INTERNATIONAL EFFECTS AND IMPACTS OF SELENIUM, NITROGEN, AND PHOSPHORUS ON THE KOOTENAI RIVER SYSTEM

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Land Resources and Environmental Sciences

MONTANA STATE UNIVERSITY
Bozeman, Montana

December 2025

DEDICATION

To my husband William, whose unwavering support, kindness, and encouragement pushed me through moments of uncertainty and doubt. You reminded me that love and strength grow in the presence of kindness.

ACKNOWLEDGEMENTS

I extend my gratitude to my advisor, Dr. William Kleindl, whose mentorship, encouragement, and guidance have been pivotal to the overall research and writing process. I would also like to extend gratitude to my graduate committee for the valuable and insightful feedback which strengthened my final paper.

My final appreciation to the faculty within the Land Resources and Environmental Sciences program. The intellect, depth of expertise, and enthusiasm for the subject matter have profoundly shaped my learning experience and my academic journey.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

GLOSSARY or NOMENCLATURE

Throughout this paper, the term *stream gage* refers to USGS-monitored stations, consistent with agency terminology, while *stream gauge* is used in a general hydrologic sense.

Selenium tissue (drymass basis) refers to biological tissues samples retrieved from plants, animals, and/or soil and sediment sampled in the watershed

ABSTRACT

The Kootenai River watershed, a transboundary system shared between British Columbia (Canada) and Montana and Idaho (United States), has been increasingly affected by nutrient and selenium pollution associated with historic and ongoing coal mining in the Elk River Valley. Elevated concentrations of selenium, nitrogen, and phosphorus have raised both ecological and policy concerns within this transboundary system. Therefore, my study analyzed nutrient and pollutant data collected by the U.S. Geological Survey (USGS) from 2019 to 2023 at three sampling sites: the Kootenai River below Libby Dam, near Libby, Montana; the Fisher River, near Libby, Montana; and the Yaak River, near Troy, Montana. I evaluated pollution trends of spatial and temporal nutrient loading patterns with simple linear regressions and single-factor ANOVA. My results indicate that the Kootenai River below Libby Dam exhibited the highest frequency and concentration of selenium samples, indicating upstream and dam-related influences. The Yaak River sampling site showed limited nutrient activity reflecting low monitoring effort on some monitoring stations and reduced anthropogenic impacts. Across the sampling sites, selenium was recorded more than the nitrogen and phosphorus, highlighting policy significance and the ongoing impacts of coal mining discharges entering Lake Koocanusa. Overall, my analysis supports the conclusion that selenium remains the most persistent transboundary pollutant of concern. Nitrogen and phosphorus concentrations suggest potential for trophic shifts toward mesotrophic or eutrophic conditions. Effective long-term management of the Kootenai watershed will require coordination between the governments of the United States and Canada. This includes stable USGS funding for consistent monitoring and policies that address both mining and agricultural nutrient pollution within the transboundary Kootenai watershed.

INTRODUCTION

The Kootenai River (sometimes referred to as the Kootenay River) is within a transboundary watershed between British Columbia, Canada, and Montana and Idaho, USA (Figure 1). Transboundary watersheds are those that mark, cross, or are located on boundaries between two or more states or nations (UNECE, 2021). Because the Kootenai River Watershed has a history of mineral extraction in the Elk River Valley in British Columbia dating back to the 1800s (Elk Valley Coal News, 2025), its transboundary nature results in shared effects from these mining operations in both Canada and the United States.

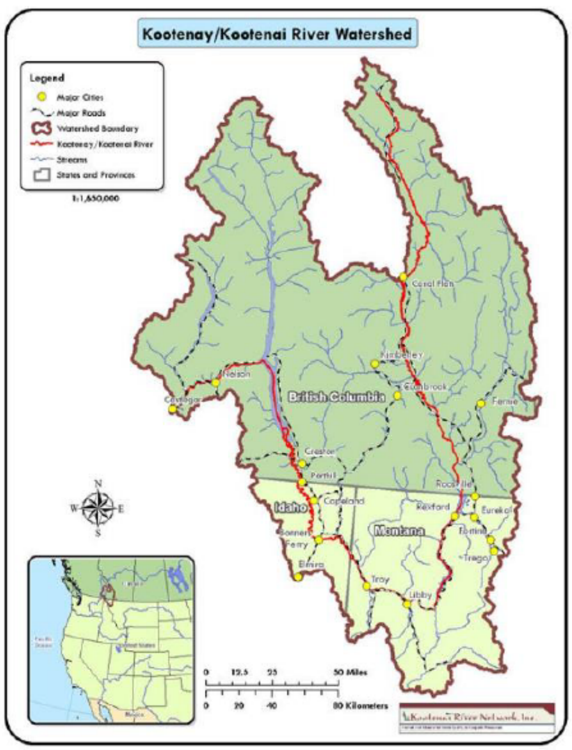

Figure 1: The Kootenay/Kootenai River Watershed Map (Kootenai River Network, Inc, 2015).

Initial mining operations were small-scale compared to today's, leading to the establishment of mining towns and the development of Elk Valley as a major metallurgical coal-producing area (Elk Valley Coal, n.d.). By the mid 20th century, the footprint of mining activity in the valley had expanded to five larger open pit mining operations (Figure 2), which would eventually all transition to operation by Teck Resources (Elk Valley Coal, 2025). Currently, one of the mines, called Coal Mountain is not actively producing, leaving four larger open pit mining operations present day (Government of British Columbia, 2024).

Mining activities, both historic and ongoing, have increased nutrient concentrations in the Elk River and its tributaries, resulting in higher levels of selenium, nitrate, and phosphorus downstream in the Kootenai River Watershed (USGS, 2025). This change in nutrient loading has affected the watershed downstream of the confluence of the Elk River and the Kootenai River. Historically, Lake Koocanusa has been characterized as oligotrophic to mesotrophic (very low to moderate nutrient levels), with total phosphorus typically in the low range, which can limit productivity and reduce biodiversity in the system (Schindler et al. 2005). Recent monitoring still indicates oligotrophic phosphorus concentrations in Lake Koocanusa, but elevated dissolved inorganic nitrogen levels, highlighting the potential for nitrogen and phosphorus imbalances (Province of B.C., 2023). These nutrients can contribute to eutrophication, biodiversity loss, and declining water quality. Recent data at USGS stream monitoring stations along the Kootenai River indicate noticeable increases in these nutrient concentrations (USGS, 2025). The monitoring of aquatic conditions for Lake Koocanusa and the broader watershed was prompted by the U.S. Congress in 2019, in response to concerns about water quality and aquatic health (USGS, 2025). Coal mining pollution can alter nutrient cycling, and downstream flows of these pollutants can infiltrate other connected watersheds (USGS, 2025). Understanding these changes is essential not only for assessing ecosystem health but also for shaping effective cross-border policy decisions and environmental protection.

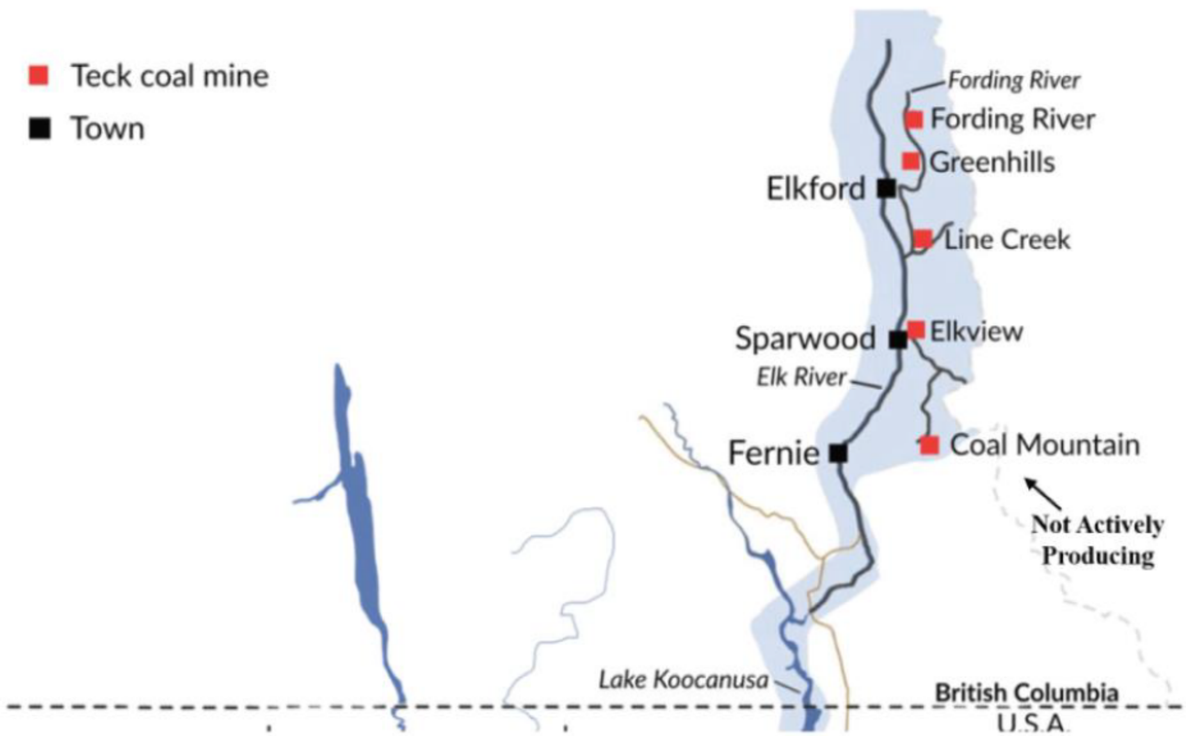

Figure 2: Mines within Elk River Valley in British Columbia, Canada (Elk Valley Coal News, 2025).

