A	7.15	16.1	1.39	4	52	44	Silty Clay
15A	6.9	14.7	1.48	10	44	46	Silty Clay
16A	7.15	18.1	0.82	18	58	24	Silty Clay
17A	7.2	11.7	1.09	34	32	34	Silty Loam
18A	7.0	16.6	0.74	20	50	30	Loam
19A	7.2	11.2	1.07	—	—	—	—
20A	7.0	6.3	0.50	16	59	25	Silty Loam

Notes: Source Iskandar and Shukla (1981)

More recent conventional analysis has been conducted on sediments collected in both the Canadian portion of Lake Koocanusa (Teck 2017) and the U.S. portion of the lake (Feldman and McNeil 2014). An extensive study of sediments upstream and downstream of the Elk River (see Figure 2-1 for general location) in British Columbia was conducted from 2014 to 2016 (Table 3-2). Sediments in the Canadian portion of the reservoir were slightly basic (mean pH range from 8.0 to 8.1) with low TOC (mean TOC range from 1.2 to 1.6 percent). Grain size analysis showed that the sediments both upstream and downstream of the Elk River were dominated by silt and clay (range of 90 to 100 percent). However, sediments collected upstream of the Elk River were consistently sandier (annual means of 2 to 10 percent) with less clay (annual means of 17 to 19 percent) than those collected downstream (annual means of < 1 percent sand and 26 to 30 percent clay). Benthic sediment pH data collected in 2013 at three locations in the U.S. portion of Lake Koocanusa were similar to the Canadian study by Teck (2017) and ranged from a mean pH of 7.70 at the forebay station, 7.85 at the Ten Mile Creek station, and 8.04 at the International Border station. The greater sediment pH values measured from 2013 to 2016 compared to the 1977 values is likely due to the greater influence in-reservoir processes have had on the composition of the sediments during the past 40 years.

Table 3-2. Sediment Quality Data Collected Upstream and Downstream of the Elk River in British Columbia from 2014 to 2016

