2020 Elk Valley Regional Water Quality Model Update - Annex D

Water Quality: Model Projections Comparison

Rev0

March 2021

This report was prepared with assistance from:

GOLDER ASSOCIATES LTD.

Amanda Snow, MASc
Senior Water Quality Specialist

J.P. Bechtold, MASc, PBiol, RPBio
Principal, Senior Water Quality Specialist

Contents

Tables

Figures

Appendices

1 Introduction

This report includes a description of the methods used to generate projections of potential future concentrations of nitrate, selenium, sulphate and cadmium at Compliance Points, Order Stations, and other locations in the Elk Valley. It also includes the resulting projections, taking into consideration permitted development and the water quality mitigation measures described in the 2019 Implementation Plan Adjustment (2019 IPA). This work was conducted as part of the 2020 Regional Water Quality Model Update. The regional water quality model (RWQM) was initially developed in 2014 to support the development of the Elk Valley Water Quality Plan (EVWQP). It was subsequently updated in 2017 pursuant to Section 9.9 of *Environmental Management Act* (EMA) permit 107517 and used to develop the 2019 IPA. The need to update the RWQM every three years is identified in EMA Permit 107517; hence, the 2020 RWQM Update has been undertaken to continue to meet this permit condition.

The RWQM is a planning tool that is used to support water quality and broader environmental assessments, as well as development and modification of water quality management strategies (such as those outlined in the 2019 IPA). Similar to its predecessors, the 2020 RWQM is used to simulate historical and future aqueous concentrations of nitrate, selenium, sulphate and cadmium at Compliance Points, Order Stations and other locations in the Fording River and Elk River watersheds. It has been calibrated to historical information and used to evaluate how water quality constituent concentrations may change in future due to mining in the Elk Valley and the implementation of water quality management and mitigation.

This report (Annex D) is one of five documents included in the March 2021 submission to the British Columbia (BC) Ministry of Environment and Climate Change Strategy (ENV) and the BC Ministry of Energy, Mines and Low Carbon Innovation (EMLI). The other four documents consist of:

- The 2020 RWQM Update Report - this is the main report, which includes a description of the 2020 RWQM Update, a discussion of model performance, future projections that include the water quality management measures included in the 2019 IPA and a discussion on key uncertainties and how they will be addressed to support future model updates.
- Annex A: Geochemical Source Term Methods and Inputs for the 2020 Update of the Elk Valley Regional Water Quality Model - this report includes a description of the geochemical models for constituent release and updates made to the geochemical source terms used to define constituent loading rates in the Elk Valley.
- Annex B: 2020 RWQM Update: Hydrology Modelling - Set-up, Calibration and Future Projections Report - this report includes a description of updates made to the flow component (FC) of the 2020 RWQM, details on the performance of the updated flow component and the methods used to generate future flows.
- Annex C: 2020 RWQM Update: Water Quality Modelling - Set-up and Calibration Report - this report outlines updates made to the water quality component (WQC) of the 2020 RWQM and describes its performance in terms of replicating measured concentrations of Order constituents in the Elk River and Fording River mainstems, as well as in mine-influenced tributaries.

The 2020 RWQM Update submission is a model methods submission. It details how the model has been updated and changed to reflect new learnings and incorporate feedback collected since the 2017 RWQM Update. It describes (in the aforementioned annexes) the changes made and how the updated model performs, with reference to the simulation of historical conditions. This submission also includes projections into the future, based on the updated configuration of the model and the mitigation measures outlined in the 2019 IPA. In addition, as this document is a methods submission, it includes unmitigated future projections in order to identify what has changed and to evaluate how the 2020 RWQM performs in comparison to the 2017 RWQM. Neither the mitigated or unmitigated projections reflect expected future concentrations, because mitigation has not yet been adjusted. As a result, this report does not include a discussion of how future projections compare to compliance limits or Site Performance Objectives (SPOs), and the future projections outlined herein should not be used to assess potential effects to water quality or aquatic health.

Adjustments to the Implementation Plan are underway and will be described in a separate submission; an integrated aquatic effects assessment will be completed, as appropriate, and included in the separate submission. Adjustments to the Implementation Plan have been initiated in response to new learnings around the use and performance of saturated rock fills (SRFs), changes to blast management practices that have been implemented across Teck's operations, improved understanding of surface water – groundwater partitioning at Kilmarnock Creek and in response to the model updates outlined herein. The next IPA is being developed, consistent with the AMP and permit requirements related to the 3-year model updates. It will be advanced in consultation with Ktunaxa Nation Council (KNC) and regulators. Comparisons of future projections to compliance limits and SPOs will be discussed in that separate submission.

2 Methods

2.1 Comparison of Model Projections

The 2017 RWQM produces estimates of instream flow based on analogue hydrographs. Future projections developed using that version of the RWQM are based on three flow conditions: low, average or high flows.

The 2020 RWQM model is climate-driven, and future projections are developed using climate information from 2000 to 2019. The climate information is run repeatedly through the model, so that each year in the future simulation period experiences climate conditions equivalent to those recorded from 2000 to 2019. In other words, the model loops through the 2000 to 2019 dataset 20 times, with each loop being referred to as a realization and the starting date of the historical climate dataset being offset by one year from that used in the previous realization. For example, during the first realization, the climate information starts in 2000 and ends with that from 2019. In the next realization, the climate information starts in 2001 and ends with that from 2000, and so on through the 20 realizations. When the duration of the simulation exceeds 20 years, the climate information is repeated. For example, the first realization of a 40-year simulation will begin with climate information from 2000 and run through the 2000 to 2019 climate dataset twice over the course of the simulation.

This approach results in 20 individual estimates of flow and constituent concentration for each week of each future year. The individual weekly estimates are used to calculate temporally-connected monthly and annual average concentrations within each realization. The resulting monthly and annual average datasets are summarized by calculating median (P50), 10^{th} percentile (P10) and 90^{th} percentile (P90) values across the 20 realizations for each future month and each future year.

A potential benefit to the configuration of the 2020 RWQM is that the influences of climate and, in turn, flow on instream water quality are easier to connect (i.e., it is easier to identify the climate conditions that trigger a given projected response in instream water quality). In contrast, flow statistics are input into the 2017 RWQM to assess how variations in climate (and hence flow) may influence future water quality conditions, which makes it more challenging to create direct linkages between given climate patterns (as experienced in a given year) and projected instream water quality responses. Both approaches are effective at developing projections of potential future instream water quality; the 2020 RWQM simply offers an easier mechanism by which to move back and forth between projections of instream water quality response and the climate conditions that drive them.

Projected P50 concentrations developed using the 2020 RWQM were compared to those developed by the 2017 RWQM under average flow conditions. It is acknowledged that comparing a P50 water quality concentration to one developed using average flow conditions is not a direct comparison. However, it is considered a reasonable point of comparison because it involves comparing the mid-point of the 2020 RWQM dataset to the mid-value generated by the 2017 RWQM. A strict comparison cannot be achieved because of the changes made to the RWQM. The 2017 RWQM produces future projections based on analogue hydrographs and flow statistics generated using monitored flow information from 1995 to 2016. The 2020 RWQM generates future projections using climate data from 2000 to 2019, and calculating average concentrations from the climate-driven output is not equivalent to generating future projections using average flow statistics.

The comparisons were completed with and without consideration of the mitigation measures outlined in the 2019 IPA. Locations considered in these comparisons are shown in Figure 2-1; they consist of the Order Stations and Compliance Points outlined in Permit 107517, and include both:

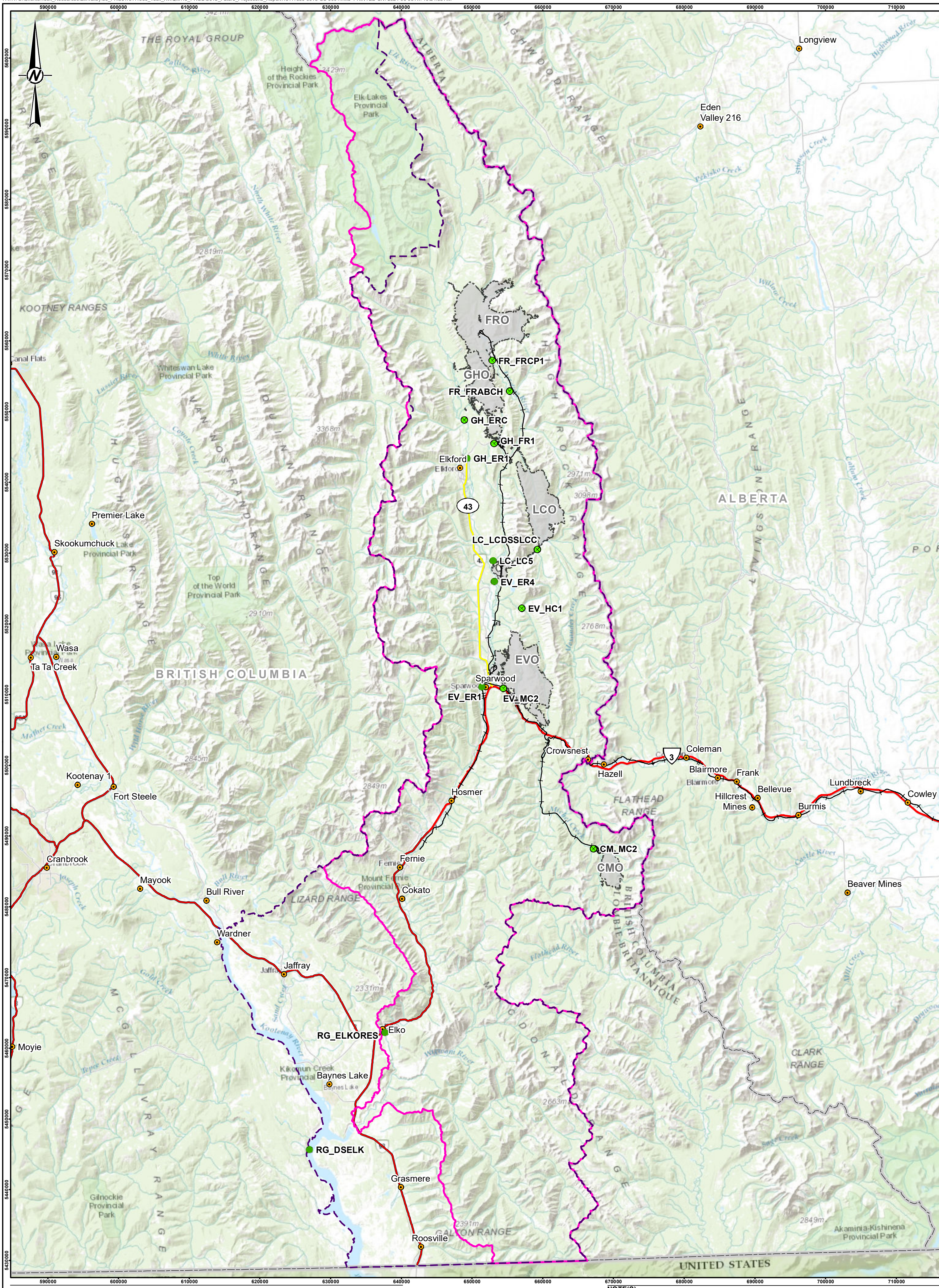
- the old Fording River Operations (FRO) Compliance Point, located in the Fording River 525 m downstream of Cataract Creek (FR_FRCP1; E300071)
- the new FRO Compliance Point, located in the Fording River approximately 100 m upstream of Chauncey Creek (FR_FRABCH; E223753)

Comparison to future projections without mitigation were conducted and included to identify how updates to the RWQM influence future projections; however, future projections without mitigation do not provide any indication of Teck's plans to manage water quality. Beyond the movement to a climate-driven model framework, changes to the RWQM include, but are not limited to, the following (as outlined in more detail in Annexes A, B and C):

- updates to catchment-specific geochemical source terms to account for:
    - additional monitoring data collected since the 2017 RWQM
    - recent improvements in blasting practices (i.e., lining of blast holes)

    - an initial soluble load of selenium and sulphate that accompanies waste rock when first deposited
    - the correlation of cadmium release to that of sulphate and the management and storage of potentially acid generating waste rock originating from the Morrissey Formation
    - the attenuation of cadmium both within and downstream of waste rock spoils
    - the finite nature of constituent inventories in waste rock
- changes to the methods used to simulate the leaching of nitrate, as well as those used to simulate the seasonal and interannual release of constituents, from waste rock
- development and inclusion of a waste rock hydrology module that allows for a more mechanistic representation of water flow through waste rock
- incorporation of variable hydraulic lag for new spoils, in reflection of recent observations at LCO Dry Creek
- changes to the methods used to simulate the release of constituents from rehandled materials by accounting for hydraulic lag and leaching efficiency
- updates to historical waste rock deposition schedules and volumes to reflect current drainage delineations, aerial photography and recent survey information
- updates to explicitly account for surface water – groundwater partitioning and its influence on measured estimates of total flow
- recalibration of both the FC and WQC of the RWQM

The water quality mitigation measures considered when developing future projections with the 2020 RWQM included those outlined in the 2019 IPA, with one exception. Water quality mitigation measures at Elkview Operations (EVO) were adjusted to reflect the *Operations Application for the Elkview Operations Saturated Rock Fill Phase 2 Project* (Teck 2020), which was approved during the completion of the 2020 RWQM Update. A summary of the water quality mitigation measures considered when developing the future projections outlined herein are provided in Table 2-1.



LEGEND

- EMA PERMIT 107517 ORDER STATION
- EMA PERMIT 107517 COMPLIANCE STATION
- CITY/TOWN/COMMUNITY
- CANADIAN PACIFIC RAILWAY
- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- MINE PERMIT BOUNDARY
- ELK RIVER WATERSHED BOUNDARY
- DESIGNATED AREA (GEOGRAPHIC EXTENT OF THE MODEL)

0 10 20

1:510,000 KILOMETRES

NOTE(S)

REFERENCE(S)
1. BASE DATA: CANVEC, 2018
2. TECK WATER NETWORK AND WATER MANAGEMENT DATA, 2019-09-26
3. BASEMAP: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 11N

TECK COAL LIMITED

Teck

YYYY-MM-DD	2020-10-08
DESIGNED	PR
PREPARED	PR
REVIEWED	CG
APPROVED	AS

PROJECT
2020 REGIONAL WATER QUALITY MODEL UPDATE
FUTURE PROJECTIONS REPORT

TITLE
ORDER STATIONS AND COMPLIANCE POINTS

PROJECT NO.	CONTROL	REV.	FIGURE
18111630	0013	0	2.1

Table 2-1: Configuration of the Water Quality Mitigation Measures Considered in the 2020 RWQM

Site	Sources Targeted for Treatment	Treatment Facility	Treatment Capacity (m³/d)	Associated Diversions and Conveyance of Mine-Influenced Water	Date Fully Effective in 2020 RWQM[(a)]
FRO	Swift Creek, Cataract Creek and Kilmarnock Creek	Fording River South Phase I	20,000	• Diversion of Upper Kilmarnock watershed • Convey mine-influenced water to treatment • Discharge to the Fording River in the 2019 IPA and Kilmarnock Creek in the 2020 RWQM	December 31, 2021
			5,000		December 31, 2029
			20,000		December 31, 2035
	Clode Creek, North Spoil and Swift Pit	Fording River North Phase I	30,000	• Convey mine-influenced water to treatment • Discharge to the Fording River	December 31, 2023
LCO	West Line Creek and Line Creek	WLC Phase I	6,000	• Diversion of Upper Line Creek, Horseshoe Creek and No Name Creek • Convey mine-influenced water to treatment • Discharge to Line Creek	December 31, 2018
		WLC Phase II	1,100		December 31, 2019
		WLC Phase III	12,500		December 31, 2025
		WLC Phase IV	32,500		December 31, 2033
	LCO Dry Creek	LCO Dry Creek Phase I	2,500	• Convey mine-influenced water to treatment • Discharge to the Fording River	December 31, 2037
		LCO Dry Creek Phase II	2,500		December 31, 2049
GHO	Leask, Wolfram, Thompson, and Greenhills creeks	Greenhills Phase I	5,000	• Convey mine-influenced water to treatment • Discharge to Thompson Creek	December 31, 2031
		Greenhills Phase II	2,500		Post 2100
EVO	F2 Pit and Natal Pit West	EVO SRF Phase I	10,000	• Convey mine-influenced water to treatment • Discharge to Bodie Creek	January 1, 2018
	F2 Pit, Erickson Creek and Natal Pit West	EVO SRF Phase II	10,000	• Convey mine-influenced water to treatment • Discharge to Erickson Creek	January 1, 2021
	Erickson Creek and Natal Pit West	Elkview Phase III	20,000	• Convey mine-influenced water to treatment • Discharge to Erickson Creek and Bodie Creek	December 31, 2027
		Elkview Phase IV	5,000		December 31, 2043

[(a)] The fully effective date refers to the date when the treatment facility is built, seeded, commissioned and effective at the hydraulic capacity listed above.

EVO = Elkview Operations; FRO = Fording River Operations; GHO = Greenhills Operations; LCO = Line Creek Operations; RWQM = Regional Water Quality Model; SRF = Saturated Rock Fill; WLC = West Line Creek; m^3/d = cubic metres per day.

Source: Teck (2019) and Teck (2020).

2.2 Sensitivity Analysis

In addition to the comparison of outputs from the 2020 RWQM to those from the 2017 RWQM, the sensitivity of the mitigated projections developed using the 2020 RWQM was examined with reference to:

- variations in climate
- changes to the model inputs related to improvements in blasting practices (nitrate only)
- changes to the model inputs related to selenium and sulphate release rates

2.2.1 Variations in Climate

The sensitivity of future projections to variations in climate was evaluated with a focus on the following mainstem locations:

- Fording River downstream of Line Creek (LC_LC5; 0200028)
- Elk River upstream of Grave Creek (EV_ER4; 0200027)
- Elk River downstream of Michel Creek (EV_ER1; 0200393)

These locations correspond to Order Stations situated downstream of Teck's operations. The evaluation itself consisted of comparing P50 projections at each location to the corresponding P10 and P90 projections developed using the 2020 RWQM.

2.2.2 Changes to Model Inputs Related to Blasting Practices

Lining of blast holes began in 2017 at Teck's operations in the Elk Valley, the purpose of which is to limit the loss of explosives prior to blasting. Limiting the loss of explosives reduces the amount of explosive residual associated with freshly blasted waste rock, which, in turn, reduces the release of nitrate from waste rock spoils.

The 2020 RWQM accounts for the use of liners, as per the methods outlined in Annex C. From 2017 onward, liners are assumed to be present in some proportion of blast holes as defined by historical loading information and mine plans. Their effectiveness at preventing the loss of explosives prior to blasting is modelled as 50%, a value informed by field investigations (see Annex A for details). A sensitivity analysis was undertaken to understand how changes to this value affect projected concentrations of nitrate. Values considered in the analysis were 0% (no loss prevention), 20% (a lower degree of loss prevention), and 90% (a higher degree of loss prevention more closely aligned with Teck's goals). This analysis was conducted with a focus on the following locations:

- Kilmarnock Creek downstream of the Rock Drain (FR_KC1; 0200252)
- GHO Fording River Compliance Point (GH_FR1; 0200378)

The former location was selected, because the waste rock spoil in Kilmarnock Creek is one of the largest sources of nitrate amongst spoils in the Elk Valley; it is also an established spoil, which continues to receive waste rock. Thus, model projections for this location can be used to identify how the use of liners from 2017 onward may influence nitrate leaching from older spoils.

The latter location was selected, because it is situated downstream of older established spoils and more recently established newer spoils, where changes to blasting practices are expected to have a more immediate effect on nitrate leaching. Thus, projections at the GHO Fording River Compliance Point provide insight into the potential net effect of how changes to blasting practices may potentially affect future nitrate concentrations in the receiving environment.

This sensitivity analysis was conducted using P50 flows, rather than running the WQC through 20 complete realizations for each alteration to the assumption around liner effectiveness. This approach was adopted for computational simplicity and to speed the execution of the analysis.

2.2.3 Changes to Model Inputs Related to Selenium and Sulphate Release Rates

Results from longer-term humidity cell tests indicate that selenium and sulphate release rates from waste rock decline over time as sulphide minerals are depleted, as discussed in Annex A. The decline tends to follow first order decay kinetics. The 2020 RWQM includes functionality to maintain selenium and sulphate release rates unchanged over the entire simulation period or to allow the release rates to decline over time, on a sub-catchment by sub-catchment basis, once spoiling in a given area has effectively stopped. The 2020 RWQM has been calibrated and future projections generated assuming no decline in selenium and sulphate release rates over time.

A sensitivity analysis was undertaken to identify how future projections could change with consideration of decay. Three rates of decay were evaluated. They are referred to as Decay Rate 1, 2 and 3, and are defined as outlined in Annex A. This evaluation was conducted with a focus on West Line Creek, with decay set to start January 1, 2000.

West Line Creek is a waste-rock dominated catchment, wherein spoiling was largely finished by the end of 1999. More specifically, approximately 90% of the 214 million BCM of waste rock currently residing in West Line Creek was placed into this catchment by December 31, 1999. The hydraulic lag in this catchment has been estimated at 14 years. Thus, if changes in selenium and sulphate release are occurring, their influence should be reflected in the monitoring data collected from this catchment after the bulk of the waste rock has been placed and the hydraulic lag has passed (i.e., from 2014 onward), which provides a point of reference from which to interpret the results of the sensitivity analysis.

This sensitivity analysis, similar to that conducted on liner effectiveness, was conducted using P50 flows, rather than running the WQC through 20 complete realizations for each alteration to the assumption around liner effectiveness.

3 Results and Discussion

3.1 Comparison of Model Projections

Model results without consideration of mitigation are included in Appendix A, and those with consideration of mitigation are outlined in Appendix B. Model results are presented for Order Stations and Compliance Points, with some of the results pulled forward to support the discussion outlined below. The format of the figures in both appendices and those included below are the same, and is as follows:

- The x-axis runs from the start of 2004 (for selenium, sulphate, and cadmium) or 2006 (for nitrate) to the end of 2053. The start date corresponds to the start of the calibration period for the 2020 RWQM. The end date (2053) corresponds to the modelled time period at which all permitted waste rock has been deposited and the lag associated with that rock has passed (i.e., all of the waste rock is contributing selenium and sulphate load).
- Projected P50 monthly average concentrations produced using the 2020 RWQM are shown as a solid blue line.
- Projected monthly average concentrations produced using the 2017 RWQM under average flow conditions are shown as a solid grey line.
- Projected annual average concentrations produced using the 2020 RWQM and 2017 RWQM are shown as dashed blue and grey lines, respectively.
- Measured monthly average and annual average concentrations are shown as light green points and dark green points, respectively.
- Modelled information shown prior to 2020 that was generated using the 2020 RWQM was developed based on calibrated flows. Those shown thereafter were developed using multiple climate realizations, as described in Section 2.1.
- Modelled information shown prior to 2017 that was generated using the 2017 RWQM was developed based on calibrated flows. Those shown thereafter were developed using average flow projections.
- Compliance limits are shown in figures displaying mitigated results as a solid black line and SPOs are shown on those same figures as a solid green line.

The information described in the bullets above is reflected in the following legend that applies to figures showing future projections with mitigation:

—— Projected P_{50} Monthly Average Concentrations from the 2020 RWQM
- - - Projected P_{50} Annual Average Concentrations from the 2020 RWQM
—— Projected Monthly Average Concentrations for Average Flows from the 2017 RWQM
- - - Projected Annual Average Concentrations for Average Flows from the 2017 RWQM
● Monthly Average Measured Concentrations
● Annual Average Measured Concentrations
—— Site Performance Objective
—— Limit

The same legend applies to figures showing future projections without mitigation, with the exception of the last two items (i.e., the figures do not include compliance limits or SPOs).

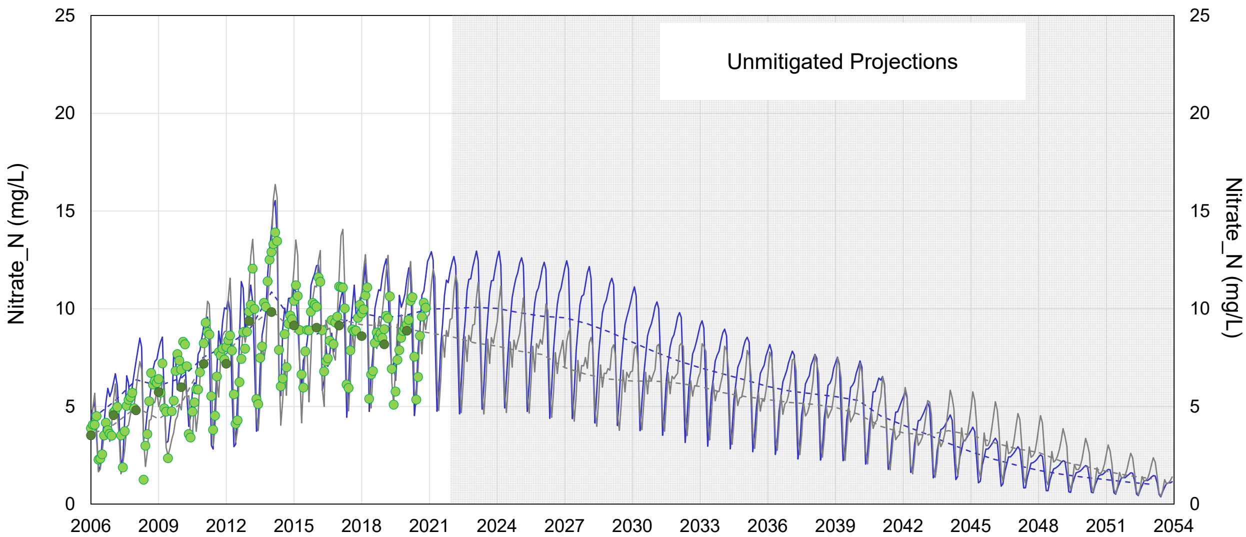
As with any model, input assumptions and projections of future conditions involve uncertainty. Model assumptions are discussed in Annex C. Model error and bias are also described therein. Appendices C and D of this report contain figures showing projected hardness levels, which are relevant to the calculation of some SPOs, and projected future flows.

3.1.1 Nitrate

Projected nitrate concentrations developed using the 2020 RWQM without consideration of mitigation were similar to those developed using the 2017 RWQM (Figure 3-1, with additional figures in Appendix A). In both cases, projected concentrations declined over time in response to leaching of nitrate from waste rock. The projected rate of leaching is slower in the 2020 RWQM than in the 2017 RWQM because of an update to the method used to simulate nitrate leaching, as discussed in Annex C. New spoils also contribute nitrate load to downstream systems within a shorter timeframe than assumed in the 2017 RWQM. The effects of slower leaching rates and the quicker response of new spoils were offset to some extent by the incorporation of updated blasting practices starting in 2017, namely the use of liners to limit the loss of explosives prior to blasting (as described in Teck [2021]).

Comparisons of modelled projections that account for mitigation as per the 2019 IPA yielded similar findings. Projected nitrate concentrations declined over time, reaching a similar end point (Figure 3-2). One exception involved the slower response of projected nitrate concentrations in the Fording River above Chauncey Creek. The slower response in the projections developed using the 2020 RWQM is due to the release of treated water from the Fording River Operations Active Water Treatment Facility - South (FRO AWTF-S) to Kilmarnock Creek and the subsequent movement of this water along subsurface flow paths to the Fording River. Travel times along these subsurface flow paths have been estimated to be in the order of 1 to 6 years (see Annex C for details). Thus, the benefits of treatment achieved by the FRO AWTF-S were projected by the 2020 RWQM to take some time to fully materialize in the Fording River. This outcome is being taken into consideration as work on the next IPA progresses.

(a) Fording River downstream of Line Creek (LC_LC5; 0200028)



(b) Elk River downstream of Michel Creek (EV_ER1; 0200393)

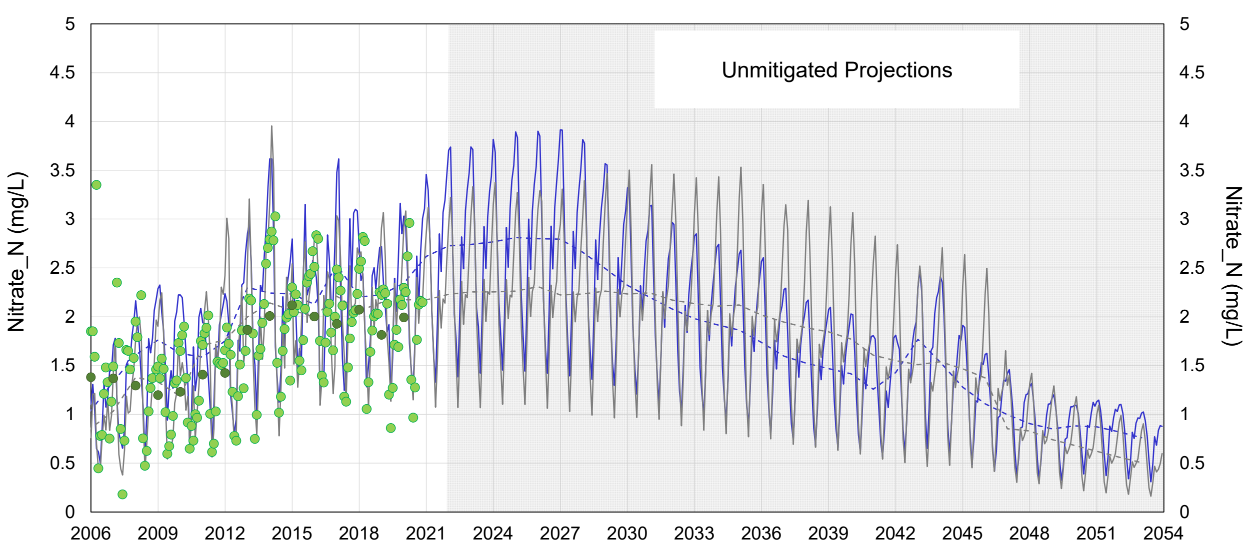
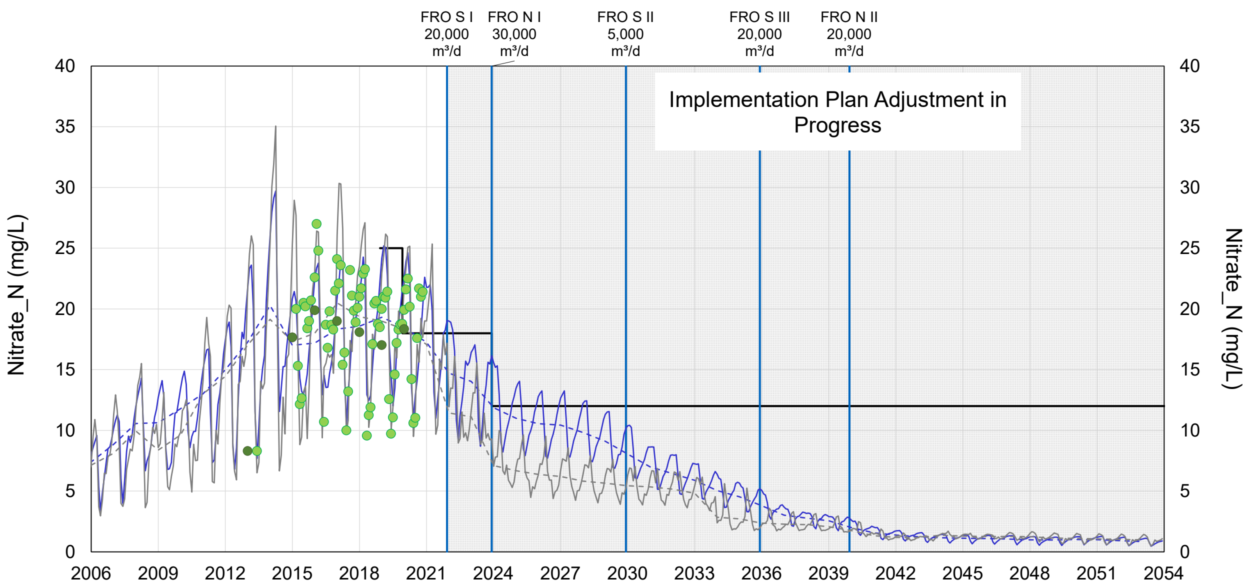


Figure 3-1 Projected Concentrations of Nitrate in the Fording River downstream of Line Creek and in the Elk River downstream of Michel Creek Without Consideration of Mitigation, 2006-2053

(a) FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)



(b) Fording River downstream of Line Creek (LC_LC5; 0200028)

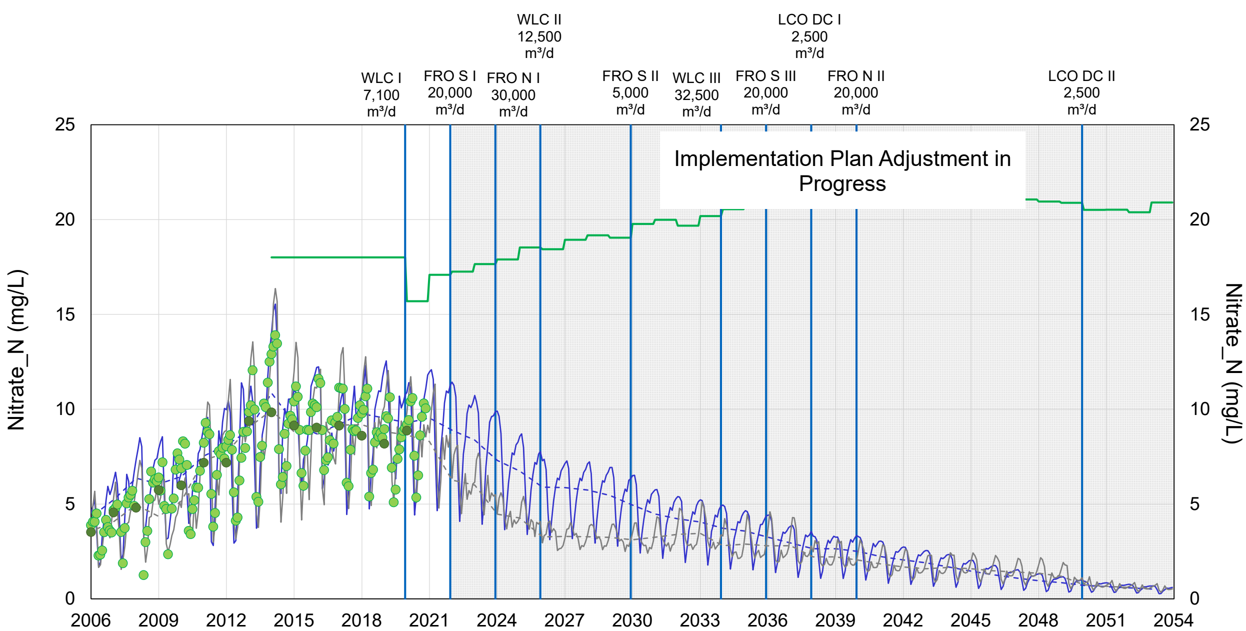
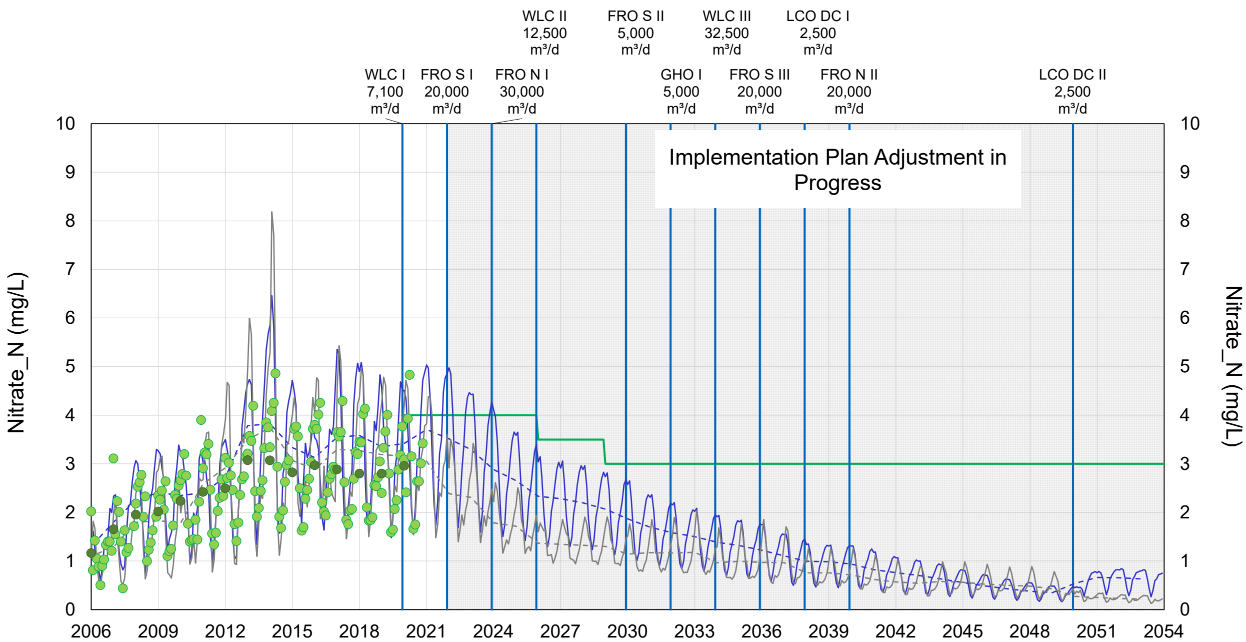


Figure 3-2 Projected Concentrations of Nitrate at Two Locations in Each of the Fording River and Elk River Mainstems With Consideration of Mitigation, 2006-2053

(c) Elk River upstream of Grave Creek (EV_ER4; 0200027)



(d) Elk River downstream of Michel Creek (EV_ER1; 0200393)

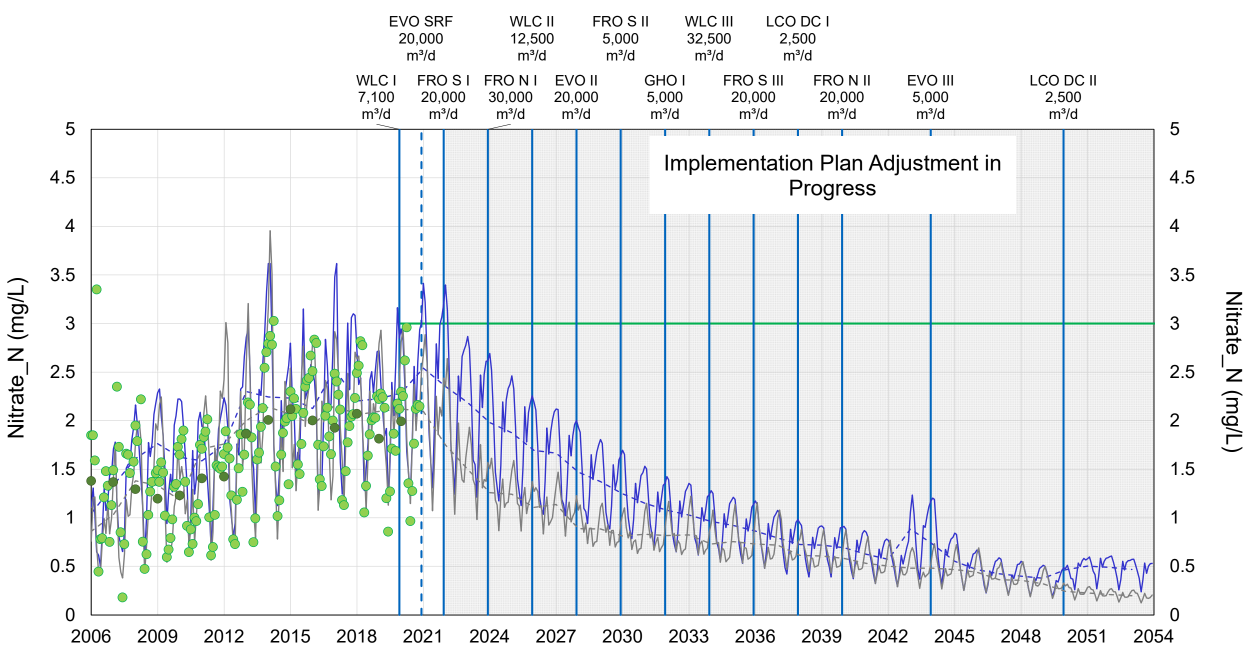


Figure 3-2 Projected Concentrations of Nitrate at Two Locations in Each of the Fording River and Elk River Mainstems With Consideration of Mitigation, 2006-2053

3.1.2 Selenium

Projected selenium concentrations developed using the 2020 RWQM without consideration of mitigation were typically higher than those developed using the 2017 RWQM (Figure 3-3, with additional figures in Appendix A), at least in terms of peak monthly average concentrations. Differences in the unmitigated selenium projections are largely attributable to three changes to the RWQM:

- explicit consideration of surface water – groundwater partitioning at tributary monitoring stations
- incorporation of variable hydraulic lag as it applies to new waste rock spoils, along with the presence of the immediately available initial soluble load
- updated methods to simulate waste rock flow

Explicit consideration of surface water – groundwater partitioning results in higher estimates of total yield in some tributaries, compared to those generated using only surface measured flow data (as was done in the 2017 RWQM Update). In most mine-influenced tributaries, constituent concentrations are similar to those in surface water, based on the evaluation of site-specific groundwater monitoring data. The similarly in constituent concentrations between surface and groundwater indicates that the constituent load released from waste rock mixes with the total yield (i.e., total flow) from a tributary catchment. Thus, as estimates of total yield increase, so must the estimated release rates from waste rock to replicate measured concentrations. Higher release rates produce higher estimates of future loading as more waste rock is added into tributary catchments, which can lead to higher than previously projected concentrations in the receiving environment.

Through the evaluation of the data collected from LCO Dry Creek and from monitoring locations downstream of the FRO North Spoil, it was determined that new spoils release constituent mass more quickly than previously assumed in the 2017 RWQM. In reflection of this new learning, a variable lag for new spoils was incorporated into the 2020 RWQM, whereby hydraulic lag times are initially short (i.e., 1 to 2 years) and increase over time as the spoils expand. The 2020 RWQM was also updated to account for the presence of initial soluble load that is created through pyrite oxidation occurring in newly blasted waste rock prior to placement in a spoil. Shorter hydraulic lag and the presence of initial soluble load result in constituent mass being released more quickly than previous estimated using the 2017 RWQM, which can result in higher constituent concentrations in the receiving environment sooner than would have previously been expected.

Water movement through waste rock is now modelled explicitly, and the methods used result in more of the total yield from waste rock being released in fall and winter and less in spring (see Annex B for details). In other words, in the 2020 RWQM, the dampening effect of waste rock spoils on the annual hydrograph is more pronounced than estimated using the 2017 RWQM, an effect supported by more recent flow data collected from Cataract Creek (see Annex B). This shift produces a commensurate change to the proportions of water in the river mainstems that originate from spoil areas versus non-mine affected areas, with a larger proportion of the fall and winter flow consisting of water originating from spoil areas; the larger proportion of mine-influenced water under lower flow conditions can result in higher projected unmitigated selenium concentrations during those times of year, in comparison to projected concentrations developed using the 2017 RWQM.

The change to the methods used to simulate waste rock flow has a larger influence on the future projections than the incorporation of variable lag or consideration of surface water – groundwater partitioning, because it applies to all spoils. The other two updates are either spoil or catchment-specific, with a smaller influence on the overall system.

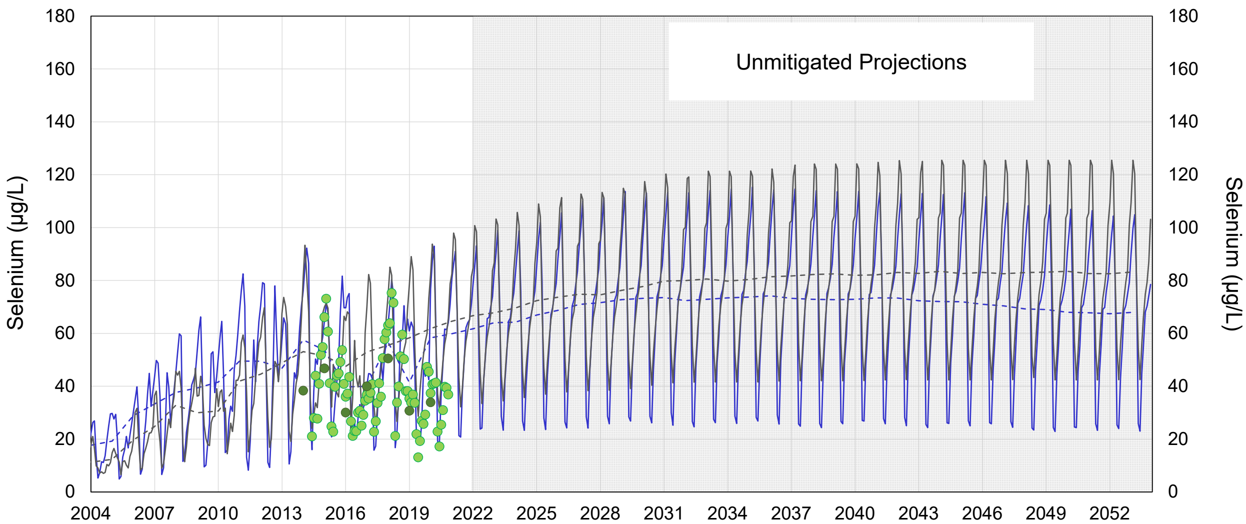
The above-noted changes affect selenium, sulphate and nitrate. However, their influence on projected nitrate concentrations is muted by the loss of nitrate from waste rock over time.

Projected selenium concentrations at the LCO Compliance Point produced using the 2020 RWQM without consideration of mitigation were generally lower than those developed using the 2017 RWQM (Figure 3-3). The contrasting finding at this location is due, in part, to an improved understanding of water flow in West Line Creek.

In the 2017 RWQM, an analogue hydrograph is applied to West Line Creek, with estimated total yield being notably lower than those of other catchments in the Line Creek watershed. The lower estimate of total yield was supported by surface monitoring data collected at the mouth of West Line Creek. However, subsurface flow pathways between West Line Creek and Line Creek have been identified since the completion of the 2017 RWQM Update (SNC 2021). Application of a climate-driven modelling approach to West Line Creek also results in much higher total yield estimates than previously identified in 2017, with total yields being more comparable to those of other catchments in the Line Creek watershed. Thus, a subsurface flow path is included in the 2020 RWQM framework connecting West Line Creek to Line Creek. Flow along this pathway is set to 60% of the estimated total yield, up to a maximum of 10,000 m^3/d. Only 30% of the load being released from the spoil in West Line Creek is moving via the subsurface flow path, based on a review of available surface and groundwater monitoring information (see Annex C for details). Consequently, inclusion of this subsurface flow path results in an improved representation of the total runoff coming from non-mine influenced areas in this catchment that reports to Line Creek.

In addition, the calibrated selenium release rate applied to waste rock in the upper portions of Line Creek is lower than that in the 2017 RWQM. The combination of a lower calibrated release rate and a better representation of non-mine affected runoff served to offset some of the change induced by the updated methods to modelling flows from waste rock, as described above.

(a) LCO Compliance Point (LC_LCDSSLCC; E297110)



Note: The West Line Creek Active Water Treatment Facility has been turned off in the model from January 1, 2020 onward.

(b) Fording River downstream of Line Creek (LC_LC5; 0200028)

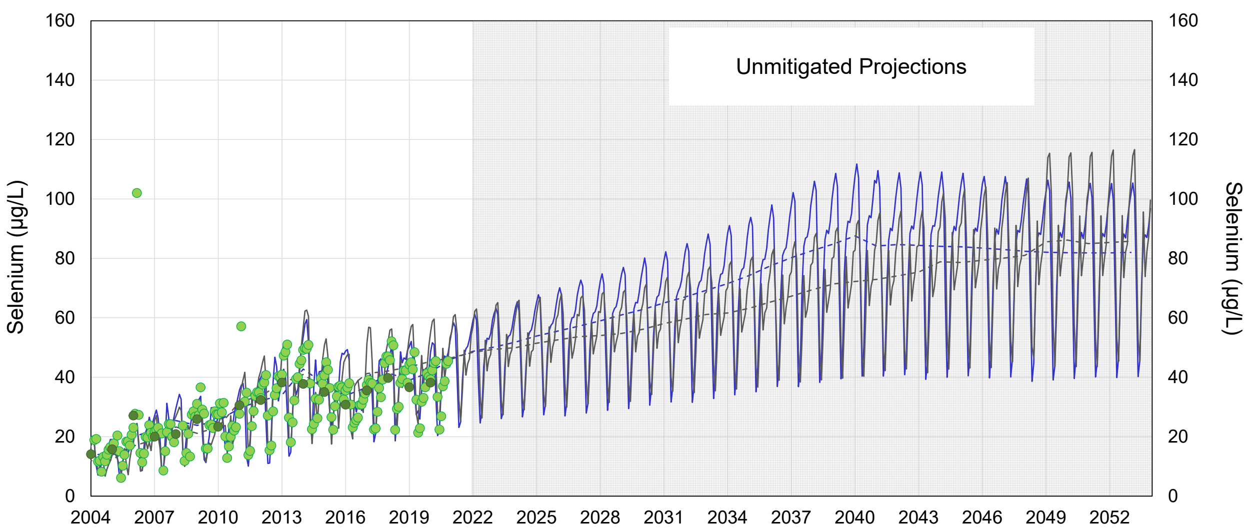


Figure 3-3 Projected Concentrations of Selenium in the Fording River Downstream of Line Creek, at the LCO Compliance Point and in the Elk River Downstream of Michel Creek Without Consideration of Mitigation, 2004-2053

(c) Elk River downstream of Michel Creek (EV_ER1; 0200393)

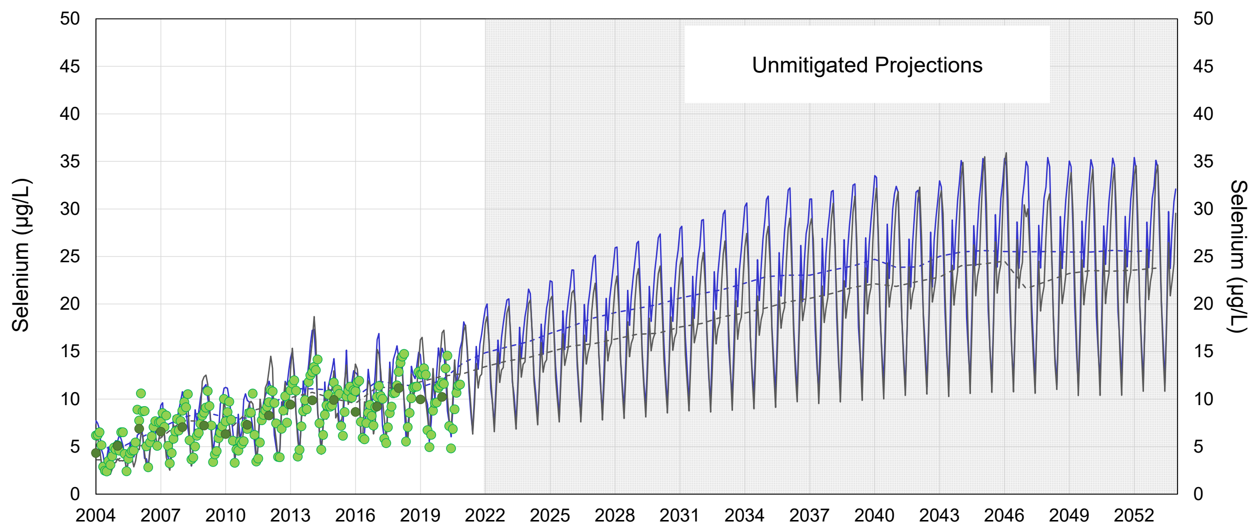


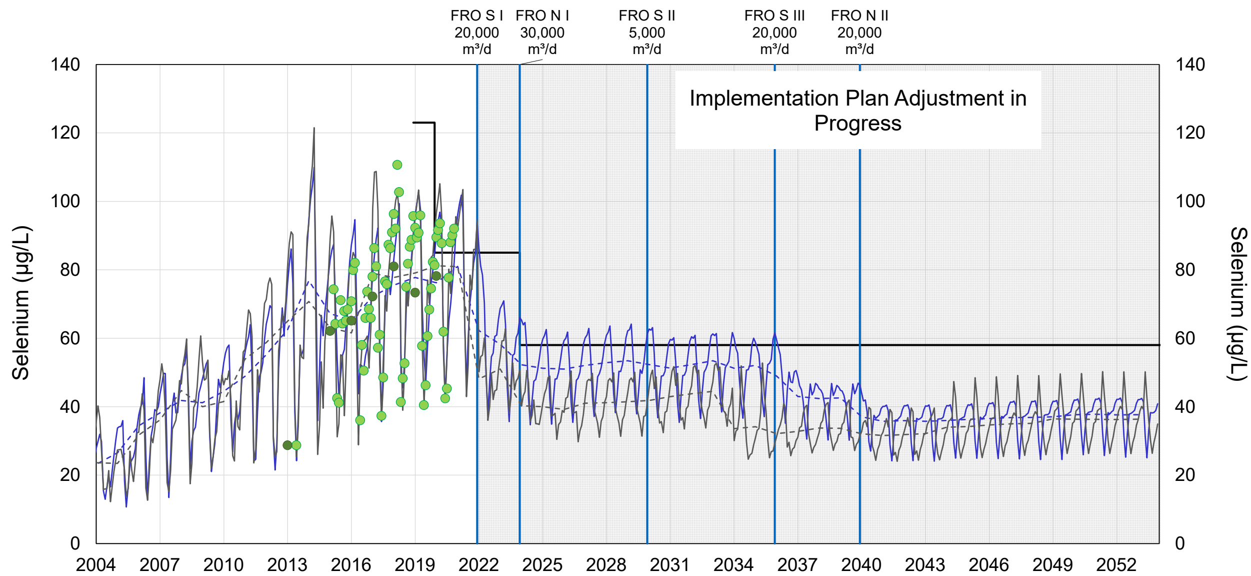
Figure 3-3 Projected Concentrations of Selenium in the Fording River Downstream of Line Creek, at the LCO Compliance Point and in the Elk River Downstream of Michel Creek Without Consideration of Mitigation, 2004-2053

In general, when accounting for the mitigation outlined in the 2019 IPA, projected selenium concentrations produced using the 2020 RWQM were higher than those developed using the 2017 RWQM (Figure 3-4, with additional plots included in Appendix B). Differences are due in large part to the aforementioned changes to the methods used to simulate the production of flow and load from waste rock and the commensurate change to the proportions of water in the river mainstems that originate from spoil areas versus non-mine affected areas, as well as the explicit inclusion of surface water – groundwater partitioning and variable hydraulic lag for new spoils.

