OVERVIEW OF SELENIUM IN SURFACE WATERS, SEDIMENT AND BIOTA IN RIVER BASINS OF WEST-CENTRAL ALBERTA

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ABSTRACT

This report includes the initial findings of a study begun in spring 1999. The study was designed to obtain data on the concentrations of selenium in surface water, sediment and aquatic biota at about 30 sites, including areas upstream (reference sites) and downstream of four coal mines located in west-central Alberta. Sample sites were mostly in lotie systems, but also included an end pit lake and a reference lake.

Data from all surveys showed low concentrations of selenium in water at the reference sites. Most of these concentrations were less than the CCME water quality guideline for the protection of freshwater aquatic life. The highest selenium concentrations, often an order of magnitude greater than both the CCME and US-EPA chronic guidelines, were found at sites immediately downstream of 3 mines. Similar high concentrations of selenium were found in the end pit lake compared to the reference lake. Selenium concentrations generally decreased downstream of the mines. Almost all of the selenium in the water samples was in the dissolved form. Selenium concentrations in samples of littoral sediments were always higher in the pit lake than in the reference lake.

Selenium concentrations in rainbow trout eggs were greater than in muscle. Selenium in eggs was positively related to selenium in muscle tissues. With few exceptions, the lowest concentrations of selenium in muscle and eggs were found at the reference sites compared to the remaining sites. Greatest mean concentrations of selenium in both muscle and egg tissues were found at the pit lake and stream site closest to one mine. Mean selenium concentrations in rainbow trout muscle and eggs showed a positive correlation with selenium concentrations in surface waters.

INTRODUCTION

This study includes the initial findings of a study begun in spring 1999 by Alberta Environment (AENV). The study was designed to obtain data on the concentrations of selenium in surface water, sediment and aquatic biota at about 30 sites, including areas upstream (reference sites) and downstream of four coal mines. The mines, Cardinal River Coals Ltd. (CRC), Gregg River and Coal Valley mines owned by Luscar Ltd. and Smoky River Coal Ltd., aie located in west-central Alberta. Sample sites were located in the McLeod, Lovett, Pembina and Smoky river basins, and at Fairfax Lake, a reference lake, and Lac des Roches, an end pit lake at the CRC mine. The study is being conducted with the assistance of the coal mines. The main objectives of the study are: (1) to determine concentrations of selenium in surface waters and aquatic sediments in streams and lakes of the Gregg River, McLeod River, Lovett River and Smoky River systems, and (2) to document and assess selenium concentrations in fish and other aquatic biota at some of these locations.

STUDY APPROACH AND METHODS

Collection of samples was initiated in May 1999 to obtain seasonal data for selenium in surface waters and sediments of headwater streams, mainstem sites and lakes of the Gregg, McLeod, Pembina (primarily Lovett River) and Smoky River basins (Figures 1 and 2).

At most sites, grab samples of the surface water were taken once during spring, summer and fall. At each flowing-water site, a grab sample of water was taken in a well-mixed zone. A composite sample of the upper 1-2 cm of sediment was taken in depositional areas. Sampling of sediment was restricted to the fall during low flow conditions when sediment was more accessible. At Lac des Roches, an end pit lake, and Fairfax Lake, the reference lake, water and sediment samples were taken in spring and summer. At each lake, a composite sample of the upper water column was taken at several points (>6 sites) around the lake and a composite sample of cores of the upper 3-5 cm of sediment was taken from the littoral area. At Lac des Roches (maximum depth >100 m) discrete water samples were also taken at various depths throughout the water column. Conductivity, pH, dissolved oxygen and temperature were measured using field meters at all sites; profiles of these parameters were taken in the lakes.