Along with the Elk River mine in British Columbia, there is the Zolonite Mine near Libby, Montana. The Zolonite Mine began mining vermiculite around the 1920s and closed in 1990. The Libby mine produced 80% of the world's vermiculite, which is used in building insulation and as a soil conditioner. The vermiculite was contaminated with a toxic form of asbestos, which, after the Environmental Protection Agency (USEPA) investigated, was found in the air, water, animal and fish tissues, and various other media (USEPA, 2025).

Current literature does not identify vermiculite as a significant source of selenium, phosphorus, or nitrogen contamination in aquatic systems. Vermiculite is primarily a concern for asbestos pollution. Vermiculite is primarily studied as a sorbent material, often used to reduce nutrient mobility rather than contribute to it. Laboratory and field studies show that modified vermiculite can effectively adsorb phosphorus from wastewater and is sometimes used as a medium for nutrient capture rather than release (Zhang et al., 2021). Similarly, engineered vermiculite iron complexes have been tested for their ability to immobilize selenium in solution rather than act as a selenium source (Chen et al., 2008). Nitrogen research likewise indicates that vermiculite amendments tend to decrease nitrogen losses from soils rather than increase them (Huang et al., 2017). The available research does not support vermiculite as a major contributor of selenium, nitrogen, or phosphorus pollution to waterways.

<u>Transboundary Water and Legal Concerns</u>

The transboundary Kootenai River requires coordination between Canada and the United States to navigate through different jurisdictions. The river originates in British Columbia before crossing into Montana and Idaho, making this river system subject to both federal and provincial/state regulations. The primary legal framework governing the policy is the 1909 Boundary Waters Treaty, administered by the International Joint Commission (IJC: International Joint Commission, 1909). This treaty utilizes the concept of “equitable and reasonable use” and prohibits either country from polluting or diverting waters to the detriment of the other (International Joint Commission, 1909). In addition to the Boundary Waters Treaty, the Kootenai basin is also subject to broader agreements, such as the Columbia River Treaty. This treaty coordinates with hydropower and flood control operations (Government of Canada, 1961).

However, nutrient management issues, such as those related to selenium and phosphorus from the Elk Valley coal mines, are less directly regulated under these agreements. This has led to the present-day policy and could lead to potential conflicts between the Montana Department of Environmental Quality (DEQ) and the British Columbia Ministry of Environment.

Recently, transboundary working groups have attempted to address these pollution challenges by sharing data through joint monitoring programs, including the Lake Koocanusa Monitoring and Research Working Group (Province of British Columbia, 2023). Legally, enforcement across borders remains limited today. Montana and the USEPA can regulate pollutants within the United States jurisdiction. The Environmental Management Acts and the Mines Act place responsibility on Teck Resources Ltd. to manage waste discharges (Teck Resources Ltd, 2023). However, Canada, like the United States, lacks the legal authority to extend its protection beyond its borders as well as beyond the treaty agreements. Effective governance of the Kootenai Watershed depends on creating policies that enable the United States and Canada to collaborate on this issue rather than act separately. Future policy should aim to create a cleaner, less polluted watershed, but without the necessary policy and legal framework to transcend borders and collaborate, achieving progress concurrently is difficult. This framework is crucial for aligning conservation goals with the international water system to ensure the long term ecological health of the system.

Although increasing nutrient loads have been documented and multiple governance frameworks exist, there remains no unified policy mechanism capable of addressing upstream selenium and nitrogen driven pollution across jurisdictional boundaries. The complexity of this watershed lies not only in the contaminants but also in the limits of transboundary governance, which operate under different regulatory, political, and legal constraints on each side of the border. As a result, scientific conclusions and policy responses must integrate ecological data with institutional context to move beyond single jurisdiction analysis. This disconnect between ecological processes and regulatory capacity creates a critical gap in both scientific interpretation and policy implementation within the watershed.

To address this gap, my paper synthesizes water quality data, historical mining impacts, and international governance structures to evaluate how transboundary pollutants move through the Kootenai River system and how management strategies may be improved. I evaluated nutrient pollution and cross border policy documents whether current pollutant trends support this system interpretation and whether governance structures adequately address transboundary impacts. My paper seeks to address two questions:

1. What are the pollutant fingerprints of mining within the Kootenai watershed, and how do we trace them?
2. How is transboundary policy unique, what problems does that create, and how do we resolve them?

METHODS

My paper examines nutrient loading trends from 2019 to 2023 across three USGS gaging sites on the Kootenai River, evaluating potential sources of increased nutrient inputs and considering the broader ecological and policy implications of these findings. Site selection for data collection was determined by location and distance from Lake Koocanusa, as well as the downstream flow of the Kootenai river.

Land & Water Background

The study sites are near two towns in Montana, and one in Idaho, along the downstream flow from Lake Koocanusa. The towns are Libby, Montana (population 2,775), Troy, Montana (population 797), and Bonners Ferry, Idaho (population 2,520) (U.S. Census Bureau, 2020). The combined population near the study site is 6,092. Pollution due to urbanization is not a significant concern near this study site.

I used two monitoring stations in northwest Montana and one in northeast Idaho. The Department of Environmental Quality (DEQ) creates an impaired waters list in their integrated reports and 303(D) lists every two years or so. There are four categories of beneficial uses on identified waterbody locations. They are: aquatic life, agriculture, drinking water, and recreation. They are each categorized by fully supporting, threatened, not fully supporting, insufficient information, or not assessed. There are 23 impaired waters in the middle Kootenai and one in the lower Kootenai (DEQ 2020). These locations are situated within the Kootenai sub-basin (Figure 3). The Kootenai River, from Libby Dam to the Yaak River, Lake Koocanusa, and the confluence of the Kootenai River with the Yaak River to the Idaho border, are three points of interest as they are connected to the three USGS monitoring stations used for this study. Because these monitoring locations are within reaches that the DEQ has evaluated for water quality concerns, understanding the status of impaired waters in the Kootenai sub-basin provides essential context for interpreting conditions at the study sites.