The mitigation included in the 2019 IPA was designed around the understanding that capturing and treating fall and winter flow volumes is an effective means to lower selenium concentrations in the receiving environment, but that additional gains were achieved through the treatment of early spring flow volumes. Thus, additional capacity is added over time to capture more and more of the initial spring flow when concentrations are projected (with the 2017 RWQM) to increase in mine-influenced water faster than runoff from non-mining areas is being generated.

Results produced using the 2020 RWQM continue to indicate that treating fall and winter flow volumes is an effective means to lower selenium concentrations in the receiving environment. However, due to the increased dampening of the annual hydrograph projected by the 2020 RWQM, the focus of subsequent phases of treatment may need to shift. To that end, mitigation planning will focus on maximizing the benefits of treatment facility operation through adjustments to timing and magnitude of facility inputs that is based on an optimized assessment of available sources that includes the collection of groundwater in catchments that are currently targeted for treatment.

(a) FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)



(b) Fording River downstream of Line Creek (LC_LC5; 0200028)

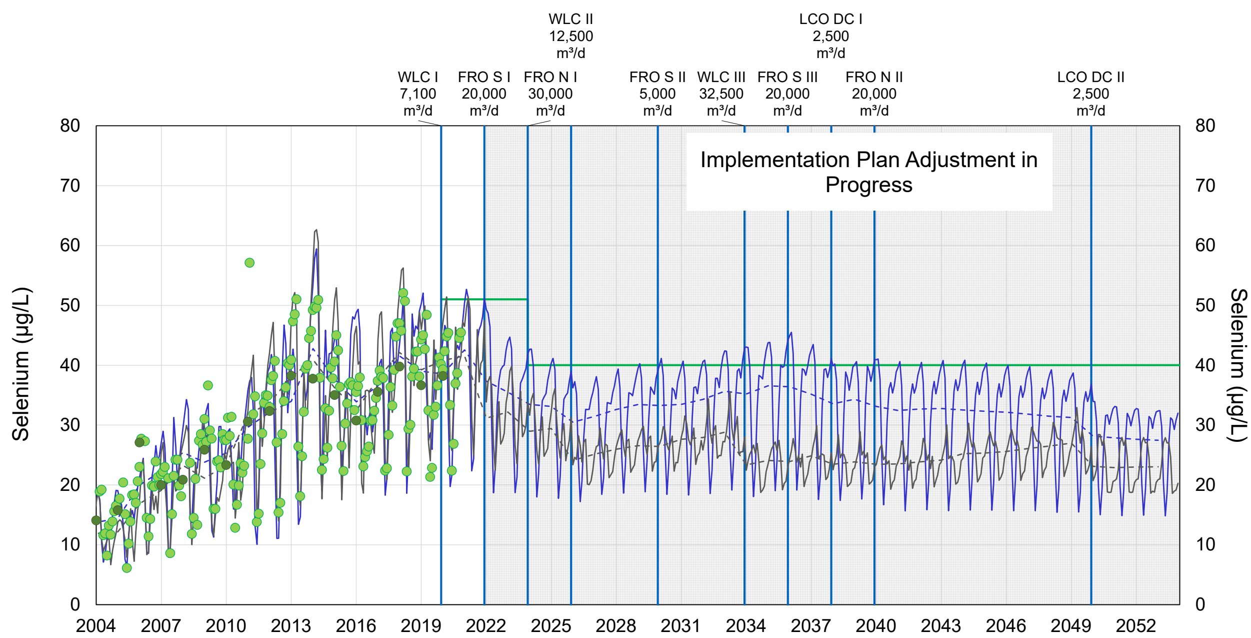
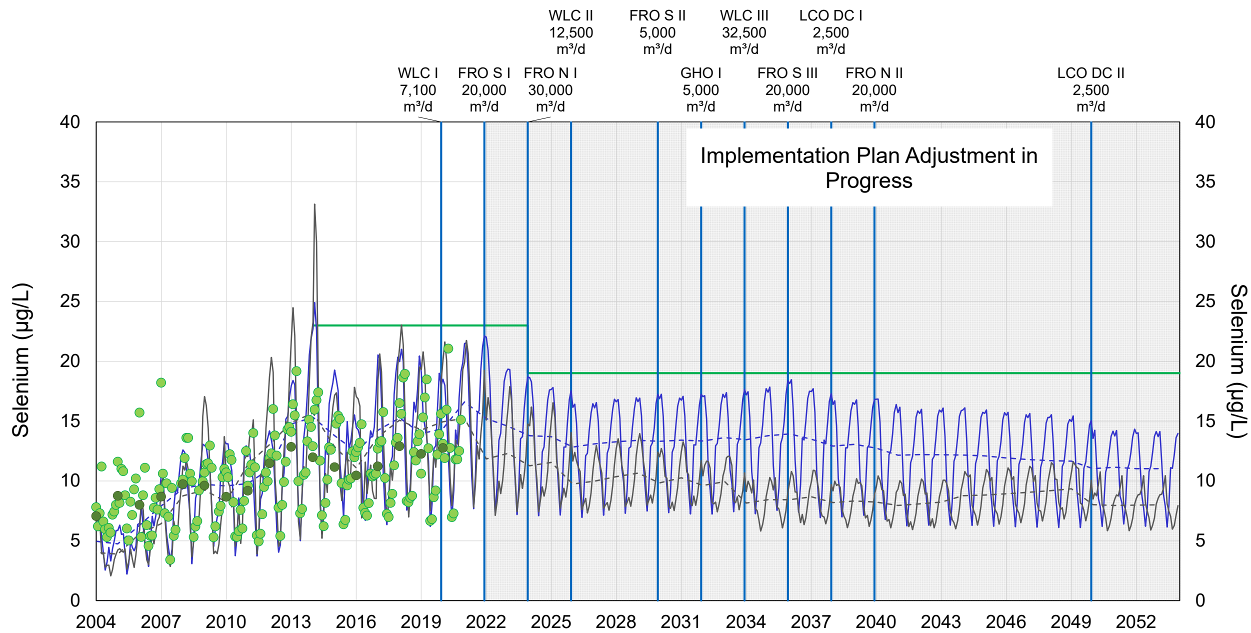


Figure 3-4 Projected Concentrations of Selenium at Two Locations in Each of the Fording River and Elk River Mainstems With Consideration of Mitigation, 2004-2053

(c) Elk River upstream of Grave Creek (EV_ER4; 0200027)



(d) Elk River downstream of Michel Creek (EV_ER1; 0200393)

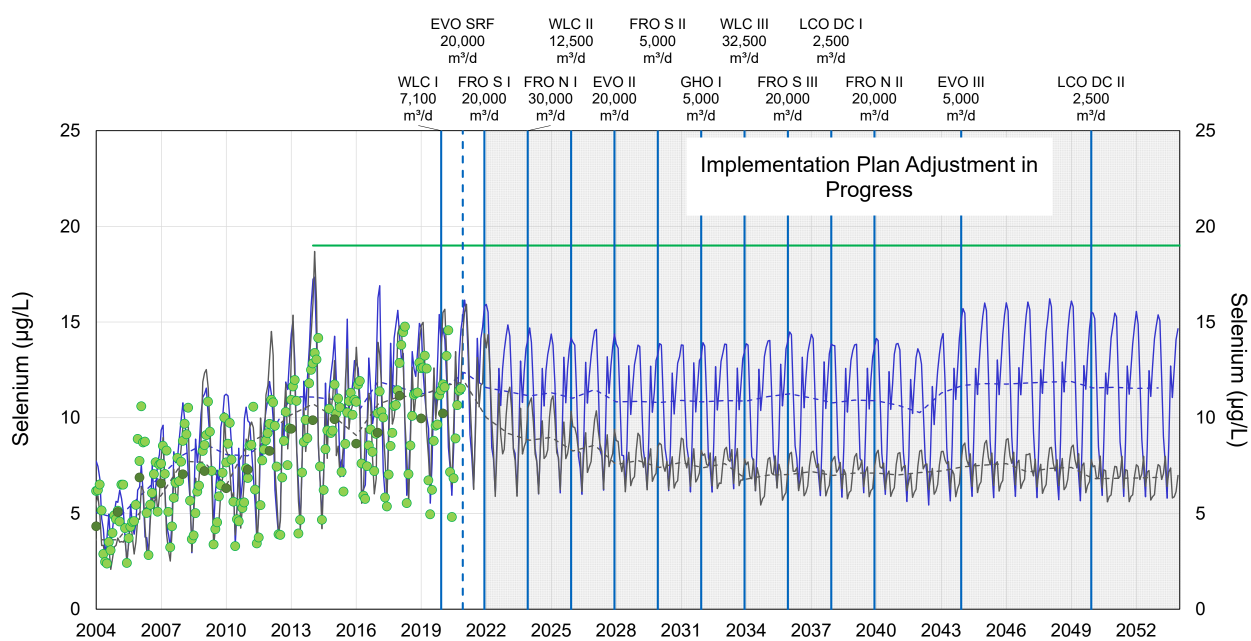


Figure 3-4 Projected Concentrations of Selenium at Two Locations in Each of the Fording River and Elk River Mainstems With Consideration of Mitigation, 2004-2053

3.1.3 Sulphate

The mitigation measures outlined in the 2019 IPA do not specifically target sulphate. Consequently, projected sulphate concentrations did not notably differ between the mitigated versus unmitigated model scenarios, regardless of the model used to generate them (see Appendices A and B). Where differences occurred, they result from small additions of sulphate that occur in the treatment process or as a result of differences between where water subject to treatment is collected from and discharged to (e.g., assumed collection of water from Swift Pit with modelled discharge to the Fording River downstream of Henretta Creek). As the differences between modelled scenarios were small, the comparison between the projections produced using the 2020 RWQM versus those produced using the 2017 RWQM is presented below with reference to the unmitigated results.

As with selenium, projected sulphate concentrations produced using the 2020 RWQM tended to be higher than those produced using the 2017 RWQM (Figure 3-5, with additional plots included in Appendix A). Factors contributing to the projected differences are the same as those outlined above for selenium, with the change to the methods used to simulate waste rock flows and accounting for surface water – groundwater partitioning being the primary drivers. These differences will be evaluated as work progresses on the next IPA.

(a) FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)

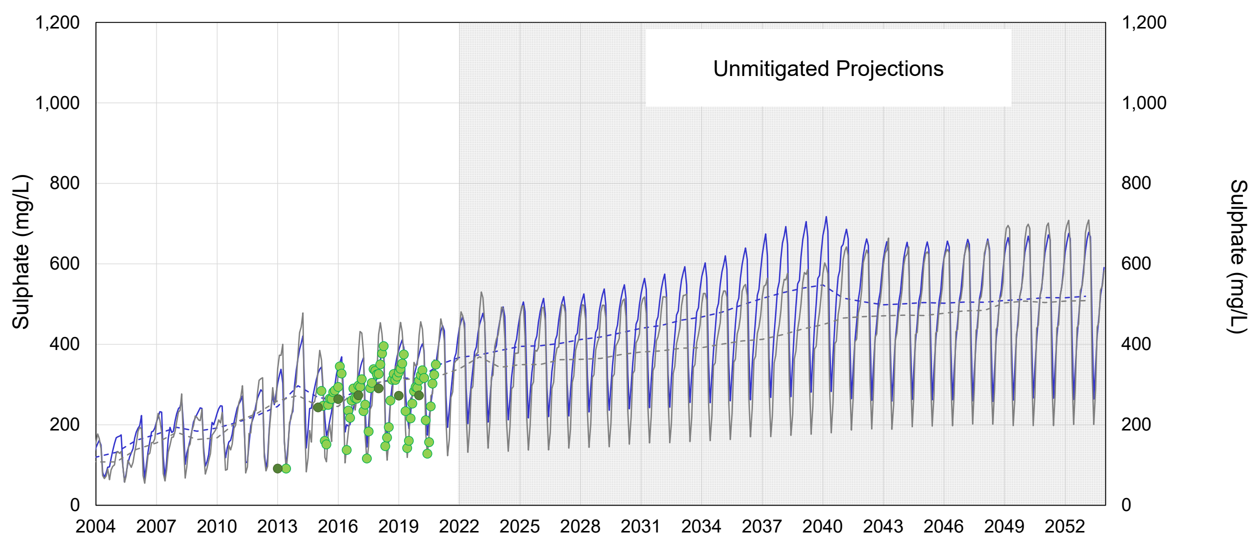
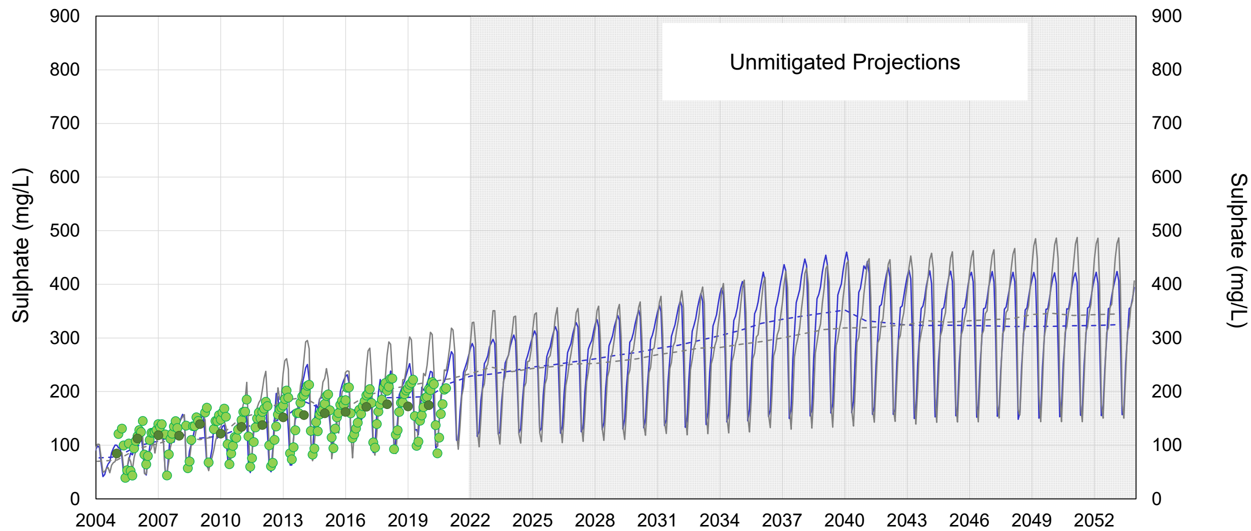


Figure 3-5 Projected Concentrations of Sulphate at Two Locations in Each of the Fording River and Elk River Mainstems Without Consideration of Mitigation, 2004-2053

(b) Fording River downstream of Line Creek (LC_LC5; 0200028)



(c) Elk River upstream of Grave Creek (EV_ER4; 0200027)

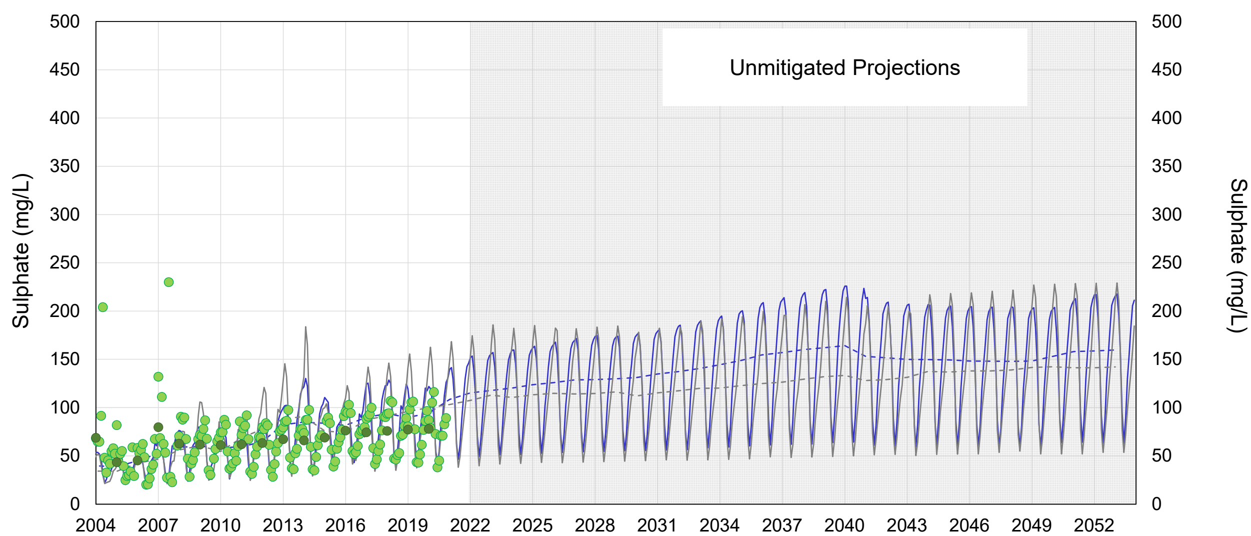


Figure 3-5 Projected Concentrations of Sulphate at Two Locations in Each of the Fording River and Elk River Mainstems Without Consideration of Mitigation, 2004-2053

(d) Elk River downstream of Michel Creek (EV_ER1; 0200393)

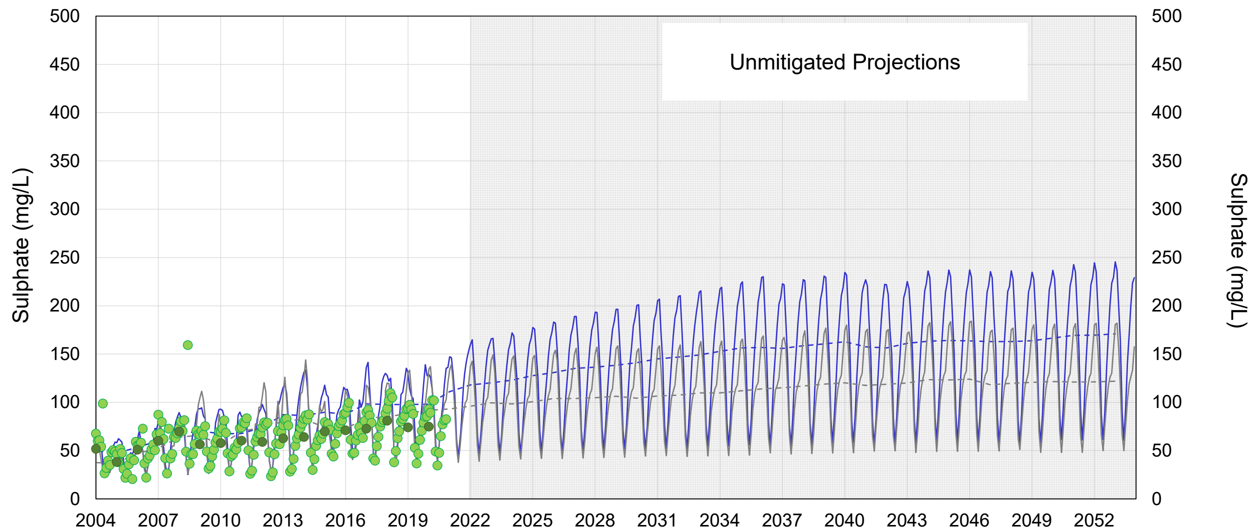


Figure 3-5 Projected Concentrations of Sulphate at Two Locations in Each of the Fording River and Elk River Mainstems Without Consideration of Mitigation, 2004-2053

3.1.4 Cadmium

Similar to sulphate, the mitigation measures outlined in the 2019 IPA do not specifically target cadmium. Consequently:

- projected cadmium concentrations did not notably differ between the mitigated versus unmitigated model scenarios, regardless of the model used to generate them (see Appendices A and B)
- comparison between the projections produced using the 2020 RWQM versus those produced using the 2017 RWQM is presented below with reference to the unmitigated results

At most locations, projected dissolved cadmium concentrations produced using the 2020 RWQM were similar to or lower than those produced using the 2017 RWQM (Figure 3-6, with additional figures in Appendix A). In the 2020 RWQM, cadmium production in waste rock spoils is linked to that of sulphate, and it is subject to the same bulk transport mechanisms. However, the 2020 RWQM also accounts for cadmium attenuation in and downstream of waste rock spoils. While the former process is implicitly accounted for in the 2017 RWQM (to some extent), the latter is not, and it more than offset changes to cadmium concentrations related to those factors outlined above with respect to selenium and sulphate (e.g., accounting for surface water – groundwater partitioning and increased waste rock flows in fall and winter).

Projected dissolved cadmium concentrations produced using the 2020 RWQM were higher than those produced using the 2017 RWQM at two locations: the EVO Harmer Compliance Point and the CMO Compliance Point on Michel Creek (Figure 3-6). The differences in projected cadmium concentrations are due to:

- the change in methods for new spoils, which results in more rapid release of constituents from new spoils in the 2020 RWQM, compared to that in the 2017 RWQM; this change is relevant to the EVO Harmer Creek Compliance Point and the permitted down-valley deposition of new waste rock in EVO Dry Creek
- the change in methods applied to modelling flow and loads from Coal Mountain Operations, as outlined in SRK (2021), a copy of which is included in Appendix A of the 2020 RWQM Update Report.

The link in the 2020 RWQM between cadmium and sulphate production from waste rock produced an increasing trend in projected cadmium concentrations that is not present in the monitored data. The presence of this trend suggests that cadmium projections developed with the 2020 RWQM are likely overestimates and should be considered with this limitation in mind.

(a) Fording River downstream of Line Creek (LC_LC5; 0200028)

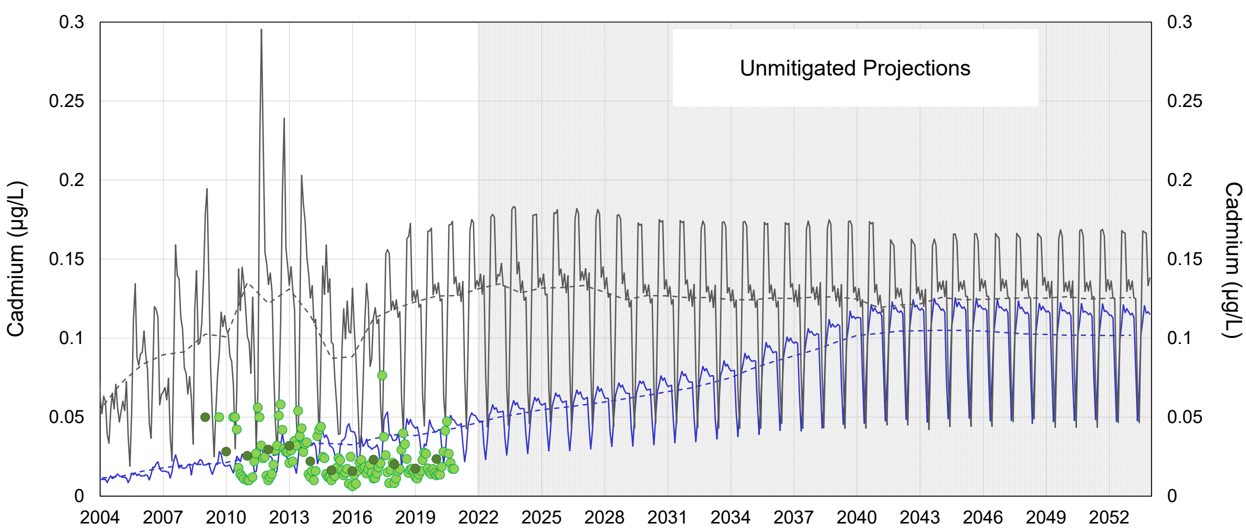
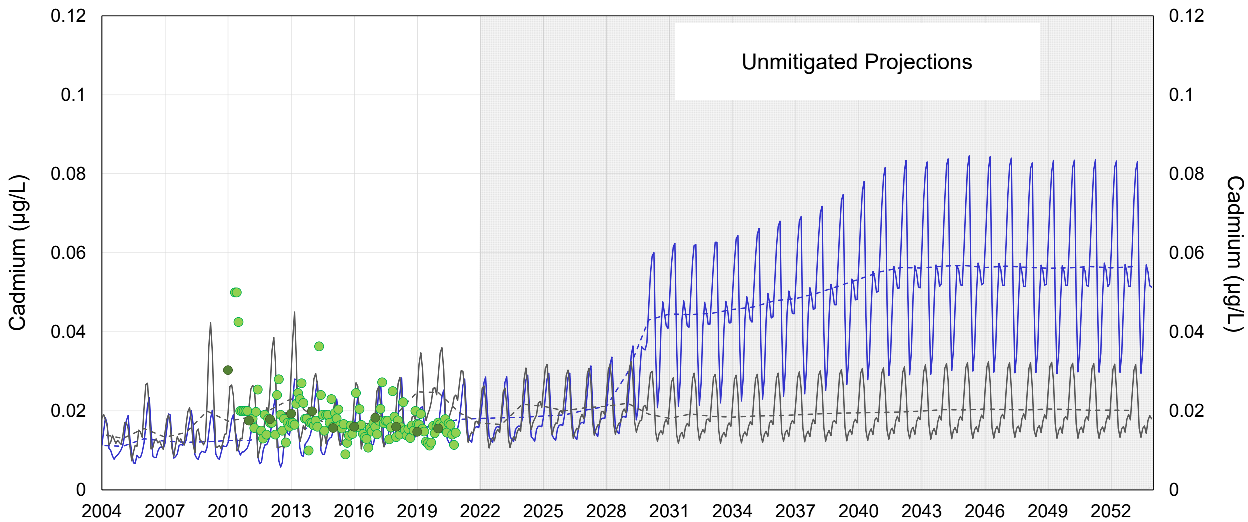
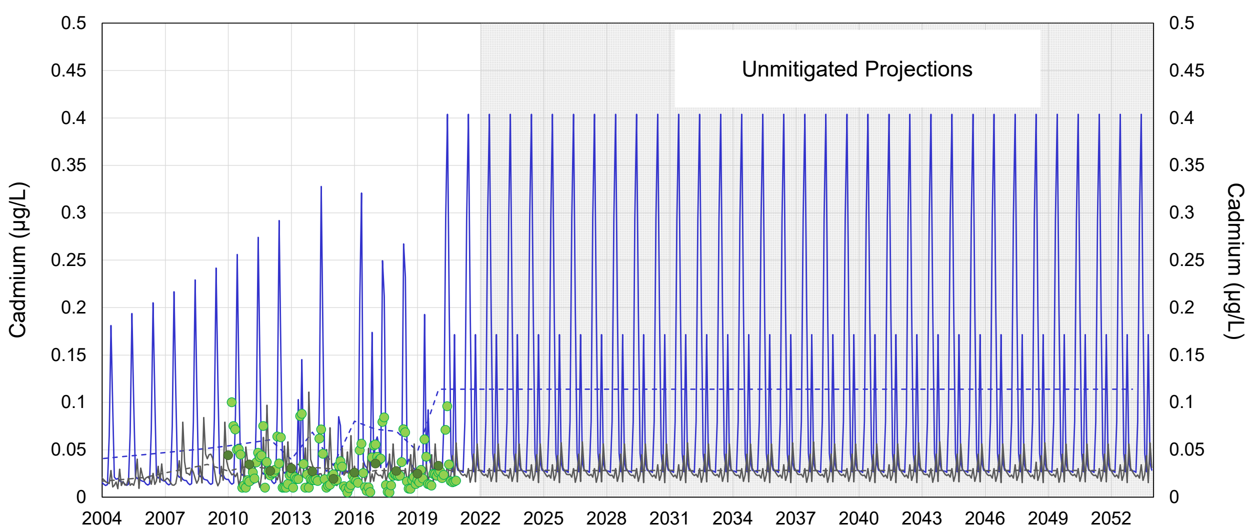


Figure 3-6 Projected Concentrations of Dissolved Cadmium at Four Locations in the Elk Valley Without Consideration of Mitigation, 2004-2053

(b) EVO Harmer Compliance Point (EV_HC1; E102682)



(c) CMO Compliance Point (CM_MC2; E258937)



Note: Projected concentrations are from the CMO Water and Load Balance Model.

Figure 3-6 Projected Concentrations of Dissolved Cadmium at Four Locations in the Elk Valley Without Consideration of Mitigation, 2004-2053

(d) Elk River downstream of Michel Creek (EV_ER1; 0200393)

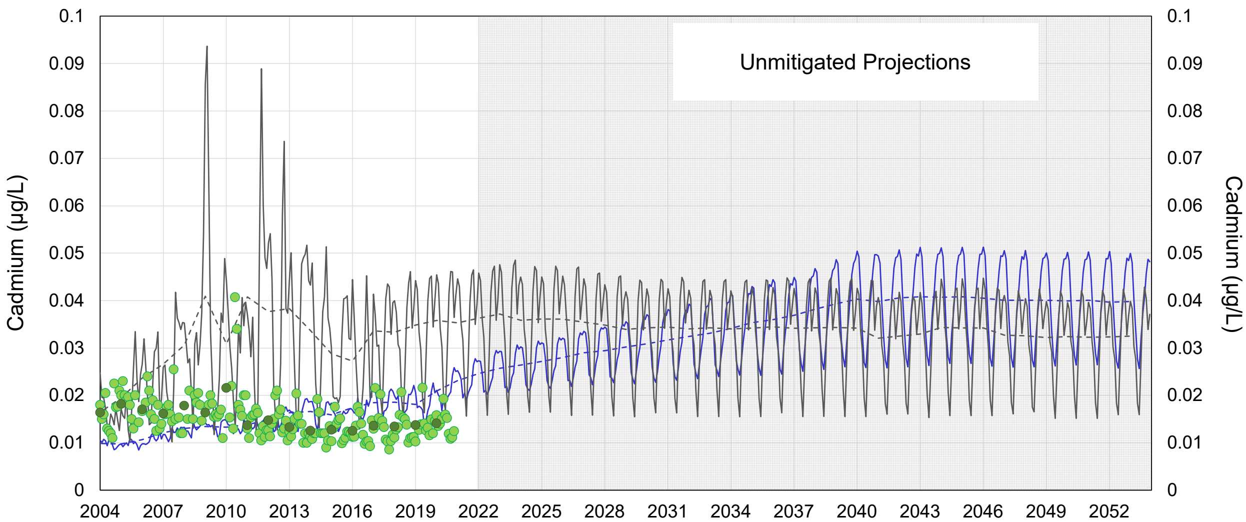


Figure 3-6 Projected Concentrations of Dissolved Cadmium at Four Locations in the Elk Valley Without Consideration of Mitigation, 2004-2053

3.2 Sensitivity Analysis

3.2.1 Variations in Climate

The 2020 RWQM is climate-driven, and future projections are developed using climate information from 2000 to 2019, as noted in Section 2.2.1. The climate information is run repeatedly through the model, so that each year in the future simulation period experiences climate conditions equivalent to those recorded from 2000 to 2019. This approach results in 20 individual estimates of flow and constituent concentration for each week of each future year. The individual weekly estimates are used to calculate temporally-connected monthly and annual average concentrations within each realization. The resulting monthly and annual average datasets are summarized by calculating median (P50), 10th percentile (P10) and 90th percentile (P90) values across the 20 realizations for each future month and each future year.

The sensitivity of future projections to variations in climate was evaluated by comparing P50, P10 and P90 results at the following mainstem locations:

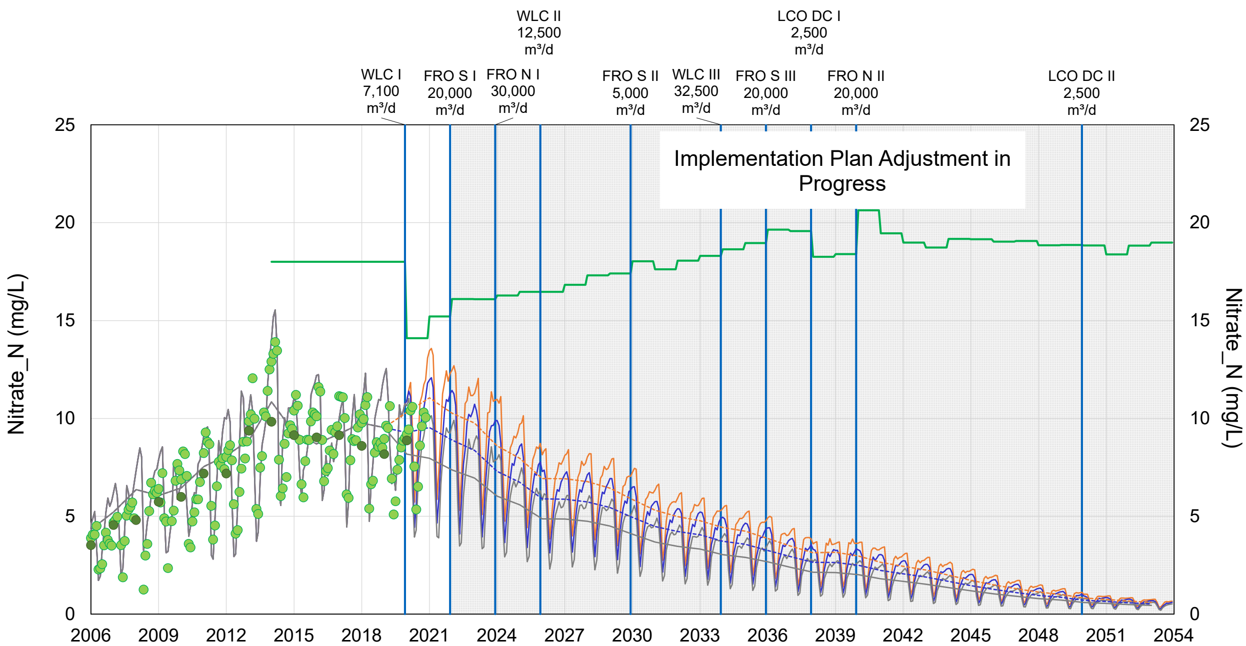
- Fording River downstream of Line Creek (LC_LC5; 0200028)
- Elk River upstream of Grave Creek (EV_ER4; 0200027)
- Elk River downstream of Michel Creek (EV_ER1; 0200393)

Although consistent downward trends were present in all three projected nitrate timeseries across all three locations (Figure 3-7), differences between projected P50 versus P90 or P10 nitrate concentrations were variable over the future simulation period. They were typically larger towards the start of the future simulation period, diminishing over time as projected P50, P90 and P10 concentrations moved towards a common endpoint, reflective of the leaching and gradual disappearance of nitrate source material.

Differences between projected peak monthly average P50 and P90 selenium concentrations were in the order of 8 to 24% across all three locations (Figure 3-8). Differences between projected peak monthly average P50 and P10 selenium concentrations across all three locations were typically higher, in the order of 12 to 25%.

Differences between projected peak monthly average P50 and P90 sulphate concentrations were in the order of 9 to 21%, as were those between projected peak monthly average P50 and P10 sulphate concentrations across all three locations (Figure 3-9). The influence of climate on future projected water quality will be taken into consideration as the IPA is updated.

(a) Fording River downstream of Line Creek (LC_LC5; 0200028)



(b) Elk River upstream of Grave Creek (EV_ER4; 0200027)

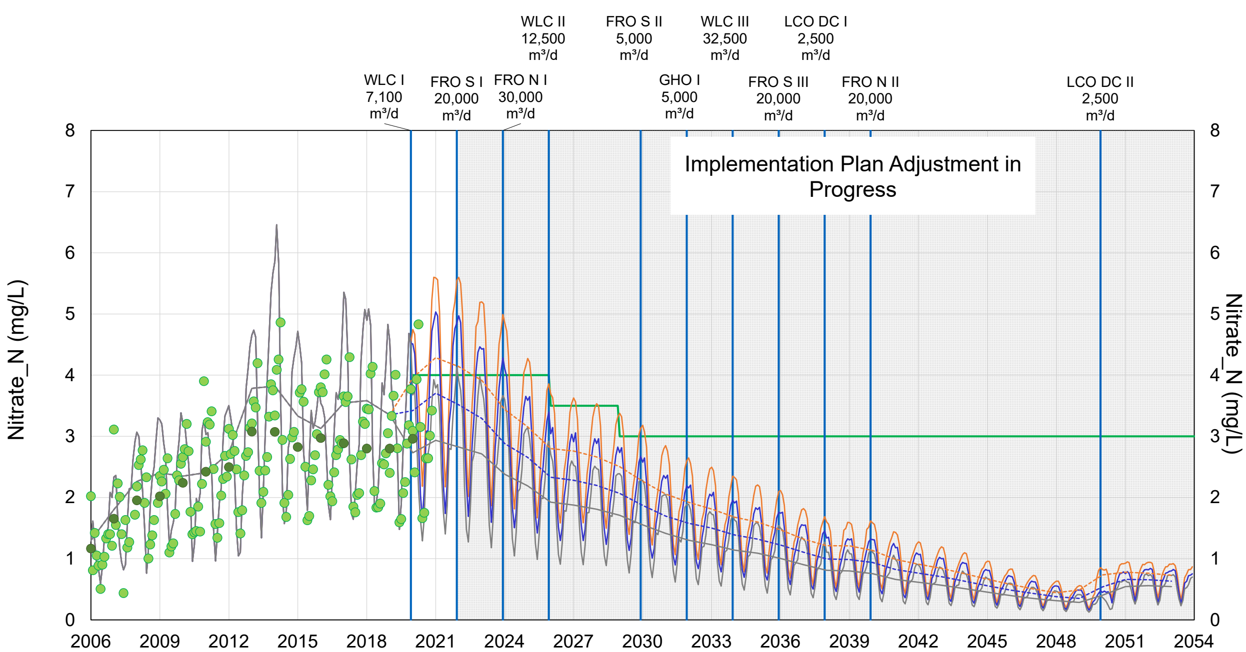
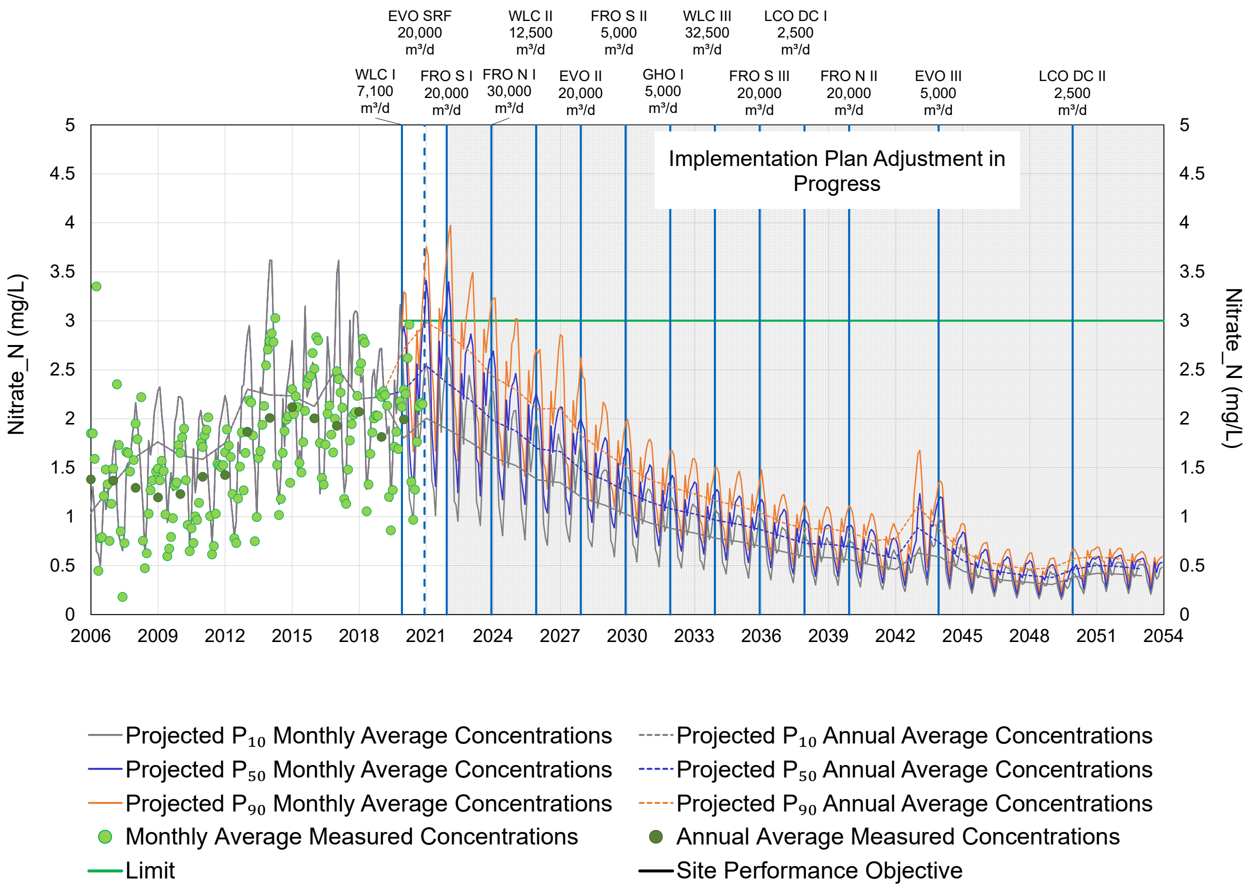


Figure 3-7 Projected Concentrations of Nitrate in the Fording River Downstream of Line Creek and in the Elk River Upstream of Grave Creek and Downstream of Michel Creek under Variable Climate Conditions, 2006-2053

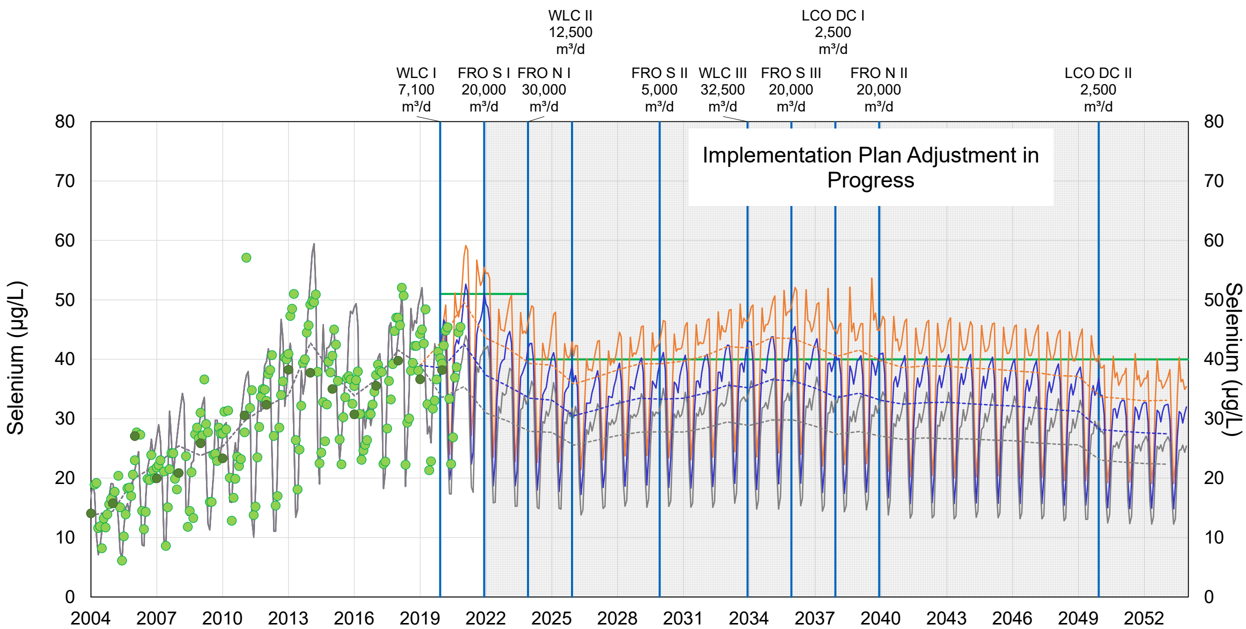
(c) Elk River downstream of Michel Creek (EV_ER1; 0200393)



Note: Simulated concentrations from 2004 to 2019 were generated using measured climate data; projected concentrations from 2020 onward were generated using climate data from 2000 to 2019, run repeatedly through the model.

Figure 3-7 Projected Concentrations of Nitrate in the Fording River Downstream of Line Creek and in the Elk River Upstream of Grave Creek and Downstream of Michel Creek under Variable Climate Conditions, 2006-2053

(a) Fording River downstream of Line Creek (LC_LC5; 0200028)



(b) Elk River upstream of Grave Creek (EV_ER4; 0200027)

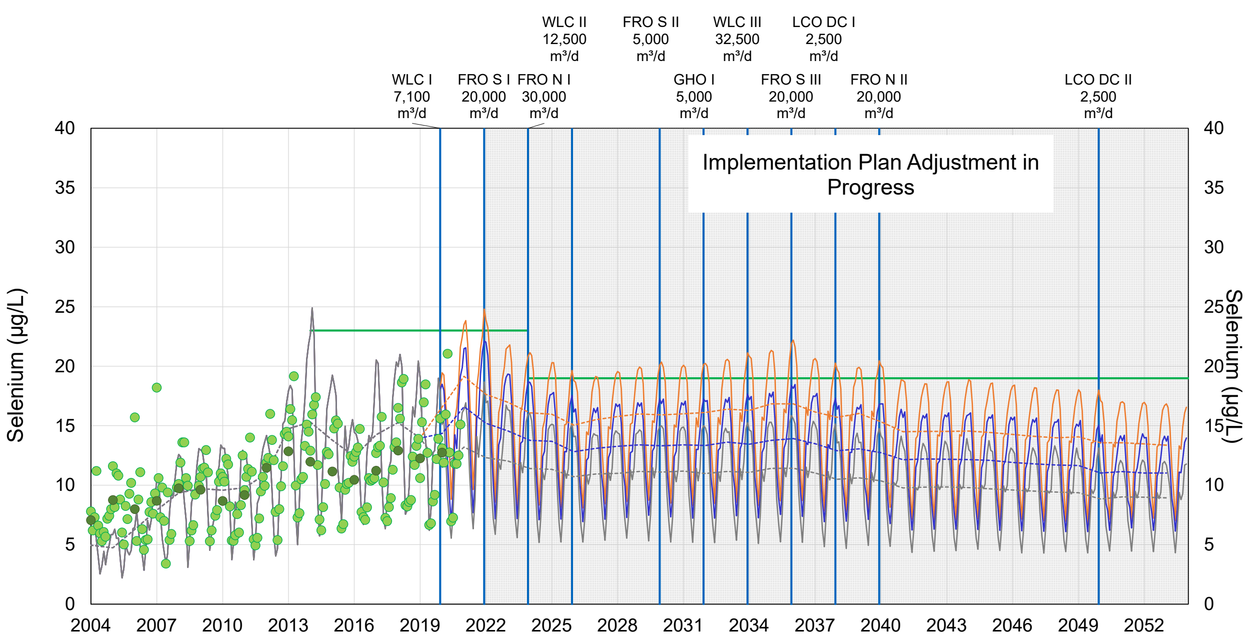
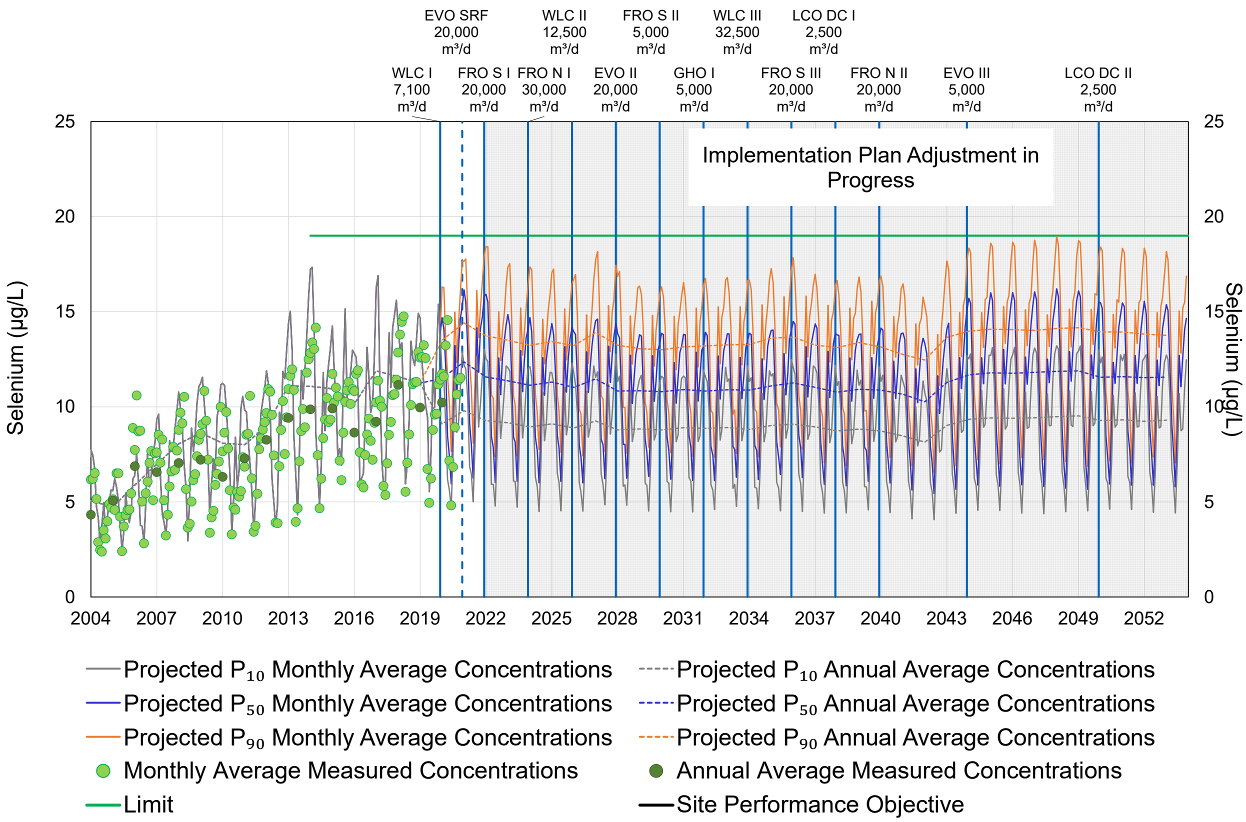


Figure 3-8 Projected Concentrations of Selenium in the Fording River Downstream of Line Creek and in the Elk River Upstream of Grave Creek and Downstream of Michel Creek under Variable Climate Conditions, 2004-2053

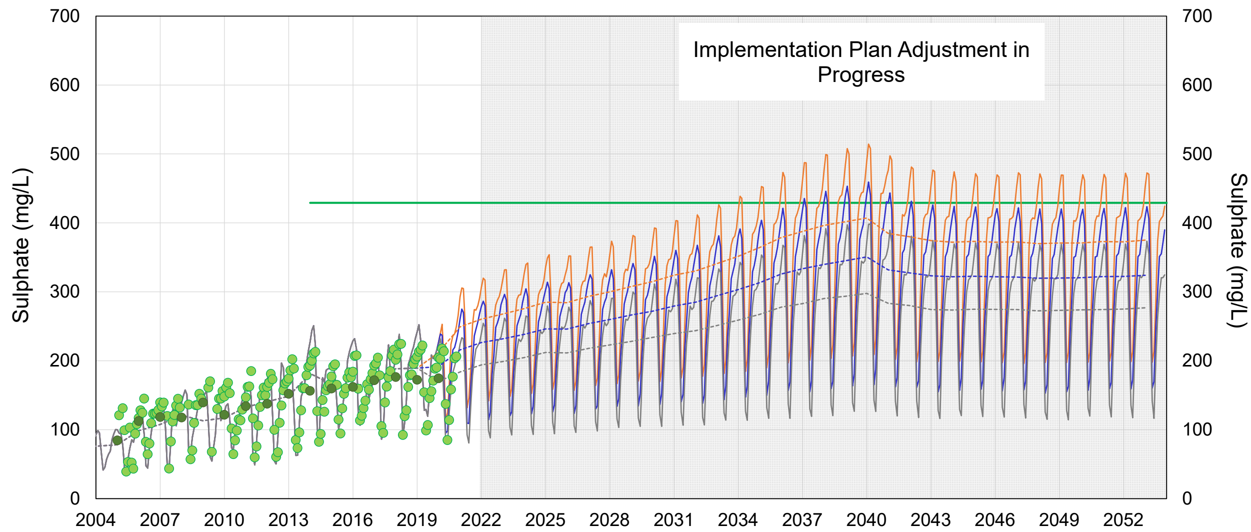
(c) Elk River downstream of Michel Creek (EV_ER1; 0200393)



Note: Simulated concentrations from 2004 to 2019 were generated using measured climate data; projected concentrations from 2020 onward were generated using climate data from 2000 to 2019, run repeatedly through the model.

