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June 4, 2013

MEMORANDUM

TO: Council Members

FROM: Tony Grover, Fish and Wildlife Division director

SUBJECT: Presentation on Toxics in the Columbia River Basin: Dr. F. Richard Hauer and Erin K. Sexton, Flathead Lake Biological Station.

Dr. Hauer and Ms. Sexton, of the University of Montana's Flathead Lake Biological Station in Polson, Montana, will discuss the results of a recent toxics/pollution study: *Transboundary Flathead River: Water Quality and Aquatic Life Use*. The goal of the study, released March 4th of this year, was to focus on potential environmental effects of proposed coal mining in the Canadian portion of the Flathead River Basin. For more information on Dr. Hauer and Ms. Sexton as well as the Flathead Lake Biological Station in general, please visit http://www2.umt.edu/flbs/.

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Transboundary Flathead River:
Water Quality and Aquatic Life Use

Final Report

Prepared For: Glacier National Park, West Glacier, MT 59936

Rocky Mountains Cooperative Ecosystems Study Unit
Coop. Agreement #H1200040001, Task Agreement # J1434080043
Coop. Agreement #H1200040001, Task Agreement # J1434080044

Prepared By: F. Richard Hauer and Erin K. Sexton
Flathead Lake Biological Station
The University of Montana
Polson, MT 59860

March 4, 2013

EXECUTIVE SUMMARY

The Federal funding for this project was provided through the National Park Service with facilitation from the Rocky Mountains Cooperative Ecosystems Study Unit to conduct a study of river water quality, sediment quality and deposition response, and aquatic life use in the “Transboundary Flathead River” of southeastern British Columbia, Canada and western Montana, USA in southeastern British Columbia. The goal of the study was to focus on potential environmental effects of proposed coal mining in the Canadian portion of the Flathead River Basin.

There have been various proposals since the early 1970’s to mine coal in the Canadian portion of the Transboundary Flathead River Basin. Most recently, in the mid-2000’s a proposal was made to conduct an open-pit, mountain-top coal mining operation in the Foisey Creek watershed that flows into the headwater regions of the Transboundary Flathead River. To many this seemed to be a very natural progression of expanded coal mining from the East Kootenai Coal Fields of the Elk River Basin to the north of the Transboundary Flathead River Basin where there has been coal mining for over 100 years and open-pit, mountain-top removal mining for the past 40+ years. To many, expansion of coal mining into the Transboundary Flathead River Basin was seen as a threat to high water quality, aquatic life from the base of the food web to the fishes, and to the quality of habitats for both fisheries and wildlife that move across the international boundary of the USA and Canada. This was of particularly high concern to the management and administration of Glacier National Park, which receives Flathead River waters as they cross the Canada – USA boundary, citizens of the Flathead Valley in Montana, and the land owners around Flathead Lake.

We organized the studies around an experimental design among tributary stream and river sites in the Transboundary Flathead Basin above the proposed mine and site below the proposed mine. In contrast, the Elk Basin tributary stream and river sites were organized as above all mining and sites below existing mines.

We found nitrate and total nitrogen concentrations were significantly elevated (1000X) at sites downstream of existing coal mining in the Elk Basin compared to what was observed either among all Flathead Basin sites or samples from Elk Basin sites above coal mines. Sulfate concentrations were also significantly elevated (40-50X) in Elk Basin sites below coal mining. This is likely due to exposure of sulfide and/or sulfate bearing ores that are oxidized when exposed to the atmosphere during the mining process. Similarly to sulfate, selenium concentrations were elevated to 7-10X above naturally occurring levels observed among Flathead Basin streams and rivers sites and Elk Basin sites above the coal mining. We had a comprehensive design to look for metal effects in sediments transported from the coal mines. We observed elevated concentrations of cadmium in Corbin Creek and in Michel Creek below Corbin, but we did not observe increased metal concentrations at sites either in the Flathead Basin or among sites in the Elk Basin above the coal mines.

Algae and macroinvertebrates are excellent indicators of nutrient and toxin pollution. There are two common effects; first is referred to as a nutrient subsidy effect, in which the productivity of algae is increased due to higher concentrations of nutrients, such as nitrogen. This, in turn, leads to increased secondary production of aquatic insects. The second is a pollution stress effect causing a decrease in biodiversity as sensitive species decline and are replaced by tolerant species. Stream invertebrates are very highly diverse in unpolluted rivers and streams of the Waterton-Glacier International Peace Park. We found significant impact to both the algae and macroinvertebrate communities in tributary streams below mining in the Elk River Basin.

In Summer 2009, the National Parks Conservation Association and other environmental NGO's petitioned UNESCO to consider investigating the threat of proposed coal mining in the Transboundary Flathead River Basin to the ecological integrity of Waterton-Glacier International Peace Park as a World Heritage Site. The UNESCO investigative mission team visited the Transboundary Flathead in both the USA and Canada in

September 2009. In 2010, UNESCO reported, "………….it is the considered view of the mission team that should open pit coal mining and coal bed methane gas production proceed in the upper Canadian Flathead watershed, this would present a serious threat, incompatible with the Outstanding Universal Value of the Waterton-Glacier International Peace Park World Heritage property. Of particular concern are the likely degradation and irretrievable losses. There is, in the view of the mission, no possibility of proceeding with mining in the Flathead watershed without creating an unacceptable direct impact on the Outstanding Universal Value of the property, and there does not appear to be a compromise position in this regard."

On February 9, 2010, at the Opening of the Second Session of the Thirty-Ninth Parliament of the Province of British Columbia, the Honorable Steven L. Point, OBC Lieutenant-Governor made the following declaration, "A new partnership with Montana will sustain the environmental values in the Flathead River Basin in a manner consistent with current forestry, recreation, guide outfitting and trapping uses. It will identify permissible land uses and establish new collaborative approaches to trans-boundary issues. Mining, oil and gas development and coal bed gas extraction will not be permitted in British Columbia's Flathead Valley."

Since 2010, our continued research during the later portion of this study was modified with agreement with Glacier National Park Resource Personnel toward development of a comprehensive conservation plan integrating Transboundary Flathead aquatic habitat conservation and conservation of fish and wildlife habitat and corridors. We are continuing this research within the framework of the Transboundary Flathead and the Crown of the Continent Ecosystem and the initiatives of the US Fish and Wildlife Service Great Northern Landscape Conservation Cooperative.

The aims of our GNLCC-framed research is to build on an existing climate change and Transboundary research program to assess the potential hydrologic, geomorphic, and thermal effects on food webs (rare and endemic macroinvertebrates), native salmonids (threatened bull trout and westslope cutthroat trout), and lotic habitats in the Transboundary (US and Canada) Flathead River system. The project will apply new and existing technologies for combining downscaled and regionalized climate models linked with specific spatial data, fine-scale aquatic species vulnerability assessments (invertebrates→fish), population genetic data, and remotely sensed riparian and aquatic habitat analysis. This information will be used to begin development of an aquatics adaptation plan.

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Appendix E cont. ARS image of Floodplain Group C (see top Figure Appendix E) in the Transboundary Flathead River showing river segments of floodplain reaches A – C.

Appendix E cont. ARS image of Floodplain Group D (see top Figure Appendix E) in the Transboundary Flathead River showing river segments of floodplain reaches A – C.

Appendix E cont. ARS image of Floodplain Group E (see top Figure Appendix E) in the Transboundary Flathead River showing river segments of floodplain reaches A – C.

1.0 INTRODUCTION

1.1 Background and Overview

1.1.1 The Transboundary Flathead and the Crown of the Continent Ecosystem

The North Fork of the Flathead River is an international watershed that originates in southeast British Columbia and drains south across the USA - Canada border, where it forms the western boundary of Glacier National Park. Approximately 40% of the watershed lies in British Columbia, where it is known as the Flathead River, with the remaining 60% of the watershed in northwest Montana, where it is known as the North Fork of the Flathead River. In Montana, the North Fork of the Flathead is protected by the national "Wild and Scenic River" classification, and is included within Waterton-Glacier International Peace Park, World Heritage Site and International Biosphere

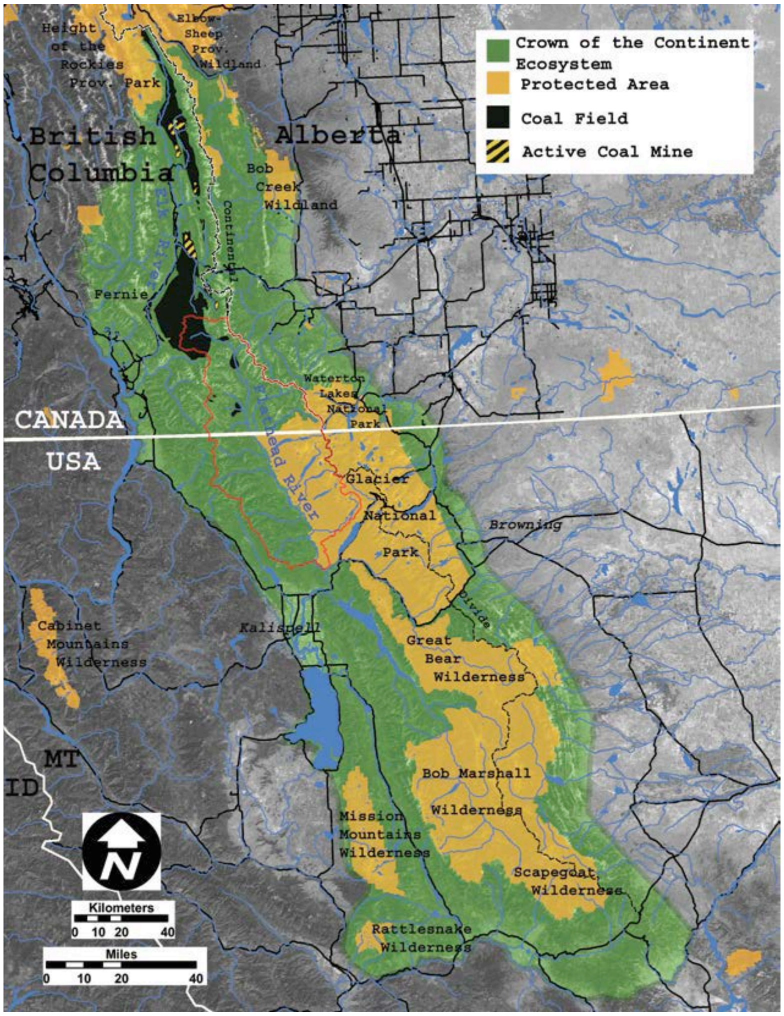

Figure 1. Map of the Crown of the Continent Ecosystem (CCE) (green). Protected areas (gold) are National, Provincial or state Parks, designated wilderness or wildlands areas. The map also shows areas of coal deposits (black) and sites of active coal mines (black and gold stripes). The Transboundary Flathead Basin (also known as the North Fork of the Flathead) is outlined in red.

Reserve. The B.C. Flathead and Montana North Fork are together known as the Transboundary Flathead. Southeast B.C. contains another transboundary watershed, the Elk River, which shares a common watershed divide with the Flathead; the Elk Basin being to the north along the continental divide and the Flathead to the south, also along the continental divide. Libby Dam on the Kootenai River in Montana forms Lake Koocanusa. The northern most reaches of the reservoir extending into British Columbia. The Elk River flows to the west into Lake Koocanusa Reservoir. Both the Flathead and Elk Rivers are part of a larger landscape known as the Crown of the Continent Ecosystem (CCE). The CCE is an approximately 18 million-acre ecosystem defined by the Continental Divide of the Rocky Mountains between British Columbia, Alberta and through western Montana.

The CCE landscape is critically important because it encompasses the pristine headwaters of three great continental river systems; the Columbia, the Missouri-Mississippi and the Saskatchewan. The Crown of the Continent Ecosystem is renowned for its relative connectivity and tremendous diversity of flora and fauna, including the full array of native carnivores and ungulates. The Transboundary Flathead and Elk Rivers (Figure 2) complete the northwest corner of the CCE and together form a connectivity corridor between Waterton-Glacier International Peace Parks and the Banff-Jasper National Parks of Canada to the north. The Flathead Valley in particular is a critical transboundary linkage within the CCE, providing low-elevation riparian habitat for wide-ranging populations of transboundary carnivores, such as grizzly bear, lynx and wolves (Weaver, 2001). The Transboundary Flathead and the remainder of the Flathead River system in Montana is one the last strongholds of bull trout and west slope cutthroat trout. Of the carnivores and native trout that inhabit the Transboundary Flathead, bull trout, grizzly bears and lynx are listed species under the U.S. Federal Endangered Species Act (ESA).

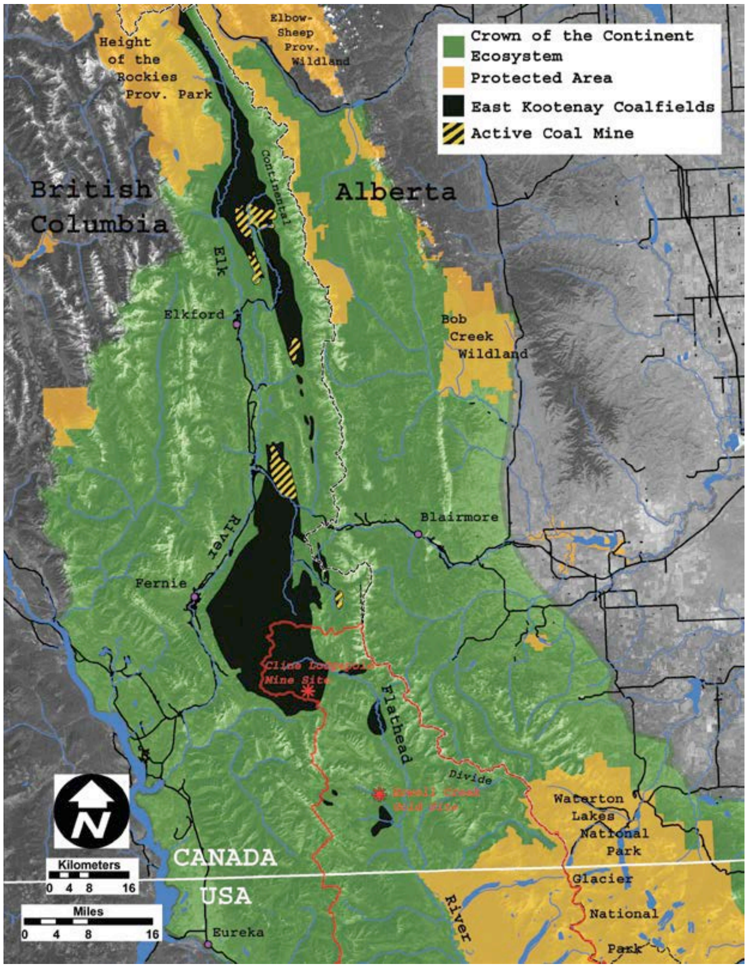

Figure 2. The northern half of the Transboundary Flathead Basin (outlined in red) and the Elk Basin to the north. Both basins are located along the Continental Divide. Areas in green are within the Crown of the Continent Ecosystem. Areas in gold are National, Provincial or State Parks or designated wilderness or wildlands. Red stars indicate locations of the Cline Lodgepole coal mine project and the site of gold exploration, respectively.

1.1.2 The East Kootenay Coalfields of Southeast British Columbia

The British Columbia portion of the Flathead Valley is underlain by a series of coal deposits that extend beneath the entire headwaters portion of the river, and occur intermittently throughout the B.C. portion of the drainage. The coal deposits are a part of the East Kootenay Coalfields, a larger grouping of coal that underlies both the Elk and Flathead River Valleys of southeast British Columbia. The East Kootenay Coalfields run from north to south along the Continental Divide between British Columbia and Alberta and contain low to high quality bituminous coal. The Elk Valley portion of the East Kootenay Coalfields contains five open-pit, mountain-top removal coal mines and two coal bed methane operations (see Figure 2).

Since the mid-1970’s the coal deposits in the B.C. portion of the Transboundary Flathead have been targeted for resource development. The original mining proposal for the B.C. Flathead, referred to as the Cabin Creek Coal Mine, was be located in the “Flathead” coal deposits that straddle Cabin Creek, which flows west to east out of the Whitefish Range in Canada into the Flathead River within 5 km north of the international border. The proposal drew international interest and concern regarding impacts to the downstream fisheries, water quality and overall aquatic and terrestrial life. Considerable ecological work was done to evaluate existing water quality, biological integrity, and air quality in the late 1970’s and early 80’s, with respect to the location and potential impacts of the Cabin Creek mine site. Much of these environmental investigations were conducted under the auspices of the Flathead Basin Environmental Impact Study (1983) by researchers at Flathead Lake Biological Station and the Montana Department of Fish, Wildlife and Parks. These data were then used by the International Joint Commission (IJC), which augmented these data with additional focused study. The IJC, created by the 1909 Boundary Waters Treaty between the USA and Canada, intervened on behalf of Canada and the United States to evaluate the potential impacts of the proposed coal mine and subsequent consequences with respect to the Boundary Waters Treaty. After several years of analysis by an international team of scientists, the IJC found that the mine proposal should not be approved due to potential damage to downstream water quality and impacts to transboundary bull trout populations (IJC, 1988).

In 2003, the B.C. portion of the Flathead River was again targeted for extractive resource development, and over the last ten years, multiple projects have been proposed and several have received exploration permits. The primary proposals include the Cline Mining Corporation’s Cabin Creek mine site (2003), Western Canadian Coal’s Lillyburt mine site (2004), the Flathead and Elk coal bed methane tenures (2004), Cline Mining Association’s Lodgepole Mine (2004), British Petroleum’s Mist Mountain Coalbed Methane Project (2008) and Max Resources Howell Creek and Crowsnest gold mine sites (2008). The most prominent of these projects has been the Cline Mining Corporation’s

Lodgepole Mine, which conducted extensive exploration beginning in 2004 and entered the B.C. Environmental Assessment process in 2005 (see Figure 2).

1.1.3 Crown of the Continent and Transboundary Flathead Research Symposiums

In response to the initiatives for coal and coal bed methane in the B.C. portion of the Flathead River, two consecutive science symposiums were held in April and November of 2005 to identify existing baseline data for the Flathead, data gaps and priority information needs. At both symposia, over thirty scientists and managers from British Columbia, Alberta and Montana attended. Proceedings from the symposia outlined critical information gaps and priority research needs for both aquatic and terrestrial science. Specifically, participants were asked to focus on four priorities; 1) Baseline data collection 2) Species and population inventories, with an emphasis on federally listed species 3) Long-term monitoring, and 4) Cumulative effects analysis.

With respect to aquatic research needs, resource managers and scientists determined that there were two primary types of data needed to accurately measure the existing or baseline condition of the watershed and also to assess the impacts of potential land uses in the B.C. portion of the Flathead Basin. These were: 1) Site-specific impacts assessment data needed to evaluate the potential impacts of current mining proposals and additional resource extraction scenarios, and 2) Comprehensive basin-wide long-term monitoring and assessment (Transboundary Flathead Research Needs Workshop, 2005). From the workshop Executive Summary:

> *"Participants concluded that overall, critical information gaps were more highly evident in the British Columbia portion of the drainage for both the terrestrial and aquatic components of the Transboundary Flathead. This is also the least impacted portion of the drainage with respect to human presence and association industry, and the area currently targeted for fossil fuel development. The scientists agreed that these information gaps must be addressed prior to major land-use changes in the basin, and that at least three years of baseline data is needed to assess the potential impacts to water quality and quantity, aquatic and terrestrial species and the overall transboundary ecosystem."*

1.2 Study Framework and Scope

The 2007 Montana Legislature provided initial funding through the Flathead Basin Commission to initiate a study of water quality and aquatic life response to potential coal mining in the Transboundary Flathead. This funding was for a two-year period from July 2007 to June 2009. Since June 2009, the study has been supported by Federal funds from the National Park Service. The Rocky Mountains Cooperative Ecosystems Study Unit provided assistance through cooperative agreement for collaboration; Cooperative Agreement #H1200040001, Task Agreement # J1434080043 and Cooperative Agreement #H1200040001, Task Agreement # J1434080044.

In Summer 2009, UNESCO was petitioned by the National Parks Conservation Association and other environmental NGO's to consider investigating the threat of proposed coal mining in the Transboundary Flathead River Basin to the ecological integrity of Waterton-Glacier International Peace Park as a World Heritage Site. The UNESCO investigative mission team visited the Transboundary Flathead in both the USA and Canada in September 2009. In 2010, UNESCO reported, "………….it is the considered view of the mission team that should open pit coal mining and coal bed methane gas production proceed in the upper Canadian Flathead watershed, this would present a serious threat, incompatible with the Outstanding Universal Value of the Waterton-Glacier International Peace Park World Heritage property. Of particular concern are the likely degradation and irretrievable losses. There is, in the view of the mission, no possibility of proceeding with mining in the Flathead watershed without creating an unacceptable direct impact on the Outstanding Universal Value of the property, and there does not appear to be a compromise position in this regard."

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Since 2010, our continued research during the later portion of this study was reoriented toward development of a comprehensive conservation plan integrating Transboundary Flathead aquatic habitat conservation and conservation of fish and wildlife habitat and corridors. We are continuing this research within the framework of the Transboundary Flathead and the Crown of the Continent Ecosystem and the initiatives of the Great Northern Landscape Conservation Cooperative.

The aims of our GNLCC-framed research is to build on an existing climate change and Transboundary research program to assess the potential hydrologic, geomorphic, and thermal effects on food webs (rare and endemic macroinvertebrates), native salmonids (threatened bull trout and westslope cutthroat trout), and lotic habitats in the Transboundary (US and Canada) Flathead River system. The project will apply new and existing techniques for combining downscaled and regionalized climate models linked with specific spatial data, fine-scale aquatic species vulnerability assessments (invertebrates→fish), population genetic data, and remotely sensed riparian and aquatic habitat analysis. This information will be used to begin development of an aquatics adaptation plan.

2.0 MATERIALS AND METHODS

2.1 Study Approach and Objectives

The purpose of this research was to assess the potential impacts of open-pit coal mining and coal-bed methane development in the Transboundary Flathead Basin. We developed a sampling design strategically directed toward a comparative analysis between the Elk River and the Flathead River. The history of coal mining and coal-bed methane extraction in the Elk River Basin provided an opportunity to conduct this comparative analysis. The focus of this report is on water quality and stream and river aquatic life (non-fish). We designed the study to directly compare surface water quality and response of aquatic life use among sites on the Elk River and its tributaries above and below the open-pit coal mines to similar sites around the proposed Cline Lodgepole Coal Mine on the Flathead River and its tributaries.

2.2 Study Area

2.2.1 Flathead River Basin (FRB) Sites

The upper Flathead River drainage originates in southeastern British Columbia and northwestern Montana, encompassing approximately 18,400 km^2. The drainage includes the North, Middle and South Forks, the mainstem of the Flathead River and Flathead Lake. The basin is a major tributary headwater of the Columbia River Basin. The study area includes the B.C. portion of the North Fork of the Flathead River, which is referred to as the Flathead River in Canada. Sample sites in the Flathead River and tributaries are located within and around Foisey Creek, a headwaters tributary of the Flathead, where the Cline Mining Company's Lodgepole coal mine was proposed (Table 1, Figure 3). There were eleven sample sites in the Flathead Basin, six sites were above or not draining the area of the proposed mine (Flathead River above McEvoy Creek, McEvoy Creek, Unnamed Creek across from McEvoy Creek, Flathead River above Foisey Creek, Unnamed Creek across from Foisey Creek, Squaw Creek and McLatchie Creek) and five sites that would be influenced by or are downstream from the proposed Lodgepole coal mine (Foisey Creek, Flathead River below Foisey Creek, Flathead River above McLatchie Bridge, and Flathead River at Flathead BC).

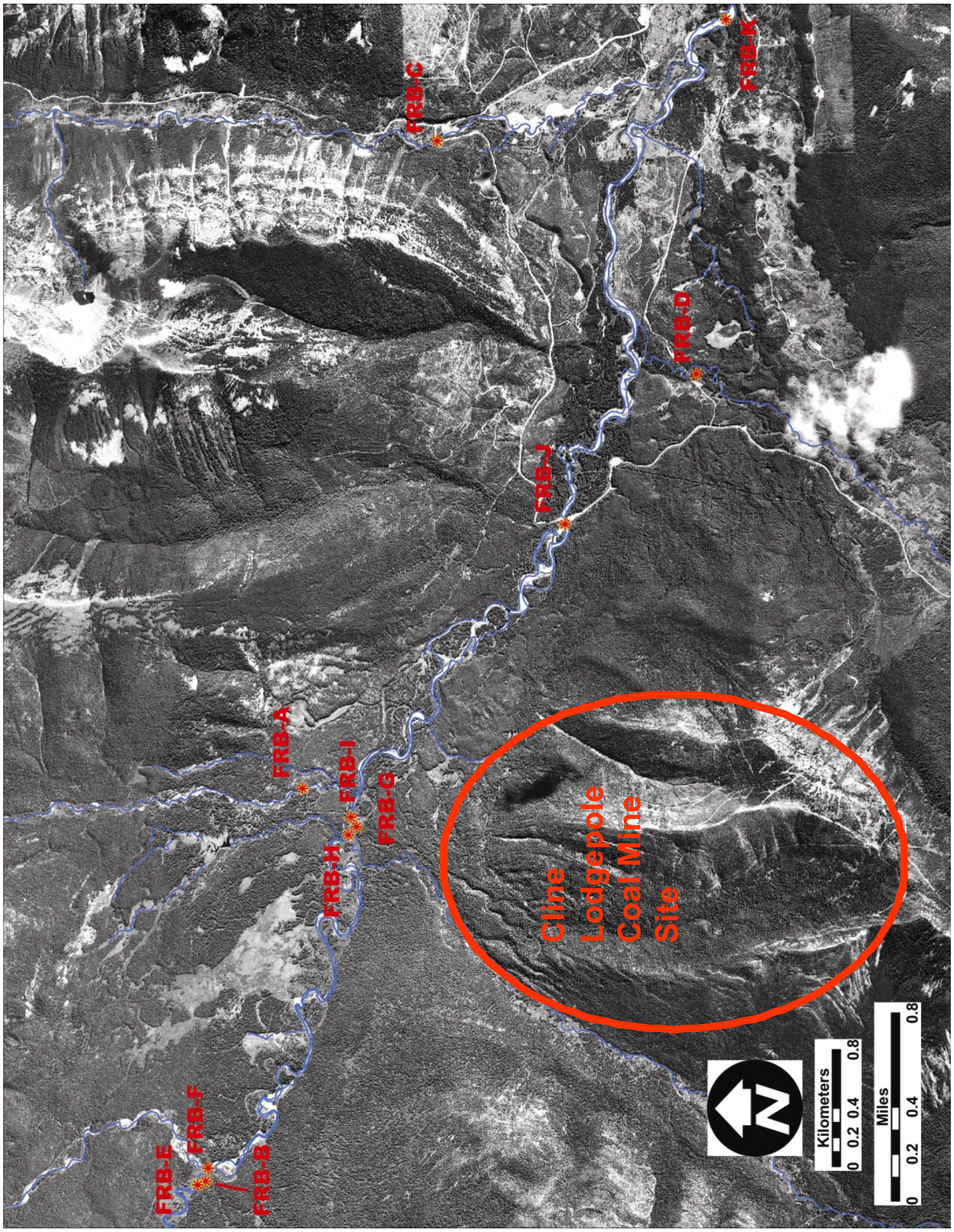

Figure 3. Satellite image of the study area in the Flathead Basin showing locations of sampling sites corresponding to Table 1 and the general location of the proposed Cline/ Lodgepole Coal Mine.