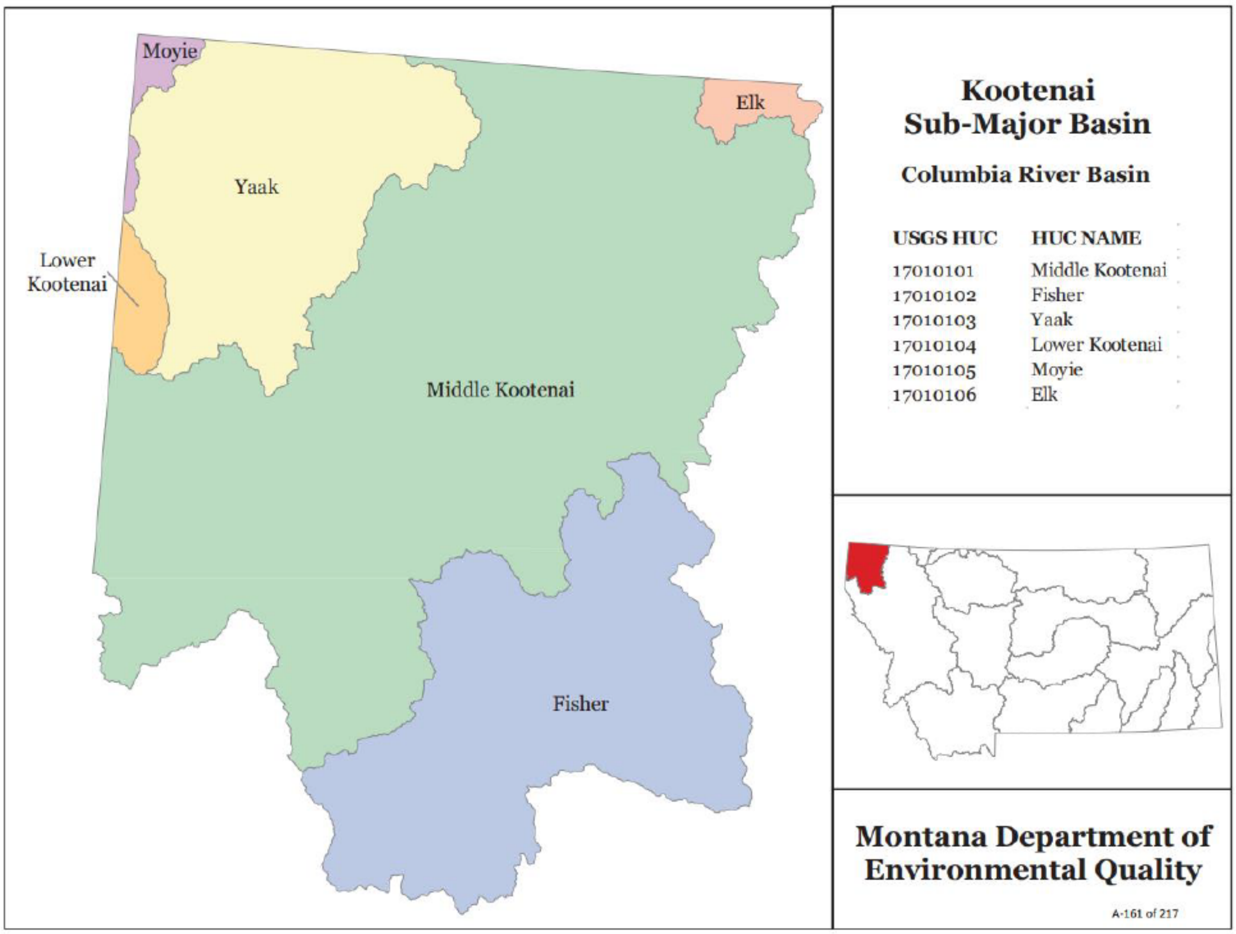

Figure 3: Kootenai Sub-Major Basin Overview Map 2020 (Montana Department of Environmental Quality, 2020).

Kootenai River, Libby Dam to Yaak River (Middle Kootenai):

This river system is 71.84 kilometer long. It supports agriculture, drinking water, and recreational uses. It does not fully support aquatic life. The causes of impaired water quality are modifications to the flow regime and temperature. The source of the cause is a dam or impoundment and impacts from hydrostructure flow regulation and modifications (Appendix A - Impaired Waters, 2020).

Kootenai River, confluence with Yaak River to Idaho border (Lower Kootenai):

This river system is 9.8 kilometers long. It fully supports agriculture, drinking water, and recreational uses. It does not fully support aquatic life. The causes of impaired water quality are modifications to the flow regime and temperature. The source of the cause is a dam or impoundment, as well as impacts from hydroelectric structure flow regulation and modifications (Appendix A - Impaired Waters, 2020).

Lake Koocanusa (Middle Kootenai):

This river system is 20.31 kilometers long. It fully supports agriculture, drinking water, and recreational uses. It does not fully support aquatic life. The causes of impaired water quality include modifications to the flow regime and the presence of selenium. The source of the cause is a dam or impoundment and sources outside state jurisdiction or borders (Elk River mining pollution in British Columbia) (Appendix A - Impaired Waters, 2020).

The reason Lake Koocanusa (Middle Kootenai) is listed as impaired in the 2020 water quality data system is partially due to selenium source from the coal mining in the Elk River.

Study & Site Data Background

My study analyzed stream water quality data near three USGS monitoring stations located in the northeastern portion of the Kootenai River watershed basin (Figure 4) in northwest Montana and northeast Idaho.

1. USGS 12301933 Kootenai River below Libby Dam near Libby Montana
2. USGS 12304500 Yaak River Near Troy, Montana.
3. USGS 12305000 Kootenai River near Leonia, Idaho

I acquired water quality data (nutrient loads and flow rate) from the monitoring station sites for the 2019-2023 water years. These data included: inorganic nitrogen (nitrate and nitrite), nitrate, phosphorus as phosphorus, water, filtered, phosphorus as phosphorus, water, unfiltered, orthophosphate as phosphate, orthophosphate as orthophosphate, selenate (Se(VI)) as selenium, water, filtered, selenium, water, filtered, selenium, tissue (dry mass basis), recoverable, and selenium, water, unfiltered (Table 1). I organized the results by the number of pollutants sampled throughout each water year and compared by date/timing to the amount of pollution per pollutant (mg/L, µg/L, mg/kg) (Table 1).

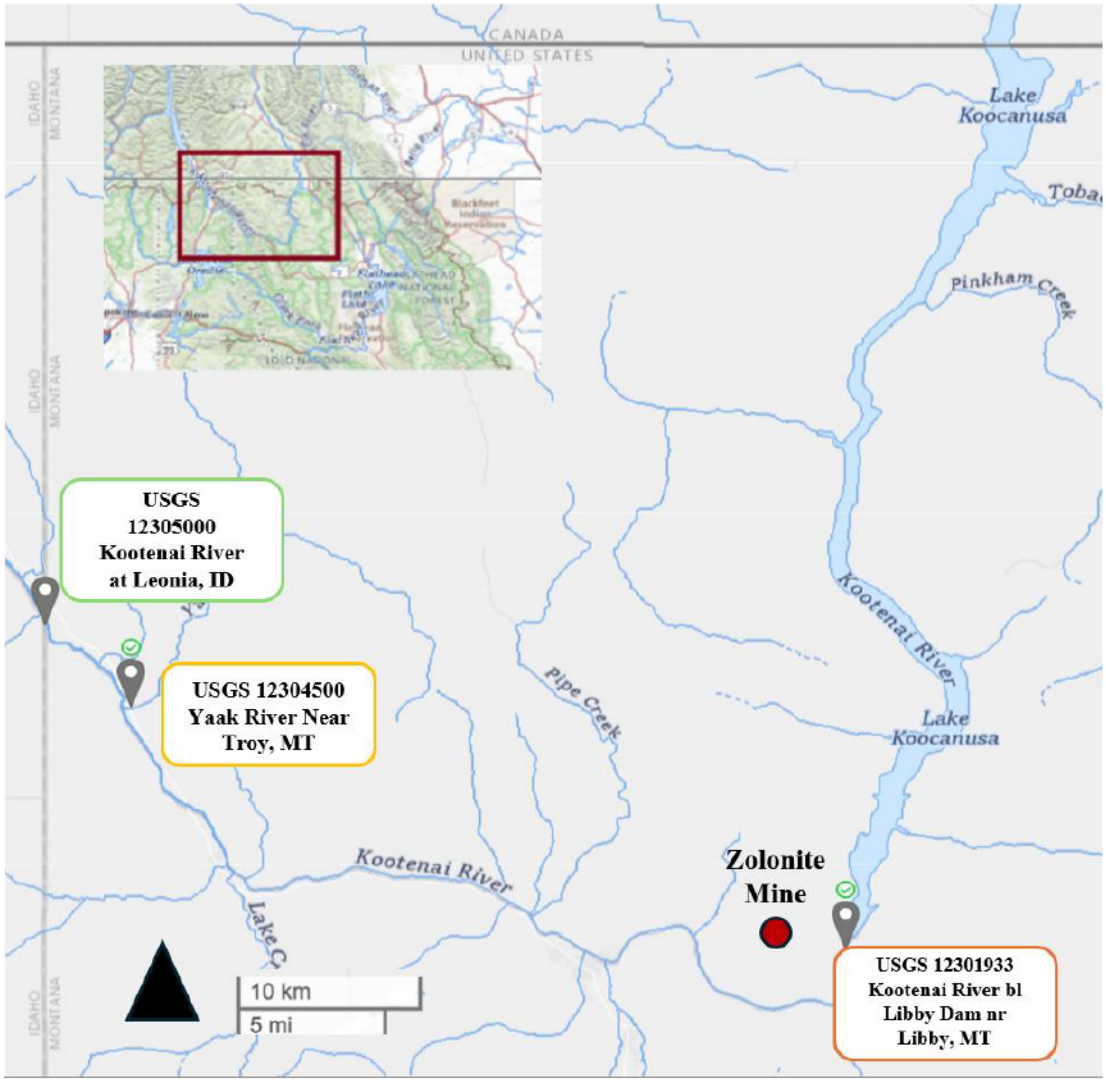

Figure 4: Monitoring Station Study Area Locations Throughout Montana (USGS 2019).

Table 1: Nutrient Sample and Concentration Measurement Units.