			2014		2015		2016	
Parameters	Units	Data Transformation	Downstream Elk River	Upstream Elk River	Downstream Elk River	Upstream Elk River	Downstream Elk River	Upstream Elk River
Non-Metals								
Moisture	%	Mean	42	38	44	43	44	37
pH (1:2 soil:water)	pH	Mean	8.1	8	8.1	8.1	8.1	8.1
Particle Size and Carbon								
% Gravel	%	Median	0.1	0.1	0.1	0.1	0.1	0.1
% Sand	%	Median	0.1	9.6	0.1	1.9	0.1	7.3
% Silt	%	Mean	73	72	70	72	74	75
% Clay	%	Mean	27	18	30	19	26	17
Total Organic Carbon	%	Mean	1.3	1.3	1.6	1.2	1.2	1.2
Metals								
Aluminum	mg/kg	Mean	12,880	11,980	13,170	12,060	12,260	11,280
Antimony	mg/kg	Mean	0.42	0.32	0.5	0.33	0.39	0.26
Arsenic	mg/kg	Mean	5.9	5.6	7.3	6.5	6.3	5.4
Barium	mg/kg	Mean	145	85	165	81	137	70
Beryllium	mg/kg	Mean	0.58	0.42	0.6	0.42	0.59	0.41
Bismuth	mg/kg	Median	0.21	0.23	0.21	0.2	0.2	0.2
Boron	mg/kg	Median	–	–	6.2	5	5.7	5
Cadmium	mg/kg	Mean	0.53	0.22	0.58	0.19	0.55	0.19
Calcium	mg/kg	Mean	102,900	109,180	107,400	112,000	96,100	102,180
Chromium	mg/kg	Mean	19	17	21	18	17	16
Cobalt	mg/kg	Mean	8.1	8.5	9.3	9.2	8	8
Copper	mg/kg	Median	15	16	17	15	22	19
Iron	mg/kg	Mean	20,200	20,760	22,970	22,600	20,240	19,980
Lead	mg/kg	Mean	14	16	14	15	13	14
Lithium	mg/kg	Mean	24	24	25	25	24	25
Magnesium	mg/kg	Mean	19,680	21,500	22,040	23,920	18,020	19,820
Manganese	mg/kg	Mean	521	429	605	464	544	399
Mercury	mg/kg	Mean	0.032	0.022	0.046	0.027	0.03	0.017
Molybdenum	mg/kg	Mean	0.99	0.66	1	0.62	0.94	0.63
Nickel	mg/kg	Mean	22	20	25	21	22	19
Phosphorus	mg/kg	Mean	626	494	785	583	670	493
Potassium	mg/kg	Mean	1,938	1,194	1,992	1,092	1,504	834
Selenium	mg/kg	Geo Mean	0.52	0.23	0.66	0.22	0.68	0.2
Silver	mg/kg	Median	0.11	0.1	0.12	0.1	0.12	0.1
Sodium	mg/kg	Median	130	130	123	108	111	91
Strontium	mg/kg	Mean	193	231	205	245	195	229
Thallium	mg/kg	Mean	0.19	0.12	0.17	0.089	0.15	0.085
Tin	mg/kg	Median	2	2	2	2	2	2
Titanium	mg/kg	Mean	99	141	89	128	61	87
Uranium	mg/kg	Mean	0.93	0.89	0.82	0.65	0.81	0.68
Vanadium	mg/kg	Mean	23	15	25	15	20	13
Zinc	mg/kg	Mean	79	70	84	70	79	66
Zirconium	mg/kg	Mean	–	–	1.1	1.4	1	1.3
Polycyclic Aromatic Hydrocarbons								
Acenaphthene	mg/kg	Median	–	–	0.005	0.005	0.005	0.005
Acenaphthylene	mg/kg	Median	–	–	0.005	0.005	0.005	0.005
Anthracene	mg/kg	Median	–	–	0.004	0.004	0.004	0.004
Benz(a)anthracene	mg/kg	Mean	–	–	0.014	0.01	0.011	0.01
Benzo(a)pyrene	mg/kg	Median	–	–	0.01	0.01	0.01	0.01
Benzo(b&j)-fluoranthene	mg/kg	Mean	–	–	0.023	0.01	0.018	0.01
Benzo(b+j+k)-fluoranthene	mg/kg	Median	–	–	0.025	0.015	0.018	0.015
Benzo(g,h,i)-perylene	mg/kg	Median	–	–	0.01	0.01	0.01	0.01
Benzo(k)fluoranthene	mg/kg	Median	–	–	0.01	0.01	0.01	0.01
Chrysene	mg/kg	Mean	–	–	0.023	0.01	0.024	0.01
Dibenz(a,h)-anthracene	mg/kg	Median	–	–	0.005	0.005	0.005	0.005
Fluoranthene	mg/kg	Geo Mean	–	–	0.018	0.01	0.015	0.01
Fluorene	mg/kg	Median	–	–	0.01	0.01	0.01	0.01
Indeno(1,2,3-c,d)-pyrene	mg/kg	Median	–	–	0.01	0.01	0.01	0.01
2-Methylnaphthalene	mg/kg	Median	–	–	0.059	0.01	0.054	0.01
Naphthalene	mg/kg	Mean	–	–	0.025	0.01	0.02	0.01
Phenanthrene	mg/kg	Median	–	–	0.06	0.01	0.046	0.01
Pyrene	mg/kg	Median	–	–	0.018	0.01	0.014	0.01

Notes:
Source: Teck (2017)

For both the 1977 Corps study and the 2014 to 2016 Teck study, TOC concentrations were low at all sites and ranged from 0.47 to 2.3 percent in the U.S. portion of the reservoir in 1977 and from 1.2 to 1.6 percent in the Canadian portion of the reservoir from 2014 to 2016 (Table 3-1 and Table 3-2). TOC concentrations showed no spatial pattern with similar TOC concentrations located both upstream and downstream of the Elk River confluence in Canada and similar concentrations from the border to the forebay. Because grain size and TOC can correlate to concentration of metals and other contaminants, these parameters are of interest when comparing sites because differences in contaminant concentrations may partly be attributed to differences in grain sizes and TOC concentrations rather than the presence or absence of contamination.

3.1.2 Nutrients

Nutrient concentrations were measured in sediments from the U.S. portion of Lake Koocanusa in 1977 and from the Canadian portion from 2014 to 2016 (Iskandar and Shukla 1981; Teck 2017). Total phosphorus concentrations in the 20 sediment samples collected in 1977 in the U.S. portion of the reservoir ranged from 750 to 1,500 mg/kg, with inorganic phosphorus the dominant form ranging from 87 to 98 percent of the total (Table 3-3). The source of such a high percentage of inorganic phosphorus was suggested to be the discharge of waste from the fertilizer plant in British Columbia. However, there was not a noticeable longitudinal decrease in sediment inorganic phosphorus concentrations between the border and forebay sediments suggesting that the majority of phosphorus discharged by the fertilizer plant may have been deposited within the Canadian portion of the reservoir (Iskandar and Shukla 1981). In general, the sediment phosphorus concentrations were low to moderate in Lake Koocanusa during the 1977 sampling event, and slightly lower than the mean sediment total phosphorus concentration of about 1,500 mg/kg determined from 30 oligotrophic lakes by Carey and Rydin (2011).