Table 1. Site Number, Site Description and Site Location (latitude/longitude) of study sites in the Flathead River Basin**.**

SITE NUMBER	*SITE DESCRIPTION*	*SITE LOCATION* **Latitude/Longitude**	
FRB A	**Unnamed Creek across Flathead R from Foisey Cr**	49 23’ 00.2 N	114 42’ 27.0 W
FRB B	**Unnamed Creek across Flathead R from McEvoy**	49 23’ 23.5	114 44’ 37.1
FRB C	**Squaw Creek near Confluence w/ Flathead River**	49 22’ 26.9	114 38’ 47.3
FRB D	**McLatchie Creek above Bridge**	49 21’ 30.1	114 40’ 10.3
FRB E	**Flathead River above McEvoy Creek**	49 23’ 23.9	114 44’ 35.7
FRB F	**McEvoy Creek Above Confluence with Flathead R**	49 23’ 23.6	114 44’ 34.9
FRB G	**Foisey Creek near Flathead River**	49 22’ 49.4	114 42’ 45.3
FRB H	**Flathead River above Foisey Creek**	49 22’ 51.8	114 42’ 45.3
FRB I	**Flathead River below Foisey Creek**	49 22’ 49.3	114 42’ 37.3
FRB J	**Flathead River above McLatchie Bridge**	49 21’ 59.2	114 40’ 59.9
FRB K	**Flathead River at Flathead BC Town Site**	49 21’ 20.7	114 38’ 10.3

2.2.2 Elk River Basin (ERB) Sites

The Elk River also originates in southeast British Columbia, northeast of the Flathead River, in Elk Lakes Provincial Park, near the Continental Divide. The Elk River drains 4,450 km^2 through the Elk Valley communities of Elkford, Sparwood, Hosmer, Fernie and Elko, and drains five open-pit coal mines before it joins the Kootenay River in Lake Koocanusa, just north of the Montana border. The Elk River is also an international watershed. There are ten sample sites total in the Elk River Basin, located above and below the open-pit coal mines in the Elk Valley. Five of the sites are above the coal mines (Elk Lakes Provincial Park, Elk River above coal mines, headwaters of Michel Creek, Michel Creek above Corbin Creek, and headwaters of Barnes Creek above trail crossing). There were five sites influenced directly by the coal mines (Corbin Creek, Michel Creek below Corbin Creek, and Michel Creek near the confluence with the Elk River, Elk River above Hosmer, and Elk River above Morrissey) (Table 2, Figure 4).

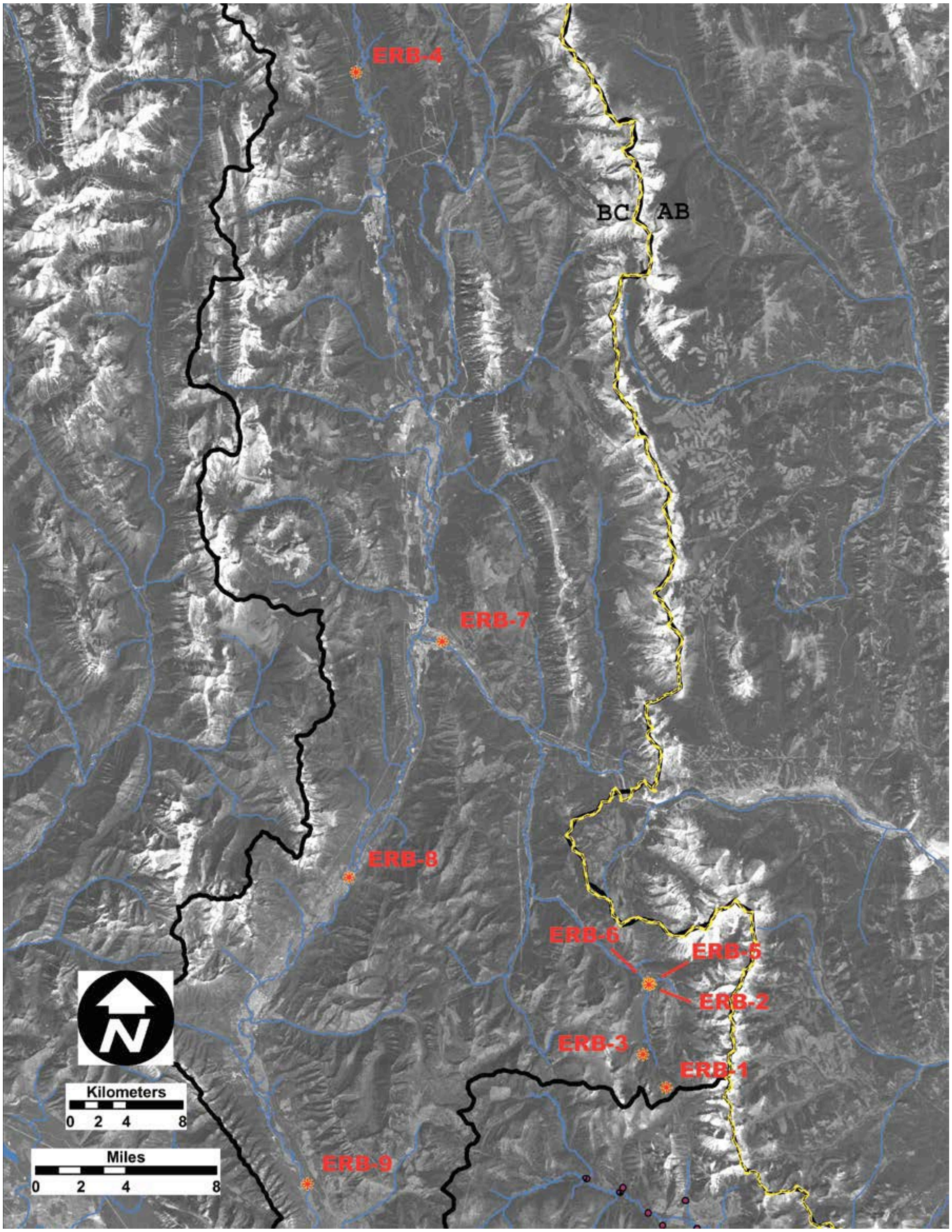

Figure 4. Satellite image of the study area in the Elk Basin showing locations of sampling sites corresponding to Table 2.

Table 2. Site Number, Site Description and Site Location (latitude/longitude) of study sites in the Elk River Basin**.**

SITE NUMBER	*SITE DESCRIPTION*	*SITE LOCATION* Latitude/Longitude
ERB 0	**Elk Lakes Provincial Park**	50 33’ 1.1 115 5’ 4.5
ERB 1	**Michel Creek Headwaters near Flathead Pass**	49 26’ 48.7 114 39’ 44
ERB 2	**Michel Creek above Corbin Creek**	49 30’ 47.5 114 40’ 34.9
ERB 3	**Barnes Creek above Trail Crossing**	49 28’ 6.9 114 41’ 2.6
ERB 4	**Elk River above All Coal Mines**	50 6’ 7.2” 114 56’21.5”
ERB 5	**Corbin Creek above Michel Creek**	49 30’47.9” 114 40’29.4”
ERB 6	**Michel Creek below Corbin Creek**	49 30' 55.6" 114 40' 35.4"
ERB 7	**Michel Creek near Elk River Confluence**	49 44’10.9” 114 52’11.8”
ERB 8	**Elk River above Hosmer**	49 35’14.5” 114 58’6.4
ERB 9	**Elk River above Morrissey**	49 23’31.6” 115 1’2.1”

2.3 Methods - Baseline Data Collection

2.3.1 Water Chemistry

The two-year data collection program was conducted to provide a baseline of physiochemical data that allows for a water quality assessment of surface waters in the headwaters of the Transboundary Flathead River Basin and the Elk River Basin. The scope of work was designed to document the existing condition of the areas targeted for, or downstream of, the proposed Cline Mining Corporation’s Lodgepole Mine sited in the headwaters of Foisey Creek. See Table 3 for laboratory methods and detection levels.

Parameters measured included:

- Field Physiochemistry
- Major Cations (Na, K, Ca, MG)
- Major Anions (chlorides and sulfates)
- Metals (Al, As, B, Be, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, Zn)
- Nutrients (Phosphorous Forms [Soluble Reactive – SRP; Total Phosphorus – TP and Nitrogen Forms [nitrate - NO3; Total Persulfate Nitrogen - TPN)
- Major Metals (As, Cd, Hg, Pb, and Se) associated with sediment

Table 3. Laboratory methods and detection levels for the primary chemical variables analyzed at the Freshwater Research Laboratory, Flathead Lake Biological Station, and the Geochemistry Laboratory at The University of Montana.

VARIABLE	METHOD	DETECTION LEVEL
Total Phosphorus (TP)	persulfate digestion: modified ascorbic acid	0.4 µg/l
Soluble Reactive P (SRP)	filtration; modified ascorbic acid	0.3 µg/l
Total Persulfate Nitrogen (TPN)	persulfate digestion/ cadmium reduction	20 µg/l
Nitrate (NO_{2+3})	automated cadmium reduction	0.6 µg/l
Ammonium (NH_3)	automated phenate	5.0 µg/l
Total Organic Carbon (TOC)	persulfate digestion; infrared CO_2 detection	0.04 mg/l
Turbidity (NTU)	nephelometry	0.5 NTUs
Total Suspended Solids	gravimetric/Metler balance ±0.0001g	0.5 mg/l
Chloride (Cl^-)	Ion Chromotography	0.1 mg/l
Sulfate (SO_4)	Ion Chromotography	0.05 mg/l
Metals		
Al	ICPMS	10 µg/l
As	ICPMS	0.1 µg/l
Ba	ICPMS	1.0 µg/l
Be	ICPMS	1.0 µg/l
Ca	ICPMS	100 µg/l
Cd	ICPMS	0.1 µg/l
Co	ICPMS	0.1 µg/l
Cr	ICPMS	5 µg/l
Cu	ICPMS	0.1 µg/l
Fe	ICPMS	5 µg/l
K	ICPMS	100 µg/l
Mg	ICPMS	100 µg/l
Mn	ICPMS	0.1 µg/l
Na	ICPMS	100 µg/l
Ni	ICPMS	0.5 µg/l
Pb	ICPMS	0.1 µg/l
Se	ICPMS	0.2 µg/l
Sr	ICPMS	0.1 µg/l
Zn	ICPMS	0.1 µg/l
Hg	EPA Method 1631, Tekran 2600	0.5 ng/l (ppt)

2.3.2 Aquatic Biota

Simultaneous with the surface water chemistry, data collection was initiated for the major components of stream and non-fish river aquatic life. As with the surface water quality data, aquatic biota data were collected in and around the area of the proposed open-pit coal mining and potential coalbed methane development. The objective was to measure and assess the aquatic life in water associated with the proposed mining, at a subset of the water chemistry sites. Specifically, objectives included:

- Determine baseline steam/river algal community - Periphyton Biomass (AFDM) and Chlorophyll – a
- Determine baseline stream/river macroinvertebrate (food-web) community composition, distribution and abundance

2.3.3 Water and Sediment Samples

Water samples were collected in the field from twenty-one total sites in the Elk and Flathead River Basins, once a month from June – October in 2007 and 2008. During each sample trip, one site was sampled in duplicate and one field blank was prepared, resulting in two additional quality control samples per trip. All samples were stored in field coolers with ice and returned as quickly as possible to the laboratories for analysis. Analyses in the laboratories were conducted with standard methods and laboratory quality control and assurance. Water samples for nutrient analyses were performed at the Flathead Lake Biological Station freshwater research Laboratory. Water samples and sediment samples for metal analyses were performed at the University of Montana, Department of Geosciences, Environmental Biogeochemistry Lab (EBL). In stream sections where fine sediment was present, sediment samples were collected after passing through a < 63 µm Nitex sieve/net, see Table 4 for field methods and lab analysis. We also conducted a sediment core survey to examine major metals associated with sediments outside of the stream corridor that may be accumulated on the floodplains of the Flathead or Elk Rivers. Sediment cores were collected from

Table 4. Field and laboratory methods and protocols for analyte collection.

Analytes	Sampling Protocols	Reference Method[1]	Code
	UNFILTERED SAMPLES		
Temperature	field measurement using Mettler Toledo EC meter		
pH	field measurement using Orion pH meter		pH
Electrical Conductivity	field measurement using Mettler Toledo EC meter		EC
Total Suspended Sediment	1 Liter plastic bottle depth-integrated unfiltered sample	EPA160.2	TSS
Total Alkalinity	125 mL plastic bottle (white), no head space	APHA2320	ALK
Total Phosphorous & Total Nitrogen	125 mL acid washed bottle, no headspace submit to FLBS		TNP
Total Organic Carbon, Dissolved Organic Carbon	500 mL baked quartz bottle, preserved with 1.0 mL H_3PO_4, submit to FLBS		TOC
Total Mercury	500 mL precleaned glass bottle (I-Chem certified, baked; cap: Teflon-lined, hot-acid washed + soaked in BrCl) filled to bottom of neck, cap and store on ice in separate plastic bag shipped promptly to EBL for acid preservation (0.5 mL Optima grade HCl)	EPA1631 mod	HgU
	FILTERED SAMPLES		
Nitrate, Ammonium, Soluble Reactive Phosphate	60 mL acid-washed Nalgene bottle, submit to FLBS		SNP
Metals (Al, As, Ba, Be, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Pb, Se, Zn)	250 mL ultra-cleaned Nalgene bottle (only 60 mL of sample are needed) EBL preserveD with 0.5 mL Optima grade HNO_3 (or 0.13 mL for 60 mL sample)	EPA200.8 or EPA6020	ME
Anions (F^-, Cl^-, SO_4^{2-})	60 mL non-acid washed bottle	EPA300.0 low-level	AN
Sampling Kit	<u>Individual Ziploc bag for each sample:</u> gloves bottles: TSS, ALK, AN, ME, Hg (+extra Hg bottles) 37 mm Gelman Supor syringe filter + ultraclean syringe	Training provided by EBL personnel	
Meters	Thermo Orion Model 135A portable pH meter, AccuPhast double junction pH combination electrode, Accumet gel electrode (backup), buffer solutions, storage box Mettler Toledo handheld EC meter with probe, calibration solutions, manual, storage box		
	Standard sediment sampler, sampling bottle		SED
	Sediment drying and grinding		
	Digestion		
	Analysis (EPA 6010/6020)		

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[1] Published by USEPA or APHA (Standard Methods for the Examination of Water and Wastewater)

alluvial soils along the river or stream banks in locations that are regularly flooded and experience fine sediment accumulations. Sediment core samples were collected from the following Flathead sites: Flathead River at Flathead BC, Flathead River at the International Border, and the following Elk Basin sites: Elk River above all Coal Mines, Michel Creek below the confluence of Corbin Creek, Michel Creek near the confluence with Elk River, Elk River near the tunnel on Hwy 3 [below Morrissey], Elk River at Elk BC in the small reservoir above the Elk Dam, and Elk River Delta near Lake Kookanusa.

2.3.4 Periphyton and Macroinvertebrate Samples

Periphyton was sampled at each site at the end of the algal growing season, typically occurring in mid-September, when the amount of biomass and chlorophyll-a is maximized for the year. Five biomass samples and five chlorophyll-a samples were taken from separate rocks collected at each site. Periphyton material was collected from a 19.625cm^2 area and filtered onto a 0.7um glass fibre filter. Filters were enclosed in aluminum foil, labeled and frozen on dry ice or in a field freezer. At the laboratory, samples were stored in the freezer and processed within the holding time for Ash-Free-Dry-Mass (AFDM) and Chlorophyll-a analysis. AFDM samples + filters were oven dried at 105^{o}C for 24 hrs and weighed on a Mettler Balance to the nearest 0.00001g to obtain the filter + dry weight. The samples + filters were then combusted at 500^{o}C for 12 hrs, wetted then dried and weighed to obtain the ash + filter weight. The difference between the two measures was the AFDM of the sample. Similarly, chlorophyll-a samples + filters were handled individually with each sample representing the quantity of material from each site. Chlorophyll-a analyses were conducted using the acetone extraction method with a Beckman UV-vis spectrophotometer.

We collected macroinvertebrates from selected Flathead and Elk Basin sites using a standard method Stanford and Hauer net (Hauer and Resh 2006) with a mesh size of 125 µm. The area sampled on the stream bottom was 0.5 m^2. Samples were preserved in the field with 70% ETOH. Within 24 hrs the preserving ETOH was decanted from the sample and replaced with fresh 70% ETOH for long term preservation until processing. Samples were processed at the Freshwater Research Laboratory at Flathead Lake Biological Station. Taxa were typically identified to the lowest nomenclature possible for the life history stage collected; this was typically to the genus or species level. Samples were processed in the laboratory by first sorting for all large organisms from the entire sample. The sample was then evenly dispersed in fine-mesh sieve (125 µm) and subsampled for the smaller organisms. Subsamples were picked entirely clean of all macroinvertebrates using binocular microscope at 50X magnification. Numbers of individuals from each taxa in a sample are based on a calculation of a combined whole sample plus subsample equated to numbers per square meter.

2.3.5 Image Data and Analyses

Following the Memorandum of Understanding (MOU) between British Columbia and Montana in February 2010, as discussed above in the Introduction Section, we changed focus in the project from water chemistry and aquatic life use to the acquisition of digital imagery of Transboundary Flathead River floodplains and tributary streams in both BC and Montana for the purpose of analysis of river and stream habitats. These efforts are still ongoing through the US Fish and Wildlife Service. The georectified and mosaicked composites of the raw images are given in the body of this report. Both raw images and composites are transferred to the GNP GIS-lab.

2.3.6 Data Analyses

We conducted statistical analyses using ANOVA within the statistical analysis software SPSS by SPSS, Inc. We considered test results to be significant at α = 0.95, highly significant at α = 0.99, and very highly significant α = 0.999. The experimental design around which we organized the analysis was a 2 X 2 block design, a) Flathead above proposed mine, b) Flathead below proposed mine, c) Elk above existing mines, d) Elk below existing mines.

3.0 RESULTS AND DISCUSSION

All nutrient and metals data are presented in their entirety as Appendices and in electronic form submitted to Glacier National Park Natural Resources with this report. In the following sections, we present a series of nutrient data from water samples collected at the Flathead and Elk Basin study sites. In each section we present three figures. The first figure is composed of headwater streams that are above sites affected by coal mines in the Elk Basin or the proposed Cline Lodgepole Coal Mine in the Flathead Basin. These sites are presented here as direct comparison sites to illustrate the underlying similarity or differences between the waters of the Flathead and Elk in their most native and unperturbed condition. The second figure is composed of all the Flathead Basin sites illustrating change along the longitudinal gradient from small creeks to the larger river. The third figure is composed of all the Elk Basin sites illustrating change due to coal mining effects as they occur along the stream/river corridor. The Results and Discussion section of this report focuses on analyses showing distinct differences between sites with and without coal mining effects.

3.1 Nutrient Concentrations

3.1.1 Nitrate Nitrogen (NO_3)

Nitrate-nitrogen is a plant growth nutrient that stimulates algal growth in freshwaters, especially when present with biologically available phosphorus (Biggs 2000). The Flathead Basin, and especially Flathead Lake has been shown to be co-limited in algal production by low levels of both nitrogen and phosphorus. The nitrate-nitrogen analysis represents one of the clearest examples of the effects of open-pit, mountain top removal coal mining on water and water quality in the Elk Basin and by inference in the probability of similar effects on Flathead Basin surface waters. Comparing Flathead and Elk Basin (Figures 5 and 6), we observe relatively little difference among headwaters from the Elk or Flathead. Two headwater sites in the Elk (Figure 6 ERB – 3 and ERB – 4) had approximately 2X the concentration of nitrate as other headwater sites.

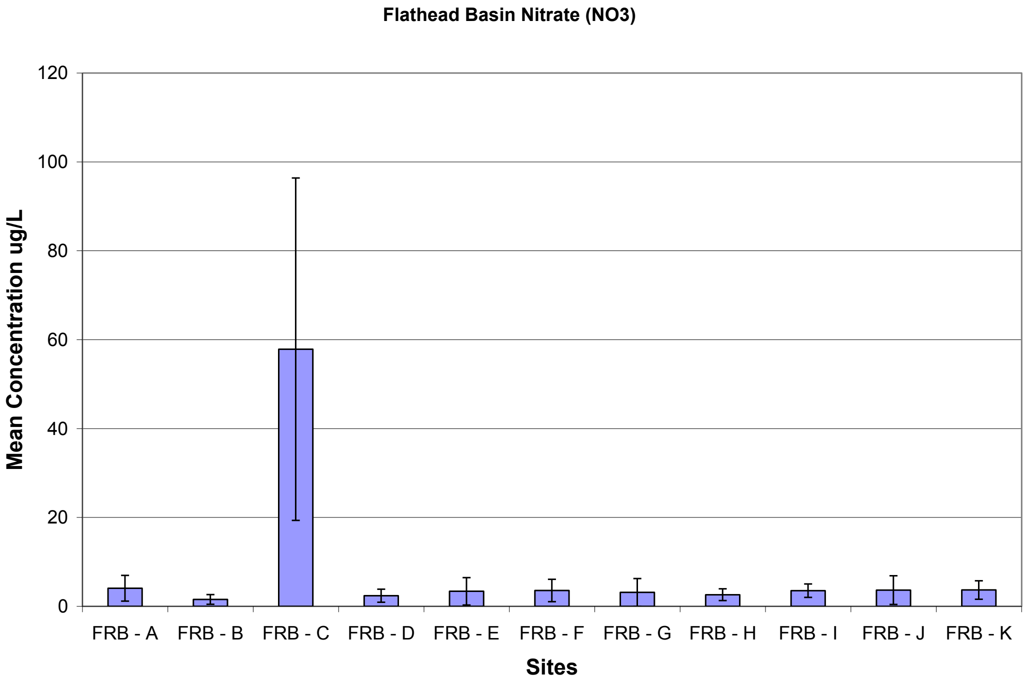


Figure 5. Mean concentration (+ 1 std error) of nitrate-nitrogen (NO_3) in the Flathead Basin. Refer to Tables 1 for site descriptions.

However, these concentrations are well within levels that would be expected, especially ERB – 4 (Elk River above Coal Mines), as this site is located well below the Elk Lakes Provincial Park and is influenced by roads and other land-uses.

In our comparison, across all Flathead Basin sites (Figure 5), we observed very low concentrations of nitrate at all sites, although site FRB – C (Squaw Creek) was approximately 5X higher than the other Flathead Basin sites. Note that all other sites had mean concentrations <10 ug/L and standard deviation maxima less than 20 ug/L. These concentrations are typical of other low impact, low land-use stream sites in the Whitefish Range. We are uncertain of the reason for the elevated concentrations in Squaw Creek which drains the Flathead Pass area to the south, especially since Site ERB – 1 (Michel Creek Headwaters) had a mean concentration of < 10ug/L. However, the road that crosses Flathead Pass and is the primary entry into the upper Flathead Basin

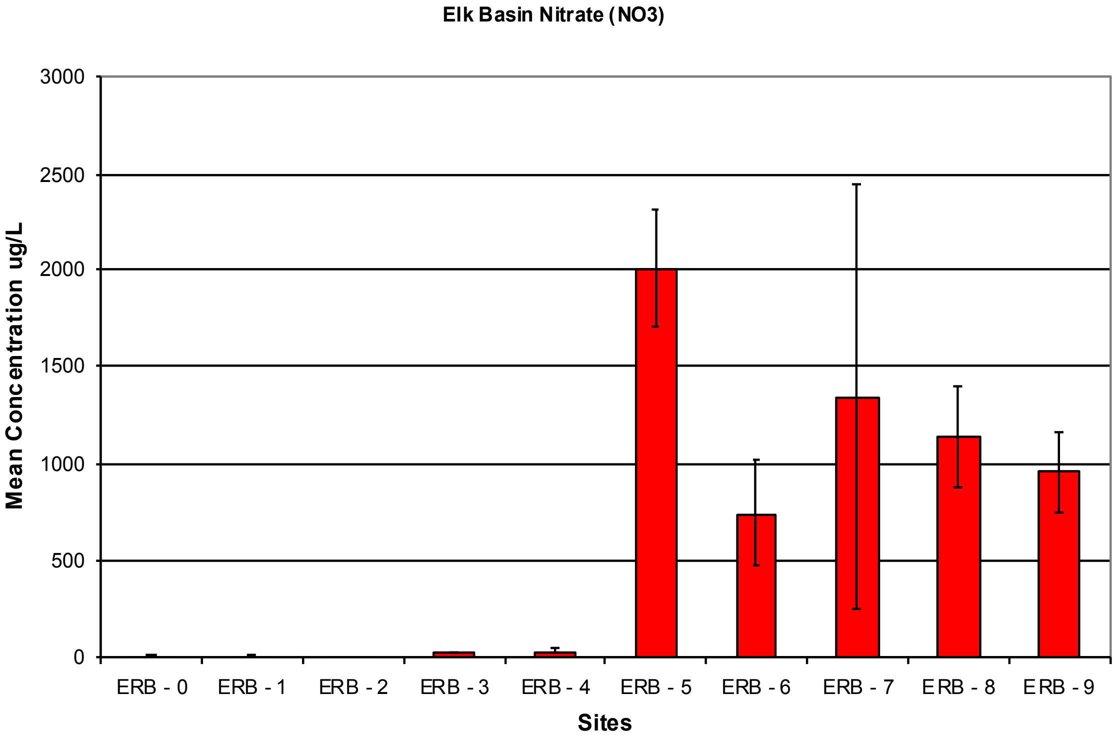


Figure 6. Mean concentration (+ 1 std error) of nitrate-nitrogen (NO_3) among the ten Elk Basin sites. Refer to Table 2 for site descriptions. [Sites ERB-5 through ERB-9 are below coal mines.]

from Fernie and Sparwood, BC, frequently crosses Squaw Creek without bridge or culvert and on several occasions runs directly down the stream bed, which may account for this difference.