Figure 3-8 Projected Concentrations of Selenium in the Fording River Downstream of Line Creek and in the Elk River Upstream of Grave Creek and Downstream of Michel Creek under Variable Climate Conditions, 2004-2053

(a) Fording River downstream of Line Creek (LC_LC5; 0200028)



(b) Elk River upstream of Grave Creek (EV_ER4; 0200027)

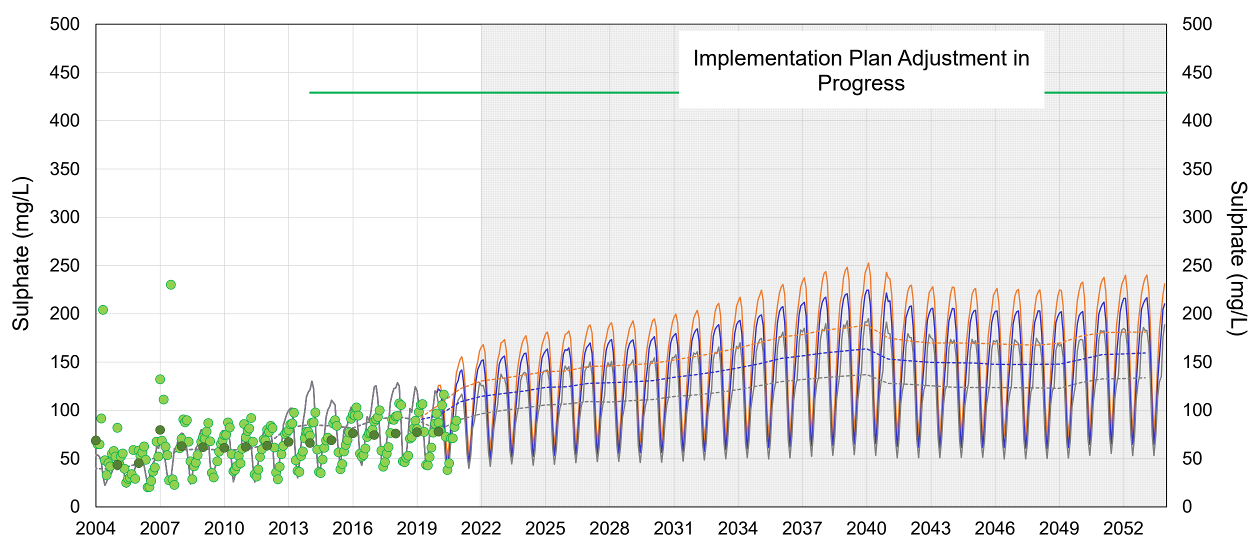
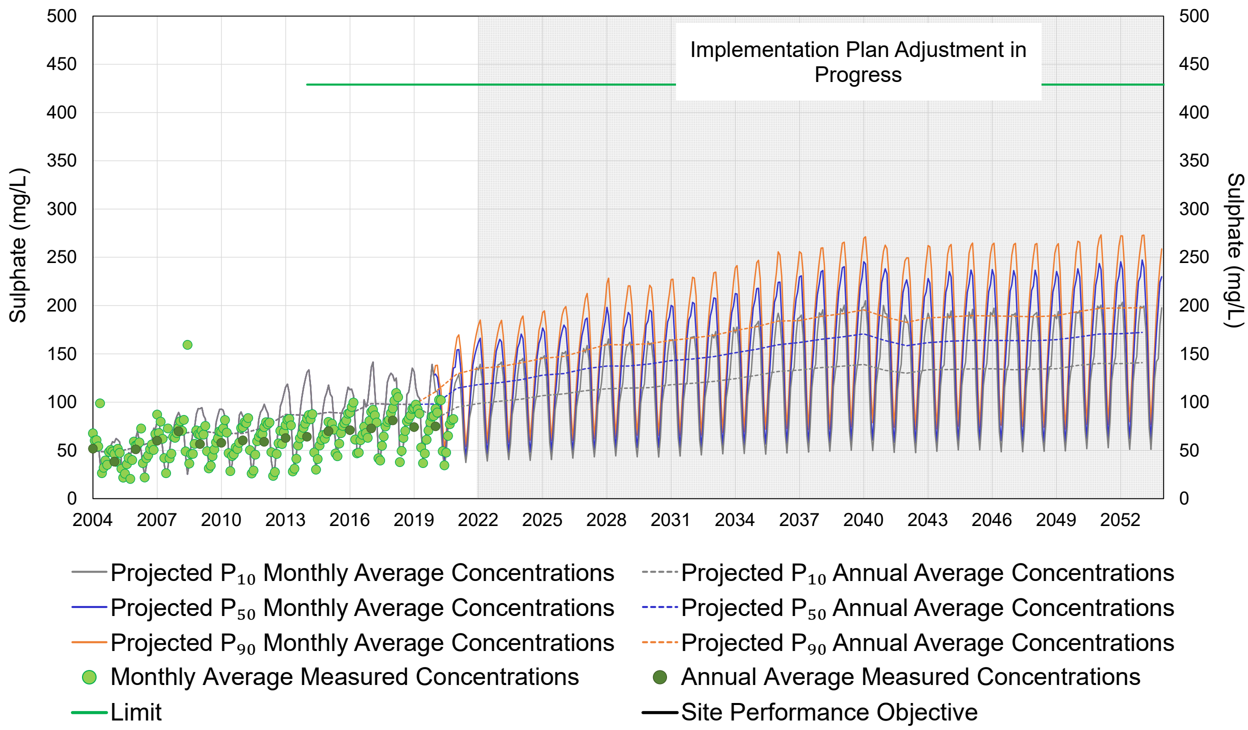


Figure 3-9 Projected Concentrations of Sulphate in the Fording River Downstream of Line Creek and in the Elk River Upstream of Grave Creek and Downstream of Michel Creek under Variable Climate Conditions, 2004-2053

(c) Elk River downstream of Michel Creek (EV_ER1; 0200393)



Note: Simulated concentrations from 2004 to 2019 were generated using measured climate data; projected concentrations from 2020 onward were generated using climate data from 2000 to 2019, run repeatedly through the model.

Figure 3-9 Projected Concentrations of Sulphate in the Fording River Downstream of Line Creek and in the Elk River Upstream of Grave Creek and Downstream of Michel Creek under Variable Climate Conditions, 2004-2053

3.2.2 Changes to Model Inputs Related to Blasting Practices

Lining of blast holes began in 2017 at Teck's operations in the Elk Valley, the purpose of which is to limit the loss of explosives prior to blasting (Teck 2021). Limiting the loss of explosives reduces the amount of explosive residual associated with freshly blasted waste rock, which, in turn, reduces the release of nitrate from waste rock spoils. In the 2020 RWQM, liner effectiveness is an input value, which was varied from 0 to 90% to understand how changes to this value affect projected concentrations of nitrate.

Projected nitrate concentrations in Kilmarnock Creek, assuming liner effectiveness of 0% and 20%, were similar to or higher than those with a liner effectiveness of 50% (Figure 3-10). The overall downward trajectory remained unchanged, but projected annual peak concentrations were up to 4.9 mg/L (or 37%) higher than those projected to occur with a liner effectiveness of 50%. When liner effectiveness was increased from 50% to 90%, projected monthly average nitrated concentrations were in the order of 3.9 mg/L (or 29%) lower than those projected to occur with a liner effectiveness of 50%. In all cases, the differences were most apparent between 2031 and 2036, after projected nitrate concentrations have appreciably declined from those recently measured. As noted in Section 2.2.2, the waste rock spoil in Kilmarnock Creek is an established spoil, which continues to receive waste rock. Thus, model projections for this location can be used to identify how the use of liners from 2017 onward may influence nitrate leaching from older spoils.

At the GHO Fording River Compliance Point, situated downstream of older established spoils and more recently established newer spoils, the influence of liner effectiveness was more apparent, at least in terms of relative change. With a liner effectiveness of 0%, projected monthly average nitrate concentrations were up to 2.5 mg/L (or 52%) higher than those generated assuming a liner effectiveness of 50% (Figure 3-10). With a liner effectiveness of 90%, projected monthly average nitrate concentrations were in the order of 2.0 mg/L (or 40%) lower than those generated assuming a liner effectiveness of 50%. In both cases, the differences were apparent over a larger proportion of the simulation period.

(a) Kilmarnock Creek downstream of the Rock Drain (FR_KC1; 0200252)

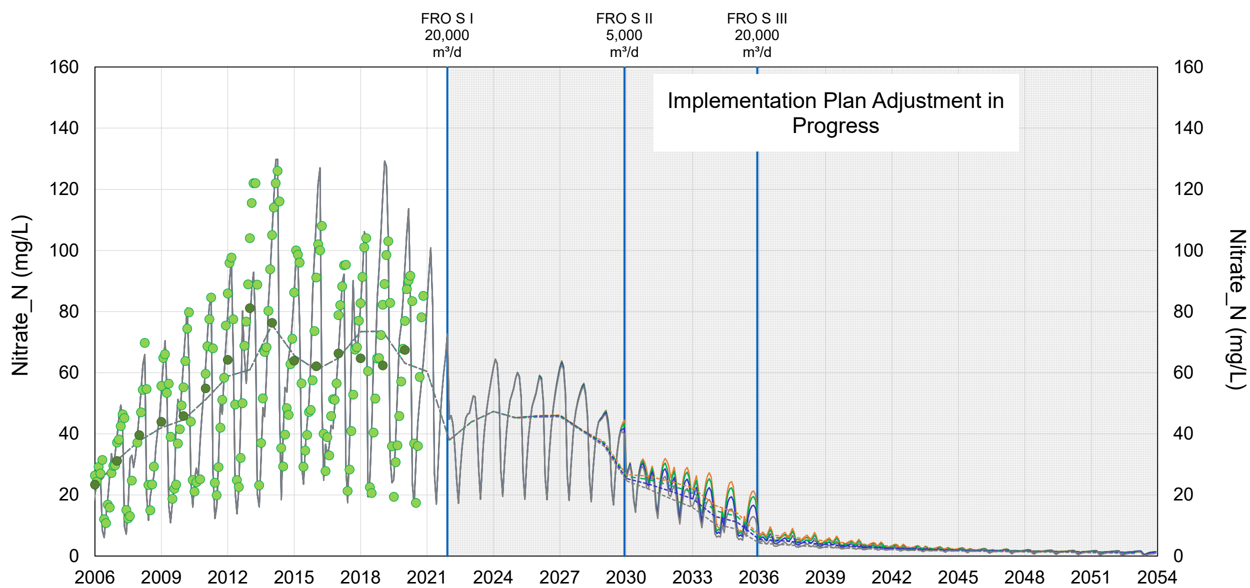
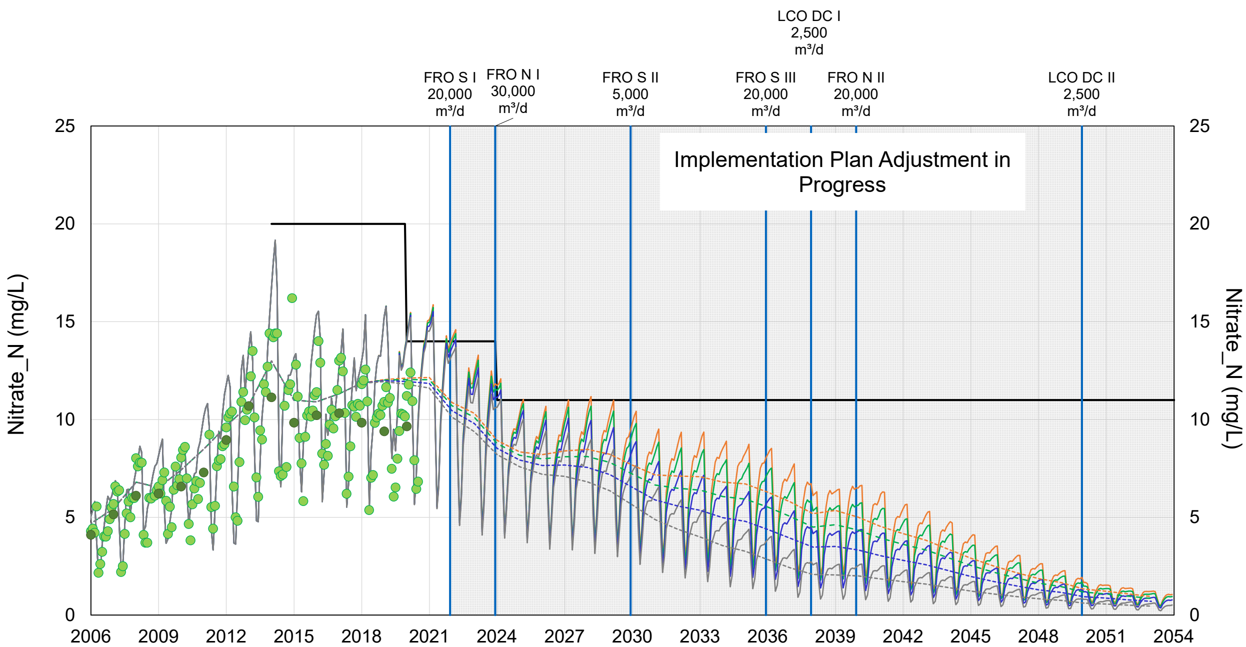


Figure 3-10 Projected Concentrations of Nitrate in Kilmarnock Creek downstream of the Rock Drain and at the GHO Fording River Compliance Point Assuming Different Rates of Liner Effectiveness, 2004-2053

(b) GHO Fording River Compliance Point (GH_FR1; 0200378)



Note: Simulated concentrations from 2004 to 2019 were generated using measured climate data; projected concentrations from 2020 onward were generated using P50 flows.

- Projected Monthly Average Concentrations - Liner Effectiveness 0%
- Projected Annual Average Concentrations - Liner Effectiveness 0%
- Projected Monthly Average Concentrations - Liner Effectiveness 20%
- Projected Annual Average Concentrations - Liner Effectiveness 20%
- Projected Monthly Average Concentrations - Liner Effectiveness 50%
- Projected Annual Average Concentrations - Liner Effectiveness 50%
- Projected Monthly Average Concentrations - Liner Effectiveness 90%
- Projected Annual Average Concentrations - Liner Effectiveness 90%
- Monthly Average Monitored Concentrations
- Annual Average Monitored Concentrations
- Site Performance Objective
- Limit

Figure 3-10 Projected Concentrations of Nitrate in Kilmarnock Creek downstream of the Rock Drain and at the GHO Fording River Compliance Point Assuming Different Rates of Liner Effectiveness, 2004-2053

3.2.3 Changes to Selenium and Sulphate Release Rates

First order decay of selenium and sulphate release rates has been incorporated into the WQC of the 2020 RWQM. It has been incorporated into the 2020 RWQM to reflect results from long term humidity cell tests, which indicate that selenium and sulphate release rates decrease as sulphide minerals are depleted (Annex A).

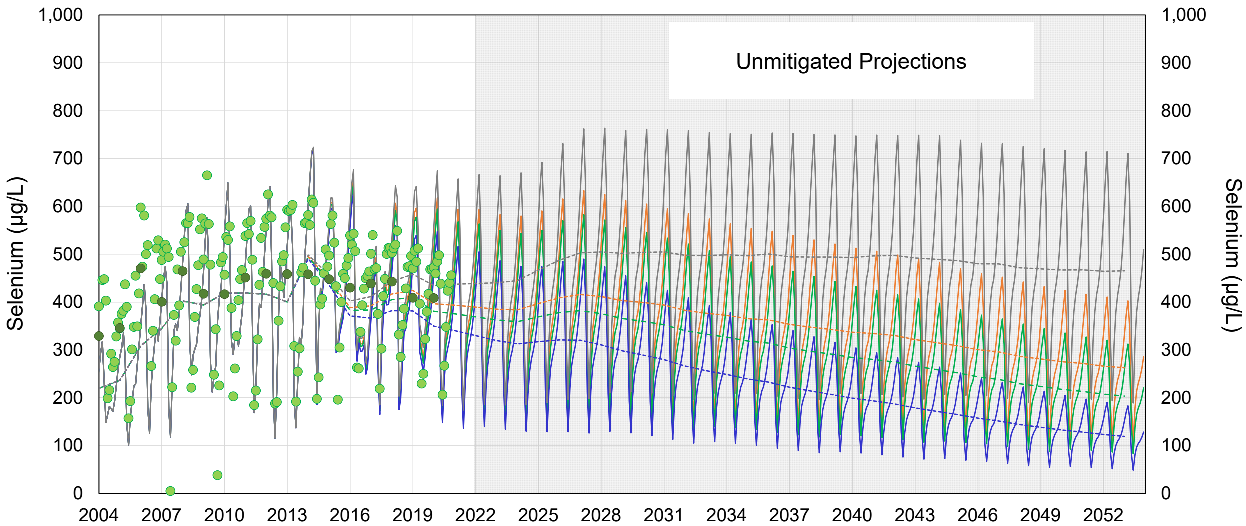
A sensitivity analysis was undertaken to identify how future projections could change with consideration of decay. Three rates of decay were evaluated. They are referred to as Decay Rate 1, 2 and 3, and are defined as outlined in Annex A. This evaluation was conducted at West Line Creek, with decay set to start January 1, 2000.

West Line Creek is a waste-rock dominated catchment, wherein spoiling was largely finished by the end of 1999. More specifically, approximately 90% of the 214 million BCM of waste rock currently residing in West Line Creek was placed into this catchment by December 31, 1999.

Application of first order decay to sulphate and selenium release rates resulted in lower projected concentrations of both constituents in West Line Creek towards the end of the 2004 to 2019 model calibration period and through the future simulation period (Figures 3-11 and 3-12). Overall model performance for selenium improved with the application of the decay function. Peak modelled monthly average selenium concentrations typically matched peak measured monthly average concentrations more closely from 2015 through 2019 with the application of decay (Figure 3-11). A greater level of improvement was achieved with Decay Rate 3, compared to that achieved with the other two rates. Modelled and measured annual average selenium concentrations tended to match more closely when Decay Rate 1 was applied, because it resulted in less underprediction of monthly average freshet concentrations compared to that which occurred when applying Decay Rate 3 to 2. That said, conditions during freshet are not those that typically drive mitigation planning or assessment of potential effects.

Improvements in model performance were also apparent for sulphate when the decay functionality was applied, although they were less pronounced than those observed with selenium (Figure 3-12). Peak modelled monthly average sulphate concentrations tended to match peak measured monthly average concentrations more closely from 2015 through 2019 with the application of the decay function. However, application of decay did not improve the ability of the model to replicate annual average sulphate concentrations.

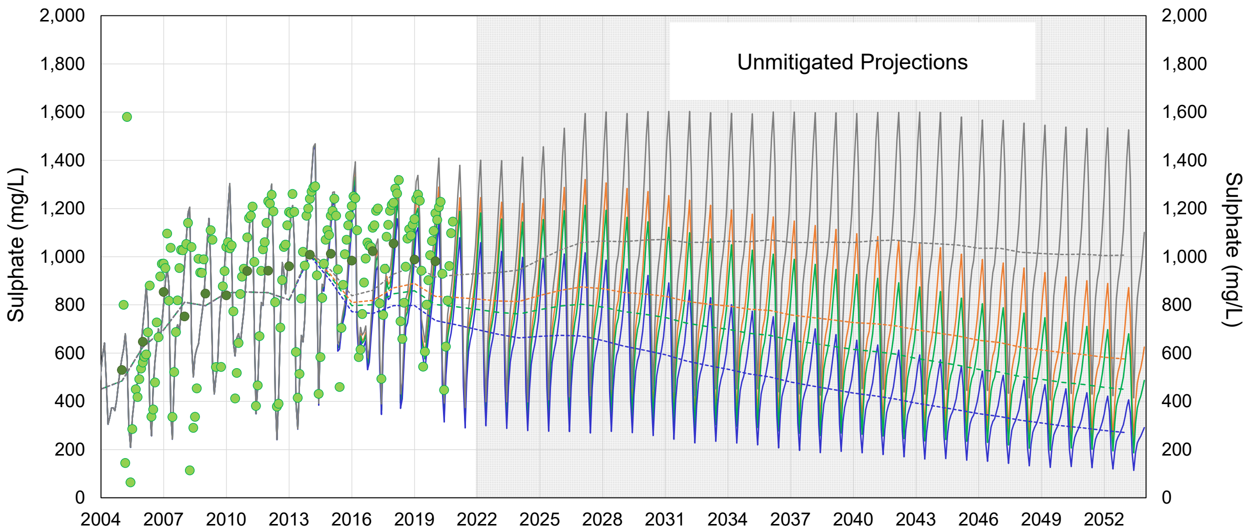
Taken together, these results would suggest that further exploration and application of decay is warranted, with a focus on completed or nearly completed spoils.



Note: Simulated concentrations from 2004 to 2019 were generated using measured climate data; projected concentrations from 2020 onward were generated using P50 flows.

- Projected Monthly Average Concentrations - No Decay
- Projected Monthly Average Concentrations - Decay Rate 1
- Projected Monthly Average Concentrations - Decay Rate 2
- Projected Monthly Average Concentrations - Decay Rate 3
- Monthly Average Monitored Concentrations
- Projected Annual Average Concentrations - No Decay
- Projected Annual Average Concentrations - Decay Rate 1
- Projected Annual Average Concentrations - Decay Rate 2
- Projected Annual Average Concentrations - Decay Rate 3
- Annual Average Monitored Concentrations

Figure 3-11 Projected Concentrations of Selenium in West Line Creek With and Without Consideration of First Order Decay in Selenium Release Rates, 2004-2053



Note: Simulated concentrations from 2004 to 2019 were generated using measured climate data; projected concentrations from 2020 onward were generated using P50 flows.

Figure 3-12 Projected Concentrations of Sulphate in West Line Creek With and Without Consideration of First Order Decay in Sulphate Release Rates, 2004-2053

4 References

SNC (SNC-Lavalin Inc). 2021. Estimated Groundwater Transport Pathways and Bypass Lines of Evidence – West Line Creek. Memo submitted to Teck Coal Limited. March 2021.

SRK (SRK Consulting Ltd.). 2021. Coal Mountain Operations Water and Load Balance Model 2020 Consolidated Report. Prepared for Teck Coal Limited. February 2021.

Teck (Teck Coal Limited). 2016. *Water Quality Adaptive Management Plan for Teck's Coal Operations in the Elk Valley*.

Teck. 2017. *2017 Elk Valley Regional Water Quality Model Update*. Prepared by Teck Coal Limited and submitted to the British Columbia Minister of Environment. October 31, 2017.

Teck. 2019. *Elk Valley Water Quality Plan 2019 Implementation Plan Adjustment.* Prepared by Teck Coal Limited and submitted July 31, 2019.

Teck. 2020. *Operations Application for the Elkview Operations Saturated Rock Fill Phase 2 Project.* Joint Application for Mines Act and Environmental Management Act Permits to Authorize Commissioning and Operations Phase Activities of the Elkview Operations Saturated Rock Fill Phase 2 Project. Submitted to Ministry of Energy, Mines and Petroleum Resources and Ministry of Environment and Climate Change Strategy. Submitted by Teck Coal Limited, Sparwood, BC. May 2020.

Teck 2021. Teck Coal Nitrogen Management Research Summary. January 2021.

Appendix A

Comparison of 2020 RWQM and 2017 RWQM Projected Monthly Average and Annual Average Concentrations of Nitrate, Selenium, Sulphate, and Cadmium at Order Stations and Compliance Points, without Mitigation

Figures

Model results for nitrate, selenium, sulphate, and cadmium, without consideration of mitigation, at Order Stations and Compliance Points are shown in Figures A-1 to A-8, respectively. The format of the figures is as follows:

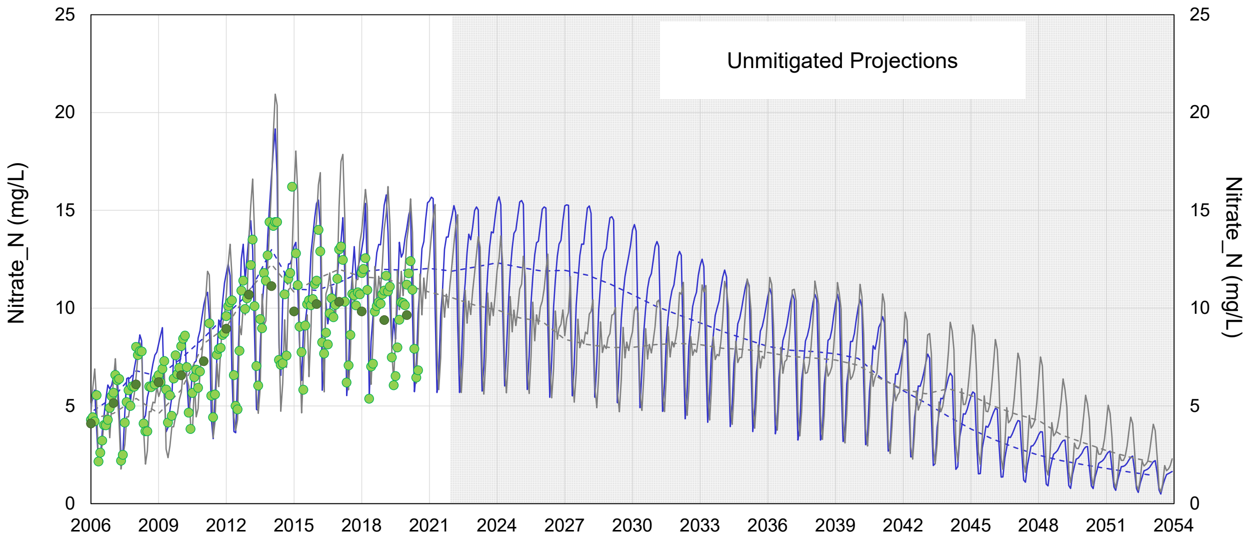
- The x-axis runs from the start of 2004 (for selenium, sulphate, and cadmium) or 2006 (for nitrate) to the end of 2053. The start date corresponds to the start of the calibration period for the 2020 RWQM. The end date (2053) corresponds to the modelled time period at which all waste rock considered in the permitted mine plans has been deposited and the lag associated with that rock has passed (i.e., all of the waste rock is contributing selenium and sulphate load).
- Projected 50th percentile (P50) monthly average concentrations produced using the 2020 RWQM are shown as a solid blue line.
- Projected monthly average concentrations produced using the 2017 RWQM under average flow conditions are shown as a solid grey line.
- Projected annual average concentrations produced using the 2020 RWQM and 2017 RWQM are shown as dashed blue and grey lines, respectively.
- Measured monthly average and annual average concentrations are shown as light green points and dark green points, respectively.
- Modelled information shown prior to 2020 that was generated using the 2020 RWQM was developed based on calibrated flows. Those shown thereafter were developed using multiple climate realizations, as described in Annex D.
- Modelled information shown prior to 2017 that was generated using the 2017 RWQM was developed based on calibrated flows. Those shown thereafter were developed using average flow projections.

The legend below applies to all time series plots in this appendix.

—— Projected P_{50} Monthly Average Concentrations from the 2020 RWQM
- - - Projected P_{50} Annual Average Concentrations from the 2020 RWQM
—— Projected Monthly Average Concentrations for Average Flows from the 2017 RWQM
- - - Projected Annual Average Concentrations for Average Flows from the 2017 RWQM
● Monthly Average Measured Concentrations
● Annual Average Measured Concentrations

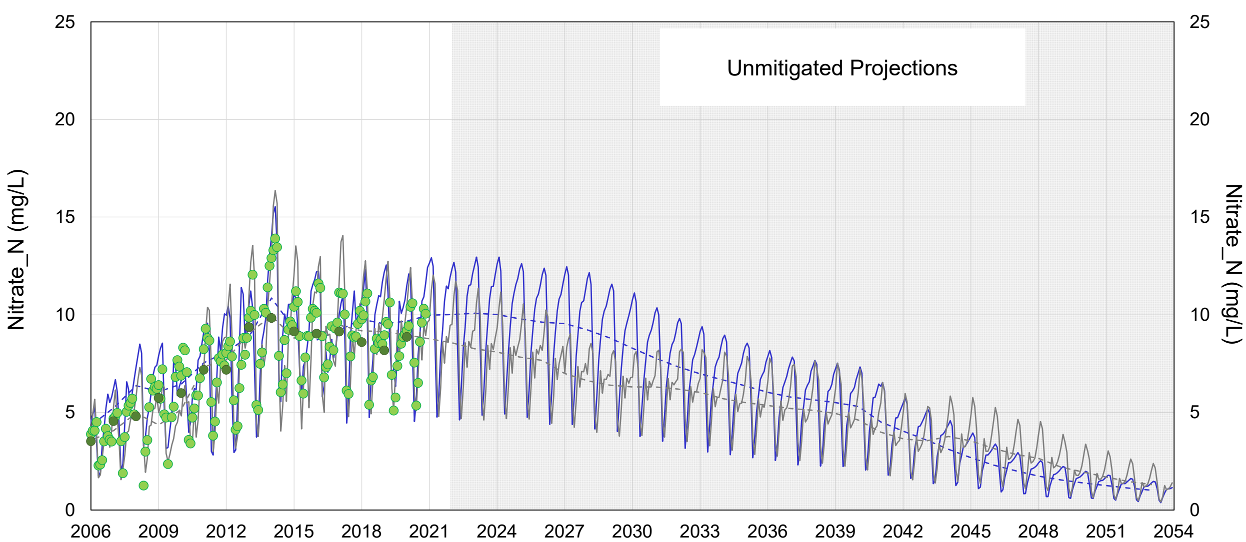
Figure A-1: Projected Concentrations of Nitrate at Order Stations without Consideration of Mitigation, 2006-2053

(a) GHO Fording River Compliance Point (GH_FR1; 0200378)

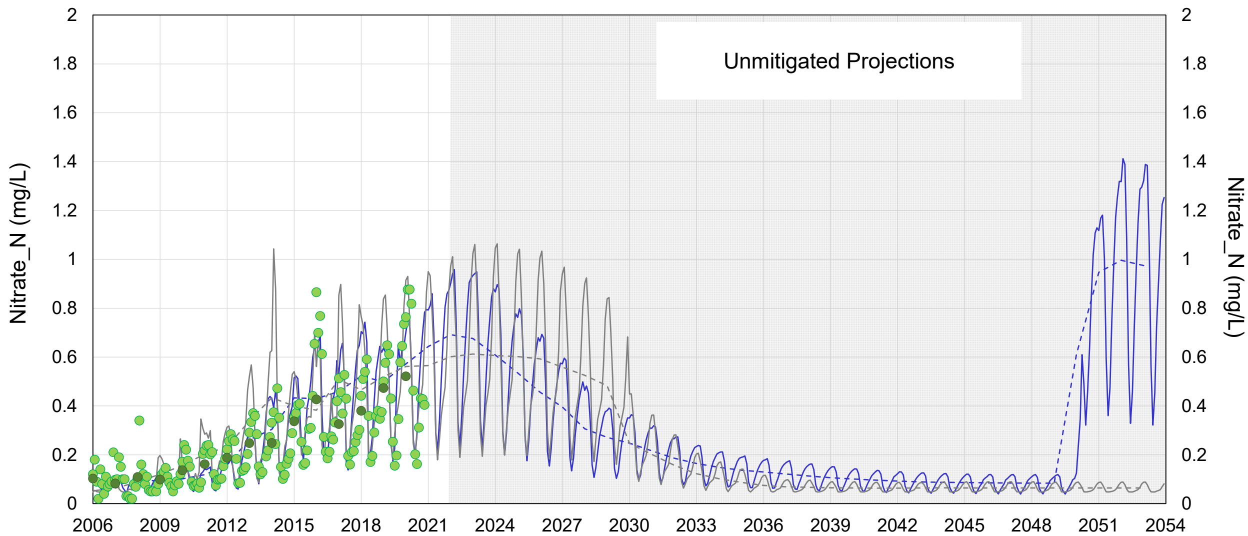


Note: This location is also the GHO Fording River Compliance Point.

(b) Fording River d/s of Line Creek (LC_LC5; 0200028)

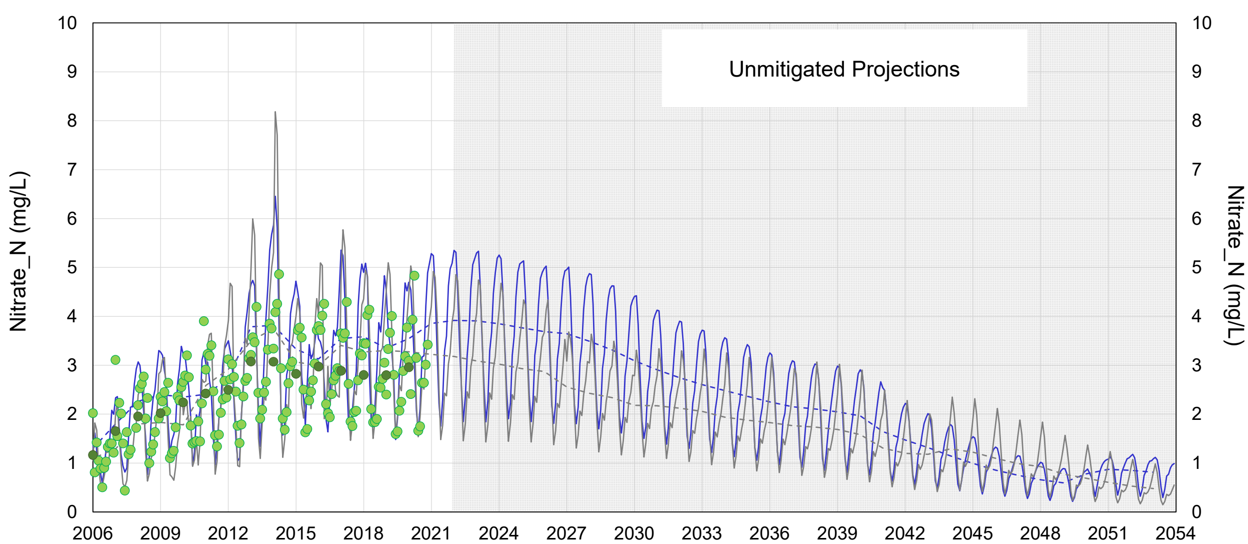


(c) Elk River u/s of Boivin Creek (GH_ER1; E206661)

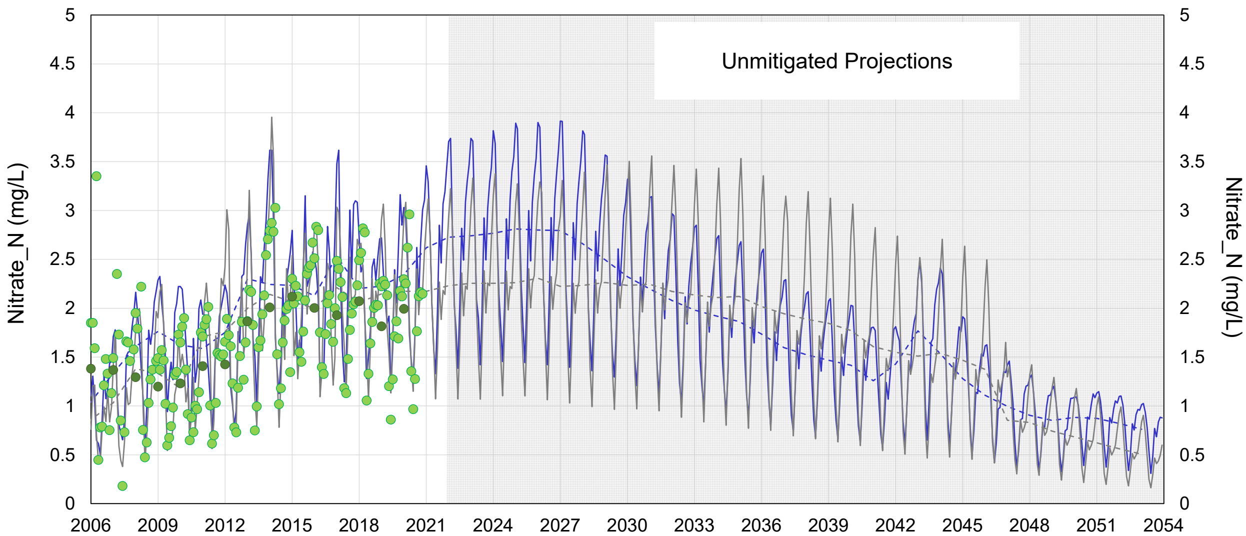


Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

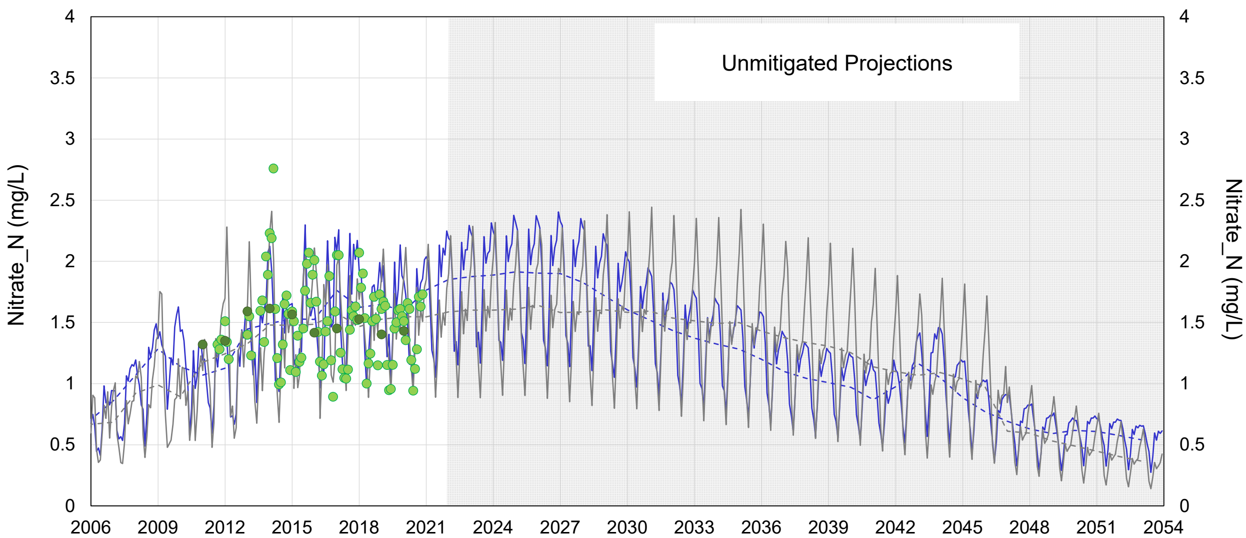
(d) Elk River u/s of Grave Creek (EV_ER4; 0200027)



(e) Elk River d/s of Michel Creek (EV_ER1; 0200393)



(f) Elk River at Elko Reservoir (RG_ELKORES; E294312)



(g) Koocanusa Reservoir (E300230)

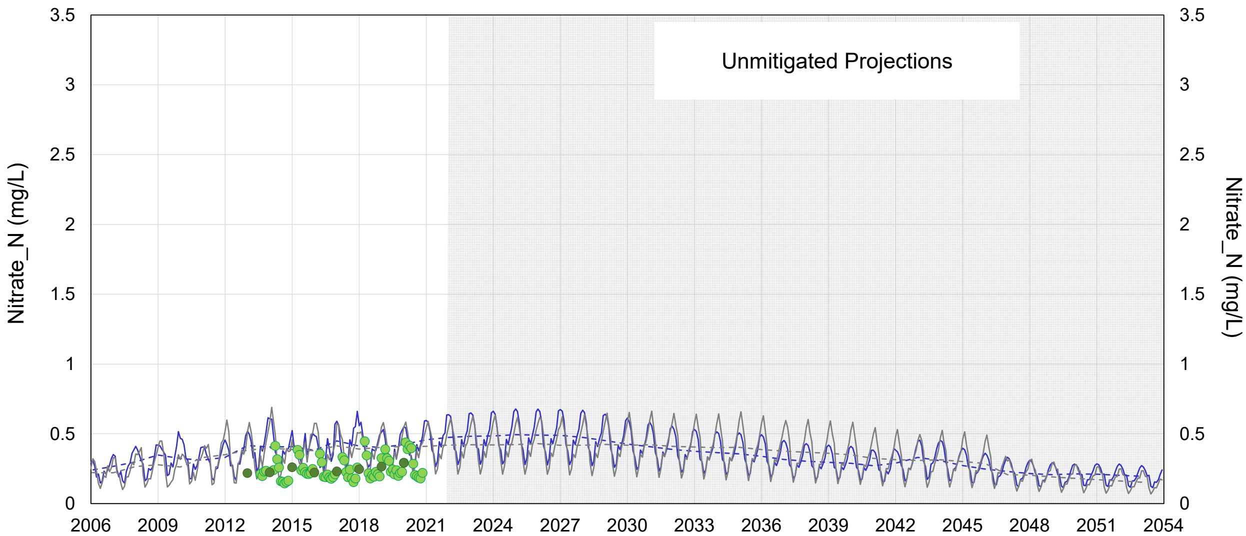
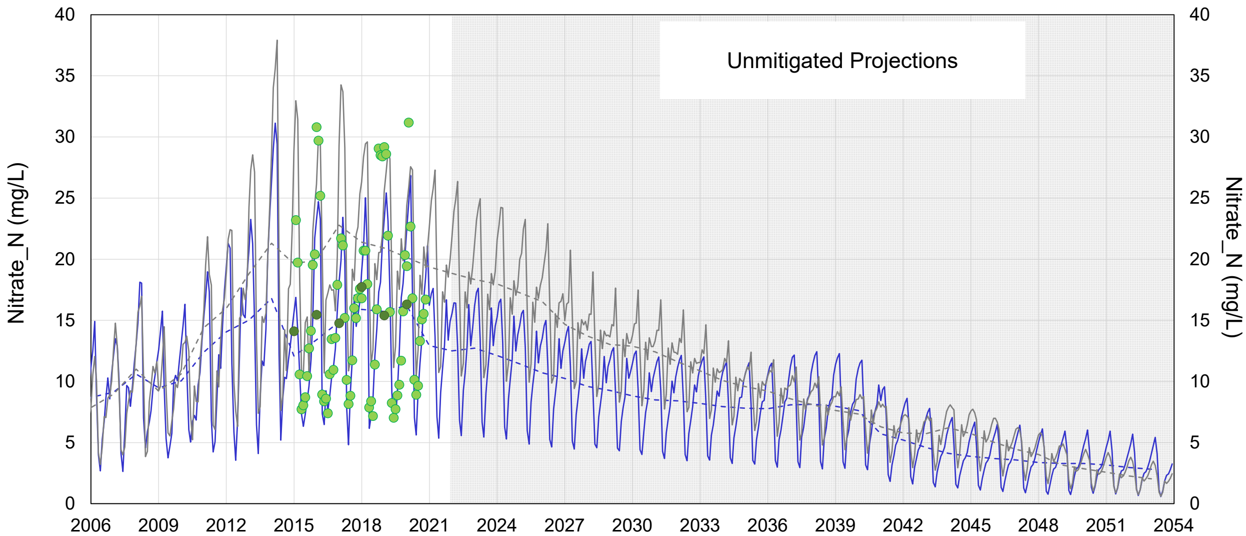
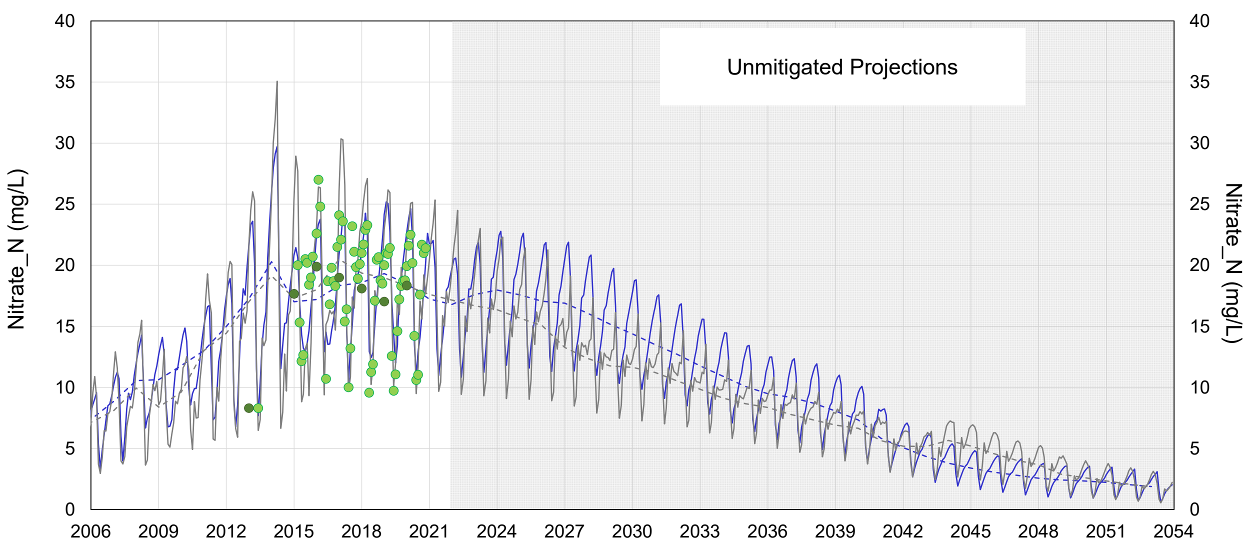


Figure A-2: Projected Concentrations of Nitrate at Compliance Points without Consideration of Mitigation, 2006-2053

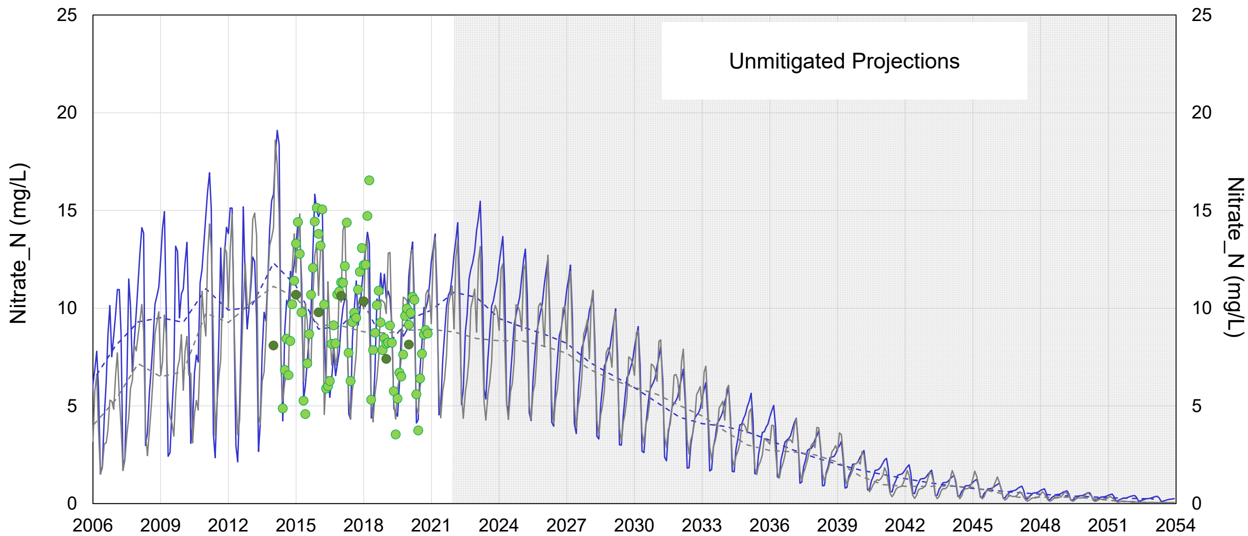
(a) Fording River, 525 m d/s of Cataract Creek (FR_FRCP1; E300071)



(b) FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)

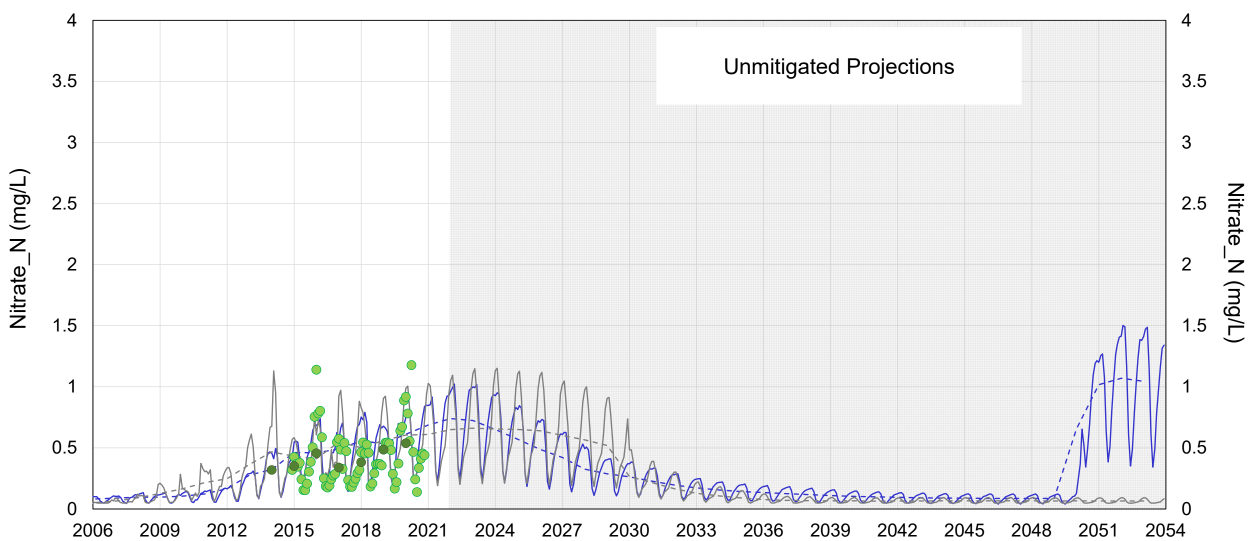


(c) LCO Compliance Point (LC_LCDSSLCC; E297110)



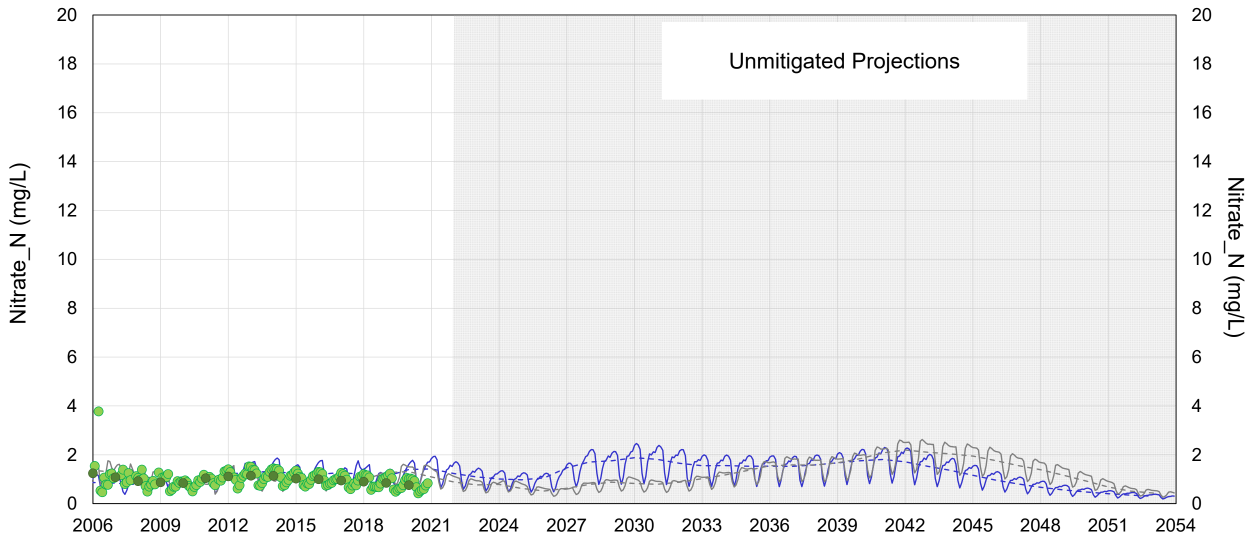
Note: The West Line Creek Active Water Treatment Facility is not active in the 2020 RWQM from January 1, 2020 onward.