Nutrient	**Species**	**Measurement Unit**
Nitrogen	Inorganic Nitrogen (nitrate & nitrite) Nitrate (NO_3^-)	mg/L
Phosphorus	Phosphorus as Phosphorus, water, filtered Phosphorus as Phosphorus, water, unfiltered Orthophosphate as Phosphate Orthophosphate as Orthophosphate	mg/L
Selenium	Selenate (Se(VI)) as Selenium, water, filtered, Selenium, water, filtered, Selenium, water, unfiltered Selenium, tissue (dry mass basis), recoverable	µg/L mg/kg

<u>Statistical Analysis</u>

My study implemented two forms of statistical analysis to determine the significance of the data collected. The first method used was Linear Regression in Microsoft Excel, to determine if there was any relation between the concentration of nutrients (dependent variable) and the date of collection (independent variable). R^2 was calculated using built-in analysis software to determine the percentage of variance in nutrient concentration that is related to the date of collection.

The second statistical analysis method used was a One-Way ANOVA test, utilizing the "Data Analysis" tool in Microsoft Excel. This was done to test if there is any significant difference in the means of nutrient concentration means and sampling years. For these One-Way ANOVAs, the following hypotheses were used. Null hypothesis: H_0 = There is no difference between sampling year nutrient concentration means. Alternative hypothesis: H_a = The is a difference between sampling year nutrient concentration means.

RESULTS

USGS 12301933 – Kootenai River below Libby Dam

The sampling rates of the three nutrients at this site were consistently higher than those at the other gauges, reflecting the location's importance to the watershed and its effects on downstream conditions, as determined by congressional guidance to the USGS (USGS, 2025). Between 2019 and 2023, a total of 894 samples of pollutants were recorded. Selenium samples (both filtered and unfiltered) comprised most of the dataset, with as many as 290 selenium-filtered samples in the 2020 water year. Nitrate concentrations were also well represented, particularly in 2021 and 2022, with up to 30 samples collected during the 2022 water year. phosphorus sampling was comparatively limited, with only a few sporadic measurements of filtered and unfiltered phosphorus species.

The Linear Regression at USGS 12301933 was nitrogen y = 1E-05x + 0.0349, R^2 = 0.0001, indicating that 0.001% of variance in sample concentration was due to the date of collection, phosphorus y = 2E -06x – 0.0788, R^2= 0.2411, indicating that 24.11% of the sample concentration variance was related to the date of collection, selenium water sample y = 0.0001x – 4.1476, R^2 = 0.0773, indicating that 7.73% of the sample concentration variance was related to date of collection, and selenium Tissue Sample Dry Mass Basis Recoverable y = 0.008x -336.68, R^2 0.0296, indicating 2.96% of sample concentration variance was related to the date of collection. Although the regression slope was positive, the extremely low R^2 value (0.0001) indicates that time explains virtually none of the observed variance.

ANOVA: Single Factor analysis F-test results were nitrogen Species water sample F 0.16646 < F-critical 2.46548 (Fail to reject null hypothesis), phosphorus Species Water sample F

30.47448 > F-critical 2.895107 (Reject the null hypothesis), selenium Species Water Sample F 17.79908 > F-critical 2.383774 (Reject the null hypothesis), and selenium Species Tissue Sample Dry Mass Basis Recoverable F 0.003121 < F-critical 3.179117 (Fail to reject the null hypothesis).

The ANOVA results indicate where we fail to reject the null hypothesis that there is no statistical significance to the variance of nutrient concentration means observed between sampling years at this location. Where we reject the null hypothesis, we see that there is evidence to support that there is a statistical significance to nutrient concentration means at the monitoring station. This is the case at sampling site USGS 12301933 for phosphorus Species Water Samples and selenium Species Water Samples testing. These results may be related to the mining activity upstream in the Elk River Valley in Canada.

<u>USGS 12304500 – Yaak River near Troy, Montana</u>

The Yaak River site exhibited a lower sampling intensity, with a total of 34 samples collected over the five year period. Monitoring efforts focused primarily on nitrogen and phosphorus pollutants, and selenium was not detected at this site. Nitrate and inorganic nitrogen concentrations were consistently low, with a sampling frequency of 1 to 6 samples per year. This implies a relatively undisturbed, limited anthropogenic impact on this part of the watershed. It should be noted that this does not draw a conclusion on whether this watershed is undisturbed or unpolluted, but also highlights the overall lack of data on this site, as selenium is not included in this monitoring station

The Linear Regression at USGS 12304500 were nitrogen y = 7E-06x - 0.2738, R^2 = 0.0077, indicating that 0.77% of the variance in sample concentration was due to the date of collection, phosphorus y = 3E-05x - 1.4976, $R^2 = 0.2554$, indicating that 25.54% of sample concentration variance was related to date of collection, and selenium water samples had no detections during the sampling period.

ANOVA: Single Factor analysis F-test results were nitrogen Species water sample F 4.335402 > F-critical 2.816708 (Reject null hypothesis), phosphorus Species Water sample F 1.352385 < F-critical 4.533677 (Fail to reject the null hypothesis), and selenium Species Water Sample F 65535 > F-critical 5.192168 (Reject the null hypothesis).

The ANOVA results indicate where we fail to reject the null hypothesis that there is no statistical significance to the variance of nutrient concentration means observed between sampling years at this location. Where we reject the null hypothesis, we see that there is evidence to support that there is a statistical significance to nutrient concentration means at the monitoring station. This is the case at sampling site USGS 12301933 for nitrogen Species Water Samples, and selenium Species Water Samples testing.

<u>USGS 12305000 – Kootenai River near Leonia, Idaho</u>

The Leonia, Idaho, Kootenai River site exhibited an intermediate density of water samples, with a total of 106 samples collected over a five year period. nitrogen species again dominate with up to eight nitrate samples annually. selenium was primarily measured in water, filtered, and tissue (dry mass basis), with recoverable selenium. The decrease in selenium data sampling may reflect the reduced pollutant monitoring. The phosphorus data were limited and sporadic, with low sample counts of 1 – 3 per year. This could also be a case of inadequate monitoring at this site or a more stable watershed at this monitoring station.

The Linear Regression at USGS 12305000 were nitrogen y = 1E-05x - 0.0524, R^2 = 0.0002, indicating that 0.02% of variance in sample concentration was due to the date of collection, phosphorus y = -3E-06x + 0.1429, R^2 = 0.3093, indicating that 30.93% of sample concentration variance was related to date of collection, selenium water sample y = 0.0001x - 5.1215, R^2 = 0.0739, indicating that 7.39% of the sample concentration variance was related to date of collection, and selenium Tissue Sample Dry Mass Basis Recoverable y = 0.0015x - 51.861, R^2 = 0.0018, indicating 0.18% of sample concentration variance was related to the date of collection.

ANOVA: Single Factor analysis F-test results were nitrogen Species water sample F 0.046615 < F-critical 2.633532 (Fail to reject null hypothesis), phosphorus Species Water sample F 0.84686 < F-critical 9.117182 (Fail to reject the null hypothesis), selenium Species Water Sample F 0.443639 < F-critical 3.259167 (Fail to reject the null hypothesis), and selenium Species Tissue Sample Dry Mass Basis Recoverable F 2.654456 > F-critical 2.641465 (Reject the null hypothesis).

The ANOVA results indicate where we fail to reject the null hypothesis that there is no statistical significance to the variance of nutrient concentration means observed between sampling years at this location. Where we reject the null hypothesis, we see that there is evidence to support that there is a statistical significance to nutrient concentration means at the monitoring station. This is the case at sampling site USGS 12301933 for phosphorus Species Water Samples, and selenium Species Tissue Samples Dry Mass Basis Recoverable testing. In connection with the results for selenium Species Tissue Samples Dry Mass Basis Recoverable testing at USGS 12301933, there may exist the possibility that selenium increases in concentration in the fish tissue due to bioaccumulation as the impacted water moves through the reach of the Kootenai River between sampling sites USGS 12301933 and USGS 12305000 over the sampling years.

<u>Overall Monitoring Station Data Trends</u>

Across water years 2019 – 2023, nitrogen, phosphorus, selenium, and selenium fish tissue measurements at USGS monitoring stations 12301933, 12304500, and 12305000 display a mix of flat, sloped, and variable trends depending on the station and pollutant. Some lines appear relatively stable over time, while others show upward or downward slopes, and several measurements exhibit substantial year-to-year variability (See Figure 5 - 7). Selenium tissue concentrations also vary across years at USGS monitoring stations 12301933 and 12305000, while no tissue samples were collected at Station 12304500 (See Figure 8).

Nitrogen levels exhibited fluctuations throughout the period, with each station showing differences in magnitude and patterns (Figure 5). Phosphorus concentrations remained generally low across the three monitoring locations, though intermittent increases were recorded at select stations in certain years (Figure 6). Selenium concentrations were consistently detectable at all stations (Figure 7). Selenium tissue samples, collected at USGS Monitoring Stations 12301933 and 12305000, also showed variation in concentration across the study period, while no tissue measurements were available for USGS Monitoring Station 12304500 (Figure 8). Together, these datasets document temporal and spatial variability in measured nitrogen, phosphorus, selenium, and selenium tissue concentrations across the three monitoring stations.