The Elk Basin sites (Figure 6) showed a dramatic difference in nitrate concentrations between sites above coal mine impacts and those sites receiving waters affected by the coal mining. Note that the five headwater sites given in Figure 6 were all within natural background levels of nitrate similar in concentration to the Flathead Basin sites (Figure 5). By contrast, the five sites below mining had very highly significantly ($P<0.001$) greater concentration of nitrate. Note the change in scale in the y-axis of Figures 5 and 6. Concentrations at sites below coal mining frequently exceeded 1000X nitrate levels in the Flathead Basin or among Elk Basin sites above coal mines. The high level of nitrate concentration among the Elk Basin streams and rivers below coal mines clearly demonstrates a major impact due to the mining activities. The consequences of the higher concentrations of nitrate are many, including increased algal production and decreased macroinvertebrate diversity, discussed in these sections below.

3.1.2 Total Nitrogen (TPN)

The total nitrogen concentration is a combination of nitrate + ammonium + organic nitrogen and thus represents a combination of both inorganic forms available for plant growth and organic nitrogen, which is generally composed of dissolved organic plus particulate organic compounds containing nitrogen. The significance of total nitrogen analysis from nitrate is that under circumstances of nitrogen limitation, nitrate can be very low because it has been incorporated into plant growth (Hauer et al. 2007). Thus, total nitrogen can provide insight into the nitrogen fraction, which has already stimulated algal growth. Similar to the nitrate, total nitrogen concentration among the streams of the Flathead and headwater Elk Basin streams was similar and relatively low, generally < 100ug/L (Figures 7 and 8). This similarity in total nitrogen among headwater streams of the Flathead and Elk Basins underscores the similarity in climate, geology, forest type, land use, and other factors known to affect natural levels of nitrogen in streams and rivers.

In our comparison of all Flathead Basin sites (Figure 7), we observed low concentrations of total nitrogen at all sites.   In contrast, Elk Basin sites affected by coal mining had significantly higher concentration ($P<0.001$) of total nitrogen (Figure 8).   This pattern is very similar to that observed for nitrate-nitrogen and confirms the strong influence of coal mining in the Elk Basin on nitrogen loading that extends through the food-web and affects organic, as well as inorganic, forms of nitrogen.

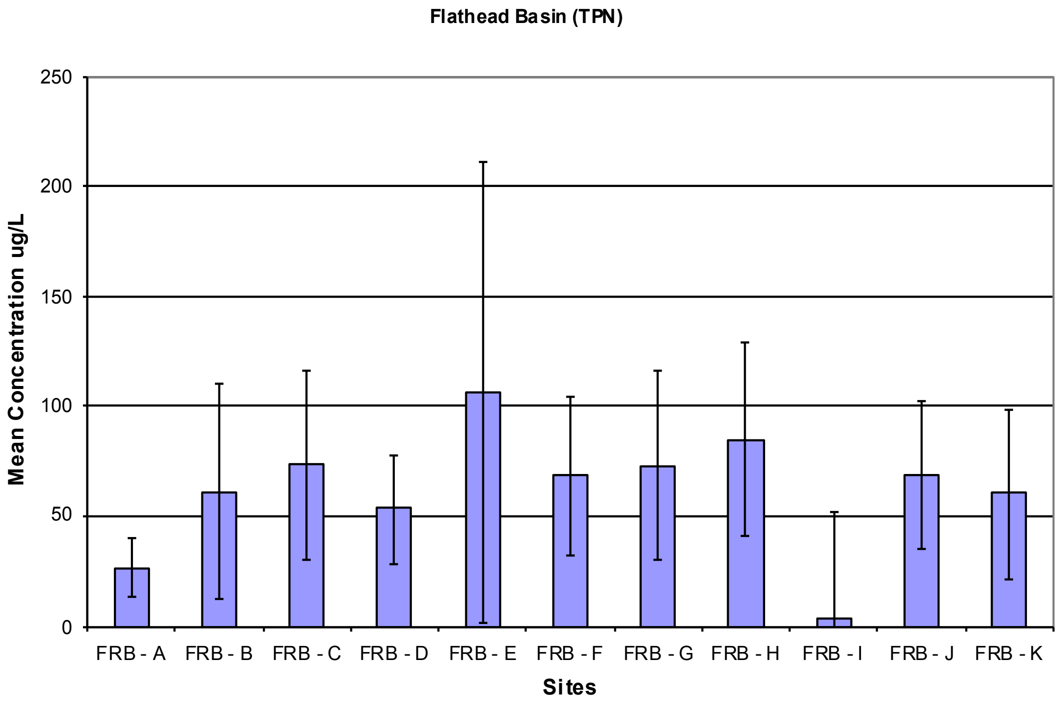


Figure 7. Mean concentration (+ 1 std error) of total nitrogen (TPN) among the eleven Flathead Basin sites. Refer to Table 1 for site descriptions.

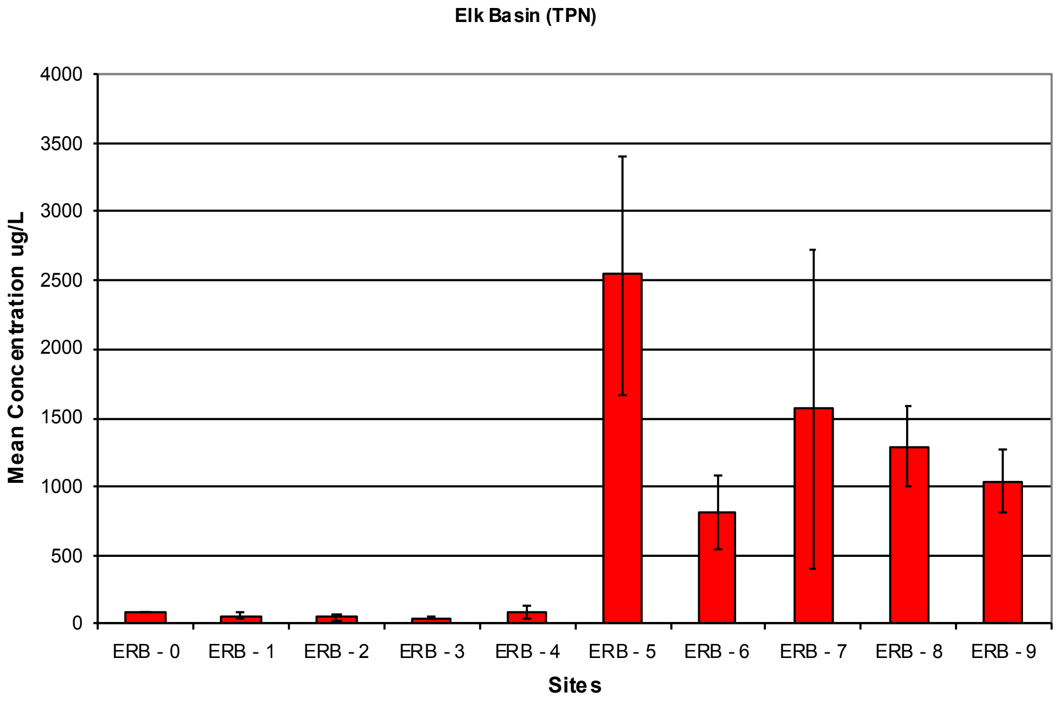


Figure 8. Mean concentration (+ 1 std error) of total nitrogen (TPN) among the ten Elk Basin sites. Refer to Table 2 for site descriptions. [Sites ERB-5 through ERB-9 are below coal mines.]

3.1.3 Soluble Reactive Phosphorus (SRP)

Soluble reactive phosphorus (SRP), also commonly referred to as biologically available phosphorus, is measured as the concentration of PO_4, a plant growth nutrient that stimulates algal growth in freshwaters, especially when present with biologically available forms of nitrogen. The Flathead Basin streams and rivers as well as Flathead Lake, have been shown to be co-limited in algal production by low levels of both phosphorus (SRP) and nitrogen (generally as nitrate or ammonium ion).

SRP concentrations in the headwater streams of the Flathead and Elk Basins were very similar, as we observed for nitrate and total nitrogen concentrations, discussed above. Indeed, there are no significant differences between the Flathead headwater sites and the Elk headwater sites (Figures 9 and 10).

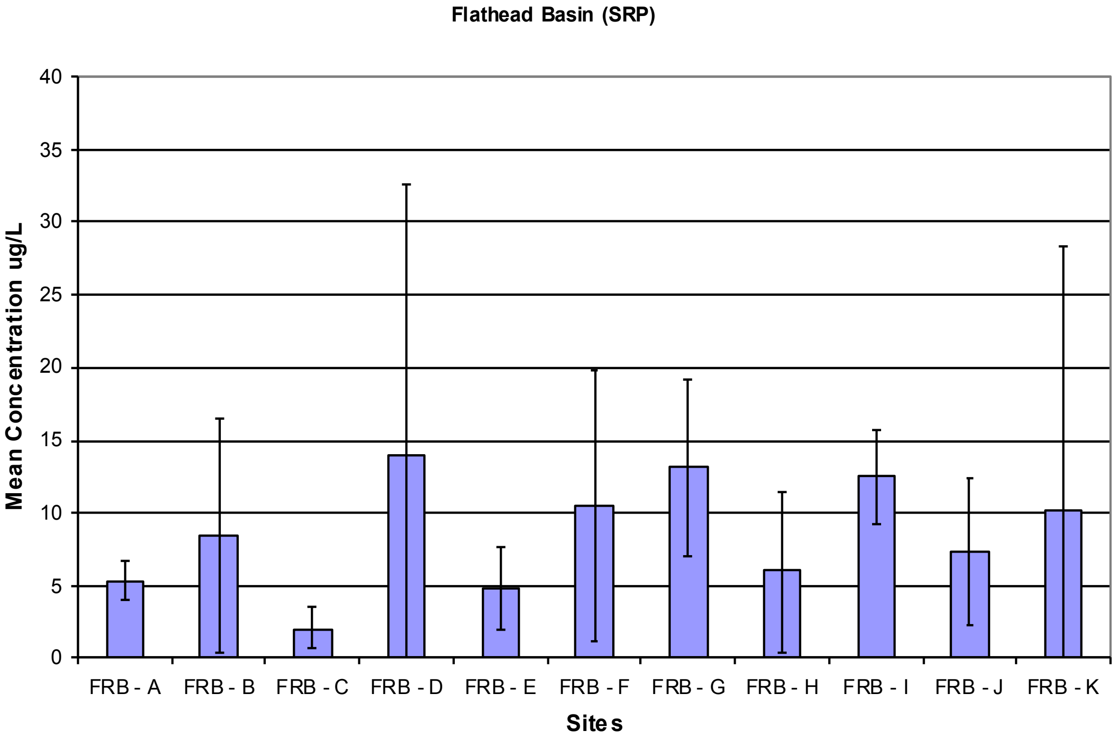


Figure 9. Mean concentration (± 1 std error) of soluble reactive phosphorus (SRP) among the eleven Flathead Basin sites. Refer to Table 1 for site descriptions.

However, these SRP concentrations are moderately higher than what we often observe in the Flathead Basin in areas dominated by Argillite mudstones of Glacier and Waterton Parks. For example, in the McDonald Creek Basin in Glacier National Park, USA, the SRP concentrations between 1992 and 1998 were generally between 1 – 5ug/L (Hauer et al. 2003). In the Flathead Basin sites of this study, SRP concentrations were typically greater than 5ug/L and occasionally greater than 20ug/L (Figure 9). This is due to the exposure of more recent geological formations, hence the carboniferous formation bearing coal deposits. However, very interestingly, we observed very low concentrations of SRP in the Elk Basin sites, especially notable among the sites affected by coal mining (Figure 10). These low SRP values, especially in contrast to the very high nitrate and total nitrogen values in the five Elk Basin sites affected by coal mining, are likely due to algal uptake of the SRP in the presence of high nitrogen concentrations.

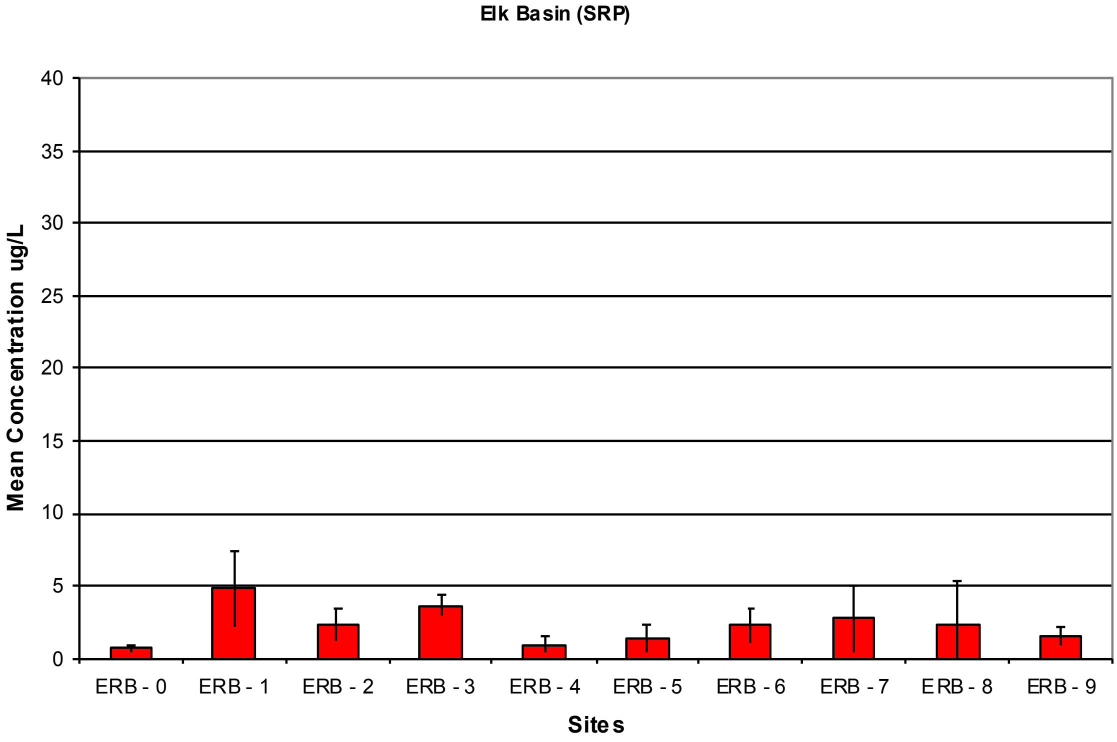


Figure 10. Mean concentration (+ 1 std error) of soluble reactive phosphorus (SRP) among the ten Elk Basin sites. Refer to Table 2 for site descriptions. [Sites ERB-5 through ERB-9 are below coal mines.]

While it would require specific experiments to answer why the SRP values are so comparatively low and the nitrogen values so high among the Elk Basin sites, we believe it is likely due to algal production in the Elk Basin sites stripping the SRP to concentrations lower than what would have been expected given the concentration of nitrogen among these same sites.

3.2 Dissolved Anions Concentrations

3.2.1 Sulfate Ion (SO_4)

Sulfate ion (SO_4) appears in freshwaters as a naturally occurring ion, generally in low concentrations. Its source is typically from minerals of calcium sulfate (gypsum) or magnesium sulfate (Epsom salts). When occurring as iron sulfide minerals, such as pyrite, which are often found associated with coal deposits (Sams and Beer 2000), oxidation of the sulfides can result in ferrous sulfate and sulfuric acid.

Sulfate ion in Flathead and the Elk Basin in headwaters above coal mining influence was generally very low, with concentrations generally <10 ug/L in the Flathead and <20ug/L in the Elk headwaters (Figures 11 and 12). We also observed sulfate values across all Flathead Basin sites to be universally low among small stream sites and in the larger Flathead River (Figure 11). In contrast, the sulfate concentrations among the Elk Basin sites occurring among stream and river segments below the coal mines had distinctly elevated concentrations of sulfate ion. This was most prominent in Corbin Creek (ERB – 5) with mean concentration > 400ug/L (Figure 12). We also observed a general decline in sulfate concentration down Michel Creek and along the Elk River gradient, yet at the lowest end of our sampling sites on the Elk River at Morrissey (ERB – 9), we still observed sulfate concentrations significantly higher ($P<0.01$) [approximately 5X higher] than in the Elk headwaters sites or among any of the Flathead Basin sites.

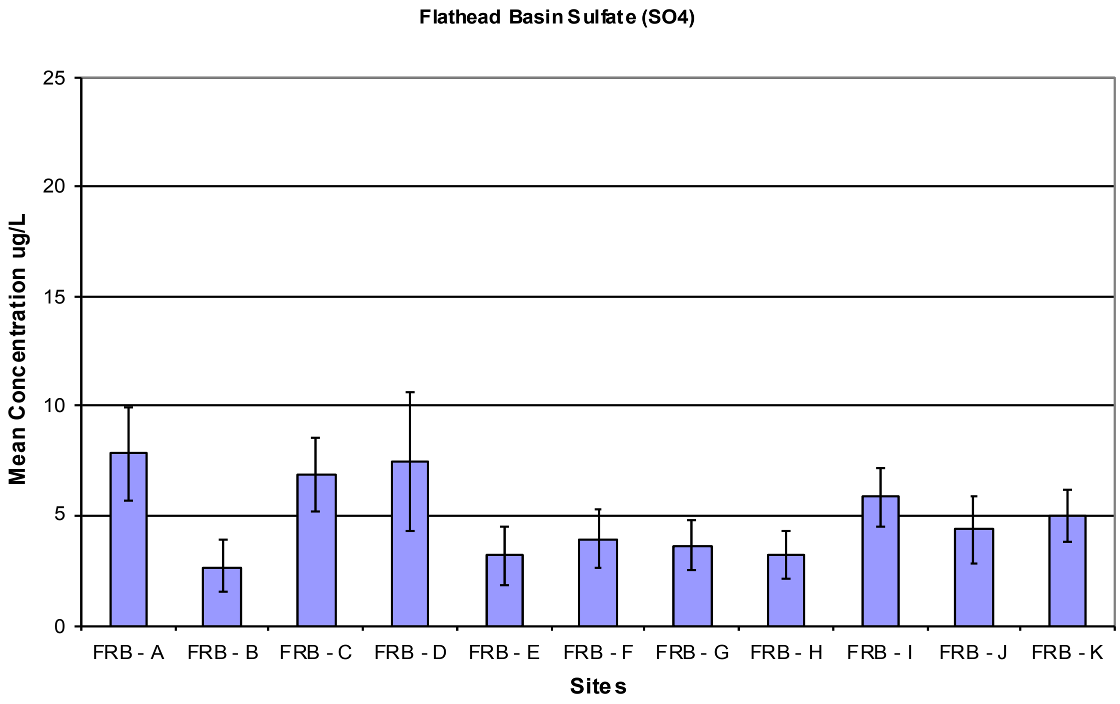


Figure 11. Mean concentration (+ 1 std error) of sulfate (SO_4) among the eleven Flathead Basin sites. Refer to Table 1 for site descriptions.

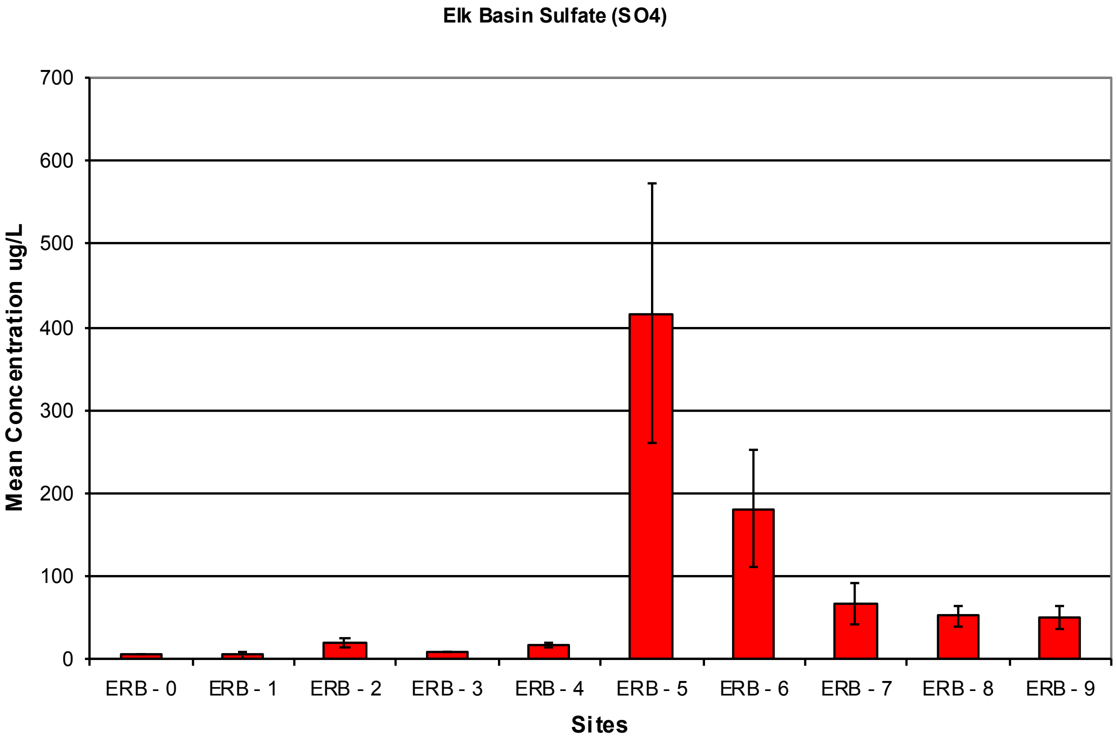


Figure 12. Mean concentration (+ 1 std error) of sulfate (SO_4) among the ten Elk Basin sites. Refer to Table 2 for site descriptions. [Sites ERB-5 through ERB-9 are below coal mines.]

3.2.2 Selenium (Se)

Selenium occurs naturally in a number of inorganic forms, including selenide, selenate, and selenite. Selenium is found in sulfide ores, such as pyrite, and partially replaces sulfur in the ore matrix. In soils, selenium most often occurs in soluble forms such as selenate (analogous to sulfate), which are easily leached into rivers by runoff. Selenium salts are toxic in large amounts, but trace amounts of the element are necessary for cellular function in most, if not all, animals. As such, selenium is often a component in vitamins or food supplements sold for human consumption.

Selenium toxicity in the environment is known to cause health problems in domestic animals and humans and is a well documented problem in fish. For example, Lemly (2002) found that waters contaminated by selenium from a coal-fired power plant had toxic impacts to the resident fish. Symptoms of chronic selenium poisoning included; swelling of gill lamellae, elevated lymphocytes, anemia, corneal cataracts, pathological alterations in liver, kidney, heart, and ovaries, reproductive failure in the form of reduced production of viable eggs due to ovarian pathology, and post-hatch mortality due to bioaccumulation of selenium in eggs, and deformities of the spine, head, mouth, and fins.

We observed selenium values across all Flathead Basin sites to also be universally low, both among small stream sites and in the larger Flathead River (Figure 13). In contrast, the selenium concentrations among the Elk Basin sites in both stream and river segments below the coal mines had distinctly elevated concentrations of selenium (Figure 14). Similar to that observed with sulfate, selenium was most prominent in Corbin Creek (ERB – 5) with mean concentration > 10ug/L. We observed selenium concentrations in the Elk River below the coal mines highly significantly ($P<0.01$) greater [approximately 10X higher] than in either the Elk headwaters sites or among all the Flathead Basin sites. Implications of these high Se concentrations in streams and rivers below the coal mines of the Elk Basin are discussed below in Section 4.0 Conclusions.

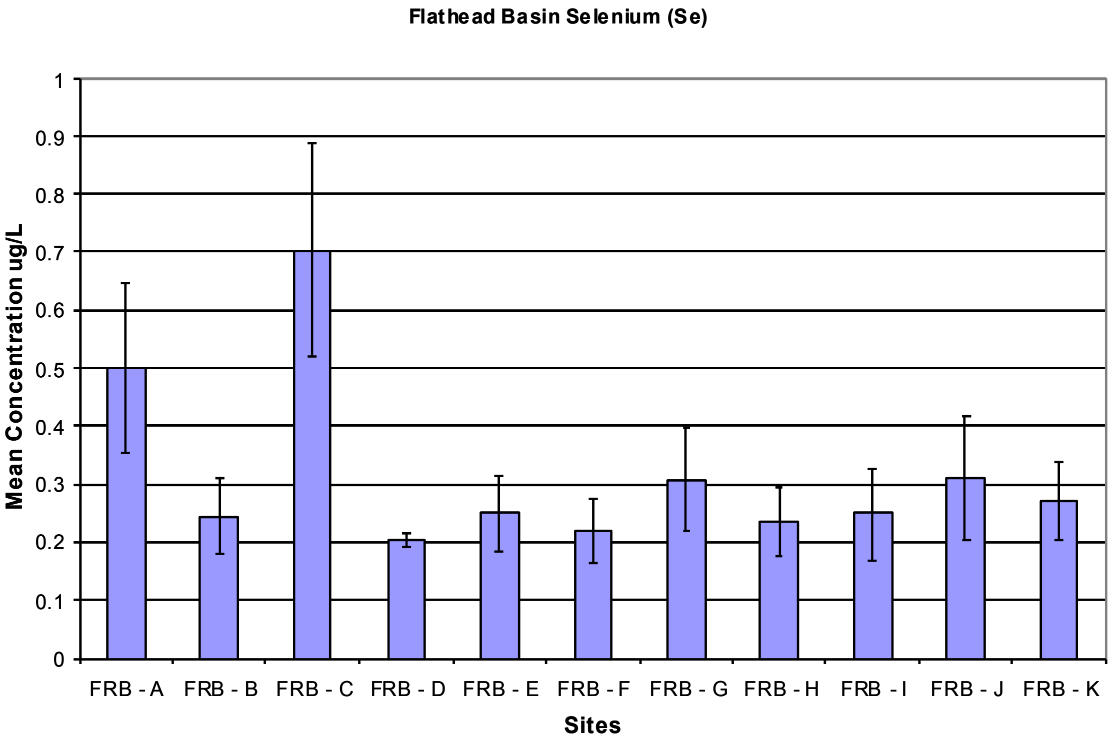


Figure 13. Mean concentration (+ 1 std error) of selenium (Se) among the eleven Flathead Basin sites. Refer to Table 1 for site descriptions.