(d) GHO Elk River Compliance Point (GH_ERC; E300090)

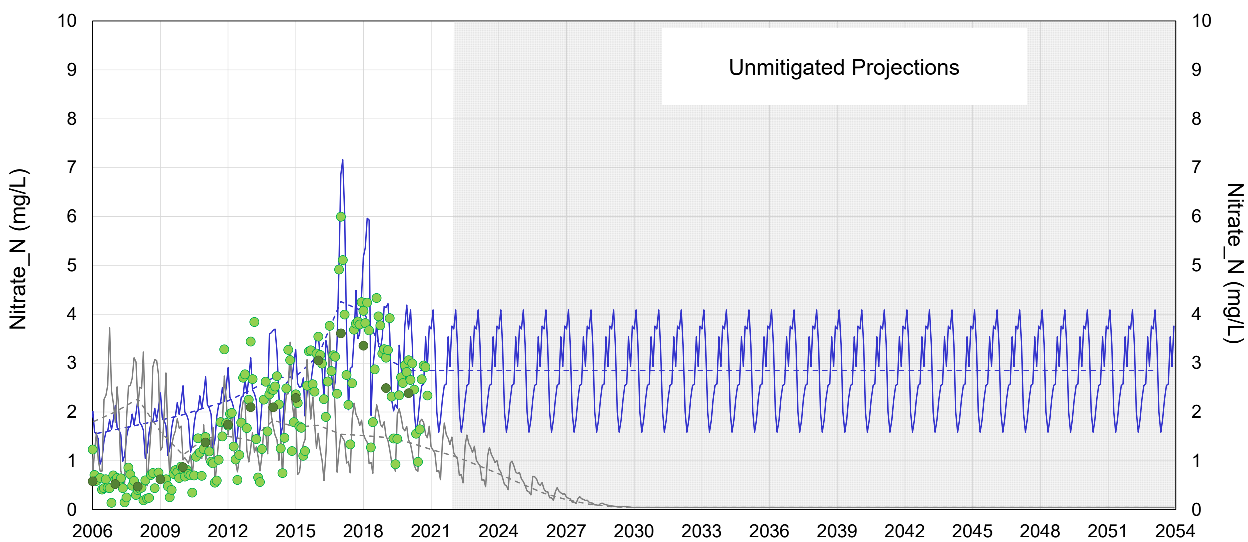


Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

(e) EVO Harmer Compliance Point (EV_HC1; E102682)

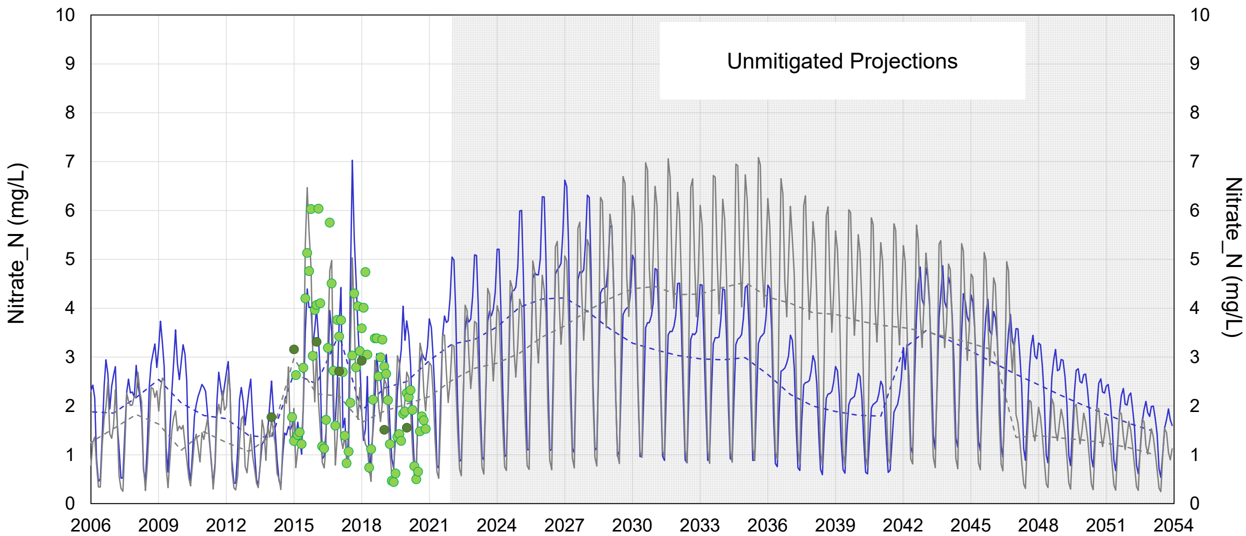


(f) CMO Compliance Point (CM_MC2; E258937)



Note: Projected concentrations are from the CMO Water and Load Balance Model.

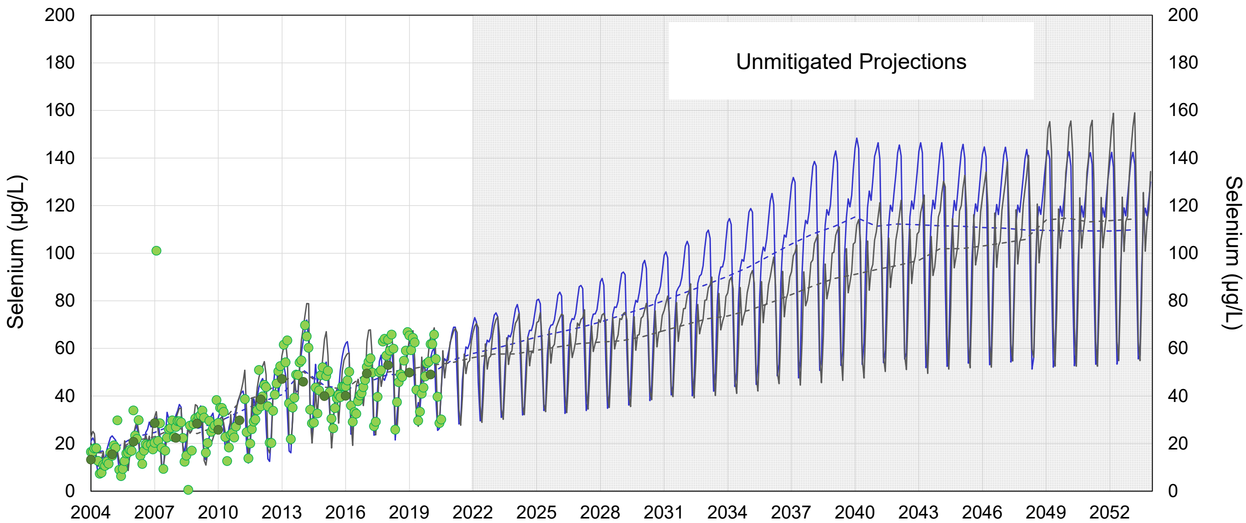
(g) EVO Michel Creek Compliance Point (EV_MC2; E300091)



Note: Projected concentrations developed using the 2020 RWQM decrease in 2037 because mining in Natal Pit West at Elkview Operations is modelled to be completed by the end of 2036 after which the pit is modelled to fill. Projected concentrations increase in 2042 because Natal Pit West is modelled to spill.

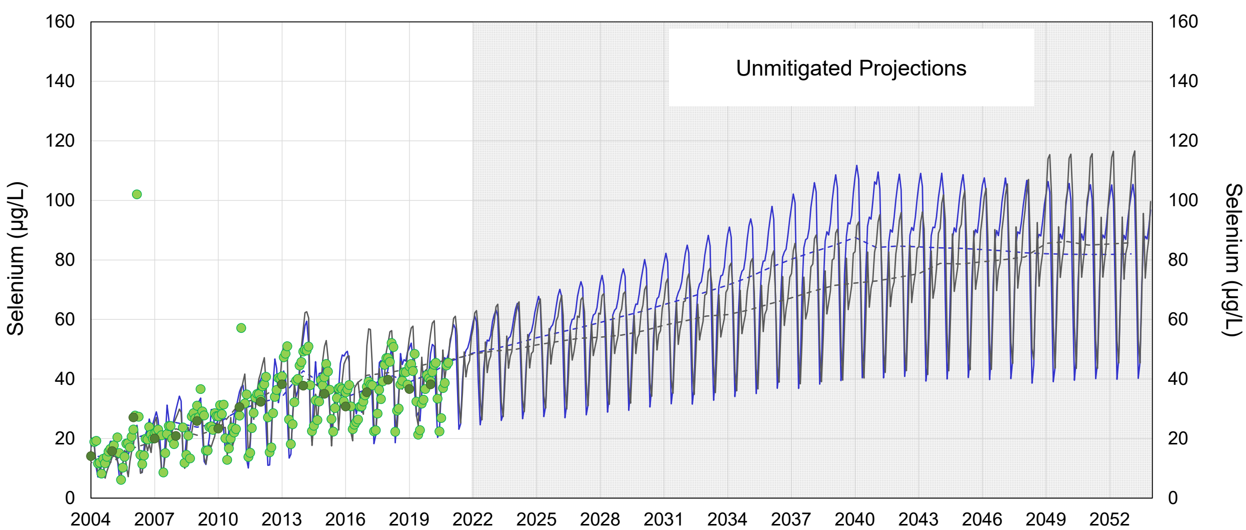
Figure A-3: Projected Concentrations of Selenium at Order Stations without Consideration of Mitigation, 2004-2053

(a) GHO Fording River Compliance Point (GH_FR1; 0200378)

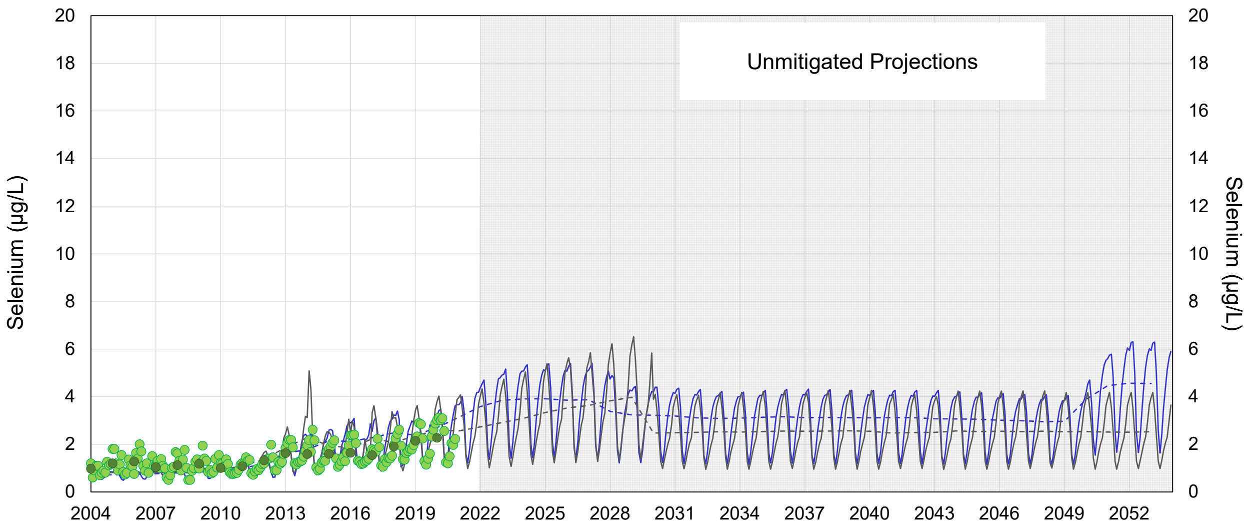


Note: This location is also the GHO Fording River Compliance Point.

(b) Fording River d/s of Line Creek (LC_LC5; 0200028)

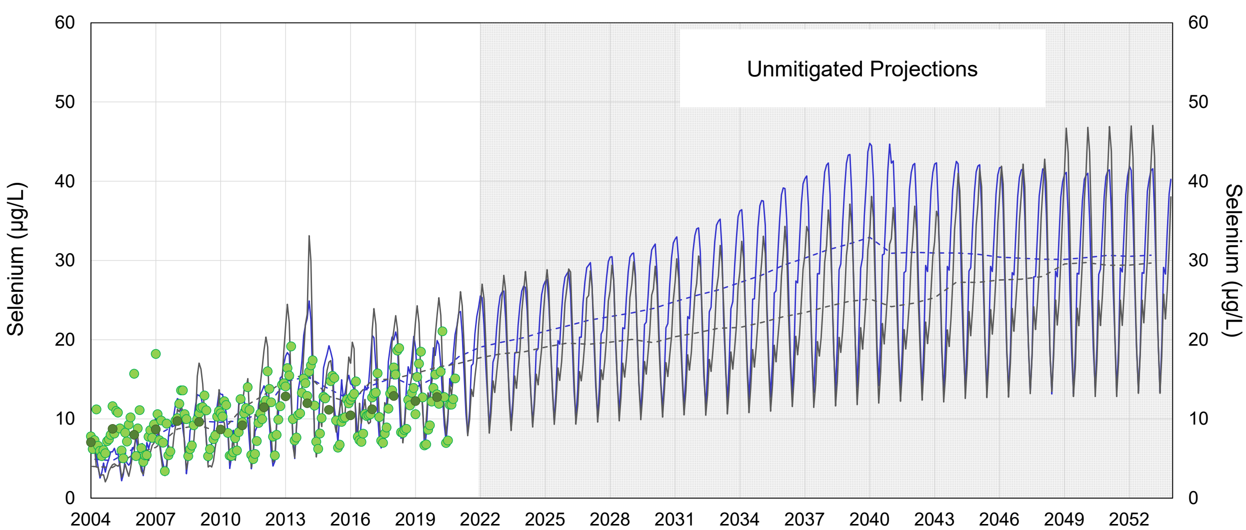


(c) Elk River u/s of Boivin Creek (GH_ER1; E206661)

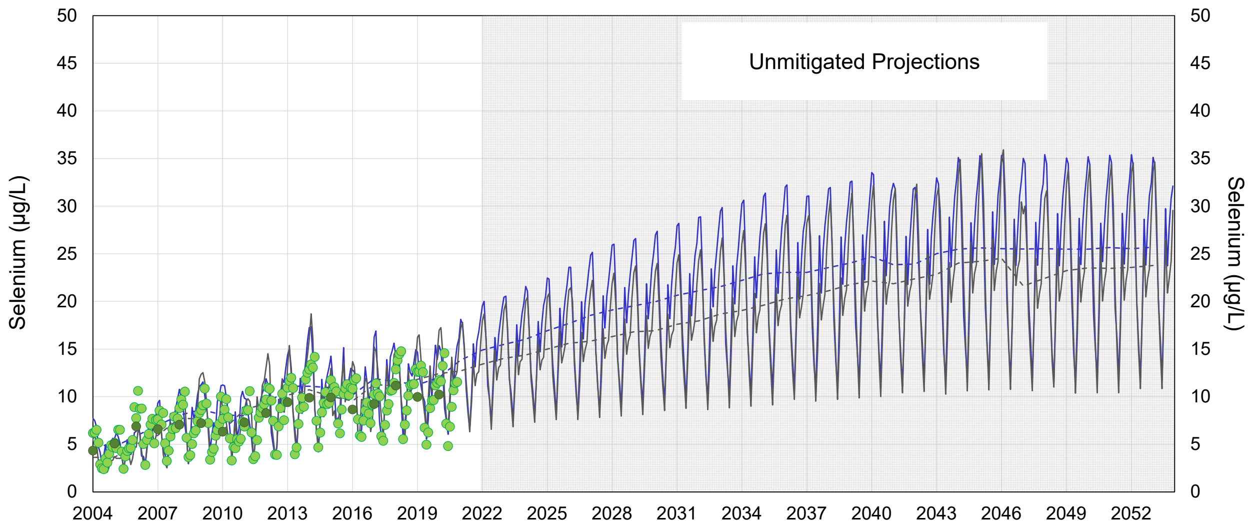


Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

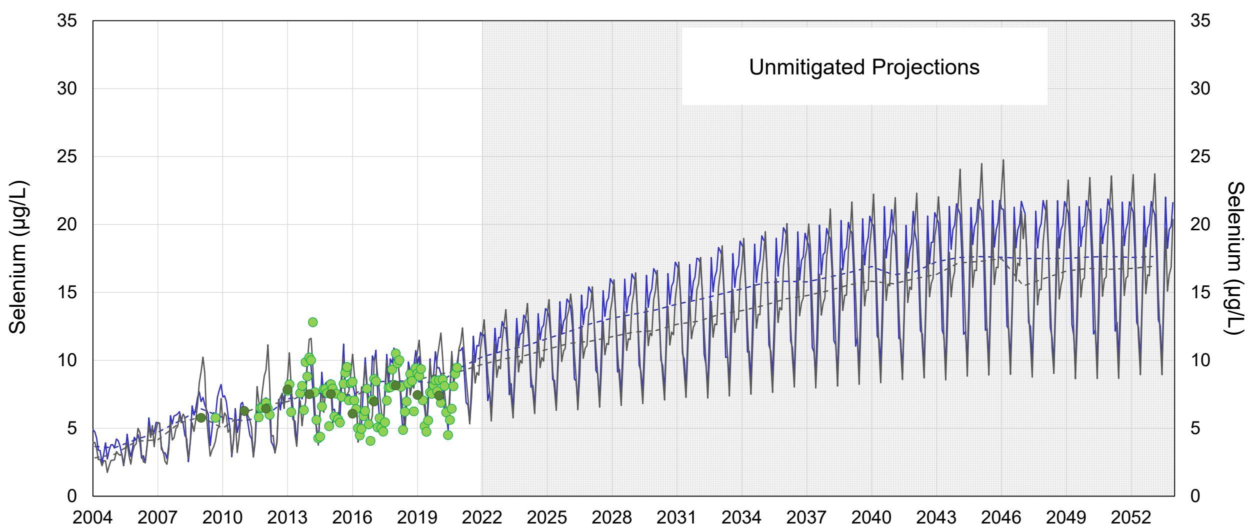
(d) Elk River u/s of Grave Creek (EV_ER4; 0200027)



(e) Elk River d/s of Michel Creek (EV_ER1; 0200393)



(f) Elk River at Elko Reservoir (RG_ELKORES; E294312)



(g) Koocanusa Reservoir (E300230)

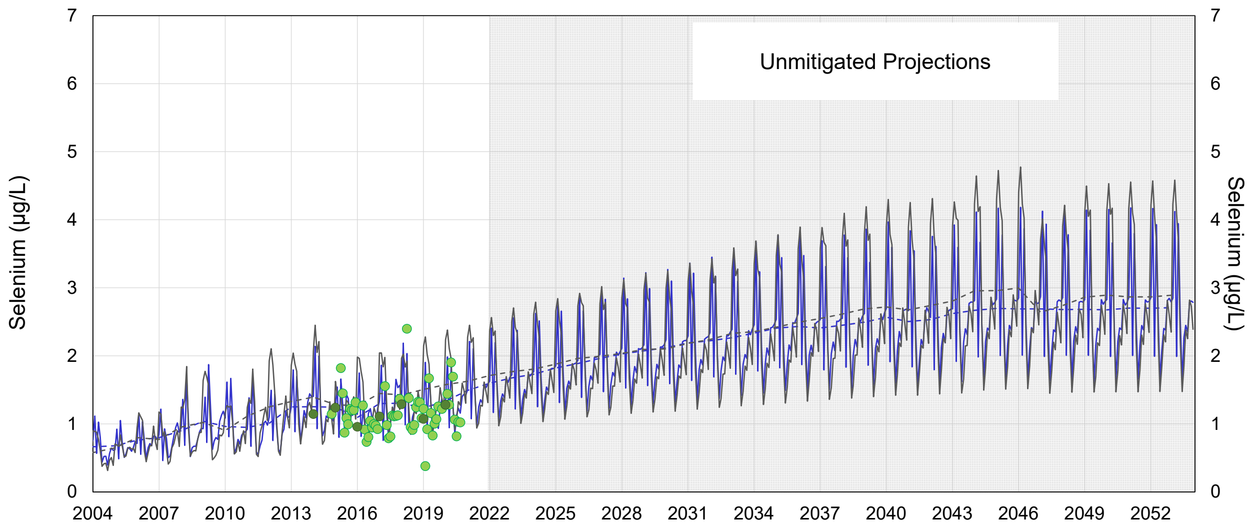
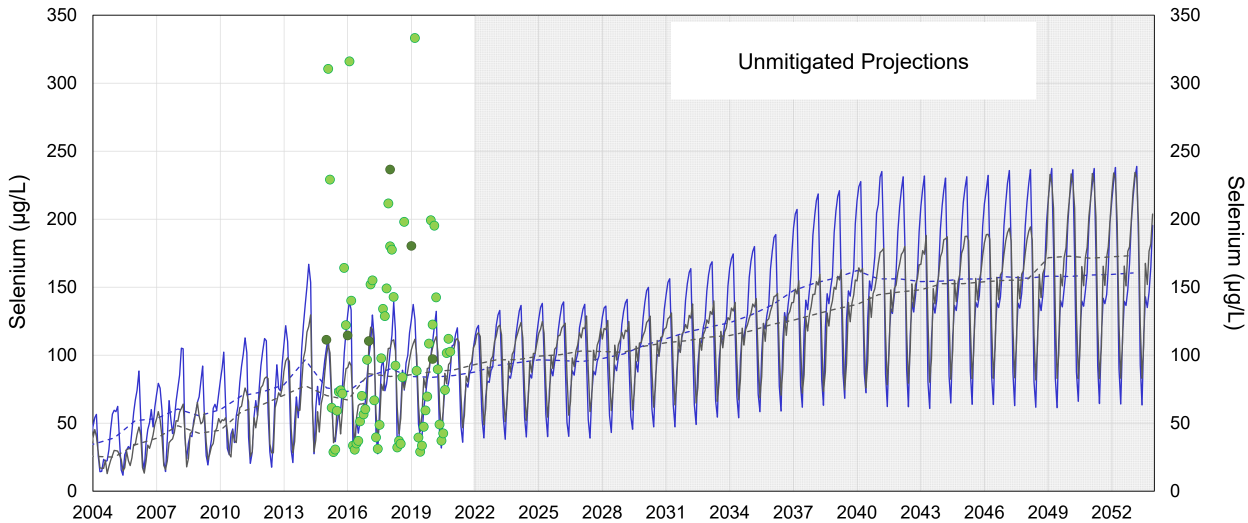
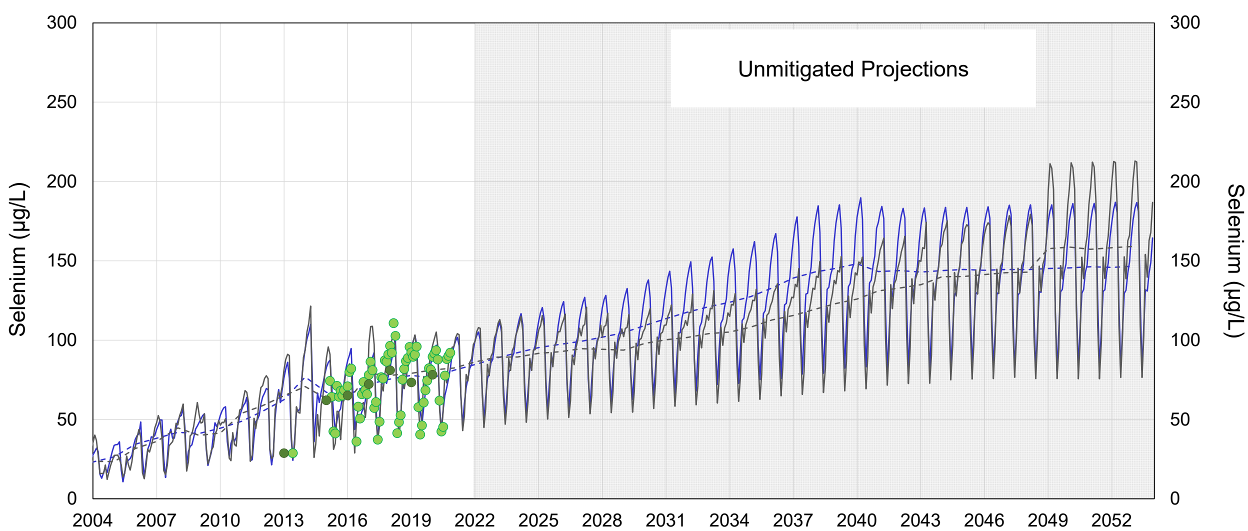


Figure A-4: Projected Concentrations of Selenium at Compliance Points without Consideration of Mitigation, 2004-2053

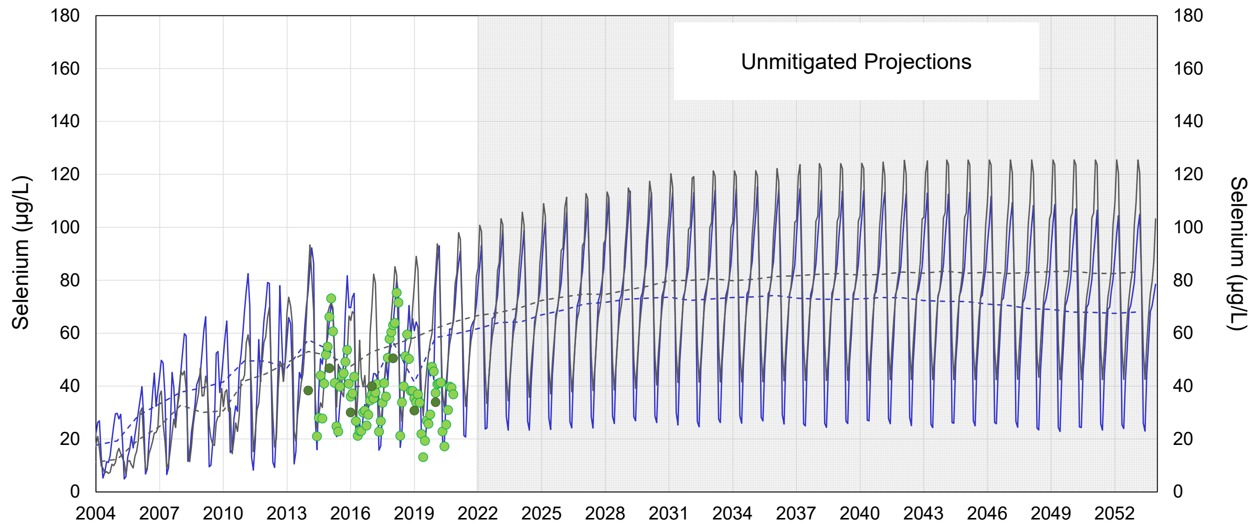
(a) Fording River, 525 m d/s of Cataract Creek (FR_FRCP1; E300071)



(b) FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)

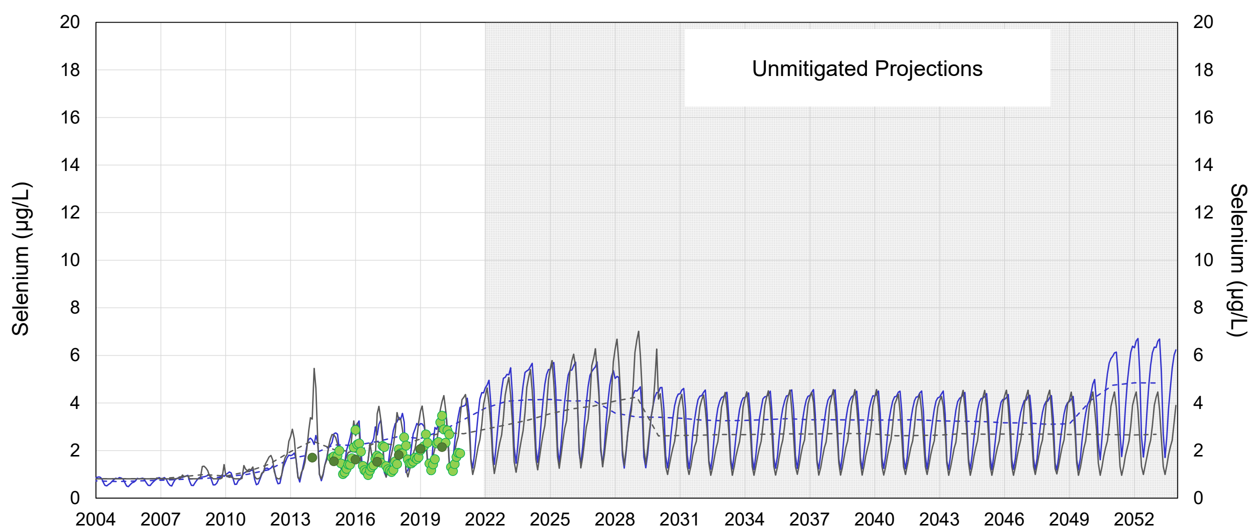


(c) LCO Compliance Point (LC_LCDSSLCC; E297110)



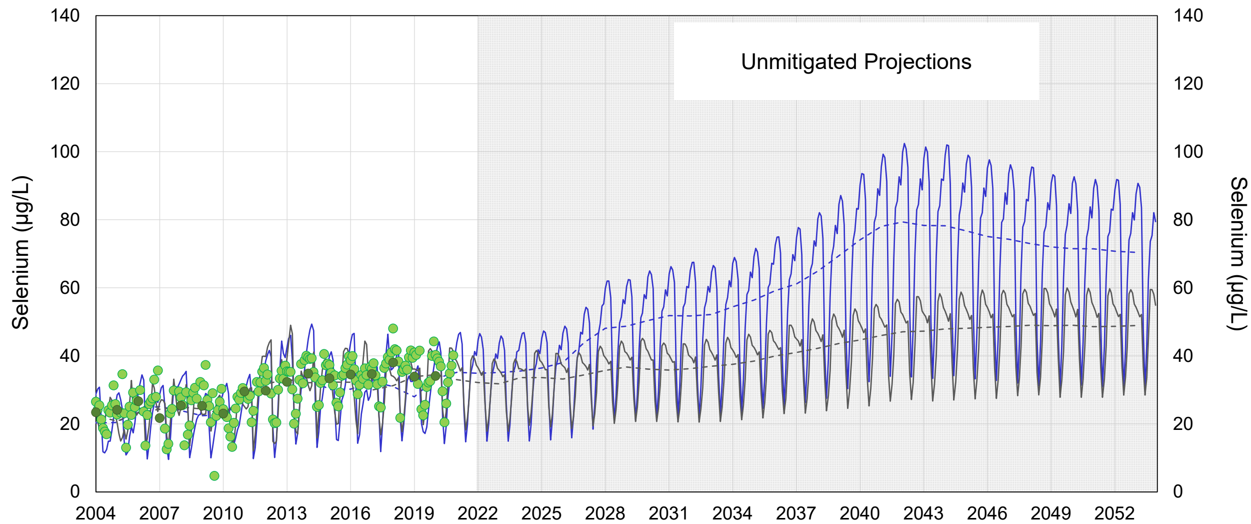
Note: The West Line Creek Active Water Treatment Facility is not active in the 2020 RWQM from January 1, 2020 onward.

(d) GHO Elk River Compliance Point (GH_ERC; E300090)

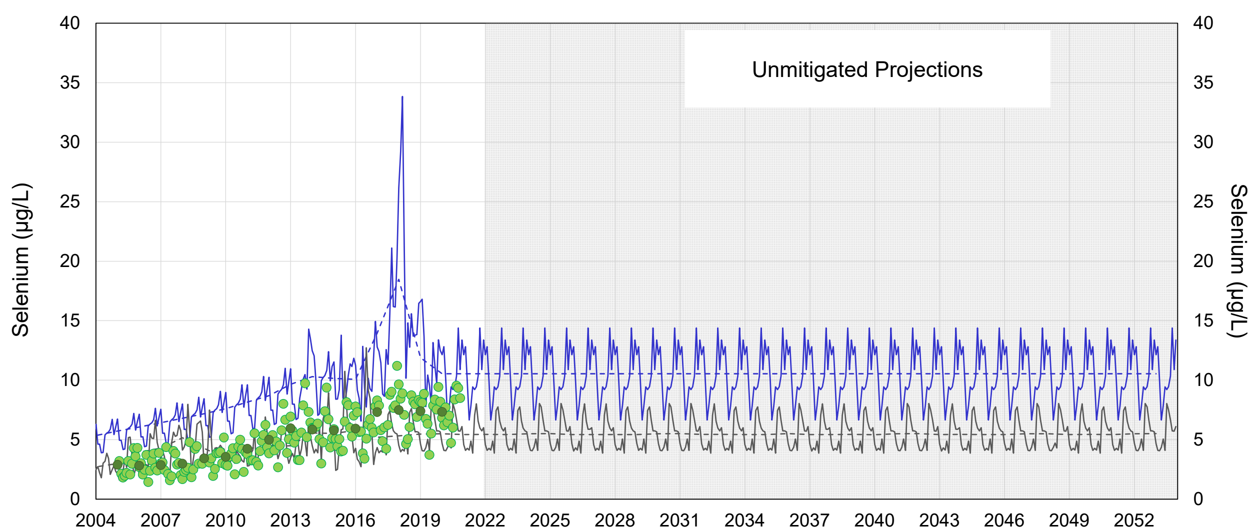


Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

(e) EVO Harmer Compliance Point (EV_HC1; E102682)

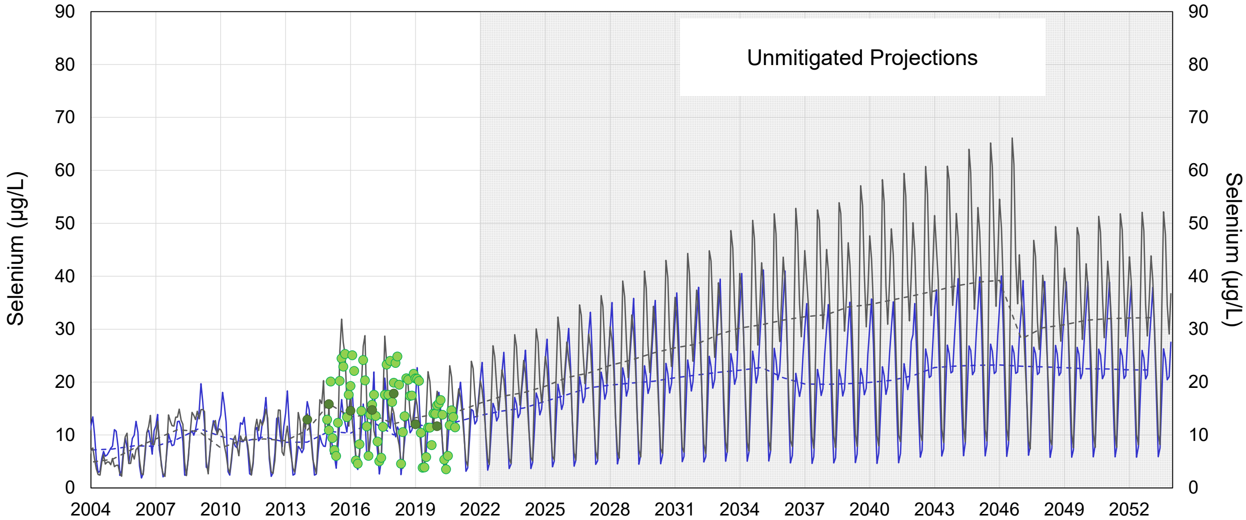


(f) CMO Compliance Point (CM_MC2; E258937)



Note: Projected concentrations are from the CMO Water and Load Balance Model.

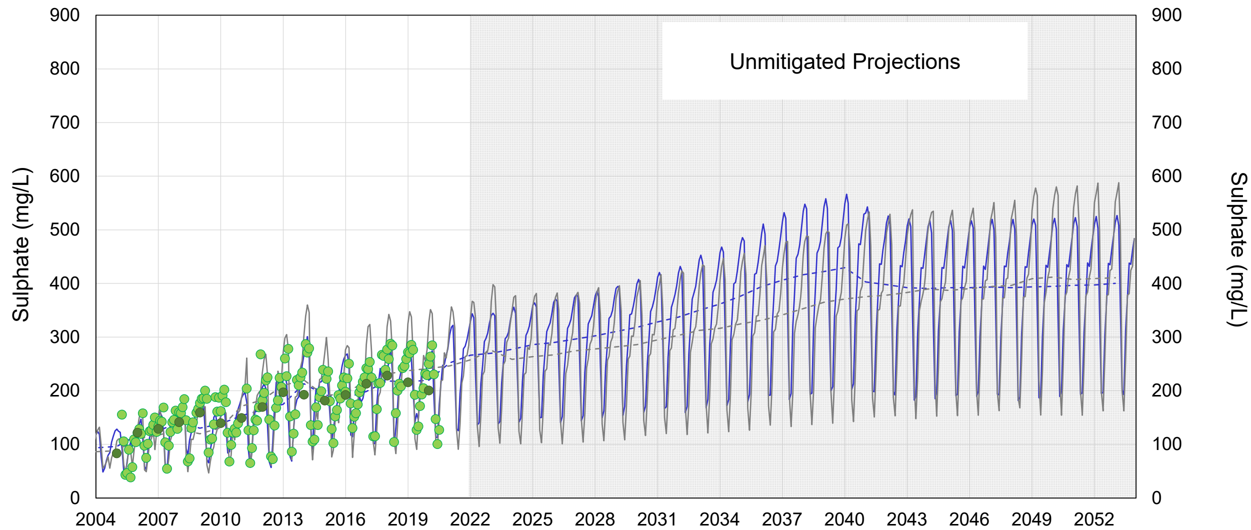
(g) EVO Michel Creek Compliance Point (EV_MC2; E300091)



Note: Projected concentrations developed using the 2020 RWQM decrease in 2037 because mining in Natal Pit West at Elkview Operations is modelled to be completed by the end of 2036 after which the pit is modelled to fill. Projected concentrations increase in 2042 because Natal Pit West is modelled to spill.

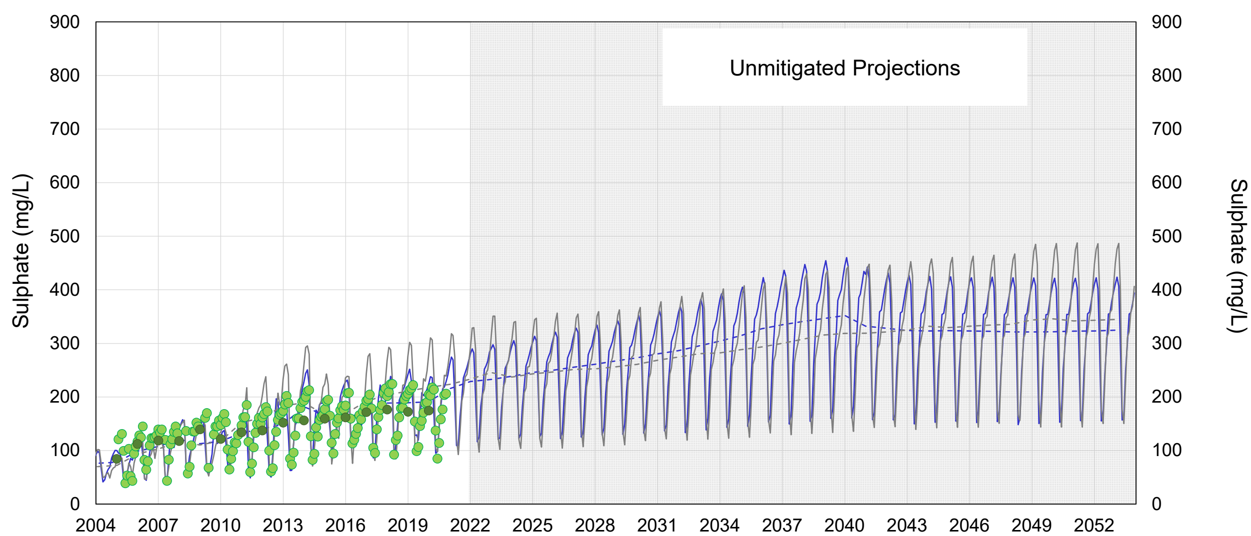
Figure A-5: Projected Concentrations of Sulphate at Order Stations without Consideration of Mitigation, 2004-2053

(a) GHO Fording River Compliance Point (GH_FR1; 0200378)

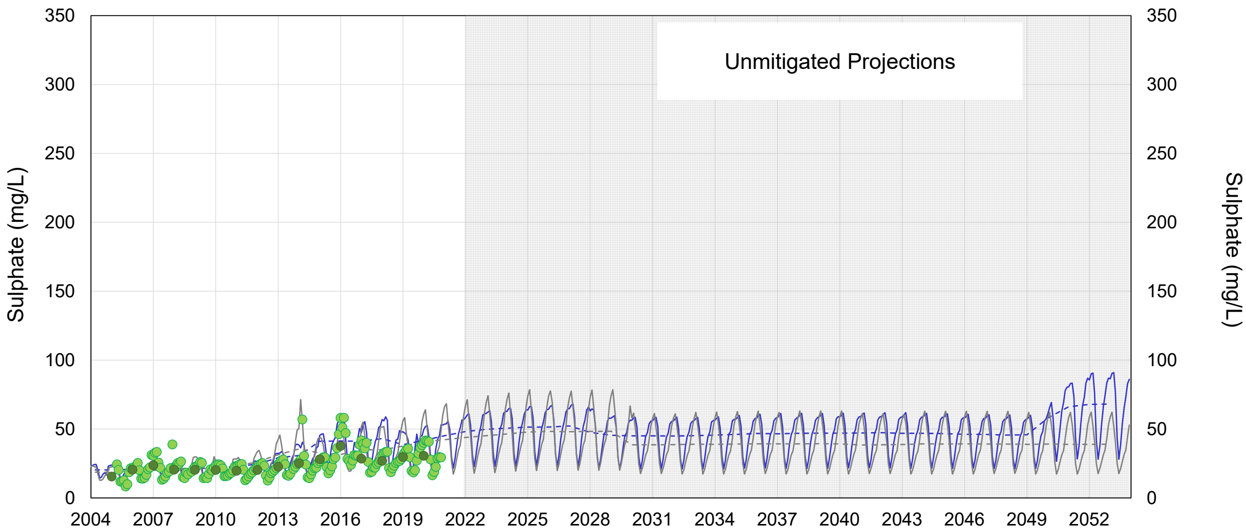


Note: This location is also the GHO Fording River Compliance Point.

(b) Fording River d/s of Line Creek (LC_LC5; 0200028)

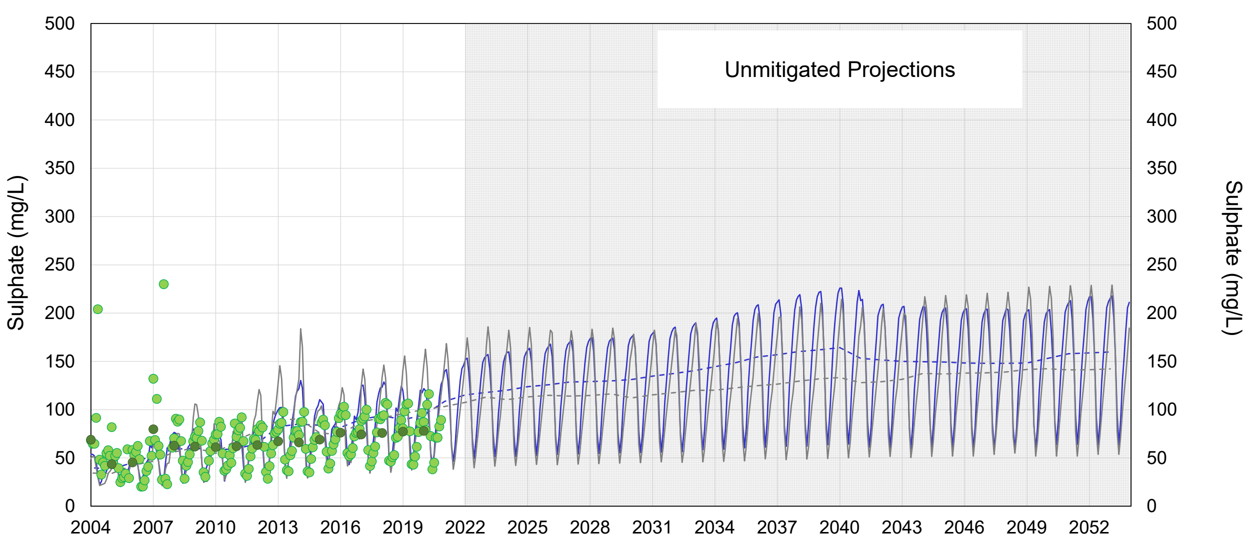


(c) Elk River u/s of Boivin Creek (GH_ER1; E206661)

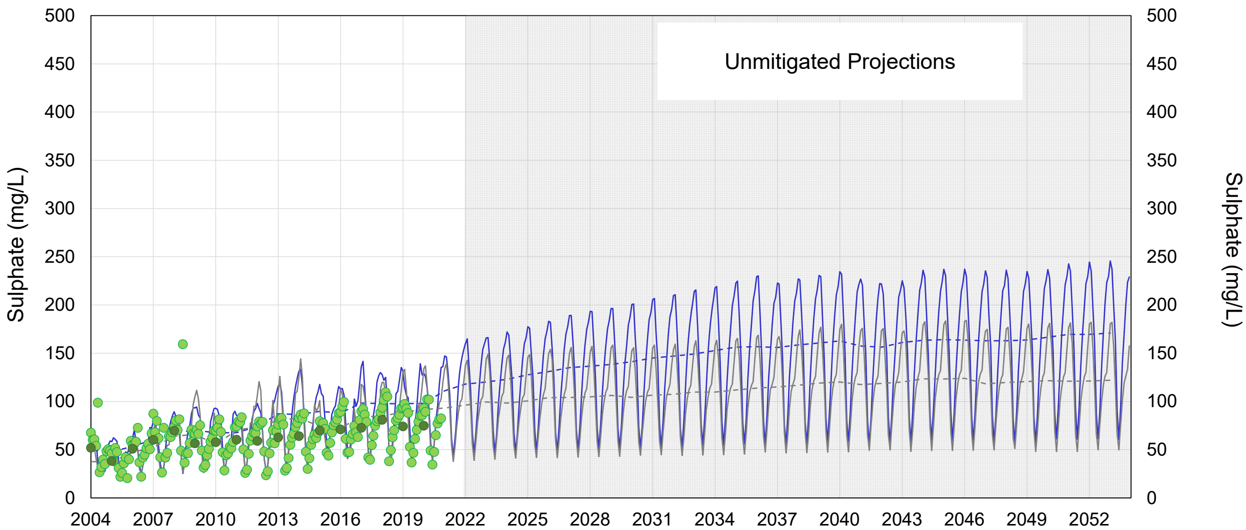


Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

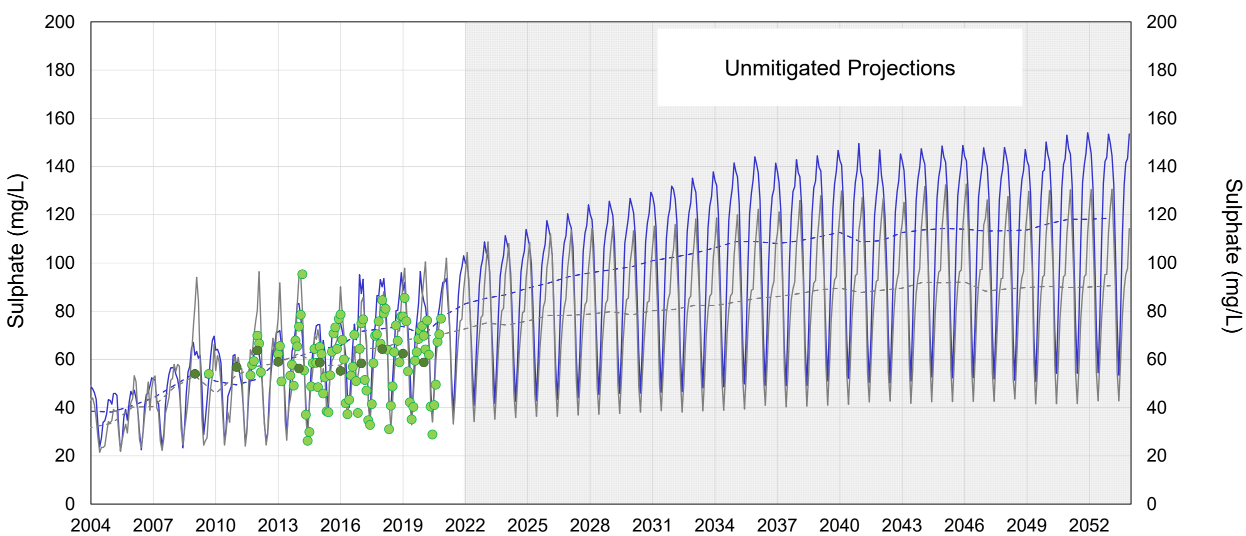
(d) Elk River u/s of Grave Creek (EV_ER4; 0200027)



(e) Elk River d/s of Michel Creek (EV_ER1; 0200393)



(f) Elk River at Elko Reservoir (RG_ELKORES; E294312)



(g) Koocanusa Reservoir (E300230)

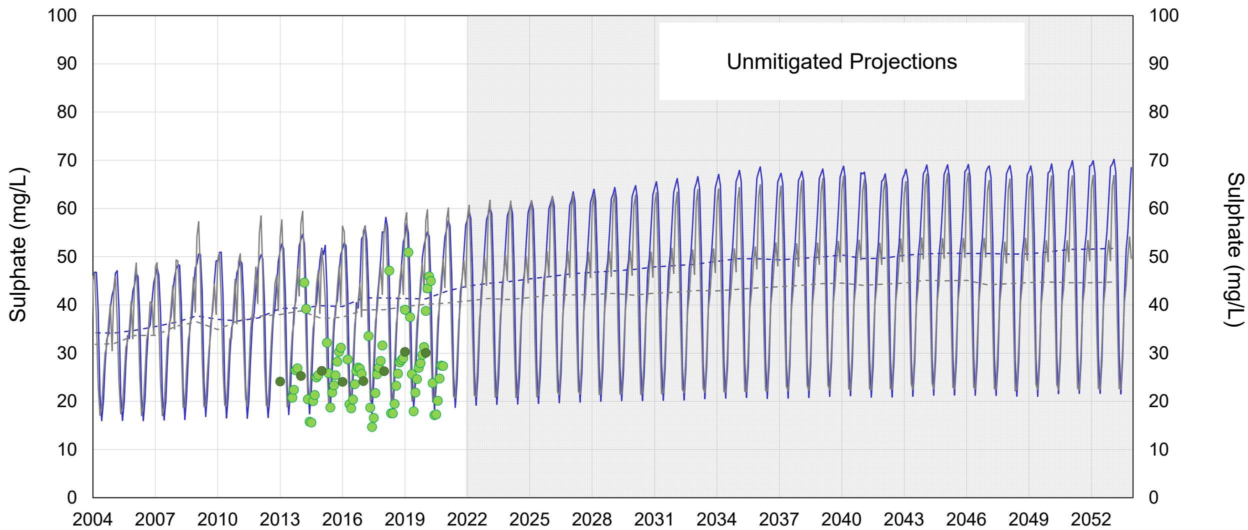
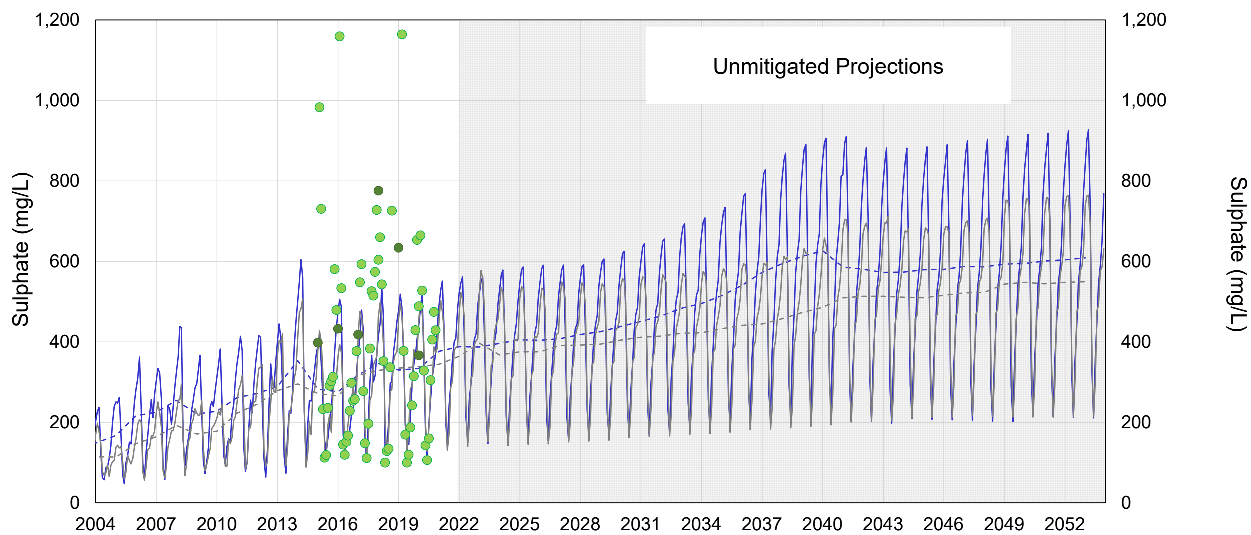
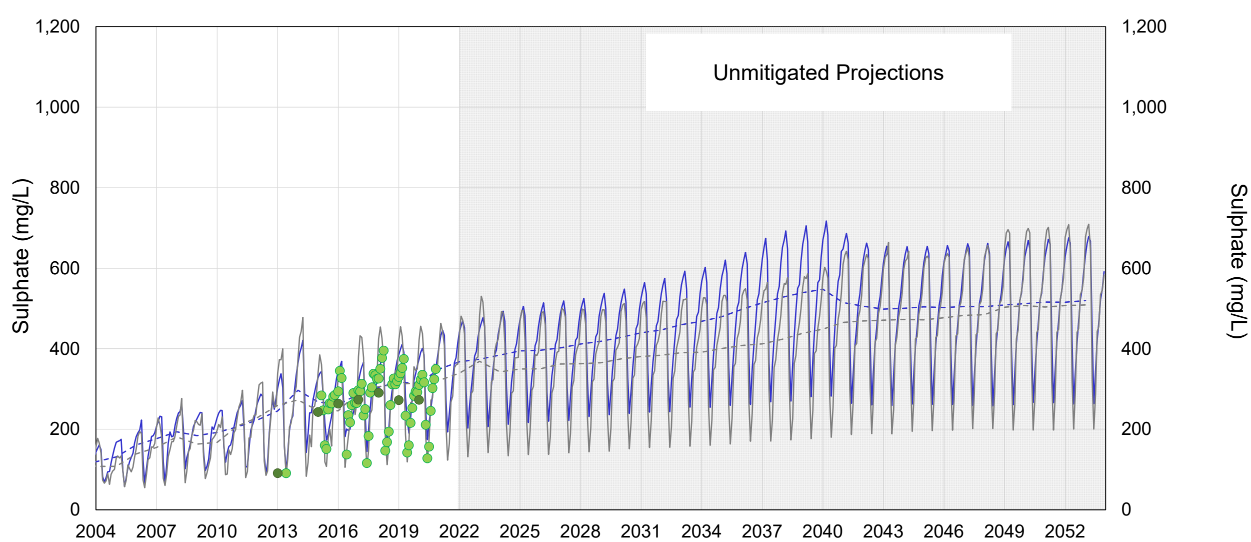