Table 3-3. Sediment Phosphorus and Oxalate Extractable Concentrations in Lake Koocanusa by the U.S. Army Corps of Engineers in 1977

	Phosphorus				Oxalate Extractable				
Sample Number	Total Inorganic	Total Organic	Total	% Inorganic	Inorganic P	Fe	Al	Fe + Al	% Ox-P of Total Inorganic P
1A	750	50	800	94	200	1310	100	1410	27
2A	950	50	1000	95	700	5800	1090	6890	74
3A	750	50	800	94	400	3200	620	3820	53
4A	950	50	1000	95	700	4700	1050	5750	74
5A	700	50	750	93	220	1700	580	2280	31
6A	1000	125	1125	89	780	5300	800	6100	78
7A	850	25	875	97	520	4500	330	4830	61
8A	850	25	875	97	660	4300	360	4660	78
9A	950	50	1000	95	700	7500	440	7940	74
10A	1100	25	1125	98	760	7900	360	8260	69
11A	1200	50	1250	96	1060	10900	1380	12280	88
12A	1300	75	1375	94	900	10000	1640	11640	69
13A	1050	125	1175	89	920	7600	1130	8730	88
14A	1350	150	1500	90	1080	10000	1450	11450	80
15A	1300	150	1450	90	1060	13200	440	13640	82
16A	850	125	975	87	520	5300	980	6280	61
17A	1210	165	1375	88	848	7200	980	8180	70
18A	1000	125	1125	89	800	9700	1300	11000	80
19A	950	50	1000	95	920	7900	1670	9570	97
20A	850	25	875	97	648	3700	950	4650	76

Notes:
P=Phosphorus, Fe=Iron, Al=Aluminum, %Ox-P=Percent Oxalate Extractable Phosphorus
Source Iskandar and Shukla (1981)

Recent sediment phosphorus concentrations collected upstream and downstream of the Elk River from 2014 to 2016 are shown in Table 3-2. Mean annual total phosphorus concentrations ranged from 493 to 583 mg/kg upstream of the Elk River and from 626 to 785 mg/kg downstream. The greater phosphorus concentrations downstream of the Elk River may be partly due to the greater percentage of silt/clay in the downstream sediments. Regardless, the total phosphorus concentrations measured from 2014 to 2016 are substantially lower than measured in 1977, likely due to the reduction in phosphorus waste to the reservoir during the past 40 years.

Oxalate extraction and phosphorus sorption tests were conducted on the sediments collected in 1977. Results showed that most of the inorganic phosphorus was associated with the amorphous iron and aluminum oxides (Table 3-3). Sorption and desorption studies concluded that sediments in the reservoir had a limited ability to sorb inorganic phosphorus, as well as a limited ability to release phosphorus. Iskandar and Shukla (1981) concluded that the sediments in Lake Koocanusa act as a phosphorus sink.

3.1.3 Metals

Metals concentrations in Lake Koocanusa sediments were sampled in 2013 for the Montana portion of the reservoir by Feldman and McNeil (2014) and from 2014 to 2016

for the British Columbia portion of the reservoir by Teck (2017). Metals are summarized in Table 3-2 and Table 3-4. In general, metal concentrations at the three stations sampled in Montana are relatively low with no concentration exceeding the SEF screening level 1, suggesting that adverse effects to the benthic community would not be expected. In addition, the highest average metal concentrations for most metals (chromium, copper, iron, lead, mercury, and ZINC) was at the Ten Mile Creek station. The data was analyzed on a spatial basis and found no correlation between distance from the Canadian border and metal concentrations.

Table 3-4. Sediment Metal Concentrations in the Montana Portion of Lake Koocanusa

	Mean Metals Concentrations in µg/g (n=8)									
Station Location and Site	**Antimony**	**Arsenic**	**Cadmium**	**Chromium**	**Copper**	**Iron**	**Lead**	**Mercury**	**Selenium**	**Zinc**
International Border										
Benthic Sediment	BDL	8.46	0.4	6.99	14.6	12370	12.91	0.04	0.27	61.02
Shoreline Soil	BDL	5.14	0.16	4.47	8.3	8769	13.22	0.02	0.23	40.35
Paired t-test p<0.05	NA	**0.008**	**0.001**	**0.0001**	**0.001**	**0.0001**	0.765	**0.002**	0.464	**0.004**
Ten Mile Creek										
Benthic Sediment	BDL	7.73	0.39	8.22	18.2	14698	15.97	0.05	0.32	77.26
Shoreline Soil	BDL	3.65	0.09	5.54	9.55	9789	10.57	0.02	0.28	46.01
Paired t-test p<0.05	NA	**0.005**	**0.007**	**0.01**	**0.005**	**0.017**	**0.038**	**0.041**	0.564	**0.007**
Forebay										
Benthic Sediment	BDL	8.28	0.23	6.87	16	11866	12.45	0.04	0.43	53.6
Shoreline Soil	BDL	2.7	0.08	4.51	4.54	6981	9.09	0.02	0.21	41.39
Paired t-test p<0.05	NA	**0.0001**	**0.018**	**0.034**	**0.0001**	**0.009**	0.19	0.094	**0.002**	0.351