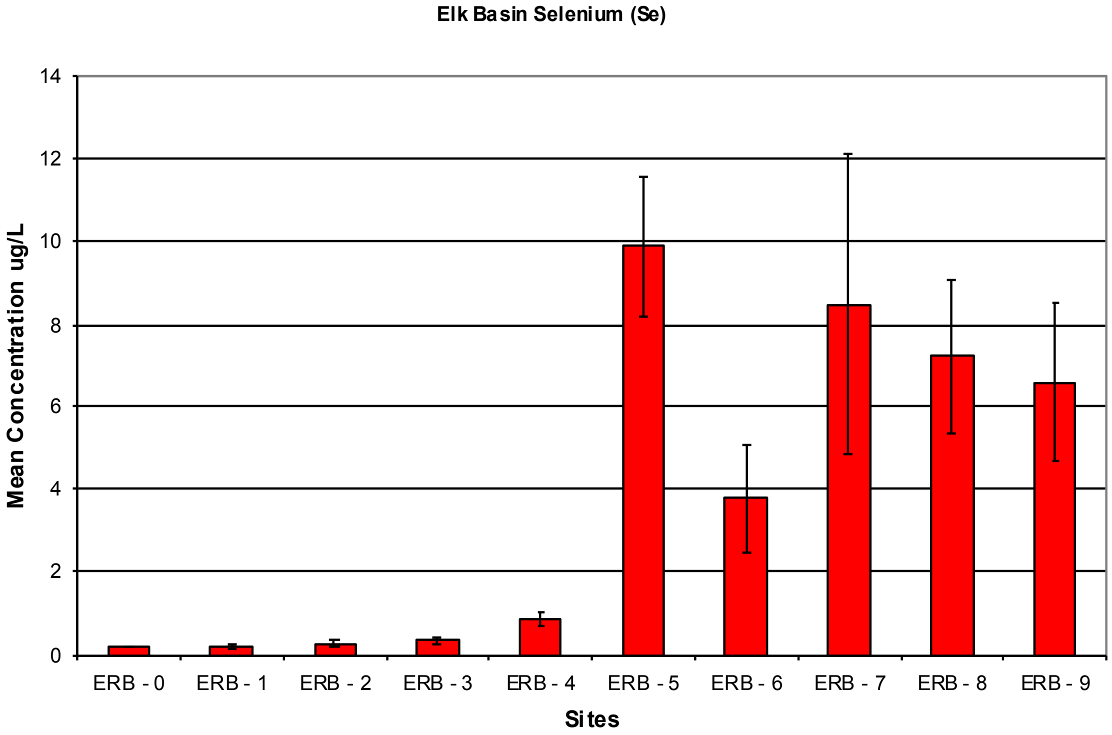


Figure 14. Mean concentration (+ 1 std error) of selenium (Se) among the ten Elk Basin sites. Refer to Table 2 for site descriptions. [Sites ERB-5 through ERB-9 are below coal mines.]

3.3 Stream and River Sediments

We collected fine sediment and core sediment samples to examine the possibility of various metals and anions being associated with the transport and deposition of sediment. We were particularly concerned about both Selenium and Mercury as elements that have been shown to be associated with coal and that may be attached to sediment particles. Furthermore, as shown above, we observed increased selenium concentrations in waters of the Elk Basin below the coal mines.

3.3.1 Stream and River Fine Sediment Deposits

We collected fine sediments along the stream or rivers edge in areas of deposition. See the methods section above for collecting protocols. The purpose of this sampling was to examine the sediment metals being transported by the stream/river systems of the Flathead and Elk Rivers and their association with existing coal mines. These sediments were analyzed for a broad suite of metals (As, Be, Ca, Cd, Co, Cr, Cu, Fe, Li, Mg, Mn, Mo, Ni, P, Pb, S, Se, Sr, Ti, V, Zn). Concentrations (mg/kg) are presented in the Appendix for all results. We observed no significant differences in sediment metals between Flathead Basin sites and those in the Elk Basin. Furthermore, we observed no differences in sediment metals, cations, and anions between Elk Basin sites above the Coal Mines versus sites below the coal mines, including those of selenium and mercury, two elements of particular concern. This was unexpected given the highly significant differences in Selenium and Sulfate concentrations in water samples.

3.3.2 Metals from Floodplain Sediment Core Samples

We collected sediment core samples from eight floodplain sites; two in the Flathead Basin [Flathead River at Flathead BC (FRB - K) and the Flathead River at the International Border], and six sites in the Elk Basin [Elk River Above all Coal Mines (ERB – 4), Michel Creek below Corbin Creek (ERB – 6) Michel Creek (ERB – 7), Elk River at the Hwy 3 tunnel near Elko, Elk River at Elko Dam Reservoir, Elk River at the delta to Lake Kookanusa. The purpose of this sampling was to examine long-term transport and accumulation of metals associated with sediment and their long-term storage in floodplain sediments. These data provide a long term perspective separately from those of the fine sediments that were samples in channel along stream and river edges at each of the sample sites.

Similar to the fine sediment metals, we found great similarity between Flathead and Elk Basin sites (see Appendix tables). We present herein the results of the cadmium (Cd) analysis, as this was the only metal that showed a significant response. We observed significantly higher concentrations (2X; $P<0.05$) of Cd metal in Michel Creek below Corbin (ERB – 6) and in Michel Creek near the Elk River (ERB – 7) than among either sites in the Flathead Basin or along the Elk River from below Hosmer to the river delta forming at the confluence of the Elk River with Koocanusa Reservoir (Figure 15). The higher cadmium concentrations in both Michel Creek sites are likely due to their proximity to Corbin Creek with the lower concentrations in the Elk River sites, likely due to dilution.

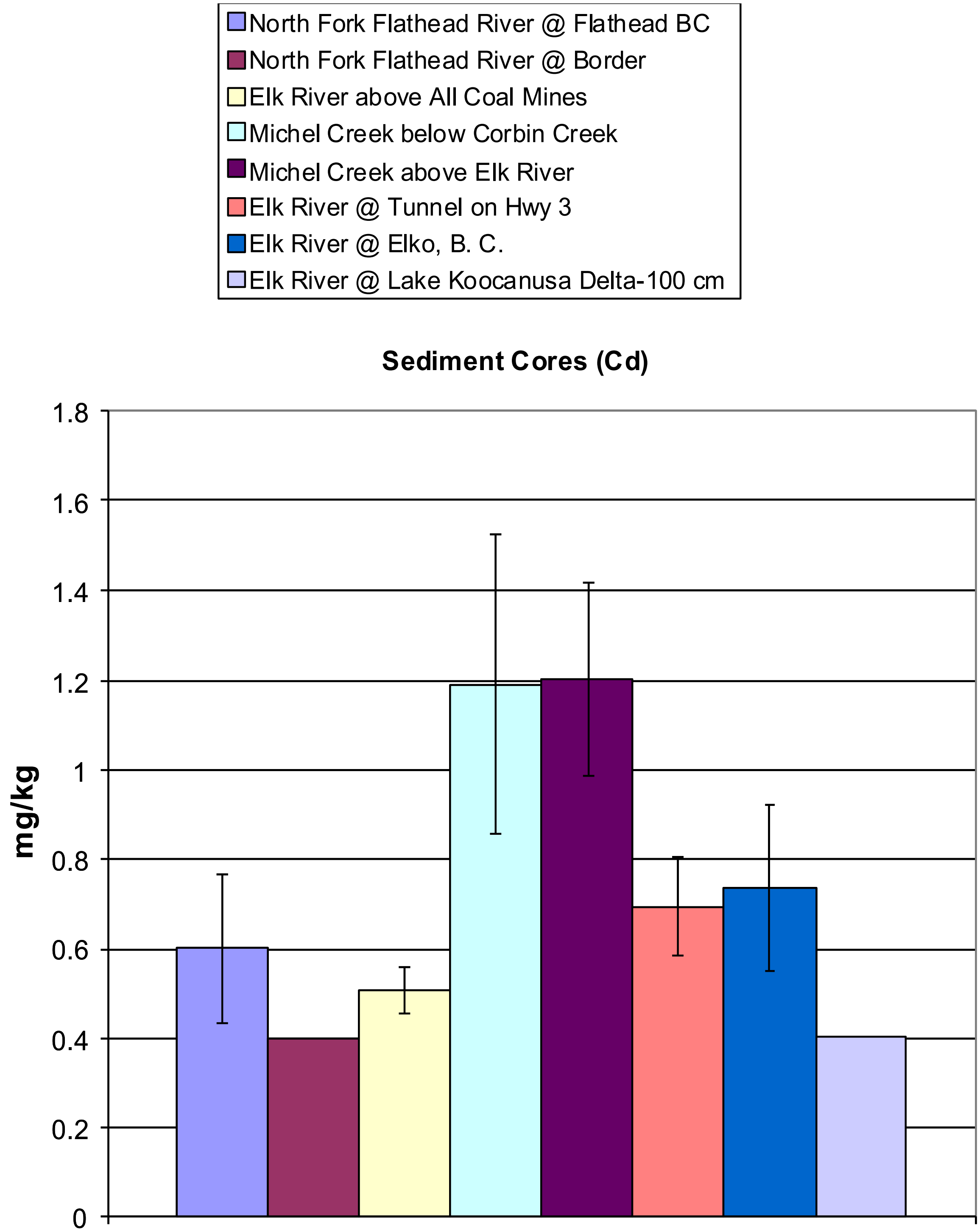


Figure 15. Mean concentration (+ 1 std error) of cadmium (Cd) among two Flathead Basin and six Elk Basin sites. Note that the Michel Creek sites were significantly greater than either the Flathead Basin sites or the Elk River sites above all coal mines.

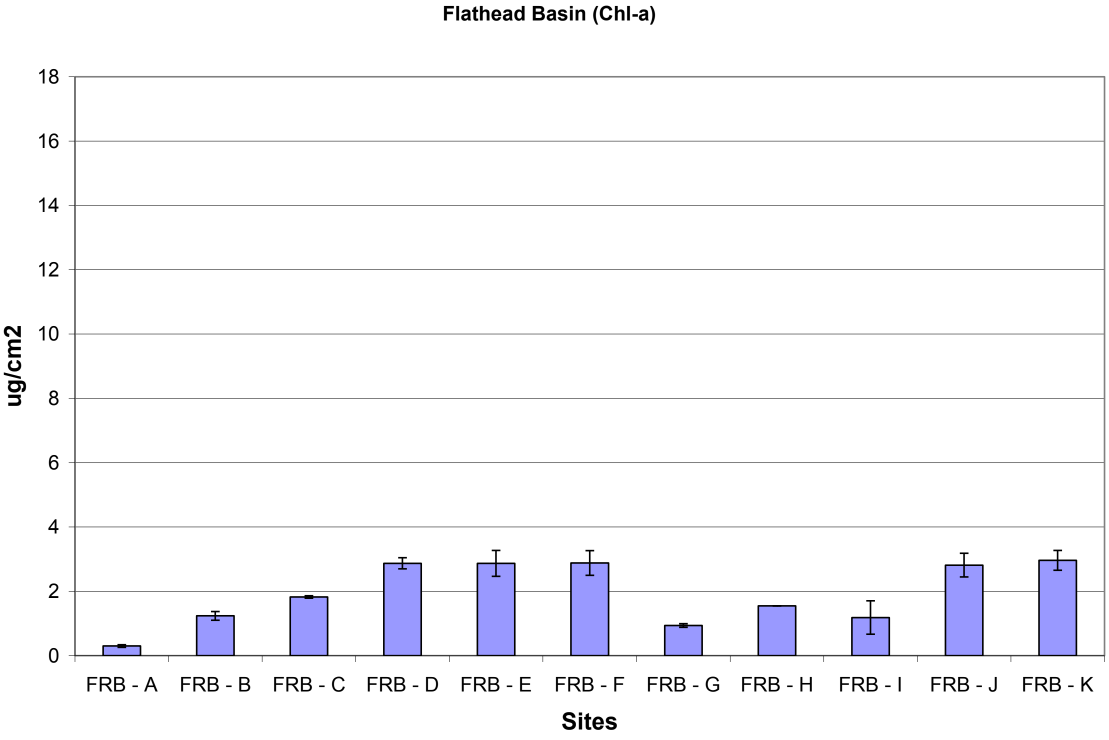
3.4 Aquatic Life

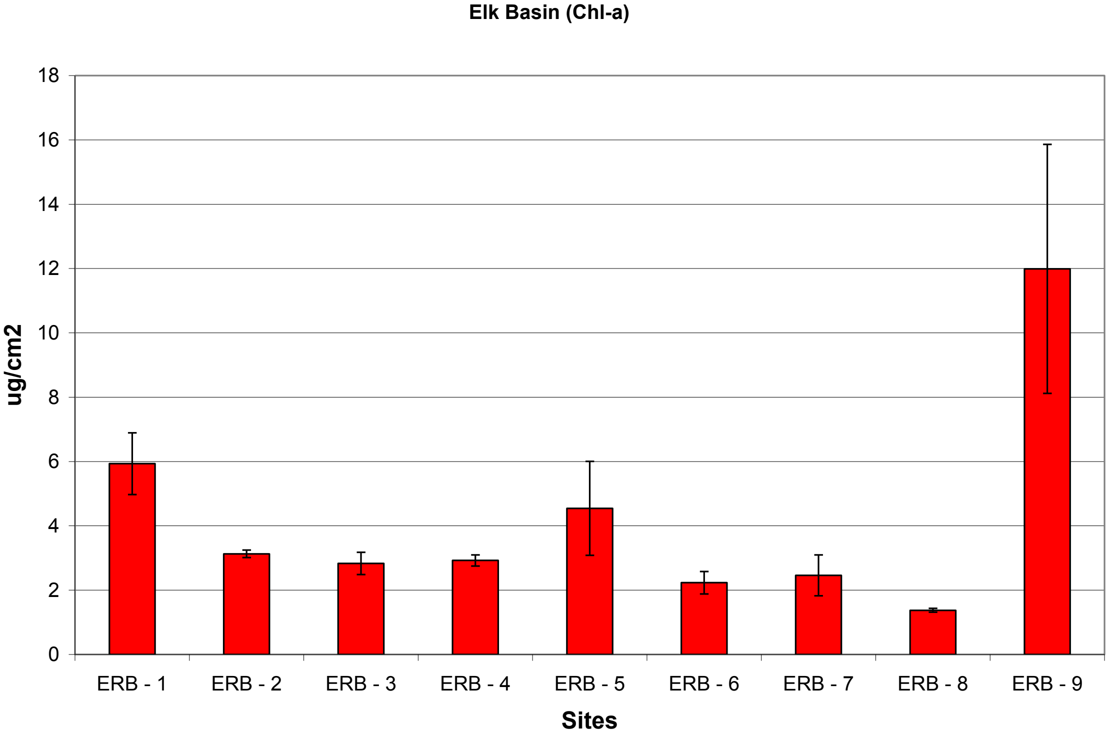
Many organisms are useful as indicators of overall biological condition because they integrate a wide variety of stressors over time (Stevenson and Hauer 2002). Each species has a specific response curve to environmental conditions. Many diatom-based indices have been used to estimate water quality based on these responses. Most of these indices assume this response curve is unimodal and symmetrical and assign each species an indicator value based on the "optima" or peak of the response curve. The weighted averages of indicator values can be used to infer environmental parameters based on the species assemblage. While Potapova et al. (2004) showed that diatom response curves are not always symmetrical and unimodal, they found that an index, which accounted for irregular response curves had no better predictive power than the traditional method.

3.4.1 Algal Periphyton

We collected periphyton samples in the summer of 2006, 2007 and 2008. The results here reflect the overall sampling effort and the trends associated with the examination of periphyton algal diatom diversity as an indicator of ecological health and the distribution and abundance of chlorophyll-a as an indicator of nutrient enrichment (Steinman et al 2006).

We found less difference in the density of chlorophyll-a (ug/cm^2) on the stream and river bottoms, but when taken as a whole, there was generally more algae and thus the stream bottom appears more green in the Elk River Basin sites below the effects of the coal mines than among the Flathead Basin sites, where chlorophyll-a density was very low at all sample locations (Figures 17 and 18).





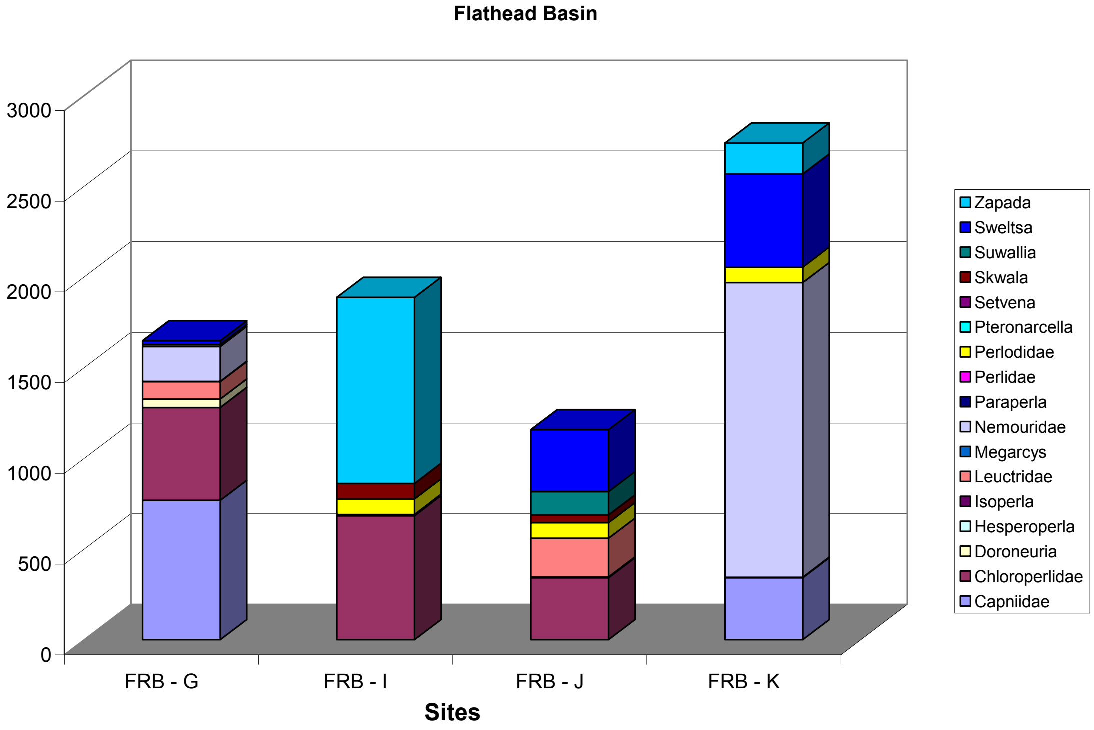
Figures 17 and 18. Chlorophyll-a density among Flathead Basin (upper figure) and Elk Basin (lower figure) sites.

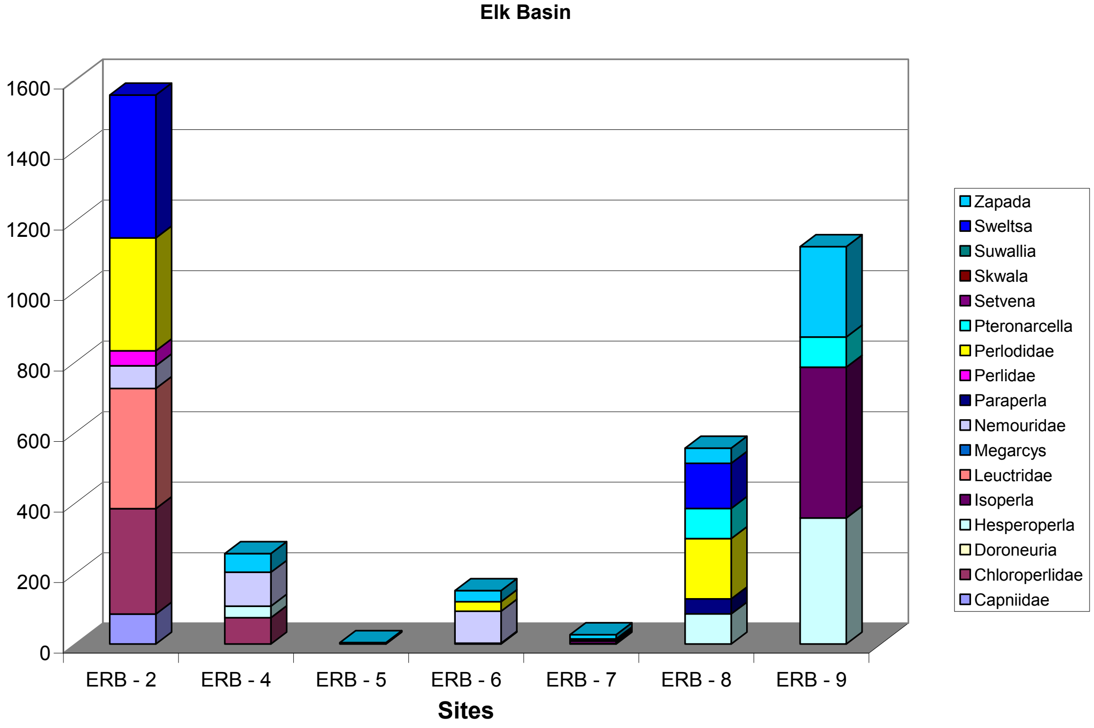
3.4.2 Benthic Macroinvertebrates

Benthic macroinvertebrates, also referred to as zoobenthos, are a reliable indicator of trends within running water systems (Carter et al. 2006). A large proportion of zoobenthos are highly responsive to changes in the algal structure and the character of a given habitat. While periphyton growth is dependent on factors such as substrata, thermal consistency, nutrient content and flux, and toxic materials dissolved in the water; these physico-chemical factors are also reflected in the distributions and abundances of benthic macroinvertebrates. It is of particular importance to understand the specific community structure of an ecosystem, both for the purpose of enhancing understanding of taxa response to the environment, but also with goal of establishing an identifiable relationship with the functional factors of that system. The relationship between structure and function, once established in an ecosystem of a particular type, can be utilized to make predictions of ecosystem structure based on observations of function, or vice versa.

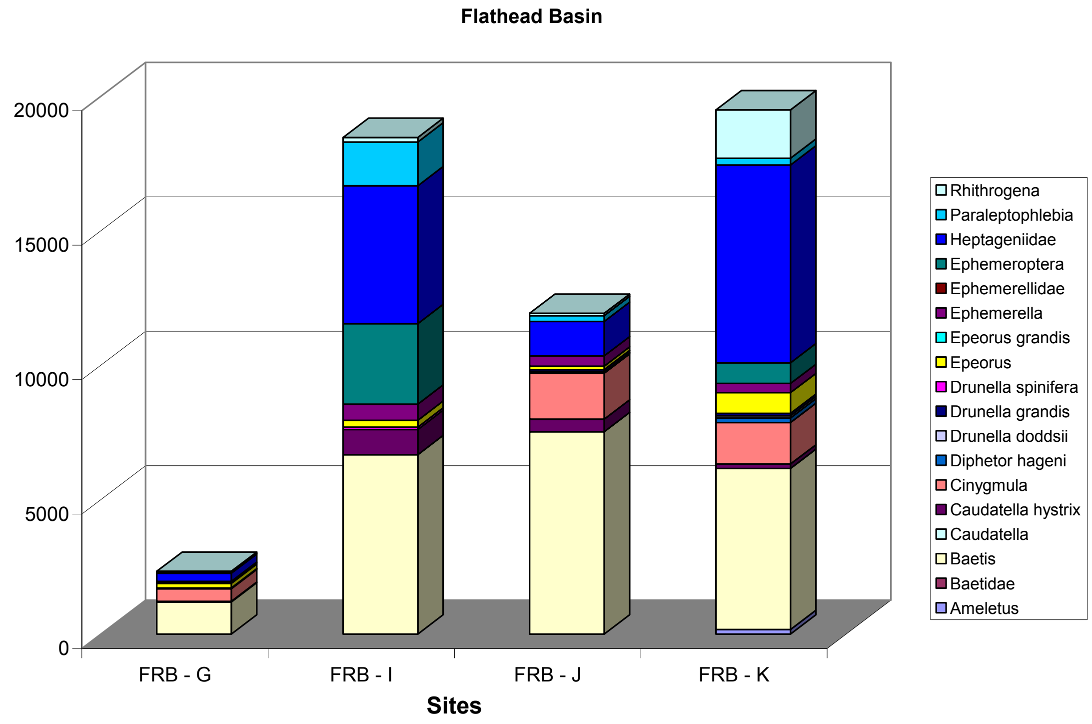
Biotic factors also determine the distribution and abundance of benthic macroinvertebrates. Both intra- and inter-specific competition may affect stream macroinvertebrates, yet may be compensated for and alleviated by habitat heterogeneity. The benthic macroinvertebrate communities that exist along stream and river corridors in the Transboundary Flathead are extremely diverse (Hauer et al 2000). The orders Plecoptera, Ephemeroptera, and Trichoptera on the Flathead River typically are diverse and compose over 95% of the benthic invertebrate biomass. The species from these three aquatic insect orders have been used extensively throughout the US and Canada as indicator taxa of stream and river ecosystem environmental condition.