Figure A-6: Projected Concentrations of Sulphate at Compliance Points without Consideration of Mitigation, 2004-2053

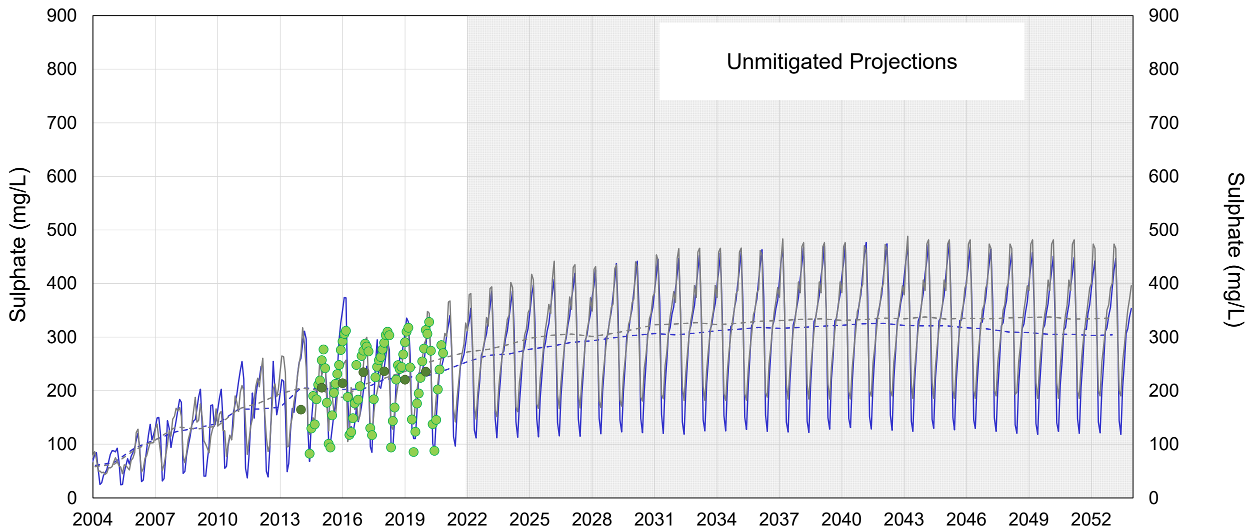
(a) Fording River, 525 m d/s of Cataract Creek (FR_FRCP1; E300071)



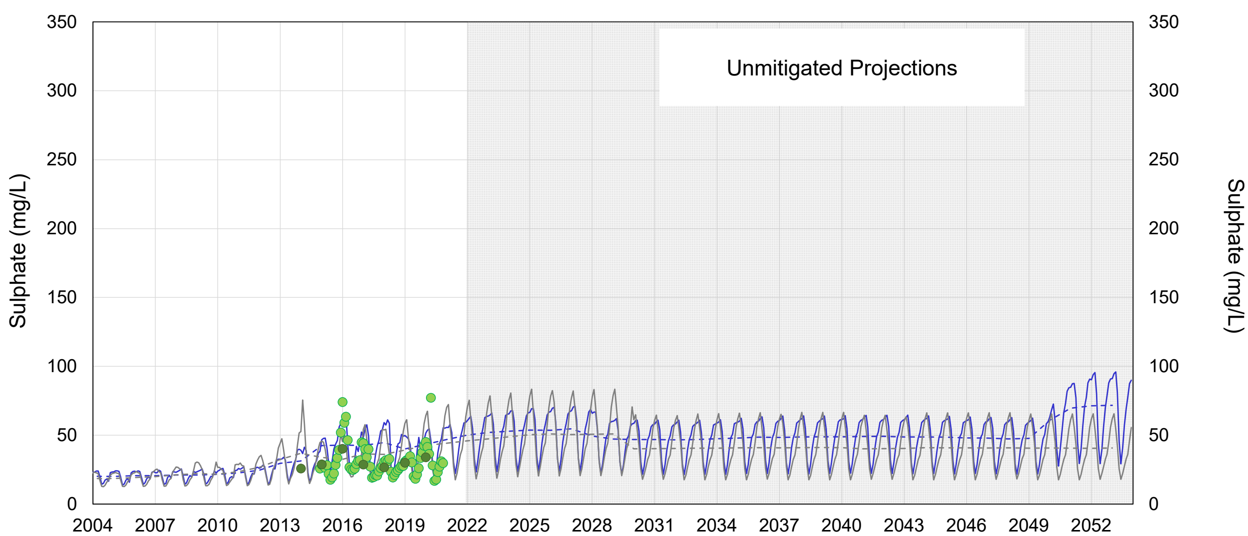
(b) FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)



(c) LCO Compliance Point (LC_LCDSSLCC; E297110)

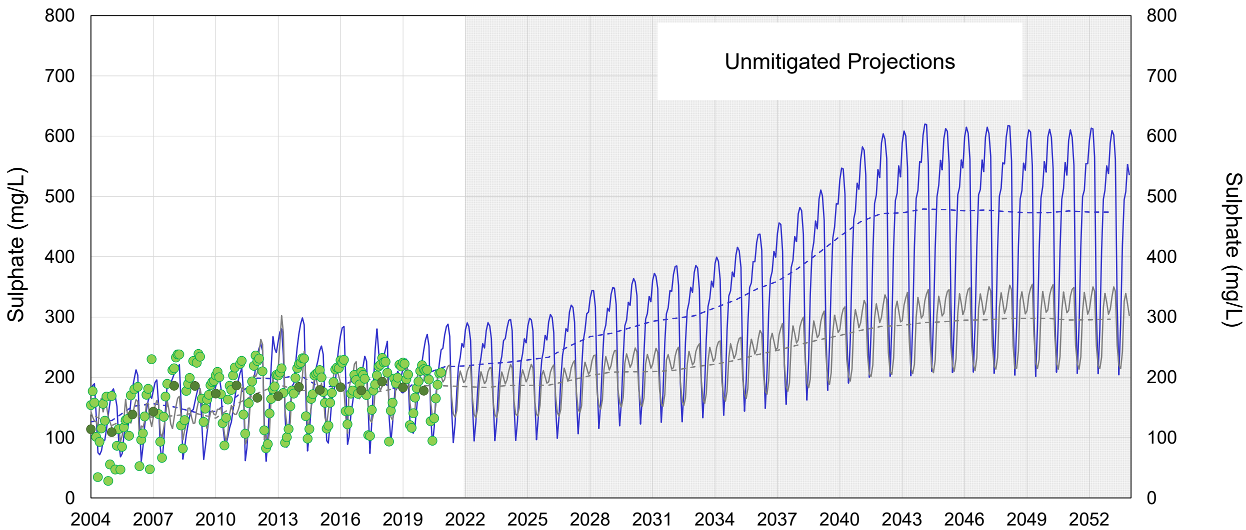


(d) GHO Elk River Compliance Point (GH_ERC; E300090)

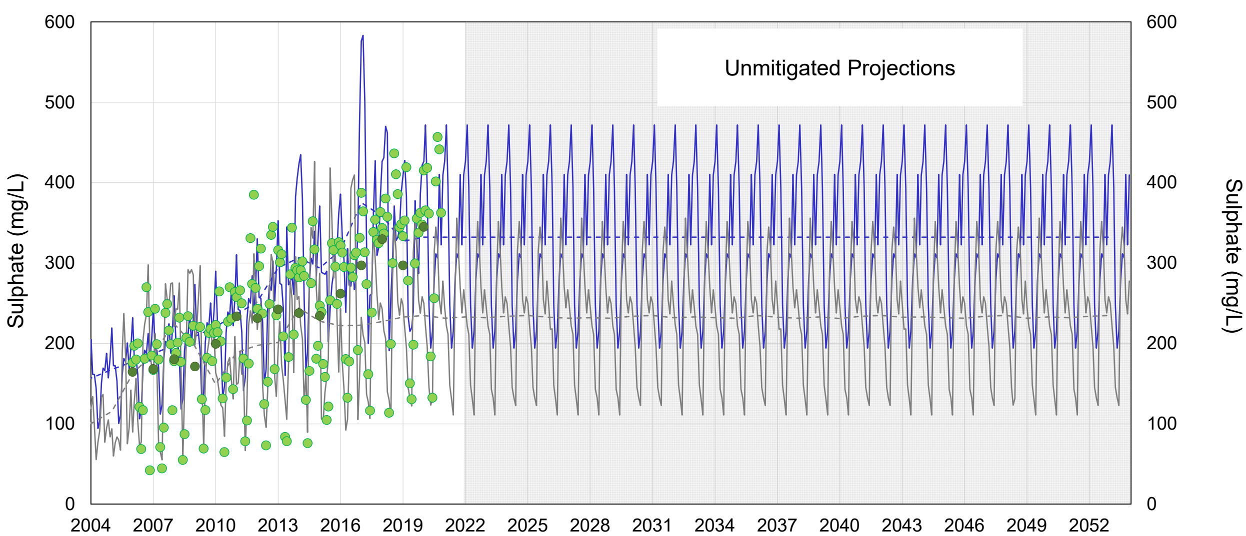


Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

(e) EVO Harmer Compliance Point (EV_HC1; E102682)

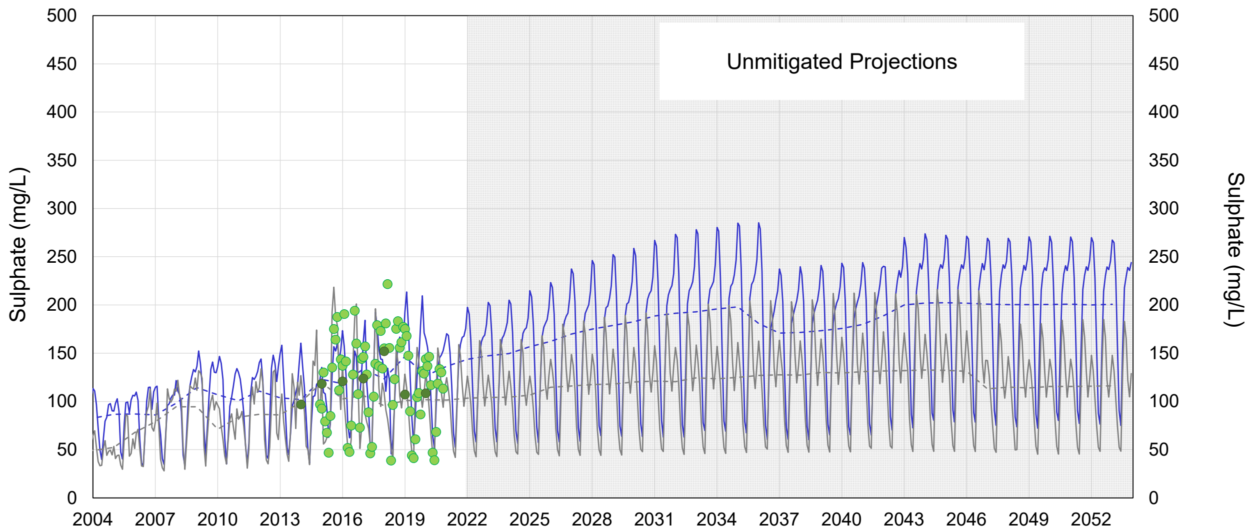


(f) CMO Compliance Point (CM_MC2; E258937)



Note: Projected concentrations are from the CMO Water and Load Balance Model.

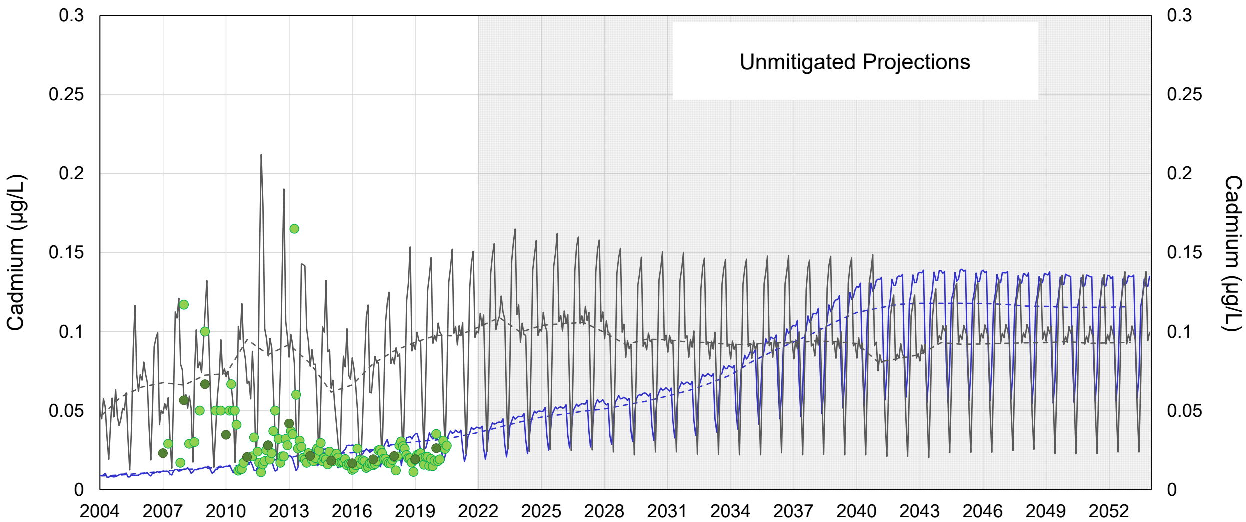
(g) EVO Michel Creek Compliance Point (EV_MC2; E300091)



Note: Projected concentrations developed using the 2020 RWQM decrease in 2037 because mining in Natal Pit West at Elkview Operations is modelled to be completed by the end of 2036 after which the pit is modelled to fill. Projected concentrations increase in 2042 because Natal Pit West is modelled to spill.

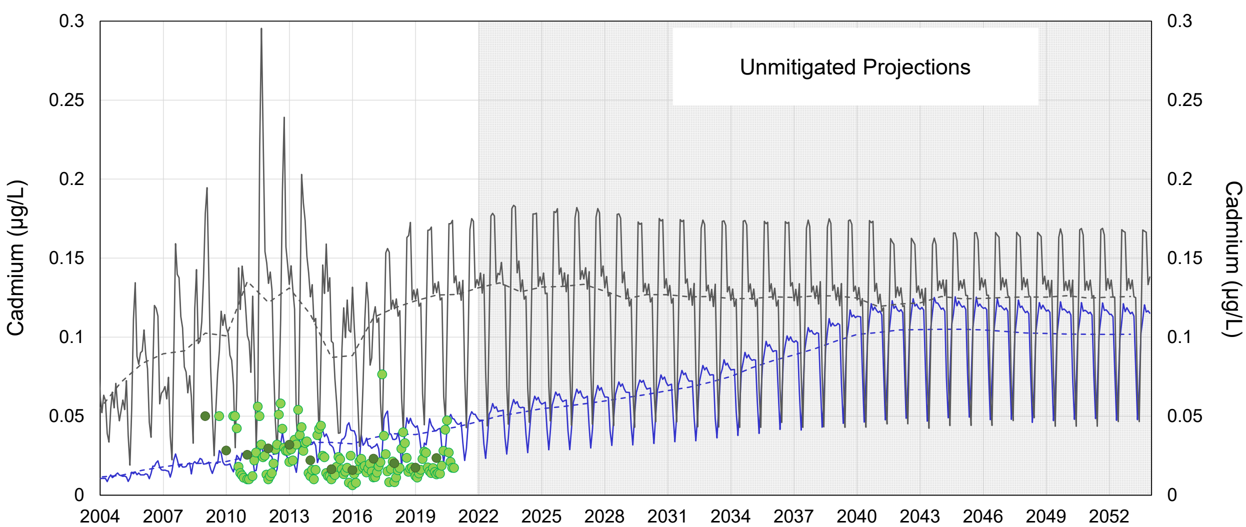
Figure A-7: Projected Concentrations of Dissolved Cadmium at Order Stations without Consideration of Mitigation, 2004-2053

(a) GHO Fording River Compliance Point (GH_FR1; 0200378)

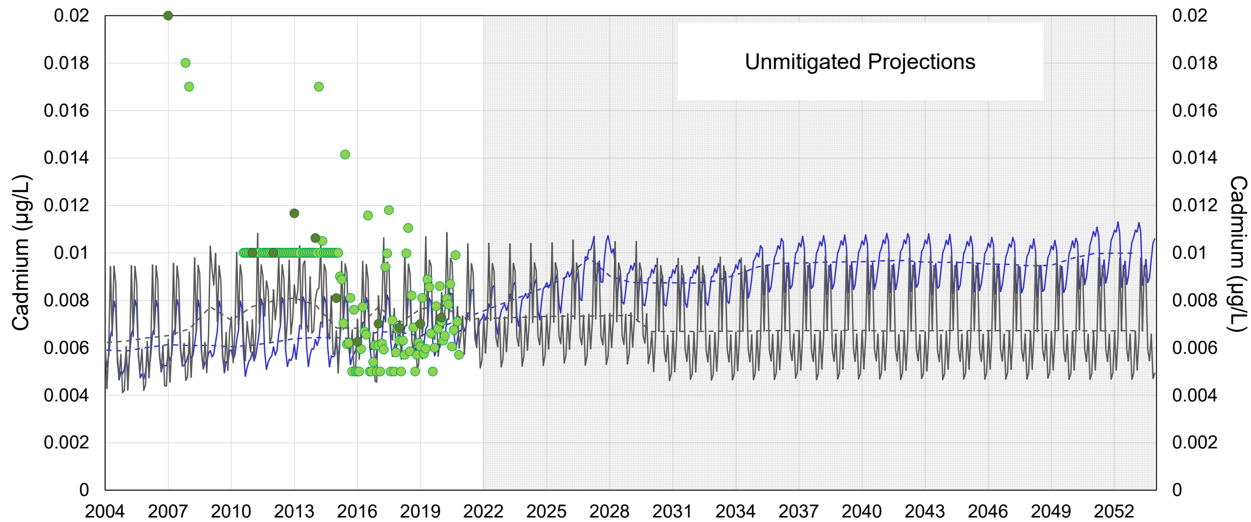


Note: This location is also the GHO Fording River Compliance Point.

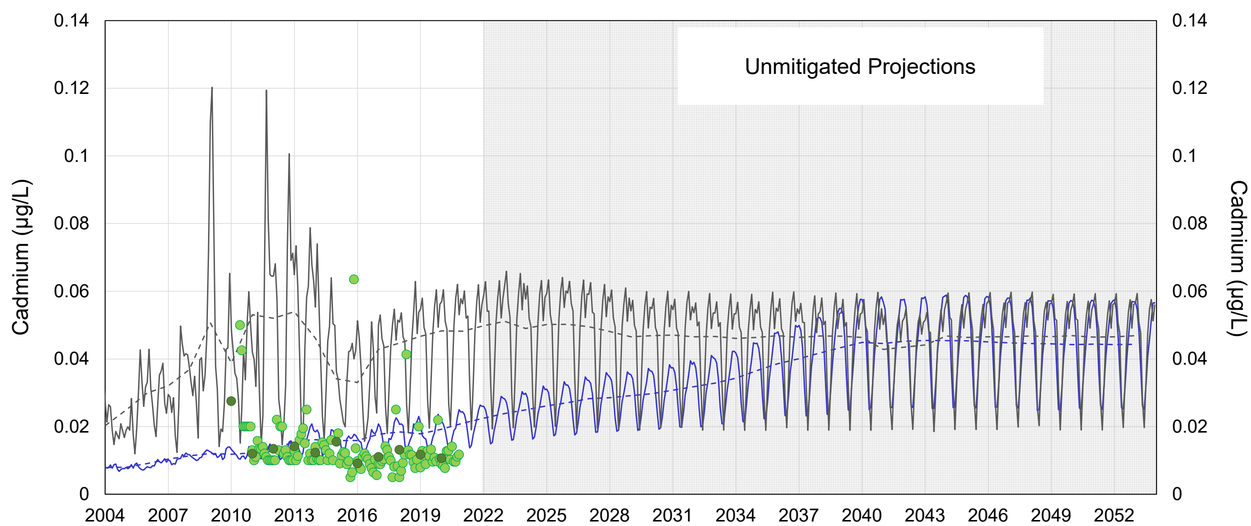
(b) Fording River d/s of Line Creek (LC_LC5; 0200028)



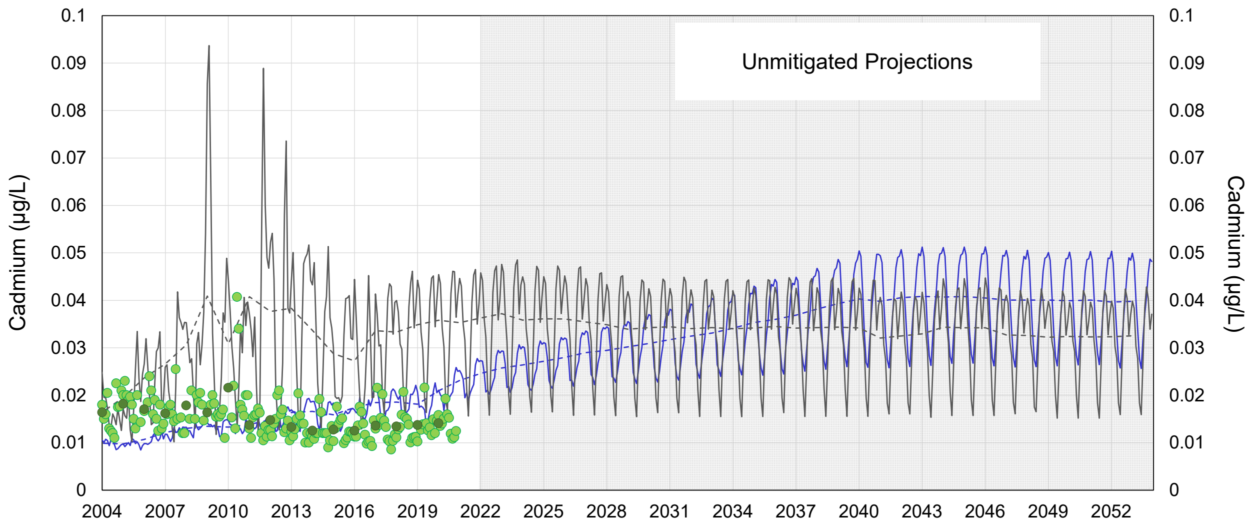
(c) Elk River u/s of Boivin Creek (GH_ER1; E206661)



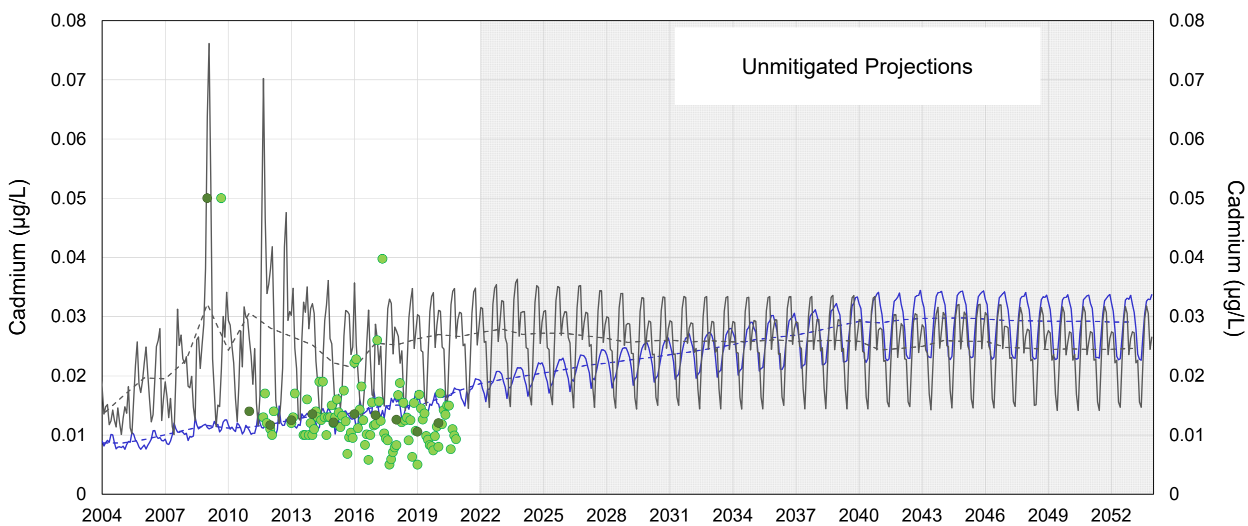
(d) Elk River u/s of Grave Creek (EV_ER4; 0200027)



(e) Elk River d/s of Michel Creek (EV_ER1; 0200393)



(f) Elk River at Elko Reservoir (RG_ELKORES; E294312)



(g) Koocanusa Reservoir (E300230)

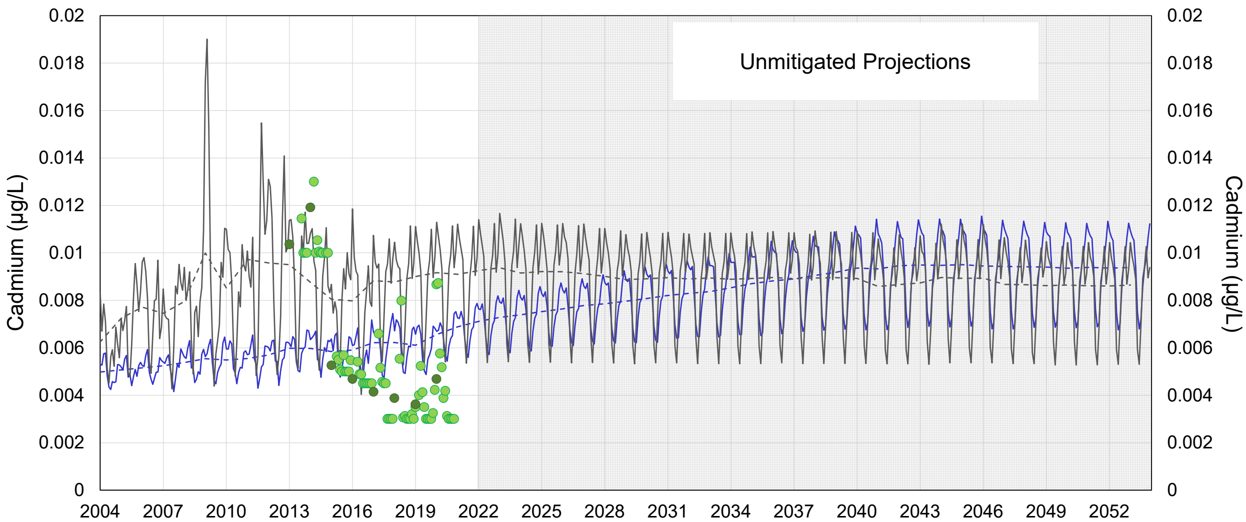
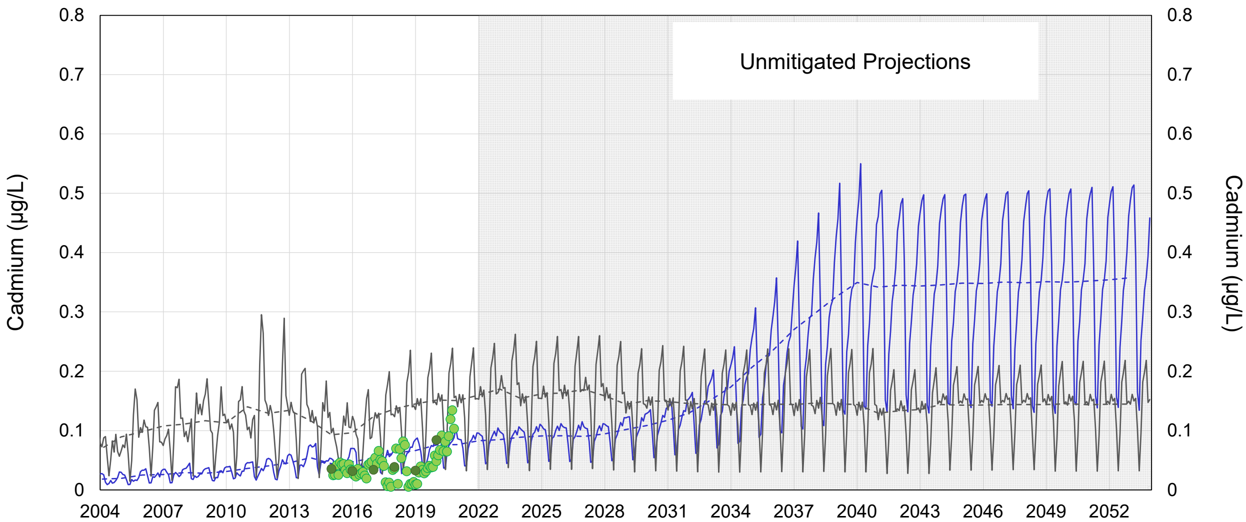


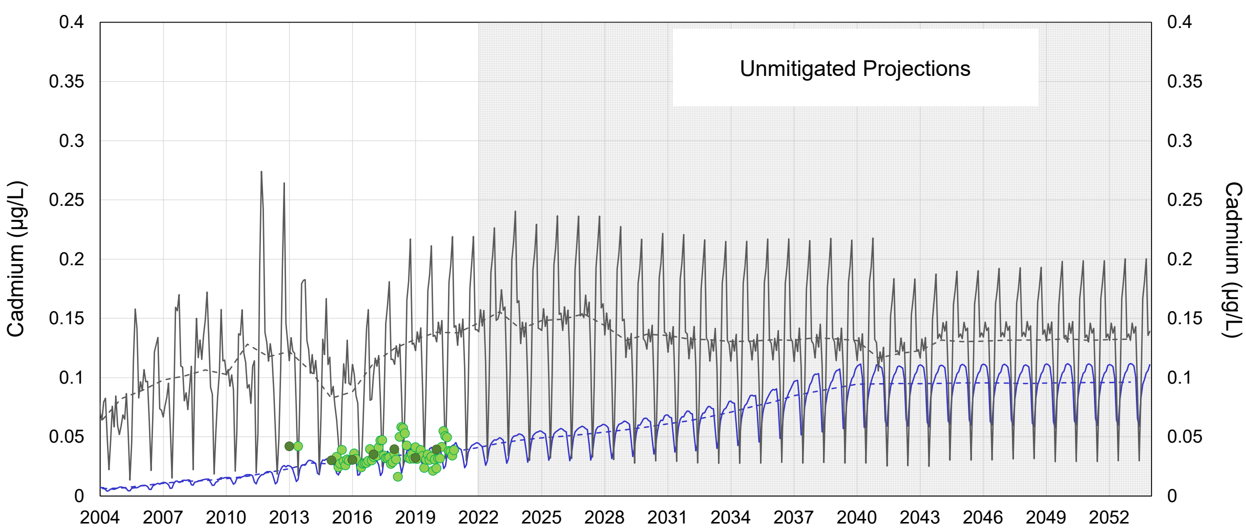
Figure A-8: Projected Concentrations of Dissolved Cadmium at Compliance Points without Consideration of Mitigation, 2004-2053

(a) Fording River, 525 m d/s of Cataract Creek (FR_FRCP1; E300071)

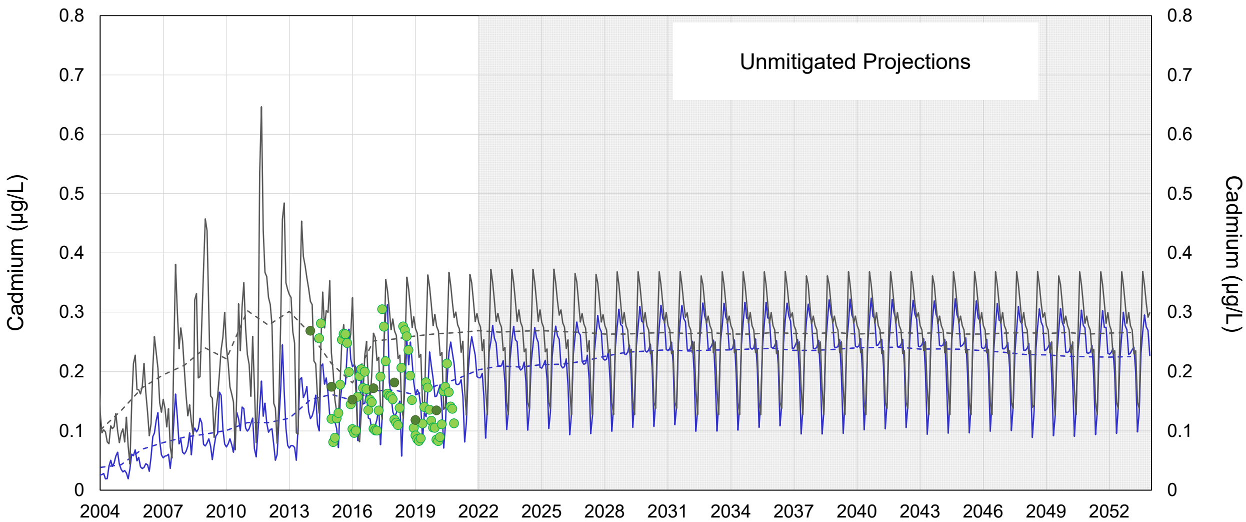


Note: Current projections developed using the 2020 RWQM are unrealistically high. Model projections for cadmium in new development areas will require additional refinement through adjustments to attenuation factors over time to match what is observed in more mature spoils.

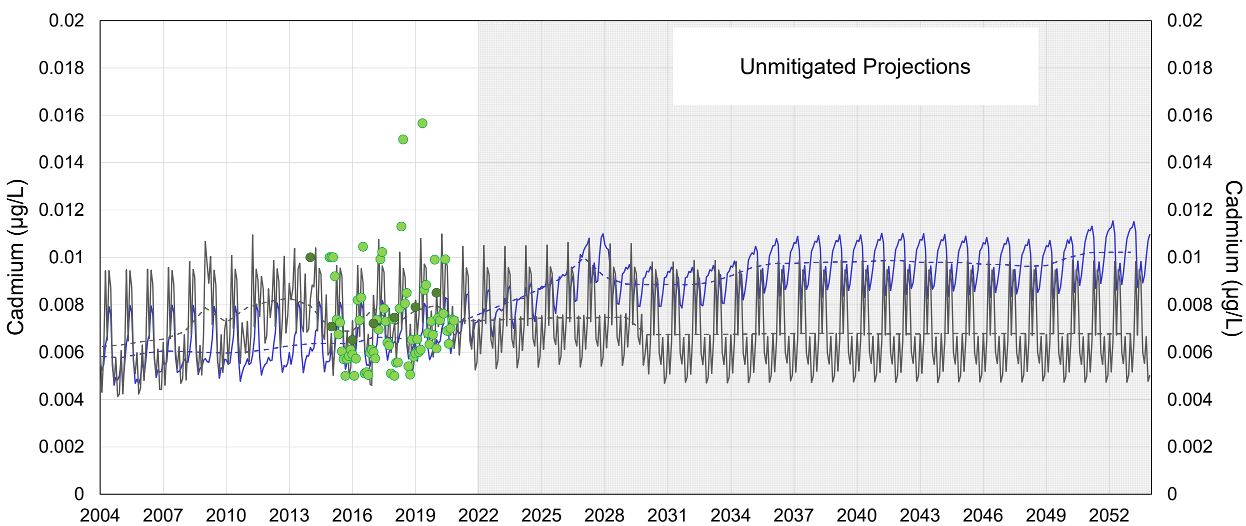
(b) FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)



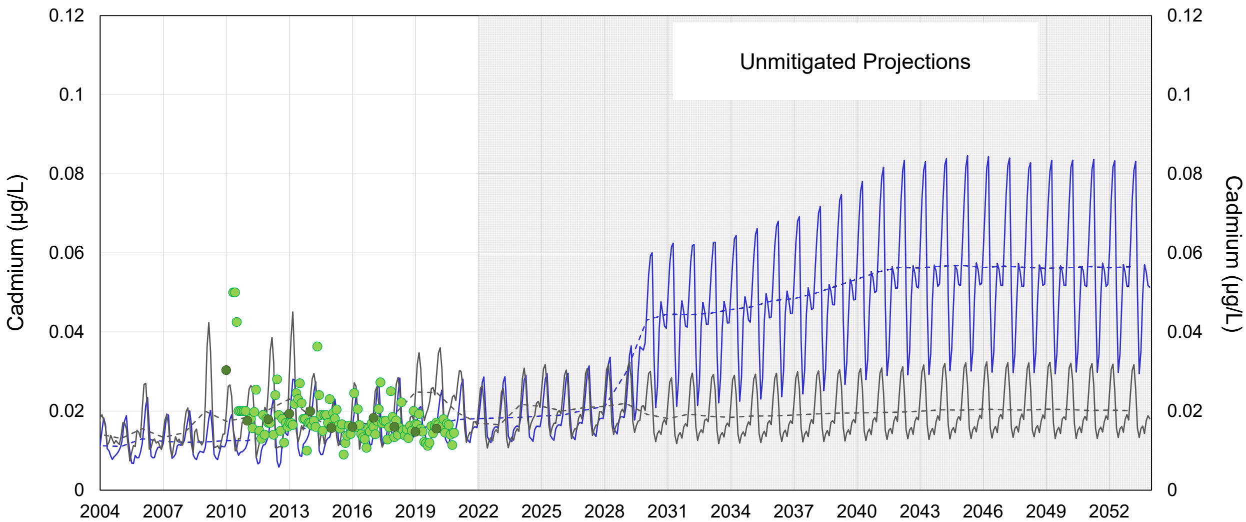
(c) LCO Compliance Point (LC_LCDSSLCC; E297110)



(d) GHO Elk River Compliance Point (GH_ERC; E300090)

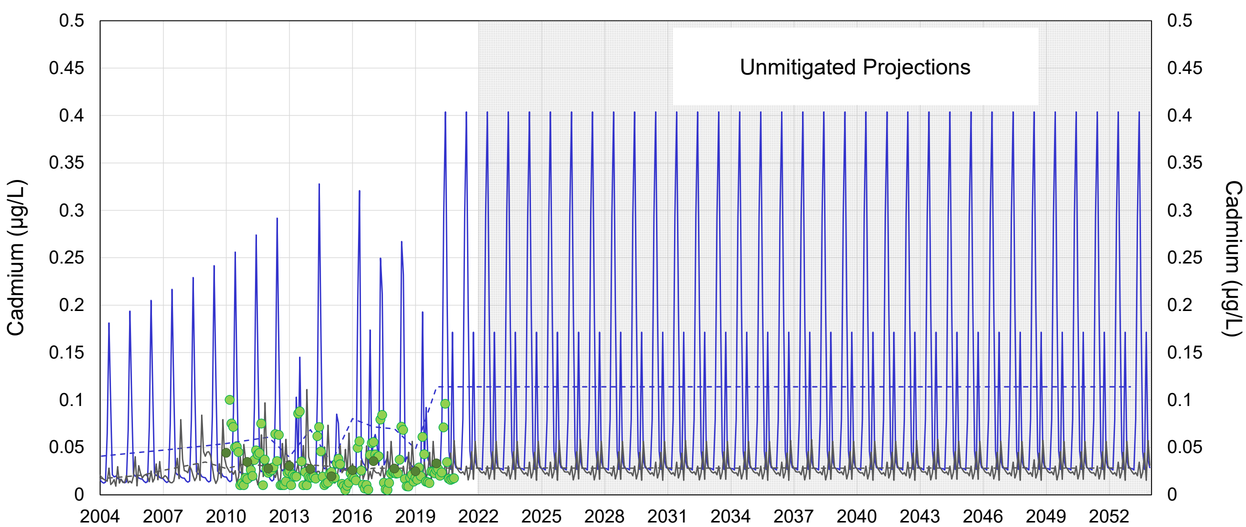


(e) EVO Harmer Compliance Point (EV_HC1; E102682)



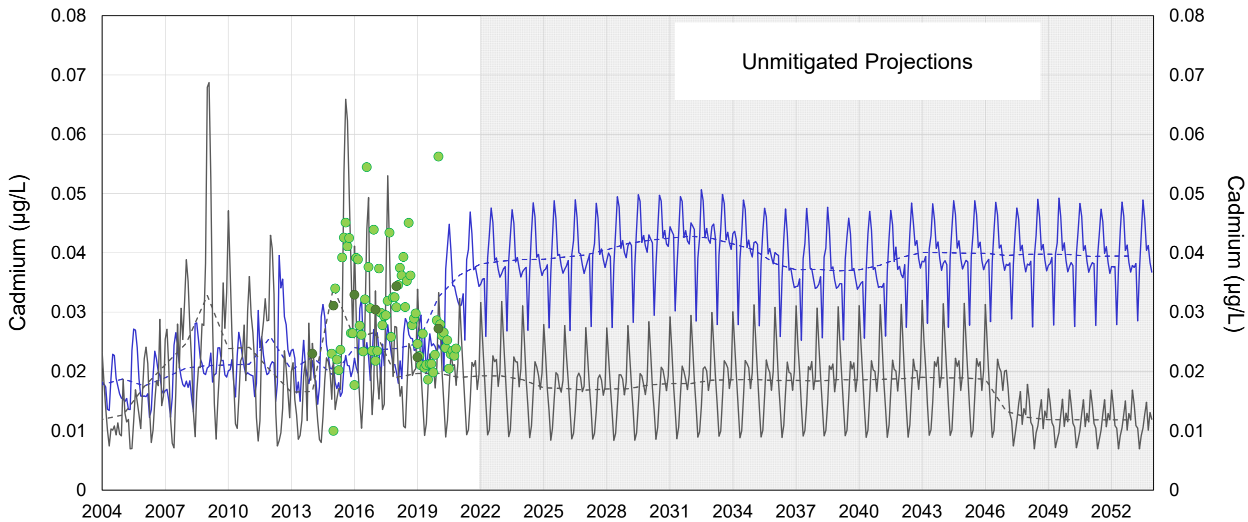
Note: Current projections developed using the 2020 RWQM are unrealistically high. Model projections for cadmium in new development areas will require additional refinement through adjustments to attenuation factors over time to match what is observed in more mature spoils.

(f) CMO Compliance Point (CM_MC2; E258937)



Note: Projected concentrations are from the CMO Water and Load Balance Model.

(g) EVO Michel Creek Compliance Point (EV_MC2; E300091)



Appendix B

Comparison of 2020 RWQM and 2017 RWQM Projected Monthly Average and Annual Average Concentrations of Nitrate, Selenium, Sulphate and Cadmium at Order Stations and Compliance Points, with Application of the 2019 Implementation Plan Adjustment

Figures

Model results for nitrate, selenium, sulphate, and cadmium, with consideration of mitigation, at Order Stations and Compliance Points are shown in Figures B-1 to B-8, respectively. The format of the figures is as follows:

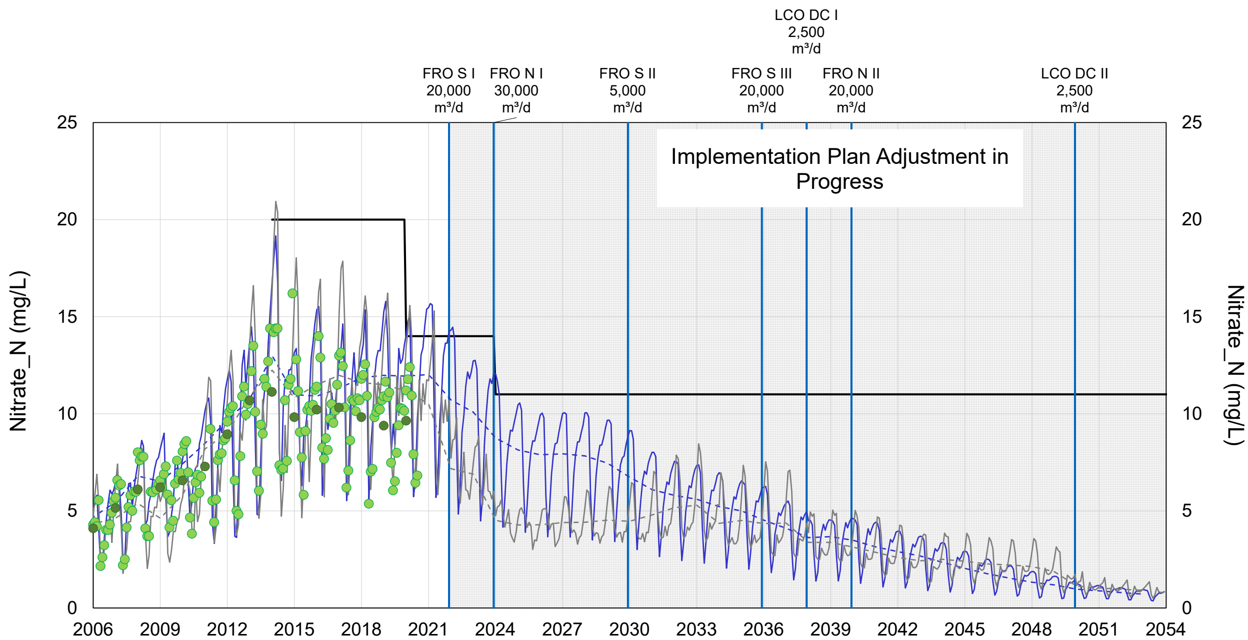
- The x-axis runs from the start of 2004 (for selenium, sulphate, and cadmium) or 2006 (for nitrate) to the end of 2053. The start date corresponds to the start of the calibration period for the 2020 RWQM. The end date (2053) corresponds to the modelled time period at which all waste rock considered in the permitted mine plans has been deposited and the lag associated with that rock has passed (i.e., all of the waste rock is contributing selenium and sulphate load).
- Projected 50^{th} percentile (P50) monthly average concentrations produced using the 2020 RWQM are shown as a solid blue line.
- Projected monthly average concentrations produced using the 2017 RWQM under average flow conditions are shown as a solid grey line.
- Projected annual average concentrations produced using the 2020 RWQM and 2017 RWQM are shown as dashed blue and grey lines, respectively.
- Measured monthly average and annual average concentrations are shown as light green points and dark green points, respectively.
- Modelled information shown prior to 2020 that was generated using the 2020 RWQM was developed based on calibrated flows. Those shown thereafter were developed using multiple climate realizations, as described in Annex D.
- Modelled information shown prior to 2017 that was generated using the 2017 RWQM was developed based on calibrated flows. Those shown thereafter were developed using average flow projections.

The legend below applies to all time series plots in this appendix.

Projected P_{50} Monthly Average Concentrations from the 2020 RWQM
Projected P_{50} Annual Average Concentrations from the 2020 RWQM
Projected Monthly Average Concentrations for Average Flows from the 2017 RWQM
Projected Annual Average Concentrations for Average Flows from the 2017 RWQM
Monthly Average Measured Concentrations
Annual Average Measured Concentrations
Site Performance Objective
Limit

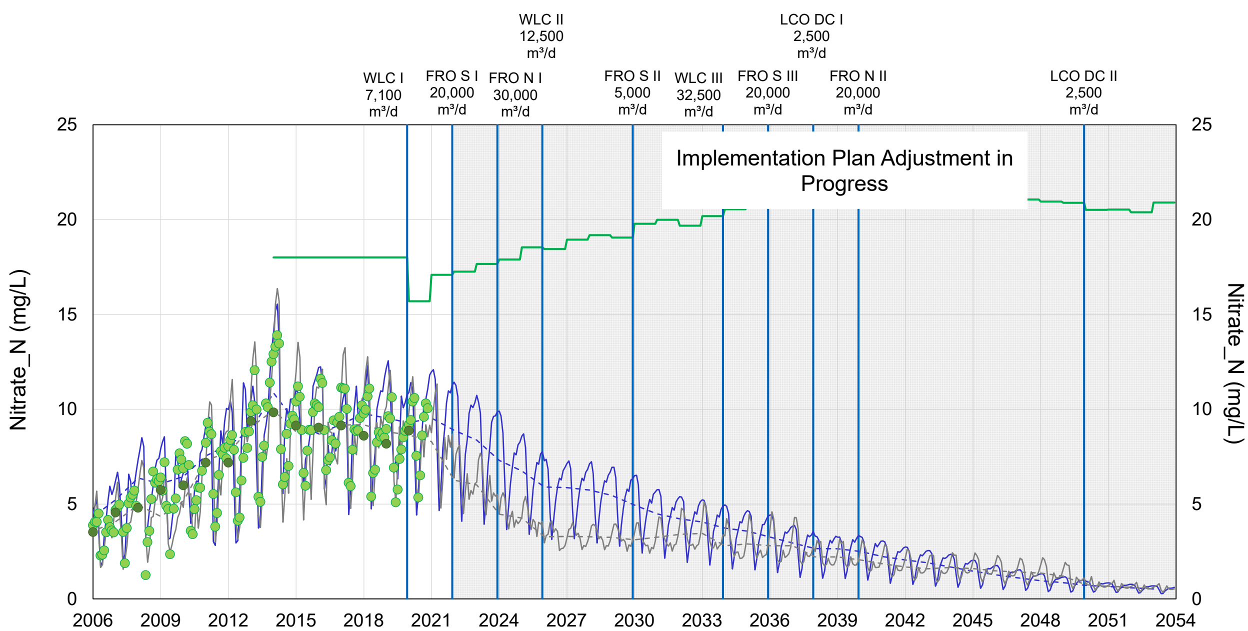
Figure B-1: Projected Concentrations of Nitrate at Order Stations with Consideration of Mitigation, 2006-2053

(a) GHO Fording River Compliance Point (GH_FR1; 0200378)

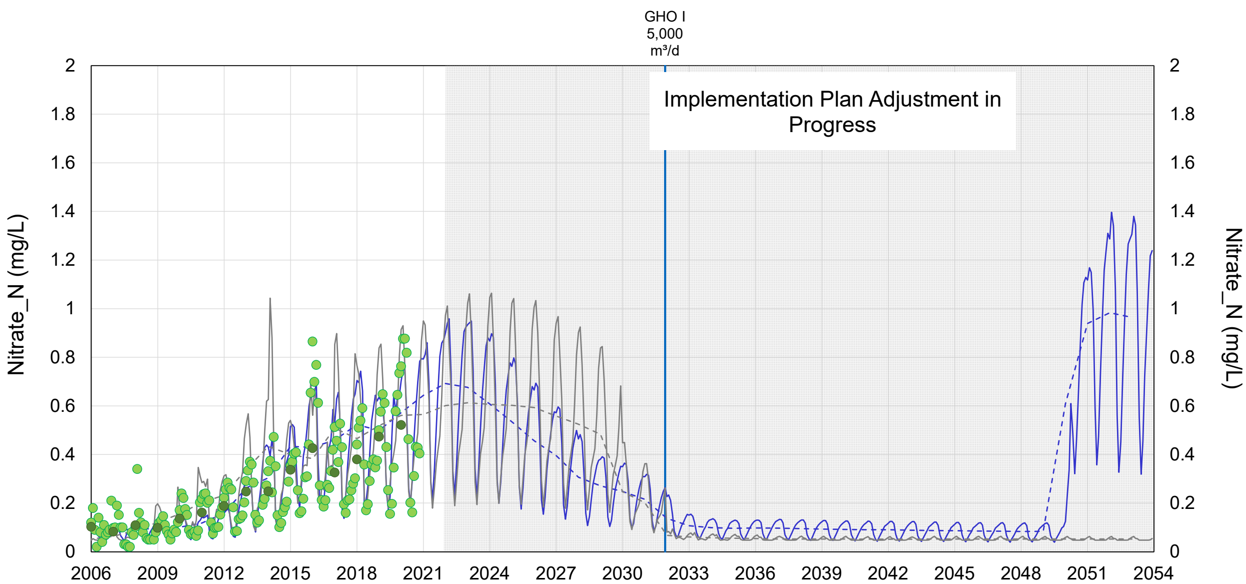


Note: This location is also the GHO Fording River Compliance Point.