Notes:
BDL - Below Detection Limit
t-test significant at p<0.05 value in bold - **0.001**
Source: Feldman and McNeil (2014)

Concentrations of most metals for the three Montana stations were greater in the deep water benthic samples compared to the shoreline samples Table 3-4). A paired t-test compared the mean and variance between the shoreline samples and the benthic samples for each metal at each sampling location. For most metals at all locations, benthic concentrations were statistically greater than the corresponding shoreline concentrations. Notable exceptions were that lead and selenium did not differ between benthic and shoreline samples at the International Boundary site; selenium did not differ at the Ten Mile Creek site; and lead, selenium and zinc did not differ at the forebay location. Feldman and McNeil (2014) concluded that the statistically greater metal concentrations in the benthic sediments indicate that these metals are accumulating in Lake Koocanusa.

A summary of annual concentrations of metals from 2014 to 2016 for the Canadian portion of Lake Koocanusa both upstream and downstream of the Elk River confluence are presented in Table 3-2. Concentrations of most metals were substantially higher in sediments collected downstream of the Elk River compared to upstream. In particular, concentrations of selenium were significantly greater at the downstream station. Although annual mean concentrations of arsenic, iron, manganese, and nickel in sediment were above the British Columbia Sediment Quality Guidelines lowest effects levels for some years, no metal concentration exceeded the SEF screening level 1

concentrations. Teck (2017) concluded that the general pattern of increasing metal concentrations at the downstream station may be related to the greater proportion of fine sediment particles in the downstream area. Upstream sediments contained a substantially greater percentage of sand and less clay than the downstream sediments. Because fine particles provide greater surface area to volume than larger particles, they are more likely to contain higher concentrations of contaminants such as metals that adsorb to the particles.

Concentrations of most metals for the Canadian portion of Lake Koocanusa were similar to metals concentrations for the benthic sediments in Montana (Table 3-2 and Table 3-4). In general, concentrations of arsenic, cadmium, copper, lead, mercury, and zinc were similar between the two geographic areas. Concentrations of chromium, iron, and selenium were substantially greater at the downstream Elk River station when compared to the Montana stations.

3.1.4 Organic Contaminants

Teck (2017) analyzed sediments for PAHs in 2015 and 2016 (Table 3-2). Concentrations of many PAHs were substantially greater in sediments collected downstream of the Elk River confluence when compared to upstream. Concentrations of all PAHs in the upstream sediment were less than the corresponding detection limit. Downstream of the Elk River, the average concentrations of 2-methylnaphthalene and phenanthrene were greater than the British Columbia low sediment guidelines but were well below the Pacific Northwest regional sediment evaluation framework screening levels. The increased PAH concentrations downstream of the Elk River when compared to upstream is likely due to the greater proportion of fine sediment particles in the downstream area resulting in greater surface area for contaminants to sorb onto.

Phillips and Bahls (1994) analyzed one sediment sample in the Montana portion of Lake Koocanusa for PCBs. A bottom sediment sample was collected in 1992 from a mid-reservoir location. No PCBs were detected in this sample.

3.2 KOOTENAI RIVER SEDIMENTS

3.2.1 Conventionals

Concentrations of total carbon ranged from 0.31 to 2.42 percent with a median of 1.02 percent (Table 3-5). Inorganic and organic carbon fractions ranged from 0.24 to 1.91 percent and <0.05 to 0.61 percent with a median of 0.87 percent and 0.15 percent, respectively. In general, inorganic carbon concentrations were greater than organic carbon at all stations. Grain sizes finer than sand (< 0.063 millimeters) ranged from 3 percent at station TB-11 to 84.9 percent at station TB-12, with a median of 5.95 percent. Sediment pH was slightly basic, and values ranged from 8.17 to 8.8 (Table 3-5). Grain size and total organic carbon can correlate to concentrations of metals and other contaminants. As such, differences in contaminant concentrations may partly be attributed to differences in these conventional parameters.