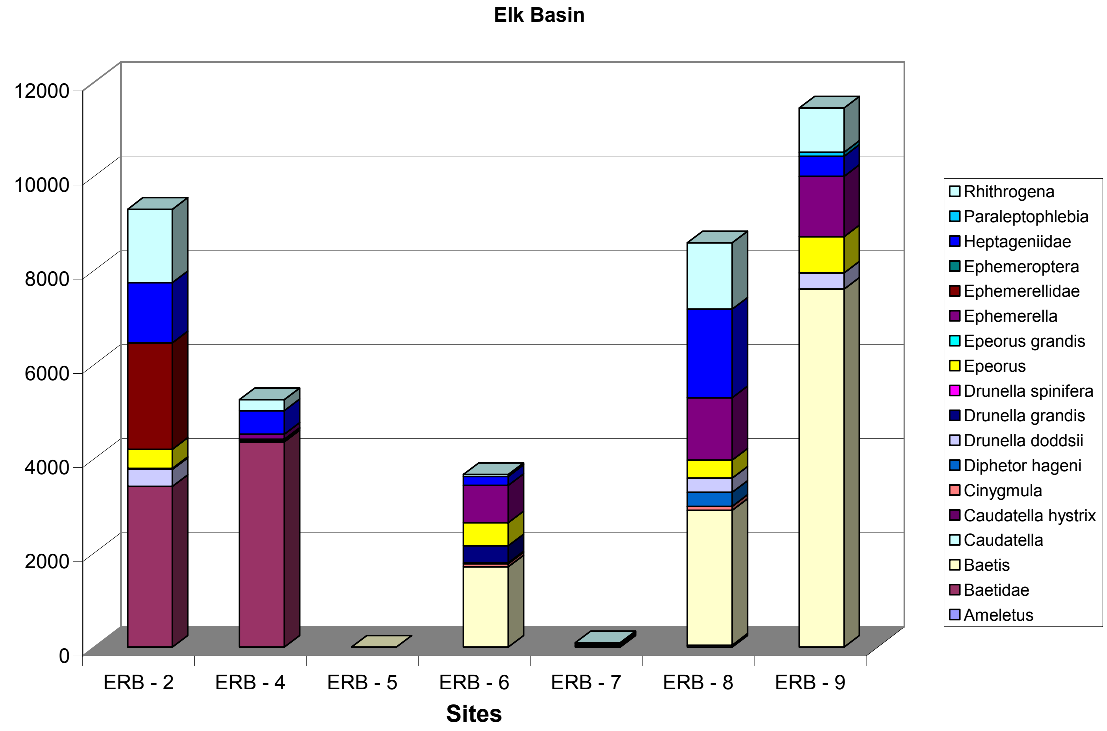
We found the Plecoptera (Figures 19 and 20) , Ephemeroptera (21 and 22), and Trichoptera (Figures 23 and 24), as well as the Diptera (Figures 25 and 26), to be diverse and responsive to environmental effects of coal mining in the Elk Basin.



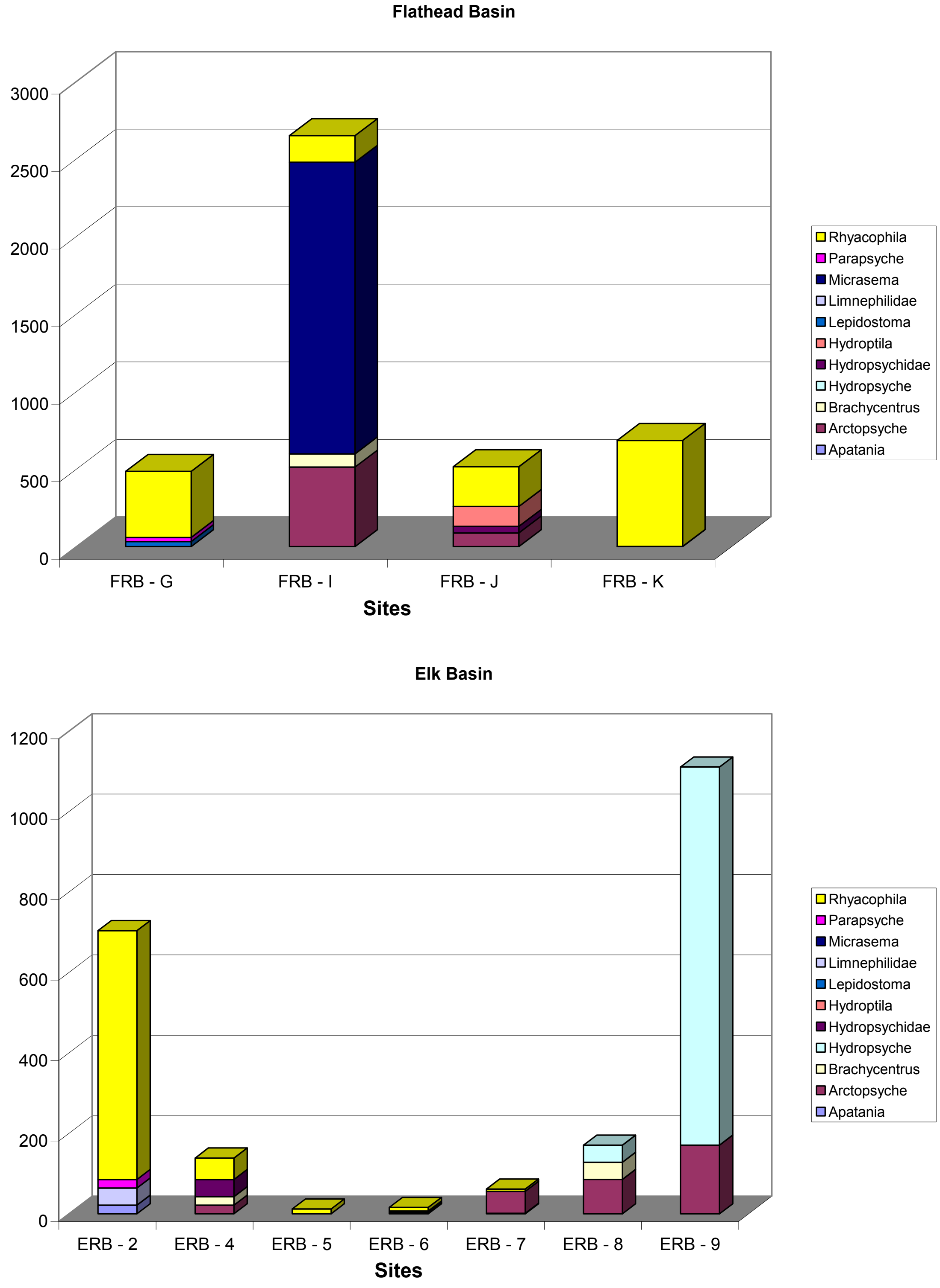


Figures 19 and 20. Plecoptera (stonefly) nymph abundance (# per m^2) among Flathead Basin (top figure) and Elk Basin (lower figure) sites. (See Tables 1 and 2 for site reference.)

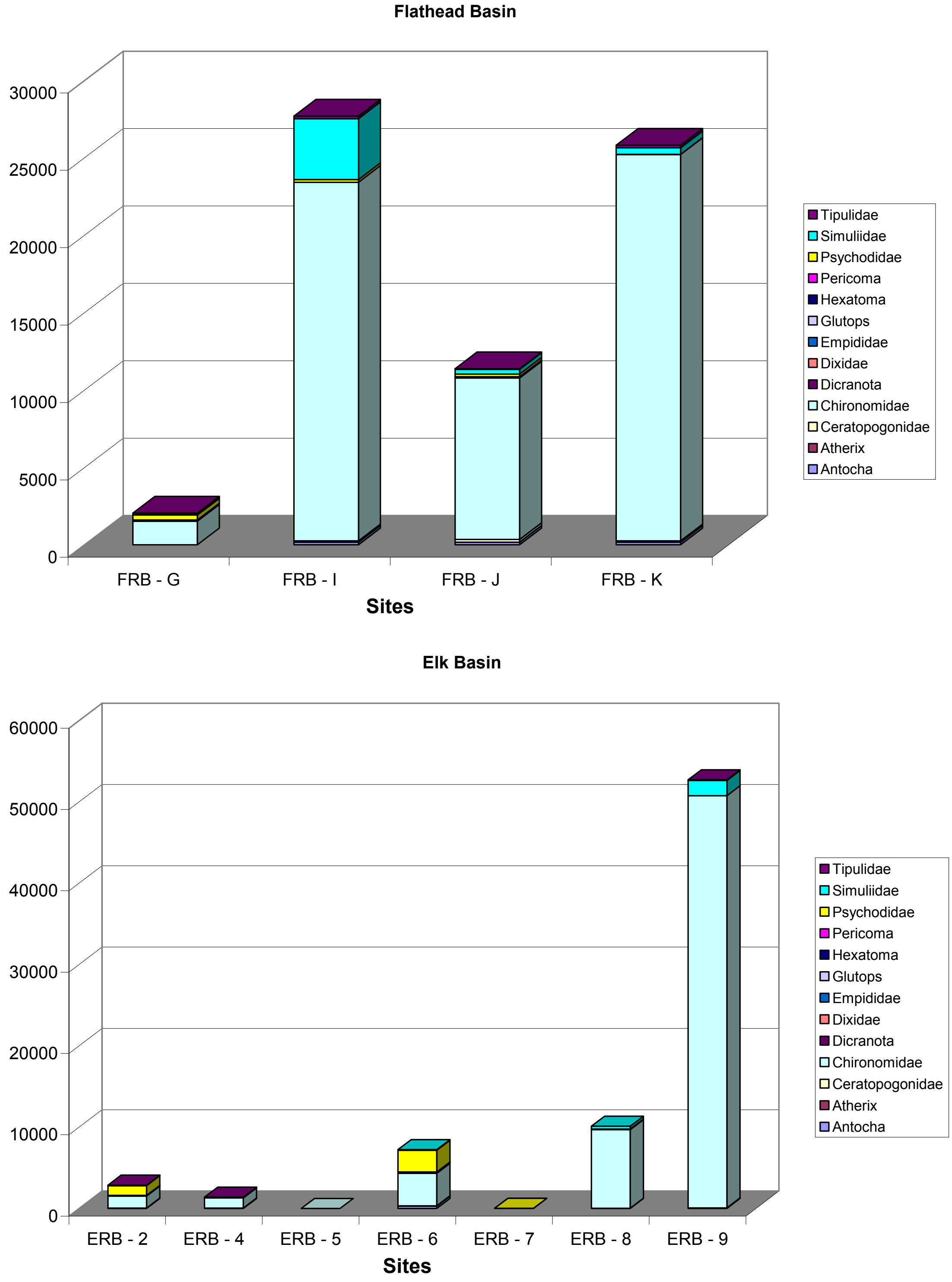




Figures 21 and 22. Ephemeroptera (mayfly) nymph abundance (# per m^2) among Flathead Basin (top figure) and Elk Basin (lower figure) sites. (See Tables 1 and 2 for site reference.)



Figures 23 and 24. Trichoptera (caddis fly) larvae abundance (# per m^2) among Flathead Basin (top figure) and Elk Basin (lower figure) sites. (See Tables 1 and 2 for site reference.)



Figures 25 and 26. Diptera (true fly) larvae abundance (# per m^2) among Flathead Basin (top figure) and Elk Basin (lower figure) sites. (See Tables 1 and 2 for site reference.)

Among the Plecoptera and Trichoptera in particular, we found the frequency of nymphs and larvae to be markedly depressed in Corbin Creek and Michel Creek below Corbin and Michel Creek near the confluence with the Elk River. In contrast, populations were very robust among all the Flathead Basin sites and in Elk Basin sites above the effects of coal mining. We also found that populations of these taxa had “recovered’ in the down river areas of the Elk River represented by our sites above Hosmer and above Morrissey, where we found relatively robust invertebrate populations.

We observed a similar pattern among the Ephemeroptera nymphs, but much of the density in the downstream reaches was related to high abundance of Baetis sp. Both Baetis and the Hydropsychid caddisflies that were very abundant at ERB – 9 are known to be tolerant of pollution and become very abundant as algal biomass is stimulated by increases in nutrients. Diptera larvae were also abundant in the Flathead Basin Sites, but showed strong negative effects of pollution in Corbin Creek (ERB - 5) some recovery at the Michel Creek below Corbin (ERB – 6), but with marked decline again at Michel Creek near Elk river confluence (ERB – 7).

3.5 *Remote Sensing of River Habitat*

Fundamental to understanding the distribution and abundance of species, development of a comprehensive conservation plan, determining the probable trajectories associated with species adaptation and potential response to landscape and climate change is quantifying biophysical space (habitat) used by species or in different life stages that promotes successful growth and reproduction. Conservation biologists sometimes refer to locally adapted populations with habitat-specific distributions or life cycles as ecologically significant units. However, habitats are constantly changing within a changing landscape. Physical and biological attributes of riverscapes and landscapes vary in time and space and interact to determine the quantity and quality of specific habitat. Sufficient habitat and complexity of habitats are not only required for species-specific persistence, but also broad biodiversity in a landscape. Of course, a given landscape is composed of multiple gradients and species responses.

Often feedback mechanisms are complex and nonlinear, making habitat for each species in the landscape very difficult to define. Nonetheless, quantifying habitat for species in very specific spatial and temporal terms is fundamental to conservation of biodiversity. Hauer and Sexton (authors of this report) and C.M. Muhlfeld, USGS aquatic Ecologist, have developed an approach to development of a comprehensive conservation plan for the Transboundary Flathead with integration across spatial scales to include the Crown of the Continent, of which Waterton – Glacier International Peace Park is a central part. This approach titled: **Predicting Effects of Climate Change on Aquatic Ecosystems in the Crown of the Continent Ecosystem: Combining Vulnerability Assessments, Landscape Connectivity, and Modeling for Conservation and Adaptation.**

Through this project we have proposed to build on our existing research projects [of which the project as focus of this report] are applied through the following specific components:

(1) Develop vulnerability assessments for native salmonids (bull trout and westslope cutthroat trout) and stream macroinvertebrates in the Transboundary Flathead and CCE, which will produce spatially explicit distribution and abundance models coupled with climate projections and response variables of aquatic biota at multiple trophic levels in the food web;

(2) Apply new and existing techniques for combining downscaled, regionalized climate models to spatially explicit habitat data. These will be coupled to population and genetic data to monitor and predict effects of climate change on connectivity, distributional shifts, gene flow, demographics and persistence for bull trout, westslope cutthroat trout, and rare macroinvertebrate populations;

(3) Develop detailed, spatially explicit hydrogeomorphic, thermal and habitat models of critical stream and riparian habitats of the North Fork river corridor using airborne remote sensing tools. These products, from headwater tributaries to the valley-bottom corridor and floodplains where much of the connectivity and response to variation in thermal and hydrologic regimes will be played out, will couple directly to the vulnerability assessments of Objective 1, the connectivity models of Objective 2 and the thermal and flow tolerance assessments of Objective 3.

(4) Develop an adaptation plan for the Transboundary Flathead Aquatic Ecosystem (Canada and USA) to identify conservation delivery options in response to climate change and other important cumulative stressors (e.g., habitat degradation and fragmentation, and invasive species).

The #3 component objectives of the proposed project are to: 1) quantify, in a spatially explicit way, stream channel habitats (e.g., riffles, runs, pools), various riparian habitats (e.g., forest, shrub and wetland complexes), and potential sites of subsurface habitats of low and high hydraulic conductance of ground water (e.g., the hyporheic zone); 2) habitat specific thermal regimes, especially linked to summer thermal refugia and winter ice cover; 3) link these physical, biological and thermal habitat markers to the distribution and productivity of foodweb species and the distribution of critical life histories of bull and cutthroat trout (especially within the context of their genomic variation); and 4) link trajectories of habitat change (persistence or spatial change) with the regionally downscaled climate models. Understanding the processes and the habitat structure associated with critical habitats of the Transboundary Flathead will be crucial in any long-term diagnosis of effects due to climate change.

3.5.1 Approach and Link to this Project and Report

We have developed over the past 5 years the technology of collecting and processing airborne remotely sensed data (ARS) for the purpose of habitat evaluation and analysis. Airborne remotely sensed data are collected with ultra-high resolution multispectral imagery system (Princeton Instruments EC16000 CCD interline imager) deployed from the FLBS/UM research aircraft Cessna 185. We collect multispectral imagery in mid-summer for riparian and water cover classification. A combination of supervised and unsupervised classifications will be used to produce a cover map for each study reach (High resolution raw image; Figure 27 A). An unsupervised classification will be used to discriminate between vegetative cover and non-vegetative cover (i.e. vegetation vs cobble and water). To help discriminate among different vegetation types, homogeneous stands of the varying cover types (e.g., cottonwood, willow, water, cobble, dry grass) are identified and associated with specific spectral signatures. These specific imagery signatures are used as “training areas” to classify the image into the different land cover types. Mean spectral signatures are calculated for each cover type and subsequently used in a supervised classification. Using the spectral signatures, the Mixed Tune Matched Filtering (MTMF) algorithm in ENVI (RSI 2000) is then applied to the vegetative component of the imagery to discriminate the varying vegetation types. For each reach, a final riparian cover map is produced consisting of dominant cover types (i.e., water, cobble, deciduous – predominately cottonwood, willow, mixed grasses, dry grasses, and shadows; See Figure 27, Panel B).

Stream and river aquatic habitats are classified using an unsupervised approach to differentiate spectral reflectance categories of different habitats within the main channel and then within the off-channel. Remote sensing data are calibrated with Accoustic Doppler Profiler data co-located with a Trimble AgGPS 132 v1.73 GPS receiver with sub-meter accuracy. An unsupervised clustering approach (ISODATA, Iterative Self-Ordering Data Analysis) is used to enumerate similar clusters of spectral reflectances. The clusters are aggregated into velocity categories (0-0.5, 0.5–1.0, 1.0–1.5, > 1.5 m/s).

A subset of the ADP data is then used to calibrate the classification relationship to spectral reflectance and assign the appropriate depth and velocity categories (See Figure 27, Panel C). The remaining ADP data are used to validate the relationship and assess the accuracy of the classification. This methodology followed the approach developed by Whited et al. (2002, 2003), Hauer and Lorang (2004), and Lorang et al. (2005). Simultaneously, we deploy an Electrophysics EC600 thermal imager that collects thermal emission data from land and water surfaces (± 0.5C^{o}; See Figure 27, Panel D).

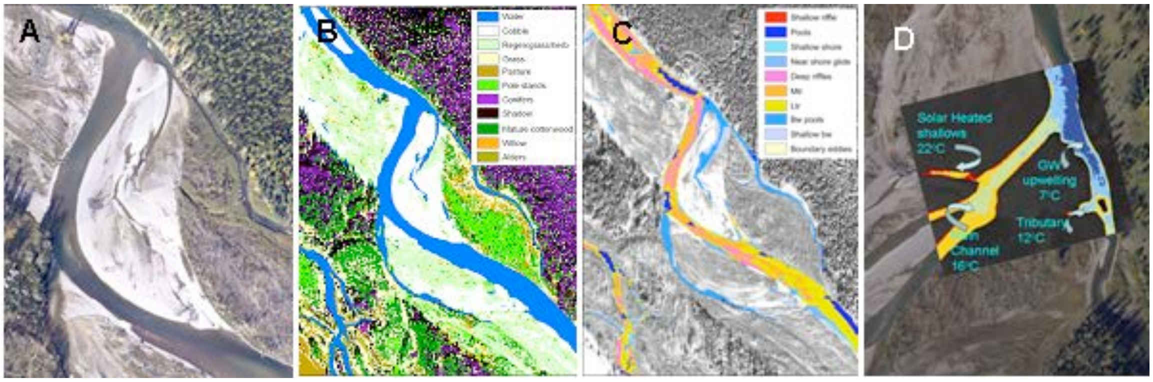


Figure 27. (A) ultra-high resolution (~10cm) image of the river channel, a cobble bar and terrestrial vegetation on approximately 1/100 of river floodplain, (B) an approx. 1m rendering and classification of floodplain cover types, (C) classified spectral reflectance of water surface showing aquatic habitats, and (D) thermal image of water surface (emissivity) classified to thermal patches (±1C^{o}) across aquatic habitats.

3.5.2 Early Results of Raw Imagery on the Transboundary Flathead River

We have developed advanced techniques for the analysis of riparian habitat, river hydraulics, potential for geomorphic change, aquatic habitat, and thermal imaging. Using high resolution (5 – 10cm) airborne remote sensing imagery and tools developed specifically for the CCE during NSF-funded research and development, we will integrate specific climate-change outputs for this project across a representative suite of river reaches from alpine to floodplains on the valley floor. The objectives of the on-going research are to: 1) continue acquisition of the remote sensing imagery for the North Fork corridor from headwaters to the confluence of the Middle Fork, 2) integrate the imagery into a GIS framework, and 3) develop riparian and hydraulic habitat maps along the Transboundary Flathead River Corridor.

In Appendix B, we illustrate in a series of GIS images: 1) Map of the Transboundary Flathead River showing the major floodplain segments of the river corridor from headwaters to the confluence with the Middle Fork of the Flathead River near West Glacier, Montana; 2) Maps/composite georectified images of each floodplain segment with river corridors; and 3) the georectified images in a high resolution format.

These maps/images are available from the Flathead Lake Biological Station website http://www.umt.edu/flbs/ as directly downloadable images available to the public or to other researchers. These data have also been transferred in both georectified and raw image form to the Glacier National Park GIS facility.

4.0 CONCLUSIONS

Nitrate and total nitrogen concentrations were highly significantly elevated ($P<0.001$) at sites downstream of coal mining in the Elk Basin compared to what was observed either at Flathead Basin sites or at Elk Basin sites above coal mines. We are uncertain the cause of this observed condition in which nitrate and TPN concentrations were around 1000X greater in water downstream of the Elk Basin coal mines compared to waters not affected by mines, either in the Flathead Basin or in the Elk Basin above the mines. Nitrate nitrogen may be coming from the coal seams as they are exposed in the mining process or may be coming from nitrogen associated with the mining process itself. It has long been known that nitrous oxides are a common by-product of coal (Davidson 1994).

Phosphorus was not similarly affected by mining. We observed natural concentrations of SRP in the Transboundary Flathead similar in concentration to those observed among the Elk Basin sites above the coal mines. In the Elk Basin water below the coal mines soluble reactive phosphorus was not significantly different from that above the mines. However, in both the Flathead headwaters and in the Elk concentrations were naturally in the range of from 2 – 15 ug/l. In waters unaffected by the coal mines in both the Flathead and Elk, comparing phosphorus and nitrogen levels we concluded that it is probable that these waters are normally N-limited with excess bio-available phosphorus; thus, making these waters particularly vulnerable to increased Nitrogen loading.

Sulfate concentrations were also significantly elevated in Elk Basin sites below coal mining ($P<0.01$). This is likely due to exposure of sulfide and/or sulfate bearing ores that are oxidized when exposed to the atmosphere during the mining process. Sulfate is very soluble in water and readily mobilized. Sulfate can be a stressor of algae, macroinvertebrates and fish at high levels and under some conditions can lead to acidic stream condition known as acid mine waste. While we did not observe acidic conditions, sulfate concentrations being 40-50X higher than what occurs naturally in Flathead Basin and Elk Basin streams cause for concern.

We observed selenium concentrations to be significantly elevated ($P<0.01$) among stream and river sites in the Elk Basin below coal mining such that the concentrations were typically 7-10X above either the naturally occurring levels in Flathead or among the Elk Basin streams and river sites above coal mining. Selenium is of particular concern because of its toxicity to plants and animals and that the concentrations in the sites below the coal mining frequently exceed the values known to cause toxicity and abnormal development in fish. Of extreme concern is the bioaccumulation affects of selenium, in which organisms of the food-web increasingly concentrate the selenium in various tissues, such as muscle, liver or ovaries. This has demonstrable effects, not only among fish and population viability, but also has potential human health implications as people consume the fish. The concentrations of selenium observed in the Elk Basin stream and river sites below the effects of mining exceeded both the British Columbia guidelines value of 2ug/L and the US EPA water quality standard of 5 ug/L. The high concentrations of sulfates and selenium in waters downstream of Elk Basin coal mines represent a significant threat to the ecological integrity of these streams and rivers. This should be of great concern to both Environment Canada and the US-EPA as the Elk is a tributary to the Kootenai River and Lake Koocanusa, which flows into the USA in western Montana.

We had a comprehensive design to look for metal effects in sediments transported from the coal mines. We were particularly concerned about selenium, mercury, cadmium, zinc and other elements associated with runoff from mining sites. We did observe elevated concentrations of cadmium in Corbin Creek and in Michel Creek below Corbin. We did not observe increased metal concentrations above those at sites either in the Flathead Basin or among sites in the Elk Basin above the coal mines. Any increase in cadmium is a concern because of the high sensitivity among aquatic organisms to this metal.

Algae growth is an excellent indicator of nutrient pollution as well as toxicity. We observed a significant difference in algae productivity, as measured by abundance of chlorophyll a, between Flathead Basin sites and Elk Basin sites below coal mining effects. Chlorophyll-a density was higher in Elk Basin sites affected by increased loading of nitrogen below the coal mines. We observed the highest density of algae in the Elk River at Morrissey. Stream invertebrates were highly diverse in the Transboundary Flathead and Elk Basins. These organisms have been used extensively throughout the US and Canada as indicator taxa of environmental degradation. We observed significant impact to the macroinvertebrate communities in Corbin Creek and Michel Creek. These sites also showed the most pronounced effects on algae and the highest concentrations of nitrogen loading, and sulfate and selenium pollution. Indeed, we observed both a decrease in ecosystem structure and ecosystem function, with an overall loss of ecosystem integrity (sensu Karr and Chu 2000).

In summary, we observed significant ecological and environmental effects of coal mining on freshwaters of the Elk Basin when compared to both the streams and rivers of the upper Flathead Basin in British Columbia and the Elk Basin streams and rivers at sites above coal mines. These effects were prevalent throughout the study period and across all seasons. All coal mining affected sites had increased nitrogen loading, increased sulfate loading, increased selenium loading, higher algal production as a result of the higher nitrogen loading, and a decrease in benthic macroinvertebrate diversity and abundance particularly of species sensitive to pollution. These factors point to a degraded freshwater ecosystem in the Elk River Basin below coal mines. These highly negative effects will require selenium abatement, as well as mitigation to prevent future losses and compensatory mitigation for past environmental loss to recover system ecological integrity.