Table 2: Monitoring Station USGS 12301933 Number of Various Pollutant Samples from Water Years 2019 – 2023.

Number of Pollutant Samples Monitoring Station USGS 12301933					
Pollutants	**Water Year 2019**	**Water Year 2020**	**Water Year 2021**	**Water Year 2022**	**Water Year 2023**
Inorganic Nitrogen (nitrate and nitrite)	2	2	8	3	11
Nitrate	4	4	16	30	22
Phosphorus as Phosphorus, water, filtered	1	0	0	0	3
Phosphorus as Phosphorus, water, unfiltered	0	0	2	5	5
Orthophosphate as Phosphate	0	0	0	0	1
Orthophosphate as Orthophosphate	0	0	0	0	0
Selenate (Se(VI)) as selenium, water, filtered	2	0	10	12	0
Selenium, water, filtered	26	290	212	49	48
Selenium, tissue (dry mass basis), recoverable	0	7	11	0	0
Selenium, water, unfiltered	0	1	14	46	47
Total	35	304	273	145	137

Table 3: Monitoring Station USGS 12304500 Number of Various Pollutant Samples from Water Years 2019 – 2023

Number of Pollutant Samples Monitoring Station USGS 12304500					
Pollutants	**Water Year 2019**	**Water Year 2020**	**Water Year 2021**	**Water Year 2022**	**Water Year 2023**
Inorganic Nitrogen (nitrate and nitrite)	2	1	3	2	1
Nitrate	4	2	6	4	2
Phosphorus as Phosphorus, water, filtered	1	0	0	1	1
Phosphorus as Phosphorus, water, unfiltered	1	0	1	1	1
Orthophosphate as Phosphate	0	0	0	0	0
Orthophosphate as Orthophosphate	0	0	0	0	0
Selenate (Se(VI)) as Selenium, water, filtered	Not monitored	Not monitored	Not monitored	Not monitored	Not monitored
Selenium, water, filtered	0	0	0	0	0
Selenium, tissue (dry mass basis), recoverable	Not monitored	Not monitored	Not monitored	Not monitored	Not monitored
Selenium, water, unfiltered	Not monitored	Not monitored	Not monitored	Not monitored	Not monitored
Total	8	3	10	8	5

Table 4: Monitoring Station USGS 12305000 Number of Various Pollutant Samples from Water Years 2019 – 2023

Number of Pollutant Samples Monitoring Station USGS 12305000					
Pollutants	**Water Year 2019**	**Water Year 2020**	**Water Year 2021**	**Water Year 2022**	**Water Year 2023**
Inorganic Nitrogen (nitrate and nitrite)	4	4	3	2	0
Nitrate	8	8	6	4	2
Phosphorus as phosphorus, water, filtered	0	0	0	0	0
Phosphorus as phosphorus, water, unfiltered	3	1	1	2	1
Orthophosphate as Phosphate	0	0	0	0	0
Orthophosphate as Orthophosphate	0	0	0	0	0
Selenate (Se(VI)) as Selenium, water, filtered	2	Not monitored	Not monitored	Not monitored	Not monitored
Selenium, water, filtered	4	4	3	2	2
Selenium, tissue (dry mass basis), recoverable	19	12	9	Not monitored	Not monitored
Selenium, water, unfiltered	Not monitored	Not monitored	Not monitored	Not monitored	Not monitored
Total	40	29	22	10	5

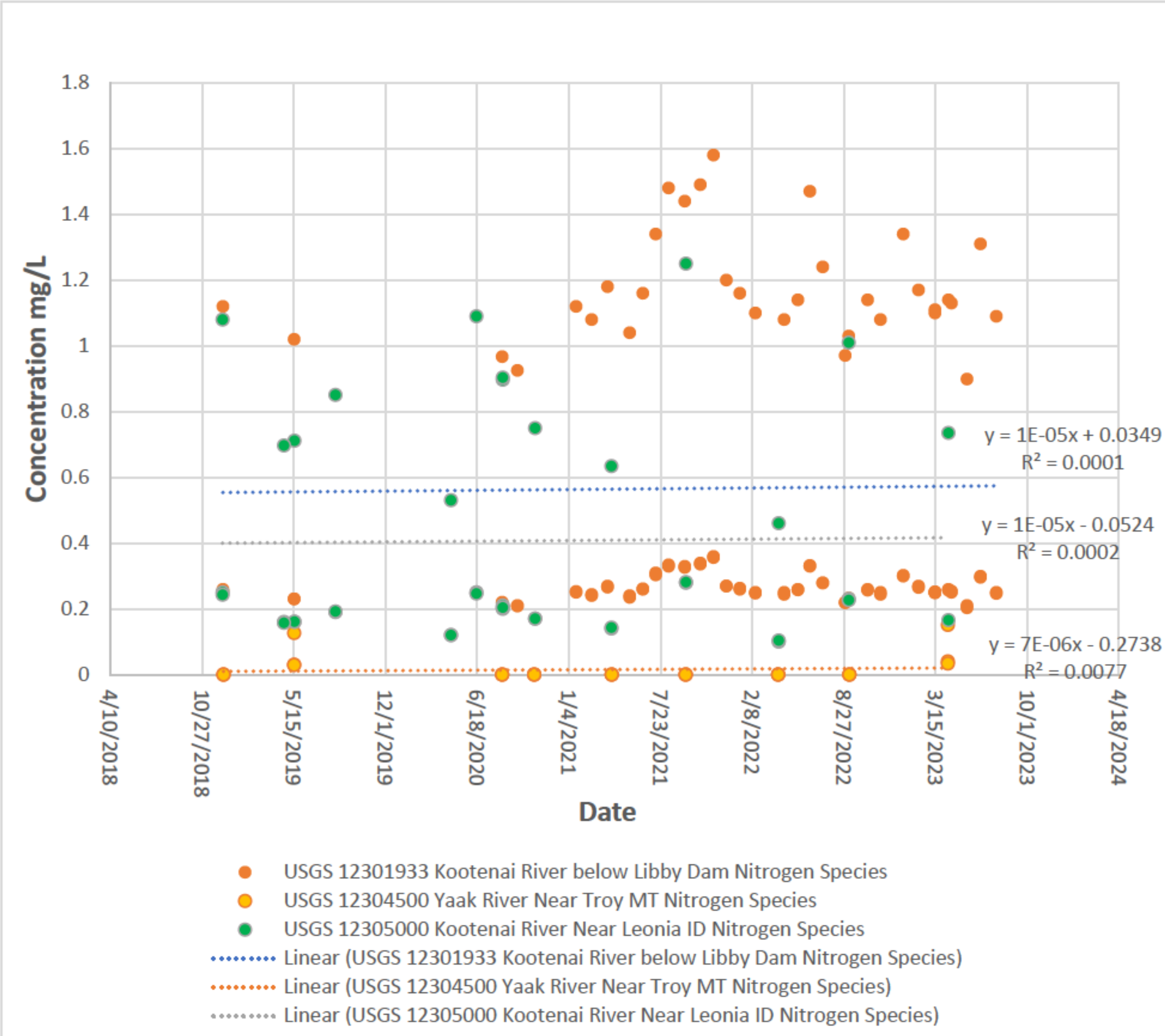

Figure 5: Nitrogen Pollutants Detected in Water Years 2019 – 2023 at USGS Stream Monitoring Station 12301933, 12304500, 12305000