Fish collections focussed on rainbow trout, a spring spawner, at a sub-set of the McLeod River basin sites. Fish samples were collected with different gear: a Smith-Root type VII backpack electrofisher on Whitehorse and Luscar Creeks; a 14-foot raft equipped with a Smith-Root type 5.0 GPP electrofishing unit on the McLeod and Gregg River mainstem sites; and gill nets in Fairfax Lake. Whenever possible, mature gravid females were taken for tissue samples. Skeletal muscle and egg samples from rainbow trout were collected in late May to early June, 1999. The fish were placed on ice immediately following field collection and transported to the laboratory where measurements of fork length and weight were taken. Each specimen was classified for sexual maturity, and otoliths and scales were removed to determine the age of the fish. Tissue samples from the fish were removed using a high carbon steel knife and forceps. Individual fillets and ovaries/eggs were removed, placed in individual whirlpack bags, labeled and frozen immediately. The samples were kept frozen until they were analysed. Eggs from seven bull trout were collected from mature gravid females in Mackenzie Creek during September, 1999. At this time bull trout migrate up Mackenzie

Creek from the McLeod River to spawn. Egg samples were stripped from females into whirlpack bags in the field, labeled, placed on ice and then frozen until they were analysed. Field measurements of bull trout included total length and classification of sexual maturity.

In addition to fish, benthic macroinvertebrates, biofilm and aquatic plants were sampled at some McLeod River and Gregg River sites during early October. Results of these samples are not presented in this report because they have not been fully analysed at this time.

Analysis of selenium and total suspended sediment (TSS) was conducted at the Alberta Research Council (ARC), Vegreville. Water samples were analysed for total recoverable and dissolved selenium, and TSS. Sediment and biological samples were analysed for total selenium (acid extraction). Selenium was measured using inductively coupled plasma mass spectrometry (ICP-MS). The detection limits were 0.5 μg/L in water and <0.5 μg/g in sediment and biological tissues. Total organic carbon and size fractions of the sediment samples were analysed by Maxxam Analytics Ltd., Calgary. Samples for quality assurance (triplicate-split and field blank water samples) were included in the field program. Additional quality assurance, including the analysis of spiked samples and replicates of water, sediment and biological samples, was carried out at the ARC laboratory.

RESULTS AND DISCUSSION

Quality assurance results (blank and triplicate-split samples taken in the field, and the spiked and replicate samples in the lab) showed the accuracy and precision of the selenium data in this project were well within those regularly achieved by AENV monitoring, and are considered satisfactory (results are given in Casey and Siwik 2000).

Surface Waters

Currently, the Canadian (CCME 1999) and US-EPA (US-EPA 1999) guidelines are used as general guidance for evaluating surface water quality for the protection of freshwater aquatic life in Alberta (AENV 1999). Total recoverable selenium concentrations at 11 reference (background) sites ranged from <0.5 to 2.2 μg/L (Table 1). Three out of the 32 samples (9.4%) at the reference sites were greater than the CCME guideline of 1 μg/L (Table 1). The remaining 21 sites in the study were downstream of active coal mines and the limestone quarry at Cadomin (Table 1). The highest concentrations of total recoverable selenium, up to a maximum of 47.1 μg/L and all more than the US-EPA chronic guideline of 5 μg/L, were found in Luscar, Berry's, Falls, Sphinx and Beaverdam creeks, Gregg River and Lac des Roches (Table 1). These sites were downstream of the CRC, Gregg River and Smoky River mines (Figures 1 and 2).

In most streams where there were sample sites at an upstream reference area and downstream of mine disturbances, there was an increase of selenium concentrations in each season at the downstream site. These streams were Luscar Creek, Berry's Creek, Sphinx Creek, Gregg River, and Beaverdam Creek (Table 1). In Sheep Creek and Lovett River, there were small increases, decreases, or no change in the concentrations of selenium between sites upstream and downstream of the Smoky River and Coal Valley mines, respectively (Table 1). Selenium concentrations in the Muskeg River near the mouth were less than or close to the detection level (0.5 μg/L)(Table 1). This site was downstream of the Rood Creek fly ash disposal site which contains fly ash, bottom ash and reject material from the coal-fired power plant beside the Smoky River mine.