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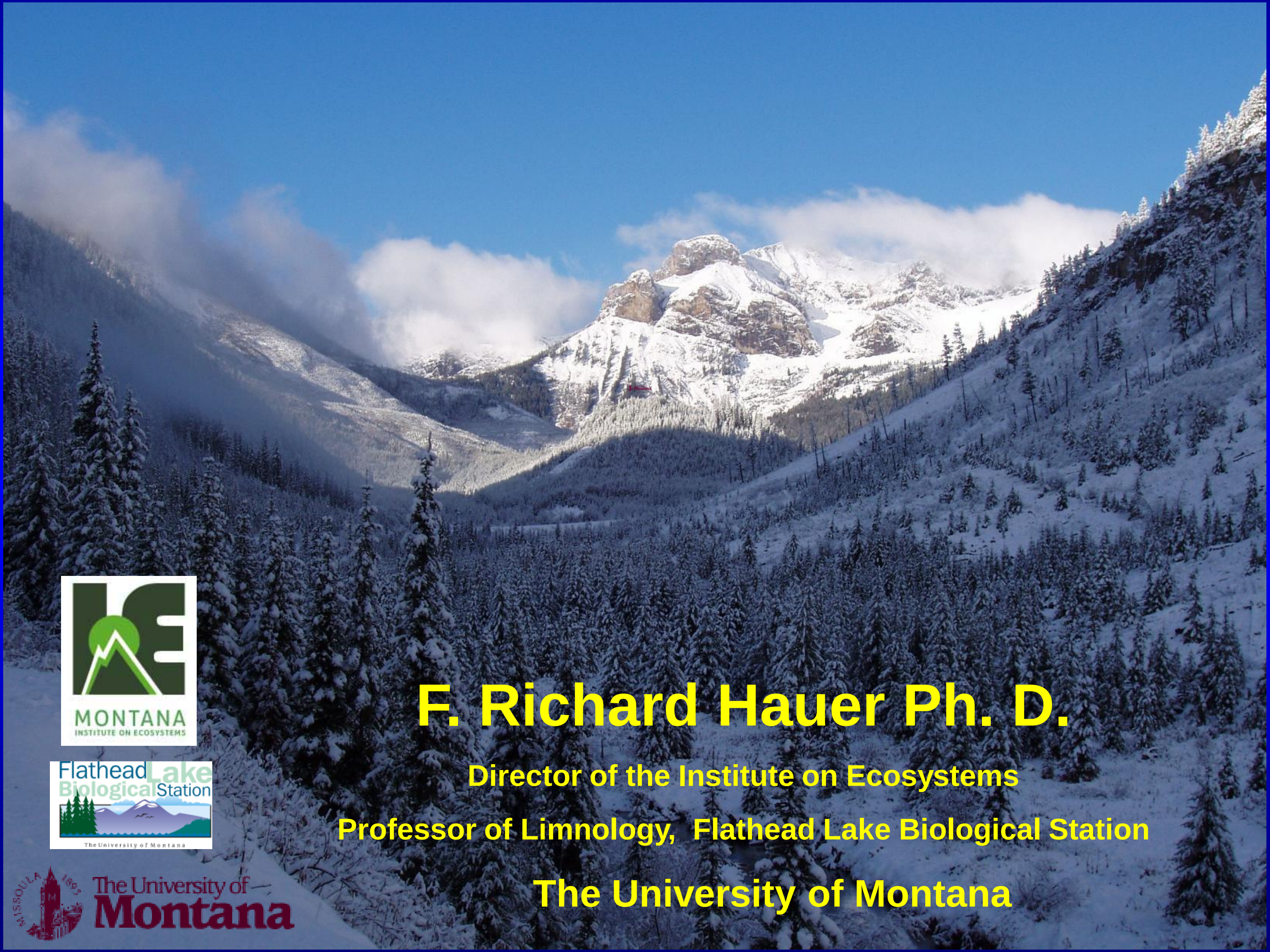
A Hierarchical Approach to Large Landscape Conservation: the Futures of Two Rivers



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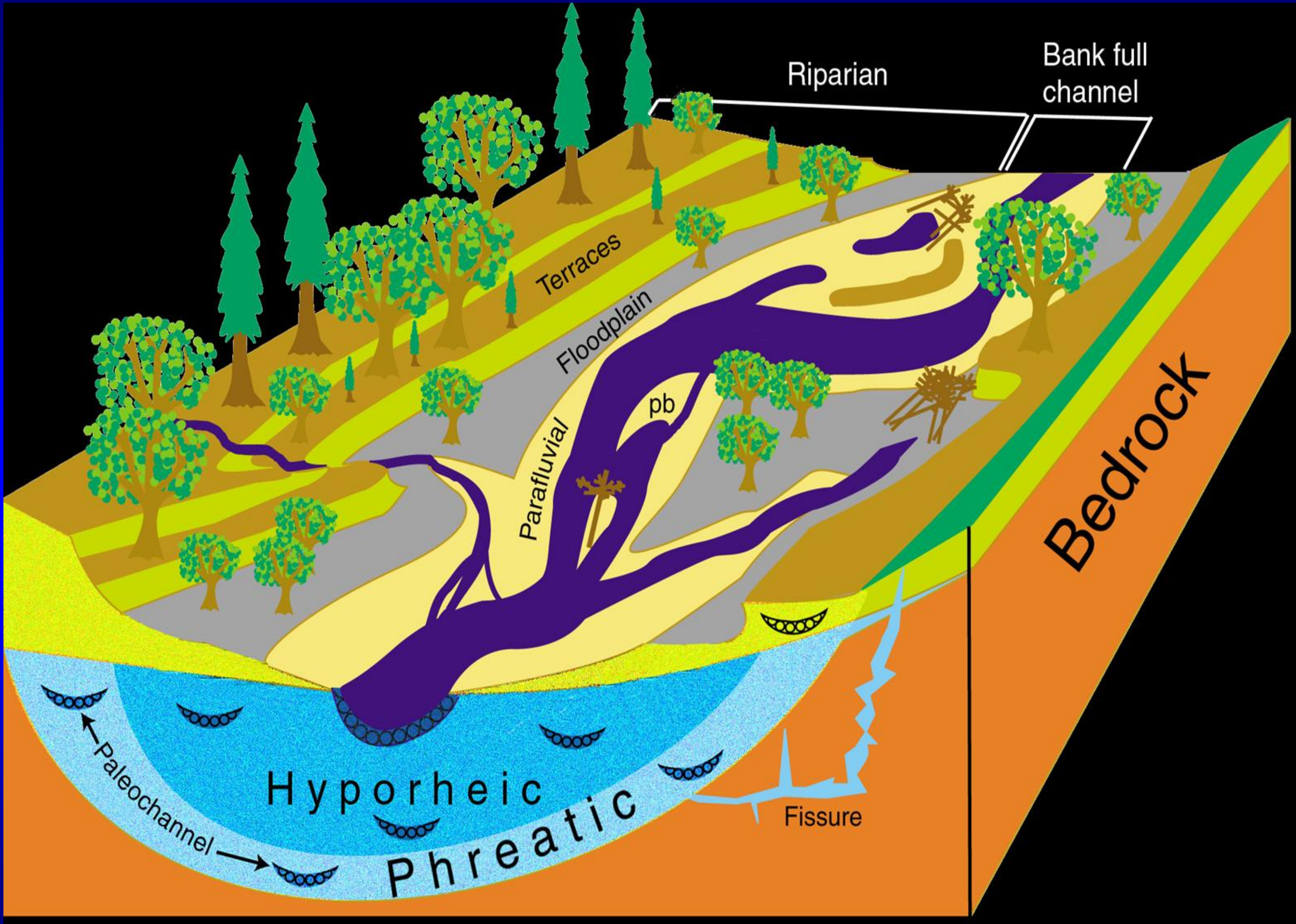
Professor of Limnology, Flathead Lake Biological Station

The University of Montana


Hudson
Bay
drainage
CANADA
Nelson River
NORTHERN
SPECIES
Waterton-Glacier
International
Peace Park
Saskatchewan River
PRAIRIE
SPECIES
Pacific
Ocean
Drainage
MARITIME
SPECIES
Columbia River
Missouri River
SOUTHERN
ROCKY
MOUNTAIN
SPECIES
UNITED STATES

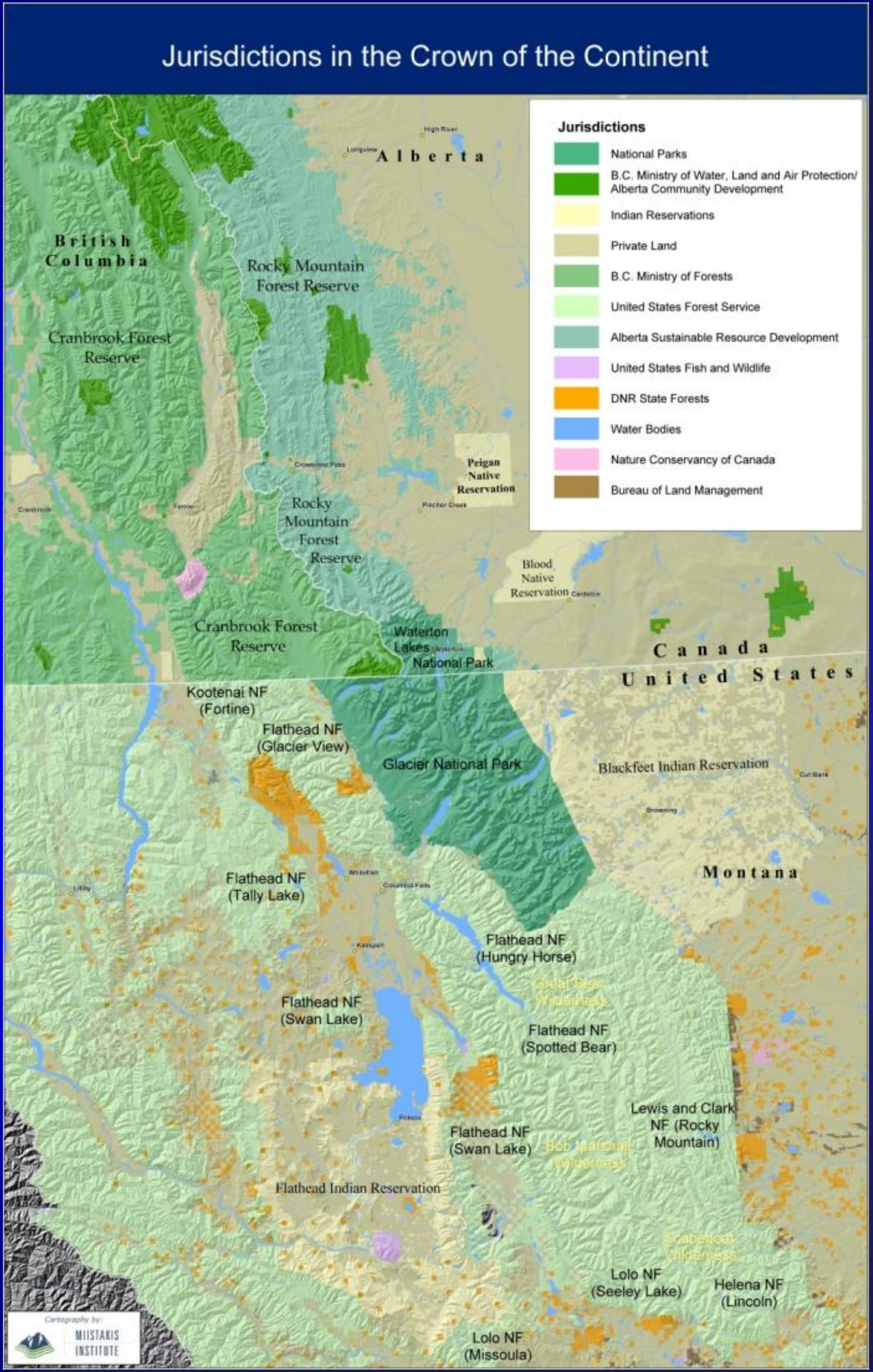
International Biosphere Reserve

World Heritage Site


Riparian
Bank full channel
Terraces
Floodplain
Parafluvial
pb
Bedrock
Hyporheic
Phreatic
Paleochannel
Fissure

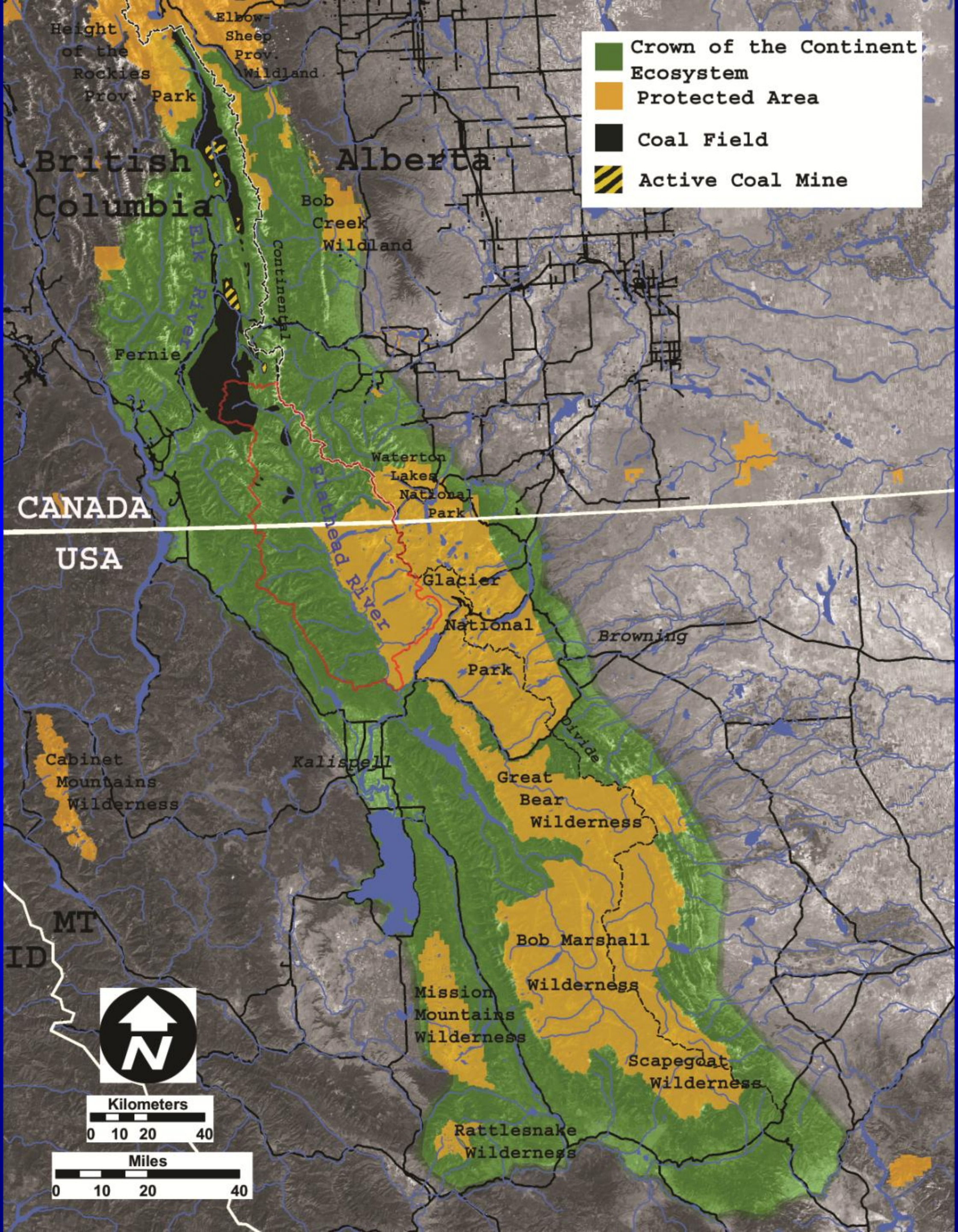
Crown of the Continent Ecosystem

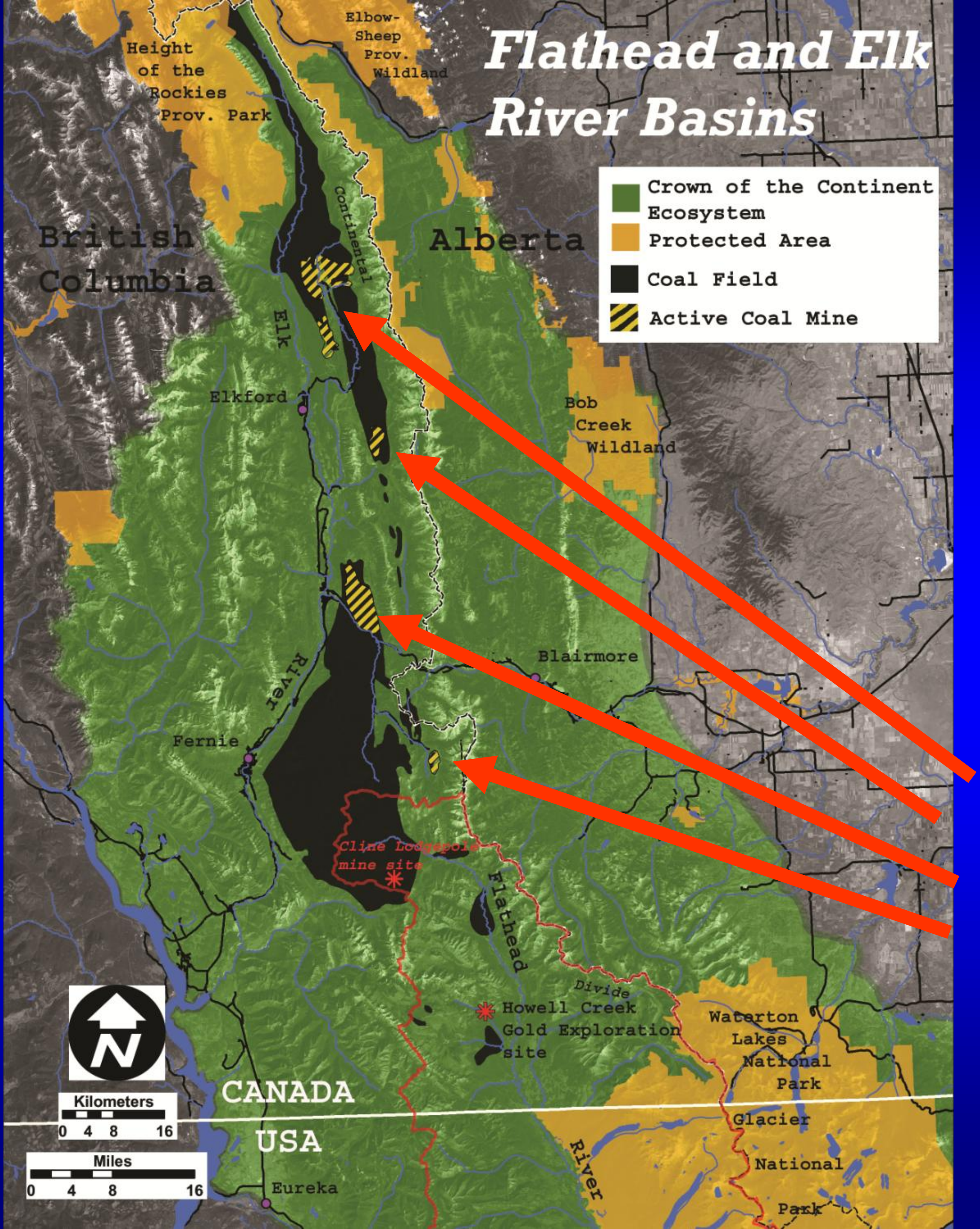
- **Coal Mining and the Flathead – Elk**
- **Implications of the Data**
- **Mitigation Strategies**