(b) Fording River d/s of Line Creek (LC_LC5; 0200028)

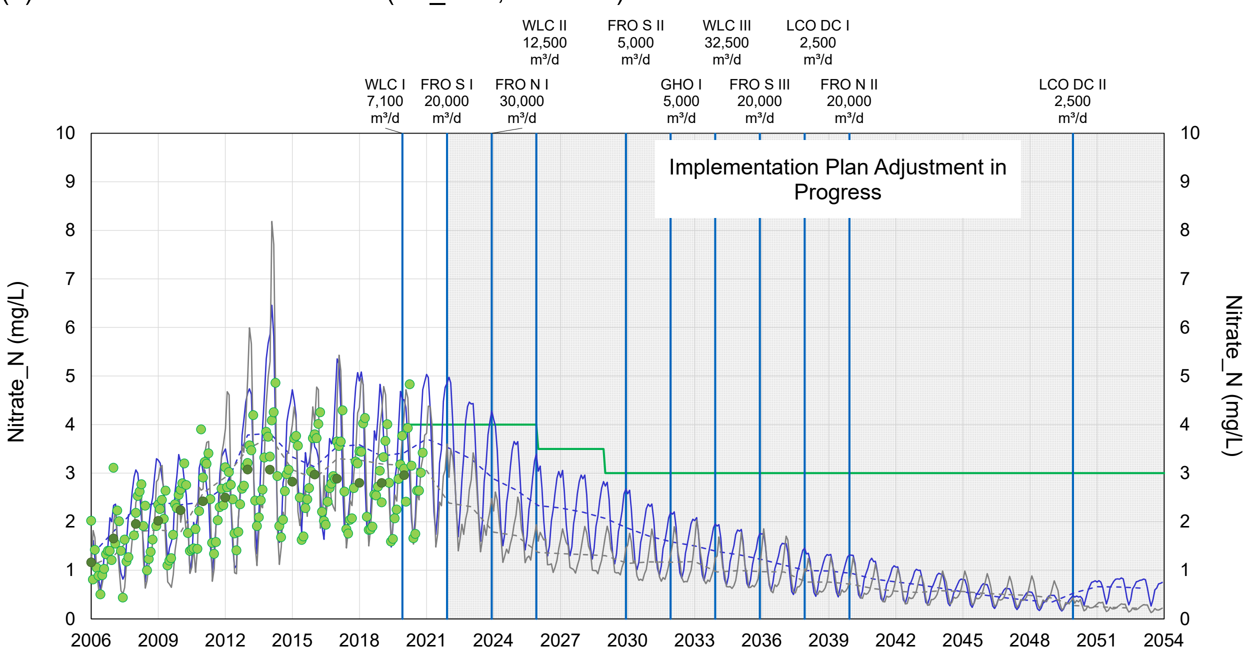


(c) Elk River u/s of Boivin Creek (GH_ER1; E206661)



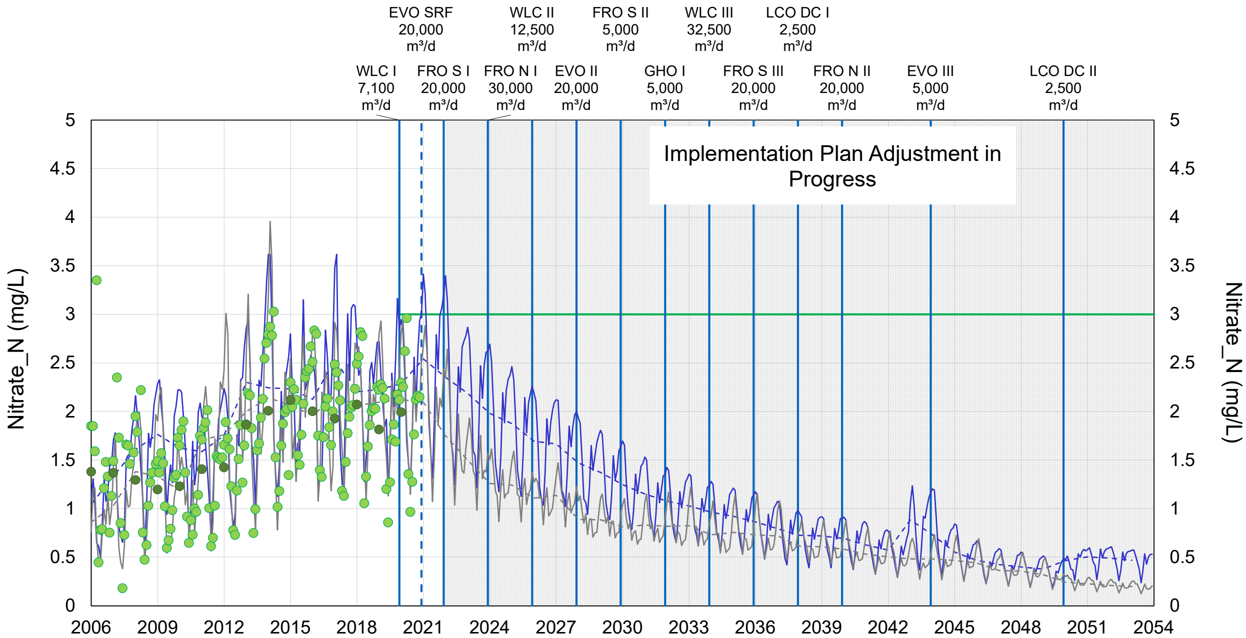
Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

(d) Elk River u/s of Grave Creek (EV_ER4; 0200027)



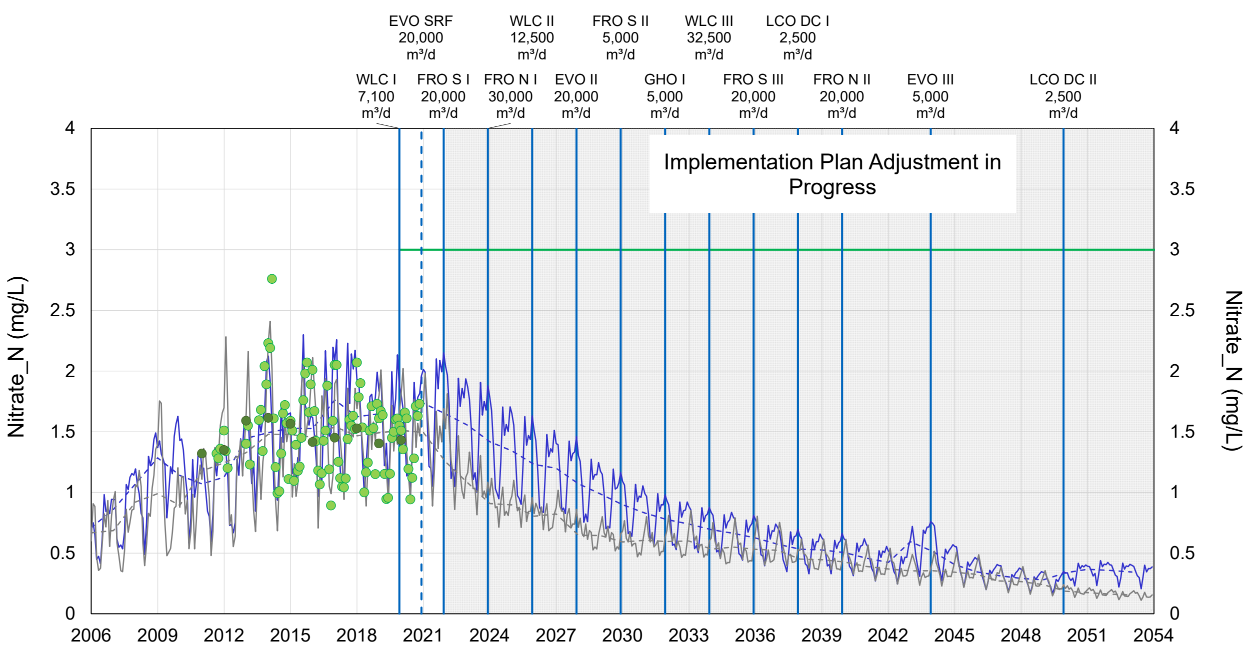
Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

(e) Elk River d/s of Michel Creek (EV_ER1; 0200393)



Note: Projected concentrations developed using the 2020 RWQM increase in 2042 because Natal Pit West at Elkview Operations is modelled to spill. Projected concentrations increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

(f) Elk River at Elko Reservoir (RG_ELKORES; E294312)



Note: Projected concentrations developed using the 2020 RWQM increase in 2042 because Natal Pit West at Elkview Operations is modelled to spill. Projected concentrations increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

(g) Koocanusa Reservoir (E300230)

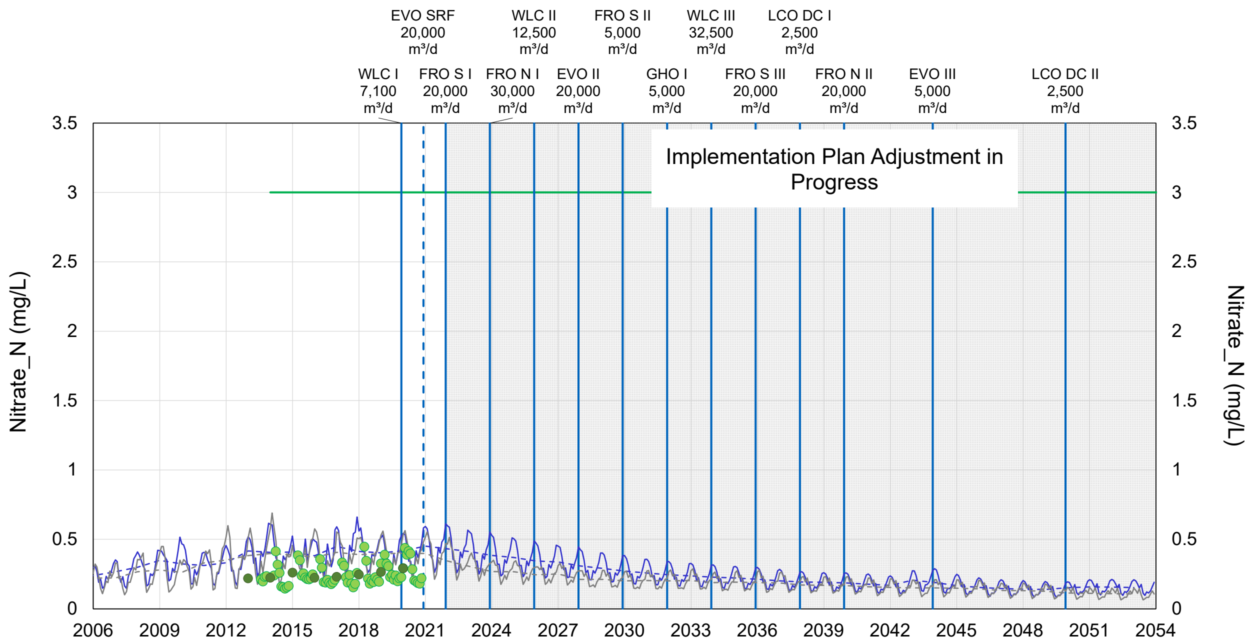
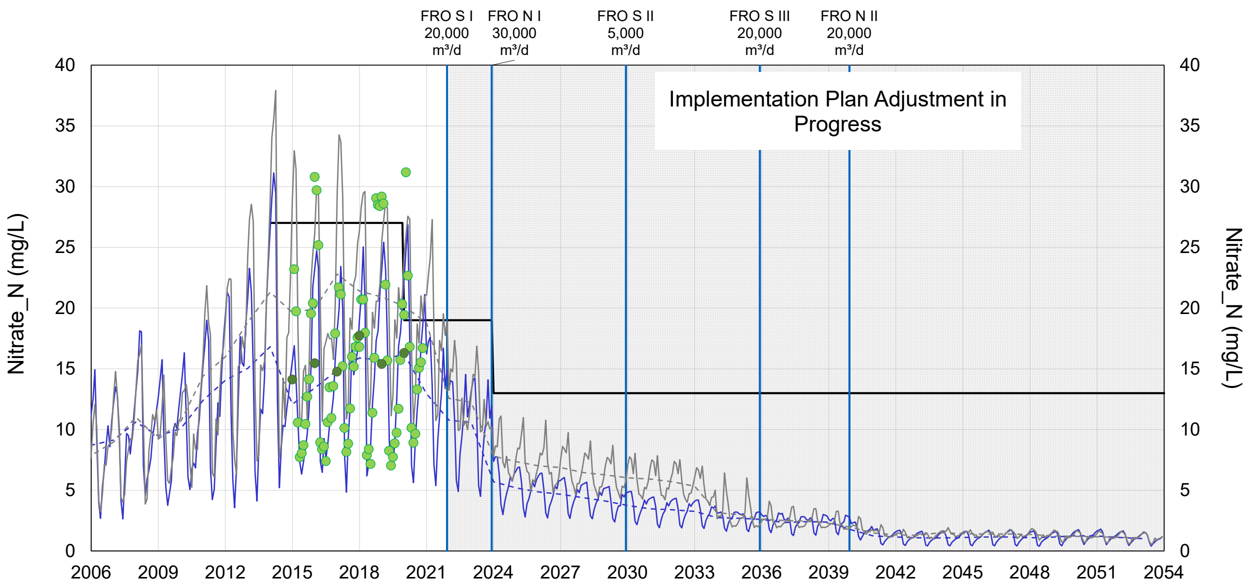
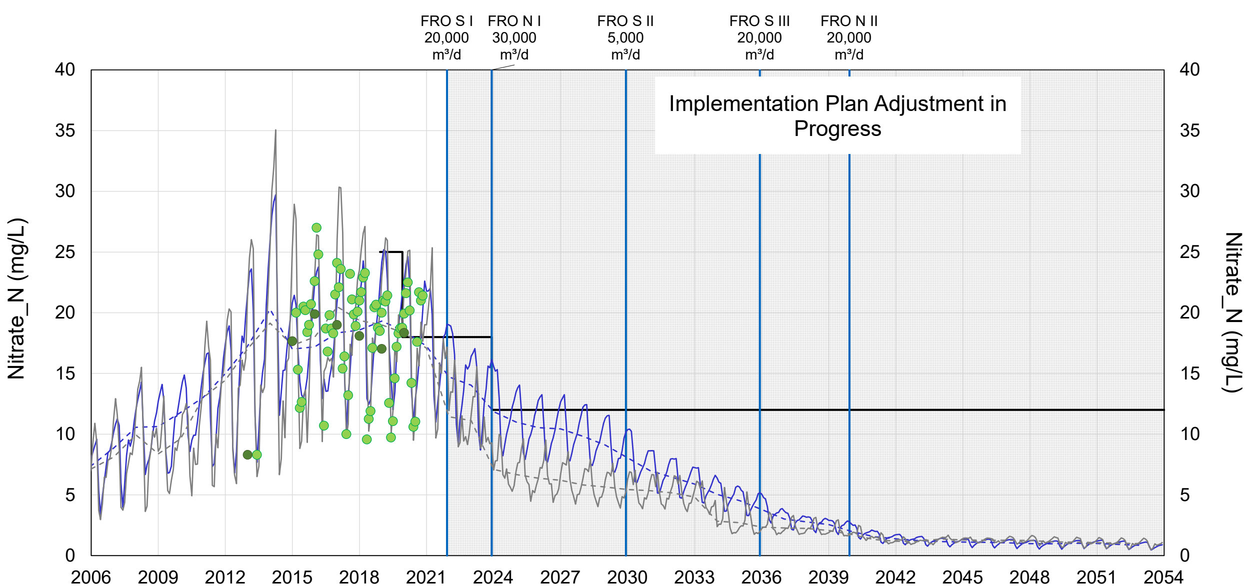


Figure B-2: Projected Concentrations of Nitrate at Compliance Points with Consideration of Mitigation, 2006-2053

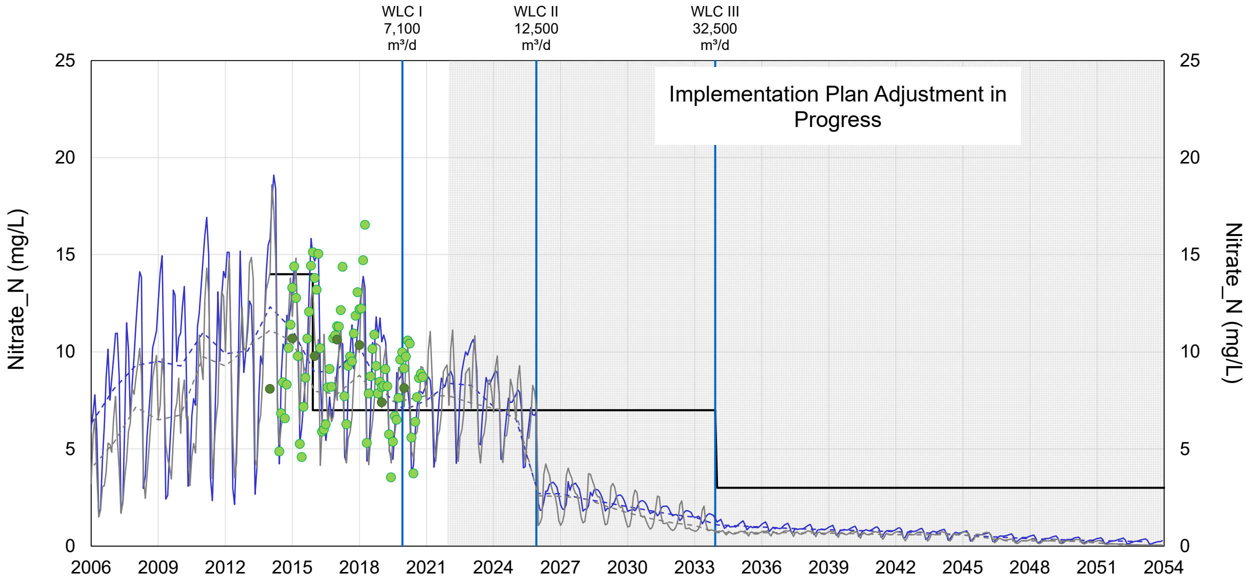
(a) Fording River, 525 m d/s of Cataract Creek (FR_FRCP1; E300071)



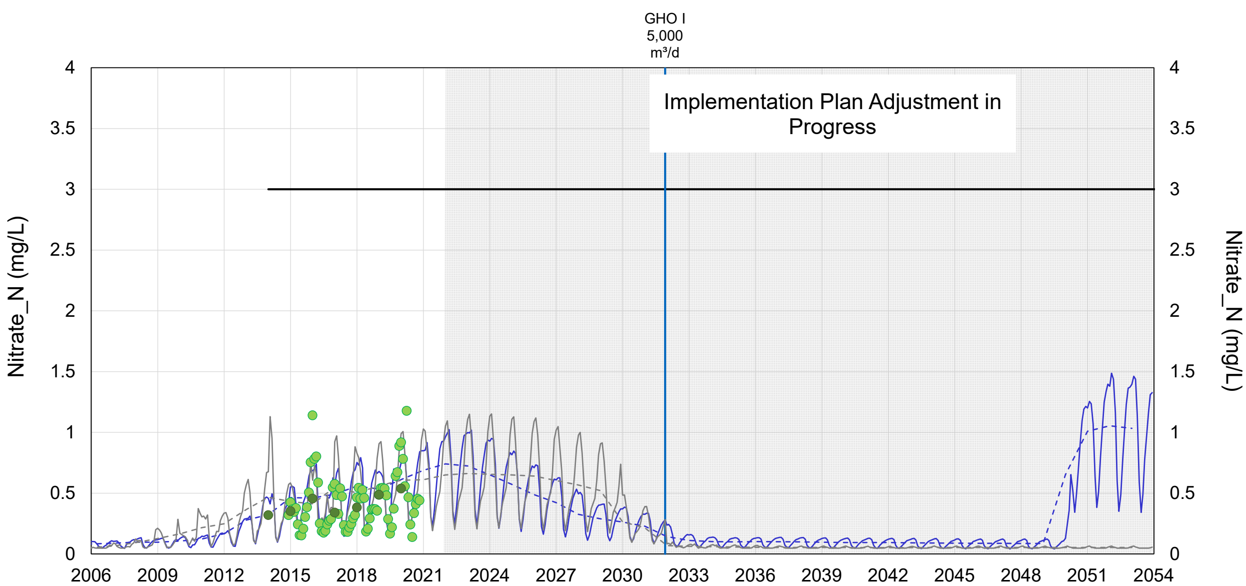
(b) FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)



(c) LCO Compliance Point (LC_LCDSSLCC; E297110)

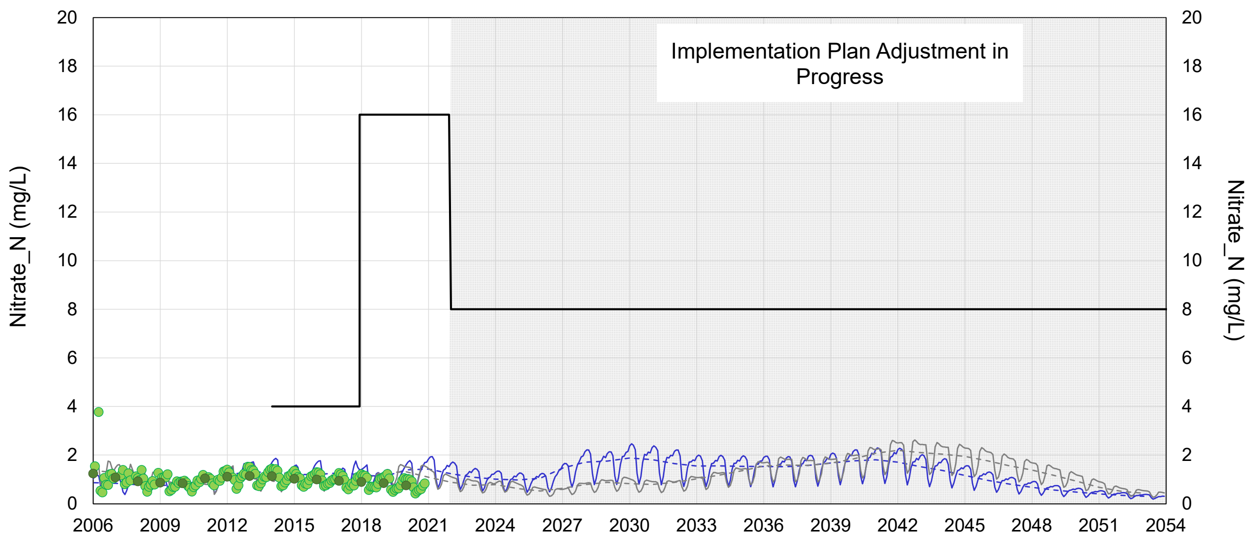


(d) GHO Elk River Compliance Point (GH_ERC; E300090)

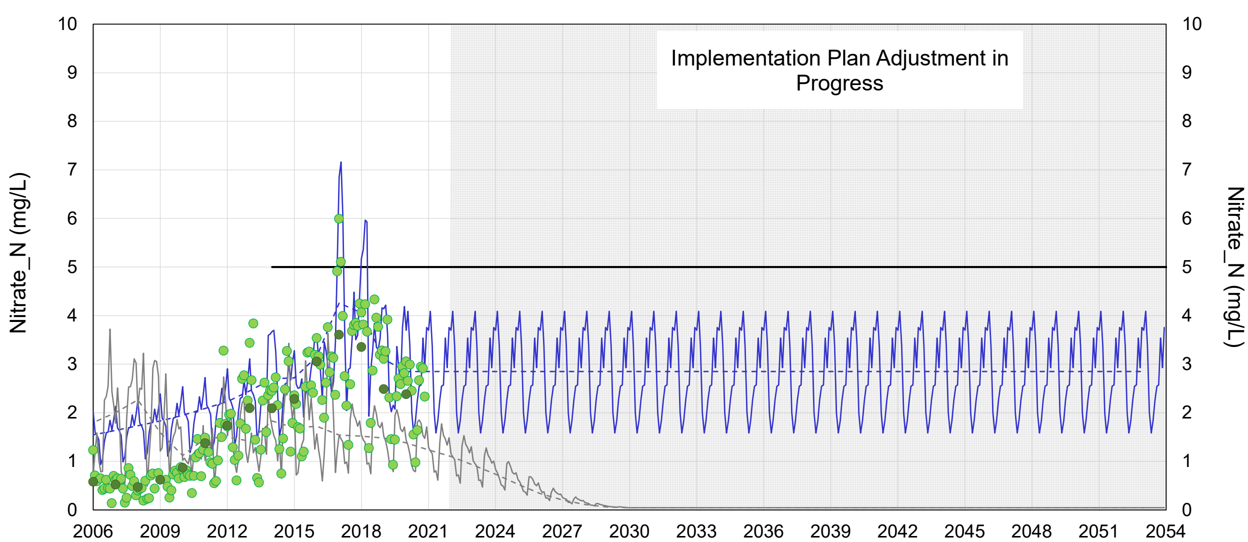


Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

(e) EVO Harmer Compliance Point (EV_HC1; E102682)



(f) CMO Compliance Point (CM_MC2; E258937)



Note: Projected concentrations are from the CMO Water and Load Balance Model.

(g) EVO Michel Creek Compliance Point (EV_MC2; E300091)

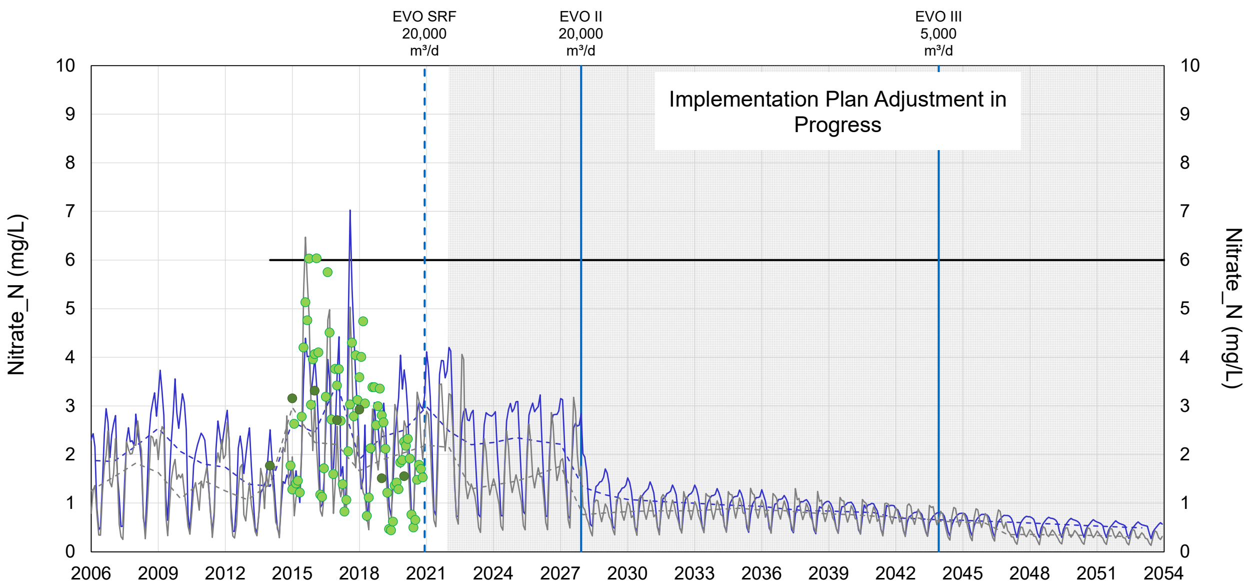
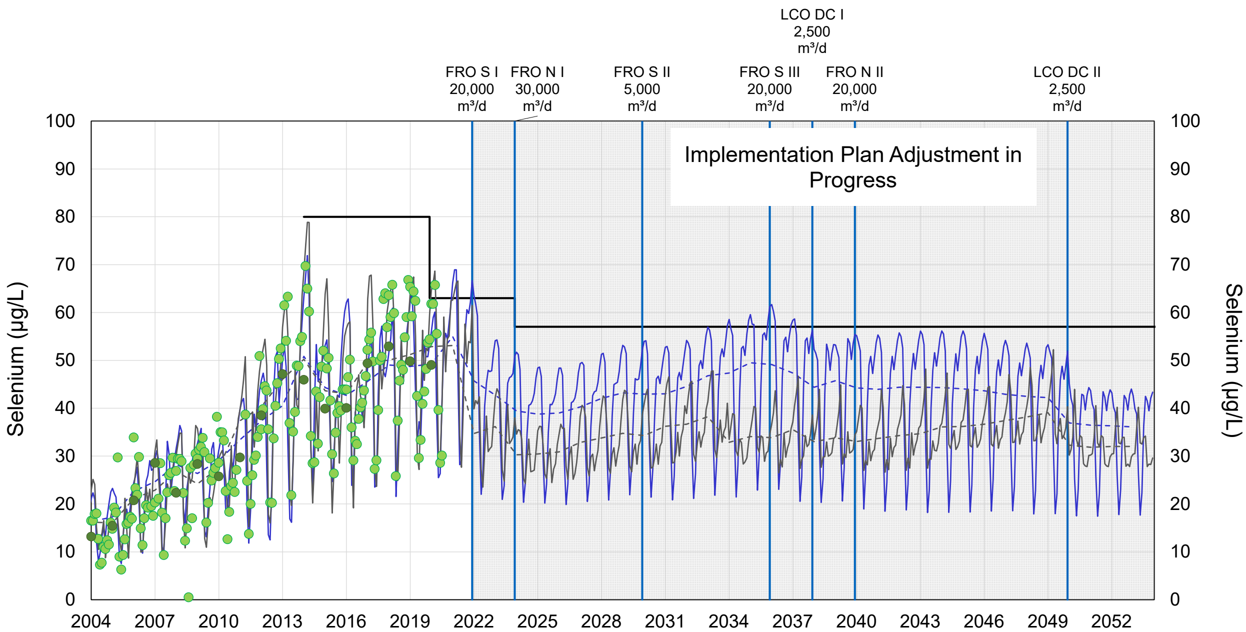


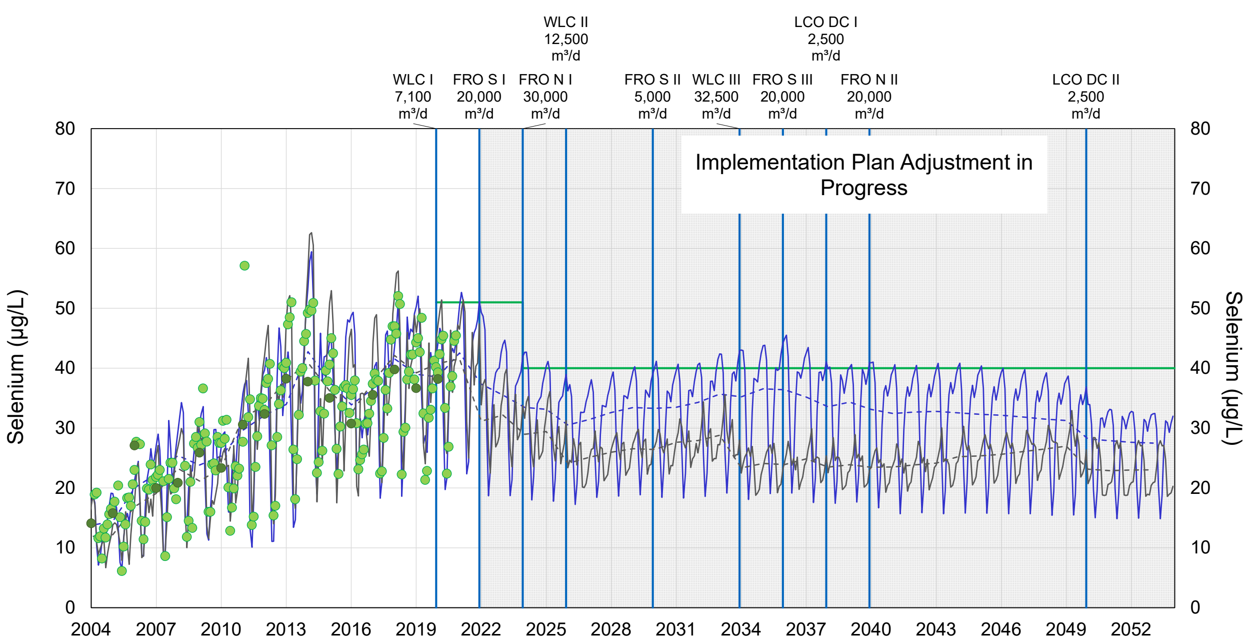
Figure B-3: Projected Concentrations of Selenium at Order Stations with Consideration of Mitigation, 2004-2053

(a) GHO Fording River Compliance Point (GH_FR1; 0200378)

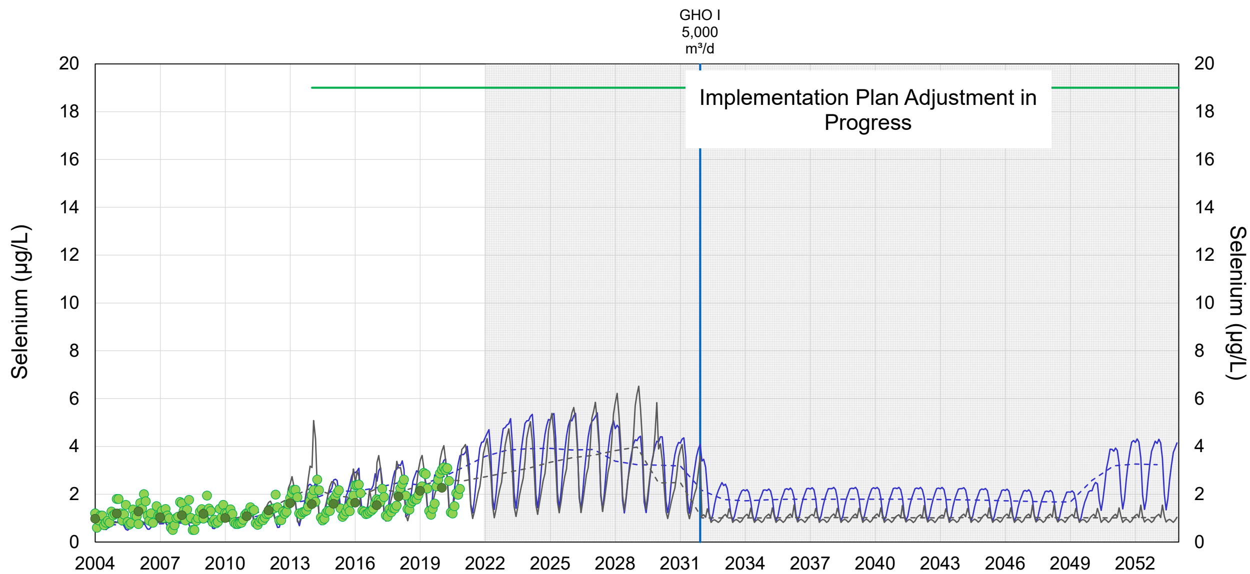


Note: This location is also the GHO Fording River Compliance Point.

(b) Fording River d/s of Line Creek (LC_LC5; 0200028)

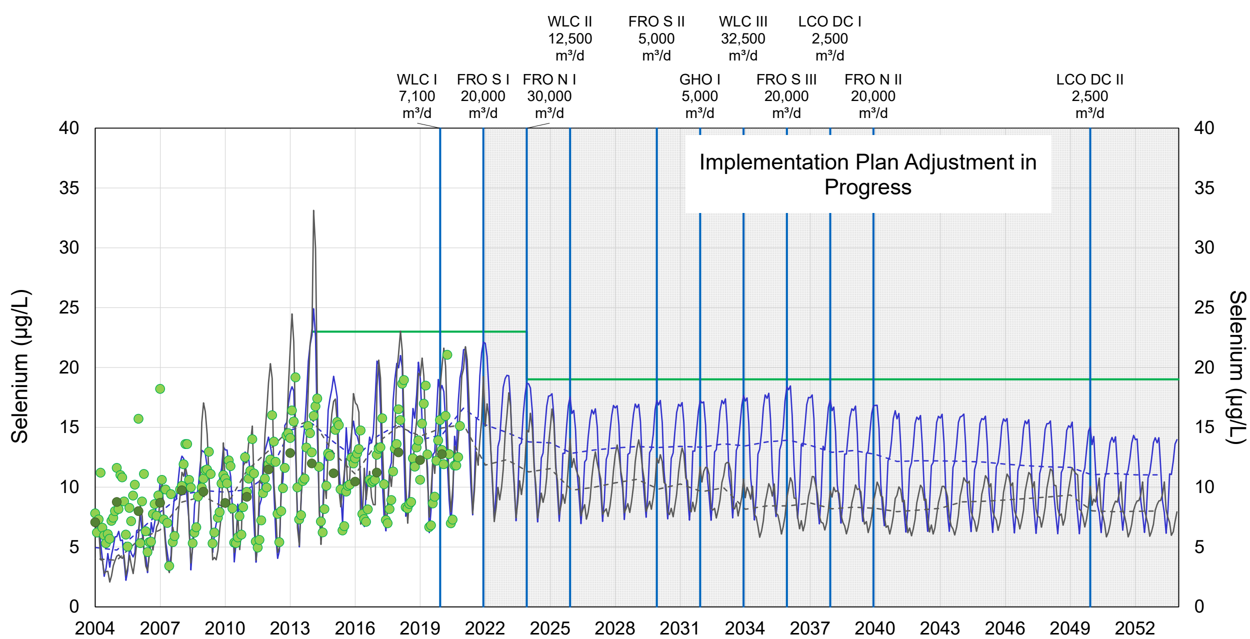


(c) Elk River u/s of Boivin Creek (GH_ER1; E206661)

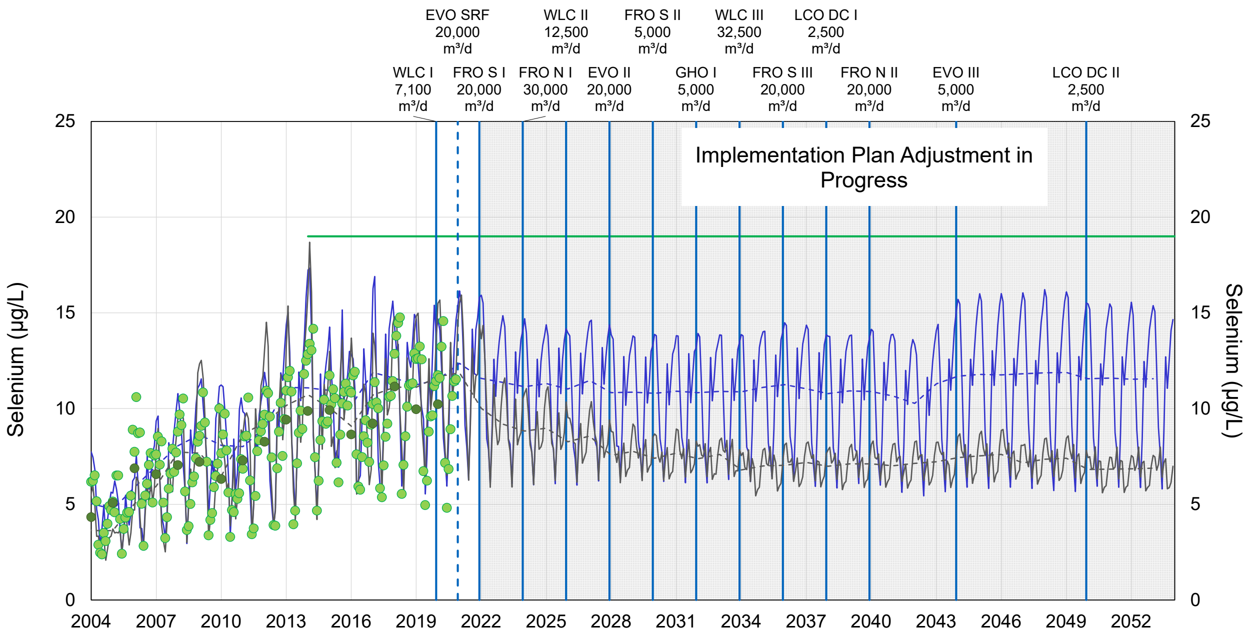


Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

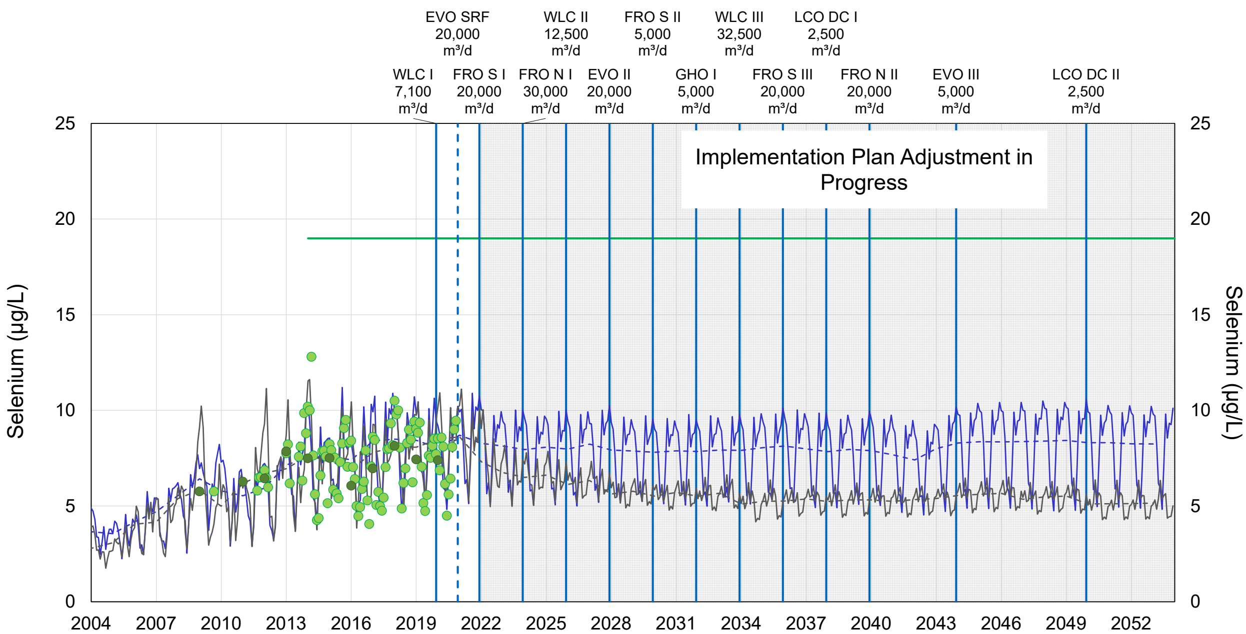
(d) Elk River u/s of Grave Creek (EV_ER4; 0200027)



(e) Elk River d/s of Michel Creek (EV_ER1; 0200393)



(f) Elk River at Elko Reservoir (RG_ELKORES; E294312)



(g) Koocanusa Reservoir (E300230)

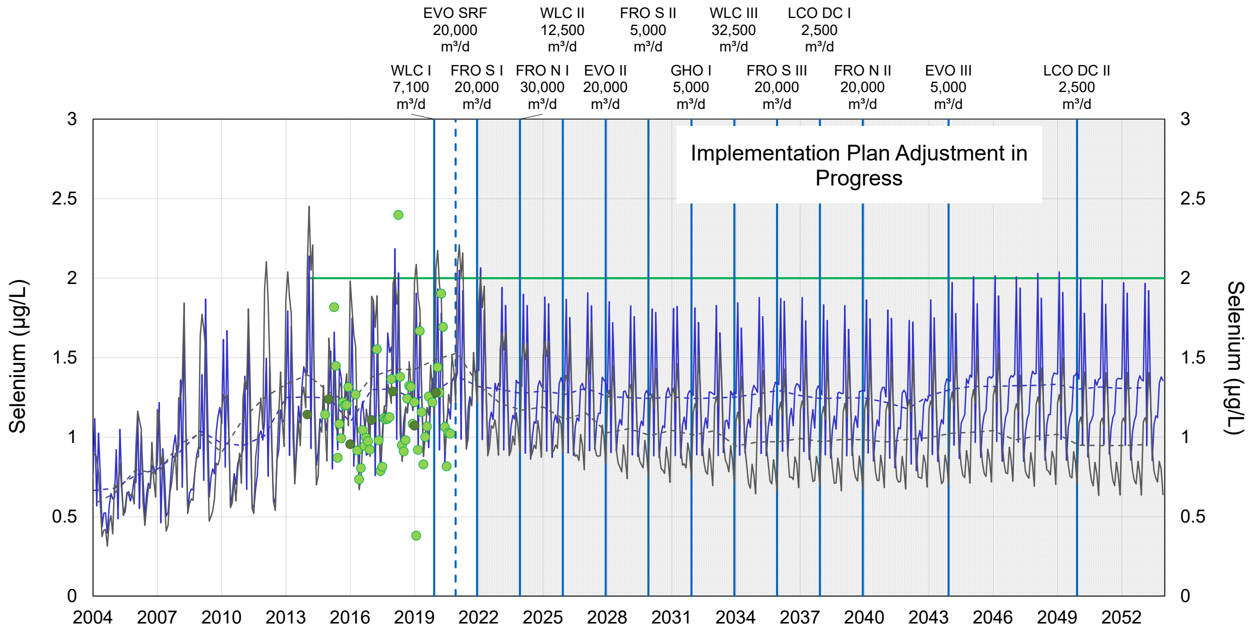
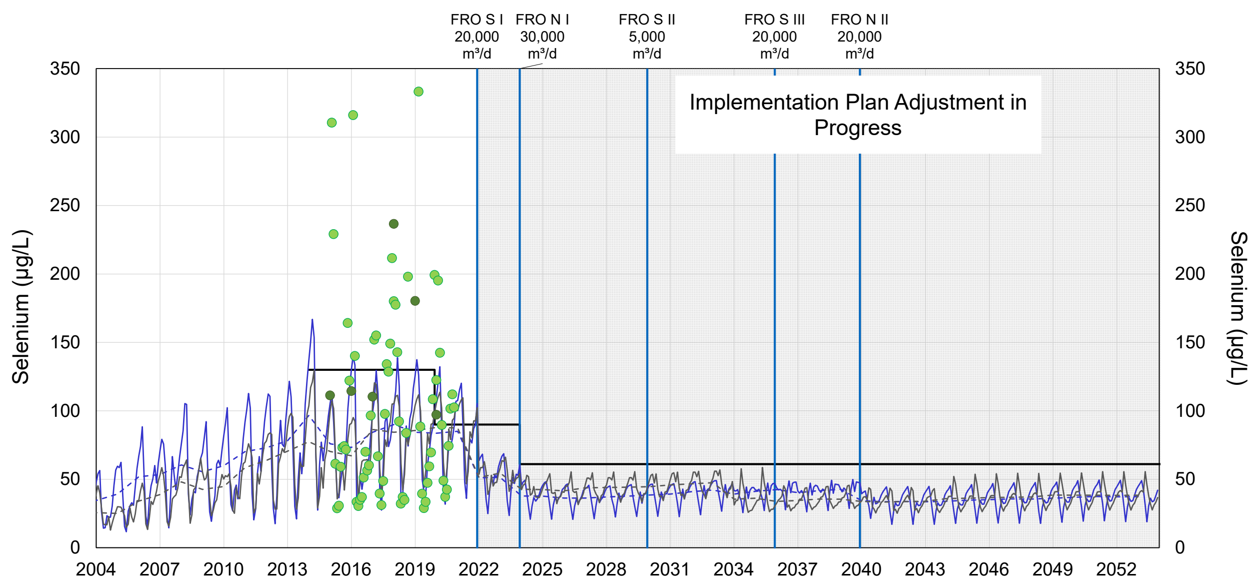
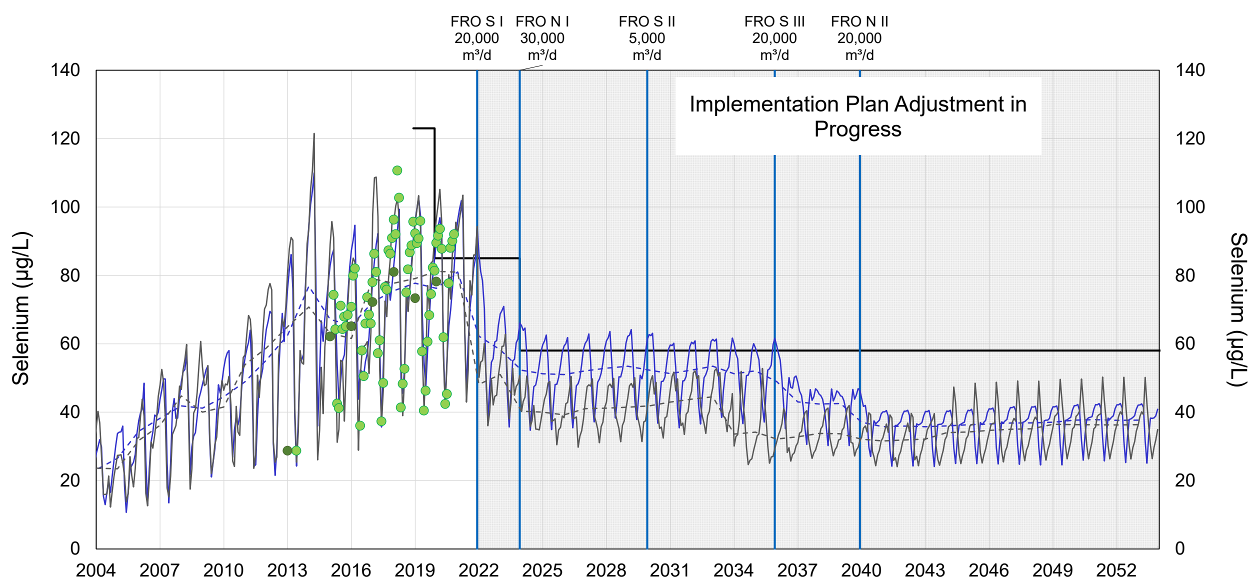


Figure B-4: Projected Concentrations of Selenium at Compliance Points with Consideration of Mitigation, 2004-2053

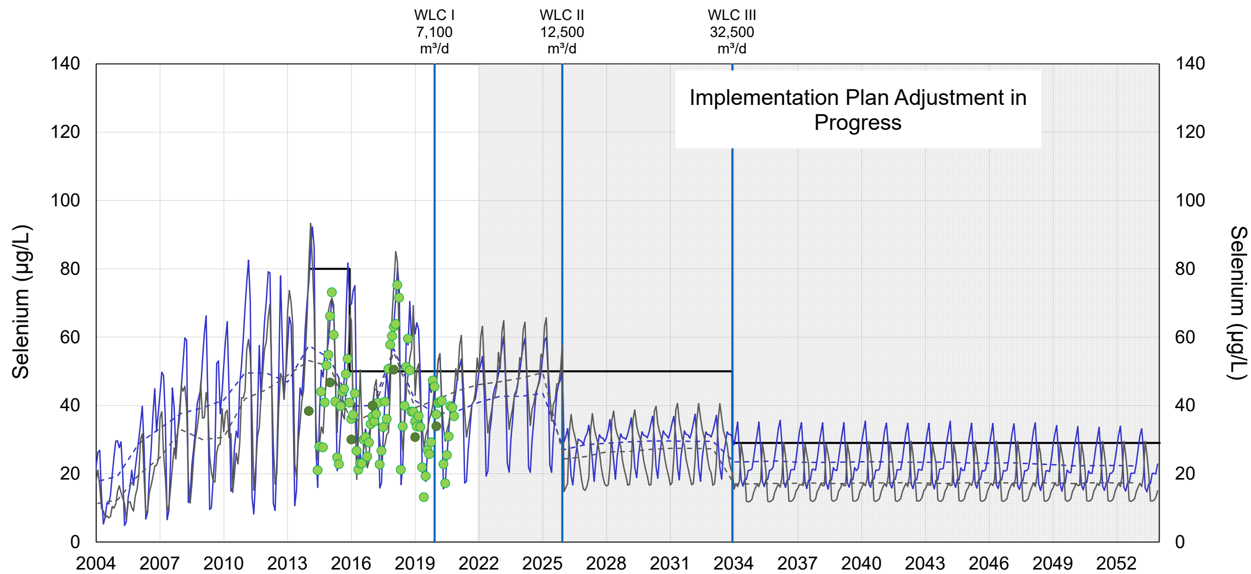
(a) Fording River, 525 m d/s of Cataract Creek (FR_FRCP1; E300071)



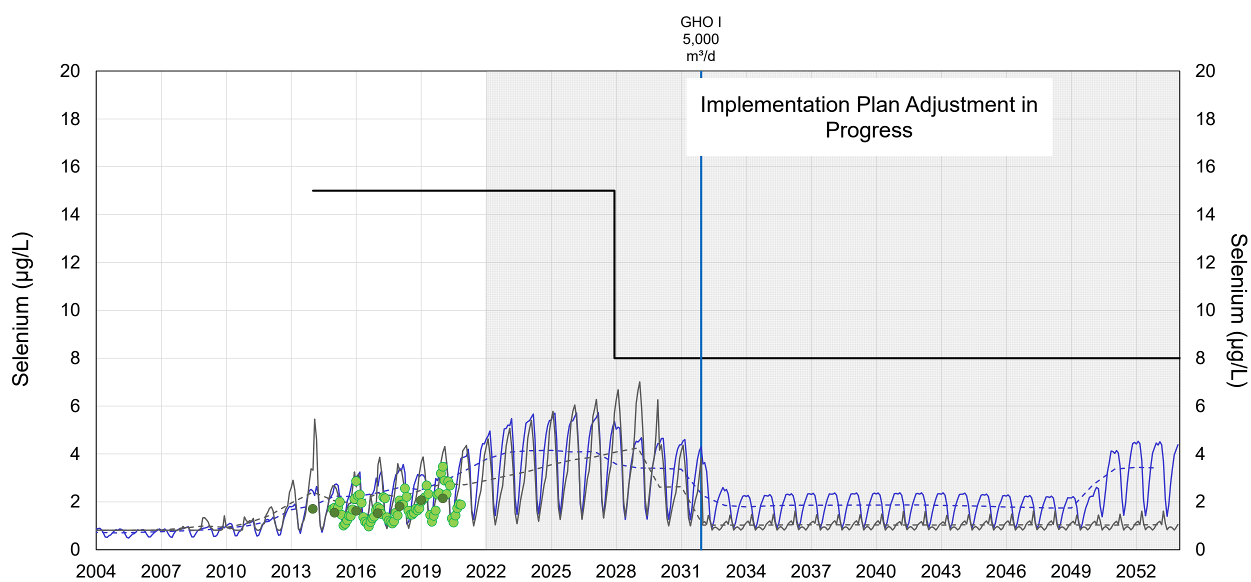
(b) FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)



(c) LCO Compliance Point (LC_LCDSSLCC; E297110)

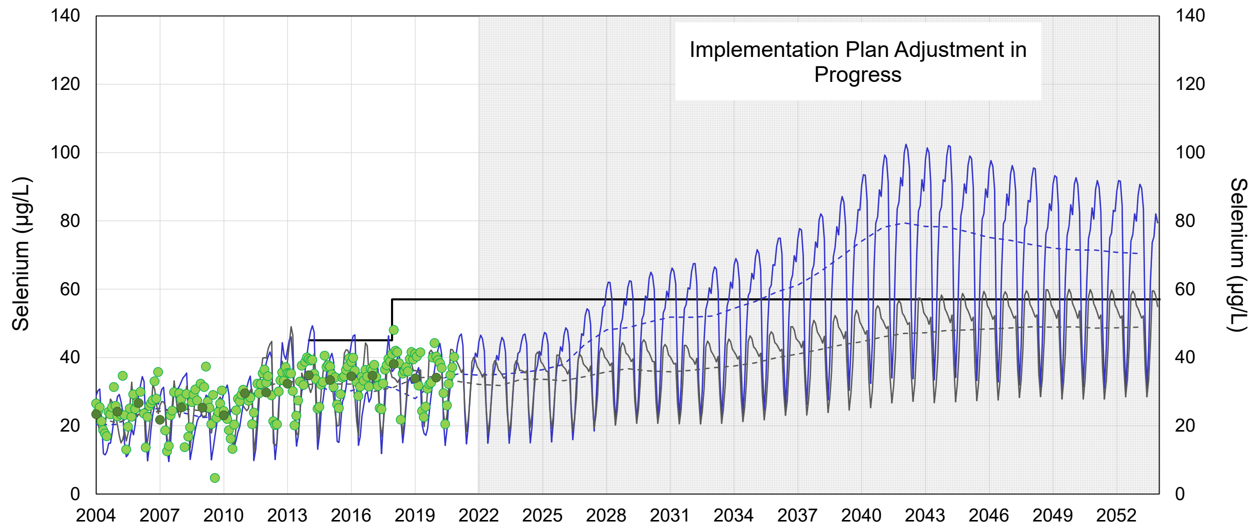


(d) GHO Elk River Compliance Point (GH_ERC; E300090)

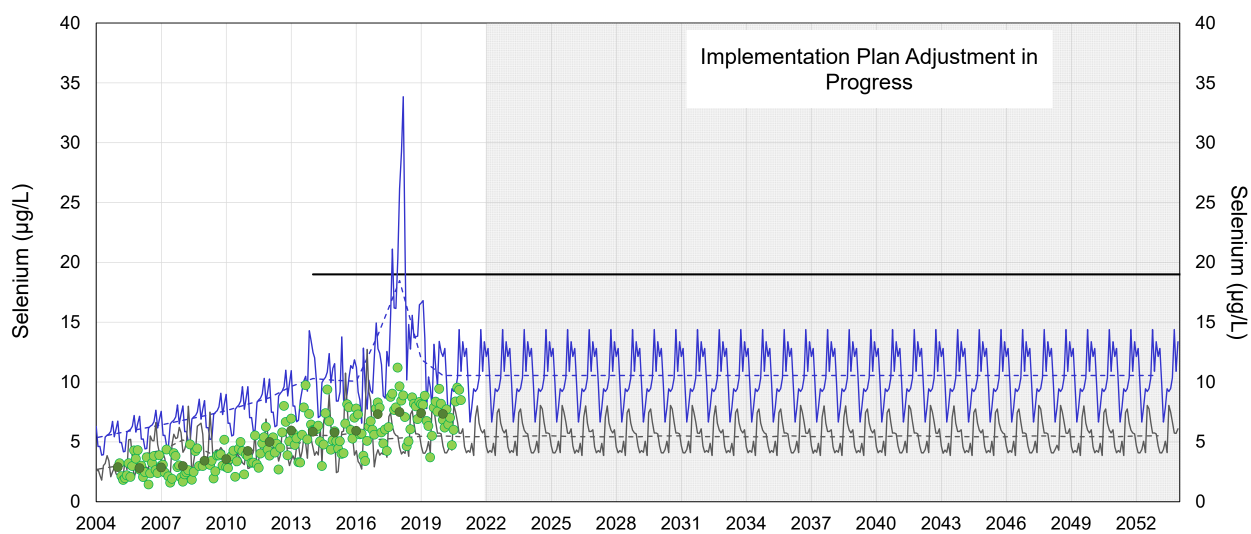


Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

(e) EVO Harmer Compliance Point (EV_HC1; E102682)



(f) CMO Compliance Point (CM_MC2; E258937)



Note: Projected concentrations are from the CMO Water and Load Balance Model.