Evaluation of seasonal patterns in the concentrations of selenium at the flowing-water sites will be conducted after completion of sampling in winter 2000. However, at most sites where selenium concentrations were greater than 1 μg/L, the lowest concentrations often occurred in the spring, compared to the summer and fall (Table 1). The lower concentrations in spring may have been caused by dilution from higher runoff and flows. Concentrations of TSS were greater in spring than in summer and fall; average TSS concentrations were 28, 5 and 1 mg/L, respectively. The higher TSS concentrations in spring were likely caused by higher runoff and flows. Therefore, selenium concentrations did not appear to be affected by TSS in the water column. Preliminary data from ARC indicate that in spring, summer and fall 1999, the selenium in water samples was almost entirely in the dissolved form.

Sediment in Lakes

In spring and summer, 1999, sediments were sampled from the littoral zone (<2 m depth) of Fairfax Lake and Lac des Roches. Selenium concentrations in all samples from Lac des Roches (range = 6.0 to 11.1, n=4) were greater than in Fairfax Lake (range = <0.2 to 1.1, n=6).

Rainbow Trout Tissues

The following summarises data for rainbow trout *(Oncorhynchus mykiss)* collected from two mainstem sites and four tributaries of the McLeod River, and two lakes in spring 1999.

Most fish were females (85%) and even though all fish were of different ages and stages of maturity, patterns in concentrations of selenium in fish tissues were found (original data tables are in Casey and Siwik 2000). Selenium concentrations in rainbow trout ranged from 0.13 to 9.34 μg/g wet weight in muscle and from 0.02

to 28.90 µg/g wet weight in eggs at all sites (Casey and Siwik 2000). For 42 out of 43 fish, there was a greater concentration of selenium in eggs compared to muscle from the same fish (Casey and Siwik 2000). Selenium concentrations in muscle and eggs showed a strong positive relationship ($r^2 = 0.72$, $p<0.01$, regression analysis).

With few exceptions, the lowest concentrations of selenium in muscle and eggs were found at the reference sites, Wampus Creek, Whitehorse Creek and Fairfax Lake, compared to the remaining sites downstream of mines (Figure 3). At Whitehorse Creek, the concentration of selenium in the eggs of three of five females were at least an order of magnitude greater than egg concentrations in the remaining fish from the other reference sites (Casey and Siwik 2000). These high egg concentrations may have been caused by migratory movements of the fish from areas with elevated selenium concentrations in the water and food. For example, there is evidence that rainbow trout in the McLeod River will migrate into the lower reaches of some of the larger tributaries, and that rainbow trout in small tributaries, such as Wampus Creek, are mostly resident (Sterling 1980).

Greatest mean concentrations of selenium in both muscle and egg tissues were found at the two sites close to the CRC mine, Lac des Roches and Luscar Creek (Figure 3). At the three remaining sites downstream of the CRC and Gregg River mines, greatest mean selenium concentrations in tissues were in the Gregg River and McLeod River, in a 1.5 km reach, immediately downstream of the confluence with the Gregg River (Figure 3).

Mean selenium concentrations in rainbow trout muscle and eggs showed a positive correlation with selenium concentrations in water samples taken about the same time (muscle: $r=0.88$, $p<0.08$; eggs: $r=0.85$, $p<0.02$). Fish results from the McLeod River site downstream of the Gregg River were not included in this analysis because a water sample was not taken at the site.

SUMMARY OF FINDINGS

Data from all surveys showed low concentrations of selenium in water at the reference sites. Most of these concentrations were less than the CCME water quality guideline for the protection of freshwater aquatic life. The highest selenium concentrations, often an order of magnitude greater than both the CCME and US-EPA chronic guidelines, were found at sites immediately downstream of 3 mines. Similar high concentrations of selenium were found in the end pit lake compared to the reference lake. Selenium concentrations generally decreased downstream of the mines. Almost all of the selenium in the water samples was in the dissolved form. Selenium concentrations in samples of littoral sediments were always higher in the end pit lake than in the reference lake.