Table 3-5. Kootenai River Sediment Data for Grain Size, Carbon and Selected PAHs and PCBs

	Sediment Sample Number																		
Analysis	**TB-1**	**TB-2**	**TB-3**	**TB-4**	**TB-5**	**TB-7**	**TB-8**	**TB-9**	**TB-11**	**TB-12**	**TB-13**	**TB-15**	**TB-16**	**TB-17**	**TB-20**	**TB-21**	**TB-22**	**TB-23**	**TB-24**
Grain Size <0.063mm (%)	8.6	3.5	5.4	3.4	3.6	7.5	4.5	10.8	3	84.9	–	6.3	7	10.3	5.6	5.5	5.5	7.5	16.8
Inorganic Carbon (%)	–	–	1.16	–	0.44	0.68	0.54	1.81	0.67	1.81	1.7	0.66	0.24	0.87	0.48	1.91	1.86	1.49	–
Organic Carbon (%)	–	–	0.26	–	<.05	0.09	0.15	0.61	0.08	0.56	0.05	0.05	0.07	0.15	0.05	0.17	0.19	0.37	–
Total Carbon (%)	–	–	1.42	–	0.47	0.77	0.69	2.42	0.75	2.37	1.75	0.71	0.31	1.02	0.53	2.08	2.05	1.86	–
Polycyclic Aromatic Hydrocarbons (µg/kg)																			
p-Cresol	–	–	<100	–	<100	<100	<100	**200**	**E20**	<100	<100	<100	<100	<100	<100	<100	<100	**E12**	–
Naphthalene	–	–	<100	–	<100	<100	<100	**68**	**E2**	<100	<100	<100	<100	<100	<100	<100	<100	**E19**	–
2-Ethylnaphthalene	–	–	<100	–	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
2,6-Dimethylnaphthalene	–	–	E4	–	<100	<100	<100	**110**	**E10**	**E13**	<100	<100	<100	<100	<100	**E4**	<100	**E19**	–
1,6-Dimethylnaphthalene	–	–	<100	–	<100	<100	<100	**92**	**E10**	**E10**	<100	<100	<100	<100	<100	**E5**	<100	**E19**	–
Acenaphthylene	–	–	<100	–	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
1,2-Dimethylnaphthalene	–	–	<100	–	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Acenaphthene	–	–	<100	–	<100	<100	<100	**E27**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
2,3,6-Trimethylnaphthalene	–	–	<100	–	<100	<100	<100	**E51**	<100	<100	<100	<100	<100	<100	<100	<100	<100	**E13**	–
1-Methyl-9H-fluorene	–	–	<100	–	<100	<100	<100	**E45**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
2-Methylanthracene	–	–	<100	–	<100	<100	<100	**E50**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
1-Methylphenanthrene	–	–	**E7**	–	<100	**E20**	<100	**90**	**E10**	**E15**	<100	<100	<100	<100	<100	**E7**	<100	**E18**	–
1-Methylpyrene	–	–	<100	–	<100	<100	<100	**E49**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Phenanthrene	–	–	**E5**	–	<100	**E18**	<100	**180**	**E14**	**E25**	<100	<100	<100	<100	<100	**E5**	<100	**E25**	–
Anthracene	–	–	<100	–	<100	<100	<100	**E54**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Dibenzo[a,h]anthracene	–	–	<100	–	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Fluoranthene	–	–	<100	–	<100	<100	<100	**220**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Pyrene	–	–	<100	–	<100	<100	<100	**190**	<100	**E8**	<100	<100	<100	<100	<100	<100	<100	<100	–
Benzo[a]-anthracene	–	–	<100	–	<100	<100	<100	**130**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Chrysene	–	–	<100	–	<100	<100	<100	**E140**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Benzo[b]fluoranthene	–	–	<100	–	<100	<100	<100	**160**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Benzo[k]fluoranthene	–	–	<100	–	<100	<100	<100	**E63**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Benzo[a]-pyrene	–	–	<100	–	<100	<100	<100	**100**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Indeno[1,2,3-cd]pyrene	–	–	<100	–	<100	<100	<100	<63	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Benzo[ghi]perylene	–	–	<100	–	<100	<100	<100	**E65**	<100	**E9**	<100	<100	<100	<100	<100	<100	<100	<100	–
4H-Cyclopenta[def]-phenanthrene	–	–	<100	–	<100	<100	<100	**E38**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
9H- Fluorene	–	–	<100	–	<100	<100	<100	**E27**	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Isophorone	–	–	<100	–	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Phenanthridine	–	–	<100	–	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	–
Nitrobenzene-d	–	–	–	–	49	60	55	52	50	53	48	44	35	50	42	46	38	76	–
Polychlorinated Biphenyls (µg/kg)																			
Total PCBs	–	–	<5	–	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	–	–

Notes:

Values in **bold** are non-censored or estimated values between laboratory detection limit and reporting limit.