(g) EVO Michel Creek Compliance Point (EV_MC2; E300091)

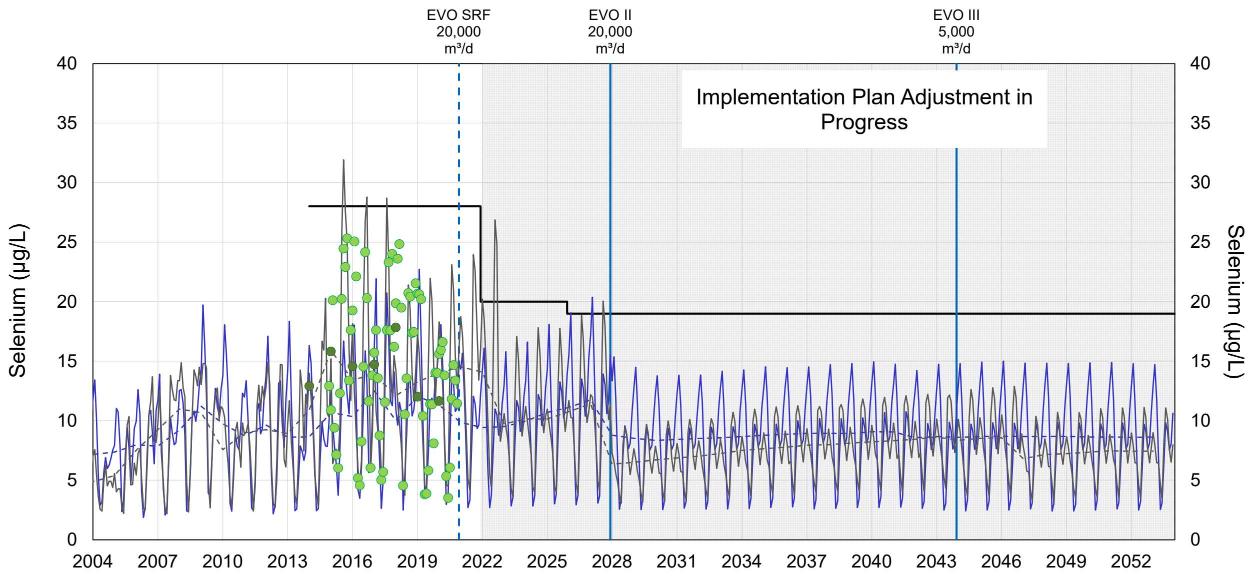
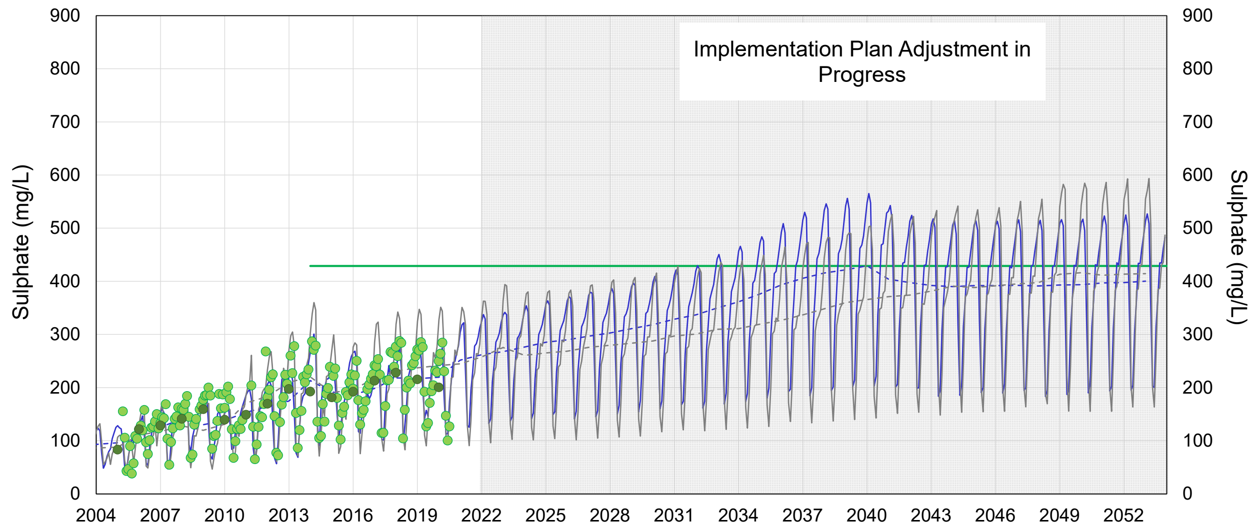


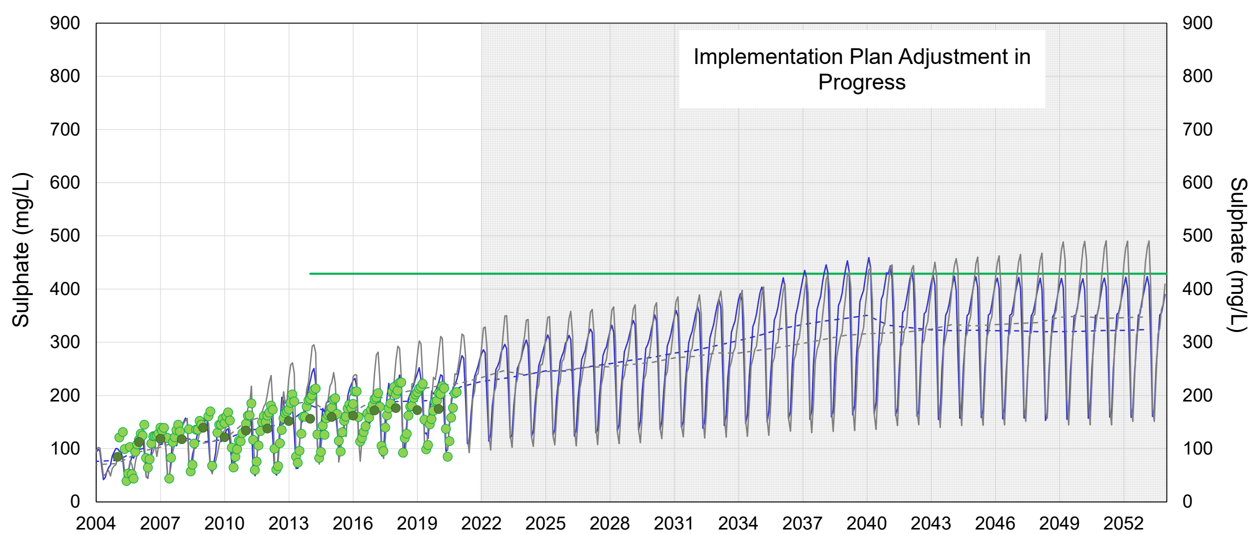
Figure B-5: Projected Concentrations of Sulphate at Order Stations with Consideration of Mitigation, 2004-2053

(a) GHO Fording River Compliance Point (GH_FR1; 0200378)

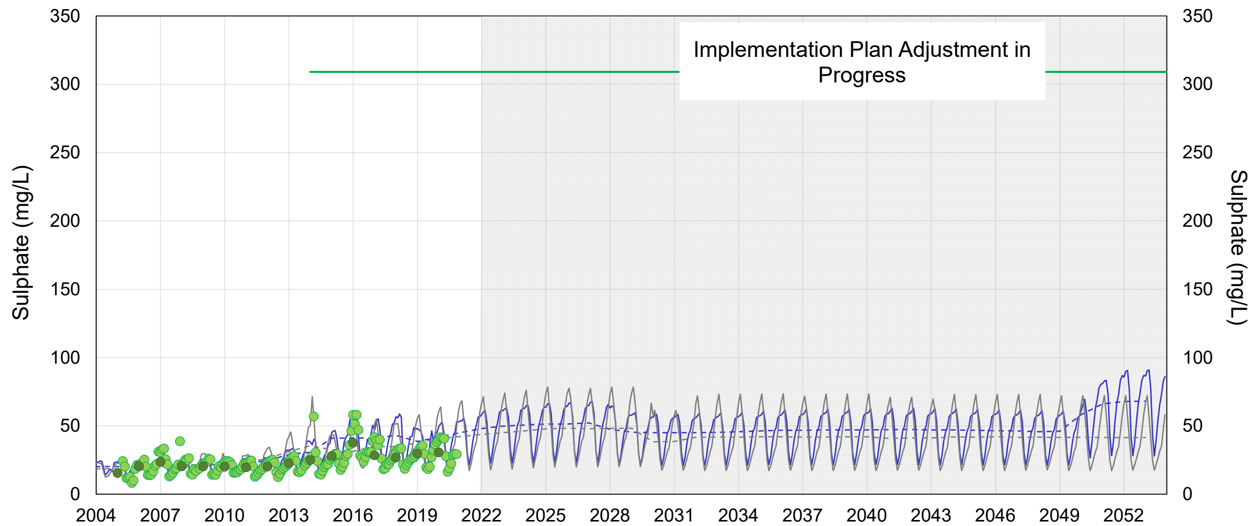


Note: This location is also the GHO Fording River Compliance Point.

(b) Fording River d/s of Line Creek (LC_LC5; 0200028)

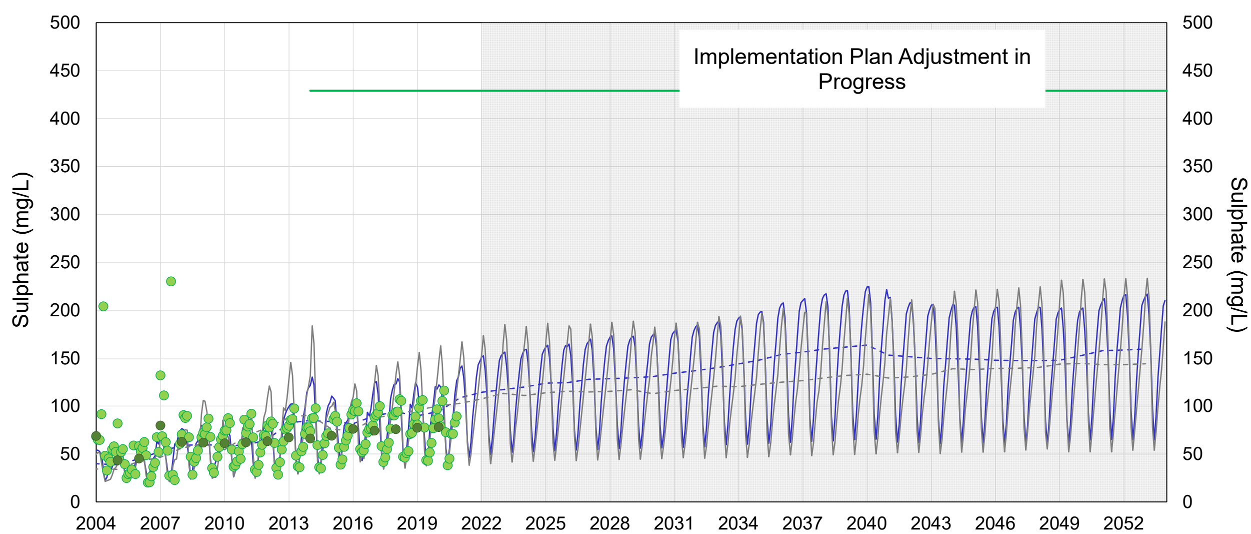


(c) Elk River u/s of Boivin Creek (GH_ER1; E206661)

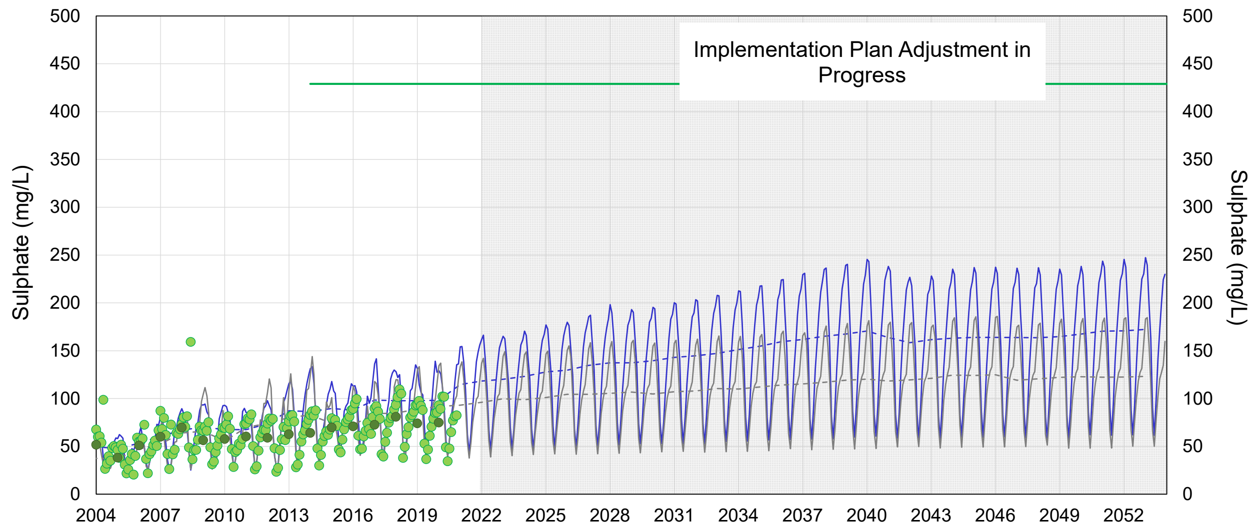


Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

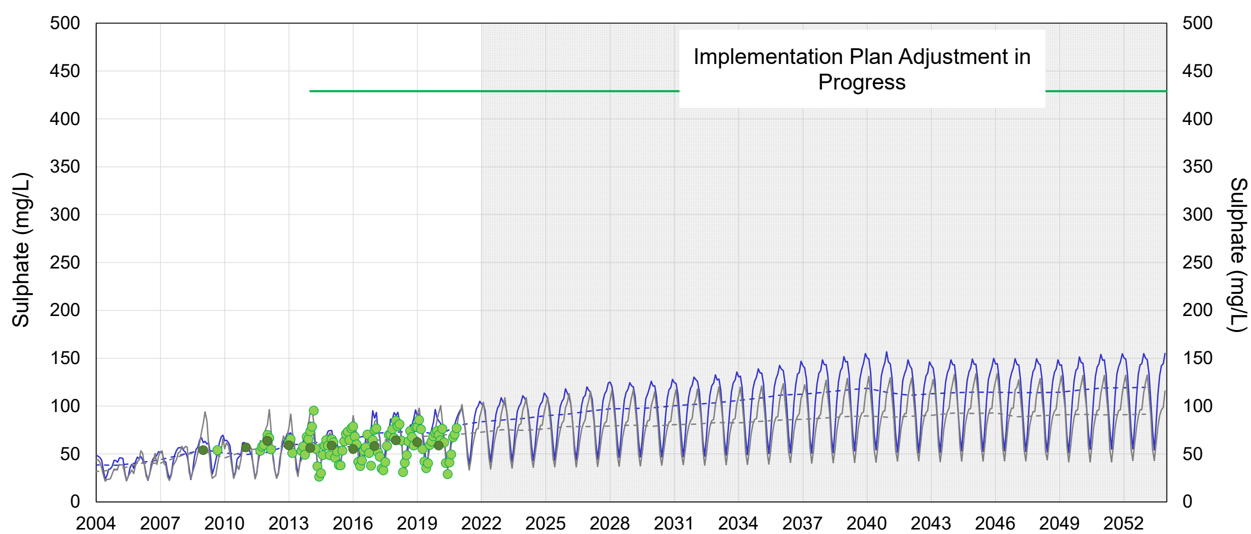
(d) Elk River u/s of Grave Creek (EV_ER4; 0200027)



(e) Elk River d/s of Michel Creek (EV_ER1; 0200393)



(f) Elk River at Elko Reservoir (RG_ELKORES; E294312)



(g) Koocanusa Reservoir (E300230)

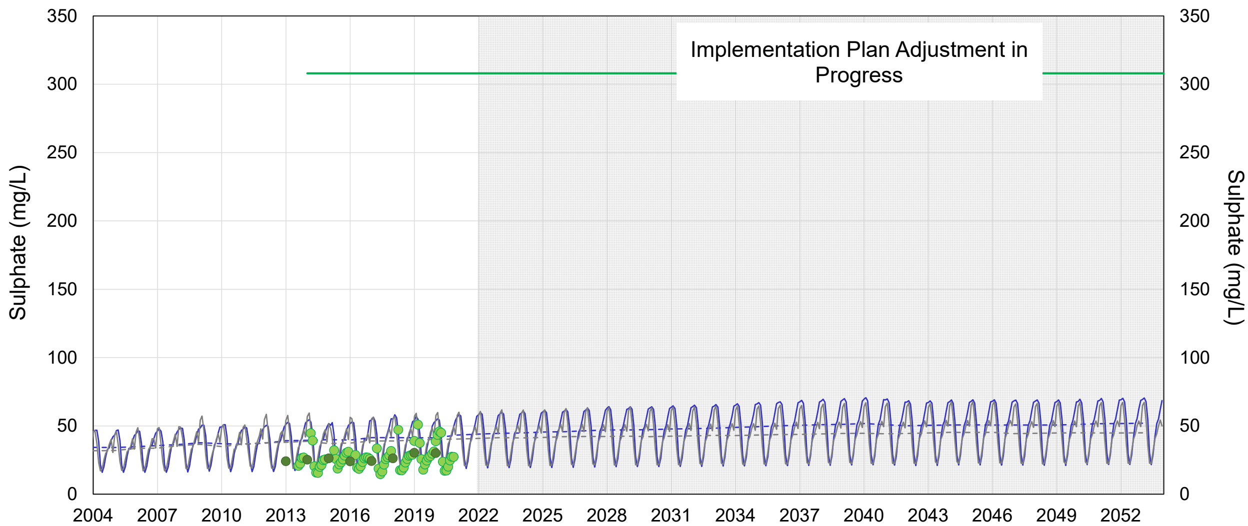
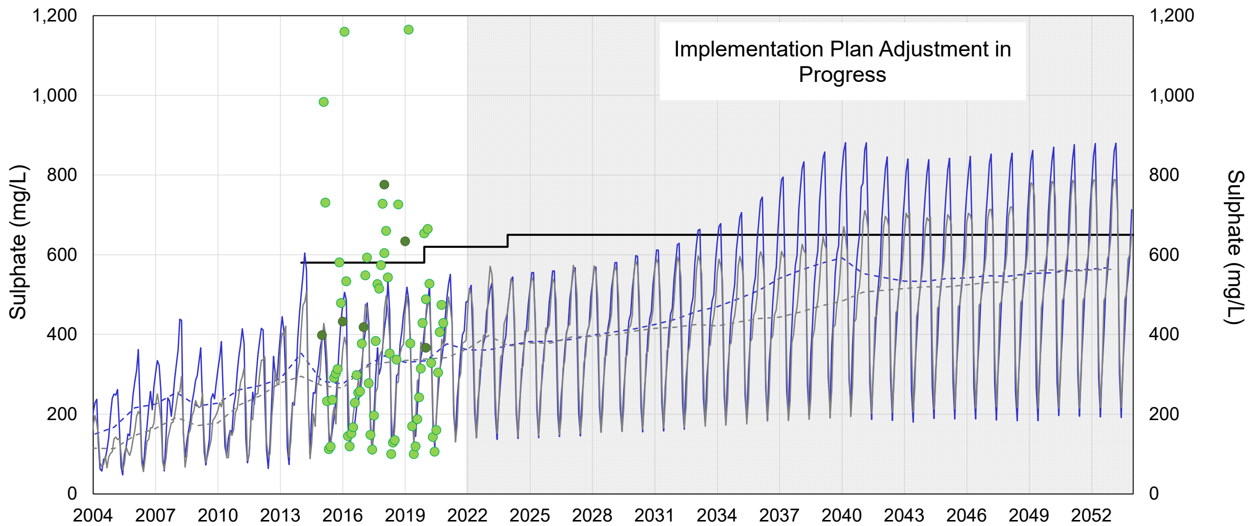
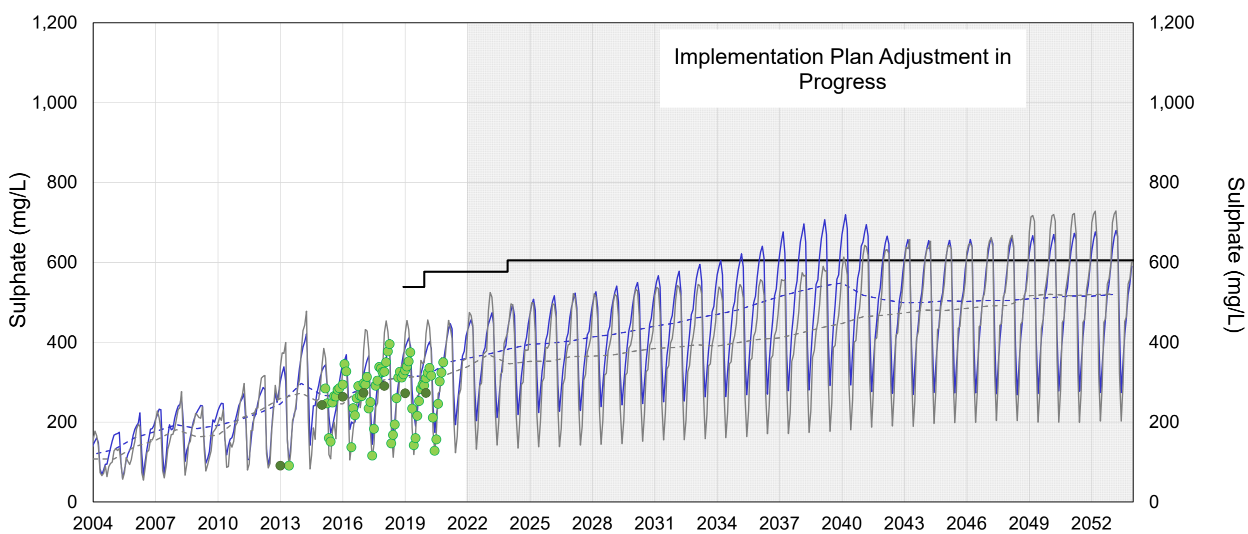


Figure B-6: Projected Concentrations of Sulphate at Compliance Points with Consideration of Mitigation, 2004-2053

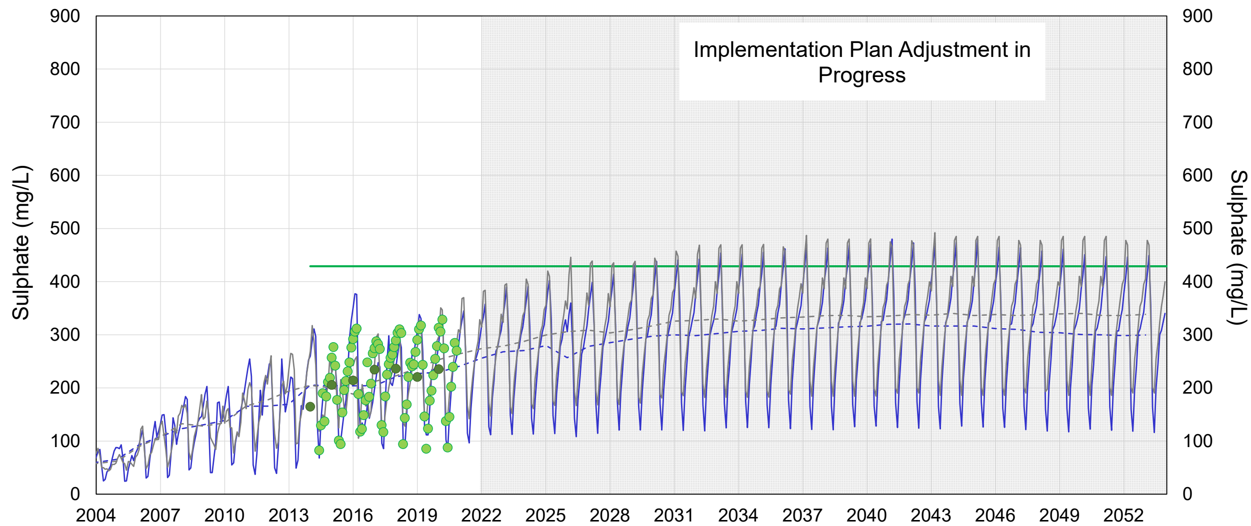
(a) Fording River, 525 m d/s of Cataract Creek (FR_FRCP1; E300071)



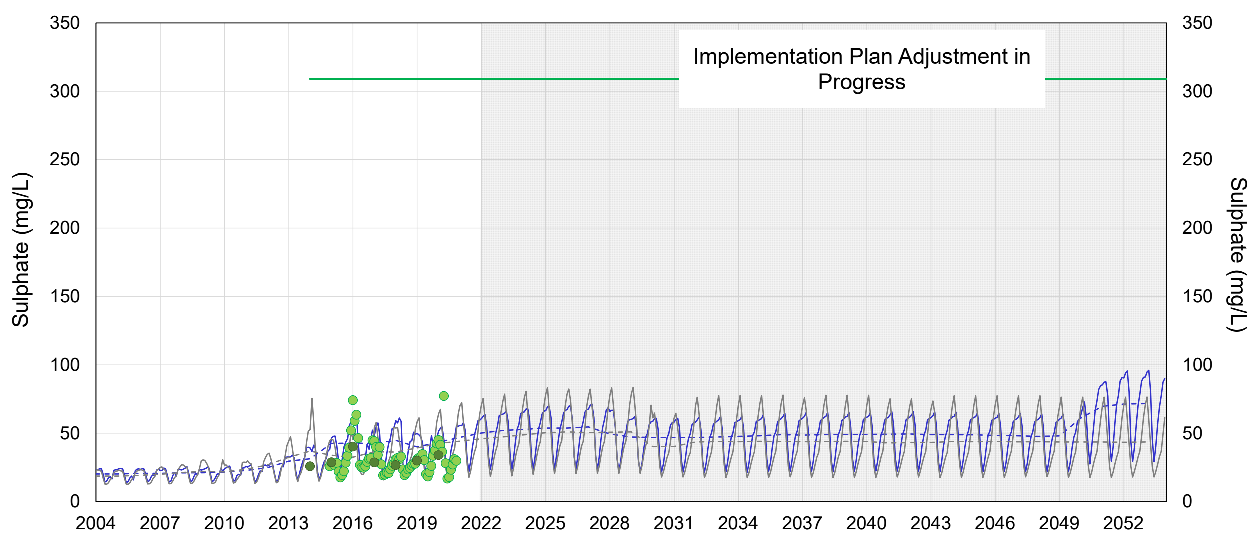
(b) FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)



(c) LCO Compliance Point (LC_LCDSSLCC; E297110)

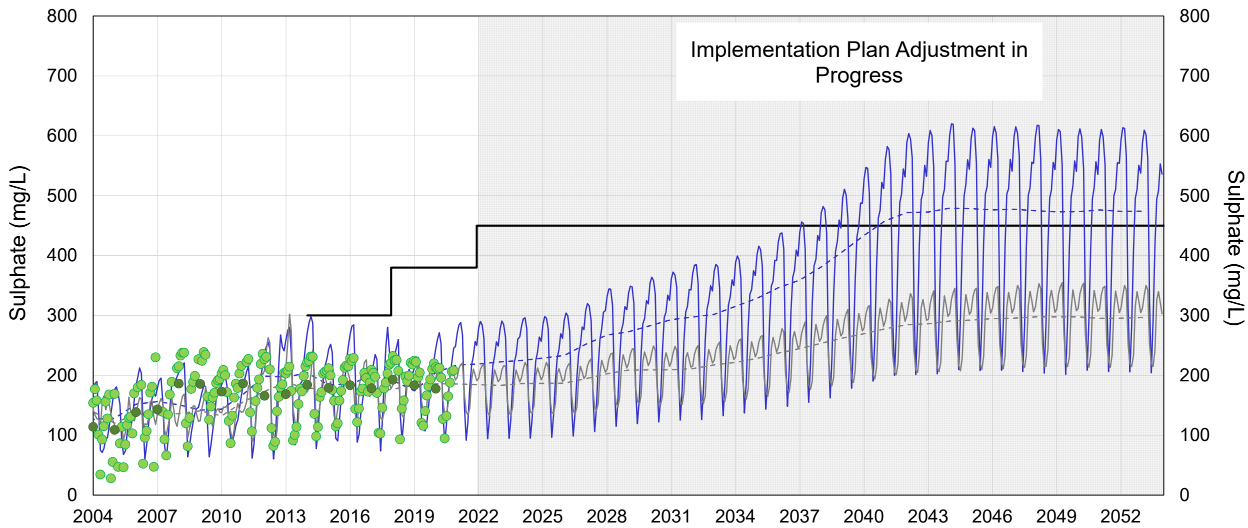


(d) GHO Elk River Compliance Point (GH_ERC; E300090)

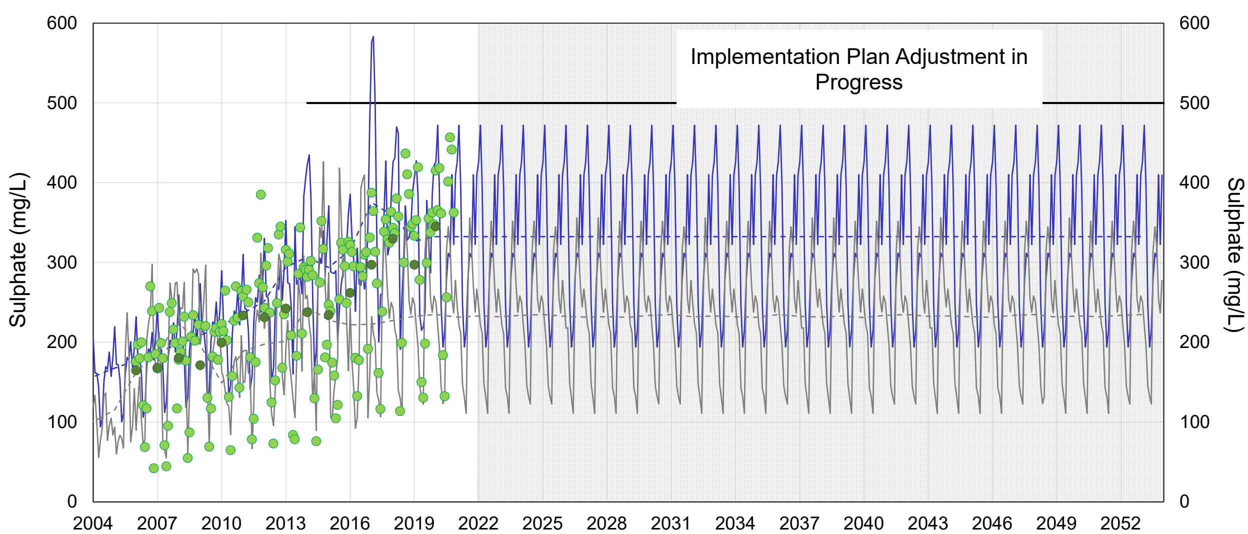


Note: Projected concentrations developed using the 2020 RWQM increase in 2050 because Cougar Pit Phase 6 at Greenhills Operations is modelled to spill.

(e) EVO Harmer Compliance Point (EV_HC1; E102682)



(f) CMO Compliance Point (CM_MC2; E258937)



Note: Projected concentrations are from the CMO Water and Load Balance Model.

(g) EVO Michel Creek Compliance Point (EV_MC2; E300091)

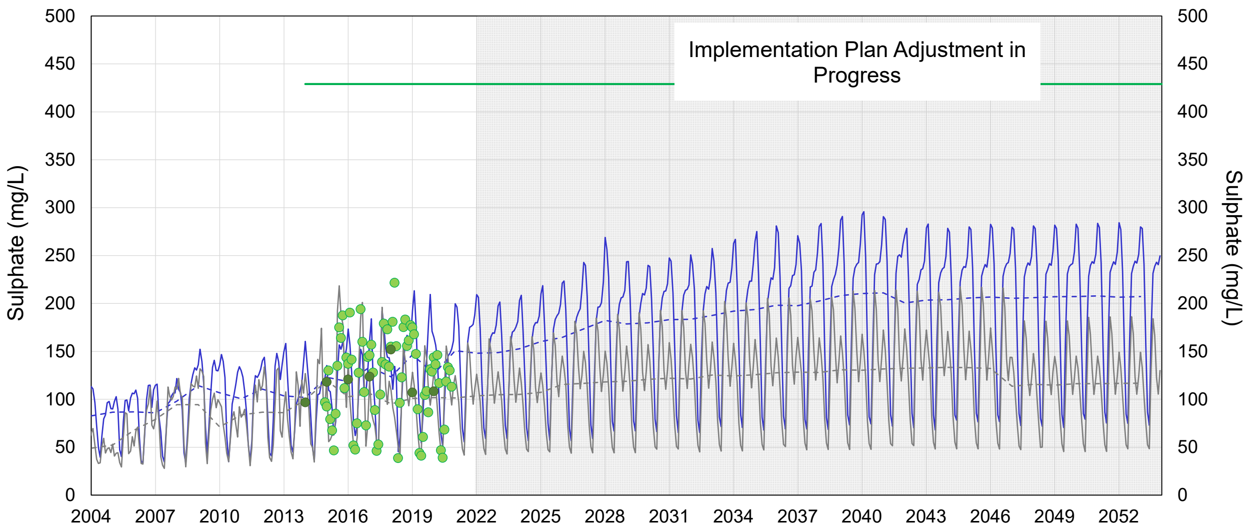
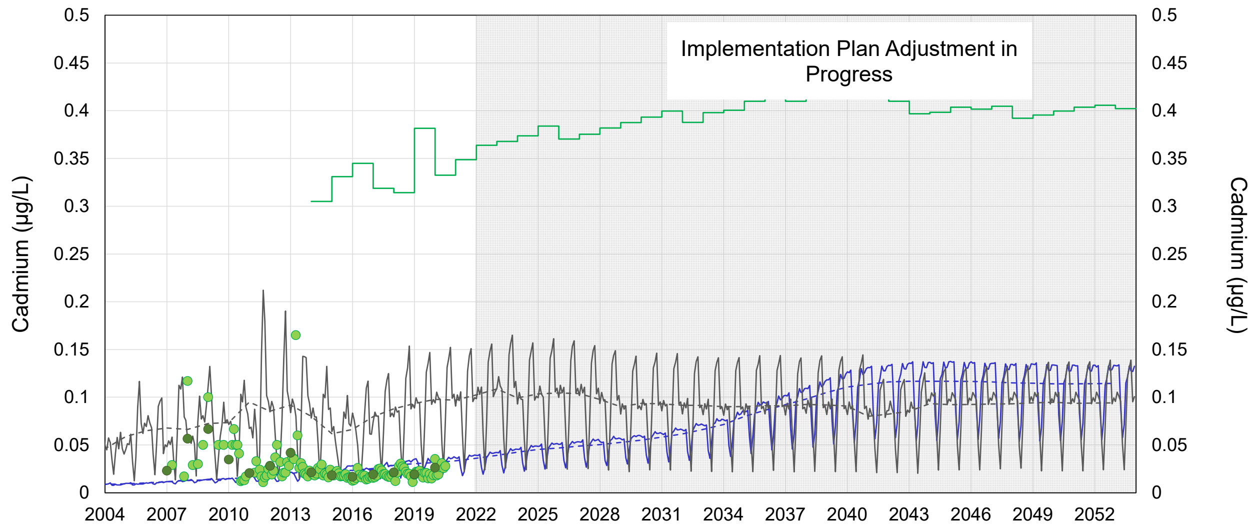


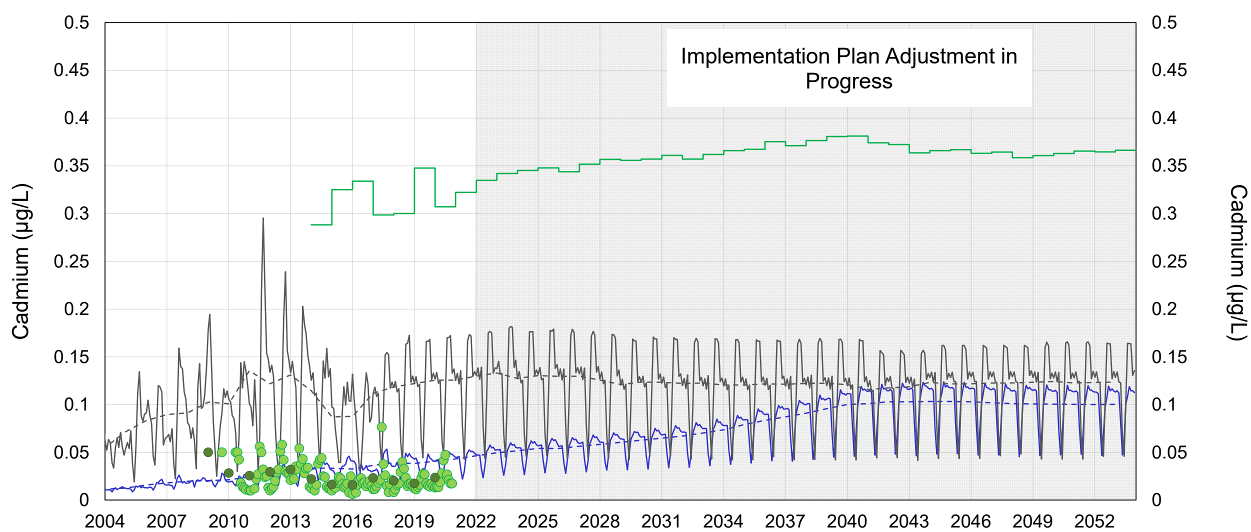
Figure B-7: Projected Concentrations of Dissolved Cadmium at Order Stations with Consideration of Mitigation, 2004-2053

(a) GHO Fording River Compliance Point (GH_FR1; 0200378)

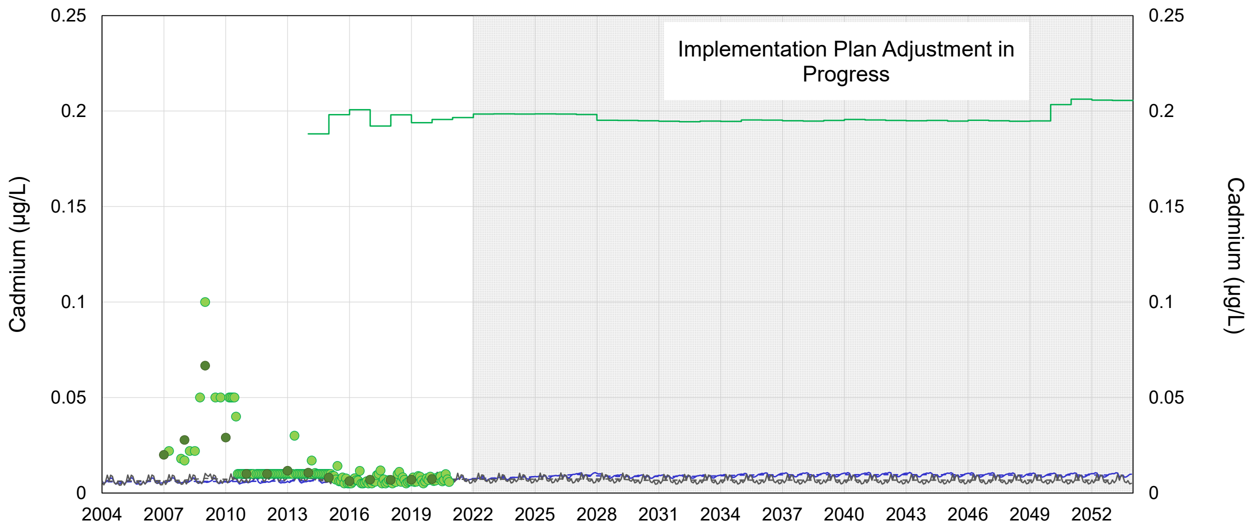


Note: This location is also the GHO Fording River Compliance Point.

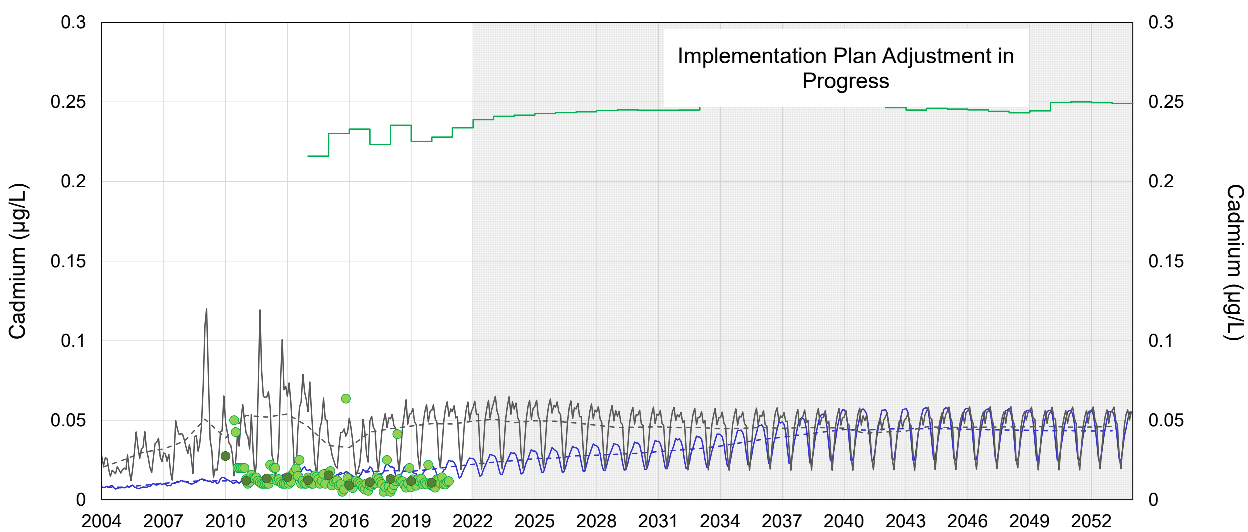
(b) Fording River d/s of Line Creek (LC_LC5; 0200028)



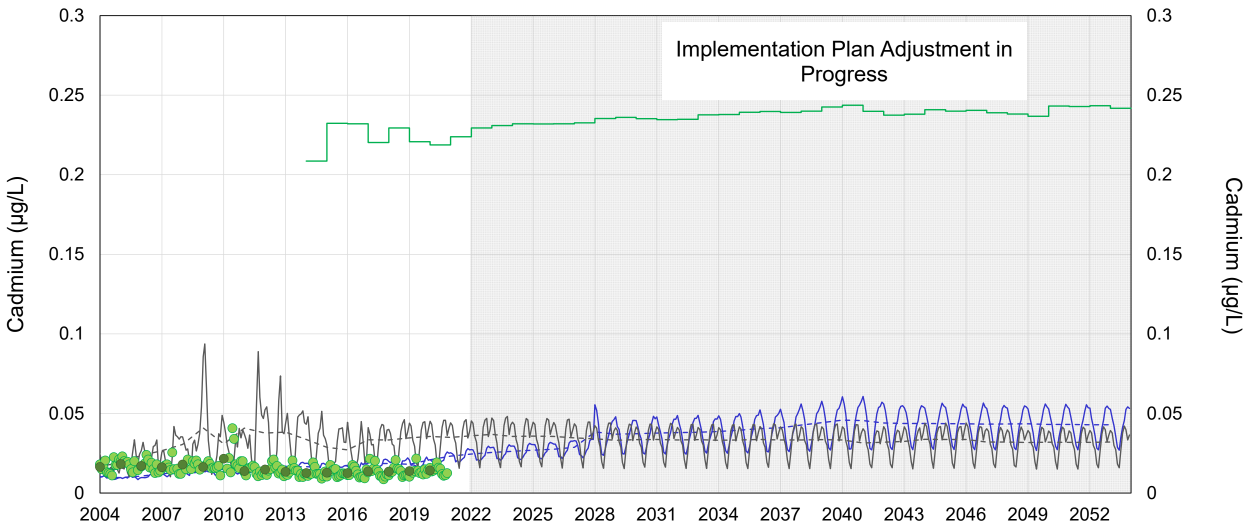
(c) Elk River u/s of Boivin Creek (GH_ER1; E206661)



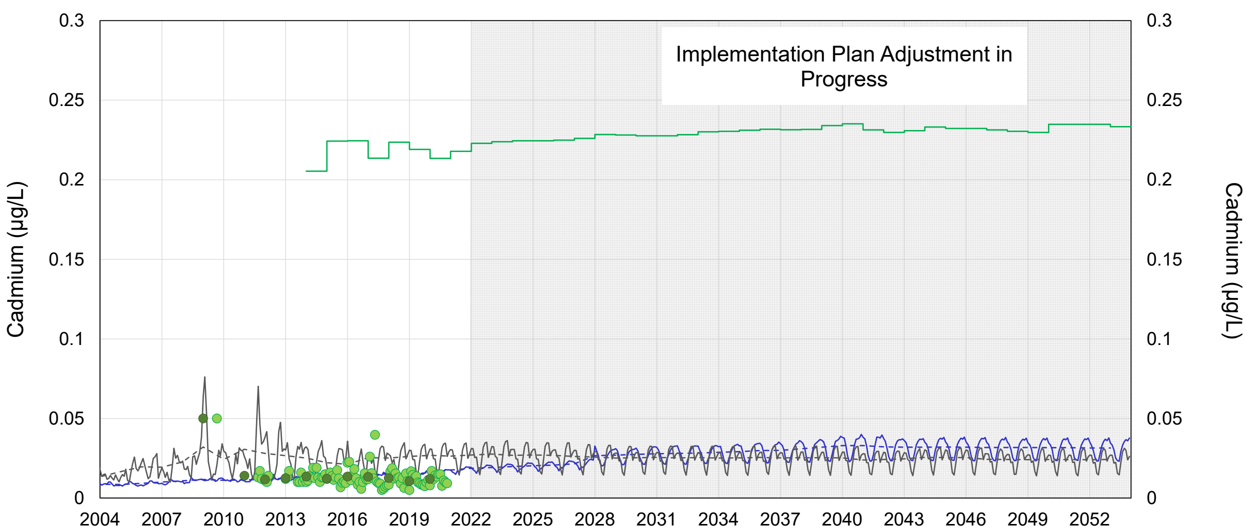
(d) Elk River u/s of Grave Creek (EV_ER4; 0200027)



(e) Elk River d/s of Michel Creek (EV_ER1; 0200393)



(f) Elk River at Elko Reservoir (RG_ELKORES; E294312)



(g) Koocanusa Reservoir (E300230)

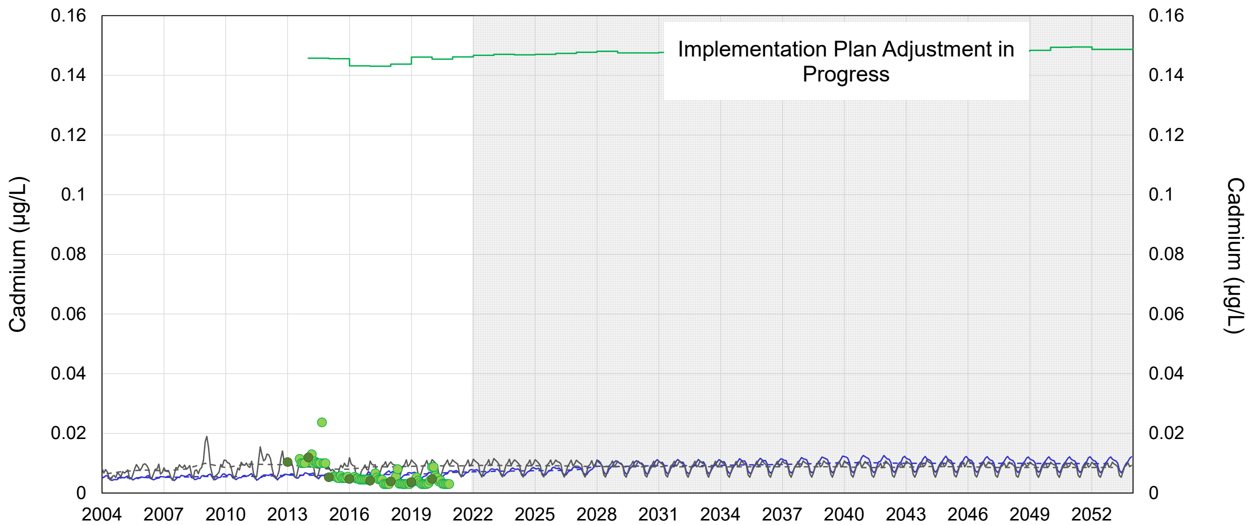
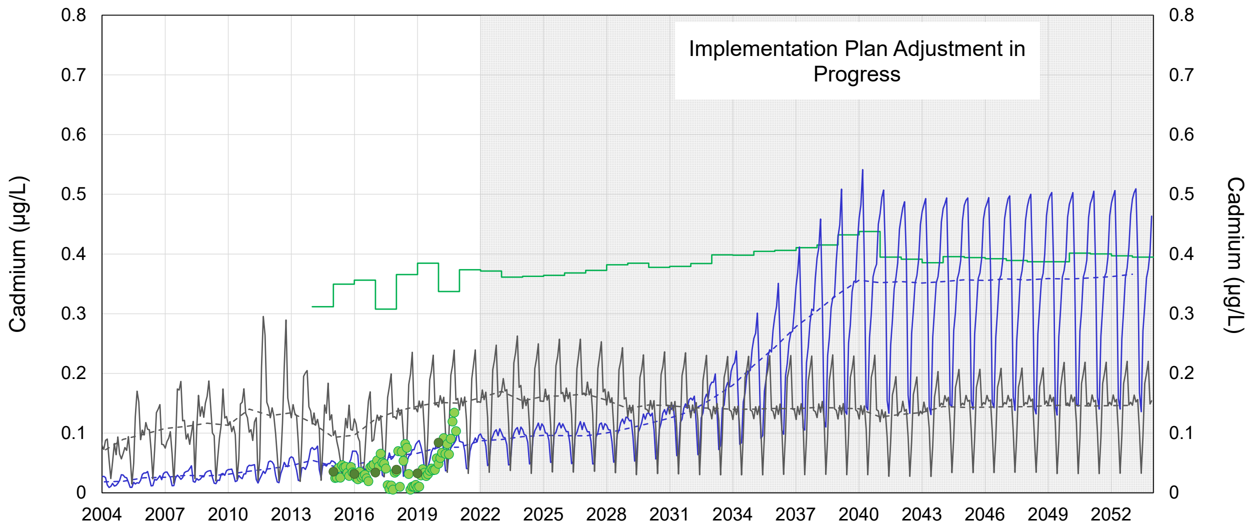


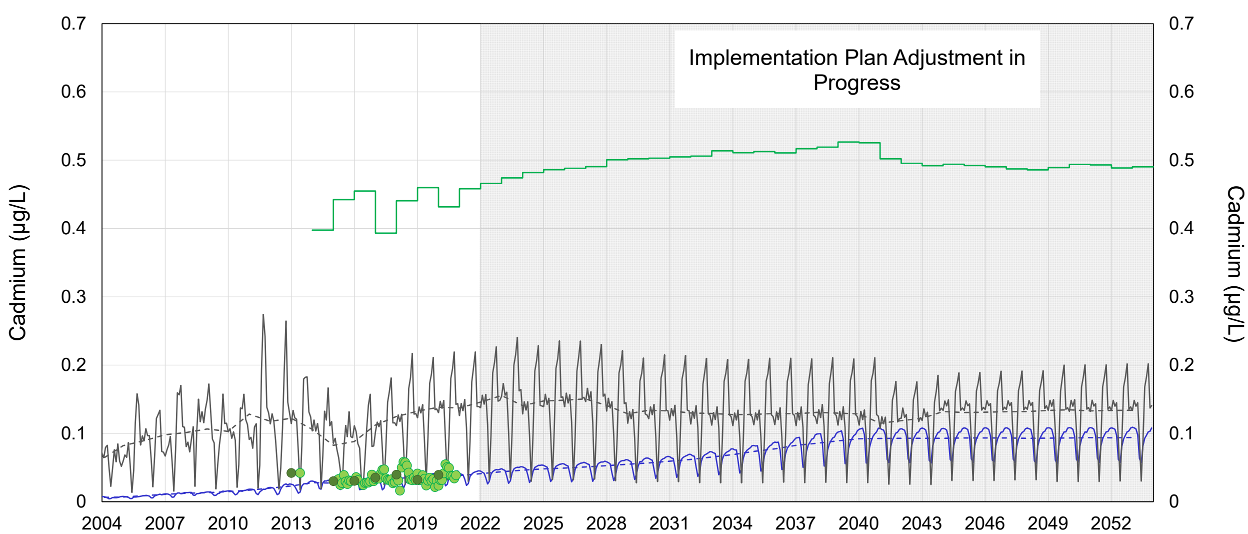
Figure B-8: Projected Concentrations of Dissolved Cadmium at Compliance Points with Consideration of Mitigation, 2004-2053

(a) Fording River, 525 m d/s of Cataract Creek (FR_FRCP1; E300071)

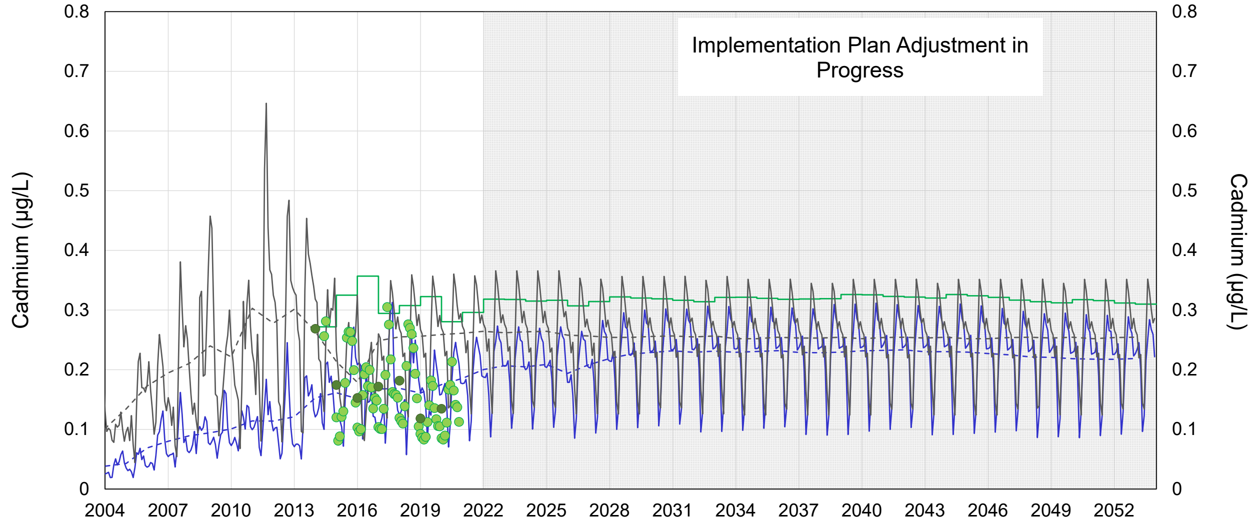


Note: Current projections developed using the 2020 RWQM are unrealistically high. Model projections for cadmium in new development areas will require additional refinement through adjustments to attenuation factors over time to match what is observed in more mature spoils.