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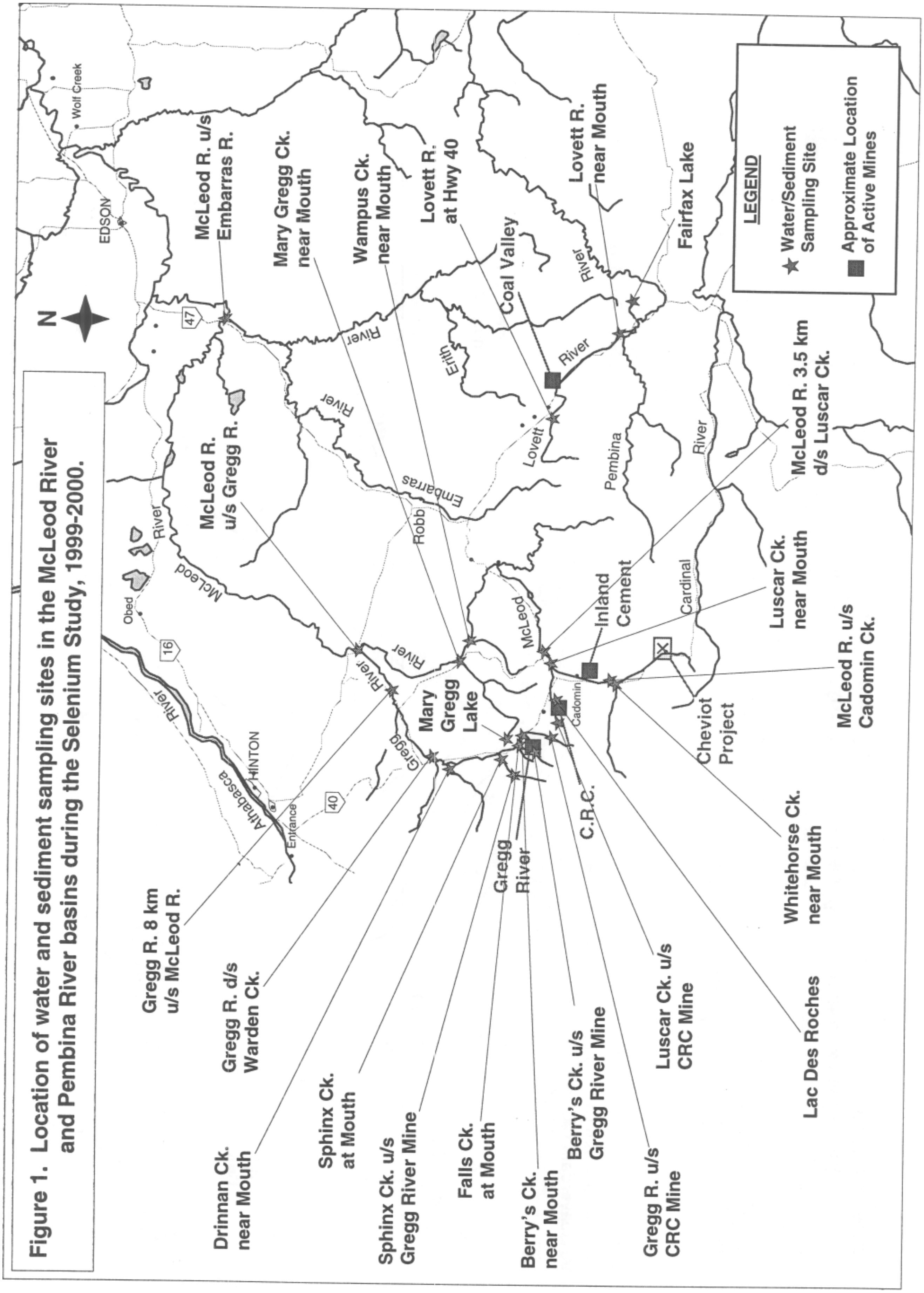

Figure 1. Location of water and sediment sampling sites in the McLeod River and Pembina River basins during the Selenium Study, 1999-2000.