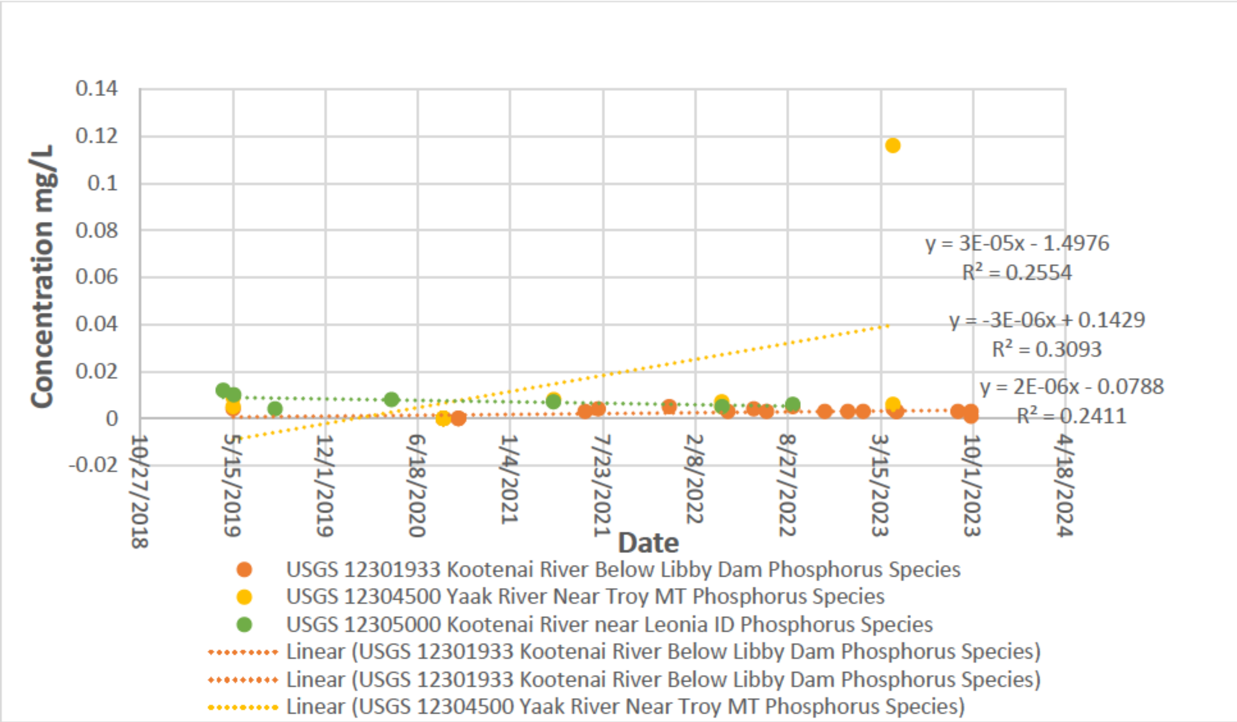

Figure 6: Phosphorus Pollutants Detected in Water Years 2019 – 2023 at USGS Stream Monitoring Station 12301933, 12304500, 12305000

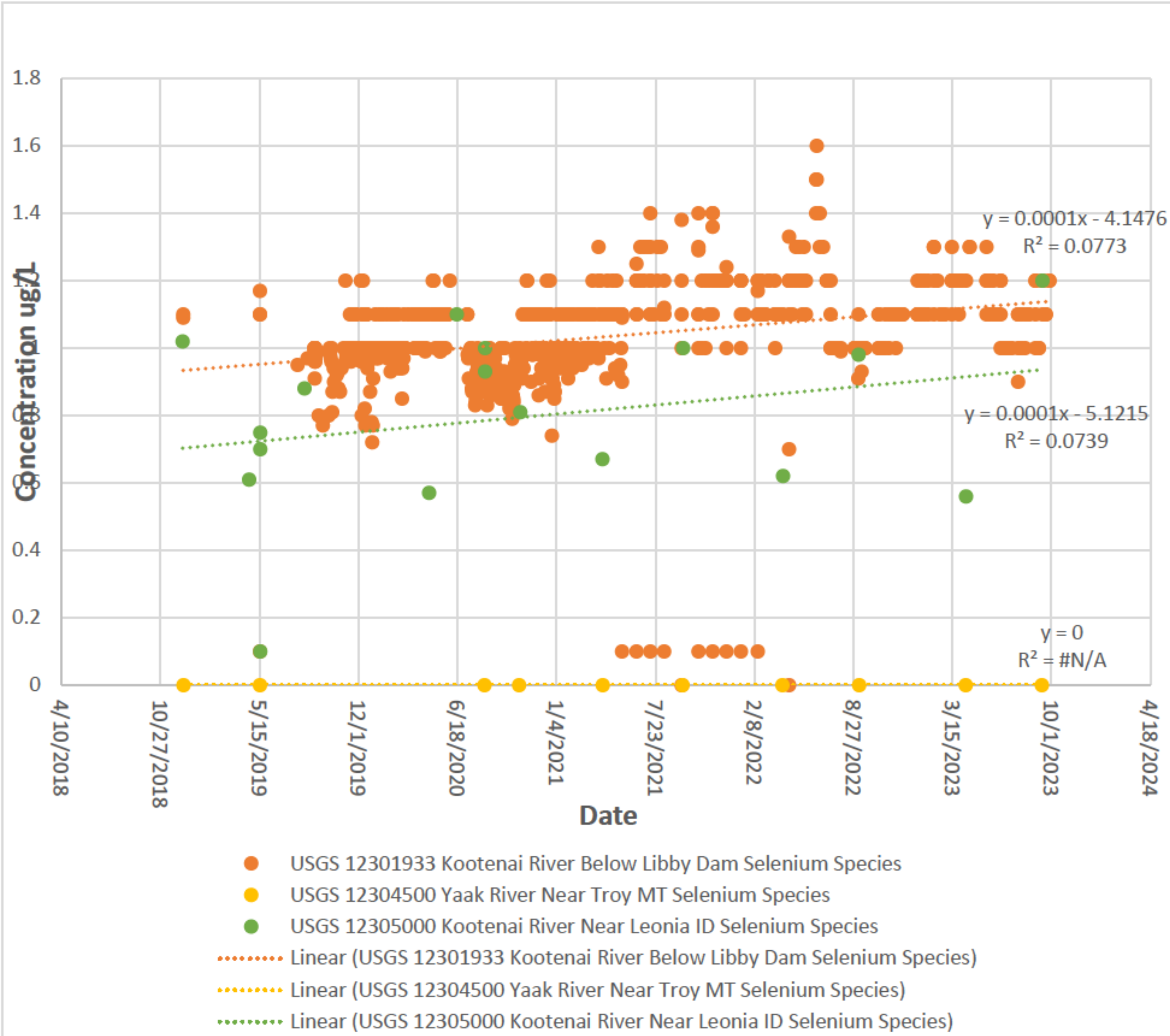

Figure 7: Selenium Pollutants Detected in Water Years 2019 – 2023 at USGS Monitoring Station 12301933, 12304500, 12305000

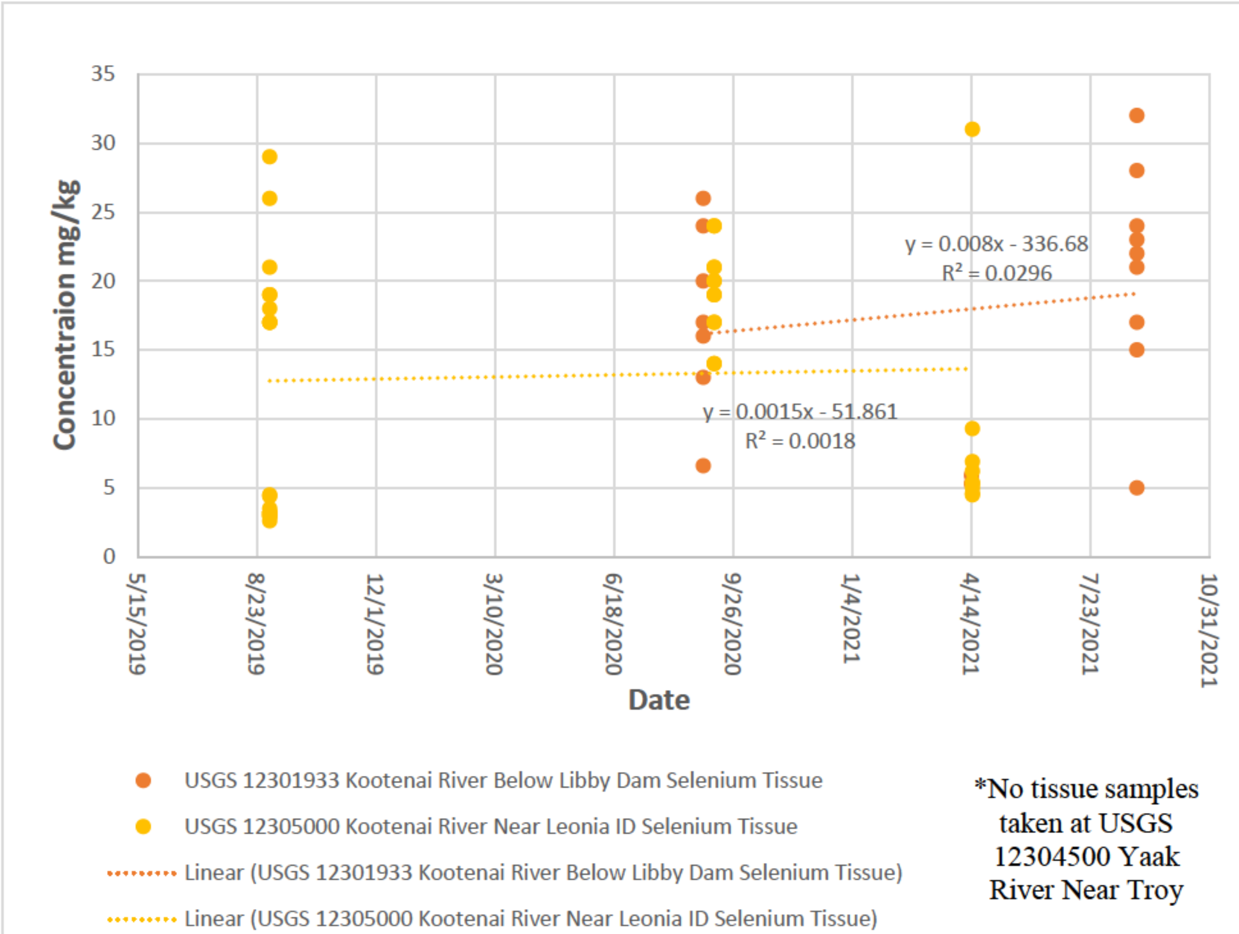

Figure 8: Selenium Tissue (drymass basis), Recoverable Pollutants Detected in Water Years 2019 – 2023 at USGS Monitoring Stations 12301933, 12304500, 12305000