Coal Mining in the East Kootenai Coal Fields

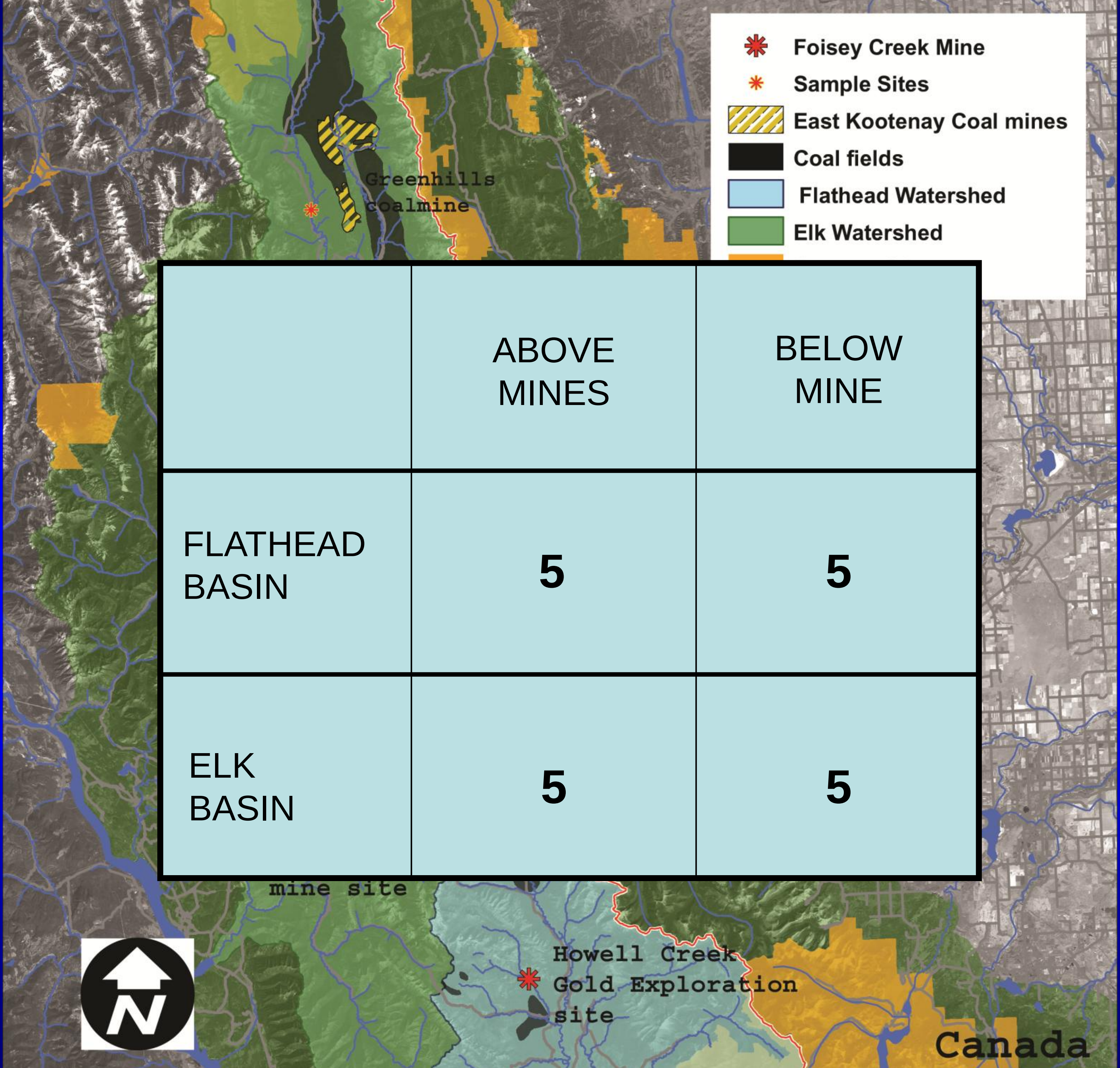
and the Flathead – Elk Basins





Elk Valley Coal Mines

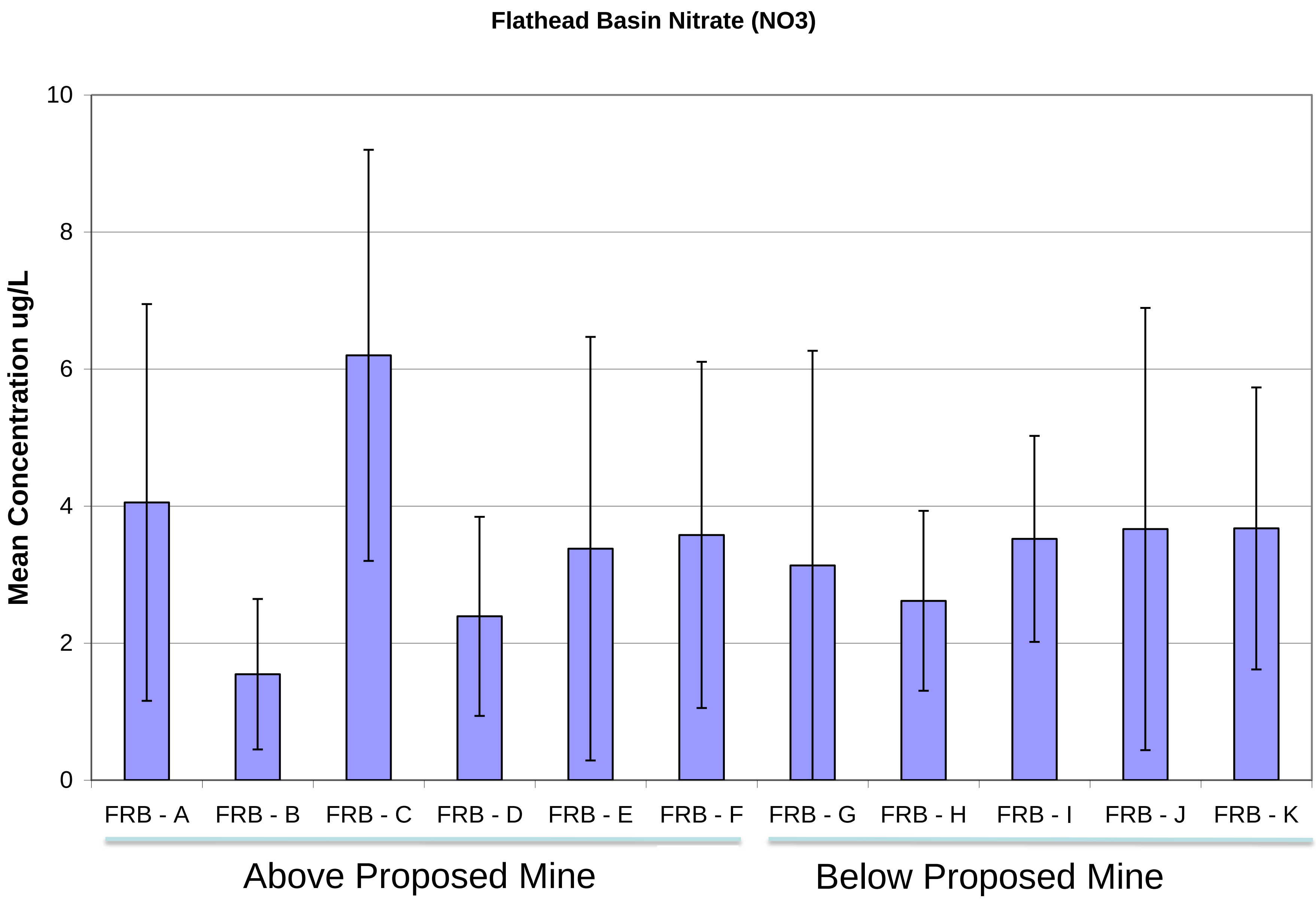
Elk Valley Mines

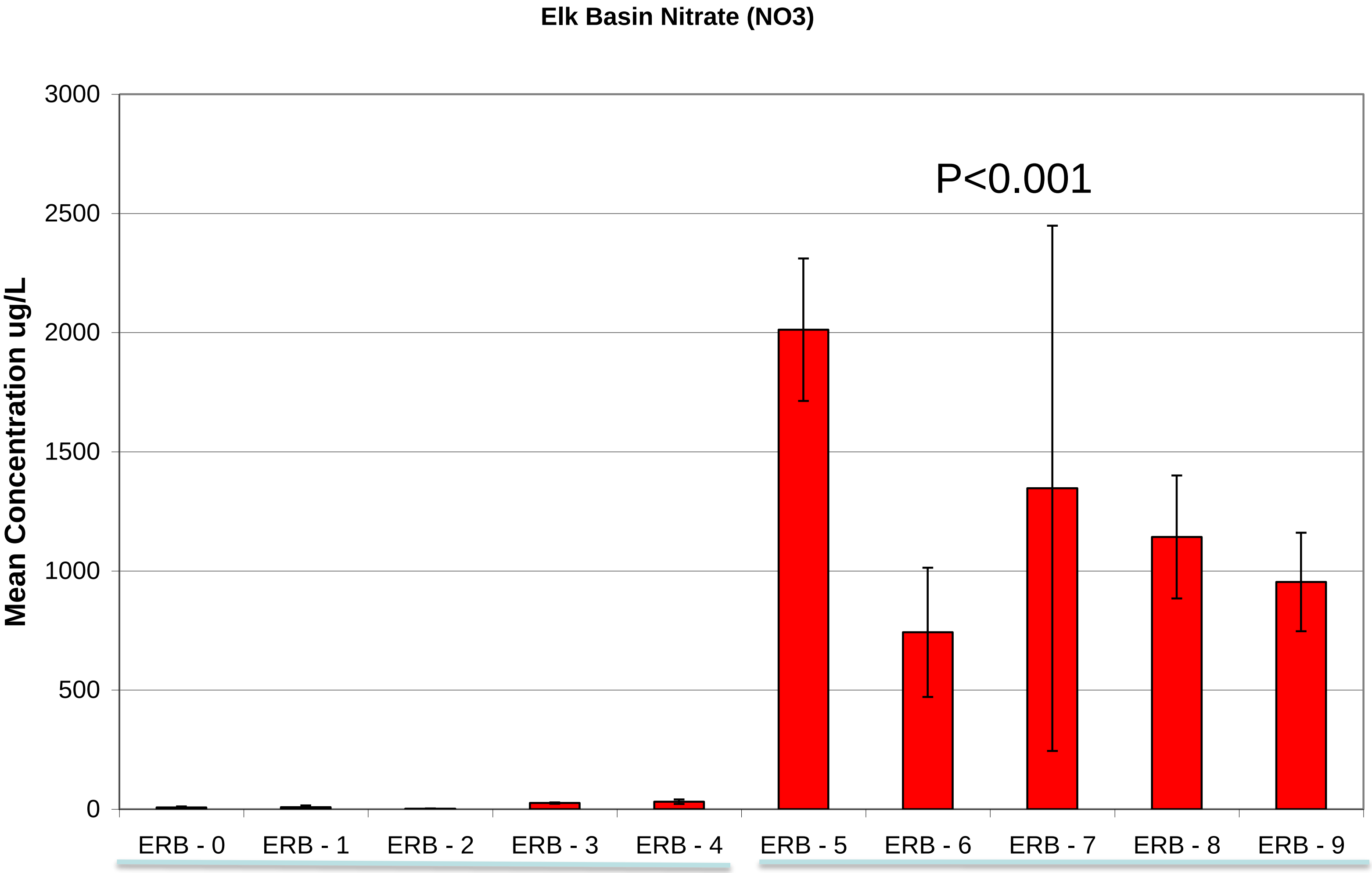


	ABOVE MINES	BELOW MINE
FLATHEAD BASIN	**5**	**5**
ELK BASIN	**5**	**5**

WATER QUALITY

- Nitrogen
- Sulfates
- Selenium

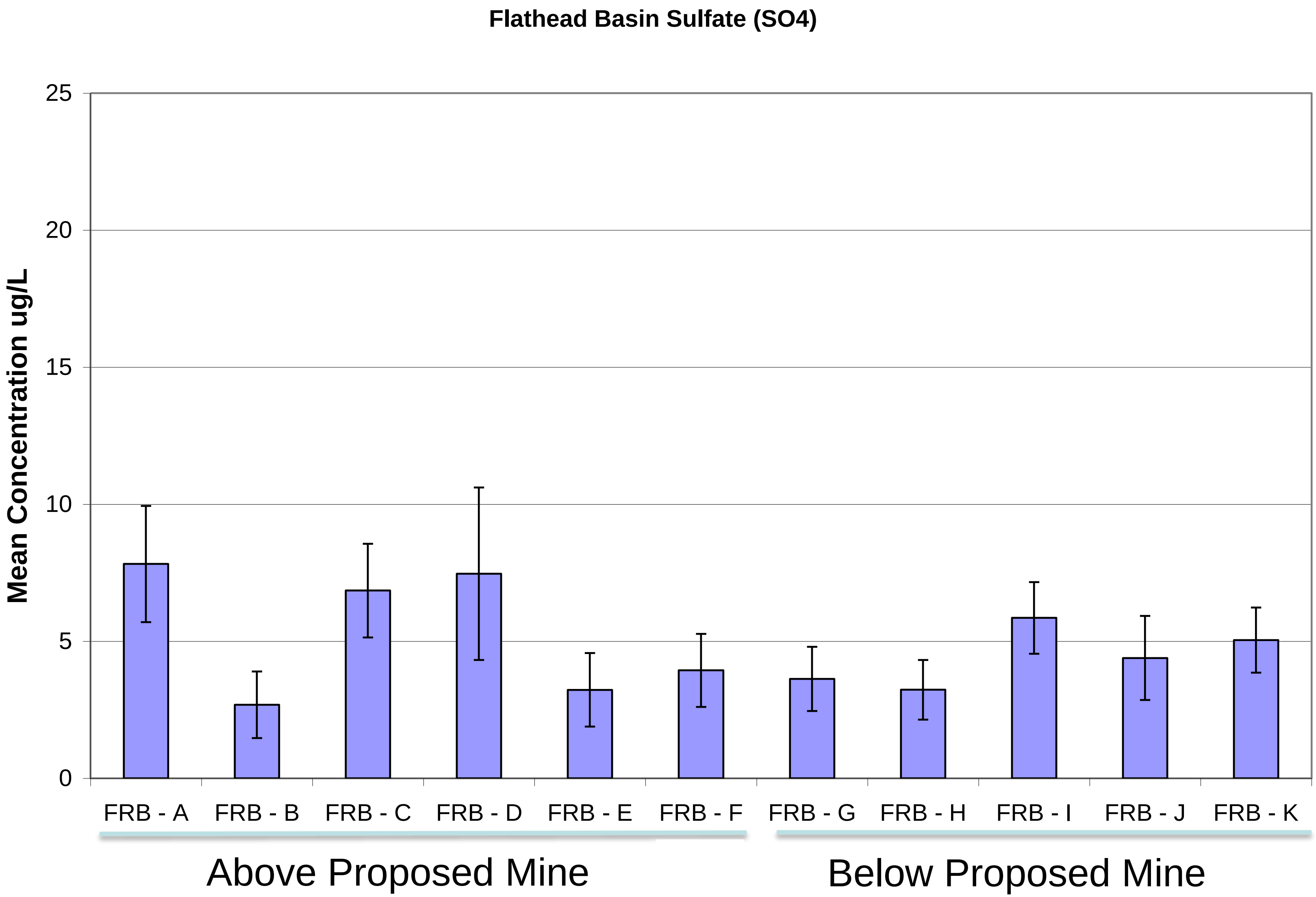

Flathead Basin Nitrate (NO3)
Mean Concentration ug/L
10
8
6
4
2
0
FRB - A
FRB - B
FRB - C
FRB - D
FRB - E
FRB - F
FRB - G
FRB - H
FRB - I
FRB - J
FRB - K
Above Proposed Mine
Below Proposed Mine



P<0.001

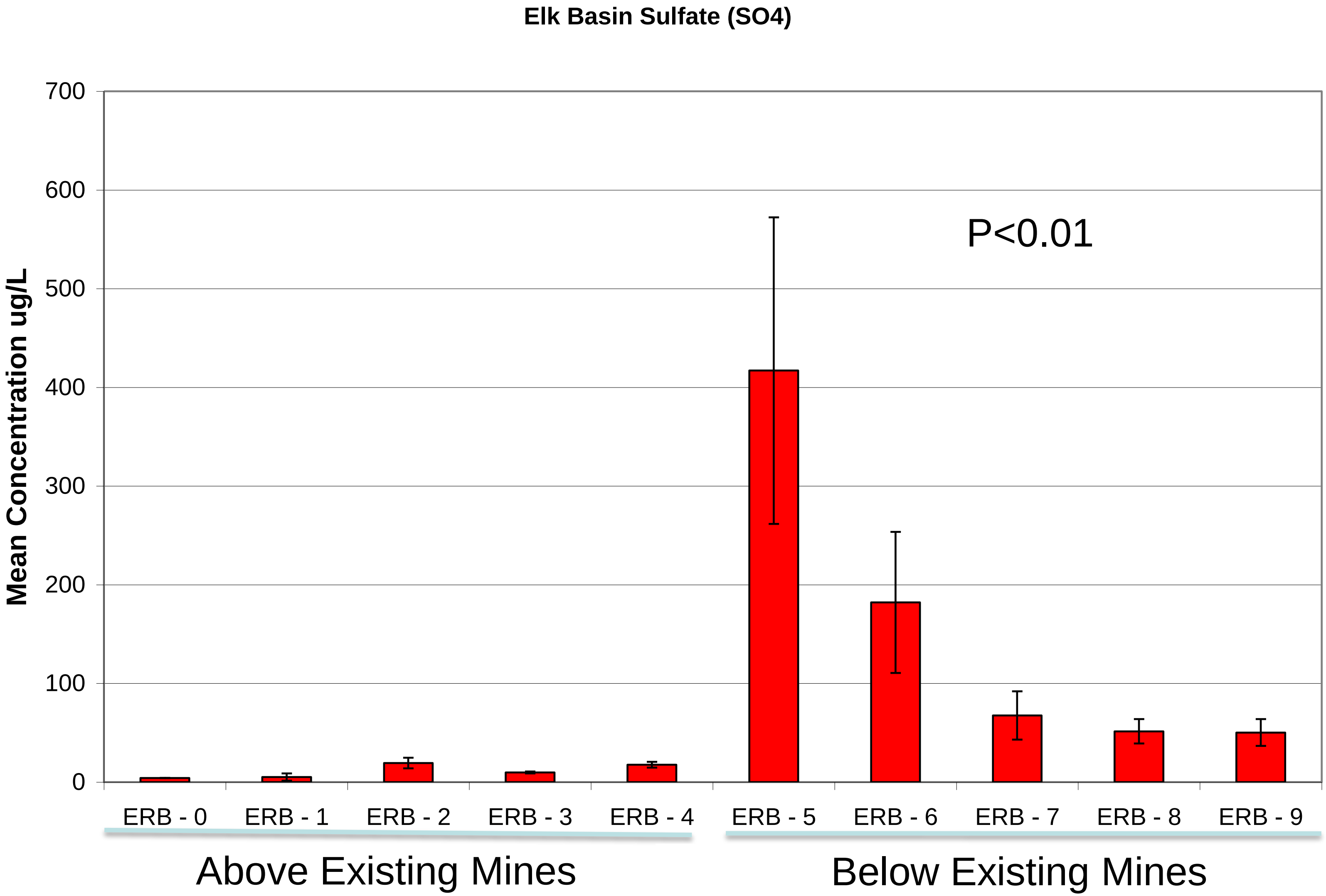
Above Existing Mines

Below Existing Mines

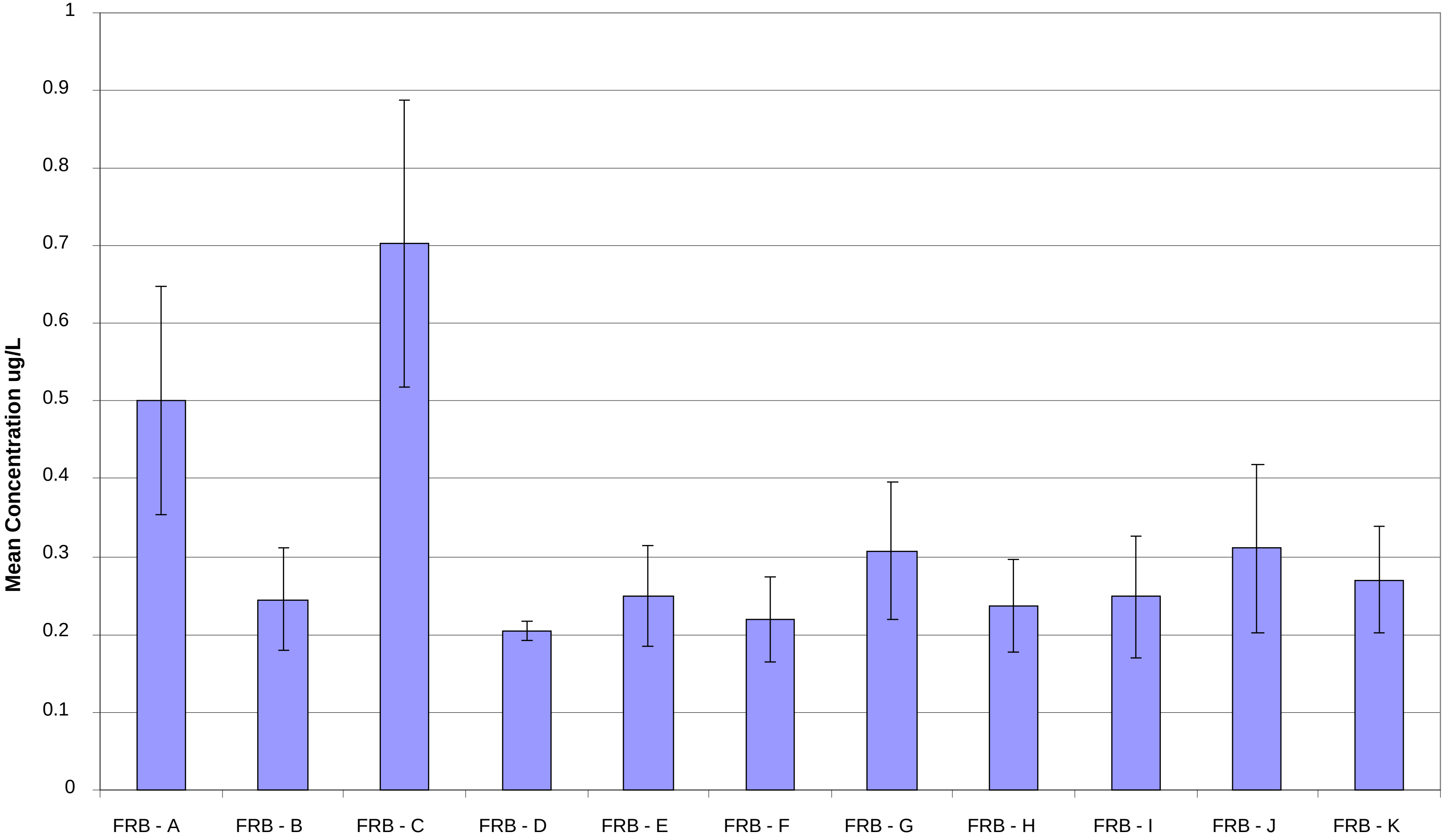


Above Proposed Mine

Below Proposed Mine

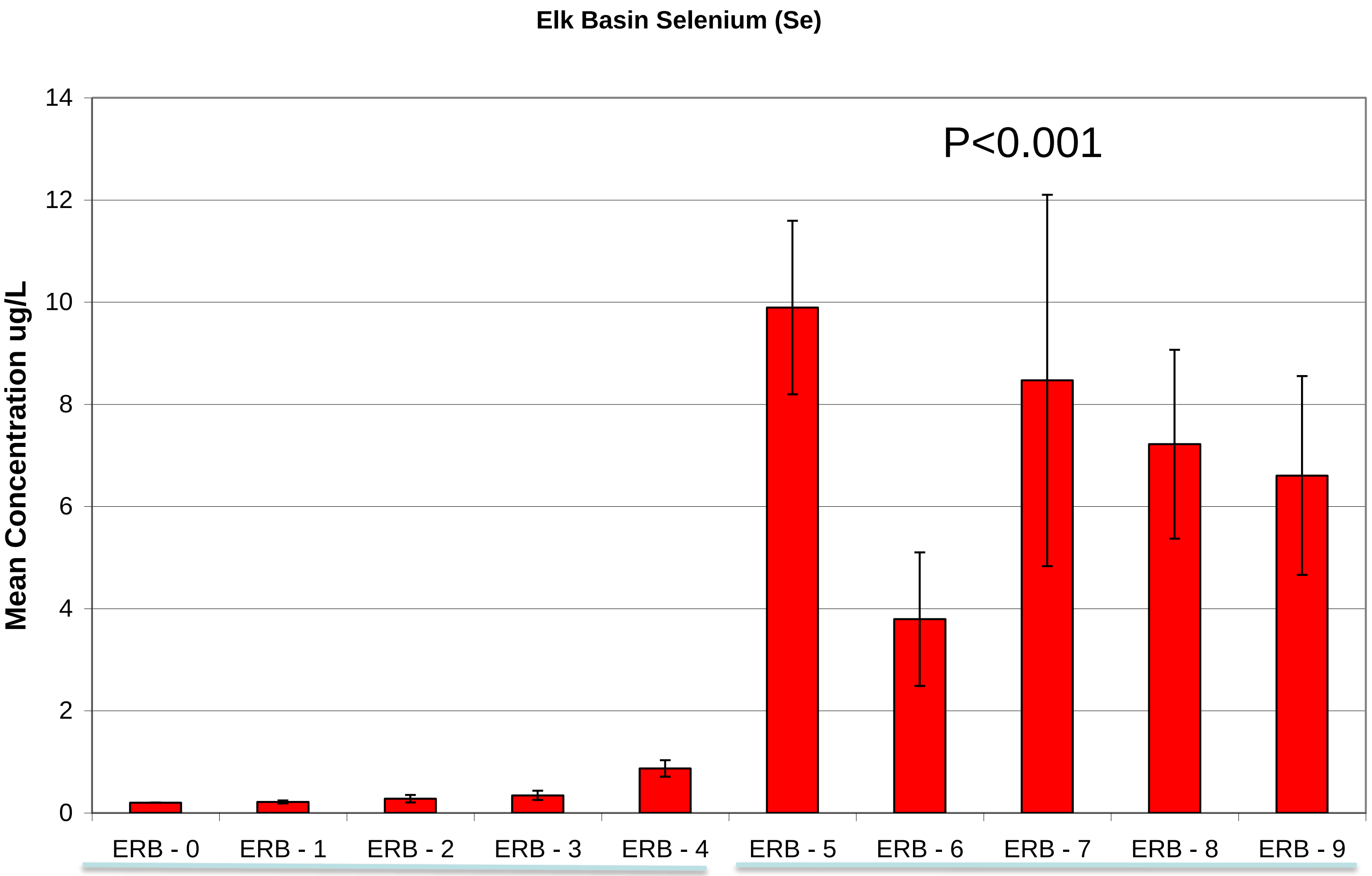

Elk Basin Sulfate (SO4)
Mean Concentration ug/L
700
600
500
400
300
200
100
0
P<0.01
ERB - 0
ERB - 1
ERB - 2
ERB - 3
ERB - 4
ERB - 5
ERB - 6
ERB - 7
ERB - 8
ERB - 9
Above Existing Mines
Below Existing Mines

Flathead Basin Selenium (Se)



Above Proposed Mine

Below Proposed Mine



Above Existing Mines

Below Existing Mines

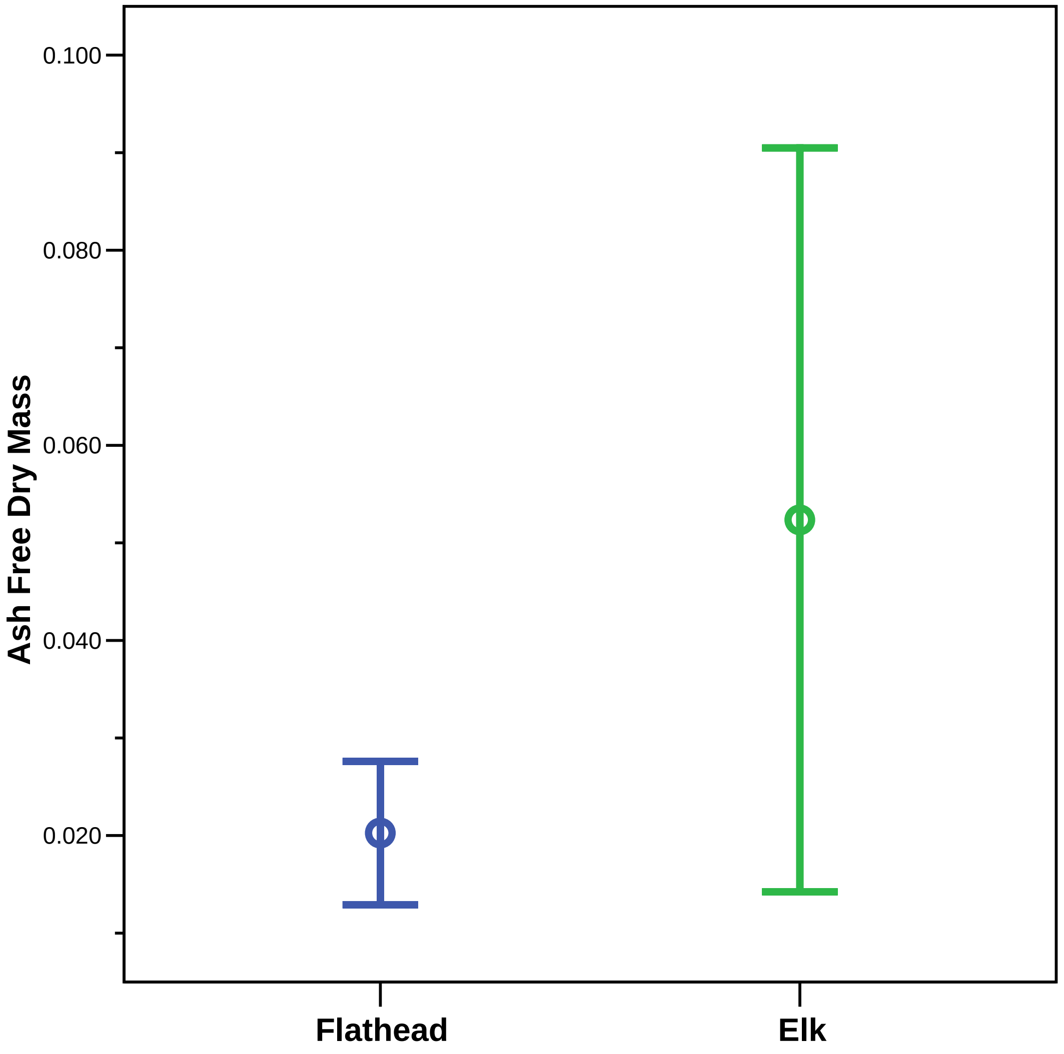
Aquatic Life

- **Algae**


NABS (www.benthos.org)