E-Estimated value

< - less than reported detection limit

Source: USGS (2011)

3.2.2 Metals

Sediment metals concentrations in the Idaho portion of the Kootenai River were sampled in 2007 and are summarized in Table 3-6. In general, metal concentrations at all stations sampled in Idaho are relatively low with no concentration exceeding the SEF screening level 1, which suggests that adverse effects to the benthic community would not be expected. The highest average metal concentrations for several metals (chromium, copper, lead, nickel, and zinc) was at stations TB-9 to TB-15. For most metals, concentrations measured in the river are similar to concentrations measured upstream in the U.S. and Canadian portions of Lake Koocanusa (Feldman and McNeil 2014; Teck 2017).

Table 3-6. Kootenai River Sediment Data for Conventionals and Metals

	Sediment Sample Number																		
Analysis	**TB-1**	**TB-2**	**TB-3**	**TB-5**	**TB-6**	**TB-7**	**TB-8**	**TB-9**	**TB-11**	**TB-12**	**TB-13**	**TB-15**	**TB-16**	**TB-17**	**TB-20**	**TB-21**	**TB-22**	**TB-23**	**TB-24**
Conventionals																			
Percent Moisture	19.8	17.7	23.1	11.8	21.2	27.3	17.7	33.3	29	18.6	27.4	23	23	20.5	23.8	24.4	20.8	30.8	29.5
pH	8.47	8.53	8.45	8.79	8.59	8.46	8.68	8.17	8.41	8.36	8.56	8.75	8.39	8.56	8.67	8.65	8.77	8.8	8.67
Total Organic Carbon (%)	0.2	<0.1	0.2	<0.1	0.2	0.2	<0.1	1.3	0.4	0.7	<0.1	0.1	<0.1	0.2	<0.1	<0.1	<0.1	0.8	0.4
Metals (mg/kg dry wt)																			
Antimony	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Arsenic	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	7.5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Barium	36.2	36.7	49.4	29.8	34.8	43.7	40.9	78.2	61	177	36.2	72.4	57.8	29.3	37.1	34.3	36.2	23	37.9
Beryllium	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.64	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Cadmium	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Chromium	7.3	8.6	9.1	8.4	8.3	8.6	7.8	44.6	16.1	17	9.1	16	7.8	9	10.6	7.2	7.3	8.1	7.5
Cobalt	4.5	4.9	5.2	5.2	4.5	4.6	4.1	7.6	5.7	9.2	7.1	7.8	4.6	5.2	4.8	4.1	4.1	3.4	4.3
Copper	7.9	8	10.6	9.9	7.5	9.9	8.6	10.4	9.4	22.2	17.8	26.6	12.9	11	13.5	6.5	7.1	7.8	8.1
Lead	<30	<30	<30	<30	<30	<30	<30	36	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Mercury	0.008	0.0068	0.0088	0.0172	0.0074	0.0106	0.0073	0.0181	0.0066	0.0345	0.0089	0.0061	<0.0050	0.0063	0.0058	0.0141	0.0096	0.0146	0.0078
Molybdenum	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Nickel	7.7	8.1	9.1	8.2	7.3	8.4	6.9	15.8	8.9	19.1	9.9	12.3	7.7	7.7	7.9	7.6	7.3	7	7.8
Selenium	<2.0	<2.0	<3.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Silver	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Thallium	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tin	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Vanadium	13.1	15.5	16.8	17.2	15.8	15.3	15.9	14.8	18.4	26.2	15.3	26.3	16.1	16	16.4	12.6	12.5	9.3	12.9
Zinc	45.2	35.3	37.9	32	46	34.1	26.6	81.2	71.6	69.8	35.9	42.3	32.1	29.2	39.7	30.7	30.4	24.3	30.4

Notes:

< - less than reported detection limit

Source: Kruse (2008)

3.2.3 Organic contaminants

This study analyzed sediments for several organic contaminants including organochlorine pesticides, PCBs, and PAHs. Sediments were analyzed for both currently used organochlorine pesticides and “legacy” organochlorine pesticides, such as DDTs (DDT, DDD, or DDE) that were banned years ago but are still found in the environment. PCBs analyzed included the most common Aroclors. Aroclors are commercial mixtures of PCBs that were developed for their thermal stability and banned in the 1970s due to toxicity concerns. PAHs analyzed included 29 of the most common PAHs found in the environment. Pesticides were measured in 19 of 24 sediment samples, while PCBs and PAHs were measured in only 16 of 24 samples (Table 3-6 and Table 3-7).