**No tissue samples taken at USGS 12304500*

Monitoring Station Patterns

Across all three sampling sites, the Kootenai River below Libby Dam consistently exhibited the highest frequency of selenium sampling and detection, which reflects the dam's influence on pollutant transport. This issue stems from the cross border concerns from upstream coal mining in British Columbia (Canada) (Kootenai River Network, 2015). Nitrogen measurements were more evenly distributed across all sites, with higher concentrations near the dam, for similar reasoning to the selenium concentrations. The dam disrupts the natural flow of the watershed, resulting in a higher accumulation of pollutants at this monitoring station site. Phosphorus sampling was sparse across all gages with no consistent trends across the water years. This suggests that phosphorus was not a primary concern in the watershed during the study period (water years 2019–2023) (USGS, 2025).

Data Processing and Analysis

Several sites had samples with no detection of the pollutant, or had no sampling occurred for certain water years (Tables 3–4 and Figures 7–8). To assess variability across the sample period, simple linear regression was used to interpret trends in the data patterns. ANOVA: Single-factor analysis was used to examine the different pollutant types at each sampling site across the sampling period (Figures 9-19 in Appendix B). I quantified the pollution concentration and sampling frequency for each water year, the differences among the three monitoring stations, and the various pollutants and their compositions. The data were plotted to visualize changes in pollutant levels over the years studied and across the stream site locations.

Overall Data Trends and Implications / Issues

Between water years 2019 – 2023, the data reveals a contrast between heavily monitored selenium dynamics at the Kootenai dam and comparatively low pollutant activity in the downstream tributaries. Selenium monitoring was more pronounced in the dataset, while nitrogen and phosphorus were secondary concerns. The peak of water year 2020 selenium sampling highlights the influence of the hydrological variabilities and regulatory monitoring practices. The findings emphasize the importance of sustained monitoring, especially in transboundary basins such as the Kootenai watershed, where industrial activities in the Elk Valley, including pollution from mining in British Columbia, can have a direct impact on water quality downstream in states like Montana.

DISCUSSION

The Kootenai watershed flows through the United States (Montana and Idaho) and Canada (British Columbia), making it an ecologically important and complex system in which transboundary water quality issues can arise. The three monitoring stations' records from 2019 - 2023 show upward trends in inorganic nitrogen (nitrate + nitrite) and orthophosphate at multiple sites. The increasing trends of nitrogen (N) and phosphorus (P) loading heighten the risk of transitioning trophic conditions. Nutrient flow can result from weathering, watershed runoff, and seasonal hydrology. However, several anthropogenic vectors align with the observed patterns within the study area. They are hydropower operations that alter timing and retention and have a history of reducing pollution delivery. Coal mining in the Elk Valley, as well as agriculture in and near Creston, B.C., contributes to nitrogen and phosphorus pollution from fertilizers and drainage, which affects the connected watershed.

Background eutrophication in watersheds is a normal process that can take thousands of years or more. When it becomes concerning is when the eutrophication process is accelerated by unnatural pollutants from runoff, urbanization, agricultural fertilizers, and, in this case, mining pollution, to hundreds of years instead of thousands. Oligotrophic watersheds are typically characterized by cold and deep conditions, often found in areas with minimal nutrient runoff (Cushman, 2023). They typically have very little aquatic plant growth and have the water chemistry of <0.015mg/L for phosphorus and <0.4 mg/L for nitrogen (Cushman, 2023). Mesotrophic watersheds are moderately productive and have features of oligotrophic and eutrophic lakes (Cushman, 2023). They typically have a buildup of nutrients, with water chemistry of 0.015– 0.025 mg/L for phosphorus and 0.4–0.6 mg/L for nitrogen (Cushman, 2023). Shallow depths, high nutrient levels, and substantial human impacts characterize eutrophic watersheds (Cushman, 2023). They typically exhibit very high aquatic plant growth and algae, with water chemistry ranging from 0.025 to 0.1 mg/L for phosphorus and 0.6 to 1.5 mg/L for nitrogen (Cushman, 2023).

The pollution in the Kootenai River has led to several restoration projects and plans within the watershed. These projects aim to address pollution sources and implement mitigation measures throughout the watershed, while also contributing to the development of policies that restore ecological health. These restoration projects and plans include the following:

A) The Kootenai River Habitat Restoration Program (KRHRP) was established by the Kootenai Tribe of Idaho in 2009. The goal of this program is to restore ecological processes disrupted by flow regulation and sedimentation. They are attempting to achieve this by establishing a strong riparian structure, rebuilding floodplain function, and enhancing habitat for native fish species (Kootenai Tribe of Idaho, 2009).

B) The Kootenai River Network developed the Kootenai River Basin Watershed Restoration Plan (WRP) in partnership with the Montana Department of Environmental Quality (DEQ). The Watershed Restoration plan was finalized in 2015. This plan identifies the complexities of the Kootenai watershed's diverse restoration needs. This includes improvements to pollution, the ecological state, and restoration funding (Kootenai River Network, 2015).

C) The International Joint Commission (IJC) developed the Elk Kootenai/y Watershed Study Board from 2024 to 2025 to address and examine the transboundary water quality issues that originate in Elk Valley’s mining operations. The goal is to improve the pollution data to help navigate potential future policy recommendations (International Joint Commission, 2025)

Nitrate from blasting residues and waste rock drainage in coal mines moves via groundwater and tributaries to the Elk River, then to Lake Koocanusa and the mainstem (Storb et al. 2023). On agricultural floodplains, ditched fields accelerate drainage, conveying dissolved nutrients through drainage networks and tributaries into the river. At the lake scale, altered N:P ratios from dam operations and restoration programs can shift phytoplankton composition, favoring blooms under warm, low flow conditions (Schindler et al. 2007).

Cross border policy and monitoring coordination is essential given the unique transboundary setting. Several improvements could be implemented, including continued high frequency monitoring (USGS/partners), reductions in mine related nitrate and selenium, and the adoption of agricultural best management practices (such as riparian buffers, controlled drainage, and crop rotation). At the lake scale, carefully balancing nutrient restoration to support fisheries with the need to avoid rapid eutrophication will remain a central challenge as the climate crisis increases the frequency of algae blooms.

The U.S. Geological Survey (USGS) stream gage, funding, policy, and staffing vary in funding and support depending on the administration in office. Under the Trump administration, the proposed budgets for 2019 – 2020 included reductions to USGS and the Department of the Interior (DOI) science programs. During the 2018–2019 federal government shutdown, non-essential operations were suspended, with only critical stream gauges remaining in operation (U.S. Department of the Interior, 2019).

Under the Biden administration (2021–2024), stabilization and increased funding for the stream gauge program were implemented. Increases specifically to the Next Generation Water Observing System (NGWOS) and the Federal Priority Stream gages (FPS) programs. In 2023, USGS launched the “Open Season” reassessment, which reviews priority sites and expanded real-time transparency through public mappers. The fiscal year 2024 budget supported ~3,490 FPS gages, and NGWOS continued expanding into additional watersheds (U.S. Geological Survey, 2024).

Under the current Trump administration, reports indicate that by 2025, there will be renewed fiscal tightening. There are proposals to close or reduce operations in USGS Water Science Centers, which could also lead to staff reductions (Inside Climate News, 2025). Although stream gauges and monitoring stations operate during shutdowns, the funding uncertainties associated with each administration raise concerns about the long-term viability of the datasets.

CONCLUSION

The Kootenai River system, shared between British Columbia, Montana, and Idaho, continues to reflect the ecological and political complexities of a transboundary watershed impacted by ongoing mining activities. The three monitoring stations analyzed in this study capture hydrologic and seasonal variation over a five year period, as well as the distinct influence of human activities upstream. Together, the patterns observed across the dataset demonstrate how upstream sources and hydrological factors can shape downstream water quality conditions.

Across all three monitoring stations, inorganic nitrogen (nitrate + nitrite) and orthophosphate exhibited upward movement at several locations. While concentrations remain within historically oligotrophic to mesotrophic ranges, the incremental increases in both nitrogen and phosphorus suggest that trophic conditions in parts of the watershed could shift more quickly than under natural processes. Background eutrophication typically unfolds over thousands of years, but anthropogenic influences can speed it up to decades or centuries. This accelerated progression toward mesotrophic state carries ecological implications.