- **Macroinvertebrates**

Biomass g/cm^2



P=0.092

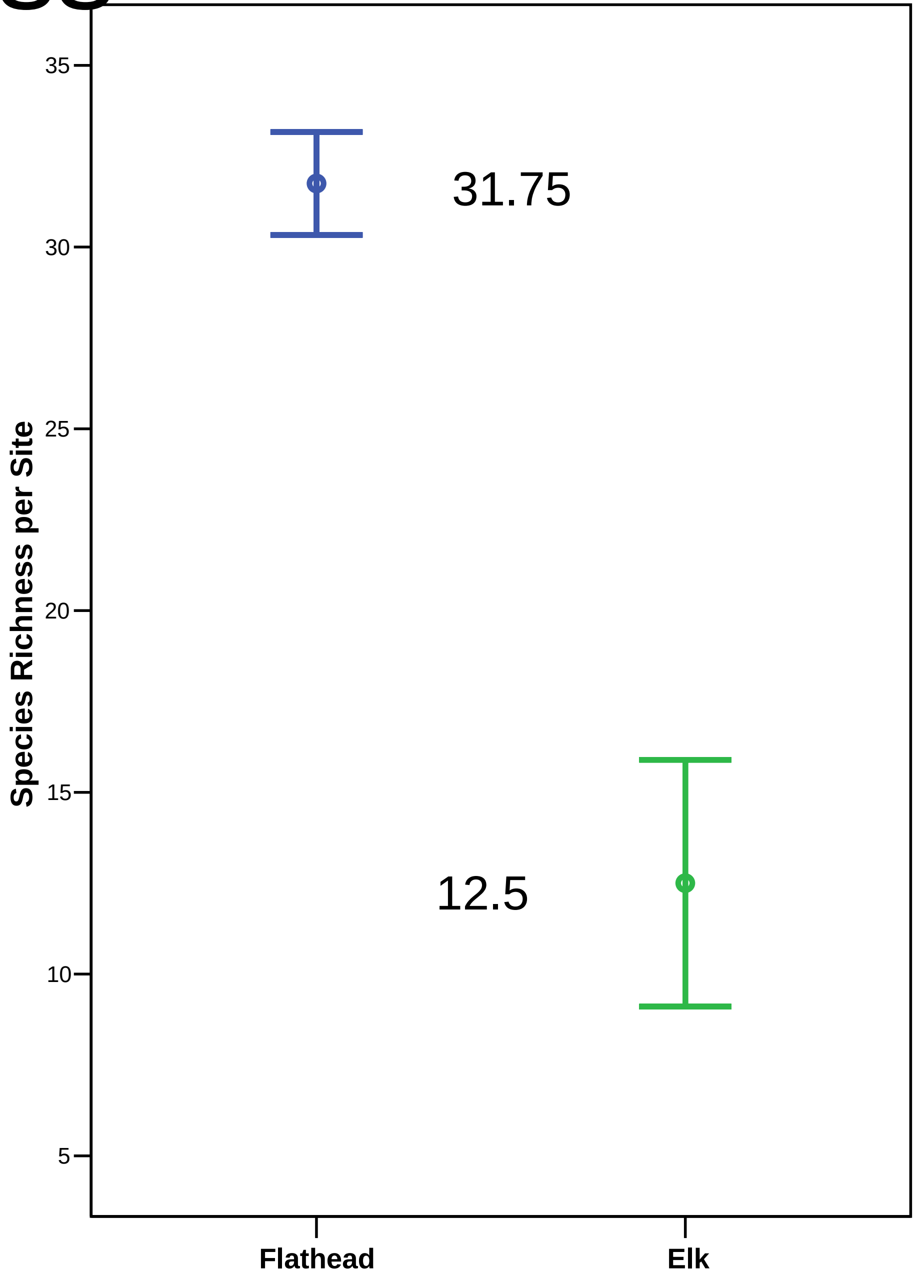
Species Richness

P<0.001

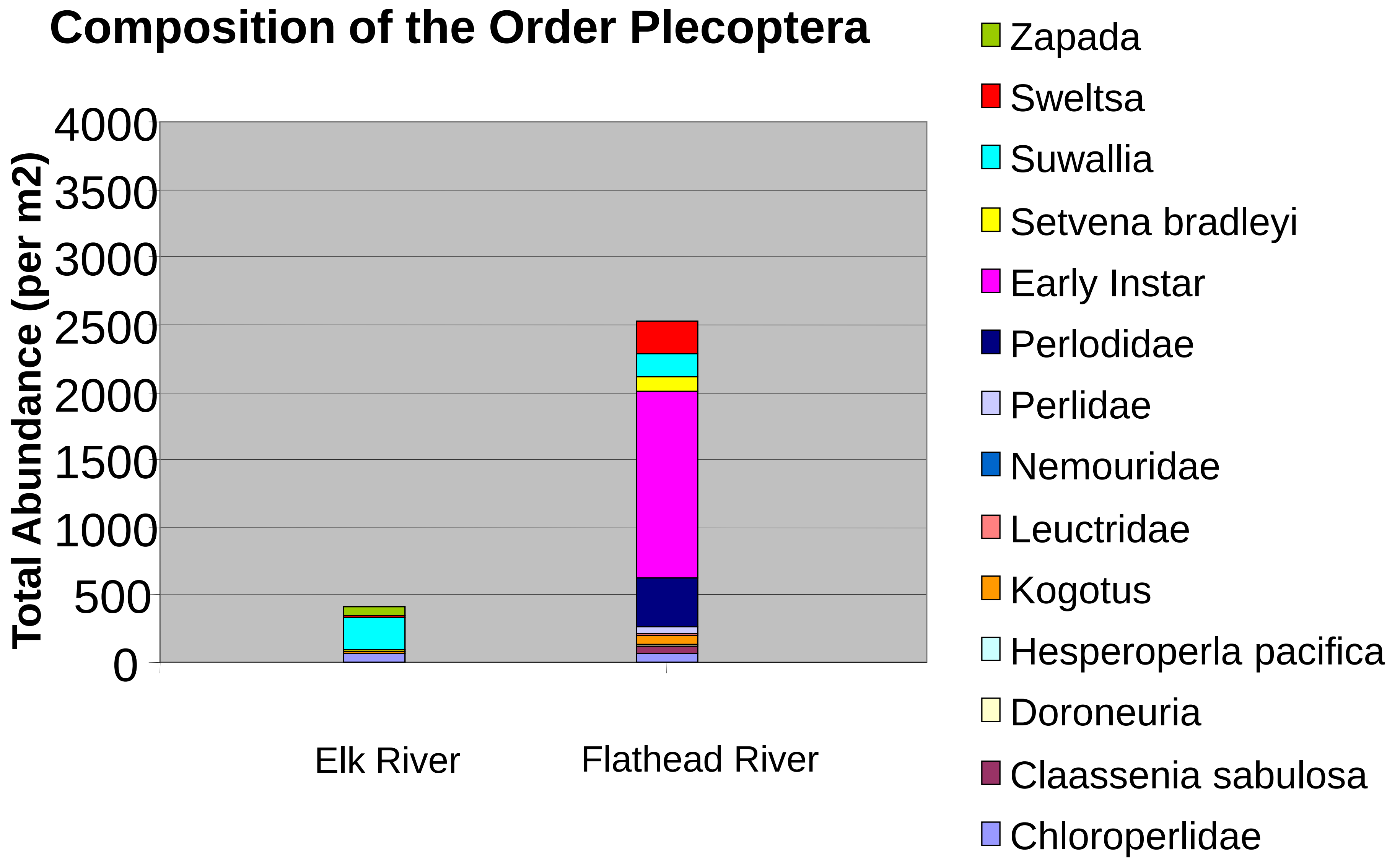
Species Totals

Flathead - 74

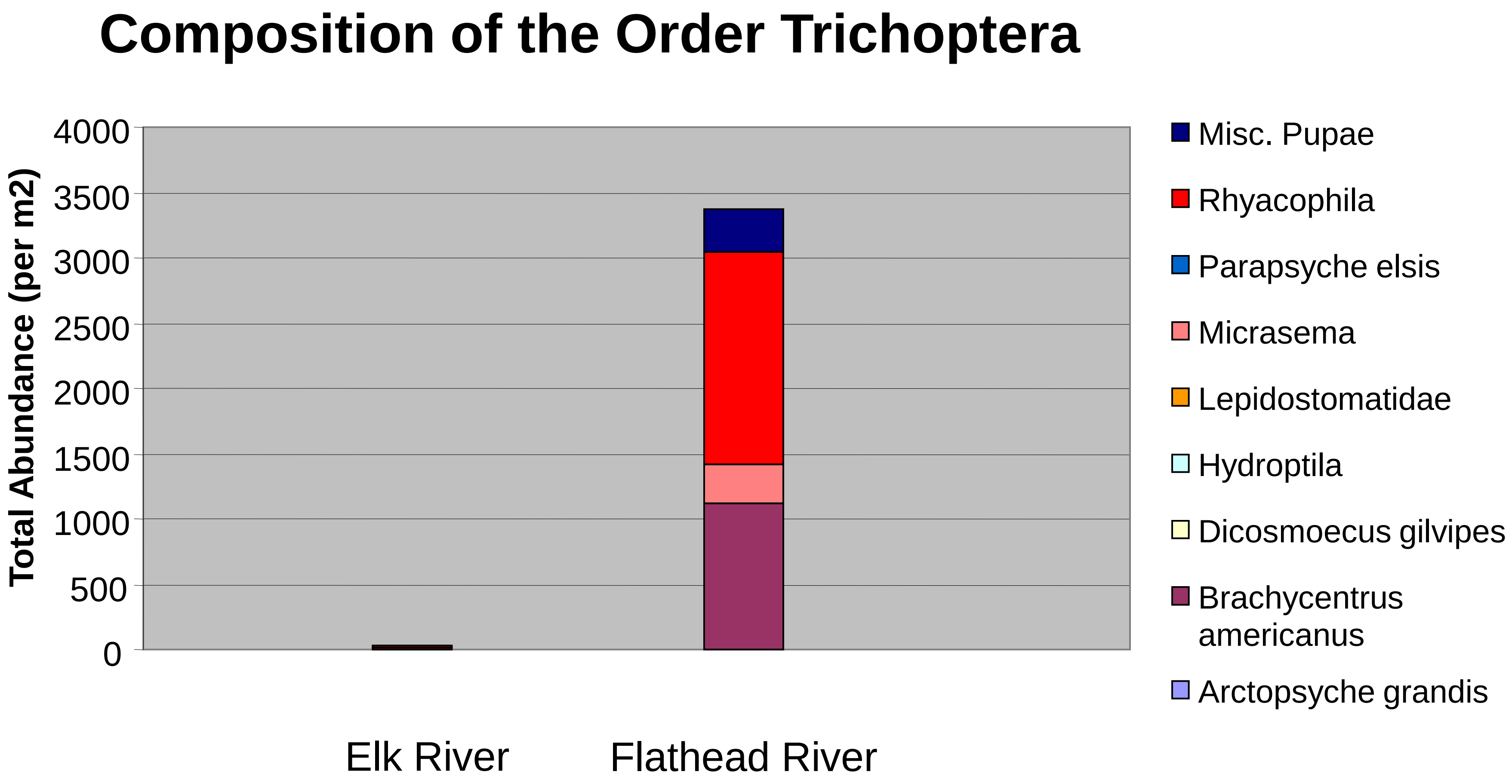
Elk - 18



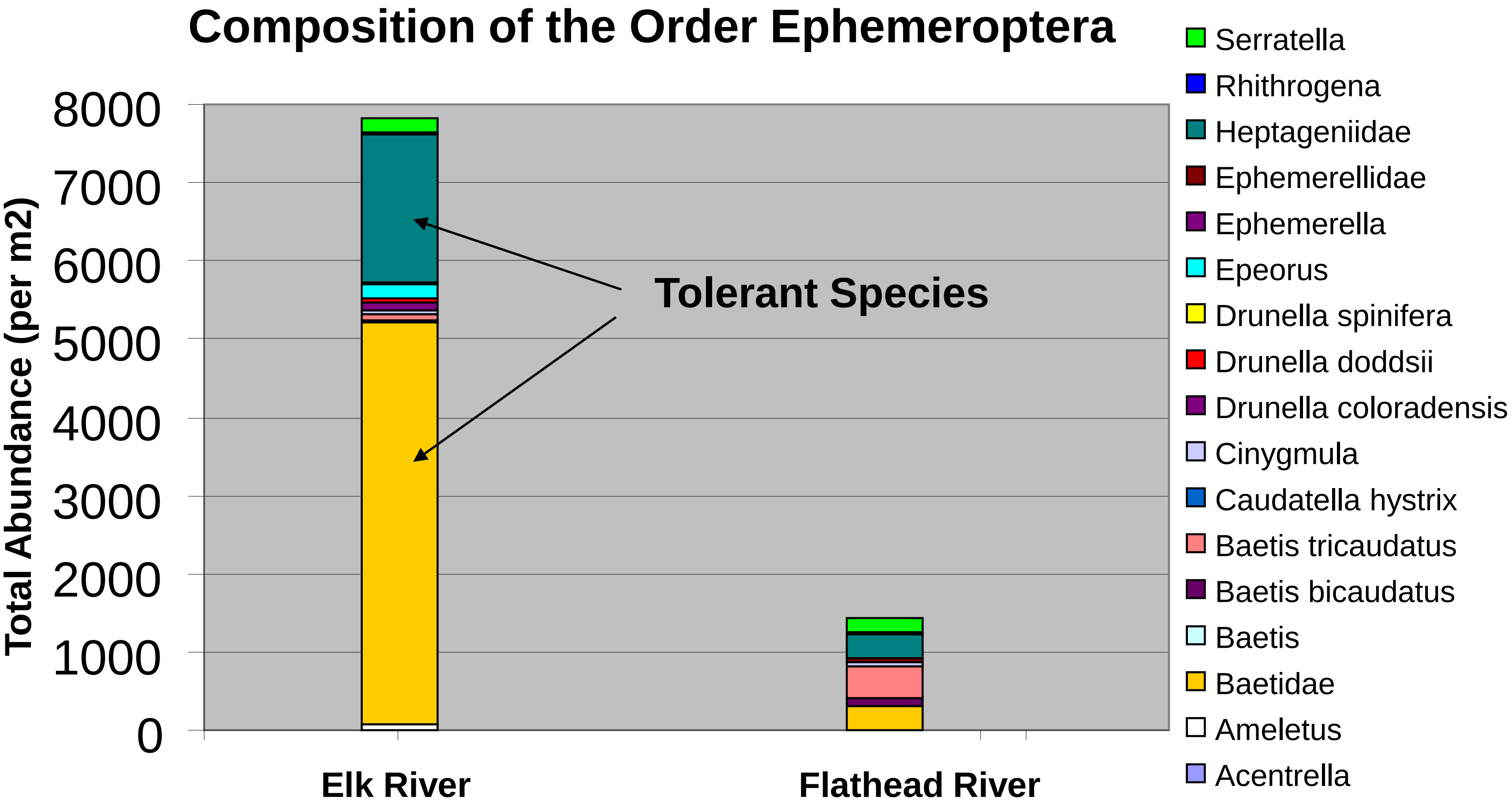
Stoneflies


Composition of the Order Plecoptera
Total Abundance (per m2)
4000
3500
3000
2500
2000
1500
1000
500
0
Elk River
Flathead River
Zapada
Sweltsa
Suwallia
Setvena bradleyi
Early Instar
Perlodidae
Perlidae
Nemouridae
Leuctridae
Kogotus
Hesperoperla pacifica
Doroneuria
Claassenia sabulosa
Chloroperlidae

Caddisflies



Mayflies

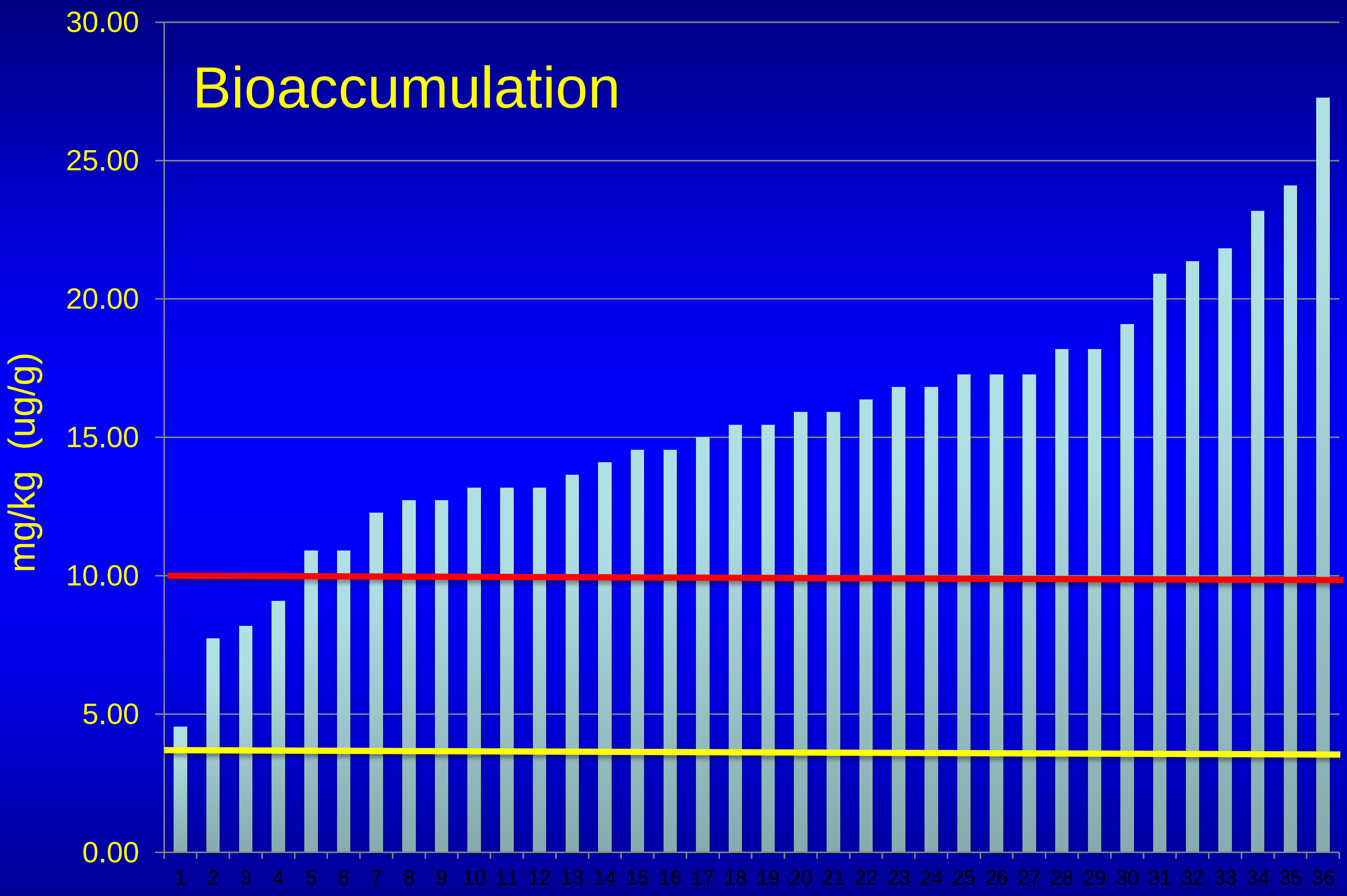

Composition of the Order Ephemeroptera
Total Abundance (per m2)
8000
7000
6000
5000
4000
3000
2000
1000
0
Tolerant Species
Elk River
Flathead River
Serratella
Rhithrogena
Heptageniidae
Ephemerellidae
Ephemerella
Epeorus
Drunella spinifera
Drunella doddsii
Drunella coloradensis
Cinygmula
Caudatella hystrix
Baetis tricaudatus
Baetis bicaudatus
Baetis
Baetidae
Ameletus
Acentrella

Selenium Toxicity

- Symptoms of chronic selenium poisoning …… fish included, (1) telangiectasia (swelling of gill lamellae); (2) elevated lymphocytes; (3) reduced hematocrit and hemoglobin (anemia); (4) corneal cataracts; (5) exopthalmus (popeye); (6) pathological alterations in liver, kidney, heart, and ovary; (7) reproductive failure (reduced production of viable eggs due to ovarian pathology, and post-hatch mortality due to bioaccumulation of selenium in eggs); and (8) deformities of the spine, head, mouth, and fins. Recommended ecologically relevant maximum concentration (**about 4 µg/g or less**)

- Selenium poisoning in fish can be ‘invisible’, because, the primary point of impact is the egg, which receives selenium from the female's diet (whether consumed in organic or inorganic forms), and stores it until hatching, whereupon it is metabolized by the developing fish. If concentrations in eggs are great enough (**about 10 µg/g or greater**) biochemical functions may be disrupted, and deformity and death may occur.

Bioaccumulation



Implications of the Data

Mining Condition

Degraded Water Quality

- Highly significant increase in nitrate pollution

  (500 – 1000x NO_3)

- Significant increase in sulfate pollution

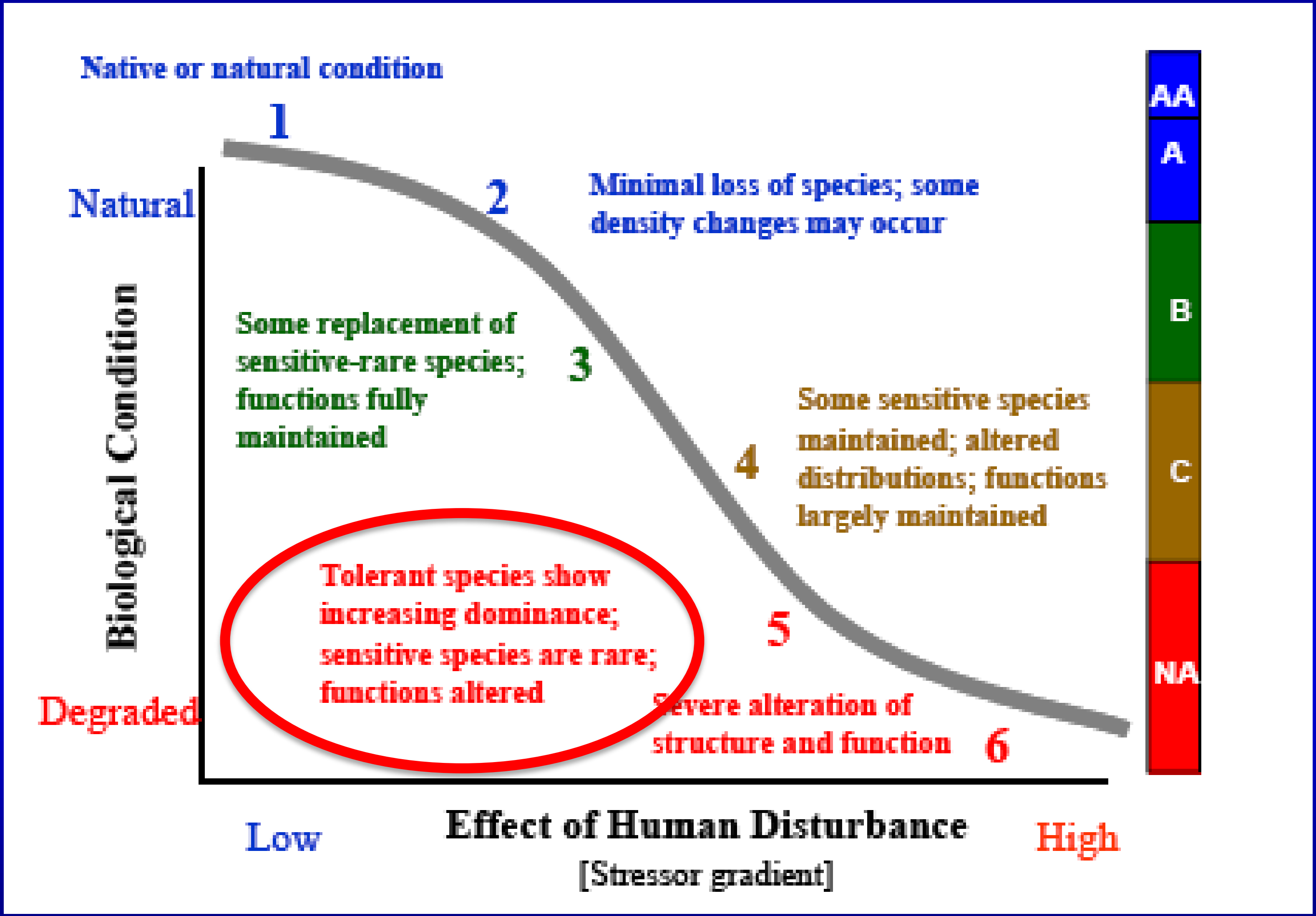
  (>50 – 100x SO_4)

- Significant increase in selenium pollution

  (>15 – 30x Se)

- Significant decrease in sensitive species
- Significant increase in tolerant species
- Selenium Bioaccumulation in Fish

EPA – Tiered Aquatic Life Use

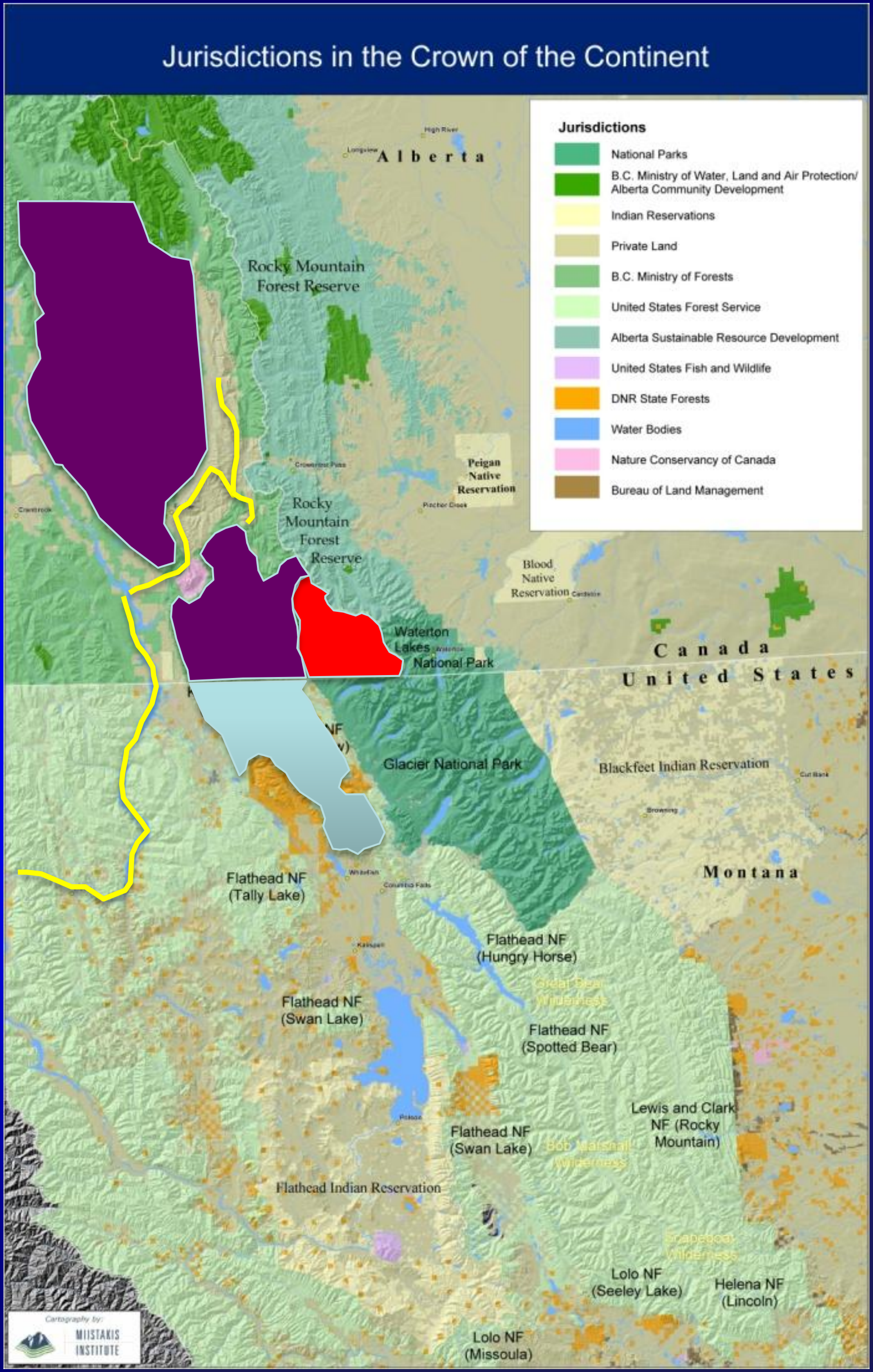


Mitigation Strategies

Remediation/reduction of Selenium and Sulfate pollution – mitigating for current effects

Compensatory Mitigation -

Enhancement of Regional Ecological Integrity



Jurisdictions in the Crown of the Continent