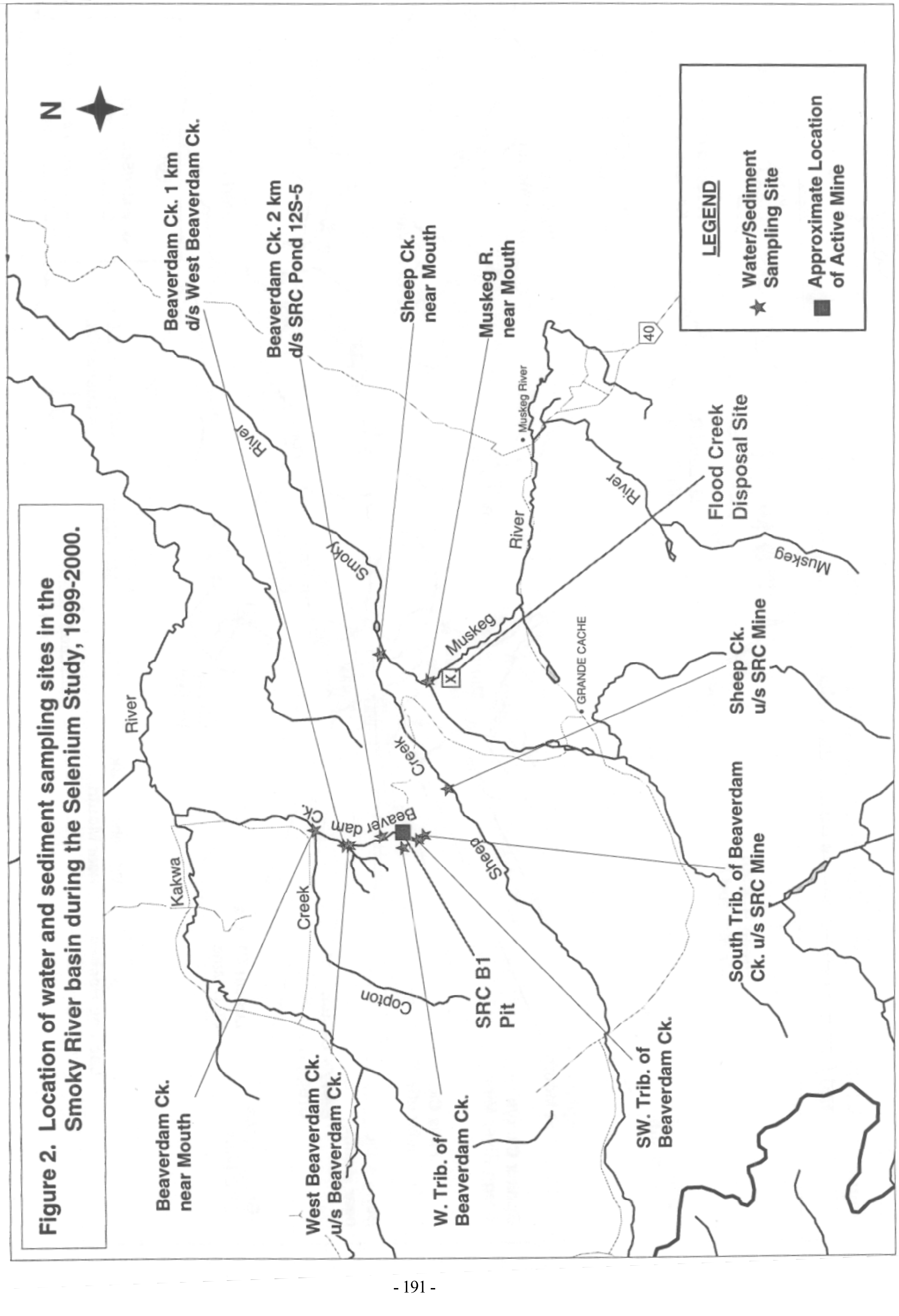

Figure 2. Location of water and sediment sampling sites in the Smoky River basin during the Selenium Study, 1999-2000.