The dominance of selenium at the Libby Dam station highlights a different transboundary issue. Selenium mobility is strongly associated with mining waste rock in the Elk River Valley. This persistent upstream pollution enters Lake Koocanusa and is detected at the dam, often at higher frequency and concentration than nitrogen and phosphorus. The reduced selenium levels at the Yaak and Leonia sites reflect either lower monitoring intensity or a decreased influence of upstream mining at those locations. However, the limited selenium detection highlights the uneven monitoring coverage across the watershed and the need for more comprehensive sampling beyond the dam.

The ongoing restoration and monitoring programs throughout the watershed reflect an awareness of these issues. The Kootenai River Habitat Restoration Program, the Watershed Restoration Plan, and the International Joint Commission's recent Elk-Kootenai/y Watershed Study Board all illustrate the need for coordinated ecological recovery across multiple jurisdictions.

However, even the best scientific data cannot be fully effective without stable institutional and political support. USGS stream gage funding remains vulnerable to federal administrative priorities. Budget reductions, delayed appropriations, and government shutdowns interrupt long term water quality datasets and jeopardize this consistent monitoring. While recent stabilization and support under the Biden administration strengthened programs like NGWOS and Federal Priority Stream Gages, new fiscal tightening under the current administration again raises uncertainty. These fluctuations make transboundary coordination more challenging.

In conclusion, the Kootenai River system reflects the intertwined effects of upstream mining, watershed hydrology, climate variability, and fragmented transboundary governance. Without stable and long term monitoring, natural resource agencies will be limited in their ability to detect and respond to emerging water quality changes. The persistence of selenium, combined with rising nitrogen and phosphorus, reinforces the need for sustained bilateral collaboration between the United States and Canada, Ensuring the long term resilience of the Kootenai River will require policy actions that not only monitor present conditions but also anticipate future challenges in this shared international watershed.

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APPENDICES

APPENDIX A

Tables

APPENDIX B

Figures

USGS-12301933 Nitrogen Species Water Sample ANOVA: Single Factor						
Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Water Year 19	6	3.114	0.519	0.18331		
Water Year 20	6	2.749	0.458167	0.142984		
Water Year 21	24	14.292	0.5955	0.2195		
Water Year 22	33	19.549	0.592394	0.219567		
Water Year 23	33	18.185	0.551061	0.181815		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.134021	4	0.033505	0.16646	0.954932	2.46548
Within Groups	19.5242	97	0.20128			
Total	19.65823	101				

Figure 9: USGS 12301933 Nitrogen Species Water Sample ANOVA: Single Factor

USGS-12301933 Phosphorus Species Water Sample ANOVA: Single Factor						
Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Water Year 19	1	0.004	0.004	#DIV/0!		
Water Year 20	7	0	0	0		
Water Year 21	2	0.007	0.0035	5E-07		
Water Year 22	5	0.02	0.004	0.000001		
Water Year 23	9	0.026	0.002889	6.11E-07		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.02E-05	4	1.51E-05	30.47448	4.99E-08	2.895107
Within Groups	9.39E-06	19	4.94E-07			
Total	6.96E-05	23				

Figure 10: USGS 12301933 Phosphorus Species Water Sample ANOVA: Single Factor

USGS-12301933 Selenium Species Water Sample ANOVA: Single Factor						
Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Water Year 19	28	26.64	0.951429	0.035761		
Water Year 20	291	287.23	0.987045	0.007551		
Water Year 21	236	241.31	1.0225	0.031134		
Water Year 22	107	116.92	1.09271	0.079552		
Water Year 23	95	106.1	1.116842	0.007586		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.857295	4	0.464324	17.79908	5.67E-14	2.383774
Within Groups	19.61739	752	0.026087			
Total	21.47469	756				

Figure 11: USGS 12301933 Selenium Species Water Sample ANOVA: Single Factor

USGS-12301933 Selenium SpeciesTissue Sample Drymass Basis ANOVA: Single Factor						
Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Water Year 19	0	0	#DIV/0!	#DIV/0!		
Water Year 20	7	122.6	17.51429	43.7181		
Water Year 21	11	198.2	18.01818	86.86964		
Water Year 22	0	0	#DIV/0!	#DIV/0!		
Water Year 23	0	0	#DIV/0!	#DIV/0!		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.086176	4	0.271544	0.003121	0.999978	3.179117
Within Groups	1131.005	13	87.00038			
Total	1132.091	17				

Figure 12: USGS 12301933 Selenium Species Tissue Sample Dry mass Basis (Recoverable)

ANOVA: Single Factor

USGS-12304500 Nitrogen Species Water Sample ANOVA: Single Factor

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Water Year 19	6	0.186	0.031	0.002421
Water Year 20	3	0	0	0
Water Year 21	9	0	0	0
Water Year 22	6	0	0	0
Water Year 23	3	0.225	0.075	0.004341

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.016385	4	0.004096	4.335402	0.00978	2.816708
Within Groups	0.020786	22	0.000945			
Total	0.037171	26				

Figure 13: USGS 12304500 Nitrogen Species Water Sample ANOVA: Single Factor

USGS-12304500 Phosphorus Species Water Sample ANOVA: Single Factor

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Water Year 19	2	0.014	0.007	0.000008
Water Year 20	4	0	0	0
Water Year 21	1	0.008	0.008	#DIV/0!
Water Year 22	2	0.012	0.006	0.000002
Water Year 23	2	0.122	0.061	0.00605

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.005464	4	0.001366	1.352385	0.352282	4.533677
Within Groups	0.00606	6	0.00101			
Total	0.011524	10				

Figure 14: USGS 12304500 Phosphorus Species Water Sample ANOVA: Single Factor

USGS-12304500 Selenium Species Water Sample ANOVA: Single Factor

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Water Year 19	2	0	0	0
Water Year 20	1	0	0	#DIV/0!
Water Year 21	3	0	0	0
Water Year 22	2	0	0	0
Water Year 23	2	0	0	0

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0	4	0	65535	#DIV/0!	5.192168
Within Groups	0	5	0			
Total	0	9				

Figure 15: USGS 12304500 Selenium Species Water Sample ANOVA: Single Factor

USGS-12305000 Nitrogen Species Water Sample ANOVA: Single Factor

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Water Year 19	12	4.854	0.4045	0.110592
Water Year 20	12	4.976	0.414667	0.122522
Water Year 21	9	3.818	0.424222	0.145311
Water Year 22	6	2.132	0.355333	0.120059
Water Year 23	2	0.901	0.4505	0.161881

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.02325	4	0.005813	0.046615	0.995717	2.633532
Within Groups	4.488909	36	0.124692			
Total	4.512159	40				

Figure 16: USGS 12305000 Nitrogen Species Water Sample ANOVA: Single Factor

USGS-12305000 Phosphorus Species Water Sample ANOVA: Single Factor						
Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Water Year 19	3	0.026	0.008667	1.73E-05		
Water Year 20	1	0.008	0.008	#DIV/0!		
Water Year 21	1	0.007	0.007	#DIV/0!		
Water Year 22	2	0.011	0.0055	5E-07		
Water Year 23	1	0.013	0.013	#DIV/0!		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.97E-05	4	9.93E-06	0.84686	0.57793	9.117182
Within Groups	3.52E-05	3	1.17E-05			
Total	7.49E-05	7				

Figure 17: USGS 12305000 Phosphorus Species Water Sample ANOVA: Single Factor

USGS-12305000 Selenium Species Water Sample ANOVA: Single Factor						
Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Water Year 19	6	4.059	0.6765	0.100398		
Water Year 20	4	3.6	0.9	0.053267		
Water Year 21	3	2.48	0.826667	0.027433		
Water Year 22	2	1.6	0.8	0.0648		
Water Year 23	2	1.76	0.88	0.2048		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.145847	4	0.036462	0.443639	0.775039	3.259167
Within Groups	0.986254	12	0.082188			
Total	1.132101	16				

Figure 18: USGS 12305000 Selenium Species Water Sample ANOVA: Single Factor

USGS-12305000 Selenium SpeciesTissue Sample Drymass Basis ANOVA: Single Factor						
Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Water Year 19	19	216.5	11.39474	84.43275		
Water Year 20	12	230	19.16667	10.69697		
Water Year 21	9	78.2	8.688889	72.21611		
Water Year 22	0	0	#DIV/0!	#DIV/0!		
Water Year 23	0	0	#DIV/0!	#DIV/0!		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	672.0127	4	168.0032	2.654456	0.049161	2.641465
Within Groups	2215.185	35	63.291			
Total	2887.198	39				

Figure 19: USGS 12305000 Selenium Species Tissue Sample Dry mass Basis (Recoverable)

ANOVA: Single Factor