Concentrations of total PCBs were below the laboratory method detection limit of 5 microgram per kilogram for all stations. Concentrations of all PAHs were well below the Pacific Northwest regional sediment evaluation screening levels. In general, the concentrations for the 29 PAH compounds analyzed were less than the laboratory reporting level as shown in Table 3-5. Only 5 PAH compounds were detected at concentrations over the reporting limits. Station TB-9 contained the most detected PAHs with 23 compounds detected, although most at concentrations less than the reporting limit. Charred organic fragments in the sample, similar to charred woody debris, are thought to be the source of the PAHs at TB-9 (Barton et al. 2012).

Table 3-7 shows TOC normalized organochlorine pesticide concentrations for 18 sediment stations sampled. A total of 9 pesticides were detected in the Kootenai River sediment samples, with the greatest number of detections for methoxychlor (15 out of 18 samples) and hexachlorobenzene (11 out of 18 samples). Methoxychlor was used as an insecticide against a wide range of pests until its use was suspended in 2000. Hexachlorobenzene was used as a pesticide until 1965 and was also used in the production of rubber, aluminum, and dyes in wood preservatives. There are no sediment regulatory screening levels for methoxychlor and hexachlorobenzene. Concentrations of organochlorine pesticides were well below any Pacific Northwest regional sediment evaluation screening levels that may exist. A common way to assess organochlorine pesticides is to look at total DDT+Metabolites (DDD, DDE, DDT). Concentrations of DDT+Metabolites were below sediment evaluation screening levels.

Table 3-7. Kootenai River Sediment Analysis for Conventionals and Selected Organochlorine Pesticides

	Sediment Sample Number																	
Analysis	**TB-1**	**TB-2**	**TB-3**	**TB-5**	**TB-6**	**TB-7**	**TB-8**	**TB-9**	**TB-11**	**TB-13**	**TB-15**	**TB-16**	**TB-17**	**TB-20**	**TB-21**	**TB-22**	**TB-23**	**TB-24**
Conventionals																		
Percent Moisture	19.8	17.7	23.1	11.8	21.2	27.3	17.7	33.3	29	27.4	23	23	20.5	23.8	24.4	20.8	30.8	29.5
pH	8.47	8.53	8.45	8.79	8.59	8.46	8.68	8.17	8.41	8.56	8.75	8.39	8.56	8.67	8.65	8.77	8.8	8.67
Total Organic Carbon (%)	0.2	<0.1	0.2	<0.1	0.2	0.2	<0.1	1.3	0.4	<0.1	0.1	<0.1	0.2	<0.1	<0.1	<0.1	0.8	0.4
Organochlorine Pesticides (µg/kg dry wt.)																		
Methoxychlor	1.05(E)	0.1(E)	0.615(E)	0.022(E)	0.245(E)	0.570(E)	0.03(E)	0.323(E)	0.388(E)	0.025(E)	<mdl	<mdl	0.2(E)	0.043(E)	0.09(E)	<mdl	0.286(E)	0.4(E)
Hexachlorobenzene	<mdl	<mdl	0.175(E)	<mdl	0.235(E)	0.195(E)	0.05(E)	0.045(E)	0.103(E)	0.033(E)	<mdl	<mdl	0.27(E)	0.044(E)	0.062(E)	<mdl	<mdl	0.058(E)
Alpha-Hexachlorocyclohexane	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	0.290(E)	<mdl	<mdl	<mdl	<mdl	<mdl
Heptachlor	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	0.461(E)	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Oxychlordane	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	3.92(E)	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
Mirex	<mdl	<mdl	0.430(E)	<mdl	<mdl	<mdl	<mdl	3.75(E)	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
o,p-DDE	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	0.652(E)	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
p,p-DDE	<mdl	<mdl	<mdl	<mdl	0.15(E)	<mdl	<mdl	<mdl	<mdl	.023(E)	.021(E)	.021(E)	.13(E)	<mdl	<mdl	.021(E)	<mdl	<mdl
p,p-DDD	<mdl	<mdl	<mdl	<mdl	0.21(E)	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
o,p-DDT	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl
p,p-DDT	2.5(E)	<mdl	<mdl	<mdl	0.225(E)	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	<mdl	5.98(E)
Total DDT + Metabolites	2.500	0.000	0.000	0.000	0.585	0.000	0.000	0.652	0.000	0.460	0.201	0.420	0.130	0.000	0.000	0.420	0.000	6.368