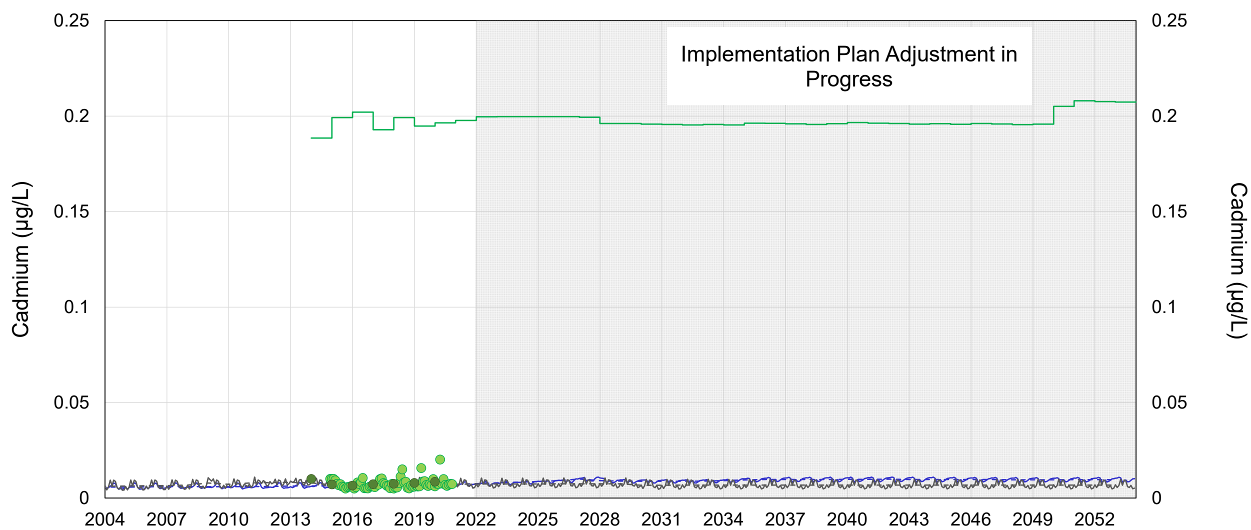
(b) FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)



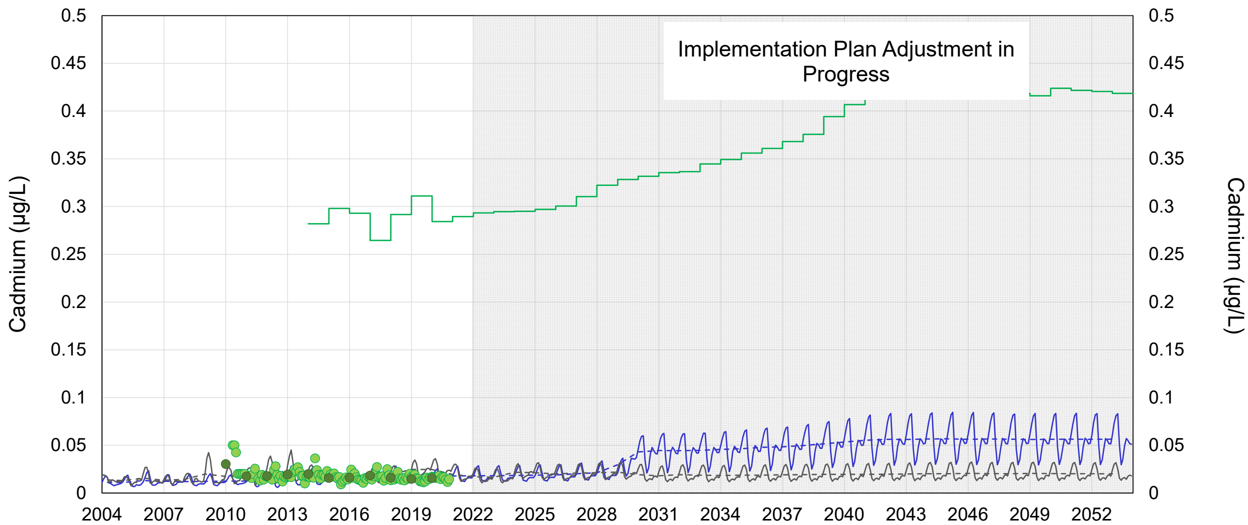
(c) LCO Compliance Point (LC_LCDSSLCC; E297110)



(d) GHO Elk River Compliance Point (GH_ERC; E300090)

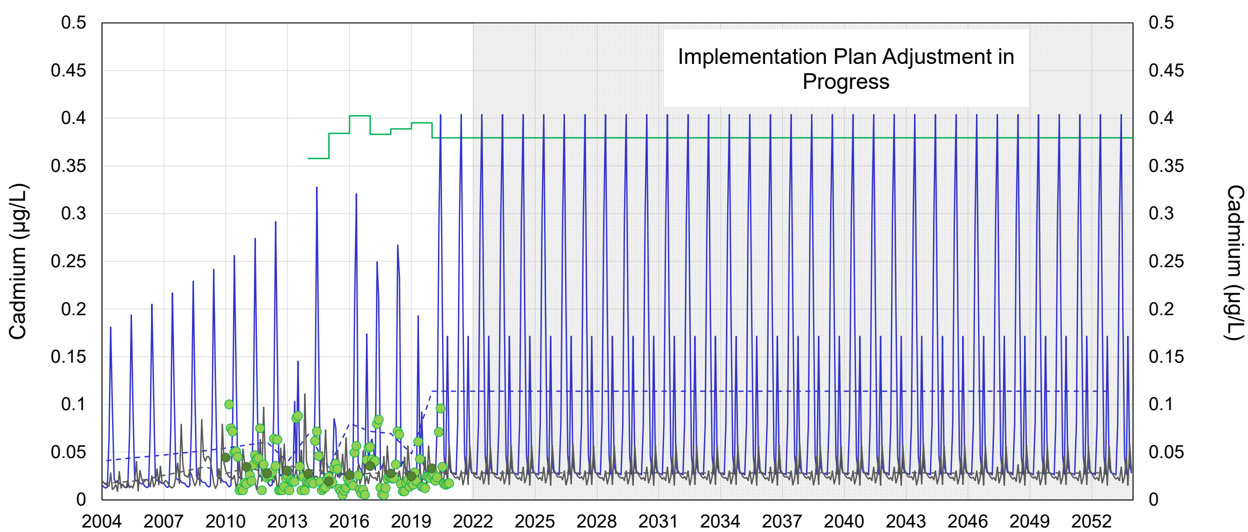


(e) EVO Harmer Compliance Point (EV_HC1; E102682)



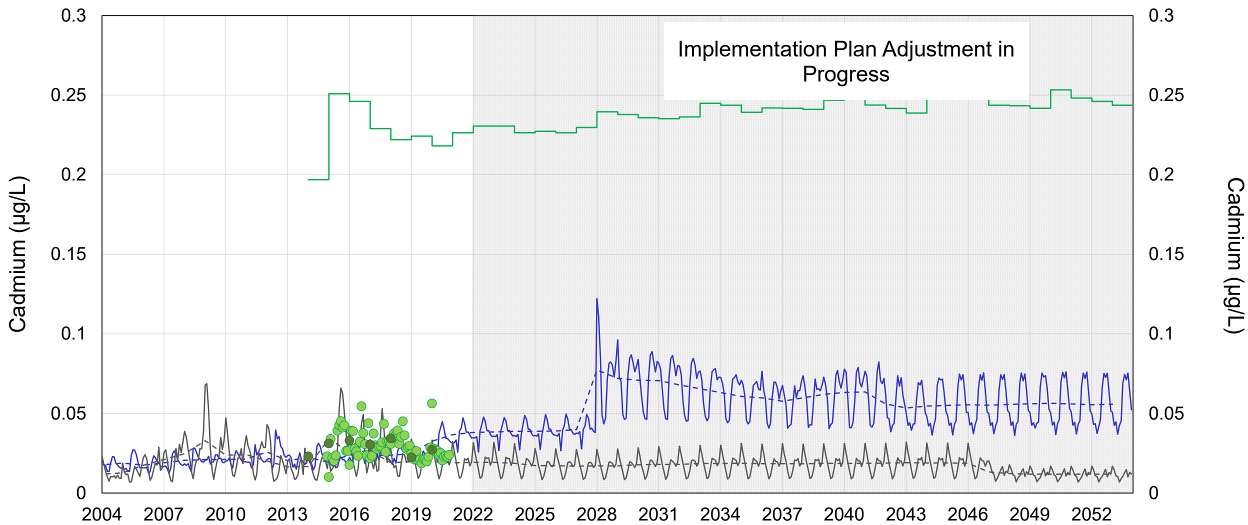
Note: Current projections developed using the 2020 RWQM are unrealistically high. Model projections for cadmium in new development areas will require additional refinement through adjustments to attenuation factors over time to match what is observed in more mature spoils.

(f) CMO Compliance Point (CM_MC2; E258937)



Note: Projected concentrations are from the CMO Water and Load Balance Model.

(g) EVO Michel Creek Compliance Point (EV_MC2; E300091)



Appendix C

Projected Hardness Concentrations at Order Stations and Compliance Points, as used to Define Hardness-Dependent Guidelines and SPOs

Tables

Table C-1: Projected Hardness Concentrations Used to Calculate the Site Performance Objective for Nitrate in the Fording River downstream of Line Creek

Year	Hardness (mg/L as $CaCO_3$)	Year	Hardness (mg/L as $CaCO_3$)
2020	519	2037	737
2021	565	2038	731
2022	570	2039	717
2023	584	2040	743
2024	591	2041	723
2025	612	2042	706
2026	609	2043	697
2027	626	2044	690
2028	634	2045	690
2029	629	2046	687
2030	653	2047	696
2031	661	2048	692
2032	650	2049	690
2033	667	2050	678
2034	679	2051	678
2035	691	2052	674
2036	723	2053	691

Notes:

Hardness values correspond to the month when maximum P_{50} monthly average nitrate concentrations are projected to occur. The site performance objective for nitrate was calculated using the following equation: $10^{1.0003 log_{10}(hardness) - 1.52}$.

$CaCO_3$ = calcium carbonate; mg/L = milligrams per litre.

Table C-2: Projected Minimum Monthly Average Hardness Concentrations Used to Calculate the Site Performance Objective for Cadmium at Order Stations

Year	Minimum Monthly Average Hardness (mg/L as $CaCO_3$)						
	GHO Fording River Compliance Point (GH_FR1; 0200378)	Fording River d/s of Line Creek (LC_LC5; 0200028)	Elk River u/s of Boivin Creek (GH_ER1; E206661)	Elk River u/s of Grave Creek (EV_ER4; 0200027)	Elk River d/s of Michel Creek (EV_ER1; 0200393)	Elk River at Elko Reservoir (RG_ELKORES; E294312)	Koocanusa Reservoir (RG_DSELK; E300230)
2014	267	250	149	176	169	166	110
2015	295	289	159	190	193	184	110
2016	310	298	161	193	192	185	107
2017	282	260	153	184	181	174	107
2018	277	262	159	196	190	184	108
2019	350	313	155	185	181	179	110
2020	297	269	156	188	179	174	109
2021	314	285	157	194	184	178	110
2022	330	299	159	199	190	183	111
2023	335	307	159	201	191	184	111
2024	341	310	159	202	192	185	111
2025	353	313	159	203	192	185	111
2026	338	309	159	204	192	185	111
2027	343	317	159	204	193	186	112
2028	350	323	156	205	195	189	112

Table C-2: Projected Minimum Monthly Average Hardness Concentrations Used to Calculate the Site Performance Objective for Cadmium at Order Stations

Year	Minimum Monthly Average Hardness (mg/L as $CaCO_3$)						
	GHO Fording River Compliance Point (GH_FR1; 0200378)	Fording River d/s of Line Creek (LC_LC5; 0200028)	Elk River u/s of Boivin Creek (GH_ER1; E206661)	Elk River u/s of Grave Creek (EV_ER4; 0200027)	Elk River d/s of Michel Creek (EV_ER1; 0200393)	Elk River at Elko Reservoir (RG_ELKORES; E294312)	Koocanusa Reservoir (RG_DSELK; E300230)
2029	357	322	156	205	196	188	111
2030	363	323	156	205	195	188	111
2031	370	327	156	205	195	188	112
2032	357	323	155	205	195	189	112
2033	368	328	156	208	198	190	112
2034	371	333	155	208	198	191	112
2035	381	334	156	209	199	191	112
2036	390	343	156	210	200	192	112
2037	382	339	156	211	199	192	112
2038	391	344	156	211	200	192	113
2039	399	349	156	212	203	194	113
2040	402	350	156	213	204	195	113
2041	392	342	156	208	200	192	112
2042	382	340	156	207	198	190	112
2043	367	330	156	205	198	191	112

Table C-2: Projected Minimum Monthly Average Hardness Concentrations Used to Calculate the Site Performance Objective for Cadmium at Order Stations

Year	Minimum Monthly Average Hardness (mg/L as $CaCO_3$)						
	GHO Fording River Compliance Point (GH_FR1; 0200378)	Fording River d/s of Line Creek (LC_LC5; 0200028)	Elk River u/s of Boivin Creek (GH_ER1; E206661)	Elk River u/s of Grave Creek (EV_ER4; 0200027)	Elk River d/s of Michel Creek (EV_ER1; 0200393)	Elk River at Elko Reservoir (RG_ELKORES; E294312)	Koocanusa Reservoir (RG_DSELK; E300230)
2044	369	333	156	206	201	193	113
2045	375	334	156	206	200	192	113
2046	372	330	156	205	201	192	112
2047	376	331	156	204	199	192	112
2048	362	325	156	203	198	191	112
2049	365	327	156	205	197	190	112
2050	370	330	164	210	203	195	113
2051	375	332	167	210	203	195	113
2052	377	331	166	210	204	195	112
2053	373	333	166	209	202	193	112

Notes:
The site performance objective for cadmium was calculated using the following equation: $10^{0.83 log_{10}(hardness)-2.53}$.
$CaCO_3$ = calcium carbonate; d/s = downstream; mg/L = milligrams per litre; u/s = upstream.

Table C-3: Projected Minimum Monthly Average Hardness Concentrations Used to Calculate the Site Performance Objective for Cadmium at Compliance Points

Year	Minimum Monthly Average Hardness (mg/L as $CaCO_3$)						
	Fording River, 525 m d/s of Cataract Creek (FR_FRCP1; 300071)	FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)	LCO Compliance Point (LC_LCDSSLCC; E297110)	GHO Elk River Compliance Point (GH_ERC; E300090)	EVO Harmer Compliance Point (EV_HC1; E102682)	CMO Compliance Point (CM_MC2; E258937)	EVO Michel Creek Compliance Point (EV_MC2; E300091)
2014	274	368	232	150	243	324	158
2015	315	418	289	160	260	353	211
2016	322	433	323	163	255	373	206
2017	270	363	256	154	225	352	189
2018	332	416	270	160	253	358	182
2019	353	438	286	156	274	365	184
2020	301	406	242	157	245	348	178
2021	341	436	258	158	251	348	187
2022	339	445	281	160	255	348	191
2023	328	455	281	160	256	348	191
2024	329	464	278	160	257	348	187
2025	331	469	279	160	259	348	188
2026	335	471	269	160	262	348	187
2027	340	474	277	160	273	348	190

Table C-3: Projected Minimum Monthly Average Hardness Concentrations Used to Calculate the Site Performance Objective for Cadmium at Compliance Points

Year	Minimum Monthly Average Hardness (mg/L as $CaCO_3$)						
	Fording River, 525 m d/s of Cataract Creek (FR_FRCP1; 300071)	FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)	LCO Compliance Point (LC_LCDSSLCC; E297110)	GHO Elk River Compliance Point (GH_ERC; E300090)	EVO Harmer Compliance Point (EV_HC1; E102682)	CMO Compliance Point (CM_MC2; E258937)	EVO Michel Creek Compliance Point (EV_MC2; E300091)
2028	350	485	285	157	285	348	200
2029	353	487	283	157	292	348	198
2030	346	488	282	157	296	348	196
2031	347	490	279	156	300	348	195
2032	353	492	277	156	301	348	197
2033	369	501	284	156	310	348	205
2034	368	498	285	156	315	348	204
2035	375	500	283	157	322	348	199
2036	377	497	281	157	327	348	202
2037	382	504	281	157	335	348	202
2038	387	507	282	156	343	348	201
2039	406	516	290	157	364	348	207
2040	413	515	289	157	378	348	208
2041	365	487	286	157	389	348	204

Table C-3: Projected Minimum Monthly Average Hardness Concentrations Used to Calculate the Site Performance Objective for Cadmium at Compliance Points

Year	Minimum Monthly Average Hardness (mg/L as $CaCO_3$)						
	Fording River, 525 m d/s of Cataract Creek (FR_FRCP1; 300071)	FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)	LCO Compliance Point (LC_LCDSSLCC; E297110)	GHO Elk River Compliance Point (GH_ERC; E300090)	EVO Harmer Compliance Point (EV_HC1; E102682)	CMO Compliance Point (CM_MC2; E258937)	EVO Michel Creek Compliance Point (EV_MC2; E300091)
2042	361	480	285	157	390	348	202
2043	354	475	283	157	391	348	199
2044	366	478	290	157	401	348	213
2045	364	476	287	157	398	348	211
2046	362	474	284	157	398	348	210
2047	358	470	279	157	395	348	204
2048	356	468	277	156	391	348	204
2049	356	472	275	157	388	348	202
2050	372	477	280	166	397	348	214
2051	371	477	279	169	395	348	208
2052	367	472	274	168	394	348	206
2053	365	473	272	168	391	348	204

Notes:

The site performance objective for cadmium was calculated using the following equation: $10^{0.83log_{10}(hardness)-2.53}$.

$CaCO_3$ = calcium carbonate; d/s = downstream; CMO = Coal Mountain Operations; EVO = Elkview Operations; FRO = Fording River Operations; GHO = Greenhills Operations; LCO= Line Creek Operations; mg/L = milligrams per litre; u/s = upstream.

Appendix D

Comparison of 2020 RWQM and 2017 RWQM Projected Monthly Average and Annual Average Flows at Order Stations and Compliance Points

Figures

Model results for flow at Order Stations and Compliance Points are shown in Figures D-1 to D-2, respectively. The format of the figures is as follows:

- The x-axis runs from the start of 2004 to the end of 2053. The start date corresponds to the start of the calibration period for the 2020 RWQM. The end date (2053) corresponds to the modelled time period at which all waste rock considered in the permitted mine plans has been deposited and the lag associated with that rock has passed (i.e., all of the waste rock is contributing selenium and sulphate load).
- Projected 50th percentile (P50) monthly average flows produced using the 2020 RWQM are shown as a solid blue line.
- Projected monthly average flows produced using the 2017 RWQM under average flow conditions are shown as a solid grey line.
- Projected annual average flows produced using the 2020 RWQM and 2017 RWQM are shown as dashed blue and grey lines, respectively.
- Measured monthly average and annual average flows are shown as light blue points and dark blue points, respectively.
- Predictions shown prior to 2020 generated using the 2020 RWQM represent calibrated flows. Those shown thereafter were developed using multiple climate realizations, as described in Annex D.
- Predictions shown prior to 2017 generated using the 2017 RWQM represent calibrated flows. Those shown thereafter were developed using average flow projections.

The legend below applies to all time series plots in this appendix.

—Projected P_{50} Monthly Average Flows from the 2020 RWQM

- - -Projected P_{50} Annual Average Flows from the 2020 RWQM

—Projected Monthly Average Flows for Average Flows from the 2017 RWQM

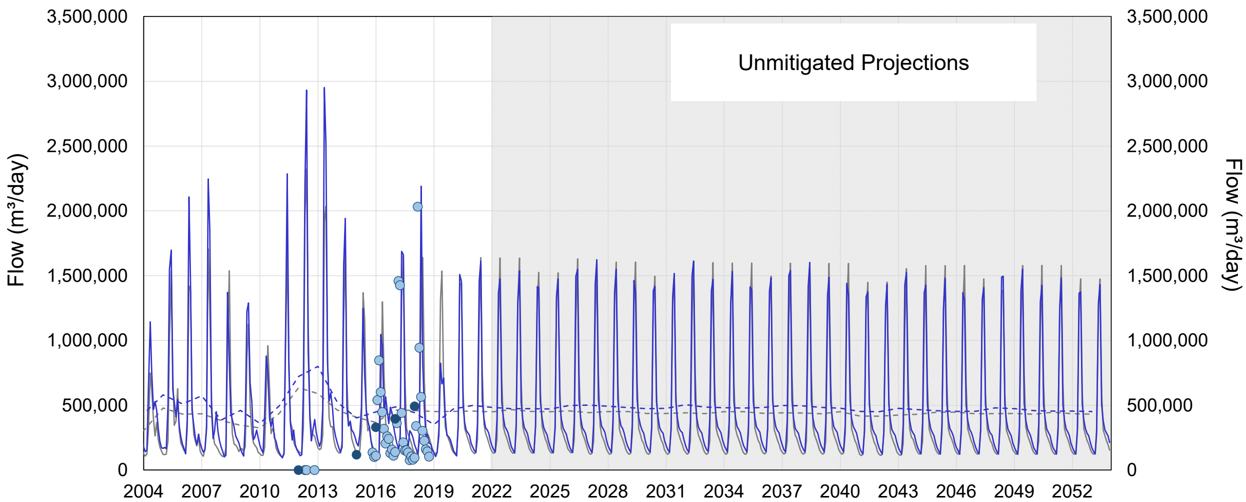
- - -Projected Annual Average Flows for Average Flows from the 2017 RWQM

○ Monthly Average Measured Flows

● Annual Average Measured Flows

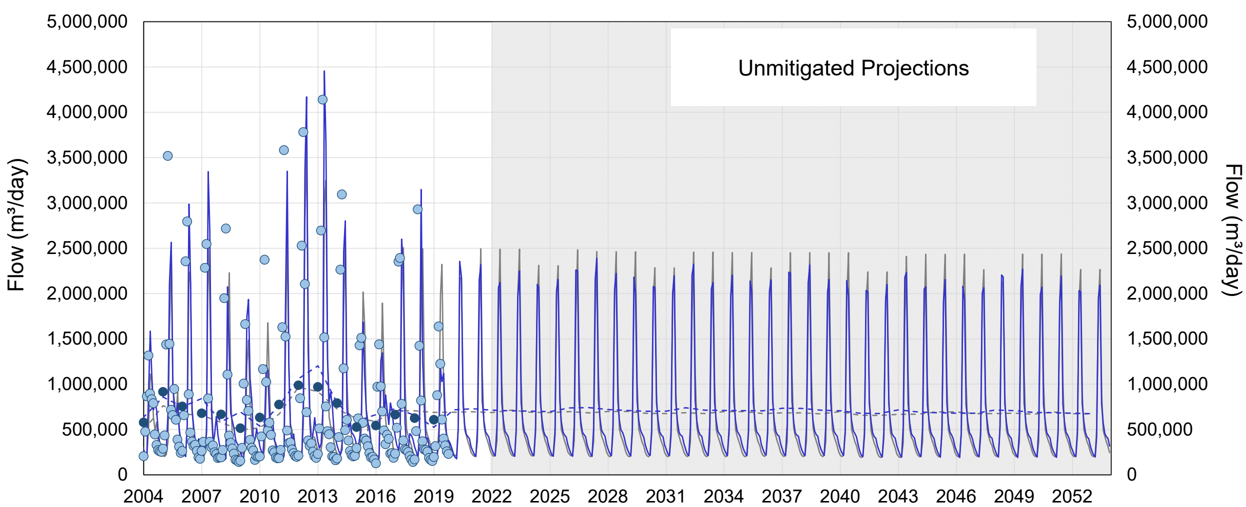
Figure D-1: Projected Flows at Order Stations without Consideration of Mitigation, 2004-2053

(a) GHO Fording River Compliance Point (GH_FR1; 0200378)

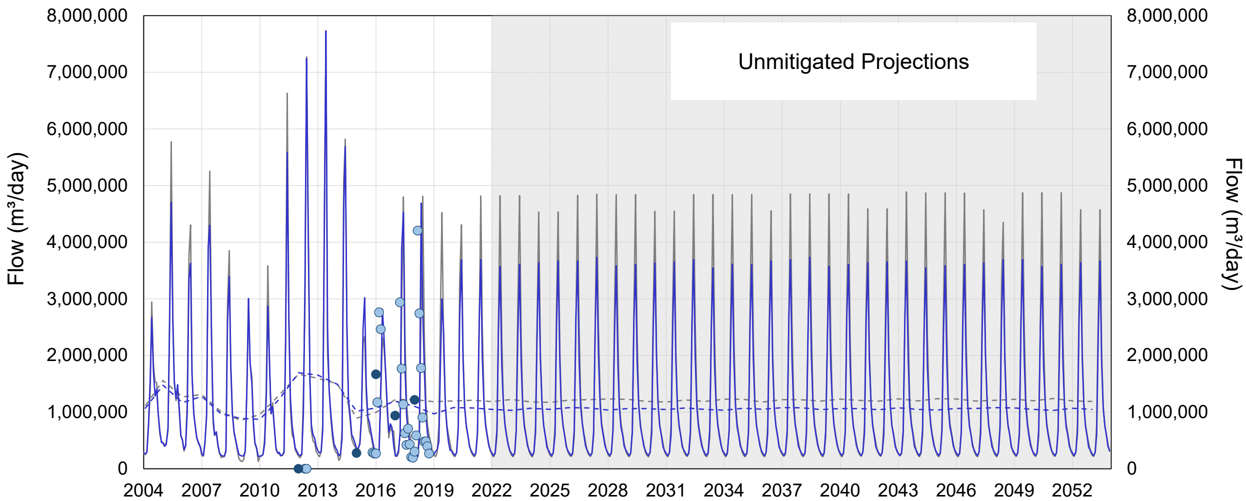


Note: This location is also the GHO Fording River Compliance Point.

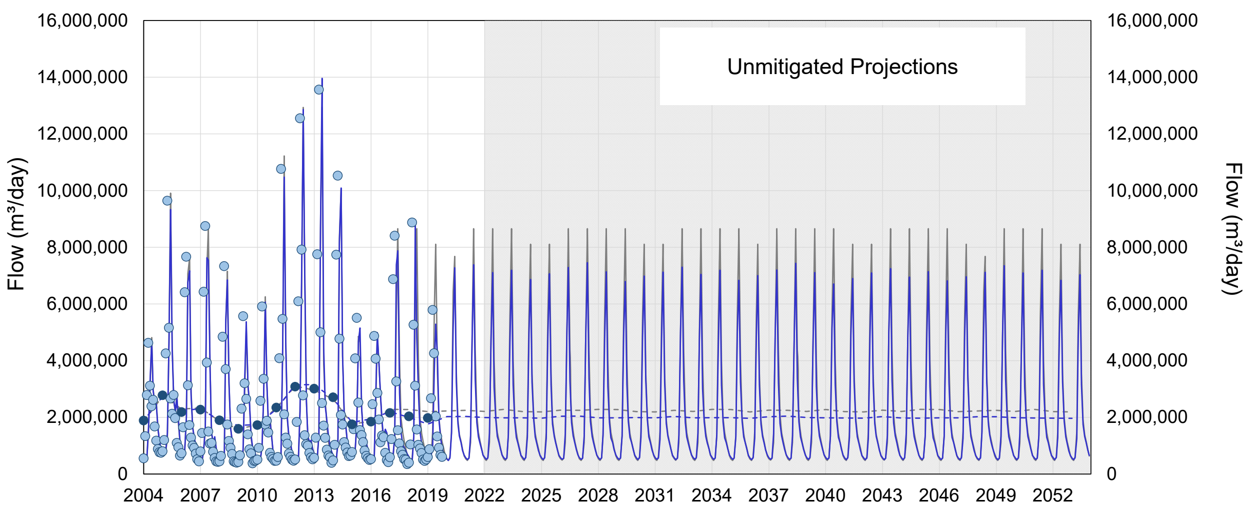
(b) Fording River d/s of Line Creek (LC_LC5; 0200028)



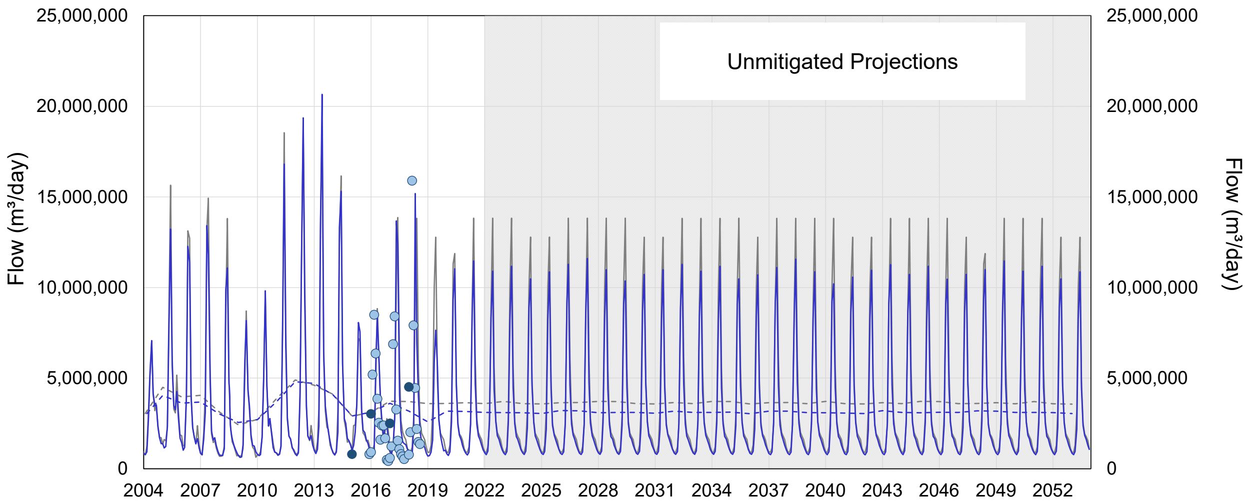
(c) Elk River u/s of Boivin Creek (GH_ER1; E206661)



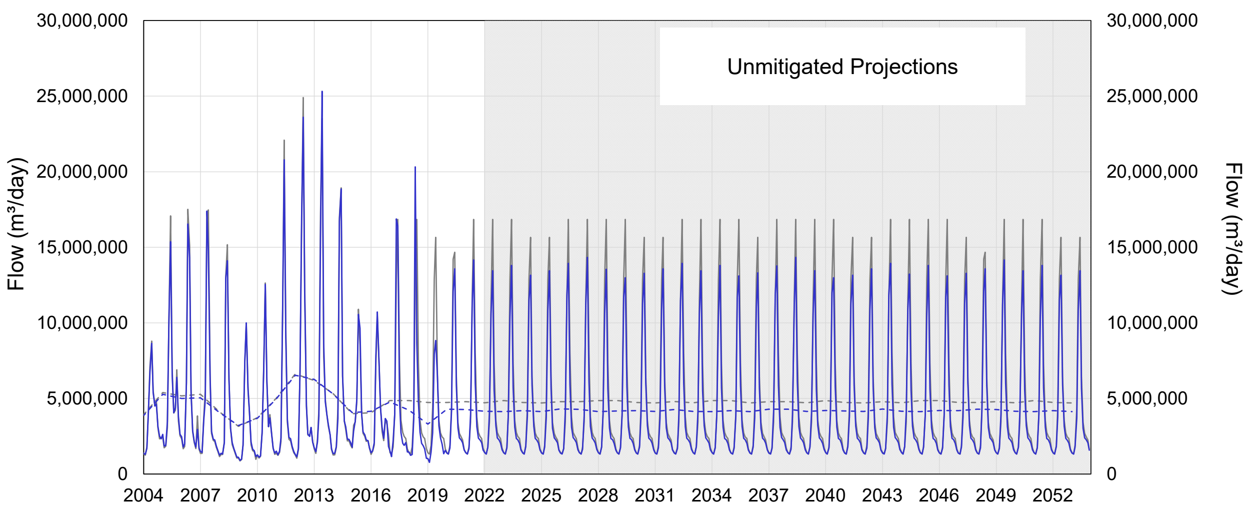
(d) Elk River u/s of Grave Creek (EV_ER4; 0200027)



(e) Elk River d/s of Michel Creek (EV_ER1; 0200393)



(f) Elk River at Elko Reservoir (RG_ELKORES; E294312)



(g) Koocanusa Reservoir (E300230)

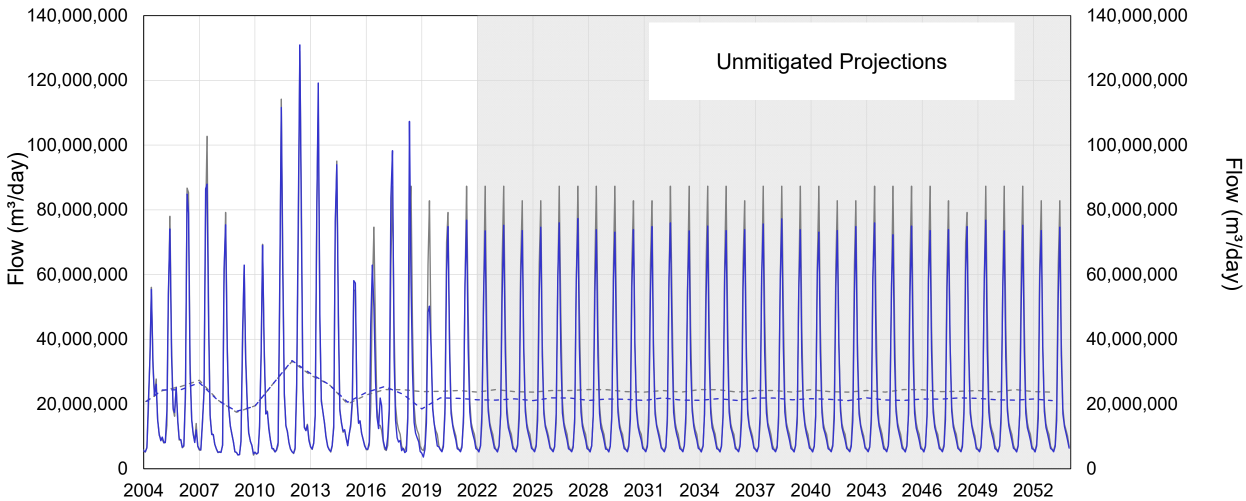
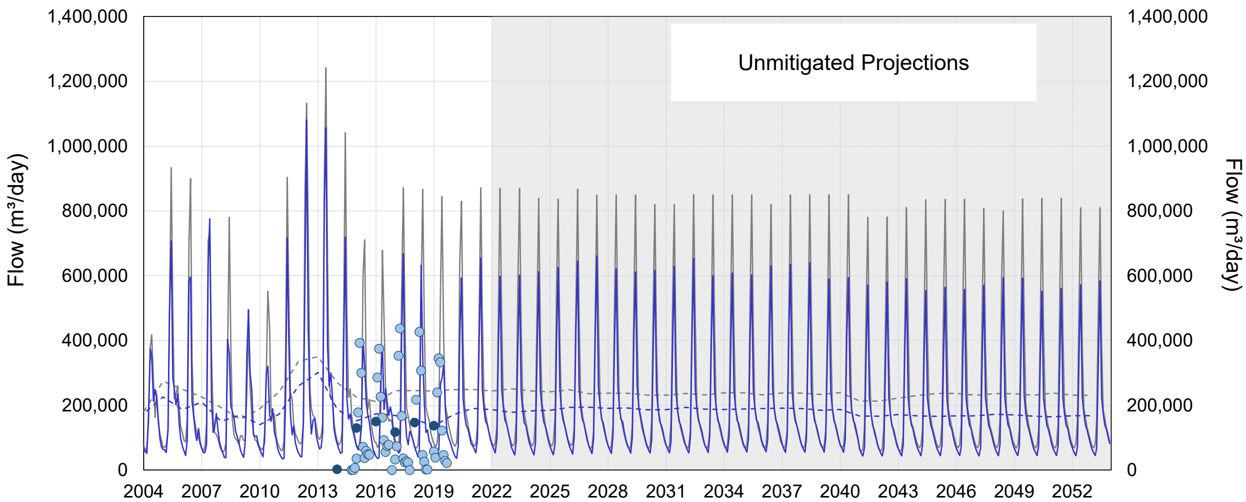
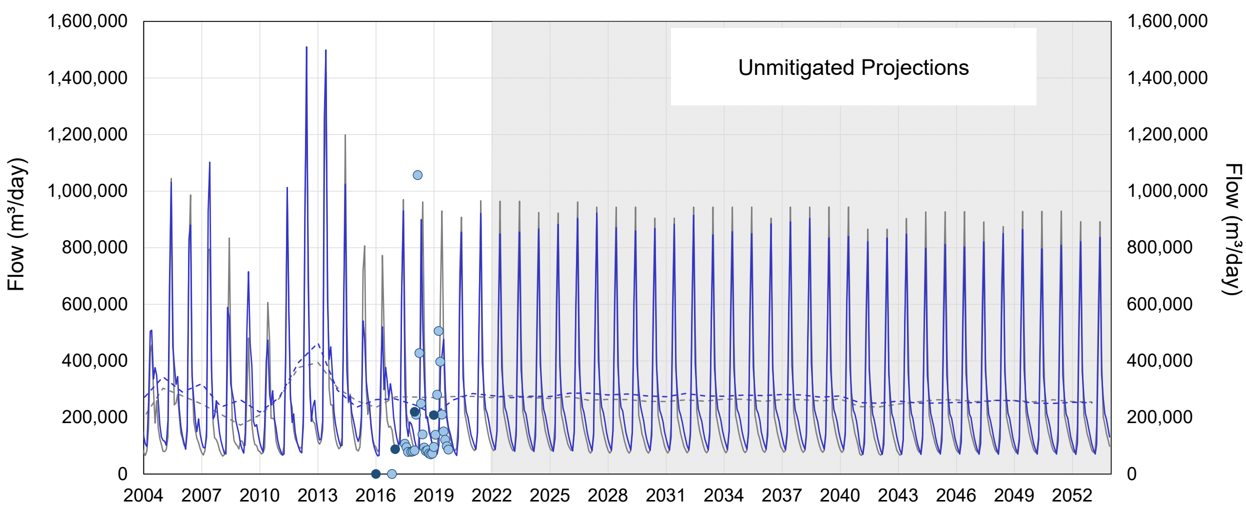


Figure D-2: Projected Flows at Compliance Points without Consideration of Mitigation, 2004-2053

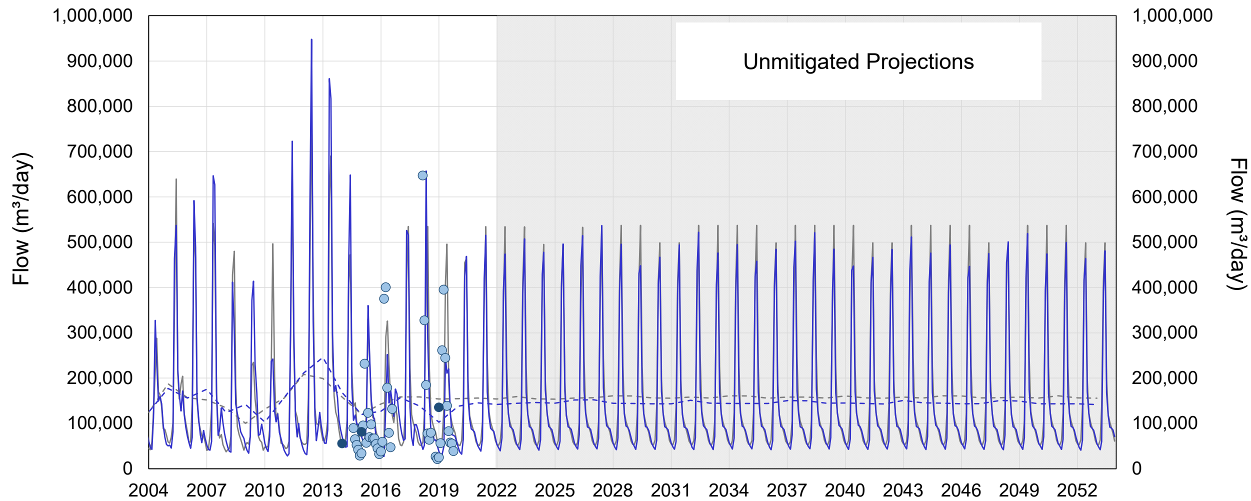
(a) Fording River, 525 m d/s of Cataract Creek (FR_FRCP1; E300071)



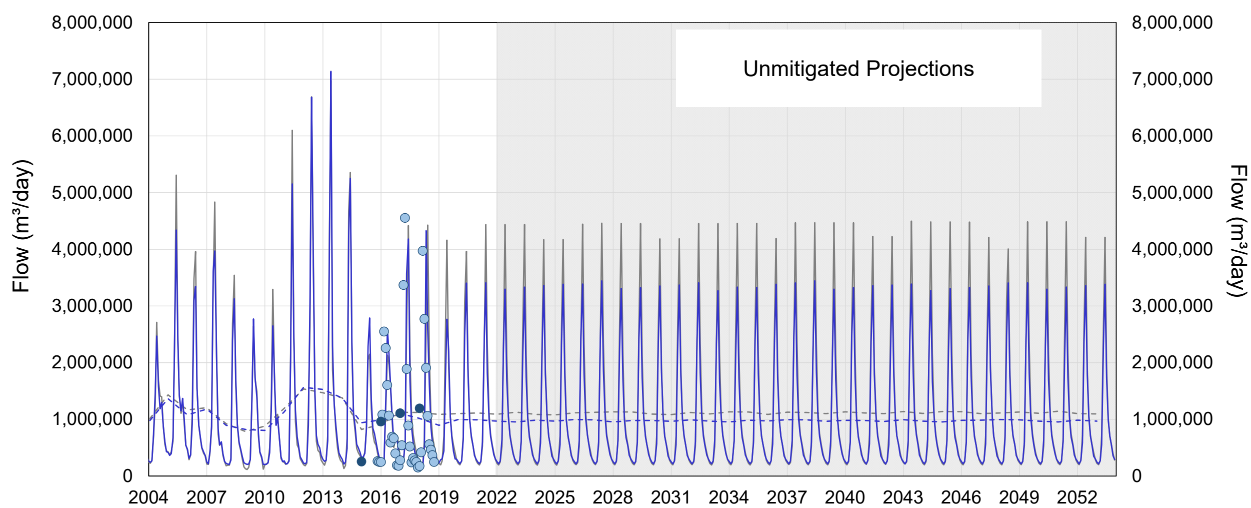
(b) FRO Compliance Point (Fording River, 100 m u/s of Chauncey Creek) (FR_FRABCH; E223753)



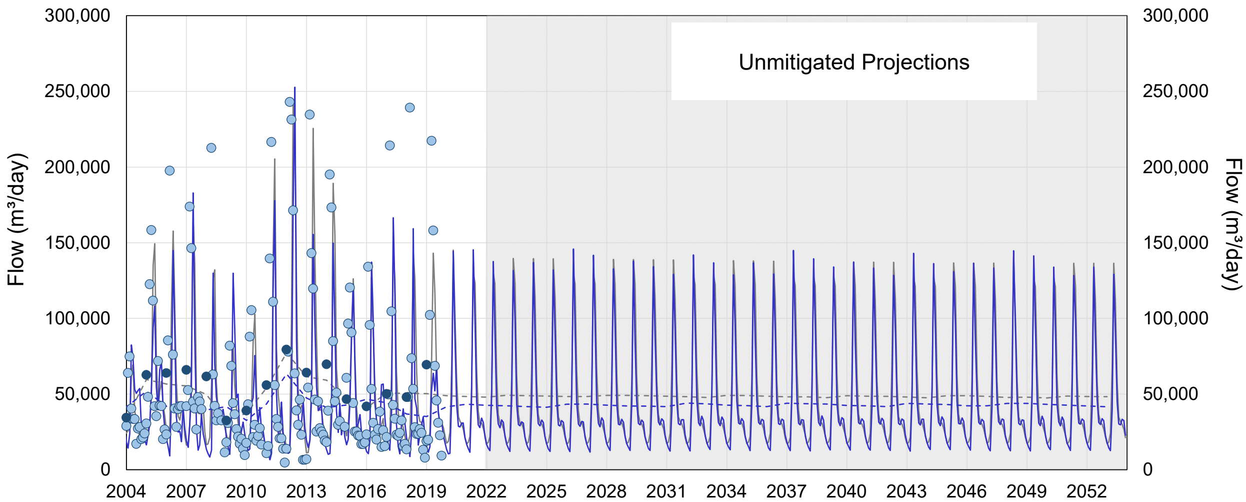
(c) LCO Compliance Point (LC_LCDSSLCC; E297110)



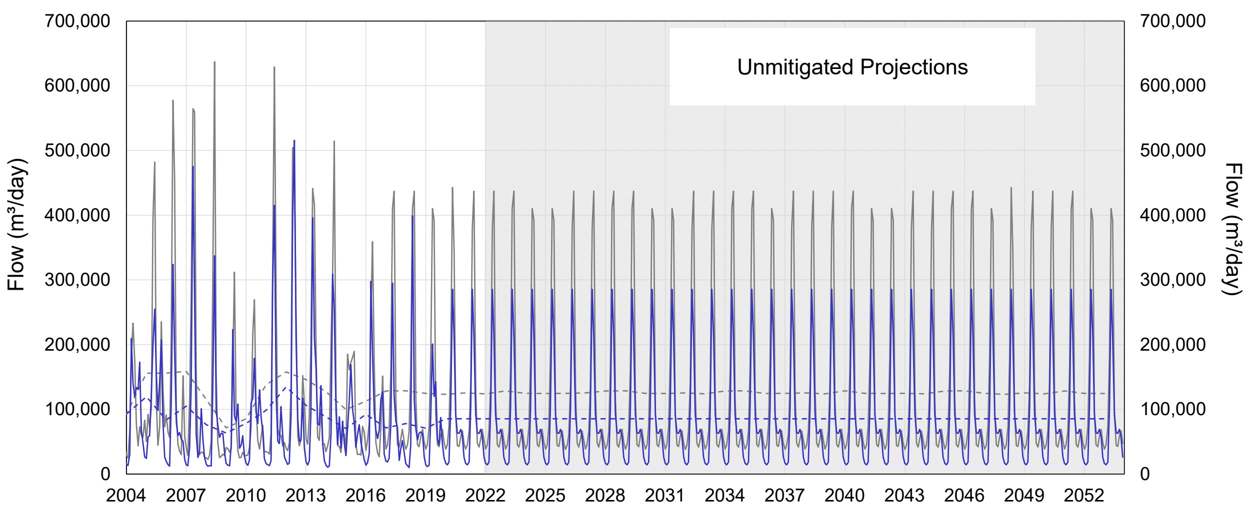
(d) GHO Elk River Compliance Point (GH_ERC; E300090)



(e) EVO Harmer Compliance Point (EV_HC1; E102682)



(f) CMO Compliance Point (CM_MC2; E258937)



(g) EVO Michel Creek Compliance Point (EV_MC2; E300091)