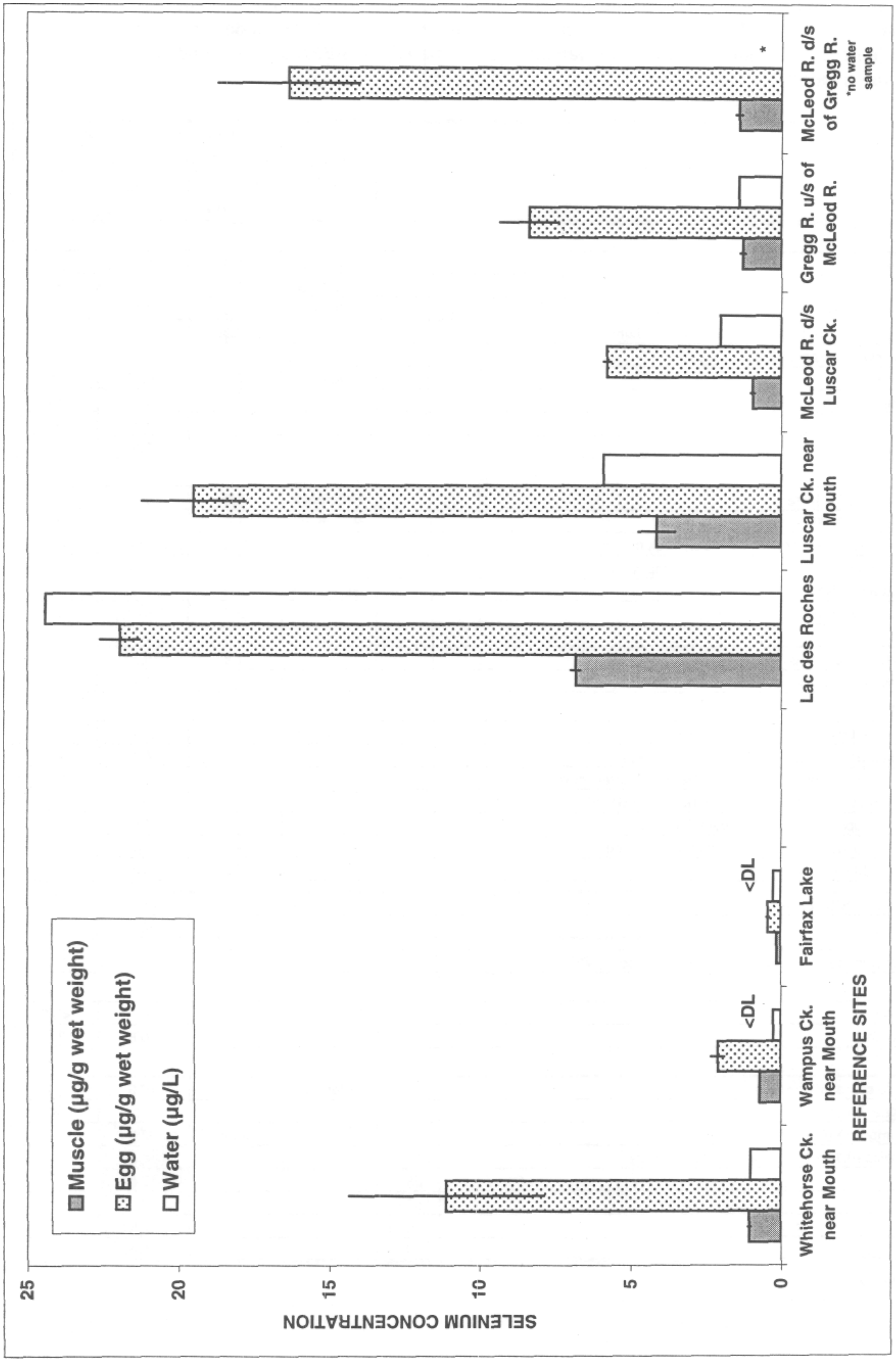

Figure 3. Concentrations of selenium in rainbow trout muscle and egg tissues (mean ± standard error), and in water in spring 1999. Selenium concentrations were less than the detection level (DL = 0.5 µg/L) in Wampus Creek and Fairfax Lake.