Notes:

E-Estimated value

Source: Kruse (2008)

< - less than reported detection limit

<mdl - less than method detection limit

3.2.4 Asbestos

Kruse (2008) reported that Kootenai River sediment samples contained very few to no asbestos structures. Of the 20 samples analyzed by Polarized Light Microscopy, none contained any detectable asbestos fibers. The 20 samples were also analyzed by Transmission Electron Microscopy. The results of the Transmission Electron Microscopt analysis showed 2 of 20 samples contained minor (< 0.1 percent) regulated asbestos, with one sample containing chrysotile and one sample containing actinolite.

SECTION 4 - CONCLUSIONS AND RECOMMENDATIONS

Limited sediment data exists in Lake Koocanusa and in the Kootenai River downstream of Libby Dam. For Lake Koocanusa, although several years' worth of sediment data exits in the Canadian portion of the reservoir, there is little current sediment data for the Montana portion. Moreover, the more recent sediment data in the Montana portion of the reservoir has focused only on selected metals with no current analysis on nutrients or organic contaminants. For the Kootenai River, limited sediment data exits in the Idaho portion of the river about 100 kilometers downstream of Libby Dam.

4.1 LAKE KOOCANUSA

Sediment nutrient data collected in 1977 showed low to moderate concentrations of phosphorus in the reservoir, with inorganic phosphorus the dominant form. Sorption and desorption studies concluded that the sediments in Lake Koocanusa were a sink for phosphorus. Recent nutrient data collected from 2014 to 2016 in the Canadian portion of the reservoir showed lower sediment phosphorus concentrations, which suggested that the reduction in phosphorus loadings to the reservoir that occurred in the 1970s and 1980s have resulted in lower sediment phosphorus concentrations. Sediment nitrogen and ammonia concentrations were not measured for these studies.

Sediment metals concentrations in both the Canadian portion of the reservoir and in Montana were low, with no metals concentrations exceeding the Pacific Northwest regional sediment screening levels suggesting that adverse effects to the benthic community would not be expected. Concentrations of benthic sediments were significantly greater than corresponding shoreline sediments for most metals suggesting that metals may be accumulating in Lake Koocanusa. Sediment metals concentrations measured upstream and downstream of the Elk River in Canada showed that concentrations of most metals, in particular selenium, were greater at the downstream station. Concentrations of PAHs in the sediments in the Canadian portion of the reservoir were low. Nevertheless, PAH concentrations were substantially greater at the downstream station. The increase in metals and PAHs downstream of the Elk River was attributed to the greater percentage of fine particles at the downstream station compared to the upstream, rather than any possible influence of coal mining operations in the Elk River watershed.

4.2 KOOTENAI RIVER

Sediment metals, organochlorine pesticides, PAHs, PCBs, and asbestos were collected and analyzed in 2007 from up to 24 samples from the Kootenai River, near Bonners Ferry, Idaho. In general, metals concentrations at all stations were low, with no concentration exceeding the Pacific Northwest regional sediment screening levels. For most metals, concentrations were similar to those measured upstream in Lake Koocanusa. Sediment PCB and PAH concentrations were low, with PCBs below the laboratory method detection limit for all samples. Concentrations of PAHs were below the laboratory method detection limit for 24 of 29 measured compounds, with 5 compounds detected at very low concentrations.

A total of 9 pesticides were detected in the Kootenai River sediment samples, with the greatest number of detections for methoxychlor (15 out of 18 samples) and hexachlorobenzene (11 out of 18 samples). Although no screening levels exist for these two compounds, they were detected at very low concentrations. Concentrations of all other organochlorine pesticides (including DDT+Metabolites) were well below any Pacific Northwest regional sediment evaluation screening levels.

4.3 RECOMMENDATIONS

A more detailed sediment sampling program should be conducted in the Montana portion of Lake Koocanusa to supplement data collected in 2013 and to compare to all data collected in the Canadian portion of the reservoir. Samples should be collected at multiple sites between the international border and the forebay. In addition to metals analysis, sediment samples should be analyzed for nutrients and PAHs.

Sediment sampling should be conducted in the 100 kilometers of river between Libby Dam and Bonners Ferry, Idaho. Historic mining and industry, as well as population centers in the area, may have impacted sediment metal, nutrient, and PAH concentrations. Sampling should be focused on the Kootenai River upstream and downstream of the city of Libby, Montana, as well as downstream of Troy, Montana.

SECTION 5 - REFERENCES

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