Table 1. Concentrations of selenium in surface waters at sites close to active coal mines in the Northern East Slopes Region (AENV), 1999. Concentrations greater than the CCME guideline of 1 ug/L are shown in bold, and concentrations of selenium greater than the US-EPA chronic guideline of 5 ug/L are shaded.

Sample Site 1999	Type of Site	Selenium Concentration (total recoverable) (µg/L)		
		Spring 19-21 May	Summer 27-30 July	Fall 4-7 Oct
McLeod River Basin				
Whitehorse Creek near mouth	Reference	1.0	0.6	0.8
McLeod River upstream of Cadomin Creek	Reference	0.8	0.7	0.7
Luscar Creek upstream of CRC Mine	Reference	0.6	**2.2**	**2.2**
Luscar Creek near mouth (d/s of Lac des Roches & CRC Mine)		**5.9**	**32.0**	**27.3**
McLeod River 3.5 km downstream of Luscar Creek		**2.0**	**4.2**	**6.0**
Wampus Creek near mouth	Reference	<0.5 *	<0.5	<0.5
Mary Gregg Creek near mouth		----	**2.5**	**2.7**
McLeod River upstream of Gregg River		<0.5	**1.6**	**1.8**
McLeod River upstream of Embarras River		0.5	**1.6**	**1.7**
Gregg River Basin				
Gregg River upstream of CRC Mine	Reference	0.5	0.5	0.8
Berry's Creek upstream of GRM	Reference	1.0	0.9	0.7
Berry's Creek near mouth (d/s of rock drains, waste rock dumps & ponds)		**18.8**	**10.4**	**12.7**
Falls Creek at mouth (d/s of rock drain, waste rock dump & ponds)		**21.3**	**47.1**	**29.2**
Sphinx Creek upstream of GRM	Reference	<0.5	0.5	0.8
Sphinx Creek at mouth (d/s of GRM & CRC Mine)		**2.7**	**5.2**	**3.6**
Drinnan Creek near mouth		----	0.6	<0.5
Gregg River d/s of Drinnan Creek & Warden Creek		**1.8**	**5.4**	**4.6**
Gregg River 8 km upstream of McLeod River		**1.4**	**4.4**	**3.2**
Smoky River Basin				
South tributary of Beaverdam Creek, upstream of SRC Mine	Reference	----	----	<0.5
West tributary of Beaverdam Creek (d/s of exploration roads)		**2.4**	**1.4**	**2.1**
South-west tributary of Beaverdam Creek (d/s of B2 dump, forest clearing)		<0.5	**1.8**	0.6
Beaverdam Creek 2 km downstream of 12S-5 Pond (d/s of B1 Pit)		----	----	**15.7**
West Beaverdam Creek upstream of Beaverdam Creek	Reference	----	0.6	<0.5
Beaverdam Creek 1 km downstream of West Beaverdam Creek		----	----	**4.5**
Beaverdam Creek near Mouth		**1.2**	**4.0**	----
Sheep Creek upstream of SRC Mine	Reference	0.7	<0.5	0.9
Sheep Creek near mouth		1.0	<0.5	**1.2**
Muskeg River near mouth, d/s of Flood Creek coal ash disposal site		----	<0.5	0.6
Lovett River				
Lovett River at Hwy 40	Reference	<0.5	**1.1**	<0.5
Lovett River near Mouth		<0.5	<0.5	0.6
Lakes				
Fairfax Lake -euphotic composite sample	Reference	<0.5	<0.5	----
Mary Gregg Lake - grab sample		----	**1.6**	----
Lac des Roches - composite (0-30 m)		**24.4**	**27.6**	----
Lac des Roches - profile (0.1 to 90 m; max. depth = ~98 m) 0.1 m -			**48.2**	
25 m -			**19.6**	
50 m -			**13.5**	
75 m -			**22.5**	
90 m -			**35.4**	

* = sample taken 11 May
---- = no